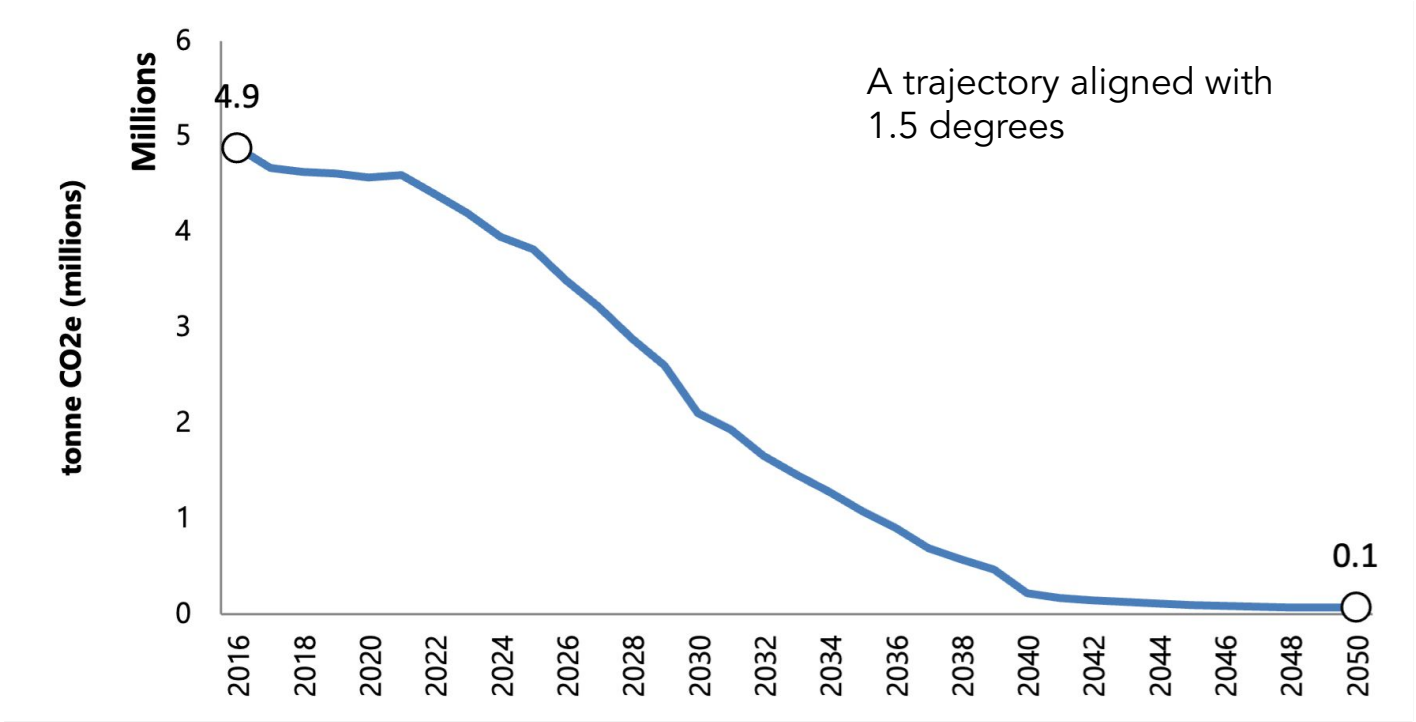
The implications of deep decarbonisation pathways for electricity grids

March 22, 2021

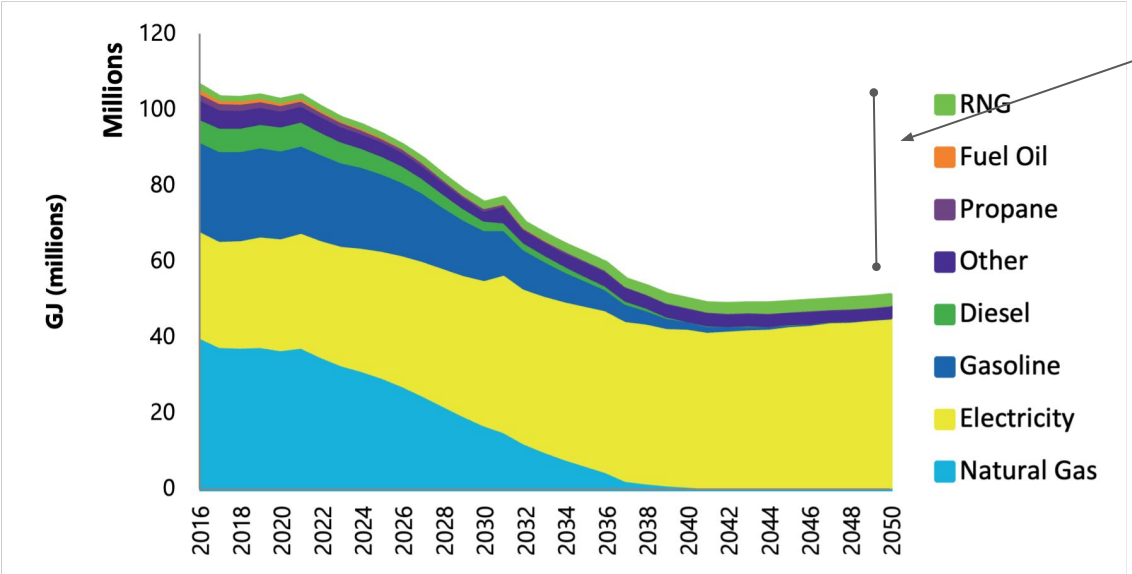
Ralph Torrie
Yuill Herbert

Energy Evolution reports available here:
https://app05.ottawa.ca/sirepub/mtgviewer.aspx?meetid=7925&doctype=AGENDA

A Decarbonisation Pathway for Ottawa



An Electrification Pathway



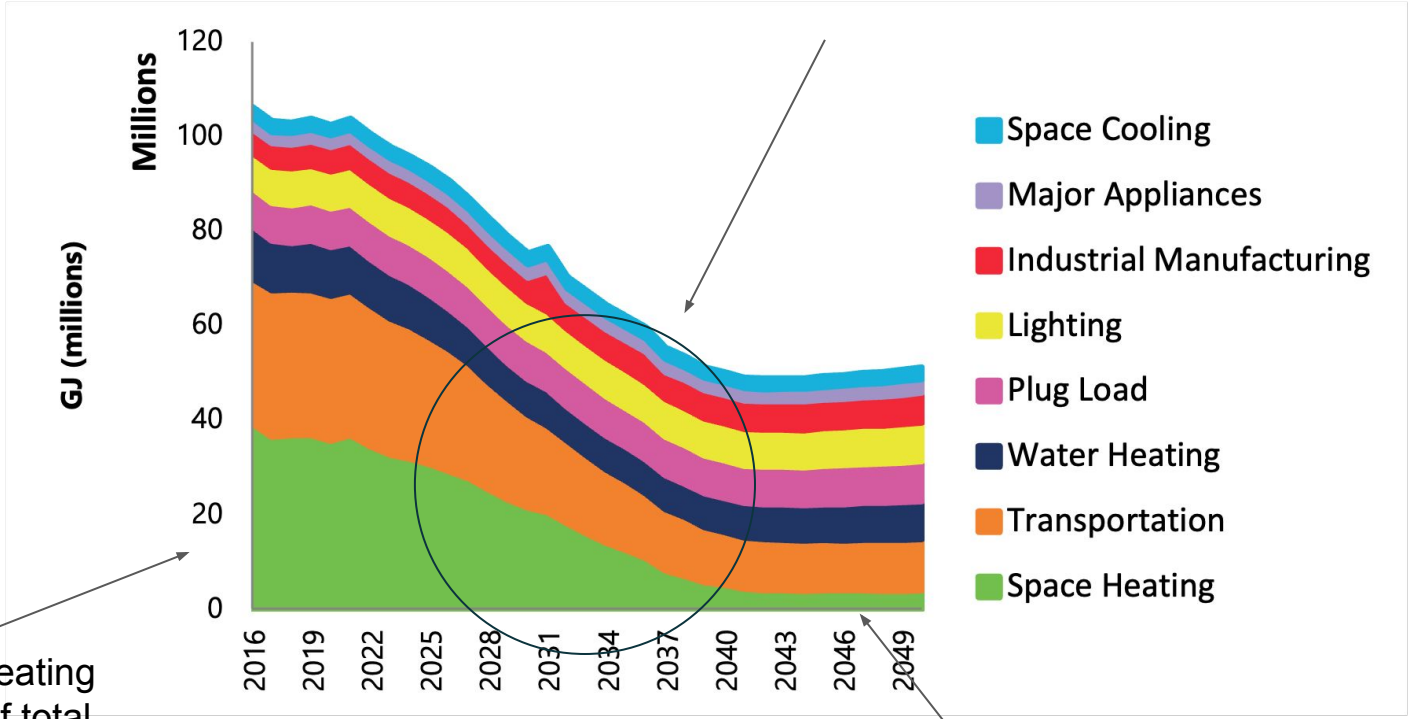
Where did the savings come from?

