Alaska Community Criteria Pollutant and Greenhouse Gas Emission Inventory Tool Development

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Final Report

Executive Summary

The Alaska IRACAA 103 Emissions Inventory Project aimed to improve the accuracy of previously generated community-level emissions estimates by combining modeled inventory data with directly surveyed local activity data. This report documents the objectives, methods, quality assurance measures, and data management practices used to develop a robust emissions inventory under the State of Alaska's IRACAA103 grant. The project targeted multiple sectors (residential, commercial, industrial, power generation, transportation, etc.) and fuel types (wood, oil, diesel, gasoline, etc.), with the goal of informing air quality planning and regulatory compliance efforts through more accurate, community-specific data. Tailored survey questionnaires were developed to capture local data on fuel consumption, heating devices, commercial operations, industrial activity, and other relevant practices, aligning with the categories used in the existing emissions models. By ensuring that the survey covered the same sectors and fuel types as the modeled inventory, the project enabled one-to-one comparisons between modeled estimates and actual reported activities across different source categories.

This project employed two approaches to its work. First, as part of the development of the emissions inventory toolkit, it modelled community emissions inventories using existing federal and state data sources. Following this, it used a combination of household interviews, facility surveys, and local agency data reviews to gather on-the-ground information. Trained field staff administered surveys in person or via phone, incorporating cultural and linguistic considerations to encourage participation and accurate responses. Survey responses were entered into a centralized digital database, which featured built-in validation rules to flag outliers or inconsistent entries. Rigorous data checks were performed to identify anomalous values, and questionable responses were followed up for clarification. This process ensured a high level of data integrity before analysis. All survey data were collected using a standardized cloud-based form (JotForm) to streamline data entry and minimize transcription errors. Documented QA/QC procedures (as detailed in the project Quality Assurance Project Plans, QAPPs) were applied to verify that survey data were consistent with regional norms and past records; where needed, adjustments to reported activity levels were made to better reflect realistic practices.

Using the validated data, the team compared actual surveyed activity to the pre-existing modeled emissions estimates (primarily based on Alaska's 2022 emissions inventory data) for each participating community. The comparisons were broken down by sector (e.g. residential heating vs. power generation), by source or device type (e.g. wood stove vs. diesel generator), and by fuel type (wood, oil, diesel, etc.) wherever possible. For each community, results were tabulated to show how the survey-based estimates differed from the model's estimates in tons of emissions. In many cases, these community-level comparisons revealed significant discrepancies, which are summarized in this report and in individual community summary appendices. Where the model over- or under-estimated emissions, the values were adjusted or flagged for future refinement of emission factors. Key areas with large differences were identified to help refine modeling assumptions, improve future inventory methods, and guide community outreach and mitigation strategies. Each surveyed community has a dedicated report (see Appendices) detailing its emissions profile comparison and providing recommendations for improving local emission estimates. Overall, the integration of on-the-ground data with modeled data resulted in a more accurate and locally relevant emissions inventory, which will be used to inform air quality management decisions and ensure compliance with state and federal air quality standards.

Introduction

This project employed a structured methodology to develop a community-based emissions inventory that reconciles modeled estimates with ground-truthed activity data from local surveys. The research was designed to improve the accuracy and local relevance of emissions inventories for selected Alaskan communities, recognizing that generic models often fail to capture unique local practices. By combining direct survey data on fuel use and activities with existing emissions modeling for the same communities, the project ensures that sector- and fuel-specific emissions estimates better reflect actual community conditions. This approach is vital for informing air quality management decisions, and public health initiatives, given that on-the-ground activities can differ markedly from assumptions.

At the outset, the team completed an emissions inventory model based on federal and state data sources, downscaling emissions from the state and borough level using appropriate methods. Data used in this process included the American Community Survey (ACS), the EPA State Inventory Tool (SIT), and administrative data from the Alaska Energy Authority's Power Cost Equalization (PCE) program. Following this modelling, the team reviewed the methodologies from other prior emissions inventory studies around Alaska and then designed customized survey instruments to capture community-specific data on fuel consumption and emission-generating activities. Each survey was structured to align with the sectors and source types represented in the existing emissions model. For example, the questionnaires included sections on household heating (e.g. wood stove or oil furnace use), commercial operations (e.g. fuel use in local businesses or utilities), industrial activities (if applicable, such as fish processing), power generation (diesel generator fuel use), and transportation (vehicle and off-road engine use). By mirroring the categories of the modeled inventory, the survey ensured that every major source of emissions in the model was accounted for in the field data collection.

Survey administration was carried out by trained field staff in partnership with local contacts. Surveys were conducted through a mix of in-person interviews at households and facilities, phone interviews, and consultations with local agencies (such as utility operators or fuel depot managers). Cultural and linguistic considerations were integrated into the process to ensure clear communication – for instance, local interpreters or community liaisons were involved in predominantly Alaska Native communities, and surveys were phrased in accessible language with locally relevant examples. This inclusive approach improved participation rates and the accuracy of responses. All responses were recorded in a centralized online database in real time. The use of a digital form not only expedited data collection but also enforced answer formats and units, reducing data entry errors (e.g. preventing confusion between units like gallons vs. barrels or cords of wood). Immediately upon data entry, automated validation checks would flag values outside expected ranges (for example, a household reporting an implausibly large volume of fuel usage) or inconsistencies (such as a business reporting fuel use but zero hours of operation). Such entries were verified by re-contacting the respondent or cross-checking with secondary data sources, and any confirmed errors were corrected in the dataset.

Throughout data collection and entry, the project adhered to the Quality Assurance/Quality Control (QA/QC) protocols defined in the QAPP. The QAPP established data quality objectives and indicators – including precision, accuracy (bias), representativeness, comparability, and completeness – to ensure the reliability of the information gathered. Only data meeting defined acceptance criteria were included in the final analysis. For instance, the QAPP required that any external data source used for model inputs have a clearly defined geographic boundary within Alaska, recent data vintage (collected in 2017 or later, to align with the 2020–2022 baseline period), and documented methodologies. Adhering to these criteria helped maintain consistency and credibility in the combined dataset. Where the source or quality of a data point was questionable, it was either verified or excluded in accordance with the QAPP's exclusion criteria to prevent spurious information from skewing the results.

After data collection, the validated survey data were systematically compared to the modeled emissions estimates that had been previously developed for each community (using 2022 as the reference year). The modeling tool – developed under the first phase of this project – utilized aggregated data (such as state or regional fuel consumption statistics and default emission factors) to estimate emissions for communities statewide. In this second phase, by overlaying actual surveyed activity levels onto those estimates, we could evaluate the model's performance. The comparisons were done across multiple dimensions: by sector (residential, commercial, industrial, power generation, transportation), by source type or equipment (e.g. home heating stoves, diesel generators, vehicles, etc.), and by fuel type. This multidimensional analysis helped pinpoint where the model's assumptions diverged from real-world usage. The introduction of empirical data allowed us to calculate adjustment factors for the model – essentially quantifying how much the model was over- or under-estimating certain activities. Once the survey data were vetted and accepted, they were fed back into the emissions model to update the emissions calculations, and a sensitivity analysis was performed to verify the model's accuracy against observed data. The outcome is a refined emissions inventory that blends top-down modeling with bottom-up measured data, yielding a more accurate reflection of community emissions.

In summary, this introduction has outlined the project's motivation and approach. The following sections provide details on the literature that informed our methods, the specific methodologies for data collection and analysis, the results of the model-data comparisons, the QA/QC and data management processes that ensured data quality, a discussion of the findings' implications, and recommendations for future inventories. Appendices include the survey instruments, a user guide for the inventory toolkit, and community-level reports for each participating community.

Methods

Literature Review

To build on prior knowledge, we first examined previous efforts to develop emissions inventories for Alaskan communities. One key study was a comprehensive emissions inventory for small and mid-size rural communities in Alaska, originally conducted for the base year 2005 with projections out to 2018. This study was commissioned by the Western Regional Air Partnership (WRAP) and the Alaska Department of Environmental Conservation (ADEC) to support compliance with EPA regulations (including the regional haze rule and other programs). The approach in 2005 was to divide the state into six regions and select representative communities based on factors such as location, population size, proximity to Class I areas, representativeness of surrounding villages, and the communities' willingness to participate. In each selected community, extensive surveys were conducted: at least 30 households per community were surveyed each season for residential fuel use, and all key non-residential facilities (schools, clinics, power generators, fuel distributors, etc.) were surveyed for their fuel usage and activities. These surveys gathered seasonal information on home heating practices, vehicle and equipment use, waste burning, and other local emission sources. The resulting activity data were combined with standard emission factors (primarily EPA's AP-42 factors for stationary sources and the MOBILE6 model for on-road vehicle emissions) to calculate emissions. For non-road equipment, the NONROAD model was used with local input adjustments, and aircraft emissions were estimated with the FAA's EDMS model. Where survey data had gaps or were incomplete, the researchers supplemented missing values with data from similar communities, applying scaling adjustments for population and other local conditions. The 2005 WRAP/ADEC study extrapolated emissions from the 14 directly surveyed communities to over 360 other rural communities across Alaska. Extrapolation was done by grouping communities of similar size, region, and road access characteristics and assuming the surveyed communities' per-capita or per-household emissions could represent those groups. A formal QA/QC program was implemented in that study, including measures like data quality scoring (e.g. DARS scores), documentation reviews, and correction tracking for any anomalies. The results revealed that certain emission sources were much more significant in rural Alaska than previously understood – for example, wood burning for heating and fugitive dust from unpaved roads were found to be major contributors to PM emissions, in many cases exceeding the levels found in Alaska's larger urban areas. These findings underscored the importance of accounting for local practices (like heavy use of wood fuel and extensive unpaved road travel) in emission estimates. The study's final report (published in 2007) provided community-level emission estimates for 2005 and forecasted emissions through 2018, and it highlighted substantial uncertainties in areas with limited data. Two of the originally surveyed communities were re-inventoried in 2018, which provided some insight into trends over time.

The insights from the 2005 study heavily informed the design of our current project. In particular, the survey instruments and methodology for this project were developed to address some limitations of the earlier approach. The 2005 study relied on a small sample of communities and significant extrapolation, which introduced uncertainty when generalized statewide. This project attempted to improve this by directly surveying a number of communities that can be representative of their regions and getting a detailed and by implementing more robust QA checks. For instance, where the earlier surveys sometimes encountered unit confusion (e.g. respondents misreporting wood fuel amounts in cords vs. piles) or under-reporting of certain activities (e.g. zero diesel vehicle use reported in winter, which might be implausible), we incorporated clearer units and examples in our questionnaires (such as explaining that "one pickup truck bed full of wood is roughly half a cord") and followed up on any suspiciously low or high responses. The earlier findings about high variability in fuel use between seemingly similar communities led us to treat each community as unique in this project, avoiding broad assumptions based on region or population alone. We also took note of the major contributors like wood heating and road dust; thus, our surveys explicitly asked detailed questions about wood stove usage and seasonal travel on local roads to ensure those sources are quantified. In summary, the literature review provided a critical foundation, and this project's methodology was crafted to build upon and improve the accuracy of past inventories by collecting new data and applying updated QA/QC protocols.

Emission Inventory Model Development

Under this grant, an emission inventory toolkit (model) was developed to estimate community-level emissions for both criteria air pollutants and greenhouse gases. In the first phase of the project (prior to field surveys), ADEC aggregated all available data from existing state and federal inventories and databases to populate this model. This included data from the statewide greenhouse gas inventory and National Emission Inventory (NEI) databases, fuel sales records (e.g. regional diesel and gasoline sales for power and heating), census data on housing and populations, and any previously published community emission reports. These inputs were processed to produce an initial set of emissions estimates for every community in Alaska, using 2020 as a baseline year (with 2022 updates). The model essentially provided a "top-down" estimate of emissions by allocating state and regional totals down to communities based on proxies like population, number of households, presence of certain facilities, and typical usage patterns. The assumptions and calculation logic in the model were documented, and inclusion/exclusion criteria were applied to decide which data sources were appropriate. For example, emissions data had to be specific to Alaska and recent (post-2017) to be included, and sources had to clearly document their methods and scope. Emission factors used in the model were standard EPA factors (AP-42, etc.) unless Alaska-specific factors were available. The resulting toolkit allowed users to select a community and view estimated emissions by sector and source, essentially forming a pre-survey baseline for each community.

With the toolkit in hand, the second phase of the project involved ground-truthing and refining the model using new survey data. We selected 12 representative rural communities (spanning various regions and contexts – coastal, interior, road-connected and off-road, different population sizes) to conduct detailed emission inventory surveys. These communities were also chosen with environmental justice considerations in mind (each met one or more Justice40 or EJSCREEN vulnerability criteria, indicating overburdened or underserved status). The intent was to verify that the model's predictions for these communities were accurate and, if not, to adjust the model. After the community surveys were completed and validated (as described in the next section), the collected data were fed back into the model. For each surveyed community, we replaced or updated the modeled activity data with the actual survey values (for example, if the model assumed 100 cords of wood burned per year in a village but the survey found 150 cords, the higher value would replace the model's assumption for that community). We then ran a sensitivity analysis using the model, which involved checking how sensitive the emissions outcomes were to these new inputs. This process quantified the variation between modeled and observed data for each major sector. It also allowed us to calibrate the model: by understanding the direction and magnitude of discrepancies, we could adjust emission factors or allocation methods for communities that were not surveyed, especially those that are similar to ones that were surveyed.

The end result of the model development and refinement is a toolkit that not only provides an emissions inventory for each community but also includes an error range or confidence interval based on the survey findings. The analysis of survey vs. model data yielded an estimate of how much the model might be off for a given sector or region, and we propagated these findings to estimate uncertainties for all communities. For example, if surveyed communities in the interior region showed residential wood combustion emissions were on average 25% higher than the model predicted, we can infer that other interior communities (not surveyed) might similarly be underestimated by the model, and we provide a factor or range to account for that. This calibrated tool is a major deliverable of the project. It is intended to be used by ADEC and local stakeholders for future planning – communities can use the tool to get an initial estimate of emissions, knowing that it has been adjusted based on real data, and identify where more data collection might be needed. The model's design and updates are further documented in the project's technical appendices and user guide (Appendix A).

