Appendix A-1

Quantitative Assessment of the Washington Agricultural Industry
1. Introduction

The successful integration of symbiosis concepts into Washington's agricultural industry is dependent on the adoption of a system-level approach that maximizes the value of the industry's three most basic resources: organic material, water, and energy. One challenge to symbiosis is identifying and communicating the opportunities for collaboratively optimizing these common resources to a multidisciplinary group of ag and non-ag stakeholders that each use their own vocabulary and operate from their own perspective. For instance, industry specific terms, like "bins of apples", "bushels of grain", and "cases of wine" are all unfamiliar measurements of volume to most people outside of a handful of industry specialists among whom these are everyday terms. Additionally, definitions of basic terms, like "large-scale" and "small-scale", can be vastly different based on context. The largest winery in Washington has the capacity to crush approximately 50,000 tons of grapes per year, while the smallest frozen French fry manufacturer far exceeds that amount with an annual capacity of more than 200,000 tons of raw potatoes per year.

The quantitative assessment, which serves as a complement to the interviews and analysis also conducted for this report, is designed to provide a broad perspective of the agricultural industry to a general audience. Instead of working directly with stakeholders to highlight individual projects, this methodology focused on identifying opportunities through sector-wide inventories and geospatial analysis to discern general solutions. By evaluating generalized solutions, we can emphasize symbiosis pathways with the largest overall potential for economic and environmental impacts.

2. Methods

Throughout the quantitative analysis, we placed an emphasis on attaining data from publicly available resources. This decision is meant to help facilitate future work, as the data presented is constantly changing along with the agricultural industry.

2.1 Facility Database

The agricultural industry is dependent on a complex network of facilities that link farms to retailers. One major undertaking of this project was to aggregate a database of facilities that either store or process agricultural goods from the sources listed in table A-1.1. For each facility, several types of key information was recorded including: coordinates, address, input materials, output materials, and operating status. When available, additional information about capacity, ownership arrangements, and waste management plans were also included in the database. Although the database has more than 800 facilities documented in it at the conclusion of this project, we acknowledge that not every supply chain participant has been included.

Information about several types of facilities is available through specialized databases, but information about many of the processors that may pose the best opportunities for symbiosis were collected using the Washington Department of Ecology’s Water Quality Permitting and Reporting Information System (PARIS) [2]. Within this database, common types of facilities like wineries, confined animal feeding operations (CAFOs), and fruit packers are regulated using sector-specific general permits that simplify the permitting process by using a standard format.

For other processors, we used data collected by the WSU Energy Program as a starting point [1]. We supplemented that data using two types of permit documents from the PARIS database. Permit “fact sheets” contain useful information about the history, industrial processes, and waste management plans for facilities. Often, the fact sheet contains all the information necessary for the ag processor database, but in some cases, permit applications can be an additional source of information, particularly about the amounts and types of material input and output in a typical year.
<table>
<thead>
<tr>
<th>Facility Type</th>
<th>Source</th>
<th>Detailed Source</th>
<th>Collection Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food Processors</td>
<td>WSU Energy Program [1]</td>
<td>See Below</td>
<td></td>
</tr>
<tr>
<td>Agricultural Product Processors</td>
<td>City Water permits</td>
<td></td>
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</tr>
<tr>
<td>Fruit Packers</td>
<td>Washington Department of Ecology, Water Quality Permitting and Reporting Information System (PARIS) [2], [3]</td>
<td>Included all active facilities with fruit packer general permits</td>
<td>Permit applications contain data about fruit types and capacity</td>
</tr>
<tr>
<td>Confined Animal Feeding Operations</td>
<td>Washington Department of Ecology, Water Quality Permitting and Reporting Information System (PARIS) [2], [4]</td>
<td>Included all active facilities with CAFO general permits</td>
<td>Manure Pollution Prevention Plans (or MPPs) contain relevant information</td>
</tr>
<tr>
<td>Ag Waste Digesters</td>
<td>United State Environmental Protection Agency AgStar Database [5]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wineries</td>
<td>Washington Department of Ecology, Water Quality Permitting and Reporting Information System (PARIS) [2], [6]</td>
<td>Included all active facilities with winery general permits</td>
<td>Information about crush and wine capacity is included notice of intents (NOIs)</td>
</tr>
<tr>
<td>Wineries</td>
<td>Liquor and Cannabis Board [7]</td>
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<tr>
<td>Milk Processors</td>
<td>United States Department of Agriculture, Agricultural Marketing Service (AMS) [8]</td>
<td>Dairy Plants Surveyed and Approved for USDA Grading Service</td>
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<tr>
<td>Milk Handlers</td>
<td>United States Department of Agriculture, Agricultural Marketing Service (AMS) [9]</td>
<td>Regulated Pool Distributing &amp; Supply Plants</td>
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</tr>
<tr>
<td>Public Refrigerated Warehouses</td>
<td>Homeland Infrastructure Foundation-Level Data (HIFLD) [10]</td>
<td>Public Refrigerated Warehouses</td>
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</tr>
</tbody>
</table>
2.2 Areas of Interest

