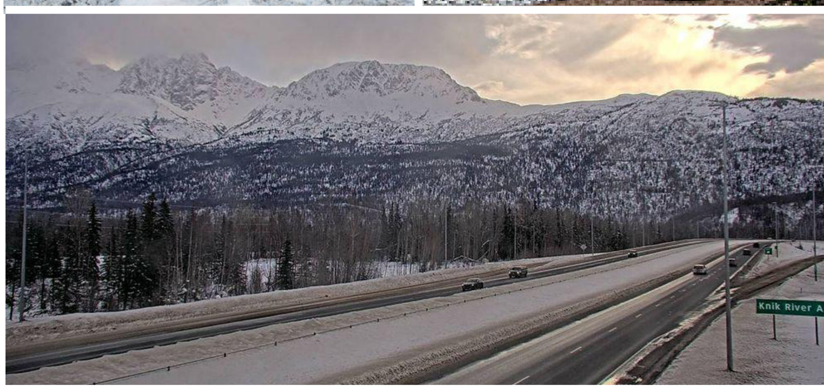
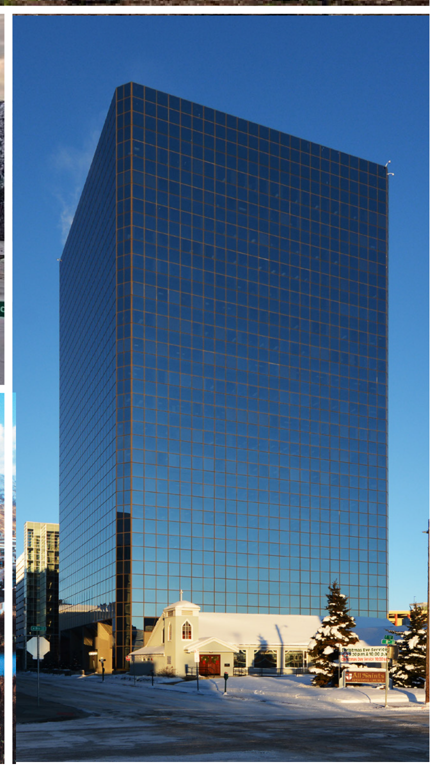
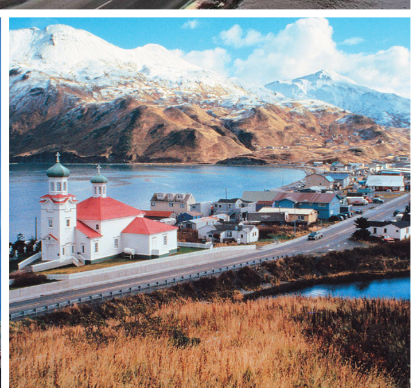
TECHNICAL APPENDIX

State of Alaska Energy Efficiency Upgrade Project





Reference Case

The reference case of this analysis includes nineteen buildings, street light upgrades and a solar PV project. For each of the buildings, an energy model of the reference case was created using the following process - The building stock data for the public buildings was taken from the dataset as well as energy volumes, such as electricity and fuel usage analyzed. The dataset included information about the building types, such as, the year-of-construction, heating-fuel, and square-footage fields.

The required parameters to index the building properties are square footage, year-of-construction, heating-fuel, and zip-code. Once this dataset was properly cleaned, a model was created for each building using the information on-hand. The models are constructed in EnergyPlus, the industry standard building energy simulation tool, using the automatic generation capability of the Constellation Navigator software. Because only the 5 main variables were available, all other energy-relevant building data was taken from the most applicable of the representative building energy models developed by NREL, PNNL, and DoE discussed below. The most applicable data source for each building was determined by comparing the year of construction, zip code, building type, and heating fuel (as assumed from other fuels in the building). This step ensures that models at the building level are not over- or under-estimating any fuel usage, and it also helps us refine the assumptions made for heating fuel at the building level.

Where one of the five required inputs for the Constellation Navigator process was not given, it was derived from Google Maps information about the building. However, for these buildings, we also have data for the annual energy cost of the building, broken down by fuel. Therefore, the additional step was taken to calibrate the energy model's outputs to match the given annual usage metrics. This is accomplished by using the Constellation Navigator machine learning model described below regarding efficiency upgrades.

