Hyacinth's Way
Net Zero Analysis

SEPTEMBER 2021

QUINN EVANS

FINAL REPORT

Building Innovation Design Assistance Grant
Grant Number 2021-2101-USA-2

QUINN EVANS

NEW ECOLOGY
Community-Based Sustainable Development

Contents

QUINN EVANS

Introduction & Project Objectives

QUINN EVANS

Project Goals

- Explore Architectural Façade Options
- Conduct Iterative Energy Models
- Conduct Renewable Energy Analysis

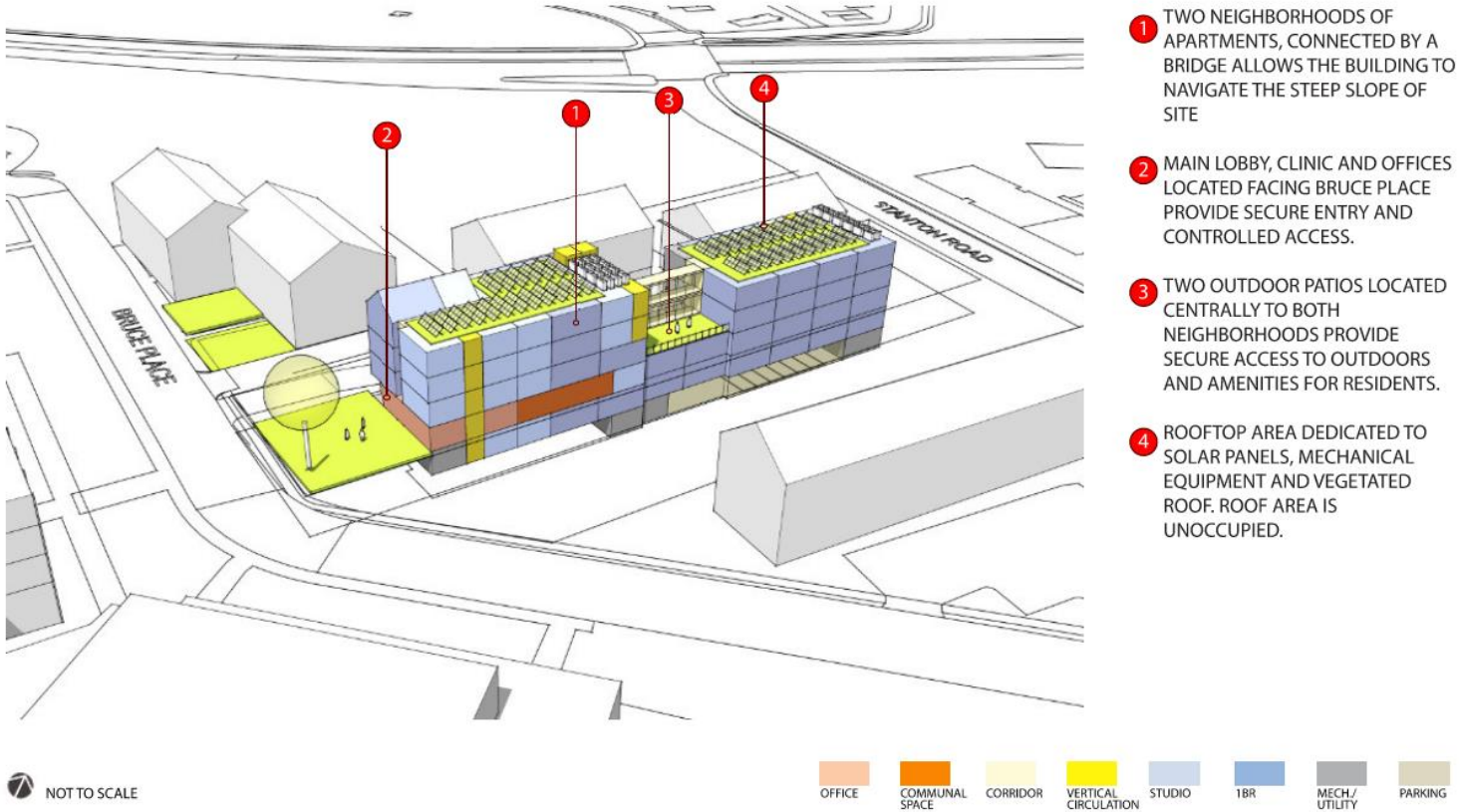
QUINN EVANS

Project Team

Quinn Evans provided design options and New Ecology conducted the energy modeling and renewable energy analysis.

The MEP Engineers at Setty & Associates and Structural Engineers at Linton Engineer were also consulted during the charrette but were not paid consultants on this grant effort.

Hyacinth's Way Project



1. TWO NEIGHBORHOODS OF APARTMENTS, CONNECTED BY A BRIDGE ALLOWS THE BUILDING TO NAVIGATE THE STEEP SLOPE OF SITE
2. MAIN LOBBY, CLINIC AND OFFICES LOCATED FACING BRUCE PLACE PROVIDE SECURE ENTRY AND CONTROLLED ACCESS.
3. TWO OUTDOOR PATIOS LOCATED CENTRALLY TO BOTH NEIGHBORHOODS PROVIDE SECURE ACCESS TO OUTDOORS AND AMENITIES FOR RESIDENTS.
4. ROOFTOP AREA DEDICATED TO SOLAR PANELS, MECHANICAL EQUIPMENT AND VEGETATED ROOF. ROOF AREA IS UNOCCUPIED.

OFFICE | COMMUNAL SPACE | CORRIDOR | VERTICAL CIRCULATION | STUDIO | 1BR | MECH./ UTILITY | PARKING

- New Construction of 70 affordable housing units
  - Formerly homeless seniors with a mental health diagnosis
- Timeline:
  - Currently in schematic design phase
  - 2022: Design complete and construction documents developed
  - 2023-2024: Construction

QUINN EVANS

Project Constraints

Located in Southeast Washington, DC, this project is located on a narrow and steep site between Bruce Place and Stanton Road.

The project is being designed for formerly homeless seniors with a mental health diagnosis, will be pursing Low Income Housing Tax Credits and targeting Net Zero Energy performance.

Energy performance, comfort, and affordability are elements that must be considered throughout the design.

QUINN EVANS

Net Zero Basics & Reduction Strategies

QUINN EVANS

Net Zero: Why it Matters

"A net-zero energy (NZE) building is an extremely energy efficient building that is designed and operated to produce as much energy as it consumes over the course of the year."

- DC's Net Zero Energy Project Guide

Building energy consumption accounts for 74% of all greenhouse gas (GHG) emissions in the District of Columbia (the District). Mayor Bowser has pledged to make Washington, D.C., carbon neutral and climate resilient by 2050 and has recommitted to honoring the goals of the Paris Climate Accord. In addition, the Sustainable DC Plan (the Plan) outlines a commitment to making the District the healthiest, greenest, and most livable city in the United States. Specific goals in the Plan include:

- 50 percent reduction of district-wide energy consumption
- 50 percent of district-wide energy from renewable sources
- 50 percent reduction of district-wide carbon emissions

QUINN EVANS

Energy Reduction Strategies towards achieving Net Zero

1. **Optimize Systems & reduce loads**:

   Prior to the award of this grant energy models were completed to determine which MEP systems would be the most energy efficient. The Chilltrix air to water heat pump was determined to be the most efficient for this particular site.

2. **Explore Passive Strategies**:

   This grant allowed the design team to explore various passive strategies to see how they would impact energy consumption on the project.

3. **Utilize Renewables**:

   This grant allowed the design team to explore the impacts of renewable energy sources to see what could work on the site.

QUINN EVANS

Hyacinth's Way Net Zero Analysis

QUINN EVANS

Project Goals:

Explore ways to optimize the design and utilize renewable energy to make this new affordable housing building Net Zero Energy

- Explore architectural design strategies to test via energy model
- Run energy models to explore Energy Reduction Measures (ECM)
- Analyze Renewable Energy options for the site

QUINN EVANS

Methodology

Step 1: Select Design Strategies to test via Energy Model

- **Charrette to decide feasible options:**
  - Baseline design, sun shading, additional Window to wall ratio
  - Insulation changes around the building: slab, wall, roof

QUINN EVANS

Methodology

Step 2: Perform iterative energy models to test Energy Reduction Measures (ECM)

- **Energy models:**
  - Roof
  - Window to Wall
  - Full Building

Cost Saving Analysis	Roof Study - Whole Building Model																			
End Use	90.1-2013 Baseline				ECM14 : R50 above the deck (U-0.02)				Energy Savings	ECM15 : R30 above the deck (U-0.032)				Energy Savings	ECM16 : R40 above the deck(U-0.025)				Energy Savings
	Electricity (kWh)	Natural Gas (Therms)	Total Energy Usage (kBtu)	Percent of Total (%)	Electricity (kWh)	Natural Gas (Therms)	Total Energy Usage (kBtu)	Percent of Total (%)	Percent (%)	Electricity (kWh)	Natural Gas (Therms)	Total Energy Usage (kBtu)	Percent of Total (%)	Percent (%)	Electricity (kWh)	Natural Gas (Therms)	Total Energy Usage (kBtu)	Percent of Total (%)	Percent (%)
Interior Lighting	135,822	-	463,425	17.9%	120,731	-	411,934	25.4%	11%	120,731	-	411,934	25.4%	11%	120,731	-	411,934	25.4%	11%
Exterior Lighting	1,752	-	5,978	0.2%	1,226	-	4,183	0.3%	30%	1,226	-	4,183	0.3%	30%	1,226	-	4,183	0.3%	30%
Misc. Equipment	118,940	-	405,823	15.7%	118,506	-	404,342	24.9%	0%	118,506	-	404,342	24.9%	0%	118,506	-	404,342	24.9%	0%
Space Heating	391	5,918	593,135	22.9%	15,589	-	53,190	3.3%	91%	16,005	-	54,609	3.4%	91%	15,732	-	53,678	3.3%	91%
Space Cooling	128,693	-	439,099	16.9%	60,895	-	207,774	12.8%	53%	60,314	-	205,791	12.7%	53%	60,641	-	206,907	12.8%	53%
Heat Rejection	-	-	-	0.0%	8,724	-	29,766	1.8%	n/a	8,854	-	30,210	1.9%	n/a	8,780	-	29,957	1.8%	n/a
Pumps & Aux	1,308	-	4,463	0.2%	44,558	-	152,032	9.4%	-3307%	44,516	-	151,889	9.4%	-3303%	44,542	-	151,977	9.4%	-3305%
Ventilation Fans	70,803	-	241,580	9.3%	71,223	-	243,013	15.0%	-1%	71,324	-	243,357	15.0%	-1%	71,259	-	243,136	15.0%	-1%
Refrig Display	-	-	-	0.0%	-	-	-	0.0%	n/a	-	-	-	0.0%	n/a	-	-	-	0.0%	n/a
Heat Pump Supplement	-	-	-	0.0%	1	-	3	0.0%	n/a	1	-	3	0.0%	n/a	1	-	3	0.0%	n/a
Domestic Hot Water		4,373	437,300	16.9%	33,945	-	115,820	7.1%	74%	33,945	-	115,820	7.1%	74%	33,945	-	115,820	7.1%	74%
Total Energy by Utility	457,709	10,291	2,590,802	100.0%	475,398	-	1,622,058	100.0%		475,422	-	1,622,140	100.0%		475,363	-	1,621,939	100.0%	
Rooftop PV production	-	-	-		-	-	-			-	-	-			-	-	-		
Total Energy minus PV production	457,709	10,291	2,590,802		475,398	-	1,622,058			475,422	-	1,622,140			475,363	-	1,621,939		
Site Energy (kBtu)	1,561,702	1,029,100			1,622,058	-			Energy Savings	1,622,140	-			Energy Savings	1,621,939	-			Energy Savings
Site EUI (kBtu/ft²)			43.51				27.24		37.4%			27.24		37.4%			27.24		37.4%
Total Cost by Type	$ 58,587	$ 12,720			$ 60,851	$ -			Cost Savings	$ 60,854	$ -			Cost Savings	$ 60,846	$ -			Cost Savings
Total Energy Cost	$		71,306		$		60,851		14.7%	$		60,854		14.7%	$		60,846		14.7%

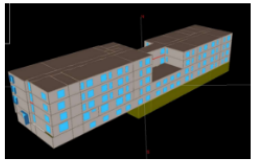
90.1-2013 Baseline
HVAC: PTAC
Heating - 80% et boiler eff
Cooling - 9.95 EER
DHW-Gas storage water heater 80% et
Envelope
Ext Wall: U-0.064
Roof: U-0.032
Slab : F-0.52 (R-15 for 24 in.)
Exposed Floor: U-0.038
Below Grade Wall: C-0.092
Window: U-0.35, SHGC-0.4
Door: U-0.5
WWR NW-17%
WWR NE-17%
WWR SE-17%
WWR SW-17%
Double Pane Window
No Shading

ECM14 : R50 above the deck (U-0.02)
HVAC: Chiltrix Heat Pump
Heating - 3.92 COP (IPLV)
Cooing - 23 EER (IPLV)
Heat Pump Water Heater - 3.75 COP
Envelope
Ext Wall: U-0.03
Roof: U-0.02
Slab : R-10 below slab
Exposed Floor: U-0.05
Below Grade Wall: C-0.063
Window: U-0.24, SHGC-0.3
Door: U-0.25
WWR NW-15%
WWR NE-15%
WWR SE-15%
WWR SW-15%
Double Pane Window
No Shading

