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Use of the COMSOL Multiphysics® Software to Model The Transient Behavior of Thermal Bridge

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OUTLINE

- NRC – who we are and what do we do
- Building Envelopes – what is it, and why is it important?
- Using COMSOL to predict the performance of building envelopes:
    - Virtual Guarded Hot Box
    - Thermal Bridging
    - Heat air and moisture transport

NATIONAL RESEARCH COUNCIL

National Research Council of Canada

- **Government of Canada's largest science and research organization**

- **Vision:** "A better Canada through excellence in research and innovation"

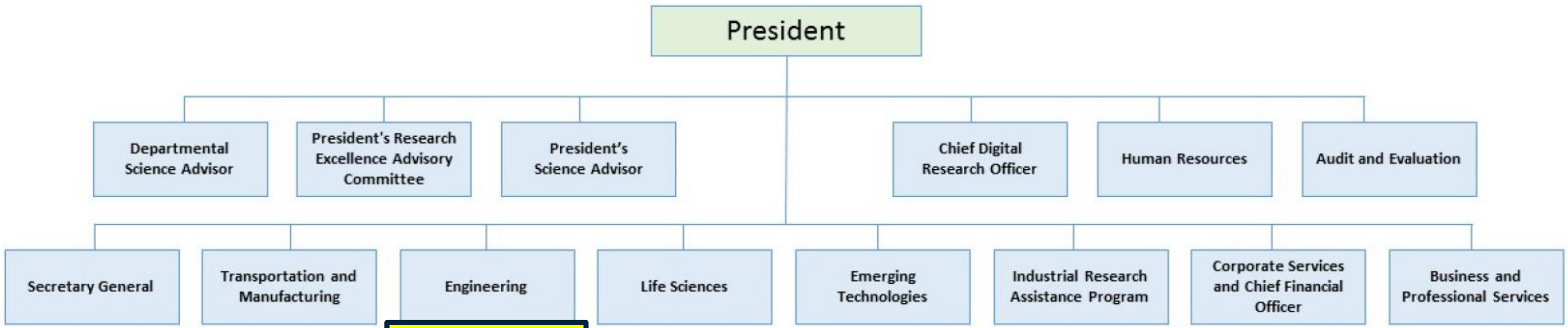
- **Mission:** "To have impact by advancing knowledge, applying leading-edge technologies, and working with other innovators to find creative, relevant and sustainable solutions to Canada's current and future economic, social and environmental challenges"

- We are responsible for several tasks including: time signal, standards measurement including kilogram, National Building Code, Fire Code, National Energy Code, EtC.

National Research Council Canada   Conseil national de recherches Canada

Canada

NRC – what do we do?



Engineering

Building Envelope and Materials Group

- Roofing Systems and Insulation Group
- Whole Building Performance Group
- Acoustic Group
- Indoor Air Quality Group
- Building Technology Optimization Group
- Façade Systems and Products Group

Evaluation of Building Envelopes

Façade systems and products ongoing research

- Methods to enhance the thermal performance of BEs to help having Net Zero Buildings.
- How climate change affects the climate loads on the buildings
  - Reducing the risks to overheating of buildings
  - Predicting long-term durability of building envelope components and assemblies
  - Collaboration with universities, industries and SME's
  - Development of research to inform on changes to the National Building Code and National Energy Code for buildings.

Variety of numerical software used to accomplish these tasks:

- **COMSOL Multiphysics**, DELPHIN, hygIRC, WUFI, THERM, Energy +

THE BUILDING ENVELOPE

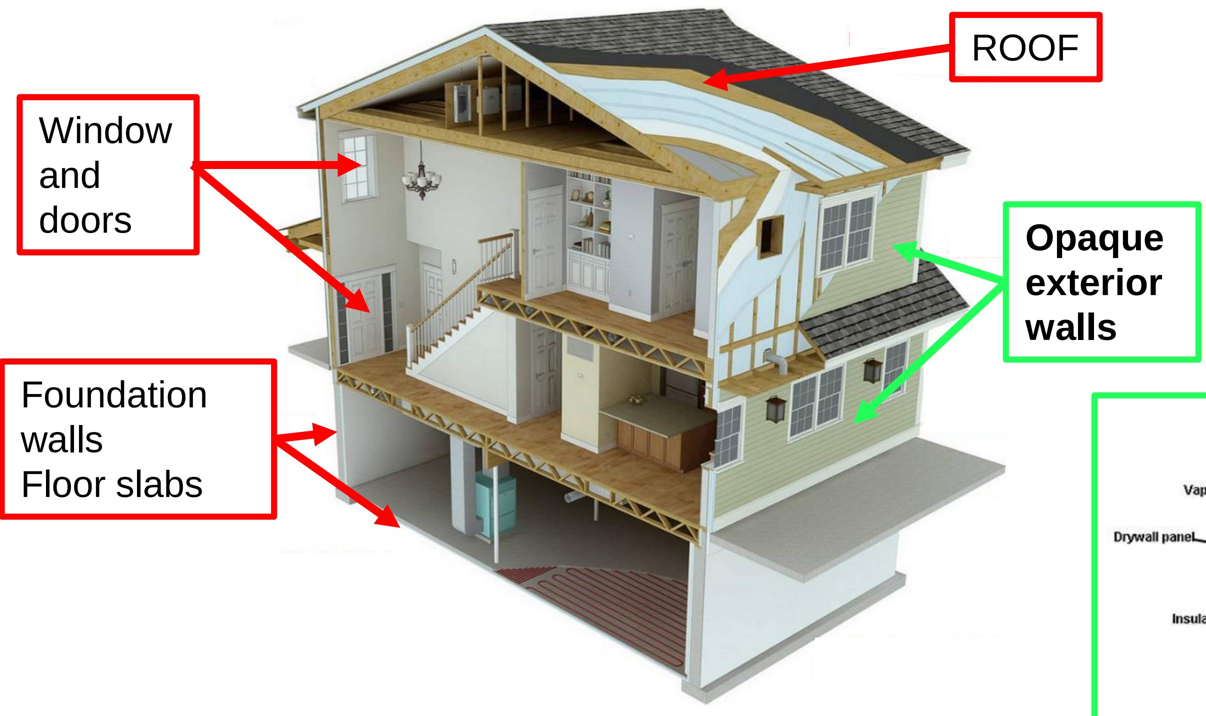
What is it?

