King County and Port of Seattle

MUNICIPAL SOLID WASTE-TO-FUELS STUDY SUMMARY

The Port of Seattle and King County recently completed the Municipal Solid Waste-to-Fuels Study (the Study) as part of their work exploring the feasibility of sustainable aviation fuel (SAF) production from municipal solid waste (MSW) to reduce greenhouse gas emissions and landfilled waste in the region. The Study found that there is enough waste in Washington and northern Oregon to support one or more SAF production facilities. However, there are still challenges to overcome. One challenge is the need for further fuel technology development. Commercial MSW-to-SAF facilities are still in their early stages, and it is not yet clear how efficient and cost-effective they will be. This uncertainty, while common in the early-stages of emerging or new technologies, can create significant challenges for project developers looking to finance a new MSW to SAF facility. Despite these challenges, the Port of Seattle and King County are partnering to explore the potential of SAF production from MSW and evaluate whether it could be a key part of the region's efforts to reduce greenhouse gas emissions and transition to a clean energy future.

King County

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THE OPPORTUNITY

The Port of Seattle and King County, as owners of the region's largest airport and landfill respectively, have a unique opportunity to dramatically reduce greenhouse gas (GHG) emissions in our region by developing sustainable aviation fuel (SAF) and other renewable liquid fuels from municipal solid waste (MSW). SAF is a drop-in fuel made from sustainable sources that can be blended with fossil jet fuel and reduces carbon dioxide emissions by 50-80% on a lifecycle basis compared to fossil jet fuel.

SEA Airport, located in King County and operated by the Port of Seattle, has set a goal to power every flight fueled at SEA with at least a 10% blend of SAF by 2028. Airlines at SEA Airport are projected to use about 700 million gallons of jet fuel per year. A 10 percent SAF blend would eliminate 70 million gallons of fossil jet fuel, which is equivalent to 682,500 metric tons of airlines' greenhouse gas emissions – the equivalent of nearly 152,000 cars driven a year.

SAF can be produced from non-petroleum-based renewable feedstocks, including some yard waste, paper, and construction waste portion of MSW, woody biomass, fats/greases/oils, and other feedstocks. Using MSW as a feedstock for fuel production can reduce the amount of methane and CO2 emitted through the decomposition of organic material in a landfill. King County, which managed more than 800,000 tons of MSW in 2022, is committed to exploring opportunities for SAF production using MSW. However, King County is also examining multiple other waste prevention and resource recovery options, as well as future disposal options to employ once the County's Cedar Hills Regional Landfill closes around 2040.

Together, the Port of Seattle and King County commissioned a study to explore the feasibility of directing MSW and other material received in King County and other regional (western WA or OR) solid waste facilities to a potential renewable fuel production facility. This study is an important step towards achieving the shared goal of reducing GHG emissions and supporting the region's commitment to sustainability. SAF production from MSW has the potential to create jobs, help boost the economy, and reduce pollution in the region.

Study Objectives and Considerations

In 2023, the Port of Seattle and King County commissioned a study by EXP, an engineering consulting service, and tasked them with:

1. Evaluating feasible MSW-to-SAF conversion technologies
2. Evaluating existing and future MSW availability to make fuels
3. Identifying & evaluating potential production facility locations
4. Reviewing project financing options and models
5. Identifying partnership opportunities

EXP also had to consider the following implications to SAF production:

- King County's 2019 Comprehensive Solid Waste Management Plan (Comp Plan), developed in collaboration with multiple regional stakeholders, included a decision to maximize the use of the Cedar Hills Regional Landfill, and to not specify the next disposal method, such as waste-to-energy or a technology such as SAF. This landfill closure date is over a decade after the Port's target date of 2028 to begin producing SAF, therefore King County's waste will not be available to support the Port's immediate SAF goals.
- When researching facility siting locations, community support for proposed SAF facilities, facility proximity to landfills, and the permitting requirements of needed facilities and operations were noted considerations.
- The fuel's carbon intensity, ensuring the lifecycle emissions (gathering, sorting, processing, delivering) are at least 50% lower carbon than fossil jet fuel.

