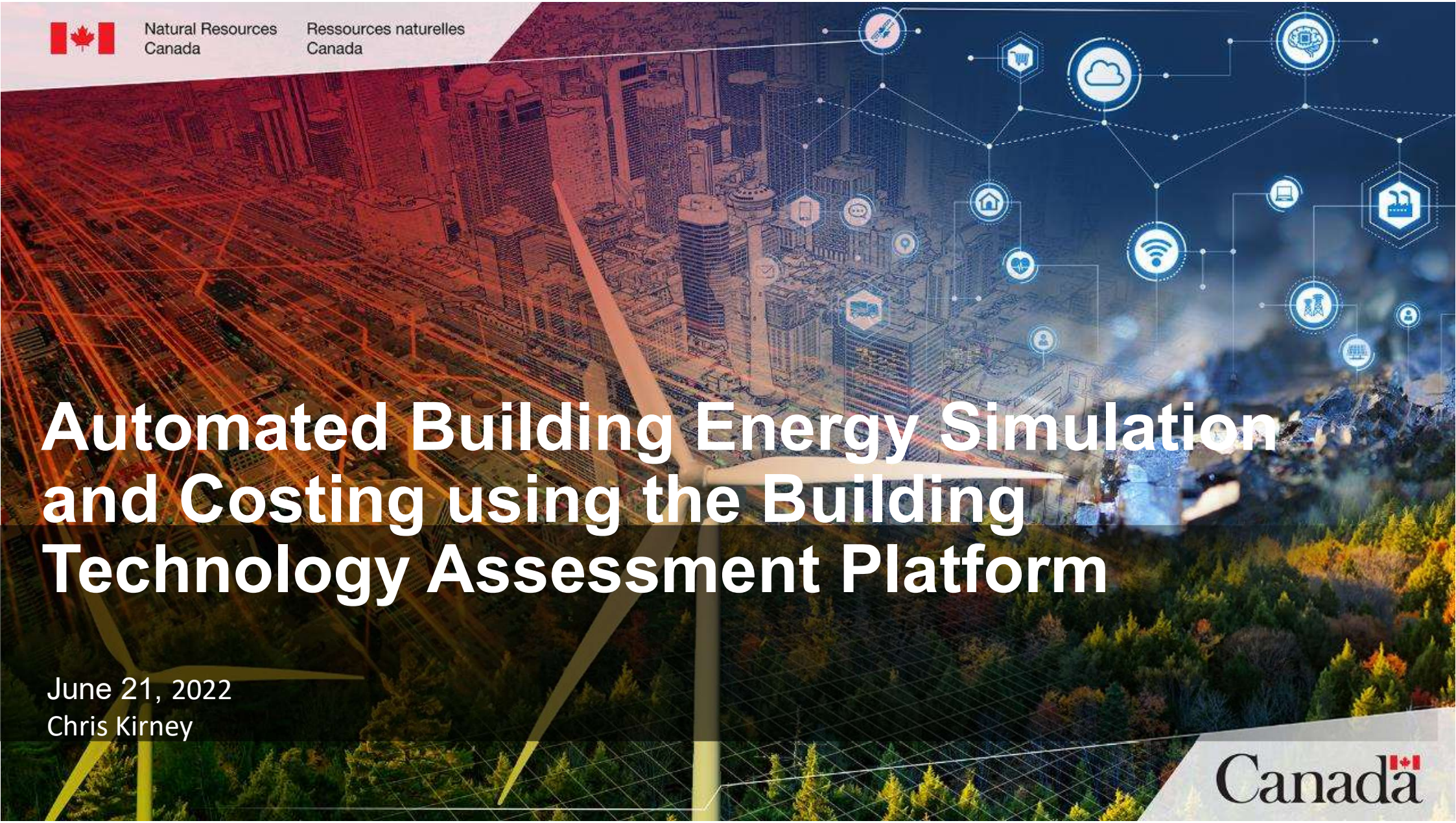

Natural Resources Canada
Ressources naturelles Canada
Automated Building Energy Simulation and Costing using the Building Technology Assessment Platform
June 21, 2022
Chris Kirney
Canada

Overview

Purpose

- Support development of building energy codes for new buildings
- Support policy and program decisions regarding energy efficiency in new buildings

How?

- Use the Building Technology Assessment Platform (BTAP) to model the energy performance and related capital costs of several building archetypes
- Apply the changes described by the policy or code to the building models to determine the impact on their energy consumption and related capital and operating costs

Assess impact of energy conservation measures on buildings built to:

- Existing Buildings (energy only)
- 2011 National Energy Code of Canada for Buildings (NECB2011)
- NECB 2015
- NECB 2017
- NECB 2020

What is BTAP?