Additionally, street light retrofits and solar project will also be developed. For the retrofit of street-lighting from High Pressure Sodium lamps to LED lights. Approximated 700 "cobra-head" and 10 high-mast lights to be retro-fitted. Efficacy of LED streetlights at reducing emissions is very high because they have a long service life and are typically warranted for at least 10 years, long term emissions reductions correlate to reduced electric power consumption, all of which comes from diesel feedstock and from combustion. DOT&PF Division of Facilities Services is currently completing a city-wide LED retrofit of DOT&PF owned lights in Anchorage. Approximately 4,000 lights have been completed to date. The contracting and project management of energy efficiency measures is one of the core functions of our division.

Anticipated energy savings of 375,000 kWh per year and a corresponding CO2 reduction of 195,487 lbs. per year (or 88.7 MT CO2). This is based on 4,380 annual hours of roadway lighting operation, 85% Light Loss Factor, .5213 lbs. CO2 per kWh, and replacing 400W HPS with 278W LED fixtures to match current streetlight retrofit designs. Progress will be tracked by design phase submittals, and fixture installation using existing GE LightGrid system for real-time installation updates.

Lastly, for the proposed renewable energy measure, a solar panel array and associated equipment will be installed at the Galena Maintenance Station located in Galena, AK, for approximately 12,000 lbs per year reduction in CO2 (or 5.43 MT CO2). The solar installation will offset electricity consumption currently provided by the city of Galena, the electricity of which is from 100% diesel generation. One of DOT&PF Division of Facilities Services core functions is the contracting and project management of this project.

Measure-specific implementation assumptions:

For envelope changes, levels of insulation and sealing as well as window upgrades were modeled. Additionally, wherever meaningful, the installation of VRF, commercial heat pumps and LED lighting, alongside variable speed drives on pumps and fans. In certain buildings, HVAC Heat Recovery and CHP installations were modeled, whereas in others Condensing Boilers and Ground-source heat pumps (GSHP) were modeled in. See energy use and emission details in the support file.

The efficiency upgrades in this set of measures include the replacement of all non-LED lighting fixtures with LED fixtures, the addition of wall and roof insulation, and air-sealing of the envelope. In the implementation of the insulation upgrade, it's assumed that the space exists to install the levels of insulation modelled, which in some cases requires the extension of the depth of the walls. The number of fixtures that are currently LED is determined based on the year of construction or last renovation of the building. For buildings which have been more recently renovated, it's assumed that they have more LEDs installed, with the converse effect also assumed.

A full audit is also planned such that other tertiary measures could be implemented, wherever applicable. For example, the audit can lead to the identification of low-cost savings opportunities not otherwise modelled, including boiler system tune-up, such as remove scaling or deposits, other maintenance; outdoor air system tune-up such as the identification of any leakage; any lighting controls measures or hot water supply temperature resets; supply air temperature resets and space air temperature setpoint setbacks, as well as adjusting demand-controlled ventilation air or tuning exhaust fan schedules.

The models show competing ECM emission reductions, which will be finalized upon the audit. Specifically, for these mutually exclusive ECMs, a baseline facility can be upgraded with either VRF, Heat pumps, as explained above; or a CHP, GSHP or condensing boiler - not all. As a result, the emission reductions for these set of ECMs are not summed up, but the mean is assumed. For the Condensing Boiler ECM (#11), the measure would replace the existing heating system with a condensing natural gas boiler. Implement a hot water supply temperature reset strategy to most effectively operate the boiler. For CHP (#12), the measure would replace existing heating system with a natural gas Microturbine, optimized for overall efficiency. Operate the Microturbine to meet all heating loads in the facility, using the generated electricity to run electric loads in the building. In times when excess electricity is generated, it could potentially sell back to the electric utility or stored. Finally, for GSHP (#13) the measure would replace the existing heating system, and cooling system if applicable, to a ground-source heat pump. The size of the ground loop and heat pump will be scaled to meet the entire heating load of the facility upon further analyses. For facilities that current has a boiler, then the heat pump installed is a water-to-water heat pump, otherwise, it is a water-to-air heat pump. Therefore, no changes to the hot water or air distribution system are required. Beyond these ECMs, the others are modeled separately, and can be implemented at the site together, but may show overall decreased performance when implemented together - due to overlapping or counteracting gains.

