Passive House and Net Zero Energy

3 Multifamily Prototypes Compared

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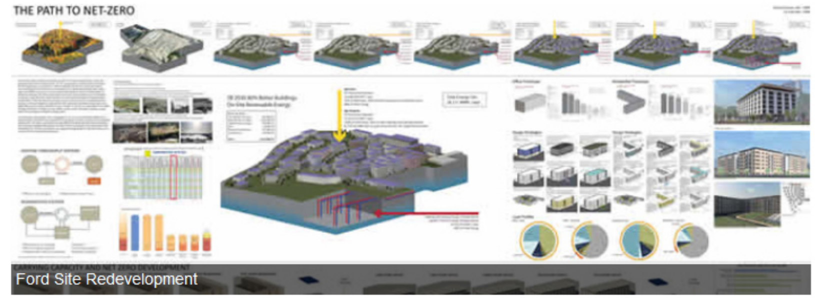
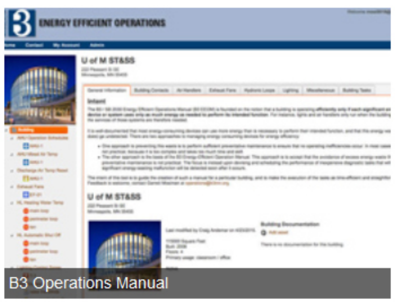
An Interview with Richard Graves

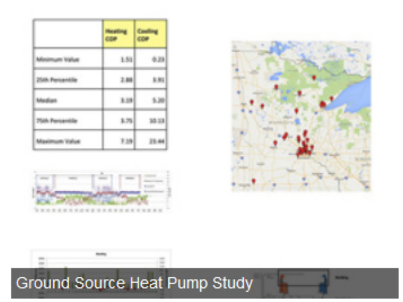


Ford Site Redevelopment



B3 Operations Manual

MNSHI Affordable Prototyping



Ground Source Heat Pump Study

The Rose

AREAS OF FOCUS

Energy and Climate Change: Provide tools, expertise, and research to support energy independence, security, and climate neutrality for the state, nation and planet.

The Water Cycle: Understand the water cycle and its relationship to the built environment in the provision, capture, use, reuse, and recharging of water in local and regional watersheds and global water cycle.

Sustainable Materials for a healthy built environment: A regenerative built environment will need a renewable source of materials that create healthy long-lasting environments.

Value and benefits of regenerative designs: Develop metrics to track the full range of value created by sustainable and regenerative designs.

Equitable designs to provide sustainability for all: Investigate building solutions to provide sustainability to all communities.

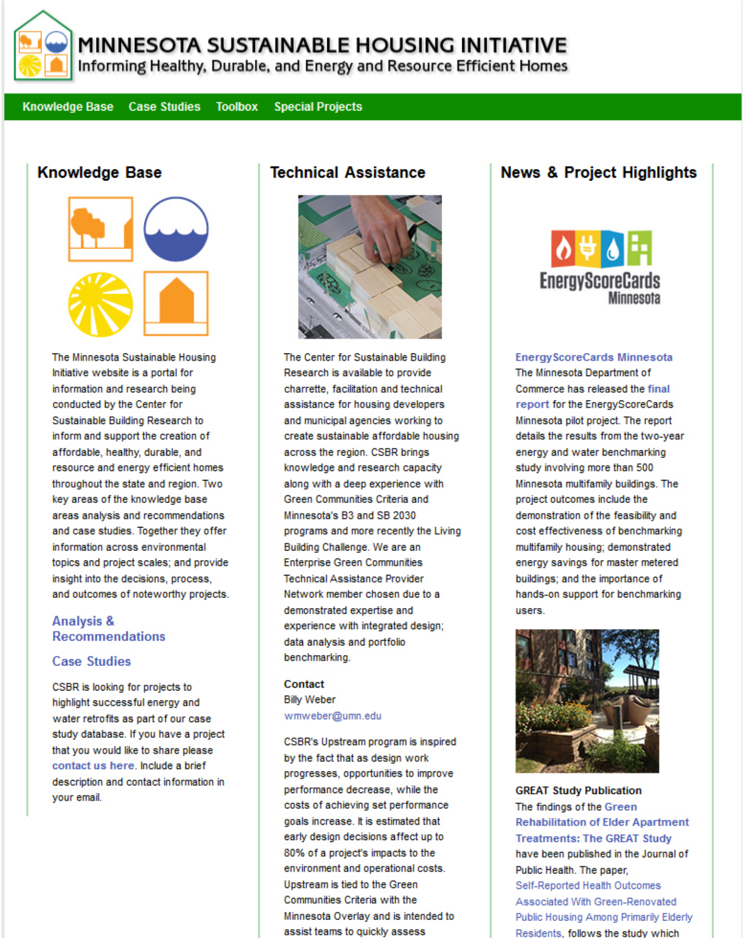
Creating Regenerative and Resilient Communities: Our communities must become regenerative and resilient not only to be sustainable, but also to respond and adapt to stress and change in a dynamic global environment.

Outline

1) Introduction – MNSHI prototype work, multifamily study
2) Modeling Process – assumptions, etc
3) Results – Enclosure comparison, Loads/consumption comparison, net zero energy implications
4) Energy Modeling – IES and WUFI Passive comparison, results comparison
5) Wrap-up & Conclusions

Intro - Minnesota Sustainable Housing Initiative

http://www.mnshi.umn.edu/



Multifamily Prototype Study

Three main goals:

1) Provide reference buildings at different scales for affordable housing developers (enclosure, mechanicals, etc). Built into this is the comparison between different buildings in terms of loads, consumption and envelope.
2) Compare energy modeling software – WUFI Passive vs IES
3) Determine potential to achieve net zero site energy

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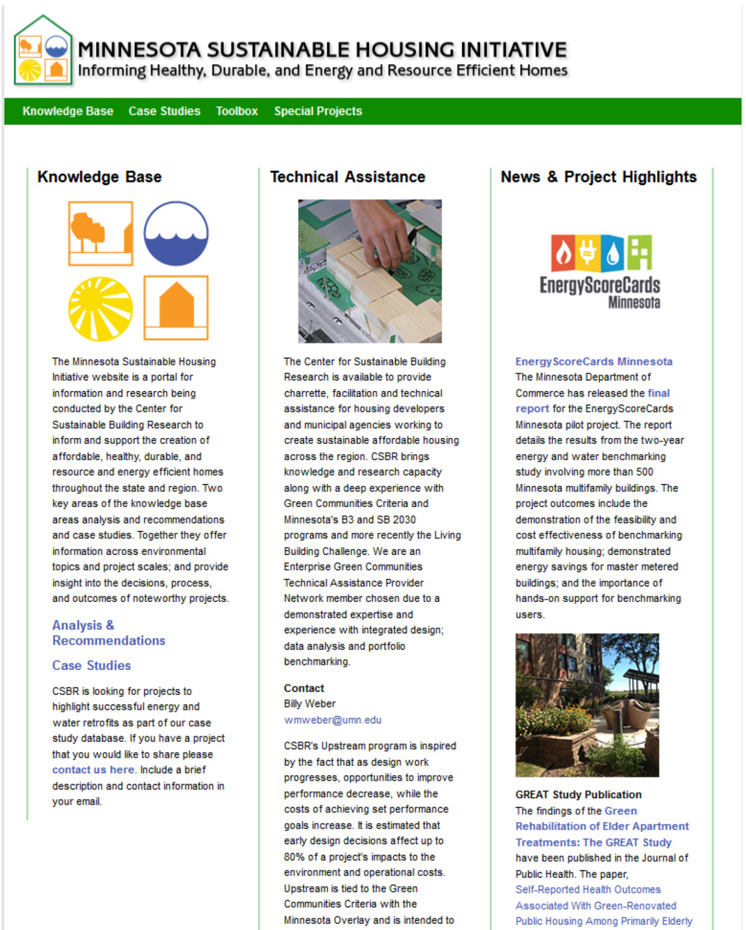

MINNESOTA SUSTAINABLE HOUSING INITIATIVE
Informing Healthy, Durable, and Energy and Resource Efficient Homes

Knowledge Base | Case Studies | Toolbox | Special Projects

Knowledge Base

The Minnesota Sustainable Housing Initiative website is a portal for information and research being conducted by the Center for Sustainable Building Research to inform and support the creation of affordable, healthy, durable, and resource and energy efficient homes throughout the state and region. Two key areas of the knowledge base areas analysis and recommendations and case studies. Together they offer information across environmental topics and project scales; and provide insight into the decisions, process, and outcomes of noteworthy projects.

Analysis & Recommendations

Case Studies

CSBR is looking for projects to highlight successful energy and water retrofits as part of our case study database. If you have a project that you would like to share please contact us here. Include a brief description and contact information in your email.

Technical Assistance

The Center for Sustainable Building Research is available to provide charrette, facilitation and technical assistance for housing developers and municipal agencies working to create sustainable affordable housing across the region. CSBR brings knowledge and research capacity along with a deep experience with Green Communities Criteria and Minnesota's B3 and SB 2030 programs and more recently the Living Building Challenge. We are an Enterprise Green Communities Technical Assistance Provider Network member chosen due to a demonstrated expertise and experience with integrated design; data analysis and portfolio benchmarking.

Contact
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CSBR's Upstream program is inspired by the fact that as design work progresses, opportunities to improve performance decrease, while the costs of achieving set performance goals increase. It is estimated that early design decisions affect up to 80% of a project's impacts to the environment and operational costs. Upstream is tied to the Green Communities Criteria with the Minnesota Overlay and is intended to assist teams to quickly assess

News & Project Highlights

EnergyScoreCards Minnesota

EnergyScoreCards Minnesota
The Minnesota Department of Commerce has released the final report for the EnergyScoreCards Minnesota pilot project. The report details the results from the two-year energy and water benchmarking study involving more than 500 Minnesota multifamily buildings. The project outcomes include the demonstration of the feasibility and cost effectiveness of benchmarking multifamily housing; demonstrated energy savings for master metered buildings; and the importance of hands-on support for benchmarking users.