Why is it important?

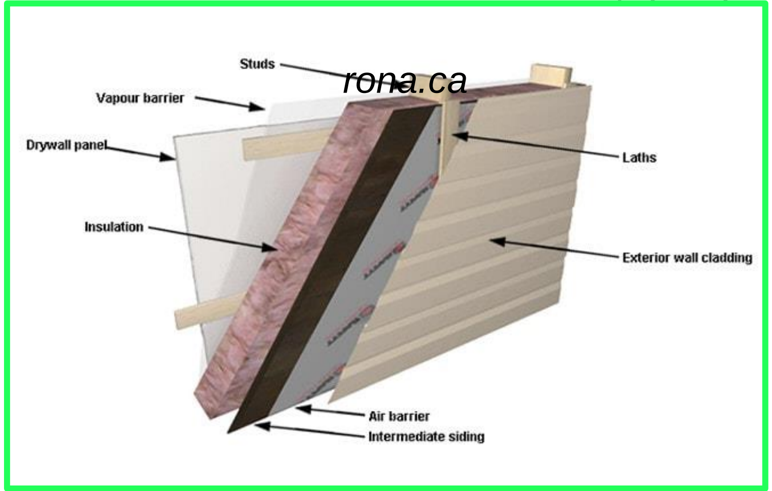
What do we research about it?

Building envelope – what is it?

Physical separation between indoor and outdoor environments.



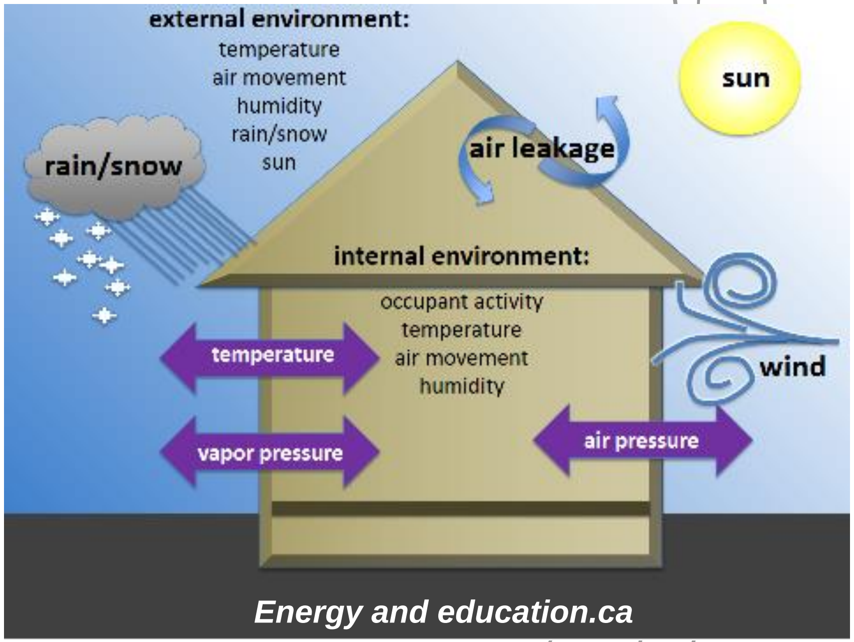
Adapted from Greenbuildingsolutions.org



Building envelope – why is it important?

Structural Support: provides structural support against internal and external loads and forces

Control of load transfer: sound, heat, air, moisture and pollutants between interior and exterior of building



Finish (aesthetics): Makes building look attractive while still performing support and control functions

Building Envelope – what do we research about it?

Canada adopted Pan-Canadian framework on clean growth and climate change in 2016. As a part of the plan, Canada should meet its 2030 emission targets. 17% of Canada's total Green House Gas emissions come from buildings.

1. **Energy Performance – thermal bridging, whole building energy performance**

2. **Long-term durability – reduce the risk of deterioration of components, by reducing potential for mould, condensation, and corrosion**

How do we use COMSOL in our work?

