PROJECT UPDATE

H2k to HPXML (EnergyPlus)

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RESEARCH

February 14, 2024

Volta Research
A Brief History

- Founded as a not-for-profit corporation in 2018 with its mission to reduce energy use and emissions in Canada
- We do research, development, analysis, and technical consulting on energy and emissions reduction processes, practices, and tools
- We focus on demographic, economic, and wider societal relationships with energy usage and emissions in Canada
- We are a small team that looks to hire and support recent graduates or new entrepreneurs to help us with our work
- Stakeholder driven and want to build everyone's capacity to talk about and reduce energy use and emissions

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Project Objectives

- Develop and test a methodology to convert HOT2000 files (.h2k) into HPXML files (.xml) which can be used as inputs in an OpenStudio (OS) workflow to run EnergyPlus simulations

- Compare simulated heating and cooling load results between NRCan's HOT2000 and U.S. DOE's EnergyPlus simulation tools

- Showcase and analyse alignment of results, identify potential gaps in translation methodology

- Produce and investigate hourly (or subhourly) simulation results from translated files

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Project Scope

- Current scope: all aspects of the h2k file *except for* mechanical systems and domestic hot water
    - HPXML has very complex "Systems" inputs
    - Focus on aligning building heating and cooling loads prior to integrating HVAC systems
- Building type limited to Houses, no single unit/whole-home MURBs
    - At the time that development started, the OS-HPXML workflow did not have a solution for MURBs, this was addressed in a recent release

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Project Status

- Prototype translation process complete and can be run/tested
  - Some gaps not yet addressed
- Material properties of components represented as overall effective R-values, not by material properties/layers
  - OS-HPXML workflow does not yet support detailed layer descriptions, may come in a later version
- Some error handling/alerts
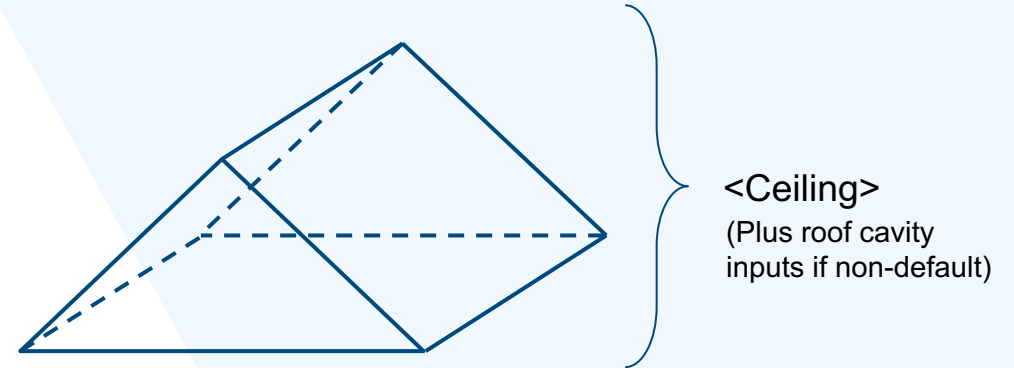- Preliminary comparison of simulated heating and cooling loads

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File Structure Alignment

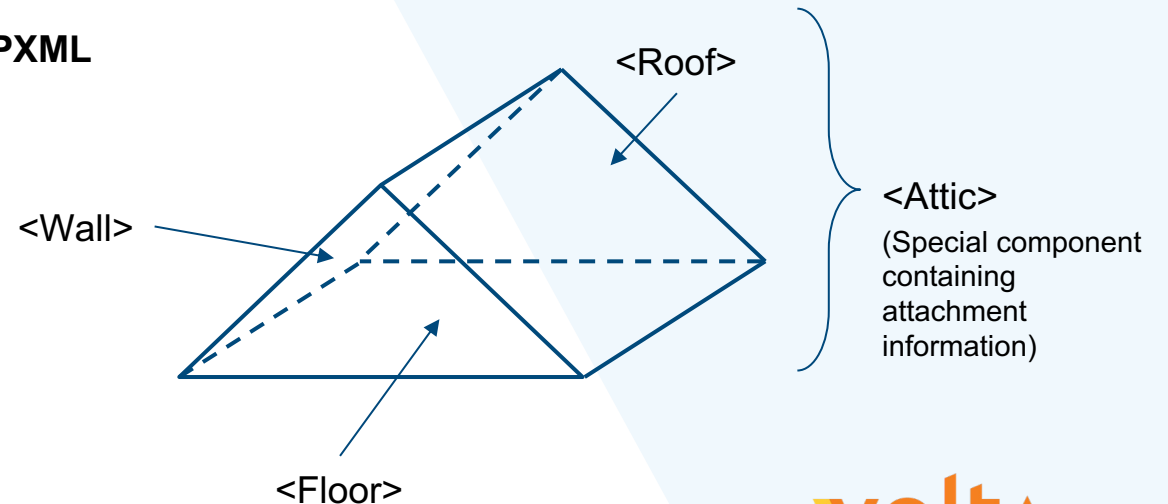| HPXML Section	H2k Section(s)	Notes
Software Info	N/A	Defines simulation timestep and utility bill scenarios
Building Site	N/A	Site identification information
Building Summary	Specifications Other (shielding information, room counts)	
Climate Zones	Weather	CWEC Weather files must be pre-loaded into OS-HPXML directory. Translation handles lookup of matching weather file
Enclosure	Natural Air Infiltration Components (Ceilings, Walls, Foundations, etc)	HPXML has some new component types (<Roof>, <FoundationWall>, <Attic>) Complex H2k components must be built by a combination of subcomponents (e.g. H2k's <Ceiling>, <Crawlspace>)
Systems	Heating Cooling Hot Water Ventilation Temperatures	Out of scope. Default systems and specifications pre-populated in translation file template (baseboard heating, electric conserver tank, temperature set points and schedule, etc)
Appliances	Base Loads	Misalignment of appliance/base load inputs had to be addressed
Lighting	Base Loads	
Misc Loads	Base Loads	

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Enclosure Translation Example – Ceilings

- HOT2000 <Ceiling> components can represent ceilings with attic space, flat roofs, cathedral ceilings, or scissor roofs.
- HPXML's equivalent must be constructed from <Attic>, <Roof>, <Wall>, <Floor> components
- Additional geometry calculations required (e.g. estimates of roof area based on slope and internal area, gable wall area)

HOT2000

<Ceiling>
(Plus roof cavity inputs if non-default)

HPXML

<Roof>

<Wall>

<Floor>

<Attic>
(Special component containing attachment information)

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HPXML "Locations"

| Value	Description	Temperature	Building Type
outside	Ambient environment	Weather data	Any
ground		EnergyPlus calculation	Any
conditioned space	Above-grade conditioned space maintained at setpoint	EnergyPlus calculation	Any
attic - vented		EnergyPlus calculation	Any
attic - unvented		EnergyPlus calculation	Any
basement - conditioned	Below-grade conditioned space maintained at setpoint	EnergyPlus calculation	Any
basement - unconditioned		EnergyPlus calculation	Any
crawlspace - vented		EnergyPlus calculation	Any
crawlspace - unvented		EnergyPlus calculation	Any
crawlspace - conditioned	Below-grade conditioned space maintained at setpoint	EnergyPlus calculation	Any
garage	Single-family garage (not shared parking)	EnergyPlus calculation	Any
manufactured home underbelly	*Underneath the belly, ambient environment*	*Weather data*	*Manufactured only*
manufactured home belly	*Within the belly*	*Same as conditioned space*	*Manufactured only*
other housing unit	*E.g., conditioned adjacent unit or conditioned corridor*	*Same as conditioned space*	*SFA/MF only*
other heated space	*E.g., shared laundry/equipment space*	*Avg of conditioned space/outside; min of 68F*	*SFA/MF only*
other multifamily buffer space	*E.g., enclosed unconditioned stairwell*	*Avg of conditioned space/outside; min of 50F*	*SFA/MF only*
other non-freezing space	*E.g., shared parking garage ceiling*	*Floats with outside; minimum of 40F*	*SFA/MF only*
other exterior	Water heater outside	Weather data	Any
exterior wall	Ducts in exterior wall	Avg of conditioned space/outside	Any
under slab	Ducts under slab (ground)	EnergyPlus calculation	Any
roof deck	Ducts on roof deck (outside)	Weather data	Any

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Base Loads Translation

- HOT2000 defines base loads/water usage in terms of consumption (kWh/year, L/day)
- HPXML defines these by *EnergyGuide Label* information (rated annual kWh, label usage, appliance capacity, label electricity/gas cost)

  - OS-HPXML workflow applies background calculation then occurs to estimate annual energy/water consumption based on correlations between label usage and "actual" expected usage

- Solution: equations used in HPXML workflow integrated into translation process to determine EnergyGuide Label information that will produce desired consumption amounts