GREAT Study Publication
The findings of the Green Rehabilitation of Elder Apartment Treatments: The GREAT Study have been published in the Journal of Public Health. The paper, Self-Reported Health Outcomes Associated With Green-Renovated Public Housing Among Primarily Elderly Residents, follows the study which

Multifamily Prototype Study

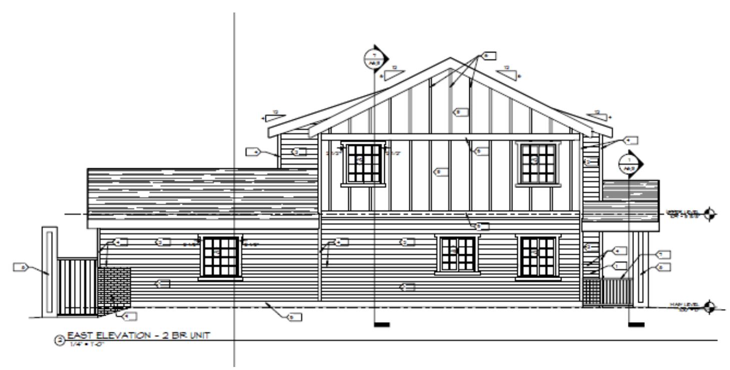
Three building prototypes based on real-world affordable housing projects:

1) Townhome
2) Low-rise
3) Mid-rise

Intro - Prototype 1 - Townhome

Based on Breckenridge Townhomes - Eagle Lake, MN

2-floors, slab on grade
4 units, 12 residents (design)
iCFA: 4,880sf total
WWR: 10%



Intro - Prototype 2 – Low-rise

Based on Grand Terrace Apartment - Worthington, MN

3-floors, slab on grade
48 units, 147 residents (design)
iCFA: 62,130sf total
WWR: 17%

Intro - Prototype 3 – Mid-rise

Based on The Rose - Minneapolis, MN

4-floors, over garage (modeled as slab on grade)
41 units, 135 residents (design)
iCFA: 53,340sf total
WWR: 36.4%

Process - Modeling

1. **General idea – create compliant projects in WUFI Passive first, then copy inputs to IES as closely as possible. Use MSP climate zone.**
2. Building shapes are entered differently, resulting in slightly different areas for floor area, façade, windows, etc.
3. Standard Passive House DHW demand (6.6 gpd/person @140F) was not deemed adequate. Separate DHW demand calculator based on Building America Research Benchmark definition was created.
4. Many of the electrical loads from WUFI Passive (lighting, appliances, etc) had to be converted to watts/sf for entry into IES.
5. IES was run without "Apache HVAC" (advanced HVAC modeling package)
6. Some mechanical system options are not available in IES (e.g. - heat pump water heater for townhome project).
7. Compare EUI calculated from WUFI Passive to rooftop PV energy production/sf of iCFA. Assume 70% roof area available for flat-roof Mid and Low-Rise projects, 50% available for Townhome.

Process - Enclosure

- General idea – modify the enclosure to meet energy performance requirements.
- However, assume a standard, airtight, prefab wall – 12inches thick, R-45 (could represent 12in SIP, 12in I-joist, 12in BuildSMART, etc.)
- Other enclosure components were adjusted on an as-needed basis.

We'll come back to this in Results section.

Process - Windows

	Townhome	Low-Rise	Mid-Rise
Frames	R-6.25 Wasco Geneo (U-0.16)	R-5 standard (U-0.2)	R-5 standard (U-0.2)
Glazing (U-value)	R-9.4 Wasco Geneo (U-0.106)	R-6 standard (U-0.17)	R-6 standard (U-0.17)
Glazing (SHGC)	SHGC-0.39 (S), 0.17 (others)	SHGC-0.25 (all sides)	SHGC-0.25 (all sides)
Window (U-value)	U-0.15	U-0.21	U-0.21
Shading	Overhangs, reveals - as designed	Overhangs, reveals - as designed	Overhangs, reveals - as designed
Site Shading	75% of full exposure	75% of full exposure	75% of full exposure

- Same level of site shading assumed for all 4 exposures on each building
- Window performance had to be improved significantly for townhome project.
- In addition, townhome project required careful attention to maximize passive solar with high SHGC glass on south side, proper orientation, correctly sized overhangs, etc

Process - Windows

	Townhome	Low-Rise	Mid-Rise
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Site Shading	75% of full exposure	75% of full exposure	75% of full exposure

Mid and Low-rise: - using ISO 13788 calculator
R6 glass (U-0.17): Surface temp = **56.8F** @ -11.2F (ASHRAE 99.6% for MSP)
Passes condensation test (43F), not comfort (61F)
R5 frames (U-0.2): Surface temp = **54.5F** @ -11.2F
Passes condensation test (43F), not comfort (61F)

Townhome: - using ISO 13788 calculator
R-8.8 glass (U-0.114): Surface temp = **60.3F** @ -11.2F
Passes condensation test (43F), not comfort (61F)
R-6.25 frames (U-0.16): Surface temp = **57.2F** @ -11.2F
Passes condensation test (43F), not comfort (61F)

Process – Domestic hot water

	Townhome	**Low-Rise**	**Mid-Rise**
Equipment	ASHP in conditioned space	Gas Boiler	Gas Boiler
Efficiency	avg. annual COP 2.3	95EF	95EF
Protocol	BA Research Benchmark - calculator	BA Research Benchmark - calculator	BA Research Benchmark - calculator
Usage	12.2 gpd/person @140F	12.1 gpf/person @140F	11.7 gpd/person @140F

DHW demand calculator: - BA research, following Parker, Fairey, Lutz (2015)
Calculator takes inputs on:

- # of bedrooms
- # of occupants - based on bedroom count but NOT = #bedrooms + 1
- Temperature of mains, water heater setpoint, mixing temperature
- Clothes and dishwasher water efficiency

Different ratios of unit types in each building (1 vs 2 vs 3 bedroom units) result in differing usage/person for each project.

Roughly, the BA calculations predict 12 gpd/person @140F.

Process - Ventilation

	Townhome	**Low-Rise**	**Mid-Rise**
Equipment	HRV Zehnder Comfoair	HRV - standard	HRV - standard
Sensible Efficiency	SRE - 90%	SRE - 80%	SRE - 80%
Electrical Efficiency	0.51 watt/cfm	0.7 watt/cfm	0.7 watt/cfm
System Efficiency	Total - 75.1%	Total - 67.5%	Total - 69.1%
Mechanical vent. Rate	15.9 cfm/person, 0.29ACH avg.	17.5 cfm/person, 0.3ACH avg.	19.9 cfm/person, 0.3ACH avg.
Natural ventilation	0.1 ACH (day and night, summer)	0.1 ACH (day and night, summer)	0.1 ACH (day and night, summer)

- Assumed minimal amount of natural ventilation
- Efficiency had to be improved considerably for Townhome project with high recovery efficiency units and very short, well-insulated duct runs.
- Avg. air flow rates were adjusted to achieve roughly 0.3 ACH.

Process – Heating/cooling

	Townhome	Low-Rise	Mid-Rise
Equipment	Mini-split ASHP	VRF	VRF
Heating Efficiency	COP 3.3	COP 2.5	COP 2.5
Cooling Efficiency	COP 4.0	COP 5.0	COP 5.0

- Townhome heating COP was estimated using PHIUS calculator, based on performance curve of Mitsubishi MSZ FH12NA, MSP climate, and monthly heat load.
- Low and Mid-rise VRF average heating and cooling season COP's were calculated more accurately in the IES dynamic model, then entered into WUFI Passive.

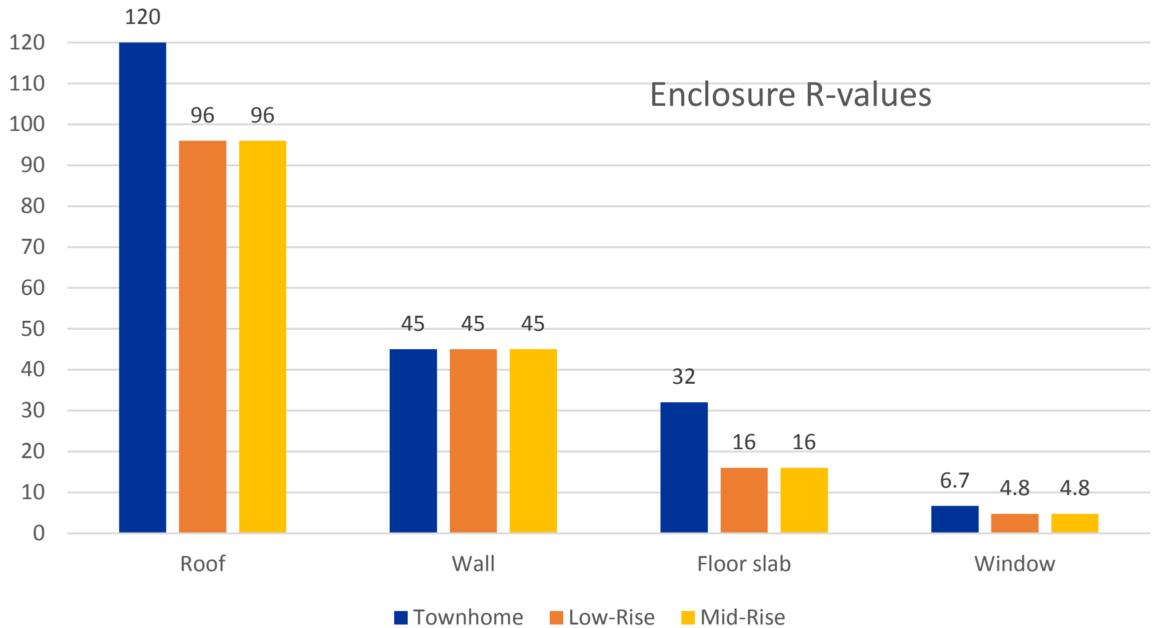
Process – Electrical loads

	Townhome	Low-Rise	Mid-Rise
Interior/Ext. lighting	PHIUS+ 2015	PHIUS+ 2015	PHIUS+ 2015
MELS	PHIUS+ 2015	PHIUS+ 2015	PHIUS+ 2015
Appliances	common Energy Star	common Energy Star	common Energy Star
Elevator	NA	6900 kWh/yr	1900 kWh/yr*

- Interior/exterior lighting and MEL's must follow PHIUS+ 2015 calculator protocol.
- These electrical loads are substantial, but cannot really be adjusted.
- Appliances can be optimized, but average Energy Star models were selected.
- Mid-rise elevator energy use was a mistake (too low).

