PUGET SOUND ENERGY

CONCEPTUAL DESIGN OF A BAINBRIDGE ISLAND BIOENERGY PROJECT

TM Number 2:
INCLUDING ALL SOURCE SEPARATED ORGANIC WASTES

IMPACT BIOENERGY

MARCH 17, 2021

Distributed Bioenergy Solutions

Summary

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Purpose

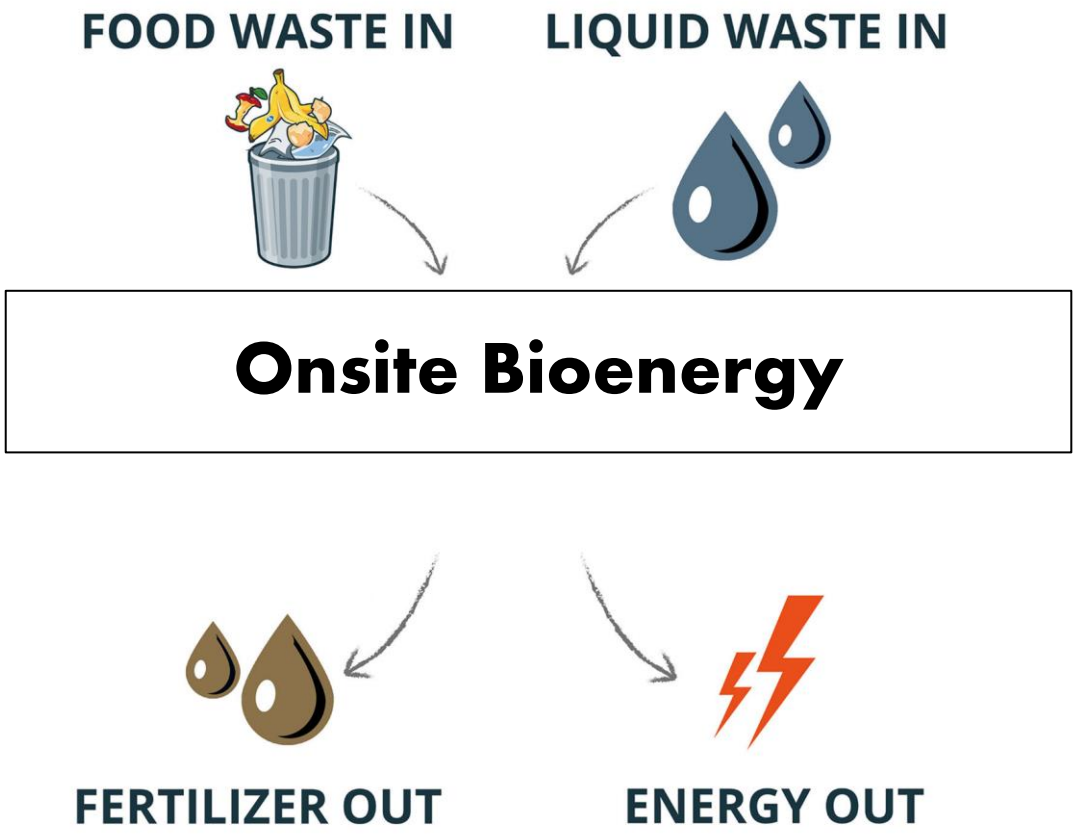
- Explore the use of Anaerobic Digestion specifically sized for Bainbridge Island - to convert residential, commercial, and agricultural organic waste into locally-generated renewable energy and soil products with zero waste.

- This study is funded by and paid for by Puget Sound Energy. PSE is committed to promoting the expansion of renewable energy sources by funding studies like this; bringing together key stakeholders to facilitate discussion; and providing relevant expertise. PSE's intent is to help uncover viable project opportunities that developers and/or the community can move forward on Bainbridge Island to own and operate; with PSE as the interconnecting entity.

