# Resource and Energy Recovery Opportunities from Waste in Juneau, Alaska

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## Introduction

The City and Borough of Juneau, Alaska has engaged with NREL through the Waste-to-Energy (WTE) Technical Assistance program to provide subject-matter expertise concerning options for waste resource and energy recovery from the City's municipal solid waste (MSW) resources. Initial motivation for the study stems from concerns regarding landfill availability and options for waste minimization with the goal of a zero-waste outcome at some point in the future.

This study provides a high-level overview of available options with the objective of helping to identify potential technology solution pathways. It focuses primarily on WTE technologies, including biological, thermochemical, and mechanical conversion processes that generate energy or energy products from waste. While some technologies overlap with resource recovery, the assessment does not cover conventional recycling or other dedicated resource recovery strategies. By concentrating on energy-producing solutions, this study provides a targeted evaluation of alternative waste management options that align with Juneau's broader energy and economic priorities.

## Waste Composition and Quantity

A MSW characterization for Juneau was completed and published by Cascadia Consulting Group in 2023, providing data to inform this analysis.[1] The waste was originally grouped into four categories: recyclable, compostable, recoverable, and reusable. For this study, those classifications have been restructured to align with resource recovery and WTE conversion technologies, as follows:

- Organics (largely food waste)
- Paper and cardboard
- Metal
- Plastics
- Wood (including construction and demolition [C&D] wood)
- Tires
- Textiles

**Assumptions and restrictions**: In the case of plastics, it is assumed that no attempt will be made to recover recyclables such as PET, PP, PS, and HDPE plastics[2] from the waste stream; indeed

[1] City and Borough of Juneau Waste Characterization Study (2024), Cascadia Consulting Group, https://juneau.org/wp-content/uploads/2024/10/Juneau-Waste-Characterization-Study-2024-Report_2024-10-8.pdf

[2] PET = polyethylene terephthalate; PP = polypropylene; PS = polystyrene; HDPE = high-density polyethylene

these recyclable plastics comprise less than 2% of the total waste stream and costs to implement sorting for purposes of recovery of recyclable plastics are likely to be greater than revenue Some textiles contain significant amounts of materials that could also be classified as organics (e.g., cotton, wool) or plastics (e.g., synthetic performance fabrics). Carpet falls into this mixed-material category as well; however, due to the lack of detailed composition data—and because carpets can be made from either synthetic (e.g., nylon) or natural (e.g., wool) fibers—it has been excluded from the Textile category. This analysis does not include other potentially available waste streams—such as wastewater treatment solids—which could offer additional feedstock for some of the WTE pathways under consideration.

**Waste resources quantity**: The City and Borough of Juneau disposed of 22,346 tons of waste in 2023 consisting of a composite from commercial, residential, and self-haul sources (Table 1). A more detailed composition of the City's MSW waste stream is presented in Table A1 (Appendix). Some of the data have been excluded from this analysis (called out in the footnotes to Table 2) as being either not relevant or poorly defined. The majority (approximately one third) of the waste is classified as organics (e.g., food waste, yard trimmings) and almost half is comprised of organics and paper/cardboard which are excellent feedstocks for many resource recovery and WTE technologies. This breakdown is important and will be used to inform the analysis of each technology pathway under consideration.

*Table 1. Composition and Quantity of MSW Generated in City and Borough of Juneau*

| Type | Organics | Paper & Cardboard | Metal & Glass | Plastics | Clean Wood | Tires | Textiles | Other* | TOTAL |
|---|---|---|---|---|---|---|---|---|---|
| Tons/Y | 6,053 | 4,312 | 1,824 | 2,084 | 2,149 | 134 | 2,202 | 3,588 | 22,346 |
| % | 27 | 19 | 8 | 9 | 10 | 0.5 | 10 | 16 | 100 |

*Other materials include e-waste, carpet, refrigerant-containing items, mattresses, household hazardous waste, etc.

## Waste-to-Energy and Resource Recovery Technologies

The diverse waste streams in Juneau present opportunities for WTE and resource recovery technologies. WTE and resource recovery are related but not identical concepts. Both aim to extract value from waste and reduce landfill disposal. They often overlap, as some WTE technologies (e.g., anaerobic digestion) recover both energy and materials. While WTE focuses on converting waste into energy (electricity, heat, or transportation fuels), resource recovery emphasizes reclaiming valuable materials (e.g., metals, plastics, organics) for reuse or recycling. In an integrated waste management system, resource recovery typically comes first (e.g., recycling and composting), with WTE handling non-recyclable waste.

