

Full Circle

Developing Stakeholder-Informed Guidelines for
Net-Zero Energy Affordable Housing Development





This project was supported by a University of Minnesota, Institute on the Environment Impact Goal grant 2023 entitled “Full Circle: Developing Stakeholder-Informed Guidelines For Net-Zero Energy Affordable Housing Development”, under Grant No. IG-93



Agenda

- Project Overview: The gap in the circle
- Participating projects
 - Solstice*
 - Firefly
 - Sundial
 - Hillcrest Village
 - Northside Passive*
 - Uptown Strawbale
- Evaluation
 - Post Construction Evaluation (the contractor perspective)
 - Post Occupancy Evaluation (the resident perspective)
 - Indoor Air Quality Analysis
 - Energy Analysis
- Findings



Research Team



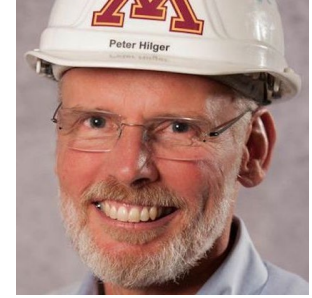
Rolf Jacobson, UMN CSBR



Daniel Handeen, UMN CSBR



Elizabeth Turner, Precipitate



Peter Hilger, UMN CM



Scott Wopata, Northfield CAC



Dr. Caren Martin, MGDR



Andi Sutton, UMN RSDP



Pat Huelman, UMN CCH

Comprehensive, supportive, holistic, affordable, energy-neutral housing design:

Resident:

User experience in Net-Zero
affordable housing units not
well studied.

Mechanical Engineer:

Need alignment and
understanding across
sectors to ensure
success.

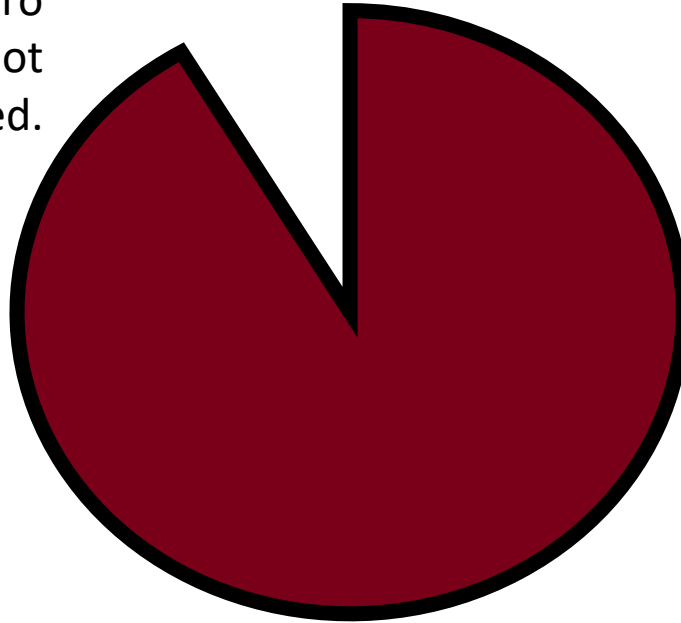
Building Scientist:

Proven strategies exist, but
industry is slow to change.

Builder:

Need more info on how to
build for high performance.

Start of a project



Architect:

Clients *want* sustainability
Architects lack understanding.

Developer:

Need info on
integrating high-
performance building
measures into
affordable housing.

Mechanical equipment contractors:

Equipment and selection process is
designed for non-energy efficient



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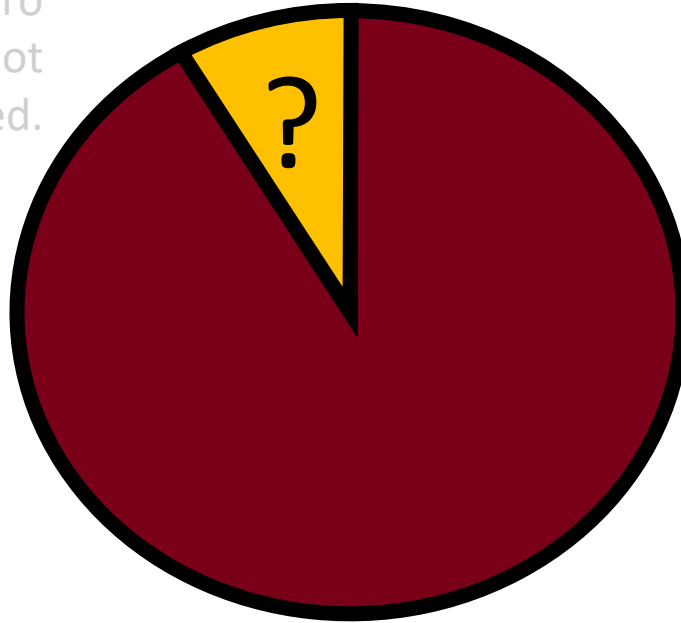
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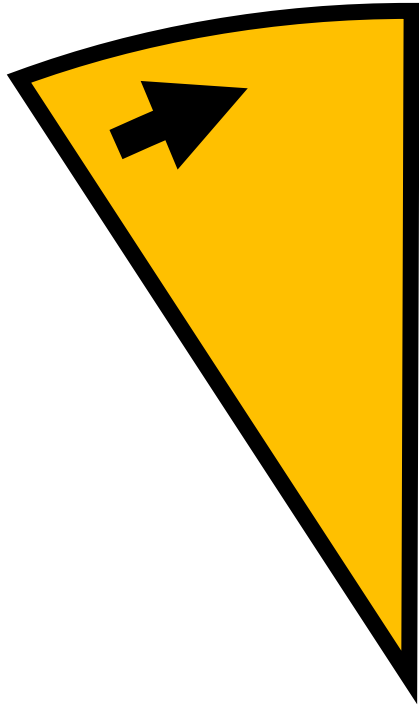
Need info on integrating high-performance building measures into affordable housing.

Mechanical equipment contractors:

Equipment and selection process is designed for non-energy efficient



Comprehensive, supportive, holistic, affordable, energy-neutral housing design:



Talk to builders, designers, and contractors

What did you learn during the design and construction of this project? How could you be better supported?

Talk to residents

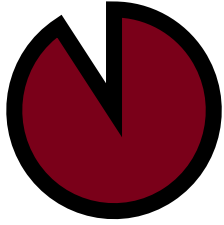
What is different? How could the design better support energy-efficient living?

Measure energy usage to see if it is operating as designed.

Share results and make recommendations

What are the key factors to be considered when starting a project that help ensure success?

The problems...



The information feedback loop is broken

- We have a lot of knowledge around best practices, but need better communication/community
- Current lack of education and training for owners, facilities managers and mechanical subs commissioning and operating equipment
- The resources (knowledge) is there, but not easily accessed
- There is growing demand for these types of high-performance affordable housing projects, especially in rural MN.



Our research approach

Collect feedback from *all* stakeholders

- Quantitative and qualitative data collection:
 - Post-occupancy evaluations
 - Interviews
 - Utility bills, IAQ monitoring
- Residents - better understand resident concerns, livability and quality of life
- Management - building community, new maintenance/management concerns
- Builders - better understand concerns, roadblocks
- Energy - are the buildings operating as intended, are energy models accurate?

Participating Projects



Project Team



Uptown Strawhouse

Owner: Katie Jones
& Peter Schmitt

Architect:
Precipitate

Energy Consultant:
Precipitate

Contractor: A+



Northside Passive

Developer:
Housing in Action

Architect:
Precipitate

Energy Consultant:
Precipitate

Contractor: JR
Remodelers &
Builders, Fortress



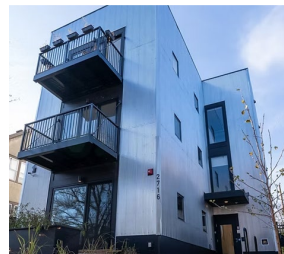
Hillcrest Village

Developer:
Northfield CAC

Architect:
Sweetgrass Design
Studio

Energy Consultant:
Precipitate & CSBR

Contractor: Reiland
Builders, Northfield
Construction Co.,
Schmidt Homes



Firefly

Developer:
Kaleidoscope

Architect: Awaken
Architecture

Energy Consultant:
CEE

Contractor: C&C
Construction



Sundial

Developer:
Heirloom Properties

Architect:
Fabrick

Energy Consultant:
Electric Housing &
Precipitate

Contractor: Langerman
Construction



Solstice

Developer:
Footprint

Architect:
Precipitate / True
North Studio

Energy Consultant:
Precipitate

Contractor:
Copeland



Participating Projects



Uptown Strawhouse
Phius 2018 Modeled
Custom Home
Minneapolis, MN
2023

1 unit
3 occupants

1715 GSF



Northside Passive
Phius 2021 Certified
Affordable Spec
Minneapolis, MN
2024

1 unit (5 total)
7 occupants

x GSF



Hillcrest Village
Phius 2021 Modeled
Affordable Rental
Northfield, MN
2022

2 units (17 total)
7 occupants /
duplex

2479 GSF / duplex



Firefly
DOE ZERH Certified
Market Rental
Minneapolis, MN
2024

12 units
22 occupants



Sundial
LBC Zero Energy Reg.
Market Rental
Minneapolis, MN
2023

12 units
31 occupants

9,684 GSF



Solstice
Phius 2021 Certified
Market Rental
Minneapolis, MN
2024

23 units
59 occupants

19,500 GSF



Envelope



Uptown Strawhouse

Roof R92.8
 24" cellulose
 Walls R23.8
 20" strawbale
 Slab R30
 Shallow 8" EPS

Windows
 Wood Frame
 Triple
 U 0.15
 SHGC 0.3-0.53



Northside Passive

Roof R60
 Blown Fiberglass
 Walls R48+15(12.7)
 12" SIPs + 3.5"
 fiber
 Slab R25.6
 Shallow 6" EPS

Windows
 uPVC Triple
 U 0.15-0.16
 SHGC 0.39



Hillcrest Village

Roof R50
 12" fiber + 2" spray
 Walls R40
 Schmidt Wall
 Slab R15
 4.8" EPS

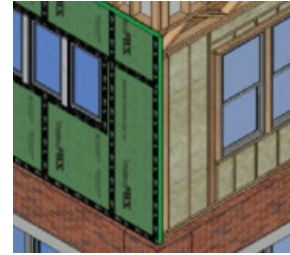
Windows
 uPVC Triple
 U 0.17-0.22
 SHGC 0.27-0.3



Firefly

Roof R60
 2" ccspf+Blown
 fiberglass
 Wall R25
 5.5" mw + 1" mw
 panel
 Slab
 3" XPS

Windows
 Fiberglass Double
 U 0.29
 SHGC 0.45



Sundial

Roof R54.6
 7" polyiso +
 3.5" mw
 Walls R12.6+21
 2.5" ZipR + 5.5"
 mw
 Slab R16.4
 4" EPS

Windows
 Fiberglass Triple/Quad
 U 0.09 -0.17
 SHGC 0.17- 0.39



Solstice

Roof R58.3
 6" polyiso + 5" cell.
 Walls R15+18
 3" GPS + 5.5" cell.
 Slab R10.42
 2" GPS

Windows
 Fiberglass Triple
 U 0.15-0.16
 SHGC 0.27



Systems



Uptown Strawhouse
Air Source Heat Pump
COP 3.96 (16 SEER 10.35 EER)

Energy Recovery
Ventilation
0.78 ASRE
0.49 w/cfm

Tankless Electric
Water Heater

Solar PV (roof)