ECM15 : R30 above the deck (U-0.032)
HVAC: Chiltrix Heat Pump
Heating - 3.92 COP (IPLV)
Cooing - 23 EER (IPLV)
Heat Pump Water Heater - 3.75 COP
Envelope
Ext Wall: U-0.03
Roof: U-0.033
Slab : R-10 below slab
Exposed Floor: U-0.05
Below Grade Wall: C-0.063
Window: U-0.24, SHGC-0.3
Door: U-0.25
WWR NW-15%
WWR NE-15%
WWR SE-15%
WWR SW-15%
Double Pane Window
No Shading

ECM16 : R40 above the deck(U-0.025)
HVAC: Chiltrix Heat Pump
Heating - 3.92 COP (IPLV)
Cooing - 23 EER (IPLV)
Heat Pump Water Heater - 3.75 COP
Envelope
Ext Wall: U-0.03
Roof: U-0.025
Slab : R-10 below slab
Exposed Floor: U-0.05
Below Grade Wall: C-0.063
Window: U-0.24, SHGC-0.3
Door: U-0.25
WWR NW-15%
WWR NE-15%
WWR SE-15%
WWR SW-15%
Double Pane Window
No Shading

Roof Study - Whole Building Model								
Building Peak Load (eQUEST LS-C Report)		90.1-2013 Baseline	ECM14 : R50 above the deck (U-0.02)	% change	ECM15 : R30 above the deck (U-0.032)	% change	ECM16 : R40 above the deck(U-0.025)	% change
Cooling -Sensible	Roof Conduction (Kbtu/h)	29.448	19.278	42%	30.099	9%	24.525	26%
Heating- Sensible	Roof Conduction (Kbtu/h)	-80.337	17.038	117%	-27.552	72%	-21.289	79%

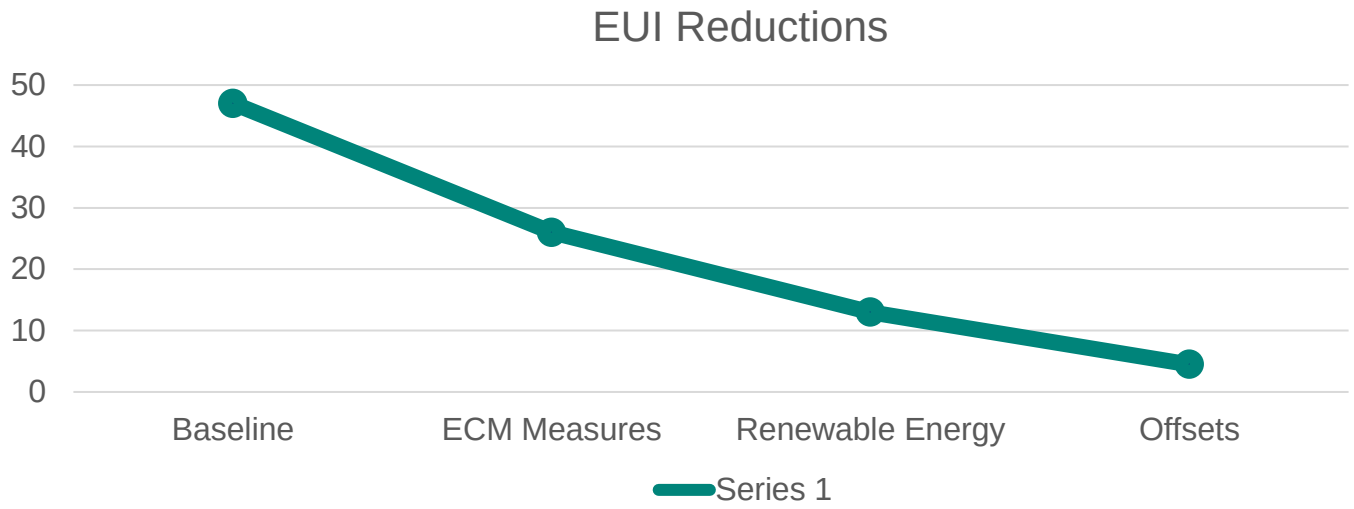


QUINN EVANS

Methodology

Step 3: Explore Renewable Energy Options to get to NetZero

- **Consider site and viability for the following renewables:**
  - Wind
  - Geothermal
  - Biomass
  - Solar PV
  - Fuel Cell



QUINN EVANS

Methodology

Step 4: Analyze Results

- **Interpret the numbers:**
  - Energy is only one part of the equation
  - Consider needs for occupant comfort and affordability and ways to impact the design moving forward.

QUINN EVANS

Challenges + Limitations

- Minimize the Variables
  - Running different scenarios required we be mindful of keeping a baseline clearly identified to ensure we were comparing ‘apples to apples’

- The Energy Model does not always tell the full story.
  - In some instances the change in percentage reduction was small but the impact would be large. We had to remember to look at the numbers holistically and think analytically instead of just focusing on the overall percentage reduction.

QUINN EVANS

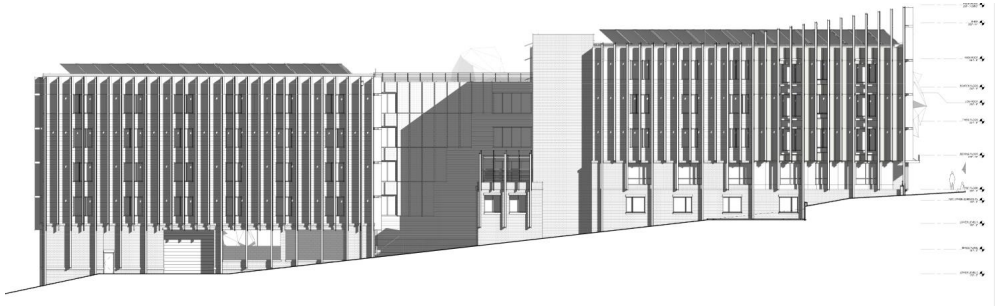
Building Façade Design Options

QUINN EVANS

Building Façade Design Options

To understand the architectural design implications we designed the following facades to test with energy models:

- Low window to wall ratio
- Higher window to wall ratio
- Sun shading on one side



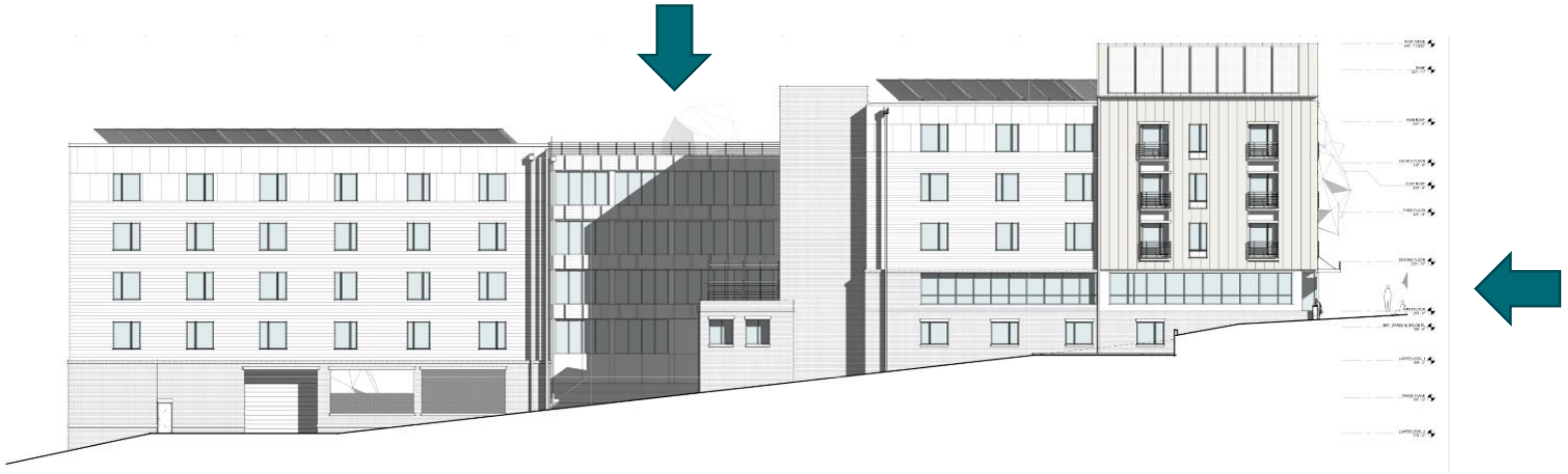
QUINN EVANS

Building Façade Option:
Low window to wall ratio (WWR)

This option kept the WWR to 15% to take advantage of the thermal advantages of walls over glazing.

QUINN EVANS

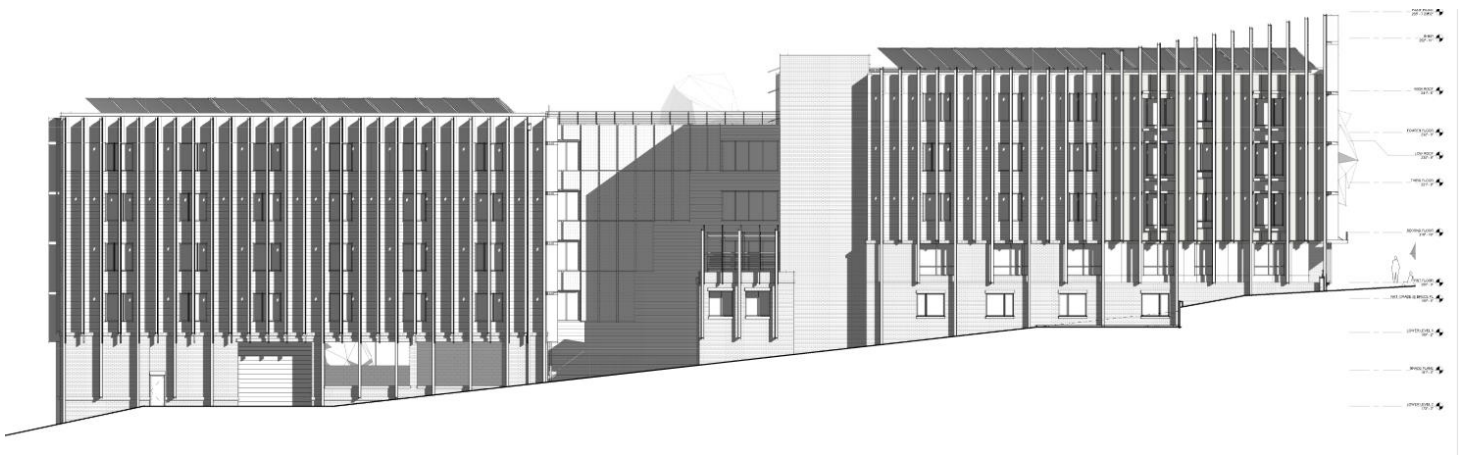
Building Façade Option:
Higher window to wall ratio (WWR)



To test how much we could increase the WWR we designed this option with expanded glazing at the ground level and in the connector bridge which increased the WWR to approximately 20%. The energy model will also test double vs triple pane glazing with different solar heat gain coeffients (SHGC).

QUINN EVANS

Building Façade Option:
Sun shading



We designed this final option to test the impacts of solar shading on the more exposed side of the building.

QUINN EVANS

Energy Model Results

QUINN EVANS

Building Energy Model: Baseline

ASHRAE 90.1-2013 used as a baseline.

The following building components were tested: **Slab, walls, window to wall ratio (wwr) and roof.**

Cost Saving Analysis				
End Use	90.1-2013 Baseline			
	Electricity (kWh)	Natural Gas (Therms)	Total Energy Usage (kBtu)	Percent of Total (%)
Interior Lighting	135,822	-	463,425	17.9%
Exterior Lighting	1,752	-	5,978	0.2%
Misc. Equipment	118,940	-	405,823	15.7%
Space Heating	391	5,918	593,135	22.9%
Space Cooling	128,693	-	439,099	16.9%
Heat Rejection	-	-	-	0.0%
Pumps & Aux	1,308	-	4,463	0.2%
Ventilation Fans	70,803	-	241,580	9.3%
Refrig Display	-	-	-	0.0%
Heat Pump Supplement	-	-	-	0.0%
Domestic Hot Water	-	4,373	437,300	16.9%
Total Energy by Utility	457,709	10,291	2,590,802	100.0%
Rooftop PV production	-	-	-	
Total Energy minus PV production	457,709	10,291	2,590,802	
Site Energy (kBtu)	1,561,702	1,029,100		
Site EUI (kBtu/ft^2)			43.51	
Total Cost by Type	$ 58,587	$ 12,720		
Total Energy Cost	$		71,306	

90.1-2013 Baseline
HVAC: PTAC
Heating - 80% et boiler eff
Cooling - 9.95 EER
DHW-Gas storage water heater 80% et
Envelope
Ext Wall: U-0.064
Roof: U-0.032
Slab : F-0.52 (R-15 for 24 in.)
Exposed Floor: U-0.038
Below Grade Wall: C-0.092
Window: U-0.35, SHGC-0.4
Door: U-0.5
WWR NW-17%
WWR NE-17%
WWR SE-17%
WWR SW-17%
Double Pane Window
No Shading

QUINN EVANS

Energy Model - Systems

The Chilltrix Heat Pump system is an air to water heat pump system (also known as a hydronic heat pump or reverse-cycle chiller) and was found to be the most energy efficient in previous energy model comparisons. This system was used as the baseline for subsequent ECMs.