While some of these processes exhibit economies of scale, small-scale and modular applications may also be feasible. However, successful implementation of these technologies will require some level of waste sorting to ensure feedstock quality and process efficiency. Many WTE technologies perform best when waste is pre-sorted to remove contaminants and separate high-energy-value materials. Sorting can be accomplished through source-separation programs, material recovery facilities (MRFs), or a combination of mechanical and manual processing methods. Without proper sorting, contamination could reduce system efficiency, increase operational costs, and limit marketability of recovered resources.

Below is an overview of suitable WTE and resource recovery technologies for waste streams.

**Biological conversion technologies** are well-suited for processing organic waste, including food waste, animal manure, wastewater sludge, yard trimmings, and fats, oils, and greases (FOG). Once separated from other waste streams, these organics can be converted into valuable products through composting or anaerobic digestion. FOG could also be collected and provided to existing regional biodiesel or renewable diesel plants where FOG can supplement other feedstock, such as vegetable oils. Technologies for biodiesel and renewable diesel production are not evaluated in this analysis, but additional information is available upon request. Similarly, data on animal manure and wastewater sludge are not included here but can be provided if needed.

**Composting** is a biological process that takes place in an open-air environment where microorganisms break down biodegradable material in the presence of oxygen. The produced product is compost, which can be used as a soil amendment. With composting, no energy (e.g., biogas) is produced, and any energy required in the process must be supplied from an outside source. Composting results in a net greenhouse gas (GHG) emissions of negative 0.12 metric tons carbon dioxide equivalent ($MTCO_2E$) per ton of organics as compared to traditional landfilling. Potential revenue streams from composting include revenue from tipping fees, compost sale, and any relevant policy incentives. Generally speaking, a lower level of training is required to run a compost system versus an anaerobic digestion system.[3]

Composting can have different cost and land requirements depending on the system used. In windrow composting, organics are piled in long rows and the piles are periodically turned to aerate the system. While this system is the simplest, it also requires a large footprint, about 15 to 20 acres on average. Capital costs for windrow composting can be $4.3 million for a 30,000 ton per year system. Operating costs for a 30,000 ton per year system range from $437 to $765 thousand annually, while operating costs for a 25,000 ton per year system were found to be $362 thousand. Costs are listed in 2020$.[4]

In aerated static pile (ASP) composting, the piles are placed directly over an air source, providing air circulation without physical manipulation of the piles. ASP is moderate in complexity and has a smaller land footprint than windrow, about 6 to 8 acres on average.[5] Capital and operating costs for ASP systems of various sizes can be seen in Table 2.

[3] https://www.nrel.gov/docs/fy22osti/81024.pdf
[4] https://www.nrel.gov/docs/fy22osti/81024.pdf
[5] https://www.nrel.gov/docs/fy22osti/81024.pdf

*Table 2. Capital & Operating Costs for ASP Composting Systems*

| System capacity (tons/year) | Capital cost (million USD) | Operating costs (thousand USD/yr) |
|---|---|---|
| 1,800 | 1.7 | 247 |
| 5,200 | 2.6 | NA |
| 40,000 | 8.9 | NA |
| 180,000 | 25 | 1,000 |

*NA – data not available. Data in 2020 USD*[6]

In-vessel is the most compact system of composting, but also the most complex. Organics are confined within a building, container, or vessel, and thus air flow and temperature are better controlled. In-vessel composting has a small footprint, about 3 to 6 acres on average.[7] These systems come in a variety of sizes: as little as 100 pounds per day to over 10 tons daily.[8] Capital costs also vary depending on complexity and location. For example, the capital cost for a 1,000 pounds per day facility could be up to $850/ton.[9]

*Ohio University, OH* – In 2009, Ohio University, a public university of approximately 30,000 students, launched a solar powered in-vessel composting system. The system is designed to accept two tons of material per day, with an overall capacity of twenty-eight tons. The facility site includes a rainwater harvesting system to assist with system water needs and a 10-kW photovoltaic array, which provides roughly fifty percent of the electricity needed for operation. Capital costs for the facility were around $800,000 (2009USD). A 2012 expansion allowed for an additional four tons per day of processing capacity. Annual operating costs are about $225,000, with three employees running the facility.[10] More information about the project can be found at Ohio University's website.[11]

For more information on in-vessel composting, BioCycle has a guide on *In-Vessel Composting Options for Medium-Scale Food Waste Generators*. The guide contains important considerations, as well as a hypothetical case study, and a list of companies that sold mid-sized in-vessel composting units at the time of publishing.[12] Sustainable Generation also has a list of project profiles and case studies of locales utilizing GORE® covered compost systems.[13]