SUMMARY OF KEY LEARNINGS

The study evaluated five areas critical to SAF production in the region: fuel conversion technologies, feedstock supply, facility locations, financing options, and the potential role of private/public partnerships. In some of these areas, the Port and King County have legislative authority or control to aid in successful project implementation, but in other areas, private sector players will need to step in and play a leadership role to move a SAF project forward.

MSW Feedstock Supply

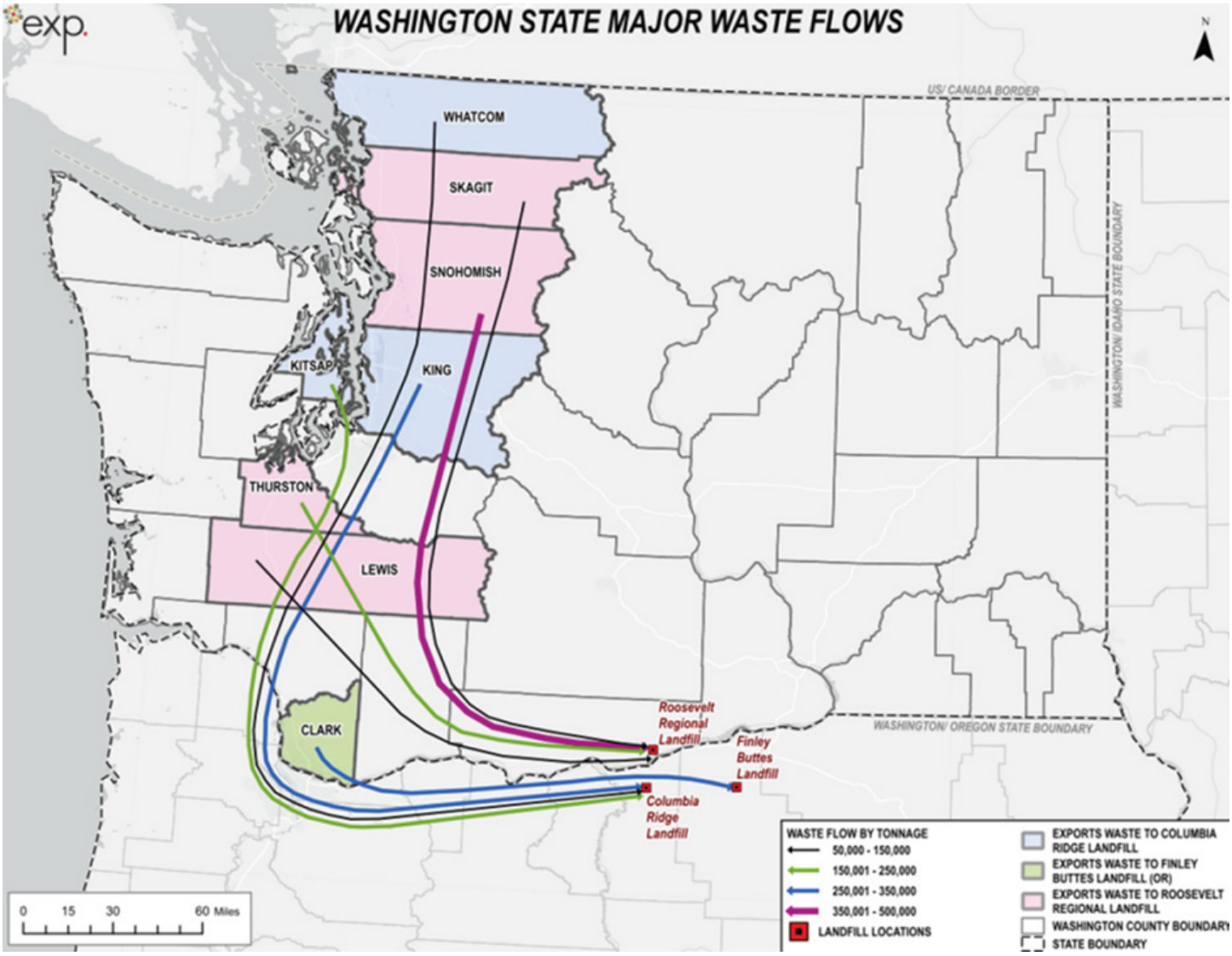
There are only five landfills in Washington and northern Oregon that receive enough waste to maximize SAF production in one location, and only two of those landfills receive sufficient MSW for a large-scale fuel production plant that is considered economically feasible given the capital investment (i.e., 25 million gallons of finished SAF per year).