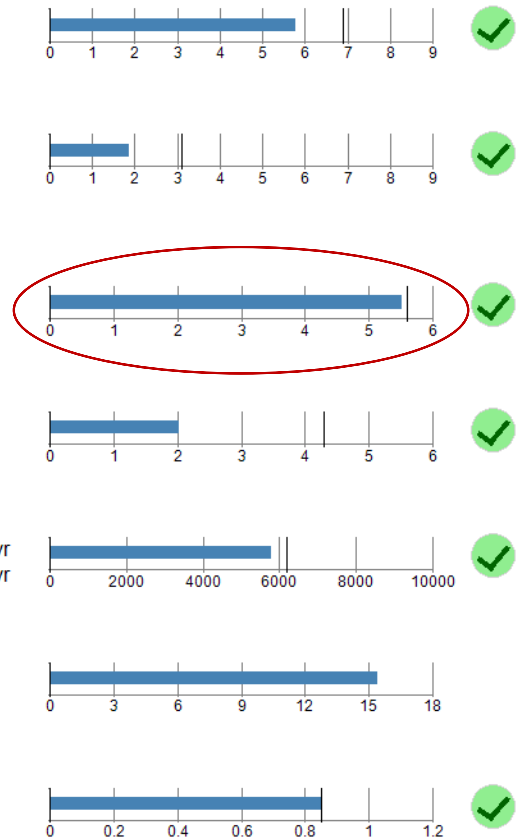
Results - Enclosure R-value comparison

- Compliance could be achieved with R-45 walls for every project. BUT…
- Heating load was a challenge for Townhome project and required higher R-values for all other components.
- Mid-rise and Low-Rise could easily meet building energy performance requirements with R-30 wall, and less insulation in roof as well.
- High roof R-values for mid and low-rise result from dense-packing the roof joist space (eliminating need for sprinklers).



Results - Townhome

- Difficult to achieve the heating load requirement with R-45 wall and U-0.15 windows
- Required highly efficient HRV with short duct runs
- Larger reduction in heating demand and load was expected with adiabatic shared walls and garage buffer on north side



PASSIVEHOUSE REQUIREMENTS

Certificate criteria: PHIUS+ 2015 Standard

Heating demand		
specific:	**5.77**	kBtu/ft²yr
target:	**6.9**	kBtu/ft²yr
total:	28170.14	kBtu/yr
Cooling demand		
specific:	**1.85**	kBtu/ft²yr
target:	**3.1**	kBtu/ft²yr
total:	9043.5	kBtu/yr
latent:	0.36	kBtu/ft²yr
Heating load		
specific:	**5.52**	Btu/hr ft²
target:	**5.6**	Btu/hr ft²
total:	26935.92	Btu/hr
Cooling load		
specific:	**2.03**	Btu/hr ft²
target:	**4.3**	Btu/hr ft²
total:	9909.28	Btu/hr
Primary energy		
specific:	**5771**	kWh/Person yr
target:	**6200**	kWh/Person yr
total:	236272.84	kBtu/yr
Site energy		
total:	15.39	kBtu/ft²yr
building systems:	76.34	kBtu/yr
photovoltaic savings:	0	kBtu/ft²yr
Air tightness		
ACH50:	**0.85**	1/hr
target:	**0.85**	1/hr
CFM50 per envelope area:	**0.05**	cfm/ft²
target:	**0.05**	cfm/ft²

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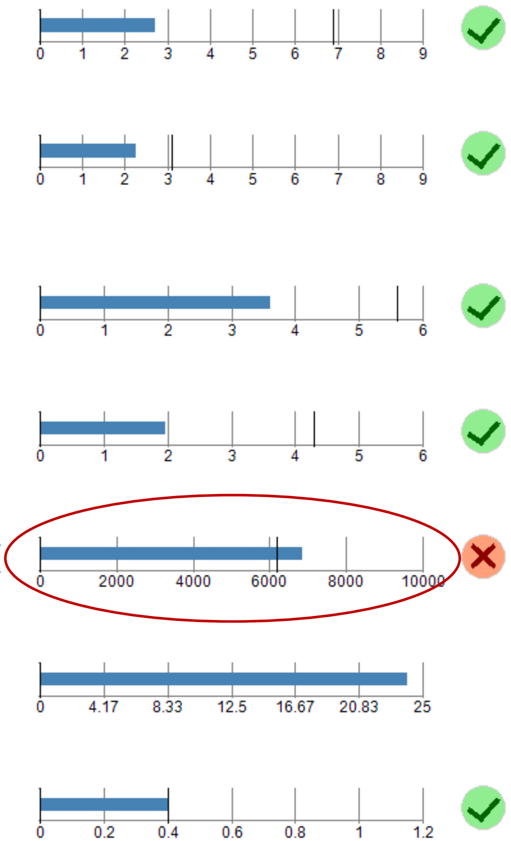
Results - Low-Rise

- Primary energy requirement not met
- Heating and cooling req.'s were easy to meet
- R-values for roof and walls could be backed off a bit
- Heating and cooling loads were close (but slightly above) level that could be met with ventilation air
- Suboptimal shape / orientation had surprisingly little effect on building-wide results

PASSIVEHOUSE REQUIREMENTS

Certificate criteria: **PHIUS+ 2015 Standard**

Heating demand		
specific:	**2.71**	kBtu/ft²yr
target:	**6.9**	kBtu/ft²yr
total:	168241.43	kBtu/yr
Cooling demand		
specific:	**2.25**	kBtu/ft²yr
target:	**3.1**	kBtu/ft²yr
total:	139737.15	kBtu/yr
latent:	0.64	kBtu/ft²yr
Heating load		
specific:	**3.61**	Btu/hr ft²
target:	**5.6**	Btu/hr ft²
total:	224047.9	Btu/hr
Cooling load		
specific:	**1.96**	Btu/hr ft²
target:	**4.3**	Btu/hr ft²
total:	121524.08	Btu/hr
Primary energy		
specific:	**6845**	kWh/Person yr
target:	**6200**	kWh/Person yr
total:	3433094.07	kBtu/yr
Site energy		
total:	24.02	kBtu/ft²yr
building systems:	34.63	kBtu/yr
photovoltaic savings:	0	kBtu/ft²yr
Air tightness		
ACH50:	**0.4**	1/hr
target:	**0.4**	1/hr
CFM50 per envelope area:	**0.05**	cfm/ft²
target:	**0.05**	cfm/ft²



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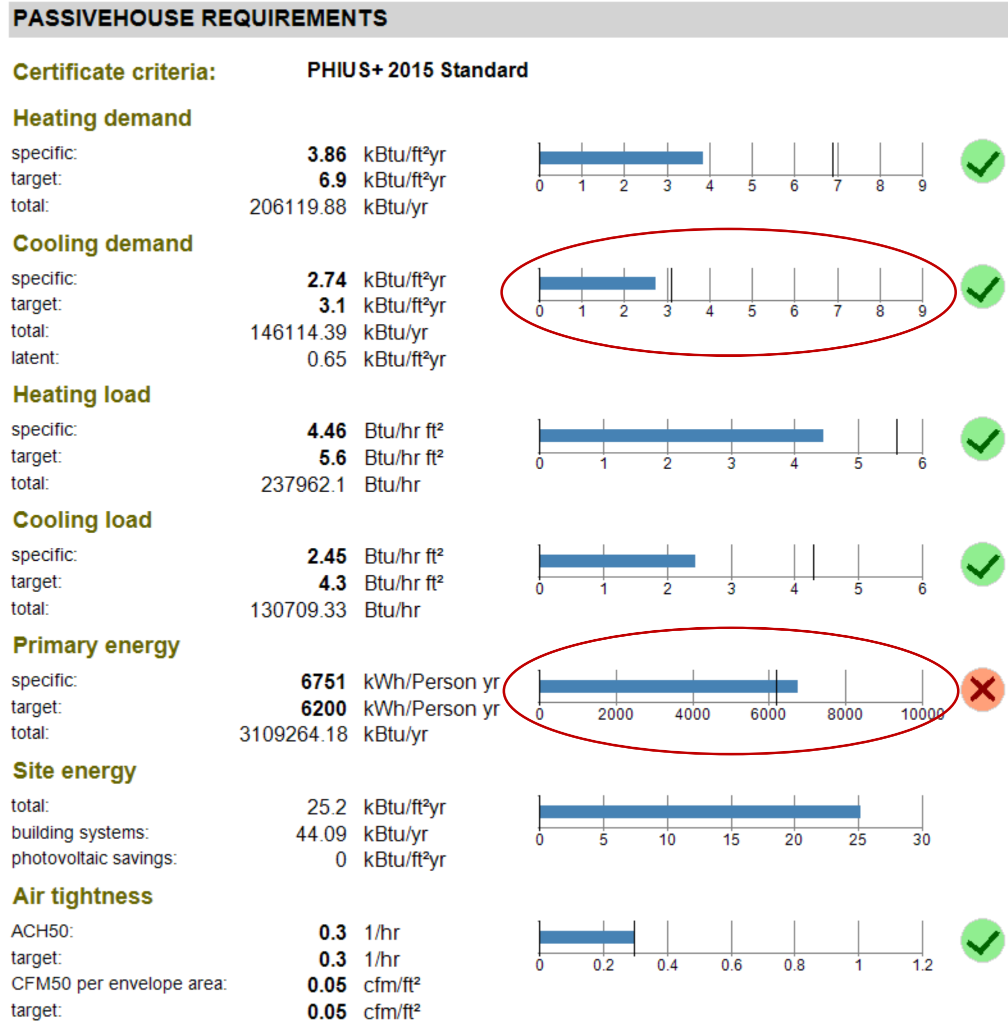
Results - Mid-Rise

- Primary energy requirement not met
- Cooling demand was difficult to meet bc of high window to wall ratio (36%)
- R-values for roof and walls could be backed off a bit
- Heating and cooling loads could not be met through ventilation air
- More optimal shape and orientation had surprisingly little effect