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[6] ttps://www.nrel.gov/docs/fy22osti/81024.pdf
[7] https://www.nrel.gov/docs/fy22osti/81024.pdf
[8] https://resource-recycling.com/recycling/2019/03/30/data-corner-the-ins-and-outs-of-in-vessel-composting/
[9] https://resource-recycling.com/recycling/2019/03/30/data-corner-the-ins-and-outs-of-in-vessel-composting/
[10] https://www.biocycle.net/site-large-scale-food-waste-composting/
[11] https://www.ohio.edu/facilities/grounds/compost
[12] https://www.biocycle.net/in-vessel-composting-options-for-medium-scale-food-waste-generators/
[13] https://www.sustainable-generation.com/project-profiles

**Anaerobic digestion** (AD) is a biological process in an enclosed environment where microorganisms break down biodegradable material in the absence of oxygen. The main product is biogas, a mixture of methane and $CO_2$, which is an intermediate that can be used to produce heat, electricity, or renewable natural gas (RNG). AD results in a net GHG emissions ranging from negative 0.04 to negative 0.14 $MTCO_2E$ per ton of organics as compared to traditional landfilling, depending on the type of AD – wet or dry – and whether the digestate is further cured or directly land applied. While AD requires energy input into the system, the energy can be supplied through its own production of biogas.[14] AD is widely practiced in cold weather climates such as Northern Europe. The low average annual temperatures in places such as Sweden and Finland can be accommodated by process design and recycle of waste heat from power generation.

Feedstocks for AD must be pre-sorted to remove inorganics such as glass and metal, as well as contaminants from C&D waste, including drywall. Plastics are non-reactive under AD conditions and should also be excluded. Several waste stream characteristics influence the feasibility of AD:

1. Organics: Well-suited for AD, with high moisture content (up to 50% by weight) that does not hinder the process.
2. Wood, paper, and cardboard: These materials are rich in recalcitrant biopolymers like cellulose and lignin, resulting in slow reaction rates and low biogas yields. However, pretreatment methods such as steam explosion can significantly improve their digestibility and gas production potential.[15]

Potential revenue streams from AD include revenue from tipping fees, selling electricity or RNG, and relevant incentives. It is important to recognize that the residual material from the AD unit (the digestate) may pose a disposal problem. Digestate is typically separated into a solid and liquid fraction. The amount of each fraction is difficult to estimate; solids are approximately equal to the fixed carbon content of the feedstock to the digester. The liquids can be re-used in the digester to some extent or for crop irrigation. The solid fraction can be used as fertilizer, animal bedding, or pelletized and used for heating, as well as used for construction material (e.g., fiberboard) and in other applications that can bring additional revenue.

Modeled capital and operating costs for AD systems of different capacities can be found in Table 3. The complexity of AD can vary depending on the system; newer systems, which have become easier to operate and maintain, have moderate complexity. A properly designed and operated AD system is very safe. However, strict gas handling standards must be maintained.[16]

[14] https://www.nrel.gov/docs/fy22osti/81024.pdf
[15] https://joneseng.com/additional-services/bioenergy/
[16] https://www.nrel.gov/docs/fy22osti/81024.pdf

*Table 3. Capital & Operating Costs for Anaerobic Digestion Systems*

| System capacity (tons/year) | Capital cost (million USD) | Operating costs (thousand USD/yr) |
|---|---|---|
| 2,500 | 3.0 | 85 |
| 5,000 | 4.7 | 171 |
| 25,000 | 12.3 | 854 |
| 50,000 | 18.6 | 1,707 |
| 100,000 | 28.2 | 3,415 |
| 200,000 | 42.7 | 6,830 |

*Data in 2020 USD*[17]

AD is generally less land intensive than composting, with a typical requirement of 3-6 acres. Modern systems can be even more streamlined to reduce their footprint. Since AD systems are fully enclosed, odors are contained. If the system is run inefficiently, such as in the case of digester spills, odor may occur. More information on AD can be found at Milbrandt, 2021[18].

**Thermochemical conversion processes** are effective for managing both solid and, to some extent, wet waste, including materials like plastics, tires, and wood (e.g., clean pallets, residential or utility tree trimmings, brush and branches from wildfire mitigation). Once separated, these materials can be transformed into valuable products through processes like combustion, pyrolysis, and gasification.

**Combustion for Combined Heat and Power (CHP)**: In principle, simple combustion provides a feasible and low-cost solution that could be applied to woody feedstock. Combustion of biomass to generate heat and power is commercial technology. Recovery and/or sequestration or utilization of $CO_2$ from the combustor flue gas (carbon capture and sequestration [CCS]) is an option that could be considered for this application; however, further evaluation of the systems required to carry out CCS would be needed. Use of wood for CHP technology at small scale has been demonstrated and deployed broadly (e.g., hospitals, schools, and office buildings) and some examples are presented below.

