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RESEARCH ARTICLE

Thermal Modeling and Electric Space Heating of a University Building in Newfoundland

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ABSTRACT

Buildings play a substantial role in global energy consumption, constituting a considerable share of the overall energy use. In Canada, they contribute to around 25% of the total final energy consumption. Notably, space heating emerges as the primary energy consumer, accounting for approximately 57% of energy utilization in institutional and commercial buildings. This paper presents a feasibility analysis of converting the space heating system of the Core Science Facility (CSF) building of Memorial University of Newfoundland (MUN). Analysis is done using RETScreen Clean Energy Management Software, known as RETScreen Expert, a software package developed by the Government of Canada, and the thermal modeling of the building using Energy3D, developed by the National Renewable Energy Laboratory (NREL). The feasibility study indicates that significant savings can be achieved if space heating is switched to electric resistive heating. The results indicate a 24.2% savings in annual energy costs, with a simple payback period of 10.5 years. The simulation results from Energy3D are compared with the measured building energy consumption data provided by the MUN Facilities Management Department. The thermal model indicates less energy consumption than the actual measured values, which is a result of transmission losses, the interconnection between the CSF building and the University Center, building occupancy, the ventilation system, and degradation of equipment that are not considered in the model.

Keywords: RETScreen expert, energy3D, thermal modeling, space heating.

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1. INTRODUCTION

1.1. *Thermal Modeling and Simulation of Buildings*

Buildings are responsible for approximately 40% of the overall energy consumption worldwide [1]. In contrast, in Canada, buildings are responsible for a significant proportion of the country's energy demand, claiming approximately 25% of the total final energy consumption, which accounts for approximately 729.52 Tera-Watt hours (TWh) [2]. Due to the extended lifespan of buildings, enhancing building energy efficiency can play a crucial role in reducing operational expenses and emissions, concurrently promoting sustainability. Research suggests that new buildings employing energy efficiency measures can reduce energy consumption significantly [1]. Furthermore, it is also suggested that the use of the most efficient walls, windows, and HVAC equipment currently available can reduce heating by up to 77% and cooling by up to 78% in commercial buildings [3]. In the context of commercial buildings in Canada, space heating accounts for approximately 57% of the total energy consumed by a building [4]. This highlights a significant opportunity for energy savings in the context of building energy consumption.

Building energy modeling (BEM), which can be developed for new builds as well as for existing buildings, can provide a detailed and predictive analysis of a building's energy performance. By integrating data on architectural design, materials, HVAC systems, lighting, and occupant behavior, energy models simulate the dynamic interactions within a building to quantify energy consumption and thermal comfort [1], [5]. Building energy models can also be used in assessing the impact of different technologies, insulation methods, and renewable energy integration, guiding decision-making to achieve optimal energy performance. The models serve as powerful tools for predicting, analyzing, and implementing strategies to reduce energy consumption, lower operational costs, and meet sustainability goals, ultimately contributing to the development of more resource-efficient and environmentally friendly buildings.

The climatic condition of a building's location is a crucial factor influencing the amount of energy consumed by that specific structure, as the climatic condition of a region has a direct influence on a building's heating, cooling, and overall energy needs. For the classification of different climates, various standards such as the ASHRAE climatic data for building design standards are employed to categorize climates based on a number of factors, including but not limited to temperature, degree-days, and degree-hours, wind, and precipitation [6]. These classifications help in selecting appropriate building materials, HVAC systems, and insulation, ensuring that energy models accurately reflect the real-world conditions a building will face. Based on this classification, the Government of Canada has developed the National Energy Code of Canada for Buildings 2017, a guideline for the provincial and territorial governments for formulating legislation governing the design and construction of buildings within their jurisdictions [7]. These standards and regulations can serve as a foundation for developing BEMs, especially when building-specific data is unavailable.

Energy3D is a simple, versatile, and user-friendly energy modeling software tool designed for simulating and analyzing the energy performance of buildings and renewable energy systems. Energy3D stands out for its simple user interface, and ability to create detailed 3D models of buildings and landscapes, allowing users to explore and visualize the impact of various design elements on energy efficiency [8]. Energy3D can facilitate an extensive scope of applications, from assessing renewable energy technologies such as wind turbines and solar photovoltaics to modeling the thermal behavior of structures [9]. With an intuitive interface, Energy3D is accessible to both students and professionals, making it a valuable tool for educators, architects, and researchers engaged in the study and optimization of energy solutions in the built environment.

1.2. Energy Project Planning

For any project to proceed, it must demonstrate technical feasibility and, perhaps more crucially, financial viability. In this context, the role of project planning becomes pivotal, underlining the significance of meticulous planning, especially in the context of embracing sustainable and low-carbon measures within energy projects. Proper planning lays the groundwork for efficient execution, monitoring, and reporting. In this regard, software platforms and simulation tools are regarded as reliable approaches in the planning of energy projects. Planning software plays a central role, facilitating not just in the detailed design of projects but also in the smooth incorporation of sustainable practices. These tools facilitate the identification of optimal approaches to cost reduction, enhancing quality and reliability to meet project objectives, all the while minimizing the project's carbon footprint from its initiation. Nevertheless, the effectiveness of planning software relies on its adaptability and precision, as deficiencies in these aspects could risk the overall success of planning and implementation of a project. Therefore, while planning software plays a crucial role, its choice and implementation require meticulous consideration to optimize its positive influence on the objectives of an energy project.

