King County GreenTools

Powered by the Solid Waste Division

Green Building and Sustainable Infrastructure Guidelines

Carbon Calculators and Mitigation Strategies

Introduction

Context

King County developed this document to help capital project managers meet the Green Building Ordinance 16147 which requires measuring the **greenhouse gas (GHG) emissions** of capital projects and **taking steps to mitigate** those impacts. As project managers work to reduce the impact of projects on the climate, they are also supporting multiple elements of the King County **Strategic Plan** and directly addressing key elements of the King County **Energy Plan and Strategic Climate Action Plan (SCAP)**.

King County has provided leadership in responding to climate change for many years. A key focus has been on reducing GHG emissions from its own operations. Today the County is actively implementing its 2010 Energy Plan, Green Building and Sustainable Development Policy, Environmentally Preferable Purchasing Policy, and other programs.

Use and Limitations

King County agencies have developed interim guidance to facilitate effective and timely consideration of climate change, including greenhouse emissions, in their actions. These interim guidelines recognize that regulations, policies, science, and technology related to GHG emissions are evolving at a high rate; consequently, the guidelines are interim and flexible and will evolve along with the regulations, policies, science, and technology. These guidelines reference tools, models, methodologies, and information resources. As a government agency, King County cannot advocate or require use of propriety products or services. Therefore, the information on models, methods, products, mitigation, and resources are for educational purposes only and are not intended to indicate a requirement or standard. Please contact a member of the GreenTools team for any additional assistance in utilizing this document.

Calculation Tools

Steps to Assessing GHG Emissions

1. Identify major project components, gather data

Categories in the Green Building Ordinance

The 2008 King County Green Building Ordinance (GBO) requires project managers assess the greenhouse gas (GHG) impacts of their projects. The draft 2013 Green Building Ordinance (GBO) update builds upon the 2008 GBO requirement by providing guidance that GHG emissions should be quantified, at minimum, from the following four sources:

1. Energy use
2. Water use
3. Construction and demolition (C&D) waste
4. Transportation

These four GHG source areas build on separate non-GHG related reporting requirements in the 2013 Green Building and Sustainable Development Ordinance. They will typically represent a project's largest sources of GHG emissions. However, in some cases, projects may have significant impacts in other areas, such as embodied emissions of materials. Other projects, such as reforestation, may have a net sequestration impact. Project managers are strongly encouraged to also report on these other areas if they are significant.

Project managers should already be collecting information on these source areas that can be translated into the GHG emissions. However, they may also need to gather additional data based on the scope of a particular project, including: projected energy use after the project is completed; the amount of fuel used by construction equipment during the project; the number of trees and shrubs being planted; and more. The exact data points to gather will depend on the project. For more information see the following section on Tools.

Determine the level of detail that is appropriate for the emissions assessment.

Project managers are responsible for determining a reasonable level of analysis. To determine a reasonable level of analysis, consider the following guidelines:

- Focus on the largest sources of emissions of your project—do not spend 80% of your time assessing 20% of your impacts. For example, the largest emissions sources for building projects will typically be related to operational energy usage and transportation, followed by the embodied emissions of materials, followed by the impacts of landscape disturbance.
- Consider all sources of emissions from all stages in the project (including construction, long-term operations, and end-of-life emissions) before determining which emissions are given priority for assessment. In most projects several sources of emissions will be substantial and should be included in the assessment. Sources of emissions include:
    - **Construction Fuel Use**: These emissions occur during construction of the project, but do not continue throughout the life of the project. These include emissions from construction equipment and emissions from the transportation of people and goods to and from the project site during construction.
    - **Deconstruction/Demolition**: The emissions from disposal of materials installed as part of the project when the project needs to be reconstructed or removed in the future.
    - **Energy usage**: The ongoing emissions generated from the use of electricity, gas, or other power source during the operations of the project after it is constructed.

- **Water usage**: The ongoing emissions generated from the use of water during the operations of the project after it is constructed. Also known as watergy, the GHG impact is actually from the energy use required to pump and treat water to potable standards.
- **Transportation**: The emissions generated from the transport of people and goods to the site after the project is completed; ongoing emissions generated from changes in land use which might affect travel demand patterns should also be considered.

Other potentially important sources of emissions include:

- **Waste**: The emissions generated from the transport and treatment of waste after the construction of the project. This includes emissions from ongoing garbage, recycling, food or yard waste, or other materials management activities.
- **Landscape disturbance**: The emissions generated through the loss of carbon storage by trees, vegetation, and soil disturbed by construction.
- **Embodied emissions from building materials**: The emissions generated from the extraction, manufacture, and transportation of the materials used in construction;

In general, the largest source of GHG emissions from building projects will be ongoing (operational) energy use, and transportation. Transportation and operational energy use (primarily heating and cooling) were the largest and second largest sources of GHG emissions in King County, respectively, based on the most recent King County GHG emissions inventory. In non-building projects, the largest GHG emissions sources should be identified based on the activities described in the list above. If there is limited ongoing transportation to and from the project site, for example, but a great deal of cement was used in construction, embodied emissions from materials use will likely he higher than transportation.

2. Calculate project GHG impacts

Using the tools described in the following section, convert the data you've gathered about the project into units of **MTCO2-e** (metric tons of carbon dioxide equivalent) so you can make an "apples to apples" comparison. These numbers are your baseline calculation of the impacts of the project *before* you have made any mitigation decisions.

3. Selecting best mitigation alternative(s)

Take note of which elements of the project have the largest GHG impact. These are the areas where you should focus your mitigation efforts. Mitigation is *not* something that is already part of your project requirements or something you are planning to do already. Mitigation *is* something additional you can do to reduce emissions from the major sources of GHGs on your project.

4. Calculate NEW project GHG impacts

After identifying a mitigation strategy, if possible, calculate the amount of **MTCO2-e** that will be avoided by pursuing this course of action.

5. Report on impact of mitigation

Use the Green Building Annual Reporting Form to report on the reduction of **MTCO2-e** that you have calculated for the whole project, as well as provide narrative on some of the specific strategies you used.

Additional Tips

If possible, quantitatively assess project GHG emissions using applicable tools.

You should be able to quantitatively assess significant sources for most projects based solely on the four required reporting categories: energy use, water use, transportation, and construction and demolition waste. However, many projects will also have sources of emissions that are difficult to quantitatively assess.

Quantifying the GHG emissions impacts of large, complex projects, such as the construction of or changes to wastewater facilities, waste management facilities, airport construction, and transit-operating bases, require more sophisticated impacts analysis than the tools recommended in this guidance can accomplish.

Record the results from your project quantitative emissions assessment (through either the tools or a different methodology). Note that each tool reports emissions differently—some only have total emissions, some provide annual emissions, and some divide the emissions in categories. End-of-project reporting should be in consistent units: $MTCO_2$-e.

What to do if an appropriate tool is not included for the key sources of emissions from your project:

Make a qualitative description of GHG emissions following this guidance if:

- Quantitative tools do not capture all GHG impacts; and/or
- The assumptions in the quantitative tool do not accurately reflect the specifics of the project, and making changes to the assumptions is not possible.

If making a qualitative assessment, see also the above section: *Determine the level of detail that is appropriate for the emissions assessment.*

If you estimate emissions using a different methodology, be sure to describe that methodology in detail.

Tools

The following seven measurement tools are recommended to help project managers quantify sources of emissions related to landscape disturbance, building materials, construction processes, tree planting or reforestation efforts, ongoing energy and water usage, transportation related sources, and more.

The following seven measurement tools are recommended to help project managers quantify sources of emissions related to ongoing energy and water usage, transportation, building materials, construction and demolition (or other) waste, landscape disturbance, tree planting or reforestation efforts, and more.

Other models and tools can be used and new tools may be considered as they are developed. Other models and tools can be used and new ones will continue to be developed and may be considered.

Note that two tools previously in use—the King County SEPA GHG Emissions worksheet, and the EPA MOBILE6 and EPA MOVES models—were previously recommended, but are either out of date or better served by the new guidance, and have been removed.

The individual tools are described further in the following sections. Use the columns on the right in the table below to identify the tools that are most appropriate for the type of project you are undertaking.

Tool Name	Source of Emissions Estimated
1. King County Emissions Calculator	a. Quantifies emissions from energy use, water use, construction and demolition waste, transportation, and materials b. Converts emissions outputs from the other six tools into comparable units (MTCO2-e)
2. Waste Reduction Model (WARM)	Waste generation and disposition (recycled, landfilled, etc)
3. URBEMIS	Transportation (VMT), construction activities, and non-building materials (e.g. asphalt)
4. Roadway Construction Emissions Model	Construction equipment fuel use and dust
5. Build Carbon Neutral	Embodied energy of building materials, construction processes, and landscape disturbance or installation / restoration
6. Tree Carbon Calculator	Tree sequestration and building shading
7. Reforestation Calculator	Large scale reforestation

1. King County Emissions Calculator

The King County Emissions Calculator converts common project data inputs, as well as the various emissions outputs from the other six tools, into a common unit (MTCO2-e) and then combines them into one comprehensive emissions estimate for your project.

This calculator contains a worksheet (Excel tab) for each of the four required items of measurement (energy, water, C&D and transportation), as well as for embodied carbon from major construction materials, and a worksheet for each of the third-party tools described below. By combining everything into one calculator, this tool helps convert your data points into units of MTCO2-e (metric tons of carbon dioxide equivalent) so you can make an “apples to apples” comparison.

For more information

- Download Emissions Calculator

2. WARM

EPA’s Waste Reduction Model (WARM) estimates GHG emissions from disposal of municipal solid waste (MSW), in combination with the waste disposition, including recycling, combustion, landfilling, and composting (where applicable). It does not measure the embodied energy of materials, but rather the lifecycle impacts of different disposal choices.

This tool includes two additional factors: the presence of a landfill gas (LFG) control system and the distance waste is transported (for vehicle emissions). King County project managers should select ‘LFG Recovery’ and ‘recovery for energy’ for the first, and the following breakdown of transport distance for the second:

Management Option	Distance (miles)
Landfill	300
Combustion	0
Recycling	20
Composting	20

WARM allows project managers to calculate emissions reductions from alternative waste management practices for 46 common material types, by calculating an alternative scenario and comparing the results side-by-side with the baseline scenario.

WARM is available both as a simplified web-based calculator, and as a downloadable Excel file. The Excel-based version of WARM offers slightly more functionality than the web-based calculator.

3. URBEMIS

URBEMIS software can be used to estimate construction, area source, and operational air pollutant emissions from a wide variety of land use projects. It should provide an accurate estimate, but note that many emissions coefficients and assumptions are tailored to California. Insert local data where possible.

For more information

- Download URBEMIS
- URBEMIS User’s Guide, FAQs, and other support

4. Roadway Construction Emissions Model

Use the Roadway Construction Emissions Model to assess your emissions from roadway construction equipment. This tool may also be useful in assessing emissions from general building or landscape construction equipment, although it may not cover all relevant equipment. This tool incorporates emissions from construction equipment only. This tool does not include emissions from employee travel to the construction site or embodied emissions from materials, nor transportation emissions from changes in community travel demand or emissions from loss of vegetation.

This tool reports the total carbon dioxide (CO_2) emissions for the project by day from:

- Grubbing/Land Clearing.
- Grading/Excavation.
- Drainage/Utilities/Sub-Grade.
- Paving.

This tool can be downloaded from CEQA Tools webpage of the Sacramento Metropolitan Air Quality Control District website, toward the bottom of the page under the "Models and Meteorological Data" heading. You will need to enable macros to use this tool.

5. Build Carbon Neutral

The web-based Build Carbon Neutral Calculator estimates the embodied energy of building materials, construction processes, and landscape disturbance or installation / restoration, for building projects. The methodology can be viewed, but cannot be changed; however, if more accurate project data is available, the methodology could be borrowed, and the data points replaced with alternative data.

6. Tree Carbon Calculator

The US Forest Service Center for Urban Forestry Research Tree Carbon Calculator quantifies carbon sequestration from tree planting projects, as well as estimating the climate benefits from reduced heating and cooling energy usage, if trees are used to shade buildings. This tool is primarily for estimating sequestration, rather than emissions.

7. Reforestation Calculator

The EPA's Reforestation/Afforestation Project Carbon Online Estimator (RAPCOE) calculates the carbon sequestered (or stored) by acre of land converted from cropland or pasture to forest. RAPCOE contains two separate tools – a Pre-Project Planning tool, and a Post-Project Monitoring tool. The Pre-Project Planning tool provides estimated cumulative carbon sequestration benefits over a 20-year period, broken into 5-year intervals. This tool is primarily for estimating sequestration, rather than emissions, and is most applicable for large reforestation projects.

Project Mitigation Strategies

Mitigation strategies are divided into the following topics:

- Required Frameworks
- Materials
- Landscape Disturbance
- Energy
- Waste
- Transportation

Each topic includes several subcategories, within which are individual strategies and information on their effectiveness, cost, and implementation considerations and resources. Note that links to online resources are listed at the end of this document in the Reference section under Online Resources.

Many of the mitigation strategies in this document are also green building and sustainable development practices for LEED certification and the non-LEED eligible "scorecards." These strategies are identified in this document with a leaf icon:

While most of the carbon mitigation strategies generate multiple benefits to natural, built, and social resources, in addition to reduction of greenhouse gas emissions, and can be considered green or sustainable, some strategies have been called out as particularly noteworthy. These recommended mitigation strategies meet at least one of the following three criteria:

- **Win-win strategies**—strategies that reduce greenhouse gas emissions while providing substantial co-benefits to another area.
- **Game-changers**—strategies that reduce greenhouse gas emissions in more than one area.
- **Cost-effective strategies**—strategies that reduce greenhouse gas emissions at low cost.