28 million

45 million [190% increase]

By End Use

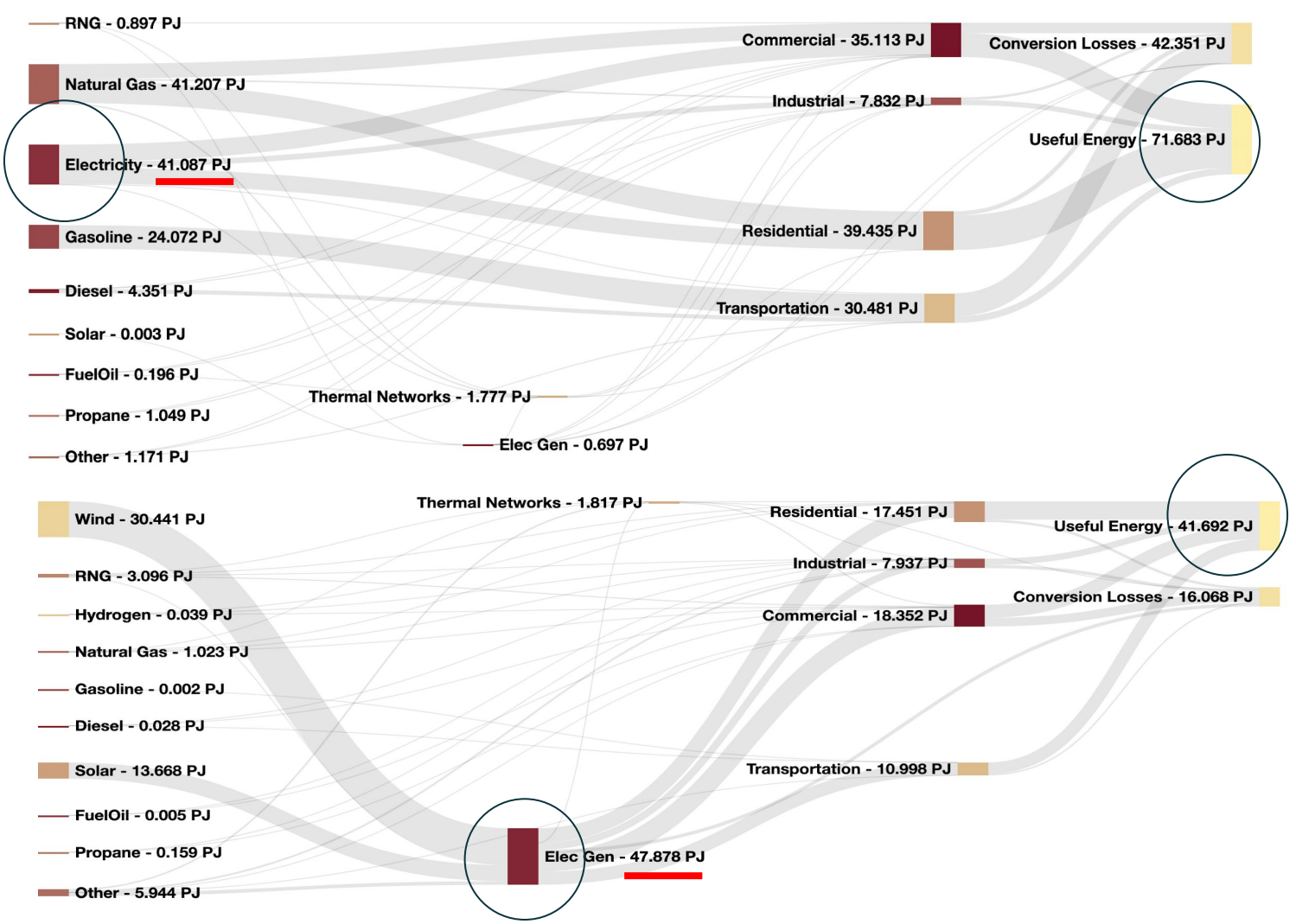
Heating and transportation
[Retrofits and EVs]



Space heating is 37% of total energy.

90% decline in space heating

Two Versions of the Future



California's Cities Lead the Way to a Gas-Free Future

By Matt Gough January 25, 2021

GRID EDGE

‘Electrification of Everything’ Would Spike US Electricity Use, but Lower Final Energy Consumption

“Higher overall efficiency of electric technologies is one reason that power demand does not grow even faster.”

JUSTIN GERDES | JULY 30, 2018

Source: Mai, Trieu, Paige Jadun, Jeffrey Logan, Colin McMillan, Matteo Muratori, Daniel Steinberg, Laura Vimmerstedt, Ryan Jones, Benjamin Haley, and Brent Nelson. 2018. Electrification Futures Study: Scenarios of Electric Technology Adoption and Power Consumption for the United States. Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-71500. https://www.nrel.gov/docs/fy18osti/71500.pdf.

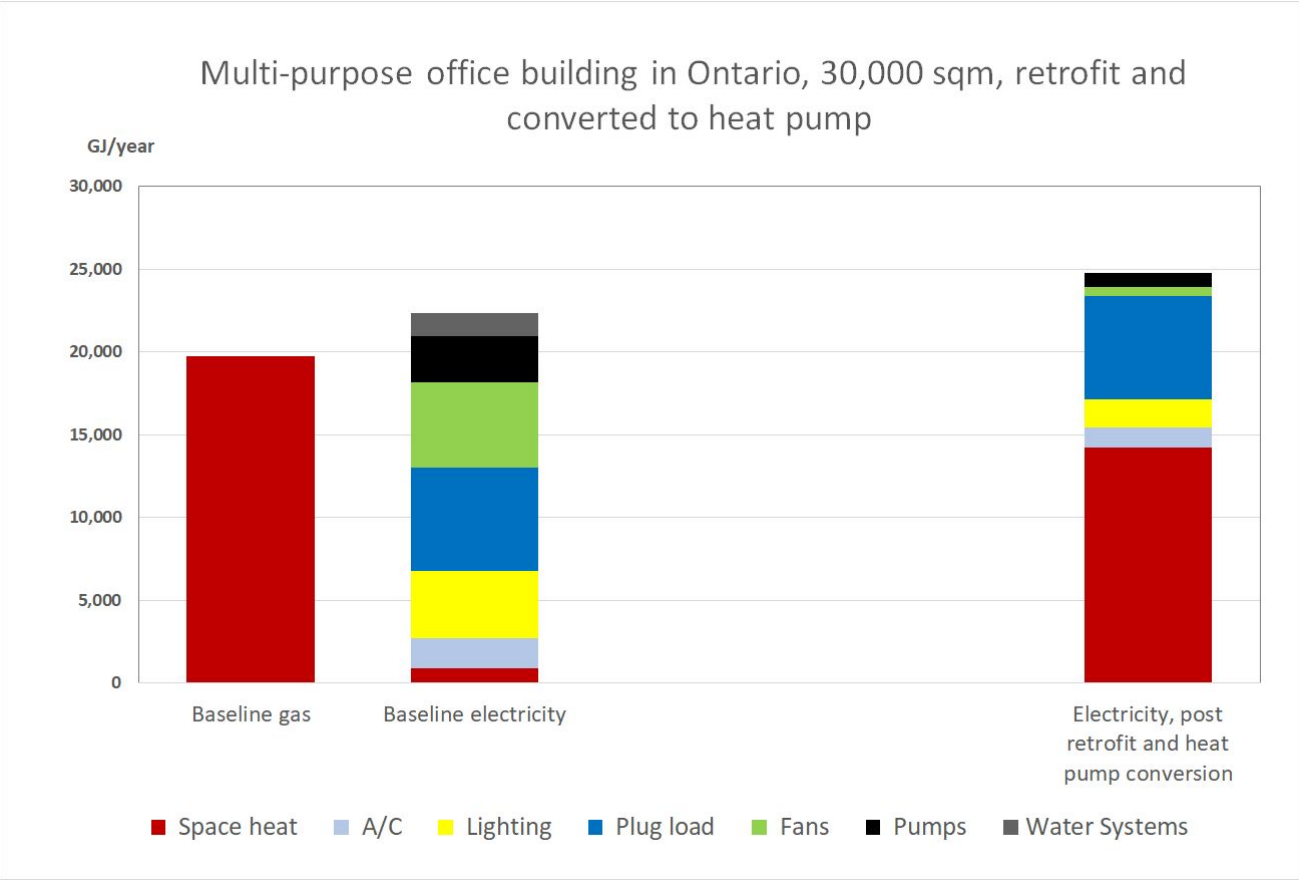
Simultaneous technological changes are driving disruptive transformation in electricity consumption patterns:

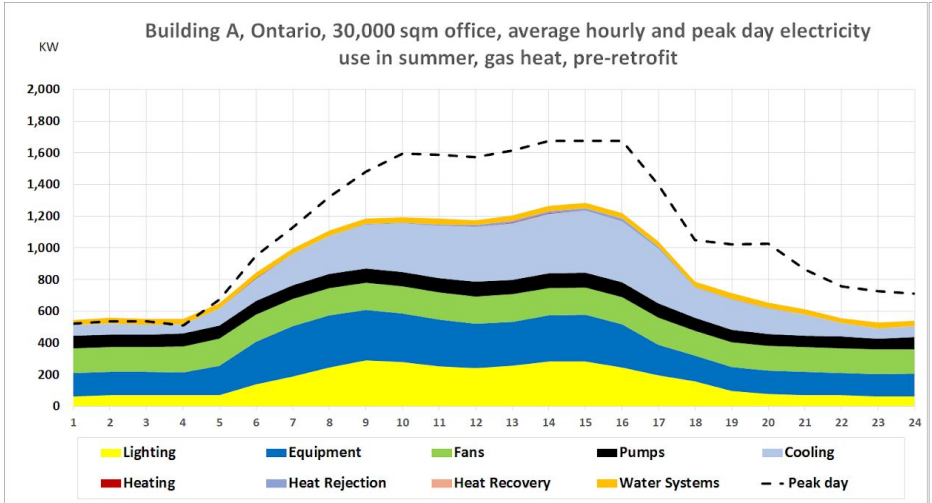
-- LED lighting and video displays, heat pumps, electric vehicles, battery storage, solar and wind technology, advanced telecommunications and information processing technologies, etc.

