Would peak electric demand management reduce carbon emissions?

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Objectives

- Smart grid control strategies to shift peak demand for dwellings that use electricity for space heating
- Characteristics of buildings and occupants that affect demand shift
- Smart grid control strategies as a mean to reduce carbon emissions

National Research Council Canada (NRC) - Overview

Three key roles:

1. Business innovation
2. Federal policy mandates
3. Advancing knowledge

- 3,700 scientists, engineers, technicians, and technology advisors
- Manages 178 buildings in 72 locations
- >$1B annual expenditure

Construction Research Centre

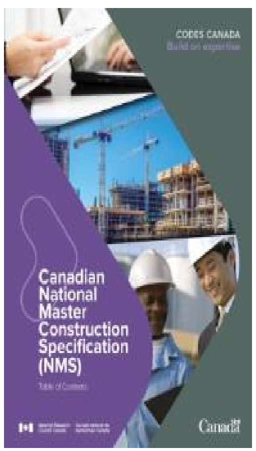
- >200 people working on Codes, Civil Engineering, Fire, Building Envelope, and Building Systems & Indoor Environment

In 2018 we worked with:

- 7,500+ SMEs (advice)
- 3,400 SMEs (funding)
- 1,000 companies (R&D collaborations)
- 152 hospitals
- 72 colleges and universities
- 34 federal departments
- 39 provincial/municipal governments
- 36 countries

High Performance Buildings Program

Goal: enable commercial & institutional buildings to generate more energy than they consume



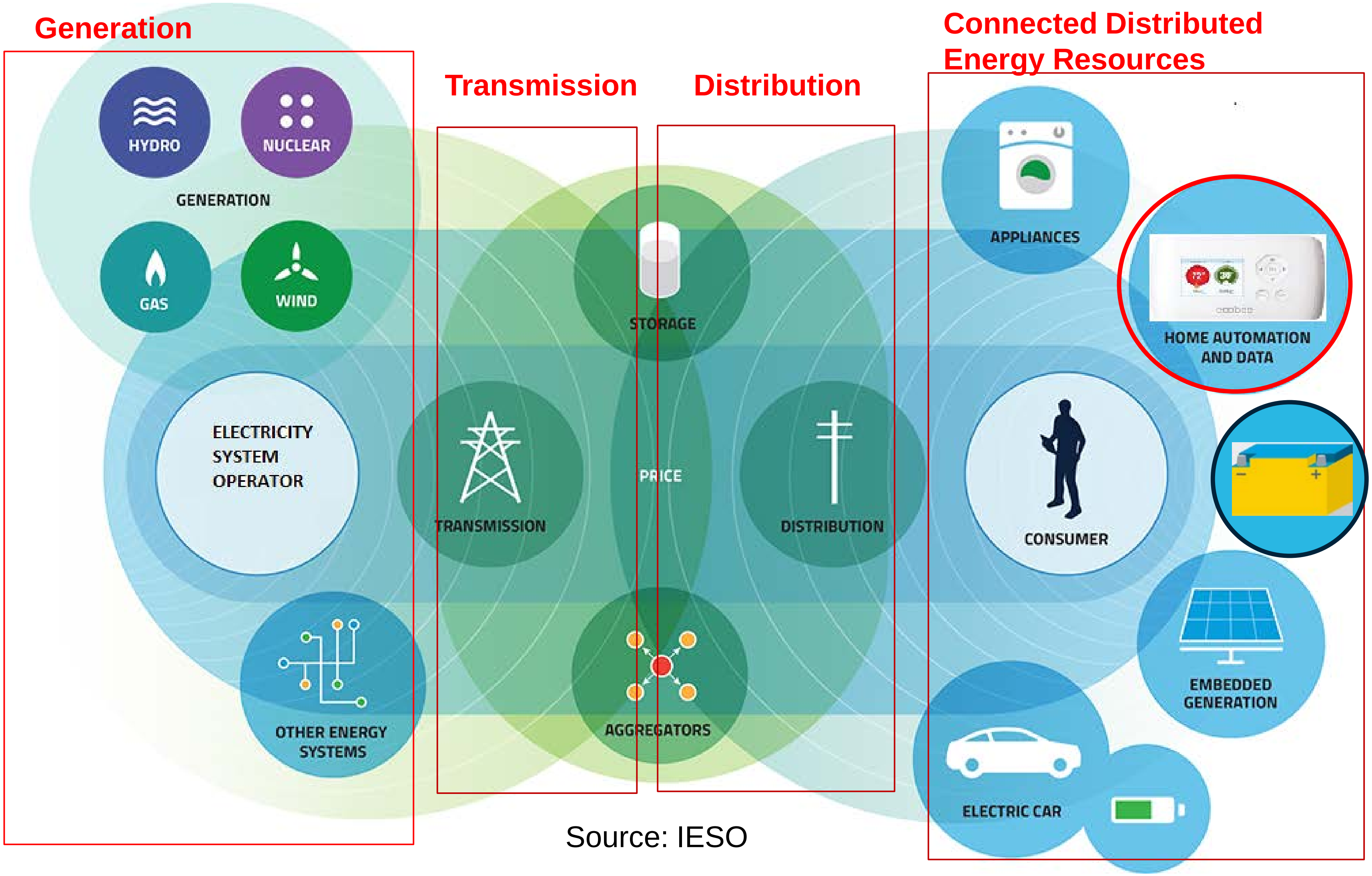
Dynamic Building Envelope
- Vacuum and advanced insulation
- Curtain walls with dynamic glazing technologies
- Advanced roofing with integrated & durable renewables

