Stephanie Bower, Architectural Illustration

Yesler Terrace

Sustainable District Study

Final Draft

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District Energy System Findings

GX/S System. Among the sustainable district energy system options defined by the Seattle Housing Authority (SHA) /CollinsWoerman (CW) team and analyzed by energy consultant WSP, the single loop hydronic system of circulating water at 73 degrees F maintained at temperature by a geo-exchange/solar hot water sources (GX/S) appears to hold the most promise for the Yesler Terrace redevelopment. It has a total projected energy cost for the development comparable to the business-as-usual (BAU) baseline under any of the base case and sensitivity analysis scenarios considered, and offers an added combination of sustainability, environmental benefits, and financial risk mitigation. These would be achieved through selection of onsite renewable fuel sources, relative simplicity of design, greenhouse gas reductions, and risk mitigation through avoidance of exclusive reliance on electricity or any single fuel.

Further analysis of this option, in addition to refining system design options and cost estimates, would allow SHA to explore more fully the opportunity to coordinate such a system with the sustainable district integrated water system described below, using sewer heat recovery as an additional environmentally sound and economical fuel source for a portion of the district heat system's requirements. **These performance features are sufficient to recommend further detailed, site-specific design and cost analysis of the GX/S option.**

District Heat Options. The natural gas-fired district heat option could, under best-case economic assumptions, provide similar economic performance outcomes to those for the BAU and GX/S options. Those best-case assumptions include significant revenue from Harborview or some other comparable user in an assumed market for excess heat that could buy down the net cost of the district heat system. While those hurdles may be overcome, this option does not offer the same range of sustainability and environmental benefits as the GX/S option unless it is able to displace high-GHG energy use through sales to Harborview. It may also entail greater upside cost risk than the GX/S district system due to its reliance on natural gas. **However, given the conceptual nature of these preliminary estimates and analysis, the natural gas-fueled district heat system with a surplus heat market has sufficient benefit to recommend further detailed site-specific design and cost analysis.**

District Water Reuse System Findings

Central Water Reuse System. Based on this conceptual level analysis, the central district water reuse option is an attractive strategy for development at Yesler Terrace. The water reuse system with the greatest potable water use reduction produces the greatest economic and environmental benefit, and further analysis should attempt to define the widest range of uses feasible. The source water for this system would be total ("black") wastewater, collected from sewer pipes within the development and diverted to the reuse facilities.

The central water reuse system would also provide environmental benefits, including reduced CSO volumes and greater preserved in-stream flows, and may improve the efficiency or lower the cost of other Yesler Terrace district systems such as a district energy system and the community gardens. **These performance features of a district water reuse system based on total wastewater are sufficient to recommend further detailed, site-specific design and cost analysis of the option.**

In addition to the central water reuse system, collected rain water or stormwater may warrant consideration as partial source for irrigation needs, on a decentralized basis.

District Solid Waste System Findings

District Yard Waste Compost System. Three-bin composting systems, including collecting and composting sufficient yard debris to serve the needs of the Yesler Terrace community gardens and district landscaping is a sustainable, low-cost, relatively simple option for Yesler Terrace.

With this internal demand served efficiently and economically, SHA collection and transport of any remaining organics generated on-site to an off-site processing facility (e.g., Cedar Grove) ensures a sustainable outcome for that portion of the compostable waste stream as well. **Additional study does not appear to be necessary, and it is recommended that an on-site, self-supporting three-bin compost system be included in Yesler Terrace site planning going forward.**

District Transportation Program Findings

Transportation Management District. Development of a Transportation Management District can fund parking and manage mobility programs required on the site. The TMD can consider development and management of consolidated parking facilities that serve multiple users. The TMD may be vested with the authority to raise capital for parking infrastructure offset by parking revenues and professionalize compliance among and between the property owners. **Based on these potentials, it is recommended that further detailed analysis be conducted for this option. All other transportation options remain open for inclusion in later phases of the design and development of Yesler Terrace.**

Seattle Housing Authority

Yesler Terrace illustrations by Stephanie Bower

Seattle Housing Authority (SHA), established in 1939, is a public corporation governed by a seven-member Board of Commissioners. The agency owns and operates buildings on more than 400 sites throughout the city, and provides long term rental housing and rental assistance to more than 26,000 people.

Since 1995 SHA has completed major public housing redevelopments of the NewHolly, Rainier Vista, and High Point developments into mixed-income, mixed-tenure communities that have transformed these areas into new neighborhoods within the City of Seattle, encompassing nearly 300 acres and creating approximately 4,300 new units of housing, as well as new infrastructure, parks and community facilities. The redevelopment plans at NewHolly, Rainier Vista and High Point have featured increasing commitments to sustainable development and increasing incorporation of green design features. At the most recently completed High Point project, SHA implemented an aggressive and highly successful green building and low impact development program in partnership with the Built Green program and Seattle Public Utilities.

Yesler Terrace

The Seattle Housing Authority (SHA) is proposing redevelopment of Yesler Terrace, a public housing community located on the southern slope of First Hill in Seattle. The 36-acre (including rights-of-way) Yesler Terrace Redevelopment site currently contains 561 public housing units, a community center and various other office spaces that primarily provide social services or serve as the administration offices for service providers. Redevelopment is proposed in order to create a mixed-income, mixed use community that is intended to better serve existing and future residents.

At the initiation of the planning effort, SHA convened a Citizen Review Committee who developed a set of Guidling Principles for the redevelopment. The Environmental Stewardship and Sustainability principles encouraged sustainable design for a positive and healthy community for current and future generations.

The Proposal and Alternatives include a mix of affordable and market-rate housing, commercial and community services uses, as well as parks and open space, and vehicular, pedestrian and bike improvements. It is anticipated that redevelopment of Yesler Terrace would take approximately 15-20 years to complete. This site is ideally suited to become a showcase sustainable community. It is centrally located within one mile of the city's largest employment area, which contains 25% of Seattle's jobs. SHA, in coordination with residents, neighborhood stakeholders and consultants, plans to build a dense, pedestrian-oriented, mixed-income, and diverse urban community consistent with surrounding uses and future land use and neighborhood plans.

SHA recently released a Draft Environmental Impact Statement (DEIS) that examines several alternative development scenarios. The three primary scenarios all increase Yesler Terrace density by varying degrees and include both increases in the number of residential units beyond the existing 561, and varying amounts of additional office space, as well as iImproved and expanded open space amenitities. This Sustainable District Feasibility Study assumes the middle-density alternative, called "Alternative 2," as the basis for analysis. Alternative 2 proposes 4,000 new residential units in a mix of mid-rise buildings and towers of between 150 to 240 feet in height. It also proposes one million square feet of office space, five acres of open space, and underground parking.

Origin of the Sustainable District Feasibility Study

SHA is currently developing and refining a plan for installing and in some cases replacing infrastructure systems at the site of the Yesler Terrace redevelopment. At minimum, the infrastructure systems will be built to meet all applicable development codes and standards. Preliminary analysis places the infrastructure costs at more than $90 million. [citation]

The City of Seattle has indicated that plans for aggressive sustainability performance by the redevelopment will be welcome. SHA, with support and participation from the City of Seattle, and partner funding from Seattle Public Utilities, has responded by sponsoring research of the feasibility of sustainable district infrastructure options at Yesler Terrace.

Opportunity for Sustainable District Systems

Multiple options exist for infrastructure replacement or improvements. Many of the more well-established approaches to sustainable development and green building design are geared toward parcel scale application. Parcel-scale sustainability best practices typically include sustainable site planning and green building that are facilitated by individual parcel developers. In the aggregate, this strategy could be expected to deliver reduced resource use intensity (RUI) for the development as a whole, while solutions designed for application across an entire redevelopment may be able to achieve much greater conservation and reductions of RUI for the Yesler Terrace site through economies of scale and potentially escalating community environmental and social benefits.

Most development projects do not have the advantage of considering and planning redevelopment at a larger neighborhood, district, or multi-block scale. The Yesler Terrace redevelopment offers a unique opportunity to leverage the multi-block scale of development, with a single initial property owner, in order to explore the application of innovative district solutions that would not be feasible at the individual parcel scale.

SHA intends to pursue the highest levels of sustainable design economically feasible for the project, which should take the project beyond a code-compliant minimum performance level. Identification of the most efficient infrastructure practices suited to the Yesler Terrace redevelopment requires a broad review and evaluation of the potential for district level designs and conservation opportunities across all major infrastructure systems including energy, water, and solid waste. Transportation strategies were initially considered and many options will be further considered in subsequent phases of the project design and development.

Definition of Sustainable District Systems

What are sustainable district systems?

This term refers to infrastructure systems within major public service areas that are scaled and designed for efficient, environmentally sound, resource conserving application at a "district" scale.

Contemporary urban infrastructure systems tend to operate at very large centralized scales. Large-scale systems can take advantage of economies of scale, which in turn can lower costs to consumers, and they can usually provide consistent high levels of service.. Electricity generation and distribution systems are usually regional and county- or city-wide in scale, respectively. Similarly, water supply, wastewater treatment, stormwater management, and solid waste processing are typically implemented at a city-, county-, or region-wide scale.

In contrast, some consumers or institutions find it advantageous to manage infrastructure systems on their own at an individual scale. Increasingly both individuals and public agencies are recognizing the long-range value of resource stewardship, including preservation of scarce resources, and are seeking sustainable approaches to providing basic utility and infrastructure services.

Sustainable district systems are intended to incorporate the most efficient approaches of each of these areas. A district system can provide infrastructure services for a large institution, a neighborhood, or a community. District systems, selected and designed correctly, can provide economies of scale similar to those of a conventional system while still offering local control, flexibility, site suitability and resource sustainability potential available only in a smaller system.

Major Utility Systems and Typical Scale

SYSTEM	SCALE
Electricity generation	Regional
Electricity distribution	City/County
Water supply	Metropolitan area
Water distribution	City
Wastewater collection	City
Wastewater treatment	Metropolitan area
Stormwater management	City
Solid waste collection	City
Solid waste processing/disposal	Regional

Benefits From Sustainable District Systems

What are the benefits of a sustainable district system versus those of conventional and individual systems?

District infrastructure systems can offer a broad range of potential benefits over larger- or smaller-scale systems. They range from strictly economic savings to environmental and social benefits. General types of benefits associated with various sustainable district systems include the following:

- **Efficient Design Scale.** District energy systems can be designed at a scale that can take advantage of locally-available resources (wind, solar, water, or geothermal energy, for example) that may not be plentiful enough to serve a regional utility. Keeping entire resource cycles within a local area can significantly lower transmission or transportation costs. And any excess capacity created by a district system can often be sold.
- **Sustainable Local Resource** Use. Use, reuse and recycling of locally available resources is often the basis for a sustainable model for long-term service. For example, a district wastewater treatment facility can make more efficient use of water resources in order to meet the district's overall water needs.
- **Positive Externalities.** District systems can produce external benefits for the larger conventional infrastructure systems that would normally serve the district, such as shifting the cost to meet peak loads off the centralized system. Adding capacity in district systems means that regional utilities can defer or avoid costs for system expansion, thereby creating cost savings and capacity benefits to the region.
- **Resiliency.** Creation of districts with a decentralized model of service delivery can also make larger central systems more flexible and resilient, and better able to respond to emergency situations, incremental changes, or technological advances due to the semi-autonomous nature of district systems. If a centralized system is stressed in extreme weather or suffers a system failure, a district system can often

continue to provide services to district customers for a period of time.

- **Synergy.** There can be potential economic benefits from synergy among two or more district systems when multiple infrastructure systems work together. The ability to make use of local, renewable energy sources and to use waste products as inputs for other systems, which can help lower costs to consumers or offset increased levels of service.
- **Environmental Value.** Reliance on renewable and reusable resources can reduce the ecological footprint of district systems.
- **Community Value.** The community can benefit in other ways from a district system. Local ownership and local control of infrastructure systems can foster better understanding of those systems and a sense of connectedness and empowerment, as well as better control of the costs associated with the systems with respect to the users.
- **Local Job Creation.** The construction, operations, and maintenance of system facilities can provide local jobs or training opportunities.
- **Community Identity.** The use of sustainable systems or renewable resources can enhance the reputation of the community and be a source of pride and identity.

Sustainable District System Feasibility Study Goals

The recognized opportunity explored by the Sustainable District System Study is district-scale infrastructure and utility system designs that are made possible by the scale of the Yesler Terrace redevelopment project. The purpose of the Sustainable District Feasibility Study is to explore and analyze these alternatives relative to the "business-as-usual" approaches to providing infrastructure services to the planned redevelopment of the Yesler Terrace neighborhood.

Identify Candidate District Systems. Identification of best sustainable practices suited to this redevelopment requires a broad review and analysis of the potential for district level designs and conservation savings for infrastructure systems including energy, water, solid waste and transportation. This study aims to develop a diverse and comprehensive set of possible solutions and integrated strategies that could reduce the environmental footprint of the Yesler Terrace redevelopment and deliver greater efficiencies to the SHA, future residents and property developers, and the City as a whole.

Profile of a Sustainable District System Candidate.

We typically convey and treat all the water that comes into the system at a large centralized plant. But due to rapid increases in technology and the subsequent lowering of costs, it is now cost effective in many markets to treat wastewater at the building or district scale. At this scale, we can reduce sanitary flows by 50% or more, and have a reliable flow of reclaimed water that is of sufficient quality for non-potable purposes such as toilet flushing and landscape irrigation. Such systems have been in place and working successfully for over 20 years. What has changed as of late is that the relative economic cost and environmental footprint of a more traditional approach is steadily becoming expensive and inflexible. In comparison both building-level and district systems are becoming more economically efficient and proving to be more flexible for addressing service needs in a time of changing demands.

Feasibility Review and Evaluation. The study's analysis will determine if more sustainable infrastructure solutions can be implemented to deliver comparable or better service than traditional approaches, while also maintaining comparable or better economic performance. Thus, the analysis seeks to identify and quantify the potential service levels that can be attained and associated financial savings that may be achieved through the use of these best practices.

Based on the preceding aims, the **overriding goal of the study** is to provide cost-benefit analysis in order to inform SHA's selection of specific district systems for design-level analysis, as well as to inform and support City of Seattle decision-making regarding infrastructure system requirements and funding in the entitlement process.

Sustainable District Feasibility Study Process

Concepts were initially generated through a design charrette that culminated in expert definition of a number of options. These concepts are expanded and evaluated in this Report. The most promising of them will be selected for the Master Plan.

Design Charrette. In stage one, a team of industry experts, known as the Synergy Team, was selected and asked to participate in an intense, integrated design charrette to generate district infrastructure options for the project. This two-day charrette, held in December 2009, brought together the Synergy Team and local experts, along with City of Seattle staff and Yesler Project Team members, to develop a diverse and comprehensive set of possible district strategies to reduce the environmental footprint of the Yesler Terrace Redevelopment and deliver greater efficiencies to future residents and the City as a whole. Three sub-groups were convened on the second day of the charrette to distill promising options in the areas of energy, water, solid waste and transportation systems, and a fifth sub-group focused on barriers to be addressed in evaluation of any of the candidate systems. The Charrette Summary is attached in Appendix A.

System Feasibility Study. Stage two of the Study is an extensive feasibility study of the list of options emerging from the Charrette, as further refined by the Yesler Terrace Project Team. It began with the selection of a small group of three expert sub-consultant firms, in energy, water and solid waste, to address specific candidate systems in their respective areas. The Project Team assigned other key research roles to a special City Barriers Analysis Team and to Collins Woerman for compilation of transportation strategies. The results of these various studies were assembled, and combined with additional operational, economic, environmental and feasibility analysis by the Collins Woerman team. This report presents the results of

This analysis consists of review and evaluation of several alternative systems within each infrastructure area at a conceptual feasibility level, combined with sufficient quantitative information on performance and cost to support decisions on preferred options for further study.

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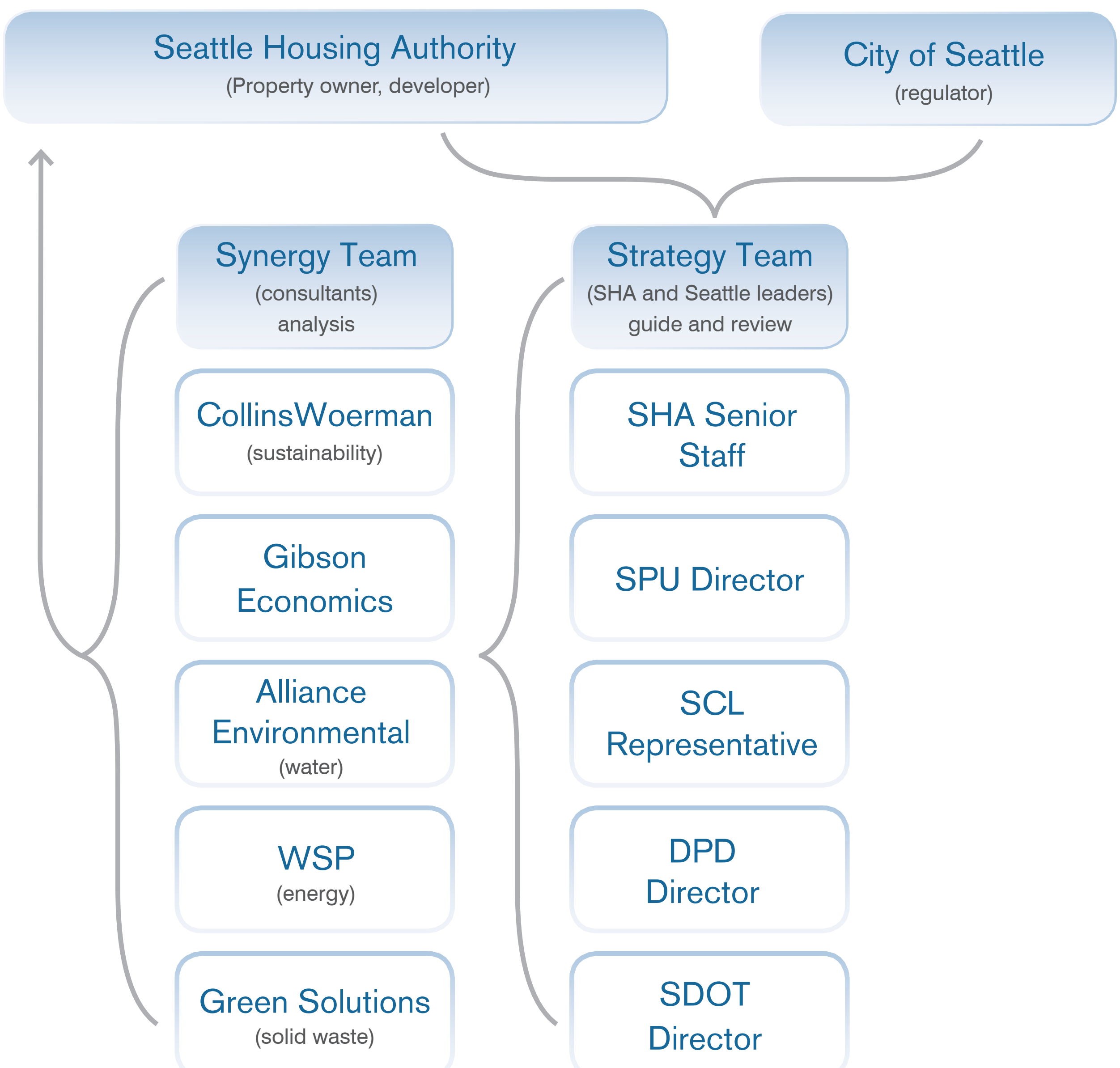
Next Steps. Next steps will include a refined, design-level analysis of the short list of promising sustainable district system concepts selected by SHA and the City of Seattle based on the analysis and evaluation in stage two. It is anticipated that this analysis will include more specific site location and facility design information tailored to the emerging Yesler Terrace Redevelopment plan, and that it will include a more thorough, design-level analysis of the costs of the systems. This analysis will not be component of this study.

A diverse assortment of groups were involved in developing the Sustainable District System Study. The organization chart below describes the complex interactions and contributions involved.

Organizational Chart:

Yesler Terrace Sustainable District Feasibility Study



I. Project Background

Overview Of Sustainable District System Feasibility Evaluation

Report Coverage

This second stage of the Sustainable District Study presents a preliminary assessment of the range of promising concepts identified in the Yesler Terrace Design Charrette. Expert sub-consultants in energy, water and solid waste expanded those concepts and prepared reports describing the sustainable system candidates in more detail and addressing major pros and cons of each. Additional examination of feasibility and implementation issues, as well as additional economic performance analysis, has also been included.

This report encompasses the entire Yesler Terrace redevelopment site (i.e., District) and evaluates sustainable options for the following utility or infrastructure systems:

- District heat, cooling or power,
- Water supply, and wastewater and stormwater management, including reuse,
- Solid waste systems, particularly recycling and composting, and
- Transportation systems and programs.

Among these service areas, energy, water and transportation systems all involve significant infrastructure systems that will be replaced or expanded as part of the redevelopment, while solid waste services rely on a combination of on-site source separation by residents and businesses, combined with vehicular collection and removal. Energy, water and solid waste services are all utility services with clear potential for district-scale service models, while transportation systems will conform to City standards, with potential for primarily programmatic approaches to transportation mode split. These distinctions influence the structure of the report sub-sections devoted to each of the four service areas.

Evaluation Steps

The study examines both the operational and financial aspects of sustainable district system candidates and the complexities associated with regulatory and policy barriers they might face, the involvement of multiple financial entities. This study:

- Evaluates them for supply adequacy, feasibility, economic, and environmental performance, and
- Assembles information on probable requirements for their implementation at Yesler Terrace.

The sequence of steps that is followed in **Section II** for each of the four service categories includes the following:

Define business as usual

Identify candidate sustainable systems

Estimate system capability

Define components

Prepare Triple Bottom Line feasibility

Assess issues of implementation

Define A "Business As Usual" (BAU) Option. Establish a baseline to both support the appropriate design for sustainable options and to define economic and environmental outcomes against which to evaluate them. This includes demand projections and supply requirements for energy, water, and solid waste management service approaches, as well as the specific nature of the BAU service approach for each.

Identify Candidate Sustainable System Options. These include both infrastructure designs and programmatic measures. One or more conceptual "on-the-ground" versions is developed for each infrastructure option, in sufficient detail to support feasibility assessment.

Estimate Sustainable Options' Capability. Project the physical performance profile and service levels for each candidate sustainable district option, including what portion of the baseline service requirements it can provide or what portion of the baseline flows or waste stream it can manage.

Define Specific District System Facility Components. Develop conceptual design information to support evaluation, including lists, descriptions and sizes of the following:

- **Space Needs.** Specific estimates include system footprint and land use requirements.
- **Central Facilities.** These include general site supply structures, pipes and service facilities.
- **Building Requirements.** These encompass all building-specific installation requirements.

Prepare Triple Bottom Line Feasibility Evaluation. Evaluate alternatives from a 'Triple Bottom Line' perspective, which encompasses performance and impacts in the following broad categories:

- **Financial Performance** – The net benefits that can be achieved with a district system need to be quantified over and above the benefits that can be achieved using parcel scale only strategies, which are assumed as part of the BAU baselines. The net benefits are estimated and presented using a variety of relevant measures, including NPV, annual cost streams, payment and benefit shares of various parties, and aggregate system cost comparisons, with the appropriate measures tailored to the service area being evaluated. The financial performance information also includes sensitivity analysis of the impacts of uncertainty concerning relevant factors for each district system.
- **Environmental Impacts** – The range of environmental impact information presented includes both quantified impacts where feasible, and descriptive information for other impacts. The relevant impacts vary among the four major service areas.**Social Impacts and Implications** – These impacts are presented primarily with descriptive information, covering a wide range of considerations.

Assess Implementation Issues. The candidate sustainable district systems generally depart in some way from the established BAU approach, and would require revised implementation procedures. These in turn may face certain feasibility barriers. Each subsection addresses these implementation requirements and potential barriers, and provides information on the steps that would be required to realize the potential of a district system.

Level of Detail and Metrics

Feasibility-Level Analysis. This study has been completed using preliminary project information and pre-design data on candidate sustainable district systems that was available for an efficient, conceptual-level feasibility analysis. Both the large, long-term nature of the Yesler Terrace redevelopment and the wide range of sustainable candidate service options suggest keeping this initial review at a feasibility-assessment level. As such, this study can be considered a foundational document to aid decision-makers in selecting which candidate strategies to pursue further. Based on those decisions, additional, more refined analysis can be outlined and undertaken.

Mix of Quantitative and Narrative Results. In addition to providing information and evaluation at a conceptual level, this report seeks to provide a broader range of information by providing a mix of descriptive narrative and quantitative metrics. Some portions of the study and some impact topics are supported by more detailed data, while some other portions and topics must at this stage rely on more uncertain or less precise data and assumptions.

In addition, the quantitative metrics employed and the specific types of environmental or social impacts are tailored to the types of sustainable district systems under consideration. For example, energy demands and impacts can most effectively be portrayed for end-use of demand that can be addressed by different supply options, while the economic impacts of those district systems for energy can be combined into an overall schedule of costs and an overall NPV. As another example, each candidate district system provides the promise of environmental benefits, but the nature of those benefits varies significantly from energy systems to water systems to solid waste and transportation systems. Consequently, the categories of environmental - and social - impacts addressed vary from one section to the next.

Planning For A Range Of Development Futures

Sources of Future Uncertainty

The extended Yesler Terrace development period makes it very challenging to project costs and performance of candidate sustainable district systems. This study attempts to illuminate the most likely ranges of conditions that may exist over the development period, and seeks to assess the impact of changes in those conditions as part of the evaluation of candidate sustainable systems' viability. Future uncertainty to consider involves both the Yesler Terrace redevelopment project itself and the environment in which it will emerge.

Yesler Terrace Development Plans. Future real estate development conditions are inherently uncertain when projecting even twenty years into the future. Assumptions can be made based on current development plans – but if and when those plans change in the future, the impacts on sustainable system implementation must also be re-evaluated.

Future Changes in Demands and Technology. The extended 15-20 year implementation of Yesler Terrace redevelopment also introduces opportunities for changing utility and transportation service needs, changing technology in rapidly emerging district and sustainable systems, and changing understanding of the environmental consequences of choices. It is inevitable that systems and technologies will evolve, and while the specific changes may be difficult to anticipate, the directions of change are in some cases more apparent, and can inform appropriate flexibility to incorporate in system design or timing. Key areas to monitor will include these:

- **Development Size.** The basis for the analysis done in this report is the middle-density development scenarios, called Alternative 2.The service demands and thus the district system designs would need to be adjusted to match any alternative development size scenario.
- **Development Phasing.** This report used current assumptions provided by SHA related to project phasing. Once phasing decisions have been made by SHA, this information may be used to adjust the estimates developed in any subsequent analysis.
- **Utility demand projections.** The service requirements of buildings at Yesler Terrace will change over time. This will be due to the code issues described below as well as such factors as the actual number and size of buildings, the number of residents and their utility use patterns, and changes in energy and water use efficiency. On the supply side, the actual sewer flows affects reuse system feasibility. All this information is crucial both for defining the BAU case and for defining appropriate conceptual design for and impacts of sustainable alternatives.
- **Future development codes and code interpretation.** There is also uncertainty related to future energy and stormwater code requirements that would affect both the baseline and sustainable district options for the project.

Planning for Change

This report provides guidance on dealing with future uncertainty in two ways. One is to emphasize information on system flexibility and suitability to phasing, both in terms of installation and financing. The other is to provide sensitivity analysis that helps illuminate the issues that may change system feasibility versus those that preserve the baseline feasibility outcome.

Minimize Risk. Even conceptual designs of district systems provide opportunities to manage the risk that future changes will require costly revisions or changes to designs and plans. This requires an understanding of how potential changes will affect the viability and performance of systems, and a forward-looking plan that can adjust to changes as they arise. Two perspectives that are applied to each service area are:

- ***Phase the implementation*** to maintain an efficient balance between supply and demand of resources and service, and to remain flexible to respond to further change. Phasing of work may involve extending a system over time or designing modular systems that can be replicated as needed through the site. In either case, the system plan must identify trigger points or thresholds that, when reached, make enlarged systems, additional system modules, or upgrades to equipment or technologies optimal.
- ***Find the solutions*** that are economically sound and perform well regardless of the actual pace of development or other potential revisions in implementation schedules. This may mean selecting district systems or equipment that can easily be upgraded or expanded as needs arise.

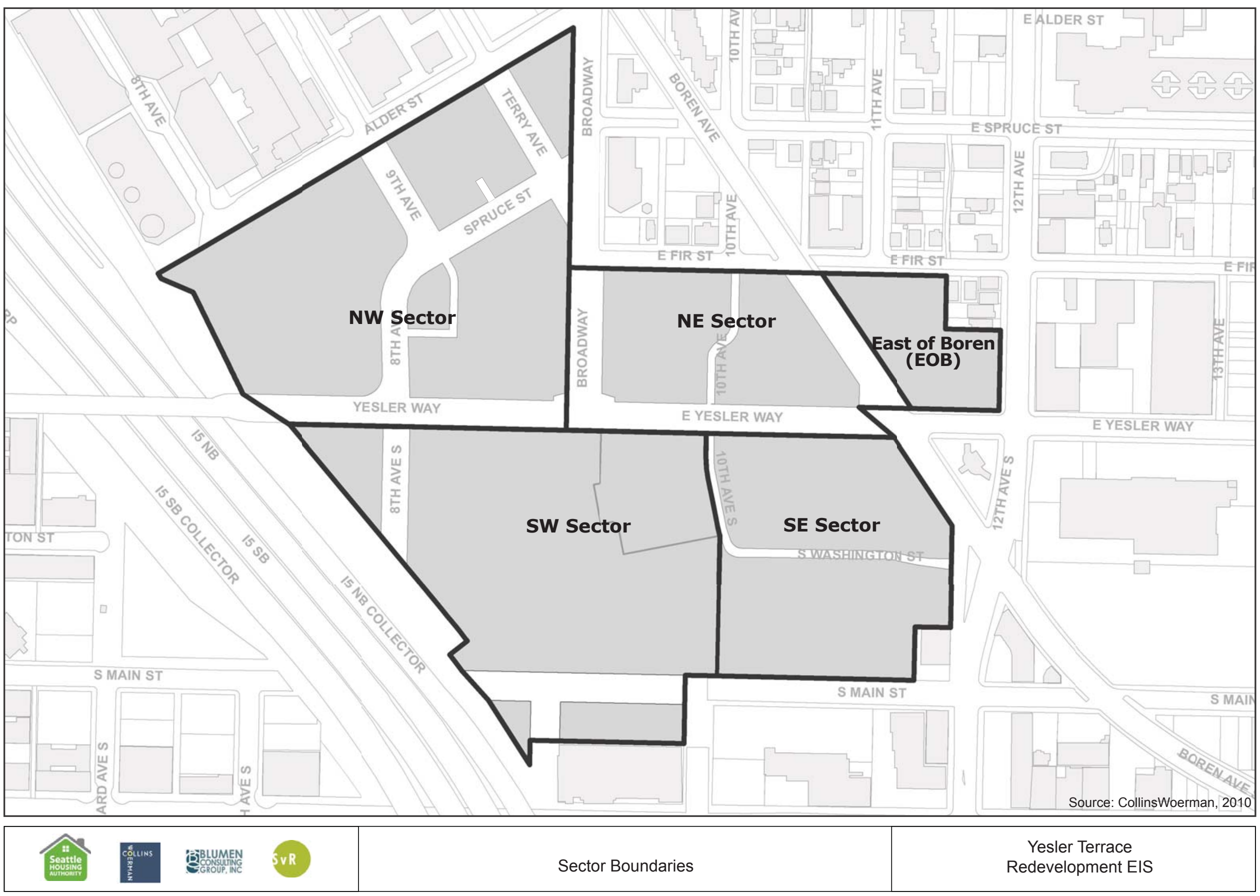
Sensitivity Analysis. The analyses presented in this report depend heavily on projections. In order to minimize the risks associated with the preceding sources of uncertainty, the report includes sensitivity analysis of key variables, to help understand the impact of alternative future conditions on the feasibility assessment results.

1. Background

The residential and commercial energy use at Yesler Terrace will include three main components: i) space heating and cooling, ii) water heating, and iii) “plug loads.” The “business as usual” (BAU) energy future of Yesler Terrace is assumed to feature electricity supplied by Seattle City Light as the primary source for serving all three of these types of energy demands.

The baseline level of energy use within the redeveloped Yesler Terrace site depends on several factors: i) the scale of the development - residential units and their size, and square feet of commercial and retail space, ii) the timing of the phased development of the four sectors of the site, which are shown in **Figure 1** below, and iii) the Energy Code provisions in place as each phase is developed.

Figure 1: Yesler Terrace Site Map, Showing the Five Sectors Listed in **Table 1**



Projected energy use by each type of building space is determined largely by the square footage of space. The assumed building square footage and the phasing of its construction at the redeveloped Yesler Terrace are shown in **Table 1**, including the assumed mixes of multi-family residential units and commercial space by geographic sub-area and time interval.

TABLE 1

Yesler Terrace Redevelopment Phasing Assumptions: Timing, Units and Square Feet by Sub-Area

Yesler Terrace Sector	Sector Completion Year	Residential Units	Residential Area, SF	Office Area, SF	Neighborhood Retail Area, SF
NE	2015	602	565,880	---	15,000
EOB	2015	253	237,820	---	10,000
NW	2020	1,055	991,700	1,001,126	20,000
SW	2025	1,129	1,061,260	---	15,000
SE	2030	961	903,340	---	---
Total		**4,000**	**3,760,000**	**1,001,126**	**60,000**

Source: WSP, October 2010.

It is anticipated that the Seattle Energy Code will continue to tighten its current standards to dictate more and more energy-efficient development as time passes. The detailed energy analysis performed by WSP for this study assumes there will be Code-driven energy efficiency improvements of 13-14% every five years. [Note: This is generally consistent with Washington RCW 19.27A.160, which establishes a goal for State Building Codes Council to improve the state energy code by 10% every 3-year code cycle from 2010 to 2031.] That means that the same type of space constructed to 2015 standards is assumed to consume 86-87% as much energy as similar space constructed in 2010, with additional five-year percentage improvements for the portions of Yesler Terrace constructed in 2020, 2025 and 2030.

The BAU baseline electricity use for Yesler Terrace corresponding to the Table 1 development plan, with increasingly tight Energy Codes over time, is shown in Table 2 below, in units of megawatt-hours per year.

The Code-driven improvements in energy efficiency assumed to occur in the next 20 years will require installation of energy efficiency measures beyond those typical for development today. The cost of those measures should be considered a baseline BAU cost of Yesler Terrace redevelopment, similar to the baseline area-wide energy distribution system infrastructure costs. The difference is that the Code-driven costs will be borne by the developer - either SHA or private - as the development occurs. They are included here for completeness, but do not represent a discretionary cost of sustainable district system choices.

Of the approximately 28,000 MWh per year of BAU electricity use at Yesler Terrace shown in Table 2, well over half is for plug loads, with area heating and cooling and domestic hot water uses accounting for

TABLE 2

Yesler Terrace Projected Electricity Use, All-Electric "Business-As-Usual" Case

Yesler Terrace Sector	Sector Completion Year	Annual Electricity Use, MWh
NE	2015	3,532
EOB	2015	1,489
NW	2020	14,827
SW	2025	4,734
SE	2030	3,359
Total		27,941

Source: WSP, August 2010.

the remainder. This total is approximately 25% less than the electricity use that would be projected for the same space at current Energy Code standards. That indicates significantly improved energy performance at Yesler Terrace in the future, even in the absence of sustainable district energy system options. It also reduces the scale of potential benefit from such sustainable district systems.

2. Sustainable District Options

Among sustainable district systems, energy system options represent the largest scale opportunities for Yesler Terrace. The potential for sustainable district energy options is inherent in the flexibility of energy sources and uses that can deliver the profile of energy needed at Yesler Terrace. On the demand side, space heating and cooling and water heating loads can be provided by either electricity or by non-electric sources. On the supply side, non-electric heating and cooling can be provided by non-electric furnaces or by circulated hot and chilled water. And even electric loads can be provided at least in part by electricity generated on site.

Assessing this range of supply and demand options, the project's energy consultant, WSP, identified two promising types of sustainable district energy options:

i. a geo-exchange/solar hot water (GX/S) system, and

ii. a combined cooling, heating and power (CCHP) system.

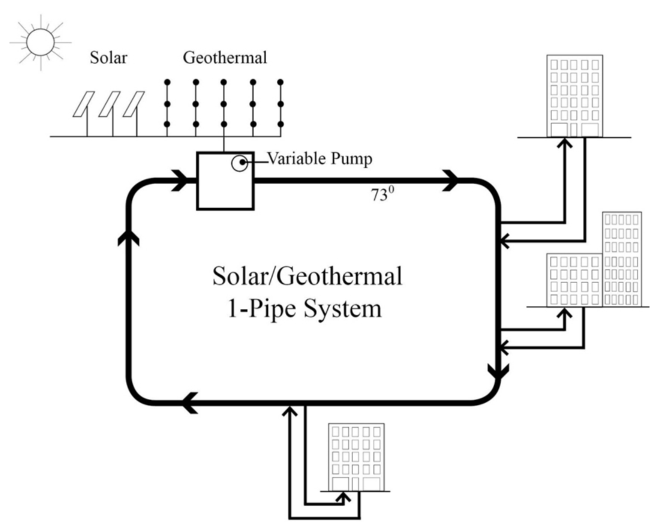
In addition, the Project Team explored a wider range of options from which these two were selected. Those primary options are defined and described below, followed by a partial listing and brief description of other potential sustainable district energy systems.

1. Geo-Exchange/Solar Hot Water System.

A geo-exchange district heat system is designed to extract usable heat from the ambient temperature of the deeper soil layers in the area, and could be designed to be augmented by a variety of additional fuel sources. The geo-exchange/solar hot water system identified by WSP would add energy from roof-mounted solar panels to supply a portion of water heating needs. Thus, it would use only on-site, renewable sources. It would be designed to serve 100% of the non-plug load portion of the Yesler Terrace energy needs, and could be scaled as a completely district source-fueled alternative for those uses, reducing residual electricity demands to just plug loads.

A schematic diagram of the key features of the GX/S district heating/cooling system is presented in Figure 2. As illustrated there, the system is relatively simple, with a main central loop circulating water throughout the site at a fairly constant temperature that is maintained by the heat contributions of ground source heat pumps and passive solar hot water installations. The central loop could also be installed and linked to building systems as several separate sub-district loops, to correspond to the development phasing.

Figure 2: Geo-exchange/Solar District System



Source: Collins Woerman, 2010.

Figure 3 shows a photo of the simple loop system required to circulate the water for a central loop GX/S system. Such a system could also operate with stand-alone geo-exchange units for individual buildings. The hydronic building HVAC requirements of a GX/S system and roof-mounted solar hot water panels are also integral parts of this sustainable district option. **Figure 4** shows an example of the type of room unit required to deliver the heating and cooling from such a system. **Figure 5** shows an installed bank of roof-mounted solar panels, similar to those included in the GX/S district option.

Figure 3: Photo of a Partially-Installed Loop During Construction

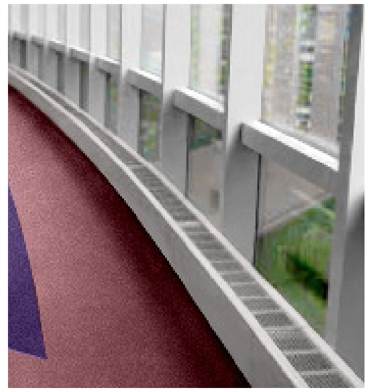


Figure 4: Photo of an Installed Hydronic Room Radiator Unit

Figure 5: Photo of an Installed Bank of Roof-Mounted Solar Panels

TABLE 3

Yesler Terrace Annual and Peak Electricity Use Impacts, “Business-As-Usual vs. GX/S District System

Yesler Terrace Sector	Annual Demand, MWh		Peak Demand, kW	
	BAU	GX/S	BAU	GX/S
NE	3,532	2,620	1,340	962
EOB	1,489	1,099	575	402
NW	14,827	11,266	7,255	3,758
SW	4,734	3,528	1,719	1,256
SE	3,359	2,517	1,182	885
Total	27,941	21,030	12,071	7,263
Savings	-	6,911	-	4,808
Savings %	-	24.7%	-	39.8%

Source: WSP, August 2010.

The energy supply capabilities of a full development GX/S system could serve the heating and cooling loads of the Yesler Terrace redevelopment. It would not supply the development "plug loads," and would require some additional electricity for water pumping in the central loop(s) and for system operation. On balance, the GX/S system would reduce net annual electricity demands from the future Yesler Terrace by approximately 25% from the BAU baseline levels, as shown in Table 3. The reduction in peak electricity demand would be higher - about 40%. This higher impact on peak demand is due to the GX/S system displacing the most peak-intensive space heating portion of the overall electricity demands.

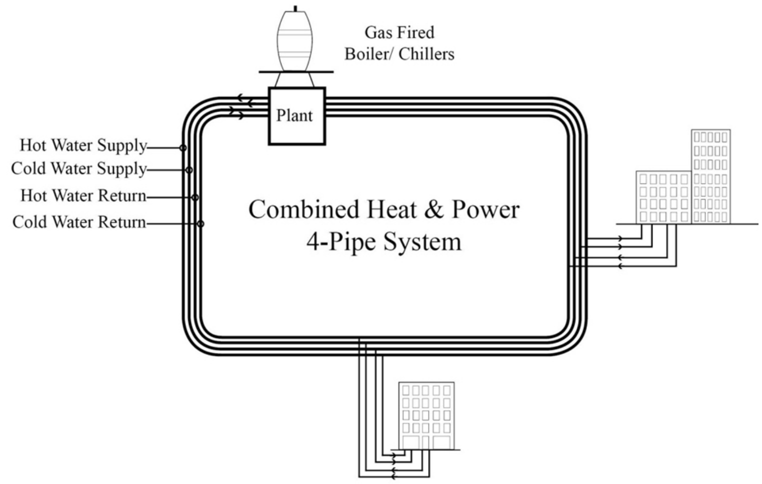
Note that the estimated energy savings shown in **Table 3** are calculated relative to a BAU baseline that already assumes levels of electricity usage of future Yesler Terrace residential and commercial space that is on average 25% lower than 2010 Seattle Energy Code levels. If future Code reductions are not as great as has been assumed, the baseline and thus the energy savings available from a GX/S system would both be greater.

2. Combined Cooling, Heating and Power (CCHP) System.

A CCHP system employs a central plant, which produces useful energy in three forms - hot water, chilled water, and electricity. CCHP systems can run on any of a variety of fuels or fuel mixes, a district CCHP plant could produce sufficient heat, chilled water, and electricity to serve all projected BAU baseline Yesler Terrace energy needs. Project energy consultant WSP evaluated three primary fuel source options for a CCHP system: a) natural gas, b) biomass gasification, and c) anaerobic digester.

A schematic diagram of the key features of a CCHP district system is presented in **Figure 6**. As illustrated there, the system is more complex than the GX/S system, with both supply and return loops for both hot and chilled water circulating throughout the site. The temperature of each system is maintained by the central "tri-generation" plant, which would also produce electricity for area plug loads.

Figure 6: Combined Cooling, Heating and Power System



Source: Collins Woerman, 2010.

A typical CCHP plant of the size that would be needed to serve Yesler Terrace would be housed in a building of approximately 10,000 square feet on a separate parcel. As noted in **Figure 6**, it would require a four-pipe plumbing system. **Figure 7** is a photo of the type of four-pipe distribution system plumbing needed to provide separate supply and return loops for both hot and chilled water in the CCHP systems. As this description and figure indicate, the capital installations of a CCHP system are significantly more extensive than those of a GX/S system.

Figure 7: Photo of A Partially-Installed Four-Pipe CCHP Distribution System

WSP estimates that a Yesler Terrace CCHP system would produce substantial excess heat and may also produce electricity on a schedule that would require coordination with City Light to absorb the CCHP system's surpluses at certain times and augment the system's capacity at others.

Not all fuel types would be suitable for Yesler Terrace. Due to space limitations for fuel storage, particularly for the biomass gasification option, any on-site district system would likely be fueled by natural gas rather than renewable sources. The WSP Report considers off-site generation with renewable fuels such as biomass gasification and notes that it would require either negotiation and management of a separate energy generation and exchange arrangement with Puget Sound Energy, the local natural gas supplier, or some suitable and acceptable location near Yesler Terrace.

3. Other Sustainable District Energy Options

Several other district energy systems could be designed to the scale of the Yesler Terrace development. These include:

- A district heating and cooling system (no electric power);
- A district heating-only system;
- District-wide Code-exceeding energy efficiency; and
- Wind or solar photo-voltaics.

Most of these sustainable systems bear clear similarities to either the BAU baseline or one of the sustainable district systems described above. However, each appears to be inferior to one or another of the primarily options described above.

District Heating and Cooling System. A district heating and cooling system with supply and return loops would be similar to the CCHP option described above, but without the electricity generation. This option can be considered in economic investment terms relative to the CCHP option. It appears that it would be outperformed by the CCHP option on that basis.

The elimination of the electricity component would allow the boiler to be down-sized somewhat and would produce fuel savings relative to the CCHP option, but other key investment components such as the complex loop system and the incremental HVAC costs would be essentially the same as for the CCHP system. In addition, building electricity payments to City Light would fall by less than half, rather than being eliminated. This combination of impacts suggests that supplying the entire energy needs of Yesler Terrace with the District Heating and Cooling system combined with electricity service would be likely to cost considerably more than the CCHP option, without any significant offsetting benefit.

District Heating-Only Systems. Heating-only district systems have been in place for a long time. Seattle Steam is one familiar local example. They generally rely on supplying either steam or hot water to serve building space heating loads only. This option can be considered in economic investment terms relative to the GX/S option. As with the preceding option, this one appears to be outperformed on that basis.

If the heat for the District Heating-Only system is produced by a dedicated boiler, that added investment would offset savings from eliminating the heat exchangers in the GX/S case. The cost of a supply loop would be comparable. And on the benefit side, this system would save less in electricity costs than would the GX/S system, since it would replace space heating loads but not space cooling or water heating loads.

A potentially interesting opportunity afforded by this type of system would be sales of surplus heat without any significant increase in capital system cost. That could occur if the system were run at levels above Yesler Terrace requirements during off-peak periods, provided a market existed for the surplus heat generated at those times. This possibility is addressed in the Economics section below.

In addition, while the GX/S system would rely on locally available renewable energy sources, the District Heating-Only system in this space-constrained development setting would almost certainly rely on natural gas (which is not considered a renewable energy source).

A related “extra-district” option would be connection to the existing Seattle Steam system and development based on steam heating. The economic issues would be similar for this sub-option, with steam purchase costs likely to equal or exceed the cost of a district heating boiler. There are also added uncertainties in this option. One of these involves the future cost of heat from the Seattle Steam system. Another involves the risk associated with reliance on an off-site, non-district source for critical energy.

District-Wide Super-Efficiency. The BAU baseline assumes energy efficiency investments that exceed current Code by increasing amounts between now and 2030. By 2030, the energy use levels would be about 55% of current levels for similar applications. WSP estimated the costs of achieving these increasingly stringent standards, which are reported in Section 3 below.

This sustainable district energy would seek to lower energy use and its environmental consequences by requiring the installation of energy efficiency investments that exceed Energy Code requirements. This strategy has two significant shortcomings.

First, assuming that the incremental efficiency improvements made in each phase would be the least expensive measures possible, the marginal cost of reaching the projected 2030 Code standards estimated by WSP is quite substantial. Further efficiency improvements would be even more costly per kwh saved. While there is considerable uncertainty about the future costs of incremental efficiency improvements, it appears from WSP analysis of energy efficiency cost curves that lowering Yesler Terrace district energy use by this approach may be cost-prohibitive. Further, "over-conserving" that is not cost-effective would also damage a building's competitiveness relative to other buildings in the same market.

Second, in order to form a sound portion of a district strategy, the “super-efficiency” investments combined with a smaller district system investment would need to be cost-competitive with the strategy of a district system alone, which again appears unlikely.

Wind or Solar Photo-Voltaics. The team considered wind as an on-site power source, but its use at Yesler Terrace at a district scale was not plausible given Seattle’s wind profile and noise issues with wind generation in a dense urban setting. The Department of Energy’s Wind Program ranks the Seattle area as the lowest potential for wind generation (mean annual wind speeds of <4.0 m/s).

Solar photo-voltaics for electricity production at the district scale were also rejected due to the relatively high costs for photo-voltaic cells. If photo-voltaic costs drop dramatically, this technology could be reconsidered for future implementation on a building by building basis by designers.

The following evaluation focuses primarily on possible GX/S and CCHP systems, in comparison to the BAU baseline, with special consideration of district heat systems also included in the Economics section.

3. Economics

WSP, in cooperation with the Project Team, developed estimates for all significant energy service delivery costs, for both the BAU baseline and the primary sustainable district energy system options. With this information, the economic performance of the various district energy systems can be measured by the present values of their system costs relative to the present value of the costs of the “business-as-usual” (BAU) baseline. The projections reported below include capital and operating costs for the various options over a 30-year planning horizon.

The categories of costs in the analysis include some that would be the same for any Yesler Terrace energy supply scenario, notably i) the costs of central electricity distribution infrastructure to be installed in the right-of-way, and ii) the costs of building energy efficiency measures expected to be required by the Seattle Energy Code over the redevelopment period. The City Light electricity supply to the area for plug loads would rely on the same neighborhood distribution system irrespective of the district energy system chosen, and none of the district energy systems would produce added costs or cost savings. Similarly, the costs of Code-driven energy efficiency investments will be determined by the building area developed and the timing of that development, which are assumed to be the same for any energy service system selected, including the BAU baseline. These uniform costs are included to provide a more complete picture of the energy-related costs that will be faced by SHA and the private developers of Yesler Terrace parcels.

The relative economic performance of options hinges on the remaining costs. These include capital and operating costs that are involved in one or more of the sustainable district energy systems and costs that would be avoided or reduced by those systems.

- A central boiler/generator system for some combination of water heating, water chilling, and electricity generation,
- Hydronic pipe loop system(s) for delivery of heat (and cooling) to the new Yesler Terrace buildings,
- District system operating and maintenance costs,
- Fuel costs for the district system,
- Building HVAC costs of installing either hydronic system heat/cooling systems or the BAU baseline electric heat systems to deliver the energy to its end users, and

TABLE 4A

Yesler Terrace District Energy Supply Options: GX/S and CHP Systems, System Costs by Component (2010 PV, $m, 2015-44)

Cost Element [1]	BAU	GX/S	CCHP-AD	CCHP-BG	CCHP-NG
Uniform Costs					
YT Infrastructure	$13.98	$13.98	$13.98	$13.98	$13.98
Energy Efficiency	$13.49	$13.49	$13.49	$13.49	$13.49
Option-Specific Costs					
System Generator	$ 0.00	$ 0.00	$17.72	$14.29	$ 7.46
System Bldg/Loop	$ 0.00	$ 0.08 [2]	$17.60	$17.60	$17.60
System O&M	$ 0.00	$ 0.00	$18.63	$18.63	$18.63
System Fuel	$ 0.00	$ 0.00	$ 1.12	$ 7.60	$17.81
System Fuel w/H'view	$ 0.00	$ 0.00	($25.98)	($19.50)	($ 9.30)
Building HVAC	$ 7.57	$17.52 [2]	$19.57	$19.57	$19.57
Electricity	$32.51	$24.83	$ 0.00	$ 0.00	$ 0.00
Present Value	**$67.55 m**	**$69.90 m**	**$102.11 m**	**$105.17 m**	**$108.54 m**
Premium, $:	**---**	**$2.3 m**	**$34.6 m**	**$37.6 m**	**$41.0 m**
Premium, %:	**---**	**+3.5%**	**+51.2%**	**+55.7%**	**+60.7%**
Present Value w/H'view	**$67.55 m**	**$69.90 m**	**$ 75.01 m**	**$78.07 m**	**$81.44 m**
Premium, $:	**---**	**$2.3 m**	**$7.5 m**	**$10.5 m**	**$13.9 m**
Premium, %:	**---**	**+3.5%**	**+11.0%**	**+15.6%**	**+20.6%**

[1] Yesler Terrace energy infrastructure costs are preliminary estimates by SvR. Other costs were estimated by WSP (see **Appendix B**). Items with blue background are central development costs; items with yellow background are costs borne by individual parcel and building developers or occupants. (Note: WSP Report estimates did not include area infrastructure costs, and were presented in 2008 present values.)

[2] These cost estimates for the GX/S system are based on assumed individual building geo-thermal wells, the costs of which are included in the HVAC cost item. Costs for central well fields with a circulating supply loop would be similar.

- Electricity costs for Yesler Terrace buildings, which will be incurred in either the BAU baseline case or for some district systems.

a. Cost Comparisons, Present Value

The district energy system cost projections for the economic assessment were prepared by WSP. They represent a conceptual level analysis, designed to determine whether any of the candidate district energy systems offers sufficient promise to justify further research. Summary cost comparisons of the four district energy systems defined by WSP and the BAU baseline are listed by cost component in **Table 4A** below.

Each of the CCHP options has been evaluated in two ways: assuming no sales of excess heat, and assuming sales of those systems' excess heat to Harborview Medical Center. The latter are shaded grey in the bottom rows of **Table 4A**.

These present value comparisons indicate that under baseline assumptions, all sustainable district energy options would be more costly than the BAU option, but by widely varying amounts. Among the district options, the GX/S system has the lowest estimated present value of costs. It is estimated to be approximately 3.5% higher in aggregate energy cost than the BAU baseline, a present value difference of $2.3 million.

The three CCHP options, by contrast, have present value cost premiums above the BAU baseline ranging from 51.2% to 60.7% without any offsetting surplus heat sales revenue, which represents a cost increment of

TABLE 4B

Yesler Terrace District Energy Supply Options: GX/S and District Heat Systems, System Costs by Component (2010 PV, $m, 2015-44)

Cost Element [1]	BAU	GX/S	DH-AD	DH-BG	DH-NG
Uniform Costs					
YT Infrastructure	$13.98	$13.98	$13.98	$13.98	$13.98
Energy Efficiency	$13.49	$13.49	$13.49	$13.49	$13.49
Option-Specific Costs					
System Generator/Loop	$ 0.00	$ 0.08 [2]	$12.05	$10.38	$ 9.30
System O&M	$ 0.00	$ 0.00	$ 0.49	$ 0.49	$ 0.49
System Fuel	$ 0.00	$ 0.00	$ 0.10	$ 0.84	$ 1.60
Building HVAC	$ 8.03	$17.52 [2]	$15.15	$15.15	$15.15
Electricity	$32.51	$24.83	$25.95	$25.95	$25.95
Present Value	**$67.55 m**	**$69.90 m**	**$81.21 m**	**$80.28 m**	**$79.96 m**
Premium, $:	**---**	**$2.3 m**	**$13.7 m**	**$12.7 m**	**$12.4 m**
Premium, %:	**---**	**+3.5%**	**+20.2%**	**+18.8%**	**+18.4%**
Present Value w/H'view	**$67.55 m**	**$69.90 m**	**$69.92 m**	**$68.99 m**	**$68.67 m**
Premium, $:	**---**	**$2.3 m**	**$2.4 m**	**$1.4 m**	**$1.1 m**
Premium, %:	**---**	**+3.5%**	**+3.5%**	**+2.1%**	**+1.7%**

[1] Yesler Terrace energy infrastructure costs are preliminary estimates by SvR. Other costs were estimated by WSP (see Appendix B). Items with blue background are central development costs; items with yellow background are costs borne by individual parcel and building developers or occupants. (Note: WSP Report estimates did not include City Light distribution infrastructure costs, and were presented in 2008 present values.)

[2] These cost estimates for the GX/S system are based on assumed individual building geo-thermal wells, the costs of which are included in the HVAC cost item. Costs for central well fields with a circulating supply loop would be similar.

$34.6 to $41.0 million. Assuming revenues from sales to Harborview Medical Center of the excess heat that would be co-generated along with electricity, those cost premiums would still be 11.0% to 20.6%, or $7.5 to $13.9 million in present value.

This high cost premium for CCHP systems at Yesler Terrace was identified by WSP as a consequence of several factors, including the relatively low electricity costs in the area and the mild marine weather, both of which reduce the cost savings from such a system in Seattle compared to many areas of the United States. This finding led the team to broaden the range of district heat systems considered, to determine whether somewhat lower cost systems not so dependent on electricity cost savings may prove more economically feasible.

Table 4B shows cost comparisons similar to those in **Table 4A**, but with the three CCHP systems (anaerobic digestion - AD, biogas - BG, and natural gas - NG) replaced by three district heat systems with the same fuel options. As before they are evaluated both with and without assumed sales of surplus heat they could generate.

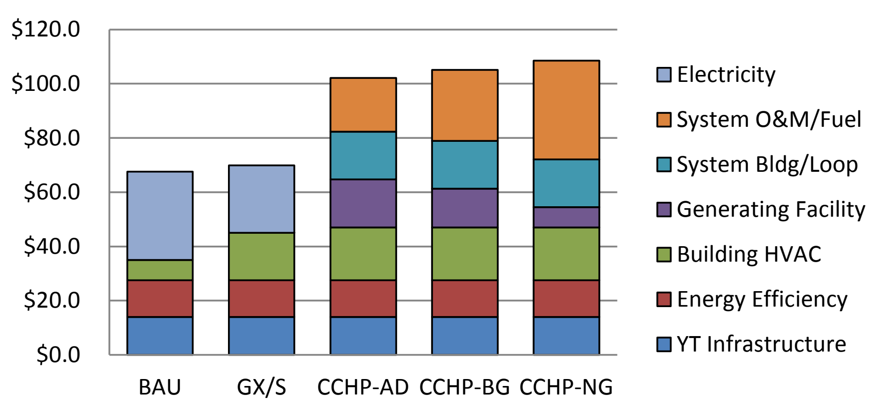
As the present values indicate, all three of the Yesler Terrace-only district heat (DH) options would be more costly than the BAU baseline by 18-20%, and more costly than the GX/S system by 15-17%. These systems sized to provide peak heating requirements within Yesler Terrace, however, could theoretically be run full-time, all year to produce additional heat. WSP examined the net cost implications if they were operated on that basis and the entire quantity of extra heat were sold to Harborview Medical Center. The net cost to Yesler Terrace would be significantly lower. That is shown in the bottom row of **Table 4B**. Note that this scenario is not a projection; rather, it represents a “best case” bookend, designed to determine whether there is potential for economically beneficial collaboration between the neighboring entities.

Another set of distinctions shown in the **Table 4A**, concerns cost category compositions, for which the payment responsibilities and the timing for the various energy system costs vary substantially among the five options, along with the total present values of cost. The cost compositions for the five options are shown in **Figure 8**, which highlights the significant differences in the energy system design approaches of the various options.

Another useful way to view these diverse costs is to segregate them into central versus building-related costs, and into up-front investment versus ongoing O&M costs. Those distinctions highlight who would bear the various costs and when the costs would occur.

- **Up-front Central Costs.** Yesler Terrace redevelopment will require extensive infrastructure

Figure 8: Yesler Terrace District Energy Options: Total NPV and Cost Components, $m



installations for electricity supply and other franchise conduits. These costs have been estimated by SvR project engineers at about $14.0 million.

In addition, each district energy option will require some level of up-front investments. If the GX/S system included a central loop, its up-front cost would be approximately $2.8 million (and the HVAC cost estimate would be lowered by a similar amount). The estimated cost for up-front installation of CCHP systems ranges from $24.0 million to $26.6 million for the three different fuel systems examined, with subsequent plant capacity increments projected to be installed at five-year intervals for subsequent development phases. These higher projections reflect the need in CCHP systems for both a central tri-generation plant and a four-pipe hot and cold water distribution system.

The up-front costs differ in their "phase-ability." The City Light electricity infrastructure cost will all be incurred when the right-of-ways are rebuilt. The majority of CCHP central elements will also be installed at the beginning of development. Any GX/S loop(s), however, may be installed in phases or even replaced by individual building systems as various sectors of Yesler Terrace are developed. If a GX/S system is built with central loops, the loops would most likely not be installed under streets with other utility infrastructure, which would allow them to be built in phases in that case, too.

- **Ongoing Central Costs.** The present value of system fuel requirements and O&M activities adds another $19.7 million to $36.4 million (PV) for the CCHP options, with virtually no corresponding fuel or generating facility maintenance cost for either the "business-as-usual" or GX/S options. The majority of these ongoing CCHP costs will be proportional to the redevelopment served, so they will start low and grow over time.
- **Up-front Building Costs.** Up-front costs for the building owners include the costs of increasing energy efficiency investments as the Energy Code tightens, costs for connections to district system loops, and costs for HVAC systems. The energy efficiency investment requirements would be the same for any option. The connection and HVAC requirements would differ among options, with the hydronic in-building systems needed for any district heating/cooling option requiring greater initial investments. In addition, building-specific geo-exchange units and roof-top solar panels are included in the HVAC cost of the GX/S option above. The present value of these combined up-front building costs is projected at $21.5 million for the BAU case, and at between $31.0 and $33.1 million for the four district energy options

  These up-front costs will be incurred on a building-by-building basis, and thus are assumed to be spread over time matching the phased development schedule.
- **Ongoing Building Costs.** In the BAU baseline, ongoing energy costs are assumed to be for electricity to serve all energy needs. The BAU present value of electricity purchases for the entire development is projected at $32.5 million. For the GX/S system that cost is estimated to decline to $24.8 million, while the CCHP systems would eliminate the BAU electricity purchase requirements altogether. Instead, CCHP system ongoing central costs would likely be assessed to building owners on an ongoing basis, through some mechanism.

b. Cost Recovery Mechanisms

Several cost recovery mechanisms will be involved in the Yesler Terrace energy systems' financing and management.

- **SHA infrastructure installation.** These up-front costs will be financed by SHA and recovered from a combination of sales revenues on parcels sold to private parties and rental charges to SHA tenants

  Building connections and HVAC system installation. These up-front building costs will be financed by building developers - both SHA and private developers. They will be recovered from lease and rental charges to tenants.

TABLE 5

Yesler Terrace District Energy Supply Options: Comparative Electricity/Fuel Costs with Alternative Baseline Energy Efficiency Levels (2010 PV, $m, 2015-44)

Cost Element	BAU	GX/S	CHP-AD	CHP-BG	CHP-NG
10% Baseline Efficiency Improvement per Five Years					
Total Present Value:	$35.24 m	$26.92 m	$1.22 m	$8.24 m	$19.31 m
Change:	+$2.73 m	+$2.09 m	+$0.10 m	+$0.64 m	+$1.50 m
13-14% Baseline Efficiency Improvement per Five Years					
Total Present Value:	$32.51 m	$24.83 m	$1.12 m	$7.60 m	$17.81 m
Change:	---	---	---	---	---
17% Baseline Efficiency Improvement per Five Years					
Total Present Value:	$29.92 m	$22.85 m	$1.03 m	$7.00 m	$16.39 m
Change:	-$2.59 m	-$1.98 m	-$0.09 m	-$0.60 m	-$1.42 m

Source: Gibson Economics, October 2010

- **Seattle City Light purchases.** These costs will be paid directly to City Light, either by tenants or by building managers who embed the cost in rental or lease rates.
- **District energy system.** The district heat or district energy system costs and their cost recovery could be managed through several models.
  - SHA could contract with a private entity to perform all design, build and operating (DBO) functions, in which case the system capital cost would be financed by the DBO firm which would recover those costs along with their operating and maintenance costs through unit charges to individual building owners or tenants.
  - SHA could also finance the capital cost of the district system, contract with a private entity for its construction, and recover that cost via either parcel sales revenue or ongoing central charges to buildings. It could then contract with a third-party operator to run the system, with payments to the third party included in the central charges from SHA to individual building owner/managers. Alternatively, SHA could manage some systems internally, although the complexity of some systems may limit this approach. In either case, SHA could retain certain administrative management functions.

c. Uncertainty and Sensitivity of Cost Rankings

Table 4A reports present value cost projections under baseline assumptions. Due to the divergent cost structures of the various options, changes in some key assumptions could affect the cost differentials among them. Three assumptions have the greatest potential for variability that might shift the net cost burdens of these various options relative to one another, and are explored below.
These are:

- actual versus projected future improvements in building energy efficiency,
- the growth rate of future costs of electricity and other fuels, and
- the discount rate used to assess cost impacts over time.

Actual Versus Projected Energy Efficiency Levels and Costs. The BAU baseline assumes steadily

TABLE 6

Yesler Terrace District Energy Supply Options:Comparative Costs with Alternative Growth in Electricity and Other Fuel Cost (2010 PV, $m, 2015-44)

Cost Element	BAU	GX/S	CCHP-AD	CCHP-BG	CCHP-NG
CPI-only Annual Growth in Electricity Rates and Natural Gas Prices					
Electricity Present Value:	$32.5 m	$24.8 m	$0.0 m	$0.0 m	$0.0 m
CHP Fuel Present Value:	$0.0 m	$0.0 m	$1.1 m	$7.6 m	$17.8 m
Total Present Value:	$67.5 m	$69.9 m	$102.1 m	$105.2 m	$108.5 m
Premium:	---	+3.5%	+51.2%	+55.7%	+60.7%
CPI + 1% Annual Growth in Electricity Rates					
Electricity Present Value:	$40.0 m	$30.5 m	$0.0 m	$0.0 m	$0.0 m
Nat Gas Present Value:	$0.0 m	$0.0 m	$1.1 m	$7.6 m	$17.8 m
Total Present Value:	$75.0 m	$75.5 m	$102.1 m	$105.2 m	$108.5 m
Premium:	---	+0.7%	+36.1%	+40.3%	+44.7%
CPI + 1% Annual Growth in Electricity Rates and Natural Gas Prices					
Electricity Present Value:	$40.0 m	$30.5 m	$0.0 m	$0.0 m	$0.0 m
Nat Gas Present Value:	$0.0 m	$0.0 m	$1.4 m	$9.3 m	$22.0 m
Total Present Value:	$75.0 m	$75.5 m	$102.4	$106.9 m	$112.7 m
Premium:	---	+0.7%	m+36.5%	+42.5%	+50.3%

Source: Gibson Economics, October 2010

tightening Energy Code efficiency requirements over the development period, as described above. If, however, energy efficiency improvements occurred either more or less quickly, the BAU baseline electricity use and the savings available from GX/S and CCHP programs would change. Table 5 shows the impacts on the various energy systems' total present values of electricity and/or fuel costs, for energy efficiency rates of 10% and 17% every five years, as compared to the 13-14% assumed in the baseline.

The results in **Table 5** indicate that while the total electricity-plus-fuel costs vary widely among the district options, and while their incremental energy costs at lower or higher efficiency standards would vary about proportionally, the differences are small relative to the baseline total present value cost differences among the options. This would be true for either increases or decreases in the energy efficiency levels required by the Energy Code.

A separate energy efficiency related cost uncertainty highlighted in the WSP analysis involves the cost of installing energy efficient measures to comply with a continually stricter Energy Code in the future (as reflected in the second row of **Table 4A** and **Table 4B**). That uncertainty, however, affects the baseline capital costs of development on the site, and thus has the same impact on both district energy systems and the BAU baseline.

Electricity and Other Fuel Cost Escalation. The benefits of the GX/S and CCHP systems depend heavily on projections of future - and for those systems avoidable - electricity costs. The baseline present value estimates in Table 4A assume that unit electricity costs rise at approximately the same rate as general inflation. That assumption is uncertain, and the present value of electricity costs for the BAU and GX/S options could be significantly higher if electricity prices increased more rapidly.

TABLE 7

Yesler Terrace District Energy Supply Options: Comparative Costs with Alternative Discount Rates (2010 PV, $m, 2015-44)

Cost Element	BAU	GX/S	CCHP-AD	CCHP-BG	CCHP-NG
4% Real Discount Rate					
Present Value:	**$59.5 m**	**$62.2 m**	**$92.9 m**	**$95.1 m**	**$97.3 m**
Premium:	**---**	**+4.5%**	**+56.1%**	**+59.8%**	**+63.5%**
3% Real Discount Rate					
Present Value:	**$67.5 m**	**$69.9 m**	**$102.1 m**	**$105.2 m**	**$108.5 m**
Premium:	**---**	**+3.5%**	**+51.2%**	**+55.7%**	**+60.7%**
2% Real Discount Rate					
Present Value:	**$77.4 m**	**$79.2 m**	**$113.0 m**	**$117.1 m**	**$122.0 m**
Premium:	**---**	**+2.3%**	**+46.0%**	**+51.3%**	**+57.6%**

Source: Gibson Economics, October 2010

Table 6 above presents comparative present values of costs with three different combinations of electricity rate and natural gas price growth assumptions. In the baseline, prices for both electricity and natural gas are assumed to grow at the same rate as overall inflation. The baseline electricity cost would be $32.5 million (PV), of which the GX/S option would save $7.7 million. The CCHP options would avoid all $32.5 million in electricity cost, but with offsetting fuel costs ranging from $1.1 million to $17.8 million.

If electricity costs are assumed to rise at 1% above the rate of inflation, the electricity cost of the BAU option would rise to $40.0 million (PV) while the cost of the GX/S option would rise to just $30.5 million, indicating an increased electricity cost-saving of $9.5 million for the GX/S system. That would reduce the total cost premium for the GX/S option from 3.5% to just 0.7% above the BAU case.

The change in relative cost would be even more substantial for the CCHP options at higher electricity escalation rates. Because the CCHP options would eliminate electricity purchases, a higher electricity price growth rate would leave the CCHP present values of cost unaffected, while it would raise the present value of the BAU case. As shown in Table 6, the cost premium for the three CCHP options over the BAU case would fall by $7.5 million, reducing their percentage premiums to between 36.1% and 44.7%, still a significant gap.

Note, however, that in an energy environment with higher electricity prices, it is likely that natural gas prices would also be rising higher than in the baseline, which would raise CCHP operating costs and partially offset the reduction in CCHP cost premium. That case is reported in the third section of **Table 6**, which shows that the BAU baseline and GX/S costs would be as in the electricity-only escalation scenario, while the CCHP costs would rise by varying amounts. The net effect would be cost premiums for the CCHP options ranging from 36.5% to 50.3%.