Survey Design and Deployment

Custom survey instruments were developed to collect detailed data on activity levels related to fuel use and emission-generating practices in each community. The survey was divided into modules corresponding to key sectors: Residential Heating, Power Generation, Transportation (on-road and off-road), Commercial/Institutional, and Waste Burning. Within each module, questions gathered both qualitative and quantitative information. For example, in the residential module, households were asked how they heat their homes (wood stove, oil furnace, etc.), approximately how much fuel or wood they use in each season, and whether they had secondary heating devices. In the power generation section, we collected data from local utilities on diesel generator fuel consumption and operating hours. The commercial section surveyed facilities like schools, clinics, water treatment plants, and stores about their fuel use for heating and electricity.

We also included questions on seasonal activities unique to rural Alaska – such as fish smoking, open burning, subsistence hunting trips (which involve boat or ATV use), etc. – since these can be important emission sources (e.g., boat engine fuel use, burning debris) often missed in generic surveys.

The surveys were administered primarily by Alaska Municipal League (AML) staff and local partners who traveled to (or contacted) the communities. Prior to deployment, the survey team identified key informants in each community (tribal environmental coordinators, city administrators, utility managers, etc.) to assist with coordination. Surveys of households were done through door-to-door visits in most communities, aiming for a target sample (for example, roughly 5–10% of households in larger communities, and a higher percentage in very small villages to ensure representativeness). For non-residential data, the team directly interviewed operators of each major facility (power plant, school, health clinic, fuel depot, etc.). Phone surveys were used in cases where in-person visits were not possible, and in a few instances community meetings were held to fill out surveys with multiple participants at once. Local engagement strategies were crucial: we translated portions of the survey or had bilingual speakers for communities where English is a second language, and we framed questions in ways that made sense locally (for instance, asking about wood use in terms of local units like "boat-loads" or "sled-loads" of wood, then converting to cords). Visual aids were employed – such as showing pictures of different stove types or fuel containers – to help respondents accurately identify and quantify their usage.

As surveys were completed, data were immediately entered into the centralized database (using a cloud-based form that could be accessed on tablets). This allowed for real-time data monitoring. If any survey response was outside of expected norms (based on either common sense or the ranges known from other communities), the surveyor would double-check the answer with the respondent or mark it for follow-up. For example, if a household reported burning 20 cords of wood in a month (an extremely high amount), the survey form would flag it and the staff would verify if perhaps the respondent meant 20 *pieces* or 2 cords, etc. By designing the survey with mostly structured multiple-choice or numeric fields (with units predefined) and providing an "Other (specify)" option, we captured data in a consistent format while still allowing flexibility for unique circumstances. The outcome of the survey deployment was a comprehensive dataset of community-specific activity data that could be directly compared to the model's estimates.

Data Management and QA/QC Procedures

Data Management: All collected survey data were compiled in a centralized relational database designed for this project. Each record was tagged with the community name, sector, and source type for easy querying. Data management followed the protocols in the QAPP to ensure traceability and security. For instance, every survey form submission was time-stamped and stored on a secure cloud server, with backup exports saved to ADEC's SharePoint repository. The project maintained a master data log tracking each community's dataset, including notes on data sources (e.g. "Community X power plant fuel use obtained from utility records, provided by

[name] on [date]”). Any updates or corrections to the data were recorded with versioning. An archived copy of raw survey inputs and a separate cleaned dataset after QA processing was kept. Documentation such as the Survey User Guide and data dictionaries (explanations of each field and unit) are provided in Appendix A.

Quality Assurance/Quality Control: A rigorous QA/QC process was implemented to ensure that the data used in the emissions inventory are accurate, reliable, and meet the project’s quality standards. The QA procedures were outlined in detail in the approved 2024 QAPP (version 1.2) and the updated 2025 QAPP (version 2.0) for this project. Key elements of the QA/QC process included:

- *Initial Data Verification*: As surveys were completed, the data were reviewed by the project team (AML and the contractor, Constellation) for completeness and logical consistency. The QAPP specified acceptance criteria that had to be met for data to be considered usable. For example, we verified that each record fell within the expected geographic boundary (no data from outside Alaska), that the time frame of data was current (we generally did not accept any activity data older than 2017 to align with the inventory’s baseline), and that methodologies or units were clearly documented (if a data point came from an external report, we checked that the report’s methods were sound and documented).
- *Outlier Detection and Resolution*: Potential outliers or anomalies in the dataset were automatically flagged by the system and then manually investigated. An outlier was defined as any value that was statistically distant from the distribution or contradicted qualitative expectations (e.g., a tiny village reporting more fuel use than a large town, or a negative value). When an outlier was identified, the team followed a prescribed procedure: first, double-check the entry for any transcription errors; second, consult with local contacts or the original respondent to confirm the value or get a corrected value; third, consult secondary data (like fuel shipment records or utility logs) if available to corroborate. The 2025 QAPP explicitly states that for any data issues discovered, the team (ADEC, AML, and Constellation) would discuss how to proceed – actions could include excluding the outlier data point, correcting it based on clarification, or retaining it with a flag if it was deemed credible. All decisions regarding data adjustments were logged in a corrective action log stored in the project SharePoint, per QAPP requirements. Any exclusion of data was justified and documented. In cases where a suspicious data point could not be verified in time, it was excluded from the analysis but noted as a gap for potential future investigation rather than simply treated as a zero. This careful handling of outliers ensured that the analysis was both robust and transparent.
- *Stakeholder Involvement in Validation*: Recognizing the value of local knowledge, the QA process included a step for community stakeholder review. After initial data cleaning, summaries of each community’s data were shared (through local liaisons or directly with key respondents) to allow them to comment on the accuracy or provide any additional context. According to the QAPP, stakeholders were given the opportunity to review the compiled data

and highlight any concerns or obvious errors. For example, if a community member noticed that the aggregated wood usage seemed too low given the number of wood stoves in their village, that feedback would trigger a re-examination of the survey entries for possible under-reporting. This participatory validation step not only improved data quality but also built local trust in the results. All stakeholder comments and how they were addressed were recorded as part of the project QA documentation.

- *Comparison with External Data*: As a higher-level QA check, the final community emission estimates derived from our data were compared against other independent data sources and benchmarks. The QAPP required that our inventory results be cross-checked with known datasets under established Quality Management Plans (e.g. EPA's National Emissions Inventory or ADEC's statewide inventory) wherever applicable. If our emissions for a given sector in a community differed greatly (by a large factor) from what an EPA or state dataset would suggest for a similar community, we investigated the cause. The QAPP specifies that if such a large discrepancy is found, the inventory team must either find an error in our data/methods or provide a scientifically sound explanation for why the discrepancy is legitimate. One example of this in practice was comparing our surveyed diesel generator emissions for a community to what the state's model had predicted; if our number was, say, double, we would verify whether the generator usage had indeed increased or whether our survey might have overestimated operating hours. Through this process, we ensured our community inventories are within reasonable bounds and any major deviations from expectations are accounted for.
- *Data Quality Indicators*: The project tracked standard data quality indicators throughout the process. Completeness was high – we successfully obtained the majority of the targeted data points for each community, though in a few cases some information could not be obtained before the end of the performance period (e.g. Arctic Village's fuel vendor data was not received in time). For those gaps, we noted them and in some cases used proxy estimates (like regional averages) with clear annotation of lower confidence. Precision and accuracy in this context relate to the consistency and correctness of responses; by using consistent survey methods and cross-checking with records, we aimed for high precision (repeat surveys would yield similar results) and accuracy (values reflect truth). Representativeness was ensured by our sampling strategy (surveying multiple households and all major facilities, capturing seasonal variations). Comparability was maintained by aligning our data with standard units and categories used in other inventories, so results can be compared directly to other studies. These DQI concepts, as defined in the QAPP, underpinned all QA/QC activities.

In summary, the data management and QA/QC process gave us a clean and reliable dataset that meets EPA's quality requirements. By systematically validating the data, involving local stakeholders, and documenting every step of the QA process, we have confidence that the emissions estimates presented are based on sound data. The thorough QA/QC also means that future updates to this inventory can build on our dataset, knowing its strengths and limitations.

Any anomalies that could not be fully resolved are explicitly noted, and recommendations are made for future data collection to address them.

Results

Survey Data vs. Modeled Estimates: Key Findings

After integrating the community survey data with the modeled emissions inventory, we analyzed the differences and patterns that emerged. Overall, the inclusion of ground-truthed data revealed both expected and unexpected discrepancies relative to the model's original estimates.

Some of the most salient findings include:

- *Higher-Than-Modeled Fuel Use in Key Sectors*: Many communities reported fuel consumption levels (and resulting emissions) higher than what the model had predicted, particularly for home heating and power generation. For instance, wood usage for residential heating in several interior villages was substantially greater than the model's estimate, underscoring that generic heating calculations had underestimated the reliance on wood in those areas. Likewise, diesel fuel use for electricity in off-grid communities often exceeded modeled values. These differences highlight the importance of direct data collection for high-variance sectors; without survey data, the model would have significantly undercounted emissions in those categories.
- *Lower-Than-Modeled Emissions in Some Cases*: In certain sectors and communities, the opposite trend was observed – the survey data showed less activity or emissions than the model assumed. For example, some communities exhibited more efficient operations or recent changes that reduced fuel consumption (such as insulation retrofits lowering heating fuel needs, or a new renewable energy project offsetting diesel use). In one case, a community's vehicle usage was lower than modeled because of carpooling and the use of ATVs instead of trucks, which the model had not anticipated. These cases suggest that the model's default assumptions can sometimes be conservative (higher) and that on-the-ground practices might yield lower emissions than estimated, indicating opportunities for recalibrating assumptions and recognizing successful mitigation efforts.
- *Substantial Variation Between Communities*: The magnitude and direction of discrepancies varied significantly from one community to another. Even communities that are geographically close or demographically similar sometimes showed divergent patterns. For example, two villages of similar size in Western Alaska had very different per-household fuel use – one had recently switched many homes from oil heaters to wood stoves (increasing wood emissions beyond the model's expectation), while the other had a bulk fuel shortage that year leading to conservation (so actual diesel use was below modeled levels). This variability suggests that local factors (like community policies, resource availability, cultural habits) can greatly influence emissions, and a one-size-fits-all model will miss these nuances. In general, we found that the model tended to under-report emissions in communities where traditional practices (wood heating, seasonal subsistence travel) are strong, and over-report in communities that had undergone recent efficiency improvements or transitions (which the

model, calibrated to older data, hadn't captured).

- *Identification of Model Assumption Gaps*: By reviewing the side-by-side comparisons, we identified specific assumptions in the model that were outdated or too generic. For instance, the model's residential heating module had assumed a certain mix of heating fuels based on statewide averages, but our survey revealed that some communities had nearly 90% wood heating while others had shifted mostly to oil or electric heat. Similarly, the model did not fully account for seasonal subsistence activities (e.g. fish camp operations, snowmachine use in winter for trapping) – activities which our surveys captured and which contribute to emissions (through gasoline for boats and snowmachines, or open burning of debris). These findings pinpoint areas where the model can be refined to include additional parameters or local data sources. In some cases, the discrepancies pointed to the need for new emission factors (for example, we noted that generators in very cold regions were operated differently, potentially requiring adjustment in the emission factor for idling diesel engines in subzero conditions).

Detailed quantitative results for each community are provided in Appendix B, including tables that compare modeled vs. surveyed annual emissions (in tons per year) by sector and source type. Table 1 below provides an example summary for an illustrative community, showing the modeled inventory alongside the survey-based inventory for key sectors:

Sector	**Source Type**	**Fuel**	**Modeled Emissions (t/yr)**	**Survey-Based Emissions (t/yr)**
Residential Heating	Wood Stoves	Wood	5.2	7.8
Residential Heating	Oil Furnaces	Heating Oil	10.4	9.5
Power Generation	Diesel Generators	Diesel	15.0	18.3
On-Road Transportation	Cars/Trucks	Gasoline	3.1	2.5
Off-Road Vehicles	Snowmachines/ATVs	Gasoline	1.0	1.6

Table 1: Example comparison of modeled vs. surveyed emissions for a sample community (values are illustrative).

In the example above, one can see the model had under-predicted wood stove emissions and power generation emissions (the surveyed values are higher), while it slightly over-predicted on-road vehicle emissions (survey data showed lower gasoline use than assumed). Patterns like these were common in the full set of communities studied. Across the 12 surveyed communities, the largest differences in absolute terms were typically in the stationary source sectors (heating and electricity), since those dominate rural emissions and had significant model assumption uncertainties. Transportation emissions (on-road and off-road) also showed differences but were generally smaller contributors to the total emissions profile of these communities.

Integration of Survey Data into the Inventory

Where significant discrepancies were identified, the project team took steps to integrate the findings and adjust the emissions inventory accordingly. In practice, this meant collaborating with the emissions modeling team to update activity inputs in the inventory for the surveyed communities and to recalibrate certain assumptions for similar communities statewide. All adjustments were documented so that the revised inventory could be traced and justified. As a result of this integration:

- The emissions inventory for each surveyed community is now grounded in actual data rather than solely on modeled estimates, improving its accuracy for regulatory and planning purposes.
- The process of combining top-down model data with bottom-up survey data has yielded a more precise and locally validated emissions dataset for the study area. By reconciling the two, we can now provide emissions estimates with an uncertainty range – essentially bracketing the previous model estimate with the survey-corrected estimate, which gives regulators a sense of the possible range of emissions rather than a single number. In many cases, the survey data served as a higher-bound (or lower-bound) check on the model, resulting in confidence intervals for community emissions.
- The integrated results allow for improved air quality management decisions. For example, if a community's survey shows much higher PM2.5 from wood stoves than the model did, state programs can focus more on wood stove change-out programs or wood seasoning education in that community. Conversely, if a community's diesel use was lower than expected, it might indicate successful local energy projects that could be models for other areas.
- Community-specific reports have been generated (see Appendix B) that detail the adjusted emissions by sector and fuel. These reports have been shared with the communities for their use and verification. This not only helps in transparency but also empowers communities with information about their own emission sources, which can be useful for local environmental planning or grant applications for mitigation projects.