Agricultural industrial symbiosis is a big concept. And even with advanced analytical tools, we found it impractical to characterize every potential application at an adequate level of detail. Instead, we determined the approach that would result in the most valuable information should begin with a series of high-level inventory assessments that could be used to identify areas of interest that would receive more detailed analyses. The high-level assessments were focused on the following criteria:

- **Monetary value and employment:** Characterizing the various segments of the agricultural industry based on the money they generate and number of people they employ is likely the first approach that is taken by people unfamiliar with the industry. So, it is useful to frame the industry using this basic approach before exploring alternatives that better illustrate opportunities for symbiosis.

- **Processing volume and processing hubs:** Ag supply chains often consist of multiple stages that include harvest, storage, shipping, and processing. Of these stages, symbiosis is most likely to occur at processors because they aggregate large amounts of biomass and use energy-intensive methods to convert raw goods into value-added products.

- **Change Over Time:** Segments of the ag industry that have changed the most in recent years are more likely to result in waste, as they are less likely to fit within the handful of well-established cooperative elements that took years to develop and mature within the existing industry.

- **Large number of similar facilities:** Some industries that are dependent on many smaller-scale facilities have waste problems because waste utilization often requires large economies of scale to be feasible. Community-level symbiosis projects could collectively result in the scale needed to support these types of facilities.

3. Results

3.1 Monetary Value

One of the focuses of the quantitative assessment is to identify opportunities to improve the economic performance of the agricultural industry. Minor improvements to the most valuable segments of the industry could result in significant overall improvements. Figure A-1.1 shows the value of agricultural commodities marketed from farms in 2021 [12]. The chart shows that almost 60% of the total value was concentrated among the 5 most valuable products: apples, cattle, milk, wheat, and potatoes. But 10 distinct product types (not hay or other) were valued at more than 100 million dollars in revenue, demonstrating that a diverse range of products are generated by the industry. It is also significant that the five highest value products are spread among several sub-categories, as fruits, grains, vegetables, and livestock are all represented.

![Figure A-1.1: 2021 value of agricultural commodities from Washington](image)

The value of the agricultural industry also varies geographically. As shown in Figure A-1.2 [13], most value is generated in Eastern Washington, especially in the Yakima Valley and the Columbia Basin. The Yakima Valley, which includes Yakima,
Kittitas, and Benton Counties, is an important contributor to the fruit, vegetable, and livestock sectors, as the counties combined hold 41% of total apple acreage, 56% of total grape acreage, 25% of potato acreage, and 41% of the state’s dairy herd. The Columbia Basin, which consists of Grant, Adams, and Franklin Counties, also grows fruit but is proportionally more responsible for the state’s vegetable and potato production. Combined, these counties hold 34% of total apple acreage, 21% of total grape acreage, 58% of potato acreage, and 21% of the state’s dairy herd. While the difference in total value between Western and Eastern Washington is stark, Western Washington is still significant, as it generated more than $1.5 billion of agricultural products in 2017. An area in Northwest Washington, consisting of Skagit, Snohomish, and Whatcom counties, holds 27% of the state’s dairy herd and 12% of the state’s potatoes. Grains, Oilseeds, & Pulses (dry beans like lentils and chickpeas), were valued at more than 1 billion dollars in 2021 but are spread out across most of Eastern Washington. Along the state’s Eastern border, in Whitman and Spokane counties, wheat is the most valuable commodity in dryland farming systems. Throughout the rest of Eastern Washington, it’s used as rotational crop along with vegetables and potatoes [14].

