CycleHouse
Final Project Report
September 30, 2019

I. CycleHouse Design Summit: Integrative Design for the District of Columbia's First Mixed-Use Net Zero Energy Building

DOEE Grant ID #: 2019-1912-USA-2 / PO606524 -NZE Design Assistance Grant - Flywheel
Award Period: 7/15/19 through 9/30/19
Progress Reporting Period: 7/15/19 through 9/30/19
Grantee Organization Name: Flywheel Development LLC
Grantee Primary Contact: Jessica Pitts, jpitts@flywheeldevelopment.com; 202.403.7338

II. Status Report

As of September 30th, 2019, the project team reports that the project is completed and has met its budget targets.

Project Overview
CycleHouse is a mixed-use new construction project delivering 16 affordable rental apartments (30-60% area median income) as well as ground floor level retail/commercial space. Located at the corner of North Capitol and Bates Streets NW in the Truxton Circle neighborhood at 1520 North Capitol Street NW, the project responds to multiple goals set by the Department of Energy and Environment (DOEE), community groups, and advances Flywheel Development's mission of building sustainable housing.

The project will achieve Net Zero Energy (using the Passive House International methodology for energy use) for the residential component of the project and will attempt to offset the commercial energy use as well. The development team is committed to delivering a project that will serve as a model for future affordable housing construction within the District and across the country.

<u>Development Program</u>
CycleHouse's development program includes 16 rental apartment units and commercial space on the ground floor and basement levels.

CycleHouse Development Program

Unit Type	Bedrooms	Baths	Median Income	Number of Units	Square Feet	Net Zero Energy
1 BR (1 level)	1	1	30-60%	10	570 (net)	Yes
1 BR (2 level)	1	1	30-60%	2	588 (net)	Yes
Studio	1	1	30-60%	3	281 (net)	Yes
3 BR	3	2	30-60%	1	1,050 (net)	Yes

Commercial (2-level)	N/A	N/A	N/A	TBD	6,323 (net)	TBD Onsite
TOTAL				**16**	**20,171 (gross)**	**All**

Sustainability

CycleHouse will be built to the highest sustainable construction standards: Passive House, Net Zero Energy and LEED Gold. The team views this project as an opportunity to work with DOEE to transition sustainable development to the mainstream and improve the sustainability of all development in the District. Flywheel hopes to document each step in the sustainable development process to support the District's sustainable city policy goals.

<u>Passive House Standard</u>

The Passive House standard is a proven method for the design and construction of quiet, comfortable, healthy and durable buildings. It is the only internationally-recognized performance-based energy standard in construction and is often considered the most rigorous voluntary standard in the industry today. Buildings that are Passive House-certified consume roughly 80% less heating and cooling energy and 90% less total energy when compared to other new buildings. Because of this dramatic reduction in the energy consumption of Passive House buildings, achieving Passive House is the most straight-forward way to achieve net zero energy performance.

The Passive House standard prescribes an energy "budget" per square foot (or Energy Use Intensity), and a maximum amount of air leakage acceptable. How to meet the rigorous requirements of Passive House is up to the project team. The flexibility of the Passive House standard enables it to be applied to any construction type, anywhere in the world.

Design & Construction

To achieve the project's construction and performance goals, the team has designed a floor plan that has been optimized for modular construction. See figure 1, below, which shows the second of four residential levels. The team has specified a built-on-site concrete CMU core containing two stairwells, an elevator, and a large area allocated for mechanical systems. The size and location of the dedicated mechanical area was designed to accommodate all the HVAC technologies currently under consideration by the design team such that the building will not have to be redesigned to accommodate any of the systems. As an example, the mechanical space was pushed to the west so that through-wall air intakes can be added on each floor in the event the design team selects an individual ERV system for each floor. If the western-most stair core and mechanical space had their positions reversed, by contrast, the building restriction line to the south would have precluded ERV air intakes and exhausts from the mechanical room.

Outside of the site-built service core, modules constructed offsite will constitute the remainder of the building's residential levels. Each module is envisioned to constitute a whole living unit where possible and also would include the adjacent hall area. In the current plan, each floor would be constructed of approximately seven 13 - 17-foot wide modules. The team has worked to overcome the project site's limitations, namely the small site, lack of south-facing windows due to a zero-lot line condition on the southern property line, and the necessity of using a less-efficient single-loaded corridor design.

The project team has worked to ensure that the early design exercise included a rigorous integrative design process that involved the project developer, architect, modular construction company, and the Mechanical/Electrical/Plumbing engineer (MEP). This strategy recognizes that integrated design is critical to solving design challenges presented by the net zero energy target. Additionally, the collaborative process helps avoid the traditional model of design-bid-build which presents problems even on well-managed conventional projects, let alone a net zero energy buildings where the pathway to success requires greater coordination.

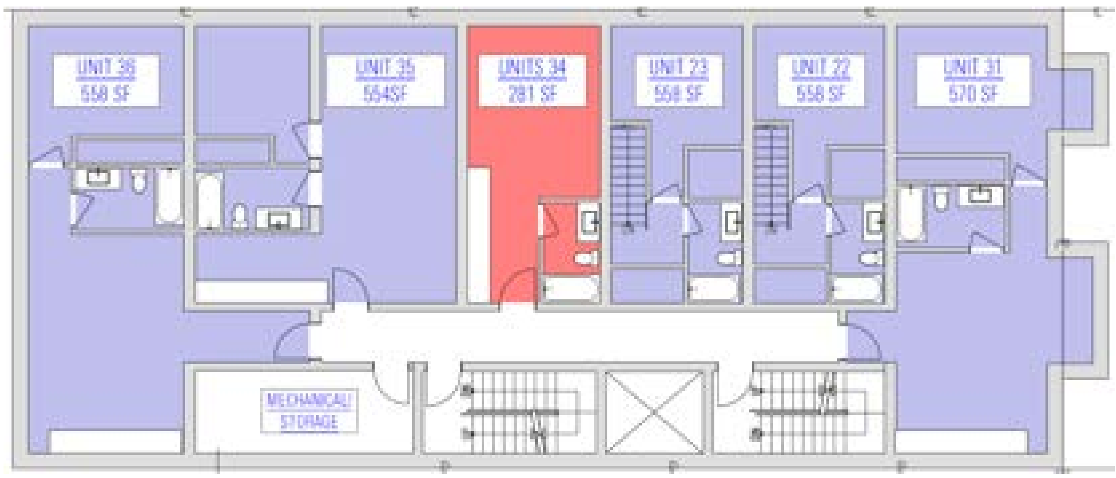


Figure 1: The project's third floor-level includes a variety of floor plans in a modular-friendly configuration constituted of a site-built service core and 7 modules. The westernmost end of the mechanical space affords access to an area where air exhaust and intake is permitted.

<u>Design Team</u>

Flywheel Development has assembled a design team of leading local and regional experts in high performance building design and construction in order to ensure that the programmatic goals for the project are met. The most technically challenging aspect of the project is Passive House certification. To ensure the team is capable of meeting this goal, Flywheel Development has engaged team members from other recent projects including Staengl Engineering, Third Level Design, and CertiPHIers, one of the preeminent Passive House certifiers in the United States, as the third-party certification agency. The team has worked to share lessons learned with the project architect, who will be working on their first Net Zero and Passive House project.

The project team conducted two charrettes to explore creative solutions to the project's engineering challenges: one with the project's architect and a second with the entire staff of the project's MEP, Staengl Engineering.

Figure 2: Charrette meeting of the project team with the MEP engineer

III. Activities/Outputs/Outcomes for Entire Project

Activity #1: Develop Schematic Basement Plans

Project team members collaborated on creation of pre-schematic basement floor plans which calculated the area of the basement, dimensions, and included a preliminary analysis of the basement programming and wall assemblies. The basement gross square footage, 3,692 square feet, will in turn be used for determine the building's required energy demand and will help determine EUI.

Circulation

The team determined that circulation from the ground floor level commercial space to the basement would best be accomplished at least in part by using the footprint of one of the existing stair cores. This strategy would restrict stair access to the basement from within the residential portion of the building on floors 2-5. This decision was made to eliminate duplication of circulation space and is possible because the only residential uses of the basement might include mechanical equipment or battery backup for the building.

Insulation

The team conducted an initial analysis on three basement wall and sub-slab insulation products which would be installed exterior to a cast-in-place concrete basement wall and would in turn be covered by a drain board to facilitate movement of water to the footing-level drains. Options for insulation included foamglass sheets, extruded polystyrene (EPS) rated for direct burial, and mineral wool. The R-values of the three products range from R-3.4 to nearly R-4.9 per inch. Highdensity EPS foam carries the highest R-value in cold conditions (R-4.9) and is the least costly option. However, it may also have the highest initial global warming potential as it is petrochemical derivative in addition to high CO2 impact of the blowing agent used in its manufacture. EPS foam also can degrade over time, even in direct burial application. Foamglass, by contrast, can be made of recycled materials, but has a lower R-value of R-3.4/inch. Mineral wool (in this case Top Rock DD) has an R-value of 4.3 per inch. Mineral wool was ruled out in this analysis because the team was not confident that it could be sufficiently water-proofed to prevent water infiltration into the material, which would substantially reduce its thermal resistance. At this conclusion of this effort, the team has yet to choose between foamglass and EPS foam, and intends to conduct a more detailed comparison of their carbon impact during project design, encompassing embodied energy and ongoing performance.

Activity Outputs, Activity #4:

1) Schematic basement plan
2) Development of sub-surface insulation product comparison

<u>Activity #2: Perform Solar Potential Analyses</u>

In order to design a Net Zero Energy building, the project team undertook several steps to evaluate the solar potential analysis and the building EUI.

Solar Potential Analysis

To ensure we achieve net zero energy performance on site, we always start with the solar potential analysis to set the maximum energy use that the building must meet in order to be net zero on site. This critical first step essentially creates an energy budget for the project. The Project Team used Helioscope and PVWatts to perform this analysis, and analyzed multiple scenarios that will be described below. The solar elements that were evaluated include: 1) a rooftop canopy that extends to the building edge; 2) solar located in the 10-foot setback around the perimeter of the penthouse; 3) a solar carport; and 4) building integrated solar (BIPV) which is constituted of solar affixed directly to the walls of the building.

<u>Scenario 1: Roof Canopy</u>

In the first scenario, a full rooftop canopy was evaluated for solar potential. This roof canopy would extend to beyond the penthouse roof to the perimeter of the building, in a fashion similar to the American Geophysical Union building solar canopy. The canopy would be designed with a flush mount 10-degree tilt configuration to the south to maximize panel count and solar power generation. A canopy configuration was considered because the setback requirements for solar in the building code (4 feet around the perimeter of the building) significantly reduces the amount of solar that can be placed on the roof. In figure 3, the image on the left is the full solar canopy, which totals 64.8 kW, and the image on the right is the solar panel locations feasible on the roof deck and the penthouse that meet the 4-foot setback requirement, which totals 18.4 kW. Note there are no panels in the north setback on the roof deck because these panels would be shaded by the 10-foot tall penthouse story. The solar canopy shown below, by contrast, is un-shaded by adjacent structures or trees.

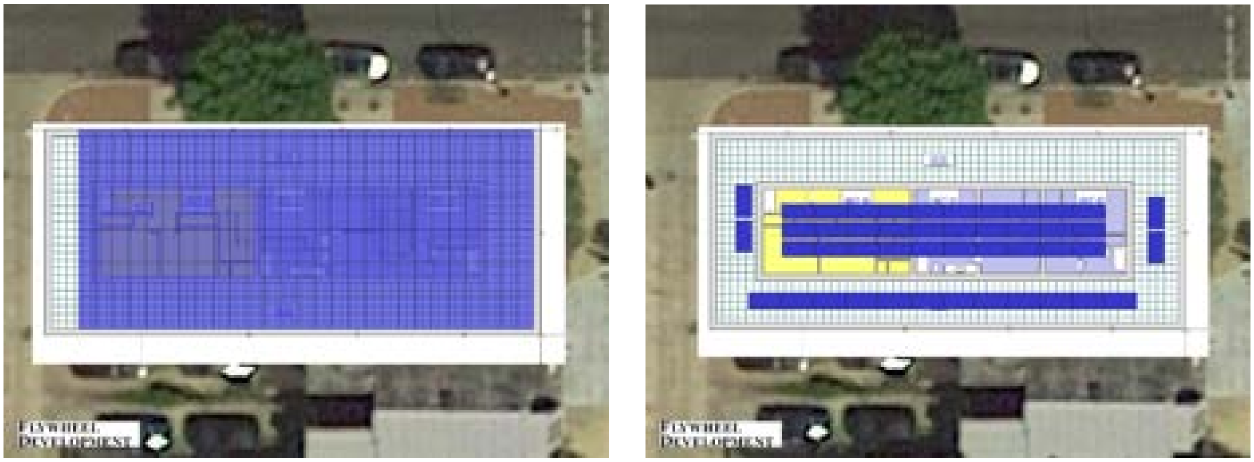


Figure 3: Solar deployment options for the rooftop of CycleHouse. At left, a rooftop array canopy covers the habitable penthouse and extends to the building's perimeter. At right, solar panels are placed on penthouse and surrounding areas – but the panel layout is dramatically reduced due to setback requirements in the building code.

<u>Scenario 2: Solar Carport</u>

The possibility to install a solar carport also exists on the site. The "dog-leg" portion of site includes space behind the adjacent property owners that front onto North Capitol Street, which at the ground level will host four surface parking spots. The parking spaces are shown in the below left picture. Evaluating the solar canopy required estimating the height of nearby structures to understand the impact of shading on the solar canopy's energy production. The image to the right shows the solar canopy with adjacent buildings that produce shading. The total size of the solar canopy is 14.4 kW, however the shading losses from adjacent buildings amount to 17% of the solar potential for the carport, which is a non-ideal shading ratio. Raising the carport from its currently modeled height of 12 feet would improve this shading ratio.

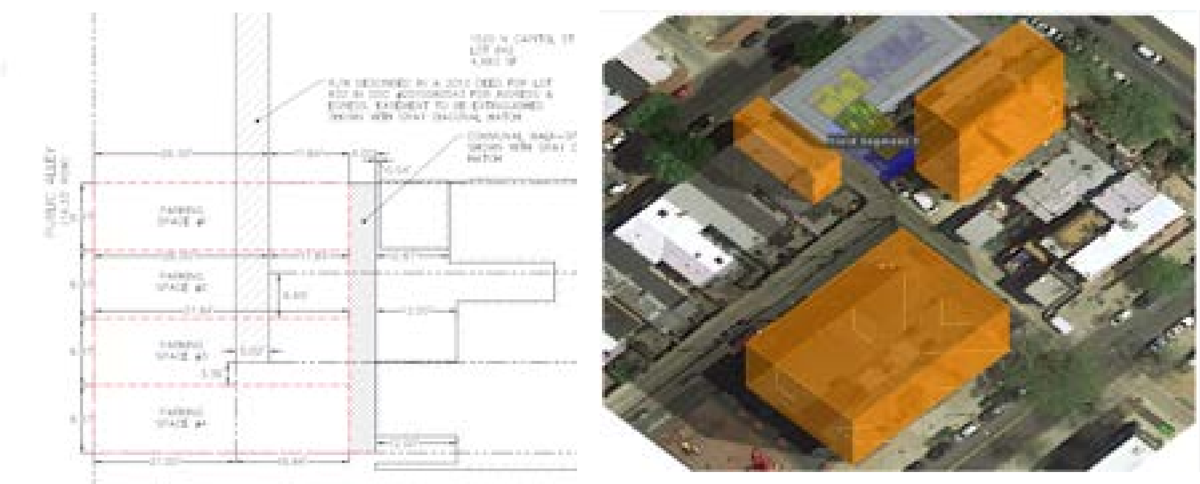


Figure 4: A solar canopy in the "dog leg" portion of the site, which extends behind neighboring storefronts, can yield additional generation. When placed at 12 feet above grade, there is significant shading, which might be reduced by raising the canopy's height.