Connect smart buildings to grid
- Remote auditing & vertical benchmarking
- Energy usage and system prognostics
- Energy management with Smart Grid interface
- Renewables & storage integration
- ROI-based retrofit decision support tools

Smart building environmental controls
- Wireless-based environmental control systems
- LED-based lighting control & market acceptance
- Plug load control & personal consumption monitoring

The National Master Specification (NMS)
- Canada's most comprehensive master specification
- Approximately 750 specs in both official languages

Distributed Energy Resources



Source: IESO

Distributed Energy Resource (DER)

DER is an electric supply source interconnected to the electric grid that fulfils one of the following criteria

- Generates electricity
- Store electricity and can supply electricity to the grid
- Involves load changes in response to price or other inducements

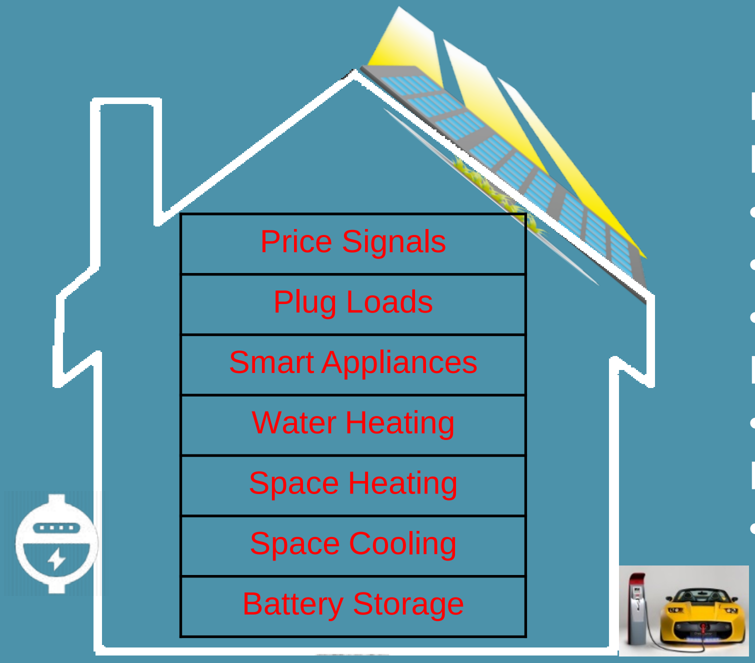
Connected DER refers to renewable generation sources embedded in the distribution system

Distributed Energy Resources

DERs represent:

- Technologies
- Strategies

through which buildings evolve from passive consumers to active partners with grid



Smart Energy Controls enabled by IOT

DER Strategies

HVAC

- Preheating
- Precooling
- Duty cycling

Electric Water Heating

- Duty Cycle

Electric Vehicles

- Time of Charging

Electricity Generation in New Brunswick

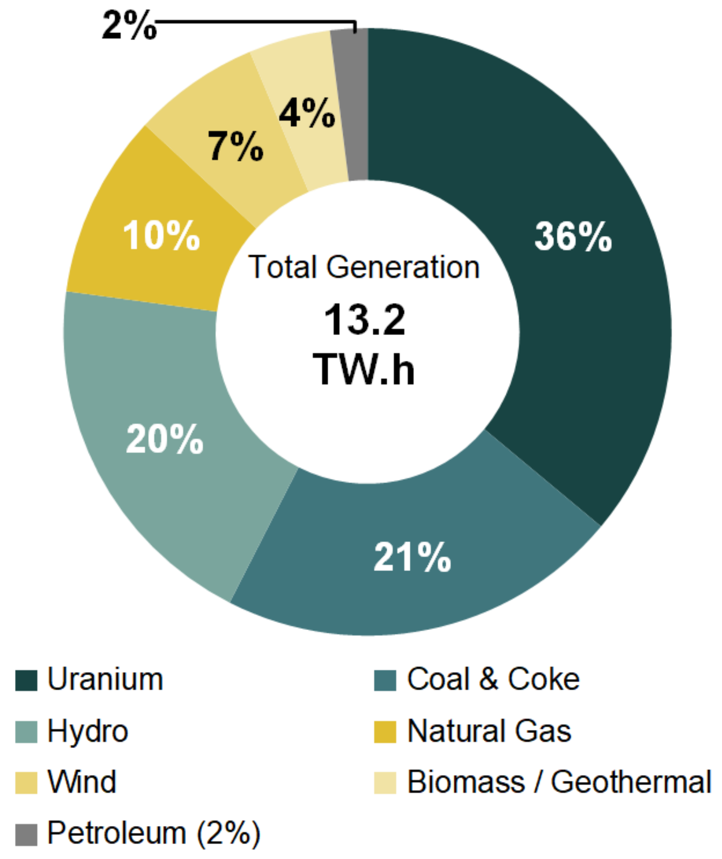
NB Power operates a total of 13 hydro, nuclear, coal, oil, and diesel powered stations:

- 705 MW Point Lepreau Nuclear Generating Station
- 450 MW Belledune coal-fired plant
  - ✓ Coal to be eliminated by 2030

Electricity (2016) consumption by sector:

- Residential: 5.6 TW.h.
- Industrial: 4.6 TW.h
- Commercial: 3.0 TW.h.