Northside Passive
Air Source Heat Pump
COP 3.3@47, 2.3@17

Energy Recovery
Ventilation
0.79 ASRE
0.32 w/cfm

ASHP Water Heater
(Tank) EF 4.09

Solar PV (roof)



Hillcrest Village
Air Source Heat Pump
19 SEER, 10.2 HSPF

Energy Recovery
Ventilation
0.77 ASRE
0.43-0.67 w/cfm

ASHP Water Heater
(Tank) EF 3.42

Solar PV (ground)

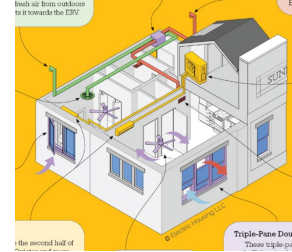


Firefly
Air Source Heat Pump
20.5-42 SEER, 14-15 HSPF

Energy Recovery
Ventilation+Direct
venting w/ MUA units
0.87 ASRE
0.57-1.7 W/cfm

ASHP Water Heaters
80g tank each floor
4.07 UEF

17kW Solar PV (roof)



Sundial
Air Source Heat Pump

Energy Recovery
Ventilation
0.63 sensible recov.
1.63 w/cfm

Shared Solar
Thermal + ASHP
Water Heater

Solar PV (roof)



Solstice
Minotaur Combined
Heat Pump (COP 3.7)
Energy Recovery
Ventilation
0.6-1 ASRE
0.85-1.1 w/cfm

Shared ASHP Water
Heater EF 4.24

Solar PV (roof)



Post Occupancy Evaluation

The Qualitative Resident Experience



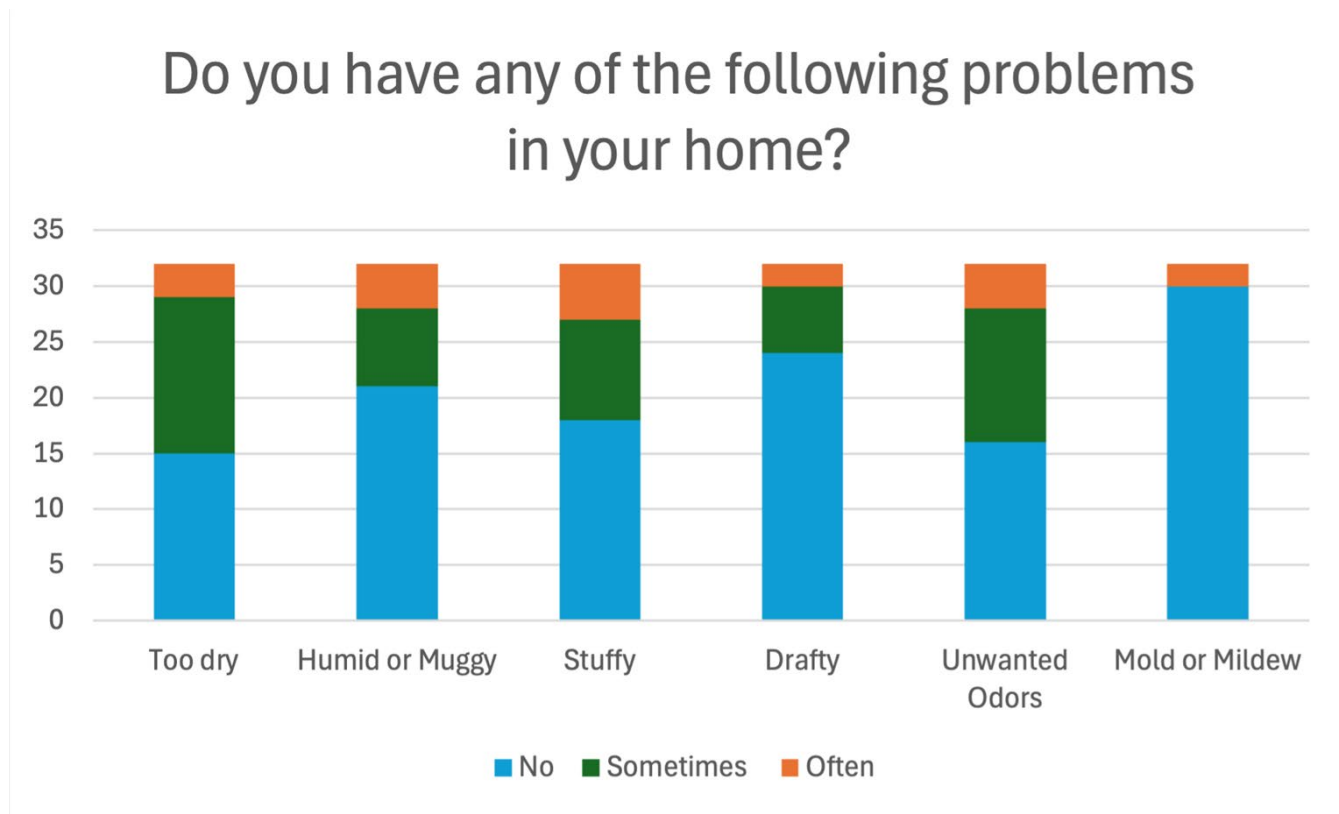
Post-Occupancy Evaluation

Only 30 responses across the 6 study sites (79 units) – despite survey incentive.

- Generally, occupants are satisfied with the quality and comfort of the spaces.
- Quality of daylighting and operable windows are frequently mentioned.

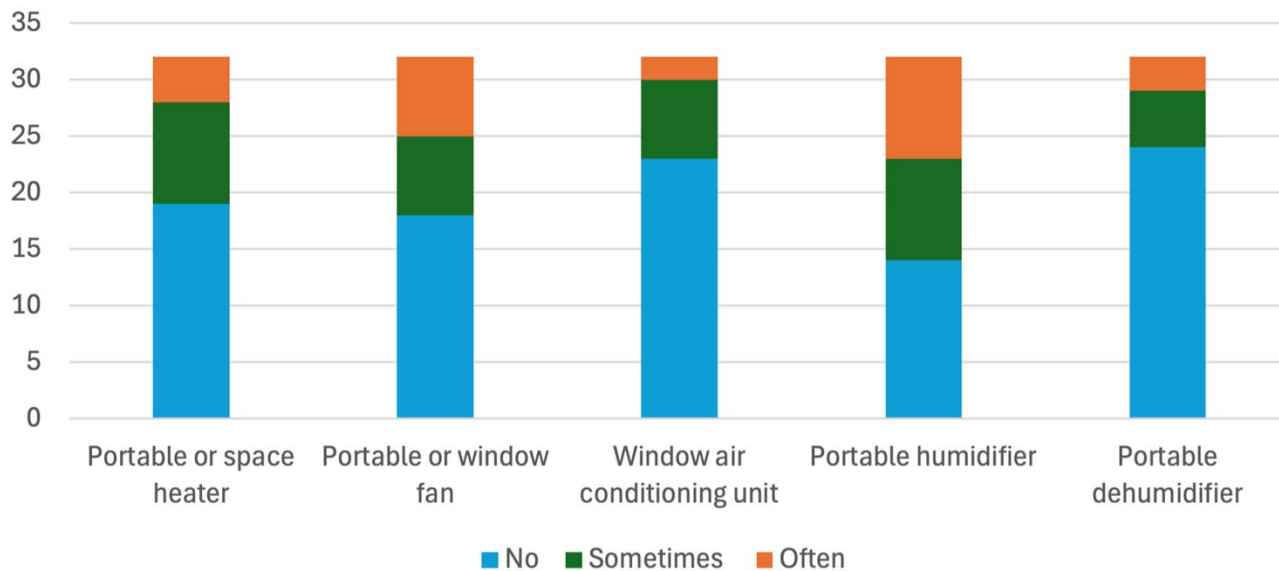


Post-Occupancy Evaluation



Post-Occupancy Evaluation

Do you use any of the following plug-in appliances?



Post-Occupancy Evaluation

- Some complaints about temp fluctuations and controls.
- Appliances are problematic!
 - Complaints about stuffy/humid conditions, indoor smoke sources, long laundry or dryer cycles.
 - Hot water metrics are generally high, except for time to delivery in bulk heater layouts.
- Billing method perceptions vary:
 - Fixed billing is appreciated for regularity, but “seems high”
 - Direct billing is appreciated for knowing that it can be affected by occupant behavior, but that it can vary considerably. Xcel bills are not helpful.
 - 3rd party billing is generally disliked because of delays in billing. Hard to know when or what affects cost.



Post-Occupancy Evaluation

Despite relatively high self-reporting on “knowledge about operating and maintaining equipment in an energy efficient home” (3.9/5), occupants generally want more education.

“I don't fully understand the airflow buttons in some rooms.”

“I do not know how to maintain the air handler.”

“How to better circulate air and keep airflow moving without opening the windows.”

“How to get the dishwasher to work better.”

“More education.”

“More educational resources.”

“A brochure when we moved in might have been useful. Everything was explained verbally, very thorough, but easy to forget pieces”

“A link to user manuals would be a good reference.”



Indoor Air Quality

The Quantitative Resident Experience



Study Format

Airthings Space Pro

Optical-based sensor measuring:

- Ambient conditions - Temp, RH, Pressure, Noise, Light
- Pollutants - CO₂, VOC, PM1, PM2.5, PM10



10 sites tracked for 2+ years (30 total units)

- 5 single family homes
- 3 apartment buildings (18 units measured plus some common spaces)
- 1 “village” development (collection of duplexes, triplexes, quads, 6 units measured)
- 1 historic institutional building (CSBR office)



Carbon Dioxide

Outside air is not a large source of CO₂.

CO₂ is produced almost entirely by resident activities (assuming well-placed OA intakes)

Ventilation rates primarily control CO₂ levels

Findings:

- Common spaces generally performing well, even without much direct ventilation
- Resident units generally not performing great



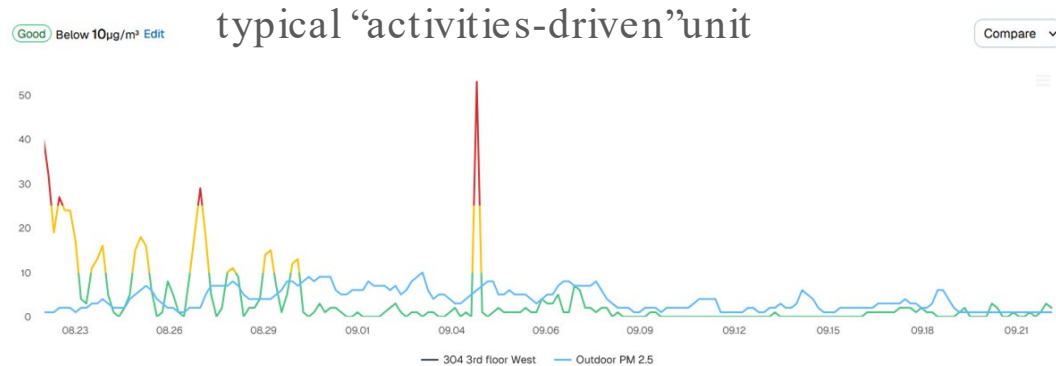
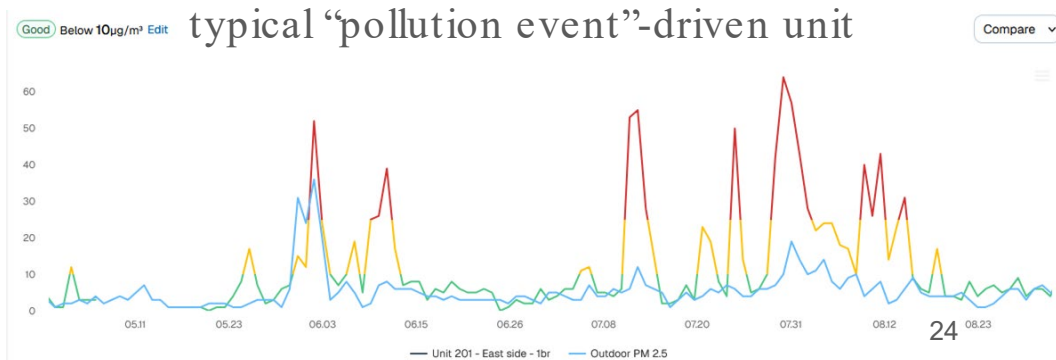
Pollutants - PM2.5

PM2.5 is frequently produced by resident activities but can also come from outdoor air during wildfire or other pollution events

Ventilation rates help control PM2.5 levels during periods of good outdoor air quality. But high efficiency filtration (MERV 13 or better) is critical during pollution events.