Scenario 3: Building Integrated PV

The final option available for the CycleHouse project is solar affixed to the walls of the building itself on the south, east and west facades. Helioscope does not work well with vertical solar configurations, so the analysis for BIPV was completed using PVWatts and hand calculations.

The window-to-wall ratio was calculated to take out losses for windows for all facades. Additionally, the south façade includes a large area of at-risk wall, which is excluded from the analysis. The areas included in the building integrated solar analysis are shown below in green.

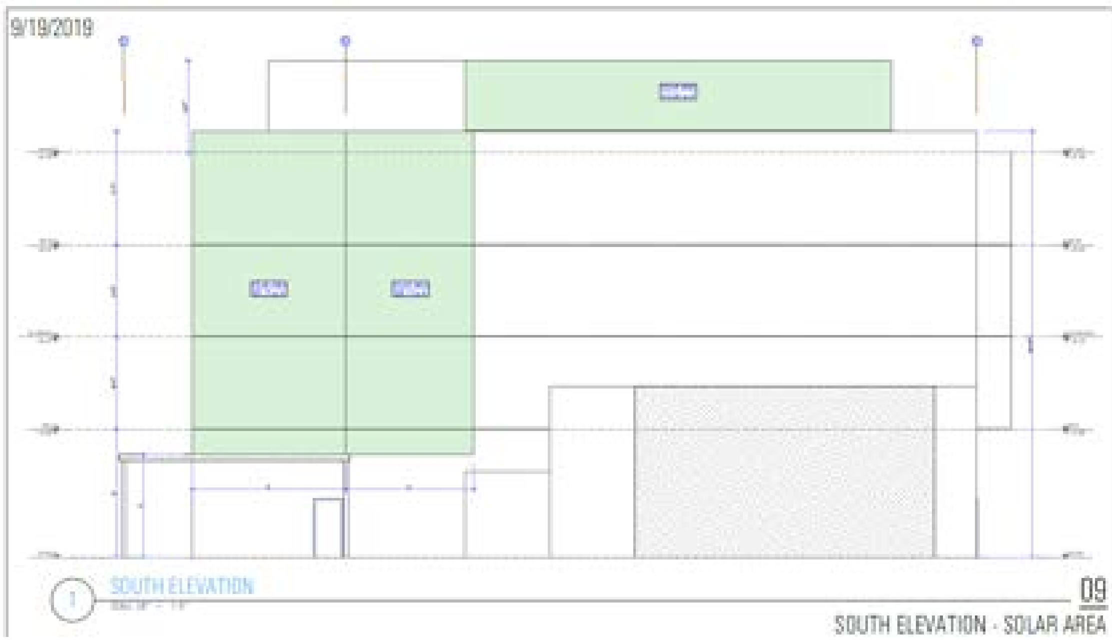


Figure 5: Potential building integrated PV options on the building's southern elevation

The window to wall ratio was factored as close to 90% for the ground floor (commercial space) which means there is limited potential to install solar on the ground floor. On floors two through four and the penthouse (residential floors) the window to wall ratio varied between 12% and 22%, depending on the façade. Since the south façade is the most energy productive façade for BIPV, a lower window to wall ratio was considered.

The west façade abuts an alley, and based on the sun studies, the top three floors and the penthouse will remain unshaded until about 6 pm on June 21st, the best day of the year. On December 21st, the worst day of the year, the second floor begins to be shaded by the adjacent building at about 3:30 pm. The east façade faces North Capitol St. There are two street trees that might shade the façade in the very early morning, but the trees do not appear tall enough to cast a shadow onto the second story and above beyond that time.

The total of the solar potential for the BIPV is shown below.

Solar Potential Analysis - BIPV			
Location	Nameplate	Production	Power Factor
West Façade	17.1 kW	11.0 MWh	0.64
East Façade	17.1 kW	13.3 MWh	0.77
South Façade	17.1 kW	15.4 MWh	0.90
West Penthouse Façade	2.55 kW	1.9 MWh	0.74
East Penthouse Façade	2.55 kW	2.0 MWh	0.77
South Penthouse Façade	10.8 kW	10.5 MWh	0.97
Penthouse Roof	16.1 kW	20.6 MWh	1.28
Penthouse Deck	6.4 kW	7.8 MWh	1.22
Total	**83.4 kW**	**82.4 MWh**	0.99

Summary of Options

A table of all of the solar options evaluated is presented below. Note that these options are not additive in all cases. For example, the Roof Canopy and the BIPV at the Penthouse level is mutually exclusive. In terms of energy generation, the total of the BIPV is about as productive, in MWhs, as the Roof Canopy alone.

Solar Potential Analysis - All Options			
Location	Nameplate	Production	Power Factor
BIPV: East + West + South	83.4 kW	82.4 MWh	0.99
Roof Canopy	64.8 kW	82.9 MWh	1.28
Carport	14.4 kW	14.3 MWh	0.99

Energy Use Intensity

The next step is calculating the energy use intensity. The Project Team uses the Passive House maximum allowable energy use per square foot of treated floor area as the "base case" for energy consumption. The Passive House Standard specifies a maximum source energy use for Treated Floor Area (TFA) of 38.04 kBtu / sq ft / year. This is equivalent to 4.29 kWh / sq ft / year of site energy use. TFA is a measure of the usable internal floor area, contained within the Thermal Envelope, which is calculated according to a prescribed method found in the PHPP 9 manual. For the purposes of the schematic-level energy analysis, the Project Team uses a conservative estimate for TFA, based on a percentage of gross floor area. The table below presents the base case for the building using the Passive House standard, and adds in some additional energy use for outdoor elements, such as lighting for the parking lot and trash areas, and security cameras. These would not be included in the PHPP, since these energy uses may not be affixed to the building. The maximum energy use for Passive House is 71,911 kWh / year, and with the additional allowance for exterior energy uses, the EUI is 12.5 kBtu / sq ft.

Passivhaus Requirements	Standard	
Total Source Energy	38.04	kBtu/ft²/year
Total Source Energy	11.15	kWh/ft²/year
Site-Source Energy Conversion	2.60	*conversion from*
Total Site Energy	4.29	kWh/ft²/year

Projected Energy Consumption			
Gross Floor Area	20,171	ft²	
TREATED Floor Area	16,771	ft²	*83.1%*
Building Site Energy Consumption	71,911	kWh/year	
Outdoor Lighting & Other Uses	2,000	kWh/year	
Total Site Energy Consumption	73,911	kWh/year	

Next, the Project Team performed a sensitivity analysis to evaluate what happens when the Passive House requirement is exceeded. Comparing the table below to the solar options demonstrates that the BIPV or the Roof Canopy equal approximately the Passive House + 15% scenario, with an EUI of 13.99. If the Carport is added to either of the BIPV or the Roof Canopy, the total solar generation increases to 97 MWh / year. This combination of solar supports a Passive House + 35% scenario, or an EUI of 16.41.

Sensitivity Analysis

Scenario	kWh/ft²/year	kWh / Yr	EUI
Passivhaus	4.29	73,911	12.50
+ 15%	4.93	82,698	13.99
+ 20%	5.15	86,293	14.60
+ 25%	5.36	89,889	15.21
+ 30%	5.57	93,485	15.81
+ 35%	5.78	97,000	16.41

Activity Outputs, Activity #2:

1) Multiple solar generation pathways exist to ensure that the building achieves Net Zero Energy performance if it hews closely to Passive House energy performance. The residential portion of the building can easily be net zero energy on-site with sufficient solar deployment.
2) It may be possible to achieve net zero energy performance for the entire building, including the commercial space, but the commercial space would need to achieve an EUI significantly better than standard commercial spaces. The energy budget exists on site for the commercial space to exceed Passive House level EUI's, however.

Activity #3: Investigate Promising HVAC Technologies

Project team members analyzed a range of HVAC technologies related to production of hot and cold water to provide hydronic heating/cooling/hot water to each unit. In all cases, the team assumed that in-unit heating, cooling, and dehumidification would be managed by small in-floor fan coil units, which it has determined are a cost-effective solution to serve the very low conditioning loads required for Passive House construction.

Technology strategies explored included:

Heating, Cooling, and Dehumification

1) Sound energy technology: the project team attempted to contact the Dutch-based Sound Energy company but was not able to connect with the company. However, the high decibel rating on the unit raised the possibility that it may not be well-suited to the small basement, which is envisioned to be rentable commercial space.

2) Air source redundant heat pump array: The project team considered a strategy of deploying "dueling" Sanden and Chiltrix-brand air source heat pump units, with each set to provide hot and cold water, respectively. These pre-packaged units have multi-speed settings and because of their high COP showed highly efficient performance in the energy model. By placing the heat pumps in close proximity, the team believes they might achieve bonus heat recovery in the cooling season where heat ejected from the Chiltrix units might be recovered by the Sanden units as they scavenge heat to produce hot water.

3) Heat pumps with ground-source geothermal field: mimicking the system Flywheel is implementing on the Stack Eight project currently in permitting, the team determined that the basement area could easily host the required Water Furnace brand heat pumps and hot- and cold-water buffer tanks and pumps. This system would require the least modification from the company's past HVAC technology selections. The team believes that the area at the rear of the property (where the solar canopy will be installed) contains enough area to drill the 3-4 geothermal walls that are expected to be necessary for the project under this scenario.

4) Heat pumps (air and water source) with CO2 refrigerant: The project team investigated heat pumps from Japanese manufacturer Mayekawa which use CO2 as their refrigerant – which lowers the global warming impact of traditional refrigerants

5) Solar Thermal Dehumidification: during the charrette, the project team discussed multiple dehumification solutions that rely on solar-thermal sourced hot water. These strategies identified included:

   - Desiccant wheel: Instead of traditional chilled water coils, desiccant wheels use hot water and a membrane to remove humidify from the building's incoming fresh air stream by transferring the humidity to the outgoing air stream. The project team is interested in this solution because energy models in the past have shown that there is surplus hot water during the summer that might otherwise not be utilized. Desiccant wheels sometimes have air cross-contamination at the desiccant wheel location, which would need to be managed.

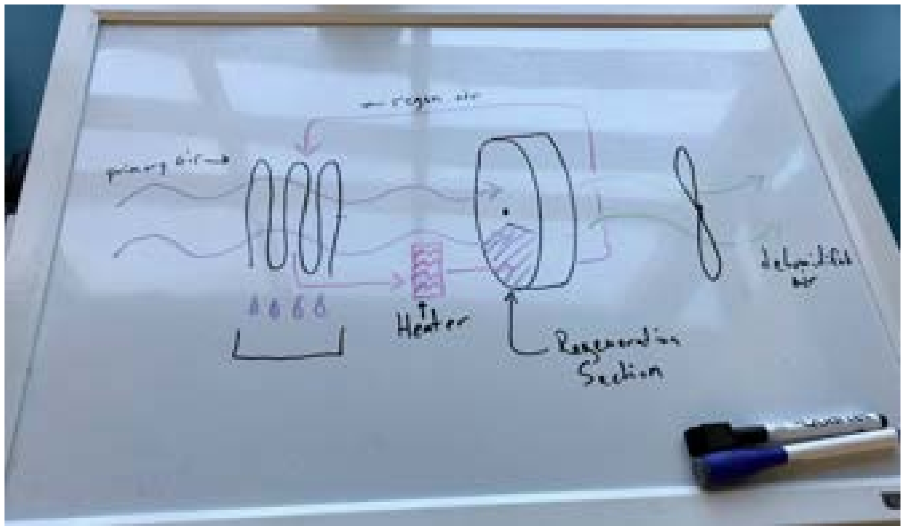


Figure 6: A depiction of desiccant wheel from the MEP charrette

- Adsorption Chillers: the project team also investigated adsorption chillers, such as those offered by Bry-Air, which provide cooling using waste heat. In some cases these systems require a cooling tower, which may prove challenging to locate given the project's need to maximize roof space for solar resources. Nevertheless, this technology seems promising.

<u>Ventilation</u>

The project team also undertook a comprehensive analysis of ventilation solutions. Core areas for consideration included 1) exploring the pros and cons of providing fresh air at the building level vs. an isolated system for each floor 2) protecting tenants from the bad indoor air quality as a result of smoking and vaping in neighboring units. While smoking and vaping will be banned in the building – and the team will investigate use of air quality monitors to remotely detect use – we believe a "belt-and-suspenders strategy" is needed to protect the air quality of residents in the event smoking occurs in a neighboring unit. Cross-contamination of the fresh air stream is now recognized as a significant problem in the District's multifamily buildings as the explosion of marijuana legalization and vaping are reversing the long term decline of indoor smoking.

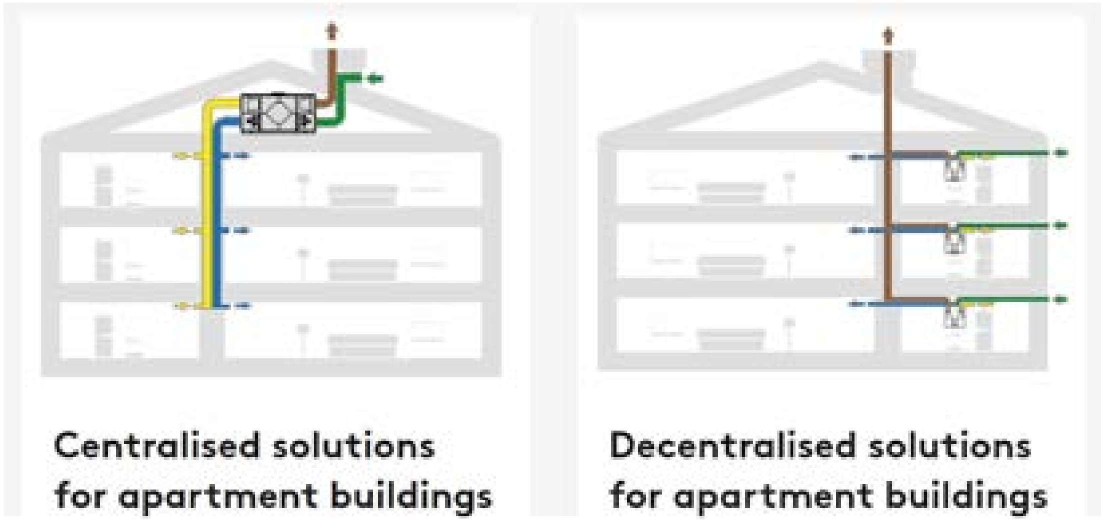


Figure 7: A depiction of ventilation solution options. Source: Swegon.com

ERV Solutions that can work at the building level included ERV products from Swegon and Ventacity. The project team also analyzed ERVs sized to serve each residential floor. These includes products from Zehnder, Jablotron, and Swegon.

Ventilation Ducting

In concert with examination of the ERVs, the team explored the potential to mitigate air cross-contamination between units using constant pressure regulating dampers, air pressure backdraft preventers and sensors that will disengage some HVAC systems when windows are opened. The latter technology is envisioned to also help avoid the split incentive problem – and ensure performance in net zero buildings where delivery of HVAC to each unit is effectively mater metered.

Activity Outputs, Activity #3:

3) Analysis of over a dozen innovative HVAC technologies for application to the CycleHouse project.
4) Identification of multiple HVAC technology combinations which are ideal for further investigation. By beginning this work now, the team will be able to select the best solution as design development progresses.