- **Use lab experiments to benchmark or validate COMSOL models, and use COMSOL models to complete parametric studies on multiple configurations/scenarios**

ddcnetwork.com

RDH Building Sciences

VTT Finland

COMSOL: THERMAL BRIDGING EFFECT

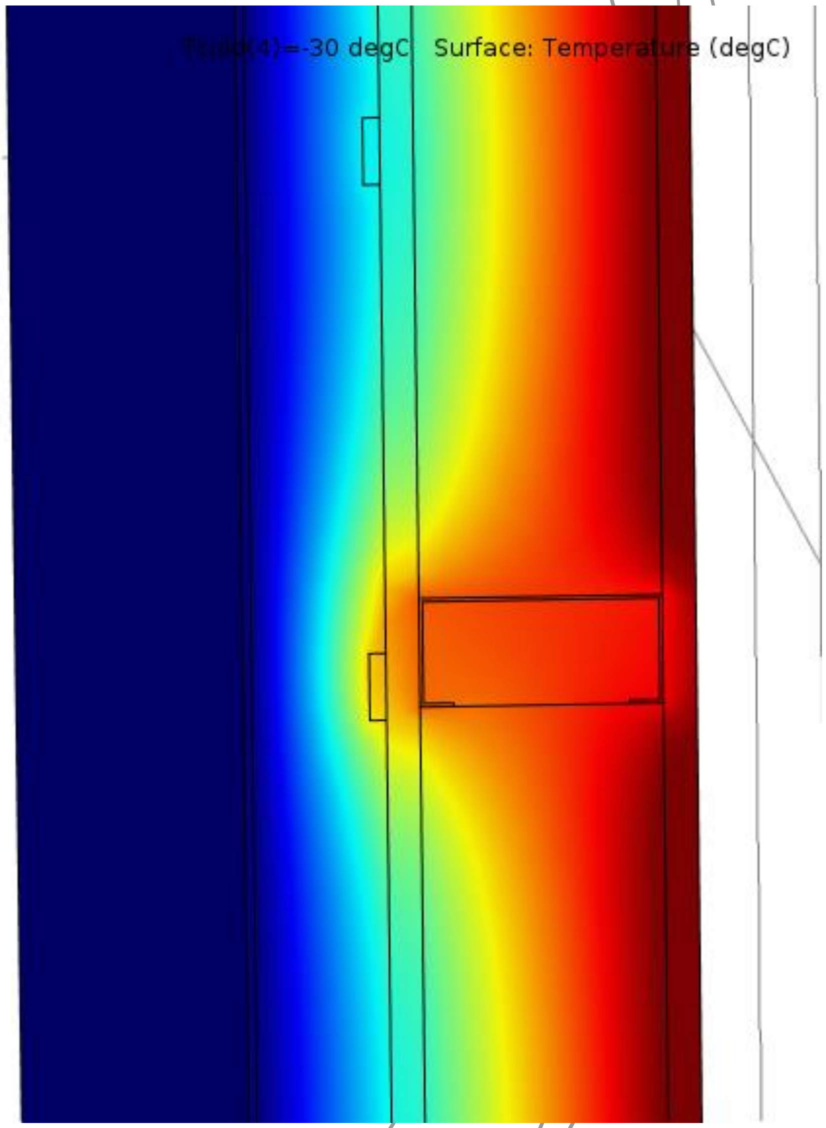
What is it?

Why is it important?

How can they be accounted for?

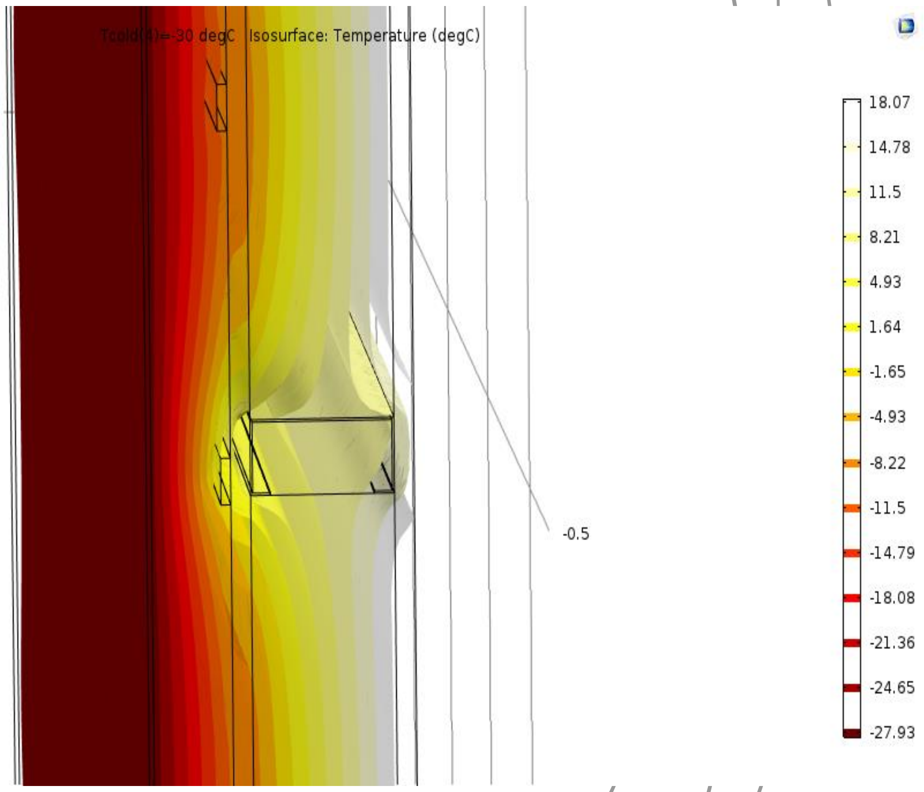
What is thermal bridging?

- It has become more and more evident that the thermal performance of the building envelope can be greatly affected by thermal bridging. Thermal bridges are localized areas of high heat flow through walls, roofs and other insulated building envelope components.
- Thermal bridging is caused by highly conductive elements that penetrate the thermal insulation and/or misaligned planes of thermal insulation. These paths allow heat flow to bypass the insulating layer, and reduce the effectiveness of the insulation.