A software tool that uses

OpenStudio + OpenStudio-Standards

To automatically create building energy models

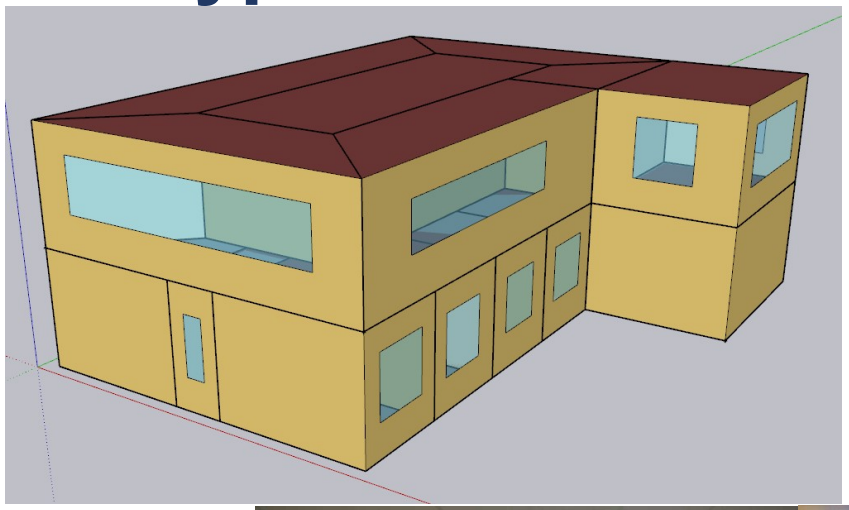
Simulated using

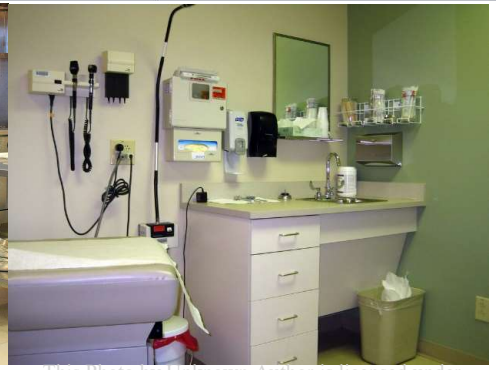
EnergyPlus

On a large scale via

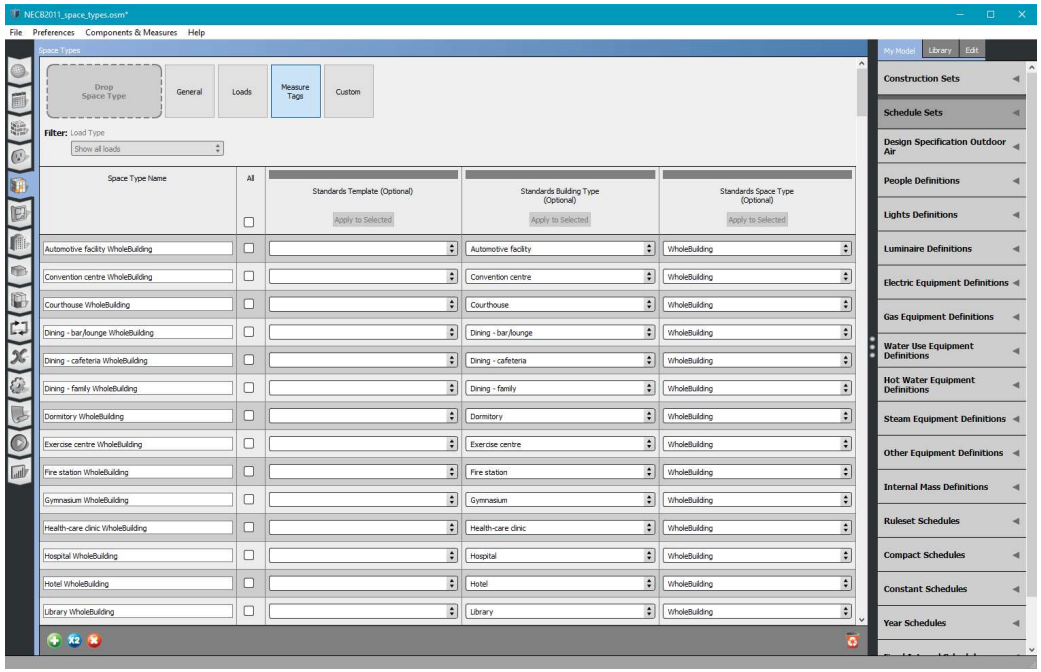
Parametric Analysis Tool + amazon web services