The Problem

- **Wasted Resource:** On Bainbridge Island – the food waste rate is 40% of all food produced (i.e. US avg)
- **Export to Landfills and Composting:** On Bainbridge Island approximately $600,000 is spent moving 11,000 tons of waste over Agate Pass by truck annually. Traffic = approximately 2,750 truck trips annually on the main traffic corridor.
- **Grid Energy:** Growing infrastructure demand and inefficiencies require more innovation to keep the island competitive and sustainable
- **Soil & Water:** 23 different pesticides have been measured in Puget Sound from petrochemical run-off (farm and landscape chemicals)

This Project: Bioenergy + Biofertilizer Generation



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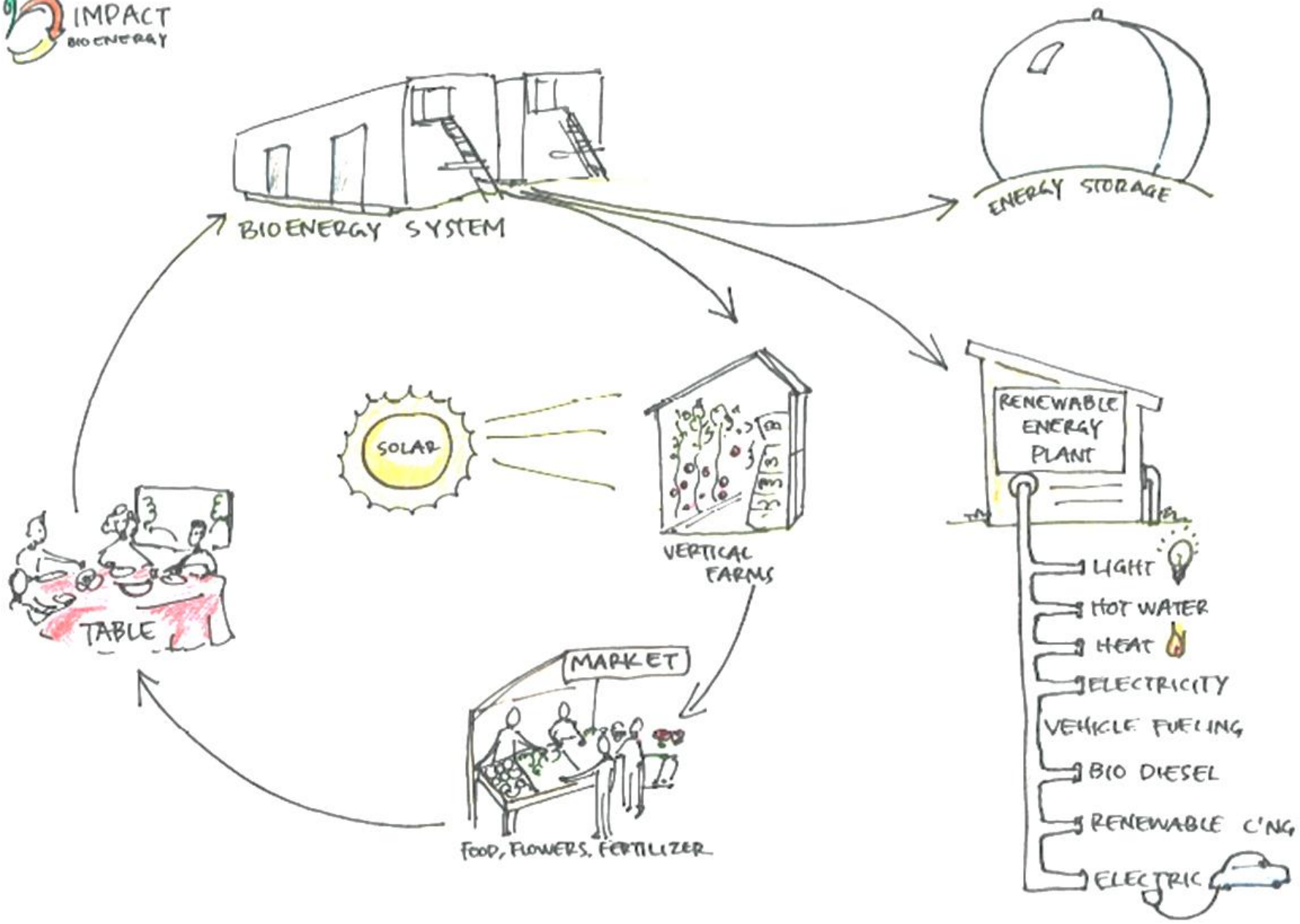

