Development and Application of Building Archetypes for Community Energy Analysis and Planning

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Outline

Introduction:

- ➢ *Issues with building energy data and opportunity to utilize archetype modelling*

Case study application:

- ➢ *SMORES Project*

Case study application:

- ➢ *DND Energy Master Plan Project*

NRCan CanmetENERGY Smart Archetypes:

- ➢ *How can model data be applied for district energy analysis & planning purposes?*

Next steps / Future work

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In an ideal world:

Property Tax Assessment Data

Building Energy Consumption Data

+

=

Quick, Easy, & Accurate Map-Based Community Energy Assessment and DH Analysis…

Municipal GIS Map

BUT:

Generally cannot obtain detailed building scale energy information for community energy planning or research initiatives

→

- **Customer Confidentiality & Privacy**
- **Misalignment of accounts with building structure information**
- **Commercial Rate Codes generally Independent of Building Type**

Sample Property Assessment Reports from MPAC, http://propertyline.ca/pages_english/products_services/product_catalogue.html
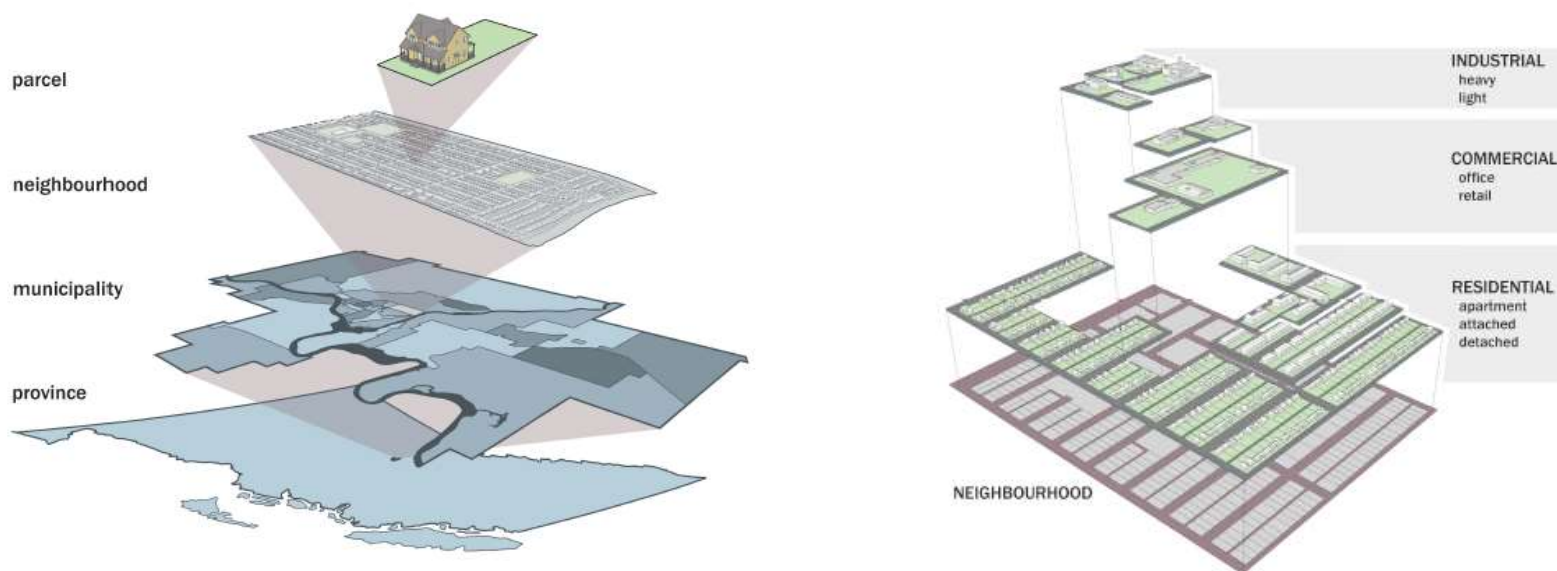
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Tract and Neighbourhood Data Modelling (TaNDM)

- Pilot project in BC aimed to improve availability of data required for Community Energy and Emissions Inventory (CEEI) reporting

- Established and tested process for aligning available property tax assessment data with utility data to enable reporting of building energy and emissions data at the neighbourhood level

Graphics Source:
TaNDM Milstone 2 Project Report: Methods to Create Neighbourhood and Building Category Energy Use Summaries, Vive le Monde Mapping, June 2012.
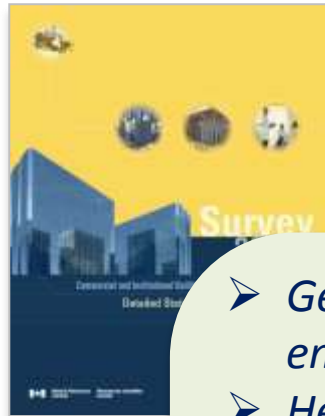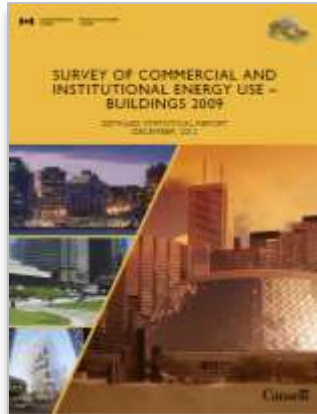
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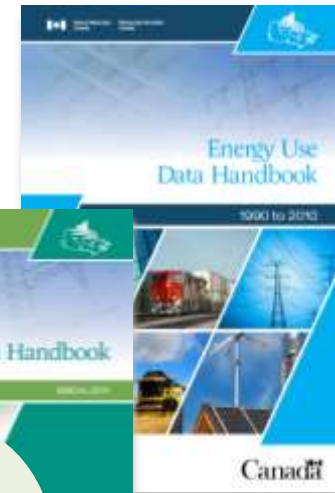Natural Resources Canada   Ressources naturelles Canada

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Energy Benchmarking Data Sources

StatCan / NRCan Survey Data:

NRCan Comprehensive Energy Use Databases

Other Sources: BOMA, REALpac, etc:

NRCan / US DOE Benchmarking Data

ENERGY STAR® PortfolioManager®

> ➢ *Generally report TOTAL energy use intensity*
> ➢ *Heating/Cooling/Elec EUI not always directly provided*
> ➢ *Building types not always consistent in datasets*
> ➢ *Values represent fuel energy not thermal energy*
> ➢ *Unable to provide temporal profile or peak estimation*

Can be difficult to apply to community/neighbourhood district energy network analysis

More Data Coming?
Ontario Bill 135, Energy Statute Law Amendment Act
→ Move toward mandatory energy data reporting and disclosure requirements

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What is a Building Archetype Model?