RETScreen Clean Energy Management Software (RETScreen) is a versatile analysis tool renowned for its effectiveness in clean energy project analysis and implementation. Having been developed by the Department of Natural Resources Canada, in collaboration with a number of Canadian and International organizations, RETScreen can facilitate a comprehensive assessment of various energy sources by analyzing costs, savings, emissions reductions, and the financial viability of renewable energy and energy-efficient technologies, enabling the process of making well-informed decisions.

2. BUILDING FOR THE CASE STUDY

This study focuses on the Core Science Facility (CSF) building, covering a total floor area of 40,817 square meters (m^2) spread across five floors. Situated on the Memorial University of Newfoundland (MUN) campus in St. John's, Newfoundland, this facility accommodates teaching rooms, research laboratories, and office spaces exclusively designated for the Department of Electrical and Computer Engineering within the Faculty of Engineering and Applied Science at Memorial University. Interconnected through Wing C's Level 2, the CSF building is linked to the University Centre (UC) of Memorial University of Newfoundland (MUN), serving as a central hub for interconnecting various other buildings and departments. The CSF building is oriented in a North-West direction, positioned at an angle of approximately 40 degrees from the North.

The CSF building utilizes two energy sources, electricity and hot water, for space heating. The hot water is sourced from the central heating plant located in the university's Utility Annex. This facility generates hot water through boilers powered by diesel oil #2. In the calendar year 2022, CSF building consumed 12,706.138 kWh of electricity and 1,100,109 litres of diesel oil #2 [10], which has been considered as the input for this study.

The Utility Annex, under the supervision of the Department of Facilities Management of MUN, intends to substitute a non-operational oil-fired hot water boiler with

Fig. 1. Core science facility building.

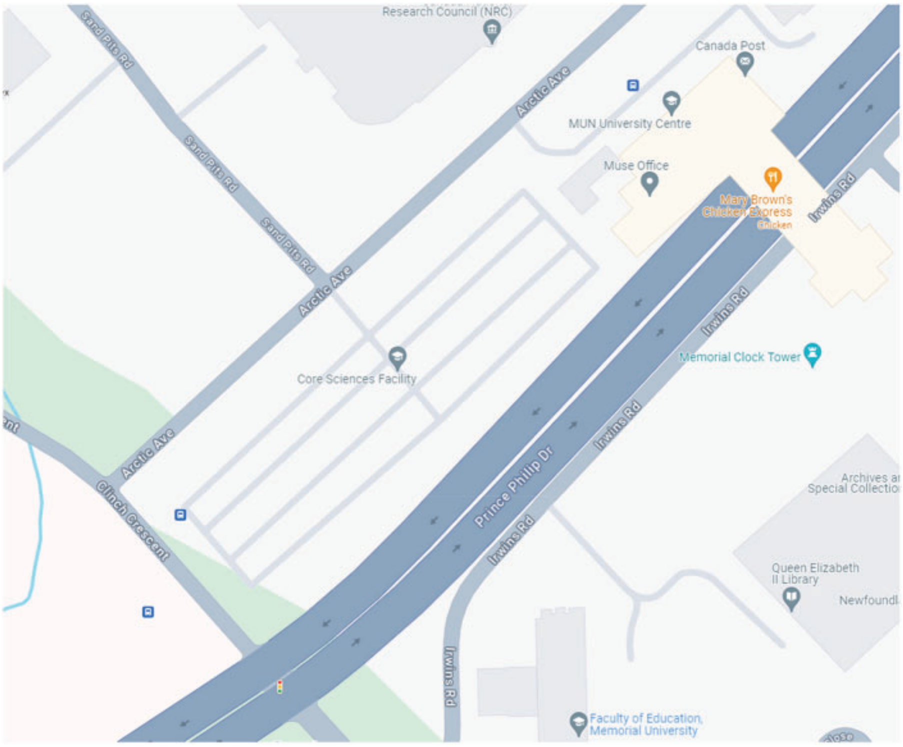


Fig. 2. Orientation of the building [12].

two electric resistive heating boilers [11]. The projected cost for this replacement, inclusive of decommissioning the non-functional oil-fired boiler, is $16.5 million. This estimate also includes expenses related to equipment, installation and commissioning, project management, contract administration, and operation and maintenance throughout the project duration.

For this study, considering the anticipated fuel savings from this project and the fuel consumption of the CSF building, it is assumed that a single electric boiler with a capacity equivalent to that of those proposed for this project can fulfil the heating needs of the CSF building. The associated cost for one such boiler, encompassing installation, commissioning, and all support services, is estimated to be $8 million.

Figs. 1 and 2 show CSF building and its location on Google Maps.

3. Project Feasibility Analysis using RETScreen

The latest version of RETScreen, version 9, available as RETScreen Expert, was used for the analysis.