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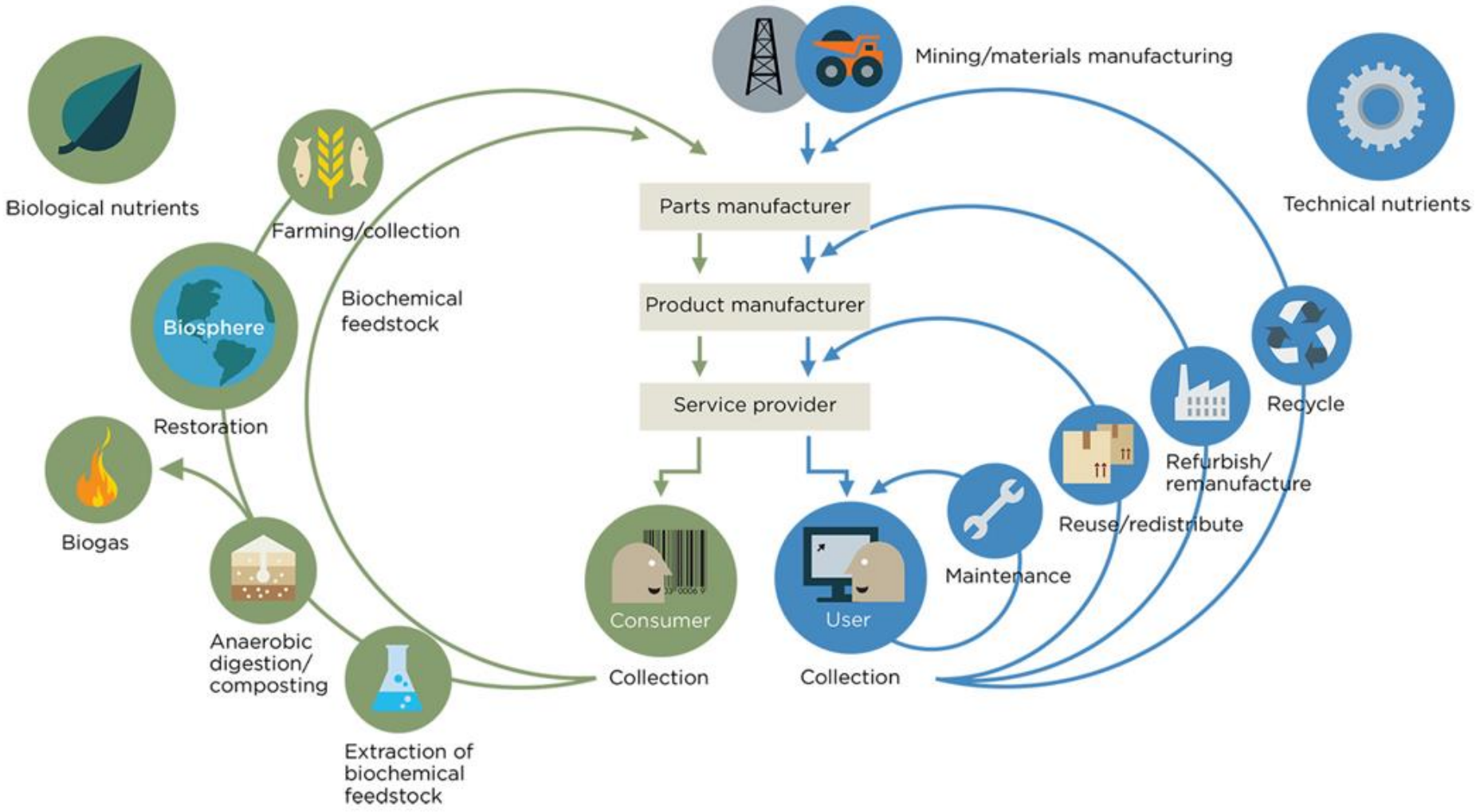


Scope of this Technical Memo

- This Technical Memorandum evaluates the potential of commingling the three organic feedstocks into a single recycling process. The service would include an anaerobic digester on Bainbridge Island to accept:
  - Commingled food, paper products, compostable foodservice products (including compostable tableware), landscape waste and animal bedding
  - Commercial, residential, and agricultural organic wastes in a commingled state (not just commercial as described in TM No. 1)
- This service could be configured as an Island-only option, or an island-plus Poulsbo and Clearwater Casino option. It would also include the concept of a finishing facility for the digester output, which uses drying, composting, screening, bagging, and soil blending. The concept design herein includes a summary of feedstock potentials, corresponding energy production possibilities, and other outputs with costs and/or revenue streams.