"Building energy modeling (BEM)—physics-based calculation of building energy consumption—is a multi-use tool for building energy efficiency. Established use cases include design of new buildings and deep retrofits, development of whole-building energy efficiency codes and standards and performance-path compliance with those codes..." – **US Office of Energy Efficiency and Renewable Energy (EERE**)

From a district energy analysis and community energy planning perspective:

Given that:

1. Building level thermal energy data is ideally needed to complete neighbourhood DH analysis.
2. Building level utility data is generally not available

How can available building archetype model data be better utilized to improve community DE assessment and planning?

Key Objective:
Improve ability to complete neighbourhood scale thermal energy analyses and assessment of DE opportunities while minimizing the number of data sources involved and the amount of raw data required

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Building Archetype Application: SMORES Project

System-wide Methodology for Optimizing Renewable Energy Solutions (SMORES)
***Project Goal*:**
To develop a methodology and tools to assess community energy usage & evaluate supply options and implementation considerations in an effort to reduce GHG emissions and increase renewable energy opportunities

Original Plan:
Work with utility partners and City officials to anonymously align property assessment data with building energy data to produce aggregated neighbourhood energy profiles in support of energy supply options analysis

Modified Plan B:
Generate building level electric and thermal energy estimates using property assessment data and a combination of published consumption data and building archetype model data

Pop: ~34,000
Buildings: ~9,000
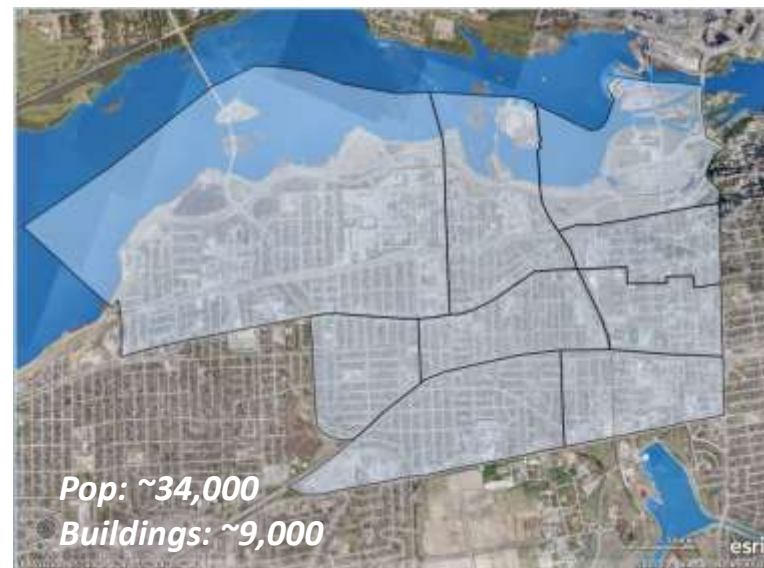
SMORES Ottawa study area

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Building Archetype Application: SMORES Project

- Use of MPAC property assessment information (property code, age, area, etc), link property code to best archetype category

- Use of available EUI data and archetype model data - HOT2000 (Housing), EE4 (Commercial Buildings) - to estimate building level consumption and demand

SMORES Archetype Categories
Small Single Residential
Large Single Residential
Multi-Unit Residential
Small Office
Large Office
Restaurant and Food Service
Small Retail
Large Retail
Miscellaneous Commercial
Mixed Use
Recreation and Places of Assembly
Health Care Facility
School, Institutional, and Public Service
Industrial
Other

Published energy data

Archetype model data for demand profiles

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There Will Always Be Issues and Errors…

Property tax assessment dataset included 200+ property types, our approach linked those 200+ property types down to ~15 Building archetypes for analysis.

The majority of properties in the SMORES analysis were representative of the defined property type and actual usage, but inconsistencies with the tax assessment data were found, for example:

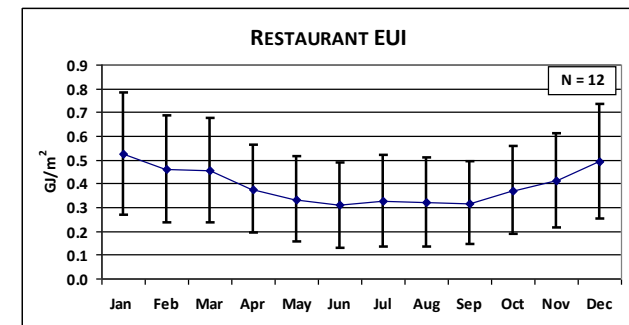*This sample property is designated with a Retail property code, but is operated as a restaurant.*

Calculations assumed this energy profile based on designated property code:
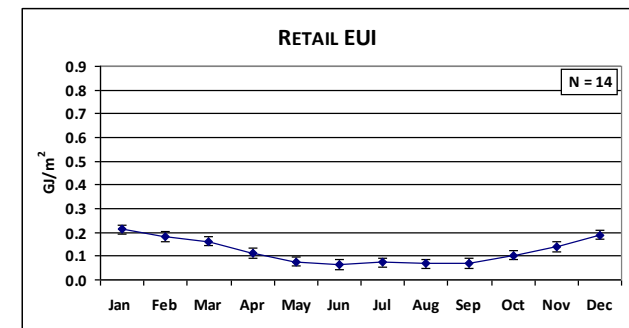
In reality, should have been this:

At a micro level, this type of issue will negatively influence an energy analysis based upon archetype data, but should not significantly impact neighbourhood level analysis