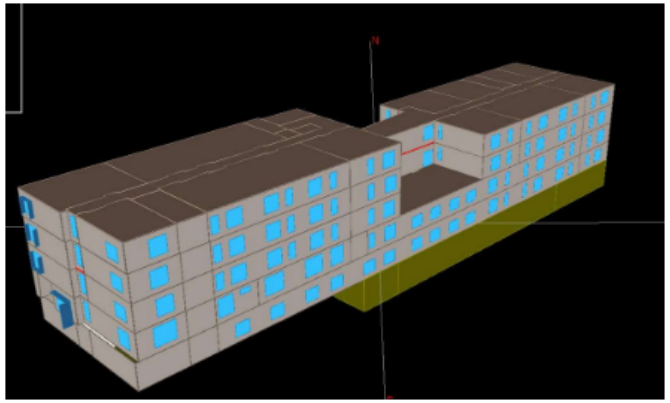
HVAC Study	Site EUI (kBtu)	Annual Energy Cost
ASHRAE 90.1 Baseline HVAC Systems: PTAC cooling, 80% gas boiler heating, 80% efficient gas storage water heater	43.51	$71,306
Proposed HVAC Systems Chilltrix Heat Pump, heat pump water heater	27.24	$60,851

QUINN EVANS

Energy Model - Slab

ECM #	Slab – Baseline – R20 under the slab (ECM-1 with Chiltrix)	Site EUI	Annual Energy Cost
17	R20 continuous under the slab	27.04	$60,388
18	no continuous insulation under the slab	27.21	$60,778
19	R10 continuous under the slab	27.24	$60,851

Slab Study - Whole Building Model								
Building Peak Load (eQUEST LS-C Report)		90.1-2013 Baseline	ECM17 : R20 under the slab	% change	ECM18 : no insulation under the slab	% change	ECM19 : R10 under the slab	% change
Cooling -Sensible	Underground Surface Conduction (Kbtu/h)	-5.875	-1.854	106%	-2.515	108%	-3.202	110%
Heating- Sensible	Underground Surface Conduction (Kbtu/h)	-7.124	-2.233	98%	-3.05	97%	-3.898	96%



QUINN EVANS

Analysis: Slab Study

Cost Saving Analysis	Slab Study - Whole Building Model																			
End Use	90.1-2013 Baseline				ECM17 : R20 under the slab				Energy Savings	ECM18 : no insulation under the slab				Energy Savings	ECM19 : R10 under the slab				Energy Savings
	Electricity (kWh)	Natural Gas (Therms)	Total Energy Usage (kBtu)	Percent of Total (%)	Electricity (kWh)	Natural Gas (Therms)	Total Energy Usage (kBtu)	Percent of Total (%)	Percent (%)	Electricity (kWh)	Natural Gas (Therms)	Total Energy Usage (kBtu)	Percent of Total (%)	Percent (%)	Electricity (kWh)	Natural Gas (Therms)	Total Energy Usage (kBtu)	Percent of Total (%)	Percent (%)
Interior Lighting	135,822	-	463,425	17.9%	120,731	-	411,934	25.6%	11%	120,731	-	411,934	25.4%	11%	120,731	-	411,934	25.4%	11%
Exterior Lighting	1,752	-	5,978	0.2%	1,226	-	4,183	0.3%	30%	1,226	-	4,183	0.3%	30%	1,226	-	4,183	0.3%	30%
Misc. Equipment	118,940	-	405,823	15.7%	118,506	-	404,342	25.1%	0%	118,506	-	404,342	25.0%	0%	118,506	-	404,342	24.9%	0%
Space Heating	391	5,918	593,135	22.9%	10,401	-	35,488	2.2%	94%	13,651	-	46,577	2.9%	92%	15,589	-	53,190	3.3%	91%
Space Cooling	128,693	-	439,099	16.9%	62,082	-	211,824	13.2%	52%	61,623	-	210,258	13.0%	52%	60,895	-	207,774	12.8%	53%
Heat Rejection	-	-	-	0.0%	8,916	-	30,421	1.9%	n/a	8,859	-	30,227	1.9%	n/a	8,724	-	29,766	1.8%	n/a
Pumps & Aux	1,308	-	4,463	0.2%	44,577	-	152,097	9.4%	-3308%	44,562	-	152,046	9.4%	-3307%	44,558	-	152,032	9.4%	-3307%
Ventilation Fans	70,803	-	241,580	9.3%	71,393	-	243,593	15.1%	-1%	71,728	-	244,736	15.1%	-1%	71,223	-	243,013	15.0%	-1%
Refrig Display	-	-	-	0.0%	-	-	-	0.0%	n/a	-	-	-	0.0%	n/a	-	-	-	0.0%	n/a
Heat Pump Supplement	-	-	-	0.0%	1	-	3	0.0%	n/a	1	-	3	0.0%	n/a	1	-	3	0.0%	n/a
Domestic Hot Water	-	4,373	437,300	16.9%	33,945	-	115,820	7.2%	74%	33,945	-	115,820	7.1%	74%	33,945	-	115,820	7.1%	74%
Total Energy by Utility	457,709	10,291	2,590,802	100.0%	471,778	-	1,609,707	100.0%		474,832	-	1,620,127	100.0%		475,398	-	1,622,058	100.0%	
Rooftop PV production	-	-	-		-	-	-			-	-	-			-	-	-		
Total Energy minus PV production	457,709	10,291	2,590,802		471,778	-	1,609,707			474,832	-	1,620,127			475,398	-	1,622,058		
Site Energy (kBtu)	1,561,702	1,029,100			1,609,707	-			Energy Savings	1,620,127	-			Energy Savings	1,622,058	-			Energy Savings
Site EUI (kBtu/ft^2)			43.51				27.04		37.9%			27.21		37.5%			27.24		37.4%
Total Cost by Type	$ 58,587	$ 12,720			$ 60,388	$ -			Cost Savings	$ 60,778	$ -			Cost Savings	$ 60,851	$ -			Cost Savings
Total Energy Cost	$		71,306		$		60,388		15.3%	$		60,778		14.8%	$		60,851		14.7%

90.1-2013 Baseline
HVAC: PTAC
Heating - 80% et boiler eff
Cooling - 9.95 EER
DHW-Gas storage water heater 80% et
Envelope
Ext Wall: U-0.064
Roof: U-0.032
Slab : F-0.52 (R-15 for 24 in.)
Exposed Floor: U-0.038
Below Grade Wall: C-0.092
Window: U-0.35, SHGC-0.4
Door: U-0.5
WWR NW-17%
WWR NE-17%
WWR SE-17%
WWR SW-17%
Double Pane Window
No Shading

ECM17 : R20 under the slab
HVAC: Chiltrix Heat Pump
Heating - 3.92 COP (IPLV)
Cooing - 23 EER (IPLV)
Heat Pump Water Heater - 3.75 COP
Envelope
Ext Wall: U-0.03
Roof: U-0.02
Slab : R-20 below slab
Exposed Floor: U-0.05
Below Grade Wall: C-0.063
Window: U-0.24, SHGC-0.3
Door: U-0.25
WWR NW-15%
WWR NE-15%
WWR SE-15%
WWR SW-15%
Double Pane Window
No Shading

ECM18 : no insulation under the slab
HVAC: Chiltrix Heat Pump
Heating - 3.92 COP (IPLV)
Cooing - 23 EER (IPLV)
Heat Pump Water Heater - 3.75 COP
Envelope
Ext Wall: U-0.03
Roof: U-0.02
Slab : no insulation below slab
Exposed Floor: U-0.05
Below Grade Wall: C-0.063
Window: U-0.24, SHGC-0.3
Door: U-0.25
WWR NW-15%
WWR NE-15%
WWR SE-15%
WWR SW-15%
Double Pane Window
No Shading

ECM19 : R10 under the slab
HVAC: Chiltrix Heat Pump
Heating - 3.92 COP (IPLV)
Cooing - 23 EER (IPLV)
Heat Pump Water Heater - 3.75 COP
Envelope
Ext Wall: U-0.03
Roof: U-0.02
Slab : R-10 below slab
Exposed Floor: U-0.05
Below Grade Wall: C-0.063
Window: U-0.24, SHGC-0.3
Door: U-0.25
WWR NW-15%
WWR NE-15%
WWR SE-15%
WWR SW-15%
Double Pane Window
No Shading

QUINN EVANS

Energy Model - Wall

ECM #	Wall - Baseline – 2x6 with 1.5” continuous insulation (ECM-1 with Chilltrix)	Site EUI	Annual Energy Cost
10	2x6 with 1.5" continuous insulation	27.22	$60,807
11	2x6 with 3” continuous insulation	27.26	$60,885
12	2x8 with 1" continuous insulation	27.20	$60,827
13	2x8 with 3” continuous insulation	27.30	$60,926

Analysis: Wall Study, whole building model

Cost Saving Analysis	Wall Study - Whole Building Model																				
End Use	90.1-2013 Baseline				ECM10 : 2x6 with 1.5" c.i.				Energy Savings	ECM11 : 2x6 with 3" c.i.				Energy Savings	ECM12 : 2x8 with 1" c.i.				Energy Savings	ECM13 : 2x8 with 3" c.i.				Energy Savings
	Electricity (kWh)	Natural Gas (Therms)	Total Energy Usage (kBtu)	Percent of Total (%)	Electricity (kWh)	Natural Gas (Therms)	Total Energy Usage (kBtu)	Percent of Total (%)	Percent (%)	Electricity (kWh)	Natural Gas (Therms)	Total Energy Usage (kBtu)	Percent of Total (%)	Percent (%)	Electricity (kWh)	Natural Gas (Therms)	Total Energy Usage (kBtu)	Percent of Total (%)	Percent (%)	Electricity (kWh)	Natural Gas (Therms)	Total Energy Usage (kBtu)	Percent of Total (%)	Percent (%)
Interior Lighting	135,822	-	463,425	17.9%	120,731	-	411,934	25.4%	11%	120,731	-	411,934	25.4%	11%	120,731	-	411,934	25.4%	11%	120,731	-	411,934	25.4%	11%
Exterior Lighting	1,752	-	5,978	0.2%	1,226	-	4,183	0.3%	30%	1,226	-	4,183	0.3%	30%	1,226	-	4,183	0.3%	30%	1,226	-	4,183	0.3%	30%
Misc. Equipment	118,940	-	405,823	15.7%	118,506	-	404,342	24.9%	0%	118,506	-	404,342	24.9%	0%	118,506	-	404,342	24.9%	0%	118,506	-	404,342	24.9%	0%
Space Heating	391	5,918	593,135	22.9%	16,393	-	55,933	3.5%	91%	15,365	-	52,425	3.2%	91%	16,074	-	54,844	3.4%	91%	14,918	-	50,900	3.1%	91%
Space Cooling	128,693	-	439,099	16.9%	59,480	-	202,946	12.5%	54%	60,724	-	207,190	12.8%	53%	59,845	-	204,191	12.6%	53%	61,323	-	209,234	12.9%	52%
Heat Reiection	-	-	-	0.0%	8,726	-	29,773	1.8%	n/a	8,680	-	29,616	1.8%	n/a	8,712	-	29,725	1.8%	n/a	8,659	-	29,545	1.8%	n/a
Pumps & Aux	1,308	-	4,463	0.2%	44,521	-	151,906	9.4%	-3304%	44,569	-	152,069	9.4%	-3307%	44,530	-	151,936	9.4%	-3304%	44,581	-	152,110	9.4%	-3308%
Ventilation Fans	70,803	-	241,580	9.3%	71,526	-	244,047	15.1%	-1%	71,915	-	245,374	15.1%	-2%	71,642	-	244,443	15.1%	-1%	72,092	-	245,978	15.1%	-2%
Refrig Display	-	-	-	0.0%	-	-	-	0.0%	n/a	-	-	-	0.0%	n/a	-	-	-	0.0%	n/a	-	-	-	0.0%	n/a
Heat Pump Supplement	-	-	-	0.0%	1	-	3	0.0%	n/a	1	-	3	0.0%	n/a	1	-	3	0.0%	n/a	1	-	3	0.0%	n/a
Domestic Hot Water	-	4,373	437,300	16.9%	33,945	-	115,820	7.1%	74%	33,945	-	115,820	7.1%	74%	33,945	-	115,820	7.1%	74%	33,945	-	115,820	7.1%	74%
Total Energy by Utility	457,709	10,291	2,590,802	100.0%	475,055	-	1,620,888	100.0%		475,662	-	1,622,959	100.0%		475,212	-	1,621,423	100.0%		475,982	-	1,624,051	100.0%	
Rooftop PV production	-	-	-		-	-	-			-	-	-			-	-	-			-	-	-		
Total Energy minus PV production	457,709	10,291	2,590,802		475,055	-	1,620,888			475,662	-	1,622,959			475,212	-	1,621,423			475,982	-	1,624,051		
Site Energy (kBtu)	1,561,702	1,029,100			1,620,888	-			Energy Savings	1,622,959	-			Energy Savings	1,621,423	-			Energy Savings	1,624,051	-			Energy Savings
Site EUI (kBtu/ft^2)			43.51				27.22		37.4%			27.26		37.4%			27.2		37.4%			27.3		37.3%
Total Cost by Type	$ 58,587	$ 12,720			$ 60,807	$ -			Cost Savings	$ 60,885	$ -			Cost Savings	$ 60,827	$ -			Cost Savings	$ 60,926	$ -			Cost Savings
Total Energy Cost	$		71,306		$		60,807		14.7%	$		60,885		14.6%	$		60,827		14.7%	$		60,926		14.6%

