DECISION-SUPPORT TOOLS FOR DUAL-FUEL HEATING SYSTEMS (CAN DUO-THERM AND CAN OPTI-WATT)

Context

Space heating represents the primary energy end use in the Canadian commercial and institutional building sector, with natural gas and electricity being the main energy sources used for heating [1].

In regions powered by low-carbon electric grids, buildings serviced by heating plants equipped with both electric and natural gas boilers can substantially lower their greenhouse gas (GHG) emissions by increasing the contribution of electric boilers in meeting heating demand.

Generally, the electricity pricing structure for commercial and institutional buildings includes a charge for both energy and maximum power demand during the billing period. To avoid excessive power demand charges, building energy managers often determine a limit, typically referred to as the building peak limit.

Problem

In buildings equipped with dual fuel heating plants (electricity and natural gas), an increased contribution of electric boilers in meeting heating demand can be hindered by two major factors:

- Inefficient and/or underutilized operation of the electric boiler in a dual-fuel heating system often remains undetected if the natural gas boiler can handle most of the building's heating demands.
- The building peak power limit might be outdated (no longer representative of current building operation or needs), or it might have been decided without taking GHG emissions into account.

To uncover these issues, a systematic analysis of operational data from the heating plant is essential.

Solution

CanmetENERGY in Varennes developed simplified software tools that automatically analyze operational data from dual-fuel heating plants and identify opportunities for increasing electric boiler contribution in meeting building heating demand. These tools require a small number of inputs (operational data and boiler specifications) and provide users with recommendations for operating electric boilers more often and at higher capacities without negatively affecting thermal comfort and heating costs. Two software tools were developed:

- **Can Duo-Therm: identifies the following inefficiencies related to electric boiler operation**
  - · Electric boiler does not provide requested power output
  - · Electricity is underused for heating given the building's peak limit
  - · Electric boiler is underutilized at low outdoor temperatures
- **Can Opti-Watt: estimates the heating costs and GHG emissions corresponding to the operation of the dual-fuel heating plant under different building peak power limits**

Results

Building case study

The calculations performed by the software and the results obtained are illustrated using a study that was carried out to increase the electric heating of a large office building located near Montreal, Quebec, Canada. The building has a total floor area of 33,000 m2 and hosts around 800 people. The building is occupied during business hours from Monday to Friday and remains mostly unoccupied during weekends/holidays. The heating plant is composed of one electric boiler (nominal capacities of 800 kW) and two natural gas boilers (nominal capacity of 1,965 kW and efficiencies of 80%) and supplies hot water in heating coils of 60 single and dual-duct air handling units to satisfy space heating requirements. The building operates under a peak demand limit of 1,595 kW and is subject to an electric utility rate structure that charges for both power demand and energy consumption. Operational data for a period of four winter months was used in this study.