Summary Conclusions

- Recycling Potential 7,200 – 11,000 TPY
  - 1,800 – 2,750 truck trips per year off island
- Energy Potential 0.23 – 3.5 MW
  - 160 – 1,100 homes per year on island
- Fertilizer Potential
  - 8,400 – 11,300 CY per year
  - 8 tons per year dry product
  - 18,000 gallons per year liquid product
- Capital Bandwidth $3.9 -10.9 MM

Scale

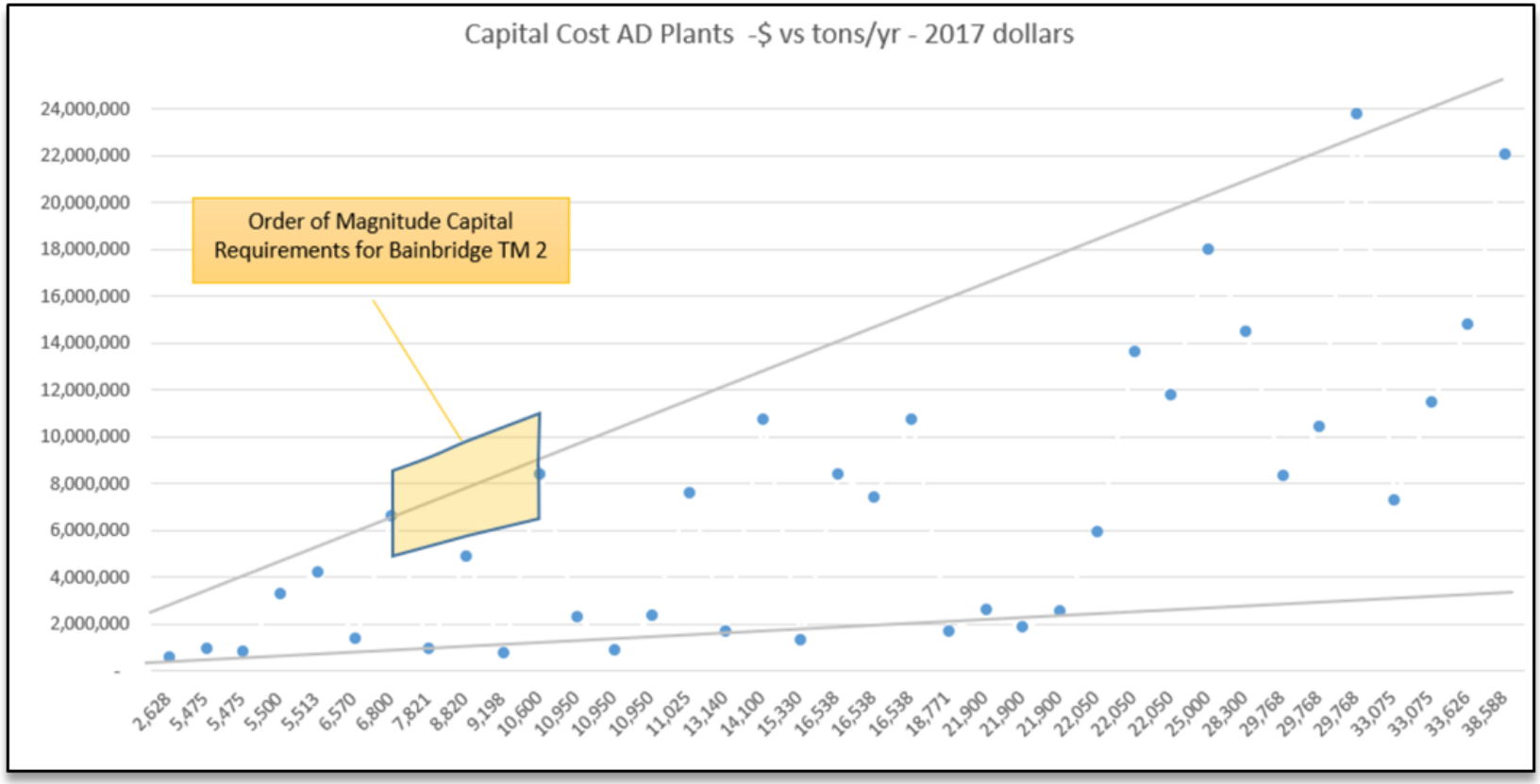
- The concept was first applied to a smaller Bainbridge Island facility without off-island organic materials or municipal biosolids. This is the minimum effective planning size (7,200 tons per year of Tier 2 feedstock).
- Then the Poulsbo area and a portion of the municipal biosolids were added for the maximum effective planning size (11,000 tons per year Tier 2 feedstock). This approach provides a bandwidth of potential capacity in the year 2035 that has been used for capital cost opinion and land requirements.
- This approach assumes Tier 1 feedstock (4,200 tons per year) is being processed by others.