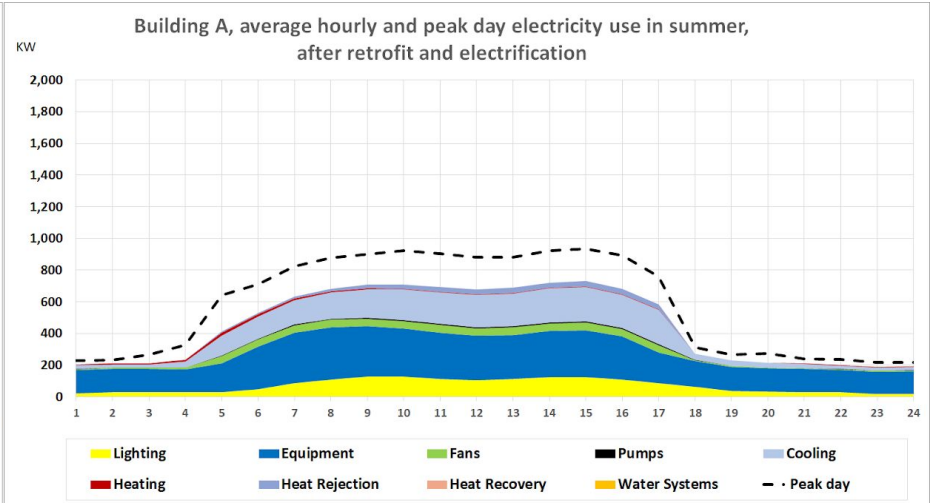
-- Electrification of vehicles and building space and water heating is a central element all zero carbon transition strategies

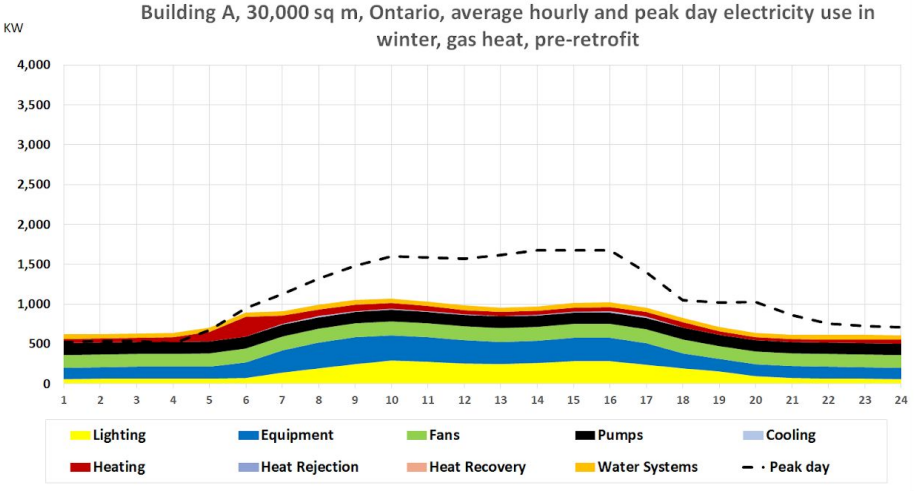
What are the implications of the new technologies to peak capacity requirements? To the ability to achieve and maintain low or zero carbon grids? To transmission and distribution investment requirements?

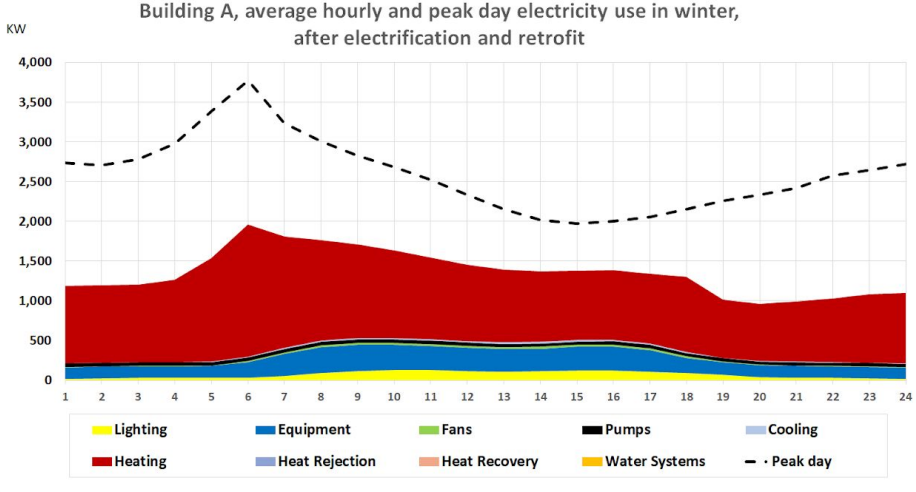
Case example A: 30,000 sqm office building in Ontario



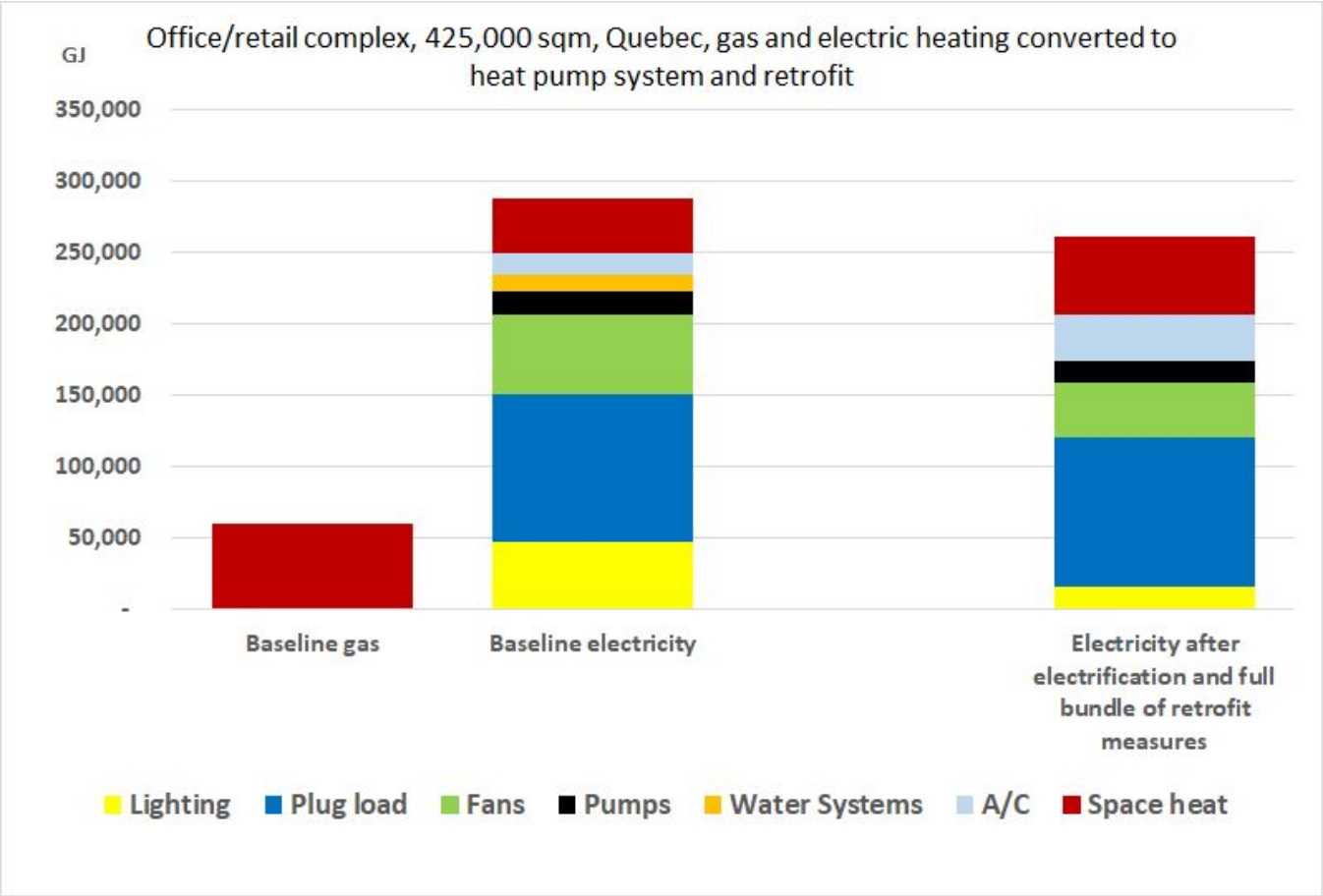

Building A, Ontario, 30,000 sqm office, average hourly and peak day electricity use in summer, gas heat, pre-retrofit
KW
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Lighting
Equipment
Fans
Pumps
Cooling
Heating
Heat Rejection
Heat Recovery
Water Systems
Peak day