It should be noted that in a few communities, data gaps remained even after our best efforts – for instance, a couple of fuel suppliers did not provide data in time or some households did not fully complete surveys. In these cases, we left placeholders in the data (or used conservative estimates). These instances are clearly indicated in the community reports. For unsurveyed communities (the majority of rural communities in Alaska), the model-based inventory remains the primary source of data, but we have applied regional adjustment factors where appropriate. For example, knowing that interior communities tended to under-report wood in the model, we increased the wood combustion estimates by a certain factor for other interior communities not surveyed, as a provisional adjustment. These kinds of adjustments are part of the sensitivity analysis outcomes, and they will be useful for future statewide inventory updates.

Overall, integrating the survey results with the model has demonstrated a clear benefit: it significantly improves confidence in the emissions estimates for rural Alaska. Where previously the margin of error was unknown (or large) due to lack of ground truth, we now have real measurements to anchor the estimates. This approach can serve as a template for future inventory improvements – essentially a hybrid method that uses broad models to cover many sources, but validates and tunes them with selective detailed measurements.

Discussion

The results of this project underscore the value of combining modeled data with community-specific, ground-truthed data. Several important themes and implications emerged:

1. Enhanced Accuracy and Confidence: By incorporating local survey data, the emissions inventory for the participating communities is far more reflective of on-the-ground reality than a model-only inventory. In many communities, certain emission sources (like wood heating or seasonal generator use) were found to be higher than previously thought, while others were lower, as detailed above. This two-way correction greatly improves the overall accuracy of the inventory. It also gives us confidence intervals for emissions estimates. For the first time, we can say not just "Community X emits Y tons of pollutant Z," but also provide a range (or error estimate) based on real variability observed. This has important implications for regulatory use of the data: agencies can better understand the uncertainty in their inventories and thus make more informed decisions (for example, when determining compliance margins or the need for additional controls, knowing the data uncertainty helps avoid over- or under-regulation).

2. Model Validation and Improvement: The exercise of comparing model predictions to actual data serves as a robust validation of the model. It revealed which sectors the model handles well and which need improvement. For instance, the model's estimations for on-road vehicle emissions were in some cases reasonably close to survey results (vehicles being a more easily estimated sector based on population and standard per capita usage), whereas the model struggled with home heating fuels, which are influenced by local climate, cultural preferences, and fuel availability. As a result, we have been able to recalibrate the model. Moving forward, the improved model (or toolkit) can be used with more reliability for communities that weren't surveyed, knowing that its algorithms have been tested and adjusted with real data. Furthermore, the validation process fulfills a key requirement of EPA-funded inventory development: it demonstrates that the inventory tool performs within acceptable bounds and any deviations can be explained scientifically. This strengthens the credibility of Alaska's emissions reporting and ensures EPA review criteria are met.

3. Importance of Local Practices and Variability: The project highlights how local practices and circumstances can lead to significant emissions variability that broad-scale models might not capture. For example, in some villages, traditional fish smoking or burning of household waste are regular practices that contribute to emissions but would be invisible to a general model. We discovered that even among the small sample of 12 communities, there were unique sources or practices (like a community with an unusually high number of snowmachines per household due to trapline use, or another where nearly every home has a backyard burn barrel). These contribute to emissions in ways that are not proportional to population or other simple metrics. The discussion point here is that inventories benefit greatly from community-specific data. One cannot assume that two villages of 300 people have the same emissions profile. This insight supports a paradigm shift towards more localized inventory compilation, especially in areas (like rural Alaska) where lifestyles differ from the norms built into national models.

4. Data Quality and QA/QC Lessons: The project's intensive QA/QC process proved essential in producing a reliable dataset. One of the lessons learned is that outlier management and follow-up add significant value. In the past, some inventories might have simply discarded outliers or averaged them out, but we chose to chase down each outlier's story. In doing so, we sometimes uncovered data entry mistakes (which could be fixed) and other times learned something new (e.g., one outlier high diesel use report turned out to be real and was due to a one-time community event – a fish processing barge visit – that used a lot of fuel). By following a structured outlier protocol and involving local stakeholders in validation, the final data is both accurate and trusted by the community. This approach of engaging communities in QA/QC, while time-consuming, is recommended for future efforts because it not only catches errors but also empowers communities and builds transparency.

5. Limitations and Remaining Uncertainties: Despite the improvements, some limitations remain. We were not able to survey every community (nor was that the intent), so there is still uncertainty in applying these findings universally. The communities surveyed were meant to be representative, but naturally there will be outliers beyond our sample. Additionally, logistical constraints meant that a few data points were missing or incomplete. For example, as noted, one community's bulk fuel data was unavailable by project's end; hence its diesel use had to be inferred from secondary indicators (with clear caution that it's an estimate). Another example is that some non-residential facilities did not respond despite repeated attempts, leading us to carry zeros or estimated values in those slots, which could understate emissions. These gaps highlight an area for future work: establishing ongoing data sharing agreements with fuel suppliers, utility companies, and communities could ensure that critical data (like fuel sales) are directly reported for inventory purposes. Moreover, certain emission sources are inherently difficult to quantify (e.g., fugitive dust from roads); while our surveys asked about activities like road travel to help estimate dust, there is still a reliance on assumptions in those calculations. Thus, while our inventory is improved, it still has error bars – especially for sources like fugitive dust or open burning where empirical data is scant. A discussion of these uncertainties is included in the community reports, and the QAPP provides guidance on data quality indicators so that users of this inventory can understand the confidence level of each data category.

6. Implications for Air Quality Management: The refined emissions data have direct implications for both state-level and community-level air quality management. For the state (ADEC and policymakers), knowing which emissions are higher than expected can influence resource allocation – for example, targeting wood stove emissions in specific villages for emissions reduction programs. For communities, having an accurate inventory is empowering; they can identify their biggest sources and potentially seek funding or programs to address them (such as grants for renewable energy if diesel generators are a major source, or road paving projects if dust is a major pollutant). The data can also help track progress over time if some of these communities are resurveyed in the future. One immediate takeaway is that community-level engagement in data collection yields actionable data – several community leaders expressed interest in using the survey results to inform their local environmental or energy plans. This

reinforces the notion that inventories should not just be a top-down exercise; when done in a participatory way, they become a tool for local decision-making as well.

7. Blueprint for Future Inventories: This project demonstrates a replicable methodology for improving emissions inventories elsewhere. The combination of a broad modeling approach with targeted ground-truthing can be applied to other regions or states. It's a cost-effective compromise between doing nothing (which leaves large uncertainties) and attempting to directly measure everything everywhere (which is impractical). The approach also lays a framework for periodic updates: we suggest that every few years, a smaller-scale survey effort (even a short "check-up" survey) could be conducted in a sample of communities to see how things have changed, and then update the model accordingly. Because we have established a digital survey instrument and a network of contacts, future data collections could be easier and possibly even community-led with the right training. The importance of maintaining the data infrastructure (the database, the toolkit, and the documentation) cannot be overstated – it will allow future analysts to pick up where we left off rather than start from scratch. The QA/QC process we followed, including version control, logging of issues, and so on, provides a template for how to manage data quality in such projects. All these points suggest that the work done under the CAA 103 grant will continue to pay dividends as Alaska refines its emissions inventories and shares lessons with others.

In conclusion, the discussion highlights that the IRACAA 103 project successfully met its objectives by creating a more accurate, community-informed emissions inventory and by developing methodologies that strengthen the practice of emissions inventory compilation. The experience gained here will be valuable for ongoing and future efforts to ensure that emissions data – which underpin air quality policies and health risk assessments – truly represent the realities of even the smallest communities.

Recommendations

Building on the findings and lessons learned from this project, we put forward the following recommendations for future emissions inventory efforts and related community projects:

- *Prioritize Direct Community Data Collection*: Whenever feasible, base emissions inventories on direct surveys or local administrative data from each community rather than relying solely on extrapolation or statewide averages. Ground-truth data significantly reduces uncertainty and can unveil local emission sources that models overlook. Even a limited sampling of households and facilities in every community is preferable to assuming one community's data can stand in for many others.
- *Improve and Tailor Survey Instruments*: Future surveys should be made even more clear and locally relevant. Use local terminology and units (with conversions to standard units in data processing) and include visual aids or examples. For instance, illustrate common quantities like a "cord of wood" versus a "truck load" with pictures or analogies that respondents understand. Providing reference points (e.g. "a 55-gallon drum looks like this and holds this many gallons") can minimize misreporting. Simplicity is key: streamline surveys to be as short as possible while covering necessary data, as this improves response rates and completeness.
- *Engage Local Partners and Cultural Liaisons*: Work with trusted local individuals and organizations to conduct surveys and collect data. Tribal councils, village environmental coordinators, regional health or housing organizations, and local utilities can be invaluable allies. Their involvement can increase community buy-in, improve survey participation, and lend insight into interpreting results. Culturally fluent staff or volunteers can explain the purpose of the inventory in local languages or contexts, which helps build trust. Moreover, local partners often have access to existing data (for example, a tribal office might have records of how many households use wood vs. oil) that can supplement survey efforts.
- *Incorporate Seasonal Context into Data Collection*: Emissions and activities in Alaska are highly seasonal, and recall can be challenging if surveys are not well-timed or well-framed. We recommend structuring surveys around local seasonal calendars and events. Instead of asking abstractly about monthly usage, tie questions to known seasonal markers (e.g. "during spring whaling season" or "over the winter holidays"). Conduct surveys in multiple seasons or ensure questions explicitly distinguish summer vs. winter activity. This will yield more accurate seasonal profiles and avoid mistakes like attributing summer fishing boat emissions to winter months. Additionally, consider multiple short surveys at different times of year rather than one long annual recall survey.
- *Strengthen QA/QC with Follow-up Mechanisms*: Continue to refine the QA/QC process by including a formal outlier follow-up protocol. When unusual data points appear, have a clear workflow: flag them, have designated personnel investigate, re-contact respondents if needed, and document the outcome (e.g. confirmed real, corrected, or removed with

justification). Do not simply discard outliers; treat them as information that either indicates an error or something important. Also, maintain a separation of data streams for very different source types (for example, keep marine vessel emissions accounting separate from land-based community emissions except where they clearly intersect). This avoids conflating data that are collected in different ways and might have different uncertainties. If linking them is necessary, document the method (a "bridge" between datasets) to maintain clarity.

- *Ensure Comprehensive Documentation and Version Control*: Future projects should maintain thorough documentation – not just of methods, but of every assumption, data source, and change made. Using a version-controlled repository for data and calculations (as we did with SharePoint and versioned workbooks) is highly recommended. This practice enables transparency (crucial for EPA review) and makes it easier for future researchers to update the inventory without repeating work or introducing inconsistencies. We also recommend preparing a public-facing summary or tool so that communities can access their own emissions data easily, which fosters transparency and utility of the inventory.
- *Plan for Periodic Updates and Sustained Data Collection*: Emissions and activities are not static. We recommend establishing a plan to periodically update community emissions data – for example, re-surveying these communities (and perhaps others) every 5 years, or integrating questions into existing household surveys (like energy audits or health surveys). Even mini-surveys or checks (such as annually collecting fuel sales data, or a short questionnaire on major changes in the community like new facilities or projects) can help keep the inventory current. When updates are made, follow a defined protocol so that changes in emissions can be tracked to changes in activity or new developments, rather than apparent changes due to method differences.
- *Feedback Results to Communities and Solicit Input*: After completing an inventory or an update, report back to the communities with the findings. This could be through community meetings, summary flyers, or interactive webinars. Encourage feedback and questions – communities might point out a missing source or explain an anomaly, which can be invaluable for interpretation. This two-way communication not only validates the data (as was done in our QA process) but also increases local acceptance and interest in the inventory. In some cases, this may even lead to citizen science opportunities, where communities take initiative in monitoring certain emissions or tracking certain activities to contribute data.
- *Leverage Regional Organizations for Broader Reach*: Regional bodies (like the Tanana Chiefs Conference, North Slope Borough, regional health corporations, etc.) often have infrastructure for data collection and community engagement. Partnering with these organizations can increase the scale and efficiency of future inventory efforts. They can assist in contacting communities, storing data, and possibly integrating emissions inventory questions into their ongoing programs (for example, a regional energy program might help gather heating data). By tapping into these networks, future projects can achieve wider coverage with fewer resources and ensure that efforts are not duplicated.

- *Address Data Gaps in Specific Sectors*: We identified particular areas where data was weakest or most uncertain – notably commercial marine emissions, aviation, and fugitive dust. Future work should target these sectors. For marine and aviation, which were largely outside the scope of our community surveys, specialized studies or data collection (like working with local harbormasters or obtaining flight fuel sale records) should be undertaken to improve those estimates. For fugitive dust, on-site measurements or at least refined activity data (like vehicle miles traveled on unpaved roads in each community) would help. While our project focused on community stationary and mobile sources, filling these remaining data gaps will move the inventory closer to completeness.

By implementing these recommendations, future emissions inventory initiatives in Alaska (and elsewhere) can build on the success of the IRACAA 103 project. The overarching theme is integration – integrating local knowledge and data into scientific inventories, and integrating the inventory results back into community and policy actions. This creates a positive feedback loop of continuous improvement in data quality and relevance.

Appendices

Appendix A: Survey Instruments and User Guide – This appendix contains the blank community survey questionnaire used for data collection, along with an accompanying user guide that was provided to field staff. The guide explains how to administer the survey, definitions of terms, units conversion charts, and QA tips for validating responses. It also includes screenshots of the JotForm electronic survey interface to illustrate how data was entered and automatically validated.

Appendix B: Community-Level Emission Inventory Reports – For each of the 12 surveyed communities, a detailed report is provided, including an introduction, methods summary, results, and discussion specific to that community. These reports present tables of modeled vs. surveyed emissions by sector and source, identify key discrepancies, and offer community-tailored recommendations. They also provide narrative context – for example, noting any unique community circumstances (such as Arctic Village's reliance on flown-in fuel, or the presence of a fish processing plant in Dillingham affecting seasonal emissions). These community profiles serve as stand-alone documents that local stakeholders can use. The appendix also documents any data limitations or assumptions for each community (e.g. if certain data were estimated due to non-response).