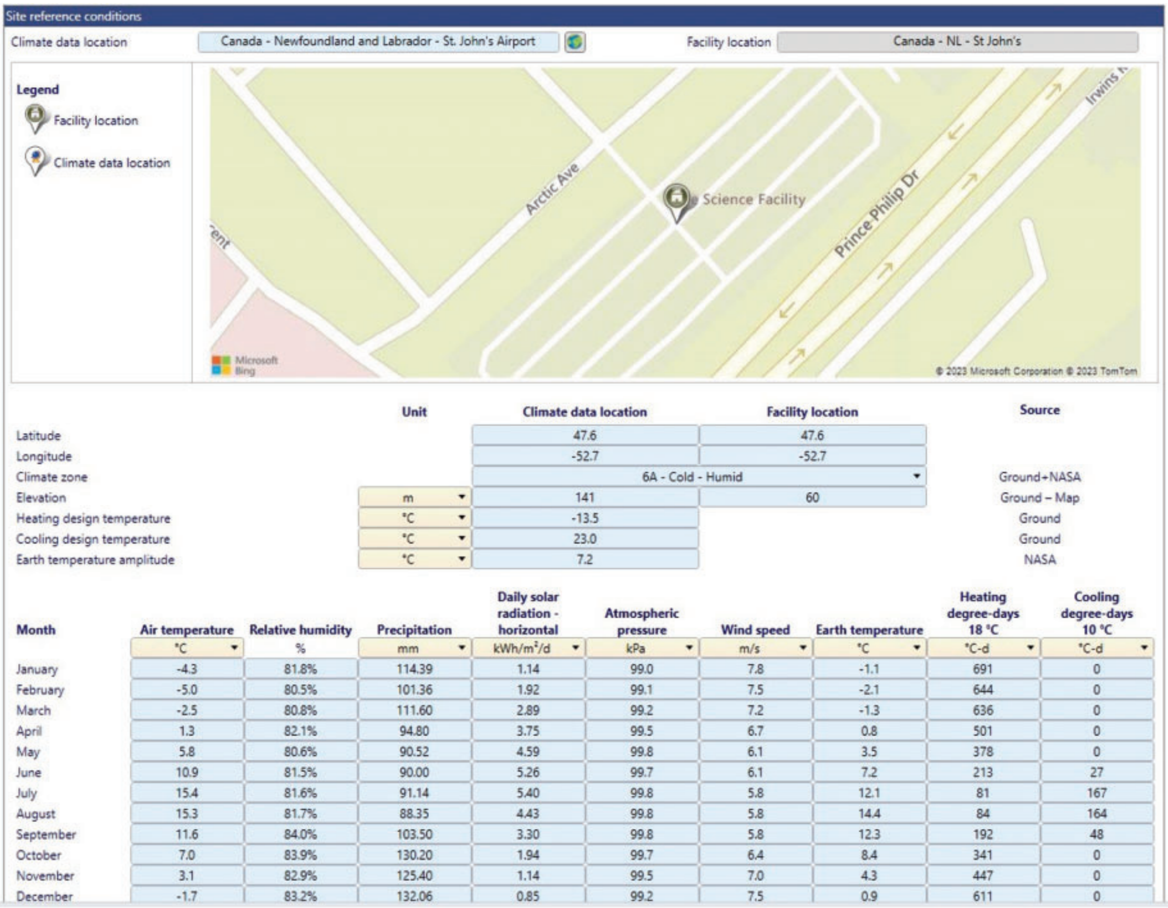
The first screen requires the user to select an option from a list of different analysis types, including a virtual energy analyzer, Benchmark, Feasibility, Performance, and an option that combines all aforementioned analyses. The scope covered under different options is graphically represented in the chart next to the list, and for this study, the feasibility option was considered.

In the next screen, the location of the project was selected. Selection of location was made through an interactive map available within RETScreen, which returned a range of data applicable to the site, including but not limited to the geographical coordinates, climate zone in accordance with ASHRAE thermal climate zones [6] and weather data on a monthly basis. These data can serve as the foundation for assessing heating, cooling, and overall energy demands accurately. Figs. 3 and 4 show the RETScreen interface and input of location and weather data.

Following the entry of the exact location, the subsequent screen, found under the Facility tab, facilitated the input of building details into the software. Information such as the type of the facility, building's floor space, annual electricity, and diesel oil consumption were provided, which in turn calculated results such as total energy consumption in kilowatt-hours (kWh) and the energy use intensity (EUI) in gigajoules per square meter of floor space (GJ/m^2). Additionally, this screen can also be used to input any anticipated energy-saving targets and benchmark the energy consumption of the building with other similar facilities. Throughout the application, the term base case was considered as the existing scenario, and the term proposed case was considered as the replacement of an oil-fired hot water boiler with an electric resistive boiler unit. Fig. 5 shows some details of CSF building in RETScreen.

In the following tab labelled "Energy," comprehensive details regarding energy consumption were input, including information on electricity and fuel types, rates for fuel and electricity, seasonal efficiency for equipment in both base and proposed cases, and fuel consumption for both base and proposed scenarios. Annual average rates of fuel were calculated from the energy report for CSF building [10]. It was assumed that the energy consumption of the building would remain the same for both the base and proposed case, with no additional energy efficiency initiatives taken. Furthermore, it was also assumed that the operational and maintenance cost would remain the

Fig. 3. Types of studies available in RETScreen.



Site reference conditions

Climate data location: Canada - Newfoundland and Labrador - St. John's Airport

Facility location: Canada - NL - St John's

	Unit	Climate data location	Facility location	Source
Latitude		47.6	47.6	
Longitude		-52.7	-52.7	
Climate zone		6A - Cold - Humid		Ground+NASA
Elevation	m	141	60	Ground – Map
Heating design temperature	°C	-13.5		Ground
Cooling design temperature	°C	23.0		Ground
Earth temperature amplitude	°C	7.2		NASA