Discount Rate. All district systems involve some degree of up-front investment in excess of that required in the BAU case, and all produce benefits in the form of reduced future electricity needs. Consequently, lower discount rates tend to show the district alternatives in a more favorable light. The projections in Table 4A are based on a real (i.e., inflation-adjusted) discount rate of 3%. Some agencies, including SPU, have also used a 2% real discount rate in assessing asset management choices in recent years. Applying that lower discount rate to the Yesler Terrace district energy options reduces the cost premium for each option relative to the BAU case. The changes, however, are not great, and leave the GX/S option with a relatively small 2.3% cost premium and the CCHP options with still-high cost premiums of 46.0% to 57.6%. Conversely, a 4% real discount rate raises the percentage cost premiums for all non-BAU options, although the increases are again fairly small. The comparisons are shown in **Table 7** above.

d. External Benefits

A district GX/S system, in addition to its direct system benefits, would produce greenhouse gas (GHG) reduction benefits from the lower fossil-fuel powered electricity production required for that option. The equivalent energy needs would be met by geothermal and solar sources without GHG impacts. Approximately 7,000 MWh/year of grid power would be replaced by the GX/S system, which would translate to a reduction of about 4,200 metric tons of CO2 per year. This environmental benefit could be monetized through trading on the national exchange, although the trading price per metric ton is quite volatile.

e. Potential System Improvements or Enhancements

For a GX/S system, there are potential system efficiency improvements not reflected in the preliminary economic assessment. First, it is possible that sewer heat recovery from lines within Yesler Terrace could provide a portion of the system's heat requirements at a lower cost and higher efficiency than the assumed geo-exchangers. Sewer flow monitoring now in the planning stage will shed light on this possibility. Second, the system could be installed with various combinations of central well fields and loops, or individual building systems. The preliminary economic assessment assumes costs sufficient to cover either system, but at the design stage SHA would be able to compare the alternatives more thoroughly and optimize their cost and development flexibility.

For either a CCHP district energy option or a district heat option, excess heat produced by the generator(s) could potentially be marketed to another party, such as Harborview Medical Center. WSP projects a wide range of possible revenue from such sales, depending on how much the Yesler Terrace system is run and the interest of a buyer. The added benefit to a CCHP system would still leave a sizeable cost disadvantage of CCHP systems relative to the GX/S and BAU alternatives. However, potentially higher levels of output from district heat options could in the best case make them competitive with the GX/S and BAU alternatives. Further discussions and research are needed to determine if such transactions would be consistent with Harborview plans, as well as what financial terms could be obtained.

4. Evaluation of Sustainable District Options

a. Yesler Terrace District Suitability

The GX/S district system is well suited to the future Yesler Terrace in several ways.

1. It would rely to a significant extent on energy that is available on-site, from the combination of geothermal, solar, and possibly sewer heat capture.
2. The projected heating and cooling demands of the site are sufficient to support a district heat system that is large enough to take advantage of economies of scale.
3. The mixed use characteristics of the redeveloped Yesler Terrace provide a demand profile that could be supported efficiently by the district heat system and its energy sources.
4. The system could easily be developed in phases and refined as appropriate in each phase. In addition, if there are central loops, they could be installed when sector loads warrant them, with the buildings developed earlier in a development phase plumbed for the district heat system but served by individual heat exchangers in the interim.

Among the CCHP systems, the Biomass and Anaerobic Digestion options would pose site suitability problems if fueled and operated at Yesler Terrace, due to a combination of the nature of the fuels and their fuel storage space requirements. The Natural Gas CCHP system, however, could be sized for the Yesler Terrace site, with no comparable fuel issues. All CCHP options would require a parcel with a dedicated building for the tri-generation plant.

The natural gas CCHP and district heat systems would share two of the attractive features of the GX/S option. The projected heating, cooling and power demands of the site are sufficient to support a CCHP system or a district heat system large enough to take advantage of economies of scale. And the mixed use characteristics of the redeveloped Yesler Terrace provide a demand profile that could be supported efficiently by either system.

b. Environmental and Sustainability Features

The GX/S option is strong on environmental and sustainability grounds.

1. By using onsite geo-thermal and solar resources (and possibly sewer heat recovery), a Yesler Terrace GX/S system would shrink the ecological footprint and improve energy reliability for the redevelopment.

2. Electricity use would be reduced, and energy transmission efficiency would be increased because production and consumption of thermal energy would occur on site.

3. Green House Gas (GHG) emissions would be reduced roughly in proportion to the reduction in electricity requirements.

4. Site visual amenities would be preserved, since this option would require little or no publicly visible buildings or power plants.

The most feasible CCHP option would use natural gas as fuel, and while natural gas is a cleaner fuel than most, it is still a non-renewable fossil fuel unless generated by a bio-fuel process. Nevertheless, the GHG impact of the natural gas fuel for CCHP is projected by the WSP Report to be an improvement over the marginal resource mix required for City Light electricity supply in the BAU baseline. In CCHP alternatives that include significant biogas, the environmental performance improves. However, the area of land needed for biological generation of fuel is significant, which lowers the benefit and raises feasibility issues.

c. Social Values

Any of the GX/S, CCHP and district heat systems would provide educational and training opportunities similar to those demonstrated by the SHA Ground Up program. And commercially any of these types of system could also become an element of branding that would be difficult for competing scattered projects to replicate.

Each system would involve some job creation. The relatively simple GX/S option would involve the least ongoing labor. Operating and maintenance labor opportunities may be slightly greater for CCHP or district heat systems with their power plant operations.

d. Synergies with Other Systems

A GX/S district system at Yesler Terrace could be coordinated with a district integrated water system to expand the heat source mix. Specifically, sewer heat recovery was estimated in the WSP study, in consultation with the sustainable district study water study, to have the potential to provide as much as 30% of the annual space heating and domestic hot water needs of the Yesler Terrace development. By using heat pump technology, this heat can be used for either heating or cooling of buildings.

There are systems available that use heat exchangers to tap into traditional sewer lines and extract sewage heat efficiently. Another available technology involves installation of a sewer collection system made from specially designed pipes containing a water jacket that can circulate cold water to extract heat from the sewage flowing through the pipe. The latter would need to be installed with other up-front sewer system infrastructure. Either approach could be linked to the district heat system, expanding the economic options and the aggregate energy potential of on-site, green energy sources for the system.

A CCHP system, on the other hand, could offer the opportunity to coordinate system plans with neighboring Harborview Medical Center. By considering consolidated energy demand composition, joint system design opportunities and economies of scale, it may be possible to improve the economic performance of both systems.

Water replacement requirements of the hydronic district heat systems have been identified in the integrated water system analysis as one of the potentially economical uses of reuse water produced by such a system. Coordinated planning could connect these systems to realize this economic potential.

Any of the hydronic district energy systems with supply loops also offer the potential for either individual trench installation or co-location with other up-front utility systems. The choice would depend on cost and convenience, with potential efficiencies available from joint installation planning.

e. Regulatory Requirements

A "barriers analysis team" of City of Seattle staff examined regulatory issues that could affect successful implementation of a district energy system. They noted the existence of other successful examples such as the systems at the University of Washington and Seattle Center, as well as the Seattle Steam franchise. These are all either heating or heating and cooling systems.

One key regulatory consideration is whether the City could require compatibility with the district system for buildings owned by various entities. It currently has that authority for commercial buildings, but not for residential buildings. Pending 2009 amendments to the Washington State Energy Code would combine multi-family with commercial properties, and it is possible that those amendments will be passed before any Yesler Terrace development begins. However, the barrier team noted that legislative changes may also be required before the City Energy Code could, for example, ban resistant heating at Yesler Terrace or require installation of systems compatible with a hydronic district heat system.

These types of changes could conceivably be part of a legislative package that includes all land use and code changes necessary for the entitlement of the Yesler Terrace properties.

Separate regulatory requirements arise in the case of a CCHP system, particularly to the extent that it functions as retail electric utility or relies on a fluctuating pattern of purchases from and sales to City Light (see Implementation Issues below).

f. Implementation Issues

Location and Size of Needed Facilities. Each of the district energy options would require a combination of central facilities and in-building HVAC systems. The GX/S system would have the smallest land-use requirements. It may include a central heat exchanger, well field and piping system, although for a GX/S system this would be a relatively small facility with a simple, easier-to-locate single-pipe design suitable for delivering uniform-temperature water to in-building heat exchangers. This option may simply avoid the central facility approach and instead require more extensive in-building systems, which would include inside heat exchangers and employ hydronic systems to deliver the heating/cooling water. It is possible that the GX/S system would involve no Yesler Terrace land use requirements.

Installation of a geothermal well fields could be phased to match development patterns. The well field locations would need to be identified in advance or accommodation made in the subfloors of new buildings to add additional capacity. Solar hot water installations would be installed as new buildings are constructed.

For the CCHP options, the central facilities would include a tri-generation plant, probably requiring its own site and building. Central piping facilities would include delivery and return piping for both hot and chilled water, four pipes in all, which would be installed underground either in a dedicated trench or along with other district infrastructure. The estimated size of the plant building is 10,000 square feet, and a larger parcel space and location would need to be identified as part of the overall site planning.

In addition both anaerobic digester and biomass gasification CCHP systems would require additional space for delivery and storage of their respective fuel stocks, which may render them infeasible for Yesler Terrace. The estimated space requirement for this storage is a concrete slab of 15,000 square feet, and a larger parcel and location would need to be identified for the building/fuel storage combination as part of the overall site planning, with likely reductions in other development potential for buildings or public spaces. As noted by WSP, these systems would be better sited at some remote location, with the fuel they produce fed into an existing natural gas supply system. By contrast, a natural gas-fueled CCHP system would run off fuel delivered to the site through the PSE system, without added space requirements.

Phasing Considerations. As noted in the Economics discussion, there are several major components of a district heat system that would be installed on different schedules within Yesler Terrace development phasing. If a GX/S system included central loops, they could be installed sector-by-sector. The central loop for either CCHP or district heat systems would need to be installed up-front, at the same time as other major utility systems for the site. Both the connections from the central loop to individual buildings and the in-building hydronic components of all systems would be installed by developers as the buildings are developed. And finally, the building and some generation capacity for central plants for CCHP options would be installed up-front, while added capacity could be installed as additional sectors of Yesler Terrace were redeveloped. These schedules are reflected in the present value analysis of the economic evaluation. More detailed cost phasing information is included in the WSP Report.

Coordination with Existing Services. A GX/S or district heat system would operate independently of City Light, providing non-electric uses that are currently provided in many Seattle buildings by entities other than City Light, such as Puget Sound Energy, individually-owned furnaces, etc. Since such systems do not have an electric power generating component, that avoids another complicating issue that arises with CCHP systems.

For CCHP systems, the plans for electricity production and its sales would determine the nature of coordination with City Light. A stand-alone system would face significant regulatory hurdles, while an interconnected system as assumed by WSP, with either sales to or purchases of net energy from City Light at different times would require separate, but also significant authorizations and coordination. According to City Light, these would include registration with the Federal Energy Regulatory Commission, application of a transmission wheeling tariff, and development of a distribution wheeling tariff. The net demands on City Light would also require special power purchase scheduling by that utility.

Building System Requirements. As noted above, individual buildings would need hydronic heating/cooling systems designed to be compatible with the district energy systems. These building systems would be most economically installed at the time of construction, which would need to be ensured to support the most economical development of a district energy system. Specifically, in order for a GX/S, CCHP or district heat system to be most economical, it would be important for individual Yesler Terrace buildings to be subject to a system compatibility requirement or possibly a resistance heat ban imposed by City Energy Code.

Roof structures for buildings that host solar hot water systems would need to be designed to accommodate the necessary hardware and load. Because Yesler Terrace will be predominantly new construction the incremental cost impact is expected to be small, and is included in the WSP cost estimates summarized above.

g. Ongoing Management

Ongoing management of a district heat system could be performed through one of several approaches. WSP has identified third-party operation/management firms as well as design/build/operators as two existing models in the industry, in addition to which it may be possible for SHA to expand its own management to encompass expanded utility system management, as it has done in the past for solid waste collection. For whatever system operation model is chosen, SHA will need to perform certain financial management roles.

5. Conclusions and Options Recommended for Further Consideration

GX/S System. Among the sustainable district energy system options defined by the SHA/CW team and analyzed by WSP, the GX/S system appears hold the most promise for the Yesler Terrace redevelopment. It has a total projected energy cost for the development comparable to the BAU baseline under any of the base case and sensitivity analysis scenarios considered, and offers an added combination of sustainability, environmental benefits, and financial risk mitigation. These would be achieved through selection of lower-impact fuel sources, relative simplicity of design, GHG reductions, and risk mitigation through avoidance of exclusive reliance on electricity or any single fuel.

Further analysis of this option, in addition to refining system design options and cost estimates, would allow SHA to explore more fully the opportunity to coordinate such a system with the sustainable district integrated water system described below, using sewer heat recovery as an additional environmentally sound and economical fuel source for a portion of the district heat system's requirements. **These performance features are sufficient to recommend further detailed, site-specific design and cost analysis of the GX/S option.**

District Heat Options. The natural gas-fired district heat option could, under best-case economic assumptions, provide similar economic performance outcomes to those for the BAU and GX/S options. Those best-case assumptions include significant revenue from Harborview or some other comparable user in an assumed market for excess heat that could buy down the net cost of the district heat system. While those hurdles may be overcome, this option does not offer the same range of sustainability and environmental benefits as the GX/S option unless it is able to displace high-GHG energy use through sales to Harborview. It may also entail greater upside cost risk than the GX/S district system due to its reliance on natural gas. **However, given the conceptual nature of these preliminary estimates and analysis, the natural gas-fueled district heat system with a surplus heat market has sufficient benefit to recommend further detailed site-specific design and cost analysis.**

CCHP Options. The CCHP options are substantially more costly than other options under all scenarios considered, even assuming sales of excess generated heat. Further, the two options with renewable fuel sources would have fuel storage requirements poorly suited to the Yesler Terrace setting, while the natural gas option would rely on non-renewable fuel sources. **These CCHP options do not appear to provide sufficient economic or environmental benefit to justify further analysis or consideration.**

1. Background

The BAU water future of Yesler Terrace is expected to feature drinking water from SPU potable water supplies, collection of wastewater to SPU sewer lines feeding into a combined conveyance system for downstream treatment by King County, and management of rainwater/stormwater by a drainage system that complies with the new SPU Stormwater code by incorporating a variety of decentralized, green stormwater infrastructure (GSI) facilities.

Until recently, GSI options were discretionary sustainable choices, which were limited in their application. Now, with the standards adopted in the Stormwater Code, a variety of these options will make the Yesler Terrace BAU case sustainable in its stormwater management. Figure 9 and Figure 10 below show examples of decentralized stormwater management installations in Seattle right-of-ways of the sort that may become part of the Yesler Terrace environment.

Figure 9: A Cascading Swale Design

Figure 10: A Vegetative Swale Design

Evaluation of the remaining components of the Yesler Terrace water resources depends on a clear picture of the baseline flows into or onto the site, and their uses. The "water budget" of the Yesler Terrace site summarizes the inflows and outflows of water to and from the site. This important perspective helps to identify sustainable and district-level strategies for managing, using, and re-using water efficiently. On the supply side, potential sources include both naturally and utility delivered flows, as well as potentially re-circulated flows. The main supply options are:

- potable water,
- rain water,
- "grey" wastewater, which consists of non-toilet wastewater, and
- "black," or total wastewater.

On the demand side, key components of potential reuse include non-potable uses such as flushing, irrigation, and process uses. And finally, residual stormwater and wastewater flows represent the net flows of water from the site. As described above, the BAU stormwater management strategy is taken as given for this study. The baseline wastewater strategy includes a sewage collection system that will be needed

TABLE 8

Yesler Terrace Non-Potable Water Demand SourcesMajor Component Demands by Geographic Sector

Yesler Terrace Sector	Flushwater	Laundry	Irrigation	District Heat Make-Up	Total
NE	10,649	12,027	6,452	7,500	36,628
EOB	4,899	5,055	1,798	3,060	14,812
NW	131,059	21,077	15,945	25,140	193,221
SW	19,489	22,556	7,830	13,200	63,075
SE	15,637	19,199	16,759	11,040	62,635
Total	**181,734**	**79,914**	**48,784**	**59,940**	**370,372**

Source: Alliance Environmental, July 2010.

for virtually any feasible sustainable district water strategy.

The baseline water demand mix is instrumental in designing potential water reuse systems, which could be an addition to the BAU service mix. Table 8 summarizes the segments of overall water demand that could potentially be served by a Yesler Terrace water reuse system.

2. Sustainable District Options

As with Energy, the potential for sustainable district options is inherent in the diversity and flexibility of water demands, but in the case of water, re-use provides another potential strategy for water delivery. Several key components of water demand require the use of potable water (e.g., cooking), but other demand components such as irrigation and toilet flushing do not. The latter could be provided by any of a variety of district water reuse systems that could lessen the burden on potable water supplies upstream, and on wastewater and stormwater collection, conveyance and treatment downstream.

Alliance Environmental (AE) was retained to examine the potential for sustainable district water reuse systems, and defined and evaluated a range of potential district-level systems for the Yesler Terrace redevelopment, selecting the most promising among them for more detailed development.

a. District Water Reuse Systems.

District water reuse schemes can be designed to use water from a variety of sources, and provide water for a variety of uses. Important source candidates for these systems include rainwater, greywater and total(“black”) wastewater. The appropriate source choice should be matched to the intended water reuse application, in terms of quantity, to provide the most efficient system.

There is a wide capacity range among potential non-potable water supply sources in a water reuse scenario, summarized by AE as follows:

> **Stormwater:** Roof runoff stormwater would be inadequate to meet any of the demands listed in **Table 8**. Further, site and grade runoff from non-roof areas are projected to be lower, and insufficient to add up to a practical supply for any of the listed demands. Based on these limitations, AE concluded that rain water or stormwater could not support a district level water reuse supply system, although it could potentially be collected efficiently to offset some irrigation needs.

Greywater: This source includes indoor wastewater with the exception of flushwater flows. It is projected by AE to be adequate for total flushwater supply requirements on a system-wide basis, although the NW sector with office development would not be self-sufficient, but would depend on excess flows from other residential sectors. Greywater may also be sufficient to provide either the irrigation or laundry demands estimated in **Table 8**. Because greywater would provide more limited supply while requiring the same treatment facilities and investments and extra investments in dual wastewater collection, AE concluded that it would be inferior to total wastewater as a district water reuse supply option.

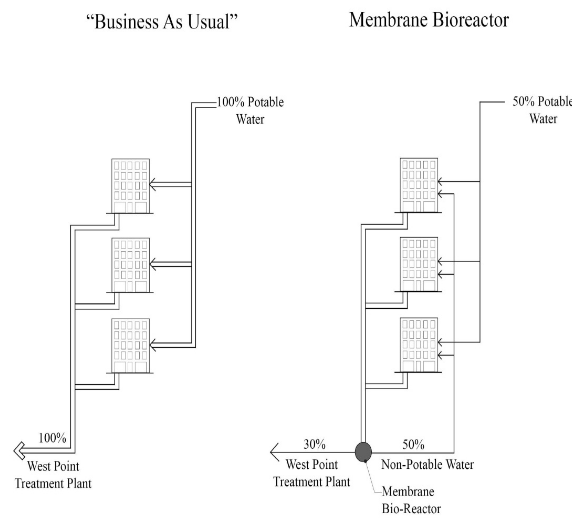
Total Wastewater: As the name implies, this source includes all indoor wastewater. It is projected by AE to provide adequate water for all potential Yesler Terrace uses listed in **Table 8**.

The total wastewater option was selected by AE as the source basis for developing a conceptual analysis for a district water reuse system. It is described below along with a schematic plan of its main components, followed by a listing of some potential building-level sustainable water options that could be pursued at Yesler Terrace.

A district-level water re-use system will require a combination of distributed facilities to collect and treat the source water to the desired degree, along with a supply distribution network to return the water to its locations of use. In addition, in-building use will also require “purple pipe” dual plumbing, installed at the time of construction.

Figure 11 contains a schematic diagram of an integrated district water reuse system. The key features of the system are the collection of “feedstock” water from existing sewer lines, treatment and storage at one of several sub-area membrane bio-reactor (MBR) water reuse treatment plants, a distribution loop and pumps to return the treated water to buildings throughout the site, and in-building dual plumbing to deliver the reuse water to its specific range of end uses.

Figure 11: ”Business As Usual” vs. Membrane Bioreactor



Source: CollinsWoerman, 2010.

As indicated in **Figure 11** by the flow loop through the small MBR plant, the reduced potable water inflow and wastewater outflows provide the benefits of the system that offset the extra facility investments. **Figure 12** shows an example of the type of MBR described for Yesler Terrace-scale installation.

Figure 12: An Installed, Modular Sized Membrane Bio-Reactor Plant

Within the general water reuse system concept defined above, there are multiple design options that could be developed at Yesler Terrace, involving the size and number of MBR plant and loop systems.

- **Size of Facilities.** Two of the demand categories in Table 8, laundry and district heat makeup are uncertain. Laundry applications depend on regulatory authorization, which is evolving rapidly in the industry but may not exist currently. District heat makeup application depends on the development of a district energy system that would require such supplies. MBR facilities would be built with capacity sizes tailored to the district application, taking into account the expected demands to be served, as they may be projected to increase over time.
- **Number of Facilities.** The layout and development phasing of Yesler Terrace make multiple MBR/loop systems an efficient design option. AE identified three different potential configurations that could work for the development, with either two or three plants each. That number and the consequent plant sizes would allow the system to achieve some economies of scale, while allowing for phased investment. The specific plan would be selected at a later time.

b. Other Sustainable District Water Systems.
Other sustainable water options could be developed within Yesler Terrace on a more limited scale. Among them are building-level rainwater collection systems, for either auxiliary irrigation supply or possibly auxiliary flushwater supply. The auxiliary irrigation supply was identified by AE as a promising addition to the district water reuse system, although it would be individual building systems, rather than a district system.

The auxiliary flushwater use of rainwater could also be developed at the building level, and could provide part of that element of demand. However, development of a successful district water reuse system would obviate the need for such building designs and investments, and would supply reuse water year-round without additional building storage or dual flushing supply.

3. Economics

Alliance Environmental, in cooperation with the Project Team, identified the set of facility requirements for a district water reuse system, including both the central system components and building connections and plumbing requirements that would be needed.

The projected economic performance of the sustainable integrated water system is determined by the net balance of the incremental benefits versus the incremental costs, measured relative to the "business-as-usual" baseline.

- The incremental costs in this case include the distributed systems for water reclamation, both treatment and redelivery to the new Yesler Terrace buildings, plus the incremental building costs of installing dual plumbing systems to deliver the reclaimed water to its end uses. It is noteworthy that the district integrated water system would continue to rely on the same in-building and central sewage collection system, delivering the source water for reuse to the central facility at no incremental cost.
- The incremental economic benefits in this case include the building-by-building cost savings from reduced water bills and reduced sewer bills, both resulting from reduced potable water purchases.

AE developed the water reuse system cost information based on an assumed design-build-operate (DBO) system service plan, under which the costs to the DBO firm would be converted into a contractual charge per gallon to the users of the system, including in this case SHA and potentially other private parcel developers. The overall benefit:cost analysis is presented on that basis, and some additional estimates of building owner investment requirements are provided to complete the cost profile below.

a. Cost Comparisons, Incremental Costs and Savings
The projections for the initial economic assessment were prepared by AE as a conceptual level analysis, designed to determine which if any of the candidate district integrated water systems offers sufficient

TABLE 9

Yesler Terrace Integrated Water Reuse Option: Major Cost Elements and Estimated Magnitudes

	Financial Transaction	Estimated Amount[1]	Responsible Party
1	Initial system construction and financing	$10.0 m	DBO Contractor
2	Periodic component replacements	Variable	DBO Contractor
3	Annual O&M plus return on capital & profit	$0.7 m/yr[2]	DBO Contractor
4	Compensation to DBO Firm	$1.9 m/yr[2]	SHA
5	Installation of Reuse Distribution System	$1.0 m	SHA
6	Installation of Building Dual Plumbing	$2.5 m	Building Owners
7	Payment for SHA Contract Costs	$2,100,000/yr[2]	Building Owners
8	Benefits from Reduced Water/Sewer Use	$2,300,000/yr[2]	Building Owners

[1] All estimates in Table 9 are from the AE Report, with the exception of the distribution infrastructure cost, which was estimated by Gibson Economics from SvR and WSP projections, and building dual plumbing cost, which was provided to Collins Woerman by McKinstry.

[2] The approximate amounts shown in the table for annual costs, payments and benefits are based on 2010 rates applied to full development of Yesler Terrace, without including any indexed or inflationary increases. In practice, since the development and implementation of the flow supply to reuse facilities would occur gradually over time, the interim costs and payments would be lower. To avoid undue capital cost burdens relative to this gradually-realized flow, AE recommends that the DBO develop the reuse facilities in either two or three stages.

Source: Gibson Economics, October 2010

promise to justify further research. The system economic scenarios examined by AE differed only in size, as a result of including different combinations of potential applications of reuse water. AE assumed in their analysis that any system would be operated as a design/build/operate (DBO) facility, with a uniform per unit payment structure. Thus, the system payments and the system avoided cost savings would both vary based on the volume of system use, and be roughly proportional to one another. The AE report contains estimated annual system payments (DBO model) and utility cost savings for several reuse scenarios varying in terms of the range of demands served. All appear to produce benefits at least comparable to the central system costs.

Summary cost projections for the largest (Scenario F) water reuse system, including savings relative to the BAU baseline are listed by cost component in **Table 9** above. The annual expense and compensation items are estimated as first-year values, based on 2010 SPU water and sewer rates and on 2010 estimates of system unit compensation levels.

The initial economic analysis prepared by AE indicated that the recommended district integrated water reuse system would be cost-effective relative to the baseline. Their water reuse system costs, however, did not include the costs of dual plumbing or the cost of installing a reuse water distribution loop, as they noted in the report. AE estimated that even with those additional costs the system would likely be cost-effective but by a smaller margin.

Table 10 lists the items from Table 9 that are revenue sources and expense items for each of the three major participant groups in a potential water reuse system. As the revenues and expenses are apportioned, it appears that all three groups would experience net savings relative to the BAU baseline. And if, for example, the

TABLE 10:

Yesler Terrace Integrated Water Reuse System: Revenues and Expenses by Participating Entity

Party	Revenue	Expense	Net
DBO Firm	#4	#1-3	Positive
SHA	#7	#4-5	Positive
Building Owners	#8	#6-7	Positive

cost of the distribution system (item #5) was higher than projected, SHA would have some latitude to raise the building charges (item #7), while still preserving net benefit for future building developers.

AE has indicated that a cost-based DBO payment structure may include indexed inflationary increases for the O&M portion of system operation, with either lower escalation or no escalation for the capital cost portion of the system operation.

The preliminary AE estimate for the capital cost of the water reuse treatment system for this option is approximately $10 million dollars, with another $650-$750,000 per year estimated for operating and maintenance costs. These would include labor, power, chemicals and laboratory analyses. For the assumed DBO management of the district integrated water reuse system, AE estimates that these costs would be borne by the DBO entity, and recovered from SHA or building owners through volumetric rates set at $0.014/gallon of system water use.

These incremental costs would be offset by annual cost savings of approximately $2.3 million in reduced utility charges. While the water reuse system (and thus its costs and benefits) could be developed in phases, these cost impact estimates are for the full Yesler Terrace development. During build-out, the DBO payments and the utility bill savings from the system would grow together.

b. Uncertainty and Sensitivity of Cost Rankings

Uncertainties of this preliminary economic projection are of three types:

- system cost uncertainty,
- avoided utility cost uncertainty, and
- system usage uncertainty.

Three alternative scenarios that examine the impacts of these various uncertainties are shown in **Table 11**, along with the base case. **Table 11** includes, for three sets of assumptions, the estimated present value for the Scenario F water reuse system over a typical 20-year contract horizon. In addition, since limitations on laundry applications may limit the scale of a water reuse system to the scale of AE's "Scenario E," impacts of that scenario are also shown in **Table 11**, retaining other base case assumptions.

- The costs of the central facilities and distribution system are preliminary estimates, and could change either upward or downward when cost estimates are refined. In **Table 11**, the risk of higher capital costs is represented in the "worst-case" scenario by: i) assuming a 50% higher cost of distribution system installation and ii) by having the capital cost portion of DBO charges escalating at the rate of inflation, raising the present value of total DBO payments by 25%.
- Similarly, the benefits associated with water and sewer cost savings could be greater or less than estimated. The base case scenario assumes that utility unit costs of service will rise by 0.5% more than inflation. Both water and sewer costs have risen well in excess of inflation over the past ten years (about 7.33%/year on average), and a continuation of that pattern could significantly improve the economics

of the project. In **Table 11,** this possibility is represented in the “best-case” scenario by rates rising by 7.0%/year.

- The case reflecting lower development utilization of a water reuse system is reflected in **Table 11** by the Scenario E case. In that case, system uses would fall by about 22%, from 370,000 gal/year to 290,000 gal/year and both the system costs and benefits would be lower. However, some relatively fixed development costs, such as installation of the central loop and installation of dual plumbing in redevelopment buildings, would fall very little. Consequently, the benefit:cost ratio for this scenario is lower than for the base case, 1.14 versus 1.21.

Scenario Assumptions

Base Case:	Water & Sewer rates increase at 3.5%/year Capital portion of DBO payment constant Central loop = $1.0 m; dual plumbing = $2.5 m
Best Case:	Water & Sewer rates increase at 7.0%/year Capital portion of DBO payment constant Central loop = $1.0 m; dual plumbing = $2.5 m
Worst Case:	Water & Sewer rates increase at 3.5%/year Capital portion of DBO payment rises 3.0%/year Central loop = $1.5 m; dual plumbing = $3.75 m

As illustrated in **Table 11**, specific sensitivity analysis cases can significantly improve or reduce net economic benefits. However, it appears that for a wide range of realistic potential scenarios a water reuse system would either produce positive net financial benefits to the Yesler Terrace project, or result in net costs comparable to those for the BAU baseline.

c. External Benefits

In addition to the direct financial impacts to SHA and the private developers at Yesler Terrace, there may also be downstream benefits to King County and upstream benefits associated with preserved in-stream flows, particularly in the Cedar River.

- The County manages the CSO sites associated with flows originating within Yesler Terrace, and may realize some flow reductions and CSO control facility cost reductions as flows from Yesler Terrace are decreased. SHA may be able to negotiate a shared savings strategy with King County, in which a portion of the King County avoided cost is applied to the SHA cost of system installation.
- SPU manages its water withdrawals from the Cedar and Tolt Rivers to meet environmental standards, but those rivers could benefit more as a district integrated water system allowed SPU to reduce withdrawals still further relative to the baseline or take on new demands without increased impact.

TABLE 11

Yesler Terrace District Water Reuse Scenarios: System Costs and Benefits (2010 PV, $m, 2015-34)

Economic Impact	Base Case	Best Case	Worst Case	Scenario E
Utility Savings	$11.85	$18.38	$11.85	$9.50
DBO Payments	$ 7.40	$ 7.40	$ 9.25	$5.93
Central Loop	$1.00	$1.00	$1.50	$1.00
Dual Plumbing	$1.42	$1.42	$2.13	$1.42
Total Cost	$ 9.82	$ 9.82	$12.88	$8.34
Impact, NPV	**+$2.03 m**	**+$8.56**	**-$1.03 m**	**+$1.16**
Impact B:C Ratio	**1.21**	**1.87**	**0.92**	**1.14**

d. Potential System Improvements or Enhancements

The system assumed above would rely on flows from Yesler Terrace buildings as they are redeveloped. By full build-out, it is projected from water budget estimates that there would be adequate source flows from these buildings to produce reuse water in the amounts projected to be needed for Scenario F applications. However, there may be periods when the balance is less reliable. As an alternative, main sewer lines on 9th Avenue and possibly Broadway carry flows originating off-site, which would be available throughout the redevelopment period, and which could provide more than adequate source flows, independent of development timing. This alternative could improve system service reliability, and might also offer efficient siting and facility design options with associated economic benefits. Flow monitoring of these main lines that is being scheduled for the second half of 2010 will assess the adequacy of both flow volume and flow constituents to serve as inputs to a district water reuse system.

Another significant improvement to the economics of the district integrated water reuse system could occur if SPU provides a partial water conservation match to the project as a cost-effective source of water saving, which could occur if a policy currently under consideration is adopted.

4. Evaluation of Sustainable District Options

a. Yesler Terrace District Suitability

The integrated district water system is well suited to the future Yesler Terrace in several ways. First, it would rely on water that is already available on-site as its source for reuse applications. Second, by employing treated wastewater, it could take advantage of sewage collection system infrastructure already needed for the "business-as-usual" development plan. Third, the source water available from a combined wastewater reuse system would provide a good match for the potential uses for that water. To the extent there is more supply available than needed, bypass valves could simply divert the excess back into the sewer collection system. And fourth, the technology involved is efficient in relatively small distributed units, bringing Yesler Terrace within the economical range for such systems, while allowing for installation of two or three separate systems over time in different sectors, to match development phasing.

b. Environmental and Sustainability Features

A significant environmental benefit of AE's recommended system would result from reducing water use 50% and wastewater production by 70%. Water use reductions add to the resilience of the regional water supply system and help Seattle Public Utilities prepare for the uncertainty of climate change. The abundant irrigation water that will be provided by the system on site can also help to lower energy costs as plant evaporation lowers summer temperatures and reduces cooling costs. Reduction in wastewater flows is another significant regional benefit. The system that Yesler Terrace drains to experiences combined sewer overflows that exceed state regulation. The benefit of reducing base sewage flows into these combined systems can measurably reduce the frequency and quantity of flows of untreated wastewater being released into Puget Sound, in addition to helping King County identify lower-cost compliance plans.

c. Social Values

The integrated district water reuse system would require management and administration, and a limited amount of operating and maintenance labor. At least some of the labor required could potentially be provided by Yesler Terrace residents. As with the district heat system, if SHA elects to manage the district water reuse system, it would be in a position to hire local labor to the maximum extent possible. In addition, a district water reuse system would provide educational and training opportunities similar to those demonstrated by the SHA Ground Up program.

d. Synergies with Other Systems

The potential for using heat captured from sewer pipes as one of the district heat system sources was noted above. The district water reuse system could also produce sufficient water to supply any makeup water requirements for a potential district heat system. In addition, an integrated water system would provide landscape irrigation supplies from reuse water. Water for the community gardens, however, may better be supplied or augmented by captured and diverted stormwater, as indicated in the AE report.

e. Regulatory Requirements

The AE report notes two important dimensions of the regulatory environment for water reuse systems in Washington State. First, "water that is more likely to come in contact with human beings is usually subjected to higher levels of treatment. For the purpose of this concept analysis we have assumed the most rigorous reuse water quality requirements." That means Class A Reclaimed Water state standards, and AE describes and assumes in its system design the technology that will produce water that is oxidized, coagulated, filtered and disinfected per those standards. Second, the state standards with regards to testing and analysis "require daily sampling and monitoring for certain parameters."

The impact of those requirements is increased operator monitoring and analysis, with associated labor costs. The AE cost analysis assumed operating costs that included that increased level of system monitoring and testing.

Further exploration of this recommended concept should include verification of treatment requirements, testing and monitoring requirements, and acceptable applications, to ensure that planned uses and their projected costs will comply with all regulations.

f. Implementation Issues

Location and Size of Needed Facilities. Any of the district water reuse options would require both central facilities and in-building dual plumbing systems. The central facilities would include two or three strategically sited wastewater treatment plants, each requiring its own site. At the anticipated scale of Scenario F production (the largest AE option), the two-plant configuration would include one plant with a footprint of approximately 5,000 SF, and another with a footprint of approximately 3,000 SF. Based on similar facilities developed in the United States, building basements or parking garage spaces provide adequate siting options, without imposing dedicated land use requirements.

A central piping loop for delivery of the reuse water would be installed underground along with other district infrastructure. Connections from that loop to individual buildings, along with installation of dual plumbing would occur as buildings were developed, and would be accommodated within normal plumbing delivery spaces.

Phasing Considerations. While there are economies of scale in district wastewater treatment systems, they can be developed economically at sizes that would allow for two or three separate plants at Yesler Terrace, as noted by AE. Thus, if development proceeds on a sector-by-sector basis, it would be possible to build the plants over a period of 10-20 years. The capital cost saving of that opportunity is reflected in the preliminary DBO cost estimate provided by AE. In addition, as treatment technology continues to improve, this may allow for more advanced, environmentally and economically superior second (and possibly third) plants.

Coordination with Existing Services. Delivery of wastewater to the treatment plant would require coordination with and approval from SPU, whether the flow was from an existing main or from new lines within the Yesler Terrace site. SHA may also need to tailor ownership and infrastructure transfer terms with SPU for the new on-site sewer collection system that would supply the MBR plant(s), to conform to SPU's existing wastewater treatment contract. Impacts on SPU system capacity and operations would generally be positive, since the reduced flows delivered to the SPU system would extend the capacity life of facilities. Monitoring flows to ensure SPU system flow adequacy to receive return solids would be necessary. King County is responsible for the combined sewer overflow facilities serving the Yesler Terrace basins, and would benefit from the flow reduction of a water reuse system. Coordination with the County would help determine the degree of flow reduction benefit, and allow the County to identify the most efficient CSO reduction strategy consistent with the anticipated Yesler Terrace flows.

Building System Requirements. As noted above, individual buildings would need dual plumbing systems to make use of the water produced by an integrated district water reuse system. In essence, reuse water would be supplied separately to toilets, irrigation and other non-potable uses in dedicated "purple" pipes. As with district heat/cooling systems, the in-building dual plumbing systems would be most economically installed at the time of construction, which installation would need to be ensured to support the most economical development of a district energy system. It would be important for individual Yesler Terrace buildings to be subject to a system compatibility requirement, and any DBO contract for such a system would likely include terms to guarantee participation or provide some form of minimum payments.

g. Ongoing Management

As with district energy, ongoing management of a district integrated water system could be performed through one of several approaches. AE currently operates similar systems it has developed as a DBO. A third-party firm could also be considered. In this case, it may not be practical for SHA to manage a district water reuse system, due to the specialized system involved, unless SHA decided to assume a more technically demanding utility operating role than it has in the past. For whatever system operation model is chosen, SHA will need to perform certain financial management roles.

5. Conclusions and Options Recommended for Further Consideration

Based on this conceptual level analysis, the central district water reuse option is an attractive strategy for development at Yesler Terrace. The water reuse system with the greatest potable water use reduction produces the greatest economic and environmental benefit, and further analysis should attempt to define the widest range of uses feasible. The source water for this system would be total ("black") wastewater, collected from sewer pipes within the development and diverted to the reuse facilities.

The central water reuse system would also provide environmental benefits, including reduced CSO volumes and greater preserved in-stream flows, and may improve the efficiency or lower the cost of other Yesler Terrace district systems such as a district energy system and the community gardens.

Water reuse options serving smaller segments of non-potable demand could also potentially be constructed and operated at costs comparable to the BAU baseline. Those options could, like the preferred option, produce net annual cost savings to apply to the cost of building connections and in-building dual plumbing, but their contributions would be smaller while the cost of the connections and dual plumbing would be unchanged.

AE suggests that in addition to the central water reuse system, collected rain water or stormwater may also provide an efficient partial source for irrigation demands, on a decentralized basis.

These performance features of a district water reuse system based on total wastewater are sufficient to recommend further detailed, site-specific design and cost analysis of the option.

IV. Sustainable District Solid Waste Management

1. Background

The waste to be managed at the redeveloped Yesler Terrace will be comprised of many components, but can be categorized into three major waste streams: i) recyclables, ii) organics (yard waste and possibly food waste), and iii) residual garbage. A fourth category consists of reusable items that might otherwise be discarded as trash. The waste composition of the future Yesler Terrace will resemble the current composition for multi-family residential households in Seattle, since that size and building type of households will comprise the residential portion of the new Yesler Terrace. The key waste stream of possibly combined yard waste and food waste will come predominantly from that sector.

Currently, the solid waste from Yesler Terrace and other SHA properties is collected by a combination of SHA vehicles, which collect garbage and yard waste, and Seattle contract haulers, who collect recycling. The "business as usual" solid waste management future for Yesler Terrace is expected to feature the same entities' collection of all three major waste streams. The collected recycling will be delivered for off-site processing and recovery, collected yard waste will be taken to an off-site composting facility, and garbage will be transferred for disposal at a regional landfill.

2. Sustainable District Options

Green Solutions (GS) was retained to examine the potential for sustainable district solid waste systems, identified organics as the waste stream with the greatest district potential, and defined and evaluated a range of potential district-level systems for the Yesler Terrace redevelopment.

a. District Composting

The most promising sustainable district options for solid waste involve the organics waste stream, partly because of the wide range of composting technologies and scales, and partly because a composting system may dovetail at least in part with anticipated on-site needs for composted materials in area landscaping and community gardens.

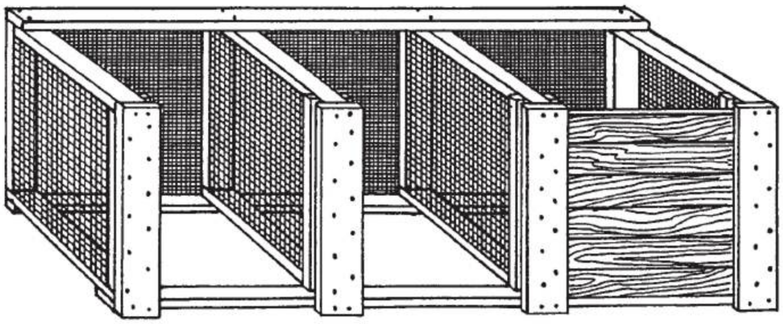
These sustainable district options can be further classified as i) those designed and scaled to support on-site composting needs, with a parallel strategy for collection and off-site processing of the remainder, and ii) those designed to compost on-site all yard waste and food waste generated on-site. Both were explored in detail in the GS Report (Appendix D).

Developing a sound strategy for sustainably supporting Yesler Terrace compost needs begins with defining the demand for on-site uses. The estimated demand for community gardens is about 25 tons per year. Other landscaping requirements would increase that somewhat. With that level of potential on-site use defined, it can be compared to the range of potential yard debris and food waste generation from the site.

Following that approach, there will be more than that quantity of either yard debris and food waste generated at Yesler Terrace, so it appears that any desired percentage combination of yard debris and food waste could be generated on-site.

The system that emerged as the most suitable for Yesler Terrace is the three-bin compost system, an example of which is shown in Figure 13. A very simple design concept, it could produce sufficient compost for all application needs at both the Yesler Terrace community gardens and the development's public spaces, relying solely on yard wastes generated within Yesler Terrace and collected and delivered to the four community garden sites at which the three-bin systems would be installed.

Figure 13: Photo of a Three-Bin Yard Waste Composting System



Wood-and-Wire Three-Bin Turning Compost Bin

b. District Garbage and Recycling

The business-as-usual approach for garbage and recycling collection at Yesler Terrace is efficient and economical. The region has developed sustainable practices in many jurisdictions, and this supports economical and environmentally sound waste diversion and processing practices. For these two waste streams, the Project Team identified no promising sustainable district alternatives.

Garbage collection options considered in a preliminary scan included a bag system for commercially developed areas and a pneumatic tube system linked by underground tubes to a central collection point. The bag program would resemble the City of Seattle's Clean Alley Program, and will remain an option for potential future refinement of the SHA garbage collection system, requiring no significant development design changes to facilitate that possible future adoption. The tube system faces significant cost and maintenance hurdles, and may not be well-suited to the large Yesler Terrace site and largely residential waste stream.

3. Economics

The economic impacts of the three-bin district compost system would be modest. There would be incremental costs associated with the compost systems at the community gardens, offset by cost savings from a combination of: a) reduced yard waste short-haul transportation and processing costs, for the newly composted tonnage, and b) reduced soil amendment purchase requirements. In addition, the improvement in soil quality would provide benefits in the form of improved productivity at the community gardens.

The incremental costs of the three-bin systems for four community garden sites are estimated by GS to cost between $100 and $500; labor is expected to be minimal, involving either volunteers or maintenance staff that would include this as one small element of their workload. The incremental benefits would also be small, with avoided processing cost benefits amounting to $1,000 per year, and other financial benefits being minimal.

4. Evaluation of Sustainable District Options

a. District Suitability

The three-bin system option represents a modest improvement on the current, successful SHA collection program. It would promote composting self-sufficiency at the district level, without interfering with the overall solid waste collection system. If food waste diversion among multi-family households becomes more prevalent, the shift in waste streams could still be collected by the current SHA collection program, and a modified mix of yard debris and food waste could still be used in part to support the on-site compost program, subject to permitting conditions.

In addition to this compost program, SHA may consider waste consolidation - of either the residential food waste stream or the garbage stream - as a future option with potential district benefits. Such a system, similar to the Seattle Clean Alley Program, could help avoid any visual or odor problems with cart and dumpster programs, although it would need to be subjected to economic feasibility review.

The large-scale composting options, by contrast, all pose site problems, either because of their space requirements or health regulations defined by the City Barriers Team that require special permits to operate a system that relies on import or export of waste.

b. Environmental Impacts

The compost program will create vibrant healthy soils that make plants thrive. Good deep friable soils also reduce stormwater runoff that might otherwise be carrying pollutants into Puget Sound. Composted soil not only reduces stormwater flows, but helps to keep the ambient temperature cooler in hot summer weather through evaporation. That translates to energy savings, too. And finally, the compost program shrinks the environmental footprint of the site by reducing the pollution from hauling waste away from the site.

c. Social Values

The recommended compost program would provide several social values to Yesler Terrace. One is low-cost support for one of the needs of the community gardens that are an established feature of Yesler Terrace culture. A second is the provision of program participation opportunities, either as an employment opportunity or a volunteer opportunity for green value supporters. And third, as shown by the SHA Ground Up program, such a program can continue to provide training and education opportunities while promoting a stronger sense of community.

d. Synergies with Other Systems

By design, this small district compost system provides value to district landscaping, which is envisioned as a significant amenity feature, and to community gardens, which will be both an amenity and an urban agriculture source of financial benefit to participating Yesler Terrace residents.

e. Regulatory Requirements

Health Department regulations require permitting for a wide range of compost programs, including many of those evaluated by Green Solutions. The recommended program, however, would fall within the range of systems and feedstocks that are exempt from those permitting requirements, because of the reliance on yard debris.

While provision of an on-site program based on yard waste alone would be straightforward, additional permitting and possible changes in the design of the compost system would be required, even for such a small program, if food waste were included in the feedstock.

f. Implementation Issues

Location and Size of Needed Facilities. The three-bin systems for composting would be housed within the Yesler Terrace community gardens. Similar facilities are included currently, and the land use requirements of a somewhat expanded system would be modest.

- Phasing Considerations. Phasing poses no obstacles for an expanded composting program. Community gardens will be developed in each of several stages, and compostable materials will be available as feedstock as needed.
- Coordination with Existing Services. SHA provides both the yard waste collection and the community garden sites that are the foundation of this program. At the collection end, it would be necessary to identify a rate of flow of compostable material to the community garden sites and Yesler Terrace public landscaped areas, so it can be diverted from the collected stream otherwise bound for Cedar Grove. At the garden end, it would be necessary to design the layouts of gardens to provide adequate space for the composting systems needed to produce sufficient compost to support both the gardens and other Yesler Terrace landscaping needs.
- Building System Requirements. Neither the collection nor the composting portions of this district system would require any revisions or limitations on building systems or design.

g. Ongoing Management

Yesler Terrace currently houses community gardens without major management requirements. The district system described above would be easy to manage, with anticipated heavy reliance on volunteer participation among the community gardening population. Diversion of a fraction of organics collected to the compost site would be a small aspect of SHA staff's solid waste collection responsibilities.

5. Conclusions and Options Recommended for Further Consideration

The recommended three-bin composting approach includes collecting and composting on-site enough yard debris to serve the needs of the Yesler Terrace community gardens and district landscaping. The technologies available for processing the amount of compost needed on-site and applying it beneficially are fully developed, relatively simple, and cost-effective.

With this internal demand served efficiently and economically, SHA collection and transport of any remaining organics generated on-site to an off-site processing facility (e.g., Cedar Grove) ensures a sustainable outcome for that portion of the compostable waste stream as well. This solution would work with or without expansion of a food waste collection program at Yesler Terrace. Additional study does not appear necessary, and it is recommended that an on-site, self-supporting three-bin compost system be included in Yesler Terrace site planning going forward.

A district strategy for on-site composting of all yard waste and food waste generated on-site is significantly different. Green Solutions, the solid waste experts retained for the study, considered several decentralized composting strategies along with several alternative central composting systems capable of processing all of the on-site waste stream. They identified "fatal flaws" in each of them for potential Yesler Terrace application, leading to low rankings in the GS Report's evaluation scale that included cost-effectiveness, diversion potential and feasibility.

Each of these "all-compost" options would face a combination of regulatory hurdles, space requirements, and cost that makes them poor choices for the Yesler Terrace redevelopment. The size of the anticipated waste stream, coupled with the reliance on multi-family construction for the residential portion of the site, effectively rules out a decentralized household-based on-site strategy. And regulatory and cost issues effectively rule out a centralized on-site strategy for the entire compostable waste stream. These "all-compost" options are not recommended for further study.

V. Sustainable District Transportation Systems

1. Background

Transportation strategies that reflect Business as Usual (BAU) are outlined here. Many of these elements are simply good design and should be expected to be included and are consistent with the intent of regulatory requirements for transportation, land use, environmental protection.

TABLE 1

Business-as-Usual BASECASE

Land use	▪ Cluster buildings near transit stops ▪ Create a mix of uses to bring jobs near housing ▪ Keep housing density high to support neighborhood businesses
Transit	▪ Enhance access to the transit network ▪ Locate transit stops for convenience and safety ▪ Enhance transit stops with lighting, shelter, seating areas, and lean rails ▪ Provide real-time transit information ▪ Provide travel information, trip planning, route and schedule information
Pedestrian infrastructure	▪ Provide a well designed, accessible pedestrian environment that connect key destinations ▪ Locate pathways near centers of activity to increase security through “eyes on the street” ▪ Provide pedestrian scale lighting ▪ Include Crime Prevention Through Environmental Design (CPTED) approaches to design
Bicycle	▪ Add shared lanes/Sharrows, consistent with the BMP ▪ Add dedicated bike lanes, consistent with the BMP ▪ Provide bike racks and secured bike parking ▪ Provide conveniently located and well-lit bike racks
Parking	▪ Include paid on-street parking ▪ Continue the Restricted Parking Zone (RPZ) ▪ Develop building-oriented structured parking and/or lots
Traffic	▪ Traffic is expected to slow at intersections given current city projections of overall city growth
Transportation Management Program	▪ Require A TMP to effectively manage the YT transportation network
Car sharing	▪ Provide ZipCar parking

Land use

Yesler Terrace is located proximate to many destinations and transportation networks. Residents can walk to many parts of downtown Seattle within 5-15 minutes; buses, light rail, and commuter rail are only a few blocks away. The new First Hill Streetcar will be fully constructed and operating directly through Yesler Terrace before the redevelopment begins. New construction at Yesler Terrace will create pleasant sidewalks with street trees and access to an expanded park and recreation area. Bicycle lanes and ample secured bicycle parking will be provided.

Transit

Yesler Terrace will be well-served by nearby transit, including the First Hill Streetcar, which will have a stop within the redevelopment area. Location and design of transit stops is equally important – convenient access and a safe and comfortable environment around stops is critical to encourage people to use transit as a primary mode of transportation.

Pedestrian infrastructure

A critical component of any strategy to reduce reliance on personal vehicles is the improvement of the pedestrian environment. Since walking is almost always the first and last part of any non-single occupant vehicle trip, convincing people to walk for more trips requires a safe, convenient, and well- designed pedestrian environment.

A good pedestrian environment needs pedestrian paths, sidewalks, and street crossings. In the business-as-usual base case, all streets in Yesler Terrace will have sidewalks on both sides of the street.

Bicycles

Shared streets, sharrows, and bike lanes are a likely BAU approach for the Yesler Terrace area. These are streets designated for bicycle use where bicycles and automobiles share lane space. In Seattle, Portland, San Francisco, and many other cities 'Sharrows' are painted on the asphalt. Implementation of shared streets is very low cost, but shared lanes are less comfortable for less confident cyclists.

Parking

Parking is often provided at levels that exceed regulatory requirements. Parking will include a combination of private and on-street spaces in the BAU case. Typical private strategies include building parking structures that can cost $30,000-$40,000 per stall or lots adjoining buildings. Street parking is limited, and is likely to become even rarer in the future. BAU also includes a Restricted Parking Zone for Yesler Terrace residents.

Paid on-street parking will likely follow redevelopment of Yesler Terrace. Paid on-street parking generally creates a better balance with off-street structured parking.

Traffic

The BAU base case will also have traffic issues as outlined in the draft EIS for the Yesler Terrace redevelopment. Traffic flow at intersections is expected to slow as natural population growth in the city adds thousands of more drivers. By absorbing a portion of that growth, the Yesler Terrace redevelopment will be contributing to that anticipated growth in vehicle traffic.

Transportation Management Program

A Transportation Management Program (TMP) incorporates, coordinates, and balances a wide range of potential strategies that work together to create a seamless array of options for mobility. A TMP should include a set of measurable objectives that serve as indicators toward achieving transportation goals, and the TMP should be regularly re-evaluated to ensure that the goals continue to be valid, that objectives are being met, and that the objectives remain reasonable indicators of progress toward goals.

Car sharing

Car share programs, like ZipCar, offer access to vehicles for an hourly rate and are a viable option for many people who need a car occasionally and can afford the cost. Car sharing is not viable for commuters due to the hourly cost.

2. District Options

The reconstruction of the Yesler Terrace neighborhood is a rare opportunity to rethink the role that transportation plays in the creation and enhancement of the community, its people, and the environment. This section outlines a series of potential strategies for enhancing the BAU outcomes for various elements of transportation at a district scale.

The recommended subset of the options discussed below have been identified as having potential to help achieve transportation goals and are recommended for consideration in the development of a Yesler Terrace TMP.

TABLE 2

District Options

Transit	▪ Provide real-time transit information at stop through enhanced information delivery mechanisms including electronic signage, social media, and digital applications ▪ Provide travel information, trip planning, route and schedule information for Yesler Terrace ▪ Consider a "guaranteed ride home" for office employees who do not drive to work.
Bicycle	▪ Consider cycle tracks/buffered lanes that provide greater separation between automobile and bicycle lanes. ▪ Separate bicycle paths/trails/streets ▪ Consider a bicycle hill climb assist for steep slopes particularly on Yesler ▪ Provide secured bicycle parking, lockers, short and long-term building by building or by sector (what are the sectors? Referenced, but no definition or map that tells us how many sectors there are) ▪ Weather protection for bike racks building by building or by sector (See Figure 1, Sector Map). ▪ Encourage showers and lockers for employees building by building or by sector ▪ Consider bike sharing program
Parking	▪ Consider consolidated parking into one or more parking facilities per sector. ▪ Require developers to allow residents to opt out of paid parking spot ▪ Consider a flex-pass for parking that limits the number of days an employee can park ▪ Consider parking maximums ▪ Consider shared parking facilities
Pedestrian infrastructure	▪ Provide mid-block connection requirement to facilitate informal pedestrian connections (do not develop super blocks!) ▪ Provide pedestrian scale lighting
Lid over I-5	▪ Widen Yesler ▪ Completely cover I-5 ▪ Create tensile structures to capture polluted air and redirect stormwater

Transit

Real-time transit information and wireless internet access can greatly enhance rider experience and broaden the appeal to people outside of core transit users. At the district scale at Yesler Terrace, a transportation management entity (see D. Implementation) can go beyond simply subsidizing transit passes and can include **travel information** (trip planning, route and schedule information, real-time arrival information), **outreach and promotional programs**, and **feedback mechanisms** to ensure that resident concerns are being addressed.

For residential areas near Harborview and Yesler Terrace offices, continue the **restricted parking zone** (RPZ) where parking regulations are differentiated between groups of users. In order to discourage commuters from parking in the residential area and walking to transit or work, parking time limits can be established. Area-specific parking permits can be issued or sold to area residents to exempt their vehicles from parking time limits. The RPZ will help ensure that parking demand in the higher-intensity area does not adversely impact the lower-intensity area.

Consider a **"guaranteed ride home"** for office employees who do not drive to work. A guaranteed ride home serves commuters who use alternative forms of transportation but need to get home quickly in an emergency or after available transit service has stopped. The ride home can be by taxi, company-owned vehicle, or car-sharing vehicle. The number of rides available per month or year may be limited.

Bicycle

Bicycle sharing programs are being implemented in cities around the world. Typically they are done at a city or regional scale rather than at the district scale. However, should Seattle initiate a bicycle share program similar to San Francisco's or Denver's, Yesler Terrace would be a logical location for a bicycle sharing facility.

Dedicated lanes provide clarity on lane use and provide a visual separation between uses. Dedicated lanes require more space than a shared street, and do not provide physical protection for cyclists. Dedicated lanes are typically inexpensive to implement and maintain. Buffered bike lanes and cycle tracks do provide cyclist and vehicle separation.

Parking

Consolidate parking into one or more parking facilities per sector, which can be freestanding or integrated into a building. One or more sector-based parking facilities can help reduce overall parking and automobile infrastructure costs by eliminating the need for separate garages in buildings (with their ramps, driveways, access gates, mechanical systems, stairs, and elevators reduced). This can add to the value of the land by freeing up space for pedestrian amenities, open space, and additional leasable real estate.

Reducing parking needs in a building reduces the impact of automobile-scale features in pedestrian zones (e.g., driveways, parking entrances, and blank facades, which are typically unpleasant spaces for pedestrians). Instead buildings can be designed to the street with attractive building entries, shops, or other pedestrian-oriented uses as the primary user experience.

Most housing is coupled with significant space for cars, whether that is in an individual garage or a parking space in the building parking lot. The cost of housing often includes the substantial cost of building parking. A district parking system can **decouple housing cost and parking cost – by allowing residents to opt out of parking** space they don't need, housing costs can be made much more affordable. And by building only the quantities of parking that are actually needed, parking facilities can be less expensive as well. In Seattle's International District, the Uwajimaya Village Apartments share space with the supermarket on the same site, and at Thornton Place (in Northgate) parking is shared between residential apartments and a cinema and shopping complex.

In coordination with consolidated parking strategies, a **flex-pass** is an option for parking that limits the number of days an employee can park. Most parking passes are sold on a monthly basis and allow unlimited parking during that month. A flex-pass would be a lower-cost option that would limit the number of days workers in Yesler Terrace office areas could park. This type of pass is a good option for employees who may take transit or ride a bike to work some days a week, but need a car at work on certain days for work or personal business

Pedestrian infrastructure

Pedestrian paths (between buildings, through open space, etc.) should be established within Yesler Terrace. This can be accomplished via design guidelines to encourage developers to accommodate a through-block connection that can be adaptable to the situation, but still provide that public connection. Because pedestrians will seek the shortest possible distance between points – a good pedestrian environment provides direct routes where possible, even where streets follow a less direct route. The current street grid of Yesler Terrace is limited, which also impacts its current pedestrian environment. Redevelopment will reintroduce new streets and driveways, but a secondary pedestrian network should be implemented.

Lighting on bollards or pedestrian-scale light standards can improve visibility without over-illumination. Maintenance of pathways, lighting, and vegetation can help give pedestrians a sense of security. Covering pathways can make them comfortable and inviting even in the worst of Seattle's weather. These types of recommendations can be included in design guidelines that developers use bring a district-level of consistency between individual projects at Yesler Terrace.

In addition to a well-designed path, pedestrian amenities along or adjacent to pathways can increase the attractiveness of walking. Pocket parks and landscaping, benches and other street furniture, and signage and way-finding can benefit pedestrians who are walking for pleasure and those who are walking as transportation.

A relatively small investment can greatly improve pedestrian environments while still contributing to a reduction in vehicle use. Good design of the pedestrian network and long-term maintenance of pathways at Yesler Terrace are critical to the effectiveness of pedestrian infrastructure towards transportation demand management.

I-5 lid

The 2008 amendments to the Seattle Comprehensive Plan included the following language in the Neighborhood Planning Downtown Transportation Policy on pedestrian circulation: "Linkages across I-5. Look for opportunities to re-establish connections between Downtown and adjacent areas by enlarging existing crossings, creating crossing under, or constructing lids over I-5 that can also provide opportunities for development of open space."

The I-5 freeway creates a significant barrier to movement to and from Yesler Terrace. As part of a citywide effort to reduce the impact of freeways on the human and natural environment, a lid over I-5 between Yesler Terrace and downtown would provide new access through the city for pedestrians, bicyclists, and vehicles; provide new open space or developable land, and reduce noise and air pollution impacts of the freeway on surrounding neighborhoods. Using conventional freeway construction, a lid could support commercial buildings of up to 2 stories without additional support creating some off-setting revenue potential.

A **freeway lid** is an expensive, lengthy project, and would require significant investment and approval from city and state agencies, and is thus beyond the scope of the Yesler Terrace redevelopment. The significant potential benefits of the project, as well as the potential efficiencies of constructing a lid in coordination with Yesler Terrace construction, make it worthy of consideration. In addition, the structured lid could support photovoltaic solar panels, solar hot water panels and/or wind generators. They could provide additional renewable energy resources to Yesler Terrace, Harborview Hospital or surrounding facilities.

Widening the Yesler Street overpass is another modified version of a lid over I-5. Cantilevered walkways and planting areas would improve the pedestrian experience and make a broader visual connection across the I-5 canyon. Costs for this solution would be high per square foot, but the total would be less than a complete lid due to the much smaller area.

Creation of a tensile structure that spans the I-5 canyon is another conceptual model. Cables and fabric strung across the canyon can be designed to capture polluted air and redirect it away from residential areas. A well designed fabric structure can last for decades and can be an artistic and functional addition to the urban landscape.

3. Economics

The set of district transportation strategies recommended for further consideration is very diverse. Some of the strategies are low-cost, pragmatic enhancements of BAU strategies. Examples include transit information programs, pedestrian-scale lighting, and design guidelines that would expand and coordinate pedestrian pathways within Yesler Terrace.

A second group of promising transportation strategies is somewhat higher cost, but still involves modest levels of investment. Examples include expanded bicycle infrastructure such as covered storage and lockers, dedicated bicycle lanes, and management of programs such as restricted parking zones, flex pass sales, etc., through a Transportation Management District.

A third group of strategies involves more substantial initial investments, with the promise of comparable returns. The main examples are consolidated parking and mini-fleet acquisition and management. For consolidated parking, SHA would provide land and financing for structures sized to serve several buildings or blocks. That investment would be offset by higher land sales revenue due to reduced building parking requirements for the developers, augmented as necessary by parking revenues for use of the consolidated parking facilities. Mini-fleets would require purchase and maintenance of the vehicles themselves, plus provision of parking space and enhanced electrical service. This would be offset by the substantial reduction in parking structure cost for the greater number of stalls saved by such a program. In addition, user fees could be sufficient to cover all other costs, while still being less than the participating fleet users would have paid for maintaining and using a private vehicle.

Finally, the cost for a concrete structured lid over I-5 that can hold soil and open space is very high. For example, in 2009 an overpass over Highway 520 for Microsoft has an estimated cost about of between $35-$40 million. Less costly alternatives include widening the Yesler Street overpass or a tensile structure that covers the freeway. All options would include significant coordination with the City of Seattle and the Washington State Department of Transportation.

4. Implementation of District Options

Much of the business as usual mobility strategies will be implemented as a matter of course during construction of Yesler Terrace. In this section implementation of selected district options is proposed.

TABLE 3

Implementation: Transportation Management District (TMD)

Formation	▪ Consider development of a Transportation Management District to fund parking and to manage mobility programs required on the site. ▪ Consider an option where this new entity could have broader authority to take on and manage other district functions such as energy or water systems.
Management	▪ A TMD can manage an array of mobility programs for the Yesler Terrace neighborhood including funding and management of consolidated parking facilities. ▪ Costs for mobility programs that would otherwise be borne by individual developers may be cost effectively shared with a TMD. ▪ A TMD can provide consistency across the Yesler Terrace neighborhood and professionalize compliance among and between the property owners
Funding	▪ A TMD can be created with the authority to raise capital for consolidated parking infrastructure offset by parking revenues. ▪ A TMD may be able to attract other funding sources or grants

I-5 lid

The following series of tasks could be undertaken as preliminary steps toward a lid:

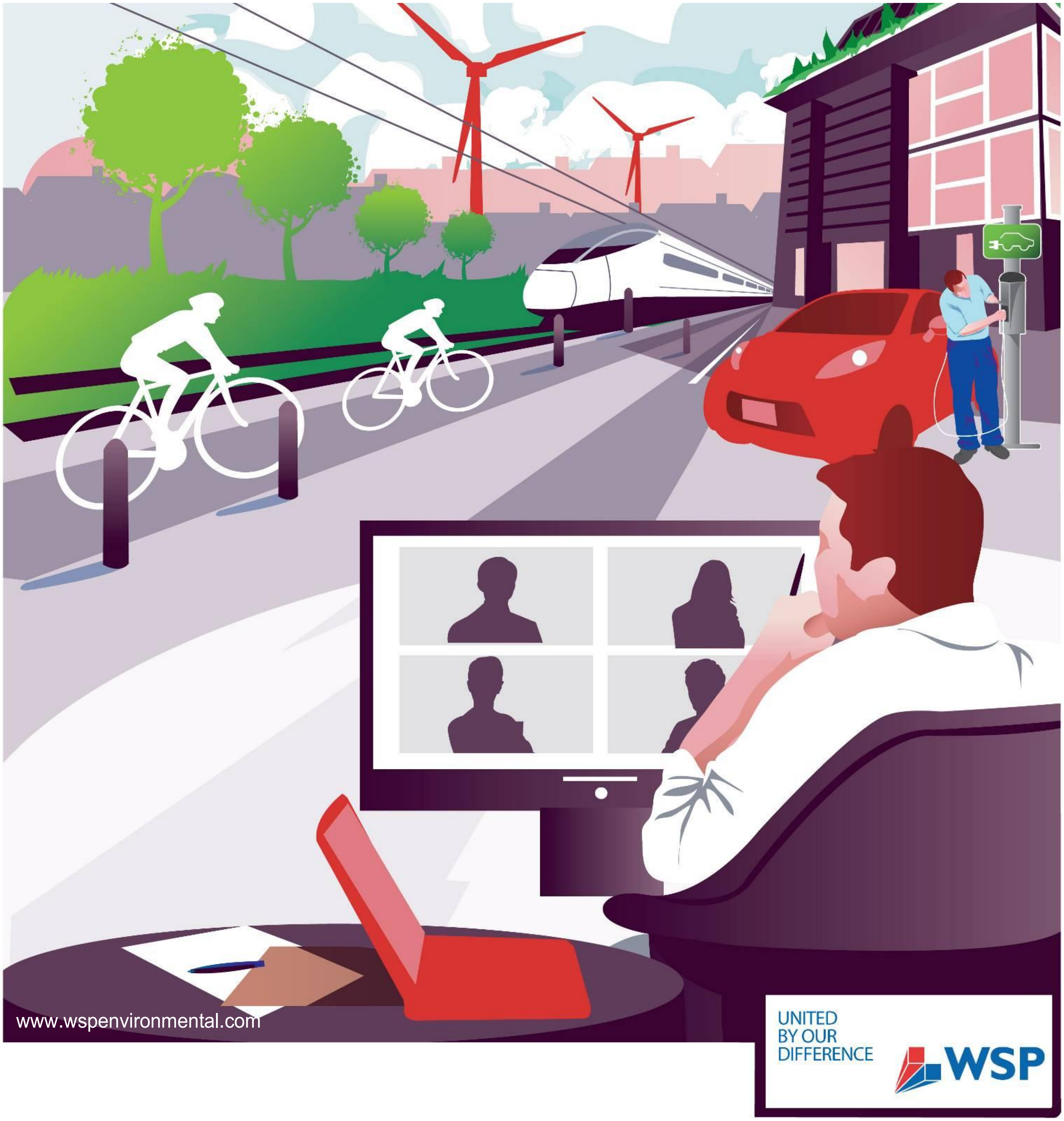
Inspire the public imagination with a design competition for structured and/or tensile lids over the freeway

Identify potential partners who would benefit from a lid such as public health advocates who seek cleaner air and quieter living environments in dense urban areas

Collaborate with the Washington State Department of Transportation on alternative solutions

Explore a local improvement district (LID) or park bond as a funding source

Appendix A



Yesler Terrace Sustainable Energy Analysis

Prepared for CollinsWoerman

Monday, 01 November 2010

QUALITY MANAGEMENT

Issue/revision	Issue 1	Revision 1	Revision 2	Revision 3
Remarks				
Date		07/12/2010	8/25/2010	10/29/2010
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Signature				
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Signature				
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Signature				
Project number				
File reference				

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TABLES & FIGURES

EXECUTIVE SUMMARY

The Client: Seattle Housing Authority (SHA), established in 1939, is a public corporation governed by a seven-member Board of Commissioners. The agency owns and operates buildings on more than 400 sites throughout the city, and provides long term rental housing and rental assistance to more than 26,000 people. Since 1995 SHA has completed major public housing redevelopments of the NewHolly, Rainier Vista, and High Point developments into mixed-income, mixed-tenure communities that have transformed these areas into new neighborhoods within the City of Seattle, encompassing nearly 300 acres and creating approximately 4,300 new units of housing, as well as new infrastructure, parks and community facilities. At High Point, SHA implemented an aggressive and highly successful green building and low impact development program in partnership with the Built Green program and Seattle Public Utilities.

Yesler Terrace: SHA is now in Phase 2 Planning to redevelop Yesler Terrace. This 38 acre site is ideally suited to become a showcase sustainable community. It is centrally located, and lies within one mile of the city's largest employment area, containing 25% of the jobs in Seattle. SHA, in coordination with residents, neighborhood stakeholders and consultants, plans to build a dense, walkable, urban, mixed-income, and diverse community. SHA is in the process of preparing an Environmental Impact Statement (EIS) that examines several different alternatives for possible development scenarios. Each of these scenarios increases density to varying degrees. Each includes increasing the number of residential units from the existing 561, by different amounts. Each proposes varying amounts of office space and open space. This study uses one of the development scenarios, called Alternative 2, as the basis for analysis. Alternative 2 proposes 4,000 new residential units of housing using a mix of mid-rise buildings and towers of between 150 to 240 feet in height. It also proposes 1 million square feet of office space, 5 acres of open space, and underground parking.