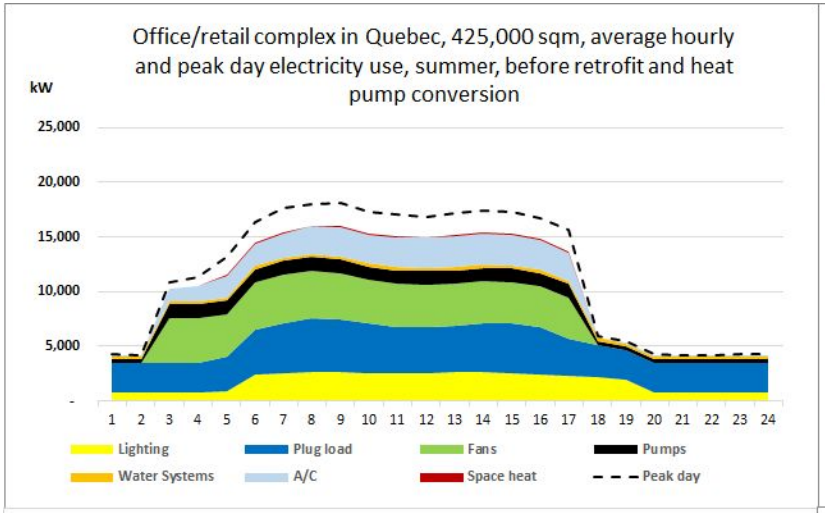

Building A, average hourly and peak day electricity use in summer, after retrofit and electrification
KW
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Lighting
Equipment
Fans
Pumps
Cooling
Heating
Heat Rejection
Heat Recovery
Water Systems
Peak day

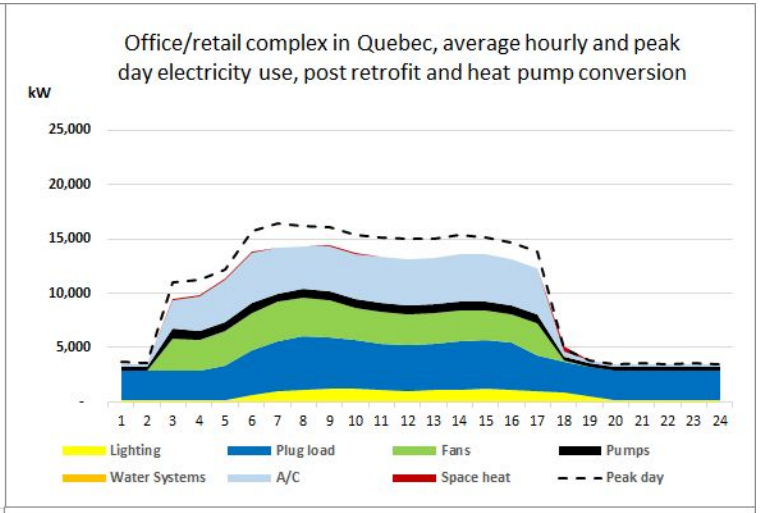

Building A, 30,000 sq m, Ontario, average hourly and peak day electricity use in winter, gas heat, pre-retrofit
KW
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Lighting
Equipment
Fans
Pumps
Cooling
Heating
Heat Rejection
Heat Recovery
Water Systems
Peak day

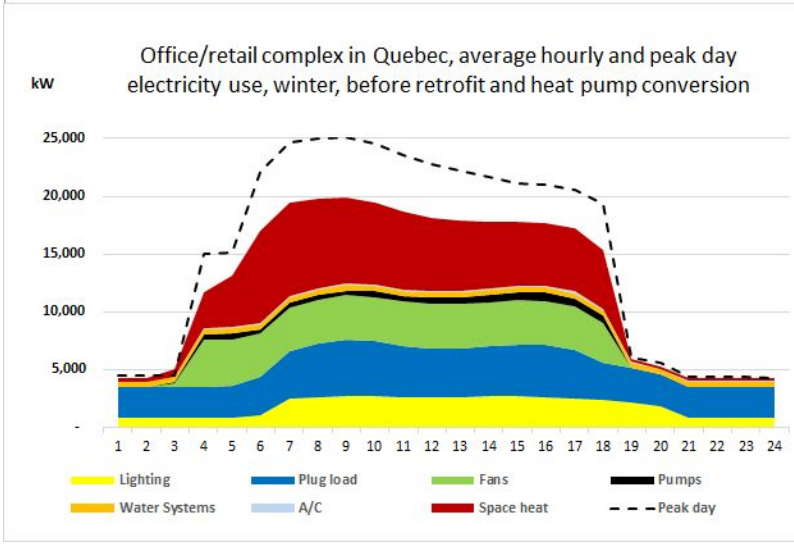

Building A, average hourly and peak day electricity use in winter, after electrification and retrofit
KW
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Lighting
Equipment
Fans
Pumps
Cooling
Heating
Heat Rejection
Heat Recovery
Water Systems
Peak day

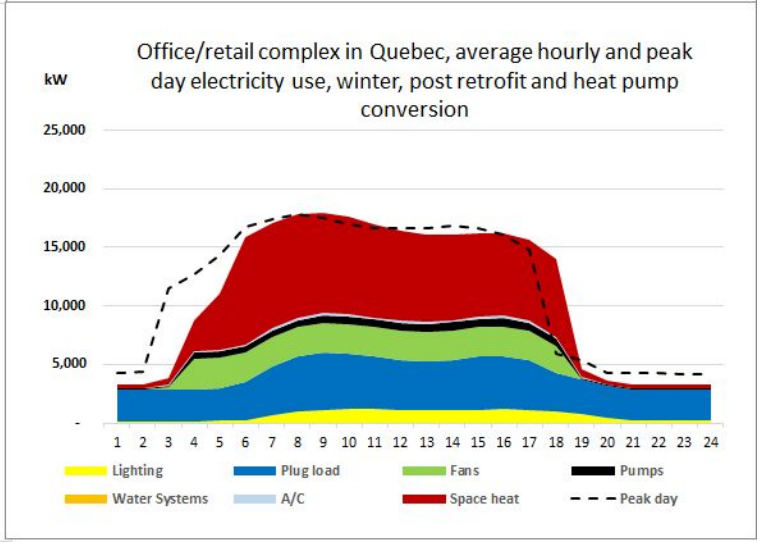
Case Study B: Large office/retail complex in Quebec:

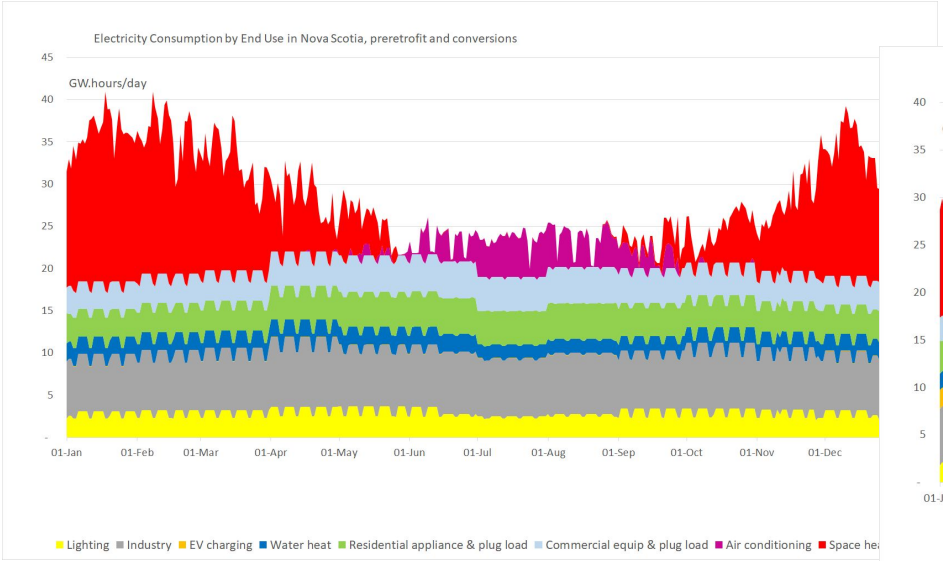


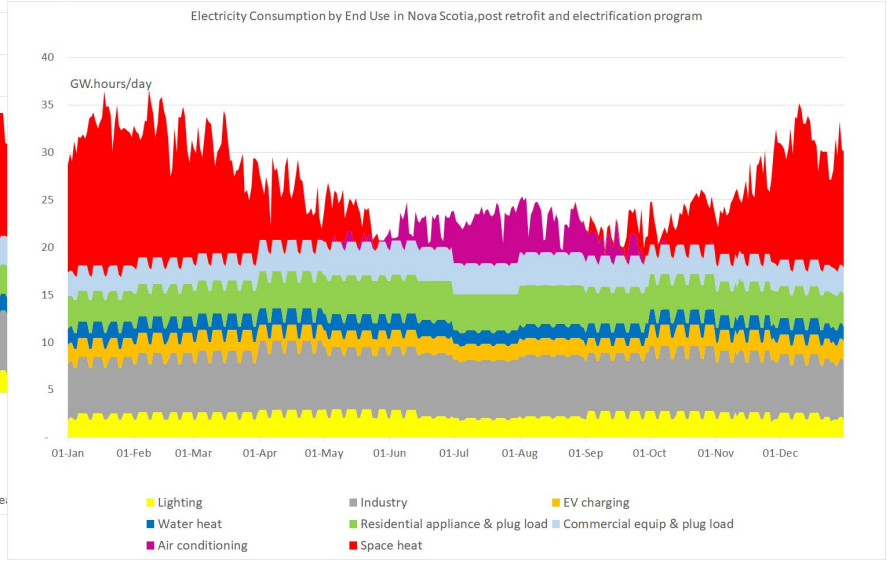

Office/retail complex in Quebec, 425,000 sqm, average hourly and peak day electricity use, summer, before retrofit and heat pump conversion
kW
25,000
20,000
15,000
10,000
5,000
-
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Lighting
Plug load
Fans
Pumps
Water Systems
A/C
Space heat
Peak day


Office/retail complex in Quebec, average hourly and peak day electricity use, post retrofit and heat pump conversion
kW
25,000
20,000
15,000
10,000
5,000
-
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Lighting
Plug load
Fans
Pumps
Water Systems
A/C
Space heat
Peak day