Findings:

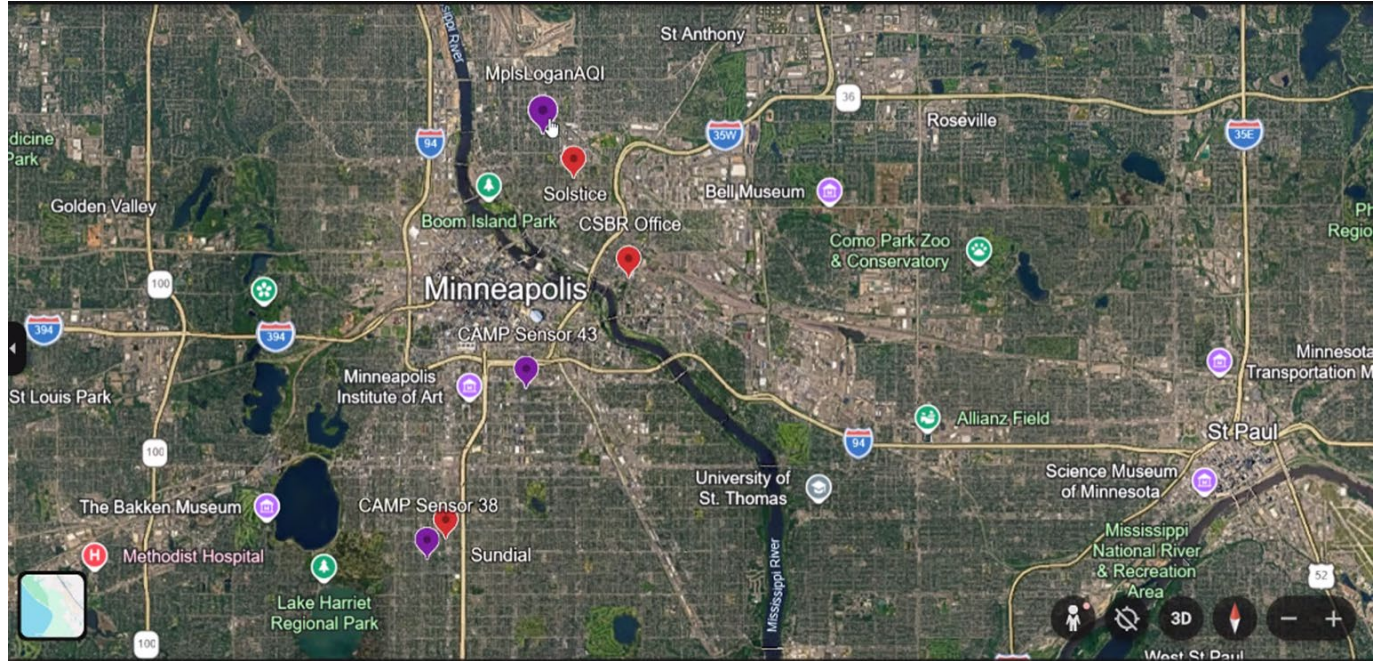
- Many units struggling to keep up with resident activities
- Almost all units show severe difficulty handling pollution events



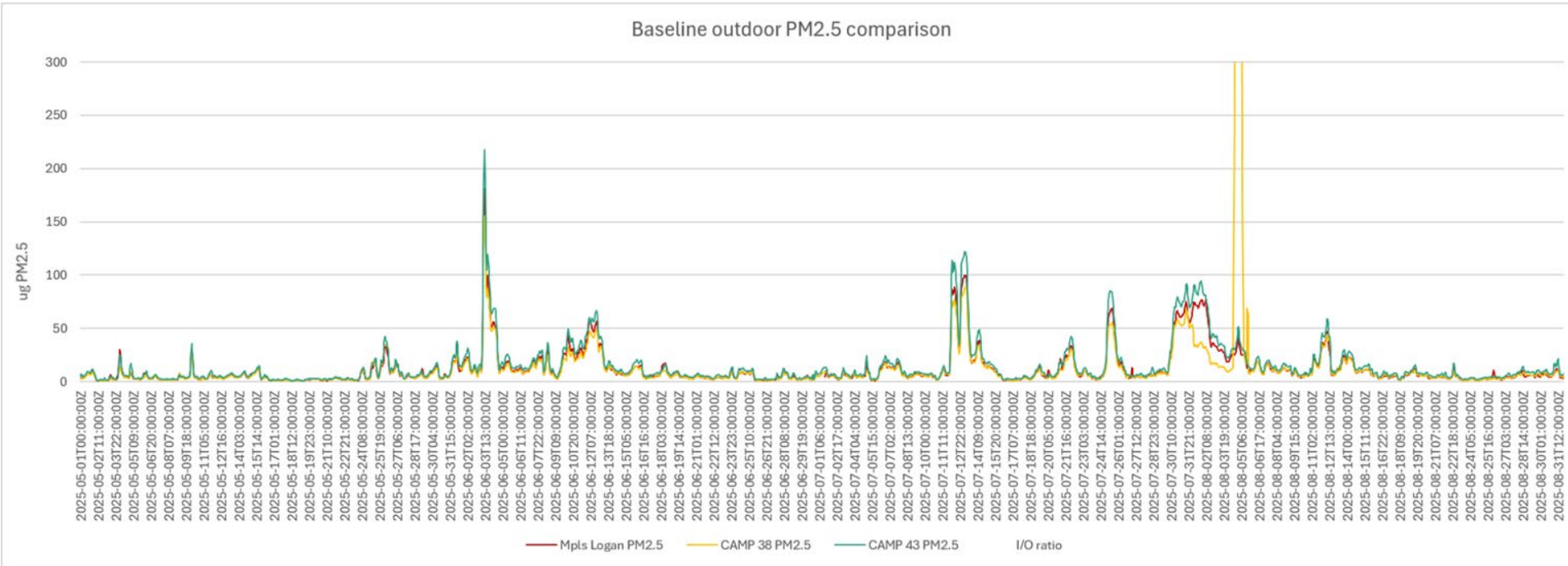
Study Format

Ambient PM_{2.5} data downloaded from 3 local sites in Minneapolis during summer of 2025 (high frequency of wildfire smoke).

Community Air Monitoring Program (CAMP) uses a network of public PurpleAir monitoring stations

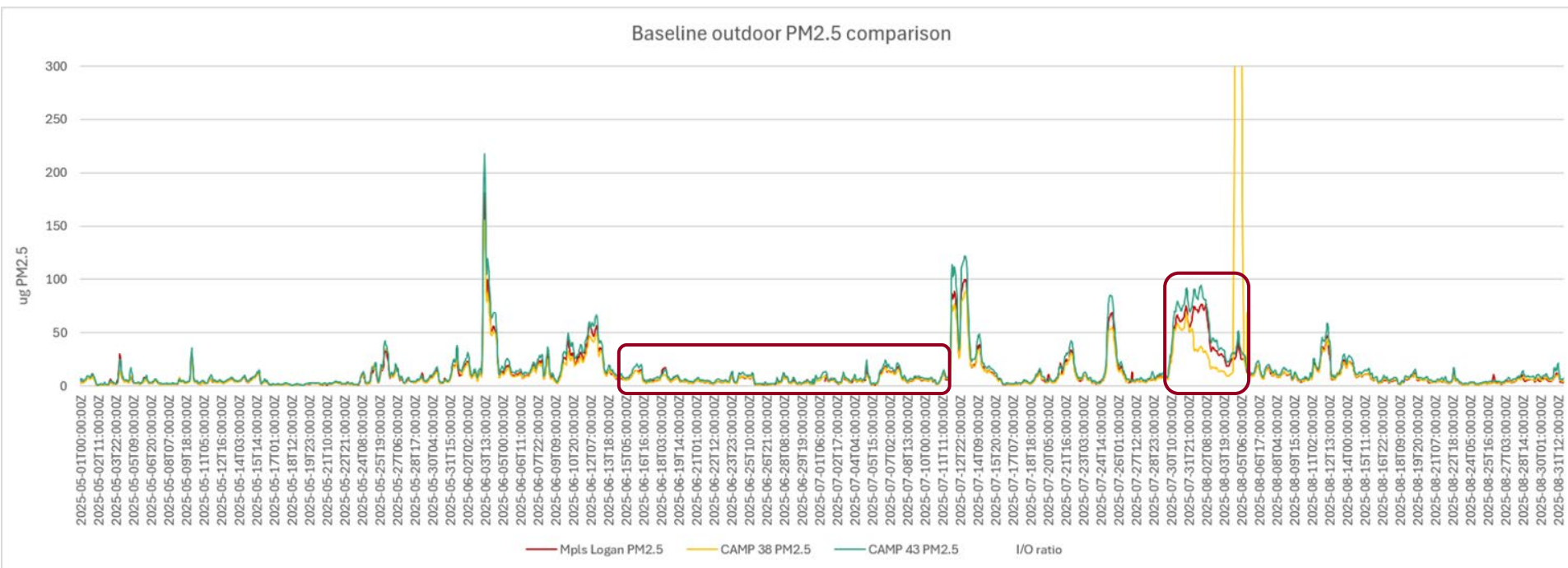


Study Format



Wildfire events clearly show up as extended periods of high PM2.5, aligned across all 3 sites, and reaching PM2.5 levels many x higher than background

Study Format



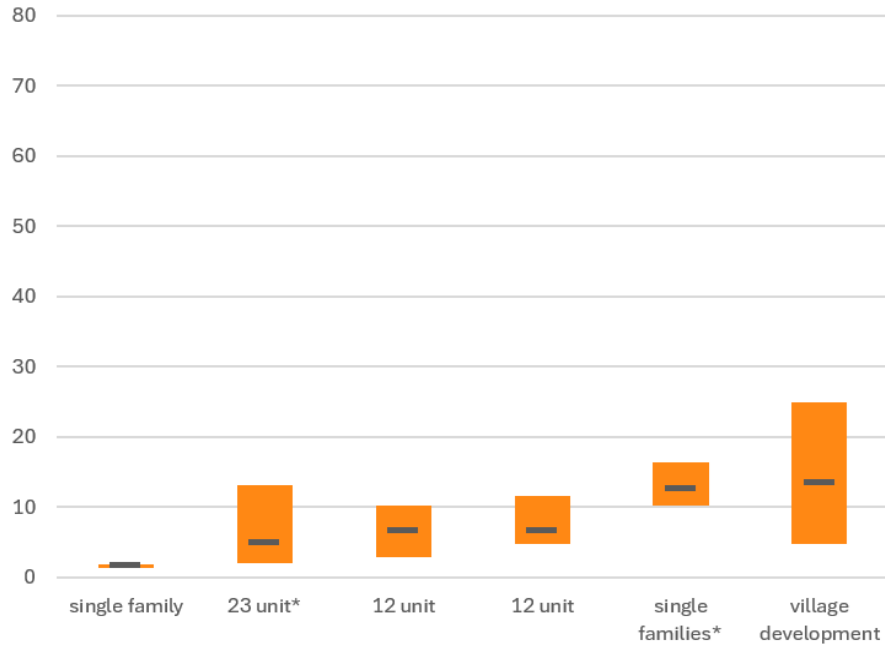
“Clean” period: 6/15/25 - 7/12/25 (generally)