Month	Air temperature	Relative humidity	Precipitation	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days 18 °C	Cooling degree-days 10 °C
	°C	%	mm	kWh/m²/d	kPa	m/s	°C	°C-d	°C-d
January	-4.3	81.8%	114.39	1.14	99.0	7.8	-1.1	691	0
February	-5.0	80.5%	101.36	1.92	99.1	7.5	-2.1	644	0
March	-2.5	80.8%	111.60	2.89	99.2	7.2	-1.3	636	0
April	1.3	82.1%	94.80	3.75	99.5	6.7	0.8	501	0
May	5.8	80.6%	90.52	4.59	99.8	6.1	3.5	378	0
June	10.9	81.5%	90.00	5.26	99.7	6.1	7.2	213	27
July	15.4	81.6%	91.14	5.40	99.8	5.8	12.1	81	167
August	15.3	81.7%	88.35	4.43	99.8	5.8	14.4	84	164
September	11.6	84.0%	103.50	3.30	99.8	5.8	12.3	192	48
October	7.0	83.9%	130.20	1.94	99.7	6.4	8.4	341	0
November	3.1	82.9%	125.40	1.14	99.5	7.0	4.3	447	0
December	-1.7	83.2%	132.06	0.85	99.2	7.5	0.9	611	0

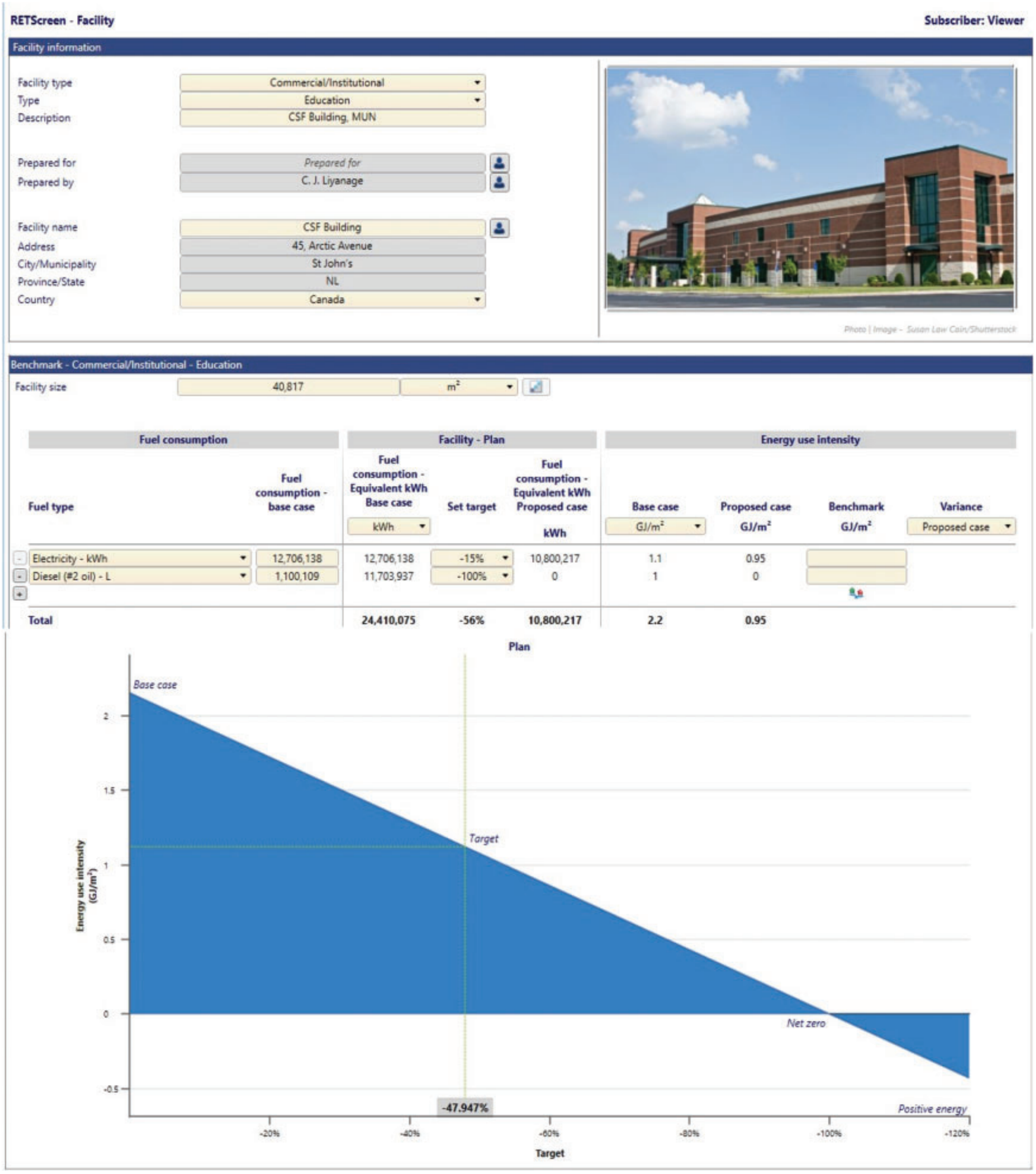
Fig. 4. Selection of location on RETScreen.

same for both cases, even though this is likely to reduce for electric resistive boiler systems when compared to oil-fired hot water boilers.

This tab also facilitates the incorporation of operational parameters, such as set temperatures for heating and cooling, and occupancy rates, which were not considered under this study. The data considered under this section is tabulated in Table I.

Upon inputting all the necessary data, RETScreen summarized the proposed project. This summary compared the base and proposed cases, highlighting the annual savings in both cost and fuel. Some RETScreen comparison results are shown in Fig. 6.