Activity #4: Perform Hygrothermal Analysis of Envelope Assemblies

As part of this task, the project team sat down with project architect to discuss potential wall assemblies. While the project team will have to wait until the final energy model is produced during design development to select the correct wall assembly, we have undertaken an analysis of multiple wall assemblies with varying R-values. At this point in the project development the team does not have an total R-value "target" for the assemblies because we will need to undertake detailed modeling on the building's unique solar orientation and potentially high internal gains.

As background, when the team began the design process, we believed we would be at a disadvantage from the lack of any south-facing fenestration, which is typically an essential feature of Passive House construction. South-facing windows are seen as essential in typical single-family Passive House construction because they provide winter-time solar heat gain and are likewise shaded in the summer months by overhangs or mechanical shades. However, on this project, the high internal heat gains from the densely packed units – from appliances, building systems, and people within the building – may reduce the need for wintertime solar heat gain significantly. Likewise, in the summer, the south-facing wall of the building may do double-duty as a monolithic insulated surface to deflect heat and as a site for building integrated PV.

For the building walls themselves, we examined a half dozen options but analyzed two assemblies with divergent R-values in greater depth. The first system constituted of a 2 x 8" stud wall with staggered studs and 2" of insulation installed exterior to the building's sheathing. The second system included 5" of exterior insulation on a 2 x 6" stud wall with standard studs.

Both walls performed well in the WUFI analysis undertaken by Third-Level Design, but the sensitivity analysis indicated that a ventilated air gap between the sheathing and cladding was essential in both cases. Additionally, the analysis showed that if the exterior insulation was removed, a smart vapor retarder would be required between the interior side of the stud wall and the interior gypsum drywall board.

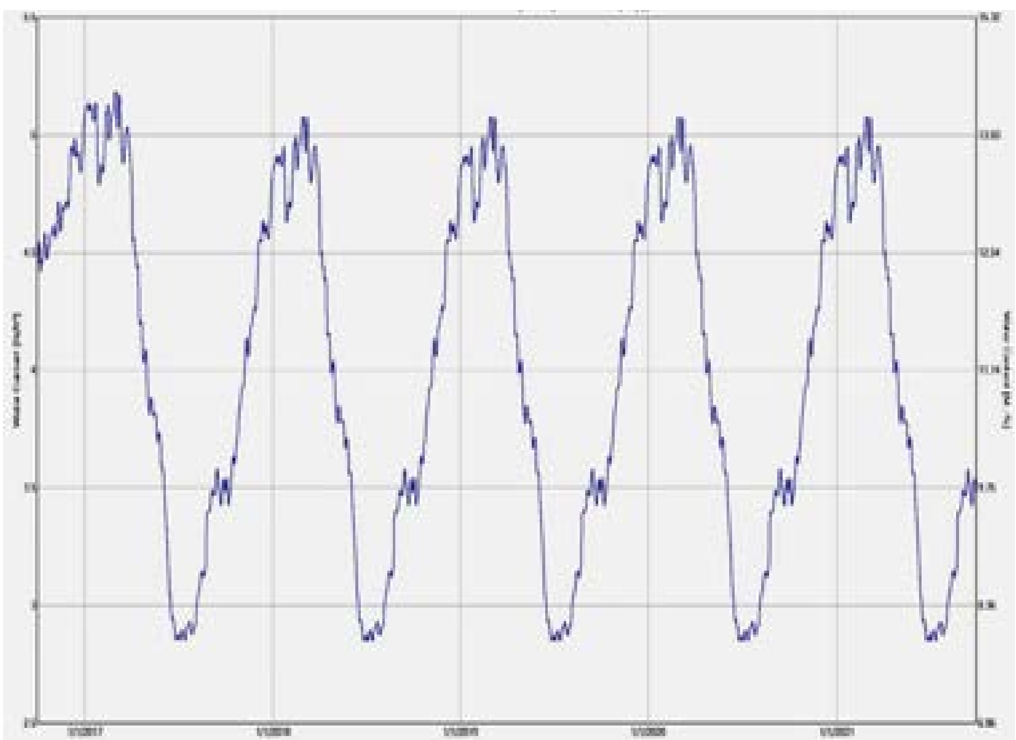


Figure 8: In a wall assembly with a 2 x 8" frame wall and 2 inches of exterior insulation, the wall sheathing moisture content (y-axis) never exceeds 14%, as long as there is an air gap between the cladding and insulation layer. Source: Third Level Design

<u>Activity Outputs, Activity #4:</u>

1) Analysis of a half-dozen wall assemblies

<u>Activity Outcomes, Activity #4:</u>

1) Identification of two workable wall assemblies for use on the project. The final wall assembly will be selected when the project's energy model is further developed.

<u>Activity #5: Perform Solar Zoning Analysis</u>

Achieving net zero energy performance on the project site requires a very-low EUI and significant on-site solar resources. The need to generate electricity on site in handicapped in many ways by the relatively narrow site and the habitable penthouse. Given the required 4' solar setback around all roofs, this diminishes the area available for PV generation. Solutions to produce additional solar power includes three primary options, some of which create new zoning challenges. These strategies and the zoning impacts are:

1) <u>Building integrated PV</u>: this solution – namely replacing the building cladding with solar panels – would add additional production in a vertical condition. While the solar production of panels mounted in this condition is diminished, the zoning impacts are negligible. In fact, zoning regulations protecting solar access would ensure the solar production is not obstructed in the future.

2) <u>A solar canopy in the mechanical penthouse setback:</u> the maximum rooftop solar yield would be achieved with a solar canopy occupying the setback from the mechanical penthouse, extending from the face of the penthouse to the plane of the building footprint below. Because a setback is required under the zoning regulations, relief would be required form the Bureau of Zoning Administration (BZA). The relevant zoning citation is:

   Subtitle C 1502 PENTHOUSE SETBACKS 1502.1 Penthouses, screening around unenclosed mechanical equipment, rooftop platforms for swimming pools, roof decks, trellises, and any guard rail on a roof <u>shall be setback from the edge of the roof upon which it is located as follows: (a) A distance equal to its height from the front building wall of the roof upon which it is located;</u> (b) A distance equal to its height from the rear building wall of the roof upon which it is located;

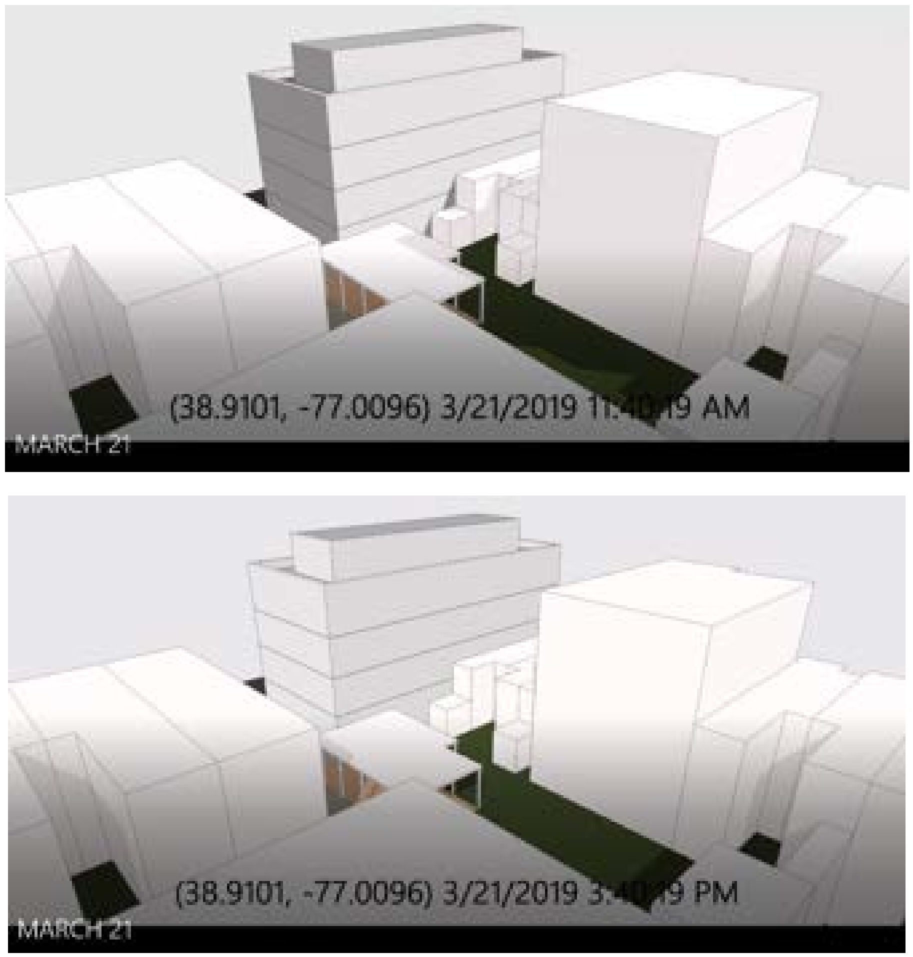
3) <u>Solar Carport at the rear of the property:</u> a solar carport on the "dog-leg" portion of the CycleHouse site behind the three neighboring storefronts could yield a large boost in solar generation for the site, but would also require zoning relief. The relief sought would include:

<u>Lot Occupancy:</u> The MU-4 zoning class caps the lot occupancy (the percentage of the site occupied by buildings) at 75%. By adding a canopy behind the building, lot occupancy would be increased to nearly 100%, which would also require zoning relief

<u>Rear Yard Setback:</u> The schematic plans currently show an approximately 8' setback from the

rear of the building to the alley. The achieve maximum effect, the solar canopy would need to extend into this space, which would require relief from the rear yard requirements.

<u>Accessory Building Height:</u> In a sun study created by the architect, the solar carport is shown set at a height of 12' above the ground. Raising the height of the canopy would significantly increase its generation, but may require zoning relief from requirements related to maximum height of accessory buildings – which is the designation applied to solar carports. At the current height, for instance, on March 31st, the system is partially shaded all hours except for four hours from 11:30 to 3:30 PM. See images in figure 9 below.



Figures 9 depicts a sun study model of the site at two times on the spring equinox (March 21). Raising the canopy from the current height of 12 feet would increase its generation by increasing the hours during which it is not shaded by adjacent buildings. However, this strategy may increase the required zoning relief.

<u>Activity Outputs, Activity #5:</u>

1) Identification of areas of zoning relief needed to increase solar production on the CycleHouse project.

<u>Activity Outcomes, Activity #5:</u>

1) Identification of typical solar use cases and recurrent zoning relief that will be required to achieve net zero performance on future projects in the District.

<u>Activity #6: Report on Work Performed and Results</u>

The project team has conducted periodic updates with DOEE staff to share ongoing lessons learned and with this document has submitted a final report to DOEE.

IV. NEP/LEP

No participants of the project qualify as NEP or LEP.

V. Work Product

Work products produced include:

1) Schematic floor plans
2) Helioscope solar analyses: carport and roof
3) Architect Wall Assembly Studies
4) Sun Study Animations (digital file)

VI. Budget Reporting

The project's final budget activities closely track the original project budget. The project MEP's billing was $1,000 less than originally budgeted and the development team's time was $1,000 higher than budgeted.

CycleHouse Grant Budget

Revised, 9.29.19

Grant Title: CycleHouse Integrated Design Summit				
Budget Category		**Amount Awarded**	**Amount Spent**	**Current Balance**
Personnel				
Staengl Engineering		$6,000.00	$5,000.00	$5,000.00
Emotive Architecture		$3,000.00	$3,000.00	$3,000.00
Third Level Design (WUFI models)		$1,500.00	$1,500.00	$1,500.00
Development Team (Solar Potential Analysis, Zoning Analysis, Report)		$9,000.00	$10,000.00	$10,000.00
Fringe Benefits		*see note below		
Travel + Training		$0.00		$0.00
Equipment		$0.00		$0.00
Supplies and Materials		$0.00		$0.00
Contractual		$0.00		$0.00
Construction		$0.00		$0.00
Other		$0.00		$0.00
Total Direct Costs		$19,500.00		$19,500.00
Indirect Costs				
Totals		$19,500.00		$19,500.00
*Fringe not shown for each company because it is included in the above totals				

VII. Certificate

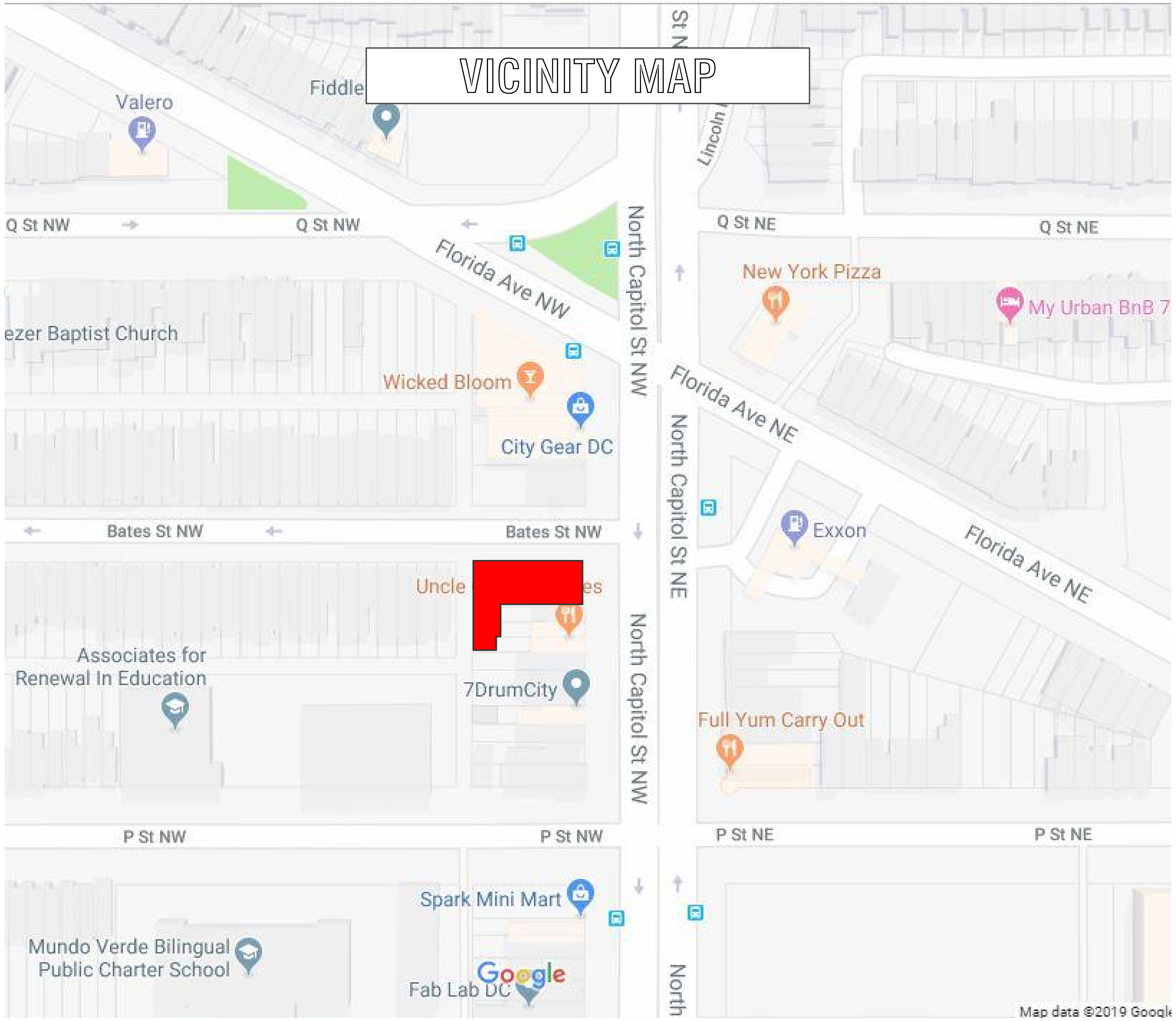
By signing this report, I certify to the best of my knowledge and belief that the report is true, complete, and accurate, and the expenditures, disbursements and cash receipts are for the purposes and objectives set forth in the terms and conditions of the Federal award. I am aware that any false, fictitious, or fraudulent information, or the omission of any material fact, may subject me to criminal, civil or administrative penalties for fraud, false statements, false claims or otherwise. (U.S. Code Title 18, Section 1001 and Title 31, Sections 3729–3730 and 3801–3812).