Across all of Washington, only 1.7% of the state’s residents were privately employed by companies that either produce agricultural products or manufacture food and beverages during the 3rd quarter of 2022 (calculated using population data [15] and employment data for NAICS classes 111, 112, 311, 312 [16]). But in some areas of Eastern Washington, the agricultural industry has a much greater impact on the local economy. As shown in Figure A-1.3, more than 10% of the populations in Yakima, Grant, and Adams counties were employed in either the agriculture or food and beverage industries. Across the state, most of these employees were involved in crop production, but this is partially due to data collection. Values are for July-September, when variable employment is at its annual peak [17]. Between July and December of 2021, employment in agriculture declined by 40% due to seasonal variations. Areas that produce products for fresh consumption, like apples, which require manual picking, versus row crops that can be harvested by machine employ more people in agriculture. When considering more-urban areas especially, it is worth noting that not all companies involved in food and beverage production are necessarily part of the state’s ag industry, but instead manufacture products using goods from around the world for quick distribution and consumption in the state’s largest population hub, the Puget Sound. For example, Starbucks, the state’s most famous beverage manufacturer, sources most of the feedstock for its Kent coffee roasting plant from foreign countries in Asia, Central America, South America, and Brazil [18].

\[\text{Figure A-1.2: Value of ag products by county}\]
3.2 Processing Volume & Processing Hubs
Assessing the state's ag industry by the capacity and locations of its processors is another approach that can be taken to characterize potential for symbiosis, especially since processors typically consume large amounts of water and energy and generate a significant amount of waste biomass through trimmings and rejected product. Previous work has suggested that large industrial processors can act as “anchor” facilities that interact with small and medium-sized firms [19]. Figure A-1.3 shows the total capacity of processors (those classified in the facility database) against the total volume of crop production in 2022 [20]. By weight, more than half of all processing capacity for fruits and vegetables is used for potatoes. High-value crops like tree fruit, including apples, cherries and pears, are mostly sold for the fresh market, meaning processing makes up a small amount of their total volume. Among all fruits and berries, grapes were processed in the largest volume. Despite the overall value of grains, oilseeds, and pulses in Washington, a relatively small amount is processed, limiting applications for symbiosis.

Applications of symbiosis likely have the potential to make the greatest impact at facilities with large processing capacities. For the purposes of this study, “large” is classified as having an annual input of at least 50,000 tons per year.

This method does not account for maximum daily throughput, which may be a more useful metric to classify facilities that process crops for a short period during harvest, like wineries and frozen vegetable manufacturers. Nor does this method account for the portion of waste generated from processing. Figure A-1.4 shows the locations of the state's 37 large processors that were identified in the facility database. Of these, 33 are in Eastern Washington while only 4 are in Western Washington. The 19 plants that primarily process vegetables are concentrated in the Columbia Basin, while the 9 plants that process fruit are primarily in the Yakima Valley. 3 of the state's 5 total dairy processors are in Western Washington.
3.3 Change Over Time

Modern agriculture has been developed through the accumulation of decades of advancements in mechanization, fertilizers, and information technology [21]. This has resulted in a massive shift to the structure of the industry, as the subsistence-level family-operated farms that once dominated the industry have slowly been consolidated into larger operations. During this shift, the composition of farms also changed. Previously a single farm may have included a small orchard, several livestock, and a few fields for hay or row crops. But modern farms tend to optimize their operations for the production of fewer goods. Figure A-1.5, which was constructed from several USDA Census of Agriculture tables [22]–[29], shows the percentage of farms involved in major sectors has dropped as farms have become more specialized over time.