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Results

- New construction archetypes (NRCan 11, Toronto Climate)
- Existing home archetypes (~570)
  - Halifax, Montreal, Ottawa, Edmonton, Vancouver
- Excluding files:
  - MURBs (both types), mobile homes
- Parameters of interest:
  - Auxiliary (Heating) Energy Required
  - Design Heating/Cooling Loads
  - Gross Heat Loss
  - Envelope Component Heat Loss
- Work done: breaking errors, not finished alignment of results
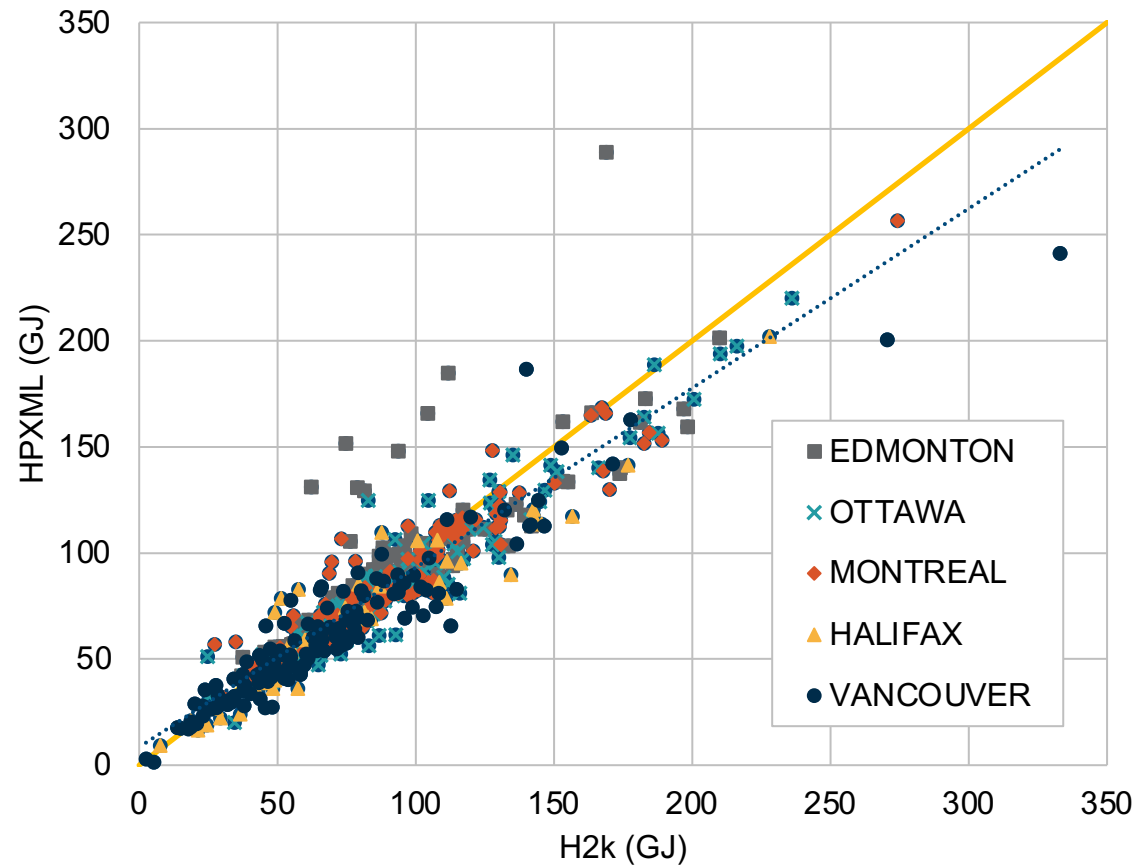
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New Construction – Auxiliary Heating

y = 1.0199x + 3.1749
R² = 0.9637

Arch2 – 1 Storey crawlspace
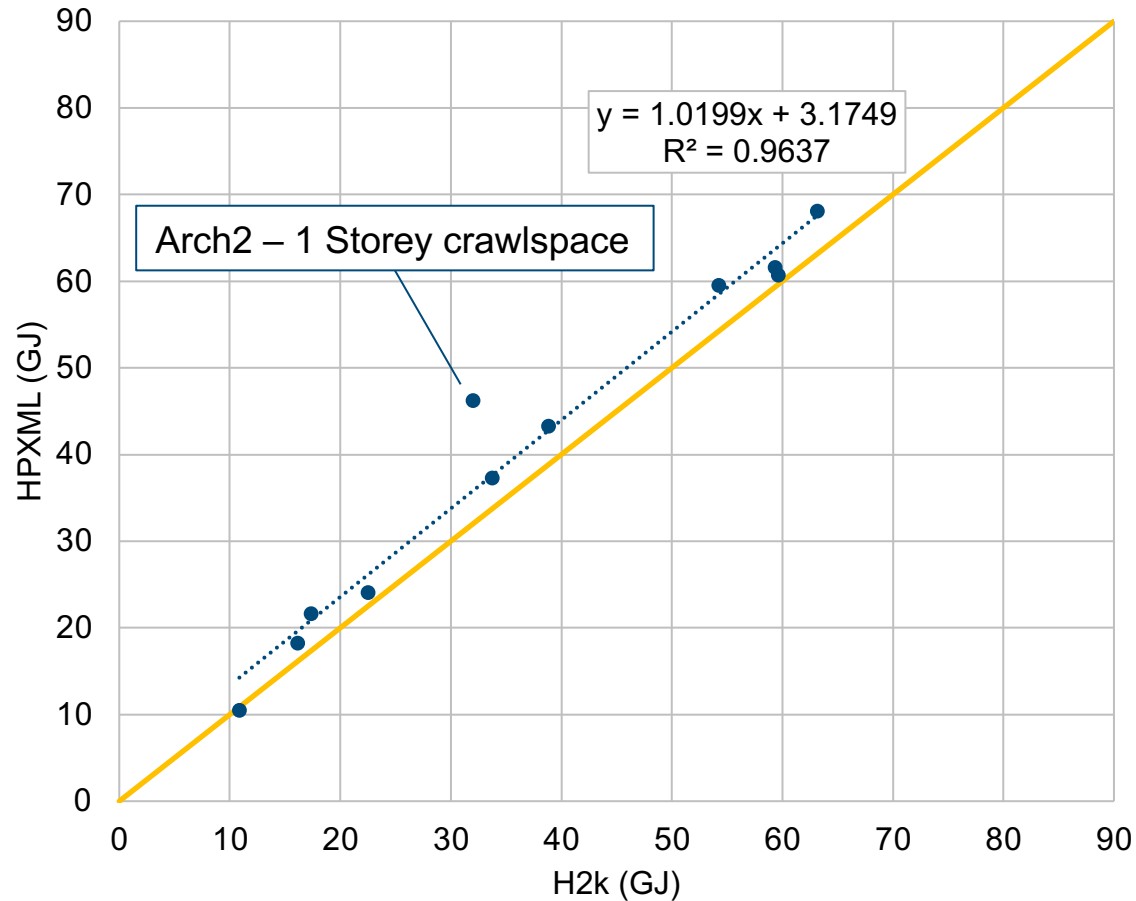
- Archetype with crawlspace shows largest error (14 GJ / 44%)
- With crawlspace archetype:
  - R^2 = 0.964
  - RMSE = 5.36 GJ (17.1%)
- Without crawlspace archetype:
  - R^2 = 0.993
  - RMSE = 3.38 GJ (11.1%)
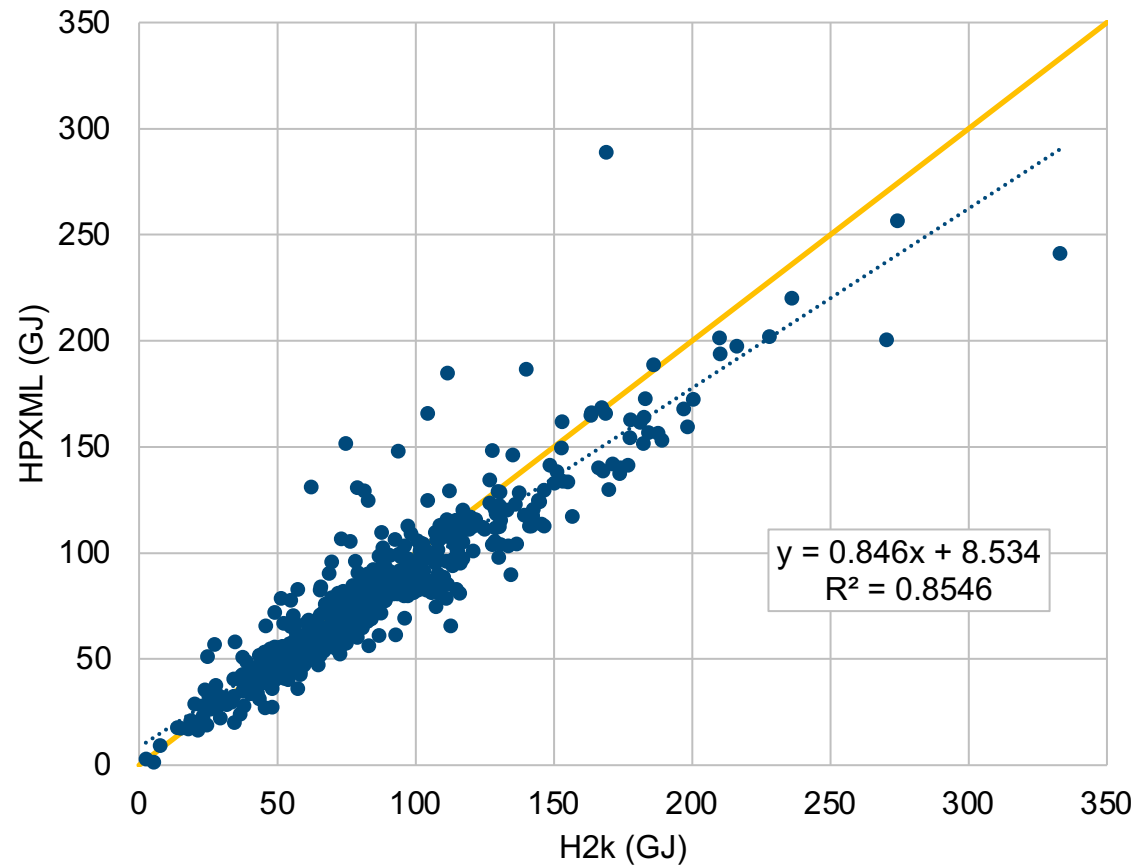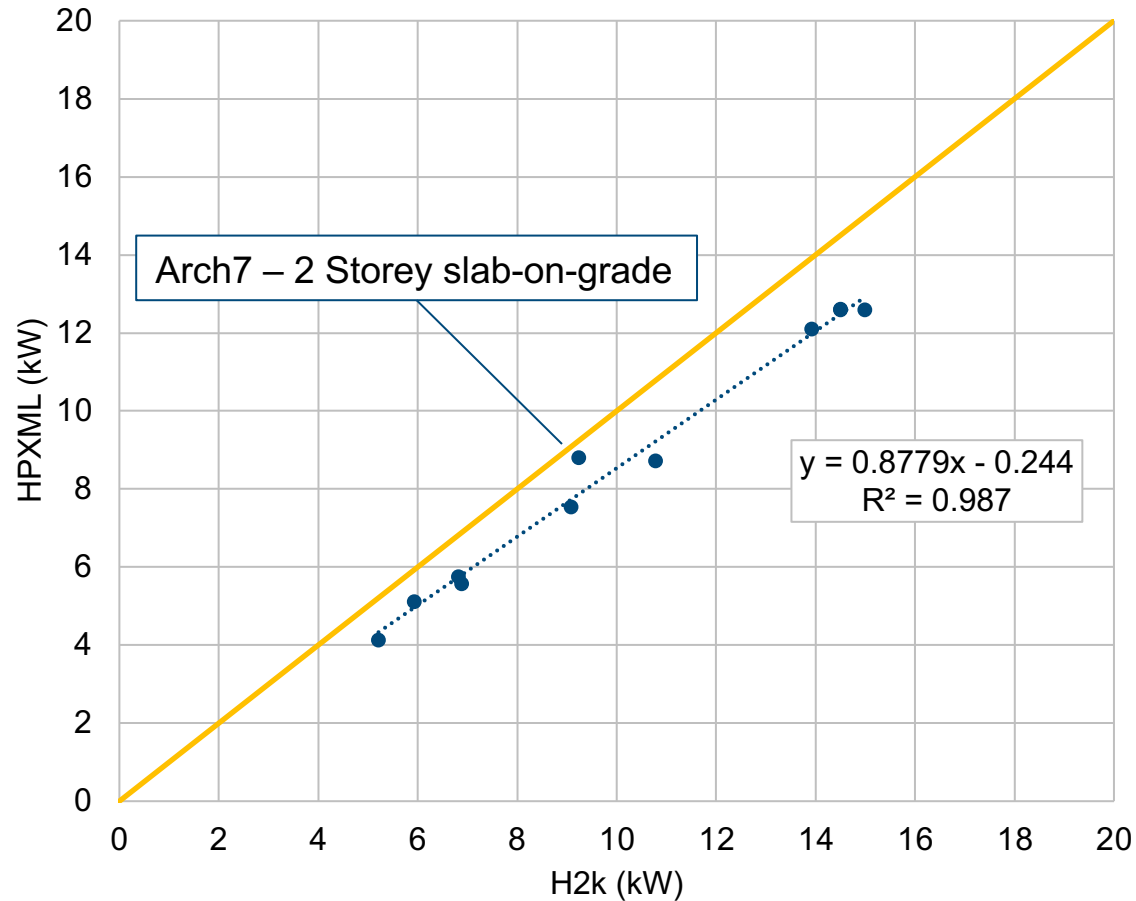
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Existing Buildings – Auxiliary Heating