*New Hanover County, NC* – New Hanover County began recycling pallets as part of its C&D recycling efforts in 2005. Pallets are collected along with mixed C&D waste at the county landfill at a cost to disposers of $59 per ton. Pallets and clean wood waste are sorted from the mixed C&D material until approximately 800 tons have accumulated, at which point pallets are ground using a contract grinder, and the mulch material is sold as boiler fuel. Costs to run the program are embedded in the total cost to manage a low-level C&D recycling operation. The C&D pad is operated by two landfill employees and the county negotiated a highly competitive rate for the grinding services[19].

*Carson City, NV:* In June 2009, the Northern Nevada Correctional Center (NNCC), located in Carson City, Nevada, completed installation of a $6.4 million biomass system. The CHP system

[17] https://www.nrel.gov/docs/fy22osti/81024.pdf
[18] https://www.nrel.gov/docs/fy22osti/81024.pdf
[19] https://www.deq.nc.gov/environmental-assistance-and-customer-service/wooden-pallets/newhanovercounty/download

produces 1 MW of electricity and requires 16,000 tons of wood annually. The system is estimated to save the NNCC $1 million per year. The wood is sourced from slash piles created from forest management activities as well as landfills where it would otherwise be buried[20].

*University of Idaho, ID* - University of Idaho uses a district energy system to heat and cool the campus. In 1986 the university secured and built a wood chip-fueled boiler using wood waste/residues from lumber mills[21].

**Pyrolysis:** The process of pyrolysis consists of heating a material to temperatures in the range between (generally) 500 – 600 °C in the absence of air such that combustion does not take place. Feedstocks suitable for pyrolysis include dewatered wet waste (e.g., sludge), paper and cardboard, plastics, wood, tires, and textiles, which represent most of the waste resources considered in this study and available in Juneau. Products from thermal pyrolysis include char, non-condensable gases (largely carbon monoxide [CO] and $CO_2$ with some light hydrocarbons), and a condensable organic liquid known as bio-oil. This bio-oil retains much of the heating value of the feed biomass and could be used for generating electricity in either a steam or gas turbine or used for home or district heating. Pyrolysis can be classified as fast or slow process depending on the heating rate, temperature, residence time, and pressure. Slow heating rates on the order of just a few degrees per minute produce mostly char with some bio-oil; fast heating rates (flash or fast pyrolysis) of hundreds of degrees per second produce more bio-oil; 60 to 70% of the feedstock can be liquefied to make bio-oil using fast pyrolysis.

The type and composition of the feedstock plays a crucial role in determining the properties of the resulting products. Bio-oil produced from the fast pyrolysis of MSW can be highly acidic (low pH), unstable, and unsuitable for direct use unless extensively upgraded to reduce its organic oxygen and water content. Char from organic sources (e.g., wood, biosolids) can be used in agriculture and environmental remediation while char from inorganic matter (e.g., waste plastic and tires) is mostly used in industrial applications.

Pyrolysis of plastic waste is still in its early stages of commercial development. Several companies are working in this space with differing end products and business models. For example, New Hope Energy (Tyler, Texas) focuses on producing petrochemical feedstocks. These feedstocks are supplied to TotalEnergies, which further processes them into circular polymers—recycled plastics suitable for food-grade packaging and other applications.

As noted earlier, pyrolysis converts waste materials into char, a valuable carbon-based product, commonly referred to as biochar when derived from biomass and recovered carbon black (rCB) when sourced from waste tires. While both are carbon-rich materials, they serve distinct purposes based on their properties and applications.

- Biochar is a porous, high-carbon product derived from biomass sources such as wood waste, crop residues, and biosolids. It is primarily used as a soil amendment, improving

[20] https://www.hurstboiler.com/news/hurst_boiler_sponsors_fuels_for_schools
[21] https://www.uidaho.edu/dfa/division-operations/utilities/energy

water retention, nutrient absorption, and carbon sequestration.[22] Additionally, biochar has applications in contaminant remediation, including binding per- and poly-fluoroalkyl substances (PFAS) and heavy metals in soil to prevent leaching into groundwater. The domestic biochar market is expanding, with California leading the country in both production and demand. Market prices in California range from $600 to $1,300 per ton, while production costs range from $200 to $1,000 per ton (2021 USD). Companies such as GECA and Biochar Now have successfully commercialized biochar production from clean wood waste, while Silicon Valley Clean Water has demonstrated biochar production from biosolids.