These changes have led to a necessary increase in total output, but they have also created challenges that were not a concern in the past. Because of specialization, managing waste has become more difficult for many farmers. For instance, crop wastes that were once used to feed on-farm livestock are often landfilled and manure that was used to fertilize adjacent fields is frequently just a nuisance [30].

While the number of farms involved in most sectors has changed significantly over time, the locations of their production has not changed nearly as much. Figure A-1.6 shows the centroids of ag production for several representative commodities between 1987 and 2017 [31]–[38]. The centroids of production for apples, cattle, potatoes, and wheat remained stable while dairy shifted from west to east of the Cascade Mountains. The most recent impact of this shift is a new facility that will be opened by Darigold in 2024 [39].
4. Discussion

The multiple methods used to evaluate the agricultural industry failed to reveal that there is one clear-cut opportunity to implement symbiosis. Instead, it was shown that opportunities can be found in multiple sub-sectors in various parts of the state. In particular, the total value, geographic concentration, and processing capacity of fruit and berry, vegetable and potato, and livestock industries in the Yakima Valley and Columbia Basin suggests that efforts in these areas are likely to make the greatest contribution to the state’s agricultural industry.

4.1 Linking Findings to Stakeholder Interviews

The results of the quantitative approach can be better understood by comparing and contrasting them with the list of existing and developing symbiosis projects presented in section IV.

Agriculture Symbiosis: Examples in Washington & Beyond. The industry that stood out using either approach was the dairy industry. 5 anaerobic digesters projects that use primarily dairy manure were included in the list. And Royal Dairy’s worm bed project also uses manure. Another area that was positively represented by either approach were the Agricultural processors in Richland and Pasco. The quantitative approach found that this area has more large agricultural processors than anywhere else in Washington, and especially projects like the
Pasco Process Water Reuse Facility could benefit a significant portion of the state’s total dairy, potato, and vegetable processing capacity.

A major difference between the projects highlights how symbiosis is feasible in a broad variety of applications. The quantitative approach’s results suggest that most opportunities for symbiosis lie east of the Cascade Mountains, while the list of current projects suggests that agricultural industrial symbiosis is feasible west of the Cascades, but typically at a smaller scale. Together, these approaches give a more-holistic capacity for adoption of symbiotic concepts in Washington.

4.2 Additional Work: Supply Chain Descriptions

To better understand how symbiosis can be implemented within the agricultural industry, we decided to conduct supply chain studies of the sub sectors we felt best represented the opportunities highlighted by the quantitative analysis. These include apples (expanded to include tree fruit), potatoes, and grapes. The purpose of the studies was to understand the industry on a more detailed level to help further identify potential synergies. Each study includes:

- Types of facilities that handle material in the supply chain
- Long-term trajectory of the industry in Washington
- Locations and capacities of farms, warehouses, and processors
- Seasonal variations in production
- Current uses for wastes including organic material, water, and energy

4.3 Additional Work: Energy-Related Symbiosis Assessment

As mentioned previously, one of the challenges of analyzing opportunities for agricultural industrial symbiosis is that a common tendency is to view agriculture as a series of loosely related but separate industries, instead of a complex and tightly-knit system. An example of this systems-level approach was demonstrated using two appendices that evaluated how an array of stakeholders have the potential to influence the agricultural industry’s demand for fossil-based energy by 1) generating energy from waste organic sources and 2) reducing energy demand by using heat sharing.

- **Biomass-to-Energy:** Appendix B includes and evaluation of potential to use anaerobic digestion to create methane and natural gas from organic wastes like manure, fruit waste, potato waste, and wheat straw.
- **Agricultural Processor Heat Sharing:** Appendix A-2 provides and analysis of processors from several industries that use heat to dehydrate or cook raw materials. The study characterizes that heat and considers opportunities to use the waste heat for other applications.
References