SMORES Project DH Analysis

Required End-User Tariff vs. Linear Heat Density

Required End-User Tariff vs. Building Density

- Modelled building archetype data was successfully used to conduct DH network assessment for seven building cluster cases against cost and efficiency
- Able to compare network cost and performance vs. building /energy density using representative spatial distribution of building types and energy loads

Additional case study analysis being undertaken by SSG as part of the IEA Annex XI Plan4DE project
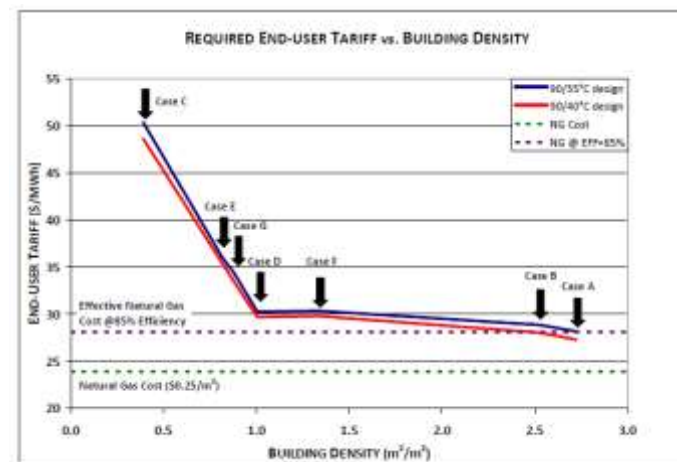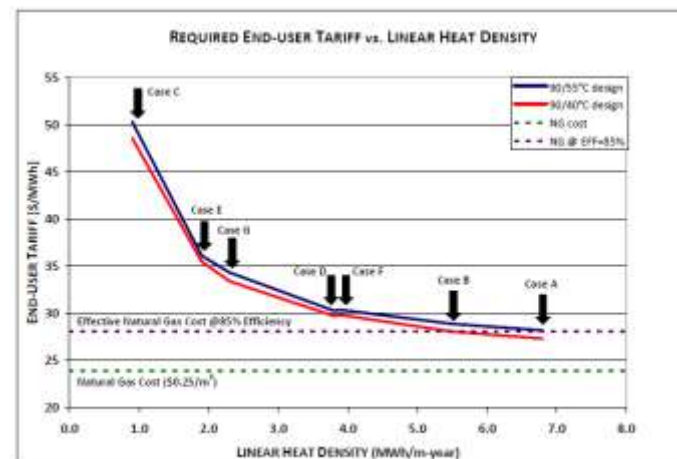
Reference Article:
Dalla Rosa, A., Boulter, R., Church, K., Svendsen, S. *District heating network design and operation toward a system-wide methodology for optimizing renewable energy solutions (SMORES) in Canada: A case study*, Energy 2012 45:960-974

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Building Archetype Application: DND Energy Master Plan

Project:
- *Assess building energy usage, investigate savings opportunities, and develop long term energy supply scenarios for two Canadian military bases*
- *Develop cost effective pathways towards reduced energy usage and GHGs and improve overall sustainability*
- *Each base had ~400 buildings with limited energy metering*

Approach:
- *Development of detailed archetype models (EnergyPlus/OpenStudio) representative of construction and operation of typical buildings on the bases to determine baseline building type usage profiles and investigate potential savings from energy conservation measures (ECMs)*
- *Use archetype data to establish base-wide energy demand and to develop potential district heating supply scenarios for assessment of supply and demand changes over the next 20 years*

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Sample DND Energy Master Plan Archetypes

MAINTENANCE SHOP

HANGAR

BARRACKS

SMALL WORKSHOP
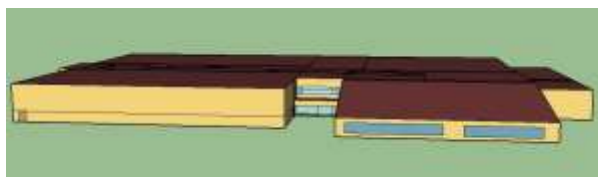
RECREATION COMPLEX

SMALL OFFICE
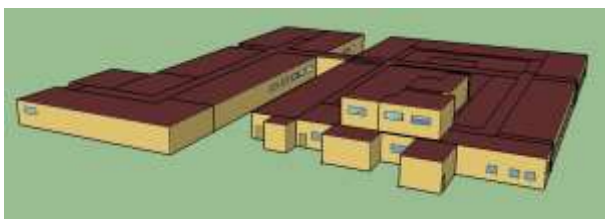
TRAINING

VEHICLE GARAGE

FIRE STATION

FOOD SERVICE
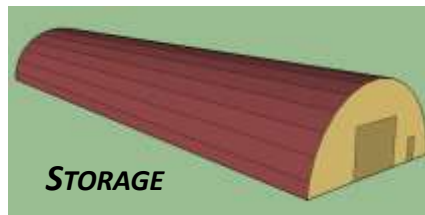
STORAGE

OFFICE

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Military Base District Heating Analysis