- Recovered Carbon Black (rCB) is a fine black powder produced from the pyrolysis of waste tires. Unlike biochar, rCB has high surface area but lacks the porosity needed for soil applications. Instead, it is used as a reinforcing filler in rubber, plastics, and coatings, providing a sustainable alternative to virgin carbon black. Companies such as Bolder Industries, Delta Ducon, and Klean Industries have developed pyrolysis technologies to recover rCB from tires. Bolder Industries produces BolderBlack®, a sustainable rCB used in new tires, coatings, and plastics, while Klean Industries integrates rCB into tire manufacturing, reducing reliance on fossil-based carbon black. These companies also produce bio-oil as byproduct, supporting further waste material valorization.

**Gasification** is another thermochemical conversion process that can transform MSW into valuable energy and products. Unlike pyrolysis, which operates in the absence of oxygen, gasification usually occurs in the presence of limited oxygen, enabling the partial oxidation of waste materials. This process generates syngas (a mixture of CO and hydrogen) and $CO_2$, which can be used to produce electricity, heat, or fuels. Gasification offers a flexible solution for MSW, particularly in areas with large waste volumes, by reducing landfill dependency while producing renewable energy. While gasification technologies require substantial infrastructure, they can be adapted to smaller-scale operations, making them suitable for both large municipal systems and more localized energy generation needs.

Large-scale MSW gasification has been successfully implemented in Europe and Asia, where it is commonly used for CHP applications. In these regions, gasification systems are integrated into district heating networks or industrial processes, providing a reliable and sustainable source of energy while reducing dependence on landfills. For instance, gasification plants in countries like Sweden and Japan have been in operation for years, demonstrating the feasibility of large-scale gasification to convert MSW into syngas for electricity and heat generation. These projects benefit from economies of scale, advanced technologies, and supportive waste management policies, making them more cost-effective compared to smaller operations. However, projects focused on fuel production, such as those by Enerkem in Edmonton, Alberta, and Fulcrum Sierra Biofuels in Reno, Nevada, have struggled to achieve the same level of success. These projects face challenges related to feedstock supply, high capital costs, and the complex nature of downstream processes required to convert MSW-derived syngas into liquid fuels, which has delayed commercial-scale operations.

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[22] Kalu, S., Kulmala, L., Zrim, J., Peltokangas, K., Tammeorg, P., Rasa, K., Kitzler, B., Pihlatie, M., and Karhu, K. Potential of biochar to reduce greenhouse gas emissions and increase nitrogen use efficiency in boreal arable soils in the long-term. Front. Environ. Sci., 10. DOI: 10.3389/fenvs.2022.914766.

Small-scale MSW gasification projects provide a flexible, modular solution for localized waste-to-energy needs, particularly in smaller municipalities or rural areas. These systems are easier to scale and deploy, making them attractive for regions with limited waste streams. However, their success depends on feedstock consistency, technology maturity, and financial backing. Economic sustainability remains a challenge, especially in areas with low waste generation, as the economics of small-scale gasification are still evolving. In China, small-scale projects (ranging from 3 t/day to 20 t/day) have successfully used modular gasification technology to convert MSW into syngas for local power generation, showcasing the potential of small-scale solutions to meet urban waste and energy needs.[23]

**Mechanical conversion processes** include **densification** which is the process of increasing the bulk density of the feedstock (biomass, MSW) by reducing its bulk volume.[24] Pelletization and briquetting are the most common densification processes. Densified products (pellets and briquettes) have benefits over raw feedstock such as more uniform properties, increased energy density, and reduced transportation costs and storage space.[25] For example, the calorific value of raw MSW is about 1,000 kcal/kg while that of fuel pellets is 4,000 kcal/kg.[26] The major markets for these products are residential and industrial heating and electricity generation. They can also be used as a uniform feed for thermochemical processes such as pyrolysis and gasification. Various biomass resources could be used to generate densified products. Typically, mill residues, forest residues, and low-quality logs are used in the production of densified products, but agricultural waste could also be used as feedstock, as well as mixed MSW or individual components such as paper/cardboard or wood pallets.[27]

Wood pellet manufacturing is a well-established process, and the general steps include drying, crushing, compressing, and cooling of the final product. In addition to being a high energy-value product, wood pellets can be easily handled and transported efficiently over long distances. The cost of a biomass pellet project can vary widely depending on several factors, including scale, feedstock, equipment, infrastructure, and labor. The project cost can range between $50,000 and $200,000 for a 1-1.5 tons/hour project to between $380,000 and $1.5 million for a 15-20 tons/hour project. [28] It takes 1.1 million British Thermal Units (MBTUs) of electrical energy to produce a ton of delivered pellets, which could be supplied with renewable energy such as solar panels.[29] While most wood pellets manufacturing in the United States occurs in the Southeast, there are recent efforts in other states as well (e.g., California, Rocky Mountain states) focused on using pine beetle kill wood and brush/branches from wildfire mitigation. There are also companies using clean wood pallets to produce pellets such as Energy Pellets of America, Hay Creek Companies, and Easy Heat Wood Pellets.