SHA wants this community to be designed to minimize its environmental impact by first incorporating energy efficiency measures to save energy and reduce peak loads and then deploying renewable energy technologies to satisfy these reduced loads. **This report is intended to frame a preliminary picture for SHA illustrating the approximate level of energy demand that can be expected to result from energy efficiency implementation while showing the potential to meet this demand with renewable energy resources.** Note that this analysis assumes that all residential units are on SCL's standard residential rate tariff, since we have no information on how many low-income units will be part of the mix.

WSP has completed a preliminary evaluation of three energy supply options: 1) district-wide ground source (geoexchange) heat pump heat exchanger fields serving distributed heat pumps in the buildings and combined with roof-mounted solar water heaters; 2) centralized combined cooling, heating, and power (CCHP) plant; and 3) district heating plant. Key outputs of WSP's analysis include estimates for the incremental capital costs required at the building level to construct Yesler Terrace to be energy code compliant in future years, incremental capital costs to implement the district heat pump option, incremental capital costs to implement the CCHP option, and incremental capital costs to implement the district heating option. All incremental capital cost estimates are in comparison to the estimated capital cost of constructing Yesler Terrace to conform with current baseline energy supply and HVAC systems (all-electric) and to be minimally compliant with the current energy code.

WSP has performed life cycle energy cost analysis to determine how these scenarios compare on a 30 year levelized basis. Table 1 shows the incremental capital costs required to build Yesler Terrace to be compatible with the three energy supply scenarios considered. All three scenarios would need to incur the estimated $19.42 million cost required to meet the assumed more stringent future energy codes (the "expected business-as-usual" case). Over and above that cost, building Yesler Terrace to accommodate one of the three energy supply scenarios considered would result in additional capital costs ranging from $10.26 million to $16.35 million compared to the estimated capital cost of the expected business-as-usual case.

TABLE 1: INCREMENTAL CAPITAL COST REQUIREMENTS ($ 2010)

Phase & Sector	Incremental Load Reduction Cost	Incremental GeoX/SHW Cost	Incremental CHP Cost	Incremental District Heat Cost
2015 (NE + EOB)	492,605	3,602,428	2,790,432	1,390,749
2020 (NW)	5,876,278	4,026,702	9,184,856	6,783,381
2025 (SW)	6,120,988	3,270,555	2,580,771	1,245,051
2030 (SE)	6,928,475	2,361,799	1,798,419	839,917
Total	19,418,345	13,261,485	16,354,478	10,259,098

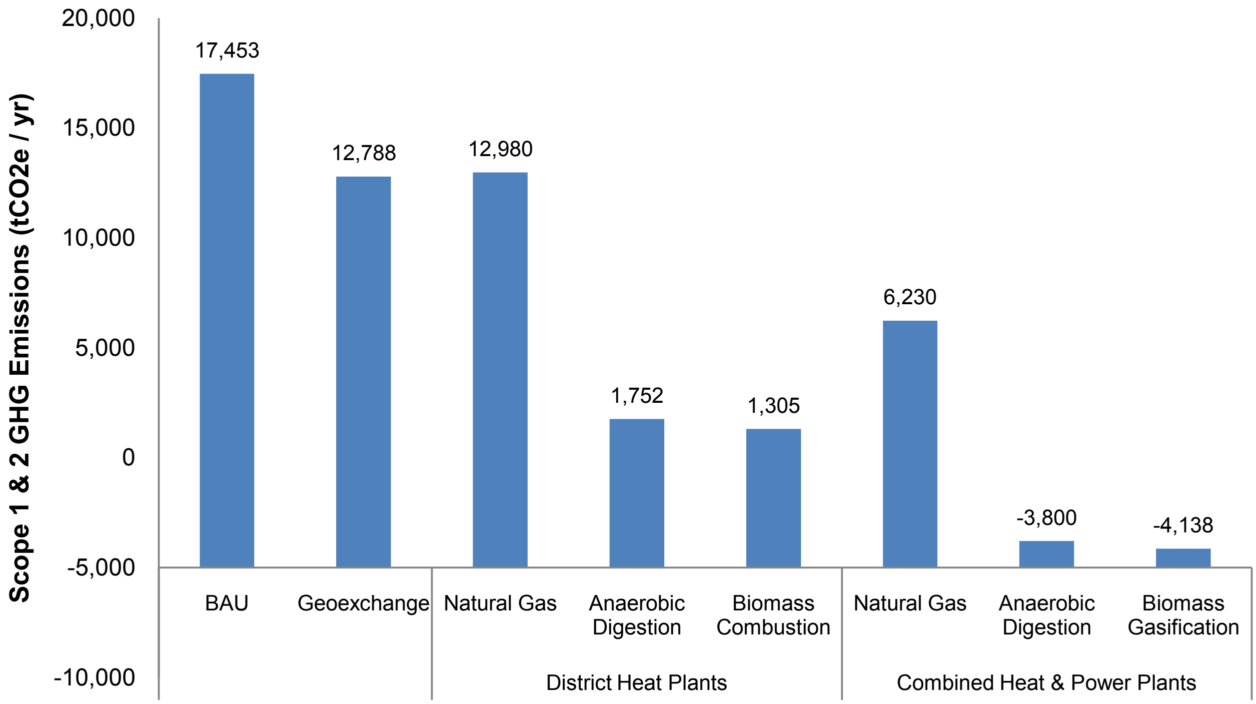
Life cycle cost analysis has been performed to consider upfront capital costs and recurring energy and operations and maintenance costs. Three different fuels were evaluated for the CCHP option – natural gas; biogas produced from fats, oils, and grease (FOG); and synthesis gas produced via gasification of biomass. Fuels evaluated for the district heating option were natural gas, biogas from FOG; and solid biomass burned directly in boilers. The cost analysis incorporates 30 years of operating expenses starting with the completion of the first phase of development (2015). Table 2 presents life cycle costs on both a 30 year cumulative and per square foot-year basis for each scenario evaluated. The life cycle costs of the alternatives to the baseline are generally 25% to 50% higher than the expected business as usual (BAU) scenario.

TABLE 2: 30 YEAR LIFE CYCLE ENERGY COST SUMMARY

Life cycle cost summary	30 yr Life Cycle Costs ($'000)	Normalized Life cycle Costs ($ / SF-yr)	% Increase from BAU
Expected BAU	47,676	0.34	
Geoexchange/SHW	49,768	0.35	4%
CCHP with sales to Harborview			
Natural gas fired	60,039	0.43	26%
Anaerobic digester gas fuelled	58,462	0.42	23%
Biomass gasification fuelled	57,040	0.40	20%
CCHP without sales to Harborview			
Natural gas fired	84,159	0.60	77%
Anaerobic digester gas fuelled	78,437	0.56	65%
Biomass gasification fuelled	81,161	0.58	70%
District heat with sales to Harborview			
Natural gas fired	41,525	0.29	-13%
Anaerobic digester gas fuelled	49,784	0.35	4%
Biomass combustion fuelled	41,802	0.30	-12%
District heat without sales to Harborview			
Natural gas fired	58,726	0.42	23%
Anaerobic digester gas fuelled	59,836	0.42	26%
Biomass combustion fuelled	59,003	0.42	24%

Site-wide emissions of greenhouse gases resulting from the use of fuels and electricity for powering, heating, and cooling Yesler Terrace buildings have been assessed. Scope 1 emissions result from the direct emissions of greenhouse gases from fuel combustion. Scope 2 emissions result from emissions associated with electricity purchased from the SCL grid. Figure 1 presents site-wide GHG emissions corresponding to the baseline, the geoexchange option, and the CHP and district heating scenarios which involve thermal energy sales to Harborview Medical Center. Negative values result for CHP scenarios involving biogas and synthesis gas displacing fossil energy currently used by the hospital.

FIGURE 1: SITE-WIDE EMISSIONS OF GREENHOUSE GASES FOR YESLER TERRACE



The district heating option with thermal energy sales to Harborview offers the lowest life cycle costs of the cases evaluated. However, without thermal sales to Harborview, district heating becomes much less compelling, and the BAU scenario has both the lowest upfront installed capital cost and the lowest life cycle energy costs of the evaluated cases. Note, however, that BAU results in the greatest release of greenhouse gas emissions associated with energy use. Seattle Housing Authority will ultimately need to balance the need for low cost energy with a desire to create a more sustainable community.

Although energy resources are quantified in this study and projections are made to illustrate renewable energy production potentials, it should be noted that additional analysis is required to identify readily deployable solutions and to sharpen the accuracy of implementation cost estimates.

Our preliminary recommendations include:

- Reduce demand for electricity for heating, cooling, and plug loads by incorporating principles of low energy use building design;
- Install underground primary piping and secondary piping in all buildings in order to accommodate either a district heating system or a central ground source heat pump system using the ground, storm water, and sewer water as heat sources and sinks;
- Based on this life cycle analysis, the next phase of work should conduct detailed studies of district heating with thermal sales to Harborview Hospital and geoexchange as potential sustainable energy supply-side options for YT;
- If either the district heating or the community wide geoexchange system is implemented, install underground electrical distribution to leverage the trenched utility corridors which would be required for either of these energy systems.

These recommendations are based on theoretical potentials that result from the assumptions presented in the report, but it should be understood that detailed analysis and holistic planning sessions will be required before a realistic plan for the site can be finalized.

1 ENERGY DEMAND-SIDE ANALYSIS

1.1 PROGRAM SUMMARY

CollinsWoerman has provided WSP with a development program summarizing the building types and square footage by sector for four alternative development programs. This report focuses on “Alternative 2”, which is in the middle of the density range being examined for this site. Each sector listed below refers to a quadrant, e.g. SW is southwest, and separately EOB refers to the area east of Boran St. These details are presented in Table 3 along with the phasing dates for each sector obtained from Seattle Housing Authority (SHA). The phasing dates guide assumptions in the analysis regarding the level of end-use energy efficiency which will be deployed and allow for an informational comparison with the Architecture 2030 Challenge goals.

TABLE 3: SUMMARY OF ALTERNATIVE 2 DEVELOPMENT PROGRAM

Sector	Build Out Year	Residential Units	Residential SF	Office SF	Neighborhood Retail SF
NW	2020	1,055	960,050	1,001,126	20,000
NE	2015	602	565,880	0	15,000
SW	2025	1,129	1,021,745	0	15,000
SE	2030	961	854,329	0	0
EOB	2015	253	232,254	0	10,000

1.2 ARCHITECTURE 2030 CHALLENGE

Although Yesler Terrace and the Seattle Housing Authority have not explicitly stated that the Architecture 2030 Challenge goals will be followed, it is instructive to compare the various scenarios under consideration with these goals. The Architecture 2030 Challenge goal for new construction in 2010 is an energy use reduction target of 60% relative to regional averages and has an end goal of net zero energy by 2030. Table 4 presents these reduction targets along with the corresponding Energy Usage Intensity (EUI) values, by year and building type, considered by this study. These numbers are incorporated in this study for informational purposes only and the analysis has not necessarily been designed to closely adhere to this target.

TABLE 4: 2030 CHALLENGE GOALS SHOWING SEATTLE BUILDING AVERAGE AND TARGET EUIs (kBTU/SF-YR) FOR FUTURE YEARS

	CBECS Seattle Average EUI (kBtu/SF-yr)	2010	2015	2020	2025	2030
2030 Challenge Reduction Target		60%	70%	80%	90%	100%
Multi-family residential	40	16.0	12.0	8.0	4.0	0.0
Office	95	38.0	28.5	19.0	9.5	0.0
Town Center Small Format Retail	56	22.4	16.8	11.2	5.6	0.0

1.3 DEFINING BASELINE BUILDING ENERGY LOADS

WSP has provided estimates of aggregate loads for electricity, space heating and cooling, and domestic hot water for Yesler Terrace. WSP has used load data produced by hourly energy simulation models for prototypical multi-family residential and commercial office buildings to estimate building energy loads by end use. These models are used to represent the BAU for office and residential buildings that are minimally compliant with Seattle energy codes at different points in time over the Yesler build-out period. The models in their present form are assumed to be equivalent to Washington State 2006 and 2009 energy code-compliant buildings. **In follow-on phases of work, explicitly code-compliant building energy models should be developed to provide more accurate energy load data with which to conduct a more in-depth analysis.** Table 5 shows the individual models considered in this study along with loads by energy end uses, normalized by square footage. Note that these values are not the same thing as "Energy Use Intensity (EUI)" since the Table 5 values represent the amount of energy needing to be delivered to or removed from a space and do not include HVAC equipment losses that occur during the conversion of fuel or electricity to usable energy and the delivery of that energy to the loads by fans and pumps. Table 5 data represent the "baseline" or minimally code-compliant loads for each building type.

TABLE 5: BASELINE BUILDING LOADS

		Building Energy Loads (kBtu/sf-yr)				
Building Type and Model	Code compliant (WA state)	Plug loads & lighting	Domestic hot water	Space heating	Space cooling	Total
Office	2006	30.4	0.1	13.2	12.7	56.4
Office (W/ SCL eff.)	2006/2009	28.6	0.1	11.8	9.5	50.1
Neighborhood Retail	2006	15.8	0.0	20.5	12.0	48.3
Multi-family, > 5 units	2006	14.9	5.2	4.3	13.2	37.5
Multi-family, > 5 units (W/ SCL eff.)	2006/2009	13.5	3.7	2.5	13.2	32.9

Table 5 presents two separate cases involving multi-family and office buildings. The second case for each, containing the text "W/ SCL eff", reflects energy efficiency measures included in the Quantec 2006 report to Seattle City Light titled "Conservation Potential Assessment". The Quantec CPA report considered energy conservation measures, their implementation cost, and incremental energy savings versus a baseline which was considered to be average buildings which were 2004 Washington energy code-compliant. For this reason, these measures are incorporated in our study as representing 2006 code compliance. Thus, they do not constitute a set of measures that are sufficient to shift our model up to being fully 2009 energy code-compliant. Rather, they are presented as compliant with a hypothetical code between 2006 and 2009 and designated as "2006/2009". Specific measure details are presented in Table 6 and Table 7. For this analysis, it is assumed that MF residential units are on average 750 SF in size.

TABLE 6: MULTI-FAMILY RESIDENTIAL NEW CONSTRUCTION ENERGY CONSERVATION MEASURES IN SCL 2006 CONSERVATION POTENTIAL ASSESSMENT

	Implementation Cost ($/SF)	**Energy Savings (kWh/SF-yr)**
Lighting & Fixtures	0.02	0.83
Equipment (freezer, ref, dryer, DW, oven)	1.00	0.51
Equipment (clothes washer, DW)	0.60	0.23
Aerators and Drain Heat Recovery	0.58	0.17
Shell / Envelope measures	5.02	0.51

TABLE 7: OFFICE NEW CONSTRUCTION ENERGY CONSERVATION MEASURES IN SCL 2006 CONSERVATION POTENTIAL ASSESSMENT

Measure	Implementation Cost ($/SF)	Energy Savings (kWh/SF-yr)
HW pipe insulation	0.00	0.03
High Efficiency Office Equipment	0.09	0.66
Windows	0.16	0.03
Cool Roofs	0.25	0.28
Roof / Ceiling Insulation	0.35	0.33
Lighting Upgrades	0.40	0.26
Lighting Controls	2.40	0.85

The assumed thermal and electrical loads, aggregated for the entire development, are summarized in Table 8. These estimates have been made using energy models for the prototype buildings along with the building type square footage assumptions provided by C-W. Note that “MWh/yr” refers to electricity required to be delivered from both the grid and from on-site power generation. **Incremental energy efficiency improvements associated with successive energy code upgrades are assumed to occur every 5 years during the YT build out phases.** WSP assumes that every five years, building energy loads decrease by 13% for commercial space and by 14% for residential space, using 2010 as a baseline. **This means that energy loads in buildings, which will be built in 2015, will consume an average of 86-87% of 2010 code-compliant buildings and buildings completed in 2030 will consume 55-57% of 2010 code-compliant buildings.** This incremental load reduction is assumed to be required by future state energy codes and thus is considered to be Business As Usual (BAU).

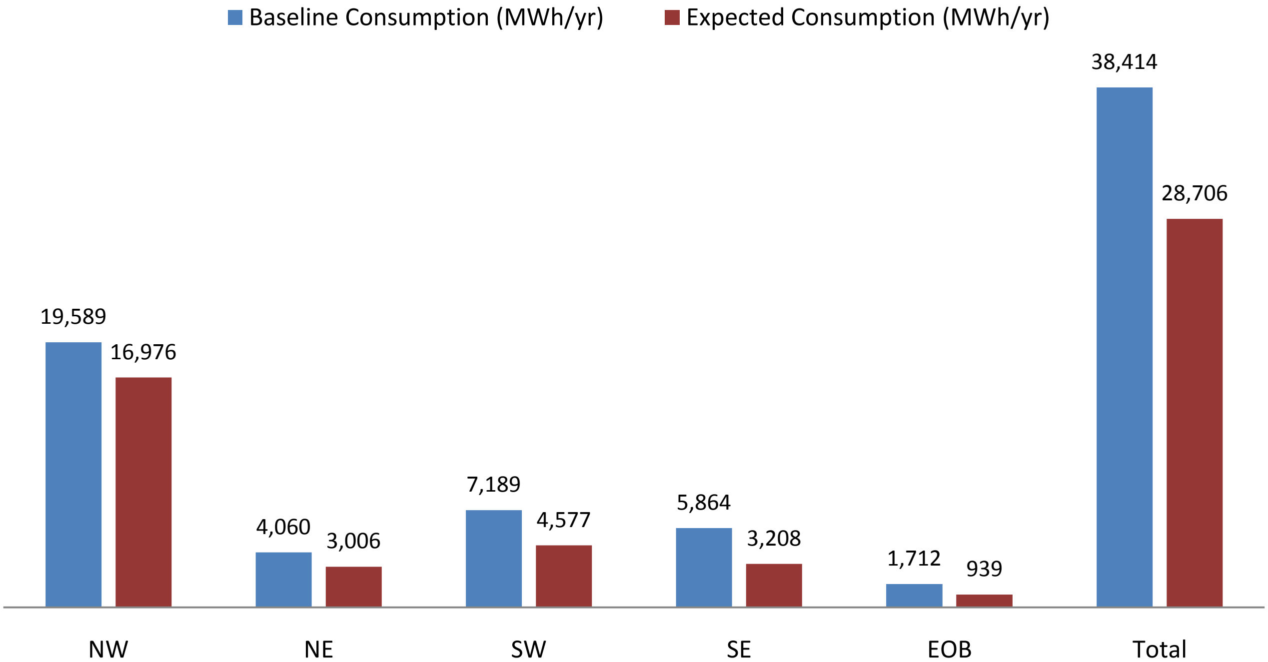
TABLE 8: EXPECTED BUSINESS AS USUAL ELECTRICAL AND THERMAL LOADS FOR YESLER TERRACE

Sector	Building Loads, fraction of 2010 baseline	Plug Loads & Lighting (MWh/yr)	Water Heating Load (MMBtu/yr)	Space Heating Load (MMBtu/yr)	Space Cooling Load (ton-hr/yr)
NW	86 - 87%	10,662	3,118	12,721	1,618,404
NE	74 – 76%	1,712	1,549	1,277	471,699
SW	64 – 66%	2,623	2,405	1,824	724,722
SE	55 – 57%	1,853	1,729	1,166	514,051
EOB	55 – 57%	530	470	434	145,463
Total		17,381	9,271	17,423	3,474,340

NOTE: The loads presented in Table 8 are used in all subsequent energy supply analyses.

Figure 2 presents how these load assumptions translate into aggregated site-wide energy consumption for each phase of construction. The “Baseline” bars in blue show what site-wide electricity consumption would be in the absence of future energy codes becoming more stringent than the assumed 2009 code. Note that both Baseline and BAU assume all-electric HVAC and DHW systems. In other words, the loads defined above in Table 5 and Table 8 are assumed to be served entirely with electric systems, and Figure 2 shows the resulting electricity consumption. The “Expected” BAU red bars show electricity consumption resulting from the load reduction assumptions presented in Table 8 for each build-out stage. Since the expectation is that future energy codes will become more stringent in future years, the “expected” scenario represents business as usual.

FIGURE 2: SITE-WIDE ELECTRICITY CONSUMPTION USING ALL-ELECTRIC ENERGY SUPPLY SYSTEMS



Note: Baseline Consumption = 2009 code compliance throughout build-out period; Expected Consumption = compliance with progressively more aggressive energy codes = Business As Usual (BAU)

1.4 THE COST OF INCREMENTAL ENERGY LOAD REDUCTIONS

In the previous section, assumptions were made on how future energy codes and improvements in building design and construction would ultimately result in decreased building energy loads. In this section, we present the economic cost of implementing these "additional measures". The approach recommended by CollinsWoerman was to develop a set of generalized curves which could relate incremental building energy load reduction to additional construction cost per square foot. The use of "generalized" curves means that these curves should be representative of a wide swath of measures which, in various combinations, would deliver assumed load reduction. Energy efficiency measures include higher-efficiency windows, higher R-value insulation, natural ventilation, higher-efficiency HVAC equipment, and others.

The approach presented here has been used since WSP was not able to find useful data in the literature. The data appears to not exist in the form required for this project. The only data available in the public domain with a sufficiently large building sample size only relates total building energy use to total construction cost, not incremental energy use (savings) versus incremental construction cost. Appendix A presents a discussion of the survey which was conducted on low energy use buildings located in the United States and the results obtained as part of this effort.

In an alternative approach, WSP incorporated studies, performed for other developments we are involved with in other parts of the country, to develop curves showing the incremental costs per square foot for a set of energy efficiency measures. Figure 3 and Figure 4 present the curves that are used in this analysis to assign incremental cost estimates to the load reduction/energy efficiency percentages presented above in Figure 2 and Table 8. Note that these data are not well-correlated and, strictly speaking, are representative of only those specific buildings with which the data are associated. However, these are the best data currently available to us. This study would greatly benefit from analysis specific to the Yesler Terrace building types, Seattle climate, materials, construction costs, and incentives.

FIGURE 3: COST CURVE FOR MULTI-FAMILY RESIDENTIAL UNITS

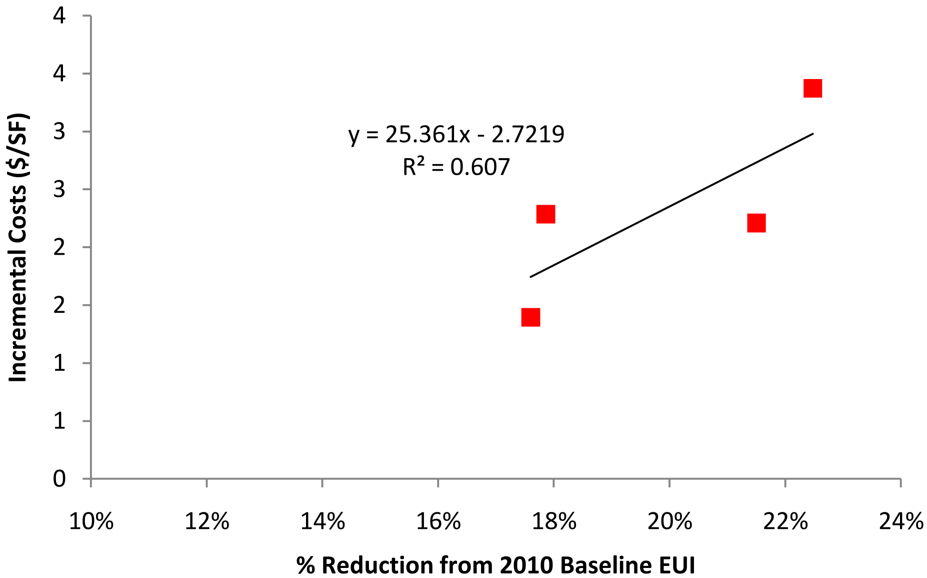
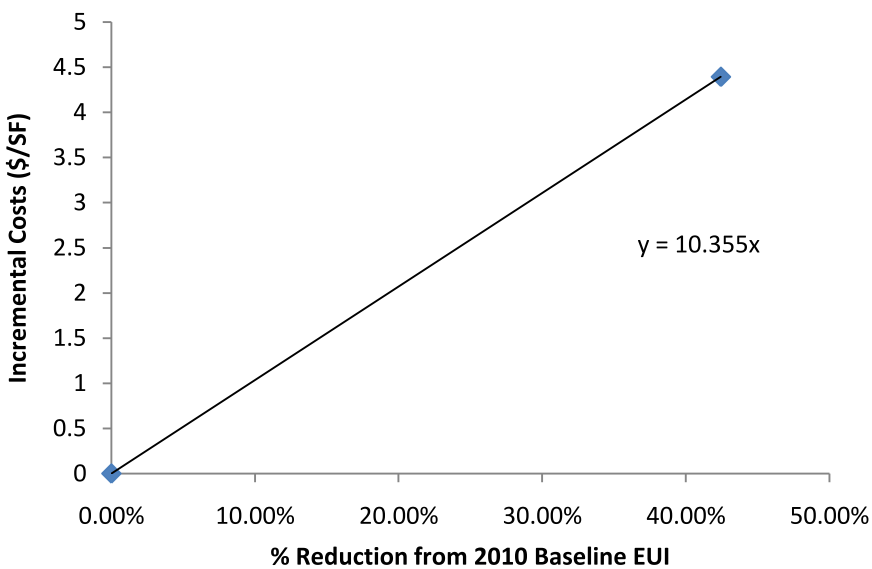


FIGURE 4: COST CURVE FOR COMMERCIAL OFFICE BUILDINGS



As discussed, it has been assumed for this study that building energy loads for new construction will decrease by 13% to 14% every 5 years, in response to progressively more stringent energy codes. Using the baseline energy-using systems assumed (all electric HVAC, DHW, and appliances), the baseline electricity consumption is presented along with the "expected scenario", or BAU, which assumes this incremental load reduction every 5 years. The improvements save 9,708 MWh per year for Yesler Terrace. This could be larger if assumptions on the phasing are adjusted. For example, it is assumed that 100% of office buildings are built out in the second phase where the loads are assumed to be 73% to 76% of baseline. If this assumption was changed such that the office space was built out in 2030, the energy savings would be much larger because of the incremental load reduction being assumed as significantly larger in future phases, due to advances in technology, advances in design best practice, etc., which enable compliance with ever-stricter energy codes.

TABLE 9: SEATTLE CITY LIGHT 2010 ELECTRIC RATE SCHEDULES

	Summer (Apr-Sept)		Winter (Oct-Mar)		
Residential Schedules	first 10 kWh ($/kWh)	additional kWh	first 16 kWh	additional kWh ($/kWh)	Service ($/day)
RLC (low income residential)	0.0193	0.0354	0.0193	0.0354	0.0579
RSC (standard residential)	0.0459	0.0955	0.0459	0.0955	0.1157
Commercial Schedules	All kWh ($/kWh)		Peak Charge ($/kW peak)		
MDC (medium general)	0.0567	$/kWh	1.22		0.71
SMC (small general)	0.0667	$/kWh			0.27

Energy costs for electricity are projected using the current Seattle City Light rate schedules, presented in Table 9. All residential space is assumed to be on the standard residential city rate, all office space is on the medium general city schedule, and neighborhood commercial is on the small general city schedule. Note that, due to lack of information on the amount of low-income housing in the project, the special low-income SCL rate is not used by this analysis. Table 10 shows the level of energy load reduction expected for code-compliant future buildings, the expected annual electricity consumption and the corresponding energy cost in $$2010, and how these compare with current or 2010 code-compliant buildings. The curves presented in Figure 3 and Figure 4 are used to generate the incremental cost of construction presented here. Although this is "incremental" in terms of current building construction costs and should be used by SHA to project out future build costs in relation to today's build costs, these values are not assumed in the supply-side analysis because they effectively will be part of the BAU case since they are mandated by code. **The incremental energy load reduction measures that will be required to keep pace with future energy codes throughout YT's development will cost an additional $19.4 million and save $875,773 per year in energy costs. The 22-year simple payback reflects the relatively low cost of conventional energy enjoyed by Seattle.**

TABLE 10: EXPECTED ADDITIONAL CAPITAL COSTS ASSOCIATED WITH BUILDING TO ASSUMED FUTURE AGGRESSIVE ENERGY CODES

Energy Use Reductions	2010-level Usage (MWh/yr)	2010-level Energy Cost ($/yr)	BAU Load % of Baseline	Expected Future Usage (MWh/yr)	Expected Future Energy Cost ($2010/yr)	Energy Cost Savings Expected ($2010/yr)	Incremental Installed Cost of Load Reduction Measures ($2010)
NW	19,589	1,410,257	86 - 87%	14,827	1,076,938	333,319	5,876,278
NE	4,060	403,539	74 – 76%	3,532	353,791	49,748	345,590
SW	7,189	721,903	64 – 66%	4,734	489,179	232,724	6,120,988
SE	5,864	593,136	55 – 57%	3,359	353,964	239,173	6,928,475
EOB	1,712	169,786	55 – 57%	1,489	148,977	20,810	147,015
Total	38,414	3,298,622		27,942	2,422,849	875,773	19,418,345

2 ENERGY SUPPLY-SIDE ANALYSIS

To analyze the various supply-side options, WSP evaluated a range of energy-generation equipment including natural gas engines, micro-turbines, ground-source heat pumps (aka geoexchange), solar water heaters, boilers, and chillers to satisfy the energy demand and achieve balance in the heating/electricity/cooling production ratios. In addition to biomass fuels, the equipment can also be configured to use natural gas and grid-supplied electricity, which is appropriate for satisfying peak loads. WSP has not conducted a resource assessment to characterize cost curves of the potentially available biomass resources. This will be a key element of the feasibility study conducted in the future if it is determined that biomass CHP fits the Yesler Terrace development objectives. Refer to Appendix A for descriptions and unit costs of the various CHP and district energy technologies considered.

Three centralized energy-supply configurations were evaluated, and a life cycle energy cost analysis was performed for each.

- In the first energy-supply options, a central geoexchange heat exchanger field would serve as a heat source and heat sink for heat pumps deployed in all the buildings. The heat pumps are assumed to supply 100% of space heating, 100% of space cooling, and to be coupled to domestic hot water (DHW) systems in order to supply a substantial fraction of the domestic hot water load via desuperheaters. In this scenario, solar-heated DHW covers 25% of the DHW load and the remaining 75% is covered by the ground-source heat pump system. All of YT's electricity requirements are met with grid-supplied electricity in this option.
- In the second energy-supply option, three combined cooling, heating, and power scenarios were evaluated and sized to supply Yesler Terrace with 100% of the thermal energy required for heating and cooling with hot and chilled water generated at a central plant. In addition, the annual electricity usage of Yesler Terrace would be generated by the CHP by net metering with the grid. The three scenarios considered operate identically at the building interfaces but process different fuels (natural gas and waste biomass) at the central plant.
- In the third energy-supply option, three district heating-only scenarios were investigated to supply 100% of the heating load with hot water generated by a central plant. The three scenarios correspond to the same feedstock and fuel processing options investigated by the CHP scenario.

2.1.1 Collaboration with Harborview Hospital

Several alternative sources of thermal energy were investigated as potential supply sources to the Yesler Terrace development. WSP approached the Harborview Hospital staff and their consultant McKinstry to inquire about the potential for purchasing condensate from condensed steam supplied to Harborview by Seattle Steam. McKinstry has been hired by Harborview to assess the potential for energy conservation at the hospital and one of the major outcomes of this study has been a recommendation by McKinstry that Harborview generate its own thermal energy in the future. The proposed alternative will involve slowly transitioning off of Seattle Steam's service while building up Harborview's own steam and hot water generation capacity. Thermal energy will be balanced between hot and chilled water demands using a campus-wide condenser loop, acting as a heat source and sink for these systems. WSP believes that condensate currently produced at Harborview does not represent a long-term viable source of thermal energy for Yesler Terrace because it will not be available if Harborview follows through with these retrofit plans.

However, other potential collaboration opportunities exist for Yesler Terrace and the hospital to share district energy infrastructure and energy. In this study, a combined heat and power option has been investigated in which excess thermal energy will necessarily be produced in order meet the annual electricity demand by Yesler Terrace. The modelling work assumes that excess thermal energy can be sold to and utilized by Harborview Hospital. This could be accomplished simply by Harborview directly using hot water produced at Yesler Terrace or the excess hot water or steam produced at Yesler could be exchanged with Harborview indirectly through the proposed Harborview condenser loop. This second option may provide a more seamless integration with Harborview's current and future infrastructure. Other options for collaboration exist which might involve building a facility sized to fit the combined thermal energy loads of Harborview and Yesler Terrace. This option would capitalize on economies-of-scale advantages in addition to the potential of siting the plant at Harborview to keep space at Yesler available for development. These and other potential synergies need to be addressed in the next phase of work through dialogue with the Harborview staff so that common objectives can be realized and a system concept can be formulated.

2.1.2 Raw Sewage Heat Recovery

Raw sewage discharged at Yesler Terrace can be mined for heat using industrial heat pumps. The availability of useful thermal energy from this source is a function of the daily waste water discharge rate and design temperature drop of the discharge stream. Sewage heat recovery systems are designed to reduce the water temperature by only a couple of degrees Celsius but due to large volumetric flow rates associated with waste water this is typically a sufficient temperature drop.

This technology uses specially designed pipes which contain a water jacket that can circulate cold water to extract heat from the sewage flowing through the pipe. These systems should be installed at the same time other utility infrastructure is installed to minimize costs. Two competing objectives associated with designing such a system are the aim to extract heat and the need to design Yesler Terrace as a low water-use community. If a community is very water efficient, there will be less thermal energy available for recovery. However, it may be possible to design a system which achieves a larger temperature drop in order to balance a lower volumetric discharge rate.

Ed Clerico at Alliance Environmental, LLC provided sewage discharge numbers to use as estimates for this analysis. It has been assumed that per-person domestic water use rates are 60 gal/day in the NE, NW and EOB sectors and are 45 gal/day in the SW and SE sectors developed later. A Yesler Terrace head count for each build-out phase is estimated using person-per-SF data presented in Seattle City Light's Residential Customer Characteristics Survey 2009. In addition, it is assumed that 20% of the people who live in Yesler Terrace also work in Yesler Terrace in order to avoid double counting. The heat recovery potential is estimated assuming a heat pump COP of 3 and a sewage temperature drop of 2 degrees. This system is assumed to be tied into the CHP plant. **The total sewer heat recovery potential is estimated to be 8,335 million Btu/year, which is about 30% of the annual space heating and DHW energy needs.** However, since the heat recovered with this system would be available only when waste water is discharged by Yesler Terrace users, **hourly energy simulations must be performed in follow-on phases of work to determine to what extent waste heat is available when space heating and DHW loads occur. Hour-by-hour analysis is required to accurately estimate how much available waste heat can actually be put to productive use.**

TABLE 11: ESTIMATED SEWER HEAT RECOVERY POTENTIAL

Year	persons	WW Discharge (gal / per / day)	Heat Extraction (kBtu/hr)	Delivered Heat (kBtu/hr)	Annual Heat Production (MMBtu)
2015	1,733	60	130	195	1,541
2020	4,587	60	345	517	4,078
2025	2,219	45	125	188	1,479
2030	1,855	45	105	157	1,237
Total			705	1,057	8,335

For purposes of the current phase of work, recovered waste heat is assumed to be available at a constant 1,057 kBtu/hr. Recovered waste heat is assumed to be upgraded to high-temperature hot water which will be used for space heating, domestic hot water, or sold to Harborview Hospital. Sewer heat recovery should be investigated in more detail once hourly building energy simulation models are developed in subsequent phases of the project.

2.2 GEOEXCHANGE/SOLAR HOT WATER OPTION

In this development-wide scenario, the entirety of space heating, space cooling, and DHW requirements of Yesler Terrace's commercial and residential spaces will be met with heat pumps coupled to a centralized ground-source geoexchange loop, supplemented with solar water heaters. All electricity required by YT will be provided in this scenario by the SCL grid. The primary geoexchange loops of the distribution systems will need to be laid before buildings are constructed and will most likely be financed with the ground-coupled heat exchanger field. The secondary loops which exchange heat between the buildings and the primary loops will be installed during individual building construction and will most likely be financed along with the buildings. Solar water heating systems will be installed on the rooftops of the individual buildings they serve. Therefore, the potential to generate domestic hot water for a given building type takes into consideration both the local solar energy resource as well as the availability of roof top area.

2.2.1 Energy Performance

The geoexchange scenario would reduce site-wide electricity consumption by 24.6% compared to the expected BAU scenario due to the higher energy efficiencies in heating and cooling mode offered by the ground-source heat pumps and solar water heaters. Additionally, the geoexchange scenario is expected to reduce system-wide peak load by 5.3 MW or 41% of expected peak load. A geoexchange system with a heating mode coefficient of performance (COP) of 4.2, and a cooling seasonal energy efficiency ratio (SEER) of 16.5 was modeled for all buildings. Site-wide electricity consumption for the geoexchange case is summarized in Table 12.

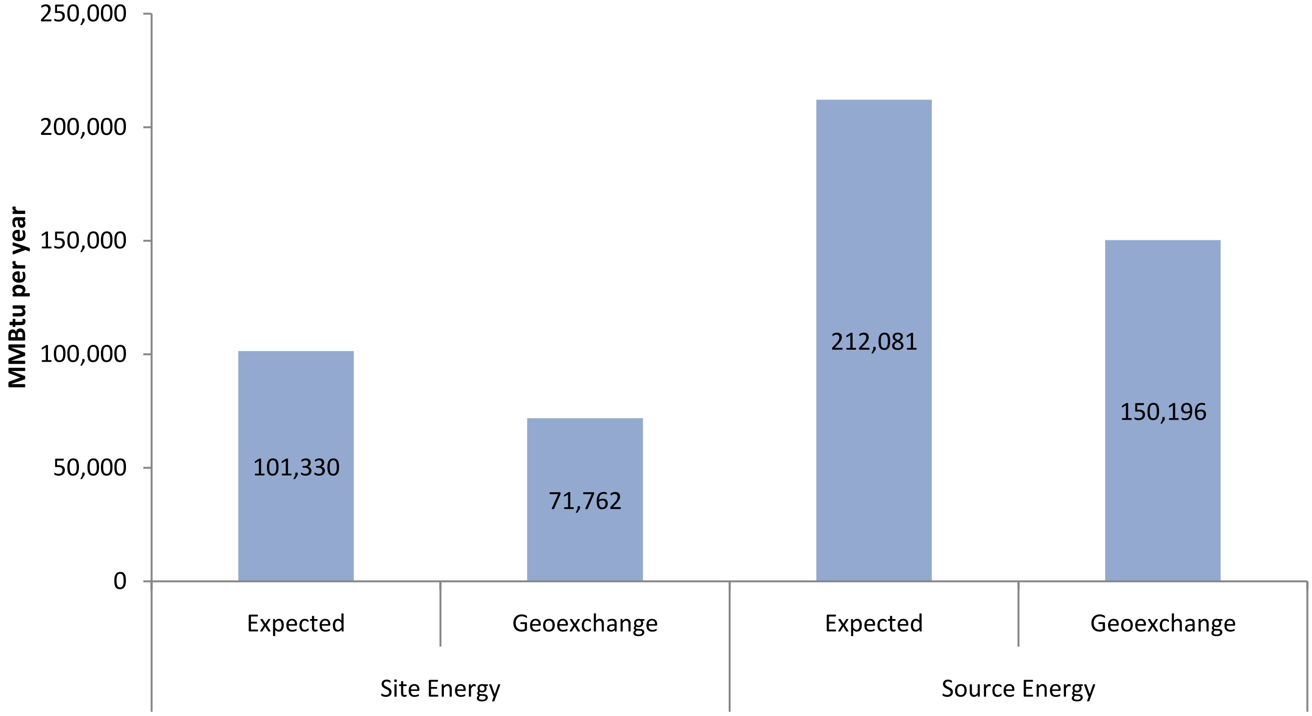
TABLE 12: GEOEXCHANGE SCENARIO ENERGY PERFORMANCE

Sector	BAU Consumption (MWh/yr)	BAU Peak Load (kW)	Geoexchange Consumption (MWh/yr)	Geoexchange Peak Load (kW)	Geoexchange Electricity Savings (MWh/yr)	Geoexchange Peak Load Reduction (kW)
NW	16,976	8,492	12,899	4,399	4,077	4,093
NE	3,006	1,145	2,230	822	776	323
SW	4,577	1,719	3,411	1,256	1,166	462
SE	3,208	1,182	2,404	885	803	297
EOB	939	365	693	255	247	109
Total	28,706	12,903	21,637	7,618	7,069 (24.6%)	5,285 (41%)

Figure 5 presents the site energy (two bars on the left) and source energy (two bars on the right) consumption for the BAU and geoexchange scenarios, aggregated for the entire Yesler Terrace site. Grid electricity consumption is the only type of energy used in both scenarios. Seattle lies in the NWPP eGRID sub-region, and 53% of the electricity flowing through this grid is derived from hydro and nuclear while 47% is derived from fossil energy sources. The heat rate of fossil energy power plants on this grid is 10,410 Btu/kWh, meaning that for every kWh of electricity generated the fossil-fired generators consume 10,410 Btus of fuel. Site energy consumption in these scenarios considers only the grid electricity consumed on-site by buildings for both scenarios. In addition to electricity consumption by Yesler Terrace, the source energy metric accounts for the fossil energy consumed by power plants to generate electricity as well as transmission and distribution (T&D) losses which are assumed to be 6.5% on average. **The geoexchange scenario would reduce source energy consumption by an annual total of 50,481 MMBtu, compared to the expected BAU scenario. It would reduce fossil energy consumption by 23,726 MMBtu/yr which is equivalent to not consuming 4,091 barrels of oil annually.**[1]

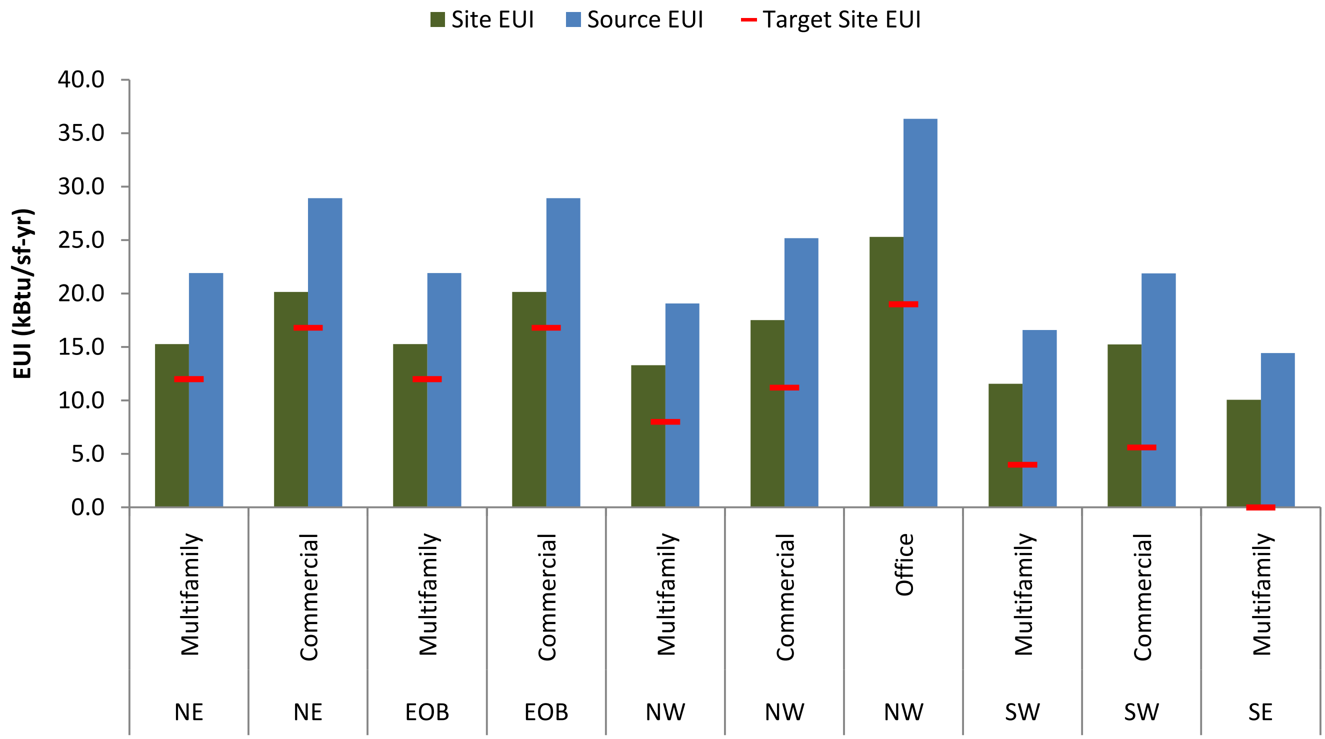
[1] A barrel of crude oil contains 5.8 MMBtu

FIGURE 5: SITE AND SOURCE ENERGY USE COMPARISON



The site-wide weighted average energy use intensity (EUI) for the geoexchange scenario is presented in Figure 6, showing both the source and site EUI values in kBtu per square foot-year. The building types by sector are shown on the x-axis in order from left to right of build-out year. The Architecture 2030 Challenge goals by building type and by year corresponding to the Yesler Terrace build out are shown in red for reference. With the deployment of incremental energy efficiency and load reduction measures (~14% reduction every 5 years) and the use of ground-source heat pumps and solar hot water, Yesler Terrace will make good progress toward the 2030 Challenge goals, particularly in the near term.

FIGURE 6: GEOEXCHANGE SCENARIO SITE AND SOURCE EUI VS 2030 CHALLENGE GOALS



2.2.2 Capital Cost and Energy Cost Estimation

The financial performance of the geoexchange option is not exceptional due to the low electricity cost and relatively low heating and cooling loads for this region. 2010 SCL electric rate tariffs are used to estimate electricity costs and are escalated at 2.8% and 3.1% annually for the commercial and residential sectors, respectively.[2] The Gibson Economics YT model will escalate 2010 energy costs over the entire project build-out period. Incremental HVAC systems costs are estimated by subtracting the system cost for expected BAU energy equipment from the estimated system costs for ground-source heat pumps and solar hot water systems.

Installed building HVAC equipment costs for residential and commercial building types have been estimated using RSMeans online cost estimation tool, CostWorks. Representative systems have been selected for electric baseboard heating systems; electric, gas and solar water heating systems; and packaged DX rooftop AC units etc. This data has been generated using Seattle-specific material and labor costs and taking building sizes into consideration. The installed costs for each individual system component including equipment and labor are presented in Appendix C. These are normalized to their peak capacity, e.g. kBtu/hr for heating systems, and are used along with the peak loads for various building types to generate cost estimates for the expected BAU and proposed scenarios. These costs are assumed to be identical for all building types considered.

Table 13 presents both the BAU HVAC and the geoexchange/SHW scenario HVAC costs. The BAU scenario costs are representative of electric baseboard heating, DX cooling, and electric tank water heating. The geoexchange system costs include the cost of groundsource heat exchangers, heat pumps, hydronic hot and chilled water distribution systems and solar hot water production and storage systems. **The total HVAC system cost for the geoexchange scenario was estimated at $23.9 million, while the BAU system cost is estimated at $10.5 million. Therefore the incremental in-building HVAC costs are $13.4 million for this geoexchange/solar DHW scenario. The weighted average incremental cost is $2.87 per square foot for all buildings.**

[2] These annual average escalation rates are representative of Washington State averages between 1990 and 2008.

TABLE 13: INCREMENTAL IN-BUILDING HVAC COSTS

	Area in Developed Sectors (SF)	BAU HVAC Costs ($)	Geoexchange Scenario HVAC Costs ($)	Incremental Costs for Geoexchange ($)	Incremental Cost ($/SF)
NW	1,981,176	5,360,457	10,747,815	5,387,358	2.72
NE	580,880	1,303,599	3,350,613	2,047,014	3.52
SW	1,036,745	1,991,506	5,151,389	3,159,882	3.05
SE	854,329	1,402,080	3,657,149	2,255,069	2.64
EOB	242,254	405,349	1,032,242	626,893	2.59
Total	4,695,384	10,462,990	23,939,207	13,476,216	2.87

Incorporating the Seattle City Light electric rate tariffs with the energy consumption projections from Table 12 generates a projection of the annual energy cost for the BAU and geoexchange scenarios. This analysis estimates that annual energy costs across Yesler Terrace would be lowered by roughly $570,000 dollars through the use of geoexchange. A simple payback of 24 years is therefore achievable with the geoexchange/solar DHW scenario. **Operation and maintenance costs have been excluded for both the BAU all-electric system and for the Geoexchange/SHW systems. In both of these cases, O&M costs are believed to be low and comparable to each other and have been neglected in the cost analysis.**

In addition to the energy system component costs, the cost of building a construction slab on which to locate the heat pump, heat exchangers and cooling towers was estimated as 7500 square feet at $13.50 per square feet, for a total of $101,250. This cost reflects an 8" thick reinforced concrete slab. The heat pump system does not need to be housed in a covered shelter. This cost is included in the upfront capital costs associated with the first phase of project development. **The geoexchange/SHW equipment is modular and therefore assumed in this analysis to be completely "phase-able". The HVAC system costs have been estimated on a cost per unit of capacity basis, and the costs are assumed to be incurred during the buildout. However, a centralized ground source heat pump would most likely be built at Yesler Terrace, and how this could be split into phases is a topic for investigation in further phases of a more detailed study.**

TABLE 14: GEOEXCHANGE SCENARIO ANNUAL ENERGY COST SAVINGS

Energy Use Reductions	BAU Electricity Cost ($/yr)	Geoexchange Scenario Energy Cost ($/yr)	Geoexchange Scenario Energy Cost Savings ($/yr)	Incremental HVAC System Costs ($)
NW	1,225,719	938,614	287,105	5,387,358
NE	304,093	231,641	72,453	2,047,014
SW	474,145	364,207	109,938	3,159,882
SE	339,466	262,763	76,703	2,255,069
EOB	97,477	74,728	22,749	626,893
Total	2,440,901	1,871,952	568,949	13,476,216

A life-cycle cost analysis (LCCA) has been conducted using the capital costs and annual energy costs presented above. In this model, energy costs are projected 30 years into the future using historical rate increases as a guide. The equipment costs for both the incremental energy conservation measures and the additional HVAC equipment required to accommodate geoexchange are incorporated and escalated by 3% annually. All future costs are discounted by 6% in order to generate a levelized life cycle cost. **The total life cycle cost of the geoexchange scenario is estimated at $49.8 million, which includes the installation and operation of all of the energy-consuming building equipment over 30 years beginning in 2010. On a normalized basis, this works out to be 35 cents/year per square foot of building space.**

TABLE 15: LIFE CYCLE COST ANALYSIS FOR GEOEXCHANGE SCENARIO

	$'000	$/SF-yr
Energy costs	$22,099	0.16
Equipment Costs	$27,669	0.20
Total	$49,768	0.35

2.2.3 Environmental Performance

Greenhouse gas (CO_2, CH_4, N_2O) emissions corresponding to the expected BAU and proposed geoexchange scenarios have been quantified. Direct emissions resulting from on-site fuel combustion do not exist in either of these scenarios since they both involve all-electric systems supplied by the SCL grid. Indirect emissions resulting from the consumption of grid electricity are quantified using EPA emissions factors[3]. The Northwest Power Pool (NWPP) non-baseload grid sub-region emission factor has been used for this analysis, which is equal to 0.608 kgCO2e per kWh. The non-baseload emission factor is representative of power generating sources operating at the margin, and so is the most appropriate basis for assessing the future impact of load additions. The expected BAU scenario is estimated to produce 18,056 tCO2e per year of GHG emissions associated with the purchase of grid electricity. The geoexchange scenario would produce 12,788 tCO2e per year, equating to a 29% annual reduction.

Additionally, "Scope 3" emissions account for emissions associated with fuel extraction and transport to power plants, and electricity T&D losses. Scope 3 emissions associated with electricity consumed by Yesler Terrace would add an estimated 2,524 tCO2e per year to the BAU case. **In total, the Geoexchange scenario would eliminate 6,005 tCO2e per year of greenhouse gas emissions when including Scope 3 emissions. This reduction is equivalent to not burning 31.4 railcars of coal every year.**

FIGURE 7: GHG EMISSIONS BY YESLER TERRACE

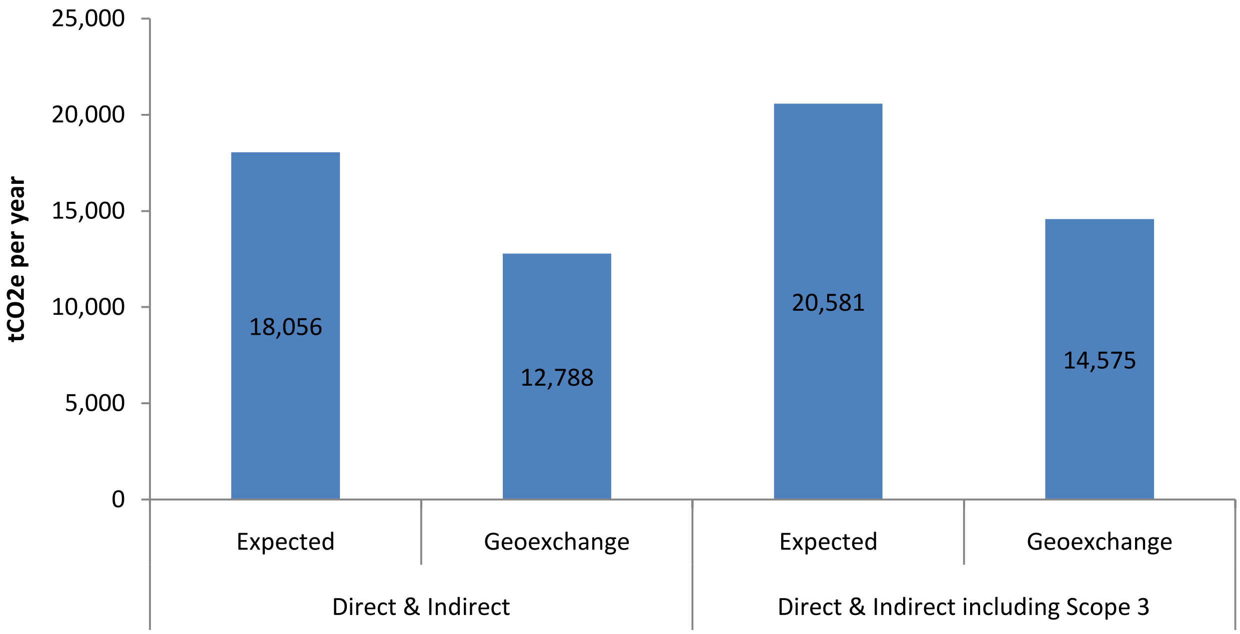


Figure 7 shows the projected annual emissions from consumption of grid electricity by Yesler Terrace as discussed above for both the expected BAU and geoexchange cases. Greenhouse gases, nitrogen oxides (NOx), and sulfur dioxide (SO_2) emissions associated with grid purchases are presented in Table 16. NOx and SO_2 emission rates are also available from the EPA's eGRID database by grid sub region, and the rates used in this analysis correspond to the NWPP sub-region. NOx and SOx emission rates are representative of the grid average mix, not the marginal mix, as used for GHG emissions, because marginal NOx and SOx marginal emission rates are not readily available.

[3] eGRID 2006 emissions factors are used for electricity purchases and EPA Climate Leaders technical resources are used for stationary combustion emissions

TABLE 16: SELECTED ENVIRONMENTAL IMPACTS

Environmental Impact	BAU	Geoexchange	Reduction
GHGs Emissions- Indirect (metric tons CO2e/yr)	18,056	12,788	5,269
GHGs Emissions - Scope 3 (metric tons CO2e/yr)	2,524	1,788	737
NOx Emissions (short tons/yr)	23.6	16.7	6.9
SO2 Emissions (short tons/yr)	18.4	13.0	5.4

2.3 COMBINED HEAT AND POWER SCENARIOS

In another basic type of development-wide scenario considered, the entirety of Yesler Terrace's commercial and residential spaces are served by a common district energy system supplying electricity, hot water, and chilled water from a central plant. The primary hot and chilled water loops of the distribution systems will need to be laid before buildings are constructed and will most likely be financed with the CHP plant. The secondary loops which exchange heat between the buildings and the primary loops will be installed during individual building construction and will most likely be financed along with the buildings. The central CHP will convert waste biomass materials and natural gas into hot water, chilled water, and electricity. This will require that all commercial and residential space be built with hydronic HVAC systems to accommodate hot water/chilled water supply and return.

This section presents three configurations for comparison to the expected BAU scenario. Again, the BAU scenario is the case where all building energy loads are met using electric systems (electric baseboard heating, rooftop DX cooling, electric DHW). The three alternative scenarios using a CHP are the following:

- **NG CHP - CHP fuelled with natural gas** using a mix of reciprocating engines, fuel cells, micro-turbines, boilers, electric centrifugal chillers, and absorption chillers;
- **AD CHP- CHP fuelled with biogas** generated by anaerobic digestion of food and organic wastes using same mix of energy production technologies;
- **BG CHP - CHP fuelled with syngas** produced by gasification of wood chips using the same mix of energy production technologies.

In all three alternative scenarios, the CHP is assumed to supply the entirety of Yesler Terrace with hot water for space heating, chilled water for space cooling, and electricity to run plug loads, lighting, and domestic hot water heaters. The expected BAU and alternative scenarios were evaluated using WSP's neighborhood CHP planning tool. The energy efficiency, GHG emissions, and water consumption are considered for each scenario.

Energy production assumptions

A number of CHP options needed to be considered in order to model a combined heat and power plant which would meet the needs of Yesler Terrace. One option would supply all of the chilled and hot water required for space cooling and heating by the development. The CHP would not only meet the annual demand but also the peak loads. With respect to electricity, it was determined that only the total annual consumption of electricity should be met by the plant and peak power loads would not be met by the CHP but would be met with some grid-supplied power. This is because the electric power grid can provide an "energy storage" function, absorbing excess power when Yesler can't consume the full CHP power output and supplying electricity to Yesler when CHP output falls short of peak loads. In future phases of work, hourly simulations must be conducted which will facilitate the evaluation of other CHP operating strategies such as load-following. A consequence of the fact that cogeneration equipment such as gas engines and fuel cells will be operated in a base load manner is that the CHP will produce excess thermal energy – hot water and steam – which Yesler will not consume. In this analysis, excess thermal energy is assumed to be sold to Harborview Hospital at a price of $10/MMBtu. This will improve both the environmental and economic performance of the plant. In summary, assumptions include:

- CHP supplies total energy to the development
  - Peak loads and annual consumption of hot and chilled water are met
  - Peak electric load is not met, but "net metering" with the grid is assumed

- Energy production units operate as base load units with a 90% capacity factor. This is sufficient to generate the same amount of electricity in a year that YT consumes, but produces excess thermal energy.
- Peaking boilers operate at a 10% capacity factor
- Chilled water production units operate at a 9% capacity factor
- The CHP relies on a mix of energy production technologies to meet the loads and project constraints
- Excess thermal energy is assumed to be sold to Harborview Hospital

The net energy loads for Yesler Terrace using a CHP are presented in Table 17 showing the building peak loads and annual consumption for electricity, hot water, and chilled water. The analysis assumed thermal losses when piping chilled water and hot water from the CHP to the individual buildings to be 8% and 10% respectively during peak loads. This is considered a conservative assumption. The Yesler Terrace CHP optimization tool is set up to satisfy these energy demands using a mix of gas engines, gas micro-turbines, molten carbonate fuel cells, boilers, and chillers. The equipment configuration has been carefully selected to maximize efficiency, and balance thermal and electrical energy production.

TABLE 17: YESLER TERRACE NET ENERGY DEMAND IN CHP SCENARIO

CHP Production Summary (From Load Analysis)	Electricity Usage (MWh/yr)	Peak Power Demand (kW)	Hot Water Usage (MMBtu/yr)	Peak HW Demand (kBtu/hr)	Chilled Water Usage (tons-hrs/yr)	Peak CHW Demand (tons)
Building Energy Demands	18,061	4,032	26,694	29,761	3,474,340	4,265
Distribution losses	1%	1.5%	8%	10%	8%	10%
Total CHP Production	18,243	4,094	29,015	33,068	3,776,456	4,739

Table 18 presents the CHP equipment selection used in the analysis tool, here showing the natural gas fuelled CHP case. It shows the rated capacities and types of equipment which have been selected for the three CHP scenarios. As an example, a 1,200 kW molten carbonate fuel cell (MCFC) has been selected which will also supply 4,300 kBtu/hr of useful thermal energy. Details on the unit cost and efficiency for these energy technologies are documented in Appendix A. For the anaerobic digestion and biomass gasification cases, the “Fuel Selection” assumes wood waste and food waste. The only difference between the natural gas cases and the two biomass cases in terms of equipment selection is that anaerobic digesters and biomass gasification systems are required in order to convert biomass into a combustible gas (biogas and syngas) which can be utilized by the various energy production units that are common to all CHP scenarios.

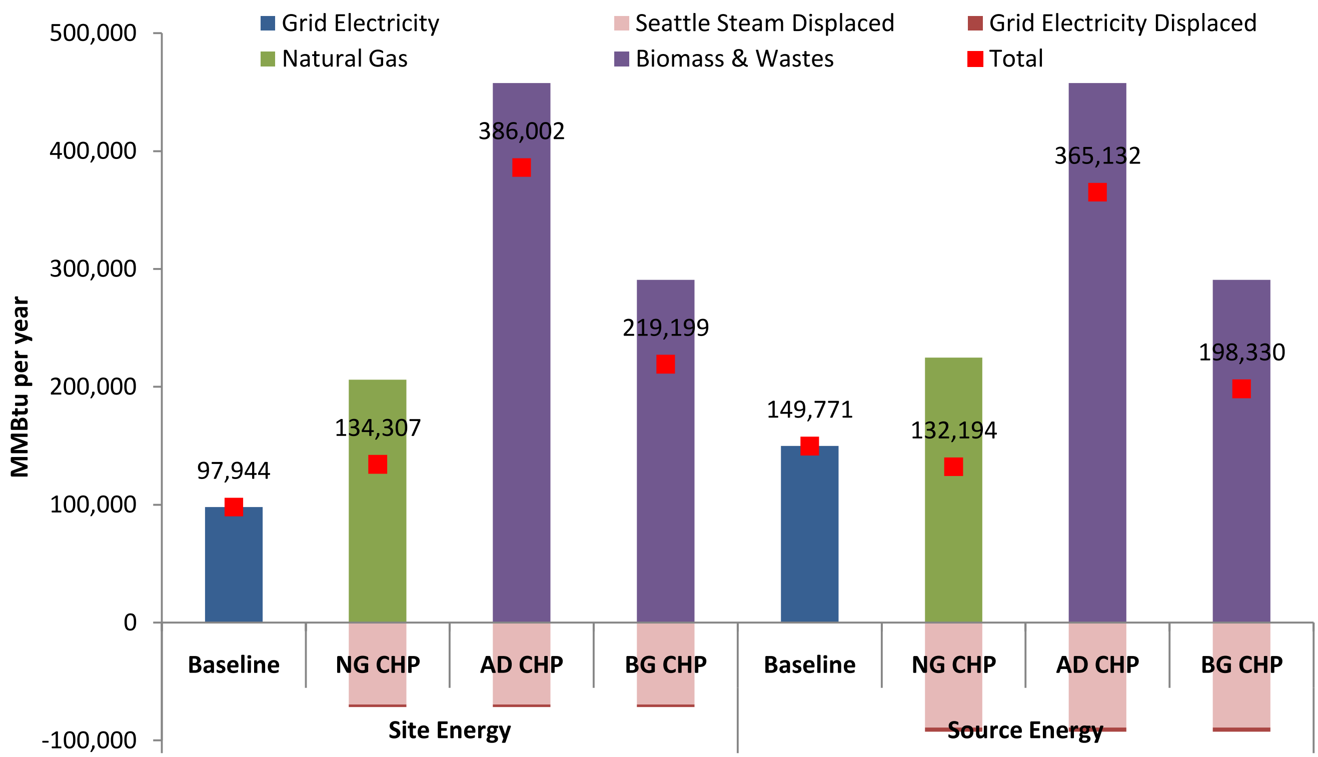
TABLE 18: CHP EQUIPMENT SELECTION AND CAPACITY

CCHP Plant Sizing Calculator	Fuel Selection	Rated Power Capacity (kW)	Heat Production (kBtu/hr)	Cooling Capacity (tons)
Power Production				
Gas Micro Turbines	Natural gas	400	2,115	
Gas Engines	Natural gas	1,050	4,299	
Gas MCFC	Natural gas	1,200	4,299	
Hot Water Production				
Condensing Gas Boiler	Natural gas		22,000	
Waste Water Heat Pump - Electric			1,057	
Chilled Water Production				
Electric Chiller				3,000
Double Effect Absorption Chiller				2,000
Fuel Production				
Gasification	Wood Waste			
Anaerobic Digestion	FOG & Food Waste			

2.3.1 Energy Performance

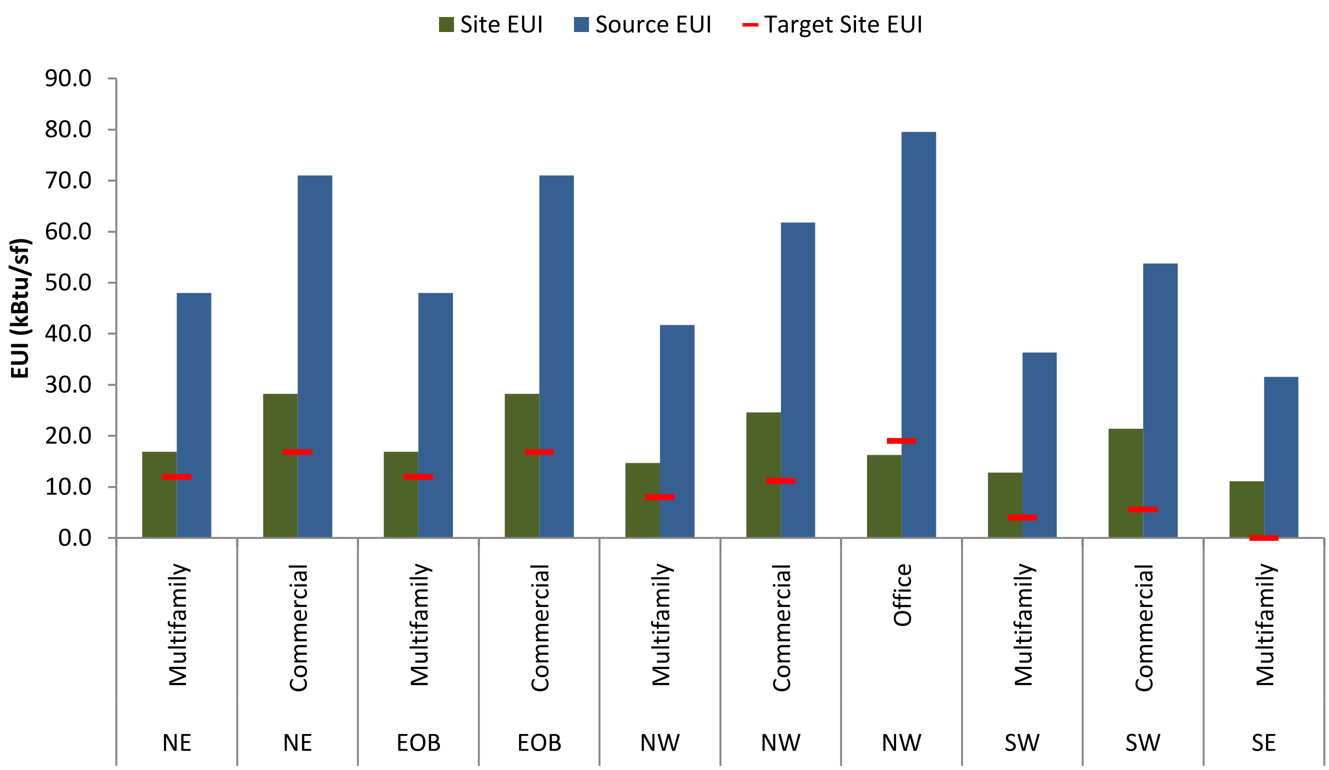
The site and source energy consumption by Yesler Terrace for the expected BAU and three alternative CHP scenarios are presented in Figure 8. Yesler Terrace only consumes grid electricity in the BAU scenario. The three alternative CHP scenarios present the site and source energy consumption showing the use of natural gas and biomass by the CHP, and the amount of grid electricity and steam displaced through the sale of excess energy production. For these cases where energy is exported from Yesler, the net energy consumption value represented by a red square is shown. All of the CHP scenarios would offer a net reduction in fossil primary energy consumption.

FIGURE 8: SITE AND SOURCE ENERGY CONSUMPTION SHOWING BAU AND 3 ALTERNATIVE SCENARIOS



The natural gas-fired CHP scenario is comparable to the geoexchange scenario in terms of site EUI; it meets the target in 2015 for office buildings but would not meet future year targets, as shown in Figure 9. The two biomass scenarios are not shown because they result in an EUI of zero kBtu/SF for all years and building types since in those cases 100% of YT's energy needs are satisfied with non-fossil energy, ie, renewable biomass.

FIGURE 9: NATURAL GAS CHP EUI FOR YESLER TERRACE



2.3.2 System and Energy Cost Estimation

Estimates for the HVAC system costs and annual energy cost savings have been made for the three alternative CHP scenarios. The incremental HVAC equipment costs for hydronic fin tube radiation systems required to utilize hot and chilled water by the individual buildings are presented in Table 19. **The in-building HVAC equipment costs for all three CHP scenarios will be the same and total $26.7 million, or $16.4 million more than the BAU scenario. On a normalized basis for all building types, this difference amounts to $3.50 per square foot.**

TABLE 19: INCREMENTAL HVAC EQUIPMENT COSTS FOR CHP SCENARIO

Stage	Area in Developed Sectors (SF)	BAU HVAC Costs ($)	CHP Hydronic HVAC Costs ($)	Incremental HVAC Costs ($)	Incremental Cost ($/SF)
NW	1,981,176	4,688,656	13,873,513	9,184,856	4.64
NE	580,880	1,532,150	3,484,524	1,952,375	3.36
SW	1,036,745	2,060,317	4,641,088	2,580,771	2.49
SE	854,329	1,468,439	3,266,858	1,798,419	2.11
EOB	242,254	642,956	1,481,014	838,057	3.46
Total	4,695,384	10,392,519	26,746,996	16,354,478	3.48

The CHP building costs have been estimated using the RS Means CostWorks online tool. It is assumed that the heat production and power generation equipment could be housed in a 10,000 SF building. The fuel storage and processing equipment required for the biomass gasification and anaerobic digestion systems can be located outside the building but require a 15,000 SF concrete slab. The building cost is estimated at $190 per square foot of building space and the slab is estimated at $13.5 per square foot. Details are provided in Table 20.