GIS Map

Site Plan

Building List

Modelled Archetype Energy Data

DH NETWORK ANALYSIS

➢ *Piping Design Layout*
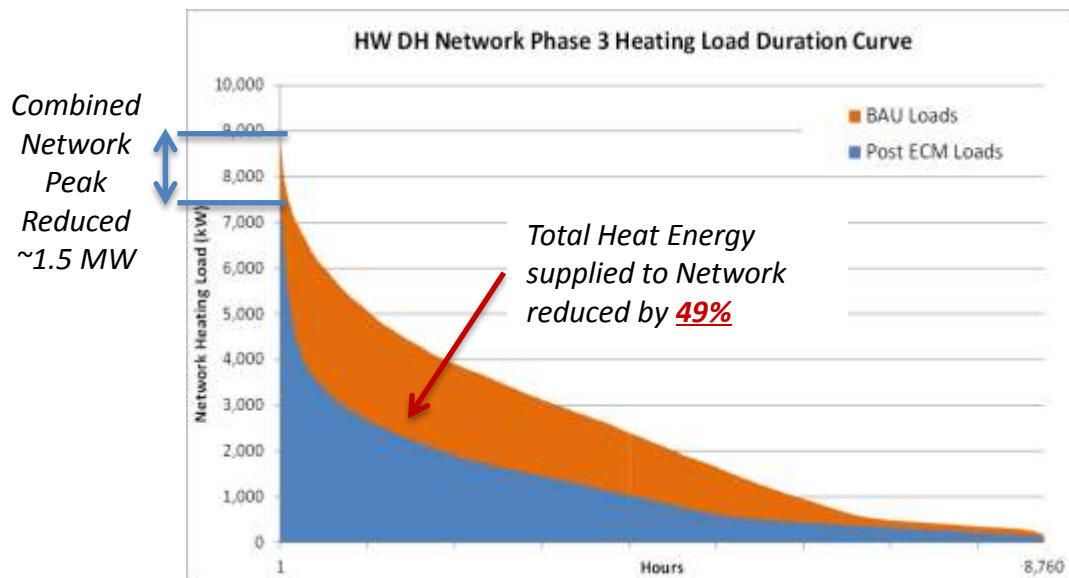➢ *Network Heat Loss*
➢ *Network Cost*

PLANT ANALYSIS

HW CHP Phase 2 (2020) BAU Heating Load

HW CHP Phase 2: Sample Plant Operation
Biomass Plant with Summer Shutdown
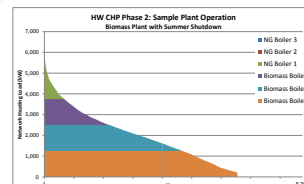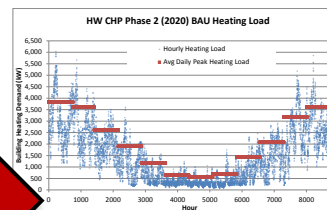
➢ *Plant technologies*
➢ *Operation & Fuel Use*
➢ *O&M*
➢ *Cost*

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Military Base Scenario Analysis & Energy Planning

Archetype models used to generate updated energy profiles factoring chosen set of Energy Conservation Measures (ECMs)

Enabled development of supply scenarios to assess impact of ECMs on DH network design, phasing of building connections, and design & operation of heating plant
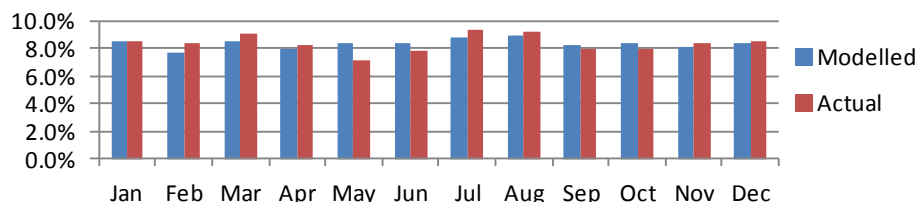

HW DH Network Phase 3 Heating Load Duration Curve

Combined Network Peak Reduced ~1.5 MW

Total Heat Energy supplied to Network reduced by 49%

Annual Total Energy

Annual GHG Emissions

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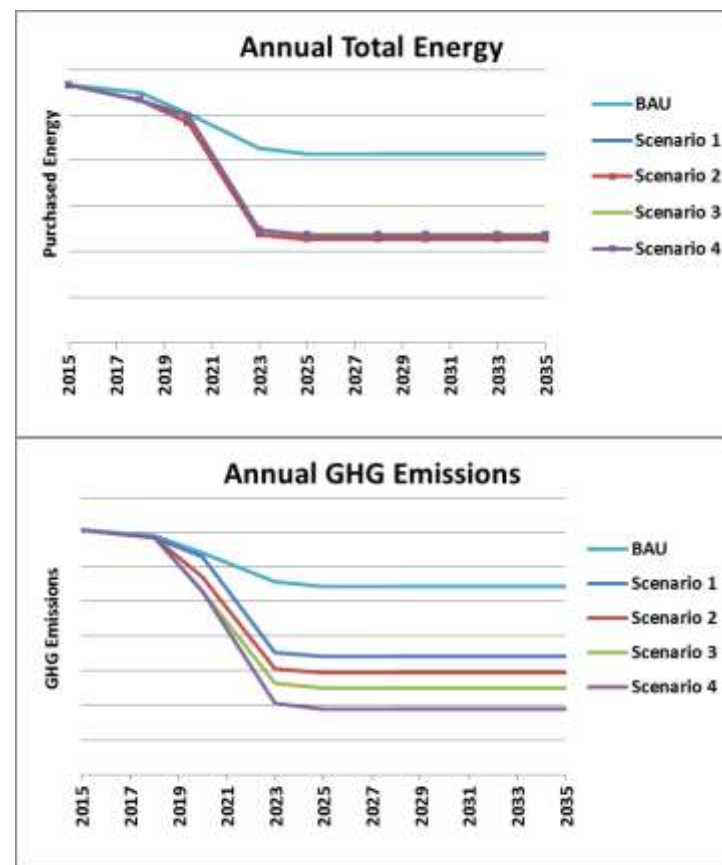
Reconciliation of Whole Base Modelled Results with Actual

Annual Building Natural Gas Usage
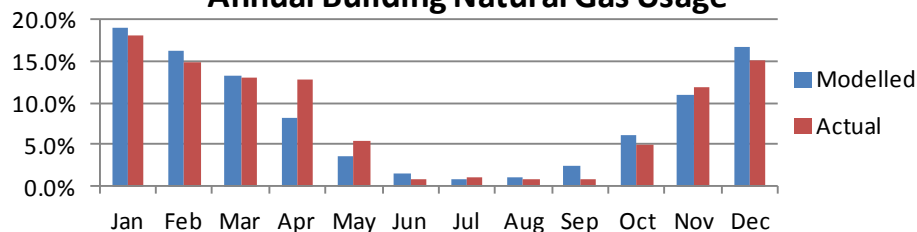
Annual Building Electricity Usage

Whole Base Electric Load Duration Curve
(No Weather or Building Area Corrections)

