# Developing a Municipal Energy Efficiency Plan for the Town of Bethel:

## A Cost-Benefit Analysis

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Dated: May 2, 2025

# Acknowledgements

We would like to express our sincere gratitude to **Dr. Sharon Klein**, our course instructor for ECO505: Sustainable Energy Economics and Policy at the University of Maine, for her outstanding guidance, support, and feedback throughout the course of this project. We are especially thankful to our project mentors from the **Bethel Conservation Commission,** particularly, **Karen Bieluch, Sarah Southam, Julie Reiff, Jeffrey Sloan, and Ann Speth** for their time, insights, and collaborative spirit. Their local expertise and thoughtful direction were essential in helping us align our work with the town's real-world needs. We would also like to extend our appreciation to **John Snell**, whose detailed energy audit report for the Town of Bethel provided the direction for our analysis. This project would not have been possible without the collective efforts and encouragement of all those involved.

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## List of Acronyms and Abbreviations

| | |
|---|---|
| BCR | Benefit-Cost Ratio |
| Btu | British Thermal Unit |
| CBA | Cost-Benefit Analysis |
| CC | Conservation Commission |
| CMP | Central Maine Power |
| CRP | Community Resilience Partnership |
| DOE | U.S. Department of Energy |
| EIA | Energy Information Administration (U.S.) |
| EPA | Environmental Protection Agency (U.S.) |
| FY | Fiscal Year |
| Gal | Gallon of Fuel (Propane or Heating oil) |
| GHG | Greenhouse Gas |
| GIS | Geographic Information System |
| HVAC | Heating, Ventilation, and Air Conditioning |
| IR | Interest Rate |
| IRR | Internal Rate of Return |
| KPI | Key Performance Indicator |
| kWh | Kilowatt-hour |
| LCOE | Levelized Cost of Energy |
| LED | Light Emitting Diode |
| MMBtu | Million British Thermal Units |
| NPV | Net Present Value |
| NREL | National Renewable Energy Laboratory |
| O&M | Operations and Maintenance |
| PV | Photovoltaic (Solar PV System) |
| RE | Renewable Energy |
| RES | Renewable Energy Standard |
| ROI | Return on Investment |
| RPS | Renewable Portfolio Standard |
| WWTP | Wastewater Treatment Plant |

## Executive Summary

This report presents the findings and recommendations from a semester-long service-learning project conducted in collaboration with the Town of Bethel, Maine, and the Bethel Conservation Commission. The project was developed as part of the University of Maine's graduate level course 'ECO505: Sustainable Energy Economics and Policy'. Following an energy audit funded by the State of Maine's Community Resilience Partnership and presented in November 2024, the Bethel Selectboard tasked the Conservation Commission with creating a five-year energy efficiency plan. The objective of this report is to support that planning process through a detailed cost-benefit analysis of existing energy use in municipal facilities and to explore the feasibility of transitioning to more sustainable energy options, including solar PV and energy efficiency upgrades.

For this analytical report, the authors considered six key municipal facilities of Town of Bethel—Town Office (Cole Block), Fire Station, Town Garage, Airport Terminal, Ambulance Barn, and Wastewater Treatment Plant —which together comprise the bulk of municipal energy demand. Energy consumption is divided between electricity, sourced from Central Maine Power, and heating fuels, including oil, propane, and wood pellets. As of FY24, heating accounted for 57.1% of total energy use (in MMBtu), while electricity comprised the remaining 42.9%. However, electricity is the dominant year-round energy cost driver, particularly in operationally intensive buildings like the Wastewater Treatment Plant.

Electricity consumption grew significantly from 228,349 kWh in FY23 to 304,300 kWh in FY24, marking a 33.3% increase, with the Wastewater Treatment Plant alone accounting for over 75% of total municipal electricity use. Although consumption is projected to decline modestly to 279,745 kWh in FY25 due to efficiency upgrades, the upward trend highlights growing operational energy demands. Correspondingly, electricity expenditures rose from $51,950 in FY23 to $60,819 in FY24, with the FY25 budget increasing to $65,740, largely to hedge against projected price increases. These trends underscore electricity's central role in Bethel's energy cost structure, where even modest consumption growth results in substantial long-term financial impacts.

To evaluate long-term viability, the report conducted a cost-benefit analysis comparing Bethel's current energy mix with a renewable alternative scenario involving a 39 kW solar PV system. Maintaining the status quo (grid electricity + fossil heating fuels) would result in over $2.1 million in projected costs over 25 years, including greenhouse gas emissions. In contrast, installing solar would yield net savings of $872,000, an IRR of 66%, and a Benefit-Cost Ratio (BCR) of 8.7, with an exceptionally low Levelized Cost of Energy (LCOE) of $0.022/kWh. A short-term five-year scenario further confirmed solar's advantage, projecting nearly $200,000 in net savings compared to current energy practices.

The report recommends Bethel should pursue a dual-track strategy for its energy transition. On the electricity side, rising consumption and long-term cost projections highlight the urgency of investing in onsite renewable generation, beginning with a phased solar PV installation at high-potential sites such as the Airport Terminal. This should be coupled with appliance upgrades and smart energy monitoring systems to reduce unnecessary load. Simultaneously, the town must address heating fuel inefficiencies by prioritizing weatherization improvements and long-term planning to phase out high-cost fossil fuels, particularly propane and heating oil. The disproportionate reliance on fuel-based heating—currently accounting for over half of the town's total energy use—makes thermal efficiency improvements essential. Together, these efforts will help Bethel manage escalating costs, stabilize municipal energy expenditures, and make measurable progress toward meeting Maine's statewide climate and clean energy goals.

# Chapter 1: Background of the Town of Bethel

## 1.1. Demographics

The Town of Bethel, located in Oxford County in Western Maine, is a small rural community known for its scenic beauty, recreational tourism, natural Androscogin River watershed and a close-knit population, encompassing an area of approximately 64.8 square miles. As of the 2020 U.S. Census, the town has a population of 2,504 residents, with a relatively low population density of about 39 people per square mile.


*Figure 1: Map of the Town of Bethel, Maine. Source: City-Data*

The community is predominantly made up of the white race, accounting for over 90% of the population, with small percentages identifying as multiracial or other racial backgrounds. Bethel has a median age of 46.2 years, indicating an ageing population. There are approximately 1,200 households in Bethel, with an average household size of 2.3 people, and about 17% of these households have children (U.S. Census Bureau, 2023). While the town maintains a steady resident population year-round, Bethel also experiences seasonal population increases due to tourism, particularly during winter, with the influx of visitors to the nearby ski resorts.

## 1.2. Economic Profile

The economic structure of the Town of Bethel is shaped by its role as a service and recreational hub within Oxford County, Maine. The town benefits from diverse local economic drivers, including hospitality services, educational institutions, and outdoor recreation industries. These sectors support employment and generate local revenue, yet also introduce complexities in maintaining consistent demand for public utilities and infrastructure year-round.

According to recent census data, the median household income in Bethel is estimated at $56,875, which is consistent with state averages but slightly below national figures. Despite this, economic inequality remains a concern, with approximately 13.8% of residents living below the poverty line (U.S. Census Bureau, 2023). Access to affordable housing and stable employment remains a challenge for segments of the population, particularly during the off-peak tourist seasons.

Bethel's local government plays a key role in supporting community development, infrastructure, and services through a modest municipal budget. While the town does not host large-scale industries or corporate enterprises, it maintains a resilient local economy rooted in natural resource stewardship, cultural heritage, and rural community values. Long-term economic planning increasingly focuses on diversification, workforce development, and enhancing the year-round economic base to ensure sustained prosperity for residents and businesses.

## 1.3. Energy Outlook

Energy planning in the Town of Bethel is entering a critical phase, driven by the need to modernize ageing infrastructure, adapt to policy changes, and respond to long-term environmental and economic pressures. As a rural municipality providing essential public services, Bethel must assess how future energy strategies can balance reliability, affordability, and sustainability. The evolving energy landscape presents both a challenge and an opportunity: to shift from legacy systems reliant on fossil fuels to more efficient and resilient alternatives suited to the town's specific geographic and operational context. Figure 2 below shows a framework of Bethel’s current energy use and what a future, more efficient scenario would look like if a more sustainable energy source is included in the town’s energy mix. Currently, no independently installed renewable energy is used by any of the town facilities for either lighting or heating.

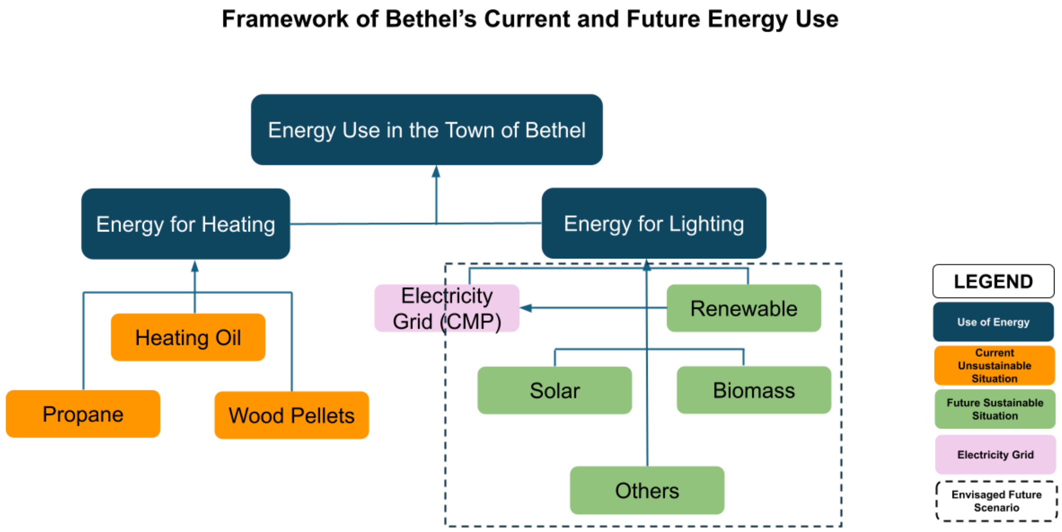


*Figure 2: Framework of the current and future energy situation in the Town of Bethel Facilities*

Currently, Bethel's municipal operations depend on a diverse mix of traditional energy sources. Electricity remains the primary energy source, particularly for lighting, water treatment, and administrative functions. At the same time, heating needs are met through oil, propane, and wood pellets (more details on the Chapter 2 'Energy Profile on Bethel Facilities' section). At the state level, Maine has established comprehensive clean energy goals, including reaching 80% renewable electricity by 2030 and 100% by 2050 (Governor's Energy Office, 2024). These targets create both external pressure and internal incentive for municipalities to develop local strategies aligned with statewide efforts. As part of this, Bethel's recent participation in the Community Resilience Partnership and its completion of a municipal energy assessment mark important milestones in developing a forward-looking energy roadmap.

Ultimately, the path forward will require not only technical improvements but also administrative coordination, access to financial support, and integration with broader regional energy frameworks. With its recent groundwork in data collection and facility analysis, Bethel is well-positioned to take the next steps in developing a sustainable and resilient municipal energy strategy.