Signed:

Jessica Pitts	John Miller
Principal, Flywheel Development LLC	Principal, Flywheel Development LLC

9/19/2019

VICINITY MAP



CYCLEHOUSE

CYCLEHOUSE
1520 - 1522 N. CAPITAL STREET, NW

URBAN GREEN

FLYWHEEL DEVELOPMENT

emotive ARCHITECTURE

9/19/2019

CycleHouse Gross Square Footage by Use Type (Within Building)*			
	Commercial	Residential	**Total**
Floor 1	2,631	1,061	**3,692**
Floor 2		3772	**3,772**
Floor 3		3772	**3,772**
Floor 4		3772	**3,772**
Penthouse		1471	**1,471**
TOTAL	2,631	13,848	**16,479**
*Excludes Patio Space and Rooftop			

UNIT SIZES

		TIER 01	TIER 02	TIER 03	TIER 04	TIER 05	TIER 06	TOTAL NET
1ST FLOOR (commercial)	Area	COMMERCIAL **2631**						**2631**
2ND FLOOR (residential)	Unit Type	1 BR	1 BR*	1 BR*	JR STUDIO	1 BR	1 BR	
	Unit No.	21	22	23	24	25	26	
	Area	**570**	**558**	**558**	**281**	**554**	**558**	**3079**
3RD FLOOR (residential)	Unit Type	1 BR			JR STUDIO	1 BR	1 BR	
	Unit No.	31			34	35	36	
	Area	**570**			**281**	**551**	**558**	**1960**
4TH FLOOR (residential)	Unit Type	1 BR	1 BR*	1 BR*	JR STUDIO	3 BR*	1 BR	
	Unit No.	41	42	43	44	45	46	
	Area	**558**	**551**	**697**	**281**	**1050**	**558**	**3695**
		* INDICATES DUPLEX UNITS						**11365**