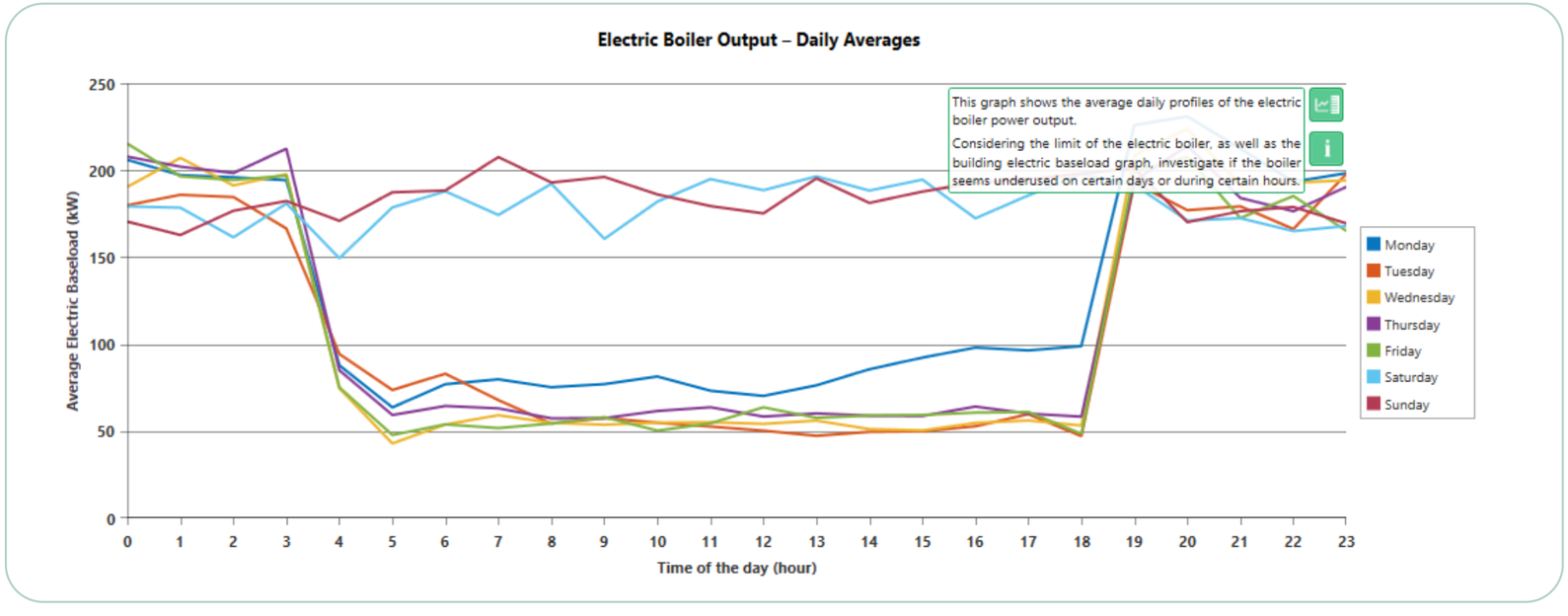

Figure 1. Electric boiler output daily average

Inefficiencies

Can Duo-Therm was used to analyze operational data from the heating plant, and the following inefficiencies were detected:

- The electric boiler delivered, on average 40% less power than requested. Upon investigating this issue, it was found that some elements were burnt.
- The electric boiler was used minimally during business hours on weekdays, despite a significant remaining power margin for the electric boiler to contribute to the heating demand without exceeding the building's limit. (Figure 1).
- The electric boiler provided much less heat in colder weather. Its share of heating demand falls from 61.2% when outdoor temperatures are between 0 and 10 °C, to only 16.4% when temperatures drop to -10 to 0 °C and even lower at colder conditions. This happens because the system's control settings favor the gas boiler: the electric boiler's low supply temperature limit prevents it from running effectively in very cold weather (Figure 2).