# Chapter 2: Municipal Energy Profile: Evaluating Bethel's Public Department Usage

## 2.1. Facilities in review

For this research, the municipal facilities in the Town of Bethel have been classified into six categories according to their primary operational functions. The classification (Table 1) clarifies how each facility contributes to overall municipal energy consumption and supports formulating department-specific energy planning recommendations.

*Table 1: Classification of municipal facilities by departmental function*

| SN | Facilities Studied | Respective Departments |
|---|---|---|
| 1 | Town Office | Administration |
| 2 | Fire Station | Fire |
| 3 | Town Garage | Public Works |
| 4 | Airport Terminal | Airport |
| 5 | Ambulance Barn | Rescue |
| 6 | Treatment Plant | Waste Treatment |

**Town Office (Cole Block) – Administration**

The Town Office serves as the central administrative headquarters of Bethel's local government. It houses the Town Manager's office, municipal staff, and several civic departments, including finance, planning, and public records. This facility is primarily used during regular business hours, with energy use concentrated in lighting, office equipment, and space heating. Occasional public meetings and community events may also influence its energy demand.

**Fire Station – Bethel Fire Department**

The Fire Station provides emergency fire response and protection services to the town. It operates on a 24/7 readiness basis, requiring constant indoor climate control, equipment maintenance capacity, and standby communications infrastructure. Energy consumption is driven by large space heating, lighting, equipment storage, and office space for training and administration.

**Town Garage – Public Works Department**

The Town Garage is the operational base for Bethel's Public Works Department. It supports road maintenance, fleet storage and servicing, and seasonal operations such as snow removal. The building has elevated heating demands due to frequent vehicle entry/exit and the need to keep heavy machinery operational during winter. It also contains workspaces for equipment repairs and parts storage, contributing to thermal and electrical energy usage.

**Airport Terminal – Bethel Regional Airport**

Bethel Regional Airport (FAA Identifier: 0B1) is a municipally owned and operated public-use airport located approximately two miles northwest of Bethel's downtown area. From an energy perspective, the Bethel Airport Terminal exhibits a relatively moderate but essential demand profile. Key energy uses include space heating, primarily through propane systems, as well as lighting, communication equipment, and general building operations. Due to its smaller size and intermittent use compared to other municipal facilities, the terminal's energy intensity is relatively high per square foot, primarily due to extensive exterior lighting, instrumentation systems, and heating requirements during winter. These characteristics make the facility an ideal candidate for targeted efficiency upgrades, installing renewable energy facilitation, and building envelope improvements to reduce heat loss and fuel consumption.

**Ambulance Barn – Emergency Medical and Rescue Department**

The Bethel Emergency Ambulance Rescue Service provides rescue services to Bethel and surrounding areas. The facility is staffed by dedicated professionals committed to serving the community's emergency medical needs. Energy demand is driven primarily by space heating, interior lighting, and the operation and storage of medical equipment and emergency vehicles. The facility currently utilizes a combination of propane and heating oil for thermal energy, which contributes to a relatively high energy consumption rate.

**Wastewater Treatment Plant (WWTP)**

The Bethel Wastewater Treatment facility stands as a crucial pillar in the community's waste management infrastructure. This facility plays a vital role in ensuring that the town's waste is efficiently and responsibly processed, contributing to a cleaner and healthier environment for all residents, which is the most energy-intensive facility in Bethel's municipal infrastructure. Operating continuously (24/7), the plant requires a substantial and consistent supply of electrical energy to support mechanical aeration systems, pumps, filtration equipment, monitoring instruments, and control systems. In FY 2024, it consumed approximately 229,690 kilowatt-hours (kWh) of electricity, accounting for the largest share of total municipal electricity usage.

## 2.2. Bethel's Current Energy Profile

### 2.2.1. Electricity

***Electricity Consumption***

This chapter examines the trends in electricity consumption, expenditure, and budget for six key municipal facilities in the Town of Bethel—namely, the Town Office, Fire Station, Town Garage, Airport Terminal, Ambulance Barn, and Wastewater Treatment Plant across FY 2023, 2024, and 2025. The analysis is based on actual energy usage, budget allocations, and anticipated costs, providing insights into the evolving energy needs and financial implications for municipal operations.

In FY 2023, the total municipal electricity consumption across the six key public facilities was measured at approximately 228,349 kWh (Figure 3). This baseline consumption level reflected routine operational energy needs, facility maintenance standards, and service demand typical of a small town's municipal operations. However, a significant increase was observed in the following fiscal year. By the end of FY 2024, the total electricity consumption rose to 304,300 kWh, an increase of 33.26% compared to FY 2023.

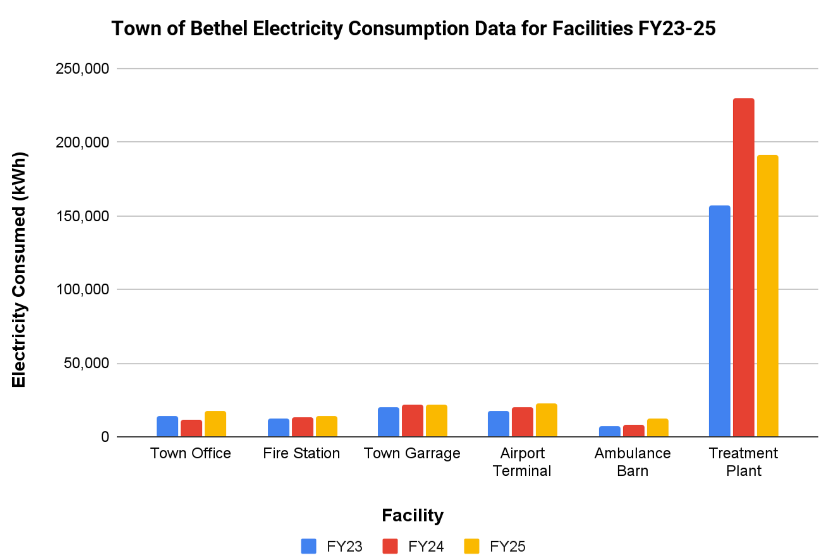


*Figure 3: Town of Bethel Electricity Consumption Data for Facilities FY23-25*

Between FY23 and FY24, all six municipal facilities exhibited varying patterns of electricity consumption growth. The Wastewater Treatment Plant recorded the most significant absolute increase, with annual consumption rising from 157,225 kWh to 229,690 kWh, maintaining its position as the largest single consumer of municipal electricity. The Airport Terminal also saw a notable increase, with consumption growing from 17,259 kWh to 19,900 kWh, reflecting its continuous operational needs. The Town Garage experienced a modest rise in electricity use, increasing from 20,236 kWh to 21,500 kWh, attributed to facility maintenance and year-round vehicle operations. The Ambulance Barn similarly recorded a slight increase, moving from 7,319 kWh to 8,240 kWh, consistent with its round-the-clock service demands. Meanwhile, the Fire Station and the Town Office demonstrated relatively stable electricity usage profiles, with only minor variations observed between the two fiscal years. These facility-level trends collectively contributed to the overall rise in Bethel's municipal electricity consumption during FY 2024.

For FY25, electricity consumption is forecasted to decrease slightly to approximately 279,745 kWh, reflecting an 8.07% decline relative to FY24. This projected reduction is attributed to anticipated operational efficiency improvements and some minor infrastructure upgrades. Despite this short-term decline, when assessed over a three-year span (FY 2023–FY 2025), the average electricity consumption growth rate remains approximately 8.40%, illustrating a longer-term trend of increasing energy demands across municipal operations.

***Electricity Expenditure and Budget Analysis***

The total electricity expenditure for the six municipal facilities rose notably over the two fiscal years under review. In FY23, total actual spending on electricity amounted to approximately $51,950 (Figure 4). By FY24, this figure had increased to $60,819, reflecting an overall 17% increase in electricity costs across municipal operations.

At the facility level, spending patterns aligned closely with electricity consumption trends:

a. The Wastewater Treatment Plant remained the highest-cost facility, with electricity expenditures rising from $35,769 in FY 2023 to $44,979 in FY 2024, constituting approximately 74% of the town's total municipal electricity spending in FY 2024.
b. The Airport Terminal and Town Garage followed, with FY 2024 spending reaching $4,289 and $3,936, respectively.
c. The Town Office, Fire Station, and Ambulance Barn represented a smaller share of total costs, collectively accounting for under 10% of the total electricity expenditure.

The year-over-year increase in actual spending reflects elevated energy usage across facilities and fluctuations in average electricity prices, emphasizing the growing financial burden of energy consumption on municipal budgets.

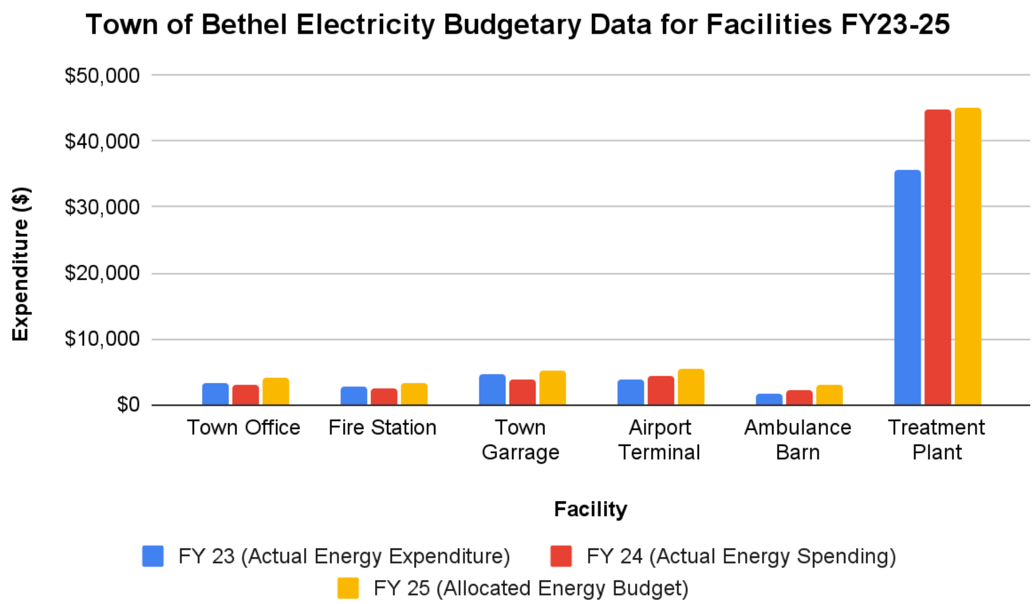


*Figure 4: Town of Bethel Electricity Budgetary Data for Facilities FY23-25*

In response to increasing electricity costs and anticipated future needs, the Town of Bethel has adjusted its energy budgeting accordingly. For FY24, the allocated municipal electricity budget was $60,950. Looking ahead to FY25, this budget is expected to rise to $65,740, representing a 7.86% increase. The facility-specific allocations for FY 2025 indicate a targeted budgeting approach:

a. The Wastewater Treatment Plant is allocated the largest portion, with $45,000, reflecting its operational significance and high energy demand.
b. Other allocations include $5,300 for the Airport Terminal, $5,100 for the Town Garage, $4,040 for the Town Office, $3,300 for the Fire Station, and $3,000 for the Ambulance Barn.