RETScreen also has the capability to conduct a more thorough assessment of energy projects, considering



RETScreen - Facility **Subscriber: Viewer**

Facility information

Facility type: Commercial/Institutional
Type: Education
Description: CSF Building, MUN

Prepared for: *Prepared for*
Prepared by: C. J. Liyanage

Facility name: CSF Building
Address: 45, Arctic Avenue
City/Municipality: St John's
Province/State: NL
Country: Canada

Photo | Image – Susan Law Cain/Shutterstock

Benchmark - Commercial/Institutional - Education

Facility size: 40,817 m²

Fuel consumption		Facility - Plan			Energy use intensity			
Fuel type	**Fuel consumption - base case**	**Fuel consumption - Equivalent kWh Base case** kWh	**Set target**	**Fuel consumption - Equivalent kWh Proposed case** kWh	**Base case** GJ/m²	**Proposed case** GJ/m²	**Benchmark** GJ/m²	**Variance** Proposed case
Electricity - kWh	12,706,138	12,706,138	-15%	10,800,217	1.1	0.95		
Diesel (#2 oil) - L	1,100,109	11,703,937	-100%	0	1	0		
Total		**24,410,075**	**-56%**	**10,800,217**	**2.2**	**0.95**		

Fig. 5. Facility information on RETScreen.

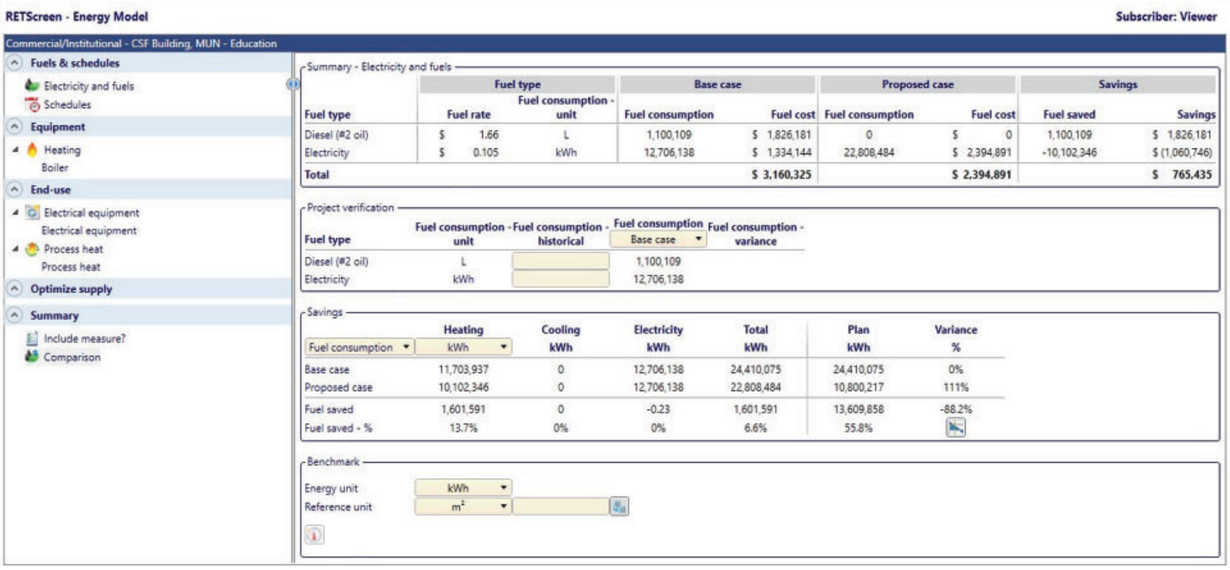
TABLE I: Parameters Considered for the Feasibility Study

Section	Subsection	Parameter	Base case	Proposed case
Fuels and schedules	Electricity and fuels	Fuel type and rate	Diesel oil #2– $1.66/liter Electricity–$0.105/kWh	Not considered Electricity–$0.105/kWh
Equipment	Heating-boiler	Fuel type	Diesel (#2 oil)	Electricity
		Seasonal efficiency	82%	95%
		Incremental initial cost	–	$8,000.000
		Incremental O&M savings	–	–
End-use	Electrical equipment	Energy consumption	12,706.138 kWh	12,706.138 kWh
	Process heat (space heating)	Energy consumption	9,597.228 kWh	9,597.228 kWh

factors such as emission savings, project financing alternatives, and sensitivity and risk analysis. However, this in-depth analysis was not incorporated into the scope of this study.

4. Building Energy Modeling in Energy3D

Energy3D requires three primary inputs, the location of the structure, geometry and properties of construction materials, and generates time graphs and heat maps, facilitating in-depth analyses [9]. The location can be



RETScreen - Energy Model

Commercial/Institutional - CSF Building, MUN - Education

Summary - Electricity and fuels

	Fuel type		Base case		Proposed case		Savings	
Fuel type	Fuel rate	Fuel consumption - unit	Fuel consumption	Fuel cost	Fuel consumption	Fuel cost	Fuel saved	Savings
Diesel (#2 oil)	$ 1.66	L	1,100,109	$ 1,826,181	0	$ 0	1,100,109	$ 1,826,181
Electricity	$ 0.105	kWh	12,706,138	$ 1,334,144	22,808,484	$ 2,394,891	-10,102,346	$ (1,060,746)
Total				$ 3,160,325		$ 2,394,891		$ 765,435

Project verification

Fuel type	Fuel consumption - unit	Fuel consumption - historical	Fuel consumption Base case	Fuel consumption - variance
Diesel (#2 oil)	L		1,100,109	
Electricity	kWh		12,706,138	

Savings

Fuel consumption	Heating kWh	Cooling kWh	Electricity kWh	Total kWh	Plan kWh	Variance %
Base case	11,703,937	0	12,706,138	24,410,075	24,410,075	0%
Proposed case	10,102,346	0	12,706,138	22,808,484	10,800,217	111%
Fuel saved	1,601,591	0	-0.23	1,601,591	13,609,858	-88.2%
Fuel saved - %	13.7%	0%	0%	6.6%	55.8%	

Benchmark

Energy unit	kWh
Reference unit	m²

Fig. 6. Comparison in RETScreen.

