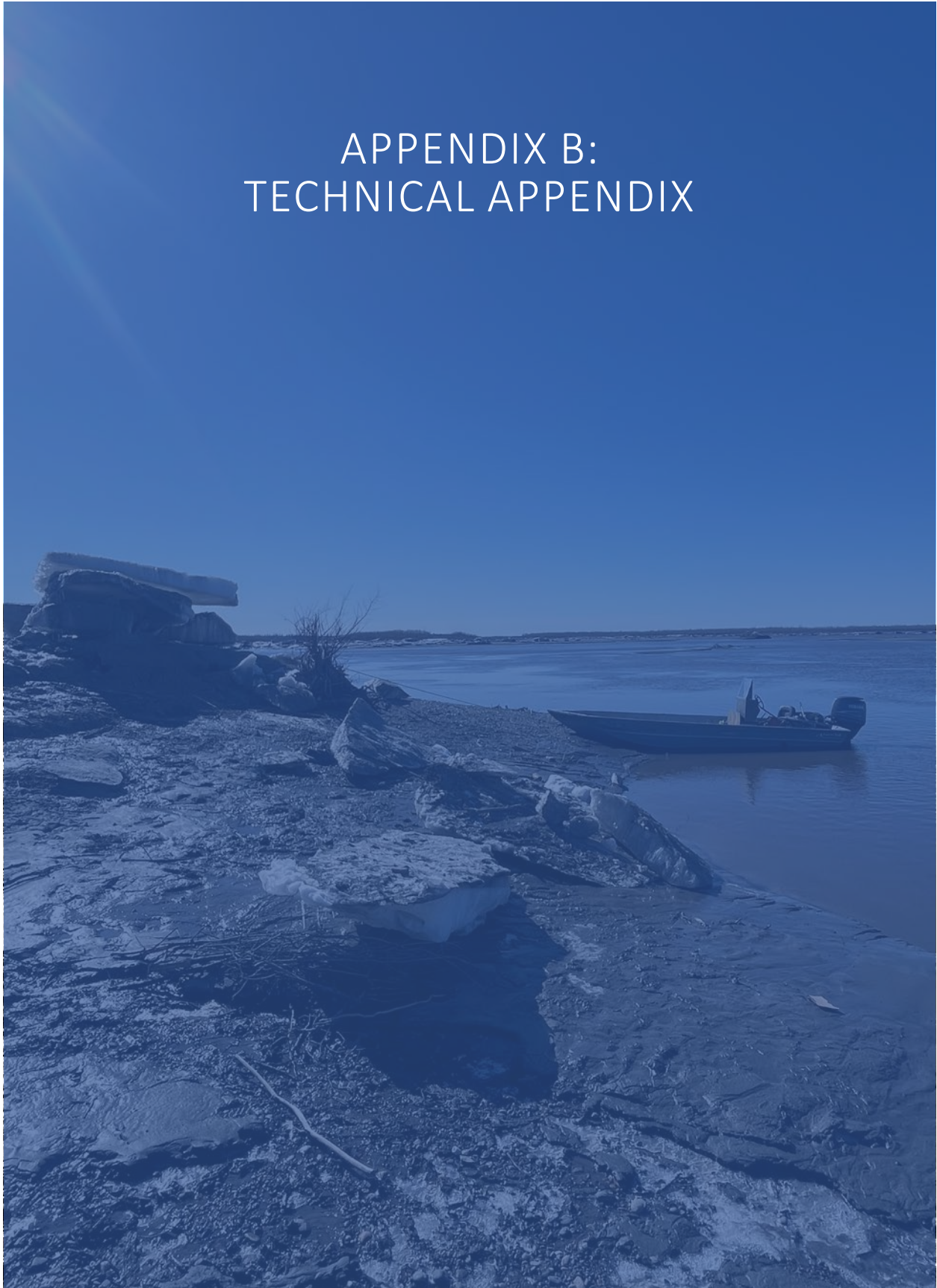


## APPENDIX B: TECHNICAL APPENDIX



## APPENDIX B: TECHNICAL APPENDIX

### Methodology

A BAU scenario projects future GHG emissions assuming no new environmental policies or mitigation actions beyond what is already in place or adopted—as if operations continue under existing trends. It serves as a baseline to estimate the emissions reduction gap between BAU and desired targets, model the incremental benefits of proposed mitigation measures, and support energy and environmental planning and funding alignment.