Start with a Model Containing Geometry, Spaces, and Space Types





Space Types

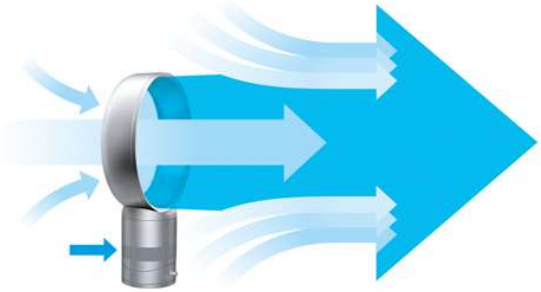


- Only require name of space type
- Can use NECB 2011, NECB 2015, NECB 2017 space type names
- Use NECB 2011 space type names if you will use your model for multiple NECB versions
- BTAP space type names can be found in the models housed here:

  https://github.com/canmet-energy/btap_batch/tree/main/resources/space_type_library

Based on the Space Type and NECB Version BTAP defines

Occupancy

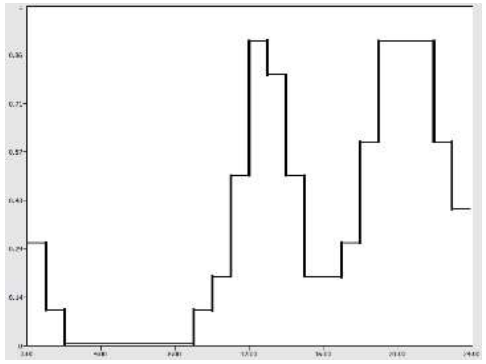


Ventilation Rates/Infiltration

Water Loads

Equipment/Lighting

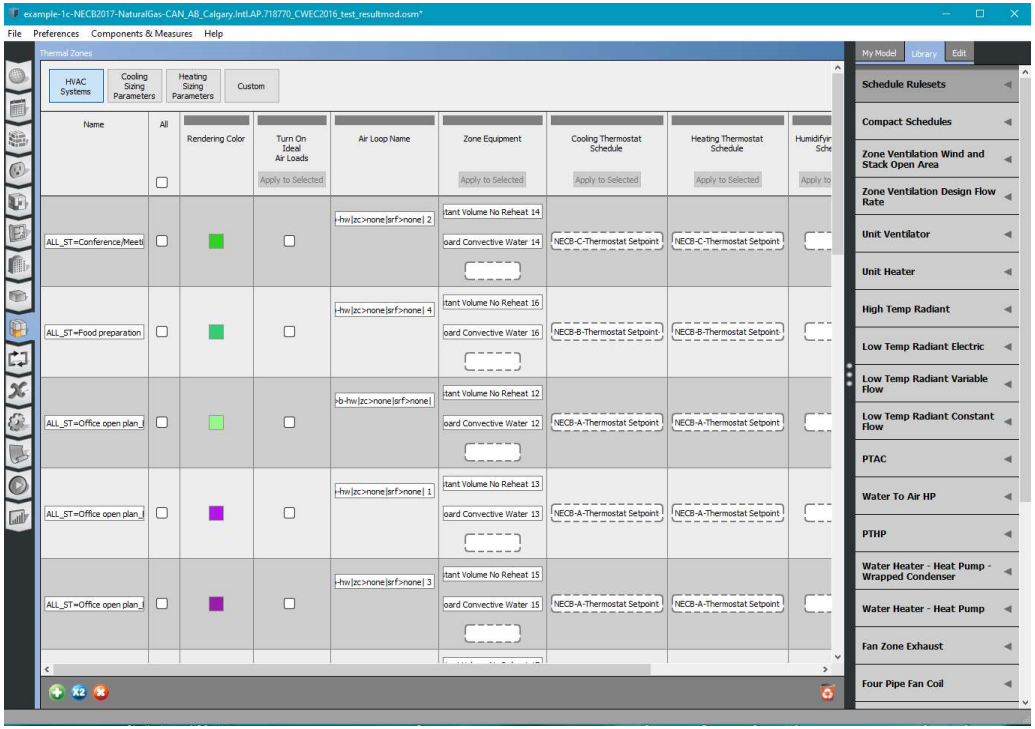
Constructions



Schedules

Auto Zoning

- BTAP looks at the NECB system type for each space (defined by the space type)
- Spaces with similar loads and system types are lumped together into one thermal zone
- Spaces with no defined system type (e.g. corridors) are combined into one thermal zone