- Correlation:
  - $R^2 = 0.855$
  - RMSE = 16.6 GJ (19.3%)

y = 0.846x + 8.534
$R^2 = 0.8546$

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Existing Buildings – Auxiliary Heating

- Correlation:
  - $R^2 = 0.855$
  - RMSE = 16.6 GJ (19.3%)

Scatter plot legend:
- EDMONTON
- OTTAWA
- MONTREAL
- HALIFAX
- VANCOUVER

Axes: HPXML (GJ) versus H2k (GJ)

New Construction – Design Heating Load

Chart: H2k (kW) vs HPXML (kW)

Arch7 – 2 Storey slab-on-grade

$y = 0.8779x - 0.244$
$R^2 = 0.987$

- Archetype with slab-on-grade deviates from the rest, but is closest to y=x

- With slab archetype:
  - $R^2 = 0.987$
  - RMSE = 1.59 kW (15.6%)

- Without crawlspace archetype:
  - $R^2 = 0.996$
  - RMSE = 1.66 kW (16.3%)

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Existing Buildings – Design Heating Load
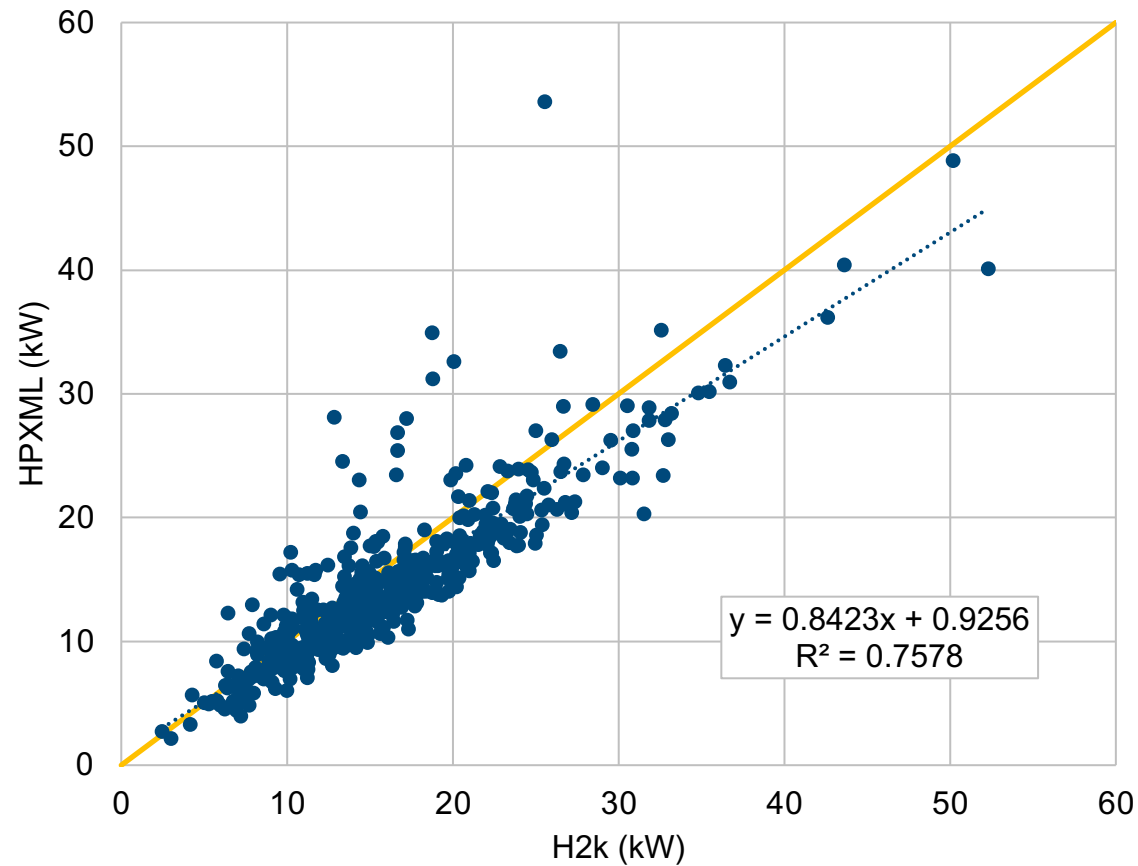
- Correlation:
  - R^2 = 0.758
  - RMSE = 3.6 kW (22 %)