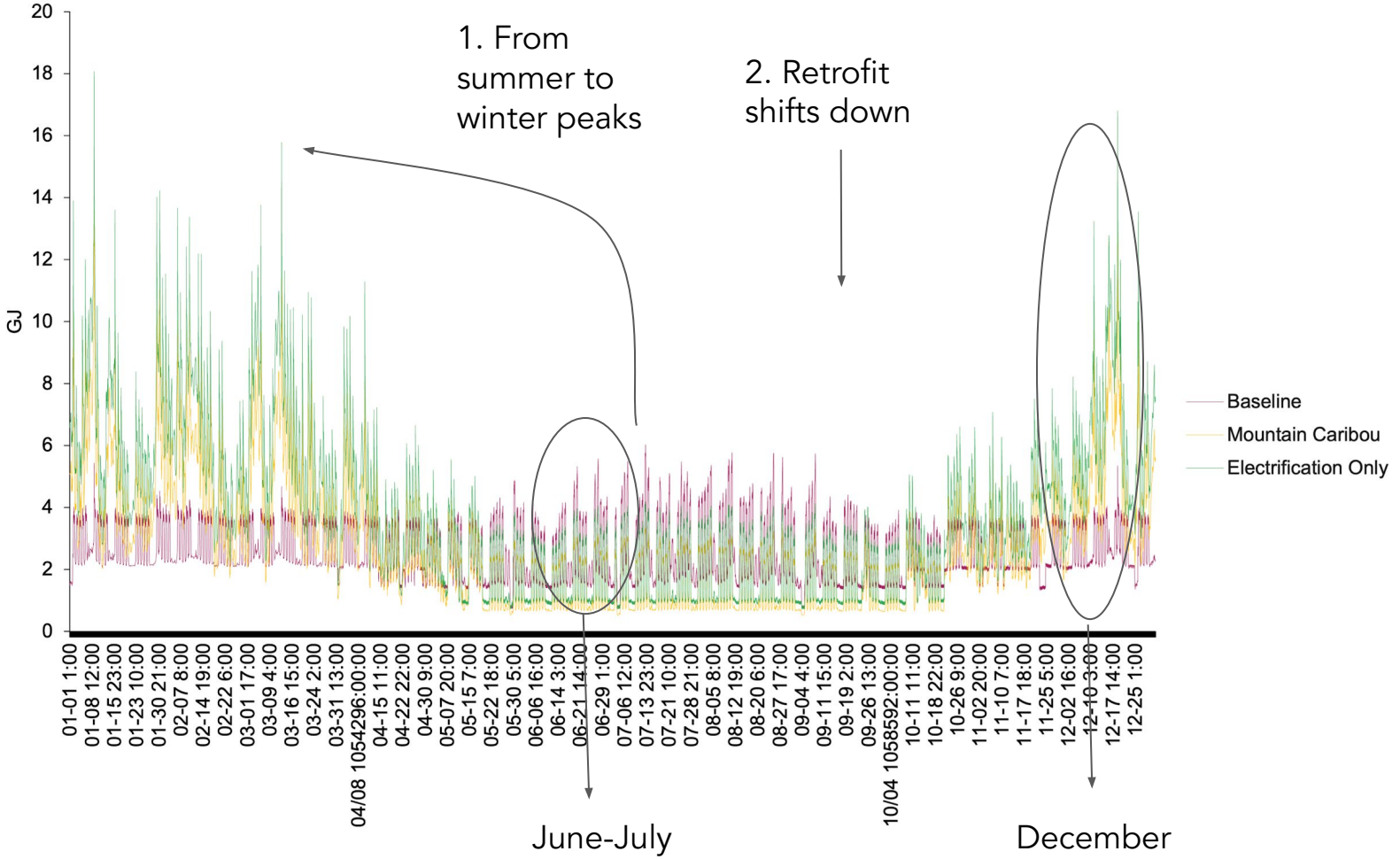

Office/retail complex in Quebec, average hourly and peak day electricity use, winter, before retrofit and heat pump conversion
kW
25,000
20,000
15,000
10,000
5,000
-
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Lighting
Plug load
Fans
Pumps
Water Systems
A/C
Space heat
Peak day


Office/retail complex in Quebec, average hourly and peak day electricity use, winter, post retrofit and heat pump conversion
kW
25,000
20,000
15,000
10,000
5,000
-
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Lighting
Plug load
Fans
Pumps
Water Systems
A/C
Space heat
Peak day


Electricity Consumption by End Use in Nova Scotia, preretrofit and conversions
GW.hours/day
45
40
35
30
25
20
15
10
5
-
01-Jan
01-Feb
01-Mar
01-Apr
01-May
01-Jun
01-Jul
01-Aug
01-Sep
01-Oct
01-Nov
01-Dec
Lighting
Industry
EV charging
Water heat
Residential appliance & plug load
Commercial equip & plug load
Air conditioning
Space he


Electricity Consumption by End Use in Nova Scotia,post retrofit and electrification program
GW.hours/day
40
35
30
25
20
15
10
5
-
01-Jan
01-Feb
01-Mar
01-Apr
01-May
01-Jun
01-Jul
01-Aug
01-Sep
01-Oct
01-Nov
01-Dec
Lighting
Industry
EV charging
Water heat
Residential appliance & plug load
Commercial equip & plug load
Air conditioning
Space heat

Insights


1. From summer to winter peaks
2. Retrofit shifts down
GJ
20
18
16
14
12
10
8
6
4
2
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01-01 1:00
01-08 12:00
01-15 23:00
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01-30 21:00
02-07 8:00
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03-09 4:00
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03-24 2:00
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07-28 21:00
08-05 8:00
08-12 19:00
08-20 6:00
08-27 17:00
09-04 4:00
09-11 15:00
09-19 2:00
09-26 13:00
10/04 1058592:00:00
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10-26 9:00
11-02 20:00
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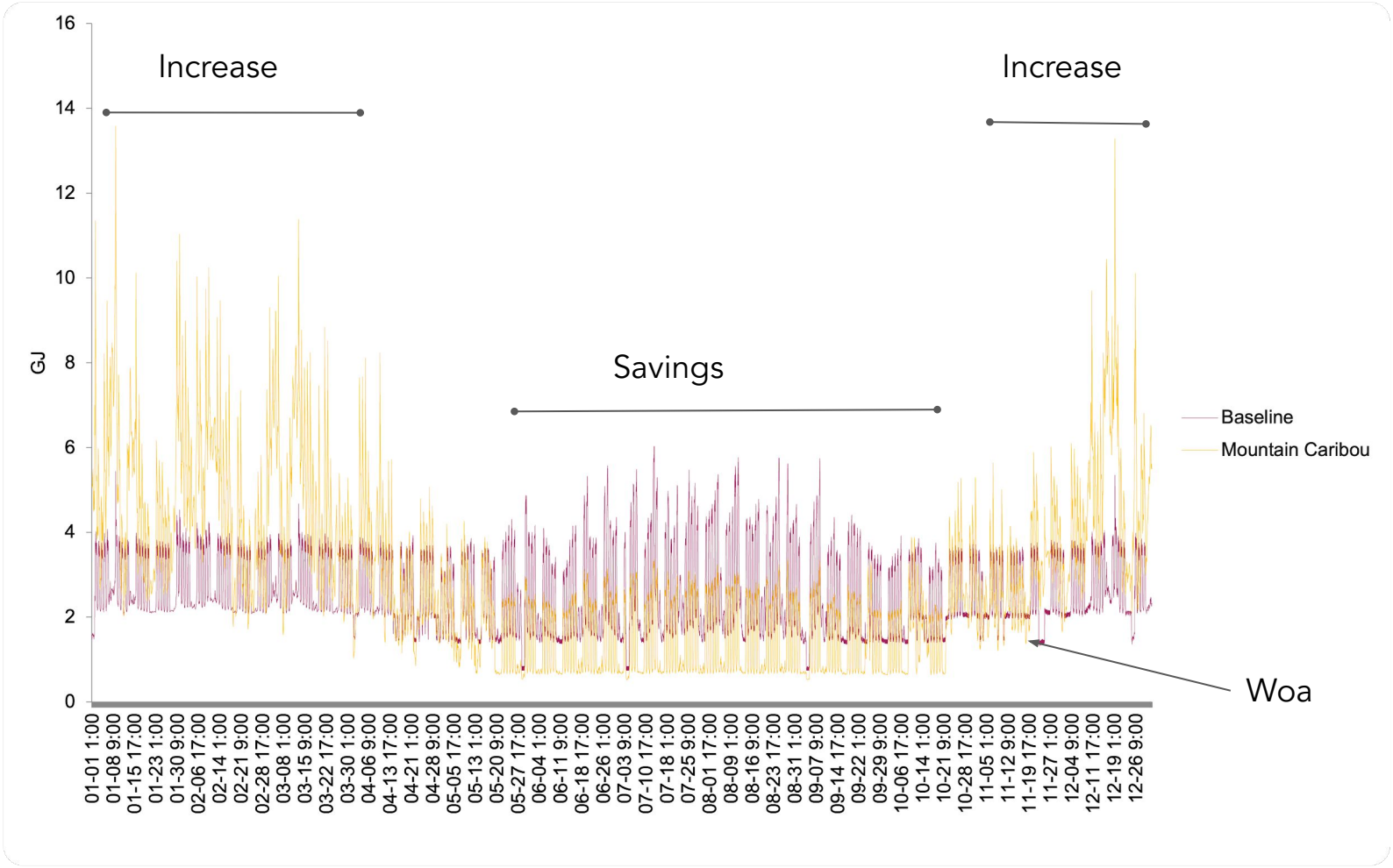
11-25 5:00
12-02 16:00
12-10 3:00
12-17 14:00
12-25 1:00
Baseline
Mountain Caribou
Electrification Only
June-July
December