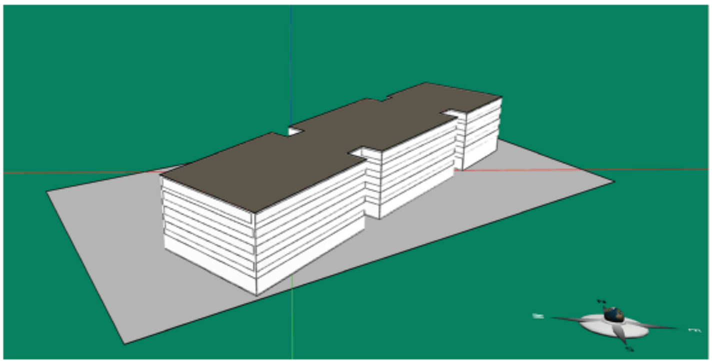


Fig. 7. Building geometry in Energy3D.

input in two ways: by choosing from the existing list of locations or by selecting a location from an interactive map. Since St. John's, NL, is not currently available on Energy3D, Halifax, NS, with climate conditions resembling those of St. John's, was selected as the location.

The creation of geometry can be undertaken through various methods, such as sketching up a structure or importing a sketch from an existing CAD file and overlaying it on a map image [9]. The building geometry was created by sketching, using the engineering drawings of the CSF facility as the foundation. The directions indicated in Energy3D can serve as the reference for orienting the sketch-up. The model assumed the absence of neighboring buildings that could induce shading effects on the CSF building, even though, in real-world conditions, the University Center connected to the CSF facility might have some impact in this regard. Fig. 7 depicts the building geometry created in Energy3D.

After the building geometry was completed, various surfaces of the structure were assigned physical properties to closely emulate the model in relation to the actual construction. Energy3D allows for the assignment of physical properties to external walls, windows, and the roof. Energy3D permits the design of internal floors/ceilings; however, it lacks the capability to assign any physical properties to them. The properties considered in this study are presented in Table II.

Two primary metrics were considered for the insulation properties of the construction materials considered in this study. For the walls and roof, insulation value was assigned in R-value in US units, measured in hour per square foot per degree Fahrenheit per British thermal unit (h.ft^2.°F/Btu). R-value is a crucial metric in insulation, representing the material's thermal resistance. A higher R-value indicates better insulation performance, signifying the material's ability to reduce heat transfer. Similarly, for windows, insulation value was assigned in U-value in US units, measured in British thermal units per hour per square foot per degree Fahrenheit (Btu/h.ft^2.°F). The U-value is a key indicator of the thermal conductivity of glass and represents its ability to conduct heat. A lower U-value indicates better insulating properties, as it signifies reduced heat transmission. Energy3D also includes recommendations for these parameters within each dialogue box, serving as reference values in instances where specific building data is unavailable. For this study, the insulation values for external walls and the roof were taken from the Insulation building code, which forms part of the legal framework derived from the building code applicable in Ontario, Canada [13].

TABLE II: Properties of Construction Materials Considered

Building component	Property	Value considered (unit)	Reference for value considered
External wall	Wall thickness	0.3 (m)	Construction drawings
	Insulation	33 (h.ft^2.°F/Btu)	Insulation building code 2021 [13]
Windows	Tint	Clear	Observation
	Insulation	0.48 (Btu/h.ft^2.°F)	Energy3D standard for double-glass windows
Roof	Insulation	55 (h.ft^2.°F/Btu)	Insulation building code 2021 [13]

TABLE III: Projected Monthly Energy Consumption for Space Heating

Month	Energy consumption for space heating, kWh	
	Daily consumption (calculated by Energy3D)	Monthly consumption
January	12,395.652	384,265.222
February	10,632.204	308,333.924
March	7,962.033	246,823.028
April	5,569.935	167,098.059
May	3,576.468	110,870.507
June	2,486.582	74,597.4520
July	1,924.666	5,9664.6364
August	2,620.119	81,223.685
September	4,287.353	128,620.599
October	6,828.859	211,694.630
November	9,415.052	282,451.555
December	12,081.783	374,535.259
Total, kWh		2,430,178.555

After confirming the accuracy of the building geometry, orientation, and material properties, the annual energy analysis for the building was calculated. Energy3D provides simulation results in a tabular format computed for daily consumption each month. This figure was then multiplied by the respective number of days in each month to determine the monthly consumption. The results for projected energy consumption for space heating are summarized in Table III and depicted in Fig. 8.

TABLE IV: Results of the Feasibility Study

Description	Unit	Estimated savings
Savings in energy	kWh	1,601.591
Savings in energy	%	6.6
Savings in fuel/year	$	765,435
Savings in fuel/year	%	24.2%
Gross annual GHG emission reduction	tCO_2	2,665

5. Results and Discussion

The results of the feasibility study in RETScreen demonstrated notable financial and energy savings, even without implementing additional energy efficiency measures. These results are summarised in Table IV.