Pollution event: 7/30/25 - 8/6/25

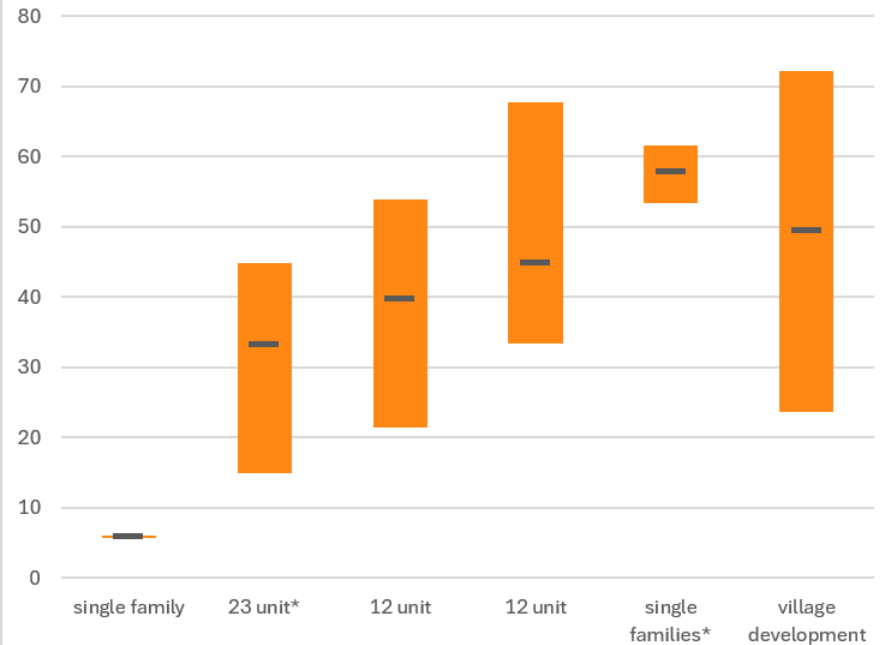


Pollutants - PM2.5

Indoor PM2.5 with "clean" outdoor conditions
(average and range)



Indoor PM2.5 during pollution event
(average and range)



Pollutants - PM2.5

EPA sets the National Ambient Air Quality Standards for Particle Pollution (NAAQS). Conversion to AQI shown.

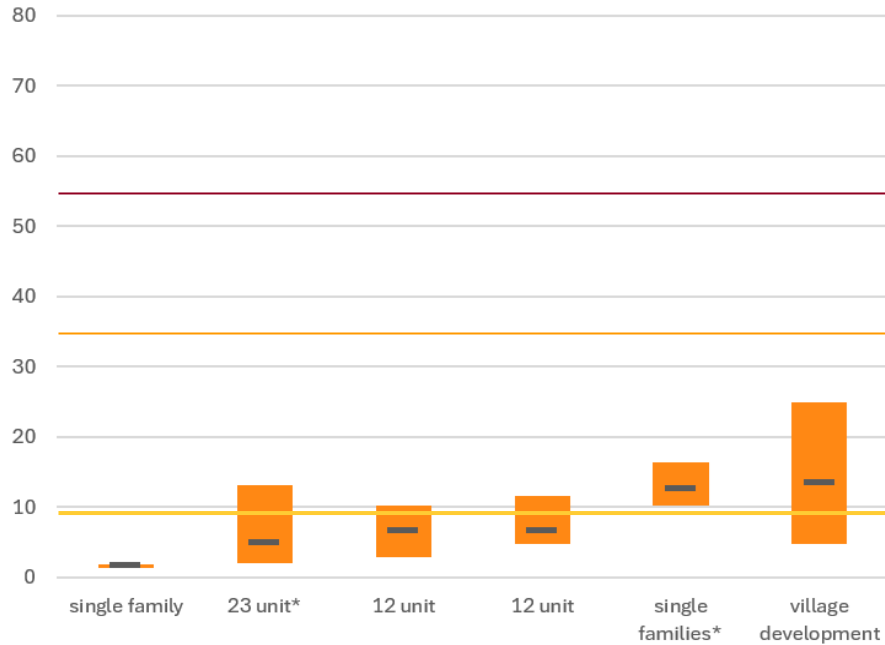
Target annual average below 12 (reduced to 9 in 2024)

AQI (US)	PM2.5 (µg/m3)	Remark
0-50	0-12	Good
51-100	12-35	Moderate
101-150	35-55	Unhealthy for Sensitive Individuals
151-200	55-150	Unhealthy
201-300	150-250	Very Unhealthy
>300	>250	Hazardous

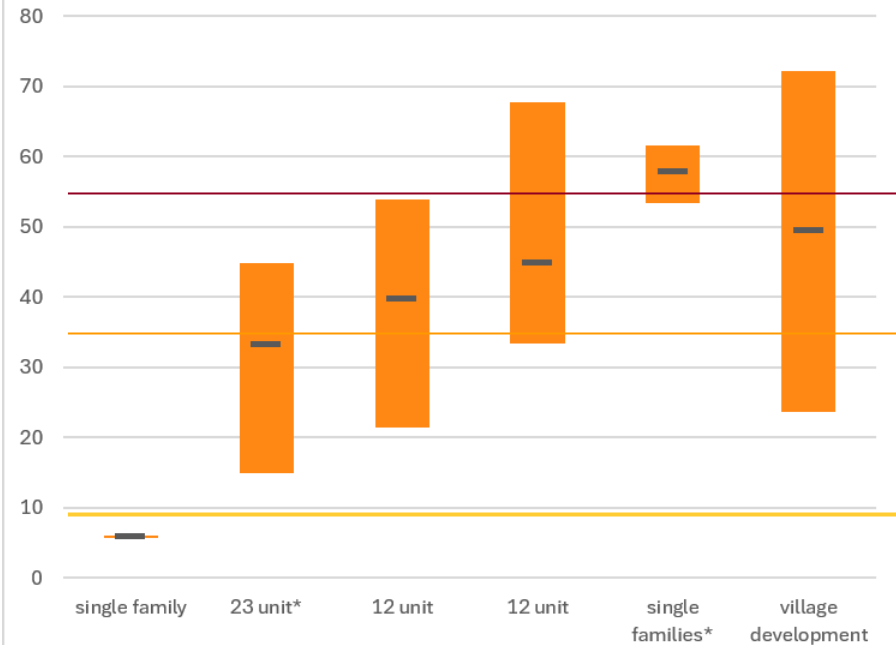


Pollutants - PM2.5

Indoor PM2.5 with "clean" outdoor conditions
(average and range)



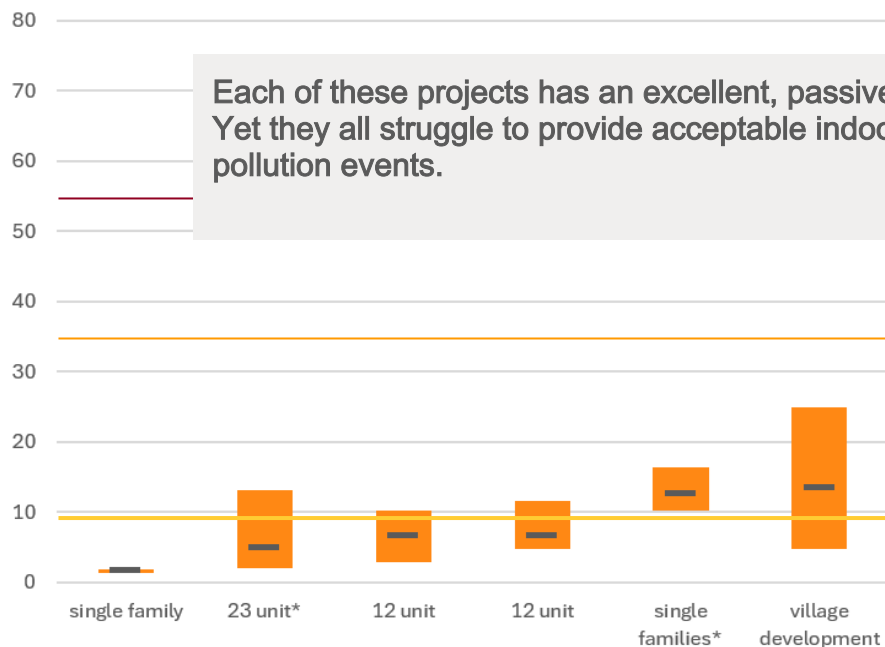
Indoor PM2.5 during pollution event
(average and range)



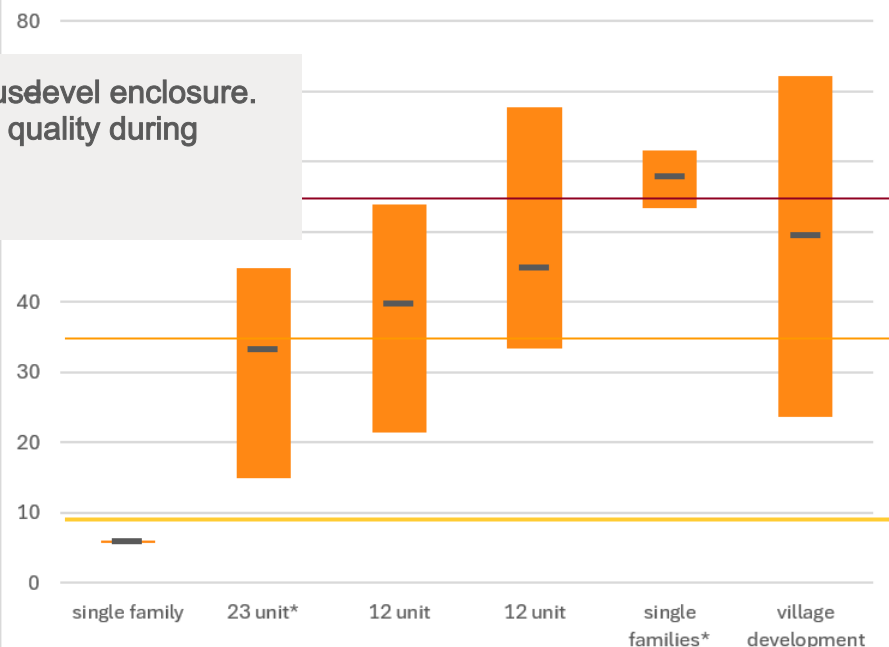
How do efficient envelopes impact PM2.5?