Buildings As Modelled
2012 Whole Base

Actual 2012 values include loads not included in modelled results eg. Exterior Lighting
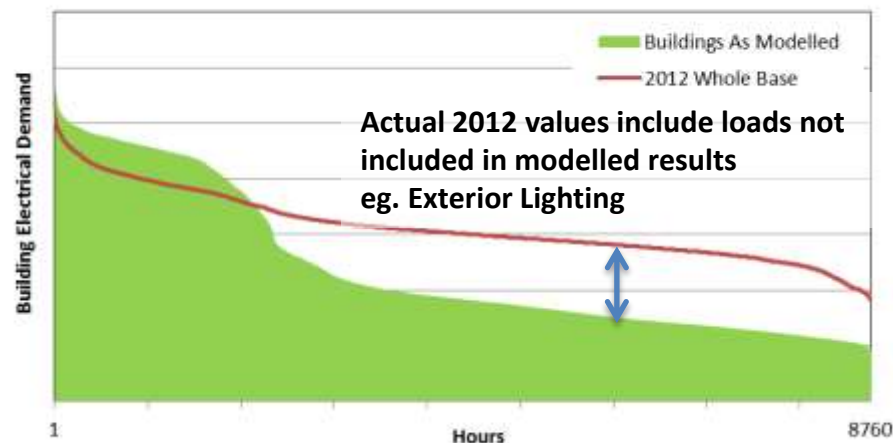
Weather & Area Corrected Consumption Comparison	Natural Gas	Electricity
Modelled / Expected	109%	72%

Good! **Pretty Good!**

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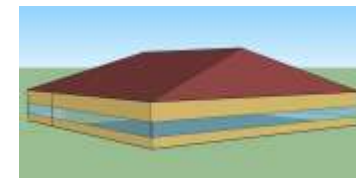
NRCan Smart Archetypes:

- *Detailed standard building models developed using OpenStudio / EnergyPlus for the CanmetENERGY Building Technology Assessment Platform (BTAP) project*
- *Current models based on NECB 2011 construction and operation*
- *Can be run against 80+ Canadian CWEC weather locations*
- *Models structured to allow for R&D on building design optimization and to assess potential design impact on capital and operation cost, energy, GHG, IEQ, etc.*
- *Additional benefit of the models is the ability to generate large amounts of useful data that could be applied elsewhere – such as for district energy analysis*

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NRCan CanmetENERGY Smart Archetypes

FULL SERVICE RESTAURANT

MEDIUM OFFICE

QUICK SERVICE RESTAURANT
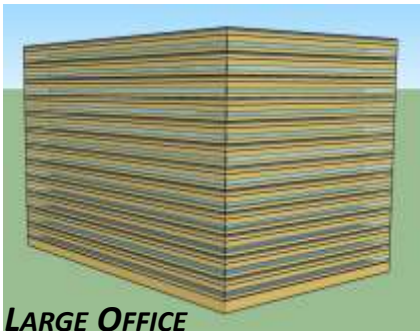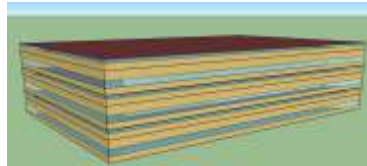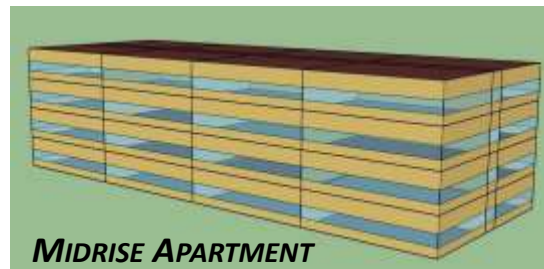
MIDRISE APARTMENT

LARGE OFFICE

SMALL OFFICE
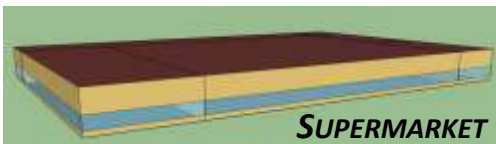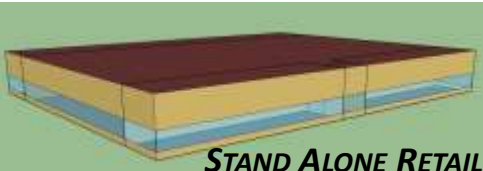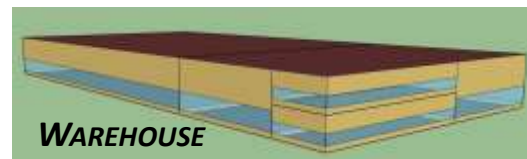
SUPERMARKET
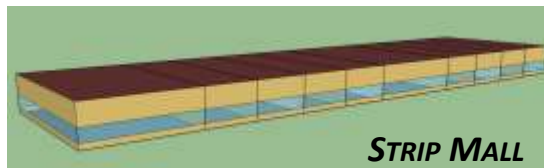
STRIP MALL
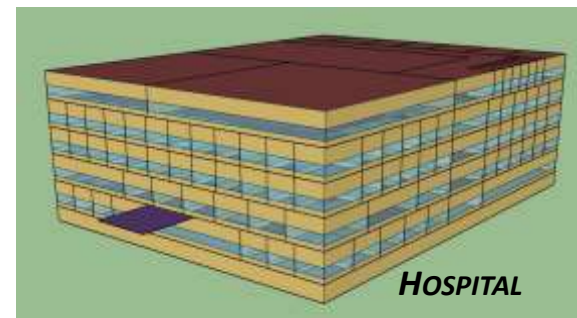
HOSPITAL