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[23] https://task33.ieabioenergy.com/wp-content/uploads/sites/33/2023/11/China.pdf
[24] https://ohioline.osu.edu/factsheet/fabe-6605
[25] https://www.sciencedirect.com/science/article/abs/pii/S1364032123003775?via%3Dihub
[26] https://www.biopelletmachine.com/biopellet-making-guidance/municipal-solid-waste-pellets-making.html#:~:text=MSW%20fuel%20pellet%20or%20briquett,excellent%20substiture%20for%20fossil%20fuels.
[27] https://biomassmagazine.com/articles/pellets-from-pallets-15549
[28] https://www.richipelletmachine.com/biomass-pellet-project-cost/
[29] https://utia.tennessee.edu/publications/wp-content/uploads/sites/269/2023/10/W214.pdf

Briquetting is a similar process to pelletization but it uses different production equipment (briquette press) and produces larger densified products (briquettes) with defined shapes such as cylinders or squares. The average briquette plant cost is $60,000 which will vary depending on configuration.[30] Biomass Secure Power Inc. (BMS PF) is developing a torrefied biomass briquette plant at Natchitoches, Louisiana. The facility will process forest residuals, cull, thinnings, slash, tree tops, woodchips, lumber mill residuals and branches. Construction will proceed in 3 phases with phase 1 producing 240,000 tonnes/yr of briquettes.[31]

## Discussion and Conclusions

The waste resources identified in the City and Borough of Juneau illustrate a range of potential feedstocks in the area, offering various pathways for energy and resource recovery. The choice of technology ultimately depends on the desired end products—whether the community prioritizes energy generation, soil amendments like compost or biochar, or other resource recovery applications. Given the city's relatively small waste generation, technologies must be appropriately sized to ensure economic feasibility.

For **biological processes**, AD and composting present viable options for managing organic waste in Juneau. The total organic waste available for AD amounts to approximately 5,400 tons per year, comprising of 4,324 tons of food waste, 893 tons of grass/leaves, and 187 tons of other compostable material. Depending on the feedstock composition and digester system, organic waste can generate between 3,000 and 6,000 cubic feet of biogas per ton.[32] This suggests a potential annual biogas production of roughly 16 to 32 million cubic feet, which could be used for heat, electricity generation, or upgraded to RNG. In energy terms, this equates to approximately 96,000 to 192,000 therms of natural gas or 9,600 to 19,200 MMBtu per year. However, upgrading biogas to RNG requires significant capital investment in gas purification technology, which can be cost-prohibitive for small-scale projects due to economies of scale.

Composting offers a simpler, lower-cost alternative for organic waste management. On average, composting reduces the original feedstock weight by 40-50%, meaning Juneau could produce approximately 2,100 to 2,700 tons of compost per year. However, the feasibility of composting depends on the local/regional demand for soil amendment. If there is no viable market or end use for the compost, the investment may not be justifiable.

When comparing these two approaches, AD involves higher capital expenditures but provides the added benefit of renewable energy generation, whereas composting is more cost-effective but relies on strong local demand for compost. The decision should consider both the city's energy needs and market potential for soil amendment products. Based on the previously outlined waste composition, roughly one quarter of the total waste stream is suitable for AD and/or composting, highlighting significant potential for waste reduction.

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30 https://www.abcmach.com/news/biomass-briquette-plant-cost-Middle-East.html
31 http://bmspf.com/html/projects.html
32 https://www.tandfonline.com/doi/full/10.1080/10962247.2017.1316326?utm_source=chatgpt.com#abstract

**Thermochemical conversion processes**, including combustion, pyrolysis, and gasification, provide alternative pathways for energy recovery. The city generates approximately 17,000 tons of waste resources annually suitable for thermochemical conversions addressing over 75% of the total waste stream (excluding metal, glass, and other materials) and thus presenting an attractive option for waste minimization. These waste streams could serve as feedstock for small- to medium-scale systems which convert waste into CHP, biochar, and other valuable products. However, these technologies can be capital-intensive, requiring careful cost-benefit analysis. Another attractive option, and potentially more cost-effective approach, may involve **densifying** MSW into fuel pellets. On average, about 15-20 tons of pellets can be produced from every 100 tons of processed waste, meaning Juneau's select MSW could yield roughly 2,500–3,400 tons of fuel pellets per year.[33] These pellets could be used for local heating applications or marketed externally, depending on regional demand and infrastructure. When comparing all these approaches, gasification and pyrolysis have high capital and operating costs, while pelletization may be more economically feasible and provide a transportable fuel product.