### Mathematical Framework

#### Index Definitions

Let  $y$  be the Year (e.g., 2000–2050) for  $s$ : State entity (e.g., Alaska) with  $k$ : Emission sector (e.g., buildings, transportation, power, waste)

Historical emissions,  $E_s^{hist}(y)$ , for  $y \leq 2022$  and BAU projection,  $E_s^{BAU}(y)$ , for  $y > 2022$

Where the target emissions under policy is  $E_s^{hist}(y)$

#### BAU Projection Modeling

EPA SIT models BAU as:  $E_s^{BAU}(y) = E_s^{hist}(2022) \times \frac{T_s(y)}{T_s(2022)}$

where  $T_s(y)$  is a trend variable (e.g., population, energy use forecast). Alternatively, for sectoral granularity:

$$E_s^{BAU}(y) = \sum_k E_s^{hist,k}(2022) \times \frac{T_s^k(y)}{T_s^k(2022)}$$

#### Scenario Adjustment with Mitigation Measures for set targets

For mitigation action  $m$  in year  $y$ , its GHG reduction is  $\Delta E_s^m(y)$ . The emissions under a mitigation scenario

$$E_s^{Mit}(y) = E_s^{BAU} - \sum_m \Delta E_s^m(y)$$

Targets often are written as percentages below the baseline Let  $E_s^{Hist}(2022) = E_0$

We can define short-term target (e.g., 2030): 15% reduction  $\rightarrow E_s^{Target}(2030) = E_0 \times (1 - 0.15)$

Mid-term (2035, if any): 40% reduction  $\rightarrow$

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$$E_s^{Target} (2035) = E_0 \times (1 - 0.40) \text{ and Long-term net-zero (2050): } E_s^{Target} (2050) = 0$$

For instance, let's suppose, Alaska's 2022 emissions  $E_0 = 100$  MMT CO<sub>2</sub>e. Then Projected growth factor by 2035:  $\frac{T(2035)=1.10}{T(2022)}$ , and thus:  $E^{BAU} (2035) = 100 \times 1.10 = 110$  MMT CO<sub>2</sub>e. If mitigation measures in 2035 reduce emissions by 40 MMT,  $E^{Mit} (2035) = 110 - 40 = 70$  MMT CO<sub>2</sub>e. The emissions gap between BAU and target by 2035 (40% reduction) is  $Gap = E^{Mit} (2035) - E^{Target} (2035)$  with  $E^{Target} (2035) = 100 \times 0.60 = 60$  MMT CO<sub>2</sub>e  
 $Gap = 70 - 60 = 10$  MMT CO<sub>2</sub>e

This gap informs policy urgency and additional mitigation needed. Here BaU reflects a future without new policies—used as the baseline for planning, with projections built using statewide studies across different sectors, or via tools like EPA SIT and sector-specific models like MOVES. Mathematical linkage connects 2022 inventory, BAU projections, mitigation scenarios, and targets, with a gap analysis highlighting where additional action is needed to meet state goals.

Next, to further expand the mathematical derivation of state-level GHG emissions under Business-as-Usual (BaU) using borough-level projections, we construct a model where the state's emissions are the sum of its boroughs, each evolving according to its own sectoral activity trends (e.g., population, economic growth, fuel mix). The framework introduces differential growth rates across boroughs and accounts for temporal dynamics and projected changes in borough composition over time.

Now let's define the following indices and sets  $t \in T$  : Year (e.g., t=2022,...,2050) and  $s \in S$  : Sector (e.g., transportation, residential, industrial) consuming  $f \in F$ : Fuel type (e.g., diesel, gasoline, natural gas, electricity) across the  $b \in B$ : Borough and  $c \in C_b$  : Community in borough  $b$ . Within each community,  $i \in I_{c,s,f}$  : facility or source unit in community  $c$ , sector  $s$ , fuel  $f$ . Now, let  $A_{i,c,s,f,t}$  be the Activity data (e.g., fuel use, VMT, heating degree days) for source  $i$ ,  $EF_{s,f,t}$  being the Emissions factor (e.g., MT CO<sub>2</sub>e per unit activity), we have  $E_{i,c,s,f,t} = A_{i,c,s,f,t} \cdot EF_{s,f,t}$ : Emissions at the facility level.