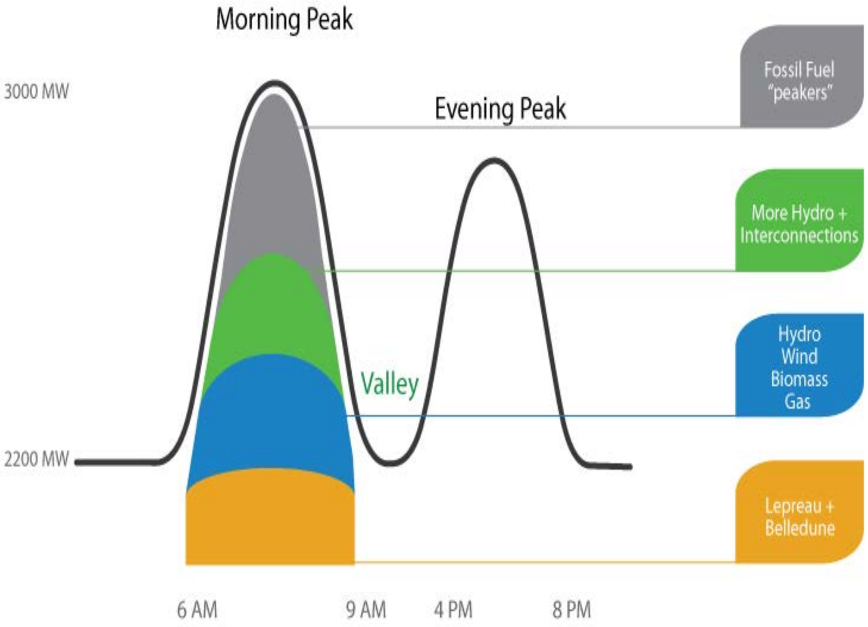
Electricity generation contributes about 31 per cent of New Brunswick's total GHG emissions as compared to 10.9% of national average.



Source: Canada Energy Regulator
https://www.cer-rec.gc.ca/nrg/ntgrtd/mrkt/nrgsstmprfls/nb-eng.html

New Brunswick: Twin Peaks Problem!

- Most dwellings use electric baseboards for space heating
- 3100 MW peak demand only for a few hours on a few days of the year
- Looking for ~600 MW reduction in demand by 2042 to avoid capital investments with retirement of older plants



Demand Response Pilot Studies in Canada – Electric Heating Focus

Utility	Type of Electric Heating	Sample Size	Peak Reduction
Quebec Hydro	50% central heating, and 50% baseboard heating	50 homes of Hydro-Quebec employees	
	Smart Thermostat Pilot with ASE Energy and Sinope	30 homes of Hydro-Quebec employees	2kW of load shift for homes with 10 SLVT and 1 kW with 4 SLVT
BC Hydro Vancouver Island	Baseboard heaters	22 homes (2016-17)	500 W – 1 kW 5 SLVT
Fortis, BC	Electric HP and furnaces	100	
Manitoba Hydro	Electric heating	88 homes	energy efficiency focus
NB Power	• Baseboard Heaters • Mini-split HP with b/b • Baseboard with secondary heat	50 homes (2015-16) 600 homes (2016-17)	• 2 kW for b/b heated homes • 1 kW for mini-split HP • 4-6 SLVT

05/24/2018

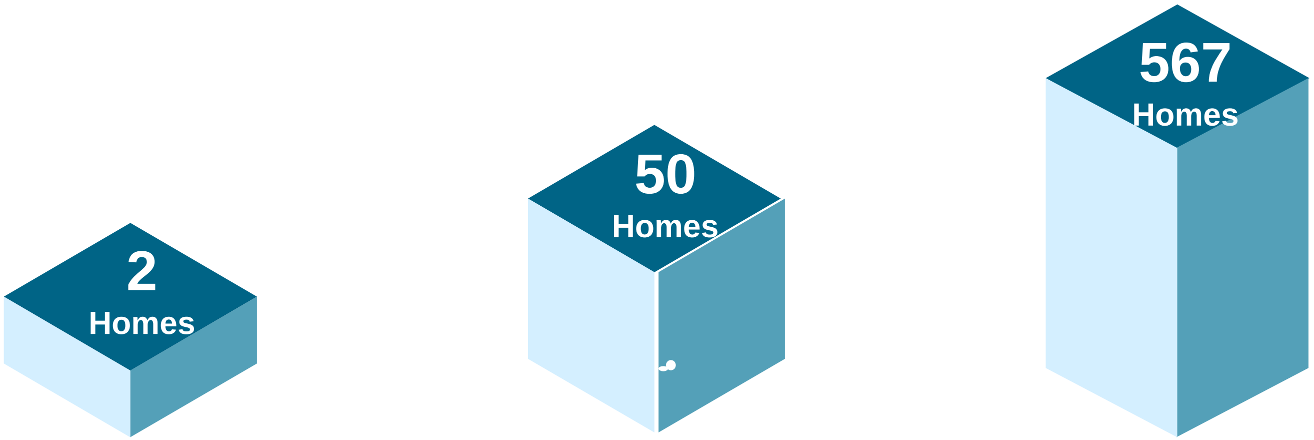
Evaluation of Smart Grid based Control to Shift Peak Demand: Pilot Goals

- Reduction of Peak Power (kW)
- Shift in Energy (kWh) / Energy penalty
- Occupant comfort
- Characteristics of homes for load shifting
- Customer acceptance of technology

Goal

To evaluate the potential of smart thermostat set point strategies to shift the peak demand for electric baseboard heated homes.