Appendix C: Quality Assurance Project Plan (QAPP) Excerpts – Key excerpts from the 2024 QAPP and the updated 2025 QAPP are included for reference. This includes the data quality objectives table, the inclusion/exclusion criteria for data sources, and the QA/QC procedures and checklists used by the project. While the full QAPPs are comprehensive, the appendix highlights sections most relevant to understanding how data integrity was maintained in this project.

Appendix D: Emission Factors and Calculation Methods – A compilation of emission factors, formulas, and any deviations from standard methods used in calculating emissions from the activity data. For transparency, we list the AP-42 sections, MOBILE6 scenarios, NONROAD model settings, etc., that were applied. If any community-specific emission factors were used (for example, adjusting wood stove emission factors for high moisture content wood in certain areas), those are noted here.

Appendix E: GHG Inventory Methodology and error analyses given data sources.

Appendix A: Survey Instruments and User Guide

User Guide: Understanding and Completing Your Energy Form

This guide will help you understand and accurately complete this energy form. Please read it carefully before starting. The purpose of this form is to gather information about your energy consumption, sources, and consumption practices. This data will be used for analyzing community level usage patterns.

- Provide the most accurate information possible. Estimates should be clearly marked as such in the notes section. If you have any questions or require assistance, please contact [Griffin Plush] at [Email Address].

General Information

- **Which community does this activity take place:** Select name of the community. If multiple communities, please fill out different forms for each.
- **Building Type (Residential/Commercial/Industrial/Agricultural):** Select the building type that best describes the property where energy consumption is being measured. *If 'Other', add this in the notes section.*

Please estimate the frequency of use of certain fuels highlighted here, for the year you have selected (e.g. 2022) - by reviewing which equipment(s) in your home or work consumes that fuel. For example, if you use fuel oil for furnaces and boilers, and diesel for generators, please keep adding these as a new "fuel type" so you can estimate them separately in terms of how much of these fuels you are consuming annually.

- **Energy Consumption:** The amount of energy used over a specific period. This is a numerical field.
- **Units:** Refer to your energy bills for the specific units used. Common units include:
    - **Electricity, Solar:** Kilowatt-hours (kWh)
    - **Natural Gas:** Therms or Cubic Feet (cf)
    - **Propane, Diesel, Gasoline, Fuel Oil:** Gallons
    - **Wood or Coal:** Tons, lbs, kg, etc.
- **Instructions:** For each energy source listed below, provide the requested information for the specified period (e.g., 12 months covering the year you selected). Feel free to use your energy bills and consumption records to accurately complete this section. If you have fuel logs, receipts or sales documentation, it can help estimate these values, if you know the price ($ per unit of fuel).
- If you do not use a particular energy source, do not select that fuel type from the dropdown field list. If you are unsure, please reach out to the contact listed, and note this in the notes section.

Tips for Accurate Completion and Submission:

- Collect your energy bills and consumption records for the specified period before starting. Look at previous energy bills, documents, forms (if available) for reference. To the extent possible use the same units of measurement throughout the form.
- Please **r**eview your completed form carefully before submitting it. Provide any relevant comments or explanations regarding your energy consumption for this specific source. For example, you may explain a significant increase or decrease in consumption due to a specific event.
- If you don't know the answer or are unsure of the question, feel free to contact us for help. If you must estimate, clearly mark it as an estimate in the notes section, and any relevant details on how you went about doing the estimation.
- Please submit the completed form here by hitting the submit button at the bottom of this page.

User Guide: Understanding and Completing Your Waste Form

If you do not know the actual waste weight or volume, you can estimate it using container volume (say per week, or per month) in which the waste is being disposed of, for the selected year.

For example, if you use the same disposal container, what is the *total* volume (in cubic meters, cubic feet, gallons, etc.) of all your waste containers? Is this the *actual* amount of waste you're throwing away, or just the *capacity* of the containers? If it's capacity, we'll need to factor in how full they typically are. Here are a few more things to consider:

- **Measurement Frequency:** Are your containers emptied *exactly* once per week or month? Or is it an average? If there's variability (e.g., some months more waste than others), averaging can be helpful but less precise.
- **Waste Type (Crucial!):** The *type* of waste significantly affects how much it weighs (density). Different materials take up different amounts of space for the same weight. Some common examples include the below, which is also a dropdown list in this form:
    - General Municipal Solid Waste (MSW)
    - Recyclables (Cardboard, Paper, Plastics, Glass)
    - Construction & Demolition Debris (C&D)
    - Food Waste
    - Yard Waste
    - Industrial Waste (specify type)

    - Hazardous Waste (This requires specialized handling and tracking; don't estimate!)
- **Units:** Make sure all volumes are consistently in the same units (e.g., cubic meters, cubic feet, gallons, kg, lbs or tons).

Here are a few examples to walk you through:

- **Annual Volume = Monthly Volume x 12**
    - If you dispose of 5 cubic meters of waste per month, your annual volume is 5 m^3 / month * 12 months/year = 60 m^3 / year.

If you're using *container capacity* rather than *actual waste volume*:

- **Estimate Fill Percentage:** On average, how full are your containers when they're emptied? Express this as a percentage (e.g., 75% full).
- **Adjusted Monthly Volume = Container Capacity x Fill Percentage**

Then, use the adjusted monthly volume in the annual volume calculation above. Let's say, you have two 3 cubic meter containers (total capacity = 6 m^3) and you estimate they're usually 80% full when emptied for your household or business, meaning the adjusted monthly volume = 6 m^3 * 0.80 = 4.8 m^3. This means the annual volume will be 4.8 m^3/month * 12 months/year = 57.6 m^3/year. If you know the waste types, say half was food waste and the other half is plastic, you can split this in half for each.

Density of waste:

- **Find Density Information:** You may need the *density* of your specific waste stream. Density is expressed as weight per unit volume (e.g., kilograms per cubic meter, pounds per cubic foot) and differs based on the content of your solid waste). If you provide the weight (lb, kg, ton) of material, we can use it directly, but if you know specific information or would like to find out, you can simply Google.
    - Search for "[Waste Type] density" (e.g., "municipal solid waste density", "cardboard density"). Look for reliable sources, such Government environmental agencies (State or EPA, state/local agencies), Waste management companies or Academic research papers.

Here are a few typical waste types and their densities that you can use to multiple your container-frequency volumes to get the weight in lb.

- Municipal Solid Waste (MSW): 100-300 kg/m ^{3} (6-19 lbs/ft^3) - This varies greatly depending on composition. Damp MSW will be denser.
- Cardboard: 30-80 kg/m ^{3} (2-5 lbs/ft^3)
- Paper: 80-120 kg/m ^{3} (5-7.5 lbs/ft^3)

- Plastics: Highly variable, 50-1000 kg/m ^{3} (3-62 lbs/ft^3)
- Glass: 200-300 kg/m ^{3} (12-19 lbs/ft^3)
- Construction & Demolition Debris: 300-600 kg/m ^{3} (19-37 lbs/ft^3) - Very variable!
- Food Waste: 300-600 kg/m ^{3} (19-37 lbs/ft^3) - High water content makes it dense.

Please keep in mind that if your waste is a *mixture* (e.g., general MSW), you'll need to *estimate the proportion* of each material and use a *weighted average* of their densities. To make it simpler, you can add multiple types separately within the form.

- **Calculate Weight per Year:**
    - **Annual Weight = Annual Volume x Density**
    - Make sure your units are compatible! If your volume is in cubic meters (m^3) and your density is in kilograms per cubic meter (kg/m ^{3}), your weight will be in kilograms (kg). You might need to convert to other units (tons, pounds, etc.).

Example (Continuing from above):

- Annual volume: 57.6 m^3/year and Waste type: General Municipal Solid Waste (MSW)
- Assume MSW density: 200 kg/m ^{3} or any overriding factor with better data, if available.
- Annual weight: 57.6 m^3/year * 200 kg/m ^{3} = 11520 kg/year
- If you want to convert to metric tons: 11520 kg/year / 1000 kg/metric ton = 11.52 metric tons/year, Convert to US tons: 11.52 metric tons/year * 1.10231 = 12.69 US tons/year

Keep in mind:

- Waste compactors significantly increase density. If you use a compactor, you'll need to account for the compaction ratio (e.g., a 4:1 compactor reduces volume by a factor of 4, increasing density by a factor of 4). Wet waste is heavier. If your waste is consistently wet (e.g., food waste), it will have a higher density.
- If your waste generation varies significantly throughout the year (e.g., higher during tourist season, after holidays, or during harvest), consider tracking data more frequently (e.g., weekly) and averaging over the entire year. The best way to get accurate data is to weigh your waste at the disposal site (if possible).

In Summary

1. **Collect your data:** Container volume, emptying frequency, estimated fill level, and most importantly, waste type. Then calculate annual volume.
2. Find the density of your specific waste stream from a reliable source. This is the most crucial and potentially inaccurate step, so please take some time to review your assumptions around estimation of this. Calculate annual weight using the formula: Annual Weight = Annual Volume x Density.

3. Be aware of the limitations of your estimate and potential sources of error, and include it within the notes on the form. Thank you once again for your help.

User Guide: Understanding and Completing Your Transportation & Equipment Form:

Estimating fuel use for a certain off-road equipment or vehicles based on usage frequency requires some assumptions and resulting calculation. Here's an example process and the factors involved:

1. Gather Equipment Information:

- **Equipment or vehicle Make and Model:** This is the *most important* piece of information. Different vehicles or equipment, such as snowmobiles or lawn equipment have vastly different fuel consumption rates, such as per hour or per mile of work. If possible, please find the exact make, model, and year of your vehicle. Although, usually under ideal conditions and may not reflect real-world usage, the ideal place to start to find some of the data is the manufacturer's website or the equipment owner's manual. Look for fuel consumption data, often expressed as miles per gallon (MPG) or liters per 100 kilometers (L/100km) or gallons per hour of operation, etc.
- **Engine Size and Type:** Size or type of engines, also have an impact - for example, Is it a 2-stroke or 4-stroke engine? 2-strokes are generally less fuel-efficient, and larger engines will generally consume more fuel than smaller ones.
- **Typical Usage Conditions:** If you have fuel volume or sales data, you do not need to consider the terrain, conditions, altitude or riding styles - However, if the equipment is being used on certain locations, like groomed trails, deep powder, mountains, or a combination, certain attributes require more throttle and thus more fuel. Leisurely cruisers, or being aggressive riders can impact acceleration and speeds which burn more fuel even for the same activity. Higher altitudes or terrain like Ice, hardpack, or deep snow, can slightly affect fuel consumption.

Gather (or estimate) data for activity and time of equipment use:

- **Average Trip Length (Hours):** How long is typical equipment use per year? Whether it is equipment run time, or vehicle travel, please attempt to collect as much information on the frequency of fueling the fuel type selected, as well as the total amount (in fuel volume or sales, in $) for those time periods. If you have a general idea of how often you use the equipment, or how often you buy fuel to refuel (or both) will give you a good estimate of annual activity. Knowing the tank size is helpful for context, such as how often do you fill up the tank and to what levels (once a week, half way full - or once a month, 100% full).

Estimate Fuel Consumption per Trip:

- Make sure your units are consistent - please convert MPG to gallons per hour (GPH) or L/100km to liters per hour (L/hr) if you only have distance-based fuel economy. To do this you will need to estimate your average speed. Then apply it to the consumption number. Based on the data you found or ballparked, estimate the average fuel consumption in gallons per hour (GPH) or liters per hour (L/hr) for *your* riding conditions and style, and estimate **Fuel per Trip =** Fuel Use per Hour x Trip Length (Hours).

If you have estimated monthly, replace the "per Hour" to "per month" or whichever granularity you have. To calculate Annual Fuel Consumption, just **Fuel per Trip x Number of Trips per Year**. Please do this for EACH equipment you had owned or used.

Example:

Let's say you have an Equipment (Snowmobile - a 2020 Ski-Doo Renegade Adrenaline 850 E-TEC, Engine: 2-stroke, 850cc.) with Riding Conditions: Primarily groomed trails, moderate riding style with Average Trip Length: 3 hours. Frequency of Use: 2 trips per month during the snow season (December to March = 4 months) so annual Trips: 2 trips/month * 4 months = 8 trips per year.

After searching your specs, you find that owners of similar sleds in similar conditions report an average of 10 MPG (miles per gallon) or 24 liters per 100 km. You estimate that on average you are traveling 30 miles per hour, therefore 10mpg is roughly .33 gallons per hour.

Fuel per trip = 0.33 gallons per hour * 3 hours = 1 gallon

Annual Fuel Consumption = 1 gallon * 8 trips = 8 gallons per year

- **Important considerations:** This is just an estimation process and actual fuel consumption can vary widely based on individual usage conditions, equipment maintenance, and other factors. It's generally better to overestimate fuel consumption slightly, especially for distance based estimations, to account for idling time during warm-up, which consumes fuel without covering any distance. If possible, please comment in the notes section of how you tracked your estimated fuel usage over a few trips to refine your estimates, such as how many gallons you put in, and how many miles you rode, or hours you operated, etc.

User Guide: Regional Bulk Fuel Sales Survey

Survey Title: Thank you for participating in this survey. Your input is crucial for understanding fuel distribution patterns and market trends in Alaska.

Primary Focus: (Select one)

- ○ ☐ Bulk Fuel Sales (Wholesale)
- ○ ☐ Bulk Fuel Sales (Retail)
- ○ ☐ Fuel Transportation/Distribution
- ○ ☐ Local government
- ○ ☐ Other (Please Specify): ___________________________

Service Area within [Region Name]: (Check all that apply. If possible, list specific counties or areas)

- ○ ☐ [Alaska Community 1]
- ○ ☐ [Alaska Community 2]
- ○ ☐ Other (Please Specify): ___________________________

Instructions: Please provide your total sales volume for each fuel type within the [Region Name] region for the calendar year [Year]. Use the units specified. If you do not sell a particular fuel type, enter "0." Please provide estimates if exact figures are unavailable, and indicate that you have provided estimates in the comments.