TABLE 20: CHP BUILDING COSTS

Scenario	Building size, SF	Building Cost	Slab size, sf	Slab Cost, $	Total Cost, $
NG CHP	10,000	1,900,000			1,900,000
BG CHP	10,000	1,900,000	15,000	202,500	2,102,500
AD CHP	10,000	1,900,000	15,000	202,500	2,102,500

A life cycle cost analysis (LCCA) has been conducted using the capital costs and annual energy costs presented above. In this model, energy costs are projected 30 years into the future using projected and historical rate increases as a guide. Electricity rate increases in the residential secotor for the state of Washington have been used to escalate electricity rates, since SCL rate increase projections were not made available. Projected future natural gas prices were obtained from the US Department of Energy's Energy Information Administration. The equipment costs for both the incremental energy conservation measures and the additional HVAC equipment required to accommodate the combined heat and power plant are incorporated and escalated by 3% annually, while O&M costs have been escalated by 2% annually. All future costs are discounted by 6% in order to generate a levelized life cycle cost. **The estimated total life cycle costs for the CHP scenarios range from $57.0 million to $84.2 million, which includes the installation and operation of all of the energy consuming building equipment and the combined heat and power plant over 30 years beginning in 2010. On a normalized basis, this works out to be a range of 40 to 60 cents/year per square foot of building space.** Table 21 and Table 22 present results without and with excess thermal energy sales to the hospital.

TABLE 21: LIFE CYCLE COST ANALYSIS FOR CHP SCENARIOS (W/O THERMAL SALES TO HARBORVIEW)

	NG CHP		BG CHP		AD CHP	
	$'000	$/SF-yr	$'000	$/SF-yr	$'000	$/SF-yr
Energy Costs	15,847	0.11	6,767	0.05	998	0.01
O&M Costs	16,585	0.12	16,585	0.12	16,585	0.12
Equipment Costs	51,727	0.37	57,809	0.41	60,855	0.43
Total Life Cycle Costs	84,159	0.60	81,161	0.58	78,437	0.56

TABLE 22: LIFE CYCLE COST ANALYSIS FOR CHP SCENARIOS (W/ THERMAL SALES TO HARBORVIEW)

	NG CHP		BG CHP		AD CHP	
	$'000	$/SF-yr	$'000	$/SF-yr	$'000	$/SF-yr
Energy costs	-8,273	-0.06	-17,353	-0.12	-23,122	-0.16
O&M Costs	16,585	0.12	16,585	0.12	16,585	0.12
Equipment Costs	51,727	0.37	57,809	0.41	64,999	0.46
Total	60,039	0.43	57,040	0.40	58,462	0.42

Careful planning is required in order to ensure that the CHP energy supply closely matches the loads coming online throughout the development of Yesler Terrace. This analysis assumes that infrastructure costs related to the CHP including hot and chilled water distribution piping and in-building hydronic distribution systems will all be developed in concert with the buildings. However, some of the key infrastructure may need to be developed upfront such as the CHP building. In theory, the 4-pipe system could be developed in stages but doing so may be more costly than developing it all at once. As this cost is one of the largest infrastructure costs related to the CHP scenarios, this would result in a significant upfront cost burden on the development. To be conservative, this study assumes that the 4-pipe distribution and CHP building infrastructure are installed upfront. Phased incremental capital costs are shown in Table 23 for the natural gas fired CHP scenario. The cost of meeting future energy codes (ECMs), the in-building HVAC systems, and the CHP costs are shown in 2010 dollars. The 2015 CHP cost figure includes the cost of a building and the primary distribution piping.

TABLE 23: NG CHP SCENARIO INCREMENTAL CAPITAL COST SCHEDULE

Incremental Costs	2015	2020	2025	2030
Energy Conservation Measures ($)	492,605	5,876,278	6,120,988	6,928,475
Building HVAC Systems ($)	4,965,538	13,873,513	4,641,088	3,266,858
CHP Equipment ($)	19,529,347	6,462,648	1,776,840	1,238,100
Phase Total	24,987,490	26,212,439	12,538,916	11,433,433
Phase % of Yesler Total	33%	35%	17%	15%

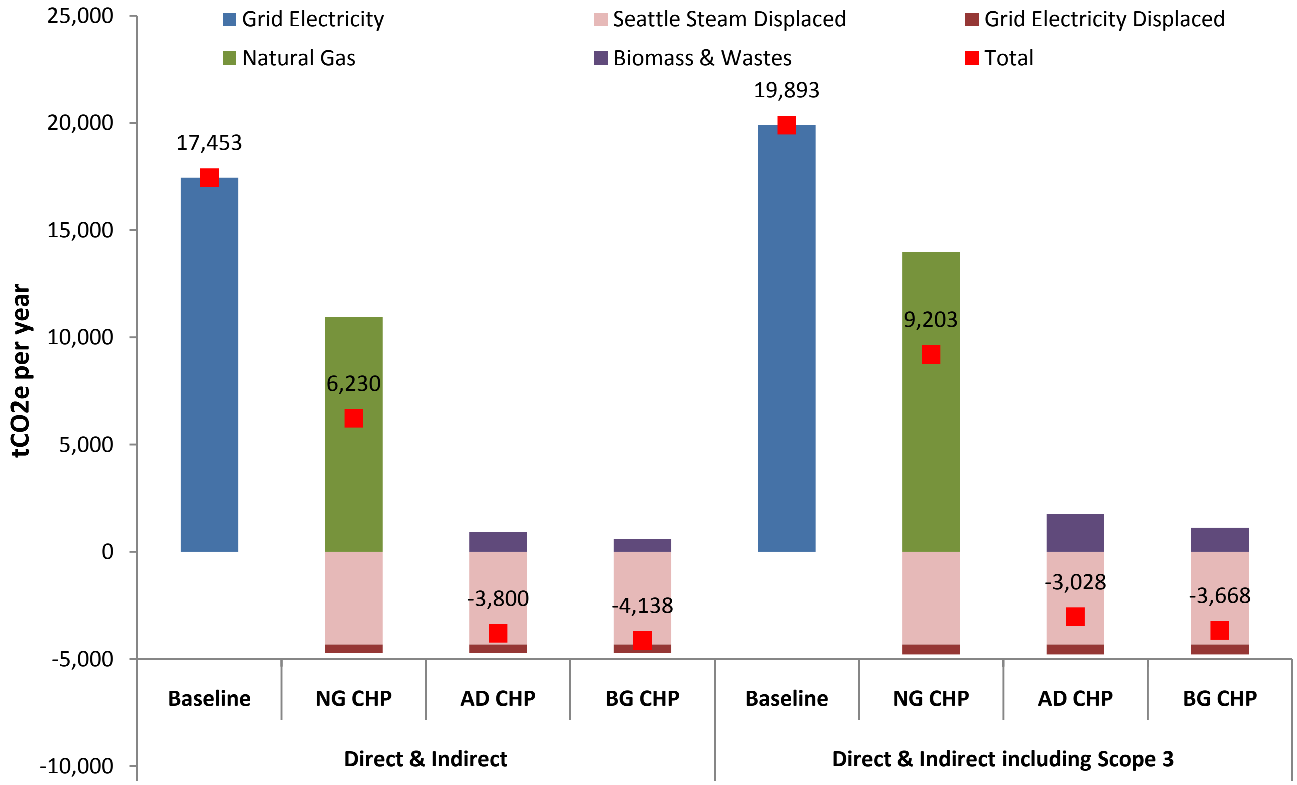
2.3.3 Environmental Performance

Emissions of the predominant greenhouse gases (CO_2, CH_4, N_2O), estimated using EPA emissions factors[4], have been quantified for the CHP scenario and the BAU scenario and include direct emissions from fuel combustion and indirect emissions from purchases of grid electricity. In the CHP scenario, emissions of greenhouse gases are kept to a minimum through the utilization of biomass materials and small quantities of natural gas to produce electricity, heating, and cooling. GHG emissions are presented in units of metric tons of carbon dioxide equivalent (tCO2e) for all scenarios.

Figure 10 presents site-wide greenhouse gas emissions by source for Yesler Terrace under the expected BAU and three alternative CHP scenarios considered. The two biomass CHP scenarios have “negative” GHG emissions due to the fact that they displace Seattle Steam usage at Harborview, thereby eliminating the GHG emissions associated with Seattle Steam. If the sale of thermal energy to Harborview Hospital were not possible, the net emissions associated with the three CHP scenarios would each be shifted upward by 4,112 tCO2e annually. Regardless of whether thermal energy can be sold to Harborview or not, the CHP option decreases GHG emissions relative to the expected BAU scenario.

[4] eGRID 2006 emissions factors are used for electricity purchases and EPA Climate Leaders technical resources are used for stationary combustion emissions

FIGURE 10: CHP SCENARIO GHG EMISSIONS FOR YESLER TERRACE (W/ THERMAL SALES TO HARBORVIEW)



2.4 DISTRICT HEATING SCENARIOS

In the district heating-only scenarios, the entirety of Yesler Terrace's commercial and residential spaces will be served by a common district heating plant supplying hot water for space heating and domestic hot water production. The primary hot water loops of the distribution system will need to be laid before buildings are constructed and will most likely be financed with the central plant. The secondary loops which exchange heat between the buildings and the primary loops will be installed during individual building construction and will most likely be financed along with the buildings. The central heat plant will convert waste biomass materials and natural gas into hot water. This will require that all commercial and residential space be built with hydronic HVAC systems to accommodate hot water supply and return pipes.

This section presents three configurations for comparison to the BAU scenario. The expected BAU scenario is the case where all building energy loads are met using electric systems (electric baseboard heating, rooftop DX cooling, electric DHW). The three alternative scenarios using a district heating system are the following:

- **NG District Heat – District Heat plant fuelled with natural gas** using high efficiency natural gas boilers
- **AD District Heat – District heat plant fuelled with biogas** generated by anaerobic digestion of food and organic wastes and used in high efficiency gas boilers
- **BC District Heat – District heat plant fuelled with wood chips** burned in biomass boilers

In all three alternative scenarios, the district heat plant is assumed to supply the entirety of Yesler Terrace with hot water for space heating and DHW. The electric loads and cooling loads are satisfied with grid electricity. The BAU and alternative scenarios were evaluated using WSP's neighborhood CHP planning tool. The energy efficiency, GHG emissions, and water consumption are considered for each scenario.

Energy production assumptions

A number of central plant options needed to be considered in order to model a district heat plant to meet the needs of Yesler Terrace. One option assumes that the heat plant will run in a load-following manner and will cover both the peak heating and annual heating loads, and this means that there is unused capacity for the majority of the year. Alternatively, the plant could be operated at full capacity and excess thermal energy would be exported to other consumers like the Harborview Medical Center. For this alternative, excess thermal energy is assumed to be sold to Harborview Hospital at a price of $10/MMBtu. This will improve both the environmental and economic performance of the plant. In summary, the analysis assumes:

- District heat plant supplies both peak and annual heating load of the development
- Electricity consumed by Yesler Terrace is supplied by the grid, as assumed in BAU
- Space cooling needs are met with conventional rooftop DX air conditioners, as assumed in BAU
- Excess hot water production capacity could optionally be used to produce additional thermal energy for sale to Harborview Hospital.

The heat loads served by this scenario are identical to those served in the CHP scenarios, while the site electricity loads for space cooling, lighting, and plug loads served in this scenario are identical to those identified in the expected BAU scenario. Also shown is the purchased fuel required by the district heat plant when using either 100% natural gas, 100% wood chips, or 100% fats/oils/grease to generate hot water.

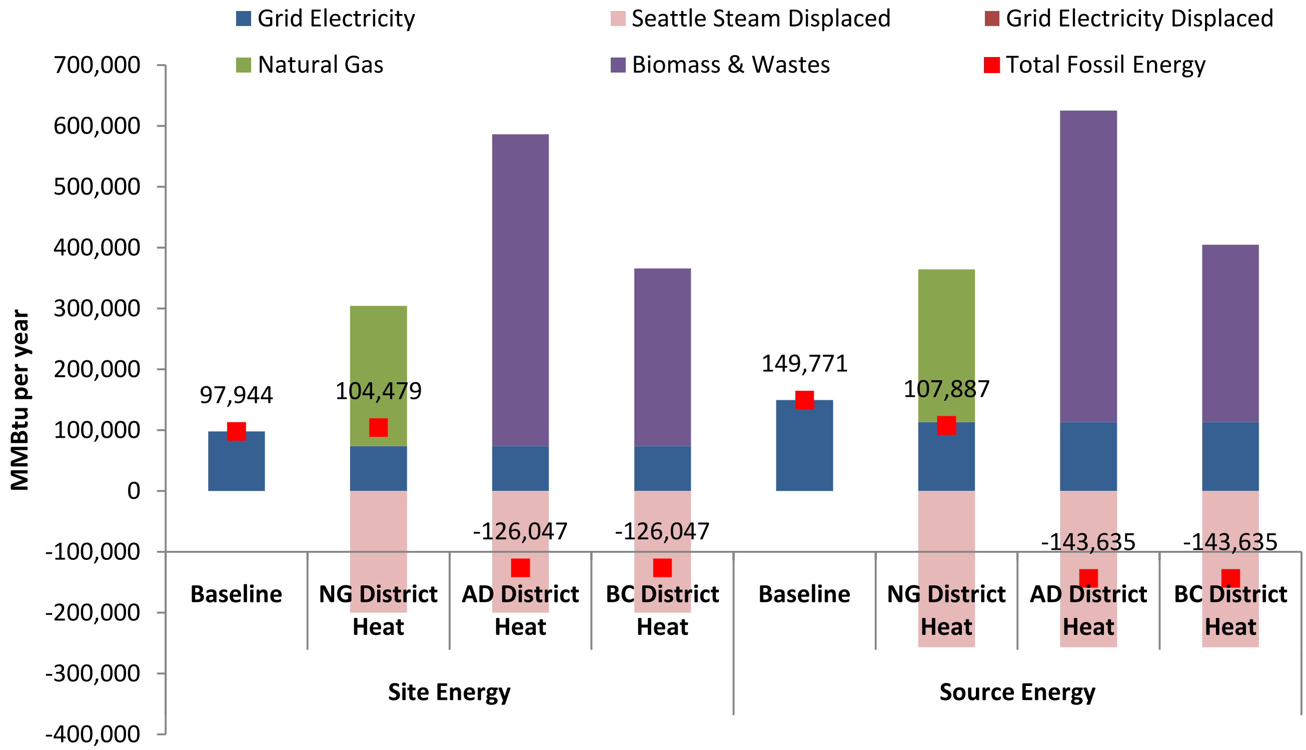
TABLE 24: SALES OF ELECTRICITY AND HOT WATER FOR THE DISTRICT HEAT-ONLY SCENARIOS.

	Electricity (MWh/yr)	Hot Water Sales (MMBtu/yr)	Natural Gas (Mmbtu/yr)	Wood Chips (MMBtu/yr)	FOG (MMBtu/yr)
W/ Sales to Harborview	21,680	228,261	230,526	292,000	512,281
W/O Sales to Harborview	21,680	28,243	23,618	29,926	52,484

2.4.1 Energy Performance

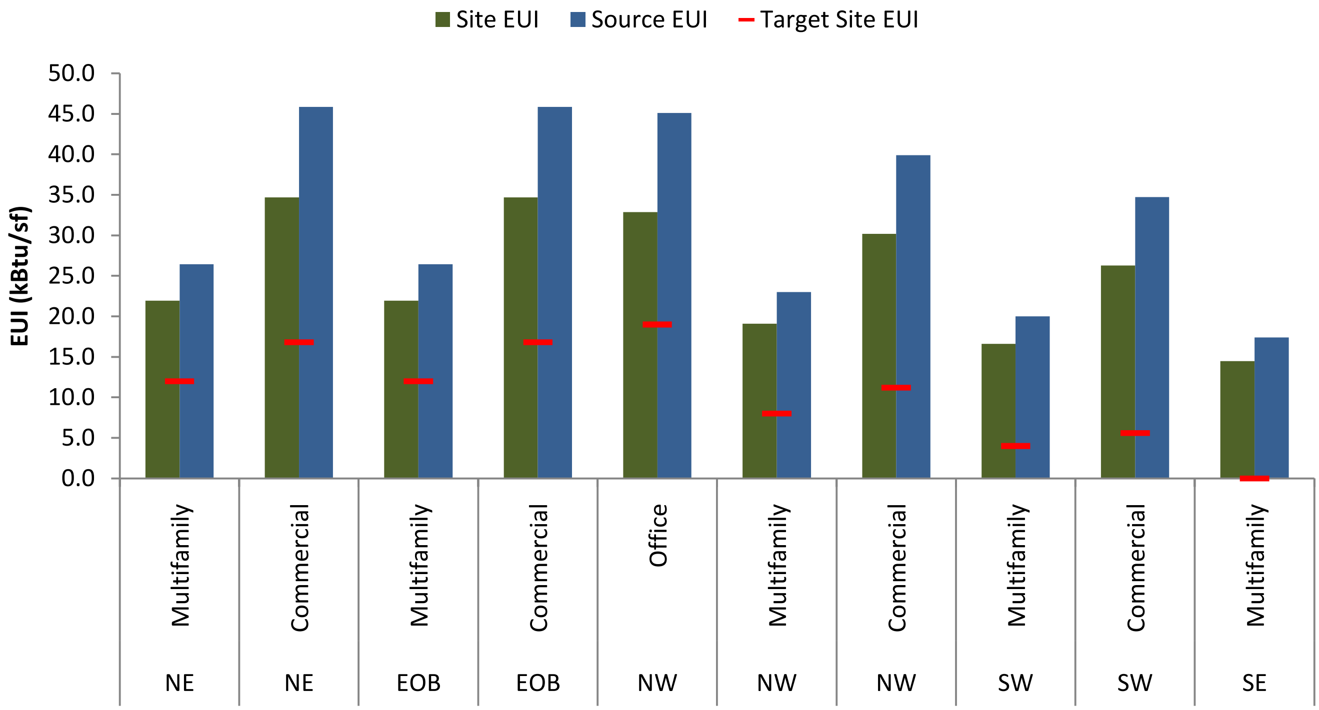
The site and source energy consumption by Yesler Terrace for the expected BAU and three alternative district heat-only scenarios are presented in Figure 11. The three alternative scenarios present the site and source energy consumption showing the use of natural gas and biomass by the district heat plant, and the amount of grid electricity and steam displaced through the sale of excess energy production. For these cases where energy is exported from Yesler, the net energy consumption value represented by a red square is shown.

FIGURE 11: SITE AND SOURCE ENERGY CONSUMPTION SHOWING BAU AND 3 ALTERNATIVE SCENARIOS



The natural gas-fired district heat scenario is comparable to the geoexchange scenario in terms of site EUI; it meets the target in 2015 for office buildings but would not meet future year targets, as shown in Figure 12. The two biomass scenarios are not shown because they result in an EUI of zero kBtu/SF for all years and building types since In those cases 100% of YT's energy needs are satisfied with non-fossil energy, ie, renewable biomass.

FIGURE 12: NATURAL GAS DISTRICT HEAT CASE ENERGY USE INTENSITY FOR YESLER TERRACE



2.4.2 System and Energy Cost Estimation

Estimates for the HVAC system costs and annual energy cost savings have been made for the three alternative district heat-only scenarios. The incremental HVAC equipment costs for hydronic fin tube radiation systems required to utilize hot water by the individual buildings are presented in Table 25. **The in-building HVAC equipment costs for all three district heat scenarios will be the same and total $20.6 million, or $10.3 million more than the BAU scenario. On a normalized basis for all building types, this difference amounts to $2.18 per square foot.**

TABLE 25: INCREMENTAL HVAC EQUIPMENT COSTS FOR DISTRICT HEAT SCENARIOS

Stage	Area in Developed Sectors (SF)	BAU HVAC Costs ($)	CHP Hydronic HVAC Costs ($)	Incremental HVAC Costs ($)	Incremental Cost ($/SF)
NW	1,981,176	4,688,656	11,472,038	6,783,381	3.42
NE	580,880	1,532,150	2,496,487	964,338	1.66
SW	1,036,745	2,060,317	3,305,368	1,245,051	1.20
SE	854,329	1,468,439	2,308,356	839,917	0.98
EOB	242,254	642,956	1,069,368	426,411	1.76
Total	4,695,384	10,392,519	20,651,616	10,259,098	2.18

The district heat plant building costs have been estimated using the RS Means CostWorks online tool. It is assumed that the heat production equipment could be housed in a 10,000 SF building. The fuel storage and processing equipment required for the biomass gasification and anaerobic digestion systems can be located outside the building, requiring a 15,000 SF concrete slab. The building cost is estimated at $190 per square foot of building space and the slab is estimated at $13.5 per square foot. Details are provided in Table 26. These assumptions are identical to those used in the CHP scenarios. A more detailed engineering design study would be required to obtain an accurate footprint of the building and slab.

TABLE 26: DISTRICT HEAT BUILDING COSTS

Scenario	Building size, SF	Building Cost	Slab size, sf	Slab Cost, $	Total Cost, $
NG CHP	10,000	1,900,000			1,900,000
BG CHP	10,000	1,900,000	15,000	202,500	2,102,500
AD CHP	10,000	1,900,000	15,000	202,500	2,102,500

A life cycle cost analysis (LCCA) has been conducted using the capital costs and annual energy costs presented above. In this model, energy costs are projected 30 years into the future using historical rate increases as a guide. The equipment costs for both the incremental energy conservation measures and the additional HVAC equipment required to accommodate the district heat plant are incorporated and escalated by 3% annually. All future costs are discounted by 6% in order to generate a levelized life cycle cost. **The estimated total life cycle costs for the District Heat scenarios range from $41.5 million to $59.8 million, which includes the installation and operation of all of the energy consuming building equipment as well as the district heating plant over 30 years beginning in 2010. On a normalized basis, this works out to be a range of 29 to 42 cents/year per square foot of building space.** Table 27 and Table 28 present results without and with excess thermal energy sales to the hospital.

TABLE 27: LIFE CYCLE COST ANALYSIS FOR DISTRICT HEAT SCENARIOS (W/O THERMAL SALES TO HARBORVIEW)

	NG District Heat		BC District Heat		AD District Heat	
	$'000	$/SF-yr	$'000	$/SF-yr	$'000	$/SF-yr
Energy costs	24,521	0.17	23,841	0.17	23,185	0.16
O&M Costs	439	0.00	439	0.00	439	0.00
Equipment Costs	33,766	0.24	34,723	0.25	36,211	0.26
Total	58,726	0.42	59,003	0.42	59,836	0.42

TABLE 28: LIFE CYCLE COST ANALYSIS FOR DISTRICT HEAT SCENARIOS (W/ THERMAL SALES TO HARBORVIEW)

	NG District Heat		BC District Heat		AD District Heat	
	$'000	$/SF-yr	$'000	$/SF-yr	$'000	$/SF-yr
Energy costs	4,596	0.03	3,916	0.03	3,260	0.02
O&M Costs	3,164	0.02	3,164	0.02	3,164	0.02
Equipment Costs	33,766	0.24	34,723	0.25	43,360	0.31
Total	41,525	0.29	41,802	0.30	49,784	0.35

Careful planning is required in order to ensure that the district heat supply closely matches the loads coming online throughout the development of Yesler Terrace. This analysis assumes that infrastructure costs related to the district heat scenario, including hot water distribution piping and in-building hydronic distribution systems, will all be developed in concert with the buildings. However, some of the key infrastructure may need to be developed upfront such as the district heat building. In theory, the 4-pipe system could be developed in stages but that may be more costly than doing it all at once. As this cost is one of the largest infrastructure costs related to the district heat scenarios, this would result in a significant upfront cost burden on the development. To be conservative, this study assumes that the 2-pipe distribution and heat plant building infrastructure are installed upfront. Phased incremental capital costs are shown in Table 29 for the natural gas fired district heat scenario. The cost of meeting future energy codes (ECMs), the in-building HVAC system costs ,and the district heat plant costs are shown in 2010 dollars. The 2015 cost figure includes the cost of a building and the primary distribution piping.

TABLE 29: NG DISTRICT HEATING SCENARIO INCREMENTAL CAPITAL COST SCHEDULE

Incremental Costs	2015	2020	2025	2030
Energy Conservation Measures ($)	492,605	5,876,278	6,120,988	6,928,475
Building HVAC Systems ($)	3,565,855	11,472,038	3,305,368	2,308,356
CHP Equipment ($)	8,888,732	1,099,634	233,080	159,490
Phase Total	2,175,106	4,688,656	2,060,317	1,468,439
Phase % of Yesler Total	26%	37%	19%	19%

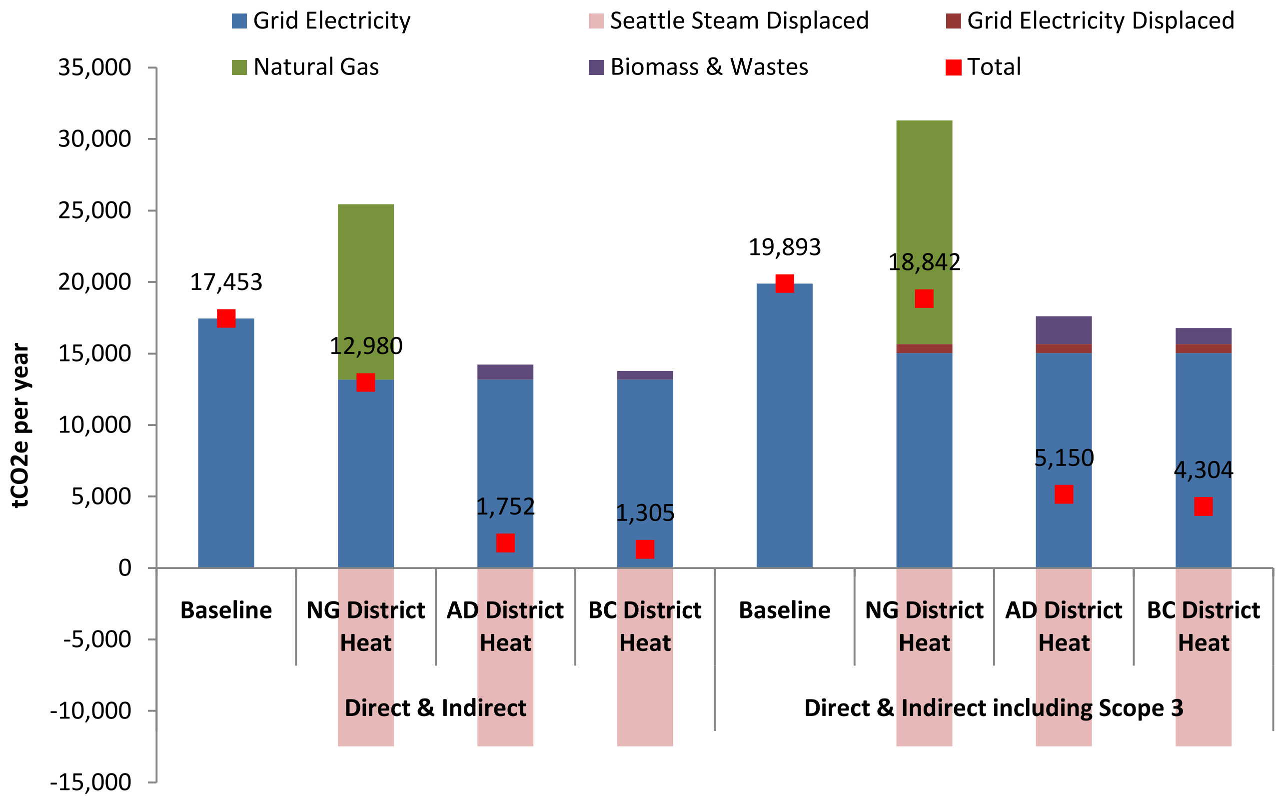
2.4.3 Environmental Performance

Emissions of the predominant greenhouse gases (CO_2, CH_4, N_2O), estimated using EPA emissions factors[5], have been quantified for the District Heat scenario and the BAU scenario and include direct emissions from fuel combustion and indirect emissions from purchases of grid electricity. In the District Heat scenarios, emissions of greenhouse gases are kept to a minimum through the utilization of biomass materials and small quantities of natural gas to satisfy space heating and DHW loads. GHG emissions are presented in units of metric tons of carbon dioxide equivalent (tCO2e) for all scenarios.

Figure 13 presents site-wide greenhouse gas emissions by source for Yesler Terrace under the expected BAU and three alternative District Heat scenarios considered. The two biomass District Heat scenarios have “negative” GHG emissions due to the fact that they displace Seattle Steam usage at Harborview, thereby eliminating the GHG emissions associated with Seattle Steam. If the sale of thermal energy to Harborview Hospital were not possible, the net emissions associated with the three District Heat scenarios would each be shifted upward by 12,469 tCO2e annually. Regardless of whether thermal energy can be sold to Harborview or not, the District Heat options decrease GHG emissions for each biomass alternative relative to the BAU scenario.

[5] eGRID 2006 emissions factors are used for electricity purchases and EPA Climate Leaders technical resources are used for stationary combustion emissions

FIGURE 13: DISTRICT HEAT SCENARIO GHG EMISSIONS FOR YESLER TERRACE (W/ THERMAL SALES TO HARBORVIEW)



3 SUMMARY

3.1 TECHNICAL AND FINANCIAL PERFORMANCE PARAMETERS

WSP's analysis aimed to develop values for several specific project parameters that can be used as inputs to the Gibson Economics project pro forma model. WSP is providing several summary tables which present the loads for the various scenarios, incremental cost of energy efficiency for the development, the incremental costs of HVAC systems required to accommodate more efficient heating and cooling delivery, and life cycle energy costs for each scenario considered. The "2010 level buildings" scenario is shown for informational purposes even though this is not considered as an option in this study since our Business As Usual (BAU) or "expected" scenario involves continual incremental improvements in building energy efficiency over time during the course of YT buildout.

The annual consumption of electricity by sector for each scenario is presented in Table 30 while the peak electric loads are summarized in Table 31. Recall that the CHP scenario does not consume electricity from the grid but rather purchases fuel and produces thermal energy and electricity for the development. The natural gas consumption is presented here. All costs are presented in $ 2010. Both grid electricity and plant fuel consumption are presented for the natural gas district heat scenario since both are required in that scenario.

TABLE 30: SUMMARY OF ANNUAL ENERGY CONSUMPTION (MWh/YEAR UNLESS OTHERWISE NOTED)

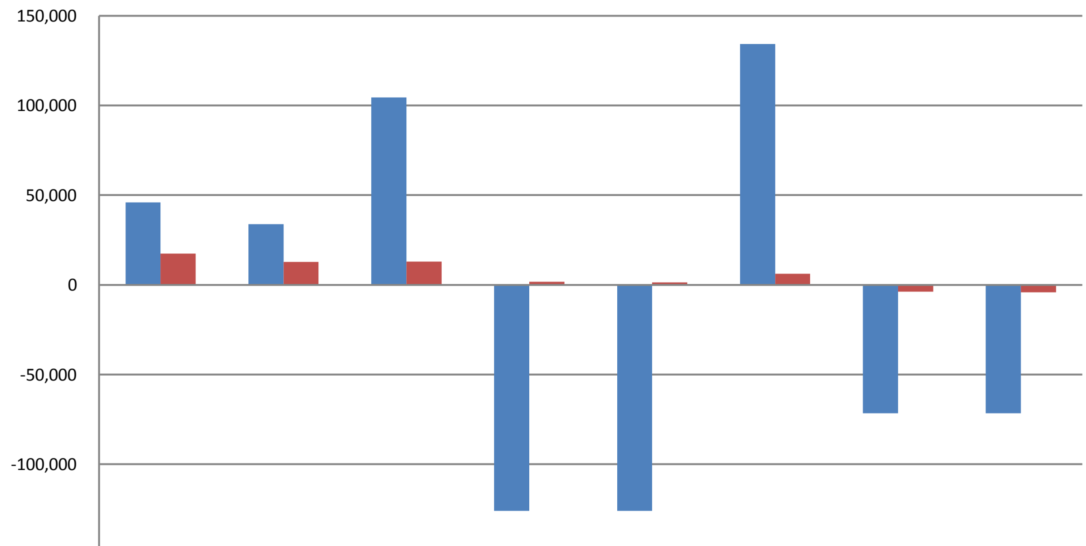
Sector	2010 Level Buildings	BAU Scenario	Geoexchange/Solar DHW	CHP Gas (MMBtu)	District Heat Natural Gas (MMBtu)	District Heat Electricity (MWh)
NW	19,589	16,976	12,899	126,899	12,334	11,140
NE	4,060	3,006	2,230	21,999	1,664	2,821
SW	7,189	4,577	3,411	33,580	2,093	3,810
SE	5,864	3,208	2,404	23,616	1,359	2,731
EOB	1,712	939	693	6,420	759	1,177
Total	38,414	28,706	21,637	212,943	18,210	21,680

TABLE 31: SUMMARY OF PEAK ELECTRIC LOADS (kW)

Sector	2010 Level Buildings	BAU Scenario	Geoexchange / Solar DHW	CHP	District Heat
NW	9,789	7,410	3,843	2,184	2,225
NE	1,545	1,344	966	458	479
SW	2,698	1,777	1,300	618	647
SE	2,161	1,238	927	443	463
EOB	663	577	405	191	200
Total	16,856	12,345	7,441	3,895	4,015

FIGURE 14 presents a summary of the primary fossil energy consumption and greenhouse gas emissions for the different scenarios considered by the study. Primary fossil energy refers to the coal, oil, and natural gas required to produce the delivered energy services, e.g. electricity at wall outlets. The BAU consumption of primary fossil energy is rather low because only 47% of the power generated in the NWPP grid sub-region is from fossil-fired power plants. Scope 1 & Scope 2 emissions of greenhouse gases arise from the consumption of grid electricity and the combustion of fuels to produce energy. Biogenic CO_2 emissions from combustion of wood and biomass wastes are neglected since these fuels are carbon-neutral. The scenarios presented in the figure match the scenarios discussed in previous report sections in which thermal energy can be sold to the Hospital. The district heat plant scenarios consider a larger amount of thermal energy sales than the CHP scenarios and result in correspondingly lower fossil primary energy consumption. Negative values reflect the primary fossil energy displaced by the use of Seattle Steam at the hospital.

FIGURE 14: PRIMARY FOSSIL ENERGY USE AND SCOPE 1 AND 2 GREENHOUSE GAS EMISSION SUMMARY



	BAU	Geoexchange	Natural Gas	Anaerobic Digestion	Biomass Combustion	Natural Gas	Anaerobic Digestion	Biomass Gasification
			District Heat Plants			Combined Heat & Power Plants		
Primary Fossil Energy (MMBtu/yr)	46,034	33,771	104,479	-126,047	-126,047	134,307	-71,625	-71,625
SCOPE 1 & 2 GHGs (tCO2e/yr)	17,453	12,788	12,980	1,752	1,305	6,230	-3,800	-4,138

3.2 LIFE CYCLE COST ANALYSIS SUMMARY

Life cycle cost analysis results are presented in the tables below. Table 32 shows the performance of the all-electric scenarios which include the baseline 2010-level buildings (no change from current code), the expected BAU scenario, and the geoexchange/SHW scenario. The BAU scenario costs 90% more than the 2010 baseline, due to the incremental costs of improved energy efficiency to meet the future stringent energy codes. The geoexchange scenario would cost a bit less than the BAU scenario over the 30 year life cycle analysis period.

TABLE 32: LIFE CYCLE COST ANALYSIS SUMMARY – ALL-ELECTRIC SCENARIOS

	2010 Level Buildings		BAU Scenario		Geoexchange	
	Site Wide ($'000)	Normalized ($ / sf – yr)	Site Wide ($'000)	Normalized ($ / sf – yr)	Site Wide ($'000)	Normalized ($ / sf – yr)
Energy Costs	37,974	0.27	28,931	0.21	22,099	0.16
O&M Costs	0	0.00	0	0.00	0	0.00
Equipment Costs	2,588	0.02	18,744	0.13	27,669	0.20
Total Life Cycle Costs	40,562	0.29	47,676	0.34	49,768	0.35
Incr from BAU		-15%				2.9%

The three combined heat and power plant scenarios are presented in Table 33 and Table 34. The first table presents the results excluding any collaboration with the hospital. In the second table excess thermal energy generated by the cogeneration units operating to meet Yesler Terrace's electrical load is sold to Harborview at $10/MMBtu. Since each scenario produces roughly the same quantity of excess thermal energy, these cost increases are proportional.

TABLE 33: LIFE CYCLE COST ANALYSIS SUMMARY – CHP SCENARIOS (W/O THERMAL SALES TO HARBORVIEW)

	Natural Gas CHP		Biomass Gasification CHP		Anaerobic Digester CHP	
	Site Wide ($'000)	Normalized ($ / sf – yr)	Site Wide ($'000)	Normalized ($ / sf – yr)	Site Wide ($'000)	Normalized ($ / sf – yr)
Energy Costs	15,847	0.11	6,767	0.05	998	0.01
O&M Costs	16,585	0.12	16,585	0.12	16,585	0.12
Equipment Costs	51,727	0.37	57,809	0.41	60,855	0.43
Total Life Cycle Costs	84,159	0.60	81,161	0.58	78,437	0.56
Inc. from BAU		77%		70%		65%

TABLE 34: LIFE CYCLE COST ANALYSIS SUMMARY – CHP SCENARIOS (W/ THERMAL SALES TO HARBORVIEW)

	Natural Gas CHP		Biomass Gasification CHP		Anaerobic Digester CHP	
	Site Wide ($'000)	Normalized ($ / sf – yr)	Site Wide ($'000)	Normalized ($ / sf – yr)	Site Wide ($'000)	Normalized ($ / sf – yr)
Energy Costs	-8,273	-0.06	-17,353	-0.12	-23,122	-0.16
O&M Costs	16,585	0.12	16,585	0.12	16,585	0.12
Equipment Costs	51,727	0.37	57,809	0.41	64,999	0.46
Total Life Cycle Costs	60,039	0.43	57,040	0.40	58,462	0.42
Incr from BAU		26%		20%		23%

The three district heat scenarios are presented in Table 35 and Table 36. The first table shows the results obtained when the district heat plant operates in a load-following manner and only produces the thermal energy required by Yesler Terrace buildings for space heating and a fraction of the domestic hot water load. In the second table, the assumption is made that the heat plant would operate in a baseload manner (24/7) to supply hot water at full output and excess thermal energy would be sold to Harborview at $10/MMBtu.

TABLE 35: LIFE CYCLE COST ANALYSIS FOR DISTRICT HEAT SCENARIOS (W/O THERMAL SALES TO HARBORVIEW)

	NG District Heat		BC District Heat		AD District Heat	
	$'000	**$/SF-yr**	**$'000**	**$/SF-yr**	**$'000**	**$/SF-yr**
Energy costs	24,521	0.17	23,841	0.17	23,185	0.16
O&M Costs	439	0.00	439	0.00	439	0.00
Equipment Costs	33,766	0.24	34,723	0.25	36,211	0.26
Total	58,726	0.42	59,003	0.42	59,836	0.42
Inc. from BAU		23%		24%		26%

TABLE 36: LIFE CYCLE COST ANALYSIS FOR DISTRICT HEAT SCENARIOS (W/ THERMAL SALES TO HARBORVIEW)

	NG District Heat		BC District Heat		AD District Heat	
	$'000	**$/SF-yr**	**$'000**	**$/SF-yr**	**$'000**	**$/SF-yr**
Energy costs	4,596	0.03	3,916	0.03	3,260	0.02
O&M Costs	3,164	0.02	3,164	0.02	3,164	0.02
Equipment Costs	33,766	0.24	34,723	0.25	43,360	0.31
Total	41,525	0.29	41,802	0.30	49,784	0.35
Inc. from BAU		-13%		-12%		4%

4 RECOMMENDED NEXT STEPS

4.1 ADDITIONAL ENERGY DEMAND-SIDE STUDIES RECOMMENDED

During the next phase of work, hourly building energy load computer simulations must be constructed for a set of prototypical buildings which can be used to more accurately estimate Yesler-wide demand for electricity and thermal energy. Ideally, this will be performed in conjunction with the architectural design phase. These models could then be used to facilitate a more in-depth cost-benefit analysis for specific energy load reduction and energy efficiency measures, thereby providing guidance to the building design process.

4.2 COLABORATION WITH HARBORVIEW

During the next phase of work, SHA should continue to evaluate collaboration opportunities with Harborview Hospital. If Harborview is willing to be a partner in a district energy system with Yesler Terrace the district heat and CHP scenarios are financially attractive. However detailed discussion and analysis will be required to determine the extent to which the hospital can help improve the overall economics of a combined system.

4.3 DETAILED FEASIBILITY STUDY

During the next phase of work, a detailed feasibility study should be performed to evaluate the technical and financial performance of the geoexchange/solar hot water scenario and the district heating scenario that includes thermal energy sales to Harborview. This study would continue the work performed for this study but would incorporate the detailed building energy loads developed in the study recommended in Section 4.1. With detailed community-wide building energy loads, a simulation of the geoexchange system can be run to determine the annual coefficient of performance (COP), annual electricity consumption, and thermal balance of the heat sink / source to determine the long-term system performance. Soil sampling and evaluation may be required to accurately simulate and predict heat flows in the ground.

The layout of these two options will assess the availability of space for the centralized equipment and will evaluate the optimal layout of primary water distribution systems which the individual buildings will plug into. In the geoexchange scenario, the follow-on study will evaluate the optimal layout of underground heat exchangers. This analysis will take into account the construction phasing and will be designed in a modular fashion to address incremental building energy loads as they come online. Results from the detailed building energy analyses will be used to predict the domestic hot water loads for each building. Solar hot water potential assessments will be matched to each building load and rooftop space requirements will be confirmed. In this phase of the study, local installers will be consulted to develop capital and O&M cost estimates for these systems.

The ideal outcomes of this study will be the following:

- Detailed prototypical building energy models that incorporate future State of Washington building energy codes and model hot and chilled water distribution produced by the central heat pump plant
- Development of more accurate energy pricing through a review of hourly average spot market electricity prices and applicable tariff rate structures, and estimation of fair market prices for hot water and chilled water sales
- Site layout diagrams for the district heating system, with interconnections to Harborview
- Site layout diagrams for the central geoexchange system and rooftop layouts for the solar thermal panels
- Detailed energy simulations to predict annual energy and water consumption of the facility and the annual increase or decrease of the ground heat source / sink to determine long-term temperature changes affecting system performance
- More accurate estimates of capital costs reflecting the development schedule, and annual operations and maintenance cost requirements
- Preliminary permitting and interconnection studies

- Development of a more rigorous financial *pro forma* for the project incorporating all relevant costs and revenues and projecting IRR, taking into account currently feasible capital structures such as use of 3rd party tax-equity financing versus a performance contract with an energy services company (ESCO).
- Detailed project development timeline – Microsoft Project document laying out the major milestones and timelines for activities in the project-development process.

Appendix A Supply Side Energy Technology Assessments

BIOMASS ENERGY CONVERSION TECHNOLOGIES

Commercialization of biomass energy technologies is advancing rapidly and it is WSP's opinion that some of these technologies currently in the commercial demonstration phase will be fully commercialized and cost-effective by the time construction of Phase 1 at Yesler Terrace is completed, and energy loads begin to manifest. An example of an emerging biomass technology is algae bioreactor technology which could be used for the production of hydrogen, oils, or biomass. Biomass can be converted to energy conventionally, via combustion, but also with gasification, pyrolysis, and anaerobic digester technologies.

Anticipating that venture capital placement and federal grant awards will result in rapid adoption of these next-generation technologies, they should be considered in any subsequent analysis for Yesler Terrace despite the fact that they may not be currently "bankable". It is WSP's opinion that a combined cooling, heating, and power plant utilizing biomass resources has the greatest potential to supply total energy to a selected portion of the development, specifically the higher-energy-intensity commercial and office areas. The residential buildings are envisioned to be best served by geoexchange technology (ground-source heat pumps).

There are numerous technical considerations relating to biomass-to-energy that need to be addressed early in the next phase of work, such as identifying feasible locations for plant siting. Depending on the plant size, technology choices, and types of energy supplied, biomass storage and conversion can be space-intensive. For example, a biomass energy facility with short-term on-site storage, sized to supply total energy to Yesler Terrace, would easily occupy over 100,000 SF of land. Actual space requirements will need to be defined when the size, deployed technologies, and feedstock storage requirements are determined. Opportunities may exist to locate a combined heat and power (CHP) plant adjacent to Yesler Terrace where land is still available. Off-site joint venture projects with biomass power project developers would dramatically reduce YT space requirements and should be explored in later phases of YT's planning process. A discussion of individual biomass energy conversion technologies follows.

ANAEROBIC DIGESTION

Anaerobic digestion of animal wastes and other organic materials produces biogas, which is roughly 60% methane. If the biogas is to be converted to energy on-site, generally only minimal gas clean-up is required to remove compounds such as hydrogen sulfide and water in order to marginally upgrade the biogas to a suitable fuel. If the methane is to be utilized at a location off-site, substantially more gas upgrading is typically performed to remove the carbon dioxide and nitrogen content, thereby producing a pipeline-quality natural gas substitute. Gas upgrading enables the long-distance transporting of bio-methane via natural gas pipelines so it can be utilized off-site.

Yesler Terrace could take advantage of this principle and purchase pipeline-quality bio-methane from an off-site project, inject it into the natural gas pipeline, and then simply withdraw conventional natural gas from the gas distribution network and burn it at an on-site CHP. By this method, Yesler Terrace could in effect produce heating, cooling, and power from renewable biomass. This solution is beneficial from two perspectives. First, the production of biogas requires a significant amount of infrastructure which is much better accommodated off the Yesler Terrace site. Second, a joint venture between two developers (on-site CHP and off-site digesters) would be much more attractive from an investment perspective because the technical risk, feedstock supply risk, and capital costs would be borne by two entities.

If on-site biomass energy conversion is required, animal manures are not the best feedstock choice since they are not available nearby. Rather, procuring Fats/Oils/Grease (FOG) will enable more cost-effective on-site conversion because these materials have a much higher energy density (Btu/lb) than animal manures, thereby minimizing transport and storage costs. FOG has much higher energy density because it has a high content of volatile solids and contains much less water than manure.

COMBUSTION AND GASIFICATION

Both gasification and combustion are suitable biomass energy conversion technologies for woody biomass and other agricultural biomass residues where the moisture content does not exceed 50%. Biomass combustion is suitable for boilers producing hot water for space heating or steam generation to produce heat and power. Biomass combustion will be cost-effective for heating or in CHP applications but will likely be cost-prohibitive for electricity-only production.

Thermochemical conversion technologies (gasification and pyrolysis) are more advanced and efficient pathways of converting biomass to a useable energy form. Synthesis gas (syngas) from gasification and bio-oil from pyrolysis are low energy-content fuels (compared with their fossil counterparts) but are very promising to fuel conventional power generation equipment such as reciprocating engines, combustion turbines, and fuel cells. Additionally, they can both be fired in boilers for hot water and steam production, but this pathway doesn't maximize the value of biomass like cogeneration will. Small-scale modular biomass gasification systems are being developed for CHP applications at the individual building and community scale. Large centralized gasification systems will be most cost-effective in the near term and also will convert biomass at much higher efficiencies than smaller-scale systems or anaerobic digesters. Depending on the intended use of the syngas (centralized power generation, distributed generation, heating, or liquid fuel production), systems will be configured differently and will have markedly different installed costs. In the Yesler Terrace context, combustion, gasification, and anaerobic digestion technologies are required to convert biomass into a form that can be utilized by the CHP technologies discussed in the next section. Readers are encouraged to refer to the Dockside Green project in Victoria, British Columbia for a case study on the use of woody biomass in an biomass gasification district heat plant located in an urban setting.

CHP TECHNOLOGIES – POWER GENERATION

CHP production provides energy savings and greenhouse gas emissions reductions by capturing waste heat from power generation equipment (engines, turbines, etc.) and generating steam and hot water to serve on-site heating and/or cooling loads. CHP has been used primarily by industries with large heat loads to produce low-cost electricity as a by-product of producing the required industrial process heat. Smaller-scale power generation equipment allows this practice to be extended to buildings and clusters of buildings. The hot combustion gases exiting these types of equipment can be converted with heat recovery boilers into hot water or steam.

The analysis performed in the Yesler Terrace context considers several power generation equipment types which can be run on natural gas, biogas (derived from landfills or anaerobic digestion of organic waste) or syngas generated by the gasification of biomass and carbonaceous wastes. Converting biomass and waste materials via anaerobic digestion and gasification allows conventional power generation equipment to be run on renewable fuels. Table 37 details the power generation technologies considered.

TABLE 37: CHP POWER GENERATION TECHNOLOGIES

Technology	Size ranges (kW)	Electrical Efficiency (LHV[6])	Heat-to-Power ratio[7]	Fuel Sources	Installed Cost ($/kW)
Gas Engines	50 to 2,000	39%	1.5	Natural gas, biogas, syngas, biodiesel	1,100
Gas Turbines	500 to 50,000	40%	2	Natural gas, biogas, syngas, biodiesel, bio-oil	550
Micro-turbines	250 to 2,500	32%	1.55	Natural gas, biogas	2,800
MC Fuel Cells	500 to 2,000	42%	0.6	Natural gas, biogas	4,000
Steam Turbine	500 to 50,000	25%	2.5	Steam: biomass combustion	1,000

[6] Refers to the efficiency of converting a fuel to electricity, based on the fuel's lower heating value

[7] Refers to the ratio of recoverable thermal energy (steam, hot water) to rated power output

CHP TECHNOLOGIES – HOT WATER PRODUCTION

To meet peak heating loads, central plants often require peak heating capacity in addition to what the CHP equipment can supply. Typically heating plants use natural gas boilers to produce hot water for space heating. Both gas and biomass boilers are considered in this analysis to supply peak heating loads. In our analysis, both biogas and natural gas can supply fuel to gas boilers and solid biomass can be used in a biomass or wood pellet boiler. Biomass combustion boilers operate most efficiently and effectively when they are base-loaded (sized to meet the portion of the overall heating load that is constant 24/7, and operated to run continuously at maximum output). Heating capacity to meet the load any time it exceeds the base load should be provided with biogas or natural gas boilers. These technologies are detailed in Table 38.

TABLE 38: CHP HOT WATER PRODUCTION TECHNOLOGIES

	Size ranges (kW)	Thermal Efficiency (LHV)	Fuel Sources	Installed Cost ($/kW thermal)
Gas Boiler	Any	85%	Natural gas, biogas, syngas	55
Condensing gas boiler	Any	95%	Natural gas, biogas, syngas	65
Biomass boiler	300 to 20,000	75%	Wood pellets, wood chips	120

CHP TECHNOLOGIES – CHILLED WATER PRODUCTION

Typical central plants utilize electric chillers to produce chilled water for building space cooling. This technology quite often makes sense because of its high efficiency and can sometimes be made even more economical with off-peak storage of chilled water or ice. However, in situations where waste heat is readily available, it makes sense to convert the waste heat (combustion flue gas or steam) into chilled water via an absorption chiller. Several types of absorption chillers are available and the choice typically is a function of capacity requirements and the conditions or quality of the heat available. Single-effect absorption chillers work well with flue gases and low-pressure steam which can be produced with boilers and heat recovery boilers. Double-effect chillers are substantially more efficient but require higher-pressure steam which is not always available. A direct-fired absorption chiller burns natural gas or biogas directly as its heat source. Direct-fired absorbers are generally not as cost-effective as electric chillers but may be attractive if sufficient biogas can be produced. Chiller efficiency is typically expressed as a coefficient of performance (COP), which is the ratio of the refrigeration effect to the energy input. Electric chillers are also rated in units of power input (kW) per unit of refrigeration capacity (ton). These technologies are compared in Table 39.

TABLE 39: CHP CHILLED WATER PRODUCTION TECHNOLOGIES

	Size Ranges (tons)	Efficiency	Energy sources	Installed Cost ($/ton)
Electric Chiller	150 to 4,000	0.68 kW/ton (5.2 COP)	Electricity	490
Single Effect Absorption chiller	500 to 1,500	0.7 COP	Low pressure steam	600
Double Effect Absorption chiller	300 to 2,000	1.2	High pressure steam, flue gas	650
Direct Fired Absorption chiller	100 to 1,000	1.14	Natural gas, biogas	600

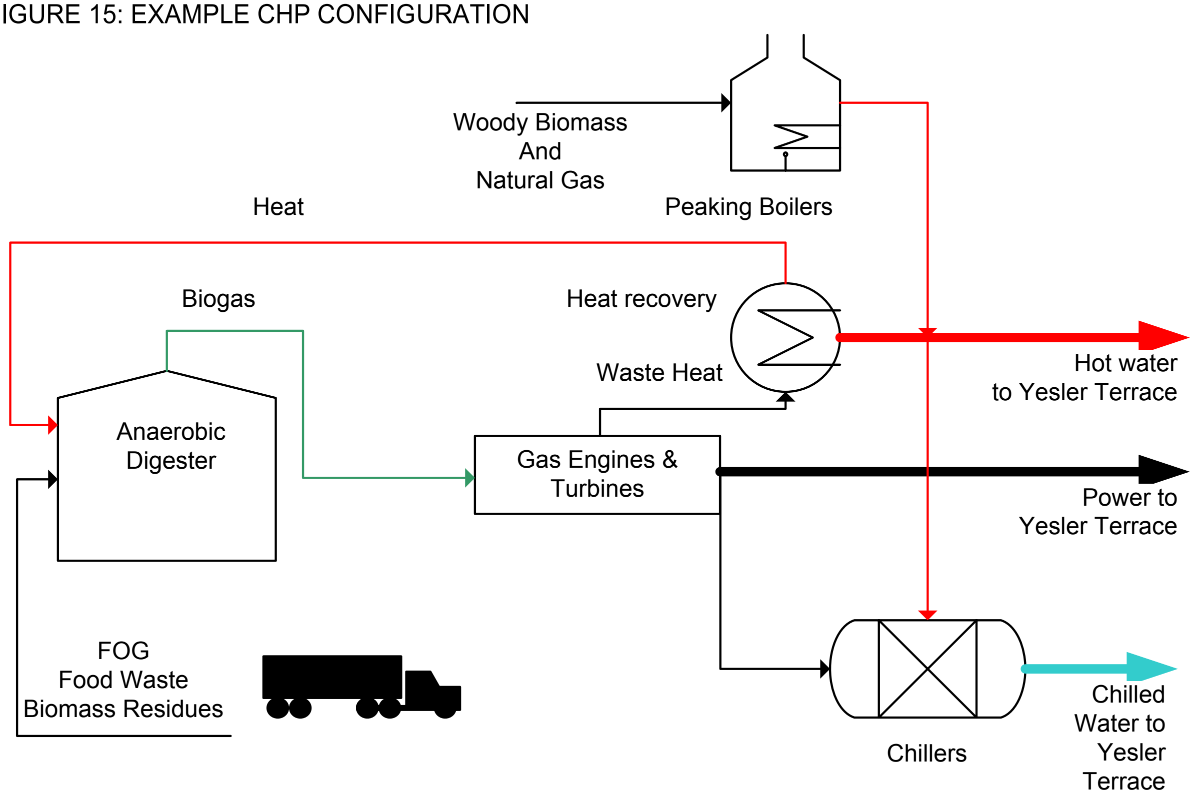
Thermal Energy Storage

Thermal energy storage is not considered in this analysis because it requires a higher level of detail than is available at this phase. Central plants can in certain instances operate more efficiently and cost-effectively with hot water storage, chilled water storage, and/or ice storage. With hot water storage, a plant can produce hot water for storage when loads are low and supply the stored energy during peak hours, thus eliminating the need for peak heating capacity. Chilled water and ice storage provide the same function during peak cooling loads but this is typically only done when grid electricity is used to drive electric chillers because they can charge storage at night when grid electric rates are lower. Thermal energy storage should be evaluated in further phases of analysis.

AN EXAMPLE BIOMASS-FUELED CHP CONFIGURATION

This section describes an example of a CHP configuration that would meet 100% of the commercial and residential electricity loads at Yesler Terrace with a mixture of biomass fuels and natural gas. A generic schematic drawing of the hypothetical system is shown in Figure 15. In this example, an anaerobic digester is used to convert FOG and food wastes into biogas which is cleaned and piped to various equipment used to generate heat and power. This particular configuration was chosen in order to make use of low-cost waste biomass resources and maximize their energy generation potential by converting them into hot water, chilled water, and electricity. Since FOG and food wastes are believed to be the lowest-cost carbon-neutral fuel available regionally, its use has been maximized. Note that vetting this assumption is one of the key objectives of the feasibility study that must be performed in follow-on phases of work. Anaerobic digestion is required to convert these materials into biogas, the most flexible renewable fuel, so that this resource can be utilized in low-cost conventional power generation equipment. A biomass tri-generation plant (hot water, chilled water, electricity production) holds the greatest potential to serve thermal and electrical loads using renewable carbon-neutral fuels while providing competitively priced energy.

FIGURE 15: EXAMPLE CHP CONFIGURATION

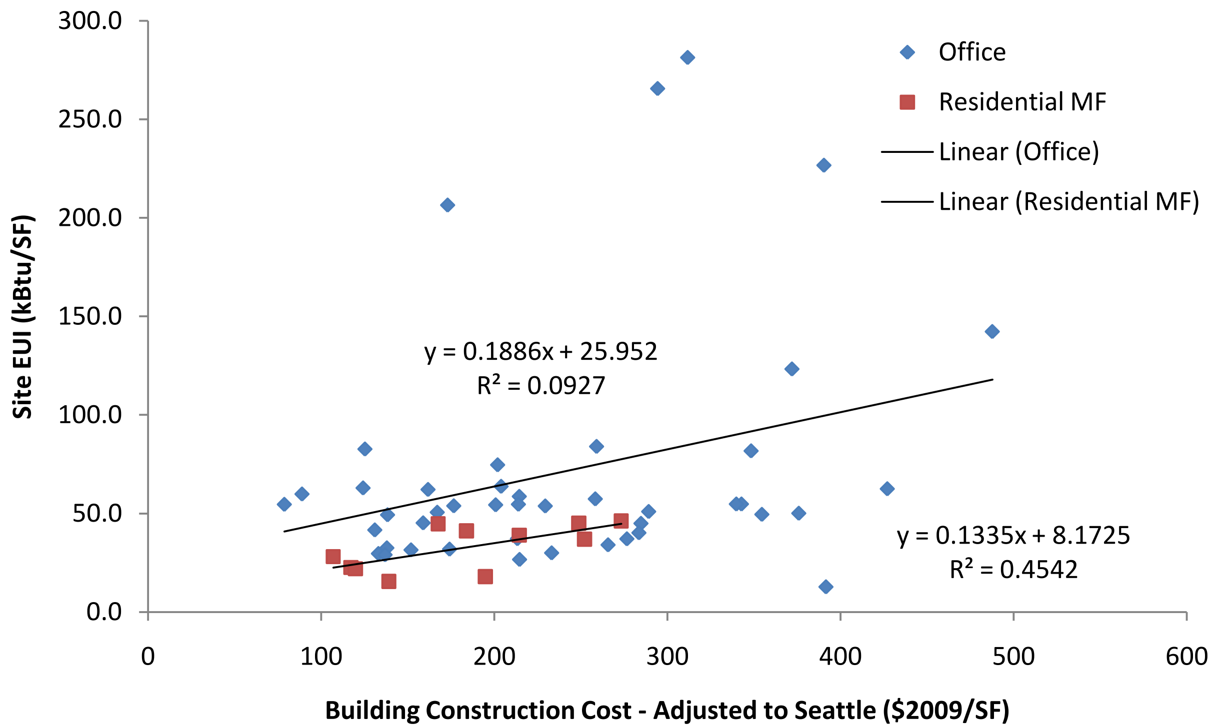


The biogas in this example is used to generate heat and power with gas engines and gas turbines. The waste heat from the engines and turbines can be used to drive absorption chillers to produce chilled water or can be used to produce hot water with a heat recovery boiler (depending on season). Additional hot water production capacity is required from a biomass boiler and a peaking natural gas boiler. Likewise, peak cooling loads can be supplied with electric chillers consuming electricity generated by the gas engines or electricity from the grid.

Appendix B Low-Energy Building Cost Survey

Our survey considered 44 commercial office and 11 multi-family residential buildings, most of which are LEED certified at a minimum. The majority of this data is available from a database on the US Department of Energy's Green Buildings website.[8] The data presented in Figure 2 has been adjusted to 2009 dollars, including an adjustment by cost of living to normalize data to Seattle equivalent costs. In addition, the EUI data are adjusted to take account of climatic effects such that they would represent EUIs for buildings in Seattle. These adjustments are necessary when comparing buildings at various locations across the country where weather and cost vary significantly. As Figure 16 shows, the general trend shows that more expensive buildings use more energy per square foot. This is because the cost of building HVAC and energy systems are low in comparison to the total building construction cost, and therefore money spent on load reduction and efficiency measures do not clearly shine through. Although this data is not useful for this study, it is presented to illustrate currently available cost and energy use data in the public domain.

FIGURE 16: SURVEY OF LEED AND LOW ENERGY USE BUILDINGS IN THE UNITED STATES



[8] http://eere.buildinggreen.com/mtxview.cfm

Appendix C In-Building HVAC Equipment Costs

Description	Ext. Material O&P	Ext. Installation O&P	Ext. Total O&P	$/MBH or $/ton
Electric water heater, residential, 100< F rise, 40 gallon tank, 8 GPH	1,401	1,044	2,446	365
Gas fired water heater, residential, 100< F rise, 40 gal tank, 32 GPH	1,702	1,312	3,014	112
Solar recirculation, hotwater, 1/2" tubing, 2 each 3' x 7' flat black collectors	3,604	4,021	7,625	1,625
Gas fired water heater, commercial, 100< F rise, 100 MBH input, 91 GPH	6,406	1,564	7,970	80
Electric water heater, commercial, 100< F rise, 150 gal, 120 KW 490 GPH	29,229	1,508	30,737	75
Solar recirculation, hotwater, 1" tubing, 4 each 3' x 7' black chrome absorber collectors	9,159	4,999	14,158	1,509
Boiler, electric, hot water, 120 KW, 410 MBH	10,110	3,965	14,075	34
Boiler, electric, steel, hot water, 120 KW, 410 MBH	6,757	1,759	8,516	21
Boiler, cast iron, gas, hot water, 200 MBH	8,659	4,831	13,490	67
Rooftop, multizone, air conditioner, apartment corridors, 3,000 SF, 5.50 ton	10	4	14	
A/C packaged, DX, air cooled, electric heat, VAV, 20 ton	25,826	7,651	33,477	1,674
A/C packaged, DX, air cooled, electric heat, VAV, 40 ton	55,556	9,522	65,078	1,627
Heat pump, central station, water source, constant volume, 10 ton	10,711	3,854	14,564	1,456
Heat pump, central station, water source, constant volume, 40 ton	37,638	10,908	48,546	1,214
Heat pump, console, water source, 2 ton	2,928	1,871	4,799	2,399
Heat pump, roof top, air/air, curb, economizer, supplemental electric heat, 10 ton	55,556	5,473	61,029	6,103
Heat pump, roof top, air/air, curb, economizer, supplemental electric heat, 40 ton	120,120	15,080	135,200	3,380
Geothermal heat pump system, 40 Tons, vertical loops 250' depth, 250 LF per ton,4 gpm per ton	71,071	139,334	210,405	5,260
Geothermal heat pump system, 25 Tons, vertical loops 200' depth, 200 LF per ton,4 gpm per ton	46,547	75,449	121,996	4,880

Appendix B

Yesler Terrace

Seattle, WA

Phase 2 Integrated Water Strategy (IWS) Assessment

July 12, 2010 (*Revised November 01, 2010*)

Prepared By:

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Phase 2 Integrated Water Strategy (IWS) Assessment
Yesler Terrace, Seattle, WA

Tables

Appendices

I. Executive Summary

The Seattle Housing Authority (SHA) is currently in the second phase of planning efforts to redevelop Yesler Terrace, a 38-acre site which is centrally located within one mile of the city's largest employment area. This report is part of a Sustainable District Study being completed by The Synergy Team. The purpose of this report is to outline our findings for an Integrated Water Strategy (IWS) infrastructure and service area.

Estimated **total water demand** for Sectors 1-4 and East of Boren (EOB) is approximately 626,149 gallons per day (gpd) including evaporative losses attributed to peak month irrigation and projected combined cooling, heating and power plant (CCHP) make-up demands. Without irrigation and CCHP uses, total water demand projections drop to 517,425 gpd and equal wastewater flow projections for the purpose of this analysis as shown in **Appendix D**.

Multiple alternatives of reuse water sources and uses were considered for this project and are discussed in detail within Section VI of this report. We evaluated the possibility of harvesting rainwater from building roofs to meet some of the reuse demands, however volumes of roof runoff are insufficient to satisfy potential reclaimed water demands without being supplemented with significant quantities of potable water, thus reducing savings in potable water use compared with the reuse of treated wastewater. Also, given the typical summer rainfall patterns, potable usage to supplement roof runoff will be highest in the summer, contrary to the overarching goal of reducing withdrawals from the Tolt & Cedar Rivers. Using the combined (total) sanitary wastewater reuse concept as discussed within Section VI and as detailed in **Appendix H** (Reuse Scenario F), potable water demand could be reduced to approximately 255,777 gpd (59.2% reduction in potable water demand) with a potential reduction in projected sewer flow of 71.6%. Potential treatment system capacities, area requirements and potential locations are discussed within Section VI.E and will be adjusted as project phasing becomes more defined. Given the benefits of economies of scale, it is recommended that reuse systems be implemented on a sector or multi-sector basis for this project with a potential natural system demonstration at the community center.

Appendix K presents a report from Gibson Economics summarizing economic benefits from the use of wastewater reclamation for Yesler Terrace. While estimates for the installation of the reuse water distribution system and the installation of building dual plumbing are conservative, they are appropriate for this level of analysis. This report concludes that a water reuse system for Yesler Terrace would yield positive net benefits under wide range of potential scenarios.

Appendix L presents a summary of water and sewer charges for the entire project based on current Seattle Public Utility (SPU) rates, along with a listing of amortized costs for reclaimed water treatment for the various potential reuse scenarios. Total annual water and sewer charges for the project are estimated to be approximately $3,373,790 without reuse. <u>A combined total wastewater reuse program providing reuse water for flushwater, laundry, irrigation and CCHP make-up is projected to reduce annual potable water and sewer charges to $1,096,359 with an annual net savings of $384,830 using an amortized reuse treatment cost of $0.014 per gallon</u>This represents an approximate savings of 14% based on current economic information and rate structure. It is anticipated that this savings may improve as water reuse system technology continues to advance and as regional sewer and water charges continue to increase (average water & sewer rate increase of 7.7% over the last 10 years).

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However, such trends are difficult to predict and could be significantly impacted by future policy changes or modifications to service charge mechanisms which could enhance or negate such benefits.

Energy recovery opportunities and environmental benefits including reduced CSO event volumes to Elliot Bay are discussed within Sections VIII and X.

II. Purpose and Scope

The Client: Seattle Housing Authority (SHA), established in 1939, is a public corporation governed by a seven-member Board of Commissioners. The agency owns and operates buildings on more than 400 sites throughout the city, and provides long term rental housing and rental assistance to more than 26,000 people. Since 1995 SHA has completed major public housing redevelopments of the New Holly, Rainier Vista, and High Point developments into mixed-income, mixed-tenure communities that have transformed these areas into new neighborhoods within the City of Seattle, encompassing nearly 300 acres and creating approximately 4,300 new units of housing, as well as new infrastructure, parks and community facilities. At High Point, SHA implemented an aggressive and highly successful green building and low impact development program in partnership with the Built Green program and Seattle Public Utilities.

Yesler Terrace: SHA is now in Phase 2 Planning to redevelop Yesler Terrace. This 38 acre site is ideally suited to become a showcase sustainable community. It is centrally located, and lies within one mile of the city's largest employment area, containing 25% of the jobs in Seattle. SHA, in coordination with residents, neighborhood stakeholders and consultants, plans to build a dense, walkable, urban, mixed-income, and diverse community. SHA is in the process of preparing an Environmental Impact Statement (EIS) that examines several different alternatives for possible development scenarios. Each of these scenarios increases density to varying degrees. Each includes increasing the number of residential units from the existing 561, by different amounts. Each proposes varying amounts of office space and open space. This study uses one of the development scenarios, called Alternative 2, (See **Appendix A**) as the basis for analysis. Alternative 2 proposes 4,000 new residential units of housing using a mix of mid-rise buildings and towers of between 150 to 240 feet in height. It also proposes 1 million square feet of office space, 5 acres of open space, and underground parking.

AE's scope of work as defined in the DRAFT Scope for Phase 2 Integrated Water Strategy (IWS) consultant dated January 25, 2010 is as follows:

"Develop and assemble physical performance and cost information, along with other associated impacts, for potential measures that could be implemented within the Integrated Water Strategy (IWS) infrastructure and service area."

This report is part of a Sustainable District Study being completed by The Synergy Team. The goal of the district study is to develop a diverse and comprehensive set of possible solutions and integrated strategies to reduce the environmental footprint of the Yesler Terrace redevelopment and deliver greater efficiencies to future residents and the City as a whole.

The purpose of this DRAFT is to outline our preliminary findings, eliminate certain topics from further consideration and refine the definition of the remaining tasks and measures to be used. The FINAL

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report will be issued within three (3) to four (4) weeks based on discussions with the Project Team and will be included within the Master Plan document being compiled by Collins Woermen.