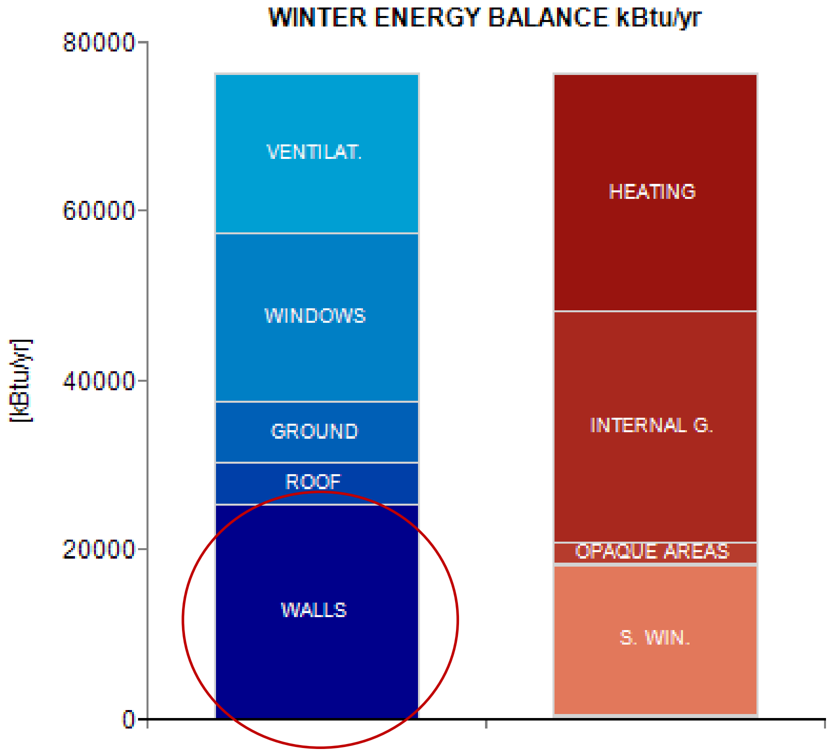
PASSIVEHOUSE REQUIREMENTS

Certificate criteria: PHIUS+ 2015 Standard

Heating demand		
specific:	**3.86**	kBtu/ft²yr
target:	**6.9**	kBtu/ft²yr
total:	206119.88	kBtu/yr
Cooling demand		
specific:	**2.74**	kBtu/ft²yr
target:	**3.1**	kBtu/ft²yr
total:	146114.39	kBtu/yr
latent:	0.65	kBtu/ft²yr
Heating load		
specific:	**4.46**	Btu/hr ft²
target:	**5.6**	Btu/hr ft²
total:	237962.1	Btu/hr
Cooling load		
specific:	**2.45**	Btu/hr ft²
target:	**4.3**	Btu/hr ft²
total:	130709.33	Btu/hr
Primary energy		
specific:	**6751**	kWh/Person yr
target:	**6200**	kWh/Person yr
total:	3109264.18	kBtu/yr
Site energy		
total:	25.2	kBtu/ft²yr
building systems:	44.09	kBtu/yr
photovoltaic savings:	0	kBtu/ft²yr
Air tightness		
ACH50:	**0.3**	1/hr
target:	**0.3**	1/hr
CFM50 per envelope area:	**0.05**	cfm/ft²
target:	**0.05**	cfm/ft²

Results – Townhome heat energy balance

- Exterior walls are the single largest source of heat loss. Higher R-value (above R-45) could be desirable.
- Significant passive solar gain (25% of total) is crucial to meeting heating demand.
- Behaves similarly to single family home



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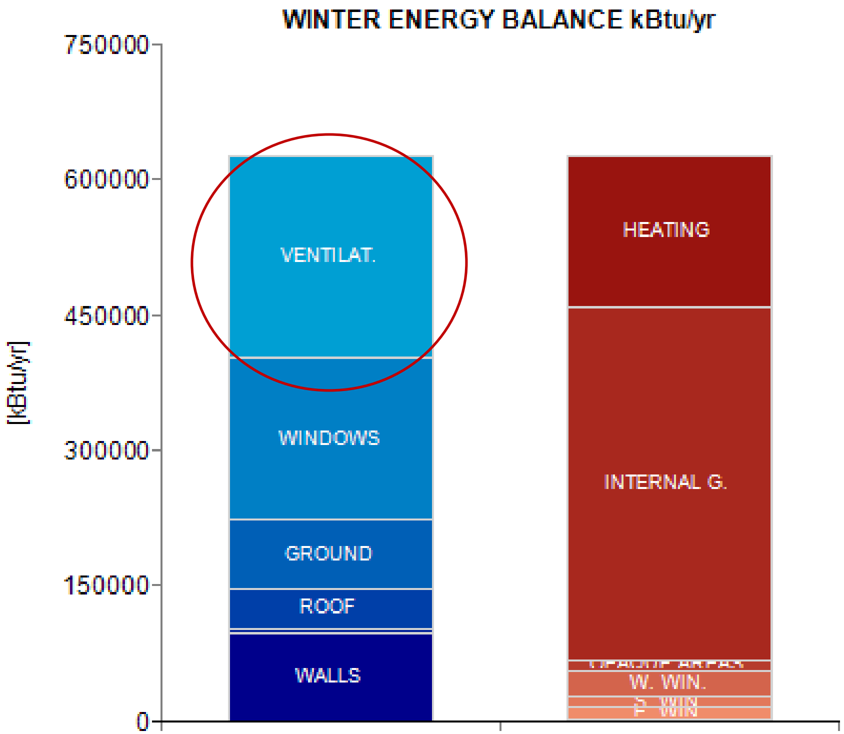
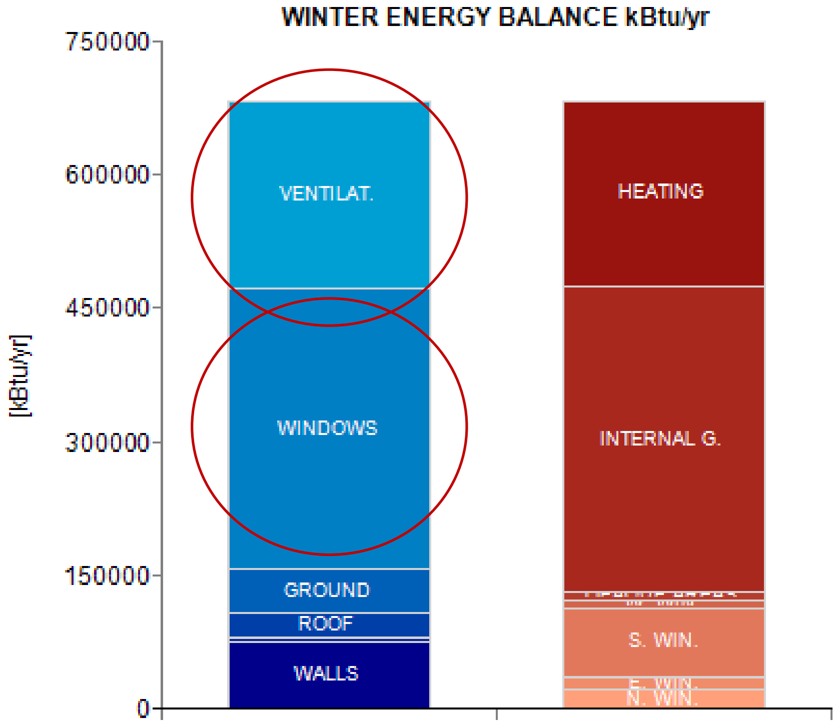
Results - Low-Rise heat energy balance

- Heat loss through the wall and roof is relatively less important (compared to townhome).
- Ventilation heat loss is the big driver.
- Windows are not a significant source of heat gain, but are a significant source of heat loss.



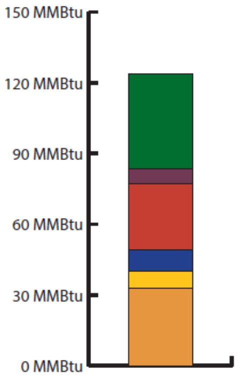
Results - Mid-Rise heat energy balance

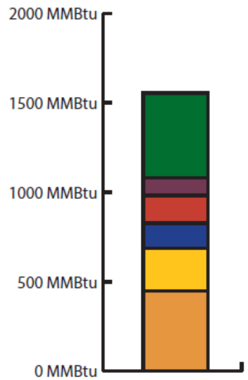
- Heat loss through the wall and roof is relatively less important (compared to townhome).
- Ventilation heat loss is again a big driver.
- Windows are the single largest source of heat loss. (High WWR 36%)

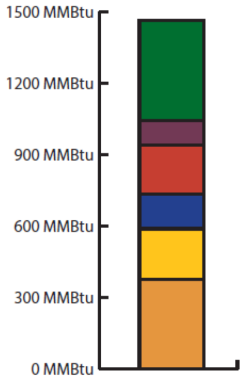


Results - Energy Loads

- For townhome, heating and cooling loads make up approx. 30% of total energy load.
- For multifamily buildings, heating and cooling loads make up 20% - 24% of total.
- DHW is the single largest energy load.