Fuel Type	Units	Total Sales Volume ([Year])	Comments (Optional: e.g., Estimation, Unusual Circumstances)
Gasoline (All Grades)	Gallons	______________________________	____
Diesel (All Grades)	Gallons	______________________________	____

Aviation Gasoline (Avgas)	Gallons	____________________ ____________	____________________ ____________________ ____________________ ____________
Jet Fuel	Gallons	____________________ ____________	____________________ ____________________ ____________________ ____________
Heating Oil	Gallons	____________________ ____________	____________________ ____________________ ____________________ ____________
Propane	Gallons	____________________ ____________	____________________ ____________________ ____________________ ____________
Biodiesel	Gallons	____________________ ____________	____________________ ____________________ ____________________ ____________
Renewable Diesel	Gallons	____________________ ____________	____________________ ____________________ ____________________ ____________
Kerosene	Gallons	____________________ ____________	____________________ ____________________ ____________________ ____________
Other (Please Specify)	[Specify Units]	____________________ ____________	____________________ ____________________ ____________________ ____________

Other (Please Specify)	[Specify Units]	____________________ ___________	____________________ ____________________ ____________________ ___________

Customer Breakdown - Approximate Percentage of Sales by Customer Type: (Must total 100%)

- ○ Transportation (Trucking, Logistics): ________%
- ○ Government (Federal, State, Local): ________%
- ○ Commercial/Industrial (Manufacturing, etc.): ________%
- ○ Residential (Heating Oil, Propane): ________%
- ○ Retail Fuel Outlets (Gas Stations): ________%
- ○ Agriculture: ________%
- ○ Construction: ________%
- ○ Other (Please Specify): **% (**%)

Feedback and Additional Information:

Do you have any additional comments or feedback regarding your data:

Thank You:

Thank you for your time and valuable contribution.

Appendix B: Community-level Emissions Inventory Reports

1. Arctic Village

Arctic Village is a predominantly Gwich'in community of 139 people located in the Interior, northwest of Fairbanks. one of a handful of communities that fly in fuel - while we made positive contact with the bulk fuel operator for the community (the tribe) we were not able to get data by the end of the performance period. The Tanana Chiefs Conference (TCC) supports energy infrastructure in the community and has supported a number of projects there. TCC has a "yellow book" of contact information that they use to contact individual community members - if a detailed inventory were to be conducted here (or in another community in the region), it might be advisable to engage TCC early on. Stationary consumption activity, especially heating in winter, diesel fuel consumption is seasonally affected.

We were unable to collect bulk fuel data for Arctic Village.

2. Bethel

Bethel is a predominantly Yup'ik community of 6022 people (2024) situated at the mouth of the Kuskokwim River, approximately 40 miles from the Bering Sea and 400 miles by plane to the southwest of Anchorage. The community is a major hub for the Southwest of Alaska, with substantial air and barge traffic serving not just Bethel, but also other nearby communities. When the Kuskokwim River freezes in the winter, barge traffic stops. In most years, this freezing also creates an ice road allowing on-road vehicle access to other communities along the river. With a tundra/boreal forest transitional climate with long, cold winters.

For stationary consumption, especially heating in winter, affects activity for diesel fuel consumption. In Bethel, there was a 4% difference between the actual data and modeled data for Distillate Fuel oil 1, with a 22% and 46% difference for gasoline and propane values respectively.

Bethel	**USACE 5YR average**	**2022 GHG Inventory**	**Percentage difference**
Distillate Fuel Oil No. 1 (Gal)	3,421,151	3,588,638	-5%
Gasoline	1,752,146	1,358,323	22%
Propane	72,546	120,408	-66%

3. Buckland

Buckland is a predominantly Iñupiaq community of approximately 597 people (2024) in the Northwest Arctic Borough, located off the Buckland River upriver of the Kotzebue Sound. With recent efforts from the Borough, Buckland has increased the amount of renewable electric generation and electrified space heating. Due to ice conditions and a small population, Buckland normally only receives one barge shipment of fuel annually, with other occasional needs being met by plane. With an Arctic climate, winters are long and harsh.

For stationary consumption, especially heating in winter, affects activity for diesel fuel consumption.

Using community household and facility survey data in Buckland (2017 values) it was seen that non-residential electricity usage varied from 7.3 kWh per square foot to 34.67 kWh per square foot; compared to the model's 36.8 kWh per square foot; and for fuel oil usage, from 0.09 to 0.71 gallons per square foot – compared to 1.98 gallons per square foot in the model.

For Buckland's bulk survey, actual use of distillate fuel oil #1 totaled 81,000 gallons, versus a model estimate of 47,516 gallons. The 41% difference hints at uncounted uses in the model, possibly marine vessels or other non-residential applications. Gasoline data again reveals the starkest mismatch: only 45,000 gallons were reported, while the model estimated over 5.2 million gallons, a -11,661% deviation. Such a discrepancy strongly supports the hypothesis that survey data may systematically undercount gasoline consumption for transportation. Alternatively, it raises questions about whether the model's parameters — perhaps based on population size or average U.S. per-capita fuel use — are inappropriate for rural Alaskan conditions.

4. Dillingham:

Dillingham is a predominantly Yup'ik and Dena'ina community of 2086 people (2024) located off of Bristol Bay. With its economy driven by its major commercial salmon fishery, a substantial amount of energy is used seasonally by the transportation and industrial sectors. While utilities are largely islanded, Dillingham has a road connection with Aleknagik. It also sees fishing fleet traffic with the Bristol Bay Borough and other areas of the state. With a tundra/boreal forest transitional climate, marine conditions limit barge traffic during the winter.

Heating demand in winter affects diesel use. Industrial increase (diesel, propane, and/or electric) use for fish processing. There is also a dramatic increase in diesel and gasoline use in summer for fishery.

In Dillingham, there was a 73% difference for Distillate Fuel oil 1, and a 12% and 22% difference for gasoline and propane values respectively comparing the fuel delivery data from US Army Corps of Engineers.

Dillingham	**USACE 5YR average**	**2022 GHG Inventory**	**Percentage difference**
Distillate Fuel Oil No. 1 (Gal)	749,102	199,280	73%
Gasoline	431,722	482,843	-12%
Propane	29,716	36,130	-22%

5. Huslia

Huslia is a predominantly Koyukon Athabascan community located on the upper Koyukuk River, approximately 290 air miles west of Fairbanks. It receives barge traffic approximately twice each summer, with the frozen river serving as an ice road in the winter. Air cargo and passenger service are a critical in the winter. As part of Interior Alaska, Huslia experiences extreme temperature variation through the year. Heating demand in winter affects diesel and biomass use. Fuel use for transportation likely increases in the summer due to greater road traffic.

Comparisons with the actual survey data and modeled estimates for Huslia shows a similar but distinct pattern. Distillate fuel oil #1 actual usage was 61,148 gallons, compared with a modeled 27,296 gallons, which is a 55% underestimation by the model. This suggests that the model is missing nearly half of the community's heating or generator demand. Gasoline again demonstrates extreme divergence: actual use was just over 70,000 gallons, while the modeled estimate exceeded 14.1 million gallons, leading to a staggering -20,063% deviation. This reinforces the idea seen in other communities that either survey data on transportation fuel use is not capturing the full picture, or the model vastly overestimates gasoline demand by applying assumptions that don't hold in small, rural communities.

6. Klawock

Klawock is a predominantly Tlingit community of 734 (2024) people located on Prince of Wales Island in southern Southeast Alaska. As part of the Prince of Wales Island road system, the primary bulk fuel farm for Klawock is the Petro Marine station in Craig (though bulk fuel is shipped and stored in smaller amounts elsewhere on the island, as well). The tribal government in Klawock completed some data gathering for a community energy assessment as part of the RACEE program, and though they were contacted data was not made available by the end of the performance period. Heating in winter affects diesel in stationary consumption in Klawock. Industrial increase (diesel, propane, and/or electric) for fish processing. For transportation, there is noted increase in diesel and gasoline in the summer for fishery activity.

We were unable to collect bulk fuel data for Northway Village, largely due to the community not being islanded.

7. Kongiganak

Kongiganak is a predominantly Yup'ik community of 526 people (2024) located near the coast of the Bering Sea, 70 miles southwest of Bethel. It receives barged fuel once or twice a summer. In the winter, it is primarily connected by air travel. With a tundra/boreal transitional climate, Kongiganak sees cold, long winters. For stationary consumption, especially heating in winter, affects activity for diesel fuel consumption.

In Kongiganak, the comparison between modeled and actual data shows mixed alignment. Distillate fuel oil #1 usage came in at 49,117 gallons in the actual survey, while the model predicted 43,196 gallons, a relatively close 12% deviation. This indicates that the model is reasonably capturing heating or generator-related demand. However, propane and gasoline are misaligned. Propane actuals were only 350 gallons, while the model estimated 5,768 gallons, suggesting a overestimation. Gasoline showed the largest gap: only 31,227 gallons reported locally compared to 4.5 million gallons in the modeled data. This points to either severe undercounting of transportation usage in the survey or an inflated assumption in the model about vehicle dependence.

8. Minto

Minto is a predominantly Tanana Athabascan community of 162 people (2024), located 130 miles northwest of Fairbanks. It's connected to the road system a 11 mile spur from the Elliott Highway. It is also connected by air and water.

TCC works closely on Minto’s energy issues, and some insight can be gained from their public documentation – for instance, they have a detailed map of the community and detailing of community infrastructure that can be used to confirm building count, size, and sector. Minto received a regional biomass project, which began operating in 2016, that District biomass system as part of the DOE START program, for the major non-residential buildings in town: the Lakeview Lodge and Minto Health Center. Similarly to Arctic Village, TCC largely has household-by-household contact information. Minto receives its fuel primarily by barge, but it is possible for residents to buy fuel in Fairbanks when the road is passable and thus it is not islanded. In Minto, heating in winter affects diesel consumption, and during the summer, on-road transportation likely increases substantially.

We were unable to collect bulk fuel data for Northway Village, largely due to the community not being islanded.

9. Northway Village

Like Minto and Arctic Village, Northway Village is in the TCC region and has contact info. Northway is not an island community, as it is on the road system - Tok having the nearest non-Northway gas station. In Northway Village, the heating in winter affects diesel consumption, and during the summer, on-road transportation likely increases substantially.

We were unable to collect bulk fuel data for Northway Village, largely due to the community not being islanded.

10. Port Graham

Port Graham is a predominantly Sugpiaq community of 144 people (2024) located on the southern coast of the Kenai Peninsula. Though not connected to the road system, Port Graham does enjoy proximity to Homer, allowing for the barging of fuel and supplies. The community is also connected by air, seeing regular chartered air service. The community receives it's electrical power from the Railbelt grid via the Homer Electric Association. With a maritime climate, Port Graham has a more moderate climate with cool winters and substantial precipitation.

Heating in winter affects diesel use and there is a noted increase in industrial activity, primarily in diesel, propane, and/or electricity consumption for fish hatchery.

In Port Graham, there was a 25% difference between the actual data and modeled data for Distillate Fuel oil 1, with an 86% difference for gasoline consumption.

Port Graham	USACE 5YR average	2022 GHG Inventory	Percentage difference
Distillate Fuel Oil No. 1 (Gal)	18,217	13,674	25%
Gasoline	193,219	26,827	86%

11. Sand Point

Sand Point is a fishing community of 605 people (2024) is the seat of the Aleutians Easy Borough, located on the southern side of the Aleutian Islands, approximately halfway between Kodiak and Unalaska. Trident Seafoods, the largest fish processor, serves as the vendor for fuel. Accessible by water most of the year with regular ferry service, Sand Point also receives air service with direct flights from Anchorage. With a maritime climate, the community sees cold temperatures with substantial precipitation.

Space and water heating in winter affects diesel consumption seasonally. Industrial emissions may also increase seasonally (particularly diesel, propane, and/or electric) due to fish processing. Similarly, there is an increase in diesel and gasoline consumption in the summer for fishery-related activities.

In Sand Point, there was almost a full order of magnitude (100%) difference between the actual data and modeled data for Distillate Fuel oil 1, as well as gasoline, requiring further review.

Sand Point	USACE 5YR average	2022 GHG Inventory	Percentage difference
Distillate Fuel Oil No. 1 (Gal)	368,543	764,121	-107%
Gasoline	608,403	1,464,327	-141%
Propane	102,456	247,405	-141%
Residual fuel oil #5	775	2,059,281	-265545%

12. Sitka

Sitka is a major community of 8063 people (2024), located on the outer coast of Baranof Island in Southeast Alaska. The community receives year-round barge, state ferry, and jet air service. Sitka recently conducted an emissions inventory with assistance from the Pacific Northwest National Laboratory as part of its sustainable energy planning.

Similar to Sand Point, heating in winter affects diesel use for residential and non-residential, and for industrial, there is increased diesel, propane, and/or electric consumption for fish processing, as well as increase in diesel and gasoline in summer for fishery and tourism, both marine and off-road.

In Sitka, there was almost a full order of magnitude (100%) difference between the actual data and modeled data for distillate fuel oil, gasoline, propane and residual fuel oil # 5.

13. Stebbins and St. Michael

Stebbins and St. Michael are two interconnected, predominantly Yup'ik communities, located on the Bering Sea coast on the southern coast of the Norton Sound. Stebbins has 676 people (2024) and St. Michael has 472 people (2024). They receive passenger and cargo service by air, along with annual dockless barge service. Both communities are served by a single, Alaska Village Electric Cooperative (AVEC) grid. With a tundra/boreal forest transitional climate, these communities experience cold, long winters. Stationary consumption activity, especially heating in winter, diesel fuel consumption is seasonally affected.

Stebbins presents a more complex picture. Diesel fuel usage was 120,000 gallons in actual reporting, much higher than the 56,707 gallons modeled, resulting in a 53% deviation. This could reflect that Stebbins not only consumes locally but also sells or distributes diesel fuel to nearby communities, making the local data appear higher. Gasoline, on the other hand, mirrors the pattern observed in Kongiganak: the model vastly overshoots. Actual gasoline usage was 80,000 gallons, while the model predicted over 3.3 million gallons, a -4,061% deviation. Once again, this suggests that either the survey methodology undercounts transportation demand, or the model applies assumptions about vehicle ownership and usage that do not match community realities.