01

UNIT MIX

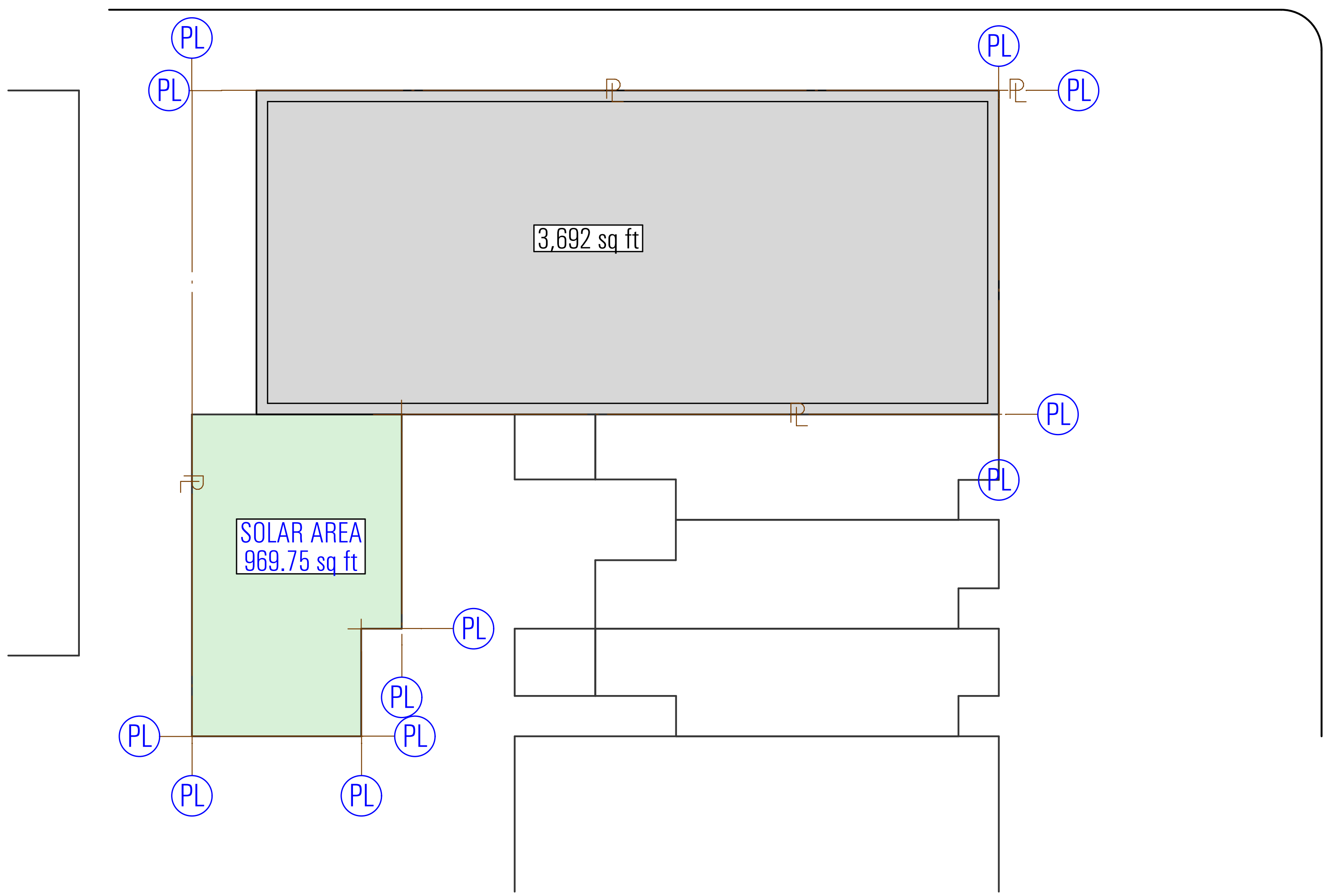
URBAN GREEN

FLYWHEEL DEVELOPMENT

emotive ARCHITECTURE

9/19/2019

N



02

SITE PLAN

CYCLEHOUSE

1520 - 1522 N. CAPITAL STREET, NW

URBAN GREEN

FLYWHEEL DEVELOPMENT

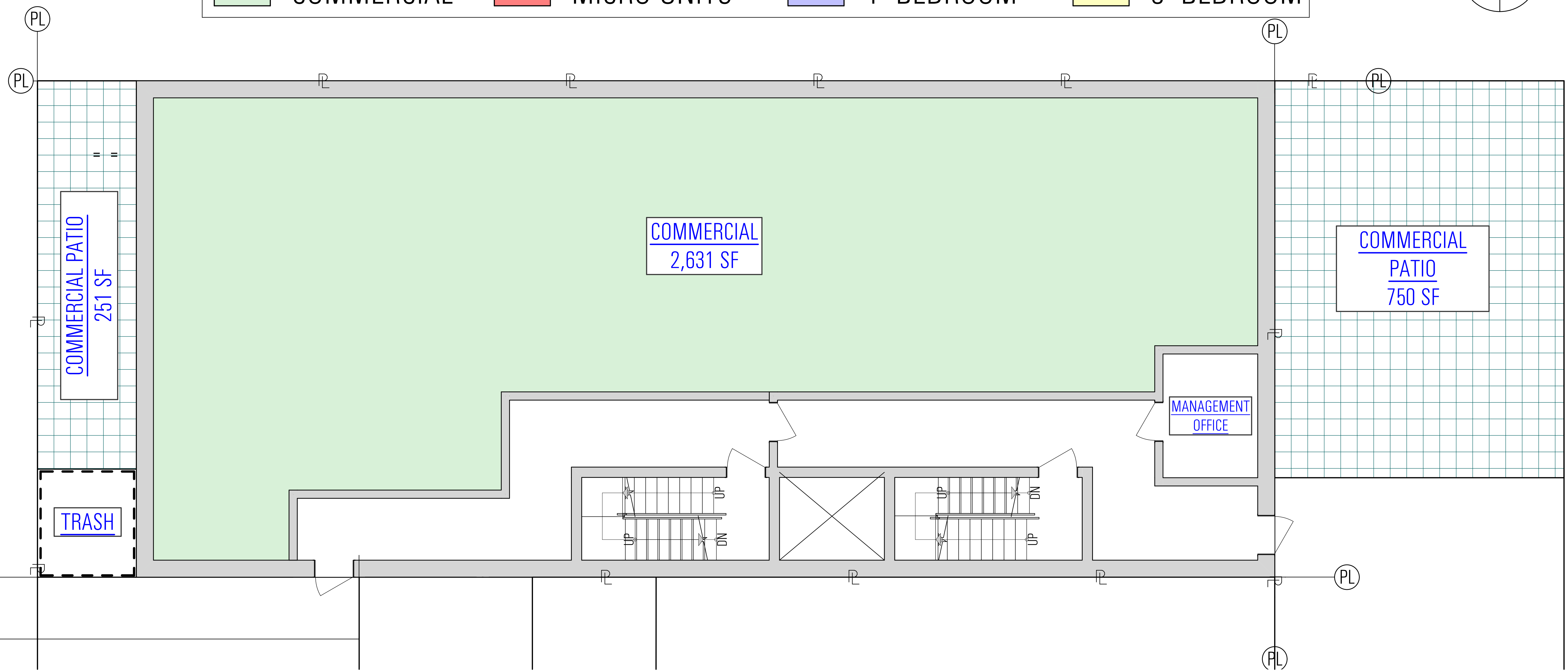
emotive ARCHITECTURE

9/19/2019

N

LEGEND

COMMERCIAL	MICRO-UNITS	1- BEDROOM	3- BEDROOM



03

FLR 1

CYCLEHOUSE

1520 - 1522 N. CAPITAL STREET, NW

URBAN GREEN

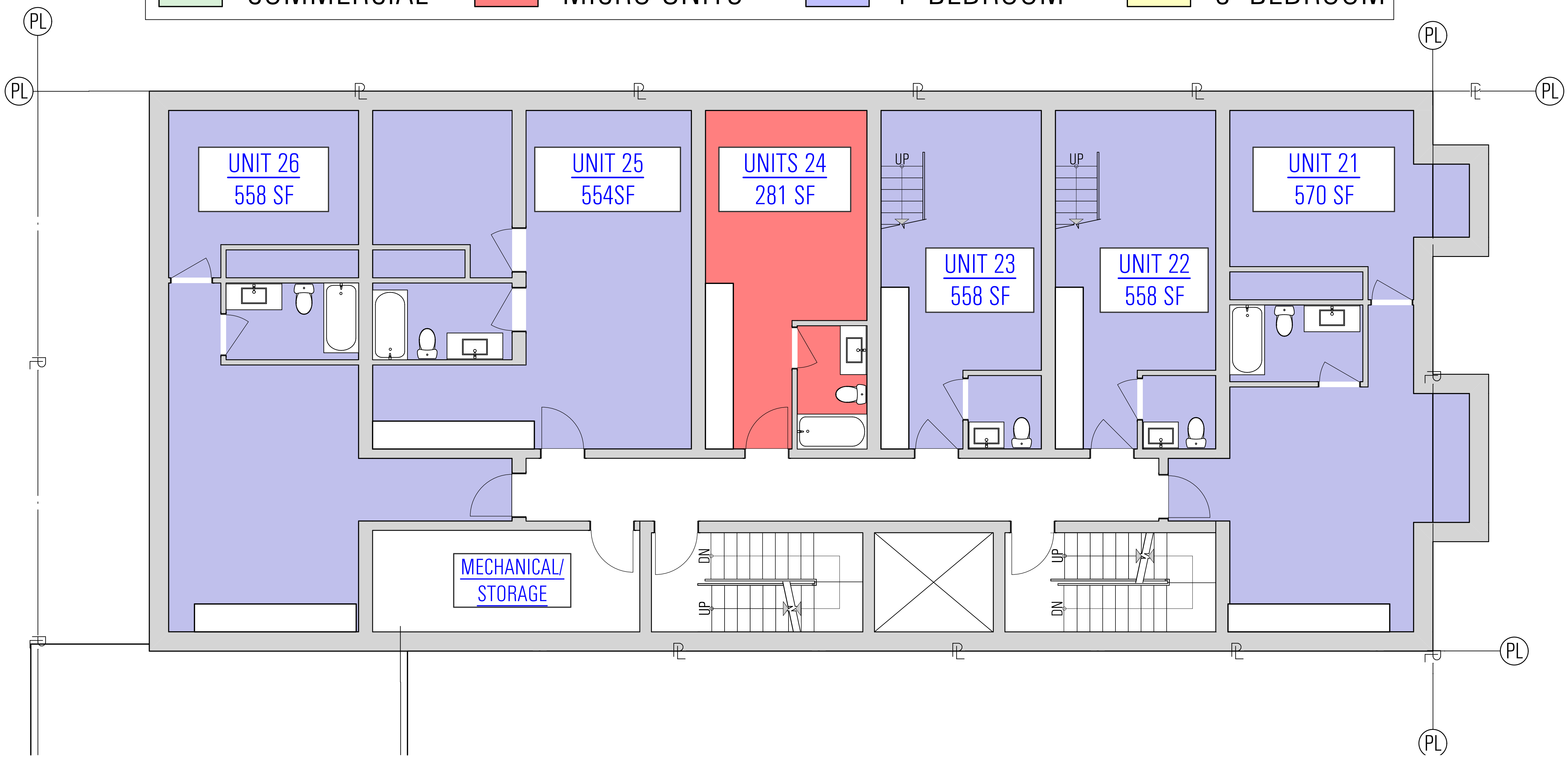
FLYWHEEL DEVELOPMENT

emotive ARCHITECTURE

9/19/2019

LEGEND

COMMERCIAL | MICRO-UNITS | 1- BEDROOM | 3- BEDROOM



N

05

2ND FLR

CYCLEHOUSE

1520 - 1522 N. CAPITAL STREET, NW

URBAN GREEN

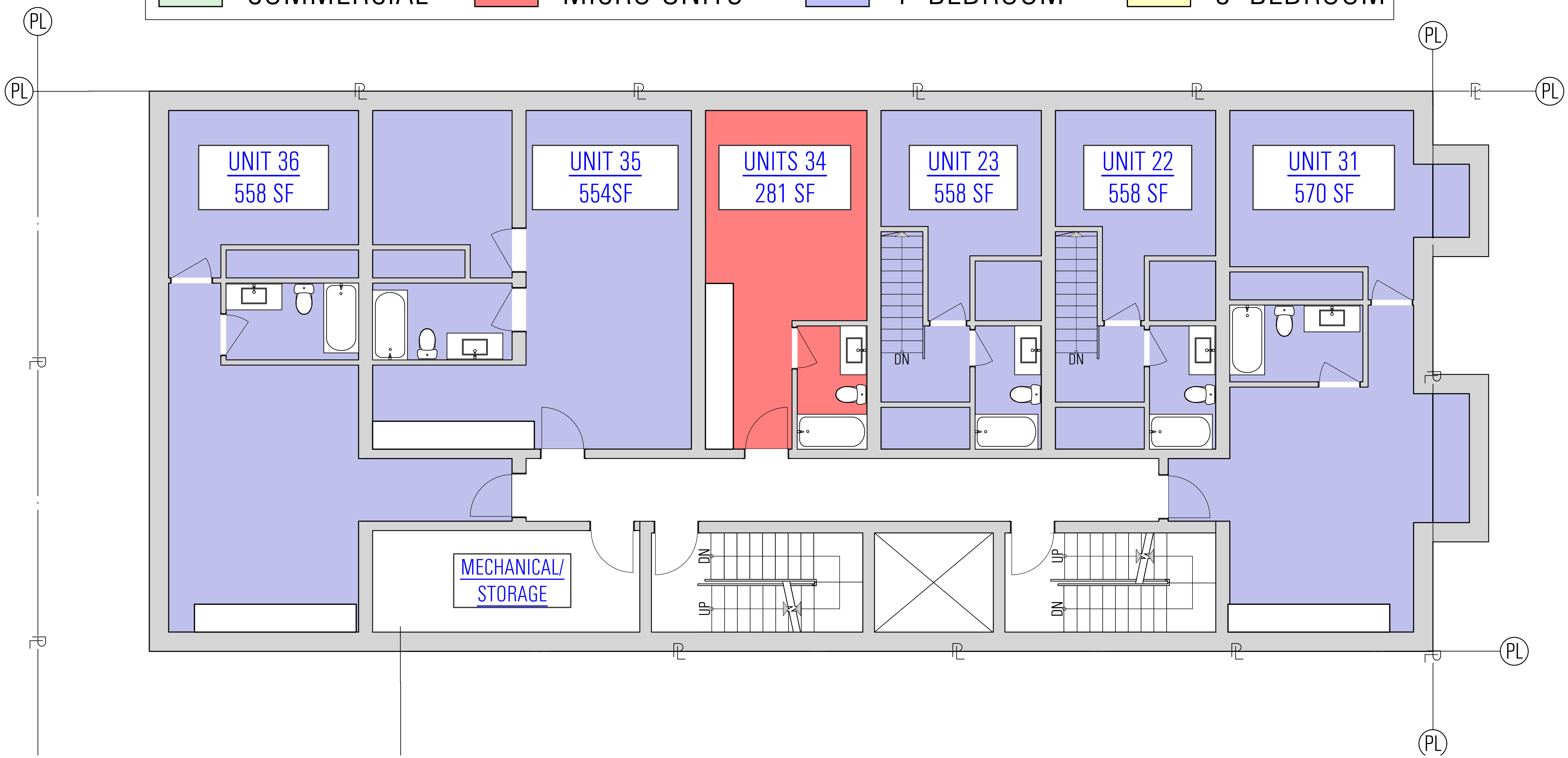
FLYWHEEL DEVELOPMENT

emotive ARCHITECTURE

9/19/2019

LEGEND

COMMERCIAL | MICRO-UNITS | 1- BEDROOM | 3- BEDROOM



06

3RD FLR

CYCLEHOUSE

1520 - 1522 N. CAPITAL STREET, NW

URBAN GREEN

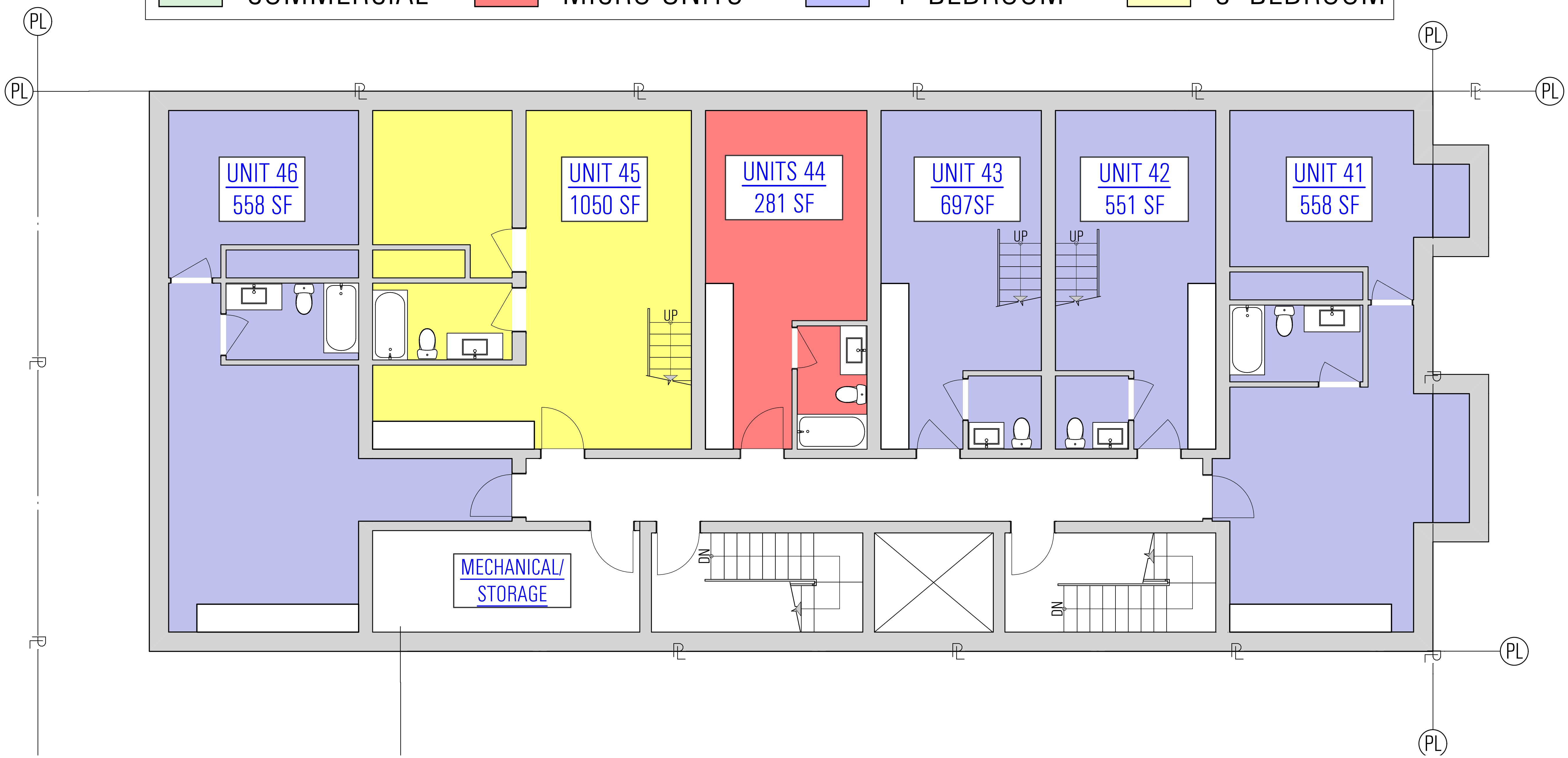
FLYWHEEL DEVELOPMENT

emotive ARCHITECTURE

9/19/2019

LEGEND

COMMERCIAL | MICRO-UNITS | 1- BEDROOM | 3- BEDROOM



07

4TH FLR

CYCLEHOUSE

1520 - 1522 N. CAPITAL STREET, NW

URBAN GREEN

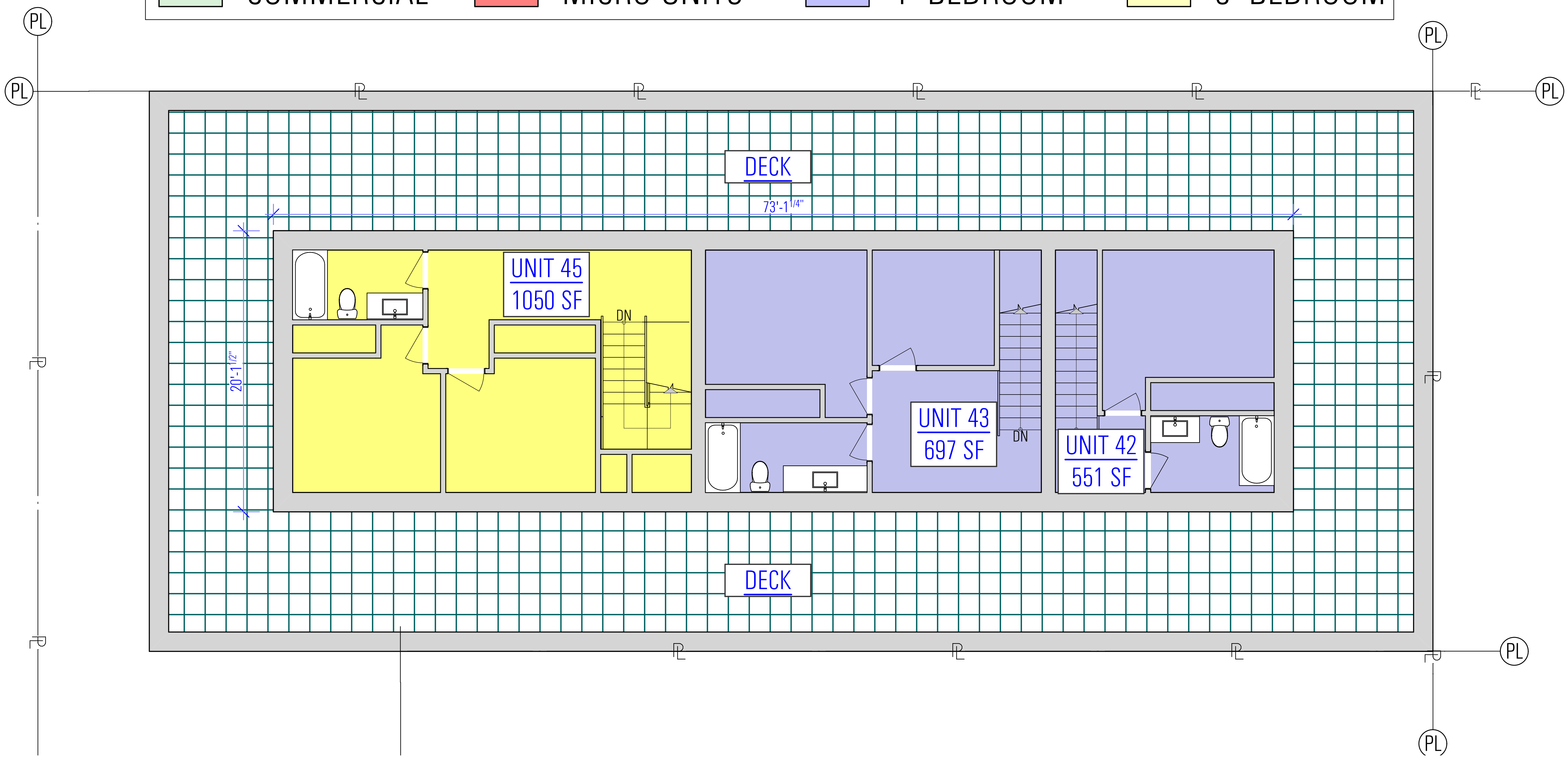
FLYWHEEL DEVELOPMENT

emotive ARCHITECTURE

9/19/2019

LEGEND

COMMERCIAL MICRO-UNITS 1- BEDROOM 3- BEDROOM



08

PENTHOUSE

CYCLEHOUSE

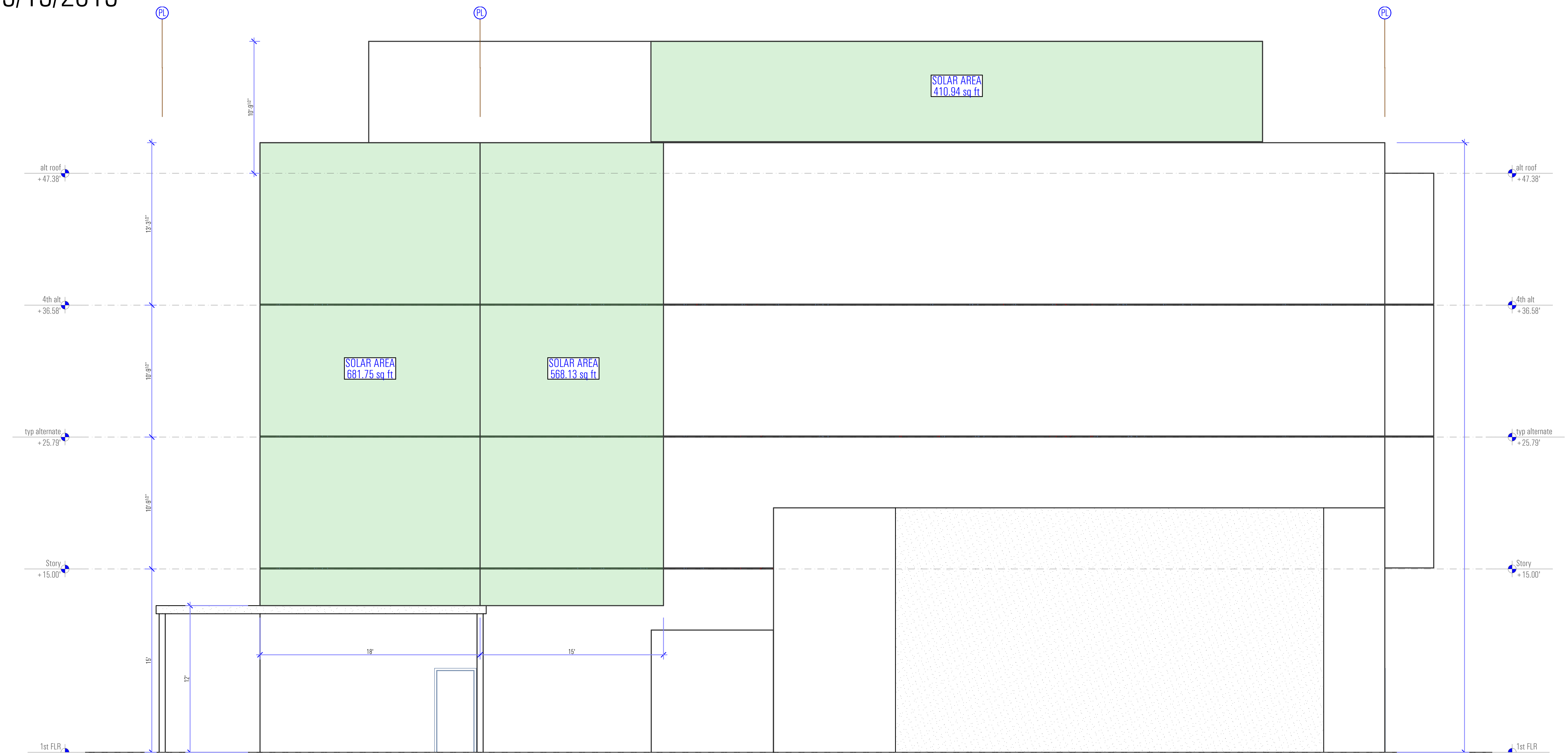
1520 - 1522 N. CAPITAL STREET, NW

URBAN GREEN

FLYWHEEL DEVELOPMENT

emotive ARCHITECTURE

9/19/2019



1 SOUTH ELEVATION

SCALE: 1/8" = 1'-0"