Peak Shift


Increase
Increase
Savings
Woa
GJ
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14
12
10
8
6
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Baseline
Mountain Caribou
01-01 1:00
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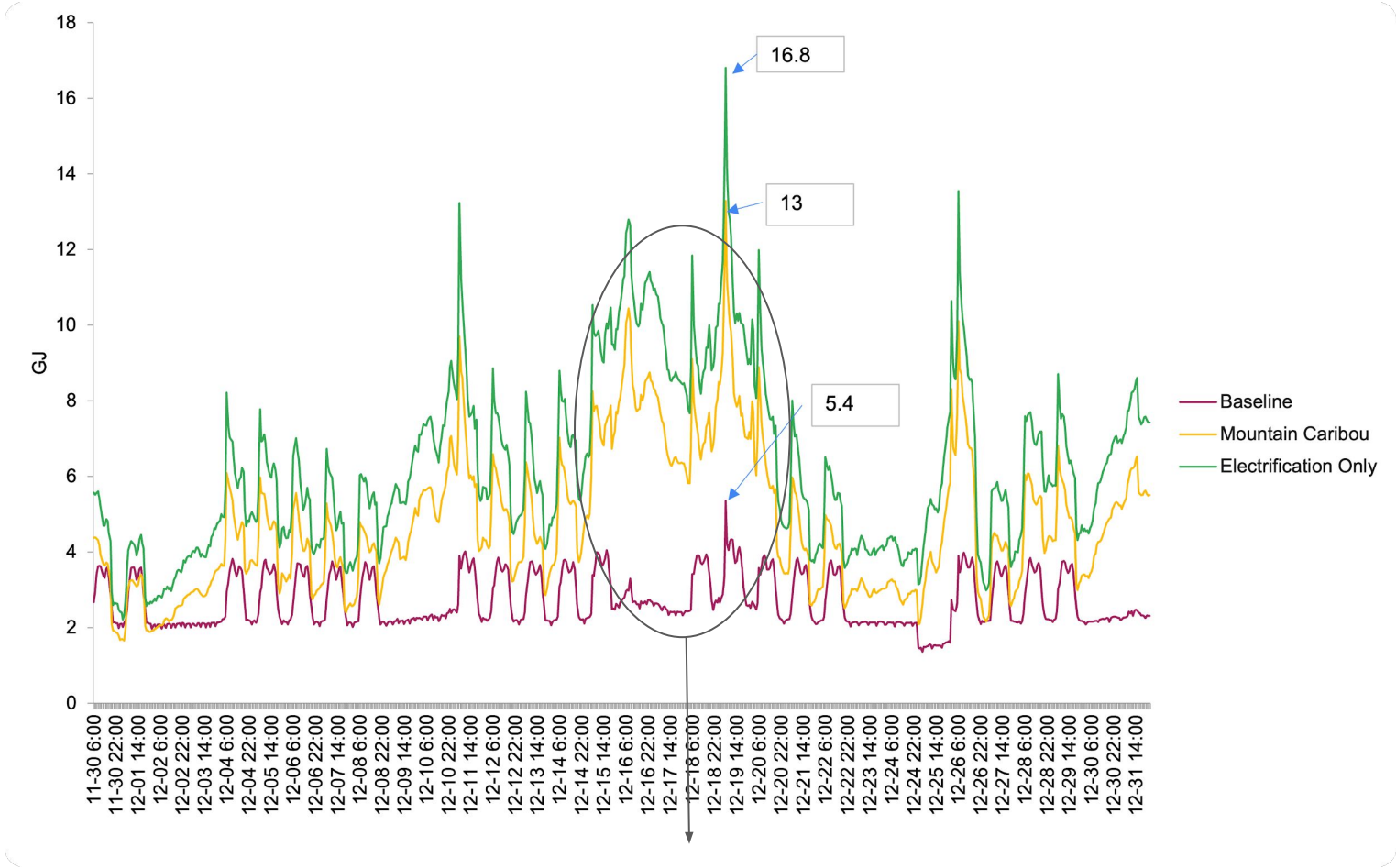
December


18
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GJ
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Baseline
Mountain Caribou
Electrification Only
11-30 6:00
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12-01 14:00
12-02 6:00
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12-03 14:00
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12-04 22:00
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12-06 22:00
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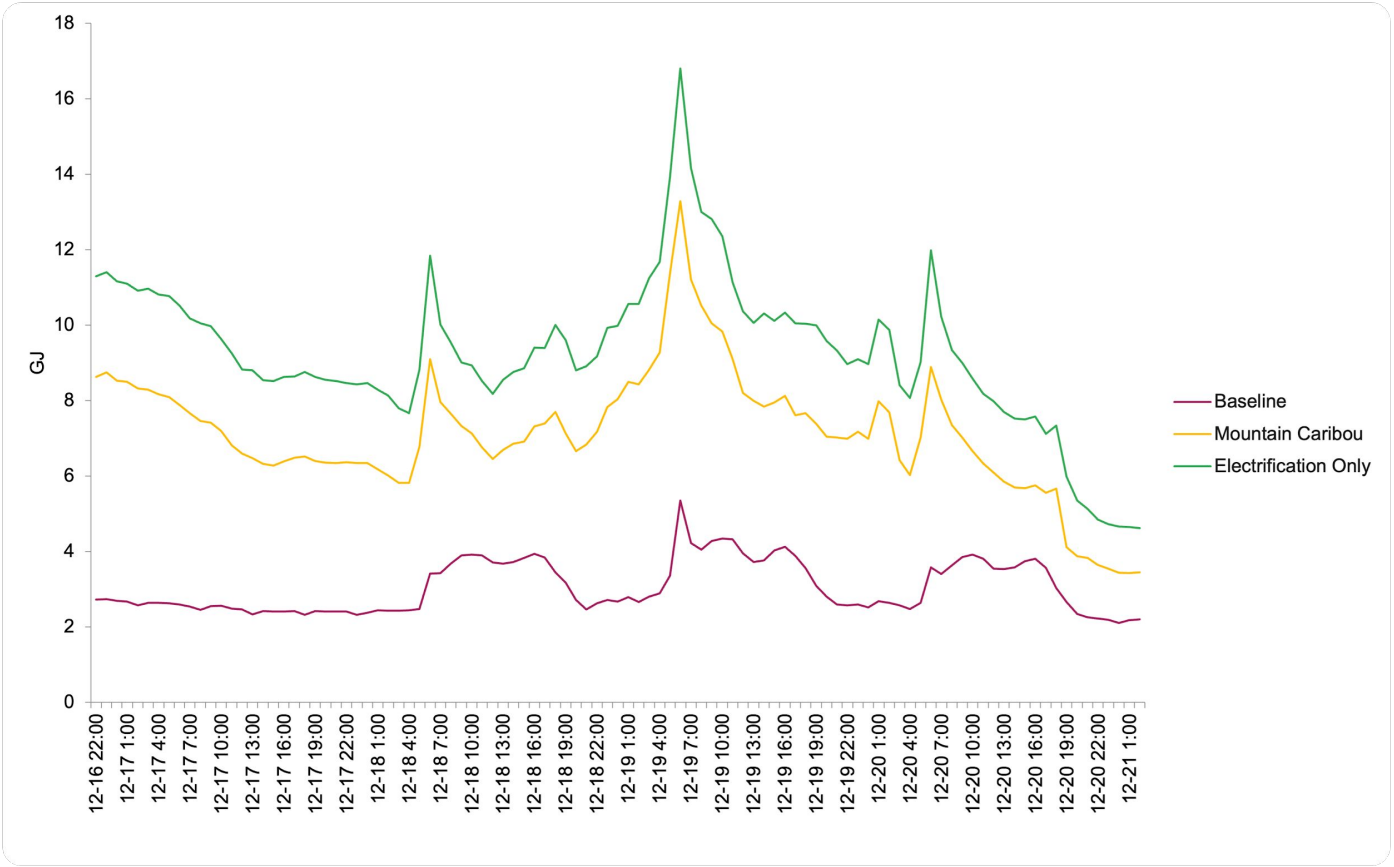
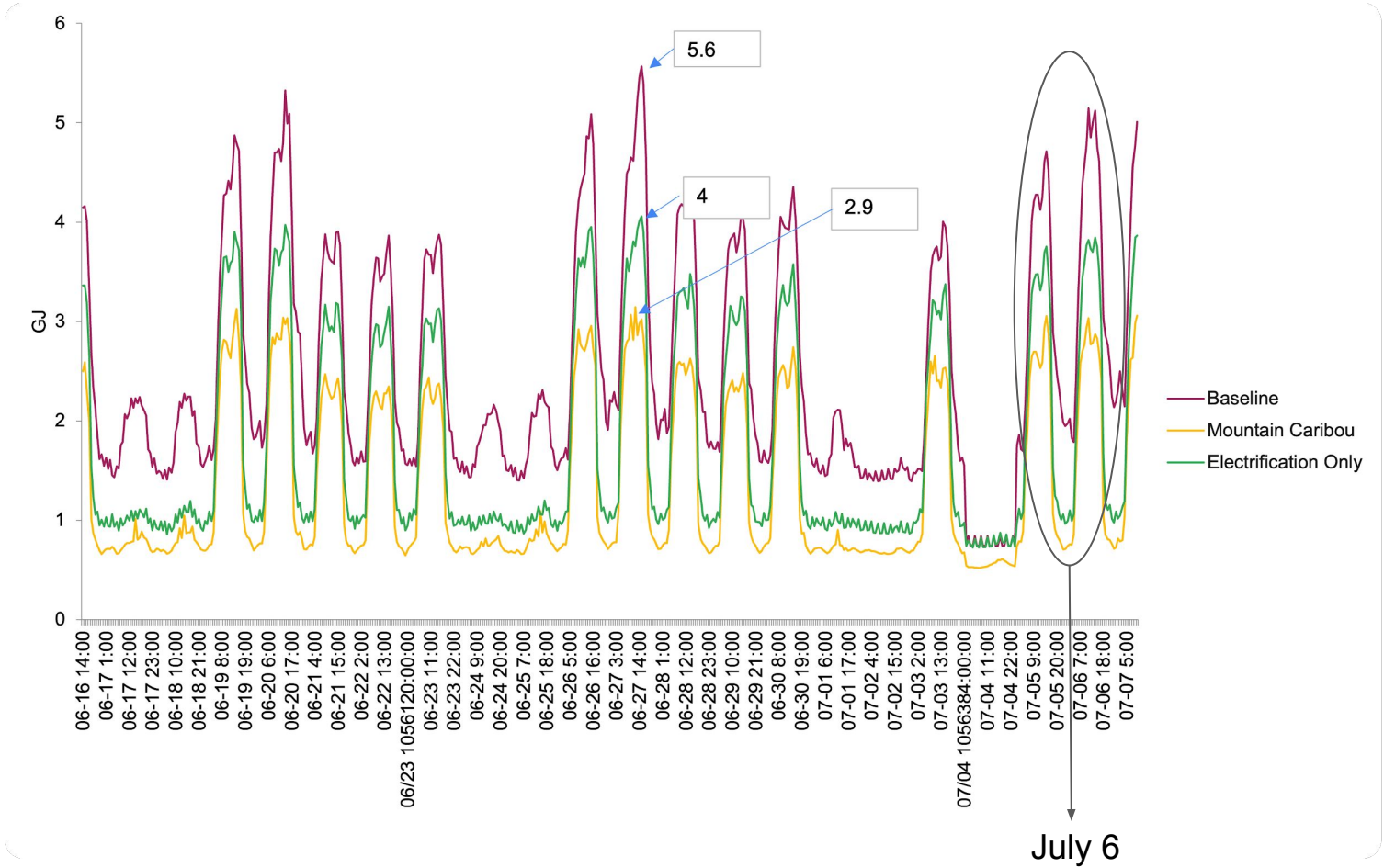
December 18