Elements to Achieve a Successful Project

The key elements for success in this type of project are shown below.

- Adequate financial capital to build and operate the facility
- A suitable real property site that is compatible with traffic, utilities, and land use
- A collection system that addresses economics, source separation education, and contaminant control
- A practical plan for the beneficial use of the renewable energy
- A practical plan for the beneficial use of the organic matter, water, nutrients and probiotics in the digestate or compost or soil products
- A strong partnership with local farmers and the land and landscape

Capital Cost



Capital Cost

Using the upper and lower boundaries in the following chart; our cost opinion reveals a wide variability in capital estimates. As the design process progresses the upper and lower boundaries can be brought closer together with greater confidence. The table and graph below show the lower and upper estimated cost.

Order of Magnitude Capital Cost Opinion

	calculated	min	max
small	$ 6,597,368	$ 5,100,000	$ 8,600,000
large	$ 8,411,457	$ 6,500,000	$ 10,900,000

Significance of Product Marketing

- It should be noted that this conceptual design is presented as a zero waste plan with only the disposal of incidental contaminants. All the outputs from the facility are monetized.
- This is expected to be possible for Bainbridge Island and vicinity. The interest in community supported agriculture and sustainable practices is high. The income and avoided costs show a value stream for recycling services, renewable energy, carbon credits, and plant food/soil amendment sales.
- These together represent a significant value stream to offset capital and operating costs.

Significance of Product Marketing

- We have conducted a market survey of plant food/soil amendments marketed at the retail level.
  - Liquid products are often concentrated and represent a dehydrated version of what might be discharged directly from the digester. The pricing ranges from $18 to $140 per gallon.
  - Likewise the retail pricing for comparable dry fertilizer product is $2 to $7 per lb., and the retail pricing of compost is $30 to $40 per cubic yard.

- This illustrates the potential for value-added marketing and branding of a new liquid product into this market.
  - This concept design illuminates a noteworthy water conservation dynamic for Bainbridge Island. Theses organic products may be valuable in the overall sustainability and irrigation demand dynamics during the dry summer months on Bainbridge Island. It can reduce demand on potable and groundwater sources. More discussion on this can be found in the Market Development of Soil Amendments below.

Summary of Project Benefits

- Production of continuous, onsite, renewable energy. The energy can be stored at night and used during the day if necessary. It does not depend upon sunlight or wind for production.
- Elimination of foodwaste dumpsters with the associated odor, birds, flies, rodents, insects, and leakage that foodwaste can produce.
- Elimination of the hauling, fuel use, and traffic impacts associated with trucking waste from the city to a distant processing facility. This reduces urban traffic congestion as well as truck exhaust emissions.
- Conversion of the organic materials into valuable plant food, compost, and fertilizer. This can be returned to the soil to improve the sustainability of local gardening.

Summary of Project Benefits

- New employment of people in the conversion of waste to bioenergy, commercial products, and the local food supply chain industry, sometimes referred to as a circular economy.
- Collaboration with local educational curriculums such as culinary arts, horticulture, sustainable agriculture, viticulture and wine technology, engineering, environmental science, business, biology, and education.
- Achieving significant diversion of waste from disposal, moving the city closer to zero-waste goals.
- Improving the local soil-water-air ecosystem by returning carbon to the soil and displacing the need for chemical fertilizers, pesticides, and herbicides.
- Improving the opportunities for farm-to-table food production and healthy food networks which will improve the well-being of its communities.