09

SOUTH ELEVATION - SOLAR AREA

CYCLEHOUSE

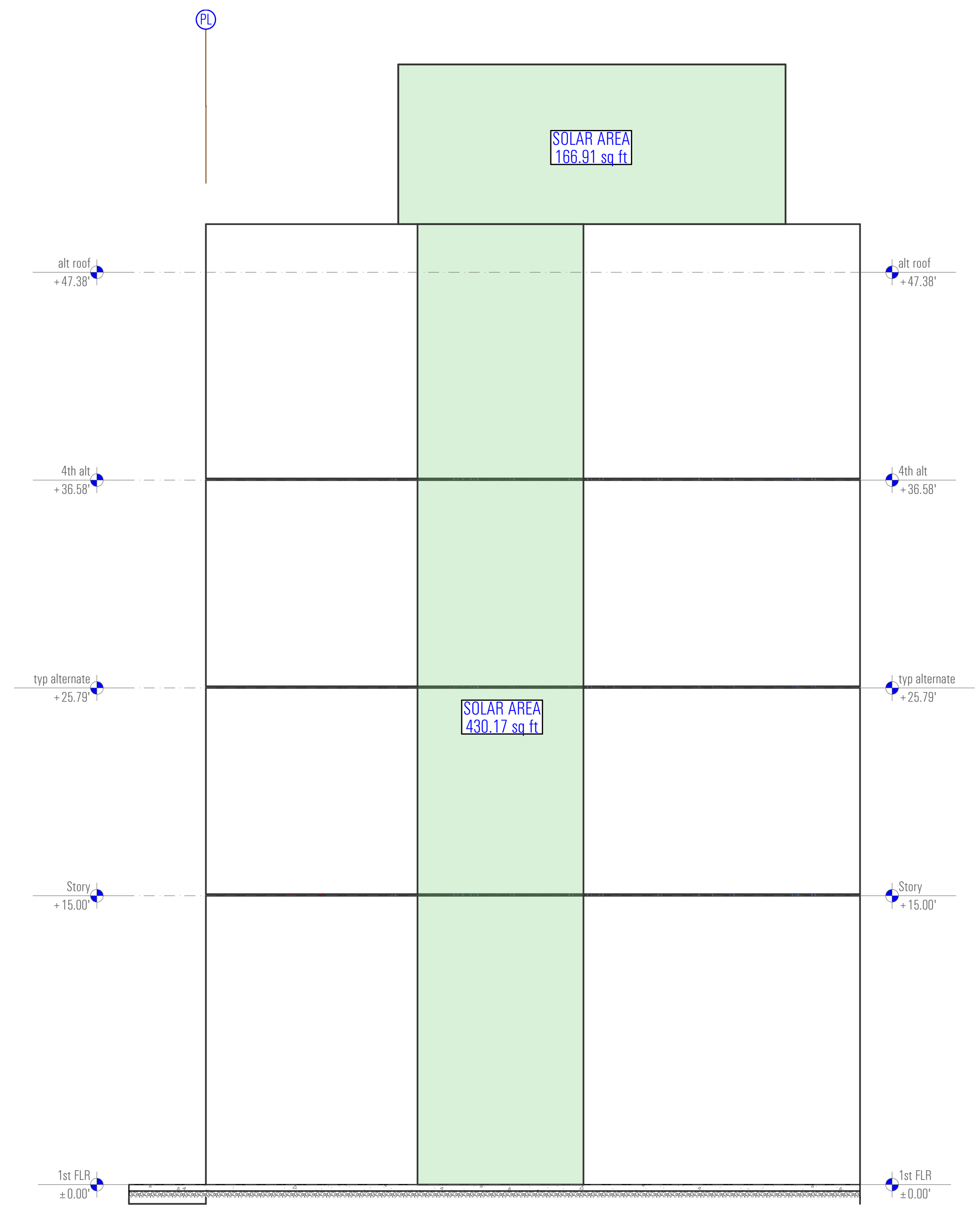
1520 - 1522 N. CAPITAL STREET, NW

URBAN GREEN

FLYWHEEL DEVELOPMENT

emotive ARCHITECTURE

9/19/2019



1 WEST ELEVATION

SCALE: 1/8" = 1'-0"

10

WEST ELEVATION - SOLAR AREA

CYCLEHOUSE

1520 - 1522 N. CAPITAL STREET, NW

URBAN GREEN

FLYWHEEL DEVELOPMENT

emotive ARCHITECTURE

Overlay Cyclehouse, 1518 n capitol st nw

Report

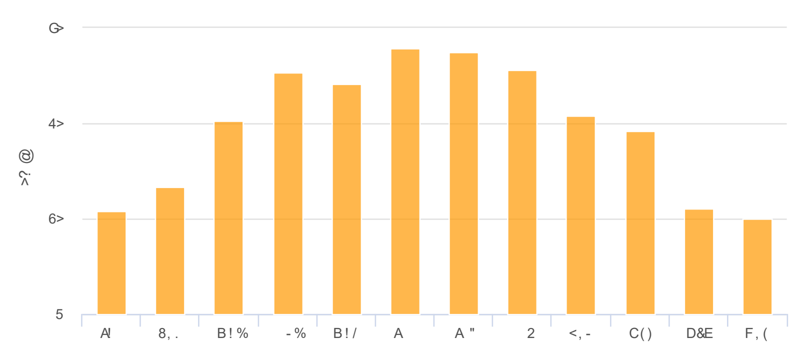
Project Name	Cyclehouse
Project Address	1518 n capitol st nw
Prepared By	Amberli Young ayoung@flywheeldevelopment.com

System Metrics

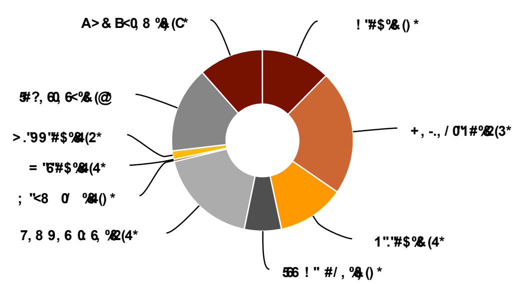
Design	Overlay
Module DC Nameplate	18.4 kW
Inverter AC Nameplate	14.7 kW Load Ratio: 1.25
Annual Production	23.58 MWh
Performance Ratio	84.5%
kWh/kWp	1,281.3
Weather Dataset	TMY, WASHINGTON DC REAGAN AP, NSRDB (tmy3, I)
Simulator Version	4b93481553-e4cc0ffa6e-b229260445-146c54f42a

Project Location

Monthly Production



Sources of System Loss



Annual Production

	Description	Output	% Delta
Irradiance (kWh/m²)	Annual Global Horizontal Irradiance	1,456.5	
	POA Irradiance	1,516.4	4.1%
	Shaded Irradiance	1,485.2	-2.1%
	Irradiance after Reflection	1,430.1	-3.7%
	Irradiance after Soiling	1,401.5	-2.0%
	Total Collector Irradiance	**1,401.1**	**0.0%**
Energy (kWh)	Nameplate	25,793.1	
	Output at Irradiance Levels	25,510.1	-1.1%
	Output at Cell Temperature Derate	24,745.1	-3.0%
	Output After Mismatch	24,728.9	-0.1%
	Optimal DC Output	24,728.9	0.0%
	Constrained DC Output	24,666.9	-0.3%
	Inverter Output	24,036.4	-2.6%
	Energy to Grid	**23,576.0**	**-1.9%**
Temperature Metrics			
	Avg. Operating Ambient Temp		16.6 °C
	Avg. Operating Cell Temp		24.0 °C
Simulation Metrics			
	Operating Hours		4422
	Solved Hours		4422

Condition Set

Description	Condition Set 1
Weather Dataset	TMY, WASHINGTON DC REAGAN AP, NSRDB (tmy3, I)
Solar Angle Location	Meteo Lat/Lng
Transposition Model	Perez Model
Temperature Model	Sandia Model
Irradiation Variance	5%
Cell Temperature Spread	4° C
Module Binning Range	-2.5% to 2.5%
AC System Derate	0.50%

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

Module Characterizations

Module	Characterization
JKM 400M-72H-BDVP (Jinkosolar)	Jinko_JKM_400M_72H_BDVP (G2.5_F40).PAN, PAN

Component Characterizations

Device	Characterization
IQ7X-96-x-INT (Enphase)	Default Characterization

Components

Component	Name	Count
Inverters	IQ7X-96-x-INT (Enphase)	46 (14.7 kW)
AC Branches	8 AWG (Copper)	3 (571.3 ft)
Module	Jinkosolar, JKM 400M-72H-BDVP (400W)	46 (18.4 kW)

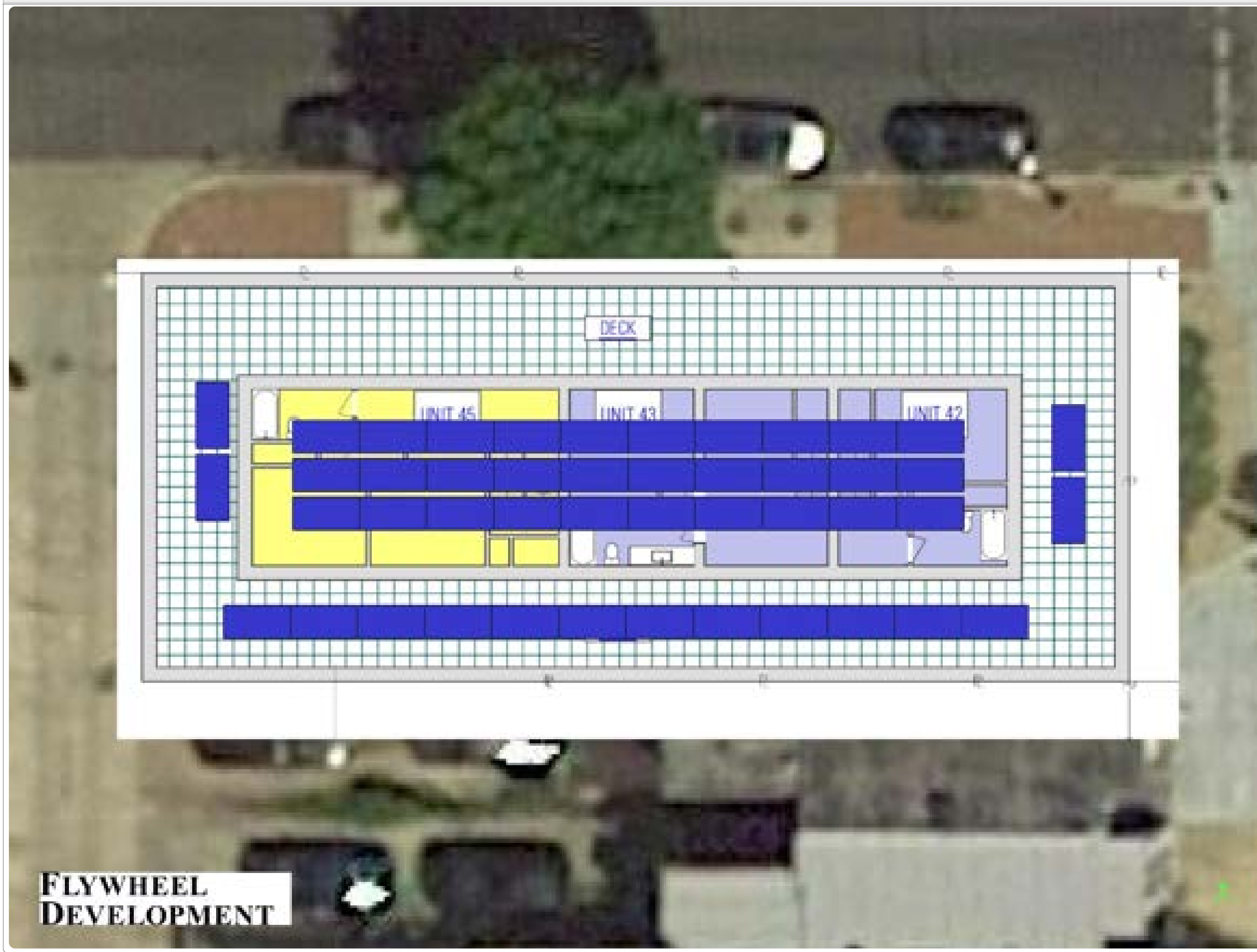
Wiring Zones

Description	Combiner Poles	String Size	Stringing Strategy
Wiring Zone	12	1-1	Along Racking

Field Segments

Description	Racking	Orientation	Tilt	Azimuth	Intrarow Spacing	Frame Size	Frames	Modules	Power
Field Segment 1	Fixed Tilt	Landscape (Horizontal)	5°	180°	0.5 ft	1x1	30	30	12.0 kW
Field Segment 2	Fixed Tilt	Landscape (Horizontal)	5°	180°	0.5 ft	1x1	12	12	4.80 kW
Field Segment 3	Fixed Tilt	Portrait (Vertical)	5°	180°	0.5 ft	1x1	2	2	800.0 W
Field Segment 5	Fixed Tilt	Portrait (Vertical)	5°	180°	0.5 ft	1x1	2	2	800.0 W

Detailed Layout



Canopy Cyclehouse, 1518 n capitol st nw

Report

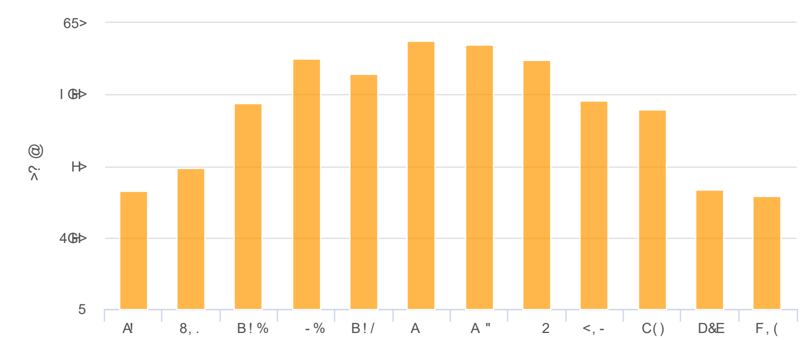
Project Name	Cyclehouse
Project Address	1518 n capitol st nw
Prepared By	Amberli Young ayoung@flywheeldevelopment.com

System Metrics

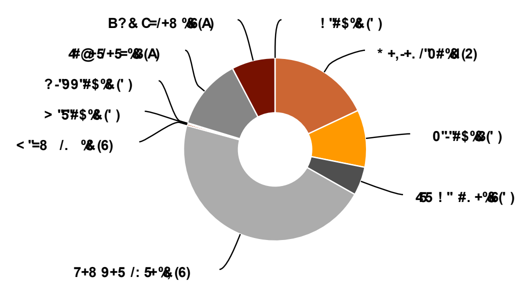
Design	Canopy
Module DC Nameplate	64.8 kW
Inverter AC Nameplate	51.8 kW Load Ratio: 1.25
Annual Production	82.97 MWh
Performance Ratio	81.7%
kWh/kWp	1,280.4
Weather Dataset	TMY, WASHINGTON DC REAGAN AP, NSRDB (tmy3, I)
Simulator Version	4b93481553-e4cc0ffa6e-b229260445-146c54f42a

Project Location

Monthly Production



Sources of System Loss



Annual Production

	Description	Output	% Delta
Irradiance (kWh/m²)	Annual Global Horizontal Irradiance	1,456.5	
	POA Irradiance	1,568.0	7.7%
	Shaded Irradiance	1,568.0	0.0%
	Irradiance after Reflection	1,512.3	-3.6%
	Irradiance after Soiling	1,482.0	-2.0%
	Total Collector Irradiance	**1,482.0**	**0.0%**
Energy (kWh)	Nameplate	96,079.2	
	Output at Irradiance Levels	95,124.2	-1.0%
	Output at Cell Temperature Derate	86,479.6	-9.1%
	Output After Mismatch	86,423.7	-0.1%
	Optimal DC Output	86,423.7	0.0%
	Constrained DC Output	86,398.4	0.0%
	Inverter Output	84,249.2	-2.5%
	Energy to Grid	**82,968.6**	**-1.5%**
Temperature Metrics			
	Avg. Operating Ambient Temp		16.6 °C
	Avg. Operating Cell Temp		33.1 °C
Simulation Metrics			
	Operating Hours		4422
	Solved Hours		4422