90.1-2013 Baseline
HVAC: PTAC
Heating - 80% et boiler eff
Cooling - 9.95 EER
DHW-Gas storage water heater 80% et
Envelope
Ext Wall: U-0.064
Roof: U-0.032
Slab : F-0.52 (R-15 for 24 in.)
Exposed Floor: U-0.038
Below Grade Wall: C-0.092
Window: U-0.35, SHGC-0.4
Door: U-0.5
WWR NW-17%
WWR NE-17%
WWR SE-17%
WWR SW-17%
Double Pane Window
No Shading

ECM10 : 2x6 with 1.5" c.i.
HVAC: Chiltrix Heat Pump
Heating - 3.92 COP (IPLV)
Cooing - 23 EER (IPLV)
Heat Pump Water Heater - 3.75 COP
Envelope
Ext Wall: U-0.042
Roof: U-0.02
Slab : R-10 below slab
Exposed Floor: U-0.05
Below Grade Wall: C-0.063
Window: U-0.24, SHGC-0.3
Door: U-0.25
WWR NW-15%
WWR NE-15%
WWR SE-15%
WWR SW-15%
Double Pane Window
No Shading

ECM11 : 2x6 with 3" c.i.
HVAC: Chiltrix Heat Pump
Heating - 3.92 COP (IPLV)
Cooing - 23 EER (IPLV)
Heat Pump Water Heater - 3.75 COP
Envelope
Ext Wall: U-0.032
Roof: U-0.02
Slab : R-10 below slab
Exposed Floor: U-0.05
Below Grade Wall: C-0.063
Window: U-0.24, SHGC-0.3
Door: U-0.25
WWR NW-15%
WWR NE-15%
WWR SE-15%
WWR SW-15%
Double Pane Window
No Shading

ECM12 : 2x8 with 1" c.i.
HVAC: Chiltrix Heat Pump
Heating - 3.92 COP (IPLV)
Cooing - 23 EER (IPLV)
Heat Pump Water Heater - 3.75 COP
Envelope
Ext Wall: U-0.039
Roof: U-0.02
Slab : R-10 below slab
Exposed Floor: U-0.05
Below Grade Wall: C-0.063
Window: U-0.24, SHGC-0.3
Door: U-0.25
WWR NW-15%
WWR NE-15%
WWR SE-15%
WWR SW-15%
Double Pane Window
No Shading

ECM13 : 2x8 with 3" c.i.
HVAC: Chiltrix Heat Pump
Heating - 3.92 COP (IPLV)
Cooing - 23 EER (IPLV)
Heat Pump Water Heater - 3.75 COP
Envelope
Ext Wall: U-0.028
Roof: U-0.02
Slab : R-10 below slab
Exposed Floor: U-0.05
Below Grade Wall: C-0.063
Window: U-0.24, SHGC-0.3
Door: U-0.25
WWR NW-15%
WWR NE-15%
WWR SE-15%
WWR SW-15%
Double Pane Window
No Shading

QUINN EVANS

Energy Model - Windows

ECM #	Windows – Baseline – Double pane, no shading, 17% WWR (ECM-1 with Chiltrix)	Site EUI	Annual Energy Cost
1	Double pane with 17% WWR	27.24	$60,851
2	Triple pane with 17% WWR	27.17	$60,691
3	Double pane with 17% WWR and window shading*	26.90	$60,046
4	Triple pane with 17% WWR and window shading*	26.70	$59,688

ECM #	Window to Wall Ratio – Baseline – 15% WWR (ECM-1 with Chiltrix)	Site EUI	Annual Energy Cost
5	Double pane with 15% WWR	27.14	$60,624
6	Triple pane with 20% WWR	27.39	$61,174
7	Double pane with 20% WWR and window shading*	27.01	$60,336
8	Triple pane with 20% WWR	27.31	$60,992
9	Triple pane with 20% WWR and window shading*	27	$60,250

Legend

- **Window shading based on individual window shading shown in the 'Hyacinth's Way_Window Study 08242021' PDF*
- *WWR = Window to Wall Ratio*

QUINN EVANS

Analysis: Window to Wall Ratio (WWR) Study, whole building model

Cost Saving Analysis	WWR Study - Whole Building Model																										
End Use	90.1-2013 Baseline				ECM5 : Double Pane with 15% WWR				Energy Savings	ECM6 : Double Pane with 20% WWR				Energy Savings	ECM7 : Double Pane with Shading with 20% WWR				Energy Savings	ECM8 : Triple Pane with 20% WWR				Energy Savings	ECM9 : Triple Pane with Shading with 20% WWR				Energy Savings
	Electricity (kWh)	Natural Gas (Therms)	Total Energy Usage (kBtu)	Percent of Total (%)	Electricity (kWh)	Natural Gas (Therms)	Total Energy Usage (kBtu)	Percent of Total (%)	Percent (%)	Electricity (kWh)	Natural Gas (Therms)	Total Energy Usage (kBtu)	Percent of Total (%)	Percent (%)	Electricity (kWh)	Natural Gas (Therms)	Total Energy Usage (kBtu)	Percent of Total (%)	Percent (%)	Electricity (kWh)	Natural Gas (Therms)	Total Energy Usage (kBtu)	Percent of Total (%)	Percent (%)	Electricity (kWh)	Natural Gas (Therms)	Total Energy Usage (kBtu)	Percent of Total (%)	Percent (%)
Interior Lighting	135,822	-	463,425	17.9%	120,731	-	411,934	25.5%	11%	120,731	-	411,934	25.3%	11%	120,731	-	411,934	25.6%	11%	120,731	-	411,934	25.3%	11%	120,731	-	411,934	25.6%	11%
Exterior Lighting	1,752	-	5,978	0.2%	1,226	-	4,183	0.3%	30%	1,226	-	4,183	0.3%	30%	1,226	-	4,183	0.3%	30%	1,226	-	4,183	0.3%	30%	1,226	-	4,183	0.3%	30%
Misc. Equipment	118,940	-	405,823	15.7%	118,506	-	404,342	25.0%	0%	118,506	-	404,342	24.8%	0%	118,506	-	404,342	25.1%	0%	118,506	-	404,342	24.9%	0%	118,506	-	404,342	25.1%	0%
Space Heating	391	5,918	593,135	22.9%	15,506	-	52,906	3.3%	91%	15,734	-	53,684	3.3%	91%	15,991	-	54,561	3.4%	91%	15,311	-	52,241	3.2%	91%	15,484	-	52,831	3.3%	91%
Space Cooling	128,693	-	439,099	16.9%	60,077	-	204,983	12.7%	53%	62,061	-	211,752	13.0%	52%	57,857	-	197,408	12.3%	55%	62,090	-	211,851	13.0%	52%	58,464	-	199,479	12.4%	55%
Heat Rejection	-	-	-	0.0%	8,420	-	28,729	1.8%	n/a	9,168	-	31,281	1.9%	n/a	8,299	-	28,316	1.8%	n/a	8,667	-	29,572	1.8%	n/a	7,929	-	27,054	1.7%	n/a
Pumps & Aux	1,308	-	4,463	0.2%	44,533	-	151,947	9.4%	-3305%	44,623	-	152,254	9.3%	-3312%	44,465	-	151,715	9.4%	-3299%	44,569	-	152,069	9.4%	-3307%	44,487	-	151,790	9.4%	-3301%
Ventilation Fans	70,803	-	241,580	9.3%	70,683	-	241,170	14.9%	0%	71,925	-	245,408	15.0%	-2%	70,353	-	240,044	14.9%	1%	71,455	-	243,804	15.0%	-1%	69,929	-	238,598	14.8%	1%
Refrig Display	-	-	-	0.0%	-	-	-	0.0%	n/a	-	-	-	0.0%	n/a	-	-	-	0.0%	n/a	-	-	-	0.0%	n/a	-	-	-	0.0%	n/a
Heat Pump Supplement	-	-	-	0.0%	1	-	3	0.0%	n/a	1	-	3	0.0%	n/a	1	-	3	0.0%	n/a	1	-	3	0.0%	n/a	1	-	3	0.0%	n/a
Domestic Hot Water	-	4,373	437,300	16.9%	33,945	-	115,820	7.2%	74%	33,945	-	115,820	7.1%	74%	33,945	-	115,820	7.2%	74%	33,945	-	115,820	7.1%	74%	33,945	-	115,820	7.2%	74%
Total Energy by Utility	457,709	10,291	2,590,802	100.0%	473,628	-	1,616,019	100.0%		477,920	-	1,630,663	100.0%		471,374	-	1,608,328	100.0%		476,501	-	1,625,821	100.0%		470,702	-	1,606,035	99.9%	
Rooftop PV production	-	-	-		-	-	-			-	-	-			-	-	-			-	-	-			-	-	-		
Total Energy minus PV production	457,709	10,291	2,590,802		473,628	-	1,616,019			477,920	-	1,630,663			471,374	-	1,608,328			476,501	-	1,625,821			470,702	-	1,606,035		
Site Energy (kBtu)	1,561,702	1,029,100			1,616,019	-			Energy Savings	1,630,663	-			Energy Savings	1,608,328	-			Energy Savings	1,625,821	-			Energy Savings	1,606,035	-			Energy Savings
Site EUI (kBtu/ft²)			43.51				27.14		37.6%			27.39		37.1%			27.01		37.9%			27.31		37.2%			27.0		38.0%
Total Cost by Type	$ 58,587	$ 12,720			$ 60,624	$ -			Cost Savings	$ 61,174	$ -			Cost Savings	$ 60,336	$ -			Cost Savings	$ 60,992	$ -			Cost Savings	$ 60,250	$ -			Cost Savings
Total Energy Cost	$		71,306		$		60,624		15.0%	$		61,174		14.2%	$		60,336		15.4%	$		60,992		14.5%	$		60,250		15.5%

90.1-2013 Baseline
HVAC: PTAC
Heating - 80% et boiler eff
Cooling - 9.95 EER
DHW-Gas storage water heater 80% et
Envelope
Ext Wall: U-0.064
Roof: U-0.032
Slab : F-0.52 (R-15 for 24 in.)
Exposed Floor: U-0.038
Below Grade Wall: C-0.092
Window: U-0.35, SHGC-0.4
Door: U-0.5
WWR NW-17%
WWR NE-17%
WWR SE-17%
WWR SW-17%
Double Pane Window
No Shading

ECM5 : Double Pane with 15% WWR
HVAC: Chiltrix Heat Pump
Heating - 3.92 COP (IPLV)
Cooing - 23 EER (IPLV)
Heat Pump Water Heater - 3.75 COP
Envelope
Ext Wall: U-0.03
Roof: U-0.02
Slab : R-10 below slab
Exposed Floor: U-0.05
Below Grade Wall: C-0.063
Window: U-0.24, SHGC-0.3
Door: U-0.25
WWR NW-15%
WWR NE-15%
WWR SE-15%
WWR SW-15%
Double Pane Window
No Shading

ECM6 : Double Pane with 20% WWR
HVAC: Chiltrix Heat Pump
Heating - 3.92 COP (IPLV)
Cooing - 23 EER (IPLV)
Heat Pump Water Heater - 3.75 COP
Envelope
Ext Wall: U-0.03
Roof: U-0.02
Slab : R-10 below slab
Exposed Floor: U-0.05
Below Grade Wall: C-0.063
Window: U-0.24, SHGC-0.3
Door: U-0.25
WWR NW-20%
WWR NE-20%
WWR SE-20%
WWR SW-20%
Double Pane Window
No Shading

ECM7 : Double Pane with Shading with
HVAC: Chiltrix Heat Pump
Heating - 3.92 COP (IPLV)
Cooing - 23 EER (IPLV)
Heat Pump Water Heater - 3.75 COP
Envelope
Ext Wall: U-0.03
Roof: U-0.02
Slab : R-10 below slab
Exposed Floor: U-0.05
Below Grade Wall: C-0.063
Window: U-0.17, SHGC-0.24
Door: U-0.25
WWR NW-20%
WWR NE-20%
WWR SE-20%
WWR SW-20%
Triple Pane Window
Shading

ECM8 : Triple Pane with 20% WWR
HVAC: Chiltrix Heat Pump
Heating - 3.92 COP (IPLV)
Cooing - 23 EER (IPLV)
Heat Pump Water Heater - 3.75 COP
Envelope
Ext Wall: U-0.03
Roof: U-0.02
Slab : R-10 below slab
Exposed Floor: U-0.05
Below Grade Wall: C-0.063
Window: U-0.17, SHGC-0.24
Door: U-0.25
WWR NW-20%
WWR NE-20%
WWR SE-20%
WWR SW-20%
Triple Pane Window
No Shading