These recommended mitigation strategies are marked by a star icon:

SYMBOL KEY

Green Building and Sustainable Development Scorecard Strategy

Recommended Mitigation Strategy

Frameworks

For any kind of capital improvement process, you are required by the Green Building and Sustainable Development Ordinance to use all of these frameworks.

Mitigation Strategy	Overview	Implementation
Use a integrated process (IP) [i]	**Effectiveness**: 37-73% total energy savings have been demonstrated on new commercial projects using an integrative process.[ii] Water and operational savings are also significant. **Cost**: Low in direct costs. Can be time-intensive as the process is iterative in nature and typically includes more upfront involvement from parties traditionally involved later in the process. May also require facilitation expertise from a professional experienced in managing the iterative process. **Additional Information**: This strategy can adapt as requirements and technology changes, and is relevant to all building and infrastructure projects. The Green Buildings and Sustainable Development Ordinance already requires this strategy.	Encourage project teams to gather data, conduct analyses, and develop an under-standing of key issues to be considered before decisions are made on design and building form to support integrative approaches aimed at achieving a high level of performance. Establish an IP plan at the beginning of the project that identifies how the following steps will be implemented on the project. 1. Conduct and eco-charrette to establish project goals and performance metrics in pre-design or early schematic design. 2. Complete energy load reduction, water systems balance, and site assessment analyses and use the results to influence design in Schematic Design. 3. Develop and compare at least two alternative designs that demonstrate the integrative approaches used. The comparison must include cost, savings, and performance analysis. Develop a rationale for the select design alternative. 4. Conduct project team meetings at the beginning of each phase to review project goals, design performance against those goals to date, brainstorm additional opportunities, and prioritize analysis, research and work during each phase. Green Building and Sustainable Development Ordinance[iii]

Mitigation Strategy	Overview	Implementation
Require life cycle cost analysis (LCCA)[iv]	**Effectiveness**: No specific relation to the effectiveness of GHG reductions; however life cycle cost analysis is an excellent tool to measure the cost effectiveness of energy-using options, assisting project managers in making decisions that are both responsible from a budget and climate mitigation perspective. **Cost**: May be time-intensive, but project managers can tap County standards, their consultant team, and other resources to assist with the calculation.	King County LCCA Guide—User guide designed to help King County Project Managers evaluate green building design options. National Institute of Building Sciences Whole Building Design Guide (Life-Cycle Costs Analysis)
Apply third-party certified green standards for design and operations.[v]	**Effectiveness:** Third-party certification standards can provide a more robust approach to the sustainable design process, and are now available for a wide variety of projects including building and infrastructure. Most include some sort of implementation guidance and resources in addition to the different achievement thresholds. **Cost:** LEED fees vary based on the size of the project. The King County scorecard does not have any associated fee. **Additional Information**: If a capital project is eligible for LEED certification, the project must achieve LEED Gold[vi]. All other projects must use the King County Green Building and Sustainable Development scorecard.[vii]	LEED King County Green Building and Sustainable Development scorecard[viii]

Materials

Recycled Materials

Mitigation Strategy	Overview	Implementation
Use salvaged and reclaimed building materials and products	**Effectiveness**: Depends on the percentage of materials or products that are salvaged and reclaimed. GHG reductions result primarily from emissions associated with the embodied energy of new material manufacturing, and if locally sourced, also reduce transportation related emissions. **Cost**: May be less expensive than new materials. **Additional Information**: Specific salvaged material needed for construction may not always be available, although local salvage markets continue to develop in this region.	Use reused materials where possible, such as railroad timbers, used brick, and other durable items like flagstones.[ix] Source locally – road transportation impacts over more than 500 miles will likely offset embodied energy savings – depending on materials' embodied energy and density. King County Green Tools: Online Exchange Seattle Public Utilities
Reduce the amount of materials required	**Effectiveness**: Depends on project. However, avoided material use is typically a more effective mitigation strategy than reuse or recycling and typically generates less waste. **Cost**: Saves costs, as building materials will not be purchased for unnecessary structures. Also, typically reduces waste disposal costs – see above. **Additional Information**: Optimum Value Engineering is a process of considering alternative materials and methods to achieve the desired level of performance. While most familiar in the context of structural framing, it can be applied to many aspects of infrastructure and building design.	Reduce material requirements through effective site layout. For example, re-routing a walkway or rotating a building can eliminate a costly retaining wall and site grading. Structures designed and sited without regard to site-specific conditions create structural, maintenance, and ecological problems.[x]
Use recycled building materials and products	**Effectiveness**: Depends on the percentage of the materials or products that are recycled, and the embodied energy involved to manufacture new products as compared to the embodied energy of the virgin materials and the relative distances over which virgin and recycled materials will be transported. **Cost**: May be more expensive than new materials.	Use materials and products with recycled content, based on life-cycle performance and where the product meets durability and functional needs of the project. King County: Environmental Purchasing—See links under Operations and Maintenance

Mitigation Strategy	Overview	Implementation
	Additional Information: The market continues to grow with new recycled content building materials for a wide range of applications, including structural, functional and aesthetic purposes. Wood substitutes made of recycled plastic are now available for a variety of products as are an increasing number of products made from recycled content carpet fibers.[xi]	

Locally-Sourced Materials

Mitigation Strategy	Overview	Implementation
Use building materials and products that are extracted and/or manufactured in the region of the project	**Effectiveness**: Variable. Materials from closer to the project site can have lower embodied emissions from transport than those farther from the project site. Given excellent ocean and rail-freight access for King County, consideration of type of transportation may also be relevant, e.g. road freight is much higher impact that ocean freight. **Cost**: Varies by supplier **Additional Information**: Specific material needed for construction may not always be available, whether from local manufacturers, salvaged material, or online exchanges. Using local building materials has a co-benefit of supporting the economy of the region.	King County Green Tools: Online Exchange

Wood Products

Mitigation Strategy	Overview	Implementation
Use sustainably harvested wood products, certified in accordance with the Forestry Stewardship Council's principles and criteria	**Effectiveness**: Same as above, plus additional benefits of sustainably managed forests. **Cost**: May be more expensive than unsustainably managed wood products.	King County Green Tools: List of Distributors

Mitigation Strategy	Overview	Implementation
Encourage use of wood products, as substitutes for fossil-fuel intensive construction materials, such as concrete, steel, aluminum, and plastics (rapidly renewable)	**Effectiveness**: Potentially 110-470 kg reductions in CO_2 emissions per square meter of floor area, based on a case study of residential buildings in Sweden and Finland.[xii] The Consortium for Research on Renewable Industrial Materials (CORRIM) Fact Sheet 2 (2004) – found 26% and 31% reductions in global warming potential when comparing wood-framed homes to steel framed homes in Minneapolis and concrete homes in Florida.[xiii] **Cost**: Varies by supplier. **Additional Information**: Where possible, use sustainably harvested wood products (see above).	This strategy has higher mitigation benefits if wood is first used to replace building materials and then after disposal, as biofuel or to be remanufactured into recycled content products.[xiv]

Low Volatile Organic Compound (VOC) Products

Mitigation Strategy	Overview	Implementation
Use low volatile organic compound (VOC) adhesives, sealants, paints, carpets and wood stain	**Effectiveness**: Variable. Depends on the percentage of VOC in the product and the amount of product used in the project. **Cost**: Varies by supplier. **Additional Information**: This strategy will reduce emissions from typical VOC intensive products that emit greenhouse gases overtime. The use of low VOC products will improve indoor air quality and the health of employees and other users of the building. VOC is a vast class of compounds that have varying global warming potentials (GWP), from 1 (equivalent to CO_2) to as much as 14,000. Where large volumes of high VOC products are required (exterior sealants, waterproofing, etc.), it may be worth researching the GWP of specific VOC ingredients.	Most large hardware stores and online distributors, such as Home Depot Eco Options and Amazon, sell low VOC products. The following sources are also resources for finding low-VOC products: Green Floors—adhesives and carpets Green Choice Adhesives—adhesives and sealants Eartheasy—paints and wood stain

Vegetation to Extend the Life of External Structures

Mitigation Strategy	Overview	Implementation
Install green roofs[xv]	**Effectiveness**: Variable. Depends on the amount of roofs installed as green roofs Because they effectively protect the weather resistive barrier of a roof system from degrading UV radiation, green roofs last up to twice as long as conventional roofs, which result in avoided CO_2e emissions from roofing replacement.[xvi] **Cost**: The costs of an extensive green roof in the U.S. range from $8 per square foot to $25 including materials, preparation work, and installation. Maintenance costs may range from $0.75 to $1.50 per square foot.[xvii] A more detailed cost estimate is provided in the green roof strategy under Wastewater and Stormwater Reduction Methods.	For information on Green roofs, see the EPA's document on green roofs: Reducing Urban Heat Islands: Compendium of Strategies: Green Roofs.
Install green walls	**Effectiveness**: Variable. Depends on the number of green walls installed. **Cost**: Higher initial costs. **Additional Information**: Properly designed and constructed green walls can last longer than conventional walls.	It is important to ensure that measures are taken to ensure that vegetation does not grow into and compromise the weather resistive barrier of the building envelope, which might negatively impact durability and result in premature failure of the building.

Cement Substitutes

Mitigation Strategy	Overview	Implementation
Use fly ash, also known as Pulverized Fuel Ash (PFA)[xviii]	**Effectiveness**: Variable. Depends on the percentage from fly ash. But emissions reductions can be high, since using fly ash reduces the amount of cement, which is highly resource intensive to produce and transport. **Cost**: Can reduce costs. High levels of fly ash substitution will result in slower cure times. Construction schedules and strength testing specifications may have to be adjusted to accommodate this. **Additional Information**: Fly ash can improve the performance of	Work with construction companies to use the highest percentage of fly ash possible, without threatening structural safety. Research on the structural safety of using higher percentages of fly ash is still in the early stages, thus construction companies could resist using high percentages of fly ash. Bids for using high-volume fly ash could be high if the contractor is unfamiliar with working with it, thus the structural engineer should discuss with the contractor early

Mitigation Strategy	Overview	Implementation
	concrete by increasing strength, reducing permeability and reducing corrosion of reinforcing steel.[xix] Since fly ash is a by-product of the coal industry, using it as a cement substitute reduces waste in landfills.[xx] Although using fly ash decreases embodied emissions of cement, it directly supports the high-emitting coal industry.	on. High-volume fly ash is appropriate for use in footings, mat foundations, slabs on grade, slabs on metal decks, cast-in place and tilt-up walls, drives, sidewalks and equipment pads. Consult with an expert before using high volume mixes in columns and with post-tension systems. For more information, refer to the Concrete Thinker website for resources.
Use slag, also known as Ground Granulated Blast-furnace Slag (GCBS)[xxi]	**Effectiveness**: Variable. Depends on the percentage from slag. But emissions reductions can be high, since using slag reduces the amount of cement, which is highly resource intensive to produce and transport. **Cost**: May reduce costs. There is no steel smelting from ore in the Pacific Northwest so all slag is transported from the Midwest or East Coast via truck or rail, or via ship from Korea, China and Japan. Transportation impacts may be significant. **Additional Information**: Slag can improve the performance of concrete by increasing strength, reducing permeability and reducing corrosion of reinforcing steel.[xxii] Since slag is a by-product of the steel industry, using it as a cement substitute reduces waste in landfills.[xxiii] Although using slag decreases embodied emissions of cement, it directly supports the high-emitting steel industry.	Work with construction companies to use the highest percentage of slag possible, without threatening structural safety. Research on the structural safety of using higher percentages of slag in still in the early stages, thus construction companies could resist using high percentages of slag. High slag cement content does not increase curing time to the same extent that fly ash does and also maintains strength characteristics, dependent on mixes. Bids for using high-volume slag could be high if the contractor is unfamiliar with working with it, thus the structural engineer should discuss with the contractor early on.[xxiv] For more information see the resources available at Concrete Thinker website.
Carefully distinguish between light-vehicular, heavy vehicular, and pedestrian paving[xxv]	**Effectiveness**: Variable. Depends on the range of different paving needs for a project. But, this strategy will reduce emissions by using lower amounts of resource intensive paving materials where they are not needed. **Cost**: Saves costs, as higher density materials will not be purchased unnecessarily. **Additional Information** Choosing alternative materials for light-vehicular or pedestrian paving that use Low Impact Development (LID), such as pervious paving products, may offer other	In landscape design, vehicular-strength paving is often used by default even for sidewalks. This unnecessarily eliminates alternative materials and wastes materials and money, since many paving materials are non-renewable and energy-intensive, and should not be wasted.[xxvi]

Mitigation Strategy	Overview	Implementation
	benefits such as improved onsite stormwater infiltration and reduced costs for conventional stormwater systems.	
For light-duty roads and paths, stabilize without pavement[xxvii]	**Effectiveness**: This strategy will reduce emissions by using lower amounts of resource intensive paving materials (i.e. cement) where they are not needed. **Cost**: Saves costs, as materials will not be purchased unnecessarily. **Additional Information**: Pavement substitutes are typically more permeable than pavement, which reduces the amount of water runoff that needs to be managed on site or processed at treatment plants. Some surfaces can even be vegetated with plants tolerant of occasional disturbance.	Correctly installed, crushed stone or brick (which can be salvaged) is a stable, porous surface. King County Green Tools: Online Exchange Proprietary chemical additives can bond soil particles for stability. Geotextile webs and strips can used to increase soil strength without affecting its drainage or growing characteristics. Such surfaces are slightly flexible, which minimizes cracking and decreases maintenance and replacement costs.[xxviii]