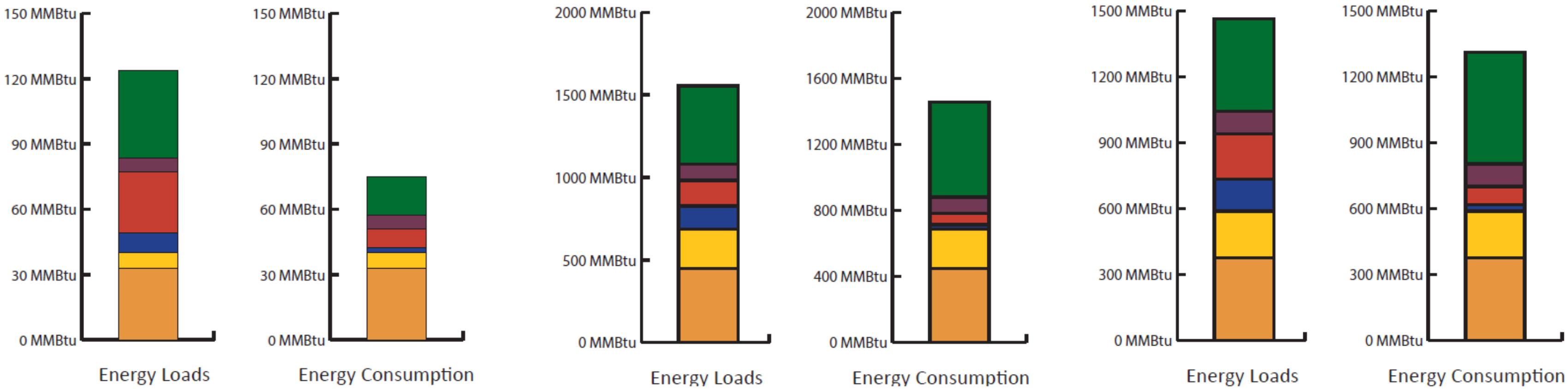


Heating | Cooling | DHW | Lighting | MELs + Appliances | ERV Fan + Defrost

Center for Sustainable Building Research

Results – Energy Consumption

- For townhome, heat pump water heater is very helpful to reduce site energy consumption.
- After accounting for heat pumps, heating and cooling energy consumption is less than 10% of total
- MELs and lighting are “untouchable” loads, determined by PHIUS calculators



Heating | Cooling | DHW | Lighting | MELs + Appliances | ERV Fan + Defrost

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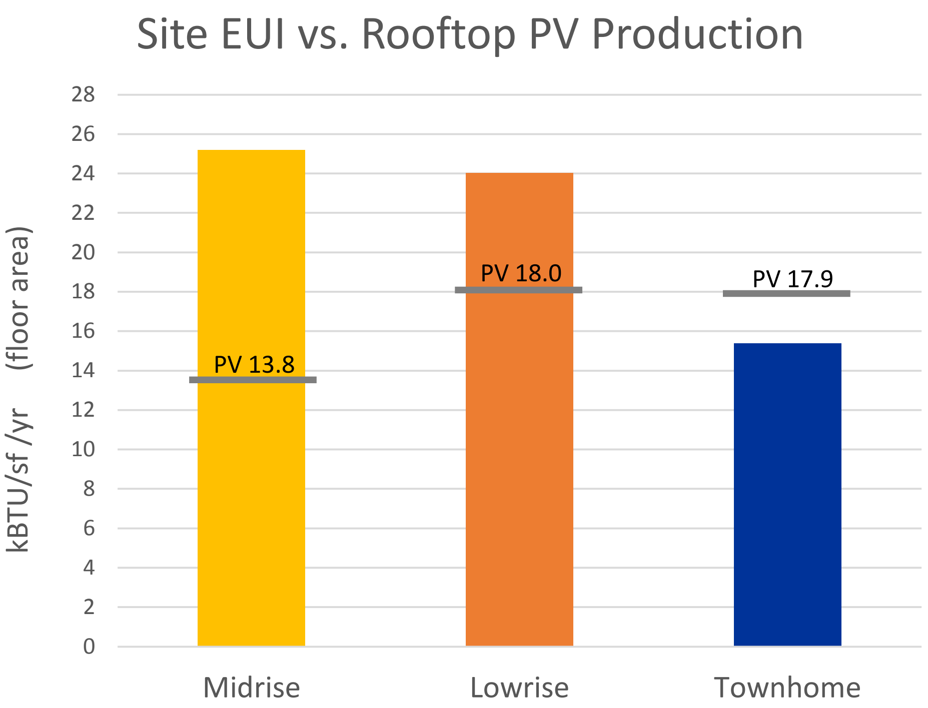
Results – Net Zero

- Townhome at 2 stories can easily generate enough energy with 50% roof area
- Low-rise with 3 stories and higher occupant density comes close, but not quite.
- Mid-rise with 4 stories is not possible, even at Passive House-level performance.

- Low-rise probably could achieve net zero if some roof space was devoted to solar hot water (2x energy density of PV) to meet DHW load. Or if large-scale heat pump water heating equipment was available.



Energy Modeling – IES VE vs WUFI Passive

VE 2017
IES VIRTUAL ENVIRONMENT
IES

WUFI®

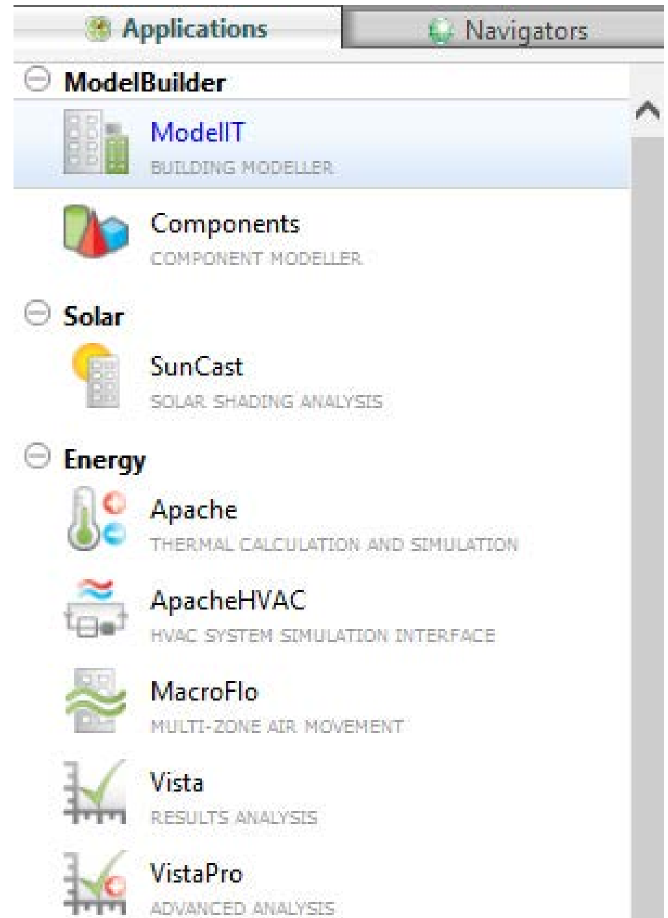
- Whole building energy simulation
- Dynamic thermal simulation including heat loss and gain, heating and cooling loads
- Compliance navigators for ASHRAE, LEED, BREEM, Architecture 2030
- Geometry can be imported from Revit, Sketchup, or built in the program

- Based on WUFI Plus, a dynamic, hourly whole building energy load and hygrothermal simulation
- Modified to include PHIUS+ metrics, certification criteria, reports, etc.
- Sketchup plugin for geometry imports
- Static Monthly Simulation for energy consumption and Passive House verification

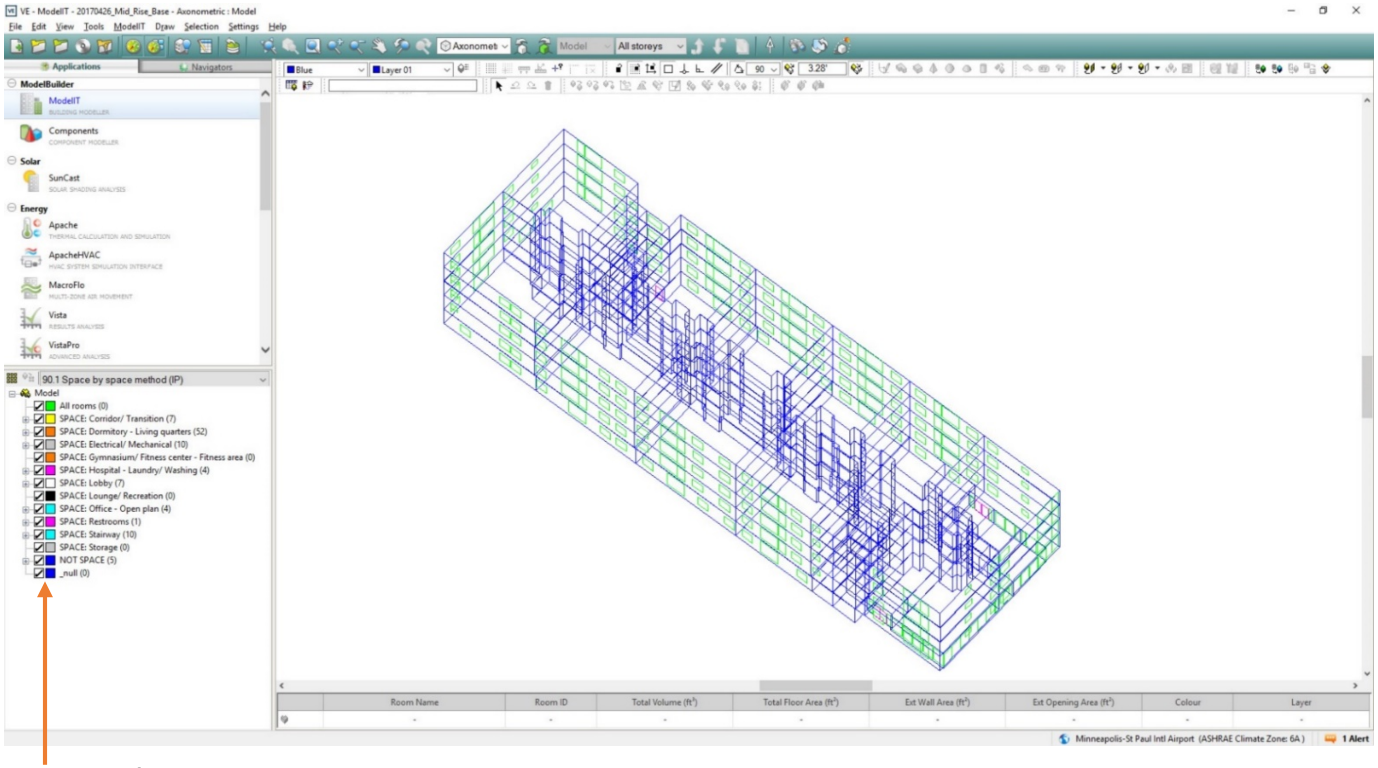
Energy Modeling – Intro to IES Virtual Environment