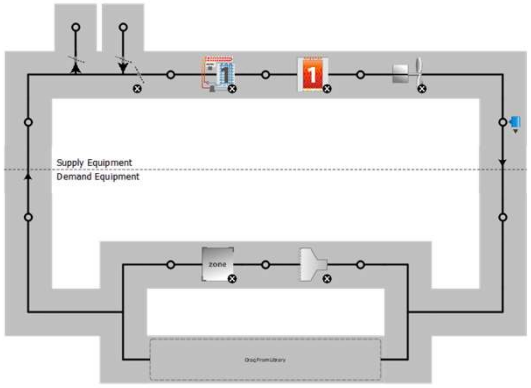
HVAC Definition

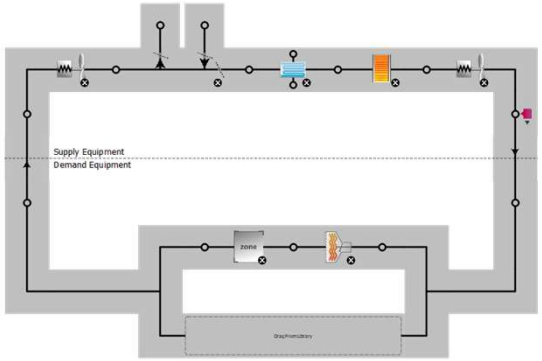
BTAP adds appropriate NECB HVAC systems and equipment based on the spaces and space types from the 7 systems below:

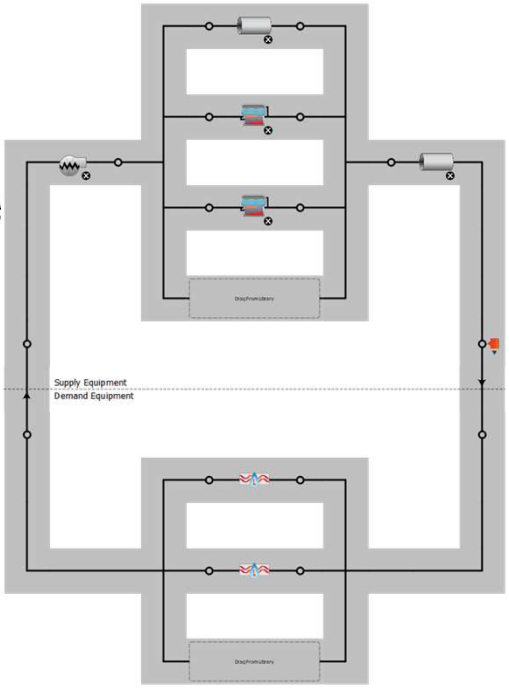
1. Unitary air-conditioner with baseboard heating
2. Four-pipe fan-coil (version 1) Single-zone packed rooftop unit with baseboard heating
3. Single-zone make-up air unit with baseboard heating
4. Two-pipe fan-coil
5. Multi-zone built-up system with baseboard heating
6. Four-pipe fan-coil (version 2)

BTAP sets the equipment efficiencies from the building:

- Equipment type
- Age/NECB version
- Loads
- Envelope
- Climate
- Heating fuel type