Landscape Disturbance

Vegetation and Soil Preservation

Mitigation Strategy	Overview	Implementation
Preserve trees and plants onsite and temporarily transplant plants disturbed by construction for replanting after construction is completed	**Effectiveness**: Variable. Depends on how many trees are kept onsite and replanted. More protected trees results in lower emissions. Furthermore, this strategy will ensure that more mature vegetation, which generally sequester more carbon than very young plants, continue to sequester carbon on the project site during and after construction. **Cost**: Low costs, although a fence may need to be purchased to isolate plants. The labor used to move the plants would be similar to the labor needed to dispose of them and replant new ones.	Protect trees by avoiding cut-and-fill in root zones (at a minimum, the area beneath the tree's outermost branches) and preventing heavy equipment from disturbing the area around and under them. The best way to protect existing vegetation is to fence groups of trees off.[xxix] Preserve trees and plants onsite within a fenced area so they are not further disturbed during construction. The fence should be placed at the outermost branches of the trees it is protecting.[xxx] Preserving vegetation in the area may make movement of construction vehicles difficult, requires strategic planning for movement of construction vehicles, and may not be possible for projects that require large equipment in many areas of the construction site.
Minimize the loss of dead organic matter (including slash) or soil carbon, by reducing soil erosion	**Effectiveness**: Variable. Depends on how much soil is protected. More protected soil results in lower emissions, as carbon is not released into the atmosphere. **Cost**: Low costs, although construction workers would need to plan for and avoid disturbing protected soil which may entail upfront planning time and training.	Protect the soil during construction[xxxi] Design for minimal grading. Where grading is unavoidable, carefully remove and stockpile existing topsoil, replacing it after rough grading. Depending on soil-test findings, the top four to six inches of soil are usually stockpiled and re-used. Plan construction sequences that minimize heavy-equipment movement over the soil; restrict all equipment, including private vehicles, generators, etc., to areas that will be paved or built over. If soil compaction is unavoidable (as with a construction-access road), restore by tillage and amendments before completing work.
Minimize drainage of forest soils, specifically peatlands	**Effectiveness**: Variable. Depends on how much forest soils are protected. More protected forest soil results in lower emissions, as carbon is	Protect the soil during construction[xxxii] Design for minimal grading. Where grading is unavoidable, carefully

Mitigation Strategy	Overview	Implementation
	not released into the atmosphere. **Cost**: Low costs, although construction workers would need to plan for and avoid disturbing protected soil which may entail upfront planning time and training.	remove and stockpile existing topsoil, replacing it after rough grading. Depending on soil-test findings, the top four to six inches of soil are usually stockpiled. Plan construction sequences that minimize heavy-equipment movement over the soil; restrict all equipment, including private vehicles, generators, etc., to areas that will be paved or built over. If soil compaction is unavoidable (as with a construction-access road) remediate by tillage and amendments before completing work.

Vegetation Planting

Mitigation Strategy	Overview	Implementation
Replace onsite plants and trees that are removed for construction	**Effectiveness**: Variable. Depends on how many trees are planted. However, this strategy is less effective than preserving original trees onsite and replanting if the new trees are younger than the original. **Cost**: More expensive than maintaining trees on the site and replanting. **Additional Information**: This strategy should only be used if removal and replanting of trees on-site is unavoidable.	Smaller transplanted trees (e.g. 1" caliper) have a higher survival rate than larger trees, but larger trees will provide carbon and stormwater mitigation and aesthetic benefits sooner. Develop effective long term maintenance and irrigation plan for transplanted trees to ensure long-term health.
Plant additional plants and trees on the project site	**Effectiveness**: Variable. Depends on how many trees are planted. **Cost**: Variable. Depends on the trees that are purchased. **Additional Information**: This strategy is best used in addition to preserving and replanting existing trees on the project site.	Smaller transplanted trees (e.g. 1" caliper) have a higher survival rate than larger trees, but larger trees will provide carbon and stormwater mitigation and aesthetic benefits sooner. Develop effective long term maintenance and irrigation plan for transplanted trees to ensure long-term health.
Plant grass or equivalent erosion control method to cover any open areas on a construction site	**Effectiveness**: Unknown, however preventing erosion will minimize soil disturbance that releases carbon into the atmosphere. **Cost**: Variable. Depends on how much area is	Refer to *King County Surface Water Design Manual, Appendix D: Erosion and Sediment Control Standards* for guidance on selection and installation of appropriate Cover Measures

Mitigation Strategy	Overview	Implementation
that will be left bare for more than a year	covered and the method of erosion control chosen.	

Stormwater Runoff

Mitigation Strategy	Overview	Implementation
Design to minimize runoff	**Effectiveness**: Limited unless: a. Project site is located in a combined sewer overflow (CSO) zone - where reductions in stormwater runoff will reduce process energy consumption at sewage treatment facilities; or b. Project site is located in a zone where stormwater is detained and pumped to another location or elevation for discharge – where reductions will reduce pump energy consumption. **Cost**: Low cost—no material costs, but requires strategic site planning. Reducing runoff that may need to be managed using a conventional stormwater system may save materials (notably concrete for conveyances and storage facilities) and cost. **Additional Information**: Low Impact Development (LID) describes an approach to stormwater management that relies on minimizing runoff and treating it as close to source as possible using natural drainage systems and on-site re-use and infiltration strategies.	In general, runoff should be infiltrated as close as possible to its source; flow concentrated over long distances picks up speed and erosive power, and disrupts the distribution patterns of natural precipitation.[xxxiii] Curbed pavement edges concentrate runoff, which increases potential for erosion and flooding. Where possible, curbless designs with pervious shoulders and gutters/ditches spread run off more broadly and reduce volume and velocity of flow.[xxxiv] LID resources include: Stormwater Management Manual for Western Washington (2005) Low Impact Development Technical Guidance Manual for Puget Sound[xxxv]
Use water permeable or "pervious paving"	**Effectiveness**: Limited unless: a. Project site is located in a combined sewer overflow (CSO) zone - where reductions in stormwater runoff will reduce process energy consumption at sewage treatment facilities; or b. Project site is located in a zone where stormwater is detained and pumped to another location or elevation for discharge – where reductions will	Pervious asphalt and concrete are made with aggregates carefully sorted to eliminate "fines" (small particles). Removing fines opens voids that allow drainage, yet pervious paving retains most of the strength of conventional paving. Pervious paving is suited to parking and lightly used roads; in high-traffic areas, combine it with conventional paving. Other permeable systems include block-lattices, which permit drainage but give stability (grass

Mitigation Strategy	Overview	Implementation
	reduce pump energy consumption. **Cost**: Typically more expensive than non-pervious paving section. However, reductions in runoff will result in reductions in the size of conventional stormwater management facilities, which can save material (notably concrete for conveyance and storage facilities) and cost.	grows in the lattice spaces, while the blocks support vehicles). Lattices are best used for occasional access (fire lanes, overflow parking); constant traffic may kill the grass, as may harsh climates. Some permeability can also be achieved by setting traditional stone or masonry pavers on sand instead of on concrete.[xxxvi]

Sustainable Practices—Landscaping and Clearing of Vegetation

Mitigation Strategy	Overview	Implementation
Avoid slash-and-burning[xxxvii] ★	**Effectiveness**: Highly effective at reducing short-term carbon emissions. Slash-and-burning releases all carbon captured and stored by vegetation on the project site into the atmosphere. **Cost**: Low cost if slash can be left on the ground or chipped and spread as mulch. **Additional Information**: Aerobic decomposition of leafy and woody materials releases CO_2 and small amounts of CH_4 (methane) over a very long time horizon. Some of the carbon in the material is sequestered in the soil and ultimately in new vegetative growth.	Consider chipping branches and vegetative debris on site and use as mulch, or leave material in brush piles for wildlife habitat if it does not create a fire hazard. If slash and burning is unavoidable, consider slash-and-charring as an alternative (see below).
Exercise selective harvesting to maintain partial forest cover[xxxviii] ★	**Effectiveness**: Variable. Depends on how much vegetation is protected. More protected vegetation results in lower emissions. **Cost**: Low costs, although a fence would need to be purchased.	Selectively remove trees throughout the project site, while leaving forest cover throughout the forest site. This allows development and movement of goods throughout the site, while minimizing damage to the ecosystem.
Encourage slash-and-charring, when slash-burning is deemed necessary[xxxix]	**Effectiveness**: Effective alternative to slash-and-burning, when clearing is necessary. Slash and char can sequester, in a stable form, as much as 50% of the carbon that would be released by slash and burning. **Cost**: Unknown – traditional on-site charring is	Typically requires the building of a char kiln on-site (a more traditional approach), or use of a mobile pyrolizer.

Mitigation Strategy	Overview	Implementation
	low cost but requires skills/knowledge not generally available. Mobile pyrolizers are not common in the market-place. **Additional Information**: Charring involves pyrolysis – the thermochemical decomposition of organic matter without oxygen. The process produces charcoal, which is a very stable form of carbon that can be incorporated into soil to improve fertility and sequester the carbon near-permanently, or used for other purposes with economic value.	
Avoid tilling in agricultural applications	**Effectiveness**: Highly effective as an alternative to conventional tillage farming, where soil is broken and turned over annually before planting new crops. Tilling releases carbon stored in the soil into the atmosphere (at a rate of as much as ½ ton per acre per year). Avoiding tilling also reduces fuel energy used to actually pull the plough. Similar results can be achieved on a reduced scale with landscape areas in the built environment, for example – top dress landscape areas with compost without tilling, replace landscaping by removing existing plants and direct seeding or transplanting without tilling first. **Cost**: No cost, beyond determining alternatives. **Additional Information**: Not to be confused with tilling of soils compacted by heavy equipment or heavy use. Tilling to break up compacted soils and introduce amendments is an important strategy for building healthy soils and improving stormwater infiltration and retention.	No-till farming is a way of growing crops without disturbing the soil. No-till is an emergent agricultural technique, which can increase the amount of water and organic carbon in the soil and which reduces loss of top soil through wind and water erosion. Care should be taken to avoid increased herbicide use in lieu of using tillage material for weed control.

Energy

Construction Equipment Emission Reduction

Mitigation Strategy	Overview	Implementation
Size all equipment to need[xl]	**Effectiveness**: Effectiveness depends on if the equipment is currently much larger than jobs require or not. **Cost**: Variable: This strategy saves money as large size equipment is usually more expensive to rent or operate and overusing undersized equipment may lead to additional replacement or maintenance costs[xli]. **Additional Information:** Undersized equipment may also contribute to excessive fuel consumption and increased engine wear.	Right size the equipment (horsepower and capacity) for each job.
Maintain Equipment and Train Operators for Optimal Use	**Effectiveness**: Variable. Depends on equipment type, maintenance needs, and corrective actions. **Cost**: Variable – maintenance and training may incur upfront costs but bring long-term savings. Sample savings include $90 per truck per year for proper tire inflation alone and $750 per forklift per year for forklift maintenance. **Additional Information**: Driver training has also been shown to effectively reduce emissions from improper operation of equipment. This includes optimizing the positioning of dump trucks to minimize the swivel angle of an excavator to excavating a slope in two stages instead of one[xlii].	Implement routine equipment inspections and create corrective action plans for various maintenance issues. Implement a driver training program to optimize operations.
Use fuel-efficient construction equipment and/or construction equipment that uses alternative fuels	**Effectiveness**: Variable. Depends on energy type and efficiency. 100% biodiesel is assumed to result in zero net carbon emissions; therefore, any increase in the use of biodiesel will lead to emissions reductions. Fuel efficiency is also increased by implementing a no-idling policy. **Cost**: No-cost solutions include a no-idling policy for fuel use reduction[xliii]. Added costs include fractional increases in fuel costs and availability impacts for various blends of biodiesel. Replacement, purchase, or rental price of fuel-efficient equipment compared to standard or sub-standard	Select equipment that gets better fuel efficiency or is capable of using biodiesel. Implement a “No Idling” policy for all equipment and vehicles.

Mitigation Strategy	Overview	Implementation
	equipment varies. **Additional Information**: Note that the range of GHG emission savings is greatly dependent on the lifecycle analysis of the fuel type and in some cases may have a net negative impact on climate for certain fuels. Additionally, some biofuels may void a vehicle's warranty. However, a 3% - 10% increase in the use of plant-based biodiesel can have a sizeable impact on emissions reductions[xliv]. Puget Sound Clean Air Agency provides guidance on Diesel Solutions. SmartWay is a public/private collaboration between the USEPA and the freight transportation industry that helps freight shippers, carriers, and logistics companies improve fuel-efficiency and save money.	
Minimize the use of equipment that use two-stroke engines	**Effectiveness**: The effectiveness depends on how much two-stroke engines are normally used and the replacement type. **Cost**: Cost and savings will vary depending on equipment choice, efficiency, and fuel costs. **Additional Information**: Two-stroke engines in chainsaws, lawn mowers and other similar equipment emit more GHGs, particulates, and carcinogens than four stroke engines, propane versions, or battery-powered counterparts. Minimizing the use of these engines will also minimize other air pollutants such as particulates.	Select equipment that uses four stroke engines, propane canisters[xlv], or electric/batter-powered alternatives.