Plot labels:
- X-axis: H2k (kW)
- Y-axis: HPXML (kW)

y = 0.8423x + 0.9256
R² = 0.7578

H2k to HPXML

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New Construction – Design Cooling Load
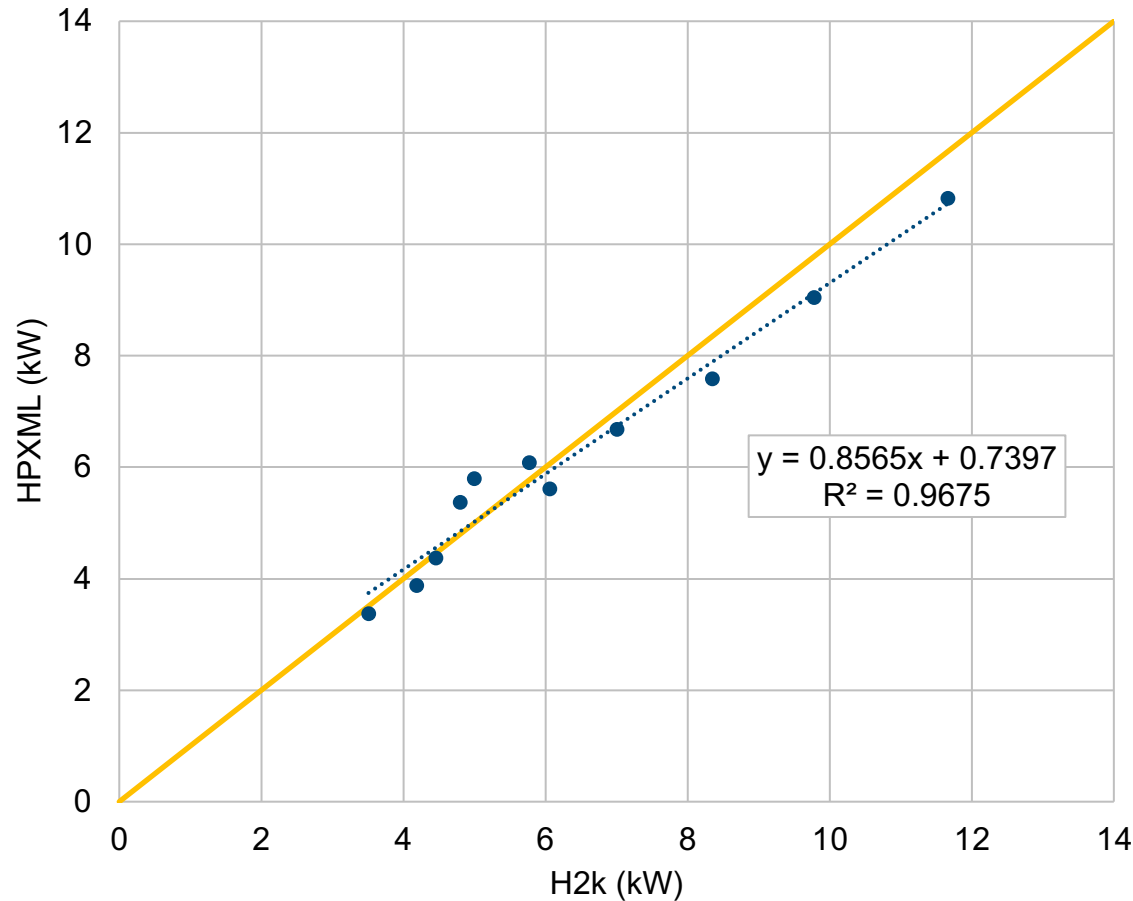
- HPXML produces similar design cooling loads to HOT2000
  - F280 produces greater values than H2k
- Correlation:
  - $R^2 = 0.968$
  - RMSE = 0.55 kW (8.3 %)
- Currently, windows are modelled using the U-value/SHGC provided by HOT2000, not using physical properties
- HPXML value = Sensible + Latent, HOT2000 does not provide breakdown
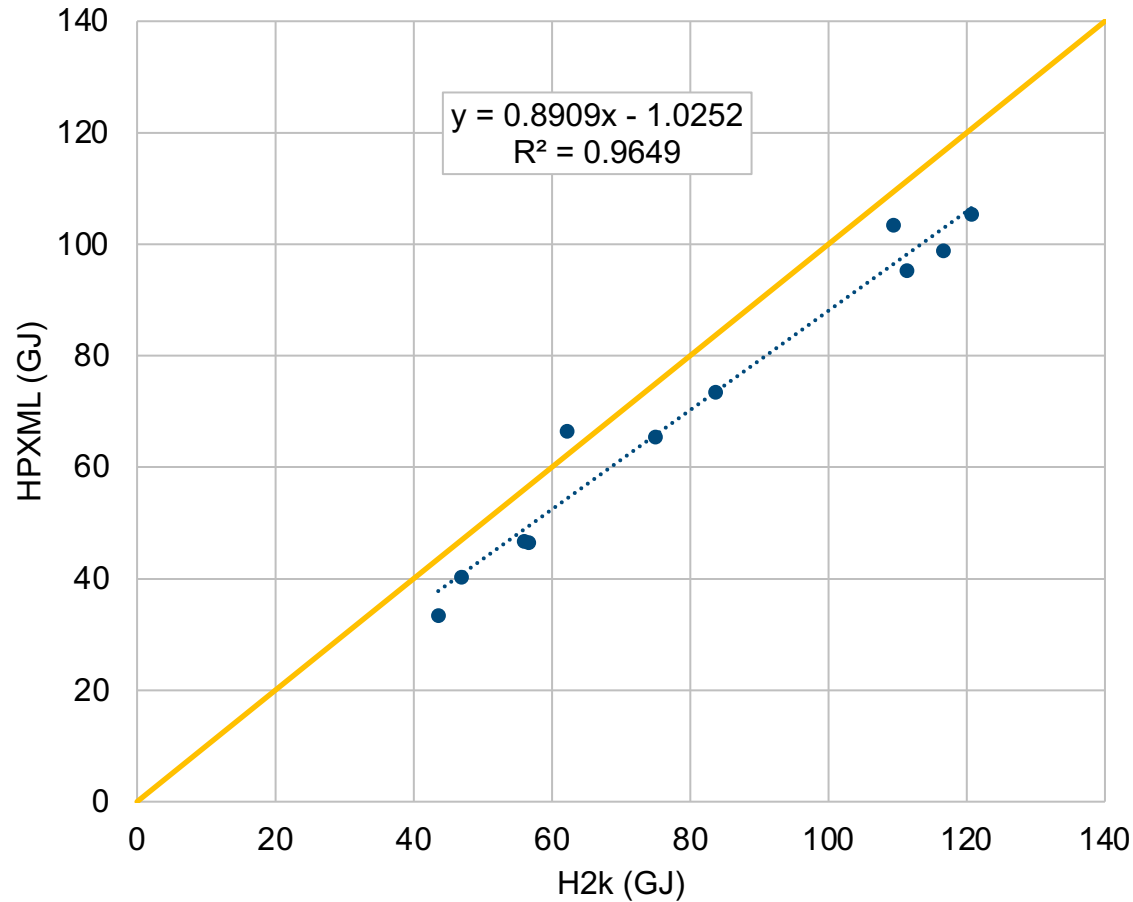
H2k to HPXML