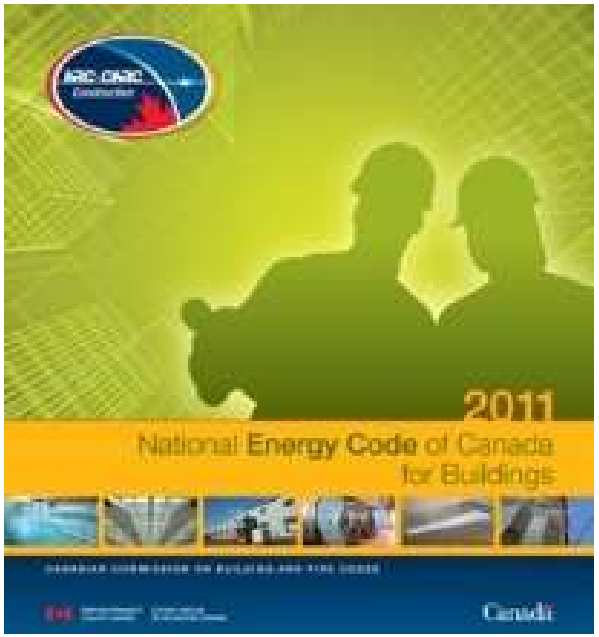




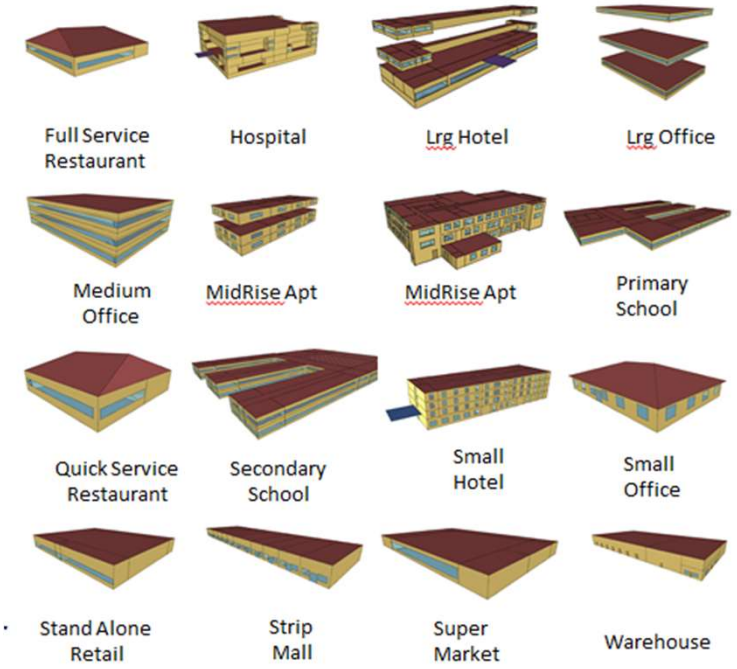
Existing Building Data Sources

Data Sources

- US Department of Energy (DOE) Commercial Reference Building Models of the National Building Stock
- 2011 National Energy Code of Canada for Buildings (NECB 2011)
- 1997 Canadian Model National Energy Code for Buildings (MNECB)
- Industry ventilation standard (ASHRAE 62-1999)
- Industry building energy performance standard (ASHRAE 90.1-1999)



Model Building Energy Performance Across Canada



What about Costing?

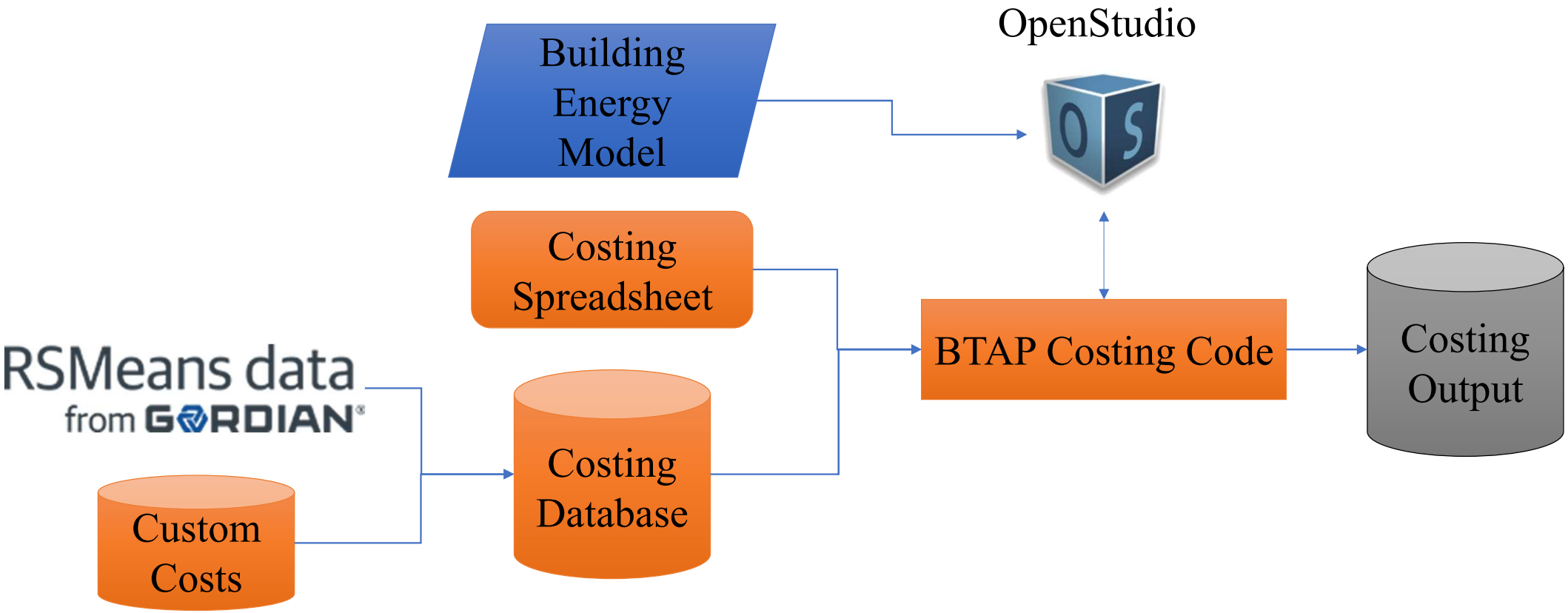
Goals:

- Estimate capital costs of building components related to energy performance
- Apply quickly and consistently across Canada
- Seamless change of costing when building is modified

BTAP Costing:

- Scripts that link model components to costing database via costing spreadsheet
- Building model describes the building
- Costing spreadsheet links model characteristics (space types, envelope or equipment characteristics, number of stories, location) to costed items
- Costing database created using RSMeans data and custom costs

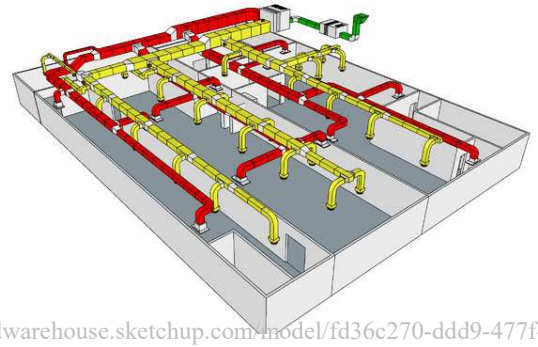
Costing Process:



Examples of costing expertise built into BTAP Costing

LIGHTING COSTS

Fixture types & costs vary by ceiling height, power densities, lighting levels



https://3dwarehouse.sketchup.com/model/fd36c270-ddd9-477f-85ad-3906e534e985/Ducting-System

DUCTING

Logic to determine mechanical room locations, duct run lengths and sizes

https://www.dreamstime.com/stock-photo-wood-framing-house-insulation-d-render-computer-generated-image-isolated-white-background-image74040490

ENVELOPE ASSEMBLIES

Space types mapped to typical envelope assemblies.
E.G. **Dwelling Unit**:
1-4 story building ➔Wood frame
5+ story building ➔Curtain Wall

BTAP Costing Advantages and Limitations

Advantages:

- Dynamic costing changes costs with changes to building loads
- Costing consistently applied with building type and location
- Using cloud computing can simulate the energy performance and related capital costs of thousands of buildings in a few hours

Limitations:

- New construction only
- Only energy performance related components costed
- Best used for comparative analyses (incremental costs)

Case Study: NECB Performance in Nova Scotia

This study examined the differences in **performance** and **cost** between the **NECB 2015** and the **NECB 2017 using BTAP**

Buildings:

- Small, medium and large office
- Mid-rise and high-rise apartments
- Retail stand-alone and retail strip mall

NECB 2017 Performance By Building

Averaged across 3 cities	Energy Savings (MJ/m2/yr)	Energy Cost Savings ($/m2/yr)	Energy Savings (%)	Incremental Capital Costs ($/m2)	Payback (years)
Small Office	**66.4**	**1.3**	**12.1**	**-2.0**	**-2.0**
Medium Office	**45.5**	**1.3**	**8.2**	**-5.1**	**-4.5**
Large Office	**27.3**	**0.8**	**6.5**	**-8.2**	**-10.3**
Retail Standalone	**161.3**	**3.6**	**22.0**	**-43.5**	**-12.1**
Retail Stripmall	**203.4**	**4.1**	**24.2**	**-35.6**	**-8.8**
Midrise Apartment	**21.0**	**0.5**	**2.9**	**9.5**	**19.2**
Highrise Apartment	**9.6**	**0.2**	**1.3**	**8.1**	**45.7**

Negative paybacks due to:

- Fenestration and door to wall ratio
- Reduced capacity of heating, ventilation and air conditioning

Longer paybacks are due to:

- Energy recovery ventilators
- Ducting

Breakdown of Incremental Capital Costing

- Averaged over 3 cities
- Higher Roof / Floor area means higher costs

- Lighting mitigated a majority of the capital costs

- Heating/Cooling capacities were reduced, costing less

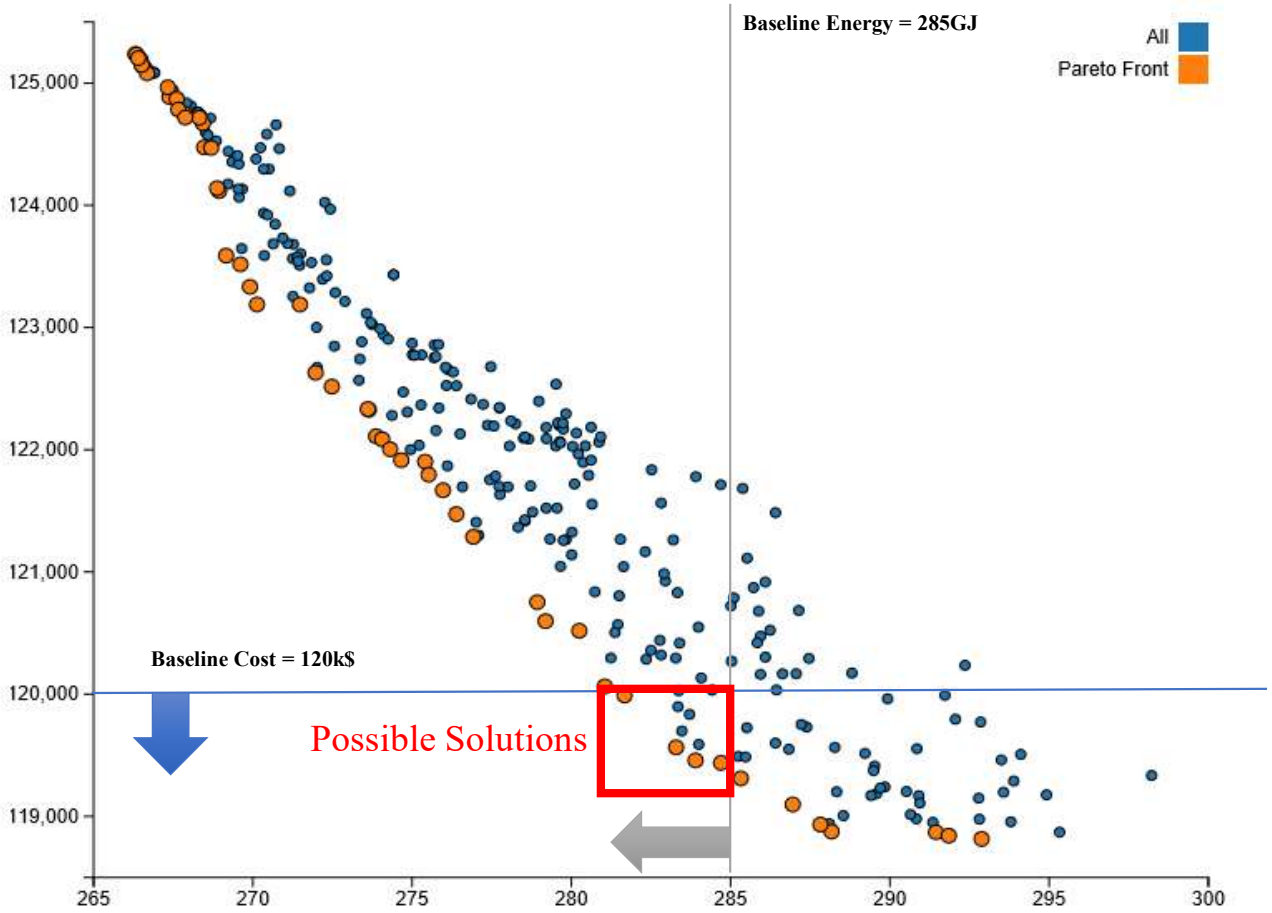
- Lower loads meant smaller air handling unit requirements. Exception was apartment units now required energy recovery ventilators.

Average Cost Change NECB2015-17 ($/m2)	Envelope	Lighting	Heating & Cooling	Service Hot Water	Ventilation	Total
SmallOffice	5.76	-5.63	-0.35	0.00	-1.79	-2.01
MediumOffice	1.97	-5.63	-0.44	0.00	-1.02	-5.12
LargeOffice	0.83	-5.81	-0.09	0.00	-3.12	-8.19
RetailStandalone	5.66	-29.41	-0.70	0.00	-19.08	-43.54
RetailStripmall	5.67	-37.90	-1.56	0.00	-1.80	-35.60
MidriseApartment	1.92	-0.23	-4.18	0.00	11.95	9.47
HighriseApartment	1.54	-0.09	-1.47	0.00	8.08	8.06

What else can it do?