Efficient Design and Performance Processes

Mitigation Strategy	Overview	Implementation
Conduct Third-Party Building Commissioning	**Effectiveness**: Up to 38% energy savings in cooling; Up to 62% energy savings in heating; 8-10% reduction in overall energy usage. **Cost**: Reduces costs—payback period of 8.5 months	Building commissioning is a quality control process that includes: Design review. Functional testing of energy systems and components. Clear documentation for the owner and operators. This strategy is most effective when the building is operated

Mitigation Strategy	Overview	Implementation
		and maintained well and when combined with continuous performance monitoring, automated diagnostics, and improved operator training. (IPCC p. 394; IPCC p. 400; CAPCOA B-20l)
Monitor performance through an online "electronic dashboard" system	**Effectiveness**: According to the Steven Winter Associates, energy dashboards help educate building occupants about their actual energy usage, which is a critical strategy toward energy consumption reduction. Results may be improved when dashboards are coupled with sub-metering, pledges, and competitions[xlvi]. Some systems report usage data only, while other systems can be integrated with building management systems. **Cost**: Initial costs of dashboard systems range from $10,000 – $80,000 with variable payback but documented immediate positive educational and engagement outcomes. **Additional Information**: If utility meters and submeters are already present, the cost of the system decreases greatly. Very low-cost alternatives exist for single circuits if monitoring is desirable on a small-scale basis. Sample Systems include[xlvii]: Resource Monitor - Agilewaves, Inc. Building Dashboard - Lucid Design Group Green Touchscreen and iBPortal Dashboard - Quality Attributes Software, Inc.	Create a system to measure, track, and report on a facility's environmental impacts and performance. Research options that integrate with your existing building management system, or explore other options.

Onsite Renewable Energy Production

Mitigation Strategy	Overview	Implementation
Install a solar-thermal system on individual buildings or structures with high sun exposure	**Effectiveness**: Meets 10-60% of combined hot water heating demand. **Cost**: Systems installed in new construction projects typically are less costly to install than in retrofit projects because of reduced installation expenses. 2004 estimates range from $60 per square foot to $225 per square foot, but cost is	For more information on these systems, see Bay Area Local Initiatives Support Corporation's Green Rehabilitation Guide. For more information about onsite renewable energy generation in general, go to the ENERGY STAR website The energy potential for solar PV ranges between 3.0 and 3.5

Mitigation Strategy	Overview	Implementation
	very dependent on the system type and location. The Whole Building Design Guide recommends calculating the savings-to-investment ratio and ensuring it is larger than 1.0[xlviii]. **Additional Information**: Options for systems include: Integrated photovoltaic (PV)/thermal collectors in which the PV panel serves as the outer part of a thermal solar collector. 'Combisystems' are solar systems that provide both space and water heating.	kwh/square meter/day in King County. For a map of the solar potential in King County, go to the Department of Ecology's King County Solar Resource Potential Maps[xlix]
Solar electric[l]	**Effectiveness**: Depends on the available un-shaded roof space of a property, the sun energy in the area, as well as what the current energy source that the system will replace. **Cost**: Depends on the system size needed to power the property. An onsite assessment is needed.	See above.
Install wind turbines on-site	**Effectiveness**: Depends on the wind potential of the site and the type of system installed. Small-scale wind systems (systems that produce up to 100kW of electrical power), include traditional turbines on large poles to access "clean" flow of wind, vertical axis turbines, building-integrated turbines[li], and micro-turbines. **Cost**: Small-scale systems cost from $3000 - $5000 for every kilowatt (kW) of generating capacity[lii]. **Additional information**: Installing wind turbines may be in conflict with protecting wildlife, and optimal height for best wind conditions may not suit local height restrictions. For more information about onsite renewable energy generation in general, go to the ENERGY STAR website	For a map that shows the wind potential across King County, visit the Department of Ecology's King County Wind Resource Potential Maps.

Electric Cooling System Efficiency

Mitigation Strategy	Overview	Implementation
Replace halocarbons (CFC's and HCFC based	**Effectiveness**: Limited. While the listed alternatives to HCFC refrigerants such as R-22 do offer significant reductions in Ozone Depletion Potential (ODP),	Some 14 brands on the market offer most of their high-efficiency equipment using R-410a (known under the trade names Puron,

Mitigation Strategy	Overview	Implementation
refrigerants) with advanced refrigerants such as HFC-134A, HCFC-407C, or HFC-410A in air conditioning and other refrigeration units.	the offer little or no reduction in Global Warming Potential. However, R-410a is approximately 5% more efficient than R-22 which does result in a small improvement in equipment performance.[liii] **Cost**: Moderately more expensive, but as high performance refrigerants are phased out, price of replacements will likely drop as economies of scale take effect. **Additional Information**: These advanced refrigerants do not contribute to ozone depletion, while traditional refrigerants do. Traditional refrigerants will no longer be manufactured as of 2010 (but their use is still legal through 2030). 407c is not generally available in the US but popular in Europe. The next generation of HVAC equipment, already on sale in Japan and Europe and available in limited quantities in the US but not yet UL-certified, uses R744 refrigerant; that is CO_2. R744 has a GWP of 1, compared to R410a's GWP of 1725. R-744 equipment is also significantly more efficient than HFC refrigerants. See ACEEE report on "Emerging Hot Water Technologies" pages 13 through 20 "Eco Cute Water Heaters."	Genetron AZ-20, or Suva 410a). These are a blend of hydrofluorocarbons (HFCs) that have less net GHG emissions than traditional refrigerants (HCFCs). (LISC)
Use heat pumps, preferably ground source.	**Effectiveness**: Ground source heat pumps are one of the most energy efficient systems available. Air source heat pumps offer both heating and cooling and can deliver very high efficiencies. With the relatively small carbon footprint of grid electricity in King County, high-efficiency heat pumps, particularly those using "inverter technology" condensing units, can offer considerable GHG emissions reductions even when compared to high efficiency natural gas heating units. **Cost**: Ground source heat pump equipment is only moderately more expensive than other mechanical equipment types. However, the cost of installing the thermal exchange loops in vertical bores or horizontal trenches can be considerable. **Additional Information**: Can be used for both heating and cooling. The next generation of HVAC equipment, already on sale in Japan and Europe and available in limited quantities in the US but not yet UL-certified, uses R744 refrigerant; that is CO_2. R744 has a GWP of 1, compared to R410a's GWP of 1725. R-744 equipment is also significantly more efficient than	Proper sizing and installation of the ground exchange loops is critical to satisfactory performance of ground source heat pumps. Make sure you use contractors with experience in this application. Soil types and groundwater conditions can significantly affect performance. Heat pump exchange loops may also be installed in the bottom of a deep pond or other body of water with stable year round temperatures. For more information about heat pump options, refer to: Toolbase Services website. Bay Area Local Initiatives Support Corporation's Green Rehabilitation Guide Page 17 of the ENERGY STAR's heating and cooling guide at ENERGY STAR's website

Mitigation Strategy	Overview	Implementation
	HFC refrigerants. See ACEEE report on "Emerging Hot Water Technologies" pages 13 through 20 "Eco Cute Water Heaters."	
Install an economizer that cools data centers with outside air or air cooled water	**Effectiveness**: On average, the normalized heating and cooling Energy Use Intensity (EUI) of buildings with economizers was approximately 13% lower than those without economizers. California data centers have estimated 30-60% cost reductions with economizers over traditional data centers, and the total annual hours of air-side economizer use is greater in Washington than in California[liv]. **Cost**: ENERGY STAR reports examples of water-side economizer payback periods of 2 to 5 years[lv]. **Additional Information:** Economizers use cool or cold outside air ("free cooling") to help cool data centers and conditioned spaces, lowering energy usage, reducing wear and tear on precision air conditioning equipment, and decreasing operational costs.	This industry whitepaper, "Utilizing Economizers Effectively in the Data Center" describes these systems and implementation in more detail. Check local utility rebate and incentive programs for both new construction and retrofit economizer opportunities.
Install a radiant chilled (hydronic) ceiling cooling system[lvi]	**Effectiveness**: More energy efficient than air-based cooling systems. **Cost**: First costs for radiant systems are comparable to traditional VAV systems, but result in energy savings benefits 25% greater than VAV systems[lvii]. Costs will vary based on building and conditioning type, climate, and conditioning needs.	A system in which a room is cooled by chilling a large fraction of the ceiling by circulating water through pipes or lightweight panels. For more information on hyrdronic radiant cooling systems, refer to the Toolbase Services Website
Choose the most efficient air conditioner systems[lviii]	**Effectiveness**: Depends on the current system in place, and if there are any leaks. Effectiveness also depends on Proper sizing and installation of your equipment, installation of a programmable thermostat, sealing air ducts, and seasonal maintenance. **Cost**: Variable depending on the appropriate size of the unit to meet the unique demands of a space, which are impacted by building shading/solar gain, number of people typically using the space, and how the space is used/how much heat is generated (such as in a kitchen). **Additional Information**: Air conditioners use refrigerants, which emit very potent GHGs.	There are various rating systems for air conditioners, including SEER, EER, and COP. For guidance on how to choose energy efficient air conditioners and make sure current air conditioners are the most efficient possible, refer to page 17 of the ENERGY STAR's guide at Energy star's website.

Mitigation Strategy	Overview	Implementation
Cool spaces using evaporative cooling systems.[lix]	**Effectiveness**: About 75% reduction in cooling energy compared to conventional air conditioner. However, they consume between 3.5 and 10.5 gallons of water per hour of operation. **Cost**: Direct evaporative coolers cost about $700 to $1000, installed, compared with several thousand dollars for conventional air conditioner and ductwork. In addition, operating costs are about 1/3 that of conventional air conditioning (including the cost of water, depending on electric and water costs). **Additional Information**: Costs for indirect evaporative coolers are much higher, but they do not contribute moisture load to the primary air stream.[lx]	A system in which water evaporates into and cools a primary (direct) or secondary (indirect) air stream, which cools the supply air through a heat exchanger without adding moisture. Unlike air conditioned rooms, windows or ceiling vents need to be open when an evaporative cooling system is operating. They do not work well in humid climates, and work best in arid climates. For more information on evaporative cooling systems, refer to the Toolbase Services website.
Use vapor compression chillers	**Effectiveness**: Large chiller plants (either central to a campus or building-specific) producing chilled water for cooling can reduce energy consumption per ton of cooling capacity by 10% to 20% for air cooled chillers, to as much 50% for water cooled chillers. Efficiency gains are offset to some extent by distribution energy loads – pumping chilled water to the point of use. **Cost**: For large scale projects, central chillers are the most cost effective solution, but they have significant O&M requirements. Air-cooled chillers are less costly than water-cooled chillers and are available to fit smaller scale projects/loads. **Additional Information**: Chillers produce chilled water. Some can also produce heated water by reversing the condensation/expansion cycle – called reverse cycle chillers. Water is then distributed to the point of use where it flows through fan coils to cool/heat air or through radiant panels to provide heating or cooling. Water cooled chillers use a significant amount of water for cooling. However, salvaged water, such as rainwater or condensate from cooling coils may be used to contribute to the water needs.	Larger chilling devices that produce chilled water rather than cooled air for use in larger commercial buildings are more effective with a cooling tower. While all HVAC equipment should be sized appropriately, chillers can be optimized for part-load operation if appropriate – for example if a large central chiller is required for a campus, but the chiller capacity will not be fully utilized until the build-out is complete. Commissioning and effective operations and maintenance are critical to optimum chiller performance.
Install ceiling fans, preferably ENERGY STAR rated	**Effectiveness**: Ceiling fans only reduce GHG emissions if they are used *in place of* mechanical air conditioning systems. This strategy is only effective as a cooling replacement and only if ceiling fans are used only when needed and to replace, not supplement, air conditioning.	Ensure ceiling fans are installed where they will be beneficial to occupant comfort. Install appropriate and accessible controls (preferably a switch not a pull-string) to ensure occupants can control their environment.

Mitigation Strategy	Overview	Implementation
	Cost: Ceiling fans cost between $200 and $400 each, installed. **Additional Information**: Ceiling fans do not lower the temperature within a space but can result in occupants feeling cooler due to increased evaporation from the skin. Ceiling fans should therefore be used as a first-stage cooling to drastically reduce energy use during the cooling season. ENERGY STAR models use fewer watts and also produce less heat. Ceiling fans operate from 15 to 100 watts which is significantly less than the energy required for central or single-zone air conditioning systems[lxi].	Consider installing occupancy sensors so that fans are not used when spaces are not occupied. Since the motors release heat, their excessive use does not result in overall cooling effect.