Existing Buildings – Design Cooling Load
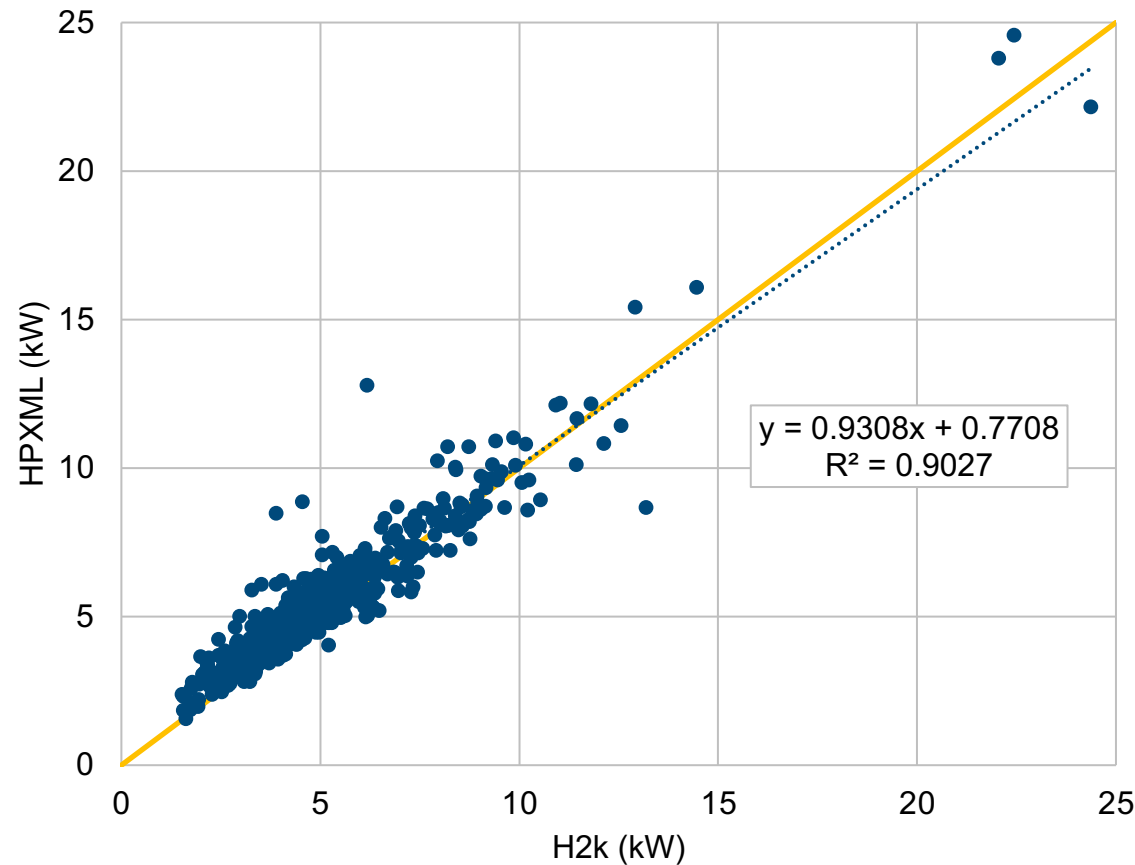
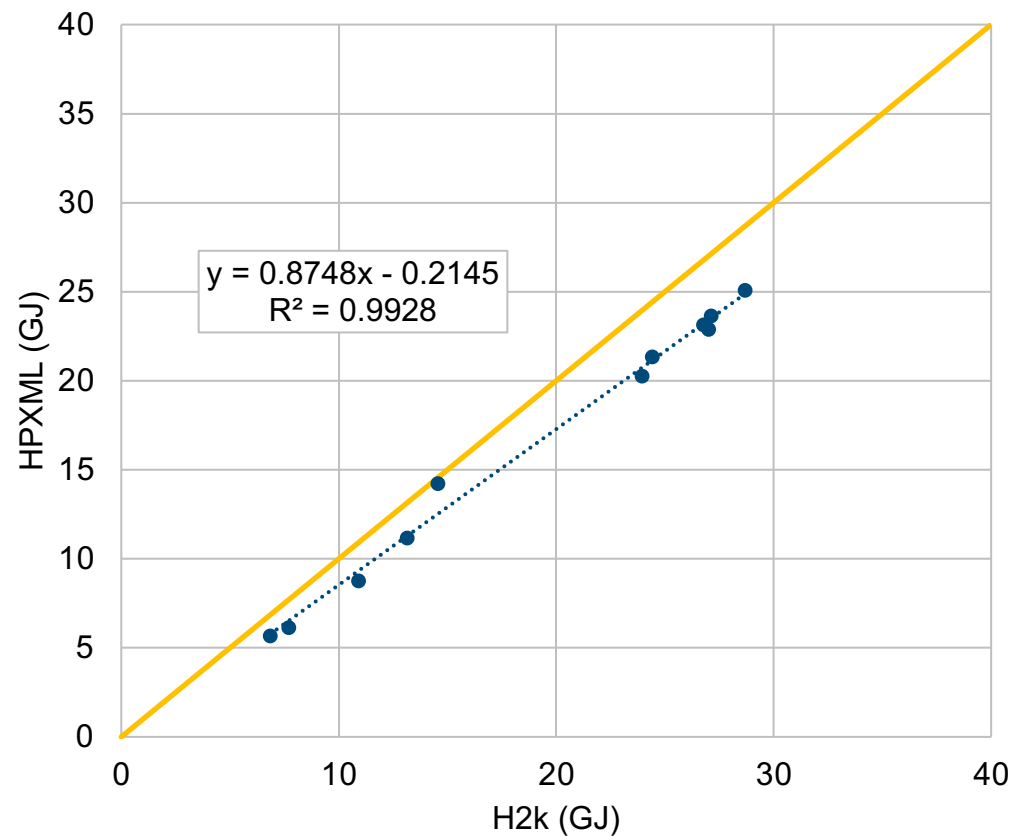
- Correlation:
  - $R^2 = 0.903$
  - RMSE = 0.9 kW (21.9 %)

y = 0.9308x + 0.7708
R² = 0.9027

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New Construction – Gross Heat Loss