1. Roosevelt Regional Landfill located in Klickitat County, Washington receives over one million tons of MSW per year from Washington. They receive additional MSW from other areas which brings their total to 2.3 million tons of MSW per year.
2. Columbia Ridge Landfill located in Gilliam County, Oregon receives over 750,000 tons of MSW per year from Washington. They also receive additional MSW from other areas, bringing their total to 3 million tons of MSW per year.

It is important to note that MSW, as shipped to a landfill, consists of various materials such as food waste, paper, glass, plastics, yard waste, metals, wood, demolition materials, textiles, and plastic film. Only small amounts of food and yard waste can be mixed in due to moisture content limits, and plastics should be kept to a minimum as they are not considered renewable and could disqualify the finished fuel from state and federal credits.

Figure 1: Washington State Major Waste Flow

As shown in this figure, western Washington generates ~5.3 million tons of MSW per year , enough combined MSW to support the development of a large-scale, cost-effective renewable fuels production facility.



Fuel Conversion Technology

There are two certified types of conversion pathways that turn MSW to aviation fuel: Fischer-Tropsch (FT) and Alcohol-to-Jet (ATJ). Both include a pre-processing step and a gasification step (Figure 2). Pre-processing involves various types of sorting, shredding, and drying of the MSW. Gasification is a process that converts that solid fuel into gases, but it does not require burning or combusting the waste.

Fischer-Tropsch (FT) is a more established process at a higher technical readiness level (TRL) with multiple technology providers in the market, but performs best when processing extremely similar feedstock, which is problematic for mixed waste. Generally, this process requires more process energy and waste CO2, which could increase the carbon intensity score. However, the carbon intensity score can be reduced by the producer through re-use of process waste heat and/or carbon storage or industry use.

Alcohol-to-Jet (ATJ), while proven, is not yet widely used, even though the step to convert MSW to alcohol (ethanol) has been demonstrated successfully. While it has many things in common with FT, one key differentiator is that the MSW could be converted to liquid alcohol near a landfill at one facility and then transported to a central ATJ facility elsewhere, perhaps near refineries where other alcohols derived from wood waste or other organic waste sources could also be transported and converted to SAF.

Figure 2: Pathways for MSW to SAF Conversion

Figure 3: Comparing FT and ATJ Conversion Pathways

This table compares the benefits and strengths of FT and ATJ, based on the results of this study along with internal qualitative assessments. Based on a scale of 1 to 10, higher numbers indicate more positive attributes. Both conversion pathways have strengths, but neither is ready for llarge-scale commercial implementation yet. There are still a number of things to address, such as funding, policies, siting, and technological maturity. Scores are not weighted or tallied because different users (producers, financiers, policy makers) will assign more importance to some criteria. The results of our qualitative analysis are shown in Table 1 below:

	FT	ATJ
Process Energy Inputs	6	5
SAF % output per unit of MSW input	8	9
Carbon Intensity of process	8	8
Technical Readiness (TRL)	9	6
Location Flexibility	5	8
Multiple technology providers	8	5

Facility Siting

Siting a new SAF production facility is a complex process that must consider a variety of factors including the following:

Proximity: In addition to MSW volume requirements, a SAF production facility would require available industrial property with proximity to either a landfill or some other easy access to the MSW, e.g., a rail yard. Any added transportation of MSW can be a significant cost and would increase the fuel's carbon intensity.

Industrial Area: An industrial site suitable for a SAF facility will have appropriate zoning and enough space for the facility and its infrastructure. A renewable-fuels production facility may be built as one plant with all process units together on a single site, or depending on the technology chosen, the plant may be split into separate units built at different locations.

Regulatory Requirements: The siting of the facility must comply with all applicable regulations, including environmental, zoning, and permitting requirements.

Community Acceptance: A renewable-fuels production facility can be controversial, so it is important to understand the impact on nearby residents, and their receptiveness to a new facility.