STAND ALONE RETAIL

WAREHOUSE
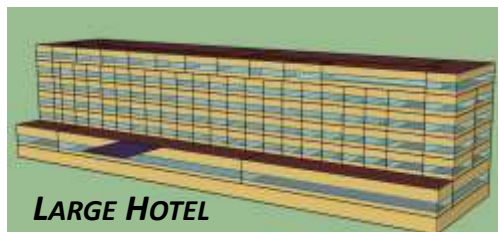
OUTPATIENT CARE
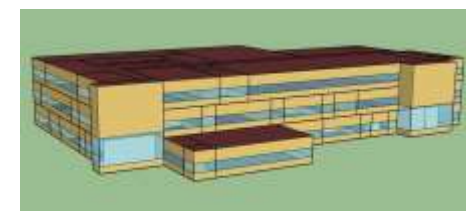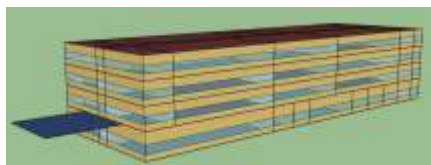
LARGE HOTEL
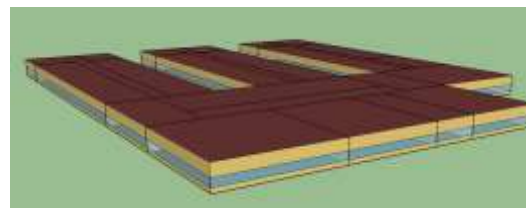
PRIMARY SCHOOL
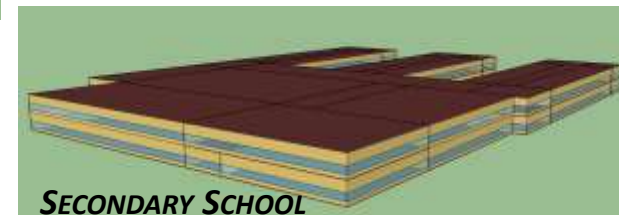
SMALL HOTEL

ALSO:
APARTMENT TOWER
LONG TERM CARE FACILITY

SECONDARY SCHOOL

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Cost of upgrading home from OBC Requirements, **no PV**
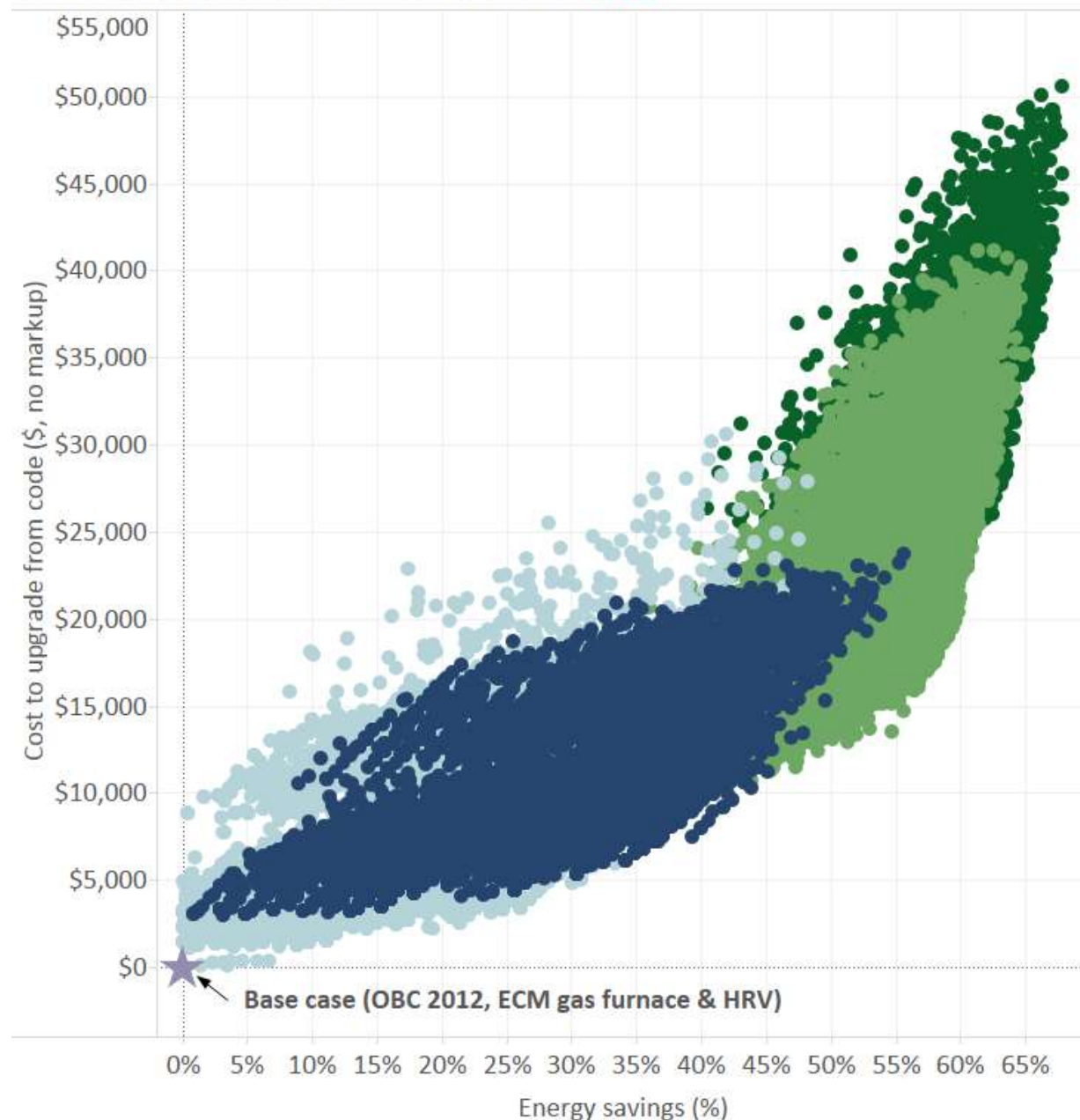
Heating
- Gas Combo (ECM) + Zoning
- Gas Furnace (ECM)
- CCASHP
- GSHP

Base case (OBC 2012, ECM gas furnace & HRV)

Housing Technology Assessment Platform (HTAP) Example:

Each dot is a complete home design. For each dot, we can examine the envelope, mechanical and renewable energy specifications that make up the price and performance trade-off.