### Borough-Level Aggregation

The total GHG emissions for borough  $b$  in year  $t$  is  $E_{b,t} = \sum_{c \in C_b} \sum_{s \in S} \sum_{f \in F} \sum_{i \in I_{c,s,f}} A_{i,c,s,f,t} \cdot EF_{s,f,t}$

This captures intra-borough variation across communities, sectors, and fuels.

### State-Level Aggregation from Boroughs

Assuming all boroughs  $b \in B$  are included in the state, total statewide emissions under BaU at year  $t$  are

$$E_{state,t}^{BaU} = \sum_{b \in B} E_{b,t} \text{ or } E_{state,t}^{BaU} = \sum_{b \in B} \sum_{c \in C_b} \sum_{s \in S} \sum_{f \in F} \sum_{i \in I_{c,s,f}} A_{i,c,s,f,t} \cdot EF_{s,f,t}$$

This construction allows borough-level dynamics (e.g., growing boroughs like Matanuska-Susitna, shrinking ones like some Arctic boroughs) to drive the net statewide emissions trajectory, yielding a nonlinear and unevenly distributed BaU pathway.

## Incorporating Borough-Specific Growth

If population or economic activity in borough  $b$  is projected to grow at rate  $g_{b,t}$ , and activity data is scaled accordingly:

$$A_{i,c,s,f,t} = A_{i,c,s,f,2022} \cdot (1 + g_{b,t})^{t-2022}$$

Different boroughs may have different growth trajectories, since urban boroughs may grow faster in transportation and buildings, and rural boroughs may maintain or reduce emissions due to migration or diesel displacement.

## Errors and Uncertainty

To account for projection uncertainties and historical extrapolations, we can include an error term  $\epsilon_{b,t}$  at the borough level:

$$\hat{E}_{b,t}^{BaU} = E_{b,t} + \epsilon_{b,t} \text{ where } \epsilon_{b,t} \sim N(0, \sigma_{b,t}^2)$$

Errors can stem from the use of outdated fuel or census data for borough-level estimates, assumptions in sectoral scaling (e.g., linear population-emission relationships) and any inaccurate or missing facility-level reporting

The state-level error thus becomes: 
$$\hat{E}_{state,t}^{BaU} = \sum_{b \in B} \hat{E}_{b,t}^{BaU} = \sum_{b \in B} (E_{b,t} + \epsilon_{b,t})$$

## Framework Co-Pollutant Reduction

The following table shows how fuel or waste activity reduction due to the measures were used to estimate changes in pollutants. This methodology first mapped each sector, probable equipment, fuels to a *device archetype* and related criteria-pollutant factors in kg/MMBtu (AP-42 or engine/turbine tables). For any “mix” fuels, this methodology computed an energy-weighted average of the device factors.

**TABLE 1: Measure-device mapping per AP-42 class**

Sector	Equipment	Fuel	Closest device you should use	Where to take factors	Notes (kg/MMBtu basis)
Residential	Home heating	Diesel Fuel	Distillate oil boiler/furnace (<100 MMBtu/hr, uncontrolled)	AP-42 §1.3 (distillate)	Use the per-MMBtu values you already have (NOx, CO, VOC, PM10/2.5); SO <sub>2</sub> = 0.460 × S (S = sulfur wt. fraction).
Commercial	Home heating	Heating mix	Energy-weighted mix of: NG small boiler (§1.4) + LPG small boiler (§1.5) + Distillate (§1.3) + Wood (§1.6)	AP-42 §§1.4, 1.5, 1.3, 1.6	See “Mix formulas” below.
Commercial	Home heating	Diesel Fuel	Distillate oil boiler	AP-42 §1.3	—
Waste	Other	N/A	Not a combustion device	—	No direct criteria emissions at “equipment” level. If you actually combust MSW/sludge, map to MSW (§2.1) or sludge incinerator (§2.2).