Site Utilities: The carbon footprint of the finished fuel and the efficiency of each site are influenced by the consumption of utilities like electricity, natural gas, hydrogen, and water, as well as how the various processes at the site rely on each other.

Three regions were short-listed as having suitable sites for a new plant:

1. Columbia River area sites with proximity to large landfills (Gilliam, Klickitat, and Morrow Counties)
2. Industrial/brownfield areas in western Washington along Interstate 5 (Cowlitz, Grays Harbor, and Lewis Counties)
3. Northwest Washington areas near refineries (Skagit and Whatcom Counties)

The Port and King County support these findings but do not have a recommended specific site at this time, as more study would need to be done by a project developer to understand each of the factors further and at a detailed level to attract investors.

Figure 4: Viable Facility Site Locations in WA and OR

Highlighted in this image are the three region shortlisted and assessed for suitability.

Financing and Risk Mitigation

Project financing for waste-to-fuel conversion projects is more challenging compared to established proven industrial projects. SAF projects face higher technology and permitting risks which must be addressed and mitigated to attract investors. Governments at multiple levels can support SAF production, provide incentives and tax credits, act as credit guarantor, and make MSW eligible as a renewable feedstock source. Strategic partnerships along the whole supply chain from waste hauling, to landfills, to landowners, and all the way to airline SAF offtake, are beneficial for obtaining project financing.

Given MSW-to-SAF commercial production is still in its infancy in the United States, there is a critical need to address risks in project development and financing. One of the foreseen risks with project development is obtaining proper permitting and navigating a complex permitting process. This risk can be mitigated by developing a comprehensive permitting plan and working closely with all relevant agencies and communities. A risk mitigation plan that also addresses technology, performance, and siting risks would provide additional confidence to investors.

There are two key areas where public sector agencies like the County and the Port can play a role to reduce project risk:

1. Government Incentives

The U.S. and Washington state provide federal and state financial support for renewable fuel projects through several policy options. The Port has made SAF incentives part of their key legislative priorities and have supported and testified for many significant bills, including the WA Clean Fuel Standard and the SAF incentives bill of 2023. As SAF demand increases, prioritization of its production must be met with amended rules and regulations, tax incentives, government grants, and other subsidies. SAF is not yet listed as a renewable fuel to receive incentives and grants in some Federal programs and does not have the same position as renewable diesel regarding GHG emission calculations. To address this inequity, tax policies and incentives require changes to provide equal to or better incentives for SAF production as compared with bioethanol and renewable diesel.

Some programs do not consider MSW as a renewable feedstock, which results in significantly different calculated lifetime GHG emissions when using the respective formulas for calculating the carbon intensity. The GREET model used in the U.S. does not have yet a published procedure with respective formulas for the MSW-to-SAF conversion process.

The Port of Seattle became the first U.S. airport operator to set a specific timetable and goals for transitioning all airlines at SEA to commercially competitive SAF. This multi-year push includes advocacy efforts for new legislation in support of SAF use.

2. Partnerships

A SAF production facility requires coordination and partnerships among multiple government agencies, public organizations, and private businesses. Together, they need to address the financing needs, the various entities in the supply chain, the marketing and sales needs for products and by-products, the challenges in regulations and permitting, and GHG emission reduction measures and credits. MSW-to-SAF projects have many potential partners, including airlines, energy companies, and waste handlers – all of which have demonstrated their willingness to partner for existing or planned renewable fuel projects. Currently, there are no partnerships set up to address these risks/issues for a project in the Pacific Northwest, but the Port and King County believe the biggest opportunity lies in the following areas:

Feedstock source and pre-processing: The following parties benefit from partnerships: Renewable fuel production facilities (feedstock security), landfills (extending its lifespan, supporting zero waste objectives, and revenue diversification), transportation partners (logistical benefits and a new stream of business), waste haulers (diversifying waste drop-off destinations, survival as 'green' initiatives are promoted), and renewable natural gas (RNG) producers (sale of RNG at a higher price than under commercial conditions yet cheaper than grid RNG).

Permitting requirements, regulatory standards, and policy framework: Failing to obtain the required permits may bring the entire project to a halt. Developing strong relationships with government agencies and the public is imperative and can assist navigating through the oftentimes complex permitting process. It will also prove instrumental in meeting the needs of this facility since the process of converting MSW to jet fuel is a relatively new process and must be incorporated into future laws, regulations, policies, tax incentives, and investments.