Indoor PM2.5 with "clean" outdoor conditions
(average and range)

Each of these projects has an excellent, passive houselevel enclosure. Yet they all struggle to provide acceptable indoor air quality during pollution events.

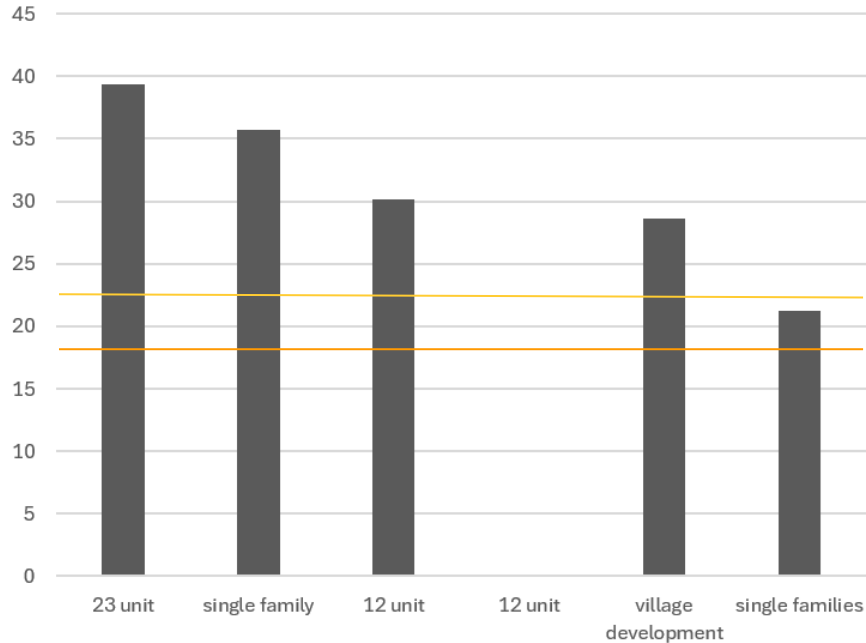


Indoor PM2.5 during pollution event
(average and range)



How about the ventilation system?

Mechanical ventilation (modeled)
cfm/occupant

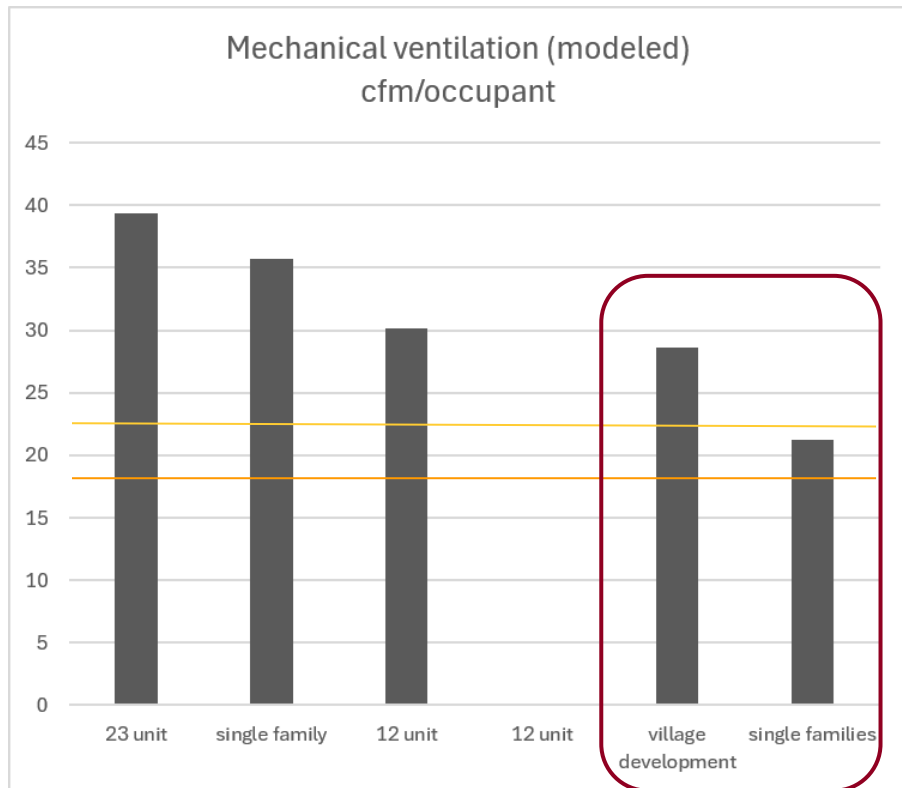


All projects - recirculating range with
bath/ kitchen exhaust routed through
ERV

All projects - designed to provide at least
18 cfm/person (Phius req.)
(ASHRAE 62.2 typically closer to 22 cfm/person
assuming 500sf/person)



How about the ventilation system?



All projects - recirculating range with bath/ kitchen exhaust routed through ERV

All projects - designed to provide at least 18 cfm/person (Phius req.)
(ASHRAE 62.2 typically closer to 22 cfm/person assuming 500sf/person)

Projects with lowest cfm/person had the highest PM2.5 levels



How about filtration?



The end effectiveness of a filtration system can be measured in terms of the Indoor/Outdoor ratio (I/O)

indoor PM2.5 / outdoor PM2.5 = I/O ratio

- $I/O < 1$ is adequate, but the lower the better
- Envelope quality and ventilation rate can also play a role
 - Very leaky enclosures or very high ventilation rates can overwhelm the impact of a filter and lead to $I/O = 1$
- Frequent indoor pollution events (smoking, burning candles, cooking, etc) can lead to $I/O > 1$
 - Very tight enclosures with inadequate ventilation rates worsen this problem
- Rolling averages are generally used to help eliminate short-term spikes in indoor data



How about filtration?

MERV Rating	Typical PM2.5 Single-Pass Efficiency (η)	Resulting Target I/O Ratio Range	Primary Particle Targets Captured
MERV 1–4	< 20%	0.80 – 0.95	Large dust, lint, carpet fibers
MERV 5–8	20% – 50%	0.65 – 0.75	Mold spores, cement dust, pollen
MERV 11–12	50% – 75%	0.40 – 0.55	Fine dust, pet dander, auto emissions
MERV 13–14	85% – 90%	0.15 – 0.30	Wildfire smoke, bacteria, virus droplets
MERV 15–16	> 95%	0.05 – 0.15	Combustion smoke, microscopic allergens

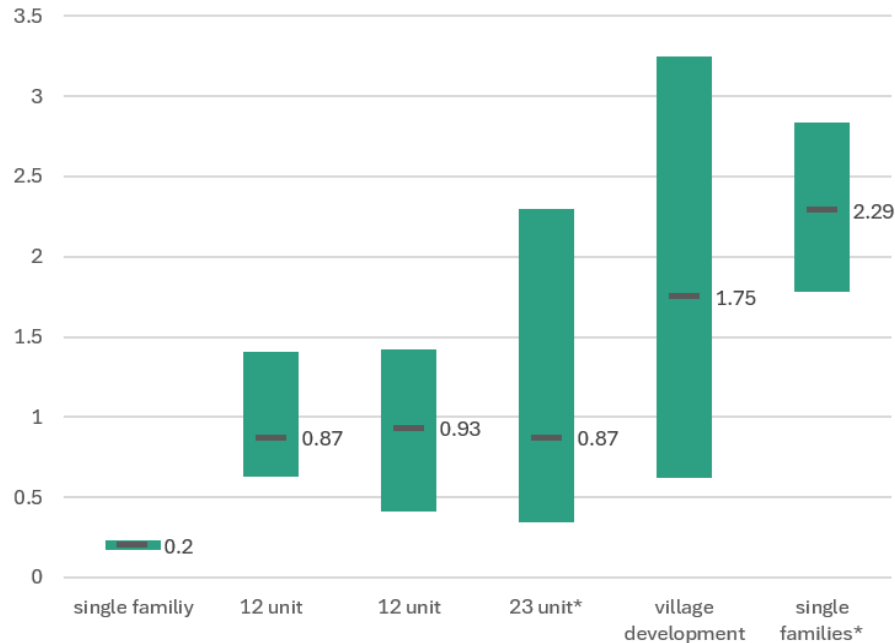
(All?) ventilation units were fitted with standard MERV 8 filters

MERV ≥ 13 is necessary to adequately control wildfire smoke

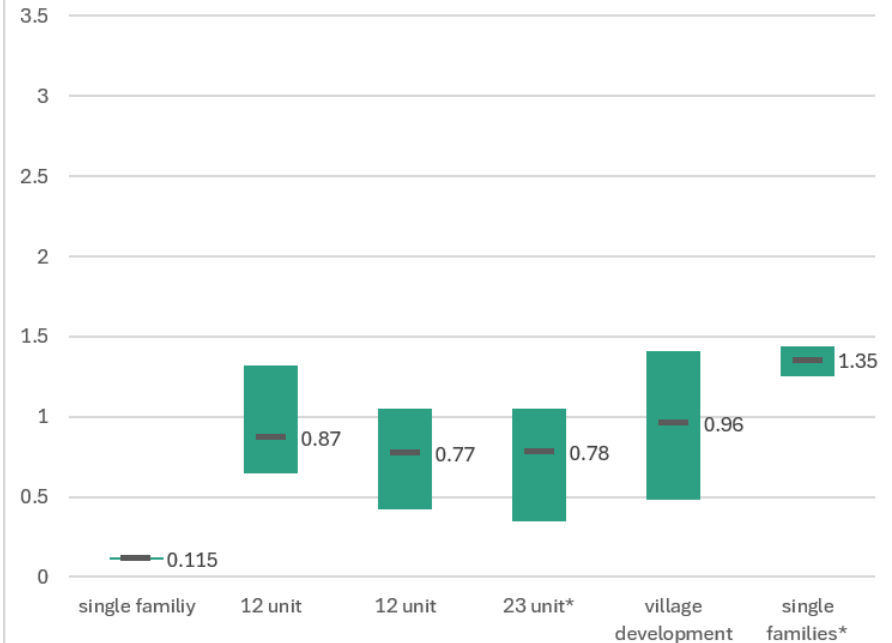


I/O Ratio (PM2.5)