Electric Heating System Efficiency

Mitigation Strategy	Overview	Implementation
Use ground-source heat pumps	**Effectiveness**: One of the most energy heating and cooling systems available. Actual effectiveness of GHG reduction depends on regional heat and cooling energy demands, as well as the heating and cooling current energy source (natural gas, hydroelectricity, coal, etc). According to LISC, use of ground source heat pumps 50-60% reduction of heating energy (compared to outside air) **Cost**: Equipment costs can be 50-100% more expensive for a GHP system when the circulating pump, indoor tubing, and water source heat pump are considered ($1000-$2000 for a 3-ton system). However, according to LISC, energy cost savings can be 30 to 70% on heating and 20 to 50% on cooling costs over conventional systems.	Heat pumps can be used for both heating and cooling. Ground source heat pumps heat or cool a space by transferring heat from the ground to the indoor air. The feasibility of installation of a ground source depends on the size of your lot, the subsoil and landscape. For more information, see The US Department of Energy's Energy Efficiency website Toolbase Services website. Page 17 of the ENERGY STAR's heating and cooling guide which can be downloaded here or from ENERGY STAR's website.
Use drain-water heat recovery or sewer heat recovery systems[lxii]	**Effectiveness**: Reduces the energy needed to heat water and associated emissions. Drain-water heat recovery (DWHR) systems transfer heat from drains to supply piping for sinks or showers. Larger scale systems, such as sewer heat recovery, take advantage of the waste heat in the large-volume sewer pipe of a building to pre-warm water flowing into	Before implementing, investigate and analyze the systems present in your building. Determine if a small-scale DWHR or the sewer heat recovery system is most appropriate.

Mitigation Strategy	Overview	Implementation
	a traditional boiler or hot water system that supplies building domestic hot water or conditioning hot water.[lxiii] **Cost**: DWHR systems cost between $300 and $500 and typically have a simple payback of 2.5 to 7 years.[lxiv] One sewer heat recovery case study on a large college campus cost $1.5 million with an estimated payback period of 15 years and offsets estimated at over 800 tons of GHG emissions per year.[lxv] **Additional Information:** These systems capture the heat from wastewater to pre-heat incoming fresh water. For more information on small scale recovery systems, see the Toolbase Services website.	
Replace electric resistance heating with electric heat pumps[lxvi]	**Effectiveness**: Electric heat pumps are more effective at reducing energy than electric resistance heating. Actual effectiveness of GHG reduction depends on regional heat and cooling energy demands, current system efficiency, and the heating and cooling current energy source (natural gas, hydroelectricity, coal, etc). **Cost**: Heating with air-source heat pumps can reduce electricity used for heating by as much as 30%-40%.[lxvii] Initial costs vary depending on the size of the system; installed cost for a residential-scale system will typically fall between $5,000 and $15,000.[lxviii] The US Energy Information Administration (EIA) provides an excel-based calculator to compare heating option prices, including for air-source heat pumps.	This strategy is preferable to electric resistance heating but may not be preferable to direct use of fuels for heating. See the strategy above, Use ground source heat pumps). For more information, see ENERGY STAR Website and the US Department of Energy's Energy Efficiency website
Use hydronic heating systems, especially floor radiant heating[lxix]	**Effectiveness**: More efficient than forced air systems. Actual effectiveness of GHG reduction depends on regional heat and cooling energy demands, as well as the heating and cooling current energy source (natural gas, hydroelectricity, coal, etc). **Cost**: Hydronic heating systems can cost anywhere from $10-$90 (or more) per panel for 'dry' system floor panels (where the heating system is placed between the flooring and a sub-floor), and from about	A heating system that circulates water rather than air. For more information, see the US Department of Energy's Energy Efficiency website. For a 'dry' residential system overview, see the Toolbase Services website.

Mitigation Strategy	Overview	Implementation
	$3-$7 per square foot for 'wet' systems (where the system is placed directly into the flooring medium, such as concrete). Manufacturers estimate a 20%-40% cost savings for radiant systems over forced air systems.[lxx]	
Use ENERGY STAR rated furnaces or boilers	**Effectiveness**: Actual effectiveness of GHG reduction depends on regional heat and cooling energy demands, current system efficiency, and the heating and cooling current energy source (natural gas, hydroelectricity, coal, etc). Furnaces that meet ENERGY STAR requirements are at least 90% efficient, as opposed to traditional furnaces which are required to have an efficiency of 78%. ENERGY STAR–labeled boilers must be 85% efficient or higher, as opposed to traditional boilers which are required to have a minimum efficiency of 75%. **Cost**: While ENERGY STAR equipment may carry higher up-front costs, the American Council for Energy Efficient Economy (ACEEE) estimates ROI for ENERGY STAR furnaces and boilers, depending on the efficiency of the existing system. As compared to new, non-ENERGY STAR equipment, a furnace yields estimated cost savings of ~$14 per $100 of annual fuel cost; a boiler yields estimated cost savings of ~$11 per $100 of annual fuel cost.[lxxi]	For information about ENERGY STAR boilers, visit the ENERGY STAR boiler website. For information on ENERGY STAR furnaces, visit the ENERGY STAR furnace website. For information on furnace and boiler efficiency, go to the American Council for Energy Efficient Economy website.

Electric Ventilation System Efficiency

Mitigation Strategy	Overview	Implementation
Install a displacement ventilation system as an alternative to conventional ventilation delivery	**Effectiveness**: Actual effectiveness of GHG reduction depends on regional heat and cooling energy demands, as well as the heating and cooling current energy source (natural gas, hydroelectricity, coal, etc). According to LISC, it can generate 30-60% reduction in use for cooling and ventilation (depending on climate) **Cost**: A displacement ventilation system carries a slight premium over conventional ventilation systems,	Displacement ventilation systems operate by introducing air at low speeds through many diffusers in the floor or along the sides of a room and is warmed by internal heat sources (occupants, lights, plug-in equipment) as it rises to the top of the room.

Mitigation Strategy	Overview	Implementation
	due to low-velocity displacement diffusers and enhanced compressor capacity controls, to maintain flow rate and temperature. The displacement diffusers carry a premium of about $1- $2 per square foot of floor space. Some of this increase may be offset by simplification of the ductwork.[lxxii]	
Install ventilation systems with variable air flow or convert constant air flow systems to systems with variable air flow	**Effectiveness**: Actual effectiveness of GHG reduction depends on regional heat and cooling energy demands, as well as the heating and cooling current energy source (natural gas, hydroelectricity, coal, etc). According to LISC, can generate up to 40% reductions in heating, cooling and ventilation energy. **Cost**: As expected, energy costs are lower for variable flow ventilation systems, as energy demand is lower. An EPA study comparing constant and variable flow systems found an annual energy cost savings of between 10%-21%, depending on climate (with warmer climates achieving greater savings). The addition of temperature economizers resulted in an additional 6%-10% energy savings.[lxxiii]	Variable speed fans adjust ventilation rates in response to ventilation loads. They generally include control systems that monitor carbon dioxide levels or relative humidity though other parameters may be more predictive of room occupancies. This reduces the amount of outside air that needs to be conditioned to maintain thermal comfort while maintaining air quality. Variable speed fans are also often driven by electrically commutated motors (ECMs), which also generally draw less power than single speed fans of similar capacity.
Install new ENERGY STAR-rated exhaust fans with appropriate controls	**Effectiveness**: ENERGY STAR exhaust fans move air more efficiently and effectively (less watts/cfm) than standard exhaust fans. Appropriate controls (such as timers and occupancy sensors) coupled with a variable-speed fan will save energy by reducing overall energy used for ventilation. **Cost**: ENERGY STAR exhaust fans have an incremental first cost but are more effective and more energy efficient (and produce less noise when installed properly) than standard exhaust fans. Fan prices (not installation costs) range from less than $100 – a few hundred dollars. **Additional Information:** Consider the ventilation needs for your space. Refer to ASHRAE 62.1 and/or 62.2 as well as the Washington State Ventilation and Indoor Air Quality Code for exhaust ventilation rates for your facility.	Follow manufacturer's recommendations for installation and always exhaust directly to the outdoors. Use controls that are most appropriate for the space and the occupants, and incorporate inspections and timer/occupancy control checks into your building's O&M Plan.

Natural Heating and Cooling

Mitigation Strategy	Overview	Implementation
Plant trees and vegetation to shade buildings or structures[lxxiv]	**Effectiveness**: Actual effectiveness of GHG reduction depends on regional heat and cooling energy demands, as well as the heating and cooling current energy source (natural gas, hydroelectricity, coal, etc). **Cost**: Siting the project to maximize the use of existing trees onsite where possible will reduce costs. Cost for tree planting is variable, depending on the trees that are purchased. Projects can expect to see energy savings from avoided cooling costs, although this savings is not as significant as other parts of the country with greater cooling needs.[lxxv]	Evergreen trees on the north and west sides afford the best protection from the setting summer sun and cold winter winds, while deciduous trees planted on the south side will protect from the summer sun and allow the winter sun to shine through. Actual placement of the tree is critical to maximizing energy savings. Smaller transplanted trees (e.g. 1" caliper) have a higher survival rate than larger trees, but larger trees will provide carbon and stormwater mitigation and aesthetic benefits sooner. Develop effective long term maintenance and irrigation plan for transplanted trees to ensure long-term health.
Cool spaces with night-time ventilation[lxxvi]	**Effectiveness**: Up to 100% reduction in cooling energy. Actual effectiveness of GHG reduction depends on building cooling energy demands, as well as the current cooling energy source (natural gas, hydroelectricity, coal, etc). **Cost**: If your building is already equipped with an economizer and ability to switch to 100% outside air, the only cost may include the labor to change the controls to adjust the scheduling settings on the equipment. Costs will vary if you need to add equipment and additional controls.	Design features that improve night-time ventilation are: courtyards, atria, wind towers, solar chimneys, and operable windows. Natural ventilation can be supplemented with mechanical ventilation as needed.
Use cool roofs	**Effectiveness**: Radiant barriers reduce 90% or more of roof deck radiant heat. Actual effectiveness of GHG reduction depends on regional heat energy demands and the heating current energy source (natural gas, hydroelectricity, coal, etc). **Cost**: Costs can range roughly between $0.50 to $6.00 per square foot.	Cool roofs, or roofs that absorb less heat, are usually roofs with a combination of high albedo (or high reflective) materials and high emittance (the ability of a material to shed heat) materials. The most efficient roofing materials are those that are ENERGY STAR–qualified. Manufacturers and qualified products are listed on the ENERGY STAR website. Cool roofs are most applicable in urban areas. All cool roof

Mitigation Strategy	Overview	Implementation
		materials require some cleaning to keep their performance levels high. For more information on the different types of roofing materials, refer to the Bay Area Local Initiatives Support Corporation's Green Rehabilitation Guide See also the Department of Energy's Guidelines for Selecting Cool Roofs.
Provide removable overhangs or trellises on south facing windows during summer months.	**Effectiveness**: **Cost**: Variable. Depends on the material used and amount of window shaded. Ongoing cost savings may result from reduced cooling needs in the summer months.	Proper sizing of overhangs is important. Sun position calculators will determine the exact dimensions appropriate for a project located at a specific latitude. Remove the overhang during the winter to allow light in for added heat.
Cool spaces using earth pipe cooling systems.[lxxvii]	**Effectiveness**: Actual effectiveness of GHG reduction depends on regional heat and cooling energy demands, as well as the current cooling energy source (natural gas, hydroelectricity, coal, etc). **Cost** : Good performance depends on the climate having a substantial annual temperature range, so it may not be cost effective to King County.	A system that cools ventilation air by drying outside air through a buried air duct. Refer to the refer to the Bay Area Local Initiatives Support Corporation's Green Rehabilitation Guide

Appliance Efficiency

Mitigation Strategy	Overview	Implementation
Purchase ENERGY STAR equipment and appliances	**Effectiveness**: Actual effectiveness of GHG reduction depends on the current appliance energy source (natural gas, hydroelectric, coal, etc) and the alternative appliance considered. **Cost**: The replacement of many appliances will save money over time through reduced energy costs. ENERGY STAR partners often offer discounts and rebates on appliance purchases. See the Special Offers and Rebates Finder, searchable by zip code and appliance type on the ENERGY	See the ENERGY STAR website for appliance and equipment listings.