Why thermal bridging is important?

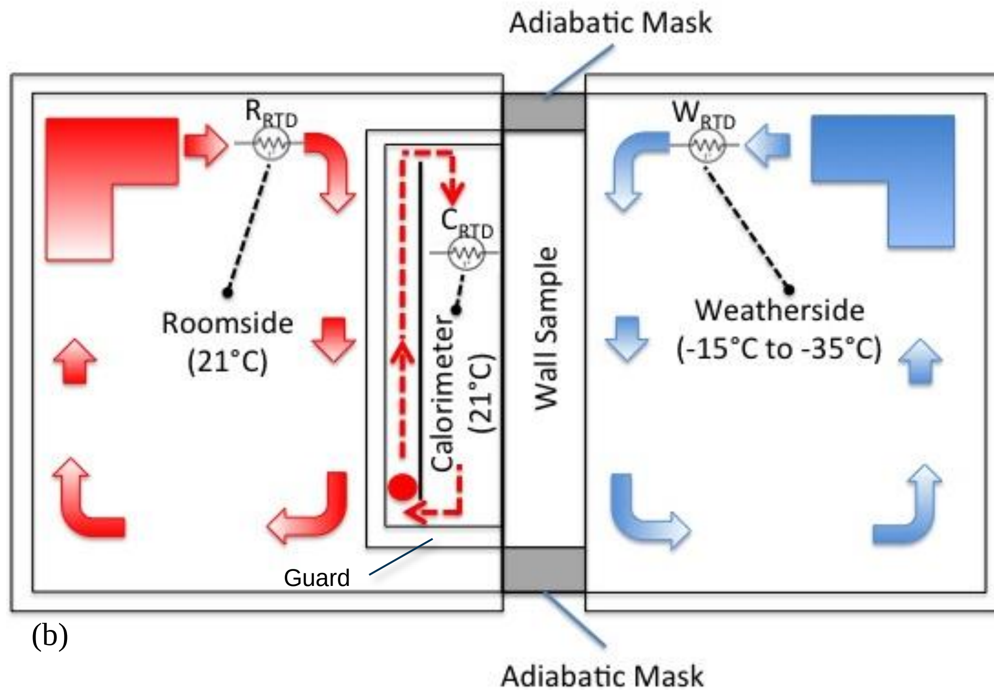
- If neglected, thermal bridging can lead to 20% to 70% overestimation of thermal resistance of wall assemblies.
- It leads to thermal discomfort of the occupants.
- It increases the cold regions on the interior which can increase the condensation risk.
- If major thermal bridges are not addressed then adding insulation to the assemblies may not provide significant benefits in reducing the overall heat flow because heat will flow through the path of least resistance.



How can thermal bridges be accounted for: Laboratory measurement

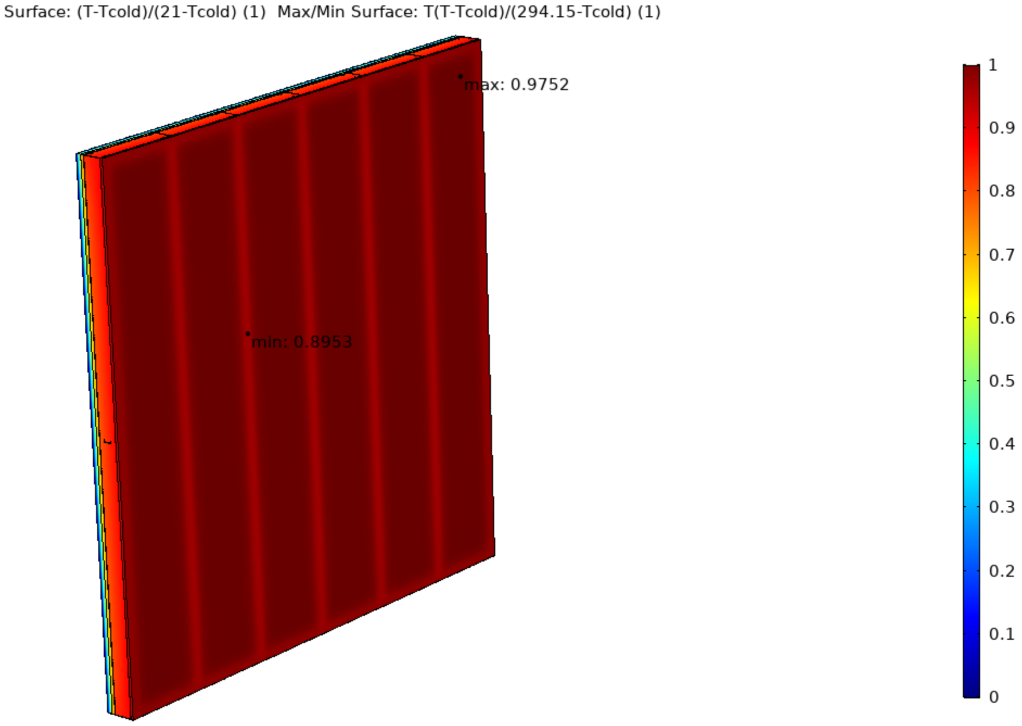
$$RSI = \frac{A * \Delta T}{Q}$$

Q = the heat input to the calorimeter (W)
A = the specimen area normal to the direction of heat transfer (m^2)
ΔT = the absolute temperature difference between the interior and exterior air (°K)