Pilot Overview - 3 years (2014-17)



Twin Test Houses
Research

2014-15

Evaluated shift potential

Canadian Centre for Housing Technologies, Ottawa, Ontario

Pilot Study
Demonstration

2015-16

Evaluated load shift and occupant comfort in detached homes

Fredericton, N.B..

Program Pilot
Scale up

2016-17

Evaluated load shift and comfort for a variety of heating systems

Three Cities: Fredericton, Moncton and Saint John, N.B.

Electrical Thermal Storage Enabled by OpenADR Thermostats

The Solution: Thermal storage of electrical energy
(Treating building fabric similar to a thermal battery)

1. Store electricity as thermal energy by pre-heating the building by 1° or 2 ° Celsius above the pre-programmed temperature set point before the onset of system peak
2. Discharge the stored energy during the peak period

567-HOME DEMAND CONTROL PILOT STUDY

2016-17

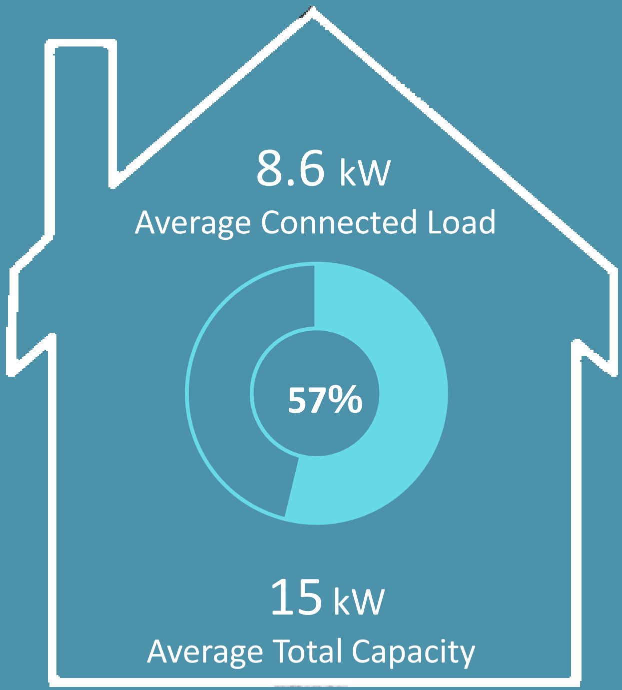
Study Parameters – home profiles

HEATING SYSTEMS

Electric Baseboard Heaters

Baseboard + Backup Heat
(e.g. Fireplace)

Mini Split Heat Pump with
baseboard backup



VINTAGE

1946-1983

1984-2000

2001 or later

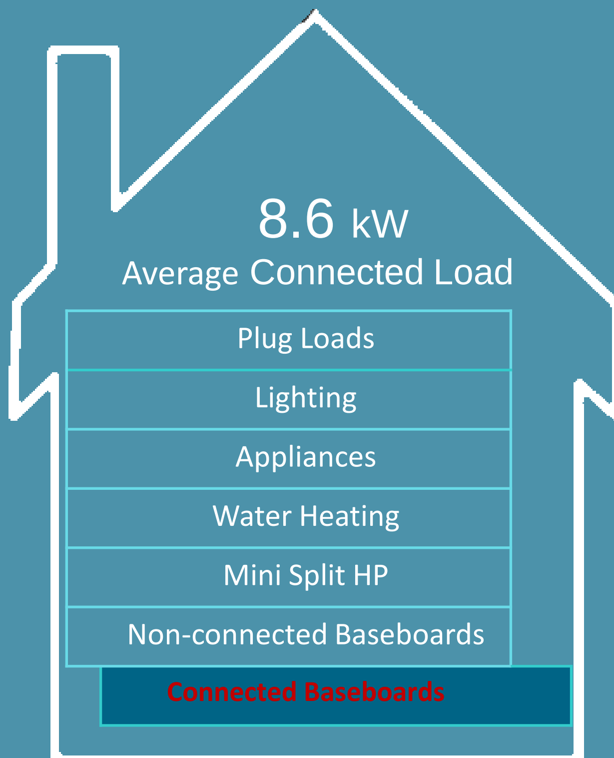
Study Parameters – Measurement Data

WHOLE HOME Meter

1 min sampling rate
- kWh

(assess impact to grid)

1 in 7 homes monitored
(no smart meters)