Despite projections of a slight decrease in total electricity consumption for FY25, the budgetary increase accounts for anticipated rises in electricity prices and potential fluctuations in facility operational demands.

***Electricity Price***

In a broader context, the historical trend of electricity prices in Bethel from FY15 to FY25 shows a transition from long-term stability to heightened volatility. Between FY15 and FY21, electricity prices remained relatively stable, fluctuating slightly around $0.14 to $0.17 per kWh (Figure 5). However, a substantial shift occurred in FY22, when the average electricity price surged to $0.23 per kWh, representing an abrupt 30.4% increase largely attributed to wider regional and national energy market factors. Following this sharp escalation, prices have remained elevated, with minor fluctuations in FY23-24.

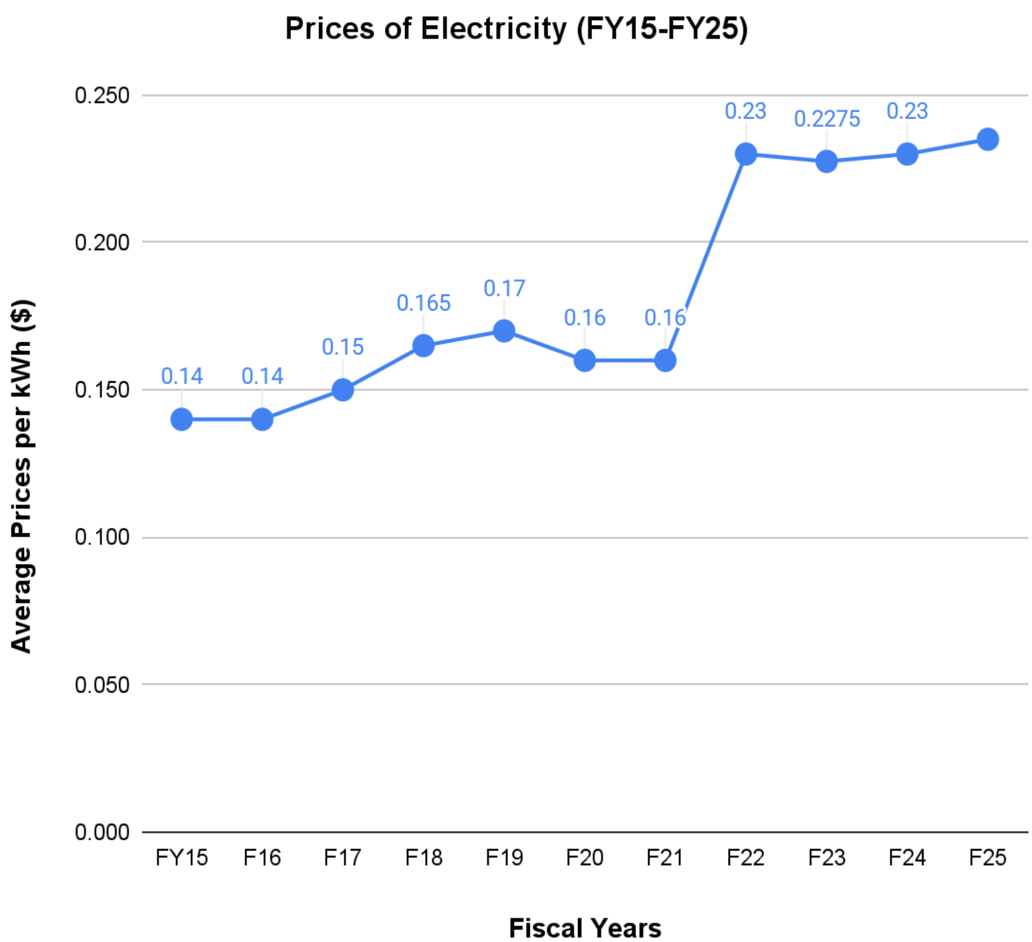


*Figure 5: Average Electricity Price Trends in Bethel (FY15–FY25)*

Projections for FY25 suggest a continued upward trend, with prices expected to rise modestly to $0.235 per kWh, an additional 2.1% increase compared to FY 2024. This long-term trend of rising electricity costs underscores the financial vulnerability associated with traditional energy reliance. It reinforces the strategic importance of implementing energy efficiency measures and exploring alternative energy sources within the town's municipal operations.

### 2.2.2. Fuel

***Fuel Consumption***

Heating fuel consumption across Bethel's municipal facilities plays an important role in supporting operational needs, particularly during the colder seasons. In FY23, total heating fuel use, combining heating oil and propane, amounted to approximately 13,896 gallons (Figure 6). This figure show that heating fuel use declined significantly in FY24 to 9,972 gallons, representing a 39.35% reduction from the previous year. For FY25, heating fuel consumption is projected to rise moderately to 11,873 gallons, an increase of 16.01% compared to FY24, though still remaining below FY23 levels.

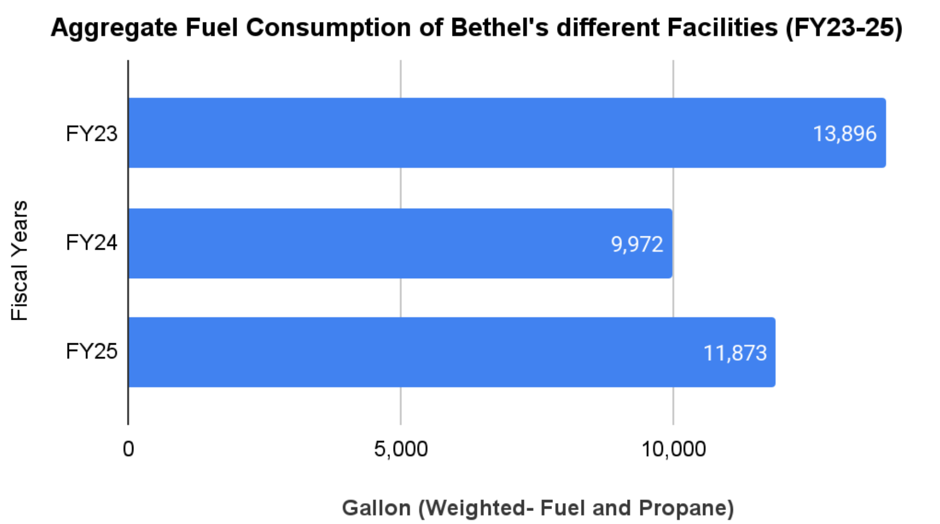


*Figure 6: Fuel Consumption of Bethel's different Facilities (FY23- FY25)*

Over the three-year period, the average consumption growth rate is approximately –7.78%, indicating a general downward trend in heating fuel usage despite short-term fluctuations. It is noted that approximately 13 tons of wood pellets were also utilized during this period, primarily for heating at the Town Office; however, for analytical consistency and due to their relatively small contribution compared to oil and propane, pellet use was excluded from the comparative analysis. Facility-level patterns show that the Wastewater Treatment Plant and Fire Station consistently accounted for the largest shares of heating fuel consumption. At the same time, facilities such as the Airport Terminal and Ambulance Barn maintained relatively lower usage levels.

***Fuel Expenditure and Budget Analysis***

Heating fuel expenditures across Bethel's municipal facilities showed moderate variation between FY23 and FY25. In FY23, total heating fuel spending across all six facilities amounted to approximately $41,613, which increased slightly to $43,682 in FY24 despite a significant drop in fuel consumption (Figure 7). This pattern reflects the influence of rising fuel prices rather than increased usage. Projections for FY25 suggest that total heating fuel expenditures will stabilize, with a slight decrease to $43,425, indicating efforts to control costs even as consumption trends shift.

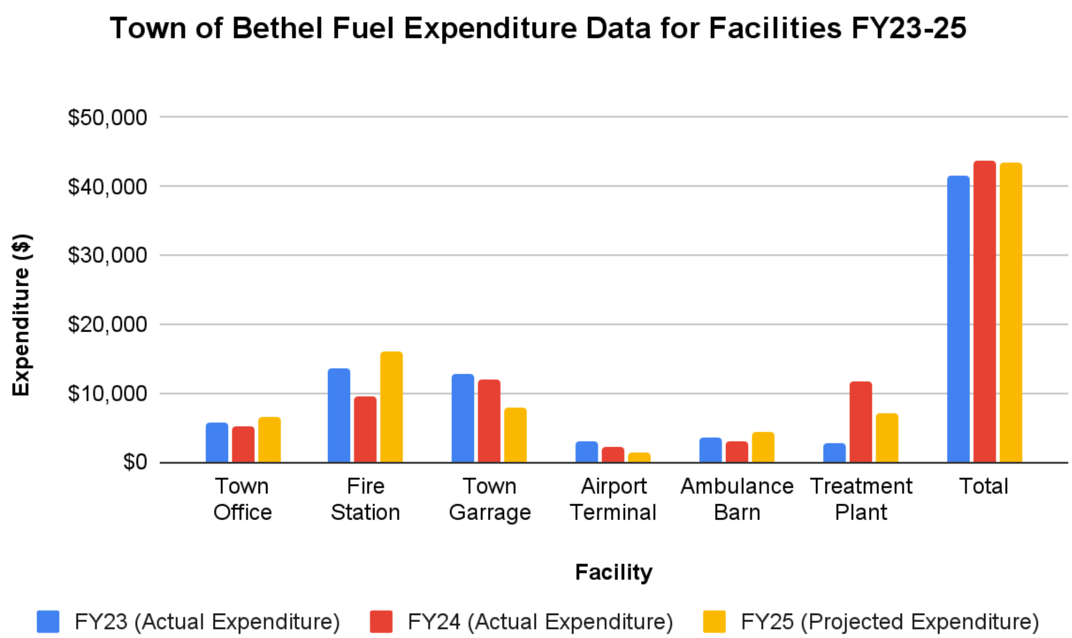


*Figure 7: Town of Bethel Fuel Expenditure Data for Facilities FY23-25*

At the facility level, the Fire Station consistently recorded the highest heating expenditures, with costs rising to a projected $16,000 in FY25. The Town Garage followed with high spending in FY23 and FY24, but is expected to see a sharp reduction to $8,000 in FY25. Facilities like the Town Office, Airport Terminal, and Ambulance Barn maintained lower heating costs, with relatively stable trends. A notable exception is the Wastewater Treatment Plant, where expenditures spiked to $11,572 in FY24 before declining again in FY25. Overall, while the town's aggregate heating costs have remained relatively stable, the significant fluctuations at the facility level highlight the need for ongoing efficiency improvements and closer monitoring of heating system performance.

***Fuel Price***

Figure 8 below shows the changing average prices of heating oil and propane over three fiscal years. In FY23, heating oil was significantly more expensive than propane, but this trend reversed in FY24 when propane prices sharply increased to approximately $5.74 per gallon, while heating oil dropped to around $3.36 per gallon. By FY25, prices for both fuels are projected to converge, with heating oil at about $3.67 per gallon and propane slightly lower at $3.57 per gallon. This fluctuation highlights the volatility in fuel markets and reinforces the need for Bethel's municipal operations to manage heating energy choices carefully.