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Off-road transportation	Boats	Diesel Fuel	Marine diesel engine (nonroad CI)	NONROAD/ engine factors (g/hp-hr) or convert	See “Engine conversions” below (g/hp-hr or kg/MMBtu).
On-road transportation	Passenger	Motor mix	Fleet mix of LD gasoline + LD diesel (on-road)	MOVES (g/mi) or convert	See “On-road conversion” and “Mix formulas”.
Power Generation	Building electricity	Railbelt electric mix	End-use electricity	—	At the equipment level, criteria pollutants = 0. (Upstream at generators: use Railbelt gen mix × plant factors per MWh, if you need upstream.)
Power Generation	Building electricity	Diesel Fuel	Stationary diesel generator (compression-ignition engine)	AP-42 §3.3 (diesel engine, lb/MMBtu or kg/MMBtu)	Typical uncontrolled engine factors: NOx ~4.41, CO ~0.95, SOx ~0.29, PM10 ~0.31 (lb/MMBtu) or convert ×0.4536.
Commercial	Home heating	Diesel Fuel	Distillate oil boiler	AP-42 §1.3	—
Power Generation	Building electricity	Diesel Fuel	Stationary diesel generator	AP-42 §3.3	—
Commercial	Home heating	Diesel Fuel	Distillate oil boiler	AP-42 §1.3	—
Off-road transportation	Aircraft	Avgas	Piston SI aircraft engine (stationary SI proxy if needed)	AP-42 §3.3 (gasoline SI, lb/MMBtu)	Use §3.3 gasoline SI factors (proxy) if you need a per-MMBtu device factor; true aircraft use ICAO EIs (g/kg-fuel).
Power Generation	Building electricity	Natural Gas	Stationary gas turbine (if genset) or NG boiler (if heat-only)	AP-42 §3.1 (turbines) or §1.4 (boilers)	Pick turbine when it’s a generator; boiler if it’s heat service/CHP.
Off-road transportation	Aircraft	Avgas	same	AP-42 §3.3 (proxy) or ICAO for aircraft	—
Power Generation	Building electricity	Diesel Fuel	Stationary diesel generator	AP-42 §3.3	—
Off-road transportation	Boats	Diesel Fuel	Marine diesel engine	NONROAD/ engine factors	—
Commercial	Building electricity	Heating mix	For equipment use, electricity = 0; if you meant space heat: use the Heating mix row above	—	Clarify if this is actually space heat vs purchased electricity.
Residential/ Commercial	Home heating	Heating mix	Energy-weighted mix of NG (§1.4), LPG (§1.5), Distillate (§1.3), Wood (§1.6)	AP-42	See “Mix formulas”.

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Residential	Home heating	Diesel Fuel	Distillate oil boiler	AP-42 §1.3	—
Commercial	Building electricity	Heating mix	If this is electricity: 0 at equipment. If space heat: use Heating mix above.	—	—
Industrial	Other	N/A	Not a combustion device	—	—

For fuel usage in boilers / furnaces (stationary), this methodology uses for natural gas (small boiler, uncontrolled) (§1.4): NO<sub>x</sub> ≈ 0.045; CO ≈ 0.038; VOC ≈ 0.0025; PM<sub>10</sub> ≈ PM<sub>2.5</sub> ≈ 0.0035; SO<sub>2</sub> ≈ 0.00027 (very low; sulfur-dependent). For LPG/Propane (§1.5): NO<sub>x</sub> ≈ 0.045; CO ≈ 0.037; VOC ≈ 0.0023; PM<sub>10</sub> ≈ PM<sub>2.5</sub> ≈ 0.0032; SO<sub>2</sub> ≈ 0.00027 (very low). For Distillate oil (§1.3): NO<sub>x</sub> ≈ (24/140)×0.4536 ≈ 0.0777; CO ≈ (5/140)×0.4536 ≈ 0.0162; VOC ≈ (0.3/140)×0.4536 ≈ 0.0010; PM<sub>10</sub>≈PM<sub>2.5</sub>≈(2/140)×0.4536 ≈ 0.0065; SO<sub>2</sub> = 0.460 × S. Finally, for Wood/biomass (stoker, wet, uncontrolled) (§1.6): NO<sub>x</sub> ≈ 0.077; CO ≈ 0.272; VOC ≈ 0.0136; PM<sub>10</sub> ≈ 0.200; PM<sub>2.5</sub> ≈ 0.150; SO<sub>2</sub> ≈ 0.011 (low sulfur).