OpenStudio Cloud Management Console

Analysis Results — Envelope Optimization



Update Chart

Select x and y variables to update the chart

X btap_results.total_end_uses_gj

Y btap_results.total_envelope_cost

Update Chart

Pareto Front

Save this pareto front for later use

X btap_results.total_end_uses_gj

Y btap_results.total_envelope_cost

Name

Save Pareto Front

Conclusions and Next Steps

Conclusions:

- Procedurally create models of new building
- Many locations across Canada
- Estimate capital and energy costs of energy conservation measures
- Inform policy makers on cost and benefit of changes to building energy related codes or policies for new buildings

Next Steps:

- Include more energy conservation measures
- New building codes
- Costing for energy code addressing retrofit of existing buildings

Acknowledgments & Questions

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Chris.Kirney@NRCan-RNCan.gc.ca

General questions
Meli.Stylianou@NRCan-RNCan.gc.ca

Appendix A: BTAP Code

BTAP and OpenStudio-Standards:

- Code to generate buildings models stored here:

https://github.com/NREL/openstudio-standards.git

- Latest BTAP code held in ‘nrcan’ branch
- BTAP uses many parts of OpenStudio-Standards, but BTAP specific code held here:

https://github.com/NREL/openstudio-standards/tree/nrcan/lib/openstudio-standards/standards/necb

- Base class for BTAP is NECB2011, all other templates are child classes of NECB2011 (some BTAP classes are child class of NECB2011 child classes)
- NECB2011 code held here (code is contained in .rb files):

https://github.com/NREL/openstudio-standards/tree/nrcan/lib/openstudio-standards/standards/necb/NECB2011

- Information used to generate NECB2011 buildings (e.g. space type information, equipment performance information, part load curves, etc.) are kept in the ‘data’ folder here (generally as .json files):

https://github.com/NREL/openstudio-standards/tree/nrcan/lib/openstudio-standards/standards/necb/NECB2011/data

- Initial building geometries for standard BTAP building types are held in the ‘geometry’ folder
- Child classes of NECB2011 are held in their own folders
- The NECB2015 folder is here:

https://github.com/NREL/openstudio-standards/tree/nrcan/lib/openstudio-standards/standards/necb/NECB2015

- Any code or data specific to the child class are held in these folders
- NECB2015 specific space type, schedule, HVAC efficiency, etc. information held in its own data folder here:

https://github.com/NREL/openstudio-standards/tree/nrcan/lib/openstudio-standards/standards/necb/NECB2015/data

- Parent class code or information is used for anything not present in the child class folders

Appendix B: BTAP Tests

- Many regression and unit tests existing to check for bugs in the BTAP code
- These test are held here:

https://github.com/NREL/openstudio-standards/tree/nrcan/test/necb

- Some of these tests can be useful for exploring how the code works and creating models using your own building types without using btap_batch
- Especially useful are the regression tests which are held here:

https://github.com/NREL/openstudio-standards/tree/nrcan/test/necb/building_regression_tests/tests

- These tests create a building according to the building type, template, and the primary heating fuel listed in the name (Calgary is used as the default location)
- For example test_necb_bldg._FullServiceRestaurant_NECB2017_NaturalGas will use BTAP to create an NECB 2017 reference model of the full service restaurant heated using natural gas in Calgary
- You can modify these tests to create different models by opening any of them and then adjusting the code on line 11 as per this link:

https://github.com/NREL/openstudio-standards/blob/8a6a4017c942fd0ae061bbcaacb77de3d1a28632/test/necb/building_regression_tests/tests/test_necb_bldg_FullServiceRestaurant_NECB2017_NaturalGas.rb#L11

- The 'create_model_and_regression_test' ultimately uses the NECB2011 class 'model_create_prototype_model' method to generate building models
- Change the 'building_type', 'primary_heating_fuel', 'epw_file', and 'template' parameters to change the type of building, primary heating fuel, weather location, and NECB version that the test uses to create a building model
- If you want to try your own geometry then put your basic OpenStudio geometry file (with spaces, space types, dummy thermal zones, and number of stories defined) in the NECB2011 geometry folder here:

https://github.com/NREL/openstudio-standards/tree/nrcan/lib/openstudio-standards/standards/necb/NECB2011/data/geometry

- Then change the 'building_type' parameter in one of the regression tests to match the name of your .osm file (without the '.osm' extension)
- The results of the test (complete OpenStudio models) are found here:

https://github.com/NREL/openstudio-standards/tree/nrcan/test/necb/building_regression_tests/expected_results

- Your test will be named following this pattern: <building type>-<template>-<primary heating fuel>-<weather file name without '.epw'>_test_result.osm
- You can take this .osm file, open it in OpenStudio, set the weather information, and then run it to check that it works