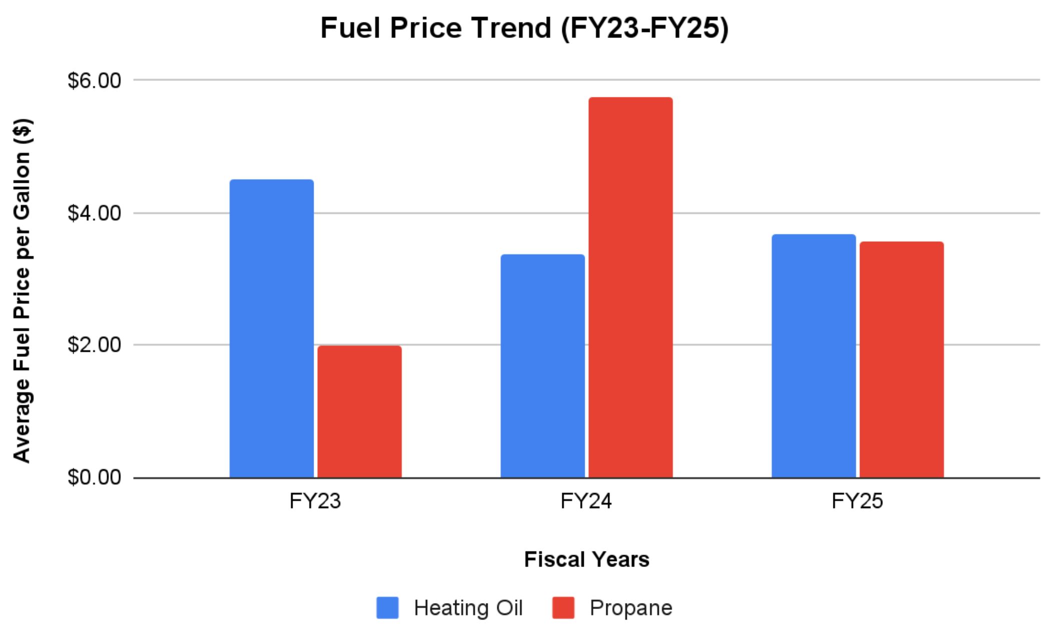


*Figure 8: Fuel price trends across Bethel's facilities (FY23-25)*

### 2.2.3. Energy Profile of Bethel Facilities

The energy use profile of Bethel's municipal facilities is shaped by two major categories: conventional electricity consumption from the Central Maine Power (CMP) grid and heating fuel consumption from CN Brown, Community Energy, and Maine Energy Systems. Together, they reflect the functional energy requirements for Bethel Town facilities.

Figure 9 presents a high-level view of energy distribution based on standardized units (MMBtu). According to the data, heating fuels account for 57.1% of total energy use, while electricity makes up the remaining 42.9%. This finding is notable because it indicates that heating-related energy needs are the dominant contributor to the town's overall energy consumption, despite electricity being used year-round for lighting, water systems, office equipment, and Heating, Ventilation, and Air Conditioning (HVAC) controls. This distribution reflects the climate-driven demand for thermal energy in Bethel, especially during the extended heating season.

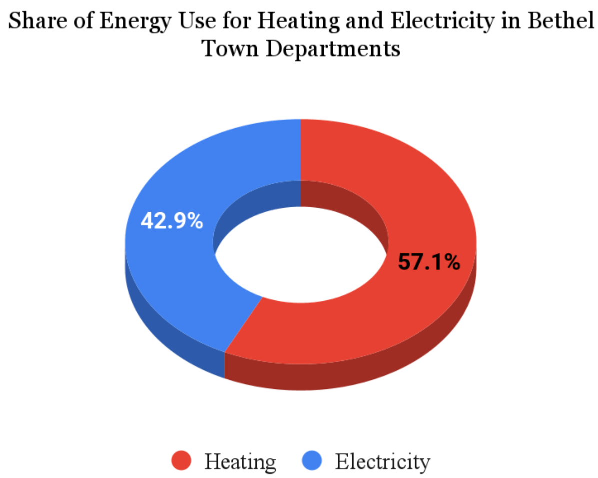


*Figure 9: Electricity and heating fuel in Bethel facilities' energy profile mix*

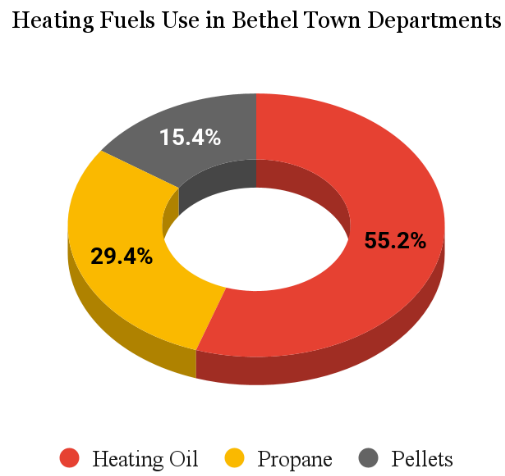


*Figure 10: Heating fuel types in Bethel facilities' heating energy profile mix*

Figure 10 further breaks down the heating portion of the energy profile. Within the heating fuel category, heating oil represents the majority share at 55.2%, followed by propane at 29.4%, and wood pellets at 15.4%. This composition demonstrates a continued dependence on fossil fuels, particularly heating oil, for space heating in municipal buildings. Facilities like the Fire Station and Wastewater Treatment Plant rely heavily on oil and propane systems to meet high thermal demands. At the same time, pellet use, though more sustainable, remains relatively limited and concentrated in smaller facilities such as the Town Office.

# Chapter 3: Shaping Bethel's Energy Future: Pathways to Sustainability and Resilience

The changing global climate and its impacts necessitate community-led mitigation and adaptation strategies. One critical area of building resilience against climate change impacts is in energy consumption. Maine is currently working on an Energy Plan that offers five key objectives and associated strategies and actions to advance the state's energy system to meet its climate and clean energy requirements (Maine Energy Plan, 2024). These objectives are listed as follows:

a. Deliver affordable energy for Maine people and businesses
b. Ensure Maine's energy systems are reliable and resilient in the face of growing challenges
c. Responsibly advance clean energy
d. Deploy efficient technologies to reduce energy costs
e. Expand clean energy career opportunities for Maine people and advance innovation

The achievement of these set objectives can only be propelled by a special-purpose vehicle that will enable communities, including small municipalities, to meet their set target. In 2024, the Office of the Governor of Maine for Policy Innovation and the Future set up the Community Resilience Partnership (CRP) program. The program is intended to provide grants and technical assistance to Maine communities to help them identify and address local priorities to reduce greenhouse gas emissions, transition to clean energy, and become more resilient to climate effects such as extreme storms, flooding, rising sea levels, and threats to public health (Maine Governor's Office of Policy Innovation and the Future, 2023).

The Town of Bethel became a member of this CRP program in 2023 and, in 2024, secured assistance to conduct an energy assessment of its six major facilities under review. This assessment enables the town to understand the cost of spending energy for electricity and heating in these facilities and the opportunities that exist in continuing the "business as usual" or switching to more sustainable and viable energy options (Municipal Sustainable Energy Assessment Report, 2024). This analysis will inform the town's energy expenditure planning for every fiscal year and form the basis for the development of its maiden 5-year energy efficiency plan and other future energy plans thereafter.

To identify Bethel's pathways to energy resilience, the paper seeks to address the questions: (a) Are Bethel town facilities' current expenditures on electricity and heating efficient? and (b) what opportunities exist for Bethel to adopt efficient electricity and heating options in its facilities?

## 3.1. Cost-Benefit Analysis of Bethel's Energy Mix

The paper employed a cost-benefit analysis (CBA) to determine the viability and efficiency of the current energy options used for electricity and heating in the respective facilities, and evaluate the viability of introducing at least solar photovoltaic (PV) as a sustainable energy option into its mix. CBA is a commonly used economic valuation technique that assesses the pros and cons of different project options. It helps identify the most effective way to maximize benefits while minimizing costs in areas such as business operations, transactions, and policy decisions. CBA can analyze both past and potential actions, weighing their expected value against associated expenses and adjust for their social and environmental externalities where possible. It is a tried and tested project appraisal tool which is widely applied in business strategy, public policy evaluation, and investment planning (Misuraca, 2014; Cellini & Kee, 2012).

For the purpose of this paper, we relied on the following five (5) metrics of CBA to evaluate the viability of the various energy options. Further description of these metrics and their application, among other variables employed in this analysis, is provided in Appendix A of this paper.

a. **Net Present Value (NPV):** a CBA metric that assesses an energy option's efficiency by comparing the present value of its expected benefits to the present value of its costs with cash flows using 2023/2024 fiscal year (FY24) as the baseline year and adjusted in present value with the Federal Bank Reserve's (primary credit rate) discount rate of 4.5% (Federal Reserve Bank, as of January, 2025) and ranged up to 5% for a long-term planning period of 25 years. This planning period was chosen because it is the average life span of a typical solar PV (Department of Energy, n.d.). Using the rule of thumb for the evaluation of NPV metric, an energy option that generates a positive and higher NPV **(i.e, NPV > 1)** after accounting for all expenditures, including social and environmental externalities, using GHG emissions as a proxy is considered more viable and efficient for investment. The GHG emissions were estimated based on the Environmental Protection Agency's GHG emission factor for units of electricity and fuels used (Environmental Protection Agency, 2025) and the Maine Legislature's carbon price set between $5-40 per MT between 2020 and 2028 (Maine Legislature (2019).

$$NPV = \sum_{t=0}^{P} \frac{B_t - C_t}{(1+r)^t}$$

b. **Benefit-Cost Ratio (BCR):** evaluates the economic value of an energy option by comparing the total expected benefits to the total expected costs, both adjusted to present value and social and environmental externalities. Per rule of thumb, an energy option that has a BCR greater than one (i.e., **BCR >= 1)** is considered more viable and efficient for investment.

$$BCR = \sum_{t=0}^{P} \frac{\frac{B_t}{(1+r)^t}}{\frac{C_t}{(1+r)^t}}$$

c. **Levelized Cost of Energy (LCOE):** evaluates the average expenditure made for each unit of electricity generated in this case, solar PV by incorporating all associated costs such as initial capital, ongoing operations and maintenance, fuel (where relevant), and financing, as fraction of the total electricity generated over the system's operational lifetime. The lower the LCOE, the better the viability of investing in the project.

$$LCOE = \frac{Total\ cost\ of\ electricity\ generated\ from\ Solar\ PV}{Total\ units\ of\ electricity\ generated\ from\ Solar\ PV\ in\ 25\ years}$$

d. **Internal Rate of Return (IRR):** indicates the annual percentage rate of return that an energy option is expected to earn over time. It is the future interest rate that makes an investment break even. When comparing different energy options, a higher IRR is most preferred.

$$IRR = Interest\ Rate\ until\ \sum_{t=0}^{T} \frac{B_t}{(1+r)^t} = \frac{C_t}{(1+r)^t}$$

e. **Discounted Payback Period (DPBP):** shows the years required to recover the initial cost of investing in an energy option by adjusting for the time value of money. The **lower the DPBP** of an energy option, the more efficient and viable it is to invest in.

$$Discounted\ Payback\ Period = Years\ until\ \sum_{t=0}^{T} \frac{C_t}{(1+r)^t} \geq Initial\ Investment$$

From all the above, the parameters are denoted accordingly: P = planning period, t = specific project time in years, B = cashflow revenue, C cashflow cost, r = interest rate (Federal Reserve Bank's discount rate), and $\sum$ = sum of all terms.