Condition Set

Description	Condition Set 1
Weather Dataset	TMY, WASHINGTON DC REAGAN AP, NSRDB (tmy3, I)
Solar Angle Location	Meteo Lat/Lng
Transposition Model	Perez Model
Temperature Model	Sandia Model
Irradiation Variance	5%
Cell Temperature Spread	4° C
Module Binning Range	-2.5% to 2.5%
AC System Derate	0.50%

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

Module Characterizations

Module	Characterization
JKM 400M-72H-BDVP (Jinkosolar)	Jinko_JKM_400M_72H_BDVP (G2.5_F40).PAN, PAN

Component Characterizations

Device	Characterization
IQ7X-96-x-INT (Enphase)	Default Characterization

Components

Component	Name	Count
Inverters	IQ7X-96-x-INT (Enphase)	162 (51.8 kW)
AC Branches	8 AWG (Copper)	9 (1,751.5 ft)
Module	Jinkosolar, JKM 400M-72H-BDVP (400W)	162 (64.8 kW)

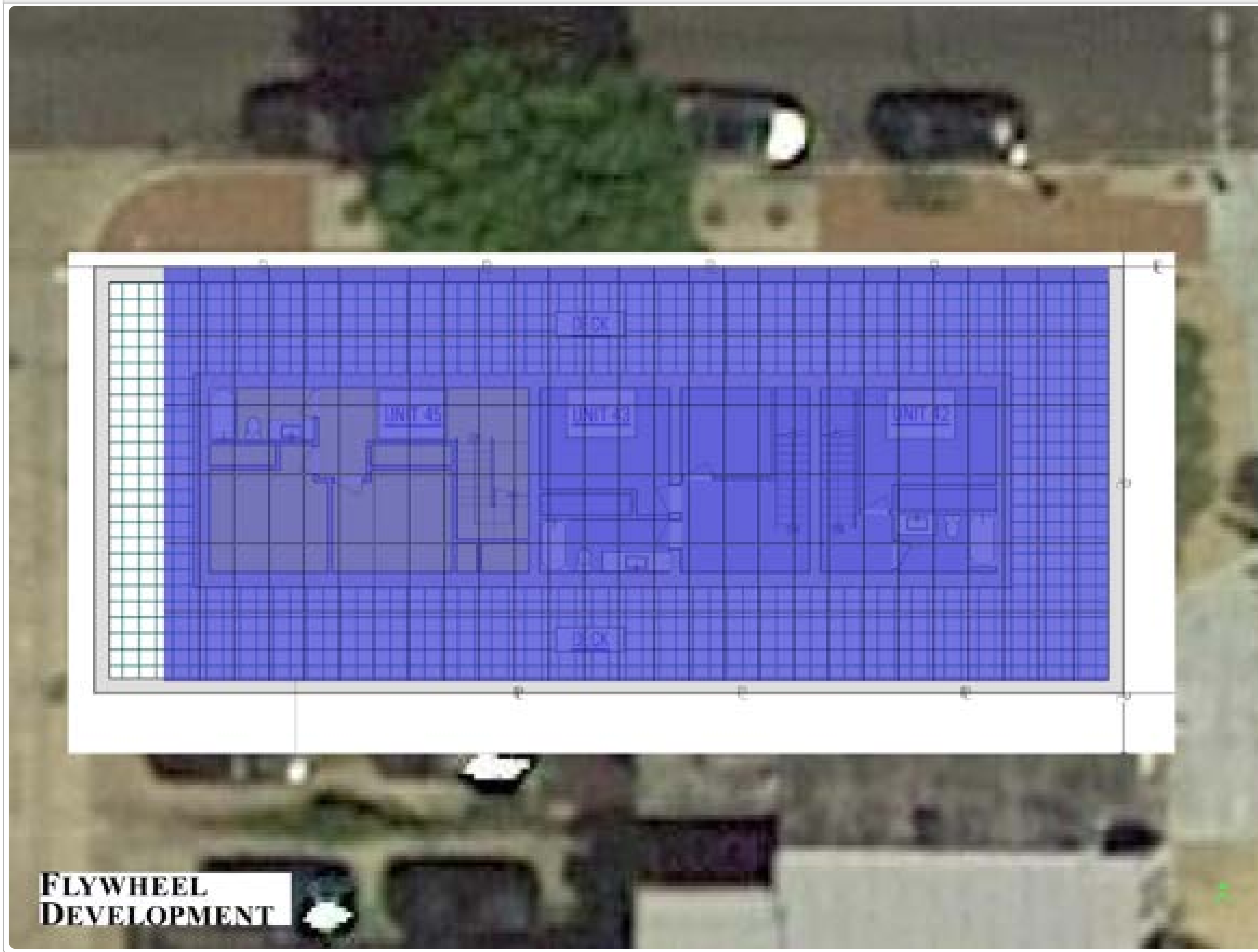
Wiring Zones

Description	Combiner Poles	String Size	Stringing Strategy
Wiring Zone	12	1-1	Along Racking

Field Segments

Description	Racking	Orientation	Tilt	Azimuth	Intrarow Spacing	Frame Size	Frames	Modules	Power
Field Segment 1	Flush Mount	Portrait (Vertical)	10°	180°	0.0 ft	1x1	162	162	64.8 kW

Detailed Layout



Carport Cyclehouse, 1518 n capitol st nw

Report

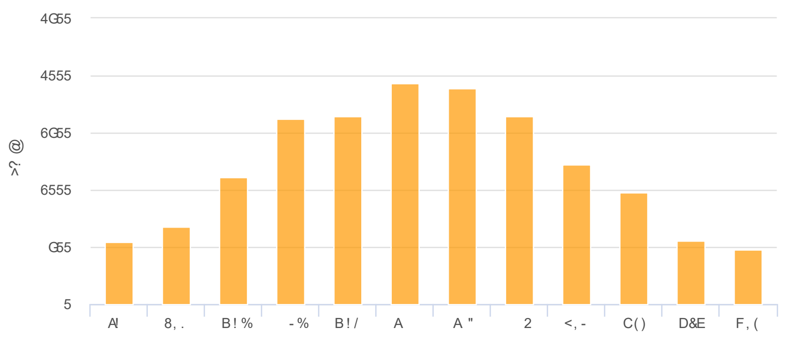
Project Name	Cyclehouse
Project Address	1518 n capitol st nw
Prepared By	Amberli Young ayoung@flywheeldevelopment.com

System Metrics

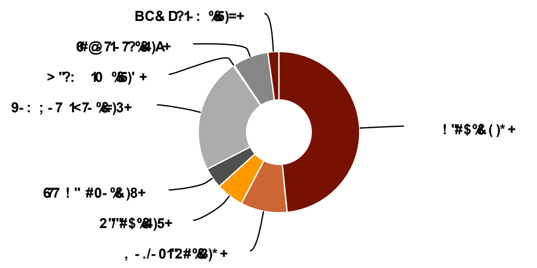
Design	Carport
Module DC Nameplate	14.4 kW
Inverter AC Nameplate	11.5 kW Load Ratio: 1.25
Annual Production	14.31 MWh
Performance Ratio	68.2%
kWh/kWp	993.8
Weather Dataset	TMY, WASHINGTON DC REAGAN AP, NSRDB (tmy3, I)
Simulator Version	4b93481553-e4cc0ffa6e-b229260445-146c54f42a

Project Location

Monthly Production



Sources of System Loss



Annual Production

	Description	Output	% Delta
Irradiance (kWh/m²)	Annual Global Horizontal Irradiance	1,456.5	
	POA Irradiance	1,456.8	0.0%
	Shaded Irradiance	1,203.0	-17.4%
	Irradiance after Reflection	1,162.5	-3.4%
	Irradiance after Soiling	1,139.3	-2.0%
	Total Collector Irradiance	**1,137.9**	**-0.1%**
Energy (kWh)	Nameplate	16,400.6	
	Output at Irradiance Levels	16,156.1	-1.5%
	Output at Cell Temperature Derate	14,816.6	-8.3%
	Output After Mismatch	14,807.2	-0.1%
	Optimal DC Output	14,807.2	0.0%
	Constrained DC Output	14,806.8	0.0%
	Inverter Output	14,425.0	-2.6%
	Energy to Grid	**14,310.5**	**-0.8%**
Temperature Metrics			
	Avg. Operating Ambient Temp		16.6 °C
	Avg. Operating Cell Temp		29.3 °C
Simulation Metrics			
		Operating Hours	4422
		Solved Hours	4422

Condition Set

<table>
<tr><td>Description</td><td colspan="12">Condition Set 1</td></tr>
<tr><td>Weather Dataset</td><td colspan="12">TMY, WASHINGTON DC REAGAN AP, NSRDB (tmy3, I)</td></tr>
<tr><td>Solar Angle Location</td><td colspan="12">Meteo Lat/Lng</td></tr>
<tr><td>Transposition Model</td><td colspan="12">Perez Model</td></tr>
<tr><td>Temperature Model</td><td colspan="12">Sandia Model</td></tr>
<tr><td rowspan="3">Temperature Model Parameters</td><td colspan="3">Rack Type</td><td colspan="3">a</td><td colspan="3">b</td><td colspan="3">Temperature Delta</td></tr>
<tr><td colspan="3">Fixed Tilt</td><td colspan="3">-3.56</td><td colspan="3">-0.075</td><td colspan="3">3°C</td></tr>
<tr><td colspan="3">Flush Mount</td><td colspan="3">-2.81</td><td colspan="3">-0.0455</td><td colspan="3">0°C</td></tr>
<tr><td rowspan="2">Soiling (%)</td><td>J</td><td>F</td><td>M</td><td>A</td><td>M</td><td>J</td><td>J</td><td>A</td><td>S</td><td>O</td><td>N</td><td>D</td></tr>
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<tr><td>Irradiation Variance</td><td colspan="12">5%</td></tr>
<tr><td>Cell Temperature Spread</td><td colspan="12">4° C</td></tr>
<tr><td>Module Binning Range</td><td colspan="12">-2.5% to 2.5%</td></tr>
<tr><td>AC System Derate</td><td colspan="12">0.50%</td></tr>
<tr><td rowspan="2">Module Characterizations</td><td colspan="6">Module</td><td colspan="6">Characterization</td></tr>
<tr><td colspan="6">JKM 400M-72H-BDVP (Jinkosolar)</td><td colspan="6">Jinko_JKM_400M_72H_BDVP (G2.5_F40).PAN, PAN</td></tr>
<tr><td rowspan="2">Component Characterizations</td><td colspan="6">Device</td><td colspan="6">Characterization</td></tr>
<tr><td colspan="6">IQ7X-96-x-INT (Enphase)</td><td colspan="6">Default Characterization</td></tr>
</table>

Components

Component	Name	Count
Inverters	IQ7X-96-x-INT (Enphase)	36 (11.5 kW)
AC Branches	8 AWG (Copper)	4 (721.2 ft)
Module	Jinkosolar, JKM 400M-72H-BDVP (400W)	36 (14.4 kW)

Wiring Zones

Description	Combiner Poles	String Size	Stringing Strategy
Wiring Zone	12	1-1	Along Racking

Field Segments

Description	Racking	Orientation	Tilt	Azimuth	Intrarow Spacing	Frame Size	Frames	Modules	Power
Field Segment 1	Flush Mount	Landscape (Horizontal)	7°	270°	0.0 ft	1x1	36	36	14.4 kW