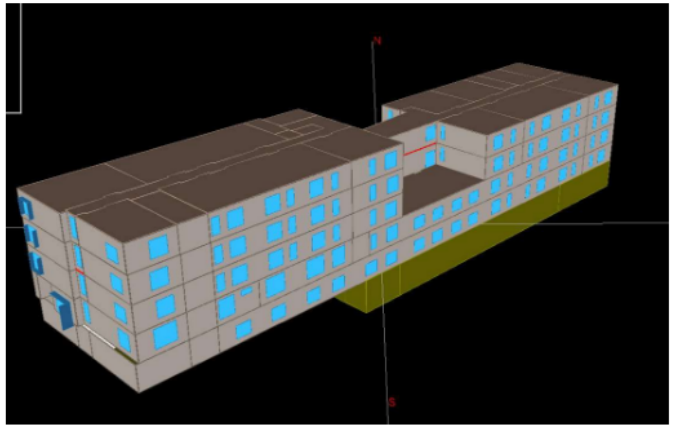
ECM9 : Triple Pane with Shading with
HVAC: Chiltrix Heat Pump
Heating - 3.92 COP (IPLV)
Cooing - 23 EER (IPLV)
Heat Pump Water Heater - 3.75 COP
Envelope
Ext Wall: U-0.03
Roof: U-0.02
Slab : R-10 below slab
Exposed Floor: U-0.05
Below Grade Wall: C-0.063
Window: U-0.17, SHGC-0.24
Door: U-0.25
WWR NW-20%
WWR NE-20%
WWR SE-20%
WWR SW-20%
Triple Pane Window
Shading

QUINN EVANS

Energy Model - Roof

ECM #	Roof – Baseline - R50 above the deck (ECM-1 with Chilltrix)	Site EUI	Annual Energy Cost
14	R50 continuous above the deck	27.24	$60,851
15	R30 continuous above the deck	27.24	$60,854
16	R40 continuous above the deck	27.24	$60,846

Roof Study - Whole Building Model								
Building Peak Load (eQUEST LS-C Report)		90.1-2013 Baseline	ECM14 : R50 above the deck (U-0.02)	% change	ECM15 : R30 above the deck (U-0.032)	% change	ECM16 : R40 above the deck(U-0.025)	% change
Cooling -Sensible	Roof Conduction (Kbtu/h)	29.448	19.278	42%	30.099	9%	24.525	26%
Heating- Sensible	Roof Conduction (Kbtu/h)	-80.337	17.038	117%	-27.552	72%	-21.289	79%



QUINN EVANS

Analysis: Roof Study, whole building model

Cost Saving Analysis	Roof Study - Whole Building Model																			
End Use	90.1-2013 Baseline				ECM14 : R50 above the deck (U-0.02)				Energy Savings	ECM15 : R30 above the deck (U-0.032)				Energy Savings	ECM16 : R40 above the deck(U-0.025)				Energy Savings
	Electricity (kWh)	Natural Gas (Therms)	Total Energy Usage (kBtu)	Percent of Total (%)	Electricity (kWh)	Natural Gas (Therms)	Total Energy Usage (kBtu)	Percent of Total (%)	Percent (%)	Electricity (kWh)	Natural Gas (Therms)	Total Energy Usage (kBtu)	Percent of Total (%)	Percent (%)	Electricity (kWh)	Natural Gas (Therms)	Total Energy Usage (kBtu)	Percent of Total (%)	Percent (%)
Interior Lighting	135,822	-	463,425	17.9%	120,731	-	411,934	25.4%	11%	120,731	-	411,934	25.4%	11%	120,731	-	411,934	25.4%	11%
Exterior Lighting	1,752	-	5,978	0.2%	1,226	-	4,183	0.3%	30%	1,226	-	4,183	0.3%	30%	1,226	-	4,183	0.3%	30%
Misc. Equipment	118,940	-	405,823	15.7%	118,506	-	404,342	24.9%	0%	118,506	-	404,342	24.9%	0%	118,506	-	404,342	24.9%	0%
Space Heating	391	5,918	593,135	22.9%	15,589	-	53,190	3.3%	91%	16,005	-	54,609	3.4%	91%	15,732	-	53,678	3.3%	91%
Space Cooling	128,693	-	439,099	16.9%	60,895	-	207,774	12.8%	53%	60,314	-	205,791	12.7%	53%	60,641	-	206,907	12.8%	53%
Heat Rejection	-	-	-	0.0%	8,724	-	29,766	1.8%	n/a	8,854	-	30,210	1.9%	n/a	8,780	-	29,957	1.8%	n/a
Pumps & Aux	1,308	-	4,463	0.2%	44,558	-	152,032	9.4%	-3307%	44,516	-	151,889	9.4%	-3303%	44,542	-	151,977	9.4%	-3305%
Ventilation Fans	70,803	-	241,580	9.3%	71,223	-	243,013	15.0%	-1%	71,324	-	243,357	15.0%	-1%	71,259	-	243,136	15.0%	-1%
Refrig Display	-	-	-	0.0%	-	-	-	0.0%	n/a	-	-	-	0.0%	n/a	-	-	-	0.0%	n/a
Heat Pump Supplement	-	-	-	0.0%	1	-	3	0.0%	n/a	1	-	3	0.0%	n/a	1	-	3	0.0%	n/a
Domestic Hot Water	-	4,373	437,300	16.9%	33,945	-	115,820	7.1%	74%	33,945	-	115,820	7.1%	74%	33,945	-	115,820	7.1%	74%
Total Energy by Utility	457,709	10,291	2,590,802	100.0%	475,398	-	1,622,058	100.0%		475,422	-	1,622,140	100.0%		475,363	-	1,621,939	100.0%	
Rooftop PV production	-	-	-		-	-	-			-	-	-			-	-	-		
Total Energy minus PV production	457,709	10,291	2,590,802		475,398	-	1,622,058			475,422	-	1,622,140			475,363	-	1,621,939		
Site Energy (kBtu)	1,561,702	1,029,100			1,622,058	-			Energy Savings	1,622,140	-			Energy Savings	1,621,939	-			Energy Savings
Site EUI (kBtu/ft^2)			43.51				27.24		37.4%			27.24		37.4%			27.24		37.4%
Total Cost by Type	$ 58,587	$ 12,720			$ 60,851	$ -			Cost Savings	$ 60,854	$ -			Cost Savings	$ 60,846	$ -			Cost Savings
Total Energy Cost	$		71,306		$		60,851		14.7%	$		60,854		14.7%	$		60,846		14.7%

90.1-2013 Baseline
HVAC: PTAC
Heating - 80% et boiler eff
Cooling - 9.95 EER
DHW-Gas storage water heater 80% et
Envelope
Ext Wall: U-0.064
Roof: U-0.032
Slab : F-0.52 (R-15 for 24 in.)
Exposed Floor: U-0.038
Below Grade Wall: C-0.092
Window: U-0.35, SHGC-0.4
Door: U-0.5
WWR NW-17%
WWR NE-17%
WWR SE-17%
WWR SW-17%
Double Pane Window
No Shading

ECM14 : R50 above the deck (U-0.02)
HVAC: Chiltrix Heat Pump
Heating - 3.92 COP (IPLV)
Cooing - 23 EER (IPLV)
Heat Pump Water Heater - 3.75 COP
Envelope
Ext Wall: U-0.03
Roof: U-0.02
Slab : R-10 below slab
Exposed Floor: U-0.05
Below Grade Wall: C-0.063
Window: U-0.24, SHGC-0.3
Door: U-0.25
WWR NW-15%
WWR NE-15%
WWR SE-15%
WWR SW-15%
Double Pane Window
No Shading

ECM15 : R30 above the deck (U-0.032)
HVAC: Chiltrix Heat Pump
Heating - 3.92 COP (IPLV)
Cooing - 23 EER (IPLV)
Heat Pump Water Heater - 3.75 COP
Envelope
Ext Wall: U-0.03
Roof: U-0.033
Slab : R-10 below slab
Exposed Floor: U-0.05
Below Grade Wall: C-0.063
Window: U-0.24, SHGC-0.3
Door: U-0.25
WWR NW-15%
WWR NE-15%
WWR SE-15%
WWR SW-15%
Double Pane Window
No Shading

ECM16 : R40 above the deck(U-0.025)
HVAC: Chiltrix Heat Pump
Heating - 3.92 COP (IPLV)
Cooing - 23 EER (IPLV)
Heat Pump Water Heater - 3.75 COP
Envelope
Ext Wall: U-0.03
Roof: U-0.025
Slab : R-10 below slab
Exposed Floor: U-0.05
Below Grade Wall: C-0.063
Window: U-0.24, SHGC-0.3
Door: U-0.25
WWR NW-15%
WWR NE-15%
WWR SE-15%
WWR SW-15%
Double Pane Window
No Shading

QUINN EVANS

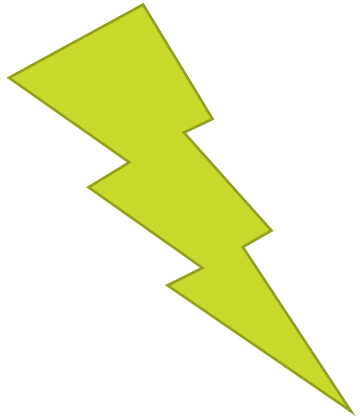
Renewable Energy Analysis

QUINN EVANS

Renewable Energy Analysis

Due to the project location, size, and *the client's desire* to have NO fossil fuels onsite - the following renewable energy analysis was completed to see which would make sense:

- Wind
- Geothermal
- Biomass
- Solar PV
- Combined Heat & Power (CHP)



100% Electric Building

QUINN EVANS

Renewable Energy: WIND Analysis

Small scale or micro-turbine wind power systems can generate electricity with much lower speed wind than the wind speed needed for utility scale wind turbines. Micro-turbines with shrouds such as the Halo 6 kW wind turbine can produce 25,000 kWh/year with average wind speeds of 9 meters/second. Wind speeds in Washington DC are generally below four meters/second at 30 meters above the ground and drop to +/- 2 meters/second in the summer months.

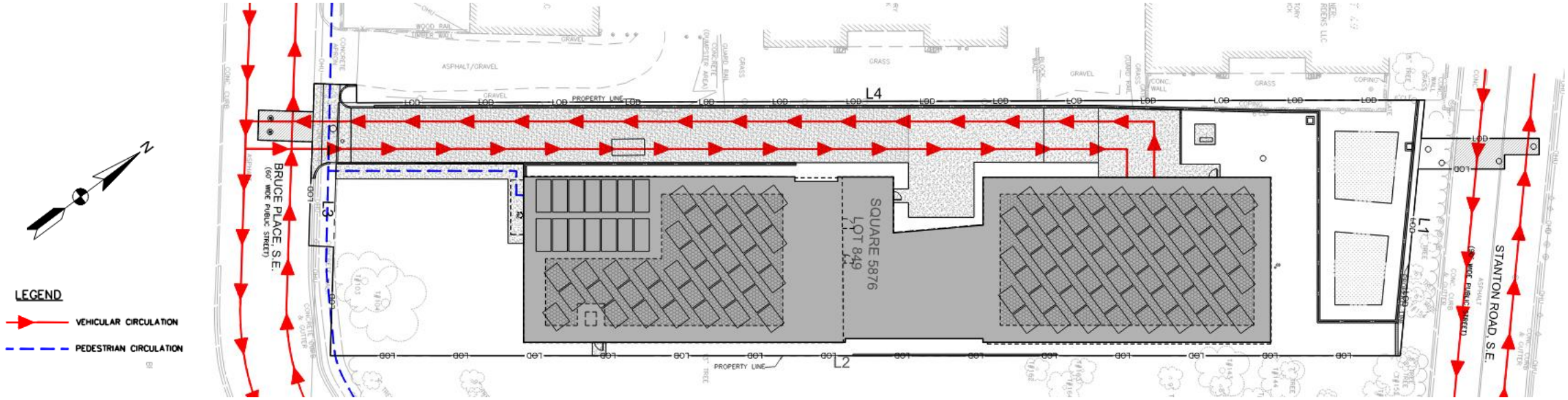
Hyacinth's Way is not a good candidate for micro-wind turbines due to the low wind speed, dense suburban location, small site area and zoning height and setback restrictions

QUINN EVANS

Renewable Energy: GEOTHERMAL Analysis

Geothermal systems are an energy efficient, long-term way to provide space heating and cooling without outdoor mechanical equipment. Geothermal systems for multifamily buildings require a large flat site with truck access for well drilling rigs and dense clay soils. Test wells are often drilled to verify the conductivity, soil type and suitability prior to selecting geothermal for a property. The site (Lot 5876 0849) is in a tight suburban location with 15-40% slopes and has Muirkirk variant complex soil (dense clay). Larger buildings require dozens of deep, vertical wells spaced 20-30 feet on center.

Hyacinth's Way is not a good candidate for a geothermal system due to the narrow, steep site with very little site area available for wells.