## 3.2. Analyzing the Efficiency of Bethel's Energy Mix

### Cost Analysis of Current Energy Use

To evaluate the town's energy efficiency, the paper first interrogated the proportion of Bethel's total expenditure across FY23-FY25 that goes into energy expenditure in all facilities when actual expenditure allocation in FY24 is used as the baseline. The expenditure lines that comprise the total expenditure for this expenditure analysis are utilities (water, electricity, and sewer), internet and telephone, contracted services, maintenance and repairs, sanitation services, supplies, heating fuel, and small equipment purchases and repairs. The graph below (Figure 11) shows that energy expenditure occupies a significant proportion of the town's total facilities expenditure in every fiscal year, representing an average of 35% per fiscal year. The energy expenditure in the Ambulance Barn is the highest, with an average share of total expenditure allocation of 75% annually, followed by the waste treatment plan with an average share of 58% (Figure 12). The facility with the least average share in annual total expenditure is the Town Office (19%).

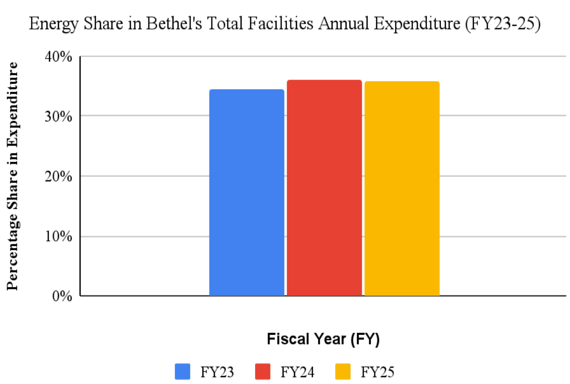


*Figure 11: Proportion of energy expenditure in total facilities expenditure*

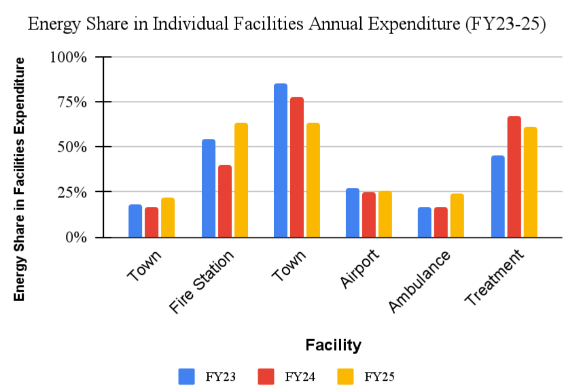


*Figure 12: Proportion of energy expenditure in individual facilities expenditure*

### Electricity Cost Analysis

Having established how significant energy expenditure is to the town's annual total expenditure, the paper conducted a cost analysis of the current electricity situation across all six facilities in the baseline year. At the prevailing interest rate of 4.5%, the electricity price of $0.20 per kWh, carbon price of $35 per MT and given that electricity consumption growth remains unchanged, if it maintains the status quo of electricity from the electricity grid for the next 25 years, the NPV cost of electricity based on financial cashflow to the town of Bethel for the next 25 years will be about $1.28 million. When adjusted for associated social-environmental cost using GHG emission of 74 MT per annum, the NPV cost of electricity, hereafter referred to as the social NPV cost becomes $1.34 million. A five-year scenario was also modelled to provide a short-term indication of the future cost of electricity. This gives an NPV of $349,559 and $370,039 based on financial cashflow and social-environmental cashflow (Table 2). This reveals how expensive continuous reliance on electricity from the grid by the town facilities will be in the future when compared with the baseline expenditure of $60,819.

*Table 2: Cost analysis of electricity use in all Bethel facilities*

| SN | Based on 25-Year Financial Cash Flow | | Based on 25-Year Social-Environmental Cash Flow | |
|---|---|---|---|---|
| 1 | NPV of Electricity Expenditure ($) | **$1,283,436** | Social NPV of Electricity Expenditure ($) | **$1,343,770** |
| 2 | NPV of Units of Electricity Consumed (kWh) | **6,421,454** | NPV of Dollar Units of GHG Emission Added ($) | **$60,335** |
| | **Based on 5-Year Financial Cash Flow** | | **Based on 5-Year Social-Environmental Cash Flow** | |
| 3 | NPV of Electricity Expenditure ($) | **$349,559** | Social NPV of Electricity Expenditure ($) | **$370,039** |
| 4 | NPV of Units of Electricity Consumed (kWh) | **1,953,569** | NPV of Dollar Units of GHG Emission Added ($) | **$20,480** |

**Fuel Cost Analysis**

A similar cost analysis of heating fuel expenditure reveals how unsustainable continuous reliance on propane and heating oil by the town facilities will be in the future, given the baseline expenditure of $44,118. Again, using the prevailing interest rate of 4.5%, a weighted average fuel price of $3.80 per gallon for heating oil and propane, carbon price of $35 per MT and assuming a constant fuel consumption growth, if the town maintains the status quo fuel mix for the next 25 years, the NPV cost of heating fuel based on financial cashflow will be about $731,012. When calculated based on social-environmental cashflow with the associated GHG emission of 166 MT per year, the social NPV cost becomes $843,220. A five-year scenario of the future cost of heating fuel also provides an NPV of $213,766 and $246,578 based on financial cashflow and social-environmental cashflow, respectively (Table 3).

*Table 3: Cost analysis of heating fuel use in all Bethel facilities*

| SN | Based on 25-Year Financial Cash Flow | | Based on 25-Year Social-Environmental Cash Flow | |
|---|---|---|---|---|
| 1 | NPV of Heating Fuel Expenditure ($) | **$731,012** | Social NPV of Heating Fuel Expenditure ($) | **$843,220** |
| 2 | NPV of Units of Heating Fuel Consumed (Gal) | **7,935** | NPV of Dollar Units of GHG Emission Added ($) | **$112,208** |
| | **Based on 5-Year Financial Cash Flow** | | **Based on 5-Year Social-Environmental Cash Flow** | |
| 3 | NPV of Heating Expenditure ($) | **$213,766** | Social NPV of Heating Fuel Expenditure ($) | **$246,578** |
| 4 | NPV of Units of Heating Fuel Consumed (Gal) | **56,205** | NPV of Dollar Units of GHG Emission Added ($) | **$32,812** |

## 3.3. Opportunities for Green and Sustainable Energy

The status quo energy consumption by the town facilities reveals a situation of increasing financial stress on the town's public coffers in the face of future electricity/fuel price escalation, among other macroeconomic uncertainties. Given available federal and state-level opportunities such as up to 30% of tax rebate to entities and homes that install solar power and the office of the Governor's CRP program that empowers communities' effort to upgrade to sustainable energy options, the paper considered in this section the possibility of including solar in the town's energy mix (EnergySage, 2021; Maine Governor's Office of Policy Innovation and the Future, 2023).

***How feasible is solar energy for Bethel?***

Based on the energy assessment conducted in 2024 by Snell (2024), it was established that every town facility has the potential to generate solar energy from rooftop solar PV installations to meet its electricity needs. The solar energy potential of every facility is shown in below (Figure 12). However, since a full-scale transition in the face of budget constraints and technical capacity cannot be cost-effective for the town, the analysis considered a step-wise upgrade onto a solar platform to smooth out the facilities' energy consumption over time. Moreover, a full-scale upgrade of all facilities to renewable energy within a short term may only result in excess generation, underutilization, and undue financial stress that will not be economically efficient for the town. Again, Figure 13 shows that the Airport Terminal has the potential to generate as much as 39 kW, which can power all six facilities' actual electricity demand of 35 kW in a year. Based on the foregoing, the paper employed 39 kW, also equivalent to 0.0388 MW, as the system capacity in the solar cost-benefit analysis.

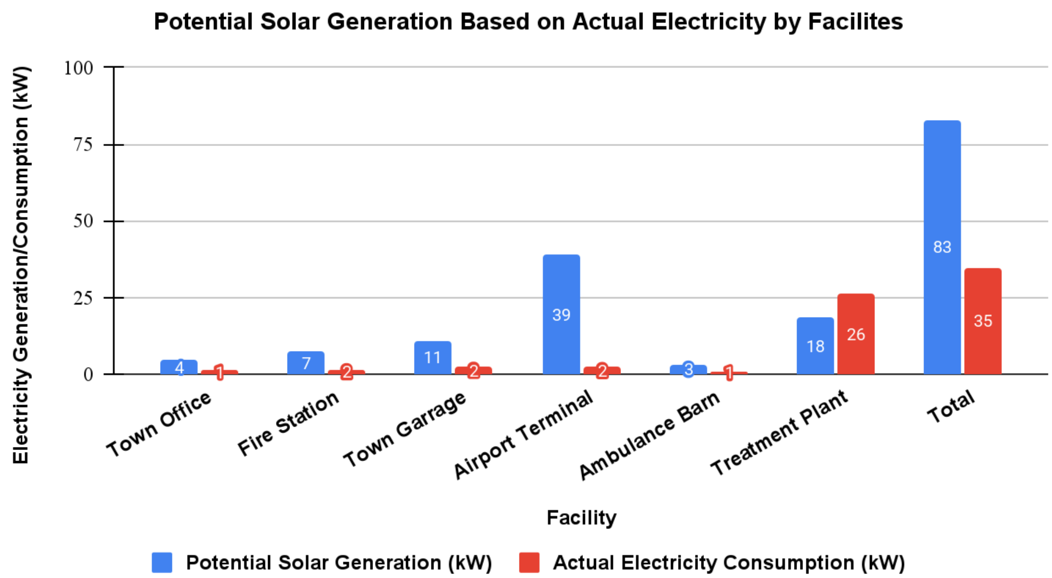


*Figure 13: Potential solar generation and actual electricity consumption capacity in all facilities*

**Cost-Benefit Analysis of Solar as a Potential Renewable Energy Option**

At the prevailing interest rate of 4.5%, the electricity price of $0.20 per kWh, solar installation cost of $2.70 carbon price of $35 per MT and given that electricity consumption growth in the future remains unchanged, if the town upgrades at least a section of the Airport Terminal to a 39 kW solar energy, for the next 25 years, the viability indicators of solar are as presented on Table 5 below.

***NPV measure***

The NPV cost of solar, based on financial cashflow and social-environmental cashflow at GHG emission of 83 MT per annum, is $872,186 and $872,227, respectively. These two NPV indicators are large and positive enough, and they do not differ significantly from each other. This is because using energy from solar is a socio-environmentally friendly investment which will not impose any unintended costs on the town. There will be some social benefits, which translate into the slightly higher social NPV recorded.