III. Water Reuse Background

The Water Reuse Association estimates that in the US, more than 2.6×10^3 Mgal/d of municipal wastewater are reclaimed and reused currently, and reclaimed water use on a volume basis is growing at an estimated rate of 15 percent per year[1]. It has also been reported that it takes 1,200 gallons of water per capita per day to operate the U.S. economy but the human population only consumes less than 1 gallon of water per capita per day. It is clear from this fact that water reuse offers tremendous opportunity to reduce our impacts on water resources because theoretically all but the 1 gallon per capita per day can be readily reused[2].

Direct water reuse involves taking water that was once considered a waste product, treating it to specialized level of treatment and using the resultant high-quality reclaimed water for beneficial reuse. The final application of the reclaimed water determines the amount of treatment that is ultimately provided. Typical examples of reuse applications are[3]:

- Toilet and Urinal Flushing
- Landscape Irrigation
- Agricultural Irrigation
- Industrial Applications (cooling water, boiler make-up water, etc.)
- Fire Protection
- Aesthetic Fountains and Lagoons
- Construction Applications (dust control, concrete production, etc.)
- Environmental & Recreation
- Groundwater Recharge
- Miscellaneous (vehicle washing, laundry facilities, etc.)

AE has been involved with a number of direct water reuse projects nationwide with multiple projects occurring in the New York City area. Typical uses within these high-rise buildings located in Manhattan include toilet flushing, cooling tower make up and landscape irrigation. The benefits of these systems are numerous:

- 48% to 95% reduction in water consumption by comparison to typical modern Buildings
- 60% to 95% reduction in wastewater discharge and waste loads
- Reduced environmental impact from Combined Sewer Overflows (CSO)
- Reduced nutrient and chemical loads to water bodies
- Consistent performance year round that is not dependant on geographical location or season
- Economical operations that use the waste as a resource, provide treatment at the source and yield a favorable Life Cycle Cost and Life Cycle Assessment.

[1] Metcalf & Eddy, *Water Reuse: Issues, Technologies and Applications*, 2007
[2] Clerico, Edward A, *Current Status of Water Reuse*, 2008
[3] Gallagher, Zachary F, *A Reclaimed Water for Beneficial Reuse (RWBR) Pilot Program for a Community in New Jersey,* 2005

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IV. Water Reuse Requirements / Regulations

There are no federal regulations governing water reclamation and reuse in the United States; thus regulations have been developed and implemented at the state level. Currently 25 states have adopted regulations regarding the use of reclaimed water, 16 states have guidelines or design standards and 9 states have no regulations or guidelines[4].

Reuse water for this project will have to meet Class A Reclaimed Water as listed in the "Water Reclamation and Reuse Standards" by the Washington State Department of Health and the Washington State Department of Ecology. A copy of the Standard is included as **Appendix M**. Class A Reclaimed Water means reclaimed water that, at a minimum, is at all times an oxidized, coagulated, filtered, disinfected wastewater. The wastewater shall be considered adequately disinfected if the median number of total coliform organisms in the wastewater after disinfection does not exceed 2.2 per 100 milliliters, as determined from the bacteriological results of the last 7 days for which analyses have been completed, and the total number of total coliform organisms does not exceed 23 per 100 milliliters in any sample. Example reuse water quality requirements for other states are also shown below in Table 1 for comparison.

Table 1: Example Water Reuse Regulations/Guidelines (Unrestricted Urban Reuse)

Parameter	New Jersey	California	Florida	Washington
BOD / CBOD	NS	NS	20 mg/L CBOD (annual average)	Not to exceed 30 mg/L (monthly mean)
Total Nitrogen	<10 mg/L*	NS		NS
Total Suspended Solids (TSS)	5 mg/L	NS	5 mg/L	Not to exceed 30 mg/L (monthly mean)
Fecal Coliform (FC) / Total Coliform (TC)	**FC** 14 col/100 mL (2.2 weekly avg.)	**TC** 240 col/100 mL (max 23 col/100 mL in any 30-day period, 2.2/100 mL weekly avg.)	**FC** 25/100 mL (75% of samples below detection limits over 30-day period)	**TC** 2.2 col/100 mL, 7 day (max 23 col/100 mL any sample)
Turbidity	2 NTU (Continuous Monitoring)**	**See Note *****	Limit NS, continuous on-line monitoring required	Not to exceed 2 NTU (monthly average); instantaneous max – 5 NTU
Disinfection	100 mJ/cm^2 (UV) / 1 mg/L (CPO) - Continuous Monitoring	Required, limit not specified - Continuous monitoring	1 mg/L (CPO)	NS
pH	NS	NS	6-8.5	NS

[4] Metcalf & Eddy, *Water Reuse: Issues, Technologies and Applications*, 2007

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Notes:

NS = Not Specified, some state parameters are specified on a case by case basis

* The NJDEP may impose a total nitrogen concentration limitation greater than 10 mg/L if the permittee can demonstrate that a concentration greater than 10 mg/L is protective of the environment.

** A statistically significant correlation between turbidity and TSS shall be established prior to commencement of the RWBR program. For UV disinfection, in no case shall the level of turbidity exceed 2 NTU while still maintaining the 5 mg/L maximum level for TSS.

*** Natural Soil / Filter Media: 10 NTU (2 NTU max avg. within 24 hr period, 5 NTU no more than 5% of time). Membrane: .5 NTU (.2 NTU no more than 5% of time)

The quality of the water after treatment is generally determined by its end use. As a result, water that is more likely to come in contact with human beings is usually subjected to higher levels of treatment. For the purpose of this concept analysis we have assumed the most rigorous reuse water quality requirements.

The technology most frequently employed to meet these requirements involves biological nutrient removal ("BNR") technology coupled with a high level of filtration which is further described in Section VI – Water Reuse Concept System Narrative.

The Washington State Department of Health (DOH) Standards for Water Reclamation and Reuse are reasonable with regards to level of treatment required but are very strict with regards to testing and analysis, requiring daily sampling and monitoring for certain parameters which require increased levels of operator attendance and the costs associated therewith. In many other states, automatic continuous monitoring of certain parameters is used to supplement weekly or monthly testing that requires laboratory analysis. This will be further evaluated during the next phase of the project and will need to be accounted for within the economic analysis appropriately pending discussions with DOH.

In addition, the Washington State Dept of Health Standard also eliminates the application of reuse water to residential dwellings where the residents have access to the plumbing system for purposes of making repairs. The definition of "access" for the purpose of this standard also requires further clarification and could eliminate certain reuse applications at Yessler Terrace depending on interpretation.

V. Water Resource Balance

At this time the following major components to the water resource balance have been considered for the purpose of identifying initial water reuse potential.

- Total Water Demand
- Wastewater Projections
- Flushwater, Laundry and Cooling Make-Up Water Demand Projections
- Stormwater Runoff Projections from Roof & Site Areas
- Irrigation Demands for Vegetated Areas

Estimated **total water demand** for Sectors 1-4 and East of Boren (EOB) is approximately 626,149 gallons per day (gpd) including peak month irrigation and projected CCHP (combined cooling, heating and power plant) make-up demands. This estimate is based off preliminary unit count information, irrigation demands and CCHP plant make-up load information. Without irrigation and CCHP uses, total water demand projections drop to 517,425 gpd. For the purpose of this analysis potable water

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consumption, leakage, etc are assumed to be negligible and wastewater flow projections without water reuse equal potable water demand without irrigation and CCHP. Wastewater Flow Projections by building and block are included as **Appendix D**.

We note that data obtained from SvR (developed under a separate contract with the Seattle Housing authority) used a design potable flow of 200 gallons/day per ERU (equivalent residential unit) with a peaking factor for the EIS report in order to ensure that potable water mains have adequate capacity. As shown by the tabulation of data in **Appendix D**, we have used flows that represent real life flows using modern, conserving fixtures, in order to consider appropriate or "right sized" reuse water treatment systems. The Seattle Public Utilities (SPU) also suggests average single family home water and sewer flows to be on the order of 138 gpd further confirming the real life estimates used for this analysis. The following assumptions were used in determining the various water use projections and potential water reuse demands:

A. Residential:
   1. Average of 2 people per unit based on 65% market rate units at 1.7 capita/unit and 45% subsidized units at 2.3 capita/unit.
   2. Average indoor water use of 45.2 gallon/capita per day based on average indoor water use in a conserving home[5].
   3. Residential uses as flows, using percentages listed in Vickers:
      i. Blackwater:
         a) Toilets – 18%
         b) Kitchen sink + dishwater – 20.5%
      ii. Greywater:
         a) Laundry – 22.1%
         b) Showers + baths – 22.2 %
         c) Lavatory faucets – 5.2%
      iii. Other – 12%

B. Office, Neighborhood Commercial & Institutional:
   1. The office towers in Sector 1 are assumed to be primarily medical offices with a total wastewater flow of 0.15 gallon/ft^2 per day.
   2. Neighborhood commercial space wastewater flow estimates are based on 0.1 gallon/ft^2 per day.
   3. For both uses, wastewater flow is considered to be 75% blackwater (toilets & urinals), and 25% greywater (lavatories and similar).

See **Appendix E** for a tabulation of various categories of wastewater flows and demands.

C. Stormwater Projections and Estimated Irrigation Demands:

Stormwater projections and estimated irrigation demands are based on total area coverage as detailed in the SvR Draft GSI Requirements document data (**Appendix B)** and the "Alt 2: Built & Natural Environment" data included within the Collins & Woerman document entitled "Yesler Terrace EIS Data" dated April 1, 2010 (**Appendix C**). Average month precipitation data from the Office of The Washington

[5] Vickers, Amy, *Handbook of Water Use and Conservation*, 2001

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State Climatologist is provided below in Table 2 and ranges from 0.95 inches per month (July) to 6.03 inches per month (December).

Table 2: Precipitation Data

Month	P (in)	P (ft)
Jan	5.01	0.42
Feb	3.92	0.33
Mar	3.80	0.32
Apr	2.81	0.23
May	1.99	0.17
Jun	1.52	0.13
Jul	0.95	0.08
Aug	1.30	0.11
Sep	1.61	0.13
Oct	3.35	0.28
Nov	5.63	0.47
Dec	6.03	0.50
Total	37.92	3.16

Irrigation demands will vary widely depending on plant type and climatic conditions. Seasonal variations will depend on rainfall, temperature, plant type, soil conditions, stage of plant growth and other factors depending on the method of irrigation being used. For the purpose of this initial concept analysis irrigation demands for "pasture/turf" were used as listed in the 1985 Washington Irrigation Guide, Appendix A for Seattle U of W 47.65 latitude. Irrigated landscape areas included park and open spaces but do not include vegetated green roof areas as typical sedum based green roofs need very little or no supplemental irrigation after the plantings become established, especially given the climate in Seattle. It is expected that irrigation requirements will vary from 2 to 6 inches per month over an irrigation period of 5 to 6 months as shown in **Appendix F**. Irrigation requirements range from 175,334 gallons per year (gpy) in EOB to 1,560,114 gpy in Sector 1 with an estimated total project annual irrigation demand of 4,763,199 gallons.

The Rational Method was used to project potential stormwater runoff volumes using a range of runoff coefficients for project surface types as detailed in **Appendix G**. Given the conceptual level of this phase of the project, and the relatively small areas, we feel that the use of the Rational Method, as opposed to continuous simulation modeling, is appropriate, especially for building roofs. Stormwater runoff volumes range from 2.3 million gpy in Sector EOB to 10.6 million gpy in Sector 1 with an estimated total project annual stormwater runoff volume of 27.3 million gpy. Roughly 35-45% of the total site runoff is contributed from building roof areas. It is assumed that 30% of the building roof area contains green roof space as detailed within the SvR EIS analysis. Green roof spaces are projected to reduce stormwater runoff by approximately 50% compared to standard roof space (C=.5)[6].

[6] US EPA, *Green Roof for Stormwater Runoff Control*, 2009

D. Combined Cooling, Heating and Power (CCHP) Plant Make-up Water Demands:

It is anticipated that later phases of the project, totaling 46.5% (3,060,000 SF), will be supplied with electricity, heat and chilled water from a CCHP. It is estimated that approximately 8,000,000 gpy of make-up water will be needed for the CCHP, with 24% for heat and power production and 76% for chilled water production.

Only a portion of the overall project will be served by the CCHP. It has also not been determined at this time which blocks/buildings will be served. For the purpose of this overall concept analysis it has been assumed that CCHP make-up demand apportioned to each sector is proportional to the percentage of total floor area per sector. Furthermore, the make-up water for heat and power production was considered to remain constant throughout the year, with make-up for chilled water production occurring over the warm summer season (120-day period). Peak month flows for the CCHP are projected to be on the order of 60,000 gpd as shown in Table 3 below.

VI. Water Reuse Concept & System Narrative

Using the water reuse concept as discussed within this section and as detailed in **Appendix H**, potable water demand could be reduced to approximately 255,777 gpd (59.2% reduction in potable water demand) with a potential reduction in projected sewer flow of 71.6%. The potable water demand reductions assume that reclaimed water would be used for CCHP make-up and landscape irrigation.

Potential reclaimed water uses (reuse demands) for this project include:

- Toilet & urinal flushwater (both residential and office)
- Laundry cold water supply
- Landscape irrigation
- Make-up water for combined cooling, heating and power plant (CCHP)

Table 3: Potential Reuse Demands

Sector	Flushwater (gpd)	Laundry (gpd)	Irrigation (gpd)*	CCHP Make-up (gpd)*
1	131,059	21,077	15,945	25,140
2	10,649	12,027	6,452	7,500
3	19,489	22,556	7,830	13,200
4	15,637	19,199	16,759	11,040
EOB	4,899	5,055	1,798	3,060
Total	**181,734**	**79,914**	**48,784**	**59,940**

*Peak month demand

Potential sources of reclaimed water evaluated for this project include:

- Stormwater: Runoff from building roofs and site areas
- Greywater: Collecting and treating all greywater or wash water (all wastewater except "blackwater" flows from toilets, urinals, kitchen sinks and dishwashers)
- Greywater without showers: Collecting and treating all greywater less flows from showers/baths and blackwater
- Wastewater: Collecting and treating all sanitary wastewater

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A. Stormwater Reuse:

1. Roof:

As shown by the water resource balance analysis and stormwater runoff projections included as **Appendix G** there is not enough building roof runoff to completely meet any of the potential reuse demands. Using historical precipitation data as shown in Table 2, building runoff could meet 100% of the irrigation demands during the months of May and October for the majority of sectors with the exception of Sector 4. Irrigation demands cannot be met from June through September within all sectors and fall as low as 11% of the irrigation demand for Sector 4 in July. Building runoff ranges from 7% to 50% of the sector flushwater demands and 29% to 48% of the sector laundry demands. Thus it would not be effective to use roof runoff to satisfy recycled water demands within the respective buildings, given the reclaimed water infrastructure including storage, treatment and dual piping that would be needed. While it may be possible to use this source to supplement other sources, given the variability in runoff volumes throughout the year, we feel that the best use for stormwater runoff is to supplement irrigation needs for this project. This will require proper storage of runoff water as mentioned in SvR's April 2, 2010 memo ("It is possible that facilities for water reclamation, rainwater cisterns for example, may be considered and could be used toward the reduction of size or quantity of the proposed GSI facilities."). Stormwater could also be stored and transferred to a combined water reuse facility during periods with low irrigation demands.

2. Site / Grade:

Due to the lower average runoff coefficients for the at grade areas, runoff volumes per unit area from this source will be less than roof runoff, and would require a higher level of treatment than roof runoff, so we feel that it is not practical to use this source to meet reuse demands other than possibly to supplement irrigation needs which can be further evaluated during the next phase of the project.

B. Greywater Reuse (See **Appendix E** for Greywater Reuse Summary):

Two variations of greywater sources were considered

- Total greywater, and
- Greywater without showers and baths

On a block basis, total greywater flow can meet 100% of the flushwater and laundry demands except for Blocks 1A & 1C which contain the office towers having a higher flushwater demand than the residential units. If treated greywater is just used for toilet flushwater, then the balance of the greywater could meet peak month and annual irrigation demands. Treated total greywater could also essentially meet flushwater and laundry demands without irrigation.

For treated greywater without shower/bath flows on a block basis, 100% of the flushwater demands could be met with the exception of Blocks 1A & 1C. On a total project basis there is enough greywater to satisfy the entire flushwater demand.

C. Total Wastewater Reuse:

Treatment systems using total building sanitary wastewater to produce reclaimed water for reuse will be most economically sized by configuring the system to have the capacity to treat enough volume to

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meet reuse demands, with the excess volume of wastewater discharged to the sewer without treatment.

On a project wide basis, there will be enough total wastewater generated by the buildings to meet all of the potential reuse demands including flushwater, peak month irrigation, laundry cold water and peak month CCHP make-up demand.

See **Appendix I** for projected reductions in potable water demand and projected sewer flow reductions by reuse scenario.

D. Potential Treatment Methods (Processes):
   1. Greywater: While greywater is considered by many to be relatively innocuous, it contains the same pollutants as combined, or total wastewater, though at lower concentrations, and must be treated and disinfected in order to be safely and effectively reused. Typical greywater treatment processes would include pretreatment/settling, attached growth biological treatment, sand or membrane filtration and ultra violet light (UV) disinfection prior to storage for reuse.
   2. Combined or total wastewater: There are many process options available to treat the combined wastewater generated by the project. Processes that we feel are appropriate, giving consideration to those that minimize space requirements and/or energy consumption include membrane bioreactors (MBR), attached growth systems, and combined attached/suspended growth systems, often termed moving bed bioreactors (MBBR). Final effluent from the chosen process will be polished and disinfected using a combination of ozone and UV prior to storage for reuse.
   3. Natural systems demonstration: There is also the possibility to employ a natural treatment system, such as constructed wetlands to treat all or a portion of the wastewater from the community center. We envision that this system could be constructed in the open space adjacent to the community center.

As discussed in Section IV – Water Reuse Requirements / Regulations, the technology most frequently employed for reuse projects meeting the most stringent requirements involves biological nutrient removal ("BNR") technology coupled with membrane filtration ("MBR facilities"). A typical MBR reuse facility schematic has been included as **Attachment J**. This combination of unit processes eliminates the need for secondary clarification and enables MBR facilities to operate at higher mixed-liquor-suspended–solids (MLSS) concentrations, which results in the following distinct advantages:

- Smaller wastewater treatment plant footprint
- High-quality effluent- low turbidity, bacteria, TSS and BOD.
- Smaller process tanks
- Less sludge production
- Better ability to automate process control

As wastewater is processed for reuse, it will be diverted from the sewer collection pipe into the water reuse treatment facility. The volume of wastewater that is not needed to meet reuse demand will be discharged to the SPU sewers. An MBR is divided into a number of steps that typically consist of:

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- Anoxic Treatment: This first biological treatment step introduces the raw wastewater into a mixed anoxic denitrifying bacteria chamber where nitrogen is removed and is vented to the atmosphere
- Aerobic Tank: This second treatment step provides aerobic biological treatment where the wastewater undergoes carbonaceous oxidation and nitrification via a complete mix tank with air diffusers fed by blowers.
- Membrane Filters: This third step is a separate stage that includes tubular pressure membrane filters that have a very fine pore size to remove virtually all particulate contaminants and produce a filtrate that is passed along for polishing. The membrane filters extract purified water from the mixed liquor that is contained in the aeration tank via a pressurized pumping system. The filters are backwashed in place automatically via backpulse pumps that send purified water in a reverse direction to purge any accumulated solids from the filters.

Upon leaving the MBR, the treatment of the water will continue in subsequent stages, most likely including:

- Ultraviolet Disinfection: The filtered water is disinfected further via ultraviolet disinfection units that subject the liquid contents to intense UV radiation.
- Ozone Treatment: To completely oxidize any remaining compounds that might leave any color in the treated water, ozone treatment is normally utilized. Following the ozone treatment, the new water is clear and odorless.
- Storage Tanks: The renewed water is typically stored in adjoining reservoirs that hold the water for subsequent reuse. These storage tanks are kept nearly full at all times and a computer controller that operates the treatment system extracts wastewater from the wastewater collection pipeline for processing as the level in the storage tanks begins to drop. In addition, a continuous loop of water is taken from the reservoirs and reprocessed through the UV disinfection and Ozone Treatment to assure that the contents of the reservoirs remain disinfected, clear and odorless.
- Water Return Distribution System: A series of high pressure pumps will draw water from the storage tanks and distribute it via a piping network that is labeled as “non-potable”, for reuse purposes.

E. <u>Potential Treatment Plant Locations & Capacities (combined wastewater treatment based on reuse scenario F – flushwater, laundry and peak month irrigation and CCHP makeup demands</u>

Yesler Terrace Treatment System & Storage Areas					
	Location	Design Flow (gpd)	Facility Area	Storage Volume	Area @ 12'(SF)
1-(2) Systems, N & S					
1.1	Sectors 1,2 & EOB	244,700	5,500	32,754	2730
1.2	Sectors 3 & 4	126,000	3,000	16,845	1404
2- (2) Sytems, E & W					
2.1	Sectors 1 & 4	256,000	5,700	34,225	2852
2.2	Sectors 2,3 & EOB	115,000	2,800	15,375	1281
3 - (3) Systems					

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3.1	Sector 1	193,500	4,600	25,936	2161
3.2	Sectors 2 & EOB	51,500	1,800	6,952	579
3.3	Sectors 3& 4	125,800	3,200	16,845	1404

* Treated effluent storage will likely be split between the treatment facility and the individual building or block.

The relative optimum configuration and locations of these treatment systems will depend on project phasing and additional considerations in this regard will be made as the project details develop further. In addition, we feel that treatment systems for greywater or total wastewater can be integrated with the below grade parking structures. The generated wastewater would be collected via conventional sewer plumbing drains from all fixtures and routed to the wastewater treatment and recycling system(s). Automatic diversion valves, or other means, will be utilized to direct wastewater into the treatment system as non-potable water is demanded. There are two possible schemes for transporting wastewater from the buildings to the treatment facilities:

1. Dedicated wastewater collection from Yesler Terrace buildings to the treatment system locations, with wastewater not needed to meet reuse demands being diverted to the sewer mains in the streets at the treatment facility locations;
2. Having each building conventionally connect to the sewers in the street, and then diverting the volume of wastewater needed into the treatment facilities from the sewers.

Issues to consider regarding the method of wastewater collection include the presence of wastewater from the hospitals located upstream from Yesler, and Seattle Public Utilities current position that for on-site treatment SHA must own the collection network.

Treated, disinfected effluent from the treatment systems will be pumped into a reclaimed water distribution network with connections to a storage tank at each building. A suitably sized booster pump system will transfer water from the storage tank and send it through the reclaimed (non-potable) piping within the buildings to the points of use.

VII. Biosolids

The membrane bioreactor (MBR) treatment and recycling systems proposed for Yesler Terrace will produce excess biosolids and other residuals that will need to be properly managed. Following is a listing of potential management methods.

1. The simplest and least costly method is to periodically discharge biosolids to the sewer, as is practiced in other urban reuse projects. This approach would have to be approved by Seattle Public Utilities and King County, and there would be no discharge of biosolids to the sewer during precipitation events that could result in CSO events.
2. Grease trap and trash trap scum layers can be periodically removed by vacuum truck for likely off-site bio-diesel feedstock use.
3. There are several other options available for the biosolids that will be produced by the wastewater treatment and recycling systems:
    a. Thicken biosolids before on-site anaerobic digestion with produced methane used for digester heating and excess methane used for hot water heating. Biosolids from the digester would be hauled by vacuum truck for offsite dewatering/composting/land

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application. While conceptually possible, small scale anaerobic digestion systems are very complex and very few commercial systems are available at this time. Such systems may be appropriate for later stages of the project as technology matures.

b. Biosolids can be thickened, using the same membrane filtration technology used in the treatment facility, and stored on site for vacuum truck removal to King County treatment facilities for dewatering and incorporation into King County's biosolids treatment program that beneficially utilizes biolsolids for uses including agricultural and forest land application and the production of compost (GroCo).

Table 4: Estimated Quantities of Biosolids*

Treatment Facility Alternate	Design Flow, Gal/day	Biosolids, lb/day (dry basis)	Biosolids, gal/day @ 6% solids
A1i	244,700	400	800
A1ii	126,000	210	420
A2i	256,000	415	830
A2ii	115,000	190	380
A3i	193,000	315	630
A3ii	51,500	85	180
A3iii	125,800	210	420

* Based on influent BOD of 250 mg/l and a yield of 0.8 lbs of biosolids per lb of BOD removed:

VIII. Energy Recovery Alternatives

There are several potential sources to recover some of the thermal energy in the wastewater using heat exchangers and/or heat pumps.

- From the feed or influent equalization tanks of either a system treating greywater or all sanitary wastewater. The wastewater in these tanks will be warm, on the order of 75 - 80° F and possibly could be used to preheat domestic hot water.
- From the treated water storage tanks from either a greywater treatment system or a system treating all sanitary wastewater. Especially with a system treating all wastewater, the contents of the treated water storage tank will have a temperature around 80° F, and similarly could be used to help preheat domestic hot water.

Based on the flows notated on SvR's 4/22/2010 "Yesler Terrace Alternative 2 - Draft Public Sanitary Sewer System Flow" diagram there appears to be the possibility of using a water source heat pump using sewer flows to provide a portion of heating and cooling needs. A general rule of thumb is that each 4 gpm of wastewater flow can provide approximately one ton (12,000 btu/hr) of heating and cooling energy. It is recommended that dry weather flow studies be performed to accurately determine flows through the sanitary sewers that pass through the Yesler Terrace site to enable a determination of the feasibility for this method of energy recovery.

IX. Economics (See Appendix K – *District Integrated Water Economics* for additional details)

Appendix L presents a summary of water and sewer charges for the entire project based on current SPU rates, along with a listing of amortized costs for reclaimed water treatment for the various potential reuse scenarios. The costs listed for the reclaimed water treatment system are conservative and would

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include some of the costs for reclaimed water distribution from the treatment facilities back to the buildings.

There will be additional costs for the non-potable reclaimed water lines in the building, though these costs would not be great as the reuse supply lines will be installed at the same time as the other plumbing lines in the building. These costs will depend on final piping configuration and location. Preliminary estimates are approximately 5% to 15% of the total plumbing contract and will be further evaluated during the next phase of design.

A significant disadvantage of the greywater reuse system, besides the relatively limited volume available compared to combined wastewater, is the added expense of running separate greywater drains within the buildings as well as separate collection lines from the buildings to the greywater treatment facility(s).

As shown in **Appendix L**, total annual water and sewer charges for the project are estimated to be $3,373,790 without reuse. <u>A combined wastewater reuse program providing reuse water for flushwater, laundry, irrigation and CCHP make-up is projected to reduce annual potable water and sewer charges to $1,096,359 with an annual net savings of $384,830 using an amortized reuse treatment cost of $0.014 per gallon</u>. This represents an approximate savings of 14% based on current economic information and rate structure. It is anticipated that this savings may improve as water reuse system technology continues to advance and as regional sewer and water charges continue to increase (average water & sewer rate increase of 7.7% over the last 10 years). However, such trends are difficult to predict and could be significantly impacted by future policy changes or modifications to service charge mechanisms which could enhance or negate such benefits.

The amortized rate is made up of approximately 60-70% capital costs and 30-40% operating costs including complete management and repairs. The capital cost is based on a treatment system that begins at the wastewater feed or interceptor tank and ends at the treated effluent storage tank (wastewater collection lines and reclaimed water distribution lines are not included) with an amortization period of 20 years at an average weighted cost of capital equal to 9.5%. The operating cost includes labor, power, chemicals, and laboratory analyses. This operating cost is based on the ability to discharge waste biosolids to the sewer which will be further evaluated during the next phase of the project.

X. <u>Environmental Considerations</u>

The use of treated wastewater for landscape irrigation will also supply some of the nutrients, especially nitrogen and phosphorus, needed by the landscaping, thus helping to reduce the amount of fertilizer needed for landscape maintenance.

We have investigated the potential of urine separating toilets with urine storage tanks at each building for collection before transport for off-site agricultural use. While this is conceptually possible and the plumbing fixtures are available for this purpose, we do not feel that there are enough successful installations existing to recommend this alternative at this time. Reevaluation of urine separation deserves further consideration at later stages of the project. Urine separation and reuse requires adequate infrastructure to fulfill a complete supply and demand fertilizer profile. This would entail product manufacture, storage, delivery, field application, etc. Given the complexity of beginning such an arrangement, this should only be considered for demonstration purposes via a program that worked

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jointly with Seattle Parks or some other public agency which could control all aspects of product handling and application.

Reuse of treated wastewater will have positive environmental impacts beyond Yesler Terrace. The significant reduction on potable water demand will serve to help increase flows in the Cedar and Tolf Rivers due to the reduced need for water extraction, thus leading to improved stream ecology, especially during the summer. The selection of water reuse technology will be given further consideration as the project evolves. Optimization of treatment efficiency with carbon footprint will be a primary goal and adequate space should be provided to allow for more passive treatment mechanisms, if possible.

The combination of Green Stormwater Infrastructure and reduced sanitary sewer discharges from Yesler Terrace will help to reduce CSO event volumes to Elliot Bay, as well as decreasing pollutant mass loading if CSO events do occur.

XI. Conclusion / Recommendations for Further Considerations

Based on the preliminary findings contained within this report AE recommends that the Project Team move forward with a wastewater reuse concept where combined sanitary wastewater will be treated using two (2) to three (3) treatment systems depending on project phasing. Treatment systems will be sized to provide reuse water to meet flushwater, laundry, irrigation and CCHP demands (Reuse Scenario F as shown in Appendix H). Given the fact that there is not enough building roof runoff water to completely meet any of the potential reuse demands and due to the variability in runoff volumes throughout the year, stormwater runoff should be used to supplement irrigation needs and will be given further consideration during future evaluations.

Greywater reuse should be removed from further consideration at this time due to the disadvantages detailed throughout the report, including, but not limited to:

- Reduced available source volume for reuse compared to wastewater
- Washington State Department of Health requirements for reuse water quality bringing the level of treatment system requirements close to those required to treat total (combined) wastewater.
- Increase in plumbing costs in order to incorporate additional risers and collection lines for greywater separation

Using the total (combined) sanitary wastewater reuse concept potable water demand is projected to be reduced to approximately 255,777 gpd (59.2% reduction in potable water demand) with a potential reduction in projected sewer flow of 71.6% (147,053 gpd). Total annual water and sewer charges for the project are estimated to be $3,373,790 without reuse. A combined wastewater reuse program providing reuse water for flushwater, laundry, irrigation and CCHP make-up is projected to reduce annual potable water and sewer charges to $1,096,359 with an annual net savings of $384,830 using an amortized reuse treatment cost of $0.014 per gallon. This represents an approximate savings of 14% based on current economic information and rate structure. It is anticipated that this savings may improve as water reuse system technology continues to advance and as regional sewer and water charges continue to increase (average water & sewer rate increase of 7.7% per year over the last 10 years).

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As detailed in Section VIII these economic trends are difficult to predict and could be significantly impacted by future policy changes or modifications to service charge mechanisms which could enhance or negate such benefits. The Washington State Department of Health (DOH) Standards for Water Reclamation and Reuse are reasonable with regards to level of treatment but are very strict with regards to testing and analysis which could impact economic feasibility for reuse. This will be evaluated further and discussed with DOH as there may be Best Management Practice alternatives and exceptions not contained within the regulatory documents.

Additional recommendations for further consideration and refinement include, but are not limited to:

- Project phasing, further detailing potential treatment plant locations
- Water balance refinement as project details become more defined including any necessary adjustments to CCHP and irrigation details
- Further detail stormwater storage and reuse opportunities, integration with site design concepts
- Potential evaluation for a natural treatment system demonstration project at the community center
- Further evaluation for energy recovery opportunities using requested actual sanitary sewer flow data
- Further evaluate other integrated infrastructure opportunities including nutrient recovery programs, biosolids production/management, anaerobic digestion, etc

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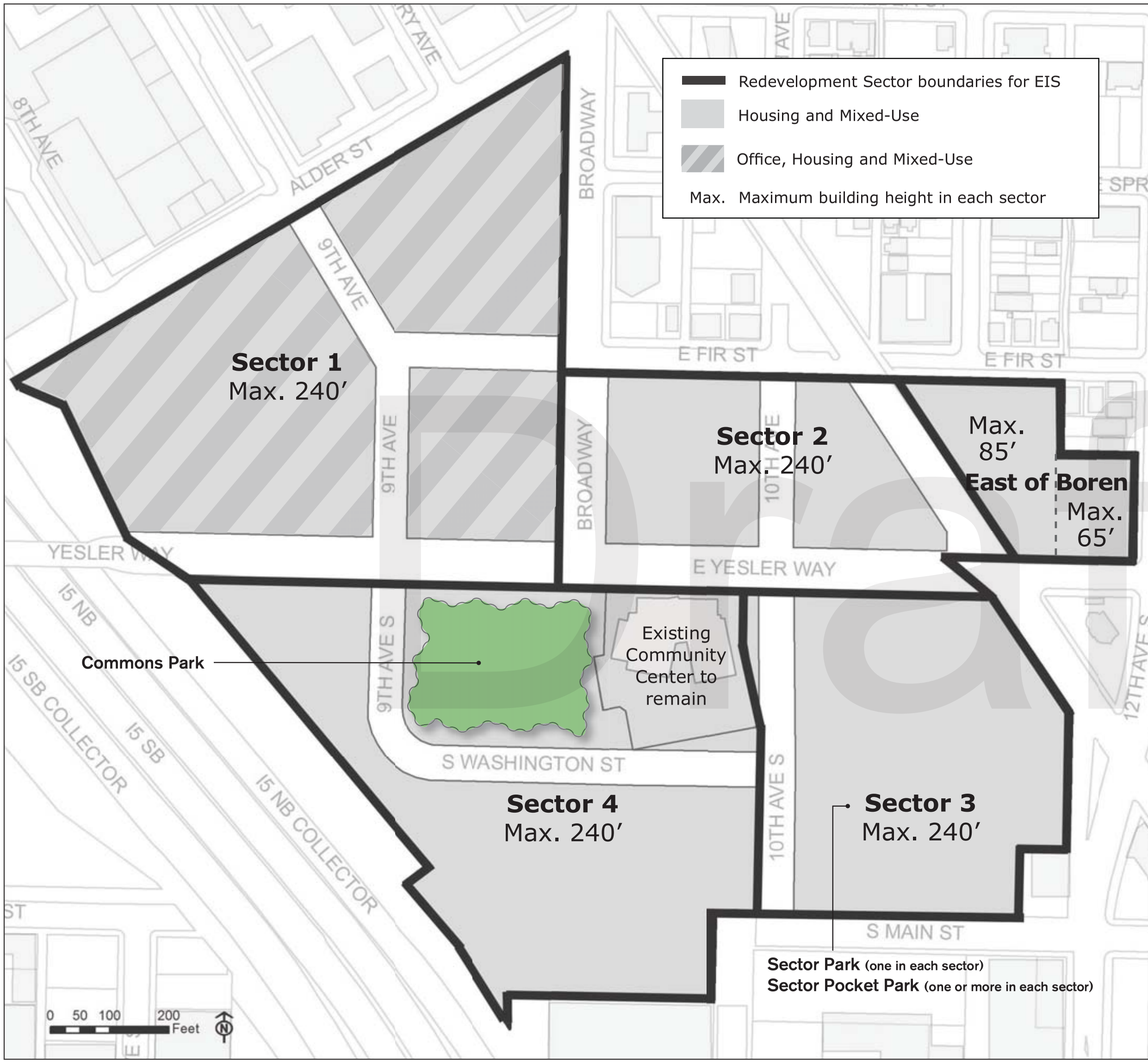

Sector	Use	Area (sq ft)
1	Housing - 1,055 units	960,000
	Office*	1,000,000
	Neighborhood Commercial**	20,000
	Institutional	13,000
12.1 Acres	*Subtotal*	1,993,000
2	Housing - 602 units	566,000
	Office*	0
	Neighborhood Commercial**	15,000
	Institutional	13,000
5.7 Acres	*Subtotal*	594,000
3	Housing - 1,129 units	1,022,000
	Office*	0
	Neighborhood Commercial**	15,000
	Institutional	9,000
6.2 Acres	*Subtotal*	1,046,000
4	Housing - 961 units	854,000
	Office*	0
	Neighborhood Commercial**	0
	Institutional (existing)	22,000
10.8 Acres	*Subtotal*	876,000
Summary of Sectors 1-4	Housing - 3,747 units	3,402,000
	Office*	1,000,000
	Neighborhood Commercial**	50,000
	Institutional	57,000
34.8 Acres	*Total*	4,509,000
East of Boren (EOB)	Housing - 253 units	233,000
	Office*	0
	Neighborhood Commercial**	10,000
	Institutional	0
1.8 Acres	*Subtotal*	243,000
Summary of Sectors 1-4 & EOB	Housing - 4,000 units	3,635,000
	Office*	1,000,000
	Neighborhood Commercial**	60,000
	Institutional	57,000
36.6 Acres	*Total*	4,752,000
Open Space for Public Use (5.0 acres)		217,726

**Office* includes large institutional uses, single-use offices, and hotels.
***Neighborhood Commercial* includes retails and small office uses.

Figure 3
EIS Alternative 2 - Medium Density

Yesler Terrace
Redevelopment EIS

DRAFT 3-31-2010

SvR DESIGN COMPANY

1205 SECOND AVE. SUITE 200
SEATTLE, WA 98101
T 206.223.0326
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NOTES

1. GSI elements are assumed for this analysis. Other elements may be feasible.
2. See typical GSI system concept details.

YESLER TERRACE
ALTERNATIVE #2
DRAFT GSI REQUIREMENTS
03/31/2010

Alt 2: Built & Natural Environment

This tab describes the built and natural environment for the entire site, including the ROW. The breakdown of each ROW segment can be found in the Common Data.

Sector 1

	sq ft	acres	% of sector area	Calculation Method
Built Environment				
Building Footprints	165,617	3.80	31.5%	100% of Building Footprints
Streets, sidewalks, hardscapes, access roads, and surface parking	221,391	5.08	42.2%	50% of private open space + 50% of public open space + 82% of arterial ROW + 75% of other ROW + 75% of private access streets + 100% of surface parking
Subtotal	**387,008**	**8.88**	**73.7%**	
Natural Environment				
Existing and new landscaped areas	138,203	3.17	26.3%	50% of private open space + 50% of public open space + 18% of arterial ROW + 25% of other ROW + 25% of private access streets
Subtotal	**138,203**	**3.17**	**26.3%**	
Sector Total	**525,211**	**12.06**	**100.0%**	

Sector 2

	sq ft	acres	% of sector area	Calculation Method
Built Environment				
Building Footprints	62,352	1.43	25.0%	100% of Building Footprints
Streets, sidewalks, hardscapes, access roads, and surface parking	130,942	3.01	52.6%	50% of private open space + 50% of public open space + 82% of arterial ROW + 75% of other ROW + 75% of private access streets + 100% of surface parking
Subtotal	**193,293**	**4.44**	**77.6%**	
Natural Environment				
Existing and new landscaped areas	55,749	1.28	**22.4%**	50% of private open space + 50% of public open space + 18% of arterial ROW + 25% of other ROW + 25% of private access streets
Subtotal	**55,749**	**1.28**	**22.4%**	
Sector Total	**249,042**	**5.72**	**100.0%**	

Sector 3

	sq ft	acres	% of sector area	Calculation Method
Built Environment				
Building Footprints	108,403	2.49	40.4%	100 % of Building Footprints
Streets, sidewalks, hardscapes, access roads, and surface parking	92,442	2.12	34.4%	50% of private open space + 50% of public open space + 82% of arterial ROW + 75% of other ROW + 75% of private access streets + 100% of surface parking
Subtotal	**200,845**	**4.61**	**74.8%**	
Natural Environment				
Existing and new landscaped areas	67,654	1.55	**25.2%**	50% of private open space + 50% of public open space + 18% of arterial ROW + 25% of other ROW + 25% of private access streets
Subtotal	**67,654**	**1.55**	**25.2%**	
Sector Total	**268,499**	**6.16**	**100.0%**	

Sector 4

	sq ft	acres	% of sector area	Calculation Method
Built Environment				
Building Footprints	128,771	2.96	27.3%	100% of Building Footprints
Streets, sidewalks, hardscapes, access roads, and surface parking	197,851	4.54	42.0%	50% of private open space + 50% of public open space + 82% of arterial ROW + 75% of other ROW + 75% of private access streets + 100% of surface parking
Subtotal	**326,622**	**7.50**	**69.3%**	
Natural Environment				
Existing and new landscaped areas	144,811	3.32	**30.7%**	50% of private open space + 50% of public open space + 18% of arterial ROW + 25% of other ROW + 25% of private access streets
Subtotal	**144,811**	**3.32**	**30.7%**	
Sector Total	**471,433**	**10.82**	**100.0%**	

Summary of Sectors 1 - 4

	sq ft	acres	% of sector area	Calculation Method
Built Environment				
Building Footprints	465,142	10.68	30.7%	100% of Building Footprints
Streets, sidewalks, hardscapes, access roads, and surface parking	642,626	14.75	42.4%	50% of private open space + 50% of public open space + 82% of arterial ROW + 75% of other ROW + 75% of private access streets + 100% of surface parking
Subtotal	**1,107,768**	**25.43**	**73.2%**	
Natural Environment				
Existing and new landscaped areas	406,417	0.27	**26.8%**	50% of private open space + 50% of public open space + 18% of arterial ROW + 25% of other ROW + 25% of private access streets
Subtotal	**406,417**	**0.27**	**26.8%**	
Summary Total	**1,514,185**	**34.76**	**100.0%**	

EOB

	sq ft	acres	% of sector area	Calculation Method
Built Environment				
Building Footprints	45,338	1.04	59.0%	100% of Building Footprints
Streets, sidewalks, hardscapes, access roads, and surface parking	16,032	0.37	20.8%	50% of private open space + 50% of public open space + 82% of arterial ROW + 75% of other ROW + 75% of private access streets + 100% of surface parking
Subtotal	**61,370**	**1.41**	**79.8%**	
Natural Environment				
Existing and new landscaped areas	15,532	0.36	**20.2%**	50% of private open space + 50% of public open space + 18% of arterial ROW + 25% of other ROW + 25% of private access streets
Subtotal	**15,532**	**0.36**	**20.2%**	
Sector Total	**76,901**	**1.77**	**100.0%**	

Summary of Site

	sq ft	acres	% of total site area	Calculation Method
Built Environment				
Building Footprints	510,480	11.72	32.1%	100% of Building Footprints
Streets, sidewalks, hardscapes, access roads, and surface parking	658,658	15.12	41.4%	50% of private open space + 50% of public open space + 82% of arterial ROW + 75% of other ROW + 75% of private access streets + 100% of surface parking
Subtotal	**1,169,138**	**26.84**	**73.5%**	
Natural Environment				
Existing and new landscaped areas	421,948	9.69	**26.5%**	50% of private open space + 50% of public open space + 18% of arterial ROW + 25% of other ROW + 25% of private access streets
Subtotal	**421,948**	**9.69**	**26.5%**	
Site Total	**1,591,086**	**36.53**	**100.0%**	

Appendix D: Wastewater Flow Projections (By Building Block)

Sector	1											2			
Block	1A	1A	1C	1C	1C	1C	1A	1A	1B	1B	1B	2A	2A	2B	2B
Building #	1	2	3	4	5	6	7 & 8	9	10	11	12	13 & 14	15	16	17
# Residential Units				135	250	129	226	88	62	94	71	271	144	87	100
Office Area (Sq Ft)	345,088	398,563	257,475												
Building Area where NC/Inst is permitted (Sq Ft)				19672	12000	18831		12917	9122	13737		14305	21907	13245	
Projected WW Flow (gpd)															
Residential Total				12,204	22,600	11,662	20,430	7,955	5,605	8,498	6,418	24,498	13,018	7,865	9,040
Blackwater															
Toilets	18.00%			2197	4068	2099	3677	1432	1009	1530	1155	4410	2343	1416	1627
Kitchen Waste	20.50%			2,502	4,633	2,391	4,188	1,631	1,149	1,742	1,316	5,022	2,669	1,612	1,853
Total Blackwater				4,699	8,701	4,490	7,866	3,063	2,158	3,272	2,471	9,432	5,012	3,028	3,480
Greywater															
Laundry	22.10%			2,697	4,995	2,577	4,515	1,758	1,239	1,878	1,418	5,414	2,877	1,738	1,998
Showers + Baths	22.20%			2,709	5,017	2,589	4,536	1,766	1,244	1,886	1,425	5,439	2,890	1,746	2,007
Lavatory Faucets	5.20%			635	1,175	606	1,062	414	291	442	334	1,274	677	409	470
Other	12.00%			1,464	2,712	1,399	2,452	955	673	1,020	770	2,940	1,562	944	1,085
Total Greywater				7,505	13,899	7,172	12,565	4,892	3,447	5,226	3,947	15,067	8,006	4,837	5,560
Office Total	51,763	59,784	38,621												
Blackwater @ 75%	38,822	44,838	28,966	339	207	325		223	157	237		247	378	228	
Greywater @ 25%	12,941	14,946	9,655	113	69	108		74	52	79		82	126	76	
Neighborhood Commercial / Institutional Total				452	276	433		297	210	316		329	504	305	
Total Projected WW Flow (gpd)	51,763	59,784	38,621	12,656	22,876	12,095	20,430	8,252	5,815	8,814	6,418	24,827	13,521	8,169	9,040
Total Block (gpd)	247,525											55,558			
Total Project (gpd)	517,425														

Appendix D: Wastewater Flow Projections (By Building Block)

Sector	3							4							EOB		
Block	3A	3A	3A	3B	3B	3B	3B	4B	4B	4B	4B	4B	4B	4A	EOB	EOB	EOB
Building #	21	22	23	24 & 25	26	27	28	29	30	31	32	33	34	35 &36	18	19	20
# Residential Units	305	92	165	244	91	109	123	120	58	104	111	156	117	295	97	74	82
Office Area (Sq Ft)																	
Building Area where NC/Inst is permitted (Sq Ft)	12000	13440	24173	15220											17155	13148	15035
Projected WW Flow (gpd)																	
Residential Total	27,572	8,317	14,916	22,058	8,226	9,854	11,119	10,848	5,243	9,402	10,034	14,102	10,577	26,668	8,769	6,690	7,413
Blackwater																	
Toilets	4963	1497	2685	3970	1481	1774	2001	1953	944	1692	1806	2538	1904	4800	1578	1204	1334
Kitchen Waste	5,652	1,705	3,058	4,522	1,686	2,020	2,279	2,224	1,075	1,927	2,057	2,891	2,168	5,467	1,798	1,371	1,520
Total Blackwater	10,615	3,202	5,743	8,492	3,167	3,794	4,281	4,176	2,019	3,620	3,863	5,429	4,072	10,267	3,376	2,575	2,854
Greywater																	
Laundry	6,093	1,838	3,296	4,875	1,818	2,178	2,457	2,397	1,159	2,078	2,218	3,117	2,337	5,894	1,938	1,478	1,638
Showers + Baths	6,121	1,846	3,311	4,897	1,826	2,187	2,468	2,408	1,164	2,087	2,228	3,131	2,348	5,920	1,947	1,485	1,646
Lavatory Faucets	1,434	432	776	1,147	428	512	578	564	273	489	522	733	550	1,387	456	348	385
Other	3,309	998	1,790	2,647	987	1,182	1,334	1,302	629	1,128	1,204	1,692	1,269	3,200	1,052	803	890
Total Greywater	16,957	5,115	9,173	13,565	5,059	6,060	6,838	6,672	3,225	5,782	6,171	8,673	6,505	16,401	5,393	4,114	4,559
Office Total																	
Blackwater @ 75%	207	232	417	263											296	227	259
Greywater @ 25%	69	77	139	88											99	76	86
Neighborhood Commercial / Institutional Total	276	309	556	350											395	302	346
Total Projected WW Flow (gpd)	27,848	8,626	15,472	22,408	8,226	9,854	11,119	10,848	5,243	9,402	10,034	14,102	10,577	26,668	9,163	6,992	7,759
Total Block (gpd)	103,553							86,874							23,914		
Total Project (gpd)																	

Appendix E - Wastewater Flow Categories Demands

Block No	Wastewater Flow (gpd)	Greywater Flow (GW) (gpd)	Greywater w/o showers (gpd)	Flushwater Demand (FW)	Laundry Demand	% FW Demand met by GW	Remaining Flow (gpd)
1A	140,230	45,344	39,042	88,770	6,273	51%	(43,426)
1B	21,047	12,699	8,144	4,088	4,535	311%	8,611
1C	86,248	38,522	28,207	38,201	10,269	101%	321
Block 1 Total	247,525	96,565	75,393	131,059	21,077		
2A	38,349	23,281	14,952	7,378	8,291	316%	15,903
2B	17,209	10,473	6,720	3,271	3,736	320%	7,201
Block 2 Total	55,558	33,753	21,672	10,649	12,027		
3A	51,946	31,530	20,252	10,001	11,228	315%	21,530
3B	51,607	31,610	20,231	9,489	11,328	333%	22,122
Block 3 Total	103,553	63,141	40,483	19,489	22,556		
4A	26,668	16,401	10,481	4,800	5,894	342%	11,601
4B	60,206	37,027	23,661	10,837	13,306	342%	26,190
Block 4 Total	86,874	53,428	34,142	15,637	19,199		
EOB Total	23,914	14,326	9,249	4,899	5,055	292%	9,428
Total Project	517,425	261,213	180,938	181,734	79,914		

Appendix F - Irrigation Demands

		Sector 1		Sector 2		Sector 3		Sector 4		Sector EOB		Total (Gal)
Month	Pasture/Turf Irrigation demand (in)	FT^3	Gal	FT^3	Gal	FT^3	Gal	FT^3	Gal	FT^3	Gal	
Jan	0.00	0	0	0	0	0	0	0	0	0	0	
Feb	0.00	0	0	0	0	0	0	0	0	0	0	
Mar	0.00	0	0	0	0	0	0	0	0	0	0	
Apr	0.00	0	0	0	0	0	0	0	0	0	0	
May	1.99	22,919	171,432	9,245	69,153	11,219	83,920	24,014	179,628	2,576	19,266	523,400
Jun	3.91	45,031	336,833	18,165	135,873	22,044	164,889	47,184	352,938	5,061	37,855	1,028,388
Jul	5.57	64,149	479,836	25,877	193,559	31,403	234,892	67,216	502,779	7,209	53,927	1,464,993
Aug	4.39	50,559	378,183	20,395	152,553	24,750	185,131	52,977	396,266	5,682	42,502	1,154,635
Sep	2.21	25,452	190,384	10,267	76,798	12,460	93,198	26,669	199,487	2,860	21,396	581,263
Oct	0.04	461	3,446	186	1,390	226	1,687	483	3,611	52	387	10,521
Nov	0.00	0	0	0	0	0	0	0	0	0	0	
Dec	0.00	0	0	0	0	0	0	0	0	0	0	
Total	18.11	208,571	1,560,114	84,135	629,326	102,101	763,717	218,544	1,634,709	23,440	175,334	4,763,199

Appendix G - Stormwater Runoff Projections

	A	B	C	D	E	F	G	H	I
1	**SECTOR #1 STORMWATER RUNOFF CALCULATIONS**					**TOTAL AREA=**	**422968**		
2	Block	Bldg #	Footprint	Pavement	Pavement	Stormwater	Rain	Park	Open
3				Private	Porous	Planter	Garden		Space
4			Imperv.	Imperv.	Imperv.	Imperv.	Imperv.	Pervious	Pervious
5			Area, SF	Area, SF	Area, SF	Area, SF	Area, SF	Area, SF	Area, SF
6	1A	1	21568						
7	1A	2	20979						
8	1A	7	10001						
9	1A	8	2771						
10	1A	9	12917						
11				21143	5727	500	900	10992	
12							900	14267	
13								9913	
14								7546	
15		Total	68236	21143	5727	500	1800	42718	75153
16									
17	BLOCK AREA 1A		215,277					117871	
18									
19									
20	1B	10	9122						
21	1B	11	13737						
22	1B	12	10356						
23				0	0	625	500	24446	
24						625			
25		Total	33215	0	0	1250	500	24446	14888
26									
27	BLOCK AREA 1B		74,299						
28									
29									
30	1C	3	17166						
31	1C	4	19672						
32	1C	5	12000						
33	1C	6	18831						
34				17323		500	300	4762	
35							800		
36		Total	67669	17323	0	500	1100	4762	42038
37									
38	BLOCK AREA 1C		133,392						
39									
40									
41									
42									
43									
44									

Appendix G - Stormwater Runoff Projections

	J	K	L	M	N	O	P	Q	R	S
1	**SECTOR #1 STORMWATER RUNOFF CALCULATIONS**									
2	RIGHT-OF-WAY AREAS - SECTOR 1									
3				**C**	**I* (FT.)**	**A (SF)**	**=**	**Q (CF)**	**Q (GAL.)**	**GPD**
4	BLOCK 1A									
5	9th AVE. (SBND)		18175							
6	PAVEMENT			0.95	3.16	17275	=	51860	387012	1060
7	RAIN GARDEN(S)			0.95	3.16	900	=	2702	20163	55
8	STORM PLANTER			0.95	3.16	0	=	0	0	0
9							Total	54,561	407,174	1,116
10	BLOCK 1B									
11	9th AVE. (NBND)		9216							
12	PAVEMENT			0.95	3.16	9216	=	27666	206466	566
13	RAIN GARDEN			0.95	3.16	0	=	0	0	0
14	STORM PLANTER			0.95	3.16	0	=	0	0	0
15							Total	27,666	206,466	566
16	BLOCK 1C									
17	9th AVE. (NBND)		8009							
18	PAVEMENT			0.95	3.16	7709	=	23142	172705	473
19	RAIN GARDEN			0.95	3.16	0	=	0	0	0
20	STORM PLANTER			0.95	3.16	300	=	901	6721	18
21							Total	24,043	179,426	492
22	BLOCK 1B									
23	E. FIR ST. (EBND)		7850							
24	PAVEMENT			0.95	3.16	7400	**=**	22215	165782	454
25	RAIN GARDEN			0.95	3.16	450	**=**	1351	10081	28
26	STORM PLANTER			0.95	3.16	0	**=**	0	0	0
27							Total	23,566	175,863	482
28	BLOCK 1C									
29	E. FIR ST. (WBND)		8685							
30	PAVEMENT			0.95	3.16	8685	=	26072	194570	533
31	RAIN GARDEN			0.95	3.16	0	=	0	0	0
32	STORM PLANTER			0.95	3.16	0	=	0	0	0
33							Total	26,072	194,570	533
34										
35										
36										
37										
38										
39										
40										
41										
42										
43										
44										

Appendix G - Stormwater Runoff Projections

	T	U	V	W	X	Y	Z	AA	AB	AC
1	**SECTOR #1 STORMWATER RUNOFF CALCULATIONS - SUMMARY TABLE**									
2	ITEM			**C**	**I* (FT.)**	**A (SF)**	**=**	**Q (CF)**	**Q (GAL.)**	**GPD**
3	BUILDING FOOTPRINT TOTAL			169120			=			
4	GREEN ROOF			0.50	3.16	50736	=	80163	598230	1639
5	NON-GREEN ROOF			0.95	3.16	118384	=	355389	2652155	7266
6	PAVEMENT PRIVATE ROAD			0.95	3.16	38466	=	115475	861753	2361
7	PAVEMENT R.O.W.			0.95	3.16	50285	=	150956	1126534	3086
8	PAVEMENT POROUS BY BLOCK			0.75	3.16	5727	=	13573	101291	278
9	PAVEMENT POROUS BY R.O.W.			0.75	3.16	0	=	0	0	0
10	PARK			0.75	3.16	71926	=	170465	1272124	3485
11	RAIN GARDEN BY BLOCK			0.95	3.16	3400	=	10207	76170	209
12	RAIN GARDEN R.O.W.			0.95	3.16	1350	=	4053	30244	83
13	STORM PLANTER BY BLOCK			0.95	3.16	2250	=	6755	50407	138
14	STORM PLANTER R.O.W.			0.95	3.16	300	=	901	6721	18
15	OPEN SPACE			0.50	3.16	132079	=	208685	1557349	4267
16							Total	1,116,619	8,332,979	22,830
17										
18										
19	ADJACENT ROADWAYS-CENTERLINE TO R.O.W. AREAS									
20				**C**	**I* (FT.)**	**A (SF)**	**=**	**Q (CF)**	**Q (GAL.)**	**GPD**
21	ALDER ST. (NBND)		37674							
22	PAVEMENT			0.95	3.16	36224	=	108744	811526	2223
23	RAIN GARDEN			0.95	3.16	450	=	1351	10081	28
24	STORM PLANTER			0.95	3.16	1000	=	3002	22403	61
25							Total	113,097	844,010	2,312
26	BROADWAY AVE.(SBND)									
27	BEGINS AT ALDER ST.		34545							
28	PAVEMENT			0.95	3.16	32795	=	98451	734706	2013
29	RAIN GARDEN			0.95	3.16	0	=	0	0	0
30	STORM PLANTER			0.95	3.16	1750	=	5254	39205	107
31							Total	103,704	773,911	2,120
32										
33	YESLER WAY (WBND)		29844							
34	PAVEMENT			0.95	3.16	29844	**=**	89592	668595	**1832**
35	RAIN GARDEN			0.95	3.16	0	**=**	0	0	**0**
36	STORM PLANTER			0.95	3.16	0	**=**	0	0	**0**
37							Total	89,592	668,595	**1,832**
38										
39			ENTIRE SECTOR #1 & ADJACENT ROADWAY RIGHT OF WAYS'							
40			STORMWATER RUNOFFS							
41			Q=	29,095		GPD AVG.				
42			Q=	10,619,495		GAL. PER YEAR AVG.				
43			Q=	1,423,012		CF				
44										

Appendix G - Stormwater Runoff Projections

	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM
1	**SECTOR #1 STORMWATER RUNOFF CALCULATIONS - GROUPED BY ITEM TYPES TABLE**									
2				**C**	**I* (FT.)**	**A (SF)**	**=**	**Q (CF)**	**Q (GAL.)**	**GPD**
3	BUILDING ROOFS			0.75	3.16	169120	=	400,814	2,991,152	8,195
4	VEHICLE			0.85	3.16	44193	=	118,702	885,839	2,427
5	PEDESTRIAN (PARK & OPEN SP.)			0.65	3.16	204005	=	419,026	3,127,062	8,567
6	STORMWATER STRUCTURES			0.95	3.16	5650	=	16,961	126,577	347
7							Total	955,504	7,130,630	19,536

NOTES:

A.) *1 -YEARLY RAINFALL

B.) "SECTOR #1 STORMWATER RUNOFF CALCULATIONS - GROUPED BY ITEM TYPES TABLE" DIFFERS FROM "SECTOR #1 STORMWATER RUNOFF CALCULATIONS - SUMMARY TABLE" RUNOFF COEFFICENTS FOR GROUPED ITEMS ARE TAKEN AS AVERAGES OF SIMILAR GROUP ITEMS

SECTOR #1- STORMWATER RUNOFF

Q=	**22,830**	**GPD AVG.**
Q=	**8,332,979**	**GAL. PER YR AVG.**
Q=	**1,116,619**	**CF**

Appendix G - Stormwater Runoff Projections

SECTOR #2		**TOTAL AREA=**	**130540**					
Block	Bldg #	Footprint	Pavement	Pavement	Stormwater	Rain	Park	Open
			Private	Porous	Planter	Garden		Space
		Imperv.	Imperv.	Imperv.	Imperv.	Imperv.	Pervious	Pervious
		Area, SF	Area, SF	Area, SF	Area, SF	Area, SF	Area, SF	Area, SF
2A	13	9900						
2A	14	4405						
2A	15	21907						
			0	2149	0	1050	11860	
	Total	36212	0	2149	0	1050	11860	22466
BLOCK AREA 2A		73,737						
2B	16	13245						
2B	17	15080						
			0	0	875	438	3292	
			0	0	875	438	3292	23873
	Total	28325						
BLOCK AREA 2B		56,803						
RIGHT-OF-WAY		PAVEMENT		RAIN GARDEN		STORMWATER		
AREAS (Sector)		POROUS AREAS		AREAS		PLANTER AREAS		
	0	0	0		0		0	
	0	0	0		0		0	
Total	0	Total	0	Total	0	Total	0	
PAVEMENT-TOTAL IMPERVIOUS			0					

Appendix G - Stormwater Runoff Projections

SECTOR #2 STORMWATER RUNOFF							
ITEM	C	I* (FT.)	A (SF)	=	Q (CF)	Q (GAL.)	GPD
BUILDING FOOTPRINT TOTAL	64537			=			
GREEN ROOF	0.50	3.16	19361	=	30591	228288	625
NON-GREEN ROOF	0.95	3.16	45176	=	135618	1012075	2773
PAVEMENT PRIVATE ROAD	0.95	3.16	0	=	0	0	0
PAVEMENT R.O.W.*	0.95	3.16	0	=	0	0	0
PAVEMENT POROUS BY BLOCK	0.75	3.16	2149	=	5093	38008	104
PAVEMENT POROUS BY R.O.W.*	0.75	3.16	0	=	0	0	0
PARK	0.75	3.16	15152	=	35910	267987	734
RAIN GARDEN BY BLOCK	0.95	3.16	1488	=	4467	33336	91
RAIN GARDEN R.O.W.*	0.95	3.16	0	=	0	0	0
STORM PLANTER BY BLOCK	0.95	3.16	875	=	2627	19603	54
STORM PLANTER R.O.W.*	0.95	3.16	0	=	0	0	0
OPEN SPACE	0.50	3.16	46339	=	73216	546385	1497
				Total	287,521	2,145,681	5,879

ADJACENT ROADWAYS-CENTERLINE TO R.O.W. AREAS								
		C	I* (FT.)	A (SF)	=	Q (CF)	Q (GAL.)	GPD
BOREN AVE. (SBND)	12620							
PAVEMENT		0.95	3.16	11420	=	34283	255842	701
RAIN GARDEN		0.95	3.16	0	=	0	0	0
STORM PLANTER		0.95	3.16	1200	=	3602	26884	74
					Total	37,885	282,726	775
BROADWAY AVE. (NBND	11530							
PAVEMENT		0.95	3.16	11530	=	34613	258306	708
RAIN GARDEN		0.95	3.16	0	=	0	0	0
STORM PLANTER		0.95	3.16	0	=	0	0	0
					Total	34,613	258,306	708
E. FIR ST. (EBND)	13999							
PAVEMENT		0.95	3.16	13599	=	40824	304658	835
RAIN GARDEN		0.95	3.16	400	=	1201	8961	25
STORM PLANTER		0.95	3.16	0	=	0	0	0
					Total	42,025	313,619	859
UNKNOWN ST.(S&N)	17652							
PAVEMENT		0.95	3.16	17052	=	51190	382016	1047
RAIN GARDEN		0.95	3.16	0	=	0	0	0
STORM PLANTER		0.95	3.16	600	=	1801	13442	37
					Total	52,991	395,457	1,083

ADJACENT ROADWAYS-CENTERLINE TO R.O.W. AREAS (CONTINUED)								
		C	I* (FT.)	A (SF)	=	Q (CF)	Q (GAL.)	GPD
YESLER WAY (WBND)	28084							
PAVEMENT		0.95	3.16	28084	=	84308	629165	1724
RAIN GARDEN		0.95	3.16	0	=	0	0	0
STORM PLANTER		0.95	3.16	0	=	0	0	0
					Total	84,308	629,165	1,724

ENTIRE SECTOR #2
& ADJACENT ROADWAY RIGHT OF WAYS'
STORMWATER RUNOFFS

Q= 11,027 GPD AVG.
Q= 4,024,956 GAL. PER YR. AVG.
Q= 539,344 CF

SECTOR #2 STORMWATER RUNOFF CALCULATIONS - GROUPED BY ITEM TYPES TABLE							
	C	I* (FT.)	A (SF)	=	Q (CF)	Q (GAL.)	GPD
BUILDING ROOFS	0.75	3.16	64537	=	152,953	1,141,438	3,127
VEHICLE	0.85	3.16	2149	=	5,772	43,076	118
PEDESTRIAN (PARK & OPEN SP.)	0.65	3.16	61491	=	126,303	942,556	2,582
STORMWATER STRUCTURES	0.95	3.16	48702	=	146,203	1,091,070	2,989
				Total	431,231	3,218,140	8,817

NOTES:

A.) *1 -YEARLY RAINFALL

B.) "SECTOR #2 STORMWATER RUNOFF CALCULATIONS - GROUPED BY ITEM TYPES TABLE" DIFFERS FROM "SECTOR #2 STORMWATER RUNOFF CALCULATIONS - SUMMARY TABLE" RUNOFF COEFFICENTS FOR GROUPED ITEMS ARE TAKEN AS AVERAGES OF SIMILAR GROUP ITEMS

SECTOR #2- STORMWATER RUNOFF

Q= 5,879 GPD AVG.
Q= 2,145,681 GAL. PER YR. AVG.
Q= 287,521 CF

Appendix G - Stormwater Runoff Projections

SECTOR #3		**TOTAL AREA=**	**220473**					
Block	Bldg #	Footprint	Pavement	Pavement	Stormwater	Rain	Park	Open
			Private	Porous	Planter	Garden		Space
		Imperv.	Imperv.	Imperv.	Imperv.	Imperv.	Pervious	Pervious
		Area, SF	Area, SF	Area, SF	Area, SF	Area, SF	Area, SF	Area, SF
3A	21	12000						
3A	22	13440						
3A	23	24173						
			9744	0	0	1600	16478	27180
	Total	49613	9744	0	0	1600	16478	27180
			Note: Private pavement equally divided between blocks					
BLOCK AREA 3A		104,615						
3B	24	9900						
3B	25	5320						
3B	26	13287						
3B	27	15928						
3B	28	17962						
			9744	0	0	1600	0	
						1400		
	Total	44435	9744	0	0	3000	0	58679
			Note: Private pavement equally divided between blocks					
BLOCK AREA 3B		115,858						

RIGHT-OF-WAY AREAS (Sector)		PAVEMENT POROUS AREAS		RAIN GARDEN AREAS		STORMWATER PLANTER AREAS	
Total	N/A	Total	N/A	Total	N/A	Total	N/A
PAVEMENT-TOTAL IMPERVIOUS =				N/A			

Appendix G - Stormwater Runoff Projections

SECTOR #3 STORMWATER RUNOFF								
ITEM	C	I* (FT.)	A (SF)	=	Q (CF)	Q (GAL.)	GPD
BUILDING FOOTPRINT TOTAL	94048			=			
GREEN ROOF	0.50	3.16	28214	=	44579	332677	911
NON-GREEN ROOF	0.95	3.16	65834	=	197632	1474869	4041
PAVEMENT PRIVATE ROAD	0.95	3.16	19488	=	58503	436589	1196
PAVEMENT R.O.W.	0.95	3.16	N/A	=	N/A	N/A	N/A
PAVEMENT POROUS BY BLOCK	0.75	3.16	0	=	0	0	0
PAVEMENT POROUS BY R.O.W.	0.75	3.16	N/A	=	N/A	N/A	N/A
PARK	0.75	3.16	16478	=	39053	291439	798
RAIN GARDEN BY BLOCK	0.95	3.16	4600	=	13809	103054	282
RAIN GARDEN R.O.W.	0.95	3.16	N/A	=	N/A	N/A	N/A
STORM PLANTER BY BLOCK	0.95	3.16	0	=	0	0	0
STORM PLANTER R.O.W.	0.95	3.16	N/A	=	N/A		N/A
OPEN SPACE	0.50	3.16	85859	=	135657	1012367	2774
				Total	489,233	3,650,996	10,003

ADJACENT ROADWAYS-CENTERLINE TO R.O.W. AREAS								
		C	I* (FT.)	A (SF)	=	Q (CF)	Q (GAL.)	GPD
YESLER WAY (EBND)	13999							
PAVEMENT		0.95	3.16	13099	=	39323	293457	804
RAIN GARDEN		0.95	3.16	0	=	0	0	0
STORM PLANTER		0.95	3.16	900	=	2702	20163	55
					Total	42,025	313,619	859
UNKNOWN ST. (NBND)	16166							
PAVEMENT		0.95	3.16	15066	=	45228	337523	925
RAIN GARDEN		0.95	3.16	0	=	0	0	0
STORM PLANTER		0.95	3.16	1100	=	3302	24643	68
					Total	48,530	362,167	992
E. MAIN ST. (WBND)	17700							
PAVEMENT		0.95	3.16	16900	=	50734	378610	1037
RAIN GARDEN		0.95	3.16	800	=	2402	17922	49
STORM PLANTER		0.95	3.16	0	=	0	0	0
					Total	53,135	396,533	1,086
BOREN AVE. (SBND)	11724							
PAVEMENT		0.95	3.16	11199	=	33619	250891	687
RAIN GARDEN		0.95	3.16	0	=	0	0	0
STORM PLANTER		0.95	3.16	525	=	1576	11762	32
					Total	35,195	262,653	720

SECTOR #3 STORMWATER RUNOFF

ADJACENT ROADWAYS-CENTERLINE TO R.O.W. AREAS (CONTINUED)

		C	I* (FT.)	A (SF)	=	Q (CF)	Q (GAL.)	GPD
12th AVE. (SBND)	11837							
PAVEMENT		0.95	3.16	11437	=	34334	256223	702
RAIN GARDEN		0.95	3.16	0	=	0	0	0
		0.95	3.16	400	=	1201	8961	25
					Total	35,535	265,184	727

ENTIRE SECTOR #3 & ADJACENT ROADWAY RIGHT OF WAYS' STORMWATER RUNOFFS

Q= 14,387 GPD AVG.
Q= 5,251,152 GAL. PER YEAR AVG.
Q= 703,654 CF

SECTOR #3 STORMWATER RUNOFF CALCULATIONS - GROUPED BY ITEM TYPES TABLE

	C	I* (FT.)	A (SF)	=	Q (CF)	Q (GAL.)	GPD
BUILDING ROOFS	0.75	3.16	94048	=	222,894	1,663,386	4,557
VEHICLE (NO POROUS PVMT)	0.95	3.16	19488	=	58,503	436,589	1,196
PEDESTRIAN (PARK & OPEN SP.)	0.65	3.16	102337	=	210,200	1,568,658	4,298
STORMWATER STRUCTURES	0.95	3.16	4600	=	13,809	103,054	282
				Total	505,406	3,771,688	10,333

NOTES:

A.) *1 -YEARLY RAINFALL

B.) "SECTOR #3 STORMWATER RUNOFF CALCULATIONS - GROUPED BY ITEM TYPES TABLE" DIFFERS FROM "SECTOR #3 STORMWATER RUNOFF CALCULATIONS - SUMMARY TABLE" RUNOFF COEFFICENTS FOR GROUPED ITEMS ARE TAKEN AS AVERAGES OF SIMILAR GROUP ITEMS

SECTOR #3- STORMWATER RUNOFF

Q= 10,003 GPD AVG.
Q= 3,650,996 GAL. PER YR. AVG.
Q= 489,233 CF

Appendix G - Stormwater Runoff Projections

SECTOR #4		TOTAL AREA=	322639					
Block	Bldg #	Footprint	Pavement	Pavement	Stormwater	Rain	Park	Open
			Private	Porous	Planter	Garden		Space
		Imperv.	Imperv.	Imperv.	Imperv.	Imperv.	Pervious	Pervious
		Area, SF	Area, SF	Area, SF	Area, SF	Area, SF	Area, SF	Area, SF
4A	35	12000						
4A	36	1501						
			0	0	0	1238	3646	
	Total	13501	0	0	0	1238	3646	61014
BLOCK AREA 4A		79,399						
4B	29	17408						
4B	30	8278						
4B	31	14898						
4B	32	15894						
4B	33	9900						
4B	34	16761						
			21359	0	0	600	11482	
						1600		
						1600		
			21359	0	0	3800	11482	157629
	Total	48970						
BLOCK AREA 4B		243,240						
RIGHT-OF-WAY		PAVEMENT		RAIN GARDEN		STORMWATER		
AREAS (Sector)		POROUS AREAS		AREAS		PLANTER AREAS		
*	8612	0	0		900		0	
*	18660				300			
					700			
Total	27272	Total	0	Total	1900	Total	0	
PAVEMENT-TOTAL IMPERVIOUS			25,372					

* 9TH AVE PLACED BETWEEN SECTOR #4 AND COMMUNITY CENTER
NOT TREATED AS AJACENT R.O.W.