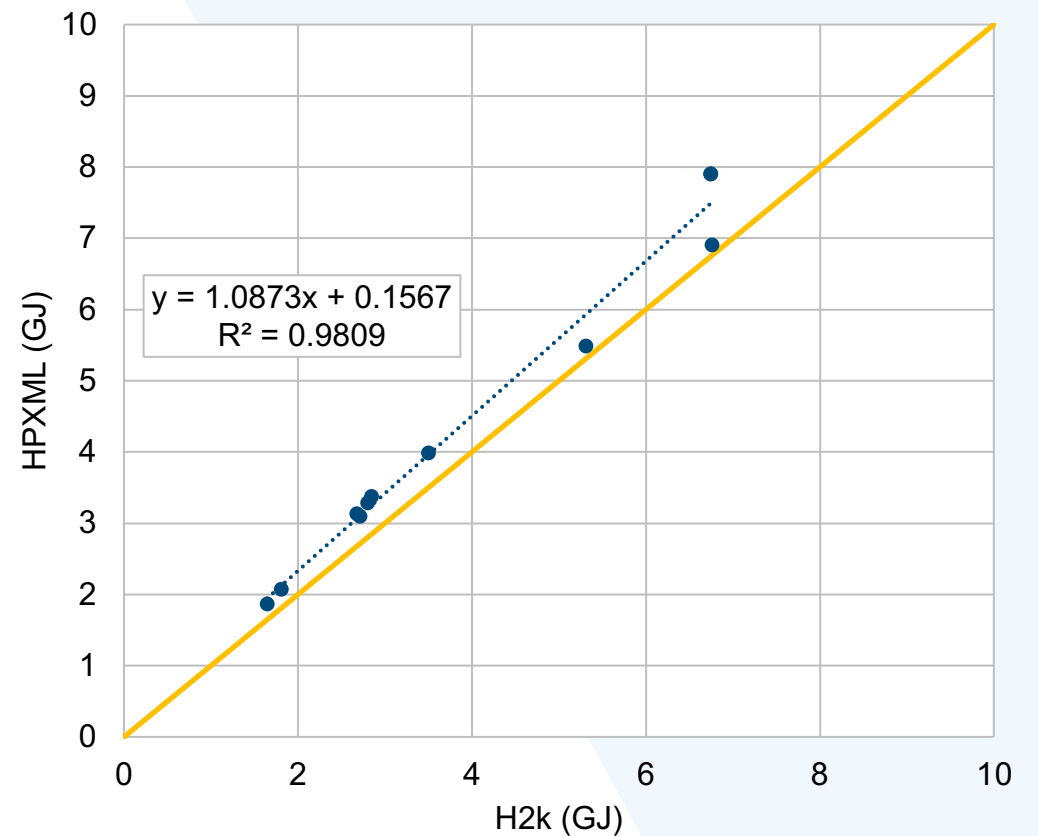y = 0.8909x - 1.0252
R² = 0.9649

- Equal to the sum of the heat loss through envelope (ceiling, walls, windows, air leakage, etc.)
- Correlation:
  - $R^2 = 0.965$
  - RMSE = 11.3 GJ (14.6%)
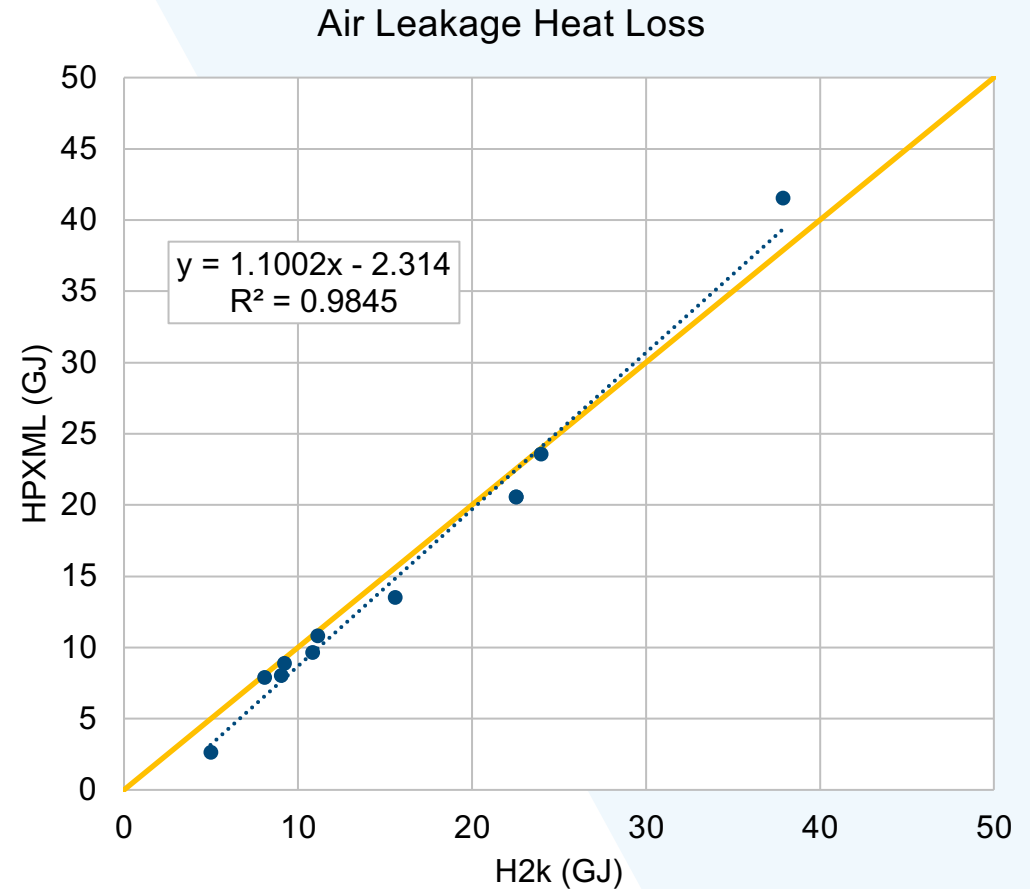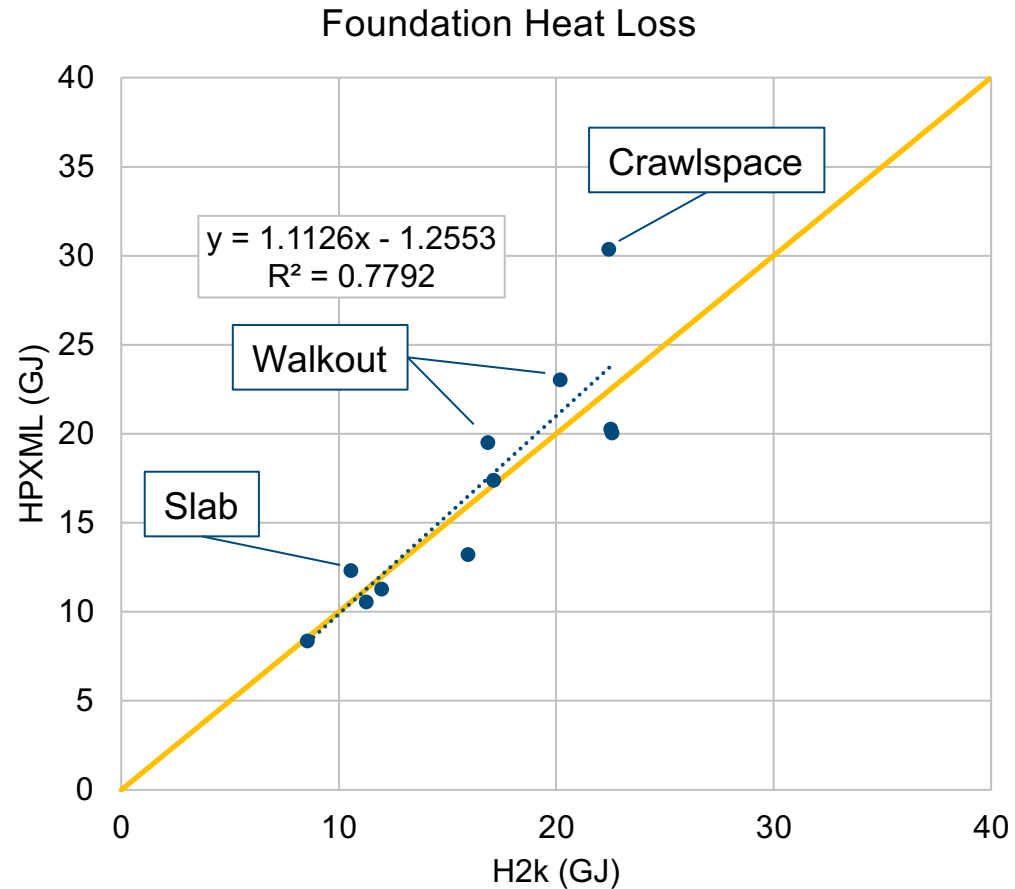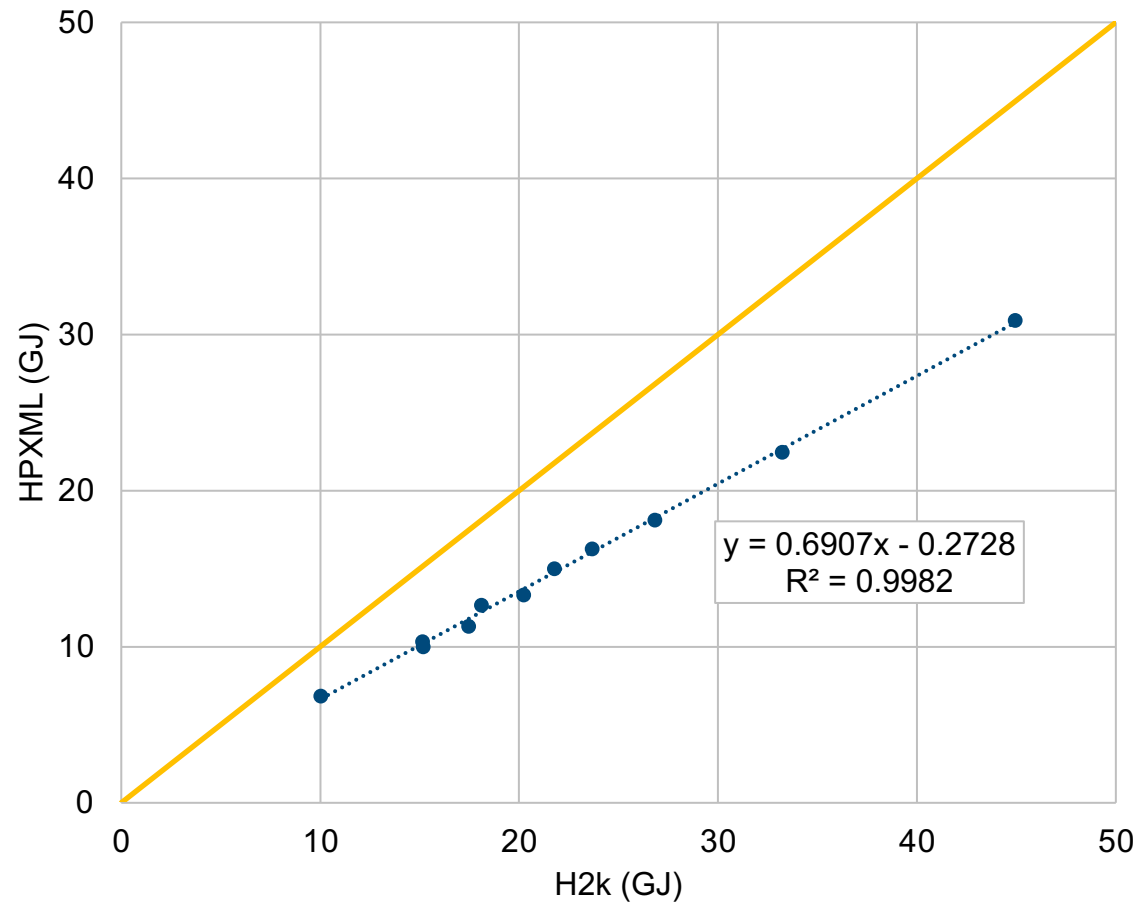
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New Construction – Component Heat Loss

Wall Heat Loss

$y = 0.8748x - 0.2145$
$R^2 = 0.9928$

HPXML (GJ) vs H2k (GJ)

Ceiling/Roof Heat Loss

$y = 1.0873x + 0.1567$
$R^2 = 0.9809$

HPXML (GJ) vs H2k (GJ)

H2k to HPXML

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New Construction – Component Heat Loss (Cont.)