December 17-20



June-July


GJ
0
1
2
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2.9
06-16 14:00
06-17 1:00
06-17 12:00
06-17 23:00
06-18 10:00
06-18 21:00
06-19 8:00
06-19 19:00
06-20 6:00
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06-21 15:00
06-22 2:00
06-22 13:00
06/23 1056120:00:00
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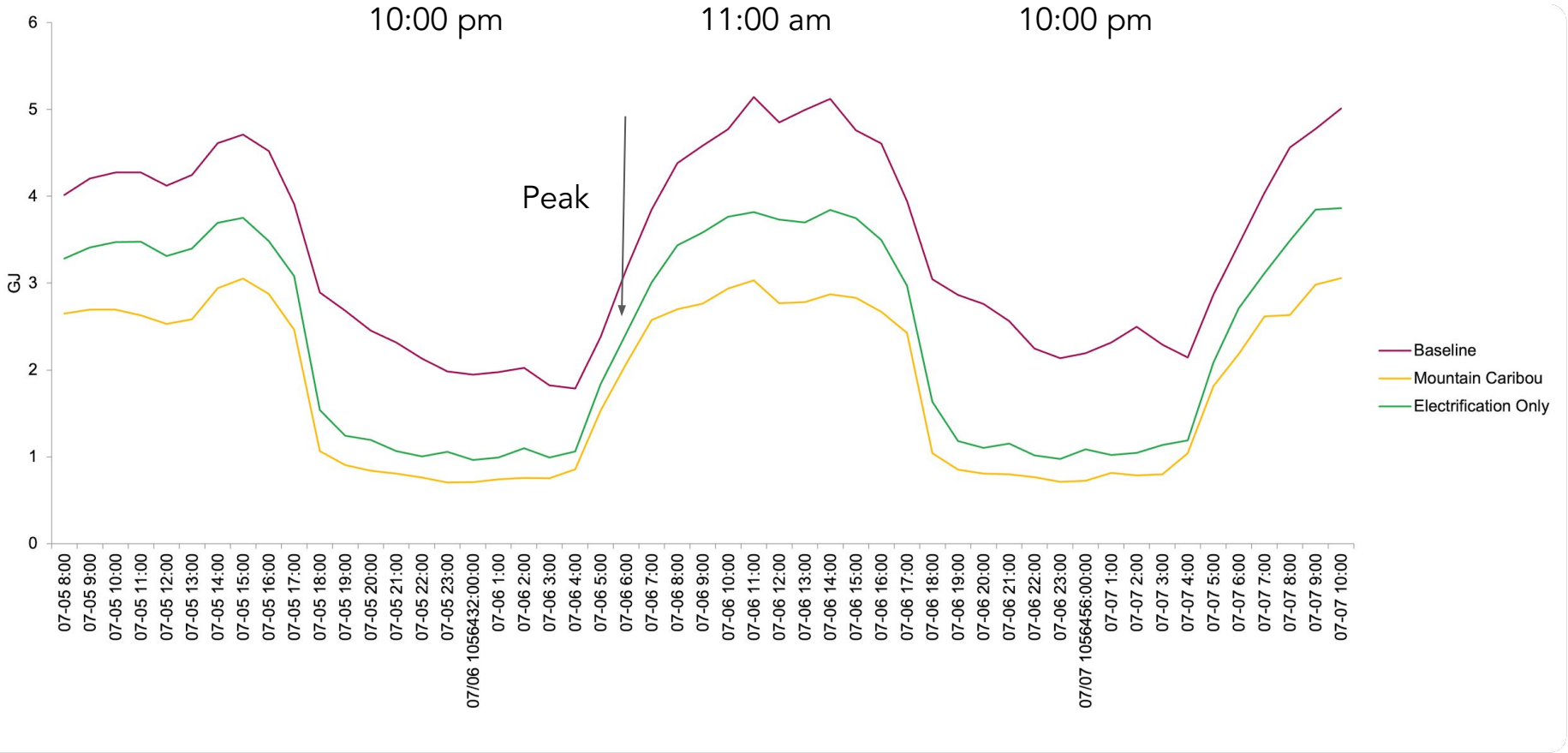
Baseline
Mountain Caribou
Electrification Only
July 6