SMART THERMOSTAT

- OpenADR compliant
- DR override feature

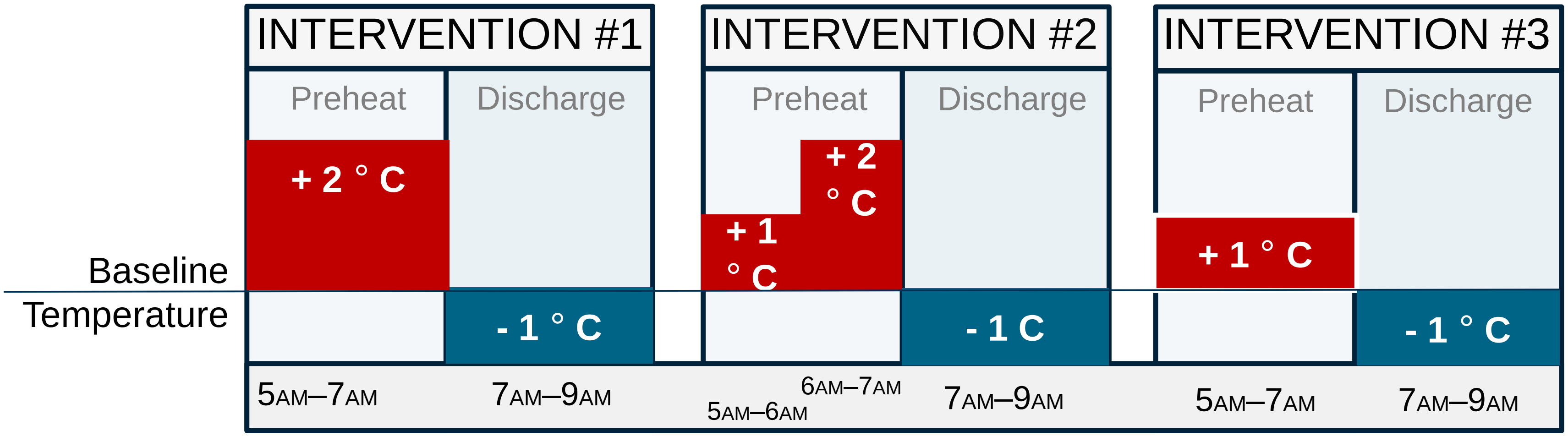
Up to 5 per home

5 min sampling rate
- kWh
- Indoor temperature
- Set points

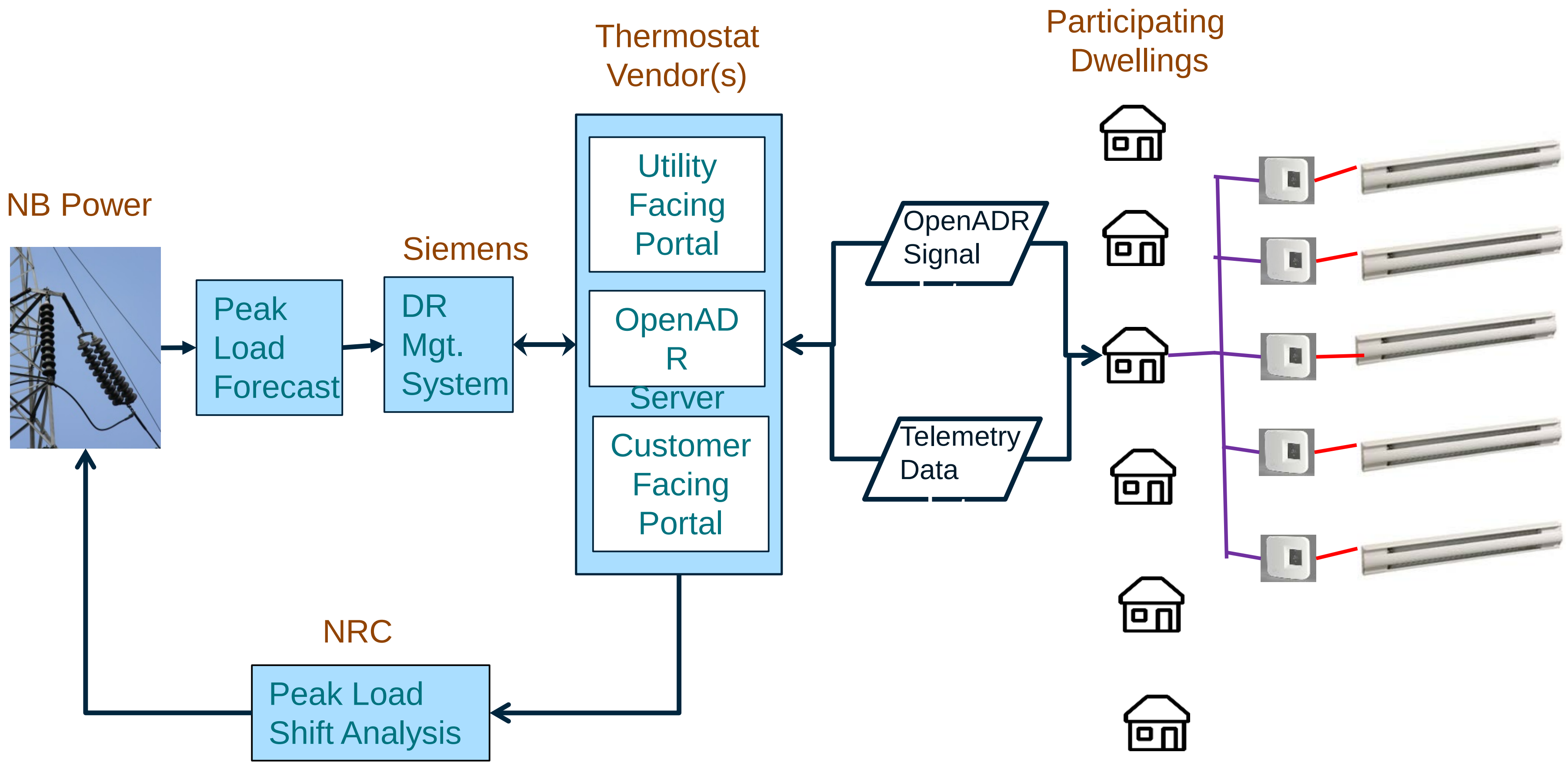
Study Parameters – 3 Variants of DR Interventions