***BCR measure***

Using the BCR, which measured the benefit-to-cost ratio of future solar investment for the next 25 years, the analysis obtained 8.7 for both based on financial and socio-environmental cash flows. This result is viable enough, as on solar's own accord, an investment will yield over 8 times more benefits than costs to the town.

### *IRR and DPBP measures*

To answer how beneficial it will be for the town to invest in solar, an IRR measure indicates that the town can return up to 66% of its initial investment cost is in a 2-year payback period of the 25-year planning period, even when adjusted for GHG emissions as a social environmental factor.

### *LCOE measure*

Additionally, to understand the cost-effectiveness of solar over its lifetime, an LCOE analysis found that it will cost the town less than a dollar per kWh ($0.022 per kWh) to run and maintain any installed solar platform in its lifetime. This indicator is $0.00 per kWh when adjusted for social-environmental factors.

*Table 4: Cost-Benefit analysis of solar as a potential energy option for Bethel*

| SN | Based on 25-Year Financial Cash Flow | | Based on 25-Year Social-Environmental Cash Flow | |
|---|---|---|---|---|
| 1 | NPV of Potential Solar Energy ($) | **$872,186** | Social NPV of Potential Solar Energy ($) | **$872,227** |
| 2 | NPV of Units of Solar Energy to be Produced (MWh) | **4801** | NPV of Dollar Units of GHG Emission to be Reduced ($) | **41** |
| 3 | Benefit-Cost Ratio (BCR) | **8.7** | Benefit-Cost Ratio (BCR) | **8.7** |
| 4 | Levelized Cost of Energy (LCOE) ($) | **$0.022** | Levelized Cost of Energy (LCOE) ($) | **$0.00** |
| 5 | Internal Rate of Return (IRR) (%) | **66%** | Internal Rate of Return (IRR) (%) | **66%** |
| 6 | Discounted Payback Period (DPBP) (years) | **2** | Discounted Payback Period (DPBP) (years) | **2** |
| | **Based on 5-Year Financial Cash Flow** | | **Based on 5-Year Social-Environmental Cash Flow** | |
| 7 | NPV of Potential Solar Energy ($) | **$196,007** | Social NPV of Potential Solar Energy ($) | **$196,020** |
| 8 | NPV of Units of Solar Energy to be Produced (MWh) | **1478** | NPV of Dollar Units of GHG Emission to be Reduced ($) | **13** |
| 9 | Benefit-Cost Ratio (BCR) | **2.8** | Benefit-Cost Ratio (BCR) | **2.8** |
| 10 | Levelized Cost of Energy (LCOE) ($) | **$0.022** | Levelized Cost of Energy (LCOE) ($) | **$0.00** |
| 11 | Internal Rate of Return (IRR) (%) | **59%** | Internal Rate of Return (IRR) (%) | **59%** |
| 12 | Discounted Payback Period (DPBP) (years) | **2** | Discounted Payback Period (DPBP) (years) | **2** |

***How cost-effective is it to continue the status quo or switch to solar in the next 5 years?***

When the analysis was narrowed down to the next 5 years for the purpose of short-term planning, it was found that solar NPV yields around $196,000, with a BCR of 2.8 and an IRR of 56% based on both financial and social-environmental cashflows. These are results also presented in Table 5. Just as in the case of a longer-term horizon analysis, this result indicates that solar remains a more viable option for the town to consider adding to its energy mix, with an NPV of almost $200,000, than electricity from the central grid and heating fuels from pumps that have present costs exceeding $200,000. The graph below (Figure 14) shows this comparison between the future benefits (discounted to present terms) for solar energy and the present cost of continuous reliance on traditional energy options for the next 5 years.

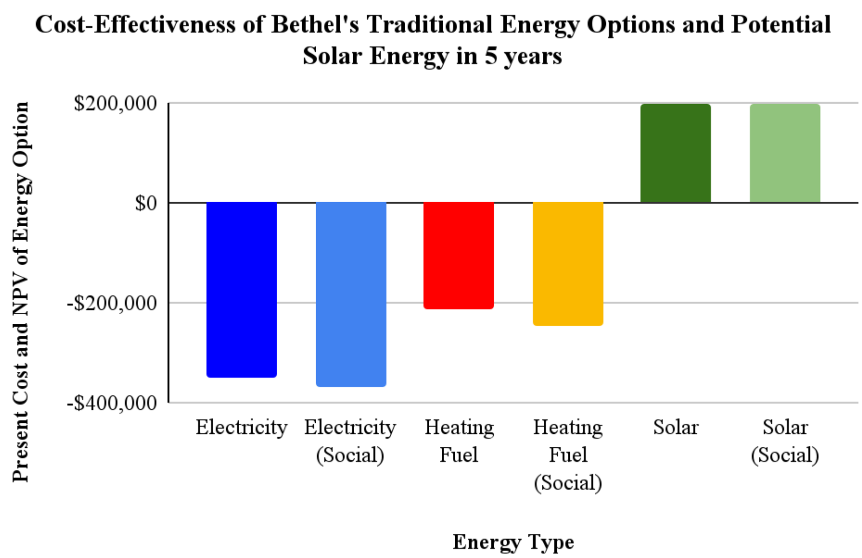


*Figure 14: Comparison between NPV of solar and present cost of traditional energy options*

**Sensitivity Analysis of Potential Solar and Traditional Energy Options for 25 years**

The paper further explored how future changes in discount rates, carbon prices, energy price escalations and energy consumption growth rates will affect the viability of solar as a potential renewable energy investment option. This was done by comparing the present cost of continuing the "business as usual" with the traditional energy options with the NPV of solar over the next 25 years. It was found that, notwithstanding future fluctuation in discount rates and other energy market indicators as earlier referenced, the NPV of investing in solar remains high enough, while the cost of using traditional energy options continues to increase, indicating a further dip into negative (Figure 15).

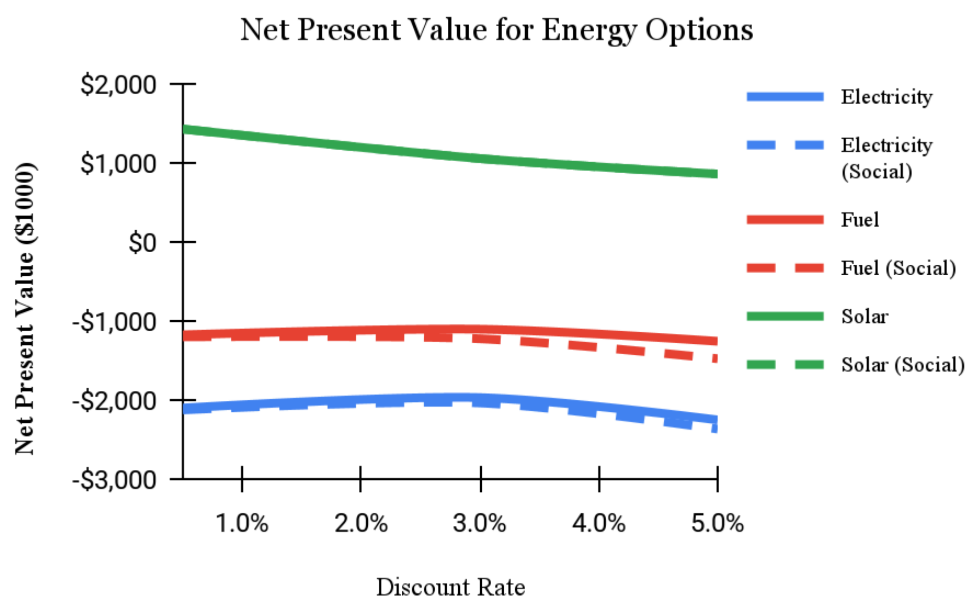


*Figure 15: Sensitivity analysis of NPV with discount rate*

These results underscore how an investment in solar PV will guarantee financial resilience and energy independence for the town office in the medium to long term.

# Chapter 4: Recommendations and the Way Forward

## 4.1. Proposed Sustainable Energy Roadmap for Bethel

**Transitioning to Renewable Energy Sources**

Based on the findings in the foregoing, the paper posits that the current traditional energy mix of the Town of Bethel only puts more financial burden on its public purse. The town can therefore make enough gains in the medium to long term if it considers diversifying its current energy mix to include at least one renewable energy option, such as solar. A cost-benefit analysis using the expected benefits of a potential solar generation in the town facilities and the expected annual expenditure for using electricity from the main grid and heating fuels from the pumps reveals that about $200,000 of financial savings can be made in the future.

While the town cannot afford an immediate transition to renewables by scaling up all facilities to rooftop solar technologies to reap the gains, it can, however, position itself to strategically begin with solar energy-efficient facilities. One of these facilities identified by this paper is the Airport Terminal. With a full solar installation cost of $3.86 per watt and a capacity factor of 23% in Maine, Bethel can plan to install at least a 39 kw solar system arriving at a full capital expenditure of $149,629 (market estimate based on PowerOutage, 2025). Moreover, with at least a 30% federal Residential Clean Energy Credit, the town can waive this to a post-rebate cost of $104,74 to finance this project.

**Energy Data Monitoring and Performance Tracking**

More so, while the town considers ensuring energy efficiency and transitioning to more sustainable energy options, it equally requires internal mechanisms that check and evaluate its energy use and expenditure over time. This effort will be conditioned on reliable and real-time data from energy expenditure, electricity consumption and heater usage by every unit within all departments of the town. This could be achieved by installing smart meters, setting key performance indicators (KPIs) as far as energy use in the town facilities is concerned, and benchmarking future energy expenditure on successful KPIs. The energy audit of the town in 2024 is a commendable starting point that must be continued and improved. The Department of Energy recommends that homes and establishments regularly do such evaluations to understand the source of their energy expenses and improve their energy efficiency (Department of Energy, n.d.). Also, the outcome of this paper affords the town a baseline understanding of efficient energy planning to develop a medium to long-term energy plan for the town facilities and even the entire municipality of Bethel.

### Prioritizing Facility-Level Efficiency Upgrades

Going forward, the Town of Bethel needs to prioritize tackling energy consumption from the appliance side. The town can significantly cut down its annual electricity expenditure and save money by replacing obsolete and faulty appliances or upgrading them to more energy-efficient ones, such as Energy Star or Energy Star's most efficient qualified products. Again, based on standardized recommendations by the Department of Energy, facility managers need to do frequent walk-through check-ups or inspections, use an infrared camera, a blower door, or other techniques to reveal the energy-inefficient sections of a facility. This paper revealed a high energy consumption in the waste treatment plant of the Town of Bethel with an average of 200,00 kWh of electricity consumed in every fiscal year, representing over $40,000 in electricity expenditure.