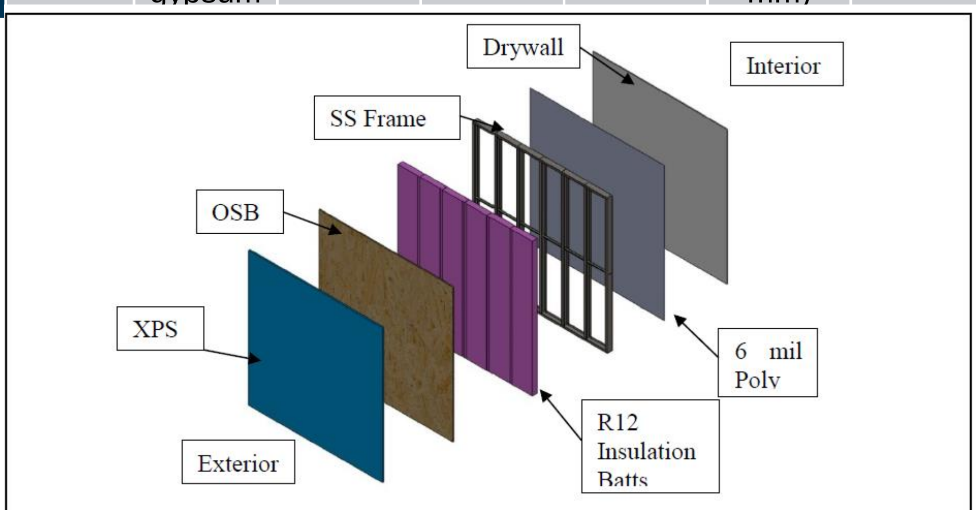
How can thermal bridges be accounted for: COMSOL

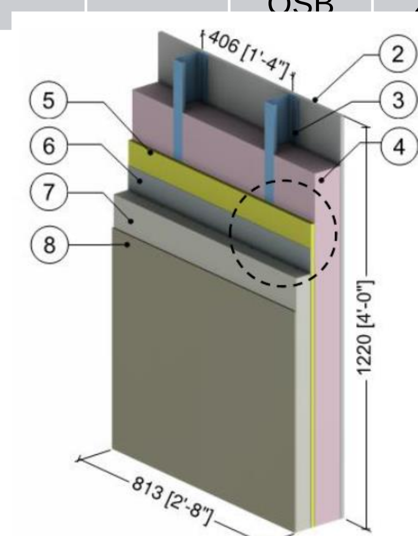
- Three dimensional heat transfer modeling is required.
- Boundary conditions
- Initial conditions
- Material properties
- Numerical resolution of equations
- Rapid
- Once benchmarked, can be used for similar walls, and in any climate zone



Summary of Walls Tested and simulated SS

ID	ASHRAE ID	Interior Sheathing	Fiberglass Cavity Insulation	Cavity Depth	Steel Stud Thickness	Steel Stud Spacing (o.c.)	Steel Stud Flange	Steel Track Thickness	Steel Track Flange	Exterior Sheathing	Exterior Insulation	Cladding
W1	SS. 19	1/2" (13 mm) gypsum	R-12 (RSI 2.1)	3 5/8" (92 mm)	20 gauge	16" (406 mm)	1 5/8" (41 mm)	1.03 mm	Not stated	5/8" (16 mm) OSB	none	none
W2	SS. 20	1/2" (13 mm) gypsum	R-12 (RSI 2.1)	3 5/8" (92 mm)	20 gauge	16" (406 mm)	1 5/8" (41 mm)	1.03 mm	Not stated	5/8" (16 mm) OSB	1" (25mm) XPS	none
W3	SS. 21	1/2" (13 mm) gypsum	R-12 (RSI 2.1)	3 5/8" (92 mm)	20 gauge	16" (406 mm)	1 5/8" (41 mm)	1.03 mm	Not stated	5/8" (16 mm) OSB	2" (50mm) XPS	none





Benchmarking with the GHB results

Benchmarking results for W1

	COMSOL results		GHB Results			No Thermal Bridging		
T_o (°C)	RSI StS	R StS	RSI StS	R StS	**Difference**	RSI StS	R StS	**Increase**
-5	1.36	7.77	1.43	8.17	**5.13%**	2.82	16.02	**106%**
-20	1.37	7.73	1.42	8.30	**3.55%**	3.03	17.20	**122%**
-35	1.45	8.14				3.14	17.82	**119%**

Benchmarking results for W2

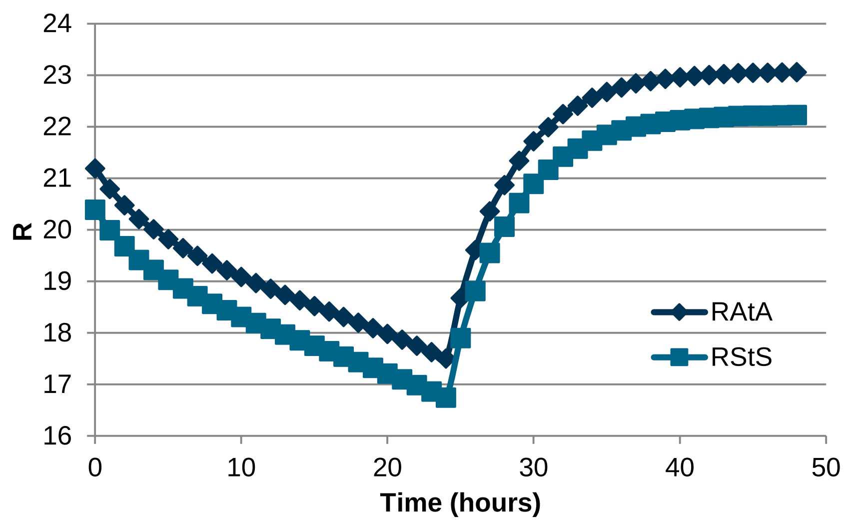
	COMSOL results		GHB Results			No Thermal Bridging		
T_o (°C)	RSI StS	R StS	RSI StS	R StS	**Difference**	RSI StS	R StS	**Increase**
-5	2.26	12.86	2.35	13.34	**3.66%**	3.59	20.40	**59%**
-20	2.39	13.60	2.40	13.63	**0.21%**	3.87	21.96	**61%**
-35	2.46	13.97	2.45	13.91	**0.39%**	3.98	22.59	**62%**