Next, for engines / turbines (stationary generation), the methodology used diesel engine-generator (§3.3, uncontrolled): NO<sub>x</sub> 4.41 lb/MMBtu or 2.00 kg/MMBtu; CO 0.95 or 0.43; SO<sub>x</sub> 0.29 or 0.13; PM<sub>10</sub> 0.31 or 0.14; (VOC often ~0.20–0.30 lb/MMBtu in various tables or ~0.09–0.14 kg/MMBtu; use your preferred §3.3 line). For gas turbine, distillate/kerosene (§3.1): NO<sub>x</sub> 0.32 lb/MMBtu or 0.145 kg/MMBtu; CO 0.082 or 0.037; VOC 4.1E-4 lb/MMBtu or 0.00019 kg/MMBtu; PM(total) 1.2E-2 lb/MMBtu or 0.0054 kg/MMBtu; SO<sub>2</sub> = 1.01 × S lb/MMBtu or 0.458 × S kg/MMBtu. Electricity at the equipment, the criteria pollutants are 0 kg/MMBtu at point of use. To allocate *upstream* Railbelt generation to the loads, for instance, this methodology calculates a Railbelt emission rate per MWh (mix of gas/diesel/renewables at generators) and converted to fuels for our volumetric activity reporting basis.

For on road vehicles this methodology tracks a mix of gasoline and diesel light-duty, from MOVES (or defaults), and took statewide BTU totals for the transportation sector, with 0.138 MMBtu/gal for gasoline/diesel energy content. For off-road vehicle like non-road or marine, particularly using diesel, while one can start with g/hp-hr for a representative marine CI engine (by tier), such that kg/MMBtu = (g/hp-hr ÷ 453.592) ÷ BSFC ÷ 0.138 where BSFC (gal/hp-hr) ~ 0.065–0.075 is a decent default; if vehicle level data is known and the 0.138 MMBtu/gal is the fuel energy content. This methodology uses an aggregated DFO total for measures and applied the pollutant factors in table 2.

Finally for waste combustors, MSW mass-burn waterwall was used (§2.1, uncontrolled): NO<sub>x</sub> 3.56/9 = 0.395 lb/MMBtu or 0.179 kg/MMBtu; CO 0.463/9 or 0.023 lb/MMBtu or 0.010 kg/MMBtu; SO<sub>2</sub> 3.46/9 or 0.384 lb/MMBtu or 0.174 kg/MMBtu; PM(filterable) 25.1/9 or 2.79 lb/MMBtu or 1.27 kg/MMBtu. PM size fractions vary. Finally, sewage sludge multiple-hearth (§2.2, uncontrolled): NO<sub>x</sub> 2.5 lb/MMBtu or 1.13 kg/MMBtu; SO<sub>2</sub> 14 lb/MMBtu or 6.35 kg/MMBtu; with other pollutants depending on device/control options.

For waste, this methodology similarly estimate criteria pollutants (NO<sub>x</sub>, SO<sub>2</sub>, CO, VOCs, PM<sub>10</sub>, PM<sub>2.5</sub>) by linking waste management pathways to published emission factors (EFs). These mostly come from EPA AP-42 (“Compilation of Air Pollutant Emission Factors”) and from the EPA WARM model for solid waste, as well as some Alaska-specific guidance for open burning and incineration. The below units are given as kg pollutant per tonne of waste disposed/combusted. Where ranges exist, it shows typical mid-values and refined when site controls (e.g., modern incinerator vs open burn) are known.