### Ensure Heating Efficiency and Gradual Phasing out of Fossil Heating Fuels

It is worth noting that the price volatility in the fuel market contributes significantly to the unstable annual heating expenditure recorded in most facilities. This underscores the need for the town to cut down its reliance on heating fuels to provide its heating energy needs. However, since the town relies largely on propane, heating oil and in some cases wood pellets to meet its heating energy needs, there is no immediate cost-effective alternative energy option to recommend, given the amount of heat used in most of the facilities. However, to guarantee efficient heating energy within the medium term, the town would have to consider some weatherization strategies as provided below, based on the Department of Energy (DOE)'s recommended standards. The DOE supports Weatherization Assistance Program (WAP) among other federal programs to provide grants to states, territories, and tribes who fund local organizations to provide help for low-income families in need of assistance with utility costs, housing or emergency services, and by extension improving their home heating energy efficiency. By administering such programs at the local level, it is imperative that the town takes the lead in ensuring its facilities are better weatherized.

a. Seal gaps around floors, walls, ceilings, windows, doors, and fireplaces with caulk, foam, and weather stripping to prevent air leaks. According to the Department of Energy, such efficiency strategies save up to 5-30% of energy annually.
b. Add insulation to the attic, crawl space or basement, and exterior walls in conjunction with air sealing to help keep spaces cool in the summer and warm in the winter
c. With electric-powered shutters, install windows and doors to seal air infiltrates to reduce heat loss through windows by 25-50%.
d. Install and set programmable thermostats that save energy by automatically regulating the

building's temperature when the office is not in use, and save 10% on heating per year.

e. Consider biomass-efficient heating systems in the long term as the town shifts to more renewables to minimize heating energy expenditure and its associated GHG emissions.

The paper thus proposes the following roadmap in Figure 16 to guide the town's transition to sustainable and efficient energy in its facilities. It recommends a step-wise energy transition from the central electricity grid to solar energy in at least the next 5 years, by a 20% minimum upgrade of every facility's electricity consumption to solar power. On the heating side, the town is recommended to follow weatherization strategies highlighted earlier on to improve its heating efficiency by cutting down on heating energy spending and consumption by at least 5% every year.

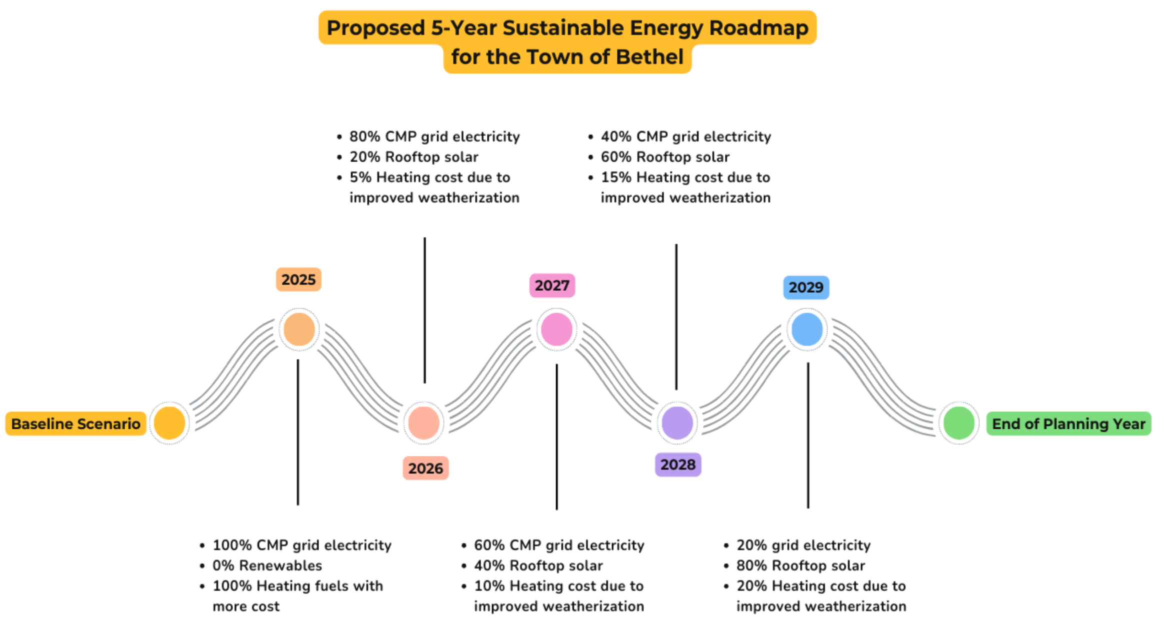


*Figure 16: Proposed energy transition and energy efficiency roadmap for Bethel*

### Funding and Financing Mechanisms

The Town of Bethel would also have to consider securing sustainable financial models to propel the transition of its facilities to solar energy in the medium to long term. This is already effectively explored by the town through its partnership in the Governor's Office CRP program to build its energy resilience against climate change impacts. This partnership can also guarantee Bethel some technical and financial assistance in this quest to ensure energy efficiency and sustainability.

## 4.2. Institutional and Regulatory Support for Energy Planning

**Role of Local Government and Conservation Commission**

Beyond improving the energy efficiency in the Town of Bethel facilities, the Conservation Commission and its allied town agencies, by adopting town-level ordinances that promote energy-efficient building codes and renewable energy installations by all public institutions. Also, by providing planning leadership, Bethel can integrate energy efficiency measures into its annual fiscal budgeting, comprehensive town plans, and dovetail into a medium to long-term energy plan. Furthermore, the Conservation Commission should spearhead community engagement initiatives, such as workshops on home energy audits and incentives for energy-saving upgrades, fostering a culture of conservation among Bethel residents and businesses. This collaborative approach will enable Bethel to reduce energy consumption, lower costs for its citizens, and contribute to a more economically and climate-resilient community within Maine.

**Alignment with State and Federal Energy Policies**

While local efforts such as what the Town of Bethel is leading is important, it is important that the the local government and the Conservation Commission actively familiarize themselves with Maine's ambitious renewable energy targets of attaining 100% renewable electricity by 2040, and greenhouse gas emission reduction goals, as well as relevant federal policies promoting energy efficiency and clean energy development such as tax credits and funding models.

The town should also enforce the Maine Building Codes and Standards, which are designed to improve energy efficiency in new construction and renovations. This directly aligns with the state's efforts to reduce energy consumption in the building sector (Department of Public Safety, 2018).

The town should actively seek and apply for state and federal grants and funding opportunities that support local energy efficiency projects, renewable energy installations, and climate resilience initiatives. This could include programs offered by the Maine Governor's Energy Office, Office for Policy, Innovation and the Future, the U.S. Department of Energy, and other agencies. It should also engage local financial institutions to design financing mechanisms for energy efficiency upgrades for homes, start-ups and local businesses.

**Interagency Collaboration and Technical Assistance**

Bethel's energy plan and policies should explicitly incorporate energy efficiency and climate resilience goals, aligning local development patterns with broader state and federal sustainability objectives. The Conservation Commission of the town would have to engage in state-level energy planning discussions and regional collaborations such as the Maine Governor's Energy Office, the Maine Governor’s Office for Policy, Innovation and the Future, and the U.S. Department of Energy, and other agencies to ensure local priorities are considered and to learn from best practices across Maine and the nation.

**Institutional Capacity Building and Workforce Readiness**

Moreover, building Bethel's capacity for energy efficiency hinges on developing skilled personnel within the town government and the local workforce to create and enforce effective energy policies, secure funding, plan strategically, and engage the community. Simultaneously, fostering a local workforce skilled in energy-efficient building, renewable energy, and energy auditing ensures the practical implementation of these initiatives. A well-informed citizenry further supports these efforts by adopting energy-saving behaviors and backing sustainable policies, creating a self-reinforcing system for Bethel's energy future.

## 4.3. Expected Challenges and Recommended Strategies

Implementing energy efficiency initiatives in Bethel would come up with numerous hurdles, including constrained budgets and funding, the increasing energy demands due to worsening climate change impacts like extreme winter weather, inefficient appliance usage, and local opposition to new technologies. Further complicating efforts will be ageing building stock requiring costly upgrades, limited access to financing and technical capacity, competing local priorities, and the difficulty of establishing effective energy data monitoring systems.

To address the above challenges, the town would have to pursue robust public education campaigns, including town forums and school outreaches, aligned with state and federal resources, which will foster awareness and local acceptability of sustainable energy transition efforts by the town authority. Furthermore, effective spatial planning would have to be employed to strategically designate areas suitable for renewable energy development. Addressing interconnection barriers requires advocating for grid modernization at the state level and potentially developing local solutions for distributed generation integration. Finally, incentives, such as tax breaks, rebates, and low-interest loans, would have to be designed to directly address the upfront cost barrier and encourage the adoption of clean energy technologies across all sectors in Bethel.

# Chapter 5: Conclusion

This paper considered a cost-benefit analysis based on a 25-year planning period of six major facilities in the Town of Bethel that featured in an energy audit conducted in 2024. Two main questions were sought to be answered by this paper, first to understand if Bethel town facilities' current expenditures on electricity and heating are efficient, and to explore the opportunities that exist for the town to adopt efficient electricity and heating options. By employing a cost analysis of the town's current electricity and heating energy use, it was found that the reliance on traditional energy only puts more financial stress on the town's budget if the prevailing energy mix is maintained into the future. Subsequently, the paper assesses the viability of including solar as an alternative energy source into the town's energy mix based on the solar potential estimates for all six faciltiies. The analysis showed that solar is a more efficient and viable alternative which far outperforms the traditional energy sources that the town relies on today for electricity and heating.

Looking ahead, the paper recommended the town to deploy a gradual transition to solar energy by converting at least one facility that has sufficient potential solar generation capacity to supply electricity to the rest of the facilities. While that is considered, the town is recommended to put in place internal mechanisms that reduce its electricity consumption and heating usage through the use of higher efficiency star energy appliances as well as ensuring weatherizing in its facilities for to improve heating efficiency . Finally, the two of Bethel would have to pursue long term plans of developing town-level regulations that align with state-level and national policies to enhance its swift transition sustainable energy over the medium to long term. Possible challenges it may encounter include local resistance to new energy technologies, inadequate financing models, extreme weather events and ageing buildings. The town can however overcome these challenges if it builds the capacity of local town workforce to enforce relevant blue-prints, effectively engage with state and regional agencies, and increase sensitization on energy efficiency behavior among households and establishments in the town.

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# Appendix

## Appendix A: Definition of Key Technical Terms

### a. Discount Rate

The discount rate is the interest rate used in economic and financial analysis to determine the present value of future cash flow, costs, or benefits. It reflects the time value of money, incorporating factors such as inflation, risk, and the opportunity cost of capital. The concept is essential in cost-benefit analysis, especially for evaluating long-term projects with future payoffs.

The present value $PV$ of a future value $FV$, discounted at an annual rate $r$ over $t$ years, is calculated using the formula:

$$PV = \frac{FV}{(1+r)^t}$$

This formula allows decision-makers to express future financial impacts in today's dollars. A higher discount rate reduces the present value of future benefits, often making long-term investments appear less favorable. Conversely, a lower rate increases the weight of future outcomes, emphasizing sustainability and intergenerational equity. The US Federal Reserve's discount rate, which is the interest rate at which banks can borrow money directly from the Federal Reserve, is currently 4.50% (as of April 2025).

### b. Net Present Value (NPV)

Net Present Value (NPV) is a method used in economic and financial analysis to evaluate the profitability or value of a project by calculating the difference between the present value of its benefits and the present value of its costs. It accounts for the time value of money, enabling comparisons between investments with costs and benefits spread over time.