July 6


10:00 pm
11:00 am
10:00 pm
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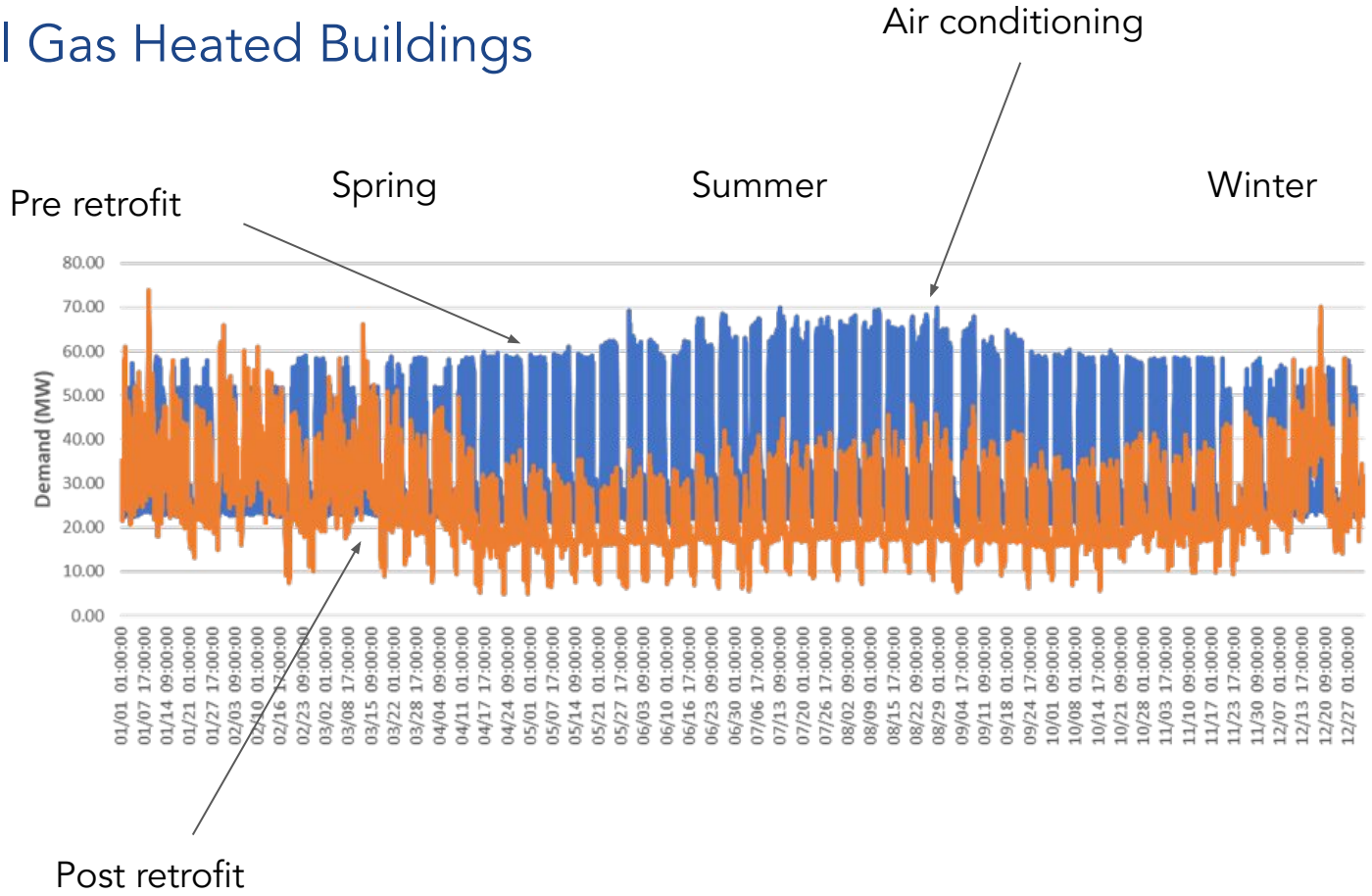
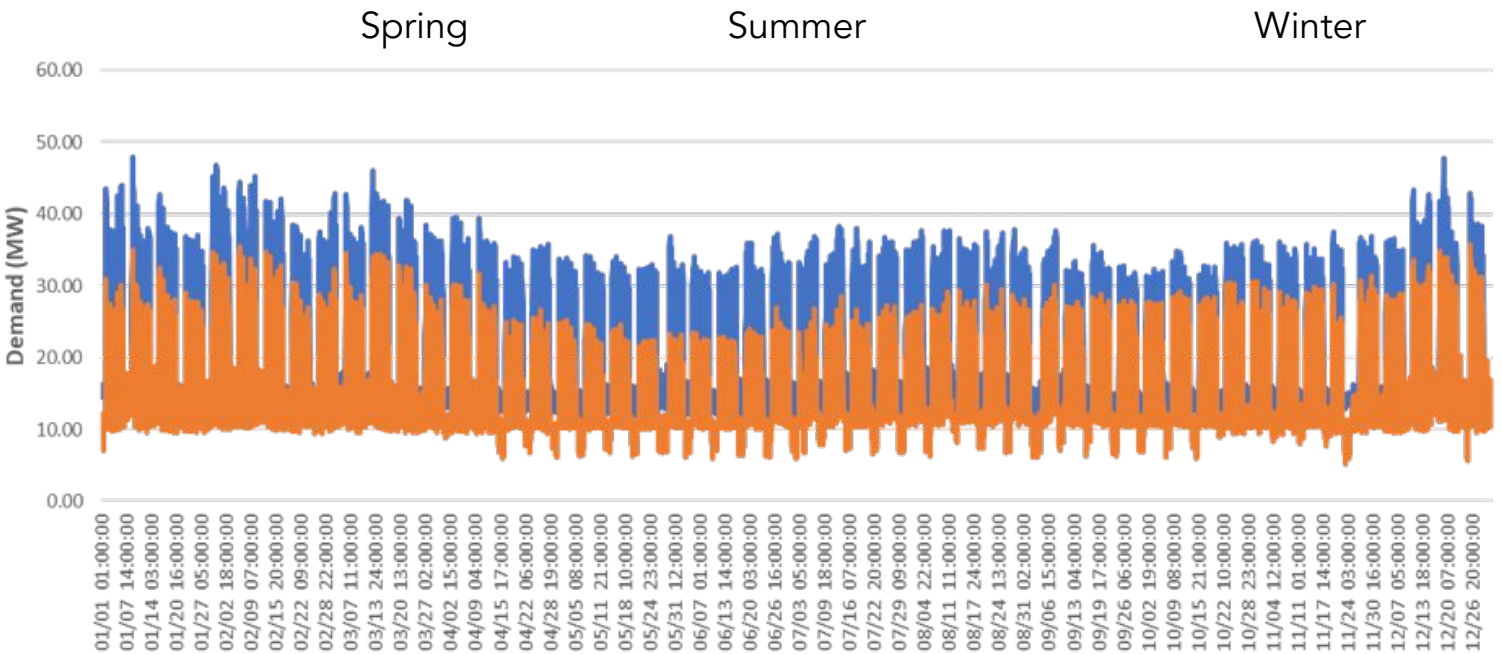
Baseline
Mountain Caribou
Electrification Only

Natural Gas Heated Buildings



Electrically Heated Buildings



Neighbourhood decarbonization simplified:

Four houses each require 100 GJ of heat, 1 with electric baseboards, 3 with high eff gas
25 GJ each for lights and appliances
75 GJ gasoline per car
Total electricity use: 200 GJ
Total emissions for four households, fuels and electricity:
If grid electricity at 100 g/kWh: 60 tonnes CO2e
If grid electricity carbon-free: 40 tonnes CO2e

Retrofits reduce heat requirement to 60 GJ per house
Heat pumps with 290% seasonal efficiency
25% improvement in lights and appliance efficiency
Electric vehicles at 20 kWh/100 km
Total electricity use: 200 GJ
Solar on two homes each generate 4,000 kWh/year
Total emissions, fuel and electricity:
If grid electricity at 100 g/kWh: 20 tonnes CO2e
If grid electricity carbon-free: Zero emissions

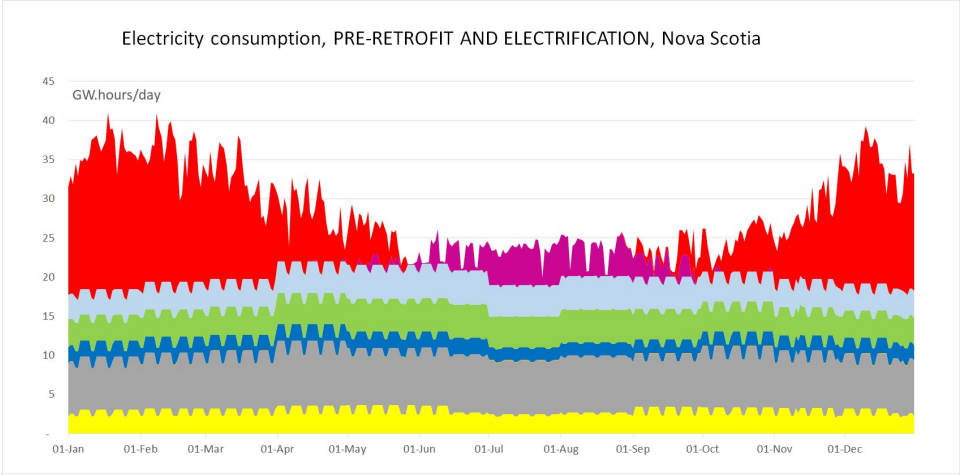
Pre (top) and post (bottom) retrofit and electrification scenario for Nova Scotia -- very similar level and pattern of demand before and after, but demand and peak down slightly, even with extensive vehicle and building conversion to electricity.

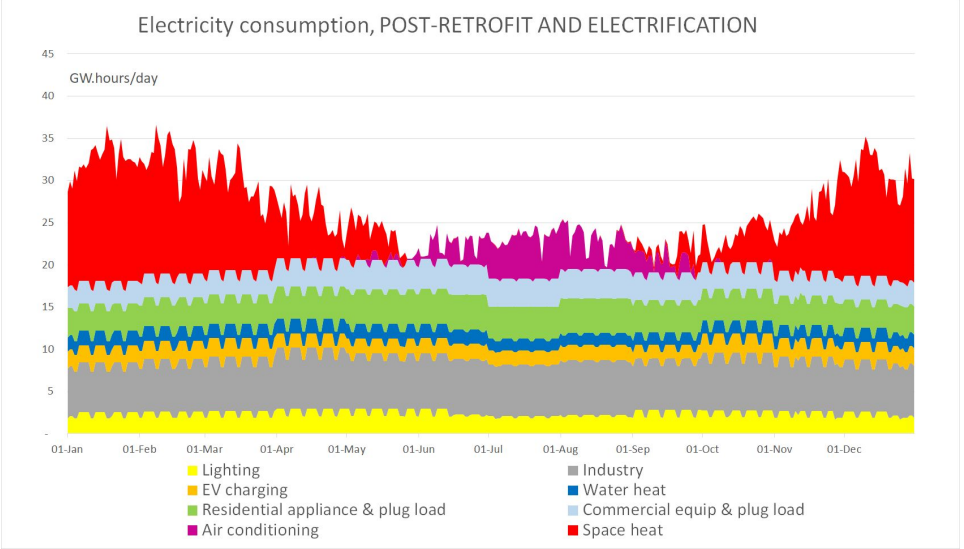
-- Half the personal vehicle fleet electrified.

-- Share of residential and commercial building floor area heated with electricity up 125%.

-- Thermal loss of housing stock, down 43% and commercial buildings down 36%.

-- Electric resistance heating phased out in favour of heat pumps.





Findings

1. Electrification of heating need not increase the peak
   a. Retrofits and heat pumps for electric resistance heating
   b. Heat pump efficiencies + retrofits for gas buildings

2. The peak shifts
   a. Peak demand shifts from summer to winter
   b. Peak increase is moderated by resistance-to-heat pumps

3. The base share of electrical heating is a resource.
   E.g. Residential sector: electrification of building space and water heating (via heat pumps) will result in decreases or only modest increases in aggregate electricity consumption, for most Canadian provinces.

4. Electrification of transportation is more "controllable"
   a. V2G: EVs as portable storage capacity

> Efficiency, electrification and decarbonization are interconnected and interdependent

> Realizing their full potential will require an integrated, systems approach to both policies and business strategies.