SECTOR #4 STORMWATER RUNOFF							
ITEM	C	I* (FT.)	A (SF)	=	Q (CF)	Q (GAL.)	GPD
BUILDING FOOTPRINT TOTAL	62471			=			
GREEN ROOF	0.50	3.16	18741	=	29611	220980	605
NON-GREEN ROOF	0.95	3.16	43730	=	131277	979676	2684
PAVEMENT PRIVATE ROAD	0.95	3.16	21359	=	64120	478505	1311
PAVEMENT R.O.W.	0.95	3.16	25372	=	76167	568409	1557
PAVEMENT POROUS BY BLOCK	0.75	3.16	0	=	0	0	0
PAVEMENT POROUS BY R.O.W.	0.75	3.16	0	=	0	0	0
PARK	0.75	3.16	15128	=	35853	267562	733
RAIN GARDEN BY BLOCK	0.95	3.16	5038	=	15124	112866	309
RAIN GARDEN R.O.W.	0.95	3.16	1900	=	5704	42566	117
STORM PLANTER BY BLOCK	0.95	3.16	0	=	0	0	0
STORM PLANTER R.O.W.	0.95	3.16	0	=	0	0	0
OPEN SPACE	0.50	3.16	218643	=	345456	2578029	7063
				Total	703,311	5,248,593	14,380

ADJACENT ROADWAYS-CENTERLINE TO R.O.W. AREAS								
		C	I* (FT.)	A (SF)	=	Q (CF)	Q (GAL.)	GPD
E. YESLER WAY (EBND)	14549							
PAVEMENT		0.95	3.16	13799	=	41425	309139	847
RAIN GARDEN		0.95	3.16	750	=	2252	16802	46
STORM PLANTER		0.95	3.16	0	=	0	0	0
					Total	43,676	325,941	893
UNKNOWN ST. (SBND)	7212							
PAVEMENT		0.95	3.16	7212	=	21650	161570	443
RAIN GARDEN		0.95	3.16	0	=	0	0	0
STORM PLANTER		0.95	3.16	0	=	0	0	0
					Total	21,650	161,570	443
E. MAIN ST.(WBND)	2644							
PAVEMENT		0.95	3.16	2644	=	7937	59233	162
RAIN GARDEN		0.95	3.16	0	=	0	0	0
STORM PLANTER		0.95	3.16	0	=	0	0	0
					Total	7,937	59,233	162

ENTIRE SECTION 4 &	15,878	GPD AVG.
ADJACENT ROADWAY R.OW.	5,795,338	GAL. PER YEAR AVG
STORMWATER RUNOFF	776,575	CF

SECTOR #4 STORMWATER RUNOFF CALCULATIONS - GROUPED BY ITEM TYPES TABLE								
	C	I* (FT.)	A (SF)	=	Q (CF)	Q (GAL.)	GPD
BUILDING ROOFS	0.75	3.16	62471	=	148,056	1,104,898	3,027
VEHICLE (NO POROUS PVMT)	0.95	3.16	46731	=	140,286	1,046,914	2,868
PEDESTRIAN (PARK & OPEN SPACE)	0.75	3.16	233771	=	554,037	4,134,606	11,328
STORMWATER STRUCTURES	0.95	3.16	6938	=	20,828	155,432	426
				Total	863,208	6,441,850	17,649

NOTES:

A.) *1 -YEARLY RAINFALL

B.) "SECTOR #4 STORMWATER RUNOFF CALCULATIONS - GROUPED BY ITEM TYPES TABLE" DIFFERS FROM "SECTOR #4 STORMWATER RUNOFF CALCULATIONS - SUMMARY TABLE" RUNOFF COEFFICENTS FOR GROUPED ITEMS ARE TAKEN AS AVERAGES OF SIMILAR GROUP ITEMS

TOTAL SECTION 4- STORMWATER RUNOFF

Q= 14,380 GPD AVG.

Q= 5,248,593 GAL. PER YEAR AVG.

Q= 703,311 CF

Appendix G - Stormwater Runoff Projections

EOB		**TOTAL AREA=**	**76,901**					
Block	Bldg #	Footprint	Pavement	Pavement	Stormwater	Rain	Park	Open
			Private	Porous	Planter	Garden		Space
		Imperv.	Imperv.	Imperv.	Imperv.	Imperv.	Pervious	Pervious
		Area, SF	Area, SF	Area, SF	Area, SF	Area, SF	Area, SF	Area, SF
EOB	18	17155						
EOB	19	13148						
EOB	20	15035						
			0	0	0	1400	2126	
							2328	
	Total	45338	0	0	0	1400	4454	25709
EOB AREA		76,901						
RIGHT-OF-WAY AREAS EOB		PAVEMENT POROUS AREAS		RAIN GARDEN AREAS		STORMWATER PLANTER AREAS		
	0	0	0		0		0	
	0	0	0		0		0	
Total	0	Total	0	Total	0	Total	0	
PAVEMENT-TOTAL IMPERVIOUS			0					

Appendix G - Stormwater Runoff Projections

EOB STORMWATER RUNOFF CALCULATIONS - SUMMARY TABLE							
ITEM	C	I* (FT.)	A (SF)	=	Q (CF)	Q (GAL.)	GPD
BUILDING FOOTPRINT TOTAL	45338			=			
GREEN ROOF	0.50	3.16	13601	=	21490	160375	439
NON-GREEN ROOF	0.95	3.16	31737	=	95273	710995	1948
PAVEMENT PRIVATE ROAD	0.95	3.16	0	=	0	0	0
PAVEMENT R.O.W.	0.95	3.16	0	=	0	0	0
PAVEMENT POROUS BY BLOCK	0.75	3.16	0	=	0	0	0
PAVEMENT POROUS BY R.O.W.	0.75	3.16	0	=	0	0	0
PARK	0.75	3.16	4454	=	10556	78776	216
RAIN GARDEN BY BLOCK	0.95	3.16	1400	=	4203	31364	86
RAIN GARDEN R.O.W.	0.95	3.16	0	=	0	0	0
STORM PLANTER BY BLOCK	0.95	3.16	0	=	0	0	0
STORM PLANTER R.O.W.	0.95	3.16	0	=	0	0	0
OPEN SPACE	0.50	3.16	25709	=	40620	303136	831
				Total	172,142	1,284,645	3,520

ADJACENT ROADWAYS-CENTERLINE TO R.O.W. AREAS								
		C	I* (FT.)	A (SF)	=	Q (CF)	Q (GAL.)	GPD
BOREN AVE. (NBND)	12700							
PAVEMENT		0.95	3.16	12700	=	38125	284518	780
RAIN GARDEN		0.95	3.16	0	=	0	0	0
STORM PLANTER		0.95	3.16	0	=	0	0	0
					Total	38,125	284,518	780
E. FIR ST. (EBND)	13173							
PAVEMENT		0.95	3.16	12823	=	38495	287273	787
RAIN GARDEN		0.95	3.16	350	=	1051	7841	21
STORM PLANTER		0.95	3.16	0	=	0	0	0
					Total	39,545	295,115	809
YESLER WAY (WBND)	8856							
PAVEMENT		0.95	3.16	8856	=	26586	198401	544
RAIN GARDEN		0.95	3.16	0	=	0	0	0
STORM PLANTER		0.95	3.16	0	=	0	0	0
					Total	26,586	198,401	544
12th AVE. (SBND)	10942							
PAVEMENT		0.95	3.16	10742	=	32247	240653	659
RAIN GARDEN		0.95	3.16	0	=	0	0	0
STORM PLANTER		0.95	3.16	200	=	600	4481	12
					Total	32,848	245,133	672

ADJACENT ROADWAYS-CENTERLINE TO R.O.W. AREAS (CONTINUED)

ENTIRE EOB
& ADJACENT ROADWAY RIGHT OF WAYS'
STORMWATER RUNOFFS

Q=	6,323	GPD AVG.
Q=	2,307,812	GAL. PER YR. AVG.
Q=	309,247	CF

EOB STORMWATER RUNOFF CALCULATIONS -
GROUPED BY ITEM TYPES TABLE

	C	I* (FT.)	A (SF)	=	Q (CF)	Q (GAL.)	GPD
BUILDING ROOFS	0.75	3.16	45338	=	107,451	801,874	2,197
VEHICLE	0.95	3.16	0	=	0	0	0
PEDESTRIAN (PARK & OPEN SP.)	0.65	3.16	30163	=	61,955	462,349	1,267
STORMWATER STRUCTURES	0.95	3.16	1400	=	4,203	31,364	86
				Total	173,609	1,295,587	3,550

NOTES:
A.) *1 -YEARLY RAINFALL
B.) "SECTOR EOB STORMWATER RUNOFF CALCULATIONS -
GROUPED BY ITEM TYPES TABLE" DIFFERS FROM
"SECTOR EOB STORMWATER RUNOFF CALCULATIONS - SUMMARY TABLE"
RUNOFF COEFFICENTS FOR GROUPED ITEMS ARE TAKEN AS
AVERAGES OF SIMILAR GROUP ITEMS

SECTOR EOB- STORMWATER RUNOFF

Q=	**3,520**	**GPD AVG.**
Q=	**1,284,645**	**GAL. PER YR AVG.**
Q=	**172,142**	**CF**

Appendix G - Stormwater Runoff Projections

COMMUNITY CENTER (EXISTING)				**TOTAL AREA=**	**144,764**			
Block	Bldg #	Footprint	Pavement	Pavement	Stormwater	Rain	Park	Open
			Private	Porous	Planter	Garden		Space
		Imperv.	Imperv.	Imperv.	Imperv.	Imperv.	Pervious	Pervious
		Area, SF	Area, SF	Area, SF	Area, SF	Area, SF	Area, SF	Area, SF
		21971						
			36257	0	0	400	85389	
							747	
	Total	21971	36257	0	0	400	86136	0
EOB AREA 2A		144,764						
RIGHT-OF-WAY		PAVEMENT		RAIN GARDEN		STORMWATER		
AREAS EOB		POROUS AREAS		AREAS		PLANTER AREAS		
	0	0	0		0		0	
	0	0	0		0		0	
Total	0	Total	0	Total	0	Total	0	
PAVEMENT-TOTAL IMPERVIOUS			0					

Appendix G - Stormwater Runoff Projections

COMMUNITY CENTER STORMWATER RUNOFF CALCULATIONS - SUMMARY TABLE							
ITEM	C	I* (FT.)	A (SF)	=	Q (CF)	Q (GAL.)	GPD
BUILDING FOOTPRINT TOTAL	21971			=			
GREEN ROOF	0.50	3.16	0	=	0	0	0
NON-GREEN ROOF	0.95	3.16	21971	=	65957	492216	1349
PAVEMENT PRIVATE ROAD	0.95	3.16	36257	=	108844	812265	2225
PAVEMENT R.O.W.	0.95	3.16	0	=	0	0	0
PAVEMENT POROUS BY BLOCK	0.75	3.16	0	=	0	0	0
PAVEMENT POROUS BY R.O.W.	0.75	3.16	0	=	0	0	0
PARK	0.75	3.16	86136	=	204142	1523450	4174
RAIN GARDEN BY BLOCK	0.95	3.16	400	=	1201	8961	25
RAIN GARDEN R.O.W.	0.95	3.16	0	=	0	0	0
STORM PLANTER BY BLOCK	0.95	3.16	0	=	0	0	0
STORM PLANTER R.O.W.	0.95	3.16	0	=	0	0	0
OPEN SPACE	0.50	3.16	0	=	0	0	0
				Total	380,144	2,836,892	7,772

ADJACENT ROADWAYS-CENTERLINE TO R.O.W. AREAS							
	C	I* (FT.)	A (SF)	=	Q (CF)	Q (GAL.)	GPD
UNKNOWN ST. (SBND) 8416							
PAVEMENT	0.95	3.16	8416	=	25265	188544	517
RAIN GARDEN	0.95	3.16	0	=	0	0	0
STORM PLANTER	0.95	3.16	0	=	0	0	0
				Total	25,265	188,544	517
YESLER WAY (WBND) 25783							
PAVEMENT	0.95	3.16	24133	=	72447	540651	1481
RAIN GARDEN	0.95	3.16	1650	=	4953	36965	101
STORM PLANTER	0.95	3.16	0	=	0	0	0
				Total	77,401	577,616	1,583
12th AVE. (NBND) 7895							
PAVEMENT	0.95	3.16	7895	=	23701	176872	485
RAIN GARDEN	0.95	3.16	0	=	0	0	0
STORM PLANTER	0.95	3.16	0	=	0	0	0
				Total	23,701	176,872	485
12th AVE. (WBND) 17930							
PAVEMENT	0.95	3.16	17930	=	53826	401686	1101
RAIN GARDEN	0.95	3.16	0	=	0	0	0
STORM PLANTER	0.95	3.16	0	=	0	0	0
				Total	53,826	401,686	1,101

ADJACENT ROADWAYS-CENTERLINE TO R.O.W. AREAS (CONTINUED)

ENTIRE COMMUNITY CENTER
& ADJACENT ROADWAY RIGHT OF WAYS'
STORMWATER RUNOFFS

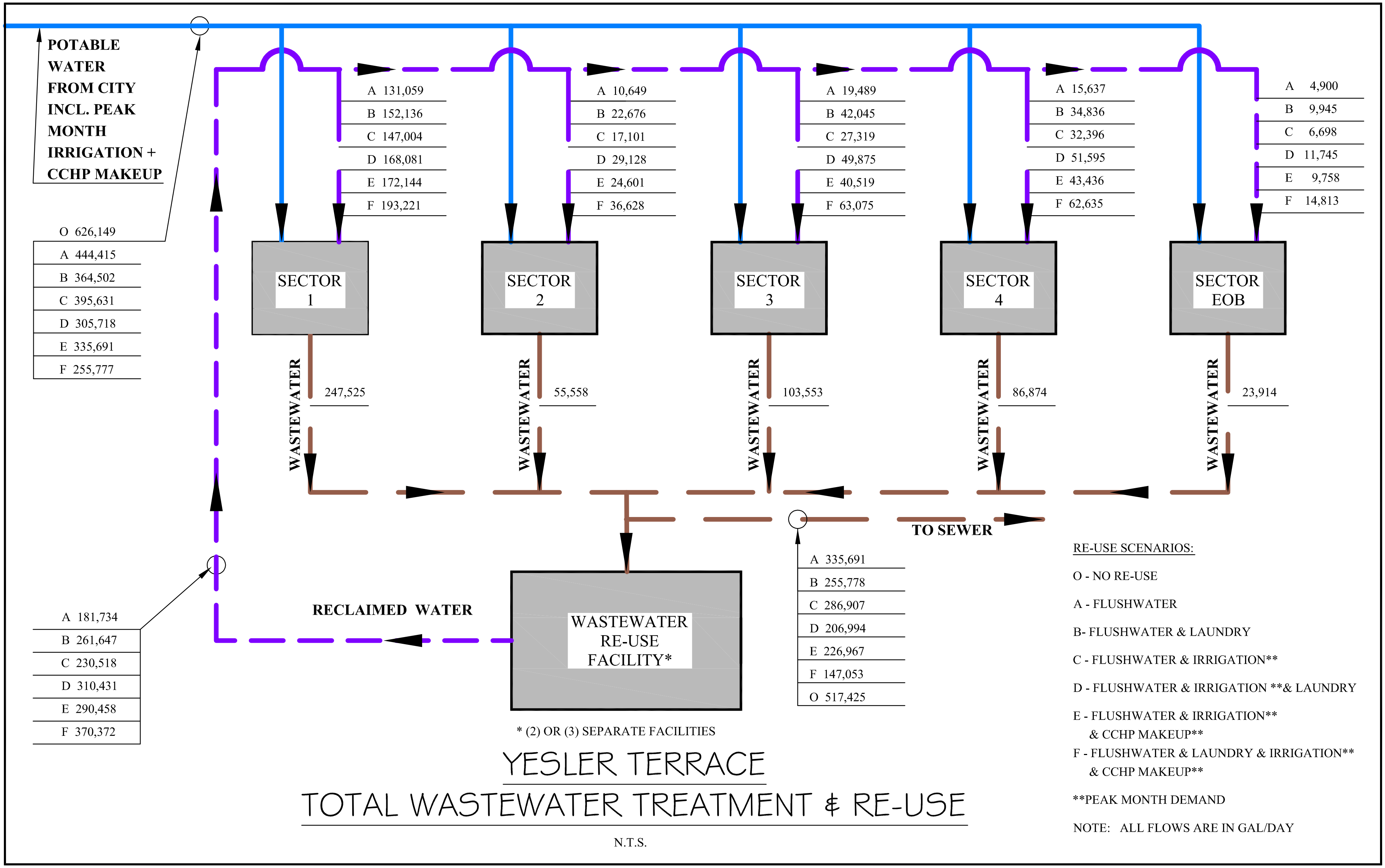
Q= 11,456 GPD AVG.
Q= 4,181,609 GAL. PER YR. AVG.
Q= 560,336 CF

COMMUNITY CENTER STORMWATER RUNOFF CALCULATIONS -
GROUPED BY ITEM TYPES TABLE

	C	I* (FT.)	A (SF)	=	Q (CF)	Q (GAL.)	GPD
BUILDING ROOFS	0.75	3.16	21971	=	52,071	388,592	1,065
VEHICLE	0.95	3.16	36257	=	108,844	812,265	2,225
PEDESTRIAN (PARK & OPEN SP.)	0.65	3.16	86136	=	176,923	1,320,323	3,617
STORMWATER STRUCTURES	0.95	3.16	400	=	1,201	8,961	25
				Total	339,039	2,530,141	6,932

NOTES:
A.) *1 -YEARLY RAINFALL
B.) "COMMUNITY CENTER STORMWATER RUNOFF CALCULATIONS - GROUPED BY ITEM TYPES TABLE" DIFFERS FROM "COMMUNITY CENTER STORMWATER RUNOFF CALCULATIONS - SUMMARY TABLE" RUNOFF COEFFICENTS FOR GROUPED ITEMS ARE TAKEN AS AVERAGES OF SIMILAR GROUP ITEMS

COMMUNITY CENTER
STORMWATER RUNOFF
Q= 7,772 GPD AVG.
Q= 2,836,892 GAL. PER YR AVG.
Q= 380,144 CF


POTABLE WATER FROM CITY INCL. PEAK MONTH IRRIGATION + CCHP MAKEUP
O 626,149
A 444,415
B 364,502
C 395,631
D 305,718
E 335,691
F 255,777
A 131,059
B 152,136
C 147,004
D 168,081
E 172,144
F 193,221
A 10,649
B 22,676
C 17,101
D 29,128
E 24,601
F 36,628
A 19,489
B 42,045
C 27,319
D 49,875
E 40,519
F 63,075
A 15,637
B 34,836
C 32,396
D 51,595
E 43,436
F 62,635
A 4,900
B 9,945
C 6,698
D 11,745
E 9,758
F 14,813
SECTOR 1
SECTOR 2
SECTOR 3
SECTOR 4
SECTOR EOB
WASTEWATER
247,525
WASTEWATER
55,558
WASTEWATER
103,553
WASTEWATER
86,874
WASTEWATER
23,914
TO SEWER
A 335,691
B 255,778
C 286,907
D 206,994
E 226,967
F 147,053
O 517,425
RECLAIMED WATER
WASTEWATER RE-USE FACILITY*
A 181,734
B 261,647
C 230,518
D 310,431
E 290,458
F 370,372
* (2) OR (3) SEPARATE FACILITIES
RE-USE SCENARIOS:
O - NO RE-USE
A - FLUSHWATER
B- FLUSHWATER & LAUNDRY
C - FLUSHWATER & IRRIGATION**
D - FLUSHWATER & IRRIGATION **& LAUNDRY
E - FLUSHWATER & IRRIGATION** & CCHP MAKEUP**
F - FLUSHWATER & LAUNDRY & IRRIGATION** & CCHP MAKEUP**
**PEAK MONTH DEMAND
NOTE: ALL FLOWS ARE IN GAL/DAY
YESLER TERRACE
TOTAL WASTEWATER TREATMENT & RE-USE
N.T.S.

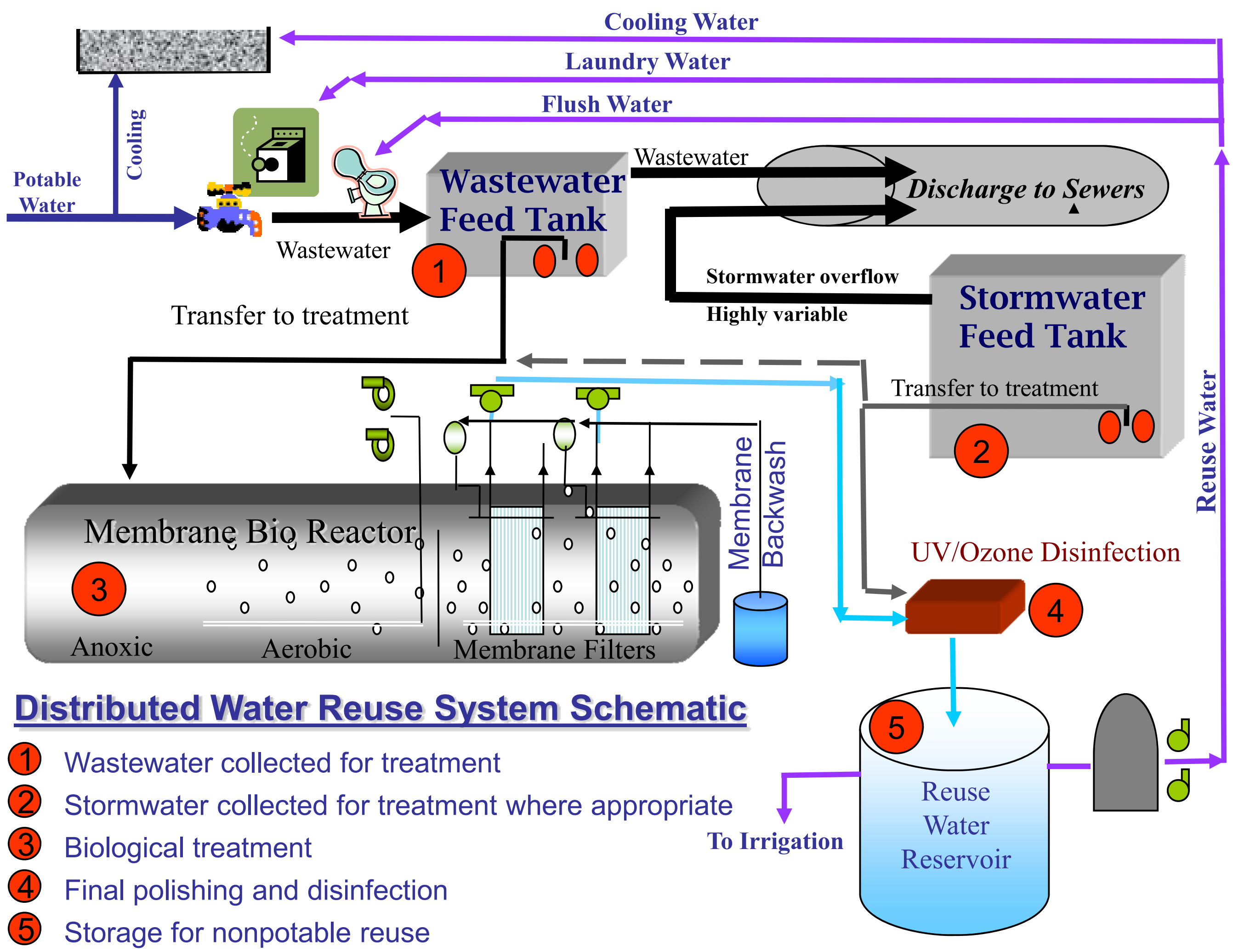
Appendix I: Water Reuse Projected Reductions in Water / Sewer Flows

Reuse Scenario	O - None		A - Flushwater (FW) Reuse Only				B - FW + Laundry (L) Reuse				C - FW + Peak Month Irrigation (I)			
Sector	PW Demand (gpd) *	WW Flow (gpd)	PW Demand (gpd)	PW % Reduction	WW Flow (gpd)	WW % Reduction	PW Demand (gpd)	PW % Reduction	WW Flow (gpd)	WW % Reduction	PW Demand (gpd)	PW % Reduction	WW Flow (gpd)	WW % Reduction
1	288,610	247,525	157,551	45.4%	116,466	52.9%	136,474	52.7%	95,389	61.5%	141,606	50.9%	100,521	59.4%
2	69,510	55,558	58,861	15.3%	44,909	19.2%	46,834	32.6%	32,882	40.8%	42,191	39.3%	38,457	30.8%
3	124,583	103,553	105,093	15.6%	84,063	18.8%	82,538	33.7%	61,508	40.6%	97,263	21.9%	76,233	26.4%
4	114,673	86,874	99,036	13.6%	71,237	18.0%	79,837	30.4%	52,038	40.1%	82,277	28.3%	54,478	37.3%
EOB	28,772	23,914	23,873	17.0%	19,015	20.5%	18,819	34.6%	13,961	41.6%	22,075	23.3%	17,217	28.0%
Total	**626,149**	**517,425**	**444,415**		**335,691**		**364,501**		**255,777**		**385,412**		**286,907**	

Appendix I: Water Reuse Projected Reductions in Water / Sewer Flows

Reuse Scenario	D - FW + L + I				E - FW + I + CCHP				F - FW + L + I + CCHP			
Sector	PW Demand (gpd)	PW % Reduction	WW Flow (gpd)	WW % Reduction	PW Demand (gpd)	PW % Reduction	WW Flow (gpd)	WW % Reduction	PW Demand (gpd)	PW % Reduction	WW Flow (gpd)	WW % Reduction
1	111,334	61.4%	79,389	67.9%	116,466	59.6%	75,381	69.5%	95,389	66.9%	54,249	78.1%
2	39,334	43.4%	26,432	52.4%	44,909	35.4%	30,957	44.3%	32,882	52.7%	18,932	65.9%
3	69,338	44.3%	53,678	48.2%	84,063	32.5%	63,033	39.1%	61,508	50.6%	40,478	60.9%
4	68,797	40.0%	35,278	59.4%	71,237	37.9%	43,438	50.0%	52,038	54.6%	24,238	72.1%
EOB	15,759	45.2%	12,161	49.1%	19,015	33.9%	14,157	40.8%	13,961	51.5%	9,101	61.9%
Total	**304,561**		**206,937**		**335,691**		**226,967**		**255,777**	59.2%	**146,997**	71.6%

Appendix J: Typical MBR Reuse Facility Schematic



Appendix K

District Integrated Water Economics

The economic performance of the sustainable integrated water system is determined by the net balance of the incremental benefits versus the incremental costs, measured relative to the "business-as-usual" baseline.

- The incremental costs in this case include the distributed systems for water reclamation, both treatment and redelivery to the new Yesler Terrace buildings, plus the incremental building costs of installing dual plumbing systems to deliver the reclaimed water to its end uses. It is noteworthy that the district integrated water system would continue to rely on the same in-building and central sewage collection system, delivering the source water for reuse to the central facility at no incremental cost.
- The incremental economic benefits in this case include the building-by-building cost savings from reduced water bills and reduced sewer bills, both resulting from reduced potable water purchases.

1. Cost Comparisons, Present Value

The projections for the initial economic assessment were prepared by Alliance Environmental (AE) as a conceptual level analysis, designed to determine which if any of the candidate district integrated water systems offers sufficient promise to justify further research. The scenarios examined by AE differed in size, as a result of including different combinations of potential applications of reuse water. Since AE assumed in their analysis that any system would be operated as a DBO, with the same per unit payment structure, the system payments and the system avoided cost savings are essentially proportional to one another.

Summary cost projections for the largest (Scenario F) water reuse system, including savings relative to the BAU baseline are listed by cost component in **Table X** below. The annual expense and compensation items are estimated as first-year values, based on 2010 SPU water and sewer rates and on 2010 estimates of system unit compensation levels.

	Table X Yesler Terrace Integrated Water Reuse Option: Major Cost Elements and Estimated Magnitudes		
	Financial Transaction	**Estimated Amount [1]**	**Responsible Party**
1	Initial system construction and financing	$10.0 m	DBO Contractor
2	Periodic component replacements	Variable	DBO Contractor
3	Annual O&M plus return on capital & profit	$0.7 m/yr	DBO Contractor
4	Compensation to DBO Firm	$1.9 m/yr	SHA
5	Installation of Reuse Distribution System	$1.0 m	SHA
6	Installation of Building Dual Plumbing	$2.5 m	Building Owners
7	Payment for SHA Contract Costs	$2,100,000/yr	Building Owners
8	Benefits from Reduced Water/Sewer Use	$2,300,000/yr	Building Owners

[1] All estimates in Table X are from the AE Draft Report, with the exception of the distribution and building dual plumbing cost, which was provided by McKinstry.

The approximate amounts shown in the table for annual costs and payments are based on full development of Yesler Terrace. In practice, since the development and implementation of the flow supply to reuse facilities would occur gradually over time, the interim costs and payments would be lower. To avoid undue capital cost burdens relative to this gradually-realized flow, AE recommends that the DBO develop the reuse facilities in either two or three stages.

The initial economic analysis prepared by AE indicated that the recommended district integrated water reuse system would be cost-effective relative to the baseline. Their water reuse system costs, however, did not include the costs of dual plumbing or the cost of installing a reuse water distribution loop, as they noted in the report. AE estimated that even with those additional costs the system would likely be cost-effective by some margin.

Table Y Yesler Terrace Integrated Water Reuse System: Revenues and Expenses by Participating Entity			
Party	**Revenue**	**Expense**	**Net**
DBO Firm	#4	#1-3	Positive
SHA	#7	#4-5	Positive
Building Owners	#8	#6-7	Positive

Table Y lists the items from Table X that are revenue sources and expense items for each of the three major participant groups in a potential water reuse system. As the revenues and expenses are apportioned, it appears that all three groups would experience net savings relative to the BAU baseline. And if, for example, the cost of the distribution system (item #5) was higher than projected, SHA would have some latitude to raise the building charges (item #7), while still preserving net benefit for future building developers.

AE has indicated that a cost-based DBO payment structure may include indexed inflationary increases for the O&M portion of system operation, with either lower escalation or no escalation for the capital cost portion of the system operation.

The preliminary AE estimate for the capital cost of the water reuse treatment system for this option is approximately $10 million dollars, with another $600-$700,000 per year estimated for operating and maintenance costs. These would include labor, power, chemicals and laboratory analyses. For the assumed DBO management of the district integrated water reuse system, AE estimates that these costs would be borne by the DBO entity, and recovered from SHA or building owners through volumetric rates set at $0.014/gallon of system water use.

These incremental costs would be offset by annual cost savings of approximately $2.3 million in reduced utility charges. While the water reuse system (and thus its costs and benefits) could be developed in phases, these cost impact estimates are for the full Yesler Terrace development. During build-out, the DBO payments and the utility bil savings from the system would grow together.

Table Z shows, for three sets of assumptions, the estimated present value for the Scenario F water reuse system over a typical 20-year contract horizon. In addition, since limitations on laundry applications may limit the scale of a water reuse system to the option defined by AE as Scenario E, impacts of that scenario are also shown in **Table Z**, under other base case assumptions.

Base Case:	Water & Sewer rates increase at 3.5%/year
	Capital portion of DBO payment constant
	Central loop = $1.0 m; dual plumbing = $2.5 m
Best Case:	Water & Sewer rates increase at 7.0%/year
	Capital portion of DBO payment constant
	Central loop = $1.0 m; dual plumbing = $2.5 m
Worst Case:	Water & Sewer rates increase at 3.5%/year
	Capital portion of DBO payment rises 3.0%/year
	Central loop = $2.0 m; dual plumbing = $5.0 m

Table Z Yesler Terrace District Water Reuse Scenarios: System Costs and Benefits (2010 PV, $m, 2015-34)				
Economic Impact	**Base Case**	**Best Case**	**Worst Case**	**Scenario E**
Utility Savings	$11.85	$18.38	$11.85	$9.50
DBO Payments	$ 7.40	$ 7.40	$ 9.25	$5.93
Central Loop	$1.00	$1.00	$1.50	$1.00
Dual Plumbing	$1.42	$1.42	$2.13	$1.42
Total Cost	$ 9.82	$ 9.82	$12.88	$8.34
Impact, NPV	**+$2.03 m**	**+$8.56**	**-+$1.03 m**	**$1.16**
Impact B:C Ratio	**1.21**	**1.87**	**0.92**	**1.14**

2. Uncertainty and Sensitivity of Cost Rankings

Uncertainties of this preliminary economic projection are of three types: system cost uncertainty, avoided utility cost uncertainty, and system usage uncertainty. Three alternative scenarios that depict these various uncertainties are shown in **Table Z**, along with the base case.

- The cost of the distributed system is a preliminary estimate, and could change either upward or downward when cost estimates are refined. In **Table Z**, this possibility is represented by having the capital cost portion of DBO charges escalating at the rate of inflation, raising the present value of total DBO payments by 25%.
- Similarly, the benefits associated with water and sewer cost savings could be greater or less than estimated. The AE baseline assumes that utility unit costs of service, will rise by 0.5% more than inflation. Both water and sewer costs have risen well in excess of inflation over the past ten years (about 7.33%/year on average), and a continuation of that pattern could significantly improve the economics of the project. In **Table Z**, this possibility is represented by rates rising by 7.0%/year.
- The case reflecting lower development utilization of a water reuse system is reflected in Table Z by the Scenario E case. In that case, system uses would fall by about 22%, from 370,000 gal/year to 290,000 gal/year and both the system costs and benefits would be lower. However, some fixed development costs, such as installation of the central loop and installation of dual plumbing in

redevelopment buildings, would not fall. Consequently, the benefit:cost ratio for this scenario is lower than for the base case, 1.14 versus 1.21.

As illustrated in **Table Z**, specific sensitivity analysis cases can significantly improve or reduce net economic benefits. However, it appears that for a wide range of realistic potential scenarios a water reuse system would produce positive net benefits to the Yesler Terrace project.

3. External Benefits

In addition to the direct benefits to SHA and the private developers at Yesler Terrace, there may also be downstream benefits to King County and upstream benefits associated with preserved instream flows, particularly in the Cedar River.

- The County manages the CSO sites associated with flows originating within Yesler Terrace, and may realize some flow reductions and CSO control facility cost reductions as flows from Yesler Terrace are decreased.
- SPU manages its water withdrawals from the Cedar and Tolt Rivers to meet environmental standards, but those rivers could benefit more as a district integrated water system allowed SPU to reduce withdrawals still further relative to the baseline or take on new demands without increased impact.

4. Potential System Improvements or Enhancements

The system assumed above would rely on flows from Yesler Terrace buildings as they are redeveloped. By full build-out, it is projected from water budget estimates that there would be adequate source flows from these buildings to produce reuse water in the amounts projected to be needed for Scenario F applications. However, there may be periods when the balance is less reliable. As an alternative, main sewer lines on 9th Avenue and possibly Broadway carry flows originating off-site, which would be available throughout the redevelopment period, and which could provide more than adequate source flows, independent of development timing. This alternative could improve system service reliability, and might also offer efficient siting and facility design options with associated economic benefits. Flow monitoring of these main lines that is being scheduled for the second half of 2010 will assess the adequacy of both flow volume and flow constituents to serve as inputs to a district water reuse system.

Appendix K - Water Reuse Economic Analysis

Reuse Scenario	Potable Water Use (gpd)	Sewer Flow (gpd)	Annual Water Charges (Off-Peak)	Annual Water Charges (Peak)	Annual Sewer Charges	Total Annual Charges	Annual Cost Savings	Reuse Treatment Cost	Annual Net Savings
O	626,149	517,425	$709,022	$397,437	$2,267,331	$3,373,790	$0	0	0
A	444,145	335,691	$502,929	$281,913	$1,470,982	$2,255,824	$1,117,966	$928,661	$189,306
B	364,502	255,778	$412,745	$231,361	$1,120,807	$1,764,913	$1,608,877	$1,337,016	$271,861
C	395,631	286,907	$447,994	$251,120	$1,257,213	$1,956,326	$1,417,464	$1,177,947	$239,517
D	305,718	206,994	$346,181	$194,049	$907,038	$1,447,268	$1,926,523	$1,586,302	$340,220
E	335,691	226,967	$380,121	$213,074	$994,558	$1,587,753	$1,786,037	$1,484,240	$301,797
F	255,777	147,053	$289,630	$162,350	$644,379	$1,096,359	$2,277,431	$1,892,601	$384,830

Notes:

1. Projected flows include peak month irrigation and CCHP make-up demands

2. Off-peak rate is equal to $3.50 per CCF at 242 days/yr

3. Peak rate is equal to $3.86 per CCF at 123 days/yr

4. Sewer rate is equal to $8.98 per CCF

5. Amortized reuse treatment cost is equal to $0.014 per gallon. The amortized rate is made up of approximately 60-70% capital costs and 30-40% operating costs including complete management and repairs. The capital cost is based on a treatment system that begins at the wastewater feed or interceptor tank and ends at the treated effluent storage tank (wastewater collection lines and reclaimed water distribution lines are not included) with an amortization period of 20 years at an average weighted cost of capital equal to 9.5%. The operating cost includes labor, power, chemicals, and laboratory analyses. This operating cost is based on the ability to discharge waste biosolids to the sewer which will be further evaluated during the next phase of the project.

Water Reclamation and Reuse Standards

September 1997

Washington State Department of Health
Office of the Secretary

WASHINGTON STATE DEPARTMENT OF ECOLOGY

September 1997
Publication #97-23

(b) Samples for TSS shall be 24-hour composite samples. Samples for TSS shall be collected at least daily. Compliance with the TSS requirement shall be determined monthly, based on the arithmetic mean of all samples collected during the month. Reduced TSS sampling for those projects that provide Class A reclaimed water (filtered) may be allowed by Health and Ecology on a case by case basis.

(c) Grab samples for coliform organisms shall be collected at least daily and at a time when wastewater characteristics are most demanding on the treatment facilities and disinfection procedures. Compliance with the coliform requirements shall be determined daily, based on the median value determined from the bacteriological results of the last seven days for which analyses have been completed. Daily coliform sampling may be waived by the Departments of Health and Ecology for only those projects using Class D reclaimed water. Criteria to be considered for reduced sampling includes: additional site access controls, disinfection reliability and irrigation methods. Reduced sampling shall be no less than two per week and must still comply with levels based on the last seven days for which analysis have been completed.

(d) Turbidity analysis shall be performed by a continuous recording turbidimeter. Turbidity measurements shall be read at least every four hours. Compliance with the average operating turbidity requirement shall be determined monthly, based on the arithmetic mean of all measurements read during the month.

(e) Grab samples for dissolved oxygen shall be collected at least daily and at a time when wastewater characteristics are most demanding on the treatment facilities.

(f) Samples collected for BOD, TSS, total coliform, turbidity, and dissolved oxygen analyses shall be analyzed by approved laboratory methods, and analyses shall be conducted in laboratories approved by the Washington Department of Ecology.

(g) Additional sampling parameters may be specified by the Departments of Health and Ecology within water quality permits to satisfy existing regulatory requirements or to meet health regulations.

Article 8. Engineering Report

Section 1. Scope and Minimum Requirements

(a) No person shall produce or supply reclaimed water for a direct beneficial use or a controlled use that would not otherwise occur unless he files an engineering report with the Washington Departments of Health and Ecology.

(b) The report shall be prepared by an engineer registered in Washington and experienced in the field of wastewater treatment, and shall contain a description of the design of the proposed reclamation system. The report shall clearly indicate the means for compliance with these standards and any other reclamation requirements specified by the Washington Departments of Health and Ecology. The engineering report shall also meet the regulatory requirements found within chapter 173-240-060 WAC (Submission of Plans and reports for Construction of Wastewater Facilities) and chapter 246-290 (Group A Public Water Systems) for applicable sections (i.e. Cross-connection control WAC 246-290-490, Water enhancement, irrigation supplies, water right replenishment or transfer and fisheries propagation.

Section 2. Other Uses of Reclaimed Water

(a) Reclaimed water may be suitable for nonpotable uses other than those included in these regulations that do not conflict with provisions of Washington Administrative Code, federal regulations, statute or other law. Reclaimed water used for such uses shall require Washington Departments of Health and Ecology consideration and approval on a case by case basis.

(b) Reclaimed water shall not be used for food preparation and shall not be incorporated into food or drink for humans.

(c) Wastewater effluent used for sewage treatment plant purposes within the bounds of the wastewater treatment facility (wash down water, yard hydrants and restricted site irrigation) is not required to meet these standards unless potential public exposure, as determined by Health and Ecology requires the use of reclaimed water.

All uses within the bounds of the wastewater treatment facility shall be in conformance with an approved cross connection control program managed by the local water purveyor if potable water service is provided to the wastewater treatment facility.

Article 6. Other Methods of Treatment

Section 1. Other Methods of Treatment

(a) Methods of treatment other than those included in these standards and their reliability features may be accepted if the applicant demonstrates to the satisfaction of the Washington Departments of Health and Ecology that the methods of treatment and reliability features will assure an equal degree of treatment, public health protection and treatment reliability.

(b) For uses where oxidized, filtered, disinfected reclaimed water is required, pilot plant or other studies may be required to demonstrate that methods of treatment other than those specified in these standards are capable of reliably producing reclaimed water that is essentially free of measurable levels of viable pathogens.

(c) Projects that propose methods of treatment other than outlined within this standard are urged to request pilot project status from the Departments of Health and Ecology as outlined within chapter 90.46 RCW.

Article 7. Sampling and Analysis

Section 1. Protocols and Minimum Frequencies

(a) Samples for BOD shall be 24-hour composite samples. Samples for BOD shall be collected at least weekly. Compliance with the BOD requirement shall be determined monthly, based on the arithmetic mean of all samples collected during the month.

(c) Reclaimed water shall not be used to flush toilets in any residential property or dwelling unit where the residents have access to the plumbing system for repairs or modifications.

(d) When authorized by a local greywater program, greywater may be used to flush toilets and urinals, including within residential property or dwelling units, but only where the residents do not have access to the plumbing system for repairs or modifications. The treatment for the greywater shall be oxidized, coagulated, filtered and disinfected, and be consistent at all times with Class A reclaimed water or better.

Section 12. Ship Ballast

Reclaimed water used for ship ballast water shall be at all times Class C reclaimed water or better.

Section 13. Washing Aggregate and Making Concrete

Reclaimed water used for washing aggregate and making concrete shall be at all times Class C reclaimed water or better.

Section 14. Industrial Boiler Feed

Reclaimed water used for industrial boiler feed shall be at all times Class C reclaimed water or better.

Section 15. Industrial Cooling

(a) Reclaimed water used for industrial cooling purposes where aerosols or other mist are not created shall be at all times Class C reclaimed water or better.

(b) Reclaimed water used for industrial cooling purposes where aerosols or other mist are created shall be at all times Class A reclaimed water or better.

Section 16. Industrial Process Water

(a) Reclaimed water used as industrial process water without exposure of workers shall be at all times Class C reclaimed water or better.

(b) Reclaimed water used as industrial process water with exposure of workers shall be at all times Class A reclaimed water or better.

Article 5. Other Uses of Reclaimed Water

Section 1. Streamflow Augmentation

(a) Reclaimed water intended for beneficial reuse may be discharged for streamflow augmentation provided the reclaimed water meets the requirements of the federal water pollution control act, chapter 90.48 RCW and is incorporated within a sewer or water comprehensive plan as applicable, adopted by the applicable local government and approved by the departments of Health and Ecology as applicable.

(b) For the purposes of these standards, streamflow augmentation projects must identify a beneficial purpose that includes but is not limited to in-stream flow

Section 4. Street Cleaning

(a) Reclaimed water used for dampening brushes and street surfaces during street sweeping shall be at all times Class C reclaimed water or better.

(b) Reclaimed water used for spray washing of streets shall be at all times Class A reclaimed water or better.

Section 5. Washing of Yards, Lots, and Sidewalks on Corporation Grounds

Reclaimed water used for washing yards, lots, and sidewalks on corporation grounds under the control of responsible maintenance personnel shall be at all times Class B reclaimed water or better.

Section 6. Dust Control

Reclaimed water used for dampening unpaved roads and other surfaces for dust control shall be at all times Class C reclaimed water or better.

Section 7. Dampening of Soil for Compaction

Reclaimed water used for dampening soil for compaction at construction sites, landfills, and elsewhere shall be at all times Class C reclaimed water or better.

Section 8. Water Jetting for Consolidation of Backfill around Pipelines

Reclaimed water used for water jetting for consolidation of backfill material around pipelines for reclaimed water, sewage, storm drainage, and gas, and conduits for electricity shall be at all times Class C reclaimed water or better. Reclaimed water shall not be used for water jetting for consolidation of backfill material around pipelines for potable water.

Section 9. Fire Fighting

Reclaimed water used for fire fighting by dumping from aircraft shall be at all times Class C reclaimed water or better.

Section 10. Fire Protection

(a) Reclaimed water used for fire protection in hydrants or in sprinkler systems located in commercial or industrial facilities or buildings, hotels, or motels shall be at all times Class A reclaimed water or better.

(b) Reclaimed water may be used for fire protection in sprinkler systems located in apartment buildings and condominiums where the residents do not have access to the plumbing system for repairs or modifications.

Section 11. Toilet and Urinal Flushing

(a) Reclaimed water used to flush toilets and urinals in commercial or industrial facilities or buildings, hotels, and motels shall be at all times Class A reclaimed water or better.

(b) Reclaimed water used to flush toilets in apartment buildings and condominiums where the residents do not have access to the plumbing system for repairs or modifications shall be at all times Class A reclaimed water or better.

Section 4. Landscape Irrigation

(a) Reclaimed water used for the irrigation of restricted access areas (e.g., freeway landscapes, or other areas where the public has similar access or exposure to the reclaimed water) shall be at all times Class C reclaimed water or better.

(b) Reclaimed water used for the irrigation of open access areas (e.g., golf courses, parks, playgrounds, schoolyards, residential landscapes, or other areas where the public has similar access or exposure to the reclaimed water) shall be at all times Class A reclaimed water or better.

Article 2. Impoundments

Section 1. Landscape Impoundments

Reclaimed water used as a source of supply for a landscape impoundment shall be at all times Class C reclaimed water or better.

Section 2. Restricted Recreational Impoundments

Reclaimed water used as a source of supply for a restricted recreational impoundment shall be at all times Class B reclaimed water or better.

Section 3. Nonrestricted Recreational Impoundments

(a) Reclaimed water used as a source of supply for a nonrestricted recreational impoundment shall be at all times Class A reclaimed water or better.

(b) Reclaimed water shall not be used as a source of supply for swimming pools **unless specifically authorized by Health and Ecology under a reclaimed water permit.**

(c) Nutrient removal to reduce levels of phosphorus and/or nitrogen is recommended for reclaimed water used as a source of supply for recreational impoundments to minimize algal growths and maintain acceptable aesthetic conditions.

Section 4. Constructed Beneficial Use and Constructed Treatment Wetlands

(a) Reclaimed water discharged to constructed beneficial use wetlands and constructed treatment wetlands shall be at all times Class A or B reclaimed water or better.

(b) Wetlands created to replace natural habitat are intended to mitigate the conversion or loss of natural wetlands and are regulated as such. If acceptable to the appropriate review agencies and done according to an approved wetland mitigation plan, Class A reclaimed water may be used as a water supply for mitigation wetlands. Otherwise, the discharge of reclaimed water to mitigation wetlands is not authorized under these standards.

(c) All constructed beneficial use wetland projects and constructed treatment wetlands that are designed to receive reclaimed water (Section 4 (a)) must be incorporated within a locally adopted and State approved sewer or water comprehensive plan. Note: These planning documents may also be referred to as general sewer plans has an agency approved site control plan. Land Treatment Systems are not regulated as reclaimed water projects.

"Long-Term Storage or Disposal" means storing or disposing of untreated or partially treated wastewater for at least 20 days.

"Multiple Point Chlorination" means the application of chlorine simultaneously at the reclamation plant and subsequent chlorination stations located at the use area and/or some intermediate point. It does not include chlorine application for odor control purposes.

"Natural Wetlands" means those wetlands that occur due to natural causes other than construction by human activities. Natural wetlands are typically classified as "waters of the State."

"Nonpotable Ground Water" means ground water that is not used or intended to be used as, or is unsuitable for, a source of water supply for domestic purposes and has not been classified as an underground source of drinking water by the department.

"Multiple Units" means two or more units of a treatment process which operate in parallel and serve the same function.

"Nonrestricted Recreational Impoundment" means a body of reclaimed water in which no limitations are imposed on body-contact water sport activities. Examples may include but are not limited to: recreational lakes, public water features (ponds) and fish ponds.

"Oxidized Wastewater" means wastewater in which organic matter has been stabilized such that the biochemical oxygen demand (BOD) does not exceed 30 mg/L and the total suspended solids (TSS) do not exceed 30 mg/L, is nonputrescible, and contains dissolved oxygen.

"Peak Hourly Flow" means the average flow rate during the highest one-hour period of the day.
"Planed Groundwater Recharge Project" means any reclaimed water project designed for the purpose of recharging groundwater, via direct recharge or surface percolation.

"Potable Ground Water" means ground water that is used or intended to be used as, or is suitable for, a source of water supply for domestic purposes and has been classified as an underground source of drinking water by the department.

"Permittee" means any person to which a reclaimed water permit is issued for operation of a reclamation plant.

"Person" means any state, individual, public or private corporation, political subdivision, governmental subdivision, governmental agency, municipality, copartnership, association, firm, trust estate, or any other legal entity whatever.

"Power Source" means a source of supplying energy to operate unit processes or other individual pieces of equipment.

"Recharge Area" means an area in which there are downward components of flow in underlying ground water and infiltration moves downward into the deeper parts of the ground water.

"Category II Wetland" means wetlands that provide habitat for very sensitive or important wildlife or plants that are difficult to replace, or provide very high functional quality, particularly for wildlife habitat.

"Category III Wetland" means wetlands that provide important functions and values, but are smaller, less diverse, and/or more isolated in the landscape than Category II wetlands.

"Category IV Wetland" means wetlands that are small, isolated, and lack vegetation diversity, and may be able to be enhanced, restored, or replaced.

"Class A Reclaimed Water" means reclaimed water that, at a minimum, is at all times an oxidized, coagulated, filtered, disinfected wastewater. The wastewater shall be considered adequately disinfected if the median number of total coliform organisms in the wastewater after disinfection does not exceed 2.2 per 100 milliliters, as determined from the bacteriological results of the last 7 days for which analyses have been completed, and the number of total coliform organisms does not exceed 23 per 100 milliliters in any sample.

"Class B Reclaimed Water" means reclaimed water that, at a minimum, is at all times an oxidized, disinfected wastewater. The wastewater shall be considered adequately disinfected if the median number of total coliform organisms in the wastewater after disinfection does not exceed 2.2 per 100 milliliters, as determined from the bacteriological results of the last 7 days for which analyses have been completed, and the number of total coliform organisms does not exceed 23 per 100 milliliters in any sample.

"Class C Reclaimed Water" means reclaimed water that, at a minimum, is at all times an oxidized, disinfected wastewater. The wastewater shall be considered adequately disinfected if the median number of total coliform organisms in the wastewater after disinfection does not exceed 23 per 100 milliliters, as determined from the bacteriological results of the last 7 days for which analyses have been completed, and the number of total coliform organisms does not exceed 240 per 100 milliliters in any sample.

"Class D Reclaimed Water" means reclaimed water that, at a minimum, is at all times an oxidized, disinfected wastewater. The wastewater shall be considered adequately disinfected if the median number of total coliform organisms in the wastewater after disinfection does not exceed 240 per 100 milliliters, as determined from the bacteriological results of the last 7 days for which analyses have been completed.

"Coagulated Wastewater" means an oxidized wastewater in which colloidal and finely divided suspended matter have been destabilized and agglomerated prior to filtration by the addition of chemicals or by an equally effective method.

"Constructed Treatment Wetland" means those wetlands intentionally constructed on nonwetland sites and managed for the primary purpose of wastewater treatment or stormwater treatment. Constructed treatment wetlands are considered part of the collection and treatment system and may receive reclaimed water in accordance with the provisions of RCW 90.46 and Section 1 and 2 of these standards as applicable. Constructed Treatment Wetlands not considered "waters of the state".

"Constructed Beneficial Use Wetlands" means those wetlands intentionally constructed on nonwetland sites to produce or replace natural wetland functions and values. Constructed beneficial use wetlands are considered "waters of the state".

"Contaminant" means any chemical, physical, biological, or radiological substance that does not occur naturally or occurs at unnaturally high concentrations in ground or surface water.

INTRODUCTION

These standards have been developed under the authorization and specific requirements delineated with RCW 90.46 (Reclaimed Water). The type of uses, treatment and legal definition within the standards were developed in association with the Reuse Advisory Committee established under RCW 90.46.

Users of this document are advised that reclaimed water suitable for reuse requires significant treatment and disinfection that is generally over and above conventional waste treatment facilities. Disinfection practices for Class A , B, C, and D reclaimed water are measured in total coliform, rather than fecal coliform traditionally used to measure wastewater disinfection effectiveness. Sampling is to be performed daily and Class A and B require less than 2.2 total coliforms per 100 milliliters based on a 7 day average.

These standards require that reclaimed water must be reliably generated. Emergency storage or alternate permitted discharge locations must be provided for reclamation facilities for use during upset conditions.. The standards also require automated alarms, redundancy of treatment units and stringent operator training and certification to meet the reliability criteria.

The standards describe allowable beneficial uses, the required level of reclaimed water treatment appropriate for each beneficial use, and any specific statutory requirements from RCW 90.46. Some treatment and beneficial uses are regulated uniquely to reclaimed water projects. The key to these uses is that it specifies "Reclaimed Water" must be generated prior to the allowance for a specific beneficial use. All reclaimed water generation and use must be covered under a reclaimed water permit that is issued jointly between Ecology and Health.

Table 2.
Monitoring Requirements

Parameter	Sample Type & Frequency	Compliance Requirements
Biochemical Oxygen Demand	24-hour composite, collected at least weekly	Shall not exceed 30 mg/L determined monthly, based on the arithmetic mean of all samples collected during the month.
Total Suspended Solids	24-hour composite, collected at least daily*	Shall not exceed 30 mg/L, determined monthly, based on the arithmetic mean of all samples collected during the month.
Total Coliforms	Grab, collected at least daily	Compliance determined daily, based on the median value determined from the bacteriological results of the last 7 days for which analyses have been completed.
Turbidity	Continuous recording turbidimeter	Filtered wastewater shall not exceed an average operating turbidity of 2 NTU, determined monthly, and shall not exceed 5 NTU at any time.
Dissolved Oxygen	Grab, collected at least daily	Shall contain dissolved oxygen.

- **TSS sampling may be reduced for those projects generating Class A reclaimed water on a case by case basis by Health and Ecology.**

Appendix C

Organic Waste Management and Food Production Options at Yesler Terrace

Opportunities for a Greener Future

November 2010

by Green Solutions

Organic Waste Management and Food Production Options at Yesler Terrace

Opportunities for a Greener Future

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with assistance from Gibson Economics

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SUMMARY

INTRODUCTION

This report addresses the potential options for organic waste management and urban agricultural activities at the future Yesler Terrace site. This work was performed as part of a larger "District Study" that also included the examination of options for recycling, storm and wastewater management, energy conservation and other aspects of the future re-development of the Yesler Terrace site. The District Study expands on work performed in the past few years to address the ideal future configuration of this site.

BACKGROUND

The Yesler Terrace site is owned and managed by the Seattle Housing Authority (SHA). The SHA, established in 1939, is a public corporation governed by a seven-member Board of Commissioners. The agency owns and operates buildings on more than 400 sites throughout the city, and provides long term rental housing and rental assistance to more than 26,000 people. Since 1995 SHA has completed major public housing redevelopments of the New Holly, Rainier Vista, and High Point developments into mixed-income, mixed-tenure communities that have transformed these areas into new neighborhoods within the City of Seattle, encompassing nearly 300 acres and creating approximately 4,300 new units of housing, as well as new infrastructure, parks and community facilities. At High Point, SHA implemented an aggressive and highly successful green building and low impact development program in partnership with the Built Green program and Seattle Public Utilities.

SHA is now in Phase 2 Planning to redevelop Yesler Terrace. This 38 acre site is ideally suited to become a showcase sustainable community. It is centrally located, and lies within one mile of the city's largest employment area, containing 25% of the jobs in Seattle. SHA, in coordination with residents, neighborhood stakeholders and consultants, plans to build a dense, walkable, urban, mixed-income, and diverse community. SHA is in the process of preparing an Environmental Impact Statement (EIS) that examines several different alternatives for possible development scenarios. Each of these scenarios increases density to varying degrees. Each includes increasing the number of residential units from the existing 561, by different amounts. Each proposes varying amounts of office space and open space. This study uses one of the development scenarios, called Alternative 2, as the basis for analysis. Alternative 2 proposes 4,000 new residential units of housing using a mix of mid-rise buildings and towers of between 150 to 240 feet in height. It also proposes one million square feet of office space, five acres of open space, and underground parking.

The major goals underlying the analysis of composting and urban agriculture were to:

- adhere to the guiding principles for the redevelopment project, including promoting social equity, economic opportunity, environmental stewardship and sustainability, and one-for-one replacement of very-low-income housing.
- recommend options that are cost-effective.
- examine alternatives that look to the future, that are built to 2015 standards but that plan for 75 years out.
- take the phased approach for the development process into account.
- allow for integration with other systems.

ON-SITE COMPOSTING OPTIONS

Substantial advancements have been made recently in programs and facilities to handle food waste. In the past few years, many communities in the Pacific Northwest have added food waste to yard debris collection programs. These programs have generally included various types of food-soiled paper (paper napkins, pizza boxes, etc.), which normally can't be recycled due to the food contamination and/or quality of the paper.

The options examined for composting of the organics from Yesler Terrace included:

- on-site composting equipment;
  - Earth Tub
  - Earth Bin
  - Containerized Compost System
  - anaerobic digestion
- on-site composting of yard debris
- household composting units;
  - green cones
  - worm bins
  - compost bins

Photo courtesy of Wikipedia.

- options for collection and off-site composting;
  - use of 96-gallon carts
  - use of a drop box

The conclusions of the assessment for on-site composting options are:

- for food wastes, the use of on-site composting equipment is relatively expensive and problematic in terms of permitting and other regulations. A cart-based collection system, possibly with consolidation in drop boxes before transportation to an off-site processing facility, appears to be the most cost-effective for food waste and could handle the broadest range of materials. One strategy would be to begin with this method and as volumes become more certain and alternative technologies become more developed, other methods could be considered in the future.

- yard debris could be composted on-site using simpler and less expensive techniques, such as open windrows (piles) or a variety of bins or boxes to hold the materials while being composted.

- three-bin composting systems or other composting units should be used at the community gardens.

URBAN AGRICULTURE OPTIONS


Lettuce seedlings, photo taken May 31, 2010.

The past few years have seen a dramatic increase in the level of interest in growing food in urban areas ("urban agriculture"). This has been caused at least in part by the economic problems that are motivating more people to grow their own food, coupled with an increasingly "eco-conscious" populace. This interest is being supported by the City of Seattle and others. In February 2010, Seattle Mayor McGinn and the Seattle City Council declared 2010 to be the "Year of Urban Agriculture" and launched a campaign to promote urban agriculture and to increase community access to locally-grown food. The Seattle City Council also adopted the Local Food Initiative in 2008 to promote local and regional food sustainability. In 2008, Seattle residents showed their support for these types of efforts through the passage of the Parks and Green Spaces Levy, $2 million of which is being used to construct new community gardens. On March 20, 2010, Tacoma Mayor Strickland announced that seven city properties would be made available for new community gardens, and other cities are also taking similar steps.

Yesler Terrace residents currently have access to three community gardens at their site, and it is anticipated that some form of urban agriculture will be included in the redeveloped site. Allowing future residents to grow part of their own food will be important for a variety of reasons, including building a greater sense of community and providing a healthier diet.

The options examined for urban agriculture at Yesler Terrace included:

- community gardens
- edible landscaping
- green roofs and living walls

The conclusion of the assessment of urban agriculture options is that all of the options examined would be worth pursuing to some extent. The use of green roofs for food production suffers from a number of potential problems, but if these issues can be resolved this method also has significant potential.

SECTION ONE
WASTE GENERATION PROJECTIONS

AMOUNT OF WASTE GENERATED

The amount of organics and other wastes generated at Yesler Terrace in the future is an important factor for sizing the various composting options, especially for on-site processing systems. Using data for current waste disposal rates from the *Residential Waste Stream Composition Study* (Seattle, 2007) and for the future population (see Table 1), future amounts of organics being generated at the site can be projected.

Table 1
Projected Population of Yesler Terrace

	Number of Units	People per Household, Estimated	Number of People
Very Low Income Public Housing Units	900	2.2	1,980
Other Units[1]	3,100	1.4	4,340
Totals	4,000		6,320

Notes: Based on data from CollinsWoerman (CW, 2010a), different estimates were used for the number of people per household for very low income units versus the other units. The figure for the number of people per household for very low income units is based on existing figures (1,250 residents in 561 units at Yesler Terrace currently), and for the other units a figure slightly lower than the Seattle citywide average is assumed (the citywide average is 1.56).

1. Includes public housing units (about 950 units) and market rate units (for the balance of the 4,000 total units, or about 2,150 units).

The *Residential Waste Stream Composition Study* shows that 55,664 tons of wastes were disposed by multi-family units (defined as 5 or more units per building) in 2006. Census data for the year 2000 (OFM, 2010) shows that there were 102,146 occupied housing units (apartments and condominiums) and 155,836 residents in buildings with five or more units per building. These figures have been adjusted slightly by the OFM to fix reporting errors and other problems, and should be further adjusted to account for population growth from the year 2000 to 2006 in order to provide a population basis comparable to the year that the waste composition study was conducted. Using OFM data for the overall change in population in Seattle from 2000 to 2006 (2.7%), the adjusted figures and waste generation rates can be calculated (see Table 2).

Table 2
Total Multi-Family Population in Seattle and Waste Disposal Rates

	Based on Number of Units	**Based on Number of People**
Census 2000[1]	102,146	155,836
Population Increase	2.7%	2.7%
Estimated 2006 Population	104,900	160,100
Multi-Family Waste, Tons (2006)	55,664	55,664
Disposal Rate	0.531 tons per unit per year	0.348 tons per person per year
Future Yesler Terrace Population	4,000 units	6,320 people[2]
Projected Waste Quantity at Yesler Terrace	2,122 tons per year	2,198 tons per year
Average of Two Projections	2,160 tons per year	

Notes:
1. Census 2000 data as adjusted by the Washington Office of Financial Management, and the figure for the number of units is for occupied units only.
2. From Table 1.

The conclusion in Table 2 for the amount of waste disposed in the future at Yesler Terrace (2,160 tons per year) is the average of two different projection methods. The first projection, based on the number of units, uses census data on the total number of multi-family units in Seattle together with data from Seattle studies on the amount of waste disposed by multi-family units in the city. The second projection method uses a similar approach except that it is based on the projected number of people expected to occupy the housing units at Yesler Terrace. Both methods were used to help address differences that could be caused by different numbers of people per unit occupying the housing units at Yesler Terrace.

The projected amount of waste disposed can be applied to composition data from the *Residential Waste Stream Composition Study* to calculate the amount of various materials anticipated to be disposed at the future Yesler Terrace site (see Table 3). The figure for the amount of yard debris has been adjusted for the average amount of diversion in 2006, but other materials have not been adjusted for the amount of recycling or other diversion that was occurring in 2006.

Table 3
Projected Tons of Select Materials Generated at the Future Yesler Terrace Site

Material	Percent	Projected Tons
Organics	**39.3**	**849 (877)**
Yard Debris	3.3	71 (99 [1])
Food Waste	30.0	648
Food-Soiled Paper	6.0	130
Recyclables [2]	**25.6**	**553**
Newspaper	2.3	50
Cardboard	2.5	54
Other Recyclable Paper	8.2	177
Plastic Bottles	1.5	32
Plastic Film and Bags	4.9	106
Aluminum Cans	0.4	9
Tin Cans	0.8	17
Other Metals	2.7	58
Glass Bottles	2.3	50
Non-Recyclable Materials	**35.1**	**758**
Non-Recyclable Paper	1.0	22
Other Plastics	4.0	86
Other Glass	1.1	24
Other Materials	29.0	626
Total	**100.0**	**2,160**

Notes: Based on waste composition data for multi-family units from the *Residential Waste Stream Composition Study* (Seattle, 2007).
1. The figure for the amount of yard debris generated has been adjusted based on the average diversion rate in 2006.
2. Does not include recyclables already diverted (for a typical multi-family unit in Seattle in 2006).

The waste disposal figures shown in Table 3 should be accurate for materials such as food waste and food-soiled paper, where little of these materials were being diverted in 2006, but may be less reliable for the recyclable materials, where an unknown amount of these materials were already being diverted in 2006. The waste disposal figures and composition figures also do not account for potential differences caused by income levels and other demographic factors for Yesler Terrace residents compared to the average multi-family resident in Seattle, but this is still the best available data.

The waste composition data shown in Table 3 is also subject to both short-term and long-term trends. For instance, the economic recession suffered in the past few years has caused substantial changes in waste generation patterns. It is unknown at this point whether these changes are only temporary, but likely there will be some impact for years to come (if not permanent changes). Another change that has occurred since the waste composition data was gathered is Seattle's requirement for single-use food packaging to be compostable, which will cause a small increase in the amount of compostable paper and plastics in the waste stream.

AMOUNTS OF COMPOSTABLE MATERIALS FROM OTHER SOURCES

The other SHA properties are a potential source of organics for composting at Yesler Terrace are. The Seattle Housing Authority currently assists with housing for 26,000 people, but only owns and operates 5,200 of these units. The current Yesler Terrace property is the largest of the low-income housing properties, contributing about 1,250 residents of the 5,200. Adjusting the number of residents to remove the current Yesler Terrace population leaves 3,950 people in other SHA units. Extrapolating the results of the previous analysis for the future Yesler Terrace population (6,320 residents) to the other residents means that there is potentially another 72 tons per year of food waste, 14 tons of food-soiled paper and 60 tons of yard debris that could be collected and brought to a composting system at Yesler Terrace (or to another site).

The commercial properties planned for the future Yesler Terrace development will also generate compostable organics in the form of food waste and compostable paper from employee lunches and related activities. A small amount of yard debris may be generated from the landscaping around these buildings and also from the green roofs on these buildings. These amounts can be projected based on the anticipated number of employees and typical waste generation rates and composition data (see Table 4). The waste generation figures shown in Table 4 (for both the total amount of waste generated as well as the percentage of that waste that is yard debris) do not include materials that may be generated from green roofs.

Another potential off-site source of organics is the Harborview Medical Center, which is adjacent to the Yesler Terrace site. As with other commercial properties, the amount of organics generated at this facility can be estimated based on their number of employees, typical waste generation rates, and composition data (see Table 4). The available composition data for medical facilities (Seattle, 2008a) shows no yard debris in the waste stream from this type of facility, but likely there is some amount of yard debris generated at Harborview since this is a large facility with a significant amount of landscaping.

Table 4
On-Site and Off-Site Commercial Waste Quantities

By Source	Estimated Number of Employees	Waste Generation Rate, tons per employee per year	Annual Tons of Waste
On-Site Commercial;			
Office Space	3,337	0.23	768
Retail	83	0.93	77
Institutional	93	0.23	21
Community Center	10	0.23	2
Total	3,523		868
Harborview Medical Center	4,432	0.75	3,324
By Material	**Yard Debris**	**Food Waste**	**Food-Soiled Paper**
On-Site Commercial	3.0%, 26 tpy	28.8%, 250 tpy	13.2%, 115 tpy
Harborview	0%, 0 tpy	12.0%, 399 tpy	8.7%, 289 tpy

Notes: Waste generation rates are from the *Recycling Potential Assessment* (Seattle, 1998) and composition data is from the *Commercial & Self-Haul Waste Streams Composition Study* (Seattle, 2008a).
Tpy = tons per year.

Other sources near Yesler Terrace could potentially include restaurants, grocery stores and other residential and commercial properties. Any proposals to transfer food waste from other properties, including the other SHA properties, to a composting system at Yesler Terrace would require permits and strict controls on handling systems as well as monitoring and testing of end-use applications.

DIVERSION POTENTIAL

The figures in Tables 3 and 4 show the total amounts of materials disposed or generated. but the actual amount of material that can be collected and diverted to alternative disposal methods (the "recovery rate") will depend on several factors that have yet to be determined. These factors include the convenience of the collection system, mandatory versus voluntary participation, the range of materials accepted, and other factors.