A total of 12 DR interventions with three variants were executed between January and March, 2017

- Thermal Charge (preheat): 5 AM – 7AM by +1° or +2° Celsius
- Thermal Discharge: 7 AM – 9 AM by -1° Celsius



OpenADR Control of Smart Line Voltage Thermostats



Study Design – Measurement & Verification

Energy Data
- Thermostat telemetry (5 min)
- Electricity usage (1 min)
- Weather (60 min)

Building Characteristics
- Type of dwelling
- Type of heating system
- Nominal heating capacity (kW)

Participant Surveys
- Noticed event?
- Daily Schedule?
- Usual habits?
- Experienced

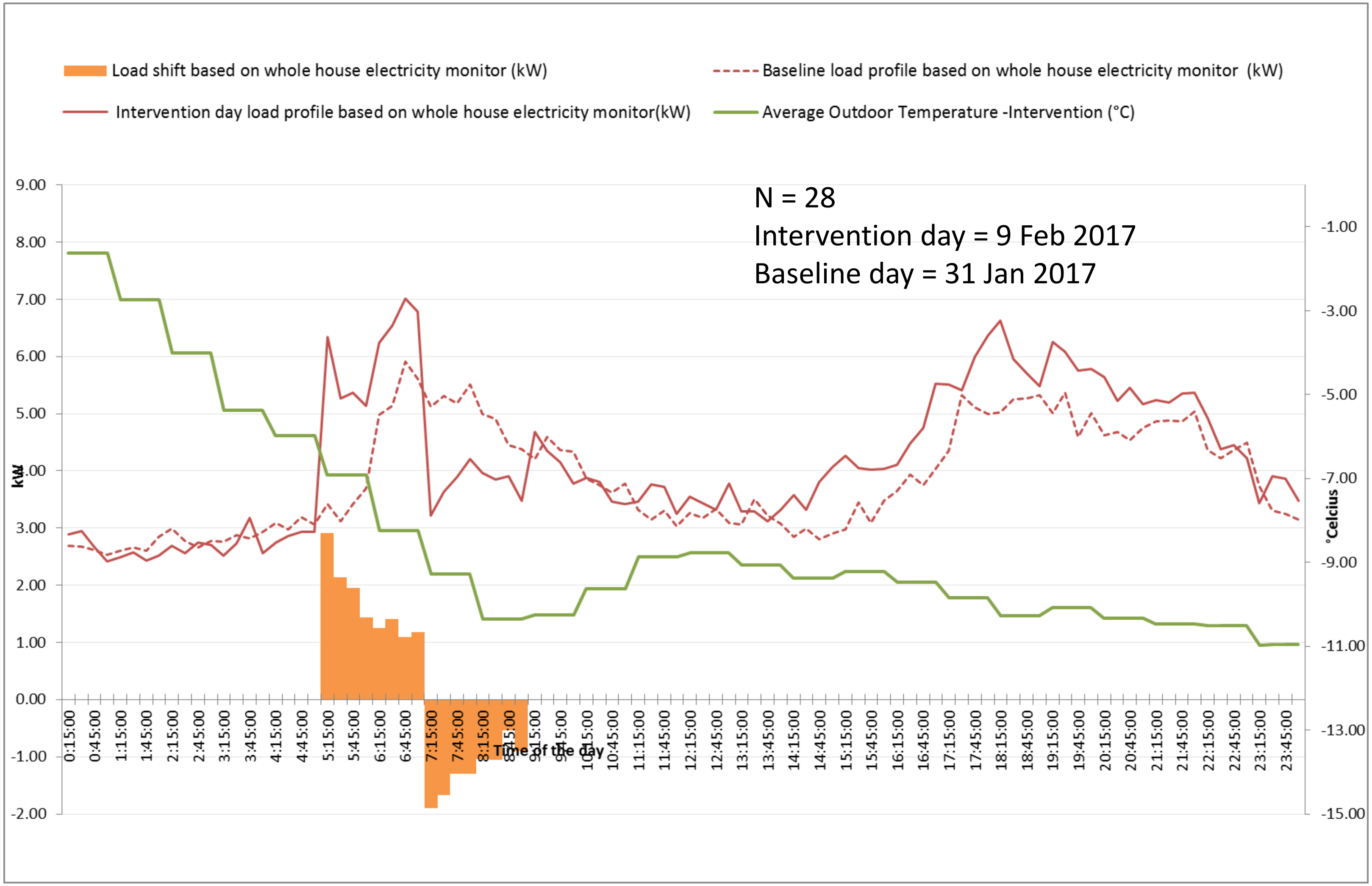
BASELINE

ANALYSIS

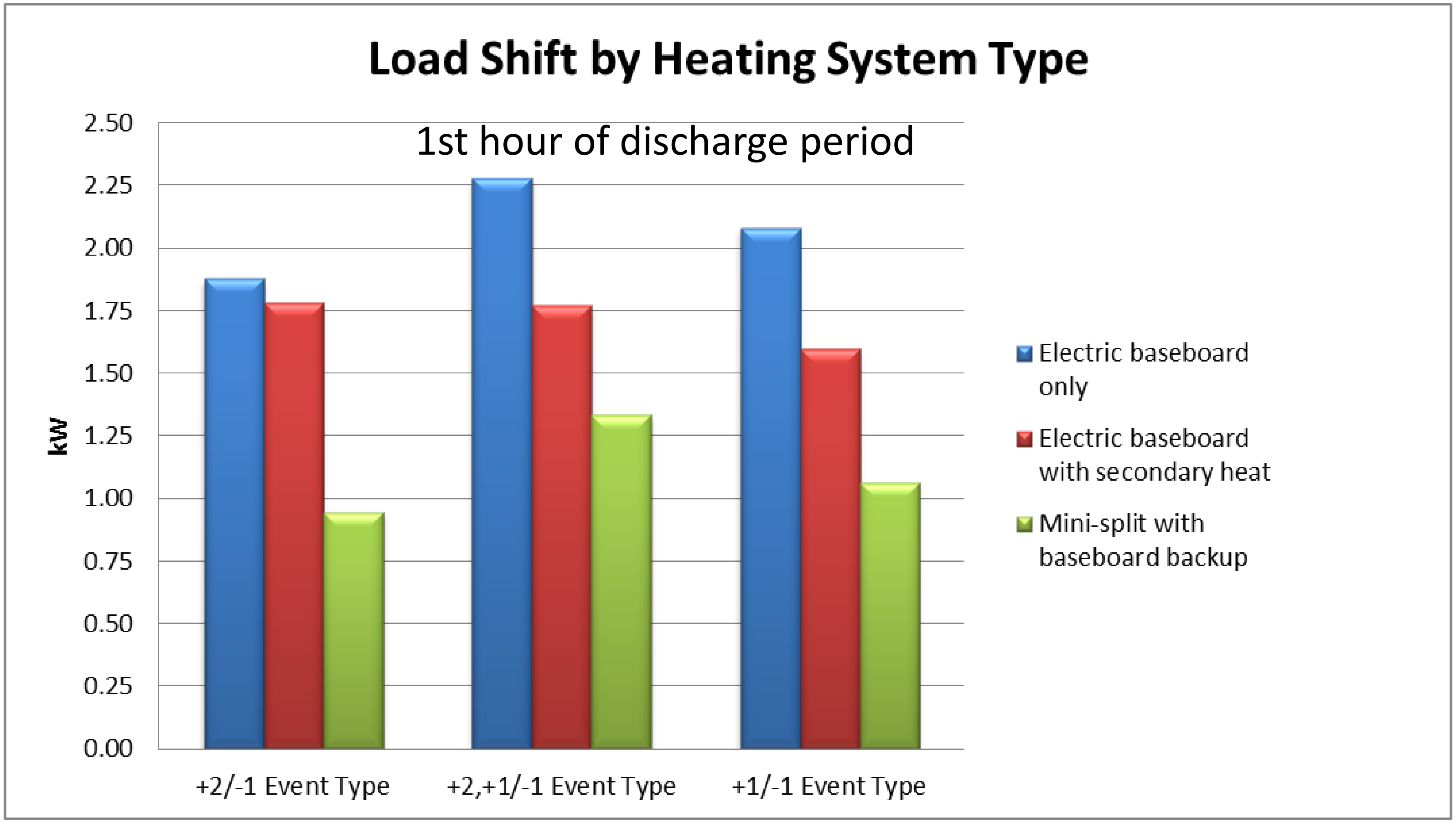
Calculate Load Shift
(using regression analysis)
- First 30 Min
- **First Hour**
- Full Period

Analyze Dependencies
- Demographics