Foundation Heat Loss

y = 1.1126x - 1.2553
R² = 0.7792

Crawlspace

Walkout

Slab

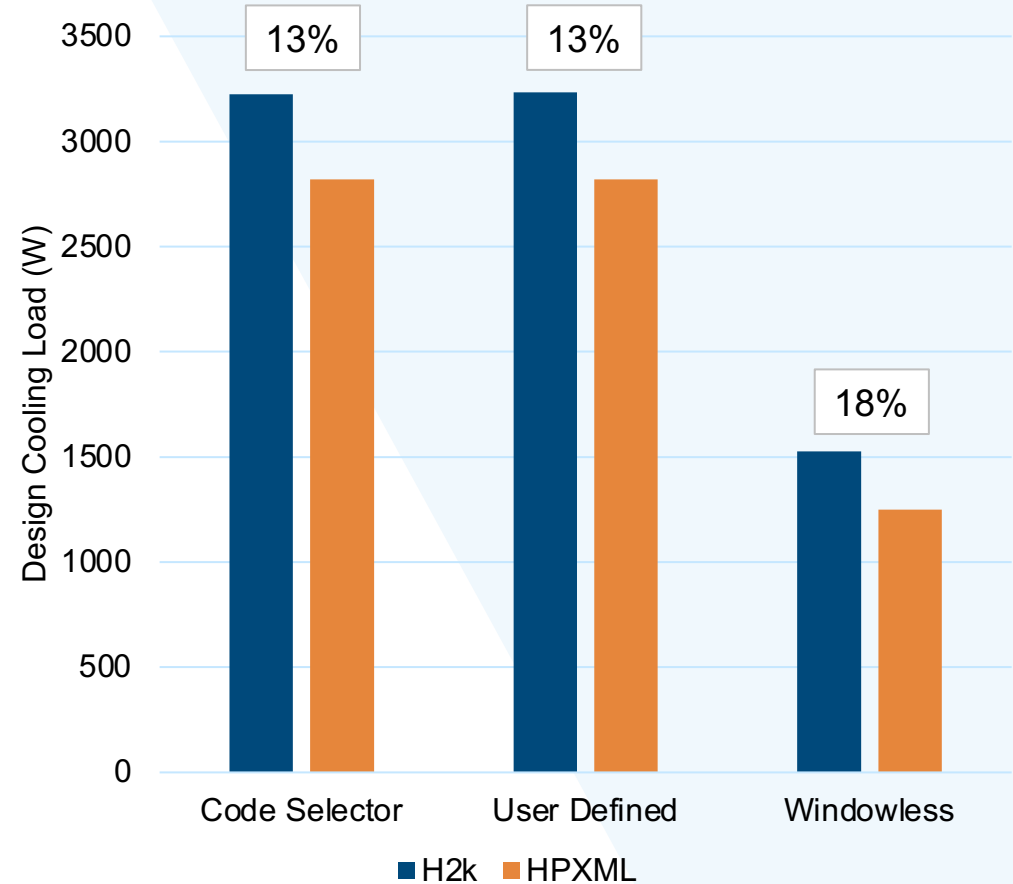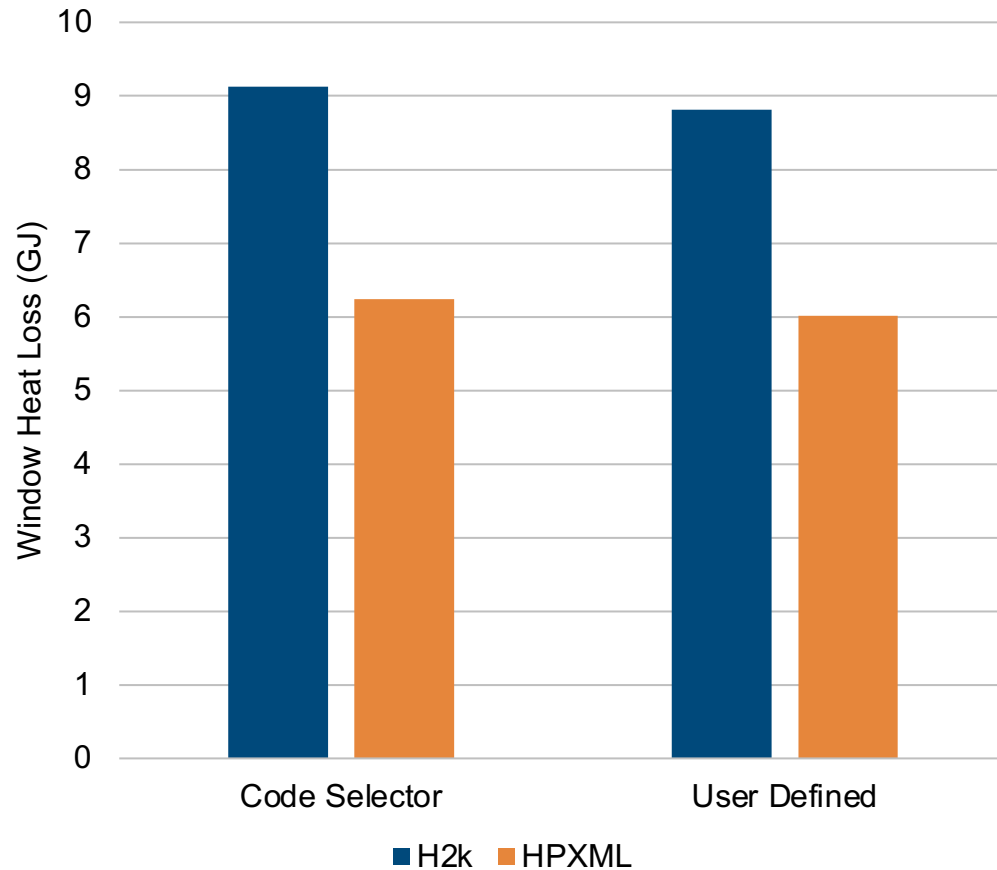Air Leakage Heat Loss

y = 1.1002x - 2.314
R² = 0.9845

H2k to HPXML

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New Construction – Window Heat Loss

- Consistent ~30% underestimation in window heat loss compared to HOT2000 (RMSE = 7.7 GJ)

Chart: HPXML (GJ) vs H2k (GJ)

y = 0.6907x - 0.2728
R² = 0.9982

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Window Heat Loss – Reality Check

Simple "box" house
One window each facing N,E,S,W
15% W:W
No Overhangs
Code Selector: RSI = 0.59, SHGC = 0.58
User Defined: RSI = 0.61, SHGC = 0.59
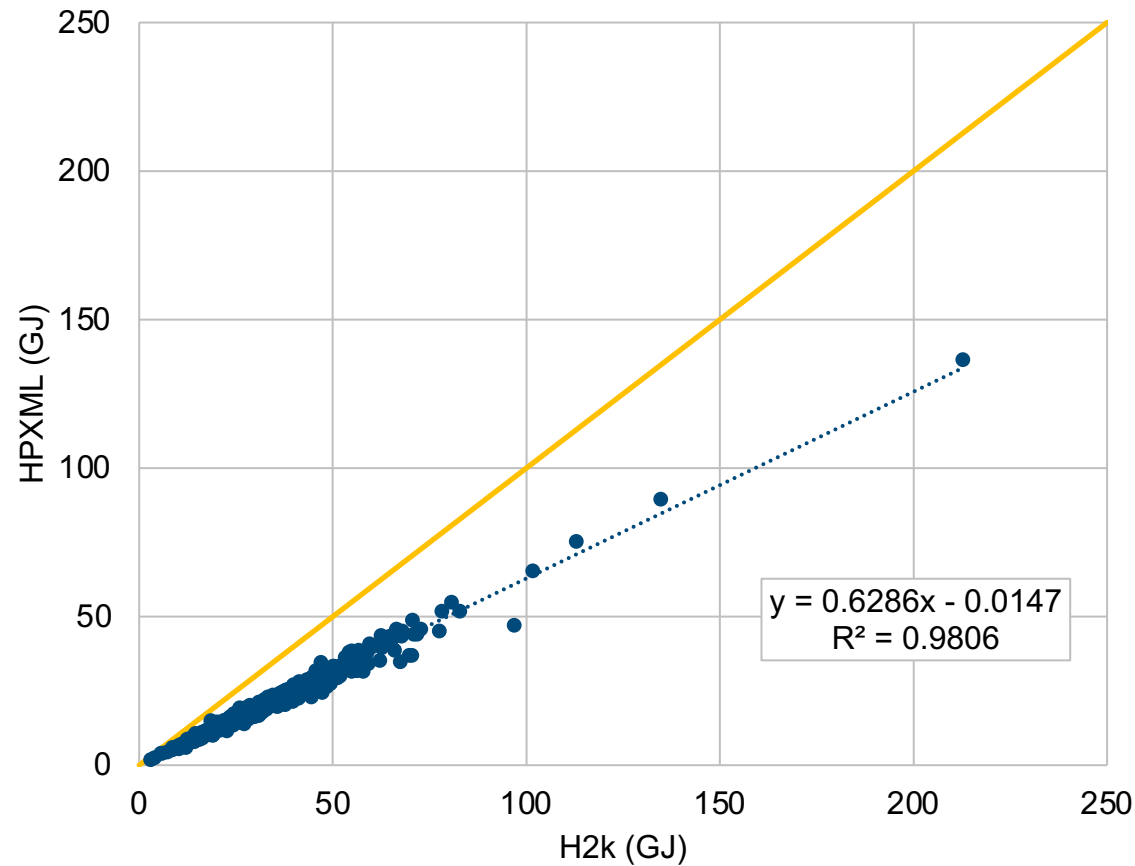