For the food waste and compostable paper from the housing units, the recovery rates will probably only be 10 to 25% at best for a system based on voluntary participation. This is due to the inconvenience of carrying messy materials such as food waste to the proper disposal containers, plus the odors and other problems associated with collecting food waste separately. The recovery rate for food waste from commercial units may be in the same range (it could also be lower, but the food waste will likely be generated in centralized areas and that will help with the recovery rate). For yard debris, the anticipated recovery rate is higher (90 to 95%) because the yard debris will be generated in fewer locations, primarily outside and potentially close to containers dedicated to this material. In addition, there is a regulatory incentive to separate this material since it is banned from disposal.

RECOVERABLE AMOUNTS

Table 5 applies the estimated recovery rates to the amounts of organics generated on-site to project the amounts that may be available for a composting system at the future Yesler Terrace site. Also shown in Table 5 are the densities of the volumes of the available materials, which have been calculated using typical density figures for each type of material (GS, 1997). Table 6 provides a summary of the results arranged by type of material rather than by source.

PROJECTED AMOUNT OF COMPOST PRODUCED

The process of composting reduces both the weight and volume of the incoming materials. The actual weight (or mass) of the finished product may only be 50% of the original weight due to the breakdown of the organic materials and subsequent releases of water, carbon dioxide and other gases. The volume is reduced by this loss of mass as well as by densification (which occurs through physical processing steps such as grinding as well as microbial degradation). The loss of mass and higher densities together often result in a finished product that has only one-sixth of the volume of the raw materials. Using this rule of thumb, a composting system that uses only on-site residential and commercial organics (yard debris, food waste and food-soiled paper) from the future Yesler Terrace site could produce approximately 330 cubic yards of compost (based on the mid-range recovery rates and other figures shown in Table 5). For the yard debris only, approximately 128 cubic yards of compost could be produced from on-site sources.

Transferring or selling surplus compost for off-site applications would likely require a variety of permits along with additional testing and monitoring of the composting process and end-products. Even for composted yard debris alone, which is exempted from permitting requirements for amounts up to 250 cubic yards (the amount that is on-

Table 5
Potential Quantities of Recoverable Organics from On-Site Sources

Source	Annual Tons	Potential Recovery Rate	Available Tons	Density, pounds per cubic yard	Annual Volume, cubic yards
On-Site Residential;					
Yard Debris	99	90-95%	89-94	300	596-629
Food Waste	660	10-25%	66-165	500	264-660
Food-Soiled Paper	129	10-25%	13-32	150	172-431
All Organics	888		168-292		1,032-1,719
On-Site Commercial;					
Yard Debris	26	90-95%	23-25	300	156-165
Food Waste	250	10-25%	25-63	500	100-250
Food-Soiled Paper	115	10-25%	11-29	150	153-382
All Organics	391		60-116		409-797
On-Site Totals;					
Yard Debris	125	90-95%	113-119	300	752-794
Food Waste	910	10-25%	91-227	500	364-910
Food-Soiled Paper	224	10-25%	24-61	150	325-813
All Organics	1,279		228-408 tons per year		1,441-2,517 yards per year
			0.6 – 1.1 tons per day		3.9 – 6.9 yards per day

Table 6
Summary of Recoverable Amounts of On-Site Organics

Source	Yard Debris		Food Waste		Food-Soiled Paper	
	TPY	C.Y.	TPY	C.Y.	TPY	C.Y.
On-Site Residential	89-94	596-629	66-165	264-660	13-32	172-431
On-Site Commercial	23-25	156-165	25-63	100-250	11-29	153-382
Totals	**113-119**	**752-794**	**91-227**	**364-910**	**24-61**	**325-813**
			Total food waste and paper = 115-288 TPY, or 689-1,723 CY per year (1.9-4.7 CY per day)			

Notes: All figures are from Table 5.
TPY = tons per year, CY = cubic yards per year.

site at any one point in time), annual testing for metals and several other parameters would be required if materials were distributed off-site.

POTENTIAL AMOUNT OF ON-SITE COMPOST USAGE

Compost can be used at Yesler Terrace in several ways, but primarily for:

- community gardens and other urban agriculture activities
- ornamental landscaping
- top dressing on lawns (or for preparing disturbed areas for planting new lawns)

The community gardens and other urban agricultural activities would likely represent the largest long-term demand. Other applications may be significant but temporary, such as restoring topsoil after construction activities. The phased approach for re-development of the site could lend itself well to the use of compost on each newly-developed area for several years to come.

The amount of compost needed for the community gardens and related urban agriculture is difficult to predict without firm plans as to the size and scope of these activities, and without knowing the soil types to which the compost would be applied. Typically, about two inches of compost should be applied in the spring to garden areas that have an average soil and that are tilled 6 inches deep. More compost can be applied to soils that are heavier in clay or sand, or that are being tilled to deeper depths. For a nominally-sized community garden that contains 20 plots that are 10′ by 10′, a 2″ layer of compost applied once annually would require 12.3 cubic yards of compost (or 6.2 tons of compost at 1,000 pounds per cubic yard). As discussed above, the future Yesler Terrace site could produce up to 330 cubic yards (160 tons) of compost just from the on-site sources of organics (128 cubic yards or 58 tons from yard waste alone). In other words, significantly more compost could be produced at Yesler Terrace than could be used on-site.

Some of the organics produced at Yesler Terrace will be brushy material that could be chipped instead of being composted, as is currently being by the GroundUp program, and then the chips could be used on paths in the community gardens and other areas. Depending on the type of composting system that might be used, wood chips may or may not be a beneficial addition to the process.

SECTION TWO
COMPOSTING OPTIONS

INTRODUCTION

This section explores composting options for organics (food waste, yard debris and food-soiled paper) at the future Yesler Terrace site. The methods reviewed below include options for collection programs, small scale units that could be used by one or a few households, and options for on-site systems that can serve the entire complex.

The first step for any of the composting options is to keep food waste and other organics separate from non-compostable wastes. This is easier to do with yard debris, which is generally produced outside as a separate material by a small group of people (primarily maintenance staff), and in fact yard debris is currently collected separately at Yesler Terrace. Food waste collection programs, on the other hand, require the involvement of all of the residents (and employees, in the case of the commercial buildings to be built at the site), who need to keep their compostable organics separate from other wastes. This will require education and promotion of the program, as well as convenient alternatives for food waste collection (such as small collection containers in the housing units and collection carts located near waste disposal containers).

Education and promotion will need to overcome potential objections from the participants, including:

- they do not want to separate their food waste.
- they do not understand what to separate.
- they have not received or do not understand communications on the project.
- the "ick" factor makes participants uninterested in handling food waste separately.
- the threat of bugs and insects in their homes.
- they do not seeing anyone else doing it (lack of peer pressure).

Education and promotion can be accomplished using messages in billing inserts, flyers for individual units and for community center, a website and other means. The messages need to be available in several languages to reach the diverse community at Yesler Terrace. It also makes sense to work with the City of Seattle on educational activities, as they have already developed educational and promotional materials.

Food-soiled paper is generally included in programs that handle food waste, including materials such as paper towels, pizza boxes and other types of paper. These types of paper generally cannot be recycled, either due to food contamination (in the case of pizza boxes) or due to the low grade of paper fibers used to make the product originally (in the case of paper towels), so composting is usually the best available option for these materials. Food-soiled paper does not work in some of the following options, meaning that a variety of methods may need to be used for maximum diversion.

The rest of this section discusses on-site composting options first, followed by options for collection and transportation of the organics to off-site processing facilities. The cost of collection carts is discussed under the latter set of options (transportation to off-site processing facilities), but it should be kept in mind that on-site composting systems will also require carts or another system to collect the organics separately.

ON-SITE CENTRALIZED COMPOSTING FOR FOOD WASTE

Types of Composting Equipment

Composting equipment allows the primary processes to occur inside an enclosed structure or reactor used to contain the material being processed and in which the various critical process parameters can be controlled. In a recent review of these types of systems (Biocycle, 2007), several vendors were identified as having system that could handle food waste (including NaturTech, Hot Rot, Siemens/iPS, Transform, and Green Mountain Technologies). The smallest unit identified is produced by Green Mountain Technologies at 7.5' in diameter by 4' high. More detailed information is available from the manufacturers' web pages (see Attachment A).

The types of on-site composting units reviewed below include:

- Earth Tubs
- Earth Bins
- Containerized Compost System
- anaerobic digesters

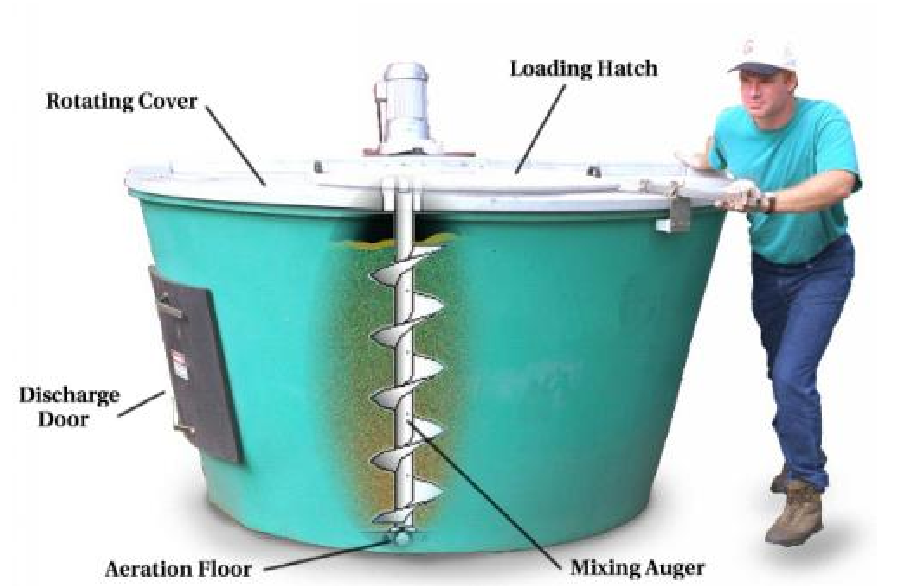
These units include mixing in some cases but not through the use of rotary digesters. Rotary digesters have a metallic barrel or drum where bacterial digestion takes place in both aerobic and anaerobic conditions. Most drum systems include blowers to maintain aerobic conditions and avoid excessive temperatures. There is a trend toward smaller rotating drums, which allows development of systems that can process five to 20 tons per day in a unit that is four to eight feet in diameter and 15 to 50 feet long. Further development along these lines may allow these types of units to serve Yesler Terrace's needs in the future, but there are currently too many questions about costs and capabilities to include these systems in the following review.

Earth Tub

The Earth Tub is designed for on-site composting of food wastes. These units can also handle yard debris and small amounts of food-soiled paper, sawdust and other materials, but yard debris can be processed through less expensive methods instead. The Earth Tub is a fully enclosed composting vessel with power mixing and aeration. To operate, organic materials are loaded through the top and then mixed. During active composting, the Earth Tub should be mixed at least two times per week. Liquids are collected and disposed to a sanitary sewer or holding tank. Heat generated in the tub rapidly breaks down the food scraps. After three to four weeks of composting, the compost is removed and held for 20 to 40 days for further stabilization.

The base price of one Earth Tub is about $10,000. With options such as a temperature probe, biofilter, and motors for sites that lack 3-phase power, the total cost would be about $12,000 (not including shipping and installation costs).

The Earth Tub is about 7.5' in diameter and 4' high. It would require a minimum floor space of 12' by 12' per unit.



Earth Tub, photo courtesy of Green Mountain Technologies.

Facilities using the Earth Tub include universities, food banks, hotels, and businesses. Washington locations using Earth Tubs include:

- Bastyr University, Kenmore
- Bernie & Boys Market, White Center
- Main Market Co-op, Spokane
- Edgewood Garden, Edgewood
- Willows Lodge, Woodinville
- Island Wood School, Bainbridge Island

Further details about two Earth Tub installations are provided below.

California Grey Bears – the Grey Bears is a non-profit that distributes food to seniors and the disabled through a Brown Bag Program. Each year, Grey Bears provides over 100,000 "Brown Bags" of recovered food to seniors and people with disabilities. Each week, approximately one ton of the food that is collected is discarded, primarily due to deterioration. Two Earth Tubs are used to compost discards from the Brown Bag Program as well as food scraps and biodegradable table service from the Grey Bears' annual Holiday Dinner.

The annual labor cost for this facility is only $780 because the operation is run primarily by volunteers[1]. One supervisor spends less than one hour per week to oversee the project, and volunteers provide approximately 4 to 5 hours per week. Equipment and installation costs were $17,802 for two Earth tubs, a cement pad, and electrical and sewer connections.

Thurston County – two Thurston County schools have set up on-site Earth Tubs. The County bought three Earth Tubs for $29,251 with grant funds. The on-site operation is very labor-intensive as they mix daily or after fresh material is added. They feel this approach works for schools with 200 students or less, and when harvested quite often. At a school with 400 students, for instance, they need to harvest on weekends. The issues and tasks outlined by Thurston County include: curing, odor, piping, drainage, shelter, security, and management of staff. The County recommends a hard-line drainage line, shelter and a cage for the unit. The County removed one tub due to the school's inability to maintain it, and it will soon to be installed at a community college. In general, however, the County does not recommend Earth Tubs for schools (Ruppenthal, 2010).

Additional design considerations for Earth Tubs: The following factors should be considered for Earth Tubs:

capacity – for on-site composting, one Earth Tub is capable of processing as little as 40 pounds per day or as much as 500 pounds per day. The modular design of the system allows it to be adapted to a wide variety of applications and configurations. Each unit holds about 3,200 pounds when full. Although materials can be added daily to the Earth Tub, once it is full the contents should be allowed to compost for two to four weeks. Thus, at least two Earth Tubs are recommended, so that food waste can be added to the second one while the first one is being processed.

[1] Labor costs would be significant without volunteers to run the Earth Tub. Up to 60 minutes per day could be required to load the units, mix the contents (when adding fresh materials or a few times per week when it's fully loaded), and to remove composted materials at the end of the composting cycle.

For Yesler Terrace, capacity requirements can be calculated based on the figures shown in Table 5. A single Earth Tub can process up to 26 tons per year, but in the future Yesler Terrace will generate 91 to 227 tons per year of just food waste from on-site sources only. This means that four to nine Earth Tubs may be needed to handle the food waste from on-site sources (and these would also generate significantly more compost than could be used on-site).

cost – at an installed cost of about $15,000 and a capacity of 26 tons per year, the capital cost would be $58 per ton (amortized over ten years using straight line depreciation) for a single Earth Tubs. Labor and other annual expenses would add significantly to this figure. The total capital cost for the number of Earth Bins that may be needed (four to nine Earth Tubs) would be $60,000 to $135,000.

Earth Bin


Earth Bin, photo courtesy of Green Mountain Technologies.

The Earth Bin is an automated version of the Earth Tub with a much larger capacity. The Earth Bin is designed for use in suburban/urban settings where large acreage is not readily available. The decomposition process takes place in a covered bin, and an operator can start the unit from an exterior control panel. The control panel allows the operator to select number of times per day that the compost is mixed. To operate, food scraps are loaded into it and then mixed (mixing takes 30 minutes and should be performed at least two times per week). The contents also need to be mixed at least once per week during the active compost phase. Active composting takes three to four weeks and then the compost is cured for 30 to 60 days.

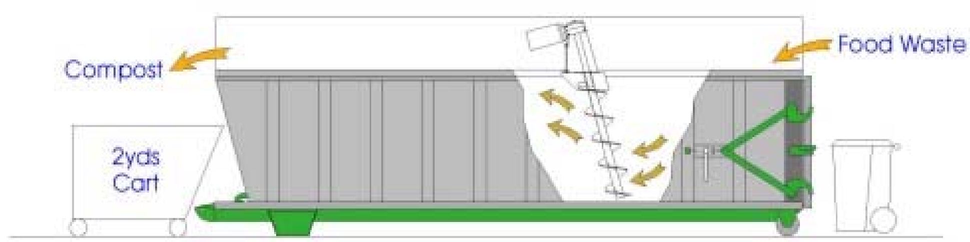


Diagram of Earth Bin, courtesy of Green Mountain Technologies.

An Earth Bin was recently installed at the Helmer Nature Center in North Carolina, and that Earth Bin can handle up to one to two tons per day. The Helmer Nature Center feels that the composting process allows the district to responsibly manage their waste, and it provides the district with their own source of compost for lawns (as a top dressing) and gardens (as a soil amendment). In addition, the project allows the nature center to provide environmental leadership to the community.

The Earth Bin at the Helmer Nature Center measures 24′ long by 7.5′wide by 8.5′ tall, and it is recessed in the ground. The enclosure surrounding the new compost area is less than 7,000 square feet, or about one-seventh of an acre. This enclosure houses the Earth Bin, piles of leaves awaiting composting, and finished compost and mulch that is stored temporarily before use. The approximate cost of this unit was $282,830, which included the cost of the bin, site work and design fees (Helmer Nature Center, 2009).

Additional design considerations for Earth Bins: The following factors should be considered for Earth Bins:

capacity – an Earth Bin with a 30-yard capacity measures 24′ long by 8′ 3″ wide by 7′ 6″ tall. Its processing capacity is up to two tons per day.

cost – at an installed cost of about $300,000 to handle 200 tons of food waste and other materials per year (the mid-range value for food waste from on-site sources at Yesler Terrace plus a small amount of food-soiled paper and other materials), the capital cost for an Earth Bin would be $100 per ton (amortized over fifteen[2] years using straight line depreciation). Labor and other annual expenses would add significantly to this figure.

Containerized Compost System

The Containerized Compost System is a modular design for composting. Composting takes place in one or more large (roll-off) containers. Composting in roll-off containers allows flexibility in system design and operation. The composting is conducted in batches in containers can be moved and emptied by roll-off trucks (such as are used for large

Containerized Compost System, photo courtesy of Green Mountain Technologies.

[2] According the manufacturer, the appropriate amortization period for an Earth Bin should be 15 or more years, since the units are built of stainless steel and thus would be resistant to corrosion.

garbage containers). The containers used for composting are airtight and constructed of stainless steel. Two sizes are available, with either 40 or 50 cubic yards of composting capacity. Labor requirements are kept to a minimum by using conveyors and other equipment.

Containerized composting units can compost from 1 to 100 tons per day. There is no standard cost information available for these units because each installation is specifically tailored to a facility.

Anaerobic Digester

An "anaerobic digester" means a vessel that processes organic material into biogas and "digestates" using microorganisms in a decomposition process within a closed, oxygen-free container. Anaerobic digestion has been used for years to process wastewater and sewage. Materials placed in an anaerobic digester are generally in the form of a slurry, but one type of anaerobic digestion, high solids anaerobic digestion, is better suited to food waste (Waste Age, 2010). In any case, naturally-occurring microorganisms break down the waste into methane and carbon dioxide, which are captured in airtight enclosures. The biogas can be combusted to produce renewable electricity, cleaned to pipeline natural gas standards, or further processes into compressed natural gas.

Photo courtesy of Qualco Energy, near Monroe, Washington. Qualco Energy is turning digested dairy manure solids into power for homes and businesses in the Pacific Northwest.

In a recent article reviewing various composting technologies, the use of anaerobic digestion was noted as requiring large volumes. “In our increasingly carbon-constrained world, there’s no doubt that anaerobic digestion, as a means of generating methane, deserves attention. However, anaerobic digestion has a fairly high economy of scale, which is around 50,000 tons per year” (Resource Recycling, 2010).

In the Pacific Northwest, anaerobic digesters are located on dairy farms with large acreages and a steady supply of manure. Since these digesters sometimes need drier materials to mix with their manure, it may be possible to work with farmers who could digest the food waste from Yesler Terrace.

Additional design considerations for anaerobic digesters: The following factors should be considered for anaerobic digesters:

capacity – anaerobic digesters typically operate with a steady supply of a fairly homogeneous waste stream, and at much larger volumes than the amount of food waste that will be generated at Yesler Terrace. Small-scale anaerobic digesters are not available at this time and this may not be a technology that can be scaled down easily.

costs – a large capital investment is needed to construct an anaerobic digester.

phased development – an anaerobic digester could not be easily started as a pilot project and then expanded to fit the needs of the community.

management issues – while anaerobic digestion serves to produce energy, materials that go though a digester must still be composted.

siting considerations – the current types of anaerobic digesters require a substantial amount of space for the digester (although that part can be underground) and related equipment and operations (such as composting the solids and then screening and curing the compost). The space for these operations easily requires a few acres for the current equipment and scale of operations in use.

The materials coming out of an anaerobic digester will still need to be composted and highly odorous at that point.

General Factors for On-Site Composting Equipment

Regulations: Information received from the Seattle-King County Department of Public Health (Lasby, 2010) is that off-site sources of organics, and/or off-site applications of the finished products would require a solid waste permit from them. In addition, a permit may be needed from the Puget Sound Clean Air Agency, and testing the products and possibly other approvals may be required depending on the exact activities being proposed. Handling food waste only from on-site sources would still require a solid waste permit due to the large volumes involved. In other words, composting the volumes of organics being projected from on-site sources at Yesler Terrace, or other sources, would cause the composting operation at Yesler Terrace to be permitted much like a larger facility (such as Cedar Grove). Likewise, moving the finished product off-site, even if only used on other SHA properties, would require the product to be tested and may require permits and approvals.

Additional design considerations for on-site composting equipment options: The following factors are relevant to all types of on-site composting equipment:

management issues – on-site composting units would likely need to be owned and operated by SHA, but in general these are very labor-intensive. Other projects rely heavily on volunteer labor and even with that are not cost-effective in most cases. On the other hand, this is a project that could potentially use a group like GroundUp, where local jobs are created in the process with the additional benefits related to that.

longevity – the primary cost associated with on-site composting units is for equipment with no moving parts (the container) and site development. With a reasonable amount of care, the main parts of an on-site composting unit should have lifespans in the range of 15-20 years. The small amount of moving parts (mixing augers and motors) will need more frequent repair and replacement.

phased development – some of the smaller units lend themselves well to the phased development and decentralized approach anticipated at Yesler Terrace. The larger units (the containerized compost unit and anaerobic digesters) do not work well for the phased development schedule.

integration potential – the on-site composting units may need to have water added to facilitate the composting process for food waste, especially for anaerobic digestion where normally the wastes being handled are in liquid form. Grey water would be a good source in this case.

ON-SITE COMPOSTING OF YARD DEBRIS

Yard debris can typically be composted using a variety of simple methods. Although yard debris could also be included to varying degrees in the composting equipment reviewed above, the approaches generally used for yard debris are much less expensive.

Yard debris composting typically employ the following steps:

- **grinding** – this step may be necessary only for brushy/woody materials.
- **piling** – yard debris is typically placed in long piles called windrows for composting. Ideally, these windrows would include forced aeration, but the composting process will occur without this (albeit at a slower rate).
- **turning** – the windrows should be turned and mixed periodically, adding water at that time if necessary.
- **screening and finishing** – the finished compost needs to be screened, with the over-sized materials returned to the active composting piles and the finished material piled and allowed to mature while awaiting application.

This process may need to be conducted under the cover of a roofed area and on an asphalt pad. Another alternative is to place the materials into long bags or to cover the piles while being composted (such as Cedar Grove does with their Gore-Tex approach, although they are the only company licensed in this area to use Gore-Tex). Either of these approaches would require forced aeration to provide sufficient oxygen to the materials being composted.

Composting yard debris by these types of simple approaches will require longer composting periods, up to one year or more depending on the amount of turning and level of other efforts that are conducted. The length of the composting process will also depend on the types of materials being composted, the ratio of carbon and nitrogen in the mixture, moisture content and other factors.

Composting only yard debris is exempt from permitting requirements in many cases, such as small piles used at single-family homes, but at Yesler Terrace the composting operation would need to maintain less than 250 cubic yards on-site at any one time to be exempt from solid waste permitting requirements (Lasby, 2010). Although at first glance this would appear to be a problem for Yesler Terrace, with projected quantities of 752 to 794 cubic yards of yard debris per year, the volume reductions caused by the composting process should allow this limit to be met as long as the finished materials are not stockpiled for too long of a time. Since composting only the yard debris would still generate more compost than could be used on-site and a portion of the material would need to be transferred to off-site applications, an annual analysis and report would be required by State law (per WAC 173-350-220 (c)).

Additional design considerations for on-site composting of yard debris:

cost – the relatively simple methods used for composting yard debris have a lower cost than the equipment used for food waste and other materials. In one case, this type of composting cost about $26 per ton of material but this cost was far outweighed by benefits that included avoided disposal costs and reduced greenhouse gas emissions, altogether which were valued at $81 per ton (Biocycle, 2009).

management issues – the on-site composting process will need to be managed by SHA, or by a group such as GroundUp under contract to SHA.

Composting up to 790 cubic yards per year of yard debris on-site will require a minimum space of 10,000 square feet, or 0.23 acres.

longevity – some heavy equipment will be needed to make and turn windrows and screen the finished products, and this equipment will need to be replaced periodically. Other than the heavy equipment, there should be no significant longevity issues.

phased development – this type of system could be started now and could be continued throughout the development process, even if it needed to be relocated at some point in that process.

integration potential – the composting system may need to have water added to facilitate the composting process. Grey water could be a good source in this case.

ON-SITE HOUSEHOLD COMPOSTING UNITS

A variety of composting units are available for residential use that could also be used by apartment dwellers. The different types of household composting units include:

- green cones
- worm bins
- compost bins (single and three-bin)

In general, these approaches are easier to use at single-family homes than at multi-family units. There my, however, be limited applications where these could be used, such as at the community gardens, and so all three are reviewed below. In addition, if these are used by individual households, the commitment level is generally higher and this can result in greater participation. These units could also be shared by several families or by each apartment building. A clear benefit to the residents of managing their own compost bin is they personally reap the benefits of the compost as well as sense of ownership in handling their food waste. There is also quick feedback as the proper way to use the units and an incentive to use it correctly. The finished compost could be used by tenants on houseplants, plants they're growing on balconies, or on edible landscaping plants. Training and public education about the use of the compost units (especially for new tenants) would prove beneficial to owners as well as tenants.

Green Cones: green cones are a user-friendly way to compost food scraps. They are one of the simplest ways to keep food scraps out of the garbage, conserve resources and improve garden soil. Their use at Yesler Terrace is problematic since an outdoor area would be needed for each cone, but it might be useful to have a few of these at community gardens and on roofs used for food production.

Green cone at Good Shepard Community Garden, photo taken March 31, 2010.

Green cones are often placed in the central area of a garden, away from fences, woodpiles and bushes if possible, with the cone buried halfway in the ground. Food waste is dumped in the top and then the lid is closed. After six months, compost can be harvested from the bottom of the cone.

Worm Bins: Worm bins are boxes filled with moistened "bedding" (brown leaves, sawdust, and shredded paper). Red worms and food waste are added, and the worms will turn the food waste into a high-quality compost (vermicompost). Worm compost is rich in nutrients, so it takes less of this type of compost than other composts to achieve the same results in gardens.

Worm bins can be purchased locally at some nurseries and garden centers, or can be made from scrap lumber or a large plastic tub. The cost of the wooden worm bins could be up to $80, and plastic worm bins range from $30 to $60. Worm bins are designed to handle food waste from a single family, so several of these would be needed if used for the entire complex or individual boxes could be used on balconies or at the community gardens. More information about worm bins can be found at http://your.kingcounty.gov/solidwaste/garbage-recycling/documents/ez-wormbin_guide.pdf (King County, 2010a).

Worm bins need regular attention (labor) to maintain the proper amount of wet food and keep it sufficiently moist. Food waste can be added regularly and can be buried in the bedding to reduce flies and odors. The finished compost will need to be periodically "harvested."

Some effort would also be required to distribute bins and educate users. This program requires the user to understand and apply the techniques of vermicomposting, for this program to be a success. This education could be offered on a voluntary basis. Worms bins could be provided to those who attend a training, and this program could be expanded as the interest grows.


Worm bin, photo courtesy of Seattle Public Utilities website.

This type of composting would not require a permit from the Seattle-King County Department of Public Health.

If worm bins are set up for an entire apartment building, the management might need to oversee the worm bin or find a responsible volunteer. Worm bins that are open to a larger group of people can easily get overfilled or suffer other problems. In the 1990's, Evergreen College piloted a very large bin, one yard wide and over 20 feet in length to compost kitchen scraps from the University. It was used for several years before it was discontinued due to problems with odor, insects and excessive dampness. The general rule in worm compost bins is "small is better."

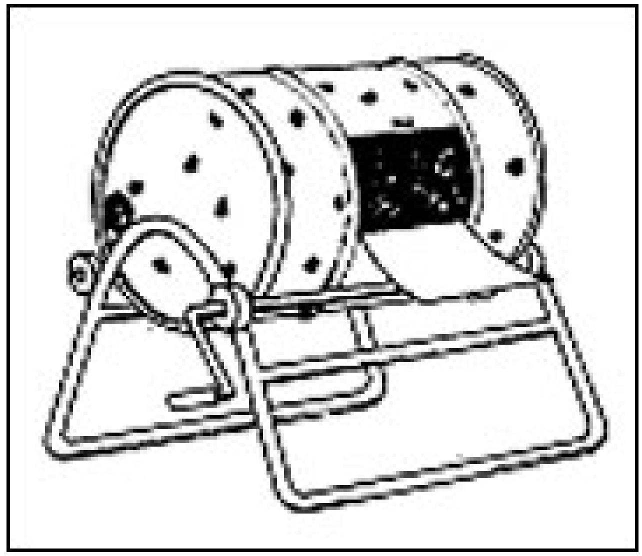
Operating a worm bin requires little water so there is little integration potential for other systems on-site, but a worm bin could be integrated into the community gardens. A worm bin could be part of a demonstration site at the garden or provided for use by the gardeners. Children are especially interested in looking for the red worms. It would be a good example for gardeners to get in the habits of throwing food waste in the worm bin for them to compost. The gardeners can also reap the benefits of the compost that is harvested after two or three months.


Photo courtesy of www.composters.com.

Compost Bins: Composting bins neatly contain composting materials, ward off animals and keep in moisture for efficient decomposition. Many types are available in stores, mail-order catalogs and online. They can also be made from wood pallets, wire fencing, cement blocks or other recycled materials. Compost bins that will include food waste need to be enclosed and rodent-proof.

There are several models of compost bins that could be used at Yesler Terrace. A stacking unit is shown in the accompanying picture. This particular unit eases the chore of mixing the compost because it is made up of several levels that are interchangeable and can be placed on the bottom or the top. When turning over the contents, the top one or two levels can be removed and used to create the base of a new unit. As materials are transferred from the old unit to the new unit, turning and mixing them in the process, additional levels can be moved to the new composting unit.

Another model involves a small rotating drum. Turning systems are designed for quick, hot composting to handle large amounts of material.



Turning compost bin, photo courtesy of University of Missouri Extension website.

King County Solid Waste Division has produced a guide on "How to Choose A Compost Bin." This document outlines tips for successful composting such as chopping and shredding materials, and mixing in water and air. They also describe what yard waste bins should have such as vents, large lids, and be light enough for a person to move. They give some pointers on how many bins may be needed, what size of bin and what to compost. More information about how to choose a compost bin can be found at: http://your.kingcounty.gov/solidwaste/naturalyardcare/documents/Binguide.pdf (King County, 2010b).

Three-Bin System: A wood and wire three-bin unit can be used to compost yard, garden and kitchen wastes. This type of composting unit is simple to operate. When the first bin is full, its contents can be transferred to the second bin and eventually to the third bin for final decomposition, or the bins can be filled sequentially.

Three-bin compost unit at Good Shepard Community Garden, photo taken March 31, 2010.

The cost of a three-bin unit would range from $20 to $230, or it can be built with scrap materials using basic tools and carpentry skills. Toronto sold three-bin compost units designed to include food waste for $150. The bins were made of rat-proof 16-20 gauge hardware cloth, cedar and corrugated fiberglass. They estimated that the device's 81 cubic feet of capacity could accept food waste from as many as 75 households.

It would be worthwhile to place a three-bin composting unit, or a variety of units, at the community gardens. Gardeners will find these to be a handy place to compost vegetable trimmings and garden debris, and it would also be convenient to mix the compost back into the community gardens once it is finished. It should be possible to maintain the compost bins with volunteer labor (to prevent dryness and encourage continual use, one gardener might be in charge of mixing and adding water periodically). The primary management concern for a compost unit at the community garden is if the compost is not maintained, the organic materials may not break down very quickly and may create odor and pest problems.

This method of on-site composting could require a small amount of water, which could be collected rainwater or possibly grey water.

Programs in other communities:

San Francisco, CA - Implemented " How to Compost at Multi-family Homes: 6 Easy Steps for Building Manager", posted in Composting by Tulip on January 21, 2010. http://blog.recology.com/2010/01/21/how-to-compost-at-multi-family.

Auburn, WA - In 2004, purchased in home food containers for $6.33 per unit for 4,900 residents in the City of Auburn.

Ontario, Canada - Implemented a multi- tenant program and reported it in the Recycling Council of Ontario. Their implementation relied heavily on volunteers. On-site composting was less successful at high-rise buildings, where tenants typically dispose of garbage in a chute, and where a convenient way to collect food waste remains a major challenge. Saving money was the motivation for composting at a condominium complex in Waterloo. The condo corporation received two three-bin composters through a demonstration project. After a year of composting and recycling, they cut their garbage dumpster size in half and saved money. The composting is so successful, there's now a waiting list for composting units in Metro Toronto (RCO, 2010).

Additional design considerations for household composting options: The following factors are relevant to all types of on-site composting:

management issues – management of household composting units should be minimal, since the residents will managing their own units. Management tasks will include training residents, purchase and distribution of bins, arranging replacements, dispute resolution and minor other tasks.

regulation – household composting units are generally exempt from any type of permit requirements, although strictly speaking that exemption applies only to single-family residences or small multi-family dwellings (containing at most five units). Even so, it is not likely that solid waste permitting requirements would be applied to household composting units used by one or a few multi-family dwellers or at a community garden.

longevity – with reasonable care, the composting units should last for at least 5 to 10 years, although accidents and vandalism will likely require a regular replacement schedule.

phased development – any of these options could easily be phased in. A pilot project may clarify which type of composting units the residents prefer.

integration potential – the household composting units could integrate very well with the urban agriculture options.

OFF-SITE COMPOSTING OPTIONS

Food waste collection programs typically combine the food waste (and food-soiled paper) with an existing yard debris collection program for curbside collection from single-family homes. This approach also makes sense at Yesler Terrace for most of the possible composting options.

Food Waste Collected in Carts and Hauled Off-Site: When implementing a food scrap collection program, decisions could include the desired collection method, frequency, types of carts, use of in-home containers or liners, and program education and promotion. The Seattle Housing Authority conducts their own collections, but the City of Seattle program can be used as a guide for this program. In the City of Seattle, food waste is collected in yard waste carts that are either 64 or 96-gallons and hauled to Cedar Grove. The yard waste carts are collected weekly on the same day as garbage. Fruit and vegetables, yard trimmings, meat, dairy, and fish are all accepted in the yard debris cart. Only compostable bags that are approved by the composting facility are accepted in the cart.

Some apartment buildings in the U.S. have garbage chutes that are used to dispose of the trash from upper floors into a container in a basement or underground parking garage. While studies have not been conducted on the practicality of using chutes to move only food waste, this may be a worthwhile possibility to explore for the future apartment units at Yesler Terrace. The ease of use would be an incentive for the residents to participate.

> The Seattle Public Utilities conducted a pilot project for apartment food waste collection at seven sites: Epicenter, Amesbury Court, Imperial Crown, Guinevere, Bagley Lofts Condominiums, and Chameleon. Their methods and success are displayed at: http://www.seattle.gov/util/stellent/groups/public/documents/webcontent/spu02_013901.pdf (Seattle, 2008b).

The cost for large quantities of 96-gallon carts is $70 to $90 per cart. Smaller food waste containers for use by individual households can be purchased wholesale for $7 to $12 per unit. Using Seattle's program and costs as a guide, city staff recommend the use of one 96-gallon cart per 60 to 150 housing units, or about 26 carts for the 4,000 units at the future Yesler Terrace site. This number of carts could only handle the lower end of the range of projected recovery amounts (689 cubic yards, see Table 6)[3]. At Seattle's current rate for servicing those carts ($7.85 per month), the total cost for this approach would be $2,450 per year.

Drop Box Collection: Another option would be to use a central container for food waste collection at Yesler Terrace, such as a drop box or roll-off container. The drop box would be hauled to Cedar Grove or another off-site processing facility as needed (when full). Smaller (96-gallon) carts would still be needed at each apartment building to provide convenient collection points for the residents. The benefit to SHA is that rather than using a truck to collect from each building and then potentially having to drive a partially-full truck to a processing facility, a smaller vehicle could be used on-site to collect from the carts and consolidate those in the drop box. This system would also be more flexible, in that collection carts could be emptied more often if necessary. There may, however, be odor and regulatory issues with storing food waste even for a short time in an open drop box.

The capacity of the drop box system could easily be adjusted to usage. Capacity could expand or decrease as needed by changing the frequency of pickup for carts and the drop box, by changing the drop box size, or through the use of additional containers. This flexibility means that this program could easily begin with a pilot project and then be extended as volumes increase.

The Beyond Recycling Study:

A report, *Beyond Recycling: Composting Food Scraps and Soiled Paper*, examines data from 121 residential organics programs in the U.S. and Canada. This study focused on the economics of various opinions for organics collection and processing, the connections among the various program components, operational implications of the volume of materials and categories that are collected, and changes needed to increase composting capacity across North America.

This study found that about one-third of the 121 programs surveyed were collecting food scraps separately, and the rest collected food and yard debris together.

The key finding of the study was that if all putrescibles are collected, in addition to recycling, residential garbage collection could be reduced to once every two weeks or even once a month. The costs saved from less frequent rubbish collection could offset the additional costs of processing the extra categories of organics. The *Beyond Recycling* report can be seen at www.beyondrecycling.org (Anderson, Liss and Sherman, 2009).

[3] 26 96-gallon carts would provide a maximum of 12.4 cubic yards of collection volume. Picked up weekly, these 26 carts would provide a maximum of 643 cubic yards of collection capacity per year, which is slightly less than the projected 689 cubic yards of food waste and food-soiled paper that would be recovered at the 10% recovery level.

The primary costs for this alternative are the carts, the labor and equipment for emptying the carts, and outreach and promotion cost.

Additional design considerations for off-site composting options:

management issues – management issues for these approaches should be minimal and would be similar to garbage collection, except that additional education of residents would be needed to maximize compliance with collection guidelines.

regulation – collecting food waste and other organics for transfer to off-site processing systems does not require permits.

longevity – beyond the occasional need to repair or replace carts and other equipment, there are no significant longevity issues with these options.

phased development – these options can easily be phased in.

integration potential – off-site composting would not directly affect other systems such as rainwater collection and grey water usage.

SUMMARY

The composting options are rated in the following table according to three criteria:

- **diversion potential** – this criteria assesses the relative amount of material that can be diverted by each option. The options are rated high (H) if paper and yard debris can be handled as well as food waste; medium (M) if only food waste or yard debris can be diverted, and low (L) if participation rates or other factors might limit the amount of material diverted.

  The four types of centralized composting are rated medium because these are primarily designed for food waste and only small amounts of other materials (although these units could also handle some types of yard debris, this would be a relatively expensive method for yard debris). Likewise, the on-site composting of yard debris is also rated medium because it only handles that material and not food waste or other materials. The three types of household composting units are rated low for diversion potential because their applicability at Yesler Terrace would be very limited. Off-site processing options are rated the highest for diversion potential because these would be able to handle the widest variety of materials and do not suffer from capacity problems.

Table 7
Evaluation of Composting Options

Type of Composting System	Diversion Potential	Cost-Effectiveness	Feasibility	Overall Rating
On-Site Centralized Composting Units;				
- Earth Tubs	M	M	M	M
- Earth Bins	M	L	L	L
- Containerized	M	L	L	L
- Anaerobic digestion	M	L	L	L
On-Site Composting of Yard Debris	M	H	H	H
On-Site Household Units;				
- green cones	L	L	L	L
- worm bins	L	M	L-M	L-M
- bin systems	L	M-H	M-H	M-H
Off-Site Processing;				
- cart	H	H	H	H
- dropboxes	H	H	H	H

Ratings: L = low, M = Medium, H = High.

- **cost-effectiveness** – this addresses the relative cost-effectiveness of each option, as an approximate measure of the cost versus the amount of material diverted through the method.

  The four types of centralized composting are rated low to medium for cost-effectiveness. Although the capital cost for an Earth Bin is fairly reasonable, the operating and other annual costs make this option fairly expensive compared to other on-site options. On-site composting of yard debris is rated high because it is relatively inexpensive. Green cones are rated low due to concerns about the use of these at Yesler Terrace, but worm bins may be slightly more useful. Compost bins would be very cost-effective in the right setting, such as at a community garden. Off-site processing options are rated high for cost-effectiveness because the cost of this option appears less than the on-site centralized units.

- **feasibility** – this is a relative assessment of the technical and political feasibility of each option, including whether there are regulatory or other significant barriers for implementation.

  The four types of centralized composting are rated low to medium due to permitting and operational issues. The feasibility of anaerobic digestion is very low at the moment, but advances in small-scale systems may change this rating in the future. On-site composting of yard debris is rated high for feasibility because it is a well-proven technique. The three types of household composting units are rated low for worm bins (due to the issues about where to put the cones on the grounds), low to medium for worm bins (because these might be a good option but only for a limited number of households), and medium to high for the three-bin composting method (although not a good choice on a household level, the three-bin approach would work well at community gardens or for other approaches for yard debris). Off-site processing options are rated high because implementation of these options is relatively simple.

- **overall rating** – this is simply the average of the previous three ratings, and is used as the basis for the conclusions that follow.

CONCLUSIONS

The following conclusions are based on the above analysis:

- the on-site centralized composting options do not appear to be a good choice at this point in time, although further advancements in small-scale anaerobic digestion could make this option more feasible in the future.

- yard debris could be composted on-site using simpler and less expensive techniques, such as open windrows (piles) or a variety of bins or boxes to hold the materials while being composted.

- three-bin composting systems or other composting units should be used at the community gardens, and for any green roofs used for food production.

- the cart-based collection system with off-site processing, with or without consolidation in drop boxes, appears to be the most cost-effective. One strategy would be to begin with this method and as volumes become more certain and alternative technologies become more developed, other methods could be considered in the future.

SECTION THREE
URBAN AGRICULTURE OPTIONS

INTRODUCTION

The redevelopment of the Yesler Terrace site provides a significant opportunity to design and construct an environment that will be more sustainable, but the potential benefits of urban agriculture go far beyond sustainability in the environmental sense. Community gardening and related activities have the potential to create a stronger sense of community beyond the boundaries of the garden, with the many far-reaching benefits that are implied by that. There is also the potential to improve the diets and health of local residents, which again could have long-term benefits. Realizing these benefits is as simple as planting a small seed on one hand, and on the other hand is as complicated as choosing from the more than 20,000 species of edible plants in the world (PFAF, 2010).

The following urban agriculture options for Yesler Terrace are addressed below:

- community gardens
- edible landscaping
- green roofs and living walls

All three of these options help satisfy development standards adopted by the City of Seattle. The "Seattle Green Factor" is a landscaping requirement for commercial properties and is also proposed for multifamily zones. The Green Factor is designed to encourage larger plants (especially trees and preservation of existing large trees) and promotes other features such as green roofs, vegetated walls, and permeable pavement. Bonus credits are provided for food cultivation and using rainwater to supply at least 50% of the annual irrigation needs of landscaped areas. Public right-of-way areas are not counted in the calculation of parcel size for Green Factor scoring, but landscape improvements in those areas can be counted.

COMMUNITY GARDENS

Benefits of community gardens: The benefits that can be derived from community gardens are broad and numerous. These benefits go far beyond the value of the food produced in a community garden, although that can be significant as well. One source estimates that in Portland, Oregon, a "good gardener can raise $500 to $1,000 worth of food on a 20′ by 20′ plot" (Gomstyn, 2008). Another source estimates the value of garden food produced in the Pacific Northwest at $2.33 (adjusted to 2009 dollars) per square foot (Solomon, 2007). Of course, the value of the food raised in a community garden plot not only depends on the level of effort by the gardener, but also on the types of food raised and the weather patterns in a given year. Likewise, the total quantity of food raised and the percentage of a person's diet that the food can provide are highly dependent on weather patterns, types of food being raised, dietary preferences, and several other factors.

Another benefit of community gardens is the potential to reduce greenhouse gases. The food found in grocery stores in the United States travels an average of 1,300 miles from field to table. In the process, it consumes 10 calories of fossil fuel to produce a single calorie of food (Gardening Matters, 2010). Other benefits of community gardens include improving the health of gardeners through improved diet and exercise, building a sense of community, and providing additional green space with the associated benefits (reducing the heat island effect, filtering rainwater, etc.).

Current gardens: There are currently three areas at Yesler Terrace that are used for community gardens:

- **Playground** site: near the playground are nine garden plots about 3′ by 6′.
- **Ballpark Garden**: south of the ballfield is a community garden containing about 20 plots ranging in size from 5′ by 10′ to 8′ by 25′. This site is fenced and contains compost bins but no shed or other structures.
- **Freeway Garden**: this garden at the southwestern corner of Yesler Terrace contains 37 plots of various sizes and shapes. About half of the plots are 4′ by 25′, and the other half average about 8′ by 8′. This site is fenced and includes a small storage shed.

Altogether, the gardens in these three areas provide 66 garden plots for the current population of 561 households. These sites are part of the Seattle P-Patch program but are open only to residents of Yesler Terrace. There are also three other SHA properties with community gardens open only to residents, at the High Point, Rainier Vista, and New Holly properties. The community gardens in these four communities are funded and managed by the Seattle Housing Authority, City of Seattle and the P-Patch Trust (a 501(c)(3) non-profit organization that supports the Seattle P-Patch program). The Seattle P-Patch Program currently oversees 73 P-Patches throughout Seattle, which take up approximately 23 acres and serve 2,056 households (Seattle, 2010). There is a high demand for community garden plots, with most of the P-Patches having waiting lists of about two years. New sites will be constructed over the next few years using $2 million of the Parks and Green Space Levy. The P-Patch Program is also experimenting with other models for operating these sites, including large tracts dedicated to food growth

Freeway Garden at Yesler Terrace, photo taken March 31, 2010.

(some plots are currently being used by individuals for flowers and other ornamental purposes), communal spaces (no individual plots), and "giving" gardens.

In addition, several households in the existing Yesler Terrace site are currently using the yards around their homes for both ornamental and food-producing gardens.

Design considerations for community gardens: The following are general guidelines for community gardens:

number of gardens – the preliminary design concept for the redevelopment of Yesler Terrace includes one or more spaces for community gardens. No details are available yet as to whether there would be one central garden or multiple gardens. Multiple gardens may be consistent with the phased construction approach anticipated for the site, but one central site could be more efficient and might do more to promote a sense of community.

size of garden and plots – the Seattle P-Patch Program recommends a minimum garden size of 2,000 square feet. The size of individual plots within the garden depends on the overall size of the garden and the amount of interest in the neighborhood, but are typically either 10′ by 10′ or 10′ by 20′. In gardens with different sized plots, larger plots are awarded to gardeners based on their needs, experience and track record. Pathways between individual plots should be three to four feet wide for the main pathways and can go down to 18″ to 2′ wide for side paths.

common areas, other structures – ideally, some space should be set aside in the garden for a plot growing herbs or other plants that would be shared by all (gardeners and other residents alike). A few fruit trees could also be grown in the garden, preferably in a location where the shade and roots from these trees wouldn't interfere with individual plots. Other structures that should be at the garden include a tool shed and composting bins. Larger tools could be kept in the shed and shared by the gardeners. One strategy employed by some community gardens is to paint these tools bright pink or another color to reduce the likelihood of them being stolen.

growing methods – all P-Patch gardeners are required to use organic methods only.

water – a community garden typically has the water shut off during the winter months (water is usually turned off around November 1 and then turned back on again in the spring). The annual amount of water usage for a community garden will vary significantly depending on the weather and degree of usage, but the average in 2009 for the Seattle P-Patch program was 4.6 gallons per square foot[4] of garden (Macdonald, 2010).

management and maintenance – overall management and dispute resolutions should be conducted by SHA staff, but as much as possible the gardeners themselves need to be responsible for maintaining the area. Work parties should be organized as needed to clean up common areas, re-mulch pathways, and conduct other maintenance.

security – community gardens should be fenced to discourage theft and vandalism. If the redeveloped Yesler Terrace site includes video surveillance, the community gardens should be included if possible.

longevity – once installed, a community garden should be able to continue indefinitely with only minor annual expenses for maintenance and repairs.

integration potential – community gardens will need water, and that water could potentially come from a grey water system or from rainwater collection. Since very little rain falls when the gardens need it the most, significant storage capacity would be needed to hold a sufficient amount of rainwater to last through the dry season.

[4] This figure for water consumption is based on total square footage of gardens, including pathways and other non-growing spaces.

The minimum recommended garden size, about 2,000 square feet, can only provide about 12 plots that are 10′ by 10′ plus a storage shed and pathways. Compared to the current number of plots available to Yesler Terrace residents (66 plots, totaling about 5,700 square feet of usable garden space) and the projected increase in population (from 561 households to 4,000), not to mention the fact that many people are currently gardening in their yards (which won't be possible when this area is converted to apartment buildings), an equivalent number of garden plots would be approximately 470. This would require a minimum space of 67,100 square feet, or 1.5 acres (assuming plots that are only 10′ by 10′ and 30% of the site devoted to paths, a shed and other common areas).

Another way to approach the question about the future size of community gardens is to use criteria established by others, such as applying the guidelines adopted by the City of Vancouver, B.C. Their guidelines state that 30% of the housing units should have access to garden plots that are a minimum of 3′ by 8′ (Vancouver, 2009). For the 4,000 housing units at the future Yesler Terrace site, this equals 28,800 square feet of garden beds, or 41,140 square feet (0.94 acres) altogether if 30% of the gardens are devoted to paths and other non-growing purposes.

Costs for community gardens: The capital and maintenance costs for a community garden could include some or all of the components shown in Table 8. The actual costs for each of the potential capital expenses would be highly dependent on the site characteristics and final design of the garden, and hence cannot be estimated at this time. In the case of Yesler Terrace's redevelopment, the apparent cost of a community garden would also depend on how grading and other costs are allocated to the gardens versus overall site improvements.

Another way to look at the costs for a community garden is that the Seattle P-Patch Program typically incurs a cost of about $40,000 to $50,000 for a new community garden of about 2,000 square feet, not including land acquisition costs (Macdonald, 2010). Annual operating costs would be driven primarily by the amount of water used, which would vary from year-to-year based on the weather, but other maintenance costs would be in the range of $500 to $1,000 per year (not including water costs or staffing) for a typical garden. These costs could be at least partially offset by plot fees (annual charges for the use of the garden spaces), as well as proceeds from fundraisers, grants and donations.

Other options for community gardens: Other options or variations for the community gardens that could be explored include:

off-site community gardens – if there isn't space to build a sufficient amount of community gardens on the Yesler Terrace site, residents may be able to use adjacent gardens in addition. Unfortunately, all of the Seattle P-Patch

Table 8
Community Garden Costs

Capital Costs:	
Clearing and cleanup	Fencing
Grading	Plot layout, paths
Retaining walls	Raised beds, bed borders
Hardscape (concrete or asphalt pathways, etc)	Soil amendments
	Mulch (for paths)
Water connection, water line, hoses and related	Shed
	Bulletin board
Electrical	Tools
Video line	Signs
	Compost bins
Maintenance Costs:	
Staffing, labor costs	Hose repairs, replacements
Tool replacements	Tilling
Compost, mulch	Fence repairs
Water	Perimeter maintenance
Liability insurance	Printing (flyers, agreements)
Lease costs	

community gardens are in high demand and may not be available, at least not without waiting one to two years for a plot to become available. Residents may also be able to participate in a large garden being developed in the Rainier Vista area (the Seattle Community Farm, which will be about three miles from Yesler Terrace), although the design of that site is different from a typical community garden and it may not provide individual garden plots.

foraging programs – another option would be for Yesler Terrace residents to participate in foraging options, where excess fruit is collected from private properties nearby. This type of program is already being conducted by Lettuce Link and others, so the primary strategy for this option might be to encourage residents to sign up as volunteers in the existing programs.

cold frames and greenhouses – gardening in the Puget Sound area can be very challenging due to the cool, wet springs. Simple greenhouse structures or cold frames can make a huge difference for extending the growing season in both the spring and fall. Cold frames can be as simple as an old window placed on top of a box-like structure, and these can be used to start spring crops of lettuce and other vegetables earlier or to protect fall crops of similar vegetables from the first few frosts.

Greenhouses are generally larger structures and can be heated or unheated. Unheated greenhouses constructed with just a single layer of plastic or other glazing will drop almost to outside temperatures during the night, but even on a cloudy day the temperature inside the greenhouse will rise to 20 degrees or more above outdoor temperatures.

Photo taken January 17, 2010.

This 24′ by 56′ greenhouse in the Cascade foothills east of Tacoma was constructed for less than $4,000 using mostly materials salvaged from the deconstruction of the double-wide home that was previously on this site. Although this greenhouse is unheated, plants grown in it are 1-2 months ahead of outdoor plants. For instance, the first cucumber was picked from it on May 21, about the time that cucumbers could just be planted outside in that area.

raised beds – raised beds are used at some of the existing P-Patch gardens but are not widely used due to the cost in constructing these and for other reasons. Raised beds do provide some advantages, however, and are almost like a cold frame or greenhouse in that the raised beds allow soil to warm up faster in the spring and there is a clear improvement in plant growth as a result. Raised beds do, however, require more watering in the summer months. Raised beds are also generally limited to four feet wide (to allow gardeners to reach into the bed from either side so as to avoid having to step on the soil inside of the bed), whereas the P-Patch program is set up for different plot sizes. Raised beds are generally constructed to be 6″ to 12″ high[5], but if handicapped accessibility is an issue the beds can be constructed higher and narrower.

salvaged building materials – greenhouses, cold frames, raised beds, sheds, trellises and other garden structures could be constructed from building materials salvaged from the demolition of the existing homes at Yesler Terrace. Dimension lumber (2x4's and larger pieces) could be salvaged for use in construction or even just for creating borders for the garden plots. Concrete blocks could be used for raised beds or short retaining walls at the community gardens. Old windows and other materials could be used for cold frames. PVC water pipe could be used to construct "hoop houses" or to support row covers. The

[5] There is an important difference between raised beds with soil below them, which allows plant roots to utilize a greater depth of soil for moisture and nutrients, versus raised beds placed on an impermeable surface, in which case the raised beds need to be deeper to achieve equivalent results.

possibilities for reuse of salvaged building materials may only be limited by the types of materials present in the existing homes and the ability to store those until needed.

EDIBLE LANDSCAPING

The Pacific Northwest has a mild climate that allows a wide range of plants and trees to be grown. People have taken advantage of this climate by planting many ornamental species, such as rhododendrons and flowering cherries. Recently, however, more and more people are realizing that the same amount of space and other resources devoted to a flowering cherry tree could instead be used for a cherry tree that bears fruit. A fruit-producing cherry tree still bears a profusion of flowers in the spring while also yielding fruit for people, birds and other wildlife. Likewise for under-utilized spaces that could be used to produce food instead of growing lawns where lawns serve no purpose[6].

For the purposes of this analysis, a line can be drawn between edible landscaping options and gardening based on the amount of maintenance and other effort required. Gardening options can be defined as those activities that require an annual cycle of planting, harvest and removal of most of the plant material, while edible landscaping is defined here to consist of plantings that generally live for more than year. Right-of-way (ROW) plantings are included as an edible landscaping option instead of as a gardening option because the most feasible options for ROW plantings at Yesler Terrace may be plants such as berry bushes and fruit trees (and not vegetable gardens), although in other areas ROW plantings do include annual vegetable gardens. While this could be done at Yesler Terrace, the extra effort involved in planting and maintaining vegetables and other annuals would lead to a feeling of ownership by the people making this effort. For the common areas discussed in this section on edible landscaping, it may be better to treat the food and herbs as being freely available to all residents (although in some cases it may also be a good idea to manage some of these through sign-up lists and/or allocations).

Options for edible landscaping can be further categorized based on location (adjacent to buildings, ROW areas, and other common areas) or based on type of plant (perennials, bushes, and trees). For the Yesler Terrace site, there are two general types of edible plants that can be considered for edible landscaping purposes:

- herbs and other perennials
- fruit and nut shrubs and trees

[6] Some lawns do serve a purpose, such as fields used for baseball and soccer, plus people have a deep ancestral association with open areas and appreciate some amount of lawn spaces. The key is to balance the amount of lawns with other, more productive landscaping options.

The general locations that could be used for edible landscaping could include:

- adjacent to buildings
- adjacent to streets (ROWs)
- open areas between buildings
- permanent/shared beds at community gardens
- green roofs and living walls

Green roofs and living walls have specific aspects that merit a separate discussion (see next section). The other locations and types of plants are discussed below.

ROW Usage: Plantings in right-of-ways (ROWs) adjacent to streets are allowed by the Seattle Department of Transportation (SDOT) as long as certain conditions are met:

- bushes must be kept under 32" (24" near intersections).
- trees can be planted, but these and hardscape elements (pavers, planter boxes, etc.) require a street use permit (there is no charge for the permit).
- trees that may drop fruit on a sidewalk and thus pose a safety hazard to pedestrians (such as cherries, apples and pears) are not allowed.
- various setbacks from the street and sidewalk must be maintained.
- vegetables can be grown, and SDOT does not regulate what types are allowed.

Participants in the charrette conducted in December 2009 raised questions related to ROW usage, including issues about ownership of cash crops and whether air pollution and soil contaminants might impact food quality. The issues about ownership have the potential to create disputes and so ROW plantings should probably be restricted only to publicly-shared plantings (fruits and nuts that are available on a first come-first-served basis, for instance). Air pollution should be only a minor concern now that lead is no longer being used in gasoline, but past practices may have created soil contamination adjacent to the streets. Construction activities for the redevelopment of the Yesler Terrace may or may not preserve the same soils adjacent to the streets, but in any case the soils should be screened for heavy metals and oil contamination (at a minimum) before using these areas for food production (to safeguard the health of residents and to limit SHA's liability).

Herbs and Other Perennials: Many plants have edible parts or have culinary or medicinal uses and could be a useful addition to landscaped areas. Many of the plants in this category are annuals or biennials (biennials have a two-year cycle of growth), and these could be included in landscaped areas but the extra effort required to plant these each year and maintain the planting areas may lead to ownership issues. Annual and biennials could be included in landscaped areas in the future at the discretion of SHA building managers, but for now this analysis assumes that only perennials would be planted and made available to all residents. There are also several perennial vegetables that are sufficiently ornamental to qualify as a landscaping plant (such as artichokes) but again these are probably better suited for non-public growing areas (such as community gardens).

Many of the perennial herbs that could be planted for the residents' use and that do well in this area are Mediterranean in origin because the Seattle area has a similar climate (cool winters and hot, dry summers). Unfortunately, this means that many of the perennial herbs that may appeal to Asian or Latino cultures cannot be included as permanent plants in the landscaping because those plants are tropical or semi-tropical and would perish at the first frost.

Perennial herbs and other useful plants that could work well at Yesler Terrace are shown in Attachment B. The preferred locations for these plants are also shown, based on growth characteristics such as the ability to withstand foot traffic or to grow tall enough that foot traffic would not be a problem in the ROW or open areas. By no means does this list show all of the potentially-useful herbs and other perennials. Other plants could be added to this list and residents should be allowed to suggest additional herbs that would meet the basic criteria (easily-maintained perennials).

Some of these, such as bay leaf and rosemary, are actually shrubs but are listed here (instead of being listed with other shrubs) because they are herbs and do not produce fruit or nuts. Others, such as mint and horseradish, have the potential to spread and would be difficult to maintain easily. Some potential herbs, such as stinging nettle, have obvious drawbacks coupled with limited usefulness and so were not included on the list.

Fruit and Nut Shrubs and Trees: Shrubs and trees that bear fruits and nuts should be part of every landscaping plan. Many of these shrubs and trees require the same amount of space and effort as shrubs and trees that do not produce food, but are just as ornamental. This doesn't mean, however, that every fruit and nut tree that grows in this area should be planted. Apple trees, for instance, require a significant amount of care in western Washington to produce quality fruit and so should probably be avoided in most cases.

This chestnut tree near Puyallup provides a bounty of nuts each fall.

Fruit and nut trees and shrubs that could be grown at Yesler Terrace are shown in Attachment B (see Table B-2). The preferred locations for these plants are also shown, based on growth characteristics such as the mature height being appropriate for that location.

Fruit and nut trees and shrubs that are not recommended for use at Yesler Terrace are shown in a separate table in Attachment B (see Table B-3), along with the reason for not recommending these. Many of the trees and shrubs not recommended simply require extra care and could still be worthwhile additions to community gardens or in other situations where a caretaker can be assigned to them.

Design considerations for edible landscaping:

water – some herbs and trees will live through the hot summer months without being watered (once established), but many of the species listed in Tables B-1 and B-2 will need to be watered regularly through the growing season.

phased approach – the phased development schedule for Yesler Terrace allows for ideas for edible landscaping to be tested in the first areas that are constructed, and then the lessons learned can be applied to other areas. Although some of the trees suggested for edible landscaping may not begin producing in time to demonstrate their value for later construction phases, it should at least be possible to see how well they grow.

management options – food and other products from edible landscaping may not need to be managed very closely if residents are simply allowed to pick fruit or other products on a first come-first served basis. If this proves to be problematic, an allocation system or another approach could be instituted.

longevity – perennials, shrubs and trees are all long-lived and may only need occasional maintenance or possibly replacement in case of damage or injury.

integration potential – many of the perennials, shrubs and trees used for food production will need to be watered during the growing season, and that water could potentially come from a grey water system or from rainwater collection. Since very little rain falls when the plants need it the most, significant rainwater storage capacity would be needed to hold a sufficient amount of rain to last through the dry season.

Some of the plants used for edible landscaping would benefit from annual applications of compost, and that compost could be produced on-site.

GREEN ROOFS AND LIVING WALLS

Green roofs are generally considered to be one of the tools for managing storm water through Low Impact Development (LID). Other LID techniques include permeable paving, rainwater collection systems and rain gardens. Living walls are usually used for similar purposes (storm water management) but also for natural cooling and for decorative purposes. The use of green roofs and living walls for urban agriculture has not been widely practiced, and in fact most often these types of activities refer to growing plants in containers on a roof or in containers on a wall. In other words, the rooftop serves simply as a sunny location for the container, and few other practical benefits are accrued. This is not to say, however, that green roofs and living walls can't be used for urban agriculture, but it should be noted that this type of application is still under development.

Tomato plant grown on a roof, Portland, OR. Photo by Dan Conroy.

Green Roofs

Green roofs are often divided into two types based on the purpose and usage (Dunnet and Kingsbury, 2008). "Extensive" green roofs are the more commonly used type. This type of roof uses a thinner layer of soil (less than six inches) and plants that do not need much maintenance (such as grasses and sedums). Hence, extensive green roofs are less expensive for construction and maintenance.

"Intensive" green roofs are those roofs that are intended to be used more like a garden on ground level. These roofs require a deeper layer of soil (six inches or more, depending on the types of plants to be grown) and regular maintenance (including watering), hence are more expensive to construct and maintain than an extensive green roof. Extensive green roofs can be planted on sloped roofs (up to 30 degrees), while intensive green roofs typically require flat roofs (up to five degrees maximum).

Using green roofs at Yesler Terrace represents significant potential for food production. The amount of rooftop space available for green roofs could be up to 11 acres (CW, 2010b), assuming the use of buildings and roof areas that are seven stories or less. This amount of space could potentially support a farmers market or other for-profit ventures (whereas the community gardens wouldn't be large enough for this), although this would require working out a management and profit-sharing system.

Design considerations for intensive green roofs: For a green roof to be used for active gardening and food production, several factors need to be considered:

cost – the Cascadia Region Green Building Council estimates construction costs for a green roof system to be $10 to $15 per square foot versus $3 to $9 per square foot for a conventional roof. Although not specified, these costs are probably for an extensive green roof and the construction costs for an intensive green roof may be higher. The higher initial costs may be offset by reduced maintenance and repair costs for the roof (the lifespan of a green roof may be longer than a conventional roof due to protection from UV rays and other benefits, although these benefits may not apply as well to an intensive system where part of the roof may be exposed and human activity on the roof may cause additional wear and tear). At $10 per square foot, the cost for an intensive green roof would be $435,600 per acre. By comparison, farmland in Eastern Washington can be found for less than $1,000 per acre, and in Western Washington the cost for farmland can range from $4,000 to $10,000 per acre.

soil depth – a minimum of six inches of soil would be necessary for gardening purposes (Dunnet and Kingsbury, 2008), but a soil layer this deep would support only a limited range of plants and would also require more careful attention to watering and fertilization. Deeper soils would support a wider range of plants, and a minimum depth of 12 inches would be a better standard to use. It should be noted that some studies have concluded that deeper soil depths (over 6”) are less effective for curbing storm water runoff.

soil type – various types of soil blends can be used, but a quality topsoil mix would provide good results over a long term period. Whatever soil is used, annual additions of compost (or the use of “green manure” crops in the off-season) should be used to restore organic matter. Pumice, perlite, expanded slate or other lightweight inert materials can be added to reduce the weight of the soil, and these can also improve the workability of the soil and the drainage characteristics.

raised beds versus other designs – other types of green roofs generally involve complete coverage of the roof, but for food-production purposes an intensive green roof would work better if designed as a series of raised beds. Raised beds should generally be a maximum of four feet wide (two feet wide if

The **Eagle Street Rooftop Farm** in New York provides an interesting example of an intensive green roof. This 6,000 acre “farm” is on top of a warehouse in Greenpoint, Brooklyn. It grows fresh produce for an onsite farmers market, local restaurants and a community supported agriculture (CSA) program. This farm also conducts classes, workshops and other educational opportunities. It was built for a cost of about $10 per square foot (or about $60,000), although that figure does not include numerous volunteer hours and possibly other expenses.

they can only be accessed from one side), because the idea is to avoid compacting the soil by stepping in the bed and so the beds should only be as wide as a person can reach from either side. Beds can be as long as practical, but shouldn't be longer than 20' or 30' for the sake of people moving around them. One variation on raised beds is to mound the soil without using boards or other materials to contain it. This reduces the construction costs and provides more flexibility in the long run, but also requires more careful attention to watering practices.

types of plants –in theory any type of plant that can be grown at ground level can also be grown on a roof, including trees and shrubs, but in reality the rooftop environment is more severe due to greater exposure to winter storms and summer heat. Plus, trees and shrubs would need greater soil depth to grow well and to be sufficiently anchored against being tipped over or even blown off the roof. So in practice, rooftop plantings should primarily target annual vegetables and hardy perennials only.

water supply – a source of running water will be needed on the rooftop to provide water during the dry season. If raised beds are used, watering may need to start as early as April and continue through October. Automatic timers and soaker hoses can be an effective and relatively inexpensive method for watering. Careful attention also needs to be paid to drainage, both from the soil and of course from the roof itself.

safety – if the roof area is going to be accessible to residents, careful consideration will need to be given to railings and other barriers to prevent falls from the rooftops, and to prevent objects from being thrown or blown off of the rooftop.

shelter from wind, other extremes – the Puget Sound area does not experience windy conditions much in the prime growing season, but it can happen. Windy conditions in the spring and fall are more likely to cause damage to crops grown on roofs. Gardens would need to be designed to withstand wind and stormy conditions, meaning that trellises and other artificial structures may need to be prohibited from these areas (these could be very dangerous to people on the ground if blown off the roof). One guideline that is being used by some is to avoid the use of buildings over seven stories, due to wind and access issues, although actual wind speeds would vary depending on the site's topography and exposure as well as shelter from neighboring buildings.

roof reinforcement – a typical topsoil blend in the Puget Sound area weighs about 2,700 pounds per cubic yard, more if saturated or less if a lightweight material such as pumice is blended in. For a soil depth of 12", this translates to 100 pounds per square foot of additional weight on the roof. For a raised bed that is

4′ by 20′ and 12″ deep, the total weight of the soil would be almost 8,000 pounds. Structural reinforcement of the roof will be necessary at this point, with careful attention paid to slopes and drainage (deflection of the roof may cause pooling of water below raised beds and lead to leakage eventually).

phased approach – the phased development schedule for Yesler Terrace allows for green roofs to be tested on the first few buildings, and then the lessons learned can be applied to later buildings.

management options – raised beds on rooftops could be managed similarly to plots in community gardens, or could be managed as a farming enterprise or other for-profit venture.

longevity – once constructed, raised beds on green roofs should only need periodic maintenance and repairs. As with other garden areas, annual additions of compost or the use of cover crops will be necessary to maintain soil fertility.

integration potential – green roofs used for food production will need water, and that water could potentially come from a grey water system or rainwater collection and storage. As with other gardening activities, the use of rainwater is somewhat problematic because very little rain falls when the gardens need it the most, hence significant storage capacity would be needed to hold a sufficient amount of rain to last through the dry season.

Green roofs could benefit from annual applications of compost, and that compost could be produced on-site.

Living Walls

Living walls, also known as vertical gardening, should not be confused with the living building concept[7]. Living walls are defined here to include those methods that allow gardening to occur on the exterior walls of a building. Plants can also be grown on the interior walls of a building, generally in well-lit atriums or entryways, or on top floors enclosed in glass, but these options are generally not cost-effective unless the building design happens to allow this[8].

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7 The living building concept is considered by some to be the next step for green building, with goals for more use of sustainable building materials and for using only as much energy and resources as can be generated on-site.

8 Although interior living walls are probably not a cost-effective urban agricultural option for Yesler Terrace, it's worth mentioning that these could provide significant benefits for indoor air quality if planted with plants known to remove toxins.

As with green roofs, most existing living walls are typically used for decorative reasons with some additional benefits for managing storm water and providing passive climate control. The use of living walls for urban agriculture poses some challenges, such as the difficulty of safely harvesting fruit or vegetables grown above 8 to 10 feet.