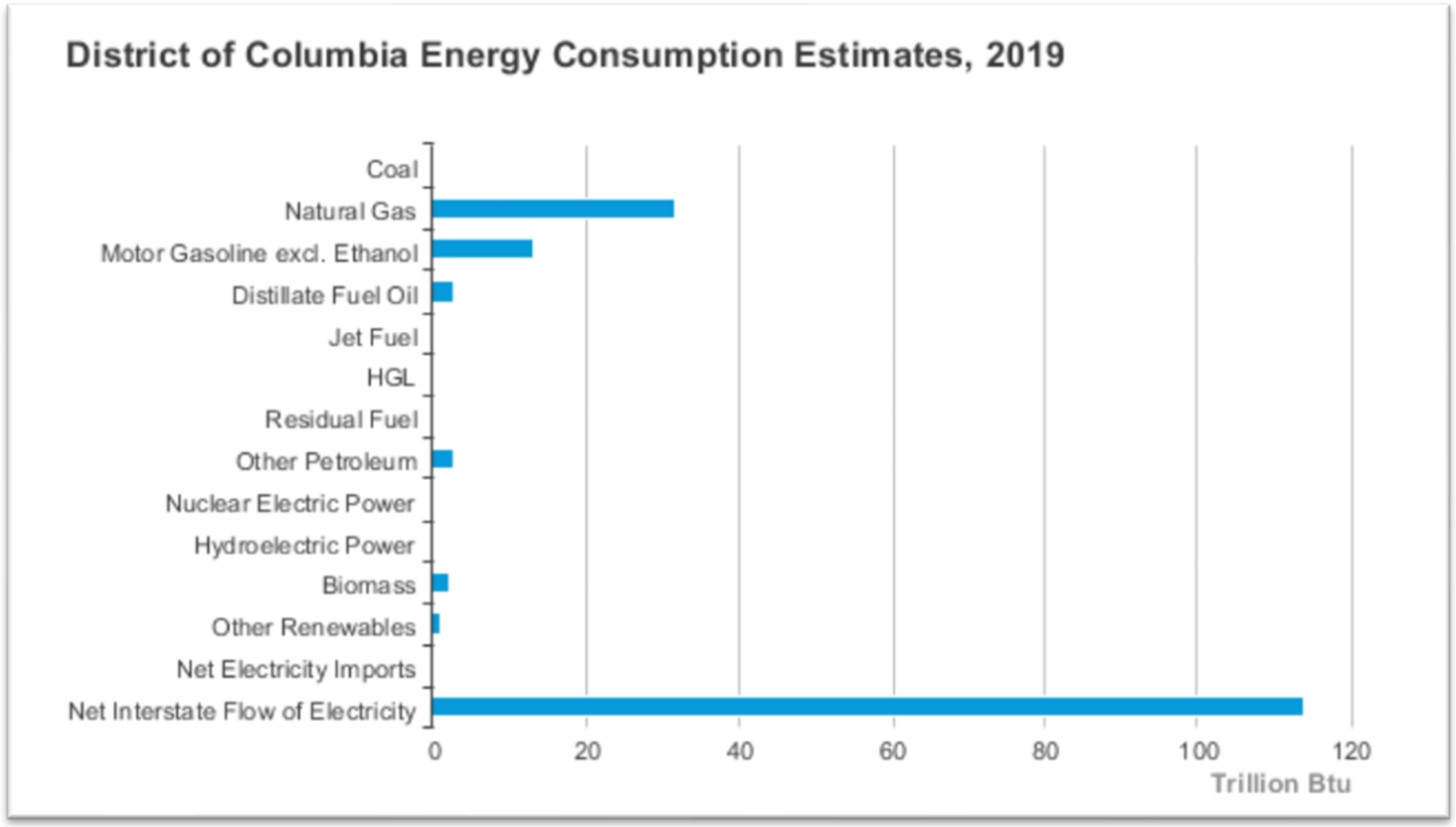


QUINN EVANS

Renewable Energy: BIOMASS Analysis

Biomass for heat or electricity generation is possible through combustion, gasification or digestion of organic materials such as wood, pellets or agricultural waste and can be well suited for municipal or campus facility scales. Biomass is rarely used for individual buildings due to challenges with fuel storage space, emissions regulations and regular maintenance requirements.

Hyacinth's Way is not a good candidate for a biomass facility due to its urban location, lack of onsite storage area and lack of trained staff to maintain a biomass facility. In the District of Columbia, utility scale biomass provided 2.1 trillion Btu of energy in 2019.



QUINN EVANS

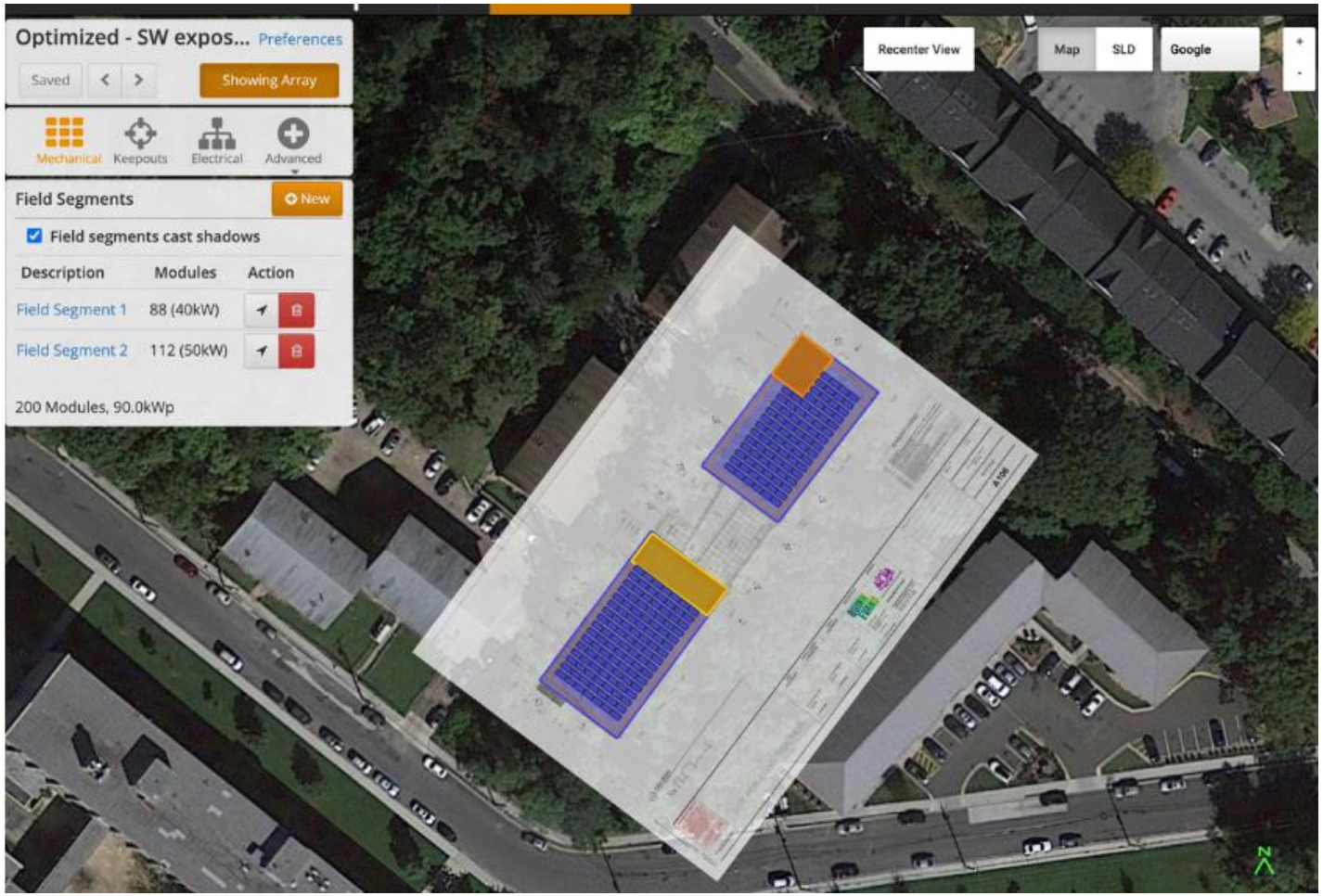
Renewable Energy: SOLAR PV Analysis

New Ecology utilized Helioscope and PV Watts, two online PV design tools, to evaluate the energy generation potential. The following data is from the attached Helioscope Design Reports based on premium equipment (LG450N2W-E6 (2021) panels, SE 100K Solar Edge inverters and P950 2020 Solar Edge optimizers). Please see the design reports for the panel orientation and detailed results. The chart below provides three panel orientation options and the corresponding energy production and dominant generation period. The Southwest panel orientation will provide the majority of energy production concurrently with the highest energy demand from the building and grid – summer afternoon/ evenings.

Hyacinth's Way is an excellent candidate for a solar PV system due to the available clear area on the flat roof and the lack of adjacent buildings. Additional financial metrics will be explored as the design progresses.

Panel Orientation	kW System Size	Annual kWh energy to grid	Dominant kWh generation period	Installation cost ($3,500/kW)	Azimuth
Due South	78	116,136	Midday	$273,000	180
Southeast	82	117,098	Morning	$287,000	127
Southwest	90	130,004	Afternoon	$315,000	216

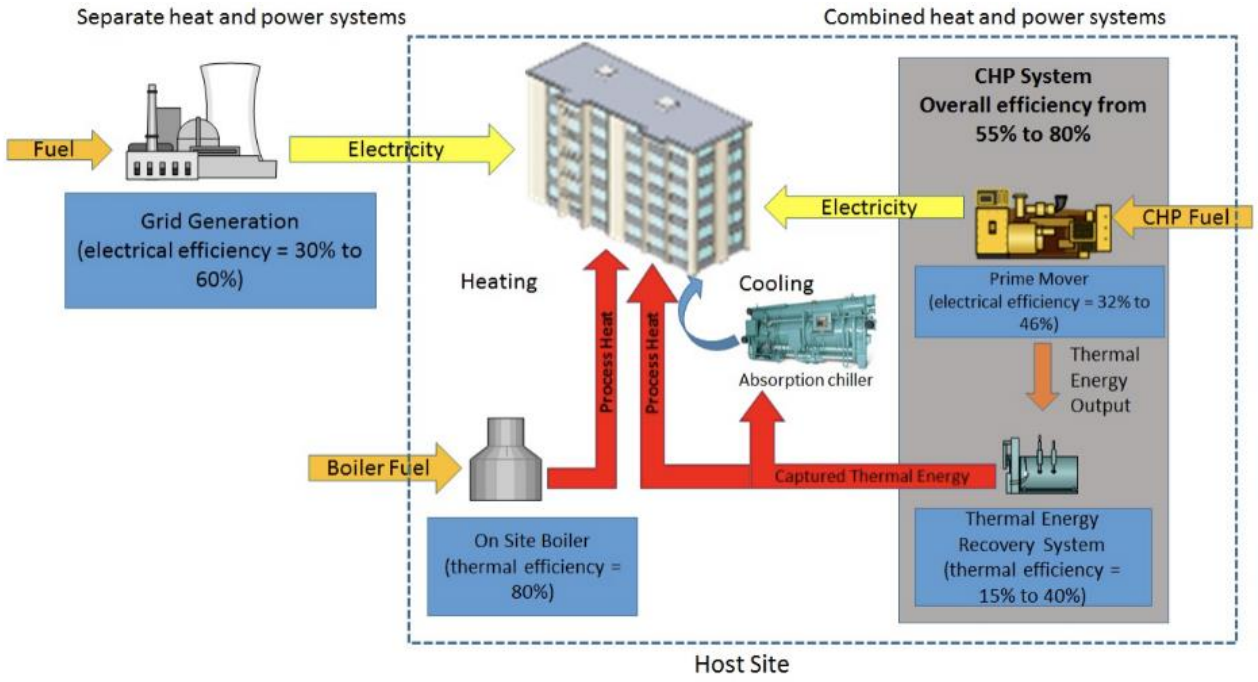
Renewable Energy: SOLAR PV Analysis (con't)



QUINN EVANS

Renewable Energy Analysis: CHP

This building is projected to use under 100kW peak demand, and New Ecology selected the PEPCO utility rate correspondingly (general service low voltage). If the electric rates were higher as in other parts of the country it would make sense to run the engine for more hours per year. Considering the above, the inclusion of the CHP is a net negative when considering financial outlays. There is a modest savings in carbon emissions with the 15kW CHP relative to the “business as usual” case, but the upfront money spent on the CHP system could probably be used elsewhere for even greater carbon savings. In other words, this building does not appear to be a good candidate due to relatively low electricity cost and limited thermal demand.



QUINN EVANS

Summary & Lessons Learned

QUINN EVANS

Detailed Findings

- Energy modeling tells a partial story of the building's performance. Resident comfort is based on their perception of temperature, relative humidity, ventilation and light levels. A resident sitting by a south facing window in July may be more comfortable if direct sunlight is shielded by an exterior sunshade or a higher performance window. Some IEQ measures (higher ventilation rates) actually increase energy usage while supporting resident health and comfort.

- Achieving net zero energy performance requires each building and site element to be optimized for energy use while maintaining resident comfort, building durability and operational costs.

Hyacinth's Net Zero Conclusions

End Use	Percent of Total (%)
Interior Lighting	25.4%
Exterior Lighting	0.3%
Misc. Equipment	24.9%
Space Heating	3.3%
Space Cooling	12.8%
Heat Rejection	1.8%
Pumps & Aux	9.4%
Ventilation Fans	15.0%
Domestic Hot Water	7.1%
Total Energy by Utility	100.0%

- Starting with a high performance baseline (R10 slab, R30 walls, R50 roof, Chilltrix air to water heat pumps and heat pump water heaters) reduces the energy devoted to heating & cooling to a small fraction of the total building usage.