I/O ratio (long term) with "clean" outdoor conditions

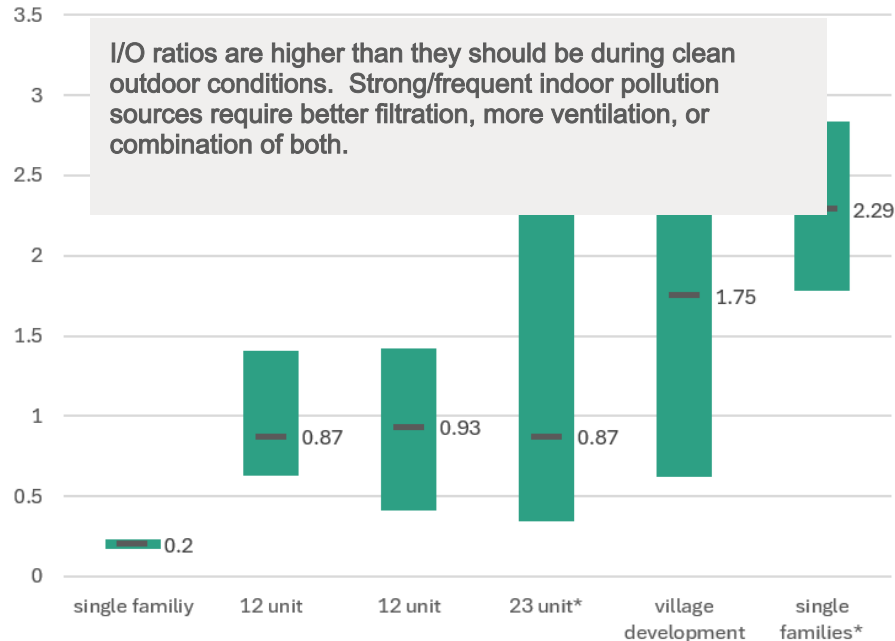


I/O ratio (long term) during pollution event

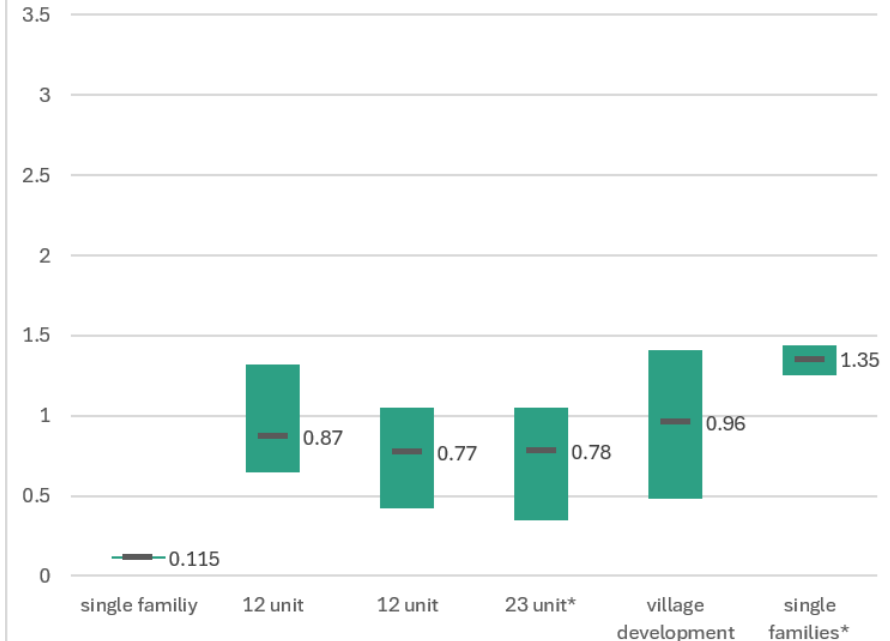


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I/O ratio (long term) with "clean" outdoor conditions

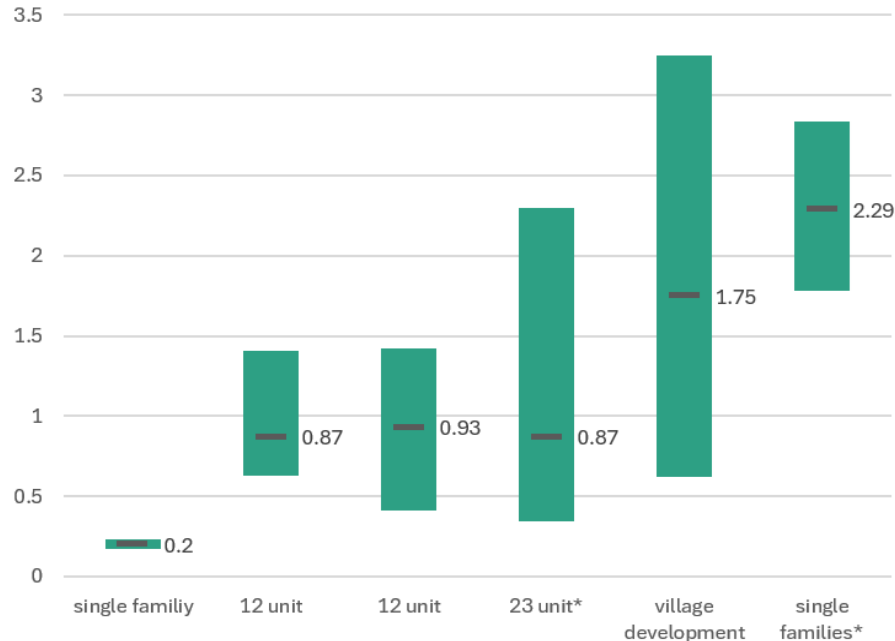


I/O ratio (long term) during pollution event

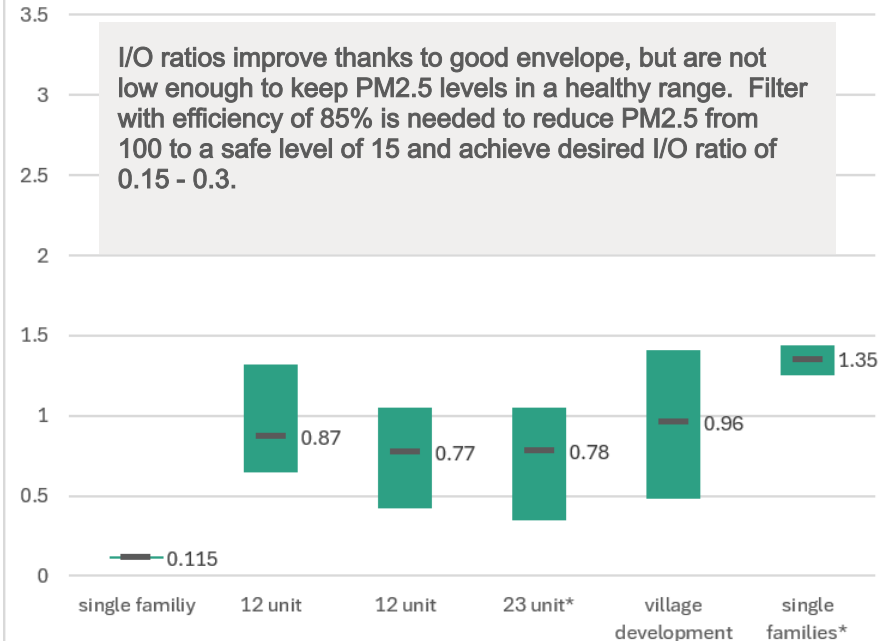


I/O Ratio (PM2.5)

I/O ratio (long term) with "clean" outdoor conditions

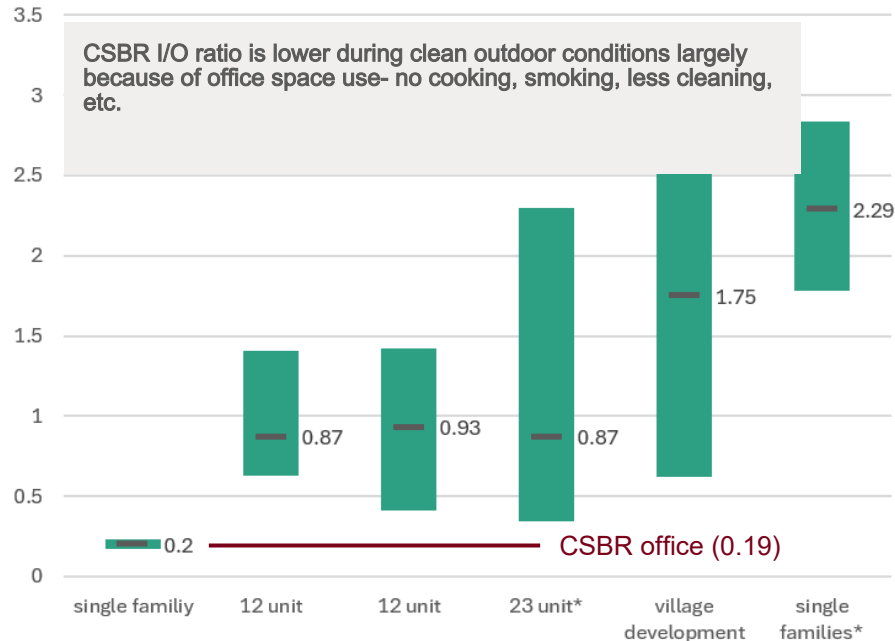


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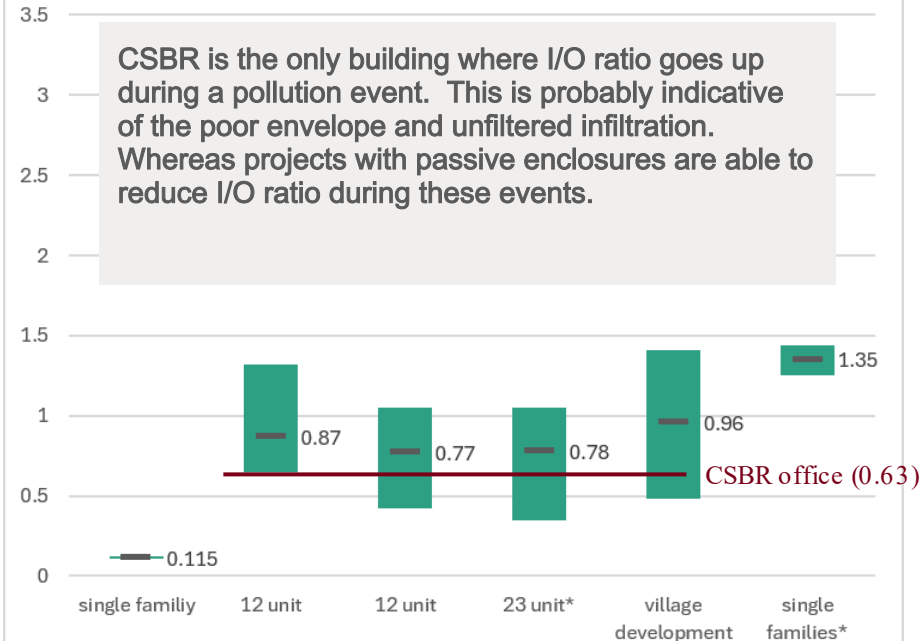


I/O Ratio (PM2.5)

I/O ratio (long term) with "clean" outdoor conditions



I/O ratio (long term) during pollution event



Energy Performance Data

Methodology

- Energy models (5 sites)
- Blower door tests
- Direct panel meters (3 sites)
 - ultimately unused
- Energy Star Portfolio Manager
 - attempted unsuccessfully so far for 5 sites, continue to try
- Utility billing statements & downloads
 - successful for 5 sites

SERVICE ADDRESS: [REDACTED]

NEXT READ DATE: 10/01/26

ELECTRICITY SERVICE DETAILS

PREMISES NUMBER: [REDACTED]

INVOICE NUMBER: [REDACTED]

METER READING INFORMATION		
METER [REDACTED]		Read Dates: 07/29/25 - 08/27/25 (29 Days)
DESCRIPTION	USAGE TYPE	USAGE
Total Del by Xcel	Actual	175 kWh
Total Delivered by Customer	Actual	912 kWh
Total Net Delivered by Xcel	Actual	0 kWh
Net Generated by Customer	Actual	737 kWh