Collection of Applications Used:

- **Model It**: create building geometry, room and building conditions
- **Sun Cast**: solar shading analysis
- **ApacheSim**:
  - Thermal insulation (type and placement)
  - Building dynamics
  - Thermal mass
  - Air tightness
  - Natural ventilation
  - HVAC systems (general)
- **Vista**: results viewer
  - 40+ measures of room performance
  - Comfort statistics
  - Loads and energy consumption
  - Carbon emissions



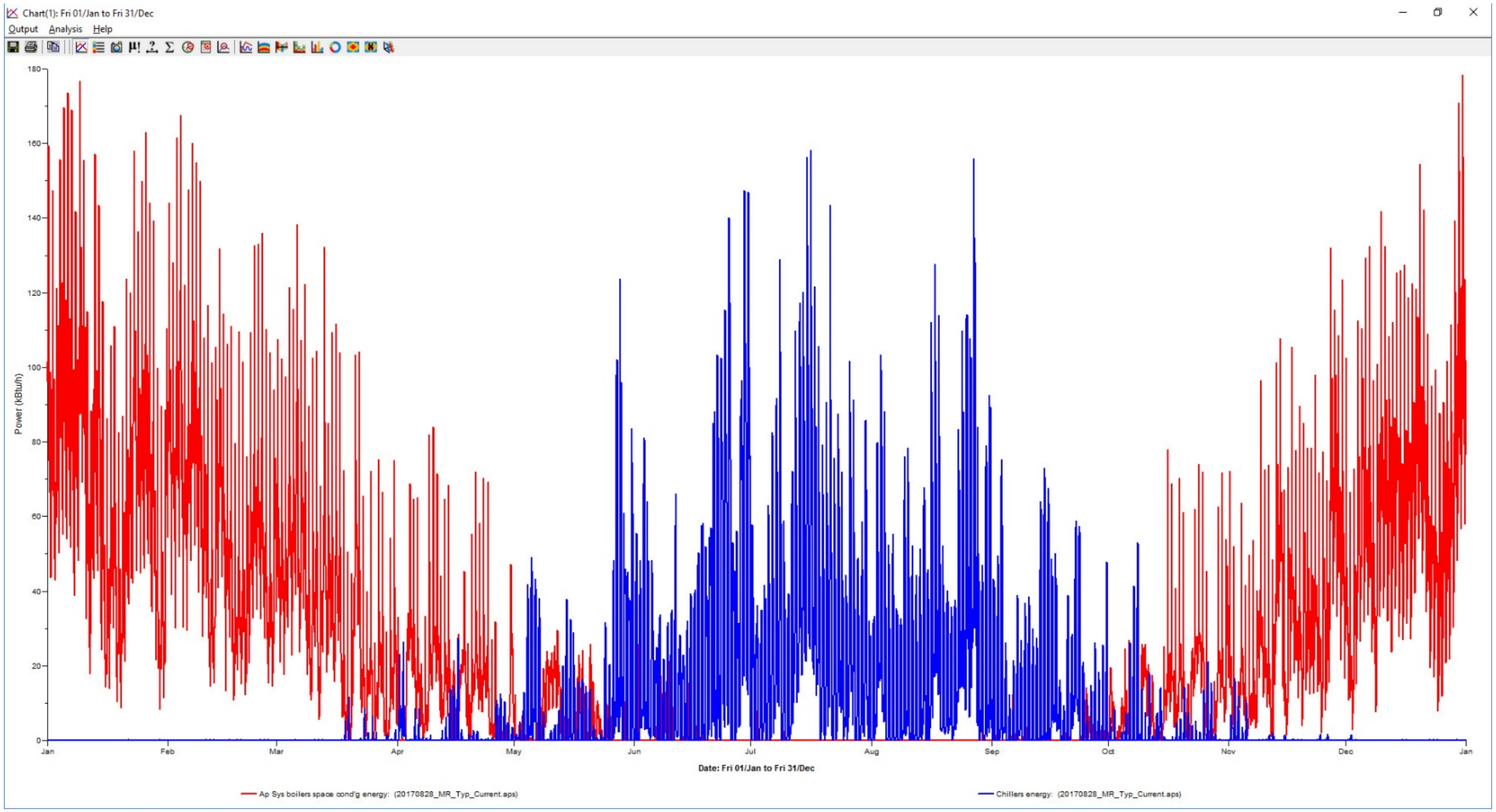
Energy Modeling – Intro to IES Virtual Environment



Space type attributes:

- Heating and cooling set points and schedule, humidity control
- DHW use rate
- HVAC system, outside air supply
- Internal gains
  - People, lighting, equipment
  - Schedules

Energy Modeling – Intro to IES Virtual Environment

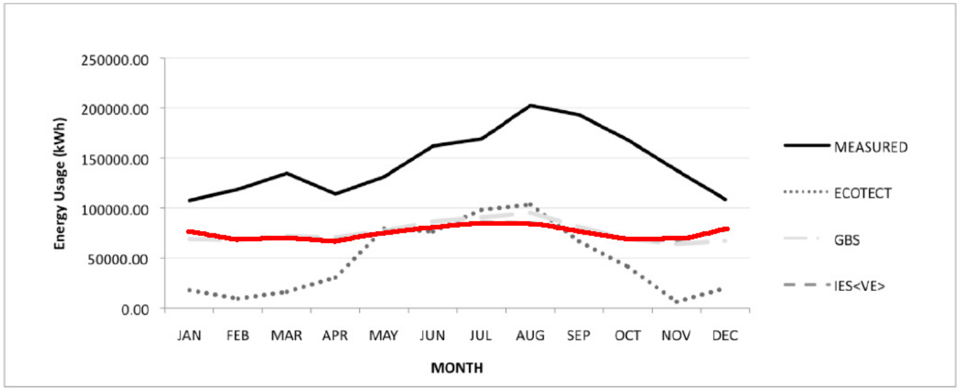


Results Reporting:

- Annual, monthly, daily
- Loads, consumption, carbon
- Building and room level information

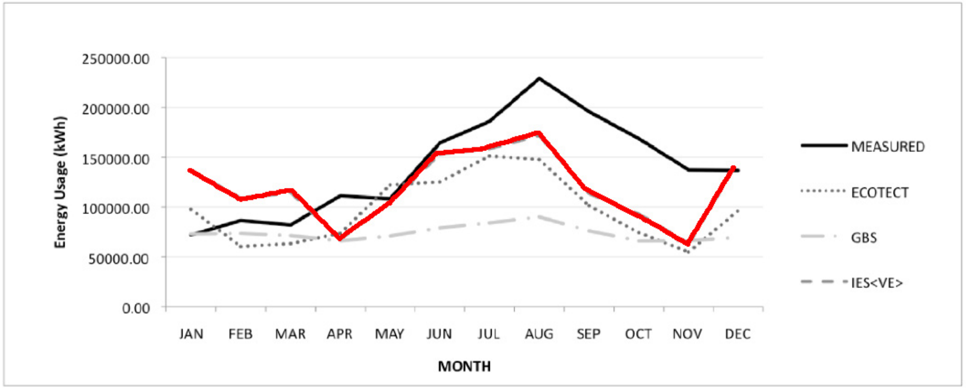
Energy Modeling –IES VE Research and Results Verification

Case study:
- Comparing modeled performance against actual building performance
- LEED Gold Building and non-LEED building
- Ecotect, Green Building Studio, IES-VE



LEED Gold Building

Annual energy use underestimated by 48%



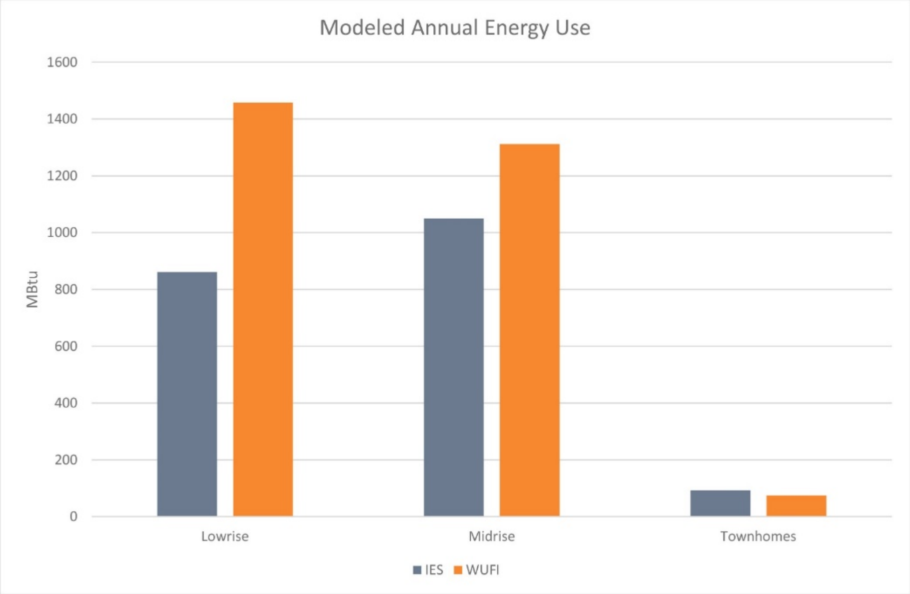
Non-LEED Building

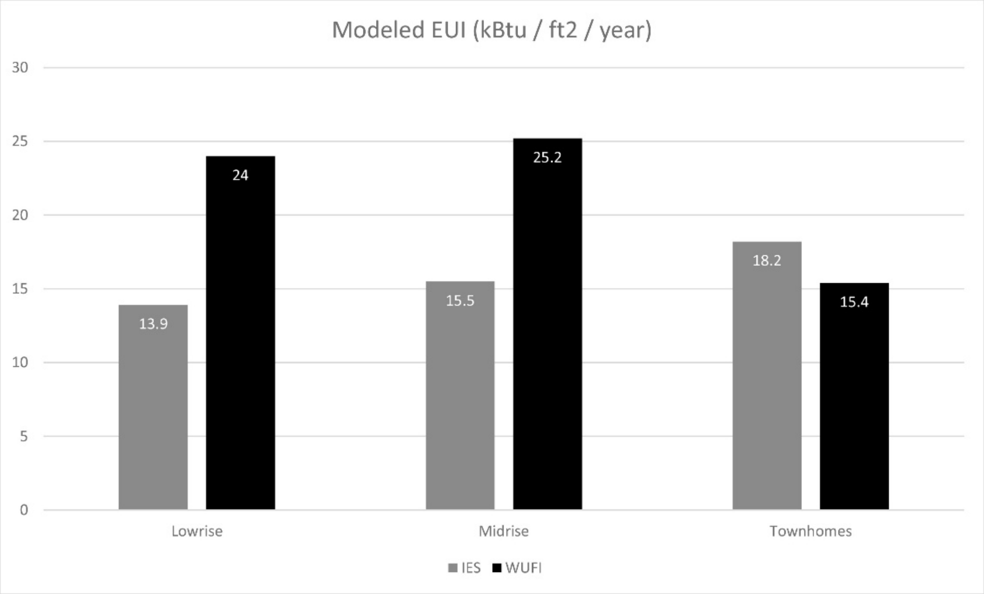
Annual energy use underestimated by 14.5%

Reeves, T., S. Olbina, and R. Issa. "Validation of Building Energy Modeling Tools: Ecotect™, Green Building Studio™ and IES<VE>™." Simulation Conference (WSC), Proceedings of the 2012 Winter (2012): 1-12. Web.