- Thermostat set points
- Building characteristics

Baseline vs. DR Day: Comparing Load Profiles



Study Results – Load Shift by Heating System



Study Participant Surveys

Surveys designed, administered and analysed by NRC:

- Survey 1
  - Household demographics
  - Baseline thermal comfort, clothing insulation, preferred thermostat settings
  - Personal values
- Survey 2-6 (after DR interventions)
  - Thermal comfort, awareness of interventions, comments
- Survey 7 (at the end of the study)
  - Satisfaction with the thermostats and pilot study

Key Findings

Load shift not dependent on: vintage, house type, # occupants, age of occupants, window orientation, income, or personal values

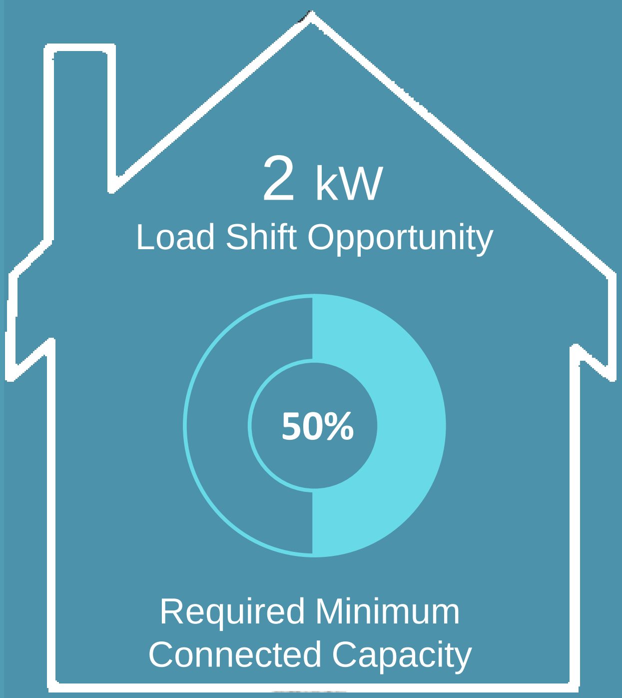
Load shift dependent on pre-existing thermostat set point profile