In the feasibility study conducted in RETScreen, both electricity and fuel tariffs were assumed to remain constant over the project's lifecycle. However, in reality, the average electricity tariff for large customers in St. John's has risen by approximately 18.8% between 2018 and 2022 [14]. Additionally, the average price of diesel fuel in Canada has experienced a substantial 71% increase from 2019 to 2022 [15]. Fig. 9 illustrates the fluctuation in diesel prices in St. John's compared to the national average. This disparity suggests that the variation in diesel oil prices is significantly higher than that of electricity tariffs in St. John's, potentially resulting in greater financial savings over the project's lifetime. Furthermore, it is estimated that approximately 96% of the electricity generated in Newfoundland and

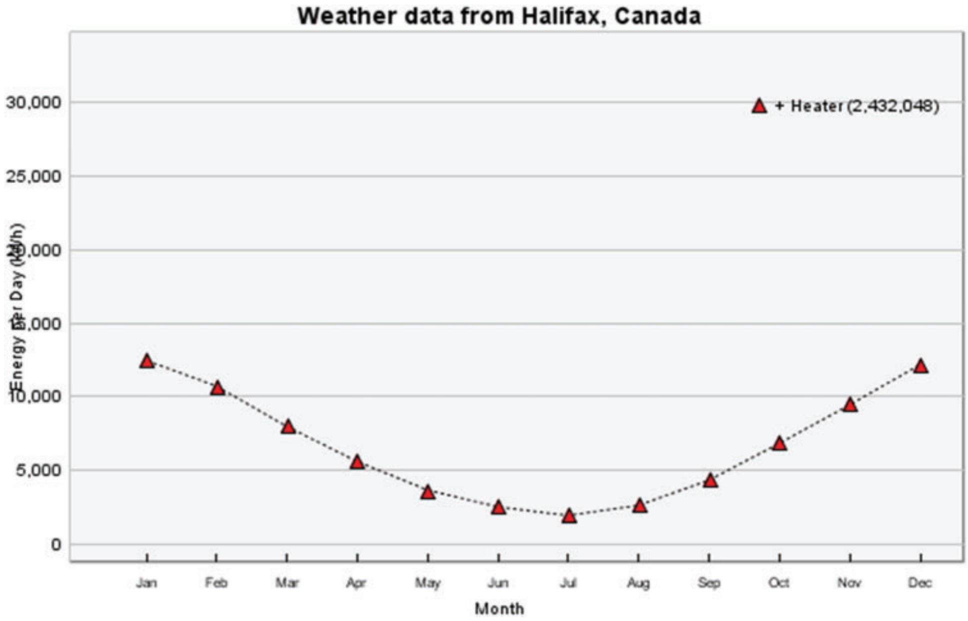


Fig. 8. Projected monthly energy consumption for space heating.

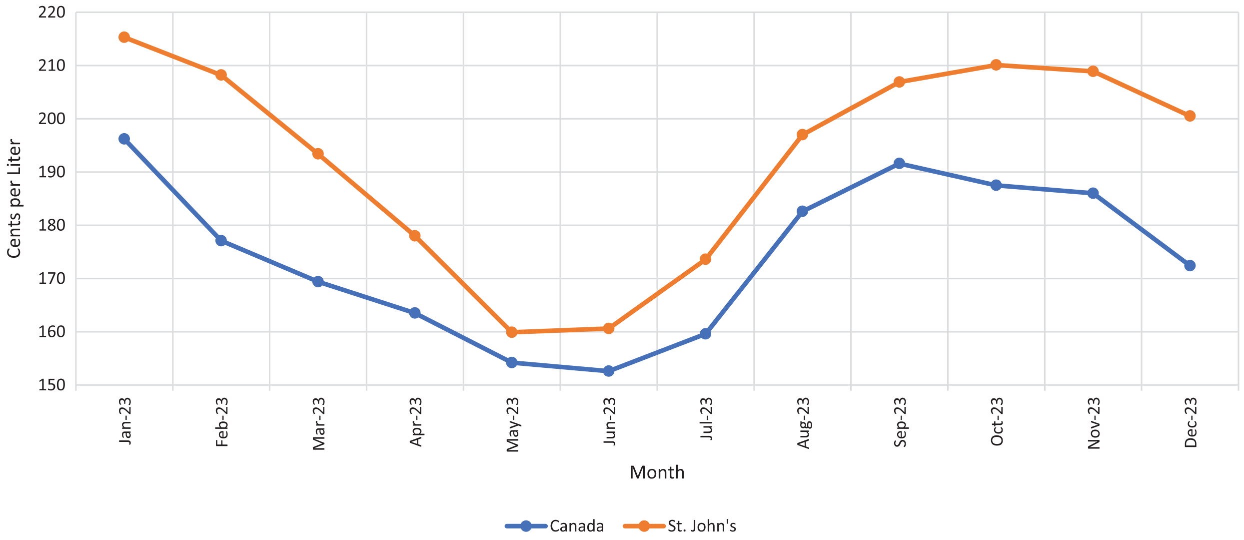


Fig. 9. Comparison of the diesel price in St. John's with the national average.