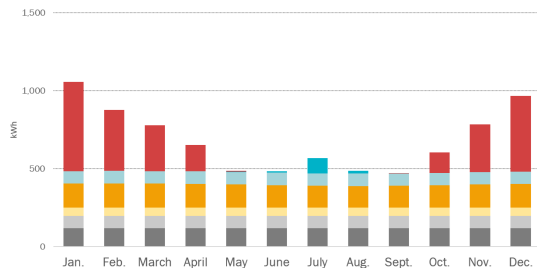
ELECTRICITY CHARGES		RATE: Net Energy Billing Svc	
DESCRIPTION	USAGE UNITS	RATE	CHARGE
Basic Service Chg			\$6.00
Basic Service Chg			\$1.90
Energy Charge Summer	0 kWh	\$0.130690	\$0.00
Energy Charge Summer	737 kWh	\$0.176560	- \$130.12 CR
Fuel Cost Charge	0 kWh	\$0.029270	\$0.00
Sales True Up	0 kWh	\$0.000410	\$0.00
Affordability Chrg			\$2.12
Resource Adjustment			\$0.15
Interim Rate Adj			\$0.43
Subtotal			- \$119.52 CR
City Fees		5.50%	\$0.48
Transit Improvement Tax		1.25%	\$0.11
Other Special District		0.25%	\$0.02
City Tax		0.50%	\$0.04
County Tax		0.15%	\$0.01
State Tax		6.875%	\$0.62
Total			- \$118.24 CR



Modeled Monthly Energy Use

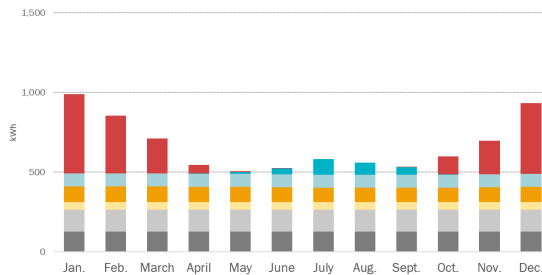
Single Family

MODELED Site Monthly Energy Use



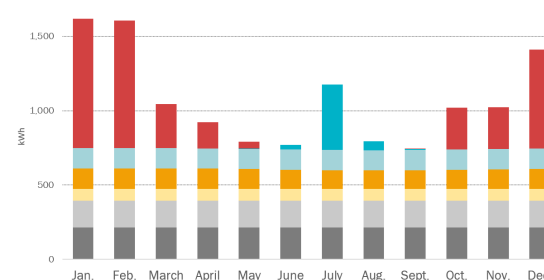
Single Family*

MODELED Site Monthly Energy Use



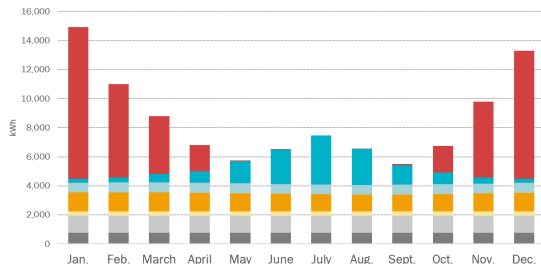
Duplex

MODELED Site Monthly Energy Use



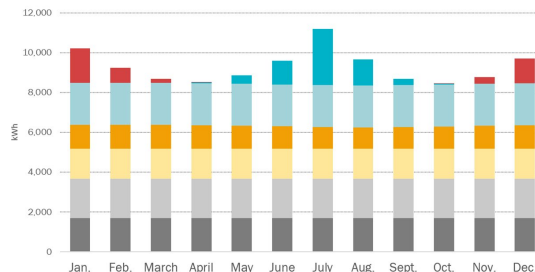
12 Unit*

MODELED Site Monthly Energy Use



23 Unit

MODELED Site Monthly Energy Use



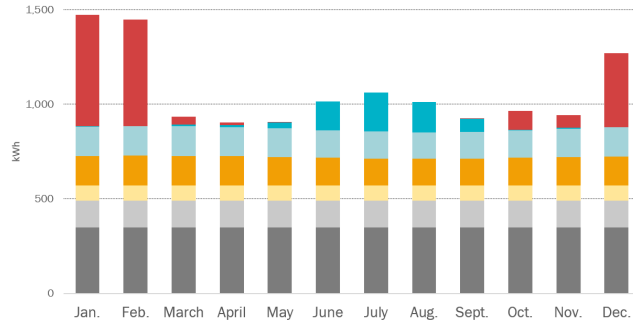
- SPACE HEATING
- SPACE COOLING
- AUXILIARY ENERGY/FANS
- HOT WATER
- LIGHTING
- LARGE APPLIANCES
- MISCELLANEOUS LOADS



Duplex Comparison

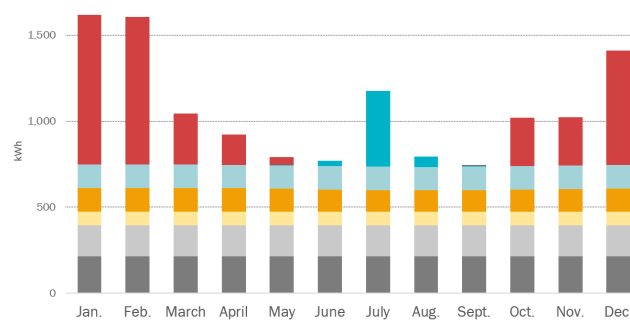
Original U0.15 Windows

MODELED Site Monthly Energy Use



Actual U0.22 Windows

MODELED Site Monthly Energy Use

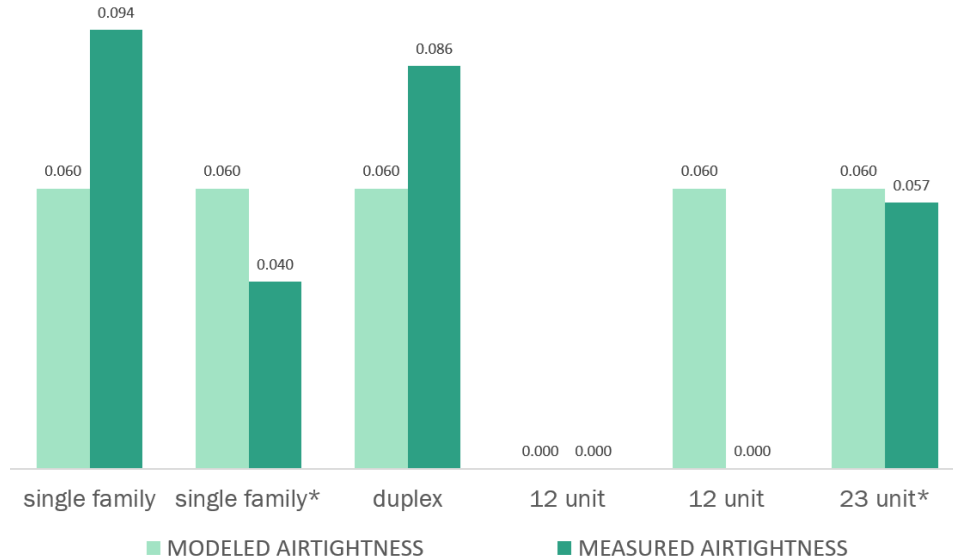


- SPACE HEATING
- SPACE COOLING
- AUXILIARY ENERGY/FANS
- HOT WATER
- LIGHTING
- LARGE APPLIANCES
- MISCELLANEOUS LOADS



Envelope Airtightness

Envelope Airtightness (cfm/SF envelope @ 50 pa)



Variance in 5 SF Phius

	Pressure	Depr.
811 31st	0.03	0.03
2207 N 4th	0.03	0.03
2207 Queen	0.04	0.05
2704 Bryant	0.05	0.05
2914 Dupont	0.05	0.04



Local Utility Billing is Suspect

What are Xcel customers experiencing?

In September 2025, CUB and Legal Services Advocacy Project submitted comments at the PUC detailing the complaints and questions from Xcel's residential customers that CUB's outreach team has fielded.

CUB AND LSAP'S COMMENTS →



Past-due customers & payment plans

Customers have reported to CUB that Xcel agents are sometimes unwilling to offer payment agreement terms that are affordable for the household and/or that properly consider extenuating circumstances.



Incorrect information in online portal

Customers report their MyAccount portals show incorrect rate information or are missing usage data.



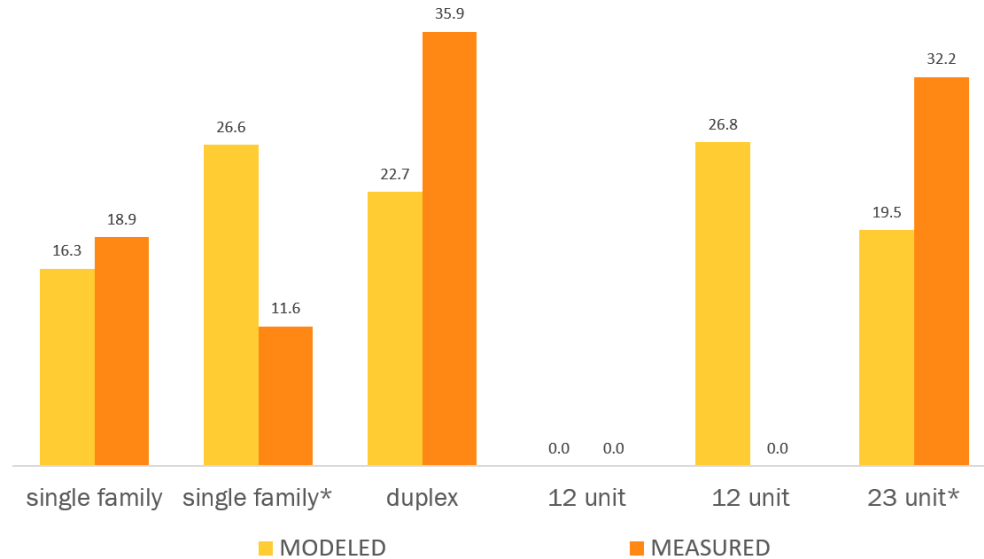
Poor information about rate and program options

Customers have reported customer service agents provide inaccurate information about rate options and do not inform eligible customers about affordability programs.



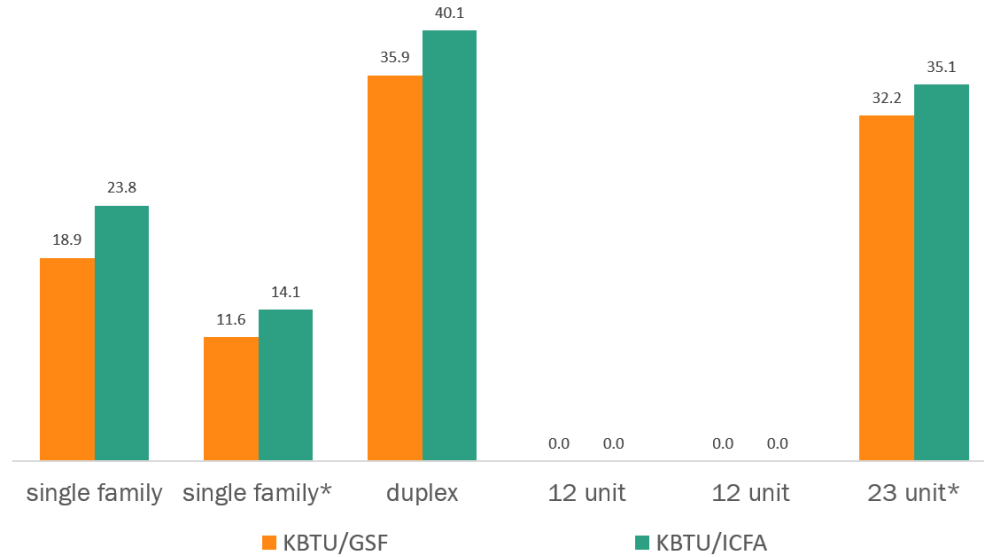
Energy Use Intensity

Energy Use Intensity (kBtu/GSF.year)