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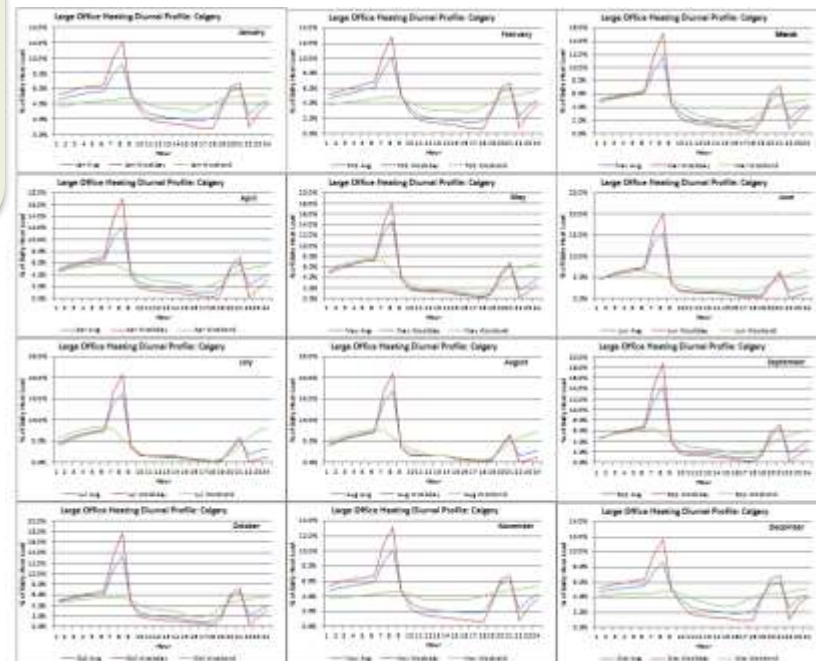
Canadá

Applying Archetype Data For Thermal Load Analysis

From the building archetype models, can output:
- *Detailed breakdown of end-use consumption*
- *Building energy vs. fuel energy*
- *Peaks and hourly (or finer) profiles*

Archetype Monthly Heating Profiles:

Archetype Energy Distribution and Load Factors:

Archetype: Large Office Calgary	Total Heating Energy (%)	Monthly Heating Load Factor (kW$_{avg}$/kW$_{peak}$)
Jan	13.9%	0.29
Feb	10.7%	0.29
Mar	10.4%	0.23
Apr	7.2%	0.23
May	5.6%	0.18
Jun	4.4%	0.17
Jul	3.9%	0.15
Aug	4.3%	0.16
Sep	5.8%	0.18
Oct	7.5%	0.22
Nov	11.7%	0.19
Dec	14.6%	0.27

Apply archetype data to estimated or actual building or building cluster information to estimate peaks & profiles for community energy analysis and energy system planning

NOTE:
Shown energy values and profiles are preliminary draft outputs provided for illustrative purposes only
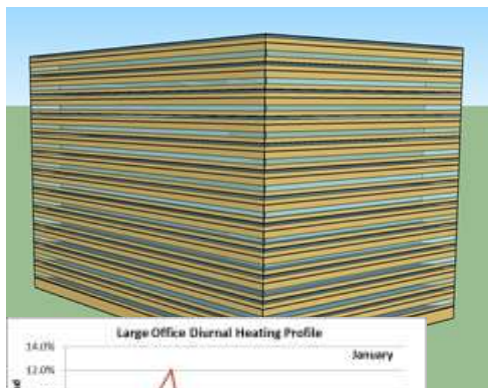
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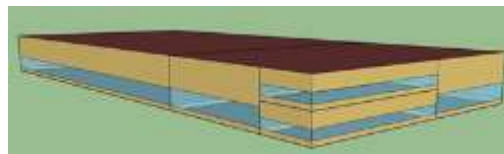Natural Resources Canada / Ressources naturelles Canada

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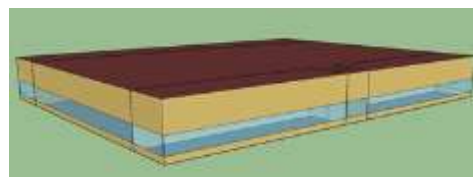# Archetype Data for Community Energy Analysis

Sample Building Cluster

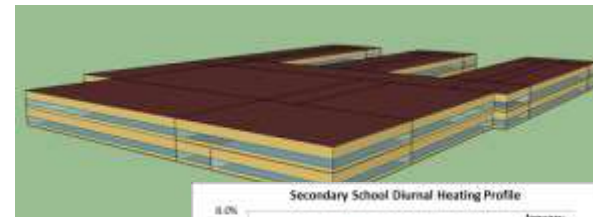**Warehouse**
Area: 4,835 m²
Heating LF: 0.23

Secondary School
Area: 19,592 m²
Heating LF: 0.39

Large Office
Area: 46,320 m²
Heating LF: 0.29

Box Store Retail
Area: 2,294 m²
Heating LF: 0.32

NOTE:
Shown energy values and profiles are preliminary draft outputs provided for illustrative purposes only

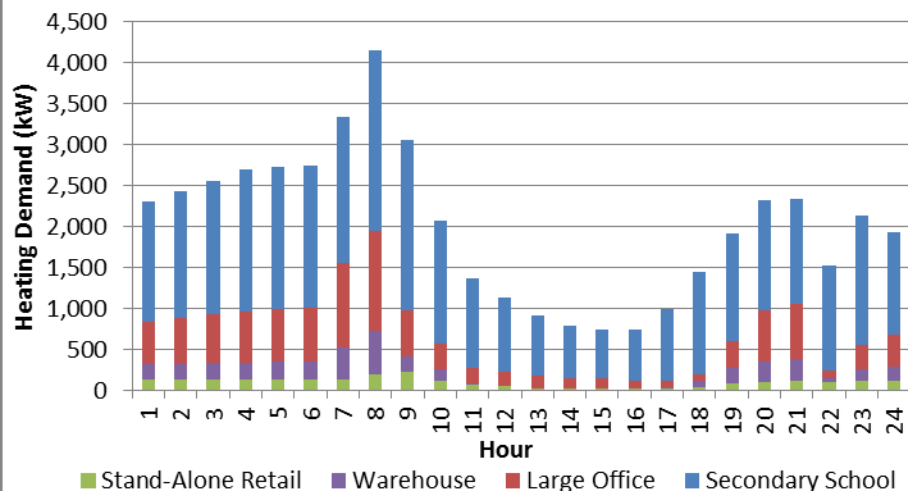_Estimate annual/monthly building energy via published EUI data or other sources_