Mitigation Strategy	Overview	Implementation
	STAR website.	
Require EPEAT Gold for all computers	**Effectiveness**: Actual effectiveness of GHG reduction depends on the current source of electricity (hydroelectric, coal, etc). **Cost:** EPEAT Gold-rated computers and computer products may carry a slight cost premium; however, some manufacturers (such as Dell) have committed to cost parity with their own products. These savings may be recaptured over the product's lifetime through energy savings.	See the EPEAT website.
Use cloud computing	**Effectiveness**: Actual effectiveness of GHG reduction depends on the current source of electricity (hydroelectric, coal, etc). **Cost:** Variable. **Additional Information:** Cloud computing is Internet-based computing, whereby shared resources, software and information are provided to computers and other devices on-demand. Cloud computing saves energy.	A recent report from Pike Research (Sept, 2011) forecast that widespread adoption of cloud based computing could result in a 31% reduction in data center energy consumption, when compared to the continued use of on-site data centers. Large scale, centralized "clouds" use large scale, high-efficiency processors and storage, and cooling systems and have higher capacity utilization rates than on-site servers. Look for cloud providers who provide information about their energy efficiency, energy sources and carbon offset strategies.
Use more efficient and better insulated water heaters or integrated space and hot water heaters	**Effectiveness**: 10-20% reduction in energy for water heaters. Actual effectiveness of GHG reduction depends on the current appliance energy source (natural gas, hydroelectric, coal, etc). **Cost**: The increased cost is recovered through savings in energy cost savings, reduced maintenance costs, and increased product life. **Additional Information**: Installing tank insulation on service hot water heaters is a low-cost measure that will prevent heat loss. For all water heating systems, the use of solar collectors can further reduce energy use and take advantage of free energy	Refer to Solar Thermal Water Heaters strategy below.
Use tankless water heaters	**Effectiveness**: Up to 30% reduction in energy for water heaters. Actual effectiveness of GHG reduction depends on the current appliance energy	For all water heating systems, the use of solar collectors can further reduce energy use and take advantage of free energy. Refer to Solar Thermal Water Heaters

Mitigation Strategy	Overview	Implementation
	source (natural gas, hydroelectric, coal, etc). **Cost**: The increased cost is recovered through savings in energy cost savings, reduced maintenance costs, and increased product life. **Additional Information**: Tankless or "instantaneous" water heaters are generally more efficient than standard tank systems since they only heat water when it is needed. Tankless systems with electric ignition use even less fuel than systems with a pilot light. Larger vents and larger gas lines may be required.	strategy below. For more information, refer to the Bay Area Local Initiatives Support Corporation's Green Rehabilitation Guide
Use solar thermal water heaters[lxxviii]	**Effectiveness**: 50-90% reduction in energy for water heaters (IPCC). For efficiency details of different types, refer to the Bay Area Local Initiatives Support Corporation's Green Rehabilitation Guide. Actual effectiveness of GHG reduction depends on the current appliance energy source (natural gas, hydroelectric, coal, etc). **Cost**: A typical multifamily solar hot water system will cost between $1,000 to $3,000 per unit, depending on the system's size. Paybacks range from three to eight years. Large central boilers can be preheated by solar collectors and cost less than individual water heaters in each unit. **Additional Information**: The systems use the sun to heat the water partway to the set point, and use a boiler or gas water heater to complete the heating process. Solar water heating is appropriate for existing buildings with south-facing roof space for panels and space for appropriate plumbing configurations in their mechanical room.	The three most common solar hot water collector systems are: Integral collector storage (ICS), or "batch." These systems are passive—they do not require any pumps or motors to circulate the hot water. The water is stored where it is heated (on the roof in most cases). Efficiency: Up to 30 %. Flat plate collector. Water or another liquid is circulated through a glass-covered, sealed box where the fluid is heated by the sun. The resulting water is stored in a tank usually located in the building. Efficiency: Up to 40%. Evacuated-tube collector. These collectors are constructed so that the fluid heating happens inside a vacuum, thus increasing efficiency. Storage is in a tank inside the building. Efficiency: Up to 60%.
Decrease the temperature of water heaters	**Effectiveness**: Actual effectiveness of GHG reduction depends on the current appliance energy source (natural gas, hydroelectric, coal, etc), current temperature settings, and extent of adjustments. **Cost**: This is a no-cost solution, other than staff time to adjust and monitor temperature settings.	Incorporate hot water temperature setting as an Operations task in your department's Green O&M Guidelines.
Use water-saving fixtures	**Effectiveness**: Effectiveness depends on current efficiency of fixtures, number of fixtures replaced, efficiency	Select faucet aerators for lavatory faucets with 0.5 gallons per minute in public restrooms.

Mitigation Strategy	Overview	Implementation
	and effectiveness of installed fixtures, and whether hot water and/or cold water is saved. For faucet and toilet replacements, savings of 25-70% are easily achievable. **Cost:** Low-flow aerators cost as little as $5-10, shower heads cost $10-$50.[lxxix] **Additional Information:** Saving water saves energy because all water requires a significant amount of energy to treat and distribute. Wastewater treatment accounts for more than half of King County's electricity usage, which in turn accounts for 15% of the GHG emissions. For more information, see pg 138 of the Greening Federal Facilities document and EPA's WaterSense.	Select shower heads with flow rate 1.75 gallons per minute or less. Where applicable work with Seattle Public Utilities and Cascade Water Alliance for standard and customized incentives and rebates. Depending on whether your water-heating system is gas or electric, work with Puget Sound Energy or Seattle City Light, respectively, for incentives and rebates.
Use water-efficient dishwashers	**Effectiveness**: Water- and energy-efficient dishwashers reduce GHG emissions through reduction in both water (and water heating), and energy use. The effectiveness depends on the extent of use and the incremental upgrade of the product. **Cost:** Variable. **Additional Information:** Saving water saves energy because all water requires a significant amount of energy to treat and distribute. Wastewater treatment accounts for more than half of King County's electricity usage, which in turn accounts for 15% of the GHG emissions (2007 Climate Action Plan). For more information, see EPA's ENERGY STAR Dishwasher website.	Incorporate a dishwasher specification for all upgrade projects and new construction. For commercial-style dishwashers, work with Seattle Public Utilities for rebates and incentives. If you use vendors, use the following language to stipulate ENERGY STAR products: "Provide products that earn the ENERGY STAR and meet the ENERGY STAR specifications for energy efficiency. The vendor is encouraged to visit energystar.gov for complete product specifications and updated lists of qualifying products.[lxxx]"
Install water-efficient toilets	**Effectiveness**: Overall water savings (and therefore energy savings) depend on the extent of upgrade (overall gallons per flush savings) and the number and use of toilets/urinals. When dual-flush toilets are used, educational signage improves effectiveness, as it helps "train" users to use the appropriate flush rate. **Cost:** New, low-flow toilets typically cost $100-$400/toilet and low-flow urinals cost $70-$900 (high-end models have electronic sensor and automatic flush).[lxxxi],[lxxxii] Costs do not include installation costs. **Additional Information**: Saving water saves energy because all water	Select toilets with 1.28 gallons per flush or less (or dual-flush with average flush rate less than 1.1 gallons per flush). Select urinals with 0.5 gallon or less per flush. Before purchasing, explore the Maximum Performance Website to determine the most appropriate toilet for your facility. This site allows you to search products both by efficiency (gallons per flush) and effectiveness (grams per flush).

Mitigation Strategy	Overview	Implementation
	requires a significant amount of energy to treat and distribute. Wastewater treatment accounts for more than half of King County's electricity usage, which in turn accounts for 15% of the GHG emissions (2007 Climate Action Plan). For more information, see EPA's WaterSense website.	

Ongoing Energy Management Systems

Mitigation Strategy	Overview	Implementation
Implement a power management system for computers[lxxxiii] ★	**Effectiveness**: Effectiveness is dependent on individual networks and user requirements. If networks include a lot of computers that are not required to be on for extended periods, an automated power management system may yield significant reductions in energy consumption. On the other hand, if most of the computers on a network are required to be on most of the time to allow for remote access or other critical but intermittent tasks, effectiveness may be limited. ENERGY STAR offers a savings calculator to estimate the effectiveness of such Power Management Systems. **Cost**: Network and "smart" plug strip power-management systems are rated very cost effective on the US Dept of Energy's Energy Efficiency and Renewable Energy website **Additional Information**: Considerations for power management systems in the federal sector are available through the Federal Energy Management Program website. ENERGY STAR Calculator See also: Dell Case Study	Possible approaches include: Automation Sleep and hibernation Provide power strips that sense the power of a control device to automatically turn off peripheral equipment
Implement a climate control system[lxxxiv] ★	**Effectiveness**: Effectiveness is dependent on multiple factors including the integrity and efficiency of the building envelope, the complexity of the mechanical HVAC system and/or natural ventilation design of the building, the variability of internal and external loads on the buildings (including daylighting), and the capacity of the building management to set up and maintain the system. **Cost**: Cost is typically quite high for large and complex	A system that automatically adjusts energy use for heating, cooling, and appliances based on the time of day and the number of employees in the building.

Mitigation Strategy	Overview	Implementation
	mechanical systems particularly if retrofitting and existing building. However, simple paybacks are commonly reported in the 3 to 8 year range **Additional Information**: Much of the cost of retrofitting a climate control system in a building was related to the data infrastructure requirements. Recent developments in the availability of wireless systems have reduced the cost and increased the feasibility of this approach.	
Adjust control system settings[lxxxv]	**Effectiveness**: Effectiveness is dependent on multiple factors including the integrity and efficiency of the building envelope, the complexity of the mechanical HVAC system and/or natural ventilation design of the building, the variability of internal and external loads on the buildings (including daylighting), and the capacity of the building management to set up and maintain the system. **Cost**: Cost is minimal if it is built into the scope of facilities management. Cost will be higher if an outside commissioning or retro-commissioning authority is brought in, but results may be more significant. Commissioning and retro-commissioning commonly have short payback periods, suggesting cost effectiveness.	If a facility is such that it has significant potential benefits from a building climate control system, it is likely that the greatest energy savings will come from a systematic and rational approach to setting up and adjusting the system, while tracking energy consumption and occupant comfort. However, this process should include extended periods of steady state operation to allow for accurate quantification and qualification of results. Process and outcomes should be thoroughly documented in O&M manuals to preserve institutional knowledge through staff turnover.
Reduce energy demand using peak shaving or load shifting[lxxxvi]	**Effectiveness**: Energy demand peak shaving or load shifting may be an effective strategy for reducing electric-consumption related GHG emissions if, as is the case in much of King County, much of the electric baseload is met with low-carbon hydro-electric power, whereas marginal or peak loads are met by other fuel-sourced electricity such as natural gas. Peak shaving may be more effective if it results in a net decrease in the overall consumption of energy; peak shaving suggests avoidance of consumption at peak times, rather than shifting demand from peak to off-peak times. However, it is unlikely that peak shaving or load shifting will have significant impact on GHG emissions on the individual building scale. Electric utilities manage power supply to ensure adequate coverage to meet demand and it would take a significant trend in peak shaving or load shifting to modify supply levels. Also, the benefits of load shifting will not be fully realized until the concept of a “smart grid” is more fully	Systems that reduce loads at peak times should be prioritized where appropriate. For conditioning systems, these commonly involve the use of thermal mass to flatten and delay peak heating and cooling loads, reducing the need for mechanical conditioning at those peak times. Improving daylighting design and adding daylight controls can be used to shave peak loads in commercial buildings, reducing lighting demand and associated cooling load during the warmest times of the day. Activity scheduling is an effective load-shifting strategy. Non time-critical activities, especially energy intensive ones can be scheduled for off-peak times (commonly night time).

Mitigation Strategy	Overview	Implementation
	implemented, allowing much narrower margins between supply and demand and more responsive management of loads. **Cost**: Depends on the strategies employed to shave or shift loads **Additional Information**: California's "Shift & Save" program estimates carbon emissions reductions of 10% to 20% for each kWh of power consumption shifted from peak demand periods to night-time base load periods.	

Insulation

Mitigation Strategy	Overview	Implementation
Construct green roofs (IWG)	**Effectiveness**: Minimal effectiveness in proving savings from thermal insulation, according to EPA's reporting which evaluated climates significantly more extreme than King County. However, green roofs are effective in providing other benefits. See Vegetation to Extend the Life of External Structures above. **Cost**: The costs of an extensive green roof in the U.S. range from $8 per square foot to $25 including materials, preparation work, and installation. Maintenance costs may range from $0.75 to $1.50 per square foot. (EPA). A more detailed cost estimate is provided in the green roof strategy under Wastewater and Stormwater Reduction Methods.	For information on Green roofs, see the EPA's document on green roofs.
Improve thermal envelope between the interior of the structure and the outside conditions	**Effectiveness**: 50-75% reduction in heating energy. Actual effectiveness of GHG reduction depends on regional heat and cooling costs, as well as the heating and cooling current energy source (natural gas, hydroelectricity, coal, etc). **Cost:** Variable.	The effectiveness of the thermal envelope depends on: Insulation levels in the walls, ceiling and ground or basement floor, including factors such as moisture condensation and thermal bridges that affect insulation performance Thermal properties of windows and doors Air-tightness of the envelope and driving forces such as wind, inside-outside temperature differences and air pressure differences due to mechanical ventilation systems or warm/cool air distribution.

Mitigation Strategy	Overview	Implementation
Insulate pipework and ductwork ★	**Effectiveness**: Actual effectiveness of GHG reduction depends on regional heat and cooling costs, as well as the current heating and cooling energy source (hydroelectricity, natural gas, coal, etc). **Cost**: Cost-saving over time. Insulation costs vary depending on the length of pipes and ductwork needing insulation.	For pipes R4 insulation is recommended. Ensure piping elbows are adequately insulated. For ductwork insulation in unconditioned space R8 is better is recommended.
Make small insulation changes in residential buildings without major renovation ★	**Effectiveness**: Up to 35% reduction in heating energy, depending on quality of insulation before the improvements. Actual effectiveness of GHG reduction depends on regional heat and cooling costs, as well as the current heating and cooling energy source (hydroelectricity, natural gas, coal, etc). **Cost**: Variable.	Small insulation changes include: Sealing points of air leakage around baseboards, electrical outlets and fixtures, plumbing, the clothes dryer vent, door joists and window joists Weather stripping of windows and doors Adding insulation in attics, to walls or wall cavities. Installation of new window and wooden door frames Sealing of suspended timber ground floors Repair of cracks in plaster
Install windows with high thermal performance ★	**Effectiveness**: Actual effectiveness of GHG reduction depends on regional heat and cooling costs, as well as the current energy source (hydroelectricity, coal, etc). **Cost**: Vinyl windows and thermally broken aluminum windows cost about $1 more per square foot than standard aluminum windows. Fiberglass, wood and composite windows are considerably more expensive than vinyl or metal. Low-e coatings add about $0.30 to $0.50 per square foot and achieve a payback of three years or less. (LISC) Low-e coatings add about $0.30 to $0.50 per square foot and achieve a payback of three years or less. (LISC) **Additional Information**: Will likely save money over time. Installing ENERGY STAR qualified windows can reduce energy bills by about 7 – 24% compared to non-qualified windows.	For more information, refer to page 15 of the ENERGY STAR's heating and cooling guide which can be downloaded here or from Energy star's website. In cool climates that have greater heating loads that cooling loads, install new windows with a low U-factor (equivalent to high insulating R-value) but a high solar heat gain coefficient (SHGC). For more information about different window types, refer to the Bay Area Local Initiatives Support Corporation's Green Rehabilitation Guide
Install energy efficient windows. ★	**Effectiveness**: Actual effectiveness of GHG reduction depends on window system before improvement, regional heat and cooling costs, as well as the heating and cooling current energy source (natural gas,	In addition to thermal performance, the air infiltration rate of windows can affect energy consumption by allowing or limiting the infiltration of unconditioned outside air.