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**TABLE 2: Screening Emission Factors for Criteria Pollutants**

Pathway / Activity	NO <sub>x</sub> (kg/t)	SO <sub>2</sub> (kg/t)	CO (kg/t)	VOC (kg/t)	PM <sub>10</sub> (kg/t)	PM <sub>2.5</sub> (kg/t)	Notes / Sources
Class I/II/III Landfill (waste degradation)	~0	~0	~0	0.3–0.5	negligible	negligible	Landfill gas contains NMOCs; VOC proxy ~0.3–0.5 kg/t (AP-42 Ch. 2.4). Criteria pollutants mainly from gas combustion if flared/energy recovered.
Landfill Gas Flaring	0.8	0.05	1.5	0.02	0.03	0.02	kg/t CH <sub>4</sub> flared, scaled to waste tonnage by gas yield. AP-42 Ch. 13.5.
Incineration / Burn Box (no energy recovery)	4–6	2–3	60–90	0.7–1.2	6–8	4–5	AP-42 Ch. 2.1 municipal waste combustors. Higher if poorly controlled (open burn).
WtE Incineration (energy recovery, controlled)	2–4	1–2	20–40	0.2–0.6	1–2	0.5–1	Controlled combustors with APC devices.
Open Burning (Class III sites, camps, rural)	5–7	1–2	80–120	2–4	10–20	6–10	AP-42 Ch. 2.5 (open burning of household waste). Higher PM and VOC.
Composting (windrow, no cover)	negligible	negligible	negligible	0.1–0.3	0.1	0.05	Minor VOCs and bioaerosols; usually not inventoried.
Anaerobic Digestion (with biogas use)	negligible	negligible	negligible	0.05–0.1	negligible	negligible	Controlled flare/ engine factors can be applied separately.
Wastewater Lagoon (fugitive emissions)	negligible	negligible	negligible	0.05–0.2 (VOCs)	negligible	negligible	VOC from anaerobic digestion of organics.
Sludge Incineration (if practiced)	3–5	1–2	30–50	0.5–0.8	3–6	2–3	AP-42 Ch. 2.2 (sludge combustors).

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First this methodology links the site classification to pathway, for example *Class III landfill with open burning* or apply “*Open Burning*” EFs with normalized units by multiplying tonnes disposed/combusted  $\times$  EF (kg/t) to get annual kg pollutant, convert to tonnes/year whenever needed before aggregating by community or region. If flaring or WtE energy recovery is known, combustion EFs were applied instead of the raw landfill degradation values. References sought were EPA AP-42, Chapter 2.1, 2.2, 2.4, 2.5, 13.5 (various combustion, landfill, flaring, open burning) as well as EPA WARM Model (2019, solid waste management GHG + co-pollutant factors) given both IPCC 2006/2019 Guidelines for waste volume and Alaska DEC rural waste burning/burn box guidance. They can be adjusted upward/downward depending on controls, combustion efficiency, and waste composition.

This methodology assumes kg pollutant per tonne disposed/combusted, multiplied by each site’s Solid Waste (tonne/yr), and then summed to community and converted to tonnes/yr. It conducts classification or factors (kg/t) using mid-point screening values, for instance, for Class I/II/III Landfill, camp/remote lodge, balefill, radar site or treated as landfill fugitives: NO<sub>x</sub> 0, SO<sub>2</sub> 0, CO 0, VOC 0.4, PM<sub>10</sub> 0, PM<sub>2.5</sub> 0. Here, criteria pollutants from flares/engines are not added unless gas control/combustion data was available. For medical Waste Treatment (incineration-like, no ER assumed) there is NO<sub>x</sub> 5.0, SO<sub>2</sub> 2.5, CO 75, VOC 1.0, PM<sub>10</sub> 7.0, PM<sub>2.5</sub> 4.5. Inert/1-time inert/industrial/sewage-solids/wood/drilling monofills, biosolids treatment or low assumes VOC 0.05, others ~0. Similarly, land application site or VOC 0.1, PM<sub>10</sub> 0.1, PM<sub>2.5</sub> 0.05 and treatment/storage/asbestos or 0 (no disposal combustion or degradable emissions assumed) if applicable. All others used the landfill default VOC 0.4. If a site practices open burning or burn boxes, which was not explicitly present in the data, open burning factors (much higher PM/CO/VOC) for those tonnes would be more appropriate. If any landfill flares or WtE are present, one should add combustion EFs for the gas portion.