An estimated 2,149 wet tons (approximately 1,700 dry tons) of **clean MSW wood** are available annually within the City and Bourgh of Juneau. This supply could be supplemented with additional woody biomass from sources such as prunings, fire-prevention thinnings, and natural tree mortality, helping improve economies of scale. Given Juneau's surrounding forested landscape, it is reasonable to assume that a substantial volume of woody biomass from forest maintenance is available through ongoing sustainable land management practices. With this resource base, Juneau could explore a range of conversion technologies, including CHP via combustion for local use, pyrolysis for biochar or bio-oil production, gasification to generate CHP or syngas, or pelletization for fuel manufacturing. Using a conservative estimate of 5,000 Btu per pound of dry wood, Juneau's clean MSW wood could generate around 17 billion Btu per year which could significantly contribute to heat and power consumption at a school, municipal building, or other local facility. One ton of woody biomass can produce approximately 30% biochar by weight (300kg), meaning Juneau's clean MSW wood could yield roughly 510 tons of biochar annually. Using the average conversion of 15–20 tons of fuel pellets per 100 tons of raw feedstock noted earlier, Juneau's clean MSW wood could produce 250–340 tons of pellets annually. These estimates would be much higher if additional woody biomass is considered as feedstock for any of these applications. When comparing all these approaches, CHP provides local energy benefits, biochar may have niche markets, while pellets can be a scalable and transportable product.

This assessment provides a high-level overview of technology options and their feasibility, serving as a foundation for more detailed evaluations. Next steps could include a cost-benefit analysis for different pathways comparing capital cost, operational expenditures, and revenue potential to determine each pathway's economic viability. If Juneau determines a specific end-product preference, a detailed feasibility study could refine technical and economic aspects further, including an examination of site-specific logistics, detailed feedstock availability, permitting requirements, and potential off-takers for energy or material products. Additionally, a market analysis would help identify demand for potential products like compost, biochar, or fuel

[33] https://www.biopelletmachine.com/biopellet-making-guidance/municipal-solid-waste-pellets-making.html#:~:text=MSW%20fuel%20pellet%20or%20briquett,excellent%20substiture%20for%20fossil%20fuels.

pellets, ensuring alignment with local and regional opportunities. Ultimately, the best approach will balance technical feasibility, economic viability, and community needs to maximize the value of available waste resources. By pursuing these next steps, the City and Borough of Juneau can make informed decisions on alternative waste management and energy solutions that align with its economic and environmental goals. Whether through localized energy generation, soil amendment production, or material recovery, these strategies have the potential to enhance resilience and resource utilization in the community.

Appendix

*Table A1. Detailed overall (composite) municipal solid waste characterization, Juneau (2023)*

*Confidence intervals calculated at the 90% confidence level. Percentages and tons for subtotals are rounded and may not sum to the totals shown.*