Measure-specific activity data:

Commercial buildings will be receiving energy efficiency upgrades. For example, E1.1.1 and E1.8. External post insulation is added to the exterior walls and roof to reach the U-value specified by ASHRAE 189 2020 (p141) for the climate zone. A secondary measure will model the envelope air tightness is reduced to 0.25 cfm/sf as specified by ASHRAE 198 2020 p88, section 10.6. Additionally, E6.5.4 and E6.3, replacing all lighting with lighting power density which meets the 2020 ASHRAE 189 LPD levels.

Models/Tools used

- Constellation Navigator automatic energy model processing: used to create reference case models, upgrade-scenario models, and compare them
- Constellation Navigator ML Calibration model at the Tier 1 level. This model was used to calibrate the likely savings of each measure based on how the modelled "average building" compared to the measured annual energy usage.
- DoE Commercial Reference Building Models: used as a source of data for building characteristics that do not exist in the building-specific datasets
- Vendor specific lighting update estimates, as well as solar proposal for the streetlight and Galena solar proposals, respectively.

GHG Reduction Estimate Method:

The difference between the reference (base) case and the modeled changes in energy due to the modeled adoption of measures discussed above, is the activity data being used to estimate the reduction in GHG. For example, after buildings are simulated using the tools and assumptions above, the estimated reduction or increase in different types of fuels, such as natural gas, coal, liquid fuels or electricity, is converted from MMBTU or its energy equivalents, into MT CO_2e using the corresponding emission factors for that fuel type, across the constituent CO_2, CH_4 and N_2O. Next, EPA's 2022 GWP values are used to convert to each MT per GHG type into aggregated annual MT CO_2e – using 1 for CO_2, 298 for N_2O and 25 for CH_4. Whenever appropriate, the emission factors of electricity, is matched using the community the buildings are in, and either the PCE based emission factors, or the grid-rates for the sub-region.

Source: https://www.epa.gov/system/files/documents/2022-04/ghg_emission_factors_hub.pdf

There are instances where, given the usage profiles, equipment assumptions and climate zone, certain ECMs can increase emissions. For example, in the case of lighting, for inefficient lighting, most of the energy lost is lost as heat into the space. Therefore, when these fixtures are replaced, the heating system has to work harder. In climates like Alaska, this effect is larger because most of the time, the HVAC system is heating. However, heat lost from lighting fixtures is not efficiently distributed and not all energy lost goes into the space, therefore almost all the time, it will save more electric energy than you increase heating energy. Separately, for other end-use ECMs, such as with VRF, which is a fuel-switching measure similar to heat pumps, while it is a more efficient way of heating, but with poor emissions factors, it's possible that it increases emissions. Next, for windows, there could sometimes be a small cooling energy increase - largely because the measure is for windows that allow a lot of solar heat gain, which is very helpful in heating periods. The buildings which show this effect the most have warmer climates, building types with more heat gain - leading to more cooling energy, and more window area. This effect should be completely overshadowed by the additional heating benefits from having a high solar heat gain coefficient.

GHG Reduction Estimate Assumptions: The quantification does not assume any impacts of "joint strategies" – that is, the simultaneous impact of multiple projects at a single location. In other words, if a project analyzes the reduction of grid emissions based on upstream integration of renewable energy, the new emission factors of electricity are not being used to measure the impact of electrification or efficiency of end-use equipment, as stated above. Instead, the reference emission factors will be used. Similarly, if competing efficiency projects are modeled such that they are not additive, but are substitutes of each other, the extent of overlap is not being modeled or predicted. Additionally, the baseline models assume annualized load profiles – and actual building performance may differ, such as from partial usage or occupancy, etc. Lastly, there are no weather normalizations done on either the activity of the reference scenario or modeled measures.

GHG Emission Reduction Calculations: See attached technical appendix with linked Spreadsheet.