Design considerations for living walls: For living walls to be used for active gardening and food production, several factors need to be considered:

design options – living walls can be created by growing plants (primarily vines) up from the ground level or by creating pockets of soil in a wall to support plant growth. The pockets-of-soil approach greatly increases the range of plants that can be grown but increases construction and maintenance costs, and leads to serious questions about how to safely plant, water and harvest. Modular building panels or self-made units, either of which can be designed as a series of shelves, could also be used to support plant growth up to 7-8′ high.

cost – the cost for a living wall system is hard to estimate because it would be highly dependent on the actual method used. For the second San Diego system mentioned in the case studies for living walls, costs charged by the garden designer are about $50 per square foot of wall space for residential customers and between $150 and $200 per square foot for commercial customers.

soil type – for the pocket or shelving approach, various types of soil blends can be used but a quality topsoil mix would provide good results over a long term period. Pumice or expanded slate should be added to reduce the weight of the soil.

Case studies for living walls:

One of the more creative methods for achieving a living wall was designed by a San Diego architect, Amelia Lima (see http://www.ameliab.com/index.php?/projects/green-wall/). She built a seven-foot tall frame along a 40-foot long wall using marine plywood, corrugated plastic and landscaping fabric. Slits were cut into the fabric to hold plants. Although this was purely ornamental (plants included ferns, bromeliads, and spider plants), this approach could possibly be used for perennial herbs or other food-producing plants.

In another example from San Diego, Good Earth Plant and Flower Company constructed a vertical garden for a restaurant. The wall was constructed of boxes that are 2′ square and 8″ deep, and that contain a fabric pouch filled with soil. The boxes are mounted to the side of a building, and planted by pushing plants through a slit in the fabric. For this project, the plants were primarily herbs (mint, rosemary, sage and chicory) and beets (but only for the decorative look of the purple and green beet leaves). A total of 324 herbs and beets are planted on this vertical garden of 72 square feet.

In the Seattle area, however, plants in systems like these would be prone to freeze damage.

types of plants – a wide range of plants could be grown in the pocket or shelving approach, but shallow-rooted and smaller plants would have a greater chance of success. For the preferred approach, where walls are used to support plants grown in the ground next to the building, the types of plants could include perennial vines (such as grapes, see Table B-2), climbing annual vegetables (such as peas, pole beans, dow gauk or asparagus bean, cucumbers, possibly loofah sponges, and a few others), and espaliered[9] fruit trees. Vines such as grapes and kiwis would benefit from the use of an arbor to support their growth horizontally and make for easier harvesting. The climbing vegetables would require a trellis and some initial work to train the vines to climb on the trellis. Espaliered fruit trees generally only reach to 8-10′ maximum and could be grown against the building without additional support, but would require annual pruning and other maintenance.

Espaliered fruit tree, photo courtesy of Wikipedia.

phased approach – the phased development schedule for Yesler Terrace allows for ideas for living walls to be tested on the first few buildings, and then the lessons learned can be applied to later buildings.

management options – food produced from living walls could be managed like edible landscaping, with residents allowed to pick fruit or other products on a first come-first served basis or on an allocation basis.

longevity – vines and other plants grown on walls will require more maintenance than plants grown in other areas, but the plants should be relatively long-lived.

integration potential – living walls used for food production will need water, and that water could potentially come from a grey water system or from rainwater collection. Since very little rain falls when the plants on living walls need it the

[9] espalier refers to the horticultural technique of training trees to create a two-dimensional growing style.

most, significant rainwater storage capacity would be needed to hold a sufficient amount of rain to last through the dry season. Living walls would benefit from annual applications of compost, and that compost could be produced on-site.

SUMMARY

The urban agriculture options are rated in the following table according to three criteria:

- **potential for food production** – this is an assessment of the relative amount of food that can potentially be produced by each option.

  For this criteria, community gardens receive a high rating because these are a proven method for producing food, at least for the people who participate in the gardens. Green roofs also receive a high rating because the potential "land" area available for these (11 acres) is significantly more than the space available for other options. Edible landscaping options near buildings and in open areas receive a medium rating because these do not produce a lot of food over an extended period during the year (although fruit and nit trees can produce a large amount of food over a short period, and without requiring much time and effort once established). ROW plantings and living walls are rated low due to the limitations on the size and types of trees, shrubs and vines that can be planted there.

- **cost-effectiveness** – this is an assessment of the relative cost-effectiveness of each option.

  For this criteria, community gardens and all of the edible landscaping options receive a high rating because these can provide a long-term return on the initial investment. Green roofs are rated low to medium because there are significant expenses associated with this approach, but a significant amount of garden space could be made available if the various issues can be resolved. Living walls receive a high rating on the assumption that initial costs for these types of plantings would be low (assuming minimal or no support structures and other building modifications would be needed).

- **feasibility** – this is an assessment of the feasibility of each option, including whether there are regulatory or significant other barriers for implementation.

  For this criteria, community gardens and two of the edible landscaping options receive a high rating because these are straightforward methods without significant risks or potential liabilities. ROW plantings receive a slightly lower rating due to questions about constraints on the types of plantings that can be used in those areas and possible problems with traffic and other issues. Green roofs are rated low to medium because these are still experimental and have a number of potential liabilities and other issues associated with them. Living walls are rated high in feasibility, because even though this method is of limited usefulness the approach is at least relatively simple and straightforward.

- **overall rating** – this rating is simply the average of the previous three ratings, and is used as the basis for the conclusions that follow.

Table 9
Evaluation of Urban Agriculture Options

Type of Urban Agriculture	Food-Producing Potential	Cost-Effectiveness	Feasibility	Overall Rating
Community Gardens	H	H	H	H
Edible Landscaping;				
- near buildings	M	H	H	H
- ROW	L	H	M	M
- open areas	M	H	H	H
Green Roofs and Living Walls;				
- green roofs	H	L-M	L-M	M
- living walls	L	M	H	M

Ratings: L = low, M = Medium, H = High.

CONCLUSIONS

The ratings in Table 9 are based on the applicability of each option to the entire Yesler Terrace site, but in reality every one of the options could be worth pursuing to some extent or in certain locations. The use of green roofs for food production suffers from a number of potential problems, but if these issues can be resolved this method also has significant potential.

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ATTACHMENT A
IN-VESSEL COMPOSTING EQUIPMENT MANUFACTURERS

The following table shows several manufacturers of in-vessel composting systems.

Table A-1
Directory of Manufacturers for In-Vessel Composting Systems

Name	Location	Website
Backhus Kompost-Technologie	New York, NY	www.backhus.us
BioSystem Solutions, Inc.	Westport, CT	www.biosystemsolutions.com
Christiaens Group	The Netherlands	www.christiaensgroup.com
Engineered Compost Systems	Seattle, WA	www.compostsystems.com
Gore Cover Systems	Elkton, MD	www.gorecover.com
Green Mountain Technologies	Bainbridge Island, WA	http://www.compostingtechnology.com/
HotRot Exports, Ltd.	Christchurch, New Zealand	www.hotrotsystems.com
NaturTech Composting Systems, Inc.	Saint Cloud, MN	www.composter.com
Poly-Flex Composting	Grand Prairie, TX	www.poly-flex.com
Siemens Water Technologies	Abbotsford BC, CAN	www.siemens.com/ips-composting
Transform Compost Systems	Abbotsford, BC, CAN	www.tranformcompost.com
VCU Technology, Ltd.	Aukland, New Zealand	www.vcutechnology.com
Versa Corporation	Astoria, OR	www.versacorporation.com

Source: Biocycle magazine, May 2007.

ATTACHMENT B
PLANT LISTS FOR EDIBLE LANDSCAPING

The tables shown in this attachment include:

- a list of perennials that could be used for edible landscaping at Yesler Terrace (Table B-1).
- a list of fruiting and nut-bearing shrubs and trees that could be used for edible landscaping (Table B-2).
- a list of fruiting and nut-bearing shrubs and trees that should not be used for edible landscaping at Yesler Terrace (Table B-3).

Table B-1
Potential Perennials for Edible Landscaping

Common Name of Plant	Possible Locations			Comments
	By Buildings	ROW	Open Areas	
Anise Hyssop	X			
Bay Leaf (Bay Laurel)	X		X	Grows to be a small tree but may be only marginally hardy in the Seattle area.
Chives	X			
Echinacea	X	X		
Feverfew	X	X		
French Tarragon	X	X		
Horseradish	X	X		Can spread invasively by roots.
Japanese Pepper	X	X		Grows to be a small tree.
Lavender	X	X		
Lemon Balm	X	X		Can spread invasively through seeds.
Lemon Verbena	X			
Lovage	X			
Mint (various types)	X	X		Can spread invasively by roots.
Oregano	X			
Pennyroyal	X			
Rosemary	X	X	X	Grows to be a medium shrub but may be marginally hardy in Seattle area.
Saffron	X			Difficult to harvest in useful quantities.
Sage	X	X		
Sorrel	X			
Thyme	X			
Winter Savory	X			

Note: All of the above plants could also be planted in shared plots at community gardens.

Table B-2
Fruit and Nut Shrubs and Trees
Recommended for Edible Landscaping at Yesler Terrace

Common Name of Shrub or Tree	Possible Locations			Comments
	By Buildings	ROW	Open Areas	
Aronia	X			Quality uncertain, native to America.
Autumn Olive	X			Quality uncertain, may be invasive.
Butternut, Buartnut and Heartnut			X	
Chestnuts			X	Spiny husks could be a problem but nuts are popular.
Cherry			X	
Currants	X	X		
Elderberry	X			
Filbert	X			Native to this area, but hybrids produce better.
Gingko			X	Husks may smell bad, leaves used as medicine in China.
Goji (or Wolfberry)	X		X	Native to China and Japan, relatively untried in this area.
Gooseberry	X	X		
Goumi	X		X	Native to parts of Russia, China and Japan, relatively untried in this area.
Honeyberry	X	X		Native to parts of Russia and Japan.
Huckleberry	X	X		Native to this area.
Jujube	X	X	X	Native to China.
Lingonberry	X	X		Native to parts of Europe.
Mulberry		X	X	Native to Central Asia.
Peach			X	
Pears, Asian			X	
Pears, European			X	
Persimmon			X	

Table B-2, continued
Fruit and Nut Shrubs and Trees Recommended for Edible Landscaping at Yesler Terrace

Common Name of Shrub or Tree	Possible Locations			Comments
	By Buildings	ROW	Open Areas	
Plum			X	
Rhubarb	X			Not a shrub or tree, but perennial.
Serviceberry	X	X	X	
Trebizond Date			X	Native to Central Asia.
Tree Hazel		X	X	Larger version of filbert.
Yellowhorn	X		X	Relatively untried in this area.
Vines: Akebia Grapes Hops Kiwi	X			Potentially useful for living walls, could also be used at community gardens or in other locations.

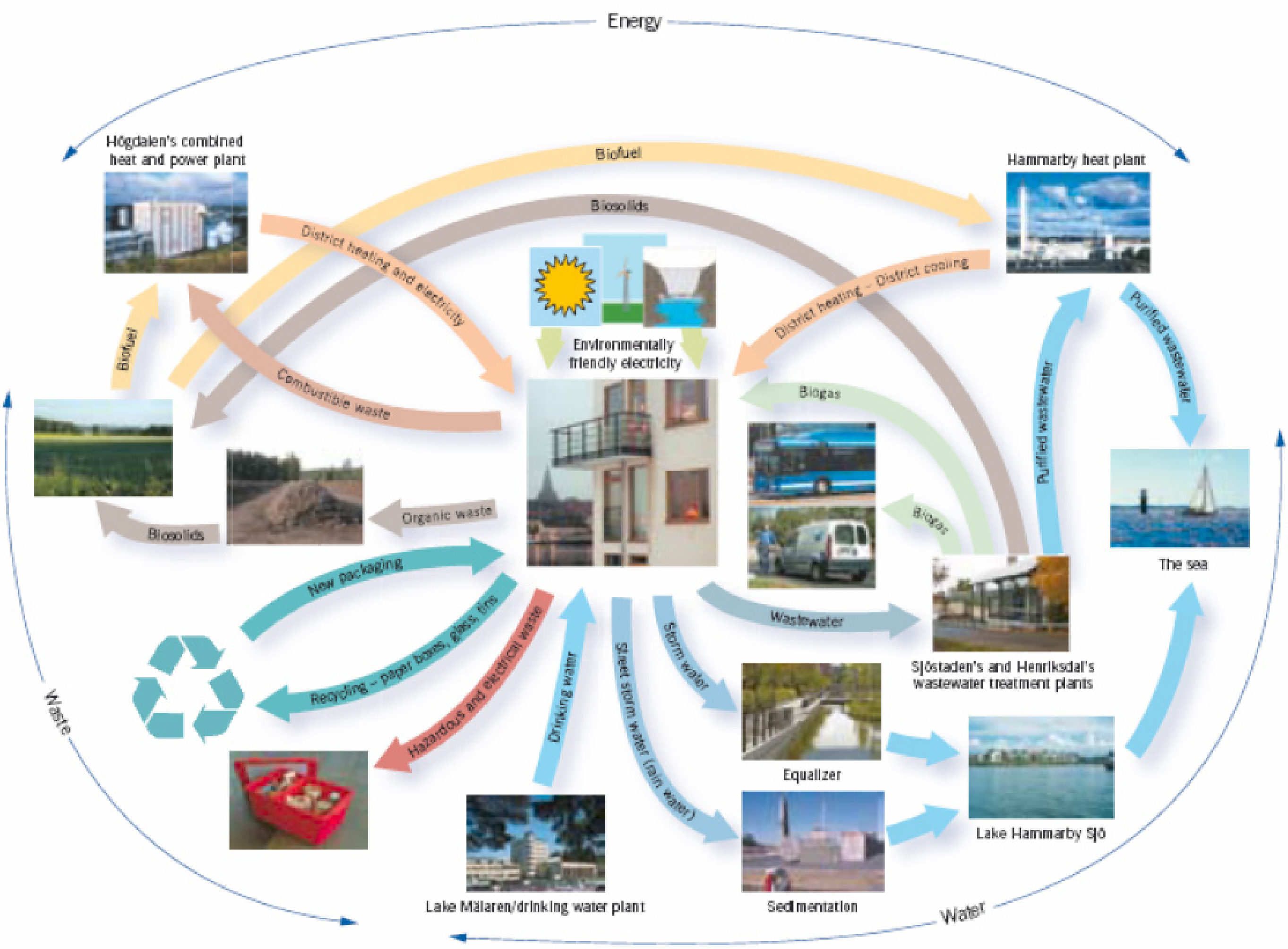
Notes: Most of the above could also be planted in community gardens, preferably using smaller varieties or planting on the north side to avoid excessive shading of the garden plots.
The "recommended species" shown above are those that would grow easily and with a minimum of care (once established). The "marginal species" are those that could grow in the Seattle area but that suffer from various problems.

Table B-3
Fruit and Nut Shrubs and Trees
NOT Recommended for Edible Landscaping at Yesler Terrace

Common Name	Comments
Almond	Doesn't do well in western WA.
Apples	Too many pest problems.
Apricot	Doesn't do well in western WA.
Blackberries	Too invasive.
Blueberries	Requires too much care (frequent watering and protection from birds).
Fig	Not completely hardy in Washington.
Nectarine	Doesn't do well in western WA.
Olive	Not completely hardy in Washington.
Paw Paw	Hard to establish.
Pistachio	Supposed to be hardy in this area but climate is probably too wet.
Raspberries	Requires too much care.
Stone Pines	Takes too long to produce pine nuts.
Strawberries	Requires too much care, prone to slug damage and other problems.
Salmonberry, Thimbleberry	Native to this area but not that productive.
Tea (Camellia sinensis)	Not completely hardy in Washington.
Walnut	Husks cause staining, nuts hard to crack.

Appendix D

Yesler Terrace Sustainable District Study
Project Case Studies



Overview

Hammarby Sjöstad is a major new mixed-use development conceived in the early 1990s a as part of Stockholm's bid for the 2004 Summer Olympic Games. About 200 ha (480 acres) of old industrial and port brownfields were converted into a modern, sustainable neighborhood. The development has a strong emphasis on water, ecology and environmental sustainability. When fully built, in 2015, there will be 11,000 residential units for more than 25,000 people. 35,000 people are anticipated to live and work in the area. Hammarby Sjostad is Stockholm's largest urban development project.

The waterfront site had a major influence on the project's infrastructure, planning and design, as did the urban fabric of Stockholm's inner city. The street grid, block size, and building envelopes are consistent with the historic city. The sensitive design, responsiveness to site, and thorough sustainability has garnered extensive international attention.

The scheme successfully connects the historic urban environment with the waterfront and surrounding aquatic ecosystem. The urban design of the development takes advantage of natural and constructed waterways to create sustainable stormwater systems, encourage biodiversity, and create great urban open spaces.

The design of buildings also enhances the sustainability of the site. Buildings are oriented to get maximum benefit from sunlight, both for daylighting and for energy generation. Green roofs, solar hot water panels, and sustainable building materials enhance the connections of buildings to the land and the environment. The development uses its own closed-loop systems for resource use and reuse, known as the Hammarby Model, which also includes a wastewater plant.

An in-house environmental information cetner, the 'GlashusEtt', helps pass on the lessons of Hammarby to residents and visitors thorugh exhibitions and demonstrations of new environmental technologies.

History

In the early 1880s the area was a popular park for the inhabitants of Stockholm. However, in the late 1800s a large bay, a part of the original area, was filled for a planned port and highway construction. The port was never built and the land was made available for storage depots and industries. However, until 1998 most of the buildings were temporary structures (Vestbro, 2005). These uses contaminated the site, so a considerable amount of remediation was needed on the site.

Hammarby Sjostad overview. Photo by Jordgubbe. Retrieved from http://commons.wikimedia.com

The project planners worked with various companies, organizations, and agencies to clean the site and create a livable sustainable habitat, and to ensure that all aspects of clean energy were considered and included. Great emphasis was placed on the importance of collaboration and synergistic thinking between these agencies, each having responsibility for different segments of the system. Hammarby Sjöstad is a full-scale, living proof that usage of clean energy and energy saving solutions do not have to increase project costs. (Novotny)

Environmental Goals

The overall environmental goal of the development is to preserve the existing natural areas as much as possible and create new parks and green areas within the city.

- The city will have at least 15 m^2 of green courtyard and 25 to 30 m^2 open court yards and park space available to each inhabitant of the city. Park area should be available within 300 meters of every apartment building.
- At least 15% of each courtyard should be sunlit for 4 – 5 hours on sunny days during spring and fall equinoxes.
- Development of the green public areas shall be conducted to benefit the biological diversity in the immediate area.
- Natural areas shall be protected from development. (GlashusEtt, 2007)

Transportation

The goal for Hammerby Sjöstad is that 80% of residents' and workers' travel is via public transportation. The transportation options include light rail, busses, a free ferry, and a shared car fleet. New residential buildings in the development are limited to 0.7 parking spaces per unit. (Novotny, 2010)

A 2008 report estimates that only 21% of residents' trips are via car - with 34% via light rail, 18% via bus, 18% via walking, and 9% via bicycle. (Grontmij, 2008)

Energy

The city uses several renewable sources of energy, such as solar cells, fuel cells, and wastewater heat recovery. The building architecture enables maximal capture of solar energy through building orientation and materials and solar panels on roofs. Solar hot water panels are also used on some buildings. In the central Henriksdal sewage plant, the city's wastewater is treated and heat is recovered and used as part of the district heating system. Wastewater sludge is converted into biogas through sludge digestion. This biogas is used for cooking and as vehicle fuel

Combustible solid waste is transferred to an incinerating plant where it is converted to heat and electricity.

Water and Wastewater Management

Water conservation is implemented by installing water conserving fixtures in the buildings but no reuse of treated wastewater is practiced. Grey water reuse was proposed. The goal is to reduce the per capita water use to 100 litres/capita/day, which is about one half of the current average water use in Sweden. Note that the average water use in the US is much larger, about 400 litres/capita/day (100 gpcd).

The area has an experimental on-site centralized wastewater treatment and resource recovery treatment plant (no water is reclaimed currently from the plant for reuse), officially opened in 2003. The plant, which receives only sanitary sewage flows, reduces the nitrogen level in the effluent to below a standard of 6 mg/l and recovers 95% of phosphorus for reuse on agricultural lands. The phosphorus concentration in the effluent is expected to be below 0.15 mg/l.

Most of the city concepts were conceived before the onset of discussions of the benefits of decentralization. Also building codes in Sweden are under rigid governmental controls. Concepts essentially followed the established codes. (Novotny)

Landscape architecture

The street dimensions, block lengths, building heights, density and usage mix were designed to take advantage of water views, parks and sunlight. Restricted building depths, set backs, balconies and terraces, large glass areas, and green roofs are the main features. Landscape architecture planning is crucial in the implementation of surface storm infiltration and drainage. Stormwater from the developed area is routed on the surface in channels into three surface canals transecting the city, each designed to maximize infiltration.

A green avenue links the city district's public green spaces creating a green corridor running through the southern part of the city. The parks are also linked to the nature conservation area and forests. Most pre-development natural areas have been preserved and new nature areas around the shoreline (former brownfield areas) were recreated.

Green roofs on some buildings in Sjöstaden are another link in the local stormwater treatment chain. (Novotny)

Solid waste recycling

Solid waste management is conducted in each building (for everyday waste and paper recycling), in each block (for other recycling and bulky items), and at an area-wide waste collection point. The area base deposition facilities receive potentially toxic wastes such as paint, solvents, and large batteries and other materials that must not be deposited with the other block level waste nor poured into household drains. These wastes are separated and handled at the hazardous waste collection location.

Combustible wastes are recycled as heat and converted into electricity in an incinerator located in South Stockholm. Food waste is composted into soil along with the sludge residuals after sludge digestion and methane extraction. The biosolids are currently used in the surrounding forest and the application will be expanded also to farmland. (Notvotny)

The city uses a sophisticated automated waste disposal system that conveys the source based waste into underground tanks separated by material and passed through an pneumatic tube system into large collection vehicles and delivered for processing.

Health and Social Well Being

Cultural sustainability is also an important element of the design of Hammarby. In addition to the open space network throughout the development, a ski slope, sports facilities, a cultural center and a library are available to residents and visitors. (Novotny)

Integrated Planning

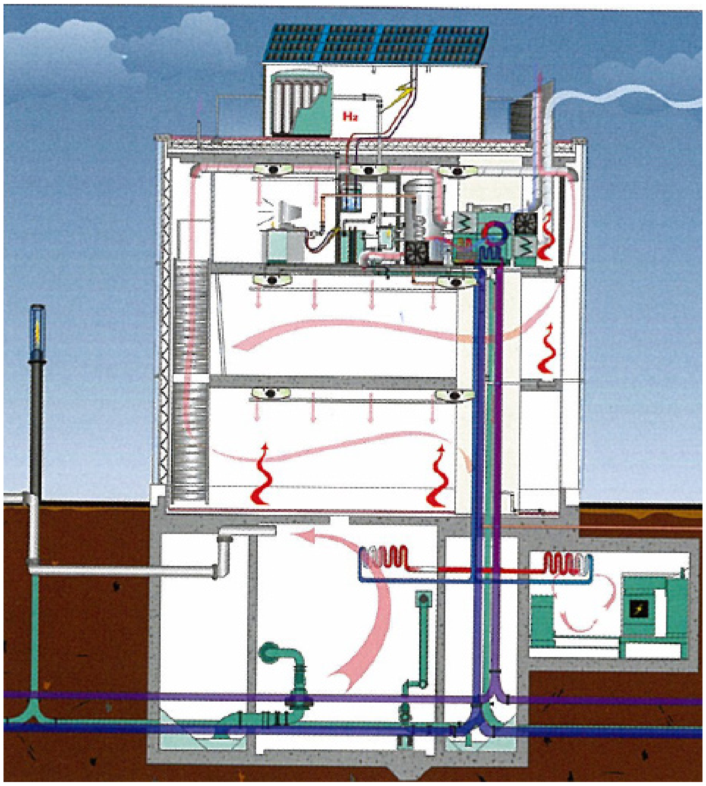
The goal of the integrated planning process was to create a residential environment based on sustainable resource use, wherein energy consumption and waste production would be minimized, and resource and energy savings maximized. The ecocycle Hammarby Model, is presented below.

Summary

Typical Swedish suburbs differ significantly from US examples - they mainly contain large blocks of apartment houses and not detached single family units typical for US suburban developments. The average population density in Hammarby Sjöstad is 133 inhabitants/ha which is in between the typical suburban density in Sweden of 34 inhabitants/ha and that in the central city ranging between 163 – 273 inhabitants/ha. Higher density developments are more environmentally friendly and have a smaller carbon footprint than typical suburban developments. A "compact" city with good transportation and other services such as recreation, shopping, etc, reduces the demand for private car ownership. (Notvotny)

Hammarby Sjöstad has documented that energy and water use can be halved in comparison to standard Swedish urban settings even when considering that typical Hammarby apartments are larger than typical for the Stockholm area (Vestbro, 2005).

Pneumatic waste disposal system. All refuse chutes are linked by underground pipes to a central collection station. An advanced control system at the station sorts waste into the appropriate container. (Novotny)



GlashusEtt: Hammarby's Environmental Information Center building. The facility features a number of advanced green building technologies, including:

- *A rooftop solar power plant*
- *Fuel cell power*
- *Biogas-powered heating system*
- *Low-energy lighting throughout*
- *Daylighting control system*
- *Vacuum based solid waste removal system and sewage pumping station*

The city development promotes a sustainable lifestyle and serves as a laboratory for sustainable development. In this sense, Hammarby Sjöstad is the first city built on ecological principles and created true sustainable urban development. It is a true lower impact development without low density developments that are common with "low-impact" development. While Hammarby does not incorporate some cutting-edge technologies and systems that could lower energy and water use for the site, it still stands as a model of effective, sustainable urban development.

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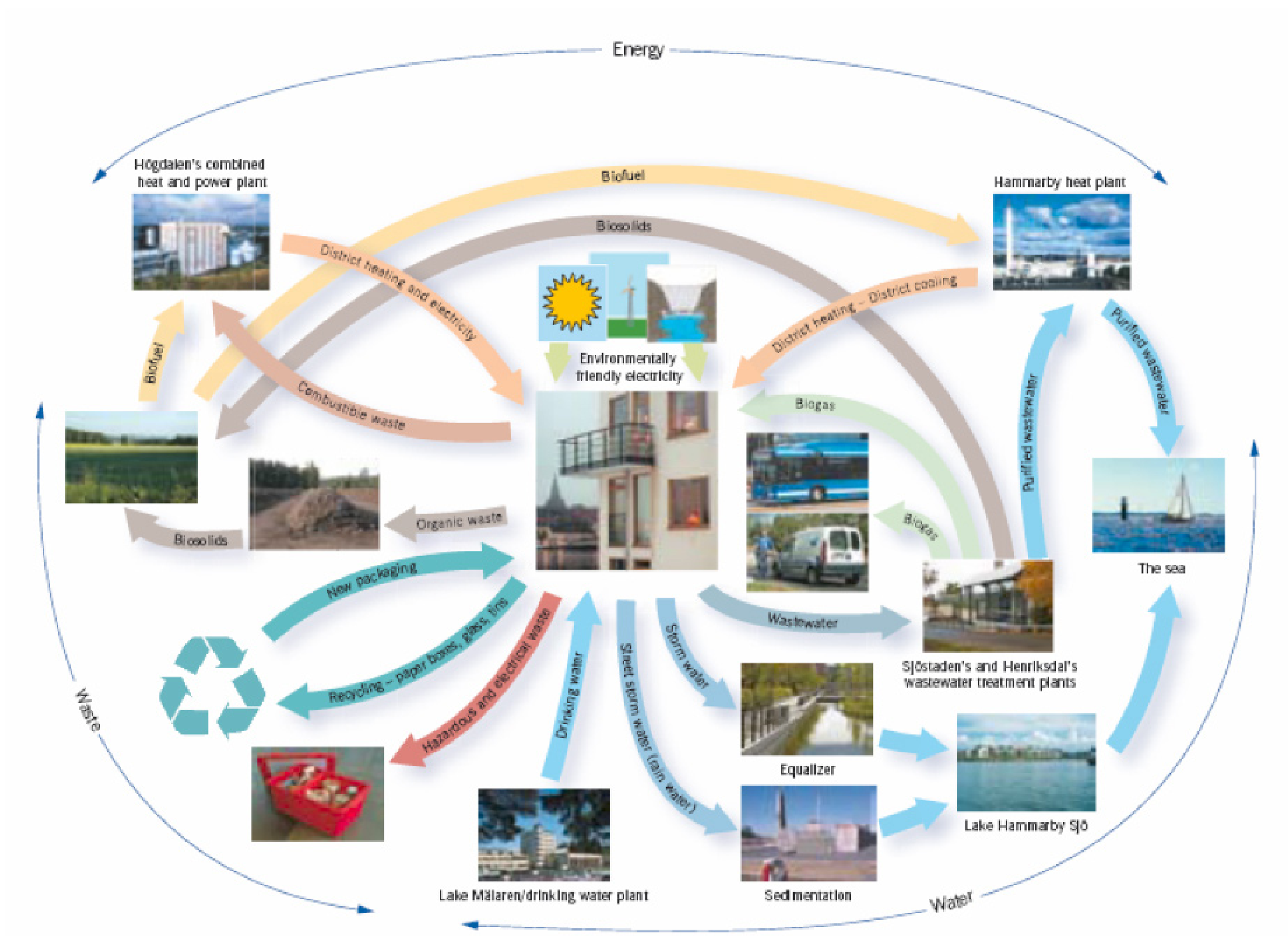


Energy	Water and Sewage	Solid Waste
• Combustible waste is converted into heating and electricity • Biodegradable waste is converted into biofuel and subsequently into heat and electricity • Solar cells convert solar energy into electricity • Solar panels use solar energy to heat water • Good heat insulation, southern exposure, solar panel and building materials reduce the energy demand	• Water consumption is reduced through the eco-friendly installations, low flush toilets and air mixed taps • A pilot wastewater treatment plant was built to treat separated sanitary wastewater and to research treatment technologies • Digestion extracts biogas from the sewage sludge • The digested solids are used for fertilization • Rainwater is drained via surface paths to the lake • Local BMP treatment of polluted street runoff	• An automated waste disposal system with three deposit chutes, a block based system of recycling rooms, and an area based environmental station sorts and disposes the waste • Organic waste is converted/digested into biosolids and used as fertilizer • Combustible waste is converted into electricity and heating • All recyclable materials are sent for recycling • Hazardous waste is incinerated or recycled

The Hammarby eco-cycle model: Energy, solid waste, and water.

Characteristics and parameters of Hammarby Sjöstad

Location	Stockholm, Swedden
Area of development	200 ha (480 acres)
Population served	25,000 – 35,000 when fully developed in 2015
Population density	133 inhabitants/ha (56/acre)
Project team	
Key partners	Exploaterings kontoret Stockholm Stad and app.20 different proprietors
Lead planners	Stadsbyggnads kontoret
Architect	Stadsbyggnadskontoret in cooperation with architects from the app. 20 other architectural and consulting companies
Water and wastewater	Stockholm Energi, Stockholm Water and SKAFAB (the city's Waste Recycling Company)
Contact web site	www.hammarbysjostad.se
Project cost	20 billon Swedish Krones (appr. US$ 2.4 billion)
Type of drainage	
Sanitary	Subsurface (sewers) connected to a centralized on-site experimental treatment plant
Storm runoff and snowmelt	Local surface channels and green roofs. Stormwater from streets with more than 8000 vehicle/day traffic is treated by local BMPs (infiltration, storage, sedimentation)
Renewable energy	Solar cells, solar panels
	Heat extraction from treated wastewater (also converted to cooling)
	Buildings green architecture
	Heat extraction from incineration of combustible solids
	Biogass production by digestion from organic solid residuals
Water conservation	Outside source, inhouse water saving fixtures (low flushing toilets, dishwasher machines, showers; potential gray water reuse)
Wastewater system and management	Linear and centralized (no water reclamation from the central treatment plant). Heat is recovered by heat pumps.
Transportation	Light rail and (free) ferry to Stockholm
	Car pools
Recreation, leasure, sports	Extensive network of foot and bicycle paths, cross country skiing, down hill ski slope
	Sports arena and a cultural center
Green areas and nature	Extensive, interconnected, natural and man made; see below

Overview

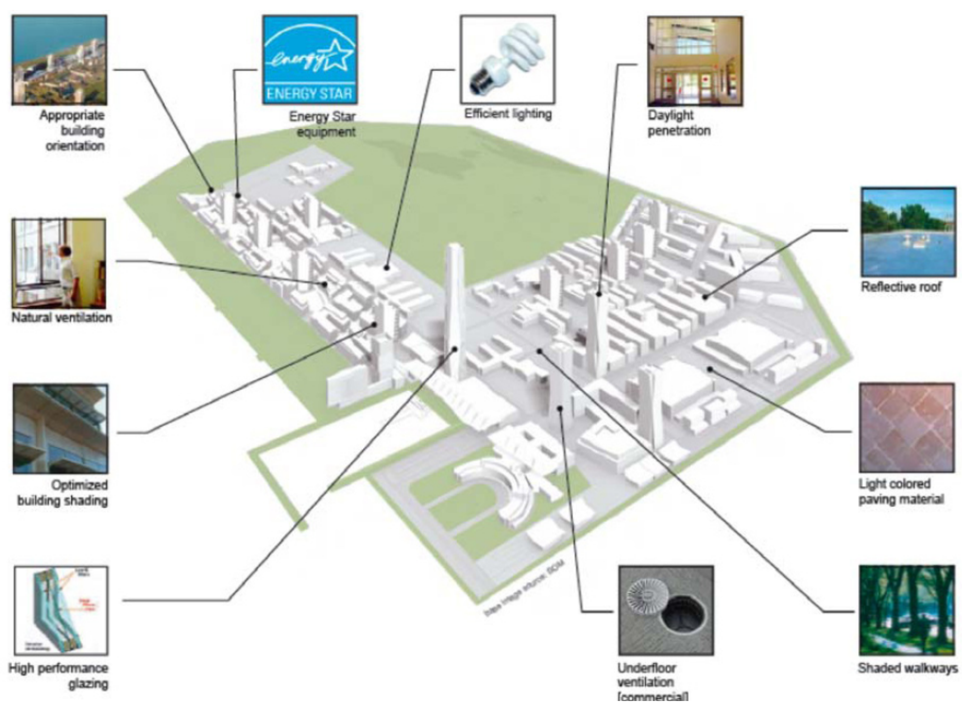
Treasure Island is a manmade island constructed to host the 1939 Golden Gate International Exposition. It was built up from dredged sediments from San Francisco Bay and was originally intended to become an airport after the exposition. The site was transformed into a center for training and dispatching military service personnel. during World War II. In 1990 Treasure Island supported a population of more than 4,500 people and a daily employee population of almost 2,000. In 1997 the naval base was closed as part of the Base Realignment and Closure III (BRAC) program and redevelopment plans have been developed to transform Treasure Island and the nearby Yerba Buena Island into the most sustainable cities in the United States.

By 2018 Treasure Island and Yerba Buena Island development will be an entirely new built community of 6,000 homes supporting 13,500 residents, a retail-focused town center including 21,800 m^2 (235,000 sq ft) of retail space, hotels with a total of 420 hotel rooms, adaptive reuse of historic structures, a marina district including ferry transport to San Francisco, a range of essential services and an extensive open space program. No official references regarding the cost are available but the total cost has been unofficially estimated to be around $3 billion. (Novtony, 2010)

Overview site plan of Treasure Island and Yerba Buena Island (TIDA, 2010)

Other important issues that need to be addressed during the construction of the Treasure Island development relate to seismic conditions and traffic. Under current land conditions, Treasure Island is expected to perform poorly in a major earthquake event resulting in possible soil liquefaction and lateral spreading. Stabilization of the island needs to take place before construction can be started. Traffic is another issue that needs to be addressed. Currently access to Treasure Island and Yerba Buena Island is only possible via the Bay Bridge. The high volume of traffic on the Bay Bridge and the design of connecting ramps to the two islands mean that vehicular traffic access will remain constrained in the future. The goal is to minimize impact on traffic volumes on the Bay Bridge. (TIDA, TICD, 2007)

Many groups are involved in the design of this project including the following government agencies: San Francisco Department of the Environment, TICD (Treasure Island Community Development) team, TIDA (Treasure Island Development Authority), and the San Francisco Public Utilities Commission. Private companies involved include Arup, BFK, BVC Architects, CMG Landscape Architects, Concept Marine Associates, CH2MHILL, Concord Group, Engeo, Geomatrix, Homberger Worstell Architects, Korve Engineering, Nelson/Nygaard, Skidmore Owings & Merrill, SMWM, Tredwell & Rollo, Tom Leader Studio, and William McDonough + Partners.



Energy saving techniques (TICD, 2007)

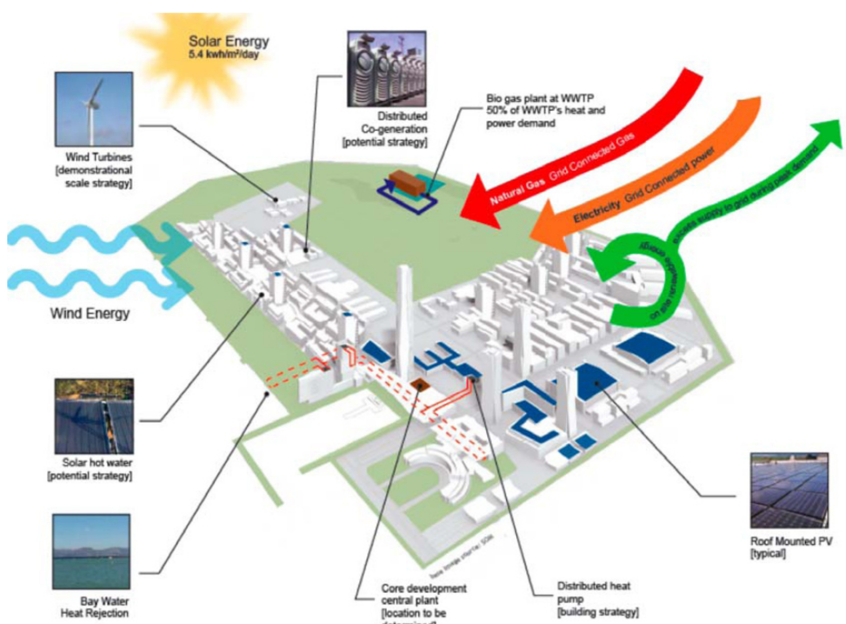
Characteristics: Open Spaces

Extensive open spaces will be provided covering approximately 120 ha (300 acres) for the entire project including 55% of Treasure Island. There will be a number of neighborhood parks spaced among the residential areas for access and use by the residential occupants. Throughout the island native or non-invasive, climate appropriate and low maintenance plants will be used. At the center of the island an organic farm is planned that will allow for the production of local foods, opportunities for training and job creation as well as a place to use composted organic wastes from the residential areas. (Novotny)

Energy

A large portion of the energy management is to reduce power demand and energy consumption. Many design criteria will be used in order to reduce the power demand throughout the island including: appropriate building orientation at 35 degrees from due south to optimize solar exposure and create wind protection, natural ventilation, high performance glazing, maximize use of day lighting, integrated lighting and energy controls, specification of energy star certified appliances, centralized heating and cooling, and solar hot water for residential areas.

A central utility plant for heating and cooling certain buildings in the central core of the development is planned to reduce energy consumption. This central plant will use a distribution heat pump loop with heat pumps in each building and plate frame heat exchanges to either reject or absorb heat from the bay depending on the season. Energy production on the island will be gained from the sun, wind, biogas and tide waters. In order to harness energy from the sun, roof mounted PV cells will be used. Solar panels will cover 70% of the rooftops generating 30 million kilowatt-hours of electricity per year. Solar power will also be used as water-heating systems that can support up to 80% of the hot water needs.



Energy production for the island (TICD, 2007)

To harness wind power, larger scale wind turbines and small-scale vertical turbines will be placed on top of buildings. Other energy solutions being considered include the installation of tide driven turbines on the floor of the Golden Gate channel and a biogas generator at the wastewater treatment plant. The biogas generator could provide half the power and heat needed for wastewater treatment.

On-island energy production will only be enough to provide 50% of the power needs of the community. Energy will need to be brought into the island to provide power during periods when solar output is low. This will be brought in through the grid from renewable energy sources. In the middle of the day, when solar output is at a maximum, more energy will be created on the island than is needed. The extra energy will be exported off the island to provide power to the grid. (Novotny).

Transportation

The main goal of the transportation design is to reduce car use and promote public transportation, walking and biking. The transportation network throughout the island is orientated first around walking and biking and provides integration into the regional transportation system via ferry and bus. 90% of the residents will live within 1.2 km (0.75 miles) from retail services and within a 15-minute walk from an intermodal transit hub. Neighborhood-oriented retail is also planned with the hope that residents do not have to leave the island for their basic needs.

An on island transit system will also be provided with a small fleet of electric or alternative-fuel shuttles. The transit system will provide transportation to residents that live more than ½ mile away from the transit terminal. The transit terminal will provide transportation to San Francisco through a bus and ferry system.

Car use will be limited by a fee and pricing system. Parking management will be based on a policy that all auto users incur a parking charge. A congestion pricing program will be applied to people who choose to use their car to get to and from the island during peak travel periods. Ramp metering will also be used to limit the number of vehicles that can leave the island during periods of bridge congestion. (Novotny)

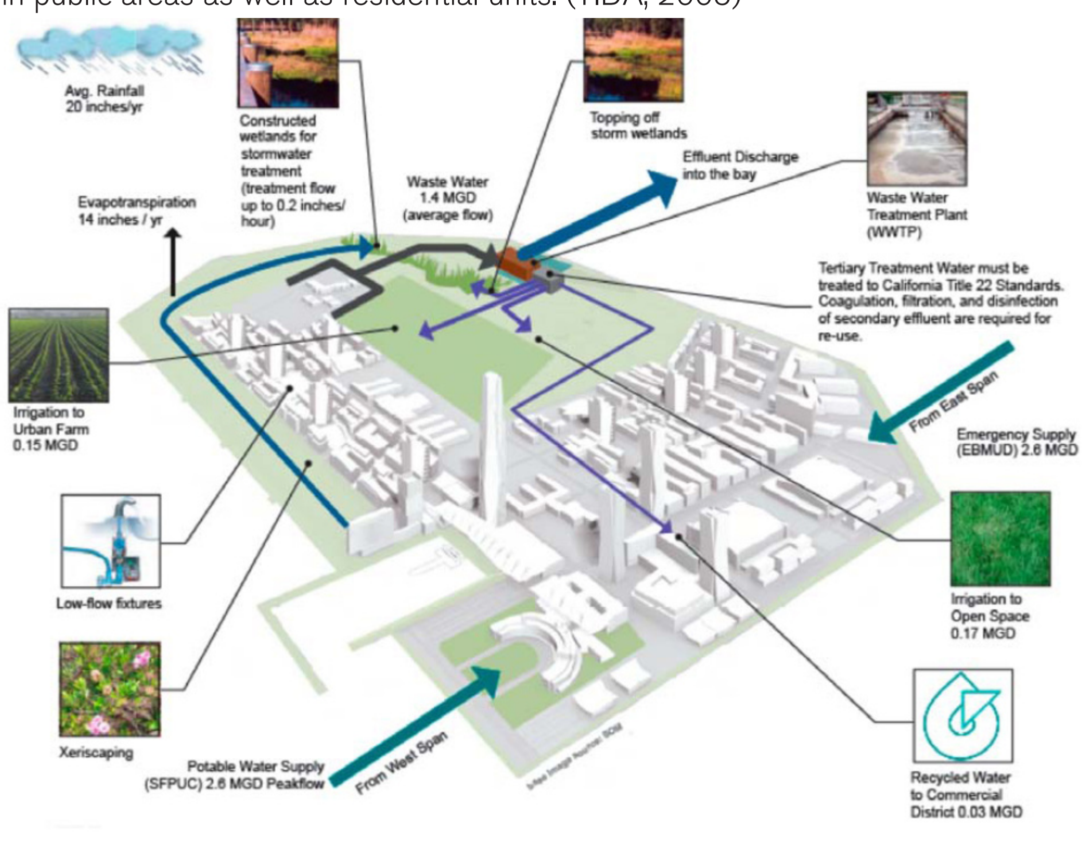
Water Use and Treatment

Potable water will be imported from San Francisco. Low flow faucets, shower heads, toilets with sensors and controls along with low water use appliances including dishwashers and side loading washers will be installed in all residential units to reduce water consumption. All of the water use practices will provide a reduction in water use from the existing 380-450 litres per capita per day (100-120 gallons) to 265 litres/capita/day (70 gallons) a 30% reduction.

Stormwater management will center on xeriscape, permeable surfaces and pavements, green roofs and routing excess runoff to be treated in a wetland. The impermeable area of Treasure Island will shrink from 64 to 39% through these practices (Ward, 2008). Once the excess runoff is collected it will be routed to a constructed treatment wetland. The treatment flow will be 0.5 cm/hour (0.2 inches/hour), which includes 80-90% of storms in the Bay Area. In the wetland the minimum retention time will be 48 hours. Stormwater in excess of the treatment flow will be collected and discharged into the bay directly.

Solid Waste

The Treasure Island development has a plan to divert 75% of the solid waste from landfills, in line with the City of San Francisco environmental goals. Organic waste will be composted and used on the island's urban farm and community gardens. A sustainability center will be developed to inform residence and business on how to reduce the amount of waste. In addition to informing the residence a strong recycling program will be implemented with the 3-bin program. Separate bins will be used from compostable, recyclables and general waste in public areas as well as residential units. (TIDA, 2005)



Proposed water cycle & water reduction strategies (TICD, 2007)

Case Study #2 — Treasure Island San Francisco, CA

Summary

The Treasure Island development including both Treasure and Yerba Buena Islands will combine high-density residential areas with large open community parks, neighborhood areas and a community organic farm. Renewable energy will provide 50% of the power required by the island by using technology such as PV cells, wind turbines, biogas digesters along with building design that reduce energy consumption. Walking and biking will be promoted through extensive bike and pedestrian paths, close proximity of residential areas to the transportation depot and commercial areas designed to fit the needs of the community. Stormwater will be treated with a centralized wetland and 25% of the wastewater will be recycled for irrigation and commercial use. With the installation of low flow appliances and fixtures, total water use will be reduced by 20%; however, the water use will be still very high and not commensurate with other ecocity development. Energy produced in the island central power plant will be mostly derived from conventional fuels and only 5% from renewable energy sources. On site composting of waste to be used on the island and an extensive recycling program will try to reduce trash exports by 100% from the island by 2020. (Novotny)

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Site Characteristics

Location	San Francisco, CA
Area of Development	1.8 km^2 (180 hectares - 450 acres)
Population Served	13,500
Populations Density	150 people per hectare of built area
Project Team	
Key Partners	Treasure Island Community Development (TICD), Treasure Island Development Authority (TIDA), City of San Francisco
Lead Planners	SMWM, SOM
Architect	SMWM, SOM with the help of 18 other architecture and consulting firms
Contact Web Site	www.sfgov.org/site/treasureisland_index.asp?id=284
Type of Drainage	
Sanitary	Subsurface connected to a centralized treatment plant
Stormwater	Green roofs, xeriscape, and gravity pipes for excess runoff to a centralized wetland area for treatment
Renewable Energy	photovoltaics, small vertical axis wind turbines, solar hot water heating, bio-gas power generation from WWTP Peak energy use 17.4 MW 5% renewable
Water Conservation	Low flow fixtures (faucets, toilets, showers, dishwashers, washing machines), Recycling 25% of water for flushing toilets, irrigation, boat washing etc. Water use 264 L/cap-day (70 gpcd)
Wastewater System and Management	Centralized. 25% of the water is recycled
Percent solid waste diverted from landfill	95 %
Transportation	100 % of the population within a 15-minute walk to the transit hub, ferry transportation to San Francisco, bus service to San Francisco and Oakland from transit hub. Car share program. Extensive network of bike paths.
Recreation, Leisure, Sports	Network of foot and bike paths, recreational center with sport fields, marina access, neighborhood parks and on island organic farm
Green Areas and Nature	Extensive, covering 56% of the 180 hectares
Affordable Housing, %	30
Probable Cost	$ 3 billion

Case Study #3 Sonoma Mountain Village Rohnert Park, CA

Overview

Sonoma Mountain Village is located 40 miles north of San Francisco in the city of Rohnert Park, CA, USA. Currently a light industrial area, the developers plan to create the first certified "One Planet Community" in North America (and only the fourth in the world. The construction and design of this village is being lead by BioRegional and Codding Enterprises at a total cost of $1 billion.

The construction of the Sonoma Mountain Village Community is expected to begin in late 2009 with models projected to be available for viewing in early 2010. House construction is projected to start in 2012 with the completion of the entire project being finished in 2020 (Sonoma Mountain Village, 2009). In total 1900 homes will be constructed on 0.8 km^2 (0.3 sq mi) of land with a mix of 900 apartments and condominiums and 1,000 single-family homes. These homes will vary between single family, rowhouses, affordable-by-design homes, townhouses, multifamily condos, lofts, flats and luxury homes ranging between 56 to 420 m^2 (600 to 4,500 sqft) and prices from $300,000 to $3M (Sonoma Mountain, Village 2009). Total population after completion is expected to be around 5000 (Sonoma Mountain Village, 2008).

The Community will include 500,000 square feet of commercial, retail and office space to serve the needs of the neighborhoods and surrounding communities. Currently 21 businesses will be located in the community as well as 27 sustainability and socially-oriented technology start-up companies (Sonoma Mountain Village, 2009).

Following the ten principles of the "One Planet Living" concept, the eco city principles for the Sonoma Mountain Village not only pertain to the final product, but also for the construction process. A number of measures are being conducted to insure that energy use and damage to the environment are minimized during the building phase, as they are when the city is complete. During construction vehicle access will be constrained to existing roads and new asphalt roads, storm drains will be protected with filter strips and settling areas as needed and any significant vehicle use off roads will be preceded by soil stabilization with gravel and the use of additional silt fences and earth dikes (Water Balance, 2006). All asphalt and concrete removed from previous construction will be reused onsite. Stockpiling of these materials will require appropriate containment areas to prevent oils and concrete dust from mobilizing. Temporary seeding and mulch-

Artistic rendition of public areas (Sonoma Mountain Village, 2009)

Characteristics of the Sonoma Mountain Village Development

Table 2.6 Characteristics of the Sonoma Mountain Village Development

Location	Sonoma Village, CA, USA
Area of Development	0.8 Km^2 (80 ha or 200 acres)
Population Served	5000 people
Populations Density	62 people/Ha (25 people/acre)
Project Team	
Key Partners	BioRegional, Codding Enterprises
Lead Planners	Codding Enterprises
Architect	Farrell, Faber & Associates, Fisher Town Design, KEMA Green, Scott Architectural Graphics, MBH Architects INC., WIX Architecture
Contact Web Site	http://www.sonomamountainvillage.com/
Type of Drainage	
Sanitary	Subsurface connected to a centralized treatment plant
Stormwater	Raingardens, biofiltration swales, pervious pavements in alleyways, construction of stream to transport runoff out of village
Renewable Energy	photovoltaic arrays on building tops
Water Conservation	rainwater harvesting, water reuse, and use of low flow devices including ET irrigation technology.
Wastewater System and Management	Centralized.
Transportation	Promote biking and walking within the city, car share/carpool programs, rail transport to nearby cities.
Recreation, Leisure, Sports	Network of foot and bike paths, sports fields
Green Areas and Nature	Green areas throughout city.
Project Cost	$ 1 billion

ing will be used to stabilize bare soils throughout the projects. Silt fences, sediment traps, basins and biofilters will be used. (Water Balance, 2006)

Open spaces, parks and communities areas will be located throughout the 0.8 km^2 land area including over 10 hectares (25 acres) of parks, many kilometers of trails for walking and bicycling, dog parks and an international all-weather soccer field (Sonoma Mountain Village, 2009). Landscaping will include groupings of plant species native to California and species adapted to the local climate. Throughout the development turf areas will be limited to neighborhood parks, plazas and private back yards minimizing the use of lawns or turf areas in residential front yards or sidewalk planting strips. Trees will also be planted along the streets and chosen for their heartiness, shade and beauty (Water Balance, 2006). Residents will have access to community gardens, fruit trees, and a year-round farmers' market (Peters, 2009). In addition to the local farmers market, 65% of all food consumed by the community will come from within 300 miles with up to 25% coming from within 50 miles promoting locally grown sustainable farming practices (Sonoma Mountain Village, 2008). In addition to all of the green spaces located on ground level, green roofs will be used throughout the community. In all 10 % of the land will be set aside for habitat and 20% of the land for green spaces with a total of 50% of the project area acquiring conservation easements using pollinator gardens on green roofs, native flowers, trees and grasses throughout the community (Sonoma Mountain Village, 2009).

Energy

The energy plan in the village community will center on solar energy and energy conservation. A $7.5 million, 1.14 MW, 5845 photovoltaic panel solar array was mounted on the roof of an existing building within the community in 2006 (Peters, 2009). This array will be used to power the construction of the development and then be used to help power the community. When the community is finished the solar power output is expected to quadruple with excess energy rerouted to the utility grid.

The energy efficiency of the buildings designed will beat the state of California's current energy code by at least 50%. The use of ground source heat pumps, ultra efficient lighting and appliances, super insulated walls, floors and roofs along with solar hot water pre-heat systems will be used to accomplish this mark

Artistic rendition of the town square (Sonoma Mountain Village, 2008)

Solar panels, placed on building in 2006 (Sonoma Mountain Village, 2008)

(Sonoma Mountain Village, 2008). By 2020 the energy use in buildings will have zero carbon equivalent emissions while average California homes CO_2 equivalent energy emission are around 8,240 tonnes (9,082 US tons) per year.

Transportation

The transportation goals in the community will center on the use of walking and biking as the primary transportation methods. Every resident will be no more than a five-minute walk to groceries, restaurants, day care and other amenities offering local, sustainable and fair trade products and services. These services will be located in the town square at the center of the community (Peters, 2009).

Narrow tree-lined streets, paths and convenient bicycle parking will be available throughout the village. Free bikes, electric vehicles that connect to the smart grid, a biofuel filling station, plug in hybrid car share programs, and a carpool concierge services will be used to reduce the car traffic throughout the village. A commuter rail station will also be located within 10 minutes of the village (Peters 2009). Overall the goal of the community is an 82% reduction of green house gas emissions from traveling to, from and within the village (Sonoma Mountain Village 2008). A typical California resident emits annual 22,140 tonnes (24,407 tons) of equivalent CO_2 whereas the people located inside this development are estimated to only emit 3,940 tonnes (4,343 tons) annual for transportation (Sonoma Mountain Village 2008).

Water Use

The goal for water used within the Sonoma Mountain Village is a reduction in water consumption by 60% from a general norm for single family homes in the region (Water Balance, 2006; Coddings Enterprises, 2007). This will be accomplished through water reduction devises, education, rainwater harvesting and re-use of water. The municipal drinking water supply will be used inside of all buildings and irrigation in private backyards. Reclaimed water will be used for irrigation of all public parks, medians, and street trees along with irrigation of all common areas, private front yards and for use in fire hydrants (Water Balance, 2006). Stormwater reuse will be used for habitat maintenance, groundwater recharge and as a supplemental irrigation supply for all landscape areas (Water Balance, 2006). There will be habitat protected bioswales acting as wetlands connected to a 15,100 m^3 (4 MG) underground reservoir from which water will be recycled for irrigation purposes (Kraemer, 2008). The savings, reclamation and reuse components of the water system are presented below.

Municipal Drinking Water Supply	Reclaimed Water	Rainwater	Graywater
All contact uses in buildings	Toilet flushing in new commercial buildings	Habitat maintenance	Small-scale private backyard subsurface irrigation
Toilet flushing in most existing commercial buildings	All common area irrigation	Groundwater recharge	
Residential toilet flushing per Title 22	Cooling tower	Common area irrigation	
Private backyard irrigation	Fire hydrants	Cooling tower	

Water saving reclamation and reuse in the Sonoma Mountain Village Development

In order to reduce irrigation watering needs, high efficient irrigation systems will be used such as sub-surface drip tubing and weather track ET irrigation controllers. ET based irrigation controllers track weather conditions through the CIMIS satellite signals to determine the best time for watering. The system combines weather forecast and current weather conditions with pre-programmed soils and plant specific data to adjust water schedules as needed. This type of system can reduce irrigation water use by 50% and reduce the amount of runoff created through irrigation by 71% (Water Balance, 2006). The system will make use of a sufficient combination of bubblers, drip lines, targeted sprayers and subsurface irrigation to minimize the amount of evaporation and over spraying in areas. Rainwater harvesting will also be used in buildings with underground parking lots, or homes and next to public parks where enough area is available for large storage tanks (Water Balance, 2006). This water will also be used to meet the irrigation needs of the community.

Inside each building, water reduction strategies will be implemented as well. Showerheads will be low-flow, commercial lavatories and residentail sinks will be fit with flow restrictors. (Water Balance, 2006). Toilets will be low-flow, urinals will be waterless and dishwashers and laundry washers will be Energy Star compliant (Water Balance, 2006). In addition fire suppression systems within buildings will use reclaimed water as opposed to municipal water. In all with extensive water conservation measures, water re-use of greywater and reclaimed water systems and a massive rainwater harvesting system no more water will be required beyond what is already being used by existing buildings despite adding around 2000 new homes (Peters 2009).

The Water Plan for the village (Coddings Enterprises, 2007) estimates average daily water use for the village as 1,186.5 m^3/day, of which 31% will be for irrigation (with reclaimed water), 60.5% for residential water demand and 8.5 % for commercial use, respectively. This would correspond to water demand of 237 litres/capita-day which is significantly lower than the typical municipal water use in California. Specifically for Sonoma County the average water use in 2005 was 605 L/cap-day (160 gpd). Of the 237 litres/cap – day, 22 % will be reclaimed water from treated effluent and stormwater, hence the average demand on the municipal grid will be 185 litres/capita-day.

Stormwater

Throughout the village stormwater management practices will be used to reduce pollutants and runoff coming from the development. Raingardens and biofiltration swales will be used as the initial primary catchment for the runoff from the main street network and from roof downspouts on large buildings. These systems will drain filtered water to the underlying aquifers, reducing runoff volumes while increasing groundwater recharge (Water Balance, 2006). Alleyways will be constructed with pervious pavements and combined with under drained substrate to reduce the amount of impervious surfaces in the development. Street trees will be used providing additional areas for the transient storage and percolation of stormwater in the soil structure (Water Balance, 2006)

Underground infiltration galleries will also be used to store and percolate runoff where space restrictions or other land use considerations limit the use of biofiltration or raingardens. A channel corridor will also be constructed running the length of the village along an existing railroad track. Along this corridor will be trails and attractive landscaping used with a channel system that will have overbank storage for flood flows to transport stormwater out of the village. In order to control peak runoff flows stormwater detentions will also be used (Water Balance, 2006). Throughout the development stormwater will mainly flow on the surface and through the soils rather than in pipes (Sonoma Mountain Village, 2008).

IEach homeowner will receive a manual welcoming them to the neighborhood and describing how to maintain their home. This manual will contain a section detailing all of the prohibited materials and the reasons why they cannot be used. These materials will prohibit use of synthetic fertilizers, but compost and naturally derived fertilizers will be allowed and will be used extensively (Water Balance, 2006).

Waste Management

Waste management throughout the community will start with the construction phase and continue through the life of the village. During construction all existing buildings and materials in the previous workplace for 2,500 workers will be reused (Kraemer, 2008). Existing buildings will be incorporated into the design. All asphalt and concrete removed from the area will be stockpiled and reused during construction (Sonoma Mountain Village, 2008). The home manufacturing will be done on site in a near zero waste panelized home production facility. All of the new construction will utilize recycled steel framing from an on-site factory run by Codding Steel Frame Solutions. This new technology will allow for the building of homes with structural members made from recycled steel rather than lumber (Sonoma Mountain Village, 2009). This facility will be run on solar power and create zero waste with the final steel frame products being 100% recyclable (Peters, 2009). The entire construction process will include 20% of the materials being manufactured on site with 60% coming from within 500 miles (Sonoma Mountain Village, 2008). Overall the amount of CO_2 equivalent green house gas emissions for the one time construction of the development will be reduced from a California average for a similar community of 113,400 to 39,690 tonnes.

After the completion of development an intensive recycling program will be put into place resulting in only 2% of the waste entering landfills by 2020. This included addressing retail and grocery packaging, food waste composting, school education and creative contest to promote waste free living (Sonoma Mountain Village, 2008). Town-wide composting will be used to create soils for the community gardens, small parks and fruit trees throughout the village. (Kraemer, 2008)

Summary

The Sonoma Mountain Village will incorporate the 10 One Planet Living (OPL) principles into the design of a small 5000 person village north of San Francisco. The community has applied for inclusion in the LEED-Neighborhood Development pilot program trying to obtain platinum LEED certification for the entire village as well as LEED certification for each individual building (Carlsen, 2007). The community is seeking endorsements from the Sierra Club Conservation Committee, the Greenbelt Alliance and the Accounting Housing Coalition in order to obtain outside certification on the sustainability of its designs (Carlsen, 2007). The development is scheduled to be completed in 2020 and upon completion could become the first development in North America to be certified as a One Planet Living community.

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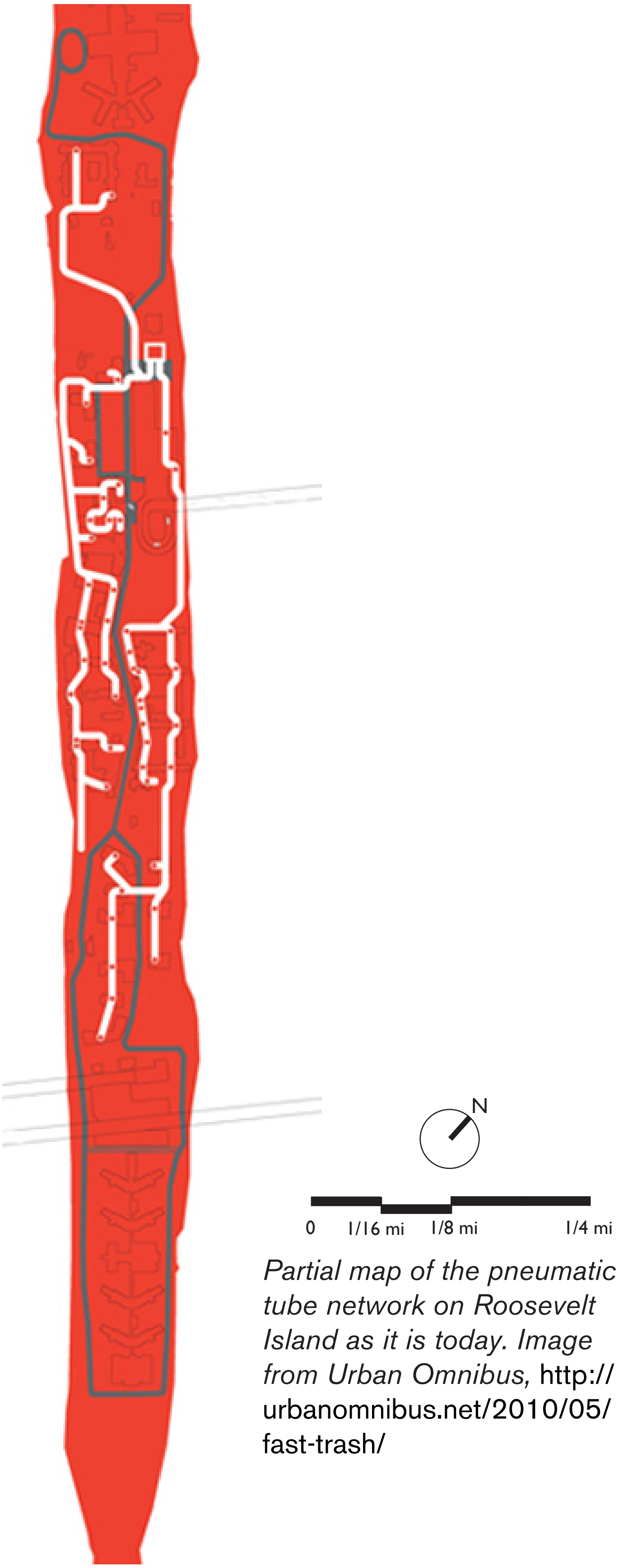
Case Study #4 Roosevelt Island Pneumatic Waste System, New York, NY



Partial map of the pneumatic tube network on Roosevelt Island as it is today. Image from Urban Omnibus, http://urbanomnibus.net/2010/05/fast-trash/

Overview

Roosevelt Island is a 2-mile-long, narrow island between Manhattan and Queens in New York City. In the late 1960's, the New York State Urban Development Corporation signed a lease for the entire island (formerly named Welfare Island and a site for New York's Insane Asylum, a prison, and several hospitals) and commissioned a master plan for redevelopment. The plan called for an advanced urban environment, including as many as 20,000 residents. As part of the planning process, a number of innovative infrastructure systems were investigated. Perhaps because of a garbage strike in New York at the time the plan was being developed, a pneumatic waste system (called an AVAC, or Automated Vacuum Collection System) was installed to serve the entire island. The system was inaugurated in 1975, and remains in use today. It is one of the earliest pneumatic waste systems to be used in North America.

AVAC system

The system includes 49 inlets in buildings thorough the island. The system of 20-inch-diameter pipes is separated into east and west sections that run alternatively, thus providing some level of redundancy in case of blockage or other system stoppage. Large fans pull air through the pipes at 60 miles per hour, pulling the trash to the AVAC facility. There, a cyclone separator divides heavy trash from light, and dust is filtered out of the air. The trash is then compacted in containers for transport.

System Goals

Roosevelt Island's AVAC was designed and built at a time when solid waste issues were coming to the forefront – garbage incinerators were being closed down due to environmental concerns, recycling programs had not yet become commonplace, returnable glass bottles were being phased out, and trash volumes were increasing. The AVAC system allows the entire system (with now 12,000 residents) to be served by only 8 staff members. The system is limited to residential buildings and to certain parts of the island – other areas use traditional truck-based service. Trash trucks still carry the compacted trash from the AVAC facility to standard transfer stations, but the 12-times-a-day trash collection does not require regular vehicular trips – estimated to avoid the need for 30 to 35 garbage trucks. The regular collection schedule reduces issues of odors and vermin, and avoids the visual blight of piles of trash and trash containers.

Roosevelt Island's AVAC does not include a recycling system, although more modern pneumatic waste collection systems often have the capability to collect recyclable or compostable materials while using a single network of pipes.

Summary

While pneumatic waste systems remain rare in North America, they are being used in many other parts of the world. The benefits to a community with a pneumatic system include a cleaner environment and a nearly silent and invisible waste collection infrastructure, and this infrastructure can be integrated into road systems or other infrastructure spines. There are other potential benefits as well: The relatively small service area of a pneumatic system (Roosevelt Island's AVAC system has a maximum service radius of about 2 miles) supports neighborhood reuse or composting of waste. The operation and maintenance of the system requires a small on-site staff, which could support local employment and training programs.

Servicing the AVAC system. Image from the Wall Street Jounal, http://blogs.wsj.com/metropolis/2010/05/18/on-roosevelt-island-garbage-is-a-series-of-tubes/

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Case Study #5 Benedict Park Place Ground Source Heat, Denver, CO

Overview

Recently started construction of the last phase of a 15-acre mixed-income development in downtown Denver included a 42-well ground source heat pump system. This system provides all domestic hot water, heating hot water, and cooling for 75 units. The developer, Denver Housing Authority (DHA), has used ground source energy on other public housing projects – the positive results of these initial systems have encouraged them to plan for the use of ground source heat pumps (also called geothermal heat pumps or geoexchange systems) in all future projects.

Ground Source Heat Pump system

The ground source heat pump (GSHP) system at Benedict Park Place consists of vertical-bore wells under the building foundation. The downtown site, already constrained by three previous phases of development, precluded the use of cheaper horizontal loops. Fluid pumped through the wells utilizes the steady temperatures underground to provide a more efficient transfer medium for the heat pump system of the building. GSHP systems typically use 25 to 50% less electricity than a conventional heating and cooling system. GSHP systems use modern heat pumps that are reversible, meaning they can provide heating or cooling for a building. Since a significant portion of the cost of a GSHP is the initial construction of the system, a GSHP installed in a climate that requires both heating and cooling can be very cost-effective in the long term.

Ground-source heat pumps are a more universally-accessible way to use the earth as an energy source, compared with a geothermal energy system that uses the heat from the earth's core (usually accessed from geysers or other heated water sources.) Geothermal energy can be used to drive turbines to generate electricity, or the heat can be used directly in a district system. Geothermal energy systems must be specifically sited at a good geothermal source, whereas ground-source heat pumps are feasible almost anywhere in the US.

System Goals

The DHA uses ground source heat pumps as a way to lower the ongoing energy requirements of its developments. Ground source heat pumps are more expensive to design and construct, but less expensive

Benedict Park Place Phase 2, www.benedictparkplace.com

Typcal equipment for drilling a vertical-bore well. From www.erdwaerme-zeitung.de/images/sondeneinbau to operate. This balance of system costs is very compatible with DHA's funding mechanisms, which use grants and other outside sources to help finance development, lowering operating costs and thus the rents DHA charges residents. It is also well suited for the scale of DHA projects, which tend to be larger developments in urban areas, where the heating and cooling systems of a building can use economies of scale, and where the incremental cost of a ground source heat pump is relatively minor. DHA estimates that ground source heat pump systems pay for themselves within 12 years.

The operating cost savings of a ground source heat pump system means that DHA can afford to either lower rents or provide more amenities to residents. The use of a ground source heat pump system also moves the HVAC equipment into the bases of buildings, freeing up building roofs for other sustainable systems, particularly photovoltaic energy generation.

Summary

The Denver Housing Authority has enough experience with ground source heat pump systems to be confident that they are both economically and operationally viable – and that these systems help advance DHA's sustainability objectives. The Authority's long-term ownership of buildings and preference for higher-density urban projects has made the use of ground source heat pumps a logical part of their standard development practice. The DHA has cultivated relationships with geotechnical and mechanical engineers and contractors who are now comfortable with the work, so the design and construction costs of ground source heat pump systems will continue to go down for the Authority in the future.

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www.benedictparkplace.com

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