- Sixty-five percent of the building energy use is from interior lighting (25%), miscellaneous equipment and plug loads (25%), and ventilation fans (15%). In schematic design the energy model uses assumptions for these building elements. As the design progresses, total energy use can be reduced through selection and control of MEP systems and equipment. Conversations with the owner, design team, and general contractor will help select the appropriate equipment to satisfy the owner's project requirements.

- Engagement of the owner and facilities personnel will be critical to training future occupants how to efficiently utilize the building.

- Each subsequent proposed envelope energy conservation measure (ECM) barely moves the dial towards the goal of net zero energy operation.

- We modeled triple pane windows, decreased window to wall ratios, window shading and increased envelope insulation with little change to the building's site EUI (kBtu/ft2) or total energy cost. When space heating accounts for 3% and space cooling accounts for 12% of total building energy use, envelope ECMs affect a percent of a percent of the total energy use. Especially since much of the cooling load is a result of internal gains, not external factors.

QUINN EVANS

Grant Funding Specific Impacts

- Additional funding for the design team to explore additional energy iterations and run more energy models which otherwise would not have happened inside the base contract.
- These take aways will impact design of future projects at QE and provide a basis for conversation with other design professionals.

QUINN EVANS

Appendix: Helioscope Reports

QUINN EVANS

Optimized - SE exposure Hyacinth's Way, 1400 Bruce Place SE, Washington DC 20020

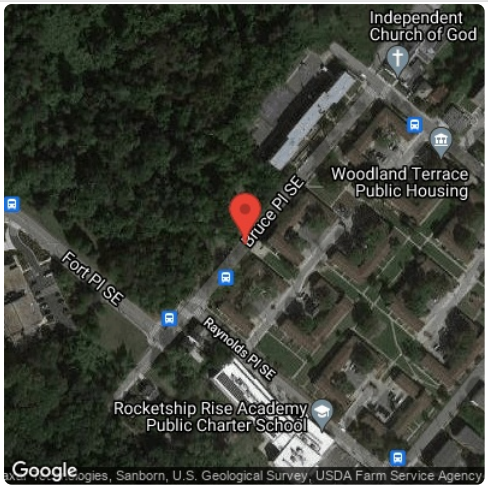
Report

Project Name	Hyacinth's Way
Project Address	1400 Bruce Place SE, Washington DC 20020
Prepared By	Thomas Chase chase@newecology.org

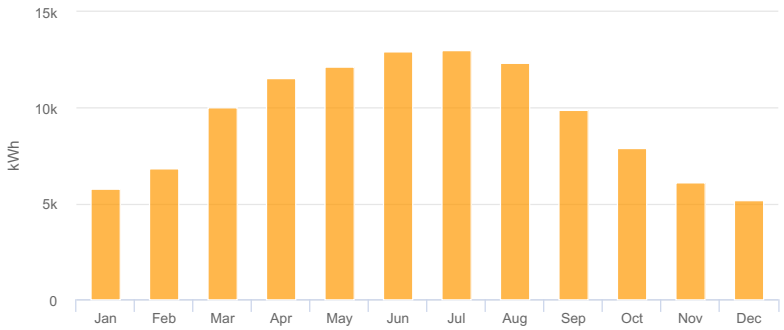
System Metrics

Design	Optimized - SE exposure
Module DC Nameplate	82.4 kW
Inverter AC Nameplate	100.0 kW Load Ratio: 0.82
Annual Production	113.7 MWh
Performance Ratio	84.9%
kWh/kWp	1,380.1
Weather Dataset	TMY, 10km grid (38.85,-76.95), NREL (prospector)
Simulator Version	362e109bb2-05c5082544-9b08ed4f25-7da5631730

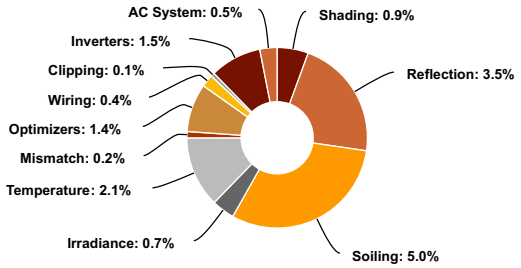
Project Location



Monthly Production



Sources of System Loss



Annual Production

	Description	Output	% Delta
Irradiance (kWh/m²)	Annual Global Horizontal Irradiance	1,549.9	
	POA Irradiance	1,625.2	4.9%
	Shaded Irradiance	1,610.4	-0.9%
	Irradiance after Reflection	1,553.8	-3.5%
	Irradiance after Soiling	1,476.1	-5.0%
	Total Collector Irradiance	**1,476.1**	**0.0%**
Energy (kWh)	Nameplate	121,675.7	
	Output at Irradiance Levels	120,868.6	-0.7%
	Output at Cell Temperature Derate	118,378.1	-2.1%
	Output After Mismatch	118,160.7	-0.2%
	Optimizer Output	116,504.7	-1.4%
	Optimal DC Output	116,083.6	-0.4%
	Constrained DC Output	115,963.5	-0.1%
	Inverter Output	114,224.1	-1.5%
	Energy to Grid	**113,653.0**	**-0.5%**
Temperature Metrics			
	Avg. Operating Ambient Temp		15.8 °C
	Avg. Operating Cell Temp		23.6 °C
Simulation Metrics			
	Operating Hours		4674
	Solved Hours		4674

Condition Set

Description	Condition Set 2
Weather Dataset	TMY, 10km grid (38.85,-76.95), NREL (prospector)
Solar Angle Location	Meteo Lat/Lng
Transposition Model	Perez Model
Temperature Model	Sandia Model

Temperature Model Parameters

Rack Type	a	b	Temperature Delta
Fixed Tilt	-3.56	-0.075	3°C
Flush Mount	-2.81	-0.0455	0°C
East-West	-3.56	-0.075	3°C
Carport	-3.56	-0.075	3°C

Soiling (%)

J	F	M	A	M	J	J	A	S	O	N	D
5	5	5	5	5	5	5	5	5	5	5	5

Irradiation Variance	5%
Cell Temperature Spread	4° C
Module Binning Range	-2.5% to 2.5%
AC System Derate	0.50%

Module Characterizations

Module	Uploaded By	Characterization
LG450N2W-E6 (2021) (LG)	Folsom Labs	Spec Sheet Characterization, PAN

Component Characterizations

Device	Uploaded By	Characterization

Components

Component	Name	Count
Inverters	SE100K (SolarEdge)	1 (100.0 kW)
Strings	10 AWG (Copper)	6 (1,121.9 ft)
Optimizers	P950 (2020) (SolarEdge)	93 (88.4 kW)
Module	LG, LG450N2W-E6 (2021) (450W)	183 (82.4 kW)

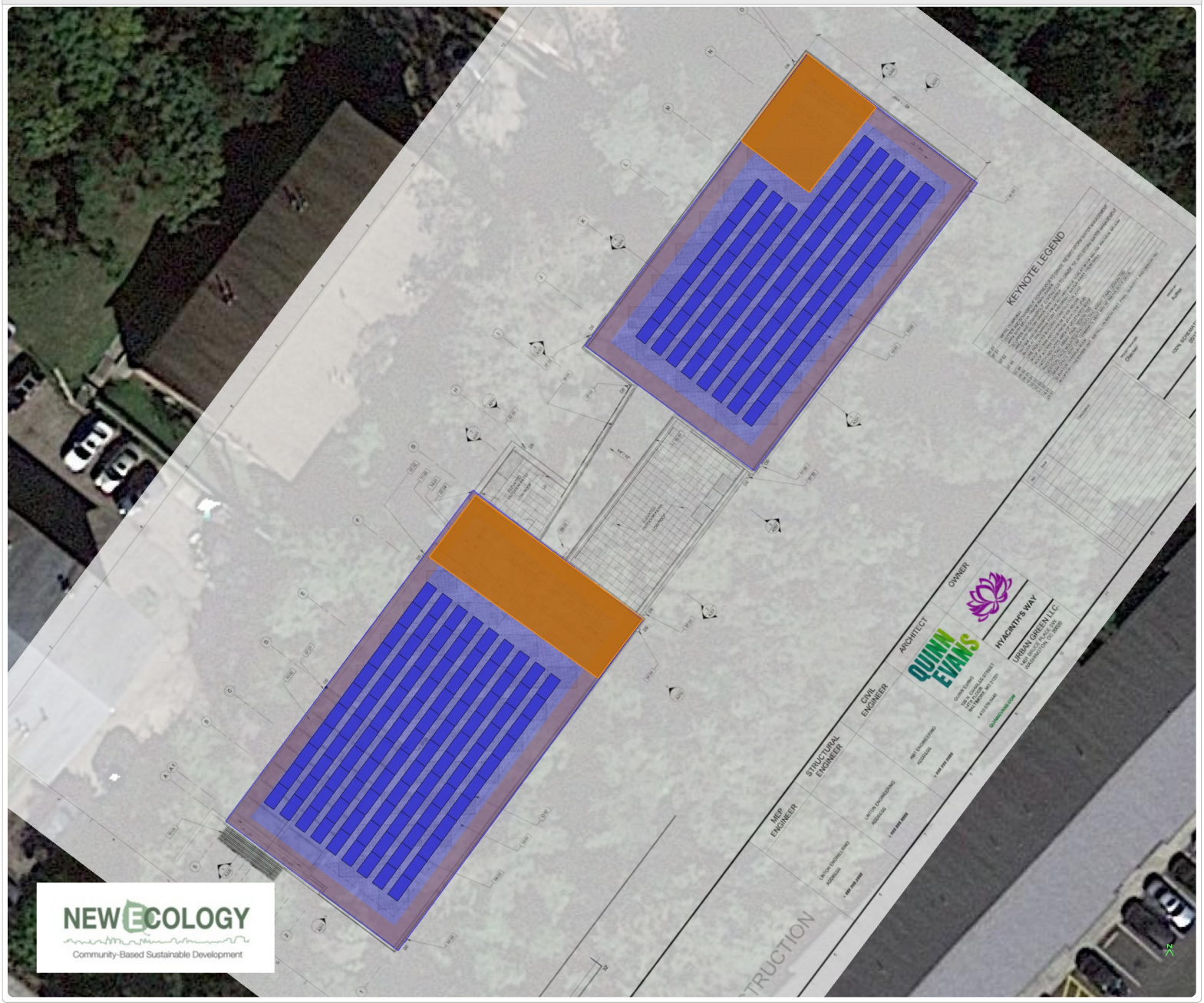
Wiring Zones

Description	Combiner Poles	String Size	Stringing Strategy
Wiring Zone	-	13-31	Along Racking

Field Segments

Description	Racking	Orientation	Tilt	Azimuth	Intrarow Spacing	Frame Size	Frames	Modules	Power
Field Segment 1	Fixed Tilt	Landscape (Horizontal)	10°	127.793945°	2.0 ft	1x1	84	84	37.8 kW
Field Segment 2	Fixed Tilt	Landscape (Horizontal)	10°	126.4883°	2.0 ft	1x1	99	99	44.6 kW

Detailed Layout



Optimized - Southern Exposure Hyacinth's Way, 1400 Bruce Place SE, Washington DC 20020

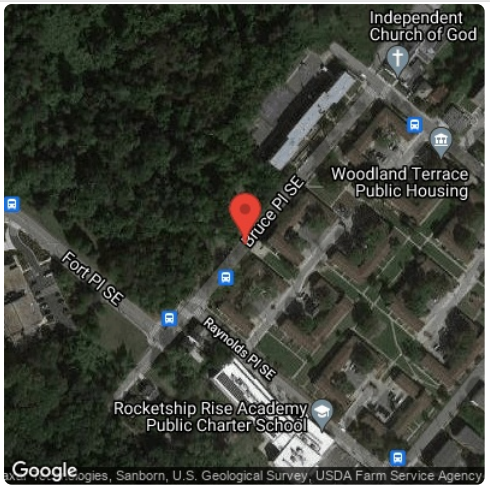
Report

Project Name	Hyacinth's Way
Project Address	1400 Bruce Place SE, Washington DC 20020
Prepared By	Thomas Chase chase@newecology.org

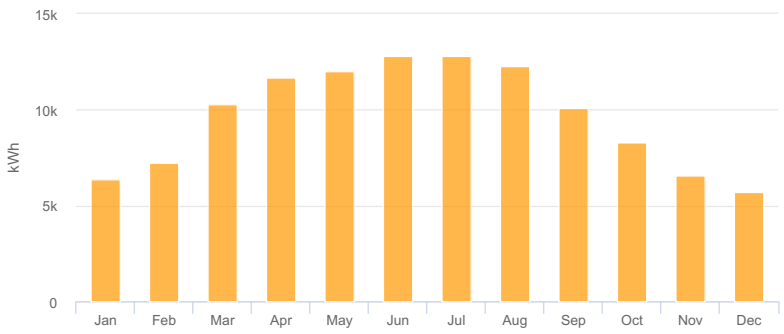
System Metrics

Design	Optimized - Southern Exposure
Module DC Nameplate	78.8 kW
Inverter AC Nameplate	100.0 kW Load Ratio: 0.79
Annual Production	116.1 MWh
Performance Ratio	87.8%
kWh/kWp	1,474.7
Weather Dataset	TMY, 10km grid (38.85,-76.95), NREL (prospector)
Simulator Version	e2238d69b7-7405e28364-14e4487edb-3db1ffd089