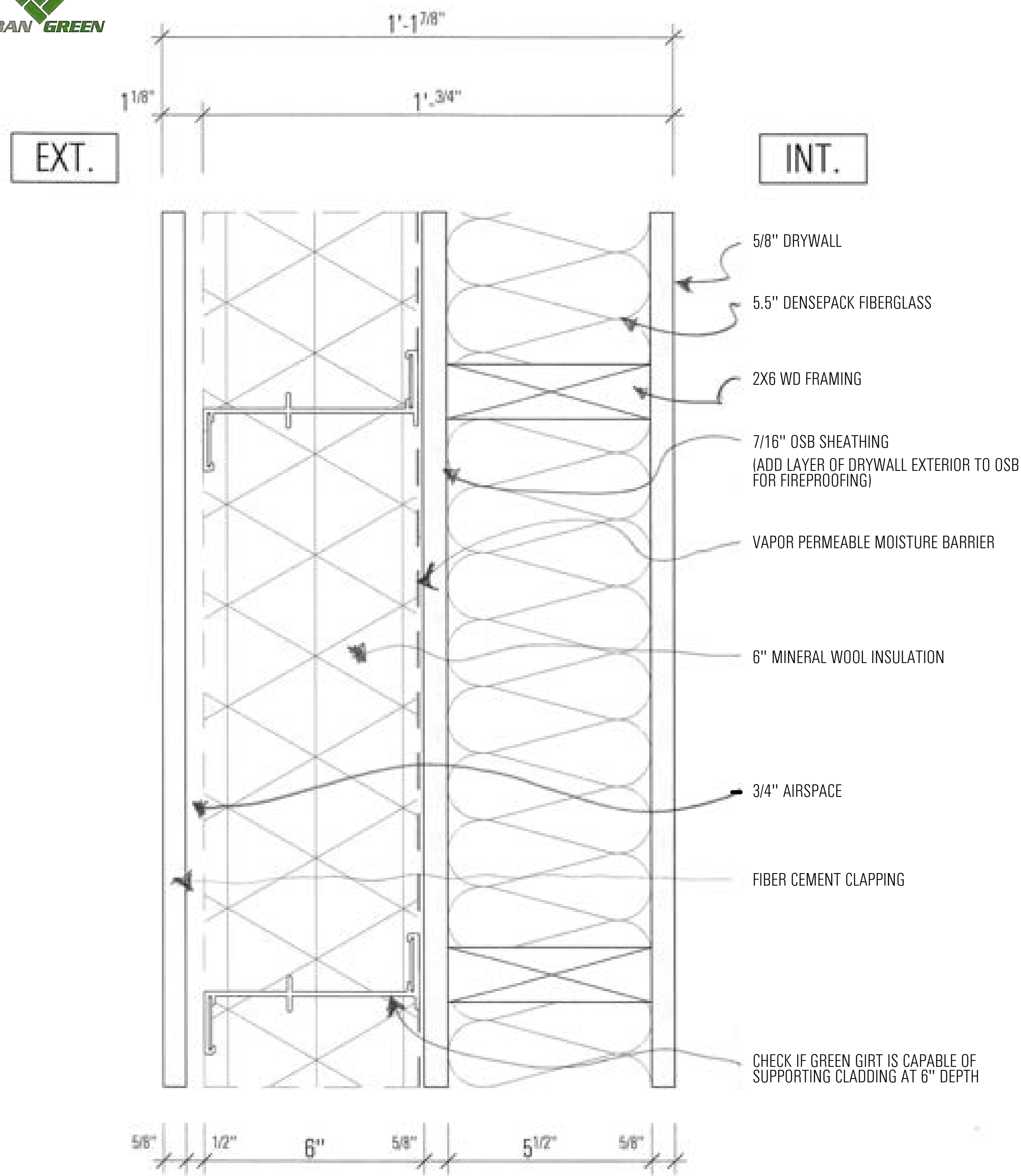
Detailed Layout

emotive ARCHITECTURE

FLYWHEEL DEVELOPMENT

URBAN GREEN

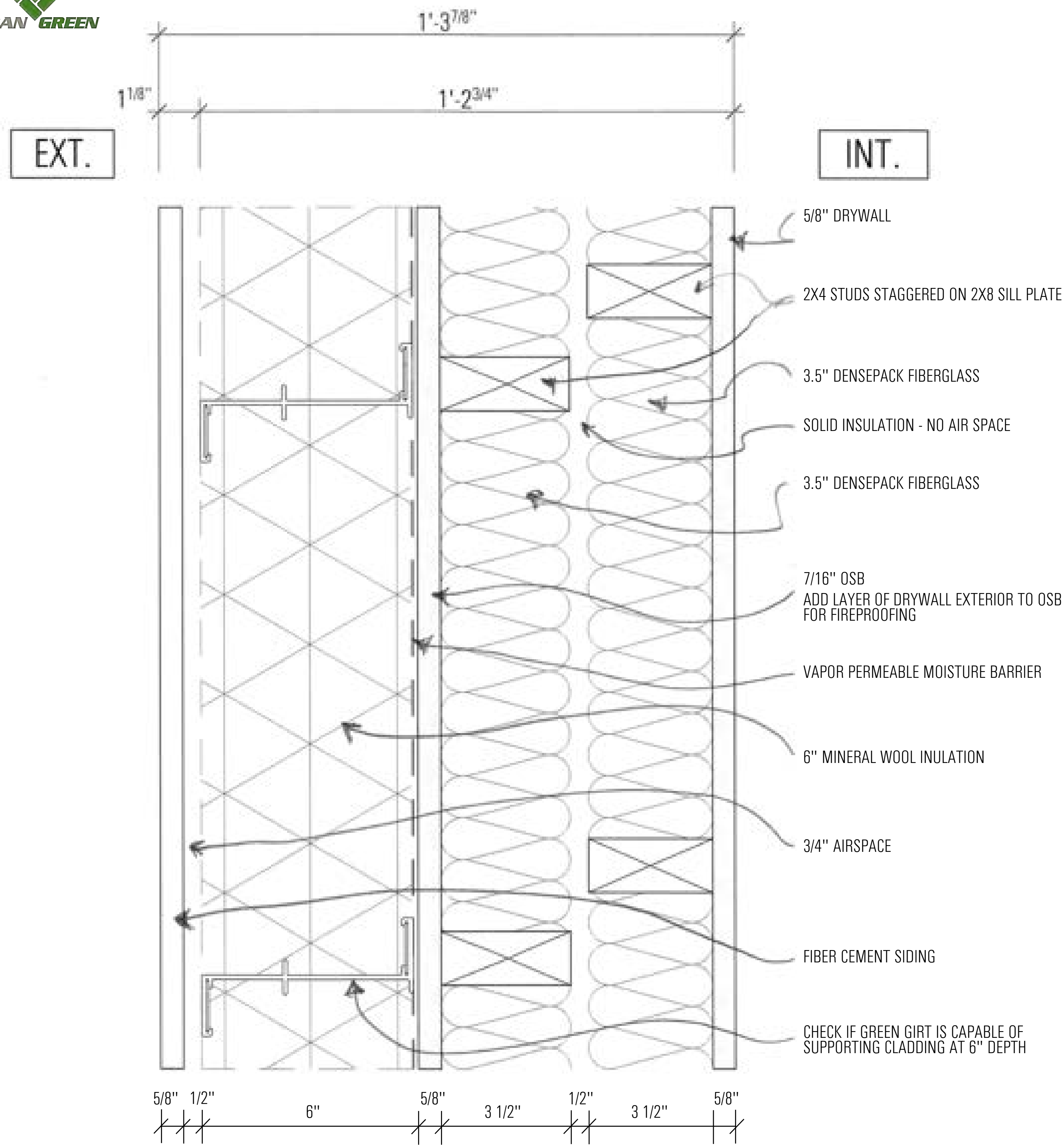
CYCLEHOUSE



PROFILE

1

CYCLEHOUSE



PROFILE

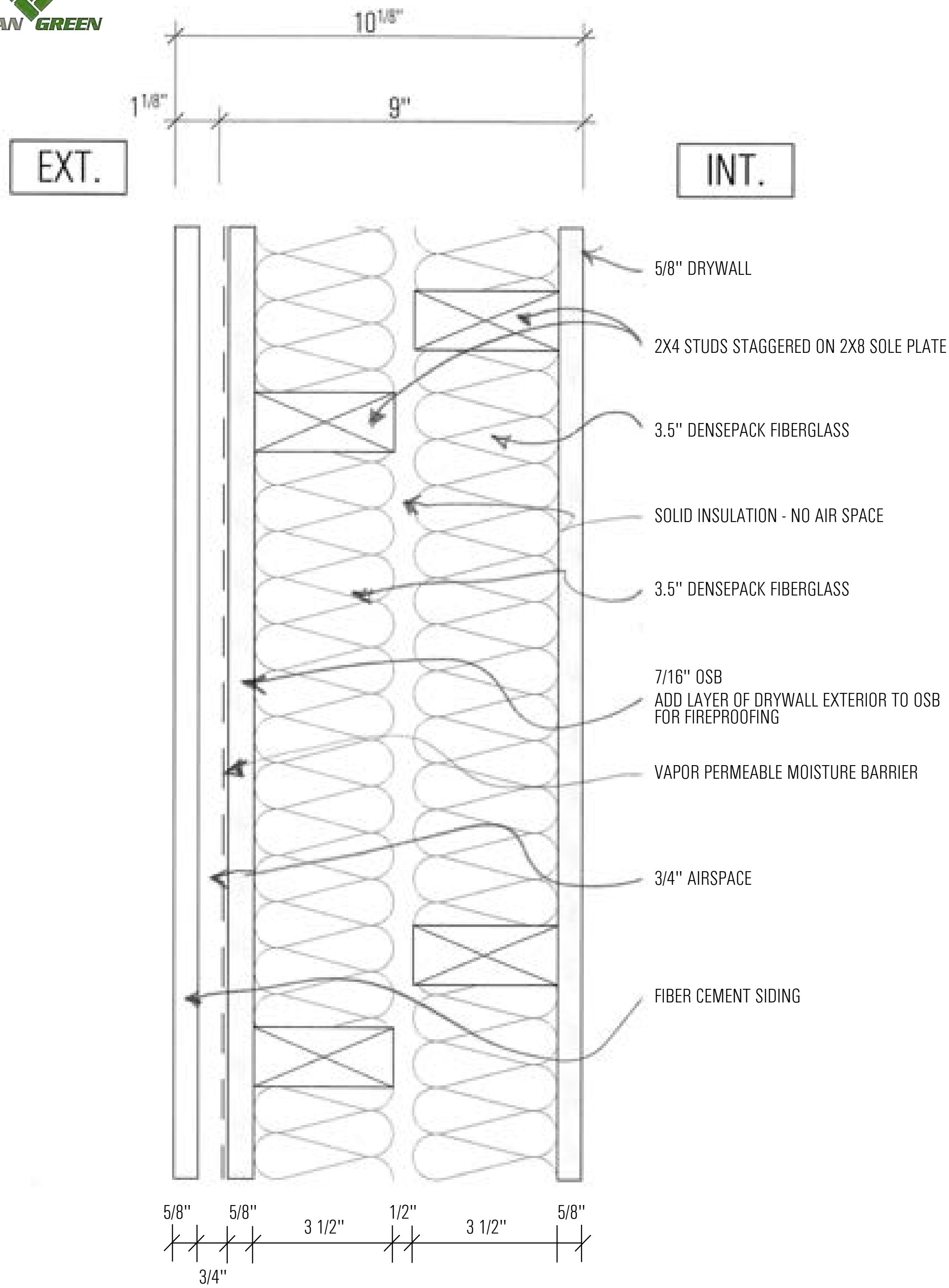
2

emotive ARCHITECTURE

FLYWHEEL DEVELOPMENT

URBAN GREEN

CYCLEHOUSE



PROFILE

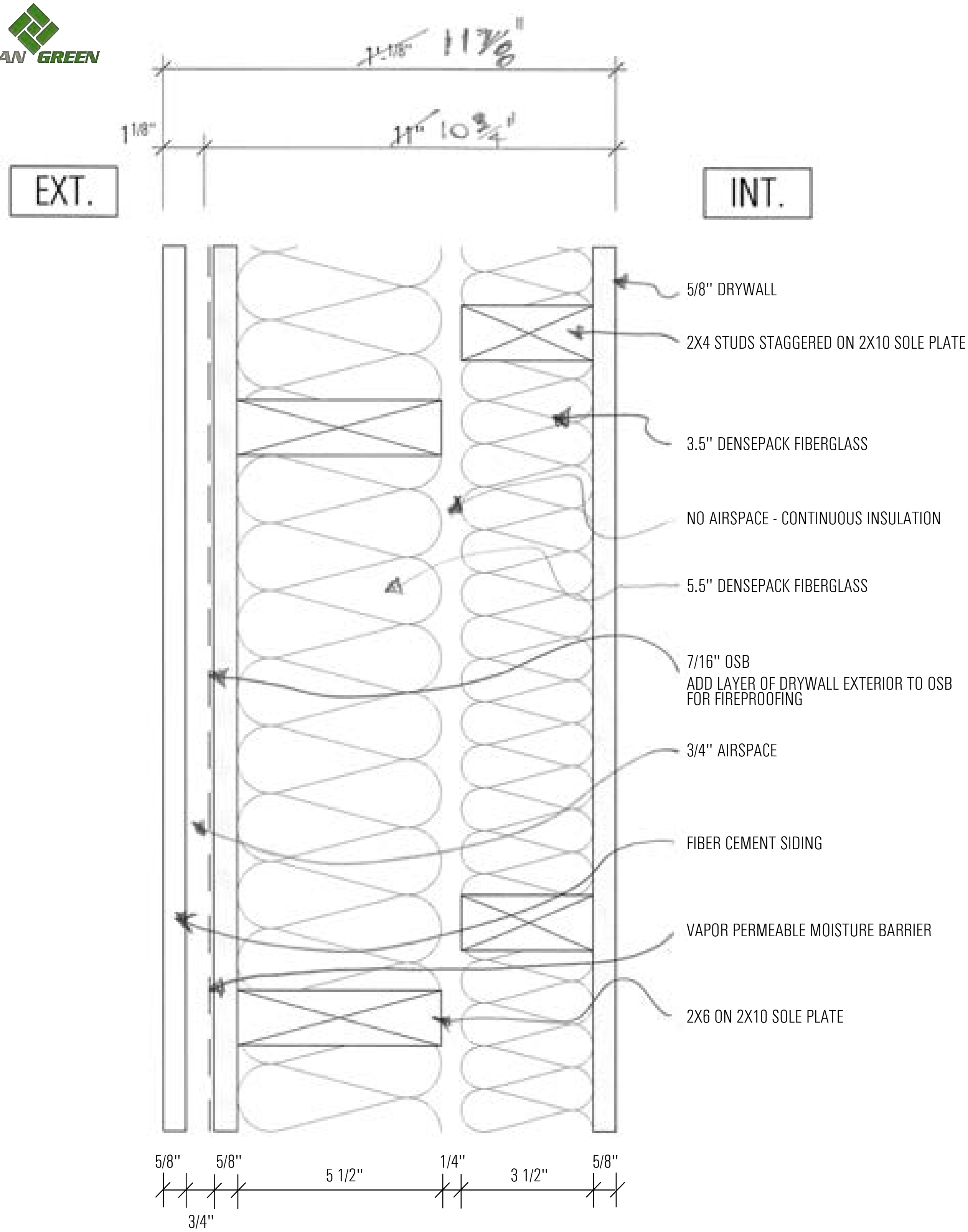
3

emotive ARCHITECTURE

FLYWHEEL DEVELOPMENT

URBAN GREEN

CYCLEHOUSE



PROFILE

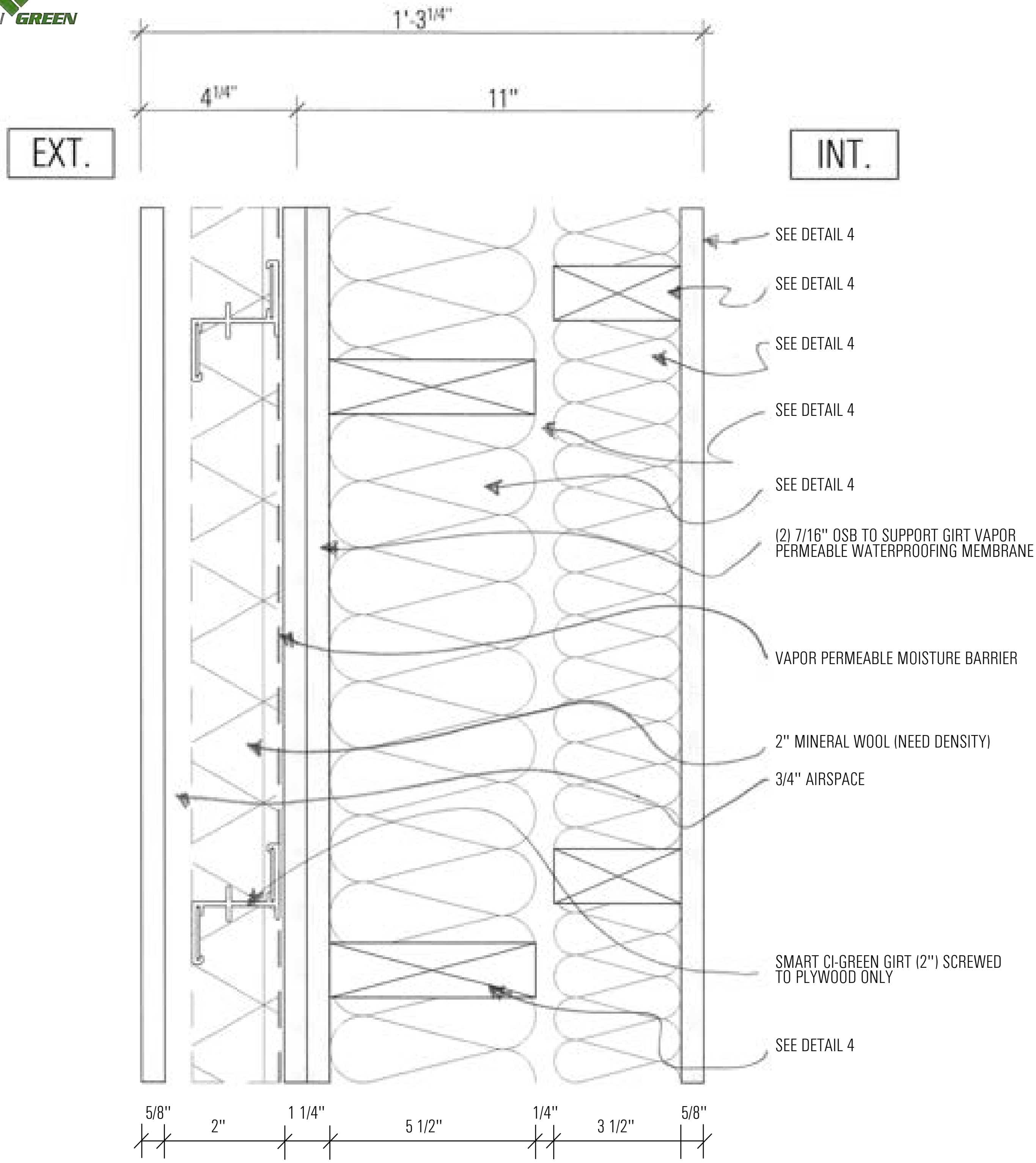
4

emotive ARCHITECTURE

FLYWHEEL DEVELOPMENT

URBAN GREEN

CYCLEHOUSE



PROFILE

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