The general formula for NPV is:

$$NPV = \sum_{t=0}^{T} \frac{B_t - C_t}{(1+r)^t}$$

Where, $B_t = benefits\ in\ year\ t$,

$C_t = costs\ in\ year\ t$,

$r = discount\ rate.$

$T = total\ time\ horizon\ of\ the\ analysis$

A positive NPV indicates that the project's benefits exceed its costs when discounted to present value, suggesting a worthwhile investment, and vice versa

### c. Carbon Price

Carbon pricing is an instrument that captures the external costs of greenhouse gas (GHG) emissions—the costs of emissions that the public pays for, such as damage to crops, health care costs from heat waves and droughts, and loss of property from flooding and sea level rise—and ties them to their sources through a price, usually in the form of a price on the carbon dioxide ($CO_2$) emitted. It is a policy tool used to incentivize the reduction of emissions by making the cost of emitting carbon visible in economic decision-making. The carbon price signals the economic value of reducing emissions and encourages investment in cleaner technologies and energy efficiency. It is a key component of market-based climate policies.

There are two primary mechanisms for implementing carbon prices:

- **Carbon Tax** – A fixed price per ton of $CO_2$ emitted, applied directly to fossil fuel use.
- **Cap-and-Trade System** – A market-based approach where a cap is set on total emissions and permits are traded among emitters, effectively setting a price on carbon through supply and demand.

Carbon prices vary by jurisdiction. For example, the Social Cost of Carbon (SCC)—an estimate used by U.S. federal agencies to value climate impacts—is currently around **$51 per metric ton of $CO_2$**. However, this figure is subject to revision based on updated climate models and policy priorities.

### d. Fuel Heat Rate

Fuel heat rate measures the efficiency of a power generation system, defined as the amount of fuel required to produce one unit of useful electrical energy. It is typically expressed in units of British thermal units per kilowatt-hour (Btu/kWh).

Mathematically, it is calculated as:

$$Heat\ Rate = \frac{Fuel\ Input\ (Btu)}{Electricity\ Output\ (kWh)}$$

A lower heat rate indicates a more efficient system, as less fuel is needed to generate the same amount of electricity. Heat rate is a key metric used to compare the performance of different power plants and evaluate energy production's environmental and economic impacts. For example, a modern combined-cycle natural gas plant may have a heat rate around 6,000–7,000 Btu/kWh. In comparison, an older coal-fired plant may exceed 10,000 Btu/kWh, reflecting lower efficiency and higher emissions per unit of electricity produced.

### e. System Capacity

System capacity refers to the maximum amount of power that an energy system is capable of producing under specified conditions. It is typically measured in kilowatts (kW) or megawatts (MW), depending on the system size.

In the context of solar energy, system capacity usually denotes the **rated output** of a photovoltaic (PV) system under standard test conditions (STC), which include specific levels of solar irradiance, temperature, and atmospheric conditions.

For example, a residential solar PV system with ten 400-watt panels has a system capacity of:

$$10 \times 400\,W = 4,000\,W = 4\,kW$$

This means the system can generate up to 4 kW of electricity when operating at optimal conditions. System capacity is a key metric for estimating potential energy production, financial savings, and grid contribution.

### f. Capacity Factor

The capacity factor is a performance metric that measures the actual output of a power-generating system over a period of time as a proportion of its maximum possible output if it operated at full capacity continuously. It is typically expressed as a percentage and provides insight into how efficiently and consistently an energy system operates.

The formula for capacity factor is:

$$Capacity\ Factor\ = \frac{Actual\ Energy\ Output\ over\ Time}{Maximum\ Possible\ Output\ over\ the\ Same\ Period} \times 100\%$$

For example, if a 4 kW solar PV system produces 4,200 kWh in one year, and the theoretical maximum output over the same year is:

$$4\ kW \times 24\ hours/day \times 365\ days\ =\ 35,040\ kWh$$

Then the capacity factor is:

$$\frac{4,200}{35,040} \times 100\% \approx 12\%$$

Capacity factors for solar PV systems typically range from **10% to 25%**, depending on geographic location, weather conditions, system orientation, and shading. A higher capacity factor indicates more consistent energy production relative to the system's rated capacity.

### g. Annual System Degradation

Annual system degradation refers to the gradual decline in the energy output of a power generation system, particularly solar photovoltaic (PV) systems, over time due to material aging, environmental exposure, and other operational factors.

This degradation is typically expressed as a percentage loss in output per year. It affects long-term energy production forecasts and economic evaluations.

The energy output in year t, considering degradation, can be estimated as:

$$E_t = E_0 \times (1\ -\ d)^t$$

Where:

$E_0$ = initial output in the first year

$d$ = annual degradation rate (as a decimal)

$t$ = number of years since installation

For example, with a 0.5% annual degradation rate, a solar system that generates 10,000 kWh in its first year would produce approximately 9,512 kWh in its 10th year:

$$E_{10} = 10,000 \times (1 - 0.005)^{10} \approx 9,512\, kWh$$

Typical degradation rates for modern solar PV panels range from **0.3% to 0.8% per year**, depending on technology and environmental conditions.

### h. Internal Rate of Return (IRR)

Internal Rate of Return (IRR) is the annual percentage rate of return that a project or investment is expected to earn over time. It is the interest rate that makes the value of all future benefits equal to the total costs, meaning the project breaks even in present value terms.

Put simply, IRR is the rate at which the money you spend on a project is paid back through the benefits or savings it generates.

IRR is found by solving this equation:

$$0 = \sum_{t=0}^{T} \frac{C_t}{(1+r)^t}$$

Where:

$C_t$ = net cash flow (benefits minus costs) in year t

$r$ = the internal rate of return

$T$ = the number of years in the project

If the IRR is higher than the discount rate (the rate used to compare future money to today's money), the project is considered a good investment. For example, if a solar energy system has an IRR of 7% and your discount rate is 3%, it means the project is likely to return more value than it costs.

### i. Benefit-Cost Ratio

Benefit-Cost Ratio (BCR) is a measure used to evaluate the economic value of a project by comparing the total expected benefits to the total expected costs, both adjusted to present value using a discount rate.

It is calculated with the formula:

$$BCR = \frac{\sum_{t=0}^{T} \frac{B_t}{(1+r)^t}}{\sum_{t=0}^{T} \frac{C_t}{(1+r)^t}}$$

Where:

$B_t$ = benefits in year $t$

$C_t$ = costs in year $t$

$r$ = discount rate

$T$ = total number of years considered

A BCR greater than 1.0 means the benefits outweigh the costs, suggesting that the project is economically worthwhile. For example, a BCR of 1.5 means that for every dollar spent, the project returns $1.50 in benefits.

### j. Payback Counter

Payback counter refers to a tracking method or tool used to determine how many years it takes for a project or investment to recover its initial costs through the savings or revenues it generates. It provides a simple way to understand when an investment "pays for itself."

Unlike more complex financial metrics, the payback counter does not account for the time value of money—it simply counts the number of years until the total savings equal the initial investment.

For example, if a solar system costs $10,000 and saves $2,000 per year on electricity, the payback counter would show a payback period of 5 years.

### k. Discount Payback Period

The discounted payback period is the number of years required for an investment to recover its initial cost, **adjusting for the time value of money**. Unlike the simple payback period, it uses a discount rate to reduce future savings or revenues to their present value, offering a more accurate financial picture.

The formula involves calculating the present value of each year's cash flow and summing them until they equal or exceed the initial investment:

$$Discounted\ Payback\ Period\ =\ Years\ until\ \sum_{t=0}^{T} \frac{C_t}{(1+r)^t} \geq Initial\ Investment$$

Where, $C_t$ = net cash flow in year t

$r$ = discount rate

This method is especially useful in evaluating projects where future savings are expected to be less valuable than current costs, helping to prioritize investments based on real economic return.

### l. Financial Cashflow

Financial cash flow refers to the actual movement of money in and out of a project or investment over time. It includes revenues, operational costs, capital expenditures, taxes, subsidies, and savings—everything that affects the project's bottom line.

These flows are used in standard financial analysis to evaluate the economic performance of a project using metrics such as **Net Present Value (NPV)**, **Internal Rate of Return (IRR)**, and **Payback Period**. Financial cash flows are central to determining whether a project is viable from an investor's perspective, independent of broader social or environmental effects.

## m. Social Environmental Cashflow

Social-environmental cash flow represents the estimated monetary value of a project's broader impacts on society and the environment that are not captured through direct financial transactions. These impacts are typically externalities—both positive and negative—associated with activities such as energy production, infrastructure development, or land use changes.

A central component of this cash flow is the cost of greenhouse gas (GHG) emissions, which is commonly estimated using the Social Cost of Carbon. This value reflects the long-term economic damage caused by the emission of one additional ton of carbon dioxide. Other elements may include public health savings due to improved air quality, benefits from reduced environmental degradation, changes in ecosystem services, and avoided regulatory fines.

Although these are not “cash flows” in the traditional accounting sense, assigning them a monetary value allows for a more complete and socially responsible assessment of a project’s overall value. Social-environmental cash flows are essential in sustainable energy economics and policy-making, where long-term social and ecological considerations must be integrated into investment decisions.

## n. Levelized Cost of Energy

The Levelized Cost of Energy (LCOE) is a key tool used to measure and compare the cost-effectiveness of different energy generation technologies over their entire lifetimes. It represents the average cost per unit of electricity generated, accounting for all costs incurred during the system’s lifespan—including capital investment, operations and maintenance, fuel (if applicable), and financing—divided by the total energy output over that period.

The LCOE is typically expressed in dollars per kilowatt-hour (e.g., $/kWh) and is calculated using present value techniques to incorporate the time value of money. This metric allows for an apples-to-apples comparison of energy sources such as solar, wind, natural gas, and nuclear, regardless of differences in project size, lifespan, or upfront costs. A lower LCOE indicates a more economically competitive energy source. For renewable technologies like solar photovoltaics, the LCOE is heavily influenced by initial installation costs, capacity factor, system degradation, and available incentives.

## o. Energy Price Escalation Rate

The energy price escalation rate represents the projected annual increase in energy costs over a specified period. This rate is crucial for forecasting future energy expenses and evaluating the long-term economic viability of energy-related projects.

The National Institufe of Standards and Technology (NIST) under the Department of Commerce developed an Energy Escalation Rate Calculator (EERC) that computes an average annual escalation rate based on energy price forecasts from the U.S. Department of Energy's Energy Information Administration (EIA). These rates can be expressed in real terms (excluding inflation) or nominal terms (including inflation) and are often weighted according to the energy types used in a project. The EERC allows users to input specific parameters, such as fuel type, project duration, and carbon pricing scenarios, to generate tailored escalation rates.

These calculated rates are particularly useful in structuring contract payments for Energy Savings Performance Contracts (ESPCs) and Utility Energy Services Contracts (UESCs), ensuring that projected energy cost savings are accurately reflected over the contract term. By incorporating standardized escalation rates, stakeholders can make informed decisions regarding energy investments and policy planning.