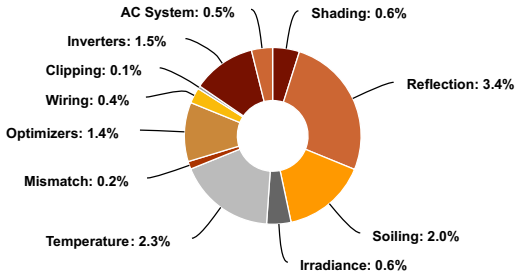
Project Location



Monthly Production



Sources of System Loss



Annual Production

	Description	Output	% Delta
Irradiance (kWh/m²)	Annual Global Horizontal Irradiance	1,549.9	
	POA Irradiance	1,678.9	8.3%
	Shaded Irradiance	1,668.3	-0.6%
	Irradiance after Reflection	1,611.6	-3.4%
	Irradiance after Soiling	1,579.3	-2.0%
	Total Collector Irradiance	**1,579.3**	**0.0%**
Energy (kWh)	Nameplate	124,494.0	
	Output at Irradiance Levels	123,775.0	-0.6%
	Output at Cell Temperature Derate	120,931.3	-2.3%
	Output After Mismatch	120,709.2	-0.2%
	Optimizer Output	119,017.7	-1.4%
	Optimal DC Output	118,578.6	-0.4%
	Constrained DC Output	118,497.1	-0.1%
	Inverter Output	116,719.6	-1.5%
	Energy to Grid	**116,136.0**	**-0.5%**
Temperature Metrics			
	Avg. Operating Ambient Temp		15.8 °C
	Avg. Operating Cell Temp		24.1 °C
Simulation Metrics			
	Operating Hours		4674
	Solved Hours		4674

Condition Set

Description	Condition Set 1
Weather Dataset	TMY, 10km grid (38.85,-76.95), NREL (prospector)
Solar Angle Location	Meteo Lat/Lng
Transposition Model	Perez Model
Temperature Model	Sandia Model

Temperature Model Parameters

Rack Type	a	b	Temperature Delta
Fixed Tilt	-3.56	-0.075	3°C
Flush Mount	-2.81	-0.0455	0°C

Soiling (%)

J	F	M	A	M	J	J	A	S	O	N	D
2	2	2	2	2	2	2	2	2	2	2	2

Irradiation Variance	5%
Cell Temperature Spread	4° C
Module Binning Range	-2.5% to 2.5%
AC System Derate	0.50%

Module Characterizations

Module	Uploaded By	Characterization
LG450N2W-E6 (2021) (LG)	Folsom Labs	Spec Sheet Characterization, PAN

Component Characterizations

Device	Uploaded By	Characterization

Components

Component	Name	Count
Inverters	SE100K (SolarEdge)	1 (100.0 kW)
Strings	10 AWG (Copper)	6 (1,200.1 ft)
Optimizers	P950 (2020) (SolarEdge)	90 (85.5 kW)
Module	LG, LG450N2W-E6 (2021) (450W)	175 (78.8 kW)

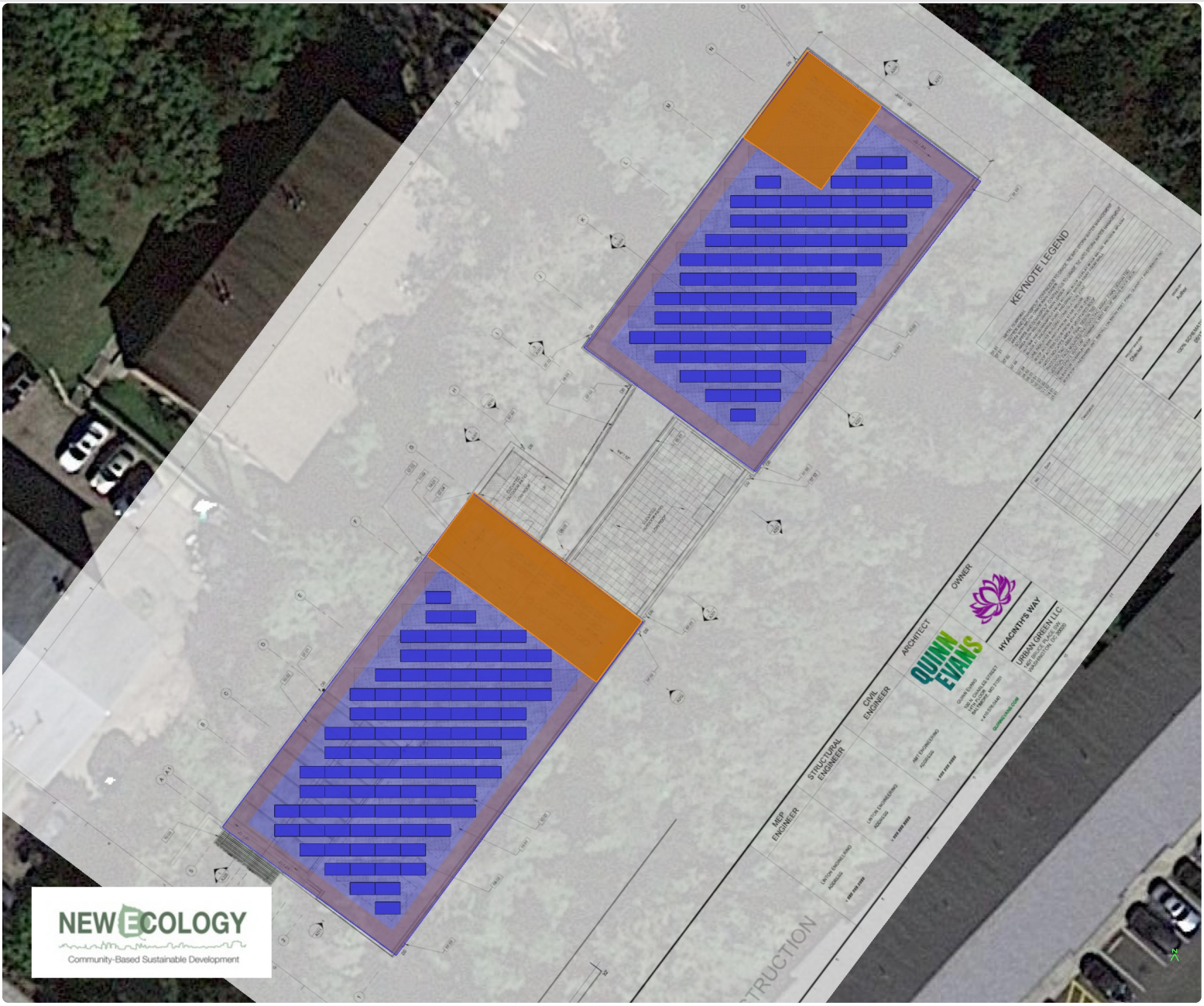
Wiring Zones

Description	Combiner Poles	String Size	Stringing Strategy
Wiring Zone	-	13-31	Along Racking

Field Segments

Description	Racking	Orientation	Tilt	Azimuth	Intrarow Spacing	Frame Size	Frames	Modules	Power
Field Segment 1	Fixed Tilt	Landscape (Horizontal)	10°	180°	2.0 ft	1x1	82	82	36.9 kW
Field Segment 2	Fixed Tilt	Landscape (Horizontal)	10°	180°	2.0 ft	1x1	93	93	41.9 kW

Detailed Layout



Optimized - SW exposure Hyacinth's Way, 1400 Bruce Place SE, Washington DC 20020

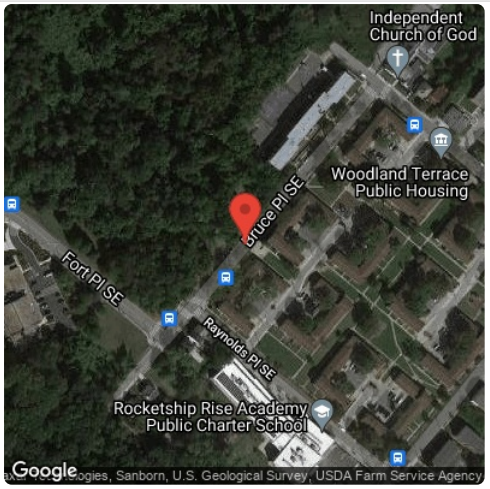
Report

Project Name	Hyacinth's Way
Project Address	1400 Bruce Place SE, Washington DC 20020
Prepared By	Thomas Chase chase@newecology.org

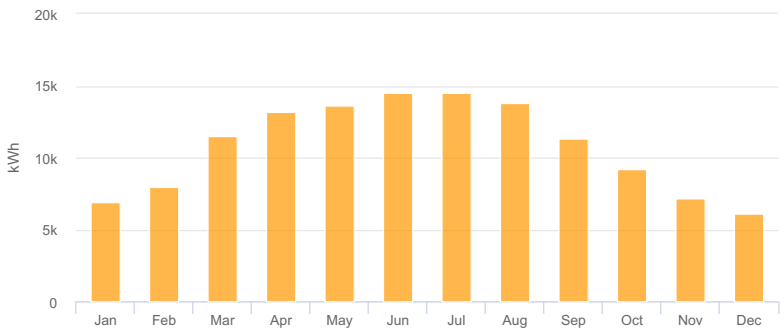
System Metrics

Design	Optimized - SW exposure
Module DC Nameplate	90.0 kW
Inverter AC Nameplate	100.0 kW Load Ratio: 0.90
Annual Production	130.0 MWh
Performance Ratio	87.5%
kWh/kWp	1,444.5
Weather Dataset	TMY, 10km grid (38.85,-76.95), NREL (prospector)
Simulator Version	e2238d69b7-7405e28364-14e4487edb-3db1ffd089

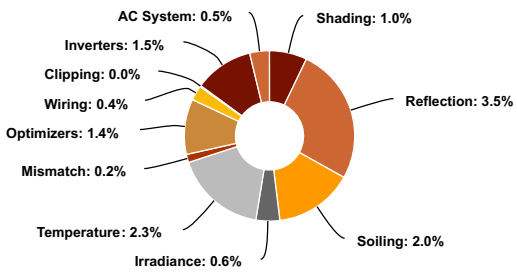
Project Location



Monthly Production



Sources of System Loss



Annual Production

	Description	Output	% Delta
Irradiance (kWh/m²)	Annual Global Horizontal Irradiance	1,549.9	
	POA Irradiance	1,651.8	6.6%
	Shaded Irradiance	1,636.1	-1.0%
	Irradiance after Reflection	1,579.2	-3.5%
	Irradiance after Soiling	1,547.6	-2.0%
	Total Collector Irradiance	**1,547.7**	**0.0%**
Energy (kWh)	Nameplate	139,429.0	
	Output at Irradiance Levels	138,585.4	-0.6%
	Output at Cell Temperature Derate	135,365.6	-2.3%
	Output After Mismatch	135,084.9	-0.2%
	Optimizer Output	133,189.0	-1.4%
	Optimal DC Output	132,685.6	-0.4%
	Constrained DC Output	132,647.7	0.0%
	Inverter Output	130,658.0	-1.5%
	Energy to Grid	**130,004.7**	**-0.5%**
Temperature Metrics			
	Avg. Operating Ambient Temp		15.8 °C
	Avg. Operating Cell Temp		23.9 °C
Simulation Metrics			
	Operating Hours		4674
	Solved Hours		4674

Condition Set

Description	Condition Set 1
Weather Dataset	TMY, 10km grid (38.85,-76.95), NREL (prospector)
Solar Angle Location	Meteo Lat/Lng
Transposition Model	Perez Model
Temperature Model	Sandia Model

Temperature Model Parameters

Rack Type	a	b	Temperature Delta
Fixed Tilt	-3.56	-0.075	3°C
Flush Mount	-2.81	-0.0455	0°C

Soiling (%)

J	F	M	A	M	J	J	A	S	O	N	D
2	2	2	2	2	2	2	2	2	2	2	2

Irradiation Variance	5%
Cell Temperature Spread	4° C
Module Binning Range	-2.5% to 2.5%
AC System Derate	0.50%

Module Characterizations

Module	Uploaded By	Characterization
LG450N2W-E6 (2021) (LG)	Folsom Labs	Spec Sheet Characterization, PAN

Component Characterizations

Device	Uploaded By	Characterization

Components

Component	Name	Count
Inverters	SE100K (SolarEdge)	1 (100.0 kW)
Strings	10 AWG (Copper)	7 (1,395.6 ft)
Optimizers	P950 (2020) (SolarEdge)	102 (96.9 kW)
Module	LG, LG450N2W-E6 (2021) (450W)	200 (90.0 kW)

Wiring Zones

Description	Combiner Poles	String Size	Stringing Strategy
Wiring Zone	-	13-31	Along Racking

Field Segments

Description	Racking	Orientation	Tilt	Azimuth	Intrarow Spacing	Frame Size	Frames	Modules	Power
Field Segment 1	Fixed Tilt	Landscape (Horizontal)	10°	216.46193°	2.0 ft	1x1	88	88	39.6 kW
Field Segment 2	Fixed Tilt	Landscape (Horizontal)	10°	216.86934°	2.0 ft	1x1	112	112	50.4 kW

Detailed Layout