H2k to HPXML

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Existing Buildings – Gross Heat Loss
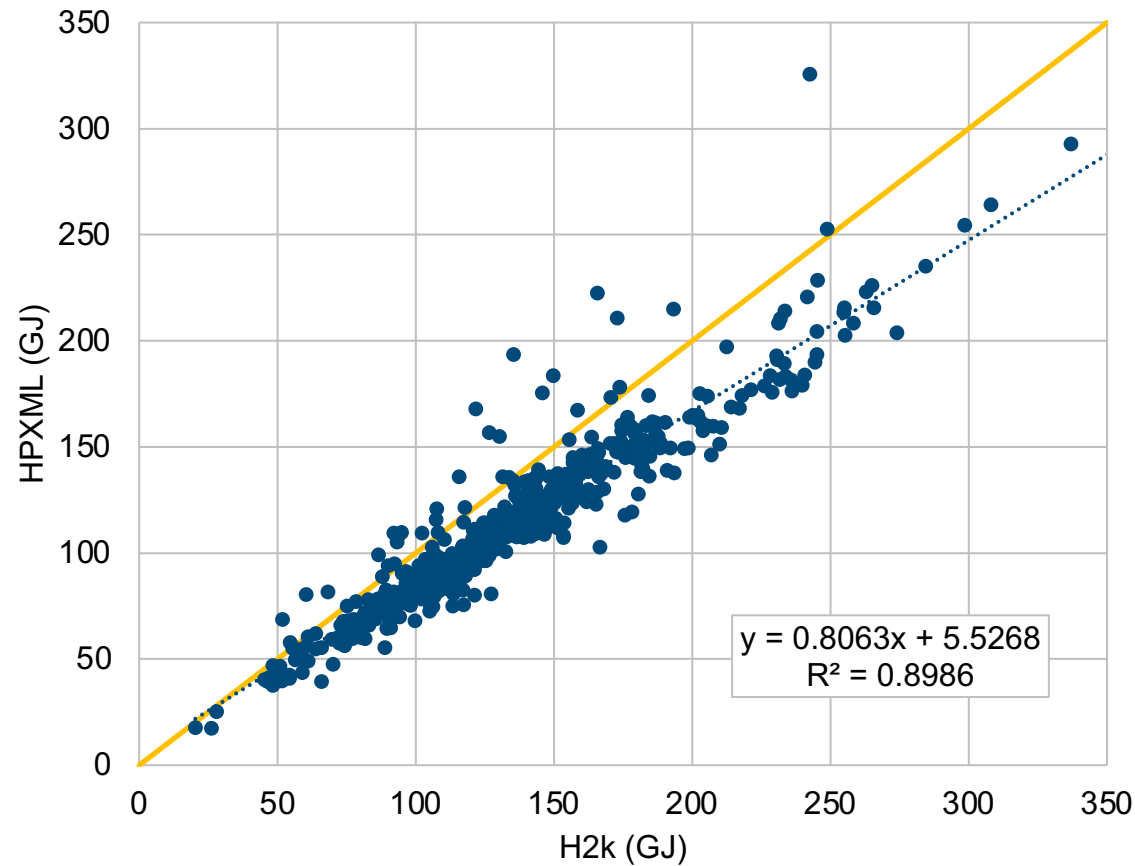
- Correlation:
  - $R^2 = 0.899$
  - RMSE = 26.7 GJ (18.0 %)

Chart details:
- Y-axis: HPXML (GJ)
- X-axis: H2k (GJ)
- $y = 0.8063x + 5.5268$
- $R^2 = 0.8986$

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Existing Buildings – Window Heat Loss

- Correlation:
  - R^2 = 0.981
  - RMSE = 13.8 GJ (37.2 %)

y = 0.6286x - 0.0147
R² = 0.9806

HPXML (GJ)

H2k (GJ)

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Existing Buildings – Foundation Heat Loss
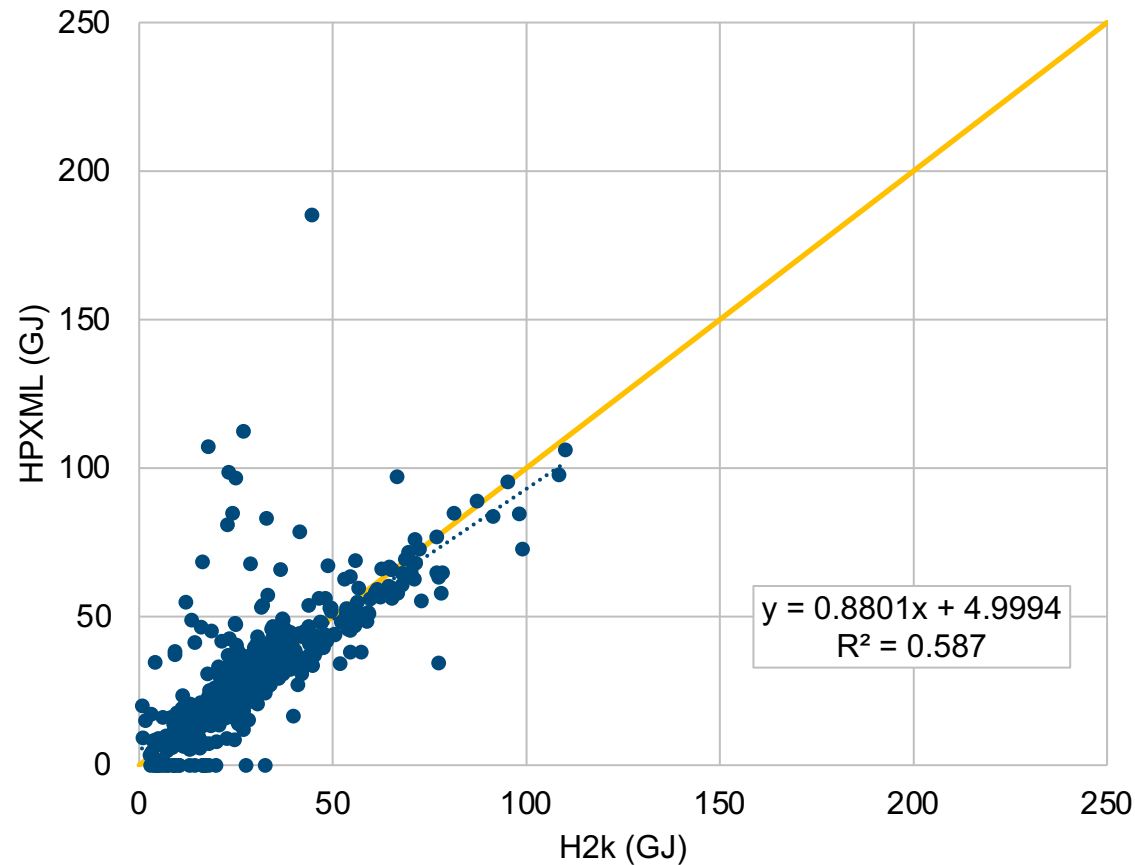
- Correlation:
  - $R^2 = 0.583$
  - RMSE = 13.6 GJ (144 %)
- Potential issues:
  - Complex, multi-component foundations
  - Crawlspaces

Chart annotations:
- y-axis: HPXML (GJ)
- x-axis: H2k (GJ)
- y = 0.8801x + 4.9994
- $R^2 = 0.587$

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Identified Gaps in Input Representation

- HOT2000 does not explicitly define shared walls between attached units
  - Attached homes in HPXML require at least one shared wall to be defined (simulation will not proceed otherwise)
  - Translation process creates these missing shared walls, attempts to create reasonable geometry (wall area estimate)
  - May be problem for MURBs (particularly single units), and houses with complex multi-component foundations
- No explicit crawlspace components in HPXML, must be constructed from <Slab>, <Floor>, <FoundationWall>
  - No clear way to model "Open" crawlspaces in HPXML, other than as an exposed <Floor> component adjacent to the exterior.

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Next Steps

Within scope:

- Continue to identify potential causes of OS simulation errors, catch and rectify where possible, produce warnings for users otherwise.

  - For example, houses without a bathroom will not simulate in OS (HOT2000's ventilation > rooms screen)

- Look into calculation discrepancies around windows and foundations
- Final reporting on translation of non-systems, including updated results (hourly analysis)

Future work:

- Development of systems translation process and associated results analysis
- Alignment with new version of HPXML-OS workflow
- Alignment with non-SOC operating conditions
- Full-scale testing

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Questions