TABLE V: Comparison of Energy Consumption (Simulation Results and Actual)

Month	Consumption from simulation (kWh)	Diesel oil #2 consumption (liters)	Actual energy consumption (kWh)
January	384,265.222	143,447	1,521,335.13
February	308,333.924	163,802	1,737,211.21
March	246,823.028	151,847	1,610,421.79
April	167,098.059	117,433	1,245,442.21
May	110,870.507	72,558	769,517.90
June	74,597.4520	60,246	638,942.30
July	59,664.6364	25,221	267,482.72
August	81,223.685	34,303	363,802.37
September	128,620.599	44,295	469,773.08
October	211,694.630	42,079	446,271.17
November	28,2451.555	106,251	1,126,850.88
December	374,535.259	138,628	1,470,226.96
Total	2,430,178.555	1,100.109	11,667,277.72

Labrador has been from hydro sources [16]. This highlights the substantial reduction in gross annual greenhouse gas (GHG) emissions that can be achieved by transitioning to electric resistive heating for space heating.

The results of the feasibility study also suggested a simple payback period of 10.5 years based on the inputs considered in the study. This calculation was entirely based on the initial capital expenditure and potential financial savings from the project, portraying it as a venture with a relatively low return on investment. Nevertheless, a comprehensive analysis, encompassing factors such as potential variations in energy tariffs, potential savings in operations and maintenance (O&M) costs, rebates based on reduced carbon footprint, and a life-cycle analysis, can reveal the complete benefits of the project.

The results from Energy3D simulation indicated the projected energy consumption for space heating in CSF building for a calendar year. Table V is a comparison between the simulation results and the actual data.

The actual energy consumption for space heating was calculated using the following formulae:

LHV of diesel (MJ/litre) = 38.18
Diesel consumption/January (litres) = 143,447
Energy consumption (heating/Jan) (MJ) = 5,476,806.46
Electricity consumption/January (kWh) = 1,521,335.13

The simulation results indicated a significant deviation from the energy consumption calculated using actual data. This variance may arise from several disparities between the actual conditions and the Energy3D model. While the main reason is electric space heating being much more efficient when compared to heating with oil, there are other factors that contribute to this deviation.

The hot water supply and return lines for the CSF building are routed from the Department of Earth Science building, spanning a considerable distance of approximately 160 meters between the two structures. The simulation did not account for any energy loss within this section, despite the likelihood of significant losses occurring in actual conditions between the measuring point and the entry points of the pipes into the CSF building.

Moreover, Level 2 of the CSF building is interconnected with the University Center (UC), with a significant airflow between the two buildings. This airflow between the two interconnected buildings can lead to heat loss from CSF building, when warm air from CSF building escapes to cooler UC. This heat loss results in increased energy consumption, as the heating system in CSF building must compensate for the dissipated heat. In addition, the UC has several openings to outdoors, which can lead to infiltration and exfiltration. These phenomena can lead to further energy losses. For the simulation in Energy3D, neither the interconnection nor the heat loss have been considered. This may lead to an estimated energy consumption that is lower than the actual values.

The CSF building, as well as the UC, is used by many occupants throughout the year. The behavior of occupants is acknowledged as a key factor contributing to the performance gap observed between the actual and simulated energy consumption of buildings [17], [18]. Furthermore, fluctuations in occupancy levels throughout a given day also affect the space heating requirements, leading to varying space heating needs and resulting in inefficiencies in heating. Moreover, maintaining a comfortable indoor environment includes maintaining a balance between the heating system and the external environment, and varying occupancy levels can have an impact on the energy consumed for space heating. Therefore, it is crucial to account for building occupancy levels when conducting building energy modeling. However, determining occupancy levels presents significant challenges, particularly for buildings with dynamic occupancy patterns, such as the CSF building, for various reasons. Moreover, modeling dynamic occupancy levels is not feasible in Building Energy Modeling (BEM) simulations, and accordingly, occupancy levels were not considered in this study.

The CSF building houses its Heating, Ventilation and Air Conditioning (HVAC) systems in the penthouse section of the building. This envelope has a smaller footprint than the other floors of the building, and as a result, due to limitations in Energy3D, this penthouse section was omitted from the simulation. Additionally, the modeling did not include the building's ventilation system, which plays a crucial role in ensuring the proper distribution of warm air throughout the building, minimizing temperature variations, and enhancing the efficiency of the heating system. Ventilation is a significant factor in BEM, allowing for the assessment of the thermal energy needed to condition outdoor air before supplying it to the indoor space. This aspect holds particular importance in colder climates like St. John's. The exclusion of the ventilation system from the energy model may have led to an underestimation of the energy required to heat incoming outdoor air, potentially resulting in a lower-than-actual energy demand.

The lifespan of equipment and operation and maintenance practices can be a deciding factor in efficiency. Even though the CSF building is relatively new, the oil-fired hot water boilers in the Utility Annex have been in operation for a few years. Over time, such equipment may experience wear and tear, affecting its efficiency. Such system degradation was not considered in this study, which can result in a disparity between the simulation results and the actual consumption.

6. Conclusions

In this paper, the feasibility of converting the space heating system of the CSF building from an existing oil-fired boiler system to electric resistive boilers was analysed using RETScreen. Furthermore, a thermal model of the CSF building was developed using Energy3D.

The feasibility study suggested that the transition can save approximately $765,435 per annum in fuel costs, accounting for 24.2% of the total cost of energy CSF building consumed in 2022. Furthermore, it also indicated that there could be a 6.6% savings in energy consumption, with a total gross annual GHG savings of 2,665 tCO_2.

The simulated results of the building thermal model suggested that the energy consumed by CSF building can theoretically be less than the actual figure. However, factors that were not considered in the development of the model, such as transmission losses, the interconnection between CSF building and the UC, building occupancy, the ventilation system, and degradation of equipment over time, can have a significant influence on the energy consumed for space heating, resulting in the higher actual energy consumption of the building.

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Conflict of Interest

The authors declare that they do not have any conflict of interest.

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