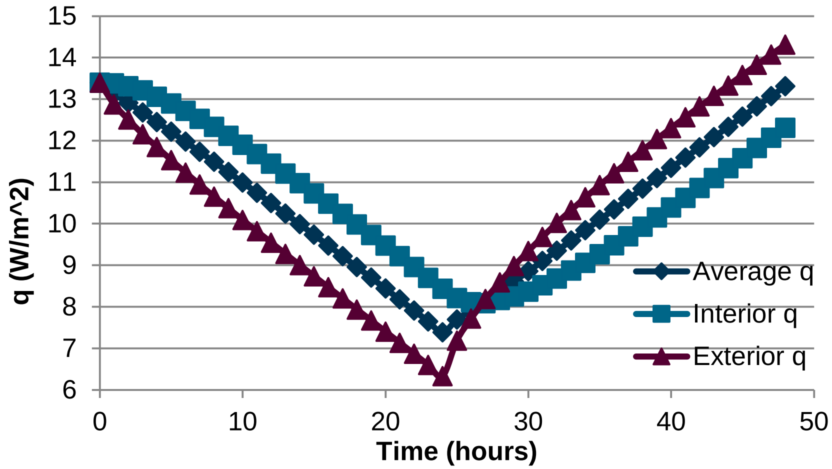
Benchmarking results for W3

	COMSOL results		GHB Results			No Thermal Bridging		
T_o (°C)	RSI StS	R StS	RSI StS	R StS	**Difference**	RSI StS	R StS	**Increase**
-5	3.27	18.57	3.15	17.89	**3.84%**	4.62	26.22	**41%**
-20	3.37	19.14	3.23	18.34	**4.37%**	4.89	27.77	**45%**
-35	3.43	19.48	3.23	18.34	**6.21%**	5.02	28.51	**46%**

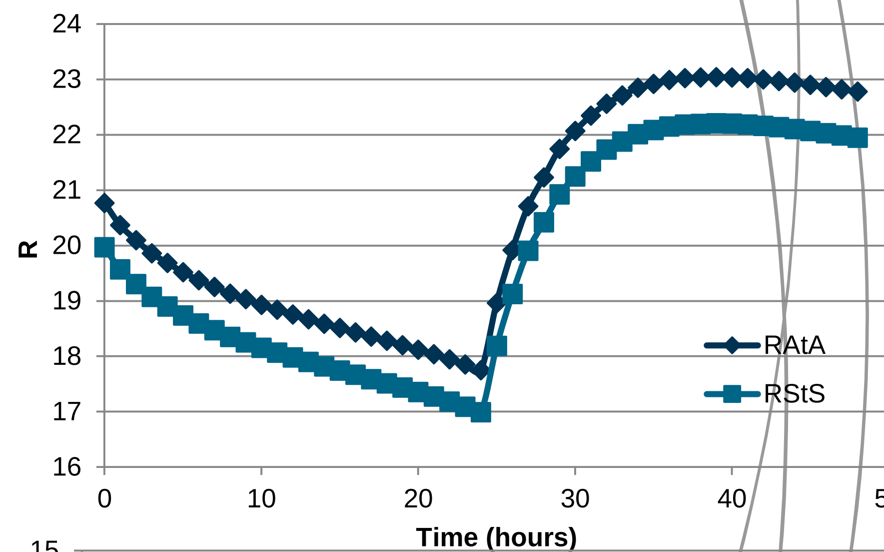
Transient Numerical Simulation: Wall 3 - Temperature cycle from -29 °C to -29 °C in 48hours

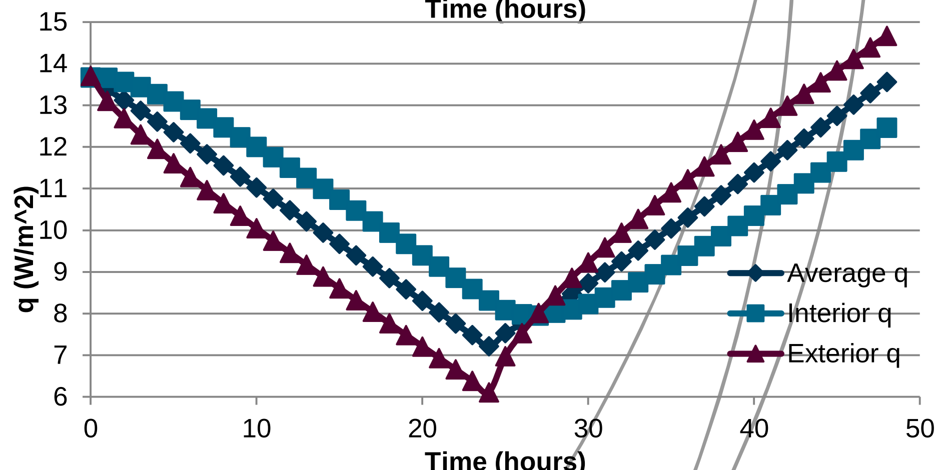
Using temperature dependent conductivities