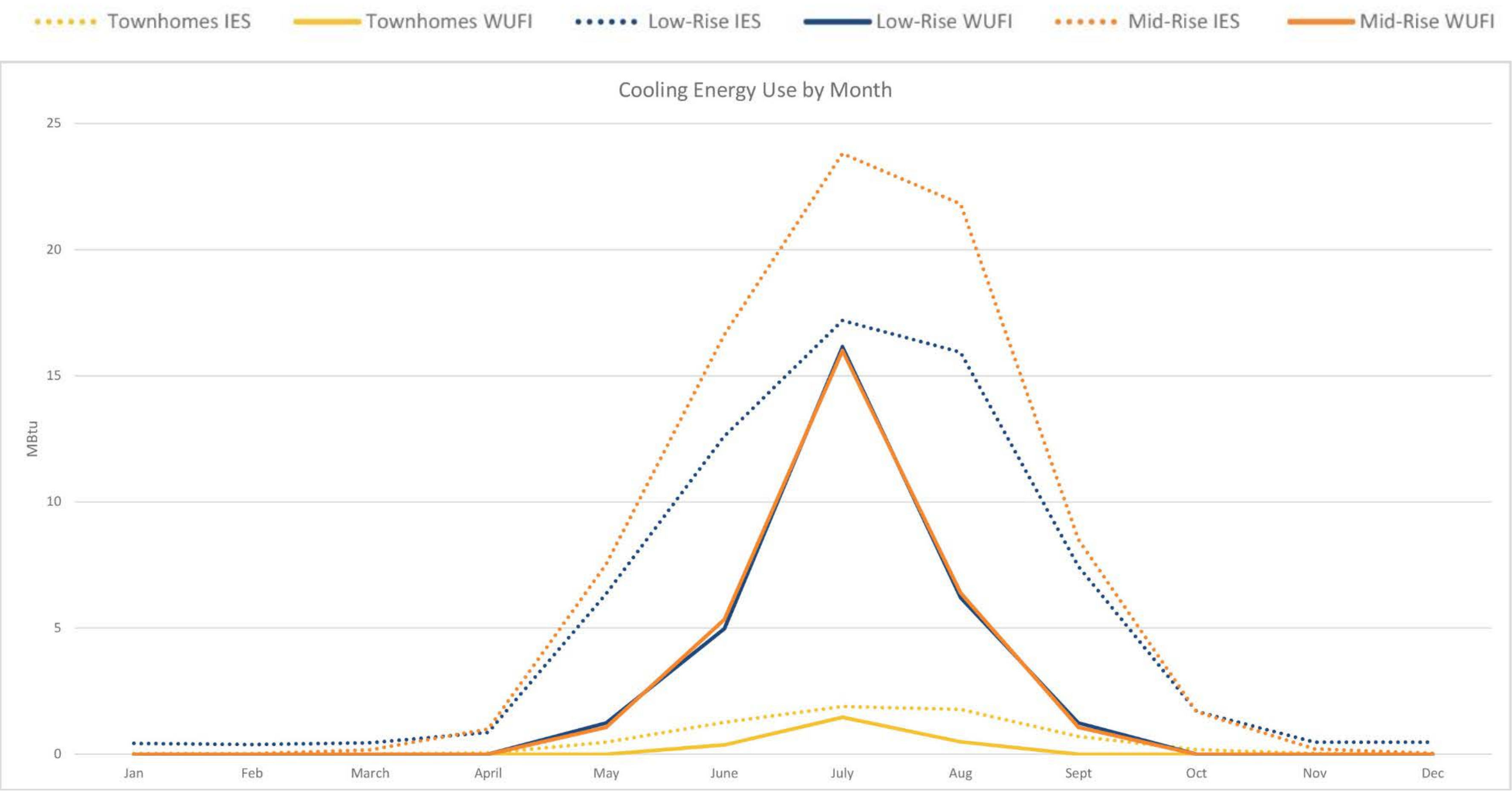
Energy Modeling – IES VE vs. WUFI Passive

- WUFI Passive model inputs translated to IES-VE inputs
  - Envelope Characteristics
  - Internal Loads and Schedules
  - HVAC System
  - Difference in units, fields, options makes a direct comparison tricky