Mitigation Strategy	Overview	Implementation
	hydroelectricity, coal, etc). **Cost**: Variable.	Compare the Air Leakage rate of windows, published on the NFRC label and cut sheets. For storefront windows and curtain walls, look for test results based on ASTM E283-04, or the North American Fenetration Standard to compare performance.

Energy Efficient Electric Lighting

Mitigation Strategy	Overview	Implementation
Use natural light (daylighting systems)[lxxxvii]	**Effectiveness**: Actual effectiveness of GHG reduction depends on regional heat and cooling energy demands, as well as the heating and cooling current energy source (natural gas, hydroelectricity, coal, etc). **Cost:** Successful daylighting strategies can lower energy costs through reduced lighting needs during the daytime. Costs for actual daylighting strategies may be integrated into overall design, or as separate costs for specific design elements such as light wells, skylights, etc. **Additional information**: Daylighting helps boost productivity of workers. For more information, see pg 182 of the Greening Federal Facilities document.	Daylighting strategies should be considered early in design to maximize opportunities present on the site, such as solar access, existing shading, and other considerations. Daylighting includes design components such as (see IEA): Use of floor plates Increased building perimeter Provision of skylights Provision of clerestories (i.e., glazed vertical steps in the roof) Use of light wells Provision of inner atria Strategic choose the size, shape and the position of windows
Orient building or structures to take advantage of natural light	**Effectiveness**: Correct orientation can contribute to more than a 30% reduction in energy. **Cost**: Variable, as other site specific issues (slope, access, etc.) may have an impact on cost effectiveness of building orientation.	Building orientation should be considered early in design to maximize opportunities present on the site, such as solar access, existing shading, and other considerations. Orient buildings or structures requiring lighting to optimize the effect of solar radiation, shade in the summer and sun light in the winter. This strategy reduces the demand for temperature control by an HVAC system. For more information on building orientation, see the Greening Starter Projects website
Use motion sensors for lighting	**Effectiveness**: Saves energy. Actual effectiveness of GHG reduction depends on the current source of electricity (hydroelectric, coal, etc), fixture	When placing sensors, avoid locations that will result in 'false tripping' from movement detected outside of the desired lighting

Mitigation Strategy	Overview	Implementation
	wattage, and fixture usage. **Cost**: Cost depends on number of motion sensors required for space. Implementation will saves money over time by lowering energy costs.	coverage area, or are sensitive to false movement (such as air movement from an HVAC diffuser). The Whole Building Design Guide includes implementation considerations and how motion sensors can be combined with other effective lighting controls.
Replace incandescent light bulbs with LED or CFL light bulbs; **Replace T12 lamps with magnetic ballasts and incandescent lamps with T8 linear fluorescent lamps with electronic ballasts.**	**Effectiveness**: CFL's produce 3 to 4 times as much light per watt than incandescent lamps and last up to 10 times longer. LED exit signs consume between 2 and 4 watts, as compared to compact fluorescent (15W) or incandescent (20 to 40W) exit signs. Actual effectiveness of GHG reduction depends on the current source of electricity (hydroelectric, coal, etc). **Cost**: A typical CFL will save $30 in energy costs over its life span. (LISC) LED exit signs have a typical payback of less than one year to four years depending on cost of the fixture, rebates, and maintenance costs.	When possible, specify hard-wired CFLs for any new and replacement light fixtures. Any recessed cans should be insulation contact air-tight (ICAT) compact fluorescent models. Tubular fluorescent lamps are commonly used for kitchen and office ceiling fixtures. The T8 lamp is available straight or U-shaped and has become the standard for new construction. The Super T8 lamp is even more efficient and advanced than the T8. Specify LED exit signs to replace fluorescent and incandescent exit signs.
Use energy efficient light bulbs for traffic lights	**Effectiveness**: A recent relamping in Denver resulted in 0.26 metric tons of CO_2 reduction *per* installed LED traffic signal.[lxxxviii] Santa Barbara, California reports 70-80% savings on related energy costs after a recent conversion to LED traffic lamps.[lxxxix] **Cost**: Relamping 20,500 traffic lights in Denver, Colorado (referenced above) with LED signals resulted in a payback period of less than 4 years and an overall lifetime savings of $6.1 million. Lifetime savings figure includes reduced energy costs as well as reduced maintenance and replacement costs. **Additional Information**: In parts of King County that receive snowfall, be aware that LEDs do not burn hot enough to melt snow, which can pose a risk to the lights being covered. If LED traffic lights are installed in these locations, provide an inspection and maintenance plan for each snow event.[xc] Since traffic intersections typically have their	When researching for relamping possibilities, see the Responsible Purchasing Network's Guide to LED Exit Signs, Street Lights, and Traffic Signals.

Mitigation Strategy	Overview	Implementation
	own electric meter, energy use reduction calculations are simple after replacement. For more information, see ENERGY STAR's Traffic Signals website	
Use directed exterior lighting	**Effectiveness**: Actual effectiveness of GHG reduction depends on the current source of electricity (hydroelectric, coal, etc). **Cost**: Generally, the capital cost savings from using lower wattage fixtures and shorter poles for parking lots more than offsets the additional costs of full-cutoff luminaires or add-on valances.	Use valances and overhangs wherever horizontal light should be controlled, or choose full cut-off luminaires (fixtures that emit no light above horizontal) or fixtures certified by the International Dark-Sky Association. For parking lots, specify shorter, lower wattage fixtures. Increase the number of fixtures and place them closer together. Because these light fixtures are directed, they require less energy than traditional exterior lighting. For more information, refer to the Bay Area Local Initiatives Support Corporation's Green Rehabilitation Guide
Use lighting sensors and actuators to control lighting based on the amount of daylight available	**Effectiveness**: Actual effectiveness of GHG reduction depends on the climate and the current source of electricity (hydroelectric, coal, etc). **Cost:** Variable.	Where occupied spaces have good access to daylight, adding daylight sensors that automatically modulate electric lighting to maintain adequate lighting levels will reduce electrical loads, particularly in commercial buildings, reducing lighting demand and associated cooling load during the warmest times of the day. See also Peak-Shaving (on page 42)
Use an automated Venetian blind system, integrated with office lighting controls	**Effectiveness**: 35% reduction of lighting energy in the winter; 40-75% reduction in lighting energy in the summer. Actual effectiveness of GHG reduction depends on the climate, the current source of electricity (hydroelectric, coal, etc). **Cost:** Variable.	Automated venetian blinds can be used to modulate available daylight and prevent glare in windows that receive direct sunlight (or light reflected from an adjacent building) for all or part of the year. They allow daylight to be exploited in locations where glare might otherwise prevent it and they can also reduce cooling loads resulting from direct solar gain (although exterior blinds and low solar heat gain treatments are more effective in this application.

Water Conservation

Mitigation Strategy	Overview	Implementation

Mitigation Strategy	Overview	Implementation
Design water efficient landscaping	**Effectiveness:** Saving water saves energy and associated GHG emissions, because all water requires a significant amount of energy to treat and distribute. The effectiveness depends both on the installation of water efficient plantings (drought-tolerant plants, "right plant right place," etc.) and the installation of water-efficient irrigation equipment and controls. **Cost:** Costs to retrofit existing landscapes and irrigation systems vary, and labor costs will vary depending on the use of in-house or vendor labor. Upgrades to irrigation equipment range from $300 - $1000 and can result in water savings totaling 20,000 gallons per year.[xci]	Minimize use of annual plants. Annuals often require more irrigation than perennials, as well as higher labor and capital inputs for seasonal replanting. For a list of native plants, see King County's native plant website. Also check Cascade Water Alliance's Irrigation Efficiency Program for Commercial Incentives and Rebates
Design or upgrade to low maintenance landscaping	**Effectiveness:** Low maintenance landscaping includes using fewer chemicals (e.g. pesticides, herbicides, fungicides, chemical fertilizers), producing fewer clippings (less frequent mowing of turf), decreasing use of engine-powered equipment for landscape maintenance, improving irrigation efficiency (mentioned in the previous strategy), and choosing appropriate plant/tree species. These measures save water, and use of gas powered equipment (or petroleum based products) - all which have associated GHG emissions. **Cost:** Some solutions are no-cost or cost-saving strategies, and reduce equipment costs, maintenance, and operation annually. Other strategies, such as installing new or different landscaping, will have first cost impacts but often immediate paybacks.	Establish high and low maintenance zones and coordinate these areas with an appropriate and efficient irrigation plan. For turf areas, lower expectations for year-around appearance, expand tolerance for a few weeds, mow higher and less frequently, correct soil deficiencies, moderate the use of natural or slow-release fertilizers, and incorporate Integrated Pest Management (see King County Green O&M Guidelines).[xcii]
Reuse rainwater	**Effectiveness:** **Cost:** Variable. **Additional Information**: Saving water saves energy because all water requires a significant amount of energy to treat and distribute. When rainwater is diverted away from storm and sewer systems, there is a decreased burden on pumping and treatment facilities. King County recently ruled to allow rainwater as the sole source for residential drinking water.[xciii]	For more information, see pg 155 of the Greening Federal Facilities document.
Install a water-	**Effectiveness:**	For more information, see pg 153 of

Mitigation Strategy	Overview	Implementation
recycling or grey water system	Saving water saves energy because all water requires a significant amount of energy to treat. Wastewater treatment accounts for more than half of King County's electricity usage, which in turn accounts for 15% of the GHG emissions (2007 Climate Action Plan). **Cost:** The cost of gray water systems varies on how simple or complex the plumbing is, how large the yard is, and who is doing the installation. For low-tech systems much of the work is digging mulch basins and digging trenches to bury pipe. Average costs for a low-tech system range from $1000 to $3000. High-end residential systems that include a sand filter to drip irrigation are between $5,000 and $10,000 depending on complexity of the plumbing and if there is a compatible existing drip irrigation system. **Additional Information**: Gray water is usually defined as water from showers, bathtubs, bathroom sinks, washing machines, and drinking fountains. It may also include condensation pan water from refrigeration equipment and air-conditioners, hot tub drainwater, pond and fountain drainwater, and cistern drainwater. Greywater systems are currently not approved by code, but may be in the future.	the Greening Federal Facilities document.

Other Energy Efficient Equipment

Mitigation Strategy	Overview	Implementation
Install gearless elevators instead of conventional hydraulic elevators or standard gear elevators.	**Effectiveness**: Elevators use on average between 4 and 10% of total building energy use, according to the U.S. Department of Energy. Gearless elevators are 2 to 3 times more efficient than conventional hydraulic elevators and 30 to 50% more efficient than standard gear elevators. Actual effectiveness of GHG reduction depends on the climate and the current source of power to the building (hydroelectric, coal, etc). **Cost:** Gearless elevators are most commonly used in high-rise buildings (more than 30 stories) but are now beginning to be cost effective for smaller buildings as well. **Additional Information**: They are smaller, easier to install and do not	Direct drive or gearless elevators typically have lower peak loads than conventional hydraulic or gear driven elevators, so the electrical service may be downsized.