| Material | Est. % | + / - | Est. Tons | Material | Est. % | + / - | Est. Tons |
|---|---|---|---|---|---|---|---|
| **Recyclable** | **18.0%** | **2.8%** | **4,025** | **Food** | **19.4%** | **4.2%** | **4,324** |
| **Compostable** | **31.7%** | **6.6%** | **7,083** | Food - Packaged Edible | 6.1% | 1.3% | 1,356 |
| **Potentially Recoverable** | **22.4%** | **5.2%** | **4,998** | Food - Packaged Inedible | 3.8% | 4.1% | 853 |
| **Reusable** | **8.5%** | **5.2%** | **1,907** | Food - Unpackaged Edible | 3.6% | 1.2% | 804 |
| **Non-recoverable** | **19.4%** | **2.5%** | **4,333** | Food - Unpackaged Inedible | 5.3% | 1.7% | 1,183 |
| **Paper & Cardboard** | **19.3%** | **3.6%** | **4,312** | Beverages | 0.6% | 0.1% | 128 |
| Uncoated Corrugated Cardboard | 4.4% | 1.4% | 992 | **Yard Debris** | **5.7%** | **1.3%** | **1,267** |
| Typically Recyclable Paper | 5.5% | 2.3% | 1,225 | Leaves & Grass | 4.0% | 1.1% | 893 |
| Food Soiled/Compostable Paper | 5.8% | 1.0% | 1,298 | Woody Yard Debris | 1.7% | 1.1% | 374 |
| Non-recyclable or Non-compostable Paper | 3.6% | 1.1% | 796 | **Other Organics** | **11.7%** | **5.4%** | **2,610** |
| **Plastic** | **9.3%** | **1.2%** | **2,084** | Manures | - | - | - |
| #1 PET Rigid Plastic Packaging | 1.0% | 0.1% | 234 | Remainder/Composite Organic - Compostable | 0.8% | 0.4% | 187 |
| #2 HDPE Rigid Plastic Packaging | 0.6% | 0.1% | 123 | Other Clean Wood | 1.4% | 1.0% | 316 |
| #4 LDPE Rigid Plastic Packaging | 0.0% | 0.0% | 4 | Reusable Clean Wood | 6.5% | 5.3% | 1,459 |
| #5 PP Rigid Plastic Packaging | 0.7% | 0.2% | 150 | Remainder/Composite Organic - Non-compostable | 2.9% | 0.9% | 649 |
| Compostable Rigid Plastic Packaging | 0.0% | 0.0% | 5 | **Special Materials** | **11.7%** | **2.9%** | **2,615** |
| Compostable Plastic Single Use Food Service Ware | 0.0% | 0.0% | 2 | Other Inert Construction Debris | 6.1% | 2.6% | 1,370 |
| Other Rigid Plastic Packaging | 0.4% | 0.1% | 97 | Carpet | 1.5% | 1.6% | 333 |
| Other Durable Rigid Plastic Items | 0.4% | 0.1% | 91 | E-waste | 0.7% | 0.3% | 148 |
| Reusable Durable Rigid Plastic Items | 1.4% | 0.8% | 304 | Tires | 0.6% | 0.6% | 134 |
| Non-compostable Plastic Single Use Food Service War | 0.1% | 0.0% | 14 | Refrigerant-containing Items | 0.1% | 0.1% | 19 |
| Single-layer Plastic Film | 3.9% | 0.5% | 865 | Mattresses | 0.0% | 0.0% | 0 |
| Multi-layer Plastic Film | 0.3% | 0.0% | 62 | Broken Metal Furniture | 1.0% | 0.6% | 219 |
| Durable Film Plastic Items | 0.0% | 0.0% | 0 | Household Hazardous Waste | 0.3% | 0.2% | 69 |
| Remainder/Composite Plastic | 0.6% | 0.3% | 131 | Reusable Inert Construction Debris | 0.3% | 0.4% | 74 |
| **Metal** | **4.4%** | **1.0%** | **988** | Reusable Wood Furniture | 0.3% | 0.3% | 70 |
| Tin/Steel Cans | 0.6% | 0.2% | 145 | Reusable Metal Furniture | 0.0% | 0.0% | 0 |
| Aluminum Cans | 0.6% | 0.1% | 142 | Special Waste | 0.5% | 0.4% | 122 |
| Other Ferrous | 1.7% | 0.8% | 370 | Broken Wood Furniture | 0.3% | 0.2% | 56 |
| Other Non-ferrous | 0.4% | 0.1% | 95 | **Textiles** | **9.9%** | **4.3%** | **2,202** |
| Remainder/Composite Metal | 1.1% | 0.6% | 236 | Textiles - Organic | 0.1% | 0.1% | 33 |
| **Glass** | **2.8%** | **0.6%** | **617** | Textiles - Synthetic, Mixed, & Unknown | 9.7% | 4.3% | 2,169 |
| Glass Bottles & Containers | 2.4% | 0.5% | 545 | **Other Materials** | **5.9%** | **0.9%** | **1,328** |
| Remainder/Composite Glass | 0.3% | 0.3% | 72 | Fines | 2.8% | 0.5% | 621 |
| | | | | Mixed Residue | 3.2% | 0.7% | 707 |
| *Sample Count* | *76* | | | **Total** | **100%** | | **22,346** |

Source: City and Borough of Juneau Waste Characterization Study (2024), Cascadia Consulting Group, https://juneau.org/wp-content/uploads/2024/10/Juneau-Waste-Characterization-Study-2024-Report_2024-10-8.pdf

Notes

1. Inert Construction Debris is considered to be not suitable for any of the WTE technology pathways considered in this report.
2. E-waste, carpet, refrigerant-containing items, mattresses, household hazardous waste, and special waste are excluded from this analysis.
3. Wood furniture is coated with chemicals and thus not considered suitable for resource and energy recovery although these materials, along with others, are often combusted in MSW incinerators.
4. Other Materials are excluded due to lack of information on characteristics.