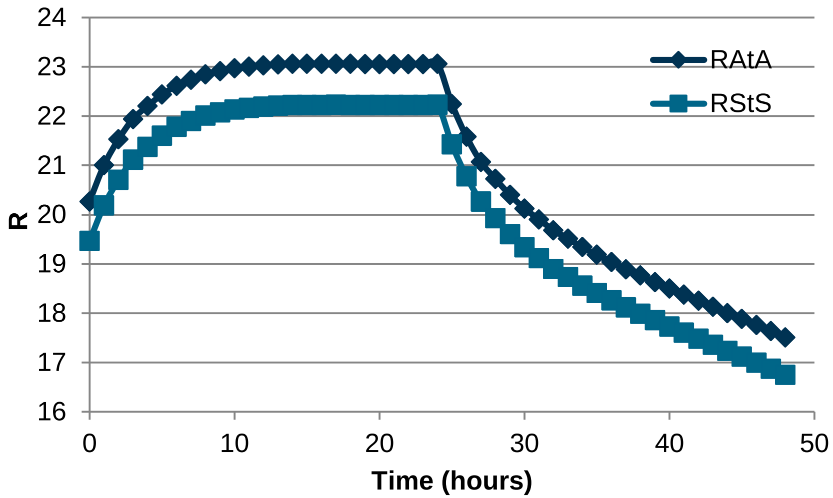
Constant conductivities



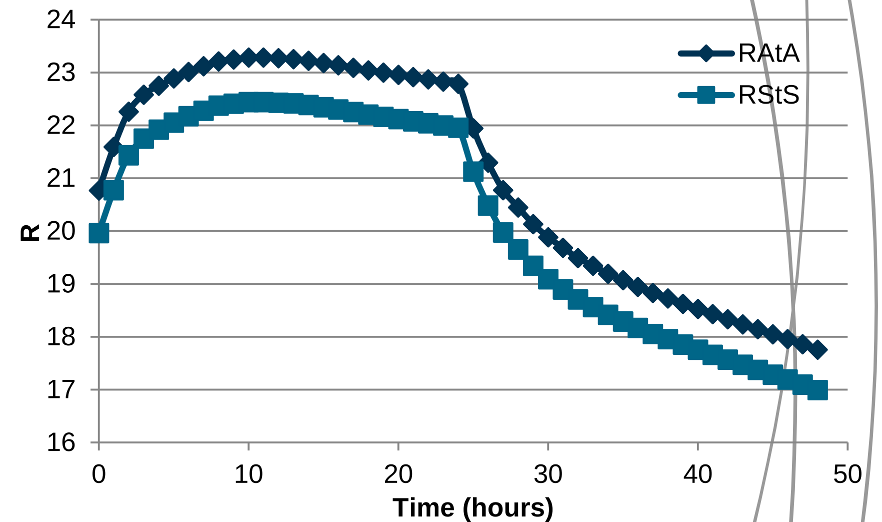


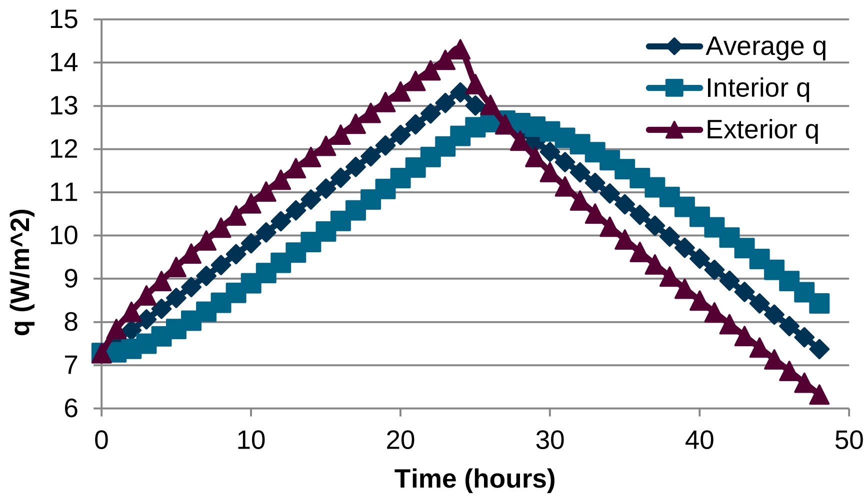
Transient Numerical Simulation: Wall 3 - Temperature cycle from -5 °C to -5 °C in 48hours