No thermal comfort issues reported

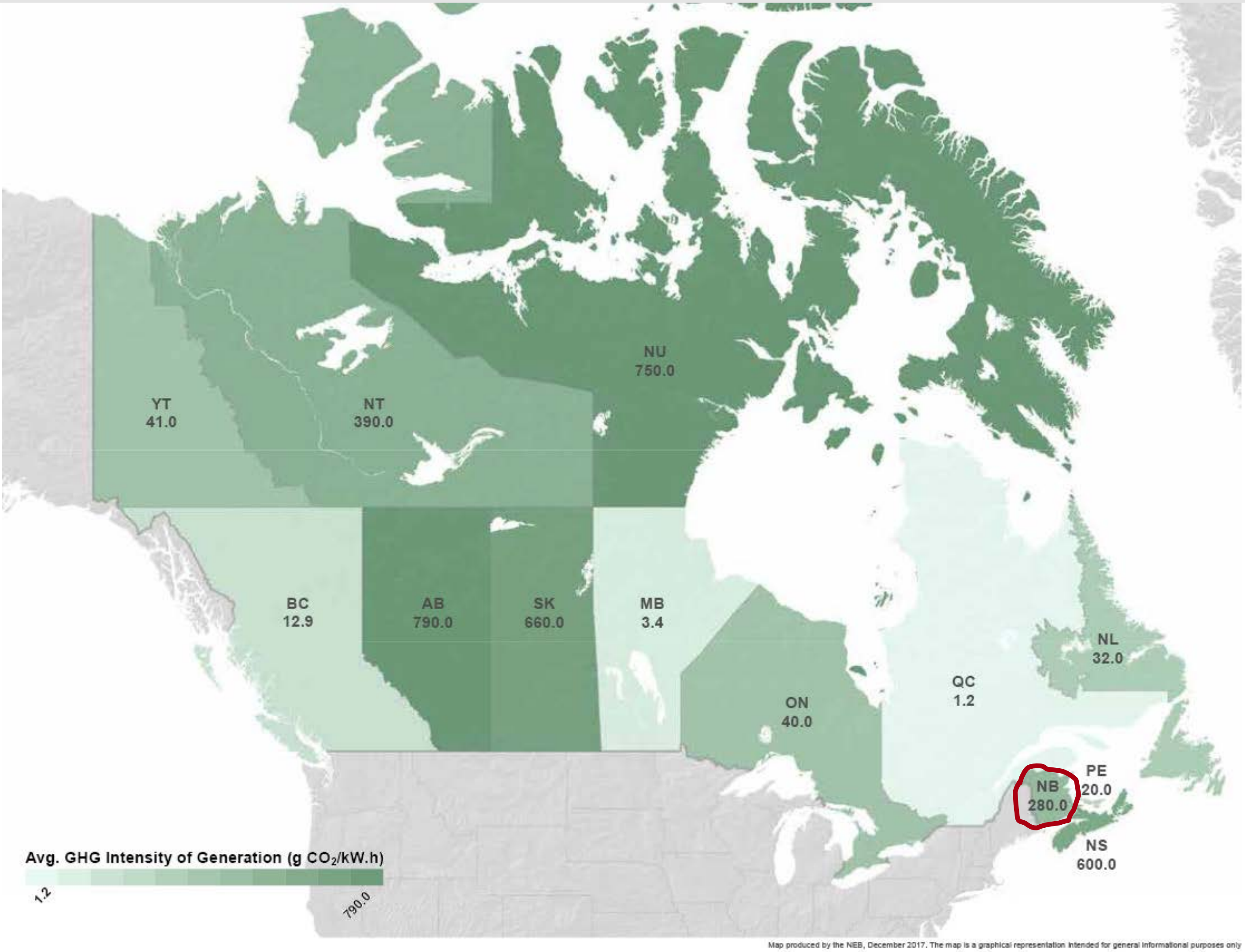
No measured rebound effect

No evidence of energy penalty

Very high satisfaction with thermostats and program



Avg. GHG Intensity of Generation (g CO_2/kWh) in Canada



Source: https://www.cer-rec.gc.ca/nrg/sttstc/lctrct/rprt/2017cndrnwblpwr/ghgmssn-eng.html

Conclusions

- Preheating curtails peak electrical heating load without adverse effects on occupant thermal comfort
- A low preheat of 1°C (1.8°F) delivered meaningful load reduction with lower risk of thermal discomfort
- Houses with certain characteristics deliver bigger load shifts
- Reduction in carbon emissions will depend on the generation mix at the time of demand response

Project Team

NRC	NB Power	Siemens
Ajit Pardasani Anca Galasiu Chantal Arsenault Guy Newsham Heather Knudsen Jennifer Veitch Sandra Mancini Steve Kruithof Trevor Nightingale Vera Hu	Jill Rogers, Norma McCarthy Sara Mudge Ted Leopkey Trupti Abhang Customer Care Team Reduce and Shift Demand Team	Brody Hanson Giles Counsell Greg Robarts Sonya Hull Terrance Cormier DRMS Team

References

Pardasani, A., Armstrong, M., Newsham, G.R., Hanson, B., “Intelligent Management of Baseboard Heaters to Level Peak Demand”, 2016 IEEE Electrical Power and Energy Conference, Ottawa, Canada, 12-14 October 2016, pp. 1-6

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THANK YOU

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