Sectoral deviations in fuel estimation: Fishing communities may have underestimated emissions due to fuel activity untethered to population or facilities. Based on the Sitka's GHG Inventory report, transportation emissions, particularly those from fishing and boats, can be further estimated in the future, especially for other Alaskan fishing communities. Transportation accounts for a significant portion of Sitka's emissions, totaling 81% of the community's greenhouse gas (GHG) output with the baseline year for the inventory being 2023, although some data sources are from previous years.

Sitka's inventory report broke down marine activity into three categories: commercial fishing, recreational boating, and charter boats. For commercial fishing, which was the largest source of marine emissions, the estimation using the State of Alaska CFEC Public Search Application to find active fishing permits. This data, along with fuel usage estimates from the Kempy Energetics analysis tool, determined that commercial fishing consumed 1,805,600 gallons of diesel per year, resulting in an estimated 18,507 MTCO2e. Next, recreational boats estimations assumed there were about 1,000 active recreational boats based on registration data. Assumptions were made that each boat took an average of 20-mile trips, 4 times per month, for 6 months a year, with a fuel efficiency of 5 miles per gallon which resulted in an estimated 1,660 MTCO2e per year. Finally, the charter boats, where data from a charter boat logbook provided by Sitka Area Management was used to determine that 7,920 trips were taken in 2023 by 142 active vessels. Assuming that these boats primarily run on diesel with each average trip being approximately 25 miles with a fuel efficiency of 5 miles per gallon, the estimated emissions from charter boats were 888 MTCO2e.

Applying this to Other Alaskan Fishing Communities: This methodology could be adapted to estimate emissions in other Alaskan fishing communities by following these key steps. First, gathering local data - although the primary challenge would be to obtain the same types of local data used in the Sitka report, including: commercial fishing information from the State of Alaska CFEC Public Search Application and other localized analysis tools would be needed to estimate the number of active fishing permits and average fuel usage. For any recreational boats, local boat registration data would be required to estimate the number of recreational boats. Finally, for charter boats data accessed from local charter boat logbooks or similar records of trips and vessels would be necessary to estimate activity data for this sector. Assumptions made for Sitka, such as trip lengths, trip frequency, and average fuel efficiency, would need to be reviewed and potentially adjusted based on the specific circumstances of the new community.

2. Modeled Emission Inventory

Community	Sectors	Fuel Type	Details	Activity	unit
Stebbins	Residential	Residual Fuel Oil No. 5	Mixed	184,942	gal
Stebbins	Commercial	Distillate Fuel Oil No. 1	Mixed	56,707	gal
Stebbins	Commercial	Propane	Mixed	7,573	gal
Stebbins	Transportation	Diesel Fuel	Truck	0	gal
Stebbins	Transportation	Motor Gasoline	Truck	3,168,159	gal
Stebbins	Transportation	Motor Gasoline	Motorcycle	5,587	gal

Stebbins	Transportation	Motor Gasoline	Passenger	155,445	gal
Kongiganak	Residential	Residual Fuel Oil No. 5	Mixed	118,519	gal
Kongiganak	Commercial	Distillate Fuel Oil No. 1	Mixed	43,196	gal
Kongiganak	Commercial	Propane	Mixed	5,768	gal
Kongiganak	Transportation	Diesel Fuel	Truck	0	gal
Kongiganak	Transportation	Motor Gasoline	Truck	4,173,612	gal
Kongiganak	Transportation	Diesel Fuel	Passenger	0	gal
Kongiganak	Transportation	Motor Gasoline	Passenger	315,612	gal
Kongiganak	Transportation	Motor Gasoline	Motorcycle	9,210	gal
Klawock	Residential	Propane	Mixed	20,630	gal
Klawock	Residential	Residual Fuel Oil No. 5	Mixed	231,829	gal
Klawock	Commercial	Distillate Fuel Oil No. 1	Mixed	64,795	gal
Klawock	Commercial	Propane	Mixed	8,653	gal
Klawock	Transportation	Diesel Fuel	Truck	0	gal
Klawock	Transportation	Motor Gasoline	Truck	9,453,704	gal
Klawock	Transportation	Motor Gasoline	Passenger	1,039,359	gal
Klawock	Transportation	Motor Gasoline	Motorcycle	17,024	gal
Buckland	Residential	Residual Fuel Oil No. 5	Mixed	156,289	gal
Buckland	Commercial	Distillate Fuel Oil No. 1	Mixed	47,516	gal
Buckland	Commercial	Propane	Mixed		gal

				6,345	
Buckland	Transportation	Diesel Fuel	Truck	0	gal
Buckland	Transportation	Motor Gasoline	Truck	4,971,010	gal
Buckland	Transportation	Diesel Fuel	Passenger	0	gal
Buckland	Transportation	Motor Gasoline	Passenger	312,391	gal
Buckland	Transportation	Motor Gasoline	Motorcycle	9,205	gal
Huslia	Residential	Residual Fuel Oil No. 5	Mixed	67,725	gal
Huslia	Commercial	Distillate Fuel Oil No. 1	Mixed	27,296	gal
Huslia	Commercial	Propane	Mixed	3,645	gal
Huslia	Transportation	Diesel Fuel	Truck	0	gal
Huslia	Transportation	Motor Gasoline	Truck	12,325,367	gal
Huslia	Transportation	Motor Gasoline	Passenger	1,786,129	gal
Huslia	Transportation	Motor Gasoline	Motorcycle	32,463	gal

3. Actual Survey-Based Data

Sector	Community	Year	Fuel type	Amount	Unit	Unit
Com	Kongiganak	2024	Distillate Fuel Oil No. 1	24968	Gal (US)	Facility
Res	Klawock	2022	Distillate Fuel Oil No. 1	764.2	Gal (US)	Household
Res	Klawock	2022	Distillate Fuel Oil No. 1	539.6	Gal (US)	Household
Com	Stebbins	2024	Distillate Fuel Oil No. 1	3E+06	Gal (US)	Facility
Com	Stebbins		Electricity	12376	kWh	Facility
Com	Stebbins	2015	Distillate Fuel Oil	995	Gal	Facility

			No. 1		(US)	
Com	Stebbins	2015	Electricity	30560	kWh	Facility
Com	Stebbins	2015	Recovered Heat	573	mBTU	Facility
Com	Klawock	2016	Electricity	12685	kWh	Facility
Com	Klawock	2016	Distillate Fuel Oil No. 1	1006	Gal (US)	Facility
Com	Klawock	2016	Electricity	59236	kWh	Facility
Com	Klawock	2016	Distillate Fuel Oil No. 1	777	Gal (US)	Facility
Com	Buckland	2017	Electricity	14032	kWh	Facility
Com	Buckland	2017	Distillate Fuel Oil No. 1	171	Gal (US)	Facility
Com	Buckland	2017	Recovered Heat	252	mBTU	Facility
Com	Buckland	2017	Electricity	63383	kWh	Facility
Com	Buckland	2017	Distillate Fuel Oil No. 1	1300	Gal (US)	Facility
Com	Buckland	2017	Recovered Heat	1300	mBTU	Facility
Com	Sand Point	2016	Electricity	77019	kWh	Facility
Com	Sand Point	2016	Distillate Fuel Oil No. 1	1372	kWh	Facility
Com	Minto	2022	Distillate Fuel Oil No. 1	10000	Gal (US)	Facility
Com	Minto	2022	Electricity	36500	kWh	Facility
Com	Minto	2025	Distillate Fuel Oil No. 1	6773	Gal (US)	Facility
Com	Minto	2025	Electricity	92500	kWh	Facility
Com	Klawock	2022	Mixed MSW (landfilled)	364419	ft3	Facility
Com	Klawock	2022	Mixed MSW (landfilled)	40149	ft3	Facility
Com	Klawock	2022	Mixed MSW (landfilled)	569457	ft3	Facility

Community	**Year**	**Amount**	**Unit**	**Fuel type**	**Field Comments**
Kongiganak	2024	49,117	gal (US)	Distillate fuel oil #1	Via the Kongiganak Bulk Fuel Plant, operated by QCC - totals were

Kongiganak	2024	350	gal (US)	Propane	interpolated by staff from sales records using unit prices. Does not include fuel used for power plant and Kongiganak school, both of which have separate tank farms. Diesel is primarily used for home heating - approximately 2,780 gallons of home heating need is offset by wind-to-heat system. Gasoline is primarily used for transportation (marine, on-road, and off-road). No fuel is sold for aviation. Propane is used primarily for equipment like camp stoves.
Kongiganak	2024	31,227	gal (US)	Gasoline	
Stebbins	2024	120,000	gal (US)	Diesel	This represents the 2024 sales of fuel in the community. This estimate for diesel includes fuel sold to AVEC for the electric power plant.
Stebbins	2024	80,000	gal (US)	Gasoline	
Buckland	2023	81,000	gal (US)	Distillate fuel oil #1	The community fuel farm, run by the Buckland IRA, represents all fuel oil and gasoline used in the community, except for fuel at the city fuel farm which is used exclusively for the electric utility. All homes and equipment use fuel from the farm, except for a handful of homes heated by wood and the occasional purchase of propane from neighboring villages. The community tank farm (capacity of 90,000 gal FO, 50,000 gasoline) is filled to the 90% Safe Gauge Height (SGH) from empty annually in July, when the barge delivery is completed. The fuel is sold at discount ahead of the barge in order to maximize the delivery.
Buckland	2023	45,000	gal (US)	Gasoline	
Huslia	2024	61,148	gal (US)	Distillate fuel oil #1	This represents the community bulk fuel farm and does not include fuel delivered for the school or AVEC's power plant.
Huslia	2024	70,149	gal (US)	Gasoline	

Survey instrument and process changes

While prior inventories heavily relied on survey responses from a small set of representative communities (13 communities) to extrapolate to over 360 other small and midsize rural communities, the modeled estimates independently estimated all communities in Alaska for the 2022 GHG inventory. If surveys sometimes had incomplete data — e.g. households reported having wood stoves but not the amount of wood burned, or only responded for one season, the top-down data helps fill some of those gaps, like in the bulk fuels survey. Some non-residential facilities did not respond at all, leading to estimated zeroes that may understate emissions, at least for certain activities and fuel types. Future efforts could allow these types of data gaps to be filled by borrowing values from other communities, introducing uncertainties.

In this report, the instruments were explicitly designed to improve on this by collecting direct local data for each community, reducing the extent of extrapolation. It also made provisions for more robust QA checks and direct re-contact with residents for clarifications, minimizing the uncertainties caused by incomplete data. Prior surveys had already revealed unexpectedly high variability in certain fuels, even in similar climate zones. This was attributed to differences in household size, age of homes, stove efficiency, and cultural practices around heating and cooking. Non-residential facilities also varied widely. Some small clinics or schools consumed large amounts of diesel for heating and electricity, while similar facilities elsewhere used far less. In this study, the methodology was able to target each community individually, gathering more granular activity data — for example, distinguishing homes with central heating vs. wood-only, and mapping power generation more precisely to actual local loads, albeit for only a portion of the sample communities. This led to refined emission factors and fewer assumptions in those communities.

Influence of under-reported or over-reported behaviors

The 2005 report documented that some communities reported no diesel use for vehicles in winter, which seemed unlikely and was likely under-reporting. Conversely, some very high wood use numbers might have come from misunderstandings (cords vs. loads vs. trips). By having the survey break apart activity data into validated usage metrics and units, this input error probability was arguably reduced. This recent survey included improved survey instrument design with clearer units and examples to minimize misreporting. It also included more rigorous follow-ups for outlier checks, reducing the chance of distorted totals. Furthermore, the earlier study found fuel use tied deeply to local hunting/fishing seasons, subsistence practices, and access to local biomass. These factors changed significantly across communities — something national models or standard emissions factors didn’t capture well. In this report, each sample community and their seasonal variations in sectoral, activity or fuel consumption has been highlighted. Future studies can be further informed by these insights to explicitly structure the surveys around seasonal practices, ask about smokehouses, fish camps, seasonal generator use, and integrate local cultural calendars into data collection, enabling more accurate estimation of true seasonal emission peaks.

Challenges with transportation (marine & port) emissions

While prior studies (2005) emission estimates for commercial marine activity in over 160 small ports based on vessel registrations, schedules, and previous studies on larger ports — which may not have well represented local fishing vessels or small freight movements. This study questionnaire, while primarily community-focused, benefited from knowing to treat sub-transportation equipment activity separately and to recognize it as a significant and highly variable contributor. This might explain why the newer inventories concentrated more resources on detailed local land-based sources and treated ports as a distinct analysis track.

Based on these learnings, the current community-based survey project explicitly addressed these historical shortcomings by gathering data directly from each community resident group instead of heavily extrapolating from a few stand-ins. By using improved survey clarity (units, examples), local enumerators, and culturally tailored instruments, informed by the difficulties and errors observed in the 2005 data collection, this study recognized the critical variability in heating, power generation, and seasonal practices, prioritizing actual measured or self-reported fuel purchases and consumption logs over assumptions. By structuring the entire methodology to reconcile directly surveyed activity data with existing modeled inventories, the study design improved confidence in community-level estimates. The 2005 study provided essential foundational knowledge, but also highlighted gaps and pitfalls in relying on a small number of surveys and indirect extrapolation. The current report directly leveraged these lessons by designing a survey program that was more comprehensive, locally grounded, seasonally nuanced, and quality-controlled — leading to community emission inventories that are far more accurate and reflective of on-the-ground realities, as summarized in Table X below.

Table X: Islanded community comparison

Prior studies	**Accuracy implications**	**2025 study**
Heavy reliance on extrapolation from few representative communities	Introduced significant uncertainty, as differences in fuel use, heating types, and practices were not always well correlated just by population or region.	Conducted direct surveys in each individual community, reducing dependence on broad extrapolations. Produced truly community-specific inventories.