Thank You

Scale

population	24000	10000	34000	43000
AD ONLY + PRIVATE COMPOSTING Selected for TM 2 Design	Bainbridge tons/yr	Poulsbo tons/yr	Total tons/yr	2035 tons/yr
commercial food waste	1,500	500	2,000	2,500
commercial paper waste	450	250	700	900
commercial landscape waste	200	50	250	300
residential food waste	1,000	-	1,000	1,300
residential paper waste	200	-	200	300
residential landscape waste	1,100	-	1,100	1,400
manure and bedding	500	-	500	500
biosolids	3,800	-	3,800	3,800
Subtotal Bainbridge Island only	4,950		5,750	7,200
Subtotal with Poulsbo & Biosolids	8,750	800	9,550	11,000
tons by sector	Bainbridge tons/yr	Poulsbo tons/yr	Total tons/yr	2035 tons/yr
commercial	2,150	800	2,950	3,700
residential	2,300	-	2,300	3,000
manure	500	-	500	500
biosolids	3,800	-	3,800	3,800
Subtotal	8,750	800	9,550	11,000
Min size, tons/yr	7,200			7,200
Max size, tons/yr	11,000			11,000

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Energy Potential

CHP sizing	Small Concept	Large Concept
tons/yr	6,810	10,610
BTU/hr gross	2,516,976	3,921,456
gross kW	737	1,148
electric efficiency assumed	38.5%	38.5%
kW output typical, 24-7 basis	284	442
heat output typical btu/hr	1,065,939	1,660,737
heat output typical therm/day	256	399
thermal efficiency	42%	42%
no of CHP units	2	2
peak output kW all units	600	900

Daily High Efficiency Generation Rate	**6,800**	**10,600**	**kWh per day**

Examples of Generator Sizing in KW

Generation Alternatives		Smaller	Larger	
Electric only	low efficiency	230	360	24/7 baseload
CHP (heat not shown) base case	high efficiency	280	440	24/7 baseload
CHP (heat not shown)	high efficiency	840	1,300	8 hr/day peak
CHP (heat not shown)	high efficiency	2,200	3,500	3 hr/day peak

Organic Product Potential

- The conversion of the soil amendments into commercially valuable products is equally important to the renewable energy generation. The table below shows the expected annual finished product value stream for both the small and large concepts.

Finished Product	Small Concept	Large Concept	
Compost	8,400	11,300	CY/yr
Dried Fertilizer 80%	8	8	tons/yr
Liquid Plant Food 20%	18,000	18,000	gal/yr

Value Engineering

A value engineering exercise was performed to evaluate opportunities to manage costs down if necessary. The capital cost could be lowered using any or all of these changes in the overall basis of design.

- Separating the composting/finishing process from the bioenergy process, with composting of Tier 2 feedstock discharged by the anearobic digestion system to be performed by an existing third party contractor at a different location.
- Phasing the scale of development into two distinct phases between now and 2035. This would de-risk the capital investment to some degree by insuring full potential and appropriate scale is reached initially.
- Elimination or delay of the liquid CSTR digester. Presuming the liquids can be initially managed within the continuous HSAD digester.
- Reduction of the size of the gas storage elements in the bioenergy process. The current concept allows for a 24 hours of biogas production to be stored for energy generation. If this were reduced the cost of gas storage could be reduced proportionately.
- Innovative contracting methods with incentives for cost underruns and collective risk minimization may reduce the overall capital cost. Developing win-win contract terms can sometimes yield quicker and more cost-effective construction without reducing quality.

Value Engineering

- Applying the compounded potential of all five elements described above creates a Cumulative Potential in reducing Capital Cost. The overall potential is shown below – representing a focal point to strive for, for cost management. This may not be completely feasible given the specific evolution of the project but illustrates how to manage capital cost.
- The land requirements for both the small and large versions of this concept design range from 1.4 to 1.6 acres. Site diagrams were prepared to show the relative size of each element and what the facility might look like in plan view.
- Cumulative Potential Results of Value Engineering

Order of Magnitude Capital Cost Opinion

	calculated	min	max
small	$ 3,958,421	$ 3,000,000	$ 5,100,000
large	$ 5,772,510	$ 4,400,000	$ 7,500,000