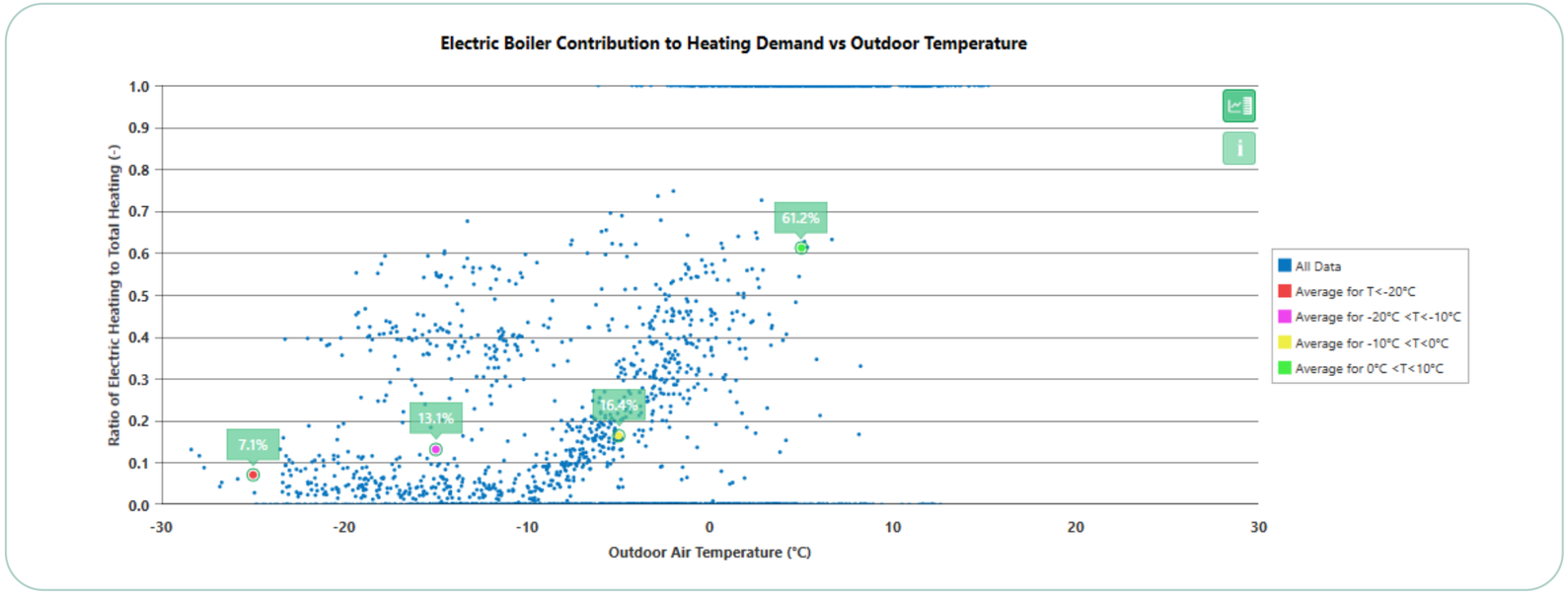

Figure 2. Electric boiler contribution to building heating demand according to the outdoor temperature

Can Duo-Therm provides users with the electric and gas boiler usage, emissions, and heating costs corresponding to the correction of each inefficiency. The results obtained for the building used in this example are shown below.

	Electric boiler use (MWh)	Gas boiler use (m^3)	Heating emissions (tCO2e)	Heating cost (CAD)
Current operation	337.2	118,423.2	228.7	78,040
Fixed burnt elements	343.1 (+1.7%)	117,722.4 (-0.6%)	227.3 (-0.6%)	77,973 (-0.1%)
Improved boiler schedule	561.9 (+66.6)	91,729.4 (-22.5%)	177.6 (-22.3%)	75,484 (-3.3%)
Improved heating plant controls	818.1 (+142.6)	61,290.5 (-48.2%)	119.4 (-47.8)	72,570 (-7%)
Combined Improvements	1,048.7 (+211%)	33,895.9 (-71.4%)	66.9 (-70.7%)	69,947 (-10.4%)

The most impactful improvements for decarbonizing the building are the electric boiler schedule and heating plant controls. These changes triple electric boiler usage and cut heating plant emissions by almost 71%.

Peak power limit modification

Can Opti-Watt evaluated the impact of raising the building peak limit from 1,595 to 1,795 kW on heating costs and emissions; it was found that a significant reduction of 48% of emissions can be achieved at a heating cost increase of approximately 10% due to increasing the building peak limit.

Peak limit (kW)	Electric boiler use (MWh)	Gas boiler use (m^3)	Heating emissions (tCO2e)	Heating energy cost (CAD)	Peak Cost (CAD)
1,595	1,048.7	33,895.9	66.9	69,947	108, 460
1,775	1,192.9 (+13.8%)	16,763.2 (-50.5%)	34.3 (-48.7%)	68,307 (-2.3%)	120,700 (+11.2%)

REFERENCES

Natural Resources Canada, Energy Use in the Commercial/Institutional Sector
Canada Energy Regulator. Provincial and Territorial Energy Profiles – Quebec 2024

Key Takeaways

- Inefficient operation of the electric boiler in a dual-fuel heating system can often remain undetected if the natural gas boiler can handle most of the building's heating demand.
- Peak power limits in buildings can restrict electric heating and should be determined through an analytic approach that accounts for both heating costs and associated GHG emissions.
- The Can-DuoTherm and Can-OptiWatt software help users identify opportunities to increase the role of electric heating in meeting building heating demand.

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