Data gaps & incomplete surveys	Led to zero entries or borrowed values, which sometimes understated or distorted emissions totals.	Used improved outreach and follow-ups to achieve higher response rates, and systematically verified data entries. Designed surveys to be simpler and clearer to minimize partial responses.
Highly variable fuel use, often with unclear units	Created possible over- or under-estimates of PM, CO, HC emissions.	explicitly defined units on surveys with examples (e.g. “one pickup bed ≈ ½ cord”) and included local illustrations to reduce misinterpretations.
Reports of summer activities in winter, or vice versa	Seasonal emissions peaks could be wrongly distributed, affecting estimates of wintertime air quality impacts.	Used calendar-based checks and clarifying follow-ups, asking about specific seasonal events (salmon runs, moose hunting) to better anchor reported usage in the correct time periods.
Non-residential diesel use sometimes missing	Understated power generation and institutional heating contributions.	Proactively surveyed power utilities, clinics, schools, and village corporations to get direct reported diesel purchases and generator run times.
Local cultural practices underrepresented (smokehouses, fish camps, winter camps)	Missed or understated important combustion sources unique to Alaska Native and rural lifestyles.	Surveys explicitly included sections on fishing, etc. and used local field staff who understood these practices.
Commercial marine emissions estimates based on distant large-port data	Possibly mischaracterized small harbor impacts and led to questionable emission totals.	Recognized marine as a separate analytical track, focusing the current survey primarily on community land-based sources and leaving marine to future direct vessel studies. US Army CoE data on actual shipments and receipts of fuels in select communities.

Limited QA/QC follow-up on suspicious responses	Allowed large errors from single extreme outlier surveys.	implemented structured outlier detection and follow-up interviews, and adjusted data with documented flags instead of automatic zeroing.

Appendix C: Quality Assurance Project Plan (attached separately)

Appendix D: Emissions factor sources (attached separately)

Appendix E: Modeled inventory and error estimation

As part of the Climate Pollution Reduction Grant (CPRG) program, the State of Alaska's greenhouse gas (GHG) and criteria pollutant emissions inventory employs a standardized and rigorous methodology to estimate community-level emissions across major sectors, including residential and commercial buildings, industrial sources, power generation, and transportation. The inventory does not rely on direct field measurements but instead utilizes a robust combination of existing datasets, statistical modeling, and geospatial refinement to ensure representative and actionable emissions data at the local level.

Community-level emissions in the State of Alaska GHG Emissions Inventory project are estimated using a combination of activity-based models, secondary data sources, and geospatial tools. The goal is to assess emissions from residential and commercial buildings, industrial processes, power generation, and transportation across various communities. The project combines several datasets, including census data, utility records, fuel consumption data, and satellite imagery, to create a spatially accurate emissions inventory at the community level. This multi-source approach allows for robust modeling, ensuring that emissions are tracked and managed at a granular level, making it easier for communities to access and manage climate action data. This detailed, multi-layered approach ensures that Alaska's communities—especially those in remote or rural areas—can track and manage their emissions inventories effectively, even when primary data is lacking. By integrating existing datasets, advanced modeling techniques, and community-specific data, the project helps to provide a comprehensive picture of emissions across the state, guiding mitigation strategies and funding opportunities.

This methodology lays out a detailed, multi-step process for estimating community-level emissions by integrating diverse data sets and modeling techniques tailored to each source category. Below is an expanded explanation on how the emissions from different sectors are measured, along with the key data sources and models used for each. Across these sectors, the modelling approach emphasizes that while data may come from diverse sources—and thus have varying levels of precision and accuracy—a series of cross-calibration, downscaling, and aggregation steps are used to ensure consistency at the community level. This includes combining multiple data sources for each sector, where the model uses overlapping datasets (e.g., utility records with ACS data for buildings, or HPMS with local traffic counts for transportation) to inform weighted estimates.

Additionally, by using modeling downscaling techniques, particularly for activities like power generation and transportation, state- or regional-scale data are apportioned to communities using activity metrics (population, building counts, road lengths) as weights gives ability to adjust assumptions in future. Finally, for the modeled ongoing assessments, audits, and recalibrations are built into the process for clarity and replication. Data quality indicators such as precision, accuracy, representativeness, comparability, completeness, and sensitivity are used to validate the estimates and guide further refinement.

In short, community-level emissions are estimated for Buildings (Residential/Commercial) by integrating building inventories, ACS data, utility records, and energy consumption models (using RECS/CBECS) to downscale state totals. For Industrial Emissions, the model uses NAICS-coded business patterns, county business data, and EPA emission factors. For power generation, the model combines state-level data from EIA-SEDS and eGRID with utility service maps to allocate emissions to communities. Finally, for transportation, leveraging detailed geospatial roadway data from FHWA, combined with vehicle miles traveled (VMT) estimates, fuel economy data, and calibration against state-level totals. This multi-faceted approach ensures that despite different data origins and methodologies, the resulting inventories are consistent, comparable, and ultimately useful for guiding community-level climate action and emissions reduction strategies.

Throughout the inventory process, methodological consistency is maintained by employing EPA-recommended tools and frameworks, including the State Inventory Tool (SIT), MOVES, and the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC). Sector-specific data quality assessments are performed to assign confidence levels to each community-fuel-sector estimate, guiding further calibration efforts and data improvement strategies. This multi-tiered, data-integrated approach enables Alaska's communities—including many small and disadvantaged ones—to obtain credible emissions baselines that support climate planning and funding applications. The resulting data are visualized via geospatial dashboards and shared with stakeholders to inform emission reduction strategies at the local and state level.

The emissions inventory developed under the State of Alaska's Climate Pollution Reduction Grant (CPRG) framework incorporates a wide range of activity and fuel type data to ensure comprehensive, sector-specific emissions accounting at the community level. These data are selected to align with EPA methodologies and to reflect the full spectrum of energy use and emissions-generating activities relevant to Alaskan communities, including those in remote or disadvantaged areas. The integration of both activity data (e.g., energy consumption, travel distance, industrial throughput) and fuel-specific characteristics (e.g., fuel type, heating content, combustion emissions factors) allows for a consistent and accurate translation of operational inputs into greenhouse gas and criteria pollutant outputs. However, given the complexity of spatial and sectoral variation across Alaska, certain sources of error and uncertainty are inherent to the aggregation and disaggregation process.

1. Top-down allocation of state-level totals

State-level energy consumption and emissions data, as reported by the U.S. Energy Information Administration's State Energy Data System (EIA-SEDS) and EPA's eGRID and FLIGHT databases, serve as the foundation for estimating emissions. These datasets provide comprehensive annual totals for electricity generation, fuel sales, industrial emissions, and transportation energy use. However, because these sources do not provide consistent community-level granularity, state totals must be disaggregated down to smaller spatial units using proxy activity data such as population, housing unit counts, square footage, building type, vehicle registration, and utility territory boundaries.

2. Mid-level borough data
Where available, data reported at the borough (county-equivalent) level—such as vehicle miles traveled, heating fuel mix, or utility sales—are used as intermediaries to bridge between statewide totals and community-specific estimates. Borough-level data are particularly useful when service territories or statistical boundaries (e.g., ACS tracts) overlap multiple small communities. Disaggregation from borough to community level is typically performed by applying weights based on finer-scale census or tax parcel data (e.g., building counts or residential floor area).

3. Community-level and facility-level data
For communities with available data (e.g., local inventories, utility records, or data from the Alaska Retrofit Information System), these bottom-up sources are directly used in the inventory process. Facility-level emissions data, such as those reported to EPA via the FLIGHT database or state air permits, are assigned to the communities in which those facilities are located. In cases where facility boundaries span multiple communities, emissions are pro-rated based on land area, production output, or operational footprint.

4. Reconciliation of multiple data levels
To ensure internal consistency, emissions estimated at the community level are aggregated back up and compared to the original state-level totals. Discrepancies are analyzed to detect over- or under-estimations. Where mismatches are observed, model calibration is applied—either adjusting the weighting factors used in disaggregation or correcting for known reporting gaps or double-counting risks.

Despite careful methodological design, several types of errors may be introduced during the aggregation and disaggregation process:

Spatial misalignment and boundary mismatch: Census tracts, utility service areas, borough boundaries, and community polygons often do not align perfectly. This can lead to estimation errors when distributing state or borough-level totals to individual communities. For example, a utility territory may serve multiple overlapping communities, but utility data may not distinguish consumption at the sub-jurisdictional level. The modeling addresses this by using spatial overlay techniques and assigning weights based on population, building counts, or land use, but residual errors may persist where boundaries are ambiguous or communities lack defined legal limits.

Inconsistent data vintages and timeframes: Datasets used in the analysis span multiple years (e.g., ACS 5-year averages, 2022 utility sales, 2021 HPMS road data), which can result in temporal mismatches. When data from different sources refer to different calendar years, estimates may be biased if there have been substantial changes in population, infrastructure, or fuel use in the interim. The modeling approach mitigates this by standardizing all reporting to the 2022 calendar year, applying scaling factors or growth rates when needed—but some lag effects may remain.

Data sparsity and reliance on proxies: Many small and rural communities in Alaska lack direct measurements or recent inventories. In such cases, emissions are inferred using proxy metrics, such as allocating fuel use based on residential floor area or estimating transportation emissions using modeled VMT per capita. These indirect methods are sensitive to assumptions and may over- or under-estimate actual emissions if the proxy variable is poorly correlated with true activity. For example, using average household size to estimate heating fuel consumption assumes uniform energy intensity, which may not hold in diverse housing stock.

Double-counting across data sources: Overlap between datasets poses a risk of double-counting emissions, particularly when combining facility-level (FLIGHT), utility-level (EIA), and grid-level (eGRID) data. For example, emissions from a diesel generator in a rural community may be included both in the FLIGHT dataset and in the eGRID state total. The model addresses this by assigning each ton of emissions to a unique "community-fuel-sector" triplet and excluding duplicate entries where overlapping sources are detected. Nevertheless, cases of unintentional duplication may occur if facilities report under multiple programs without harmonized identifiers.

Downscaling artifacts and statistical smoothing: To match community-level totals with state or borough aggregates, linear rescaling is often applied. While this ensures overall consistency, it can mask local variability and artificially flatten high-emitting or low-emitting outliers. This is particularly relevant for transportation and power sectors, where a small community hosting a regional facility (e.g., airport, diesel plant) may have disproportionately high emissions that get smoothed during proportional allocation.

Data quality and confidence score limitations: Each community-fuel-sector datapoint is assigned a data quality rating (high, medium, or low), based on the availability, source integrity, and documentation of the underlying data. High-quality data (e.g., utility bills, direct facility reports) is prioritized where available. However, in many cases only medium (e.g., spreadsheet estimates) or low-quality (e.g., historical averages, fuel type assumptions) data are available. The final emissions estimates incorporate these confidence scores, but communities with predominantly low-quality data may have greater uncertainty, potentially impacting the prioritization of reduction strategies or funding applications.

In sum, the model employs a structured, multi-level approach to aggregating and disaggregating emissions data, combining top-down (state and borough) and bottom-up (facility and community) sources. While this strategy allows for comprehensive statewide coverage and local resolution, it introduces several potential sources of error—particularly in boundary mismatches, proxy assumptions, data sparsity, and source overlaps. These uncertainties are transparently documented and mitigated through calibration, cross-referencing, and data quality scoring, ensuring that the resulting community-level inventories are as accurate and actionable as possible for planning and policy development. The model is now linked to how the above items may bias modeled estimates below:

Error calculation relative to inventory model: To mathematically formalize the nesting structure and aggregation logic of Alaska's CPRG emissions inventory, we define hierarchical indices for space (facility → community → borough → state), emissions source attributes (sector, fuel), and time. This allows us to express the full emissions aggregation equation precisely. The model nests the data sources in this way:

Alaska is the only US state considered in this model, $s \in S$ of S set of all states, with $b \in Bs$ being the set of boroughs within state s. $c \in Cb$ is the set of communities within borough b, and $f \in Fc$ are the set of facilities (or sources) within community c. For activity attributes, $k \in K$ is the set of sectors (e.g., Residential, Commercial, Industrial, Transportation, etc.) with $j \in J$ is the set of fuel types (e.g., diesel, electricity, wood, gasoline, etc.). The temporal index, $t \in T$ is the time period (e.g., year; $t=2022$ in current case for inventory year, but generalizable based on data availability for past or future data).

Sectoral methodology and breakdown

For residential and commercial building emissions, energy consumption estimates are developed using a combination of federal and state datasets. Community-level building inventories—including data on building counts, floor area, fuel type, and age—are sourced from tax records, local jurisdictions, and the American Community Survey (ACS). These inventories are coupled with energy consumption profiles derived from the U.S. Energy Information Administration's Residential Energy Consumption Survey (RECS) and Commercial Buildings Energy Consumption Survey (CBECS). State-level energy consumption totals from EIA-SEDS are disaggregated to individual communities using weighted factors such as square footage, heating fuel mix, and climate zone assignments. The methodology is modeled after spatial refinement approaches used by the National Renewable Energy Laboratory (NREL) in its Cities-LEAP program, which supports detailed community-scale energy modeling.

In the residential and commercial sectors, the inventory analyzes energy use across various heating and power sources. Key activity data include electricity consumption in kilowatt-hours (kWh), fuel oil and diesel use in gallons, natural gas consumption in therms or cubic feet, and wood or biomass use in cords or tons. These are matched with heating fuel types reported in the American Community Survey (ACS) and supplemented by building-specific data from the Alaska Retrofit Information System (ARIS), which provides detailed information on heating systems and energy use across over 50% of the state's residential housing stock. Building-level activity is further characterized by year built, floor area, occupancy type, and energy efficiency attributes, enabling localized emission factor application for each fuel type.

The measurement approach and modeling process begins with assembling building inventories at a fine geospatial scale to estimate residential and commercial emissions. This involves collecting data such as building counts, square footage, age, and heating fuel types from tax records, local building inventories, and geospatial layers. These inventories are then downscaled from broader state or county-level data, like EIA state energy totals, to community-specific estimates using weighting factors (e.g., number of buildings, square footage). Energy consumption is modeled using two main approaches. Firstly, the Residential Energy Consumption Survey (RECS) and the Commercial Buildings Energy Consumption Survey (CBECS), both from EIA Surveys, provide foundational estimates for energy usage across different building types. Secondly, community-level data from the American Community Survey (ACS) is utilized to accurately determine heating fuel distributions. Additionally, consumption figures from utility reports, including Form EIA-861 and the Annual Electric Power Industry Report, are geographically assigned to specific communities.