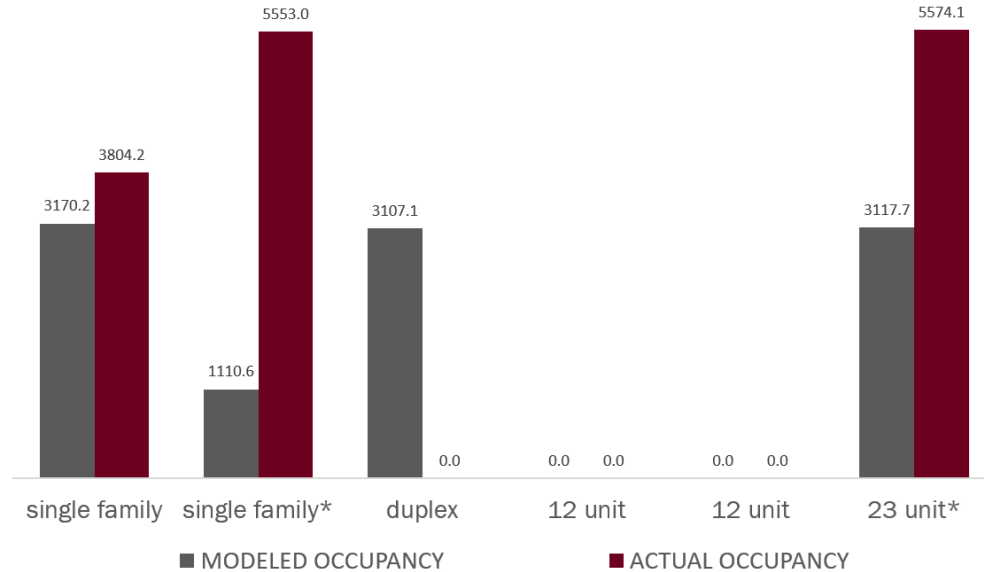
Energy Use Intensity

Energy Use Intensity (kBtu/SF.year)



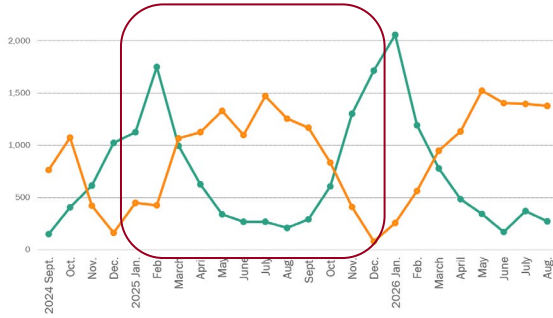
Energy Use Intensity

Energy Use by Occupant (kWh/person.year)

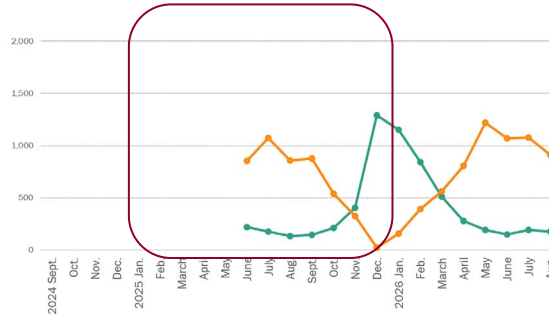


Actual Monthly Energy Use by Unit

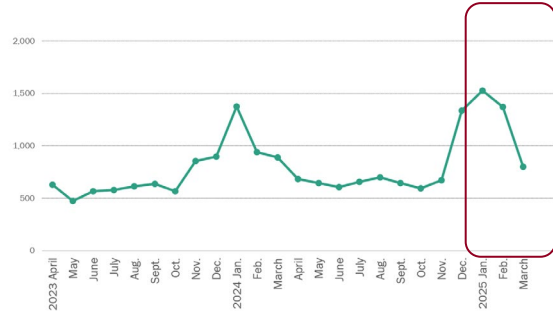
Single Family



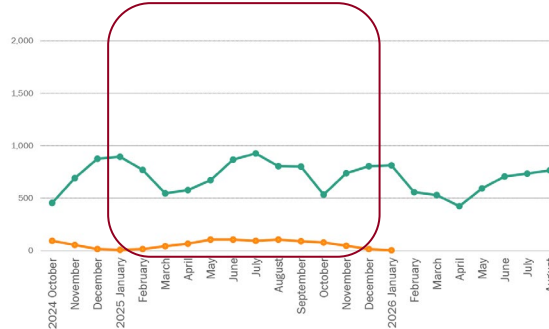
Single Family*



Duplex



23 Unit*



● KWH USED PER UNIT
● KWH GENERATED PER UNIT



Post Construction Evaluation

The Contractor Experience

Five building developers interviewed

- What were the challenges and successes?
- What material or equipment supply issues?
- What labor or management issues?
- Lessons learned and would you do it again?



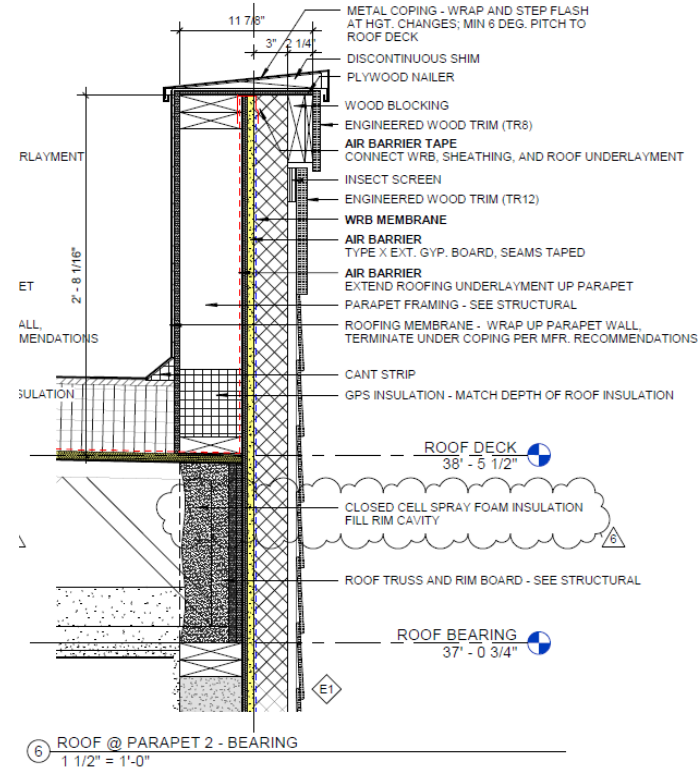
The big takeaways for builders and developers

- Expect high oversight and handholding
 - Knowledge and experience of subs was rated as “low.” This is compounded in rural areas.
 - All developers reported spending significant time on site in careful observation and in some cases performing work, particularly air sealing.
- Experience pays off over time
 - All developers are moving forward with additional high-performance projects.
 - In most cases, the same design and construction team is being used on future projects - a key recommendation.



Construction Challenges

- Air Barriers and Framing are the primary challenges in construction.
 - Difficulty with concept and continuity of air barriers.
 - Envelope sealing (such as rolling tape on the Zip System)
 - Framing tolerances affect airtightness results
 - Air barrier between units was new unknown concept
 - Nail flanges help
- Plumbers and HVAC contractors frequently resisted or struggled with unfamiliar systems.
 - “Why do waste water heat recovery?”
 - HVAC system recalibration needed post-occupancy



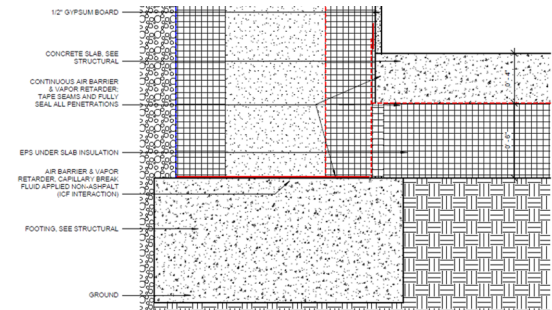
Contracts & Contingency

- Traditional bidding → negotiated partnering contracts
 - Negotiated bid models allow for better integration, closer coordination with design team, and shared pricing assumptions that lower perceived risk.
 - High-budget negotiated models or flexible contingencies fare better at mitigating budget risks.
- Risks were over-validated and healthy contingency was carried on most projects



Advice from a Builder/Developer Perspective

- Simplify the design
 - Complex wall systems to simpler, cost-effective wall designs
 - Increasing roof insulation and going Prescriptive Path to allow thinner SIPs
 - Moving away from frost protected shallow foundation to standard basement
- Perceived value of certification varies
 - Projects that obtained Phius certification this round are pursuing Phius for future projects
 - Prescriptive Path is more attainable for single family
 - Developers see value in on-site verification and testing during construction
 - For those not pursuing Phius, mixed on if will pursue in future
 - One developer pursuing Phius on next project
 - In MN market, DOE Efficient New Homes obtains max rebate, so little incentive to go beyond that level



Project Findings

Recommendations for Future Projects



Big Issue #1

Indoor air quality needs improvement even in phius projects,
and conventional ventilation strategies (i.e. - more ventilation!)
no longer work reliably.
(more fires = poor outdoor air quality)



Issue #1 Response

- Good envelopes are important, but must be paired with **high MERV filtration**
 - MERV 13+ ratings are critical during air quality events to maintain healthy indoor air
- Use **demand-controlled ventilation**
 - Reduces unnecessary ventilation energy losses, especially if using high MERV filters
- Adjust outdoor air ventilation during air quality events
 - Outdoor air quality sensors can temporarily reduce intake of ERV/HRV systems
- Use exhaust range hood in place of recirculating
 - Remove particulates quickly while cooking
- Maintain the ERV
 - Hire HVAC installers or other on 10+ year equipment maintenance contracts
 - Provide resident education on operation and expectations
- Consider separating out basic ventilation needs from PM filtration
 - i.e., use stand-alone air filters



Big Issue #2

This is new and challenging.

Builders can be resistant and labor can be unfamiliar with new practices and technology.



Issue #2 Response

- Projects need a (knowledgeable) champion
 - Be on site
 - Provide guidance & ensure proper execution
 - Build trust with builders
 - Hold the line
- Provide education opportunities for builders
 - Require builders to have site supervisors complete CPHB training
 - Offer construction tours of high performance projects - great PhiusAlliance activity
- Work with the same team on future projects
 - Provides assurance to builders that the steep learning curve will be rewarded with future work
 - Costs will come down on future projects with the same team



Big Issue #3

Occupants want (and need) more educational opportunities.



Issue #3 Response

- Provide more instructional opportunities and resources
 - In-person engagement with trusted people is best practice (e.g. - walkthroughs & workshops)

combined with...
 - Manuals, apps, or project-specific websites providing information on all unfamiliar, high-performance features for residents to reference afterward



Big Issue #4

Envelopes don't use energy, people do.



Issue #4 Response

- Evaluate and design for energy use per person (source energy target) rather than kBtu/ SF (EUI) - it tells us more
 - When high performance envelopes and systems reduce space conditioning significantly, normalizing by the square footage of envelope and conditioned space tells us less
 - Energy use starts to be driven more by occupant behavior - plug loads, ventilation, etc.
- Direct efforts at occupant education & controls
 - Automation of ventilation could reduce loads while providing extra ventilation when needed, all without placing burden on residents
 - Residents want to know more about operating their space, and those who take action (replacing filters, opening windows) likely have better air quality