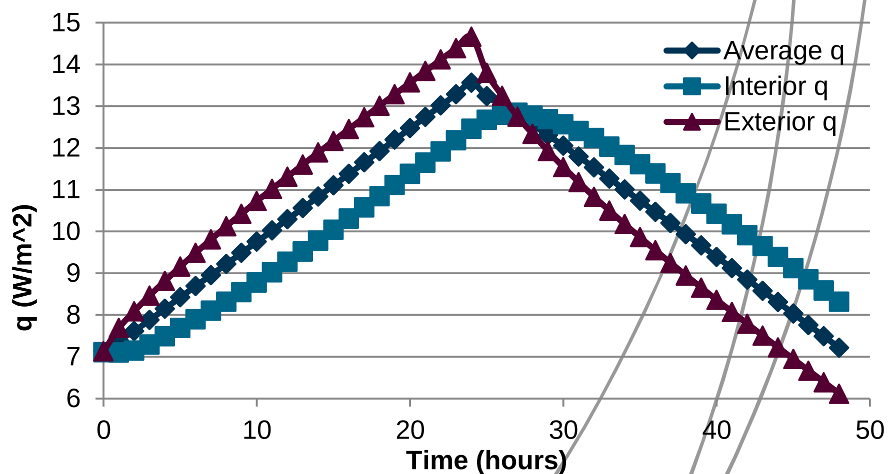
Using temperature dependent conductivities



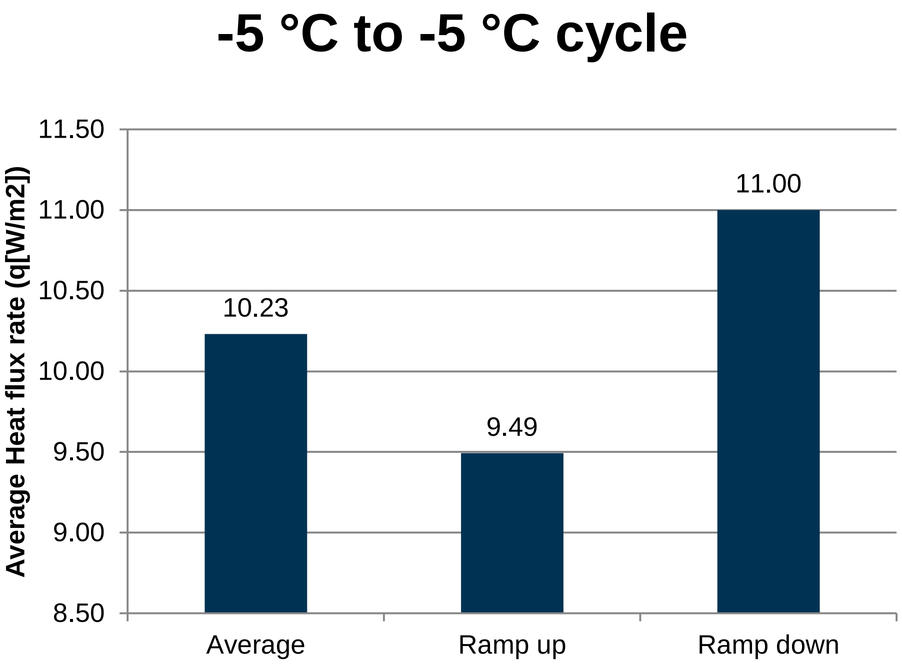
Constant conductivities

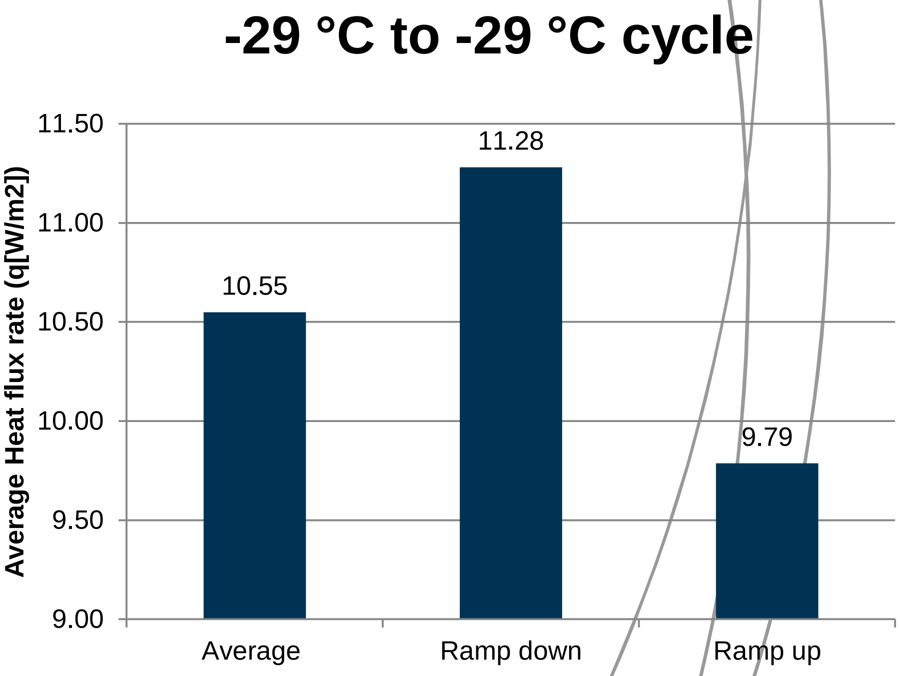






Energy Consumption Comparison





Conclusions

- **The thermal mass of the wall assemblies can affect the thermal resistance of wall assemblies under transient (dynamic) boundary condition.**
- **Extra energy on the interior is required to warm up the wall when the exterior temperature is increasing which leads to reduced thermal resistance.**
- **The thermal mass of wall can help to keep the interior warm when the exterior is getting colder which leads to increased thermal resistance values**
- **The energy consumption would be also affected through the increase or decrease of exterior temperature, however, the total amount of energy is similar in a full cycle.**
- **Additional considerations are required in characterizing the GHB in order to measure the transient (dynamic) behavior of wall assemblies.**

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THANK YOU

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