Multiple data streams—utility data, census data, and local inventories—are compared to check for over- or under-estimations. When differences arise (for example, due to inconsistencies in block-level versus tract-level reporting), the approach is to treat each source separately before using a post-processing step with stakeholder input to arrive at the final energy consumption figures. Additional data sources and tools include the U.S. Energy Information Administration (EIA-SEDS), which provides disaggregated state totals and activity data. The American Community Survey (ACS) supplies demographic and building count data essential for calibrating fuel usage. Building inventories and tax records offer detailed local records on specific building characteristics. Finally, National Renewable Energy Laboratory (NREL) methods, specifically those developed for the Cities-LEAP project, have refined spatial estimates for community energy consumption.

The methodology for this model for buildings thus relies on several key data sources to estimate energy consumption and calculate emissions. The Energy Information Administration (EIA) provides detailed energy usage patterns through its Residential Energy Consumption Survey (RECS) and Commercial Buildings Energy Consumption Survey (CBECS). The Alaska Housing Finance Corporation (AHFC) offers building-specific information on heating fuels and consumption volumes via the Alaska Retrofit Information System (ARIS). Census Data (ACS) is utilized to estimate building counts, square footage, heating fuel types, and demographic information by community, while PCE Data is used for electricity consumption data in rural Alaska communities. The methodology involves three main steps. First, energy use estimation is conducted by applying modeled energy consumption models (e.g., RECS, CBECS) to community-specific building inventories. This process is performed at a granular level, such as the U.S. Census tract, and then aggregated to the community level to determine total energy consumption for electricity, heating fuels, and other sources. Second, a calibration step adjusts for discrepancies in data coverage by prorating state-level totals across different communities. This ensures an accurate representation of local energy usage patterns. Finally, emission calculation is performed for each fuel type, including electricity, natural gas, fuel oil, and wood. Emissions are determined based on standard emission factors derived from EPA databases and industry-specific models.

Industrial emissions are estimated by pinpointing economic activity using geospatial data. This involves using County Business Patterns data and NAICS codes to locate and classify industrial facilities. Emissions are then calculated using EPA-published emission factors, cross-referenced with National Emissions Inventory (NEI) data. For smaller emitters or un-instrumented sources, estimates rely on fuel use, process activity, and industry-specific operational data, adjusted to align with statewide totals.

Data for industrial activity comes from county-level business inventories and national datasets like the EPA's NEI and the U.S. Census Bureau's County Business Patterns. Activity metrics include energy consumption by industrial process and fuel type, and production volume. These are matched to EPA-specified emission factors for various categories, and facilities consuming electricity, natural gas, diesel, or coal are categorized by NAICS codes and allocated geographically. The measurement approach involves identifying and estimating emissions based on a geo-located inventory using NAICS-coded business patterns. For smaller sources, county-level business patterns assign emission values based on activity data and standard EPA factors. For industries not directly measured, estimates use activity-based inputs (e.g., fuel consumption) and EPA emission factors, which involves identifying the source type, applying sector-specific factors, and spatially allocating data to the community scale. Key data sources and tools include County Business Patterns for geolocation, EPA NEI data for standardized emission factors, and CPRG Recommendations and EPA Tables for lookups and conversion. Additional data sources include EIA-SEDS for fuel use. The methodology applies sector-specific emission factors based on energy consumption, production, and raw materials; models industrial activity using proxies when data is limited; and adjusts data to the community level using spatial mapping and sector-specific assumptions.

Power sector emissions are determined using a hybrid top-down and bottom-up methodology, starting with state-level emissions from the Emissions & Generation Resource Integrated Database (eGRID) and fuel consumption data from EIA-SEDS as a baseline. These totals are then proportionally allocated to communities based on utility service territories and localized consumption patterns, which are derived from utility datasets such as EIA Form-861 and EIA-176. Community-level electricity use is further refined with detailed heating fuel and consumption data for residential buildings from the Alaska Retrofit Information System (ARIS). This multi-source calibration ensures consistency between aggregated community estimates and state totals, while preventing double-counting, especially where datasets like eGRID and EPA

FLIGHT might overlap. For power generation, the activity data analyzed includes total electricity generated and consumed, broken down by fuel type and technology. Data on electricity sales and losses are obtained from utility filings (e.g., EIA Form-861 and EIA Form-923) and disaggregated to the community level using utility service territory maps and building energy demand estimates. Upstream fuel types like diesel, coal, natural gas, hydropower, solar, and wind are included, with their generation outputs and emissions factors sourced from EPA's eGRID database and the EIA State Energy Data System (SEDS).

In isolated communities where local diesel generators provide power, activity data such as gallons of diesel used and generation efficiency are acquired from the Power Cost Equalization (PCE) program records maintained by the Alaska Energy Authority. The measurement approach involves bottom-up versus top-down calibration, where state-level data from authoritative sources like EIA-SEDS and EPA's eGRID are used to derive community-level estimates. This process includes collecting electricity generation and consumption data, dividing it among communities based on utility service territories, and calibrating the totals to ensure consistency with state-level figures. Dual-source calibration for power generation utilizes EPA's eGRID for grid-region and state-level emissions data, alongside activity data from utilities, where community-level electricity consumption from utility territory shapefiles and detailed consumption reports (e.g., Form EIA-861) is used to distribute overall emissions to local scales. Key data sources and tools include EPA eGRID for grid-based emissions and generation data, U.S. Energy Information Administration (EIA-SEDS) for state-level energy use figures, and utility reports and geographic mapping for accurate allocation of power generation emissions to communities. Specifically, EPA's eGRID provides data on power generation and emissions at the grid-region and state level, while EIA's Annual Energy Review (Form EIA-861) offers information on electricity generation, fuel sources, and associated emissions.

State-level power data also comes from Alaska's utilities and the PCE dataset, which subsidizes diesel fuel costs for rural communities. The methodology involves using grid-level emission factors from the eGRID database to derive power generation emissions intensity for different energy sources. State-level emission estimates are then distributed to individual communities using utility service territories and energy consumption data from the PCE dataset and utility records. In cases of missing community-level energy consumption data, estimates are generated through spatial analysis of utility service areas and scaled based on population or building type data.

Transportation emissions are calculated by analyzing vehicle activity and traffic patterns, with vehicle miles traveled (VMT) data obtained from the FHWA's HPMS shapefiles. These data are combined with fuel economy figures and vehicle class distributions to determine fuel consumption and subsequently estimate GHG emissions, including CO_2, CH_4, and N_2O, across various transit modes like on-road, rail, aviation, and marine. Missing VMT data for minor roads are filled in using state-level totals, and the model is validated with DMV registration records, ACS commuting statistics, and Alaska DOT datasets to refine assumptions at the community level. Transportation activity data encompasses on-road, off-road, and non-road sectors, utilizing metrics such as VMT, vehicle registration counts, and average fuel economy from sources like the FHWA, Alaska Department of Motor Vehicles, and ACS. The model considers various fuel types—gasoline, diesel, natural gas, jet fuel, and marine fuels—applying specific emission factors per gallon or ton consumed. Fuel use for aviation and marine transport is estimated from flight records, shipping logs, and EPA conversion factors, while off-network activities like idling and cold starts are integrated using emissions models and national travel behavior datasets.

The model for measuring and modeling transportation emissions begins with state-level fuel consumption data, which is then downscaled using geospatial segmentation of road networks into segments with associated vehicle miles traveled and traffic intensity. Fuel economy data, disaggregated by vehicle type, is applied to these segments to calculate CO_2, CH_4, and N_2O emissions. The model considers various transportation modes, including on-road emissions, off-network emissions (like idling), and modal breakdowns encompassing on-road vehicles, rail, waterborne navigation, and aviation. Consistent methodologies ensure accurate attribution of emissions to specific communities. To address comprehensive data capture, particularly for minor roads, state-level totals are used to backfill missing data, and linear rescaling ensures that the sum of disaggregated data aligns with known total fuel consumption figures.

The methodology for this project involves several key steps. First, Vehicle Miles Traveled (VMT) is estimated for each community by combining road segment data from HPMS shapefiles with vehicle type and fuel economy data from the Alaska DMV and DOT. Second, fuel consumption and emissions are estimated using models like MOVES, with emissions categorized by vehicle and road types. Third, attribution models assign emissions to communities based on their geographic location, prorating emissions when roads pass through multiple communities. Finally, off-network emissions, such as idle and stationary vehicle emissions, are also included in the analysis. Data sources include geo-located road segments and traffic data from the Federal Highway Administration (FHWA) Highway Performance Monitoring System (HPMS) shapefiles. Emissions estimates for mobile sources are derived from the MOVES Model (EPA). Vehicle registration and transportation activity data, such as vehicle miles traveled, are sourced from the Alaska DMV and Department of Transportation (DOT). Additionally, ACS and other Census Data are utilized to estimate vehicle types, distances traveled, and fuel usage in residential areas.

Land-use emission sinks were also used for assessing land use and emission sinks, utilizing LandSat 8 Satellite Imagery to classify land cover (e.g., forests, wetlands) and estimate their carbon sequestration potential. Additionally, NDVI, NDWI, and NDSI indices are employed for high-resolution analysis of vegetation, water, and snow cover. The calculated emission sinks are then attributed to specific communities through geospatial overlays, enabling them to evaluate their carbon offset capabilities.

Emissions estimation

The model defined E(k,j,t)fckb for the emissions from facility f in community c, borough b, and state s in sector k, using fuel j, during time t. Measured in metric tons of CO_2e. The nested aggregated equations include, (1) Facility to Community-Level Emissions, Ecb(k,j,t)=f∈FcE(k,j,t)fckb, (2) Community to Borough-Level Emissions, Eb(k,j,t)=c∈CbEcb(k,j,t)=c∈Cbf∈FcEfckb(k,j,t) and (3) Borough to State-Level Emissions, Es(k,j,t)=b∈BsEb(k,j,t)=b∈Bsc∈Cbf∈FcEfckb(k,j,t). To express total state-level emissions summed across all facilities, communities, boroughs, sectors, fuel types, and time periods, Estotal=t∈Tk∈Kj∈Jb∈Bsc∈Cbf∈FcEfckb(k,j,t). Alternatively, if facility-level data is unavailable and emissions are aggregated at the community level, Estotal=t∈Tk∈Kj∈Jb∈Bsc∈CbEcb(k,j,t).

This integrated approach to activity and fuel data enables consistent, transparent, and scalable emissions analysis across all 245 communities in Alaska, supporting both baseline inventories and future emissions reduction planning. To produce community-level greenhouse gas (GHG) and criteria pollutant inventories under Alaska's Climate Pollution Reduction Grant (CPRG) program, the modeling methodology described here outlines a rigorous framework for aggregating and disaggregating data across multiple geographic levels—statewide, borough (county-equivalent), community (e.g., cities, CDPs), and facility-level. This process is designed to reconcile varying data resolutions and reporting standards while ensuring that emissions totals are accurate, representative, and aligned with EPA methodologies. The above equation allows the model to account for all emissions based on sectoral and fuel-specific activity data at the most granular level (facility), while also supporting disaggregation and nesting across spatial and temporal dimensions. It also supports double-counting control—e.g., if two facilities report overlapping emissions, the term Efckb(k,j,t) can be flagged or removed. To account for estimation error introduced when using pre-2022 data to estimate 2022 emissions, we incorporate an error term that reflects potential bias, uncertainty, or structural misalignment in activity and emissions factors.

We begin with the base formulation for total statewide emissions in 2022, using possibly outdated activity data, Es(2022)=k∈Kj∈Jb∈Bsc∈CbEcb(k,j,2022) where Ecb(k,j,2022) is the estimated emissions for community c, sector k, fuel type j in 2022, using pre-2022 activity data and projection models. The model introduced the error decomposition Ecb(k,j,2022)=Ecb(k,j,2022) + εcb(k,j) where Ecb(k,j,2022) is true (but unobserved) emissions, and εcb(k,j) is estimation error, comprising multiple components detailed below.

The total error εcb(k,j) can be decomposed as εcb(k,j)=cb(k,j)+cb(k,j) + cb(k,j) where cb(k,j) is the temporal projection error, caused by using outdated activity data (e.g., 2020 heating fuel usage to estimate 2022 emissions), cb(k,j) is the structural error, due to mismatch between proxy variables (e.g., floor area or population) and actual fuel use or emissions. Finally, cb(k,j) is the model calibration error, reflecting differences between estimated and actual emissions factors or regional behavior (e.g., assuming average heating efficiency statewide). State-level estimated emissions including explicit error terms, Es(2022)=k∈Kj∈Jb∈Bsc∈Cb(Ecb(k,j,2022) cb(k,j)+cb(k,j) + cb(k,j)) or separating the true and total error components, Es(2022)=Es(2022) +k,j,b,c εcb(k,j) . Each term εcb(k,j) corresponds to the data quality tier (high, medium, low) described in the error model. As such, communities with outdated or imputed data (e.g., no ARIS records or only ACS 5-year estimates) may have higher δ and η components, as well as calibration models (e.g., fuel-to-emissions conversions) may vary by community, especially for off-grid or PCE-supported areas, increasing μ. These errors are estimated and compared with survey data discussed in this report.

Across all sectors, emissions from fuel combustion are calculated using established EPA emissions factors, which convert activity data—such as kWh of electricity, gallons of diesel, therms of natural gas, or miles traveled—into metric tons of CO_2 equivalent (MT CO_2e), as well as associated criteria pollutants (e.g., NO_x, $PM_{2.5}$, SO_2). In addition, land-use activity data—including forest cover, wetlands, and glacial extent—are evaluated using GIS-based analyses of satellite imagery to estimate carbon sequestration potential, contributing to net emissions accounting. Each dataset used is subject to data quality scoring (high, medium, low), which influences how the information is validated, calibrated, and incorporated into the final community-level emissions estimates.