Facility land acquisition or purchase, funding, ownership, development, co-location, and/or operation: Brownfield sites are "location-efficient" due to their existing connections to infrastructure (e.g., roadways and utilities), allowing project savings on infrastructure expenses compared with greenfield projects. SAF facilities can be co-located to petroleum refineries to enhance profit margins by sharing costs and utilities with the refinery, such as service facilities, buildings, and plant management team/engineers. Certain sites with sufficient space to accommodate a SAF facility (e.g., landfill adjacent) minimize logistical and transportation matters.

Utilities and required infrastructure: Utility companies and other public entities are crucial to obtain services (e.g., power, water, rail, road access, etc.). Partnerships with these companies ensure that additional investments will result in added long-term revenue.

Economic Viability Analysis

The study analyzed four scenarios combining information about the waste and technology at suitable facility locations to understand the economic viability and carbon intensity scores of SAF using smaller volumes of waste similar to what currently goes to Cedar Hills Landfill, along with larger volumes more similar to the landfills in southern WA or northern OR.

For each scenario, a Minimum Selling Price (MSP) was then computed, which is the price at which the fuel needs to be sold to recover the total amortized capital and operational costs.

Results show that smaller volumes of MSW like the volumes going into Cedar Hills Landfill resulted in SAF that (was not cost-competitive, with MSP ranging from approximately 2 to 3 dollars more per gallon than the larger waste volume scenarios, which were about $7-8/gallon without any incentives applied. Once incentives are applied to the larger MSW volume scenarios, the final SAF price is closer to $3 per gallon, although this varies widely depending on the value of the incentive in different markets at any given time.

NEXT STEPS

MSW-to-SAF is a promising technology with the potential to reduce greenhouse gas emissions, divert waste from landfills, and build our regional economy. However, there are still a number of challenges that need to be addressed before this technology can be widely implemented. Feedstock diversion or change, financing, risk mitigation, and partnerships are key areas that need to be explored further to secure MSW-to-SAF production in the Pacific Northwest.

Feedstock Diversion

King County Sourcing

There are two key factors influencing how King County Solid Waste will integrate these report findings into their next steps:

1. Given that King County's waste is not sufficient and reliable enough to be the sole supply for an at-scale economically feasible SAF/renewable fuel production facility, their ability to divert waste for that purpose relies on the existence or guarantee of a larger facility they could add their waste supply to, and;
2. An update to the Comprehensive Solid Waste Management Plan (hereafter "Comp Plan") is occurring now, and one of the major policy decisions being deliberated is long-term disposal after the closure of Cedar Hills in 2040. Five options are currently being considered, including MSW-to-SAF technologies. This update to the Comp Plan is expected to be complete in 2026, and in accordance with interlocal agreements with King County's 37 partner cities, a long-term disposal decision is made as part of the Comp Plan process.

   King County's Solid Waste Division is currently developing and implementing multiple waste prevention, recycling, and re-use projects under the Re+ banner which, in years to come, will reduce the quantity of MSW tonnage and change the types of waste within the remaining MSW. Successful implementation of Re+ programs will impact the degree to which King County's MSW could serve as feedstock for SAF production.

Regional Sourcing

There are only two landfills in Washington and northern Oregon that receive sufficient MSW for a large-scale SAF production plant that can produce at least 25 million gallons per year of fuel. Those include Roosevelt Regional Landfill located in Klickitat County, Washington which receives nearly two million tons per year, and Columbia Ridge Landfill located in Gilliam County, Oregon which receives between 2 and 3 million tons per year from all sources and states.

Regulation and Authority

There are two areas King County and the Port of Seattle have identified for further exploration:

1. Continued advocacy for regulations that mitigate risk and supports the development and use of SAF. Key topics of interest include:
   - Permitting reform
   - Financial incentives
   - How MSW is treated as a feedstock in low carbon accounting program and regulation methodologies
2. Explore additional research on specific public-private partnership models for similar developments, using up to five project examples referred to or provided in the EXP report (e.g. Enerkem MSW-to-ethanol project).