Apply Building Archetype model data to estimate peaks and generate building demand profile

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Archetype Data for Community Energy Analysis

Sample Building Cluster

Estimated Peak Day Combined Heating Profile

Legend: Stand-Alone Retail, Warehouse, Large Office, Secondary School

Potential to also generate estimate for the combined annual load duration curve of the combined network to examine possible energy supply options

Estimated Combined Heating Load Duration Curve
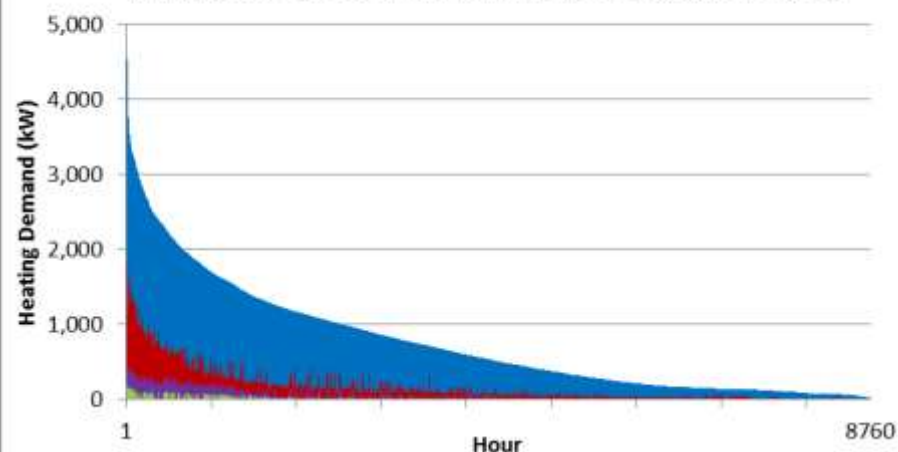
Combine building profiles to develop energy profile estimate for the building cluster

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Next Steps & Future Work

- *Finalize base set of archetype models, ability to generate profile data for ~80 Canadian locations*
- *Establish how best to package and make available the compiled modelled data outputs* → *Input and suggestions always welcome*
- *Current models factor NECB (2011) construction:*
  - *Ability to generate data for alternative archetype constructions, vintage, etc*
  - *Ability to investigate building control strategies, thermal storage options, etc., and the effect on energy peaks.*
- *Where possible, want to compare archetype data to real buildings*
  Always looking for additional building data and we greatly welcome input from DE systems and campuses
  → *Thank you to University of Calgary & University of Toronto!*
- *Modelled building data will play a key role in upcoming CanmetENERGY research on the concept of Smart Energy Networks and Smart Communities.*

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Conclusion

There is strong potential to make use of available archetype model data to improve energy assessment at the community/neighbourhood level and to aid analysis of district energy applications, especially at the preliminary investigation stage and for R&D purposes.

Having access to more and better modelled archetype data has the potential to minimize both the number of data sources involved and the amount of raw data required while providing realistic estimation of building energy demands.
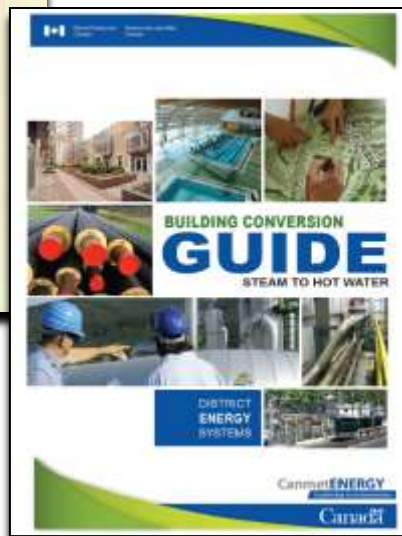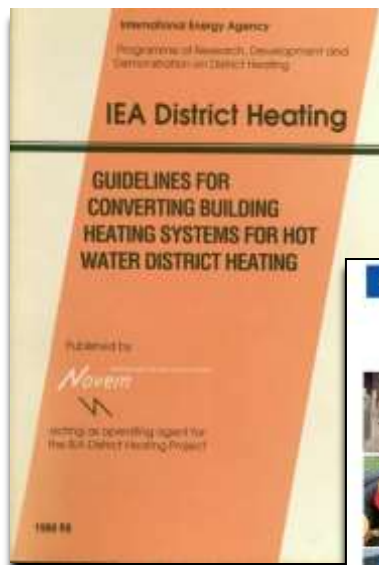
THANK YOU

IEA Guideline for Steam to Hot Water building conversions (1990)

For more information, contact:
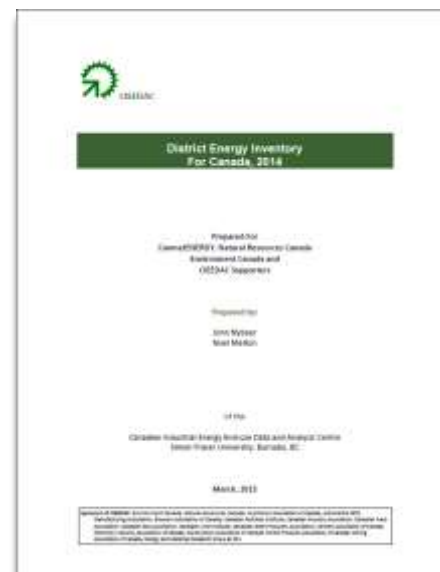
Raymond Boulter

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DE@nrcan.gc.ca

(613) 943 0951

CIEEDAC District Energy Inventory for Canada

NRCan Building Conversion Guide: Steam to Hot Water (2015)

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