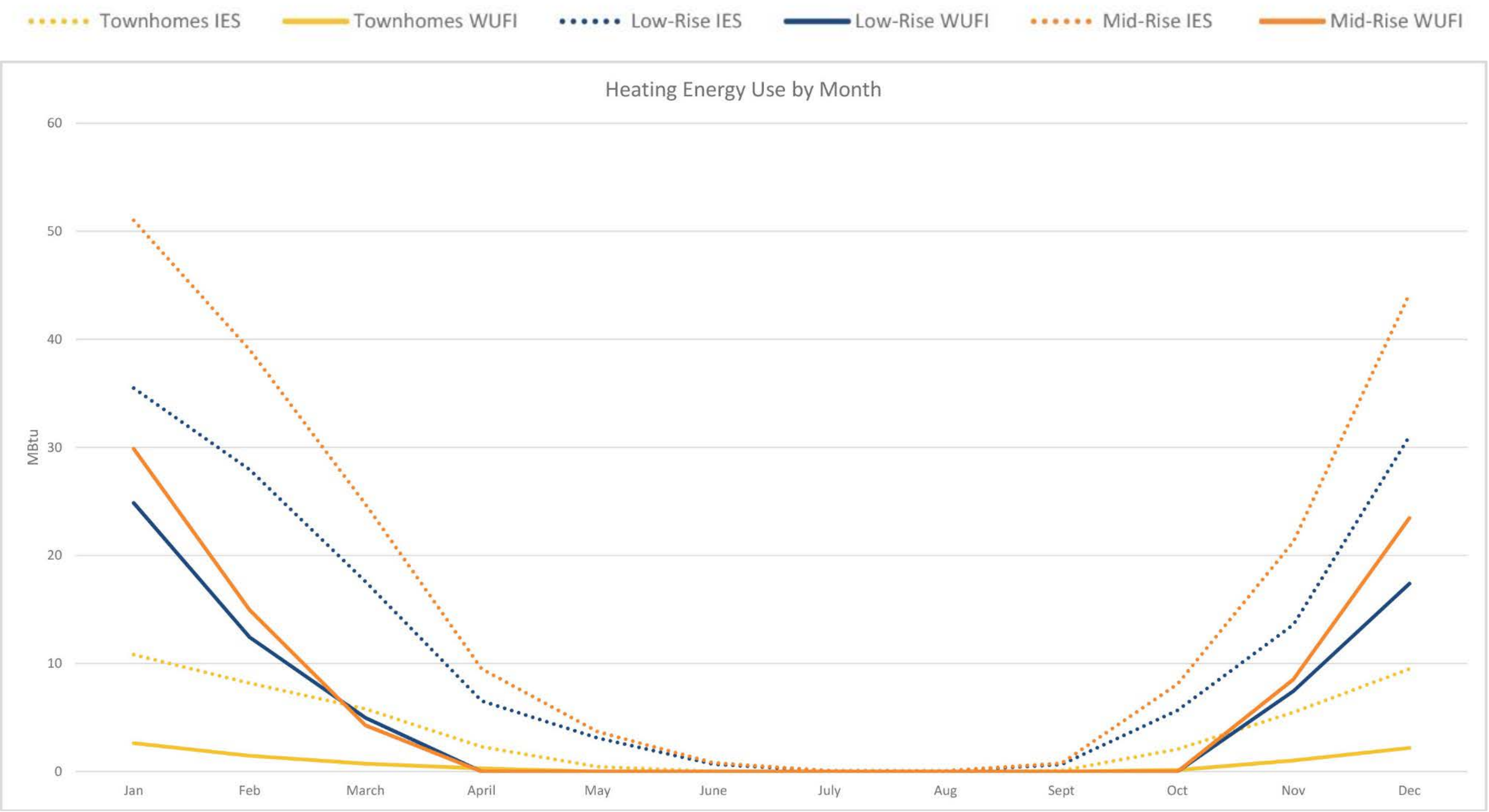




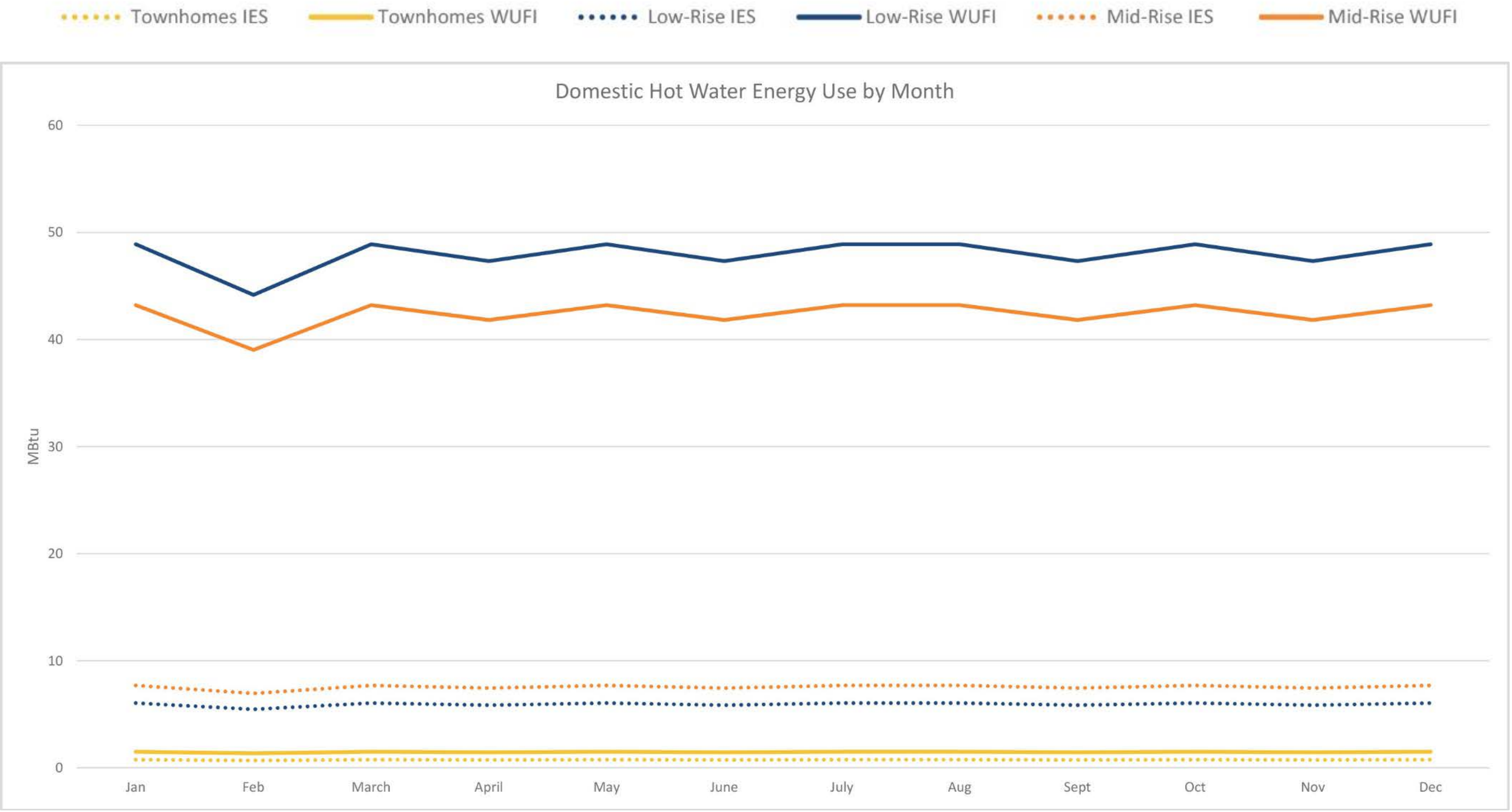
Energy Modeling – IES VE vs. WUFI Passive



Energy Modeling – IES VE vs. WUFI Passive

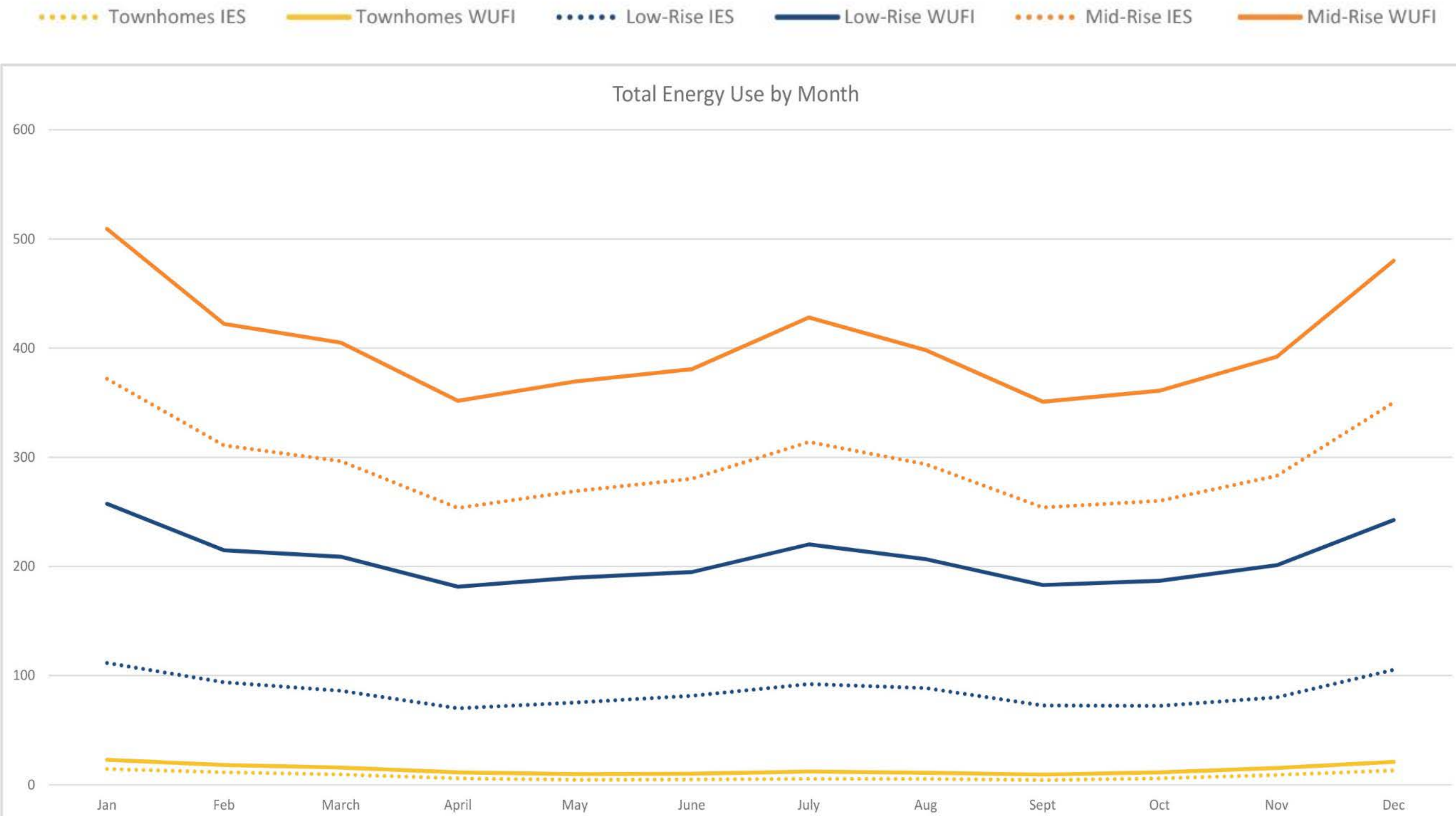


Energy Modeling – IES VE vs. WUFI Passive



Center for Sustainable Building Research

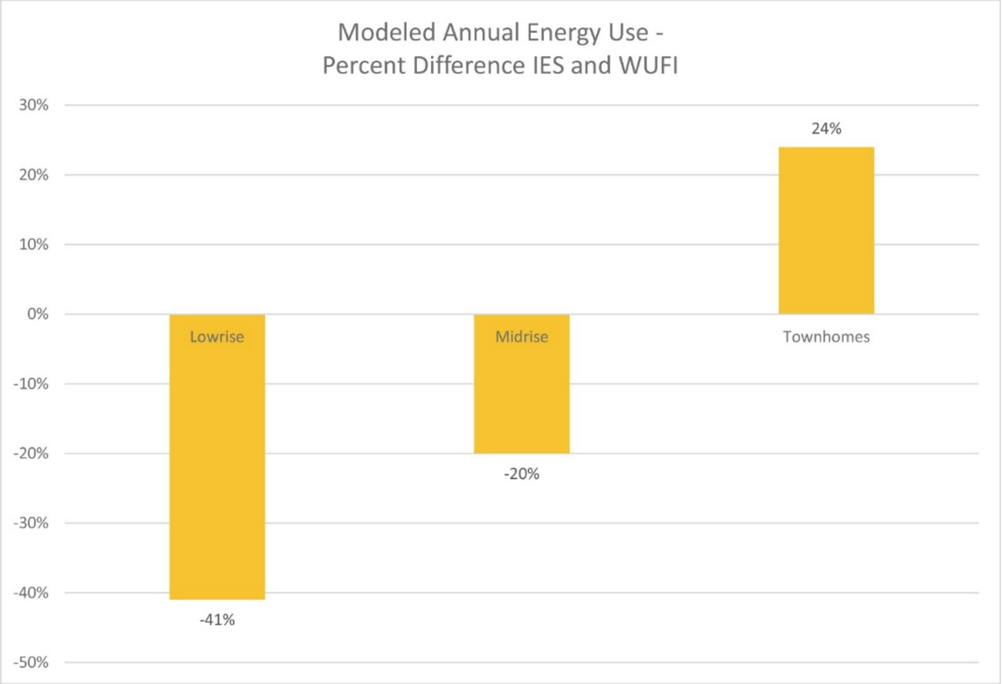
Energy Modeling –IES VE vs. WUFI Passive



Conclusion–IES VE vs. WUFI Passive

IES VE estimates:

- Higher energy use for heating and cooling systems
- Lower energy use for domestic hot water
- Townhome: 24% higher total energy use
- Low-Rise: 41% lower total energy use
- Mid-Rise: 20% lower total energy use



Conclusion– Future Research

- Need for comparison of IES and WUFI models to actual building performance
  - Necessary to accurately predict performance when sizing renewable systems
  - Identify areas for potential additional energy savings
  - Ensure that buildings are performing as designed / modeled

- Fine tune IES settings to more closely match WUFI settings and outputs
  - May require detailed HVAC system modeling

- Test WUFI Passive inputs in other modeling software
  - Create low barrier to entry for net-zero ready buildings
  - Work within existing skillsets of designers / engineers / developers