Mitigation Strategy	Overview	Implementation
	require a separate machine room. However, they are limited in size, weight, and height depending on the building structure. They do not need hydraulic fluid or the associated heat and maintenance of hydraulic elevators.	
Retrofit municipal water and wastewater systems with energy efficient motors, pumps, and other equipment	**Effectiveness:** Effectiveness depends on the type and extent of measures implemented. Examples include improved pumping system design – motor efficiencies, VFDs; improvements in the design and control of aeration systems including ECMs, innovative blower types, high-speed gearless blowers, new diffusers, innovative and emerging energy conservation measures for selected treatment processes, and energy conservation measures for solids processing.[xciv] **Cost**: Implementation costs reported in the Best Practice Guidebook (referenced under Implementation) ranged from $12,000 – $800,000 with a simple payback period of 3-13 years. **Additional Information**: Wastewater treatment accounts for more than half of King County's electricity usage, which in turn accounts for 15% of the GHG emissions (2007 Climate Action Plan).	Utilize the American Council for an Energy-Efficient Economy's Local Policy Toolkit for Water and Wastewater Treatment and the Water and Wastewater Energy Best Practice Guidebook

Waste

Construction Waste Management

Mitigation Strategy	Overview	Implementation
Require recycling of construction materials from job sites	**Effectiveness**: Depends on the materials recycled. Recycled steel saves 60% production energy, recycled newspaper 40%, recycled plastics 70%, and recycled glass 40%.[xcv] Biomass such as wood and paper emit greenhouse gases in the landfill. **Cost**: Depends on the kind of waste. In general the per-ton cost of recycling construction materials is lower than the disposal fee costs in King County. King County provides information on cost-effectiveness including a worksheet which can be found on the Cost Effectiveness of Jobsite Diversion page of the GreenTools website. **Additional Information:** Contractors and demolition firms can maximize the amount of C&D that is diverted, and qualify their project for LEED or Built Green credits. Dimensional lumber is a C&D waste with relatively good recycling options. This type of wood waste is highly desirable and is sought by processors. Lumber scraps generated during construction make an excellent feedstock for engineered wood, and can be recycled into products such as laminates, parquet, pallets, countertops, shelving, furniture, mulch, wood pellets, and fiberboard. Some dimensional scraps can be reused in non-load bearing construction.	For more information, visit the Construction and Demolition Debris Recycling page of the green tools website and the King County "What do I do with…?" website
Require contractors to have a waste management plan	**Effectiveness**: A waste management plan places waste in a featured role and can educate project crew, subcontractors and suppliers on the critical need for GHG emissions reduction. Taking the time to outline goals, and a strategy for obtaining them, sends the message that you are serious about waste prevention and minimizing GHG emissions. Requiring a contractor to have a waste management plan effectively allows for 1) predicting the quantities and types of waste that will be generated during a construction, renovation, or demolition project, 2) identifying the final destination of that waste, and 3)	Implementation information, including a waste management checklist can be found in the Design specifications of waste management plans page of the GreenTools website. A successful plan should contain the following information: • Waste recycling or reuse goals • Analysis of project waste • Disposal methods • Material handling procedures • Instructions for the crew and

Mitigation Strategy	Overview	Implementation
	estimating waste management costs. The effectiveness of the plan is largely dependent on implementation. **Cost**: Variable depending on the complexity of the project but the plan need not be lengthy and would likely more than pay for itself through avoided waste disposal costs. For example, the EPA reports that in many areas locally available construction debris recyclers are making it possible for area contractors to obtain diversion rates exceeding 80%, which can substantially reduce costs. **Additional Information**: You can determine the cost-effectiveness of your efforts by using the Recycling Economics Worksheet to calculate your disposal and recycling costs. The worksheet contains separate calculation sheets for commercial-hauling and self-hauling options, as well as samples of completed worksheets.	subcontractors
Require contractors to have a waste prevention plan ★	**Effectiveness**: Waste prevention is even more cost effective than recycling and has the greatest effect on GHG reduction. Activities that prevent waste production cut garbage and recycling collection, and reduce GHG emissions. Small changes to building practices and extra attention to detail can add up to significant savings. **Cost**: Variable depending on the complexity of the project but plan need not be lengthy and would likely more than pay for itself through avoided waste disposal costs. **Additional Information**: Include waste prevention and resource management requirements into all bid documents and contracts. Set minimum requirements to encourage "best practices" and prevent bidders that include waste prevention practices with an initial cost from losing out to lower bidders.[xcvi]	Guidelines and resources can be found on the Prevent Jobsite Waste page of the green tools website. A Waste Prevention Plan should include the following steps: Step 1) Design to Prevent Waste. Paying attention to waste potential in the building's design stage can lead to less waste on the site. Step 2) Prevent Waste by working with suppliers to buy back unused product, deliver supplies using sturdy, returnable pallets and containers. Step 4) Purchase to Prevent Waste by avoiding excessively packaged materials and supplies, ordering only what is needed and avoiding delivery of excess quantities. Step 3) Prevent Waste On-Site through proper storage and handling of materials and make revisions as necessary. Step 5) Document Waste Prevention Savings/Costs for future use. Develop a list of suppliers and recycling contacts for easy reference and use in future projects.

Mitigation Strategy	Overview	Implementation
Design for disassembly (DfD) ★	**Effectiveness**: Building-related construction and demolition (C&D) debris accounts for approximately 30% of America's solid waste according to EPA. Disassembly preserves the energy and material value of C&D and avoids GHG emissions from C&D waste disposal. Maximizing the ease and frequency of product and systems disassembly for further productive use can yield significant GHG reduction benefits. Reusing and repurposing products can decrease GHG emissions by avoiding the need to create new products. For example, 250,000 homes are demolished annually with the potential for 1.2 billion board feet of reusable lumber. GHG savings occur from reduced timber harvest (forest destruction accounts for around 20% of global GHG emissions every year) as well from reduced lumber production and lumber-based landfill emissions. In addition, disassembling and recycling materials to create new products can reduce life cycle GHG emissions. Increasing recycling of construction and demolition debris to 50% would reduce GHG emissions by 75 $MMTCO_2E$/yr.[xcvii] **Cost**: The cost-effectiveness of disassembly is determined by how the structure was designed, constructed and what building materials were used. **Additional Information**: Design for Disassembly is a building design process that allows for the easy recovery of products, parts and materials when a building is disassembled or renovated. A DfD process involves developing the assemblies, components, materials, construction techniques, and information and management systems to accomplish this goal.	Consider requiring a design team to provide a disassembly plan for your project that addresses the disposition of all components at the end of their useful life. Refer to the Design for Disassembly page on the GreenTools website for general guidance and links. For more detailed guidance, refer to the Design for Disassembly Guidance Document. Also, information is available on pg 172 of the Greening Federal Facilities document. Also refer to the US Department of Housing and Urban Development's online resource prepared by the NAHB Research Center: *A Guide to Deconstruction: An overview of deconstruction with a focus on Community Development Opportunities*,

Recycling Provision

Mitigation Strategy	Overview	Implementation
Provide for storage and collection of recycled materials	**Effectiveness**: Job-site recycling can be set up for commingled recovery (all waste goes into one container for processing), source separation (separate labeled bins for each recycled material and one for waste)	Investigate recycling options available in your area before your project begins to help identify recycling staging area and hauling needs. Some recyclers accept

Mitigation Strategy	Overview	Implementation
onsite ★	or staged pickup (recycler times the pickup according to stage of construction to keep materials separated for recovery). Options that further reduce emissions associated with the hauling and processing of recyclables are those that keep materials onsite for recycling. Recent research has added clean wood and drywall cut-off waste to concrete and masonry as waste materials suitable for grinding and use on the job site. Wood chips can be used for erosion control or mulch, and ground drywall as a soil amendment. **Cost**: There are many variables affecting cost and efficiency, including availability of local recyclers (of which King County has many options), disposal fees and fee structure (i.e., rental and pickup fees), distances to landfills and recycling facilities, and whether pickup services are available. **Additional Information**: Use material sources that have "Take-back" policies: From acoustic ceiling tiles and cardboard packaging to carpeting and clean cutoff drywall, manufacturers' systems for accepting suitable materials back into production are growing. Check with distributors and manufacturers about this before your project begins as a way to reduce the storage requirements onsite for recyclables.	self-hauled commingled loads. Materials can also be picked-up at regular intervals or an as-needed basis. Self-haul involves a greater time investment by the general contractor or project superintendent, but on small jobs, may be a cost-effective way to facilitate recycling. Effective use of this option will require keeping up to date on policies and fee structures of the various material outlets and recyclers. Depending on the composition of the waste generated, a combined approach can work most effectively. If a large quantity of concrete is being generated, it may make sense to separate and self-haul this material. For more information, see pg 169 of the Greening Federal Facilities document.
Design for easy storage and collection of recyclables (including food, paper, corrugated cardboard, glass, plastic, and metals) ★	**Effectiveness**: Making recycling easier for end users and collection will increase the recycling rate during the building or site's operations. Recycling and composting diverted nearly 70 million tons of material away from landfills and incinerators in 2000, up from 34 million tons in 1990; more than doubling in just 10 years. Recycling benefits the air and water by creating a net reduction in 10 major categories of air pollutants and eight major categories of water pollutants. Garbage is a major contributor to GHG emissions and climate change. Solid waste landfills are the single largest human source of methane gas in the United States. Methane (CH_4) is a powerful greenhouse gas that is 23 times more effective at trapping heat in the atmosphere than the most prevalent greenhouse gas, carbon dioxide (CO_2).xcviii A national recycling rate of 30% reduces GHG emissions as much as removing nearly 25 million cars from the road. **Cost**:	For more information, see pg 169 of the Greening Federal Facilities document.

Mitigation Strategy	Overview	Implementation
	A number of factors would affect cost including types of containers, design of collection area(s), any supporting infrastructure such as loading ramps, and collection site maintenance. **Additional Information**: To satisfy LEED requirements: Provide an easily accessible area that serves the entire building and is dedicated to the separation, including (at a minimum) paper, corrugated adequately sized for 3 days' worth of trash, and cardboard, glass, plastics, and metals.	
Provide recycling and composting receptacles in every room in every building as well as outdoor spaces ★	**Effectiveness**: Providing visible and easy access to recycling and composting receptacles in all areas of the project where employees, visitors, or end-users will be present is an effective way to encourage and increase recycling to result in operational GHG reductions. Opportunities are particularly great in the areas of building and equipment maintenance, office operation, housekeeping, and waste management services, where larger quantities of waste are generated. Waste reduction and recycling associated with business operations involving paper, cardboard, glass, metals, and plastics require a coordinated effort among office, cleaning, and waste management personnel and services. **Cost**: Cost will vary but typically includes container costs, maintenance, collection and disposal costs. Cost savings alone make recycling worthwhile for many buildings and sites - avoided disposal costs can be significant. For example, in 2002, Kitsap County government offices reported savings of $23,500 from office paper recycling.[xcix] For most materials, recycling is more efficient with a building or property wide collection system (an economy-of-scale issue). It also gives the property manager more control over the size, placement and number of collection containers, as well as when and how the service is provided. **Additional Information**: A waste reduction and recycling program will help to ensure success and effectiveness of the provision of recycling and composting receptacles, specifically the following elements: *Comprehensive planning*: Every aspect of a facility's operation should be included in a program so that each waste material is treated in the same manner throughout the facility. *Buy-in throughout facility*: No program for waste reduction and recycling can succeed without the	Provide waste collection areas for recyclables in any building or facility or project where waste may be generated during the operational phase, including outdoor spaces. In large, multistory buildings, this may include specialized chutes and bins for recyclables. Separate storage areas should be provided for each different material collected. Planning for storage and handling of recyclables as part of the design of a facility is strongly advised. For more information, see pg 169 of the Greening Federal Facilities document.

Mitigation Strategy	Overview	Implementation
	full knowledge and support of all staff. Implementation must be as comprehensive as the program. *Recognition*: Let staff know the impacts—both in terms of natural resources and dollar savings—of their reduction and recycling efforts; consider an awards program. *Feedback*: Every program has to be tailored both to the existing conditions at a facility and to future changes. Provide an easy feedback mechanism so that the waste reduction and recycling program responds to "ground-level" conditions.	
Provide recycling receptacles and composting receptacles on heavily used public streets	**Effectiveness**: Effectiveness can be variable but public space recycling is a highly visible way to communicate the message that recycling is for all people who live, work, or visit an area. **Cost**: Cost will vary but typically includes container costs, maintenance, collection and disposal costs. The cost of the program should be weighed against the savings from reduced landfill disposal costs, reduction in GHG emissions, and educational benefits to the community. **Additional Information**: New technology applications have been developed in waste and recycling receptacles. For example, solar-powered compactors reduce the pickup frequency required while maintaining effective receptacle placement, saving truck trips, and corresponding GHG emissions.	A 2007 Public Space Recycling Pilot project in New York City studied recycling on street corners demonstrated: • Recycling of newspapers and other paper works well but recycling of bottles & cans is problematic, with a high rate of contamination • Public area recycling requires ongoing monitoring of bins by maintenance staff • Public area recycling works best in areas dense with commuters and lunching office crowds.

Wastewater and Stormwater Reduction Methods

Mitigation Strategy	Overview	Implementation
Green roofs	**Effectiveness**: Green roofs are an emerging technology that can help communities reduce GHG emissions by mitigating urban heat islands. A green roof is a vegetative layer grown on a rooftop. As with trees and vegetation elsewhere, vegetation on a green roof shades surfaces and removes heat from the air through evapotranspiration. These two mechanisms reduce temperatures of the roof surface and the surrounding air. The surface of a vegetated rooftop can be cooler than the ambient air, whereas conventional rooftop surfaces can	For information on Green roofs, see the EPA's document on green roofs.

Mitigation Strategy	Overview	Implementation
	exceed ambient air temperatures by up to 90°F (50°C).[c] Vegetation also removes air pollutants and GHG emissions through dry deposition and carbon sequestration and storage. The reduced energy demand from green roofs reduces air pollution and GHG emissions associated with energy production. Further, because ground-level ozone forms more readily with the rise in air temperatures, green roofs help slow the formation of ground-level ozone by lowering air temperatures. **Cost**: The costs of green roofs vary depending on the components, such as the growing medium, type of roofing membrane, drainage system, use of fencing or railings, soil depth and volume, and type and quantity of plants. A 2001 report estimated that initial costs start at $10 per square foot and range to $25 per square foot. Other estimates assume $15 to $20 per square foot.[ci] Greater soil depths mean additional structural requirements and potentially increased construction costs. Care should be taken to match the green roof type with the appropriate need. Los Angeles estimated that to retrofit a building with an extensive green roof would cost from $1.03-$1.66 per square foot, on an annualized basis, while a conventional re-roofing would range from $0.51-$1.74 per square foot.[cii] In addition to construction costs, there are maintenance costs to care for the plants on a green roof. Although the level of care depends on plant selection, most of the expenses arise in the first years after installation, as the plants establish themselves and mature. Maintenance costs may range from $0.75 to $1.50 per square foot. **Additional Information**: Although a green roof might have higher initial costs than most conventional or cool roofs, a building owner can directly benefit from reduced energy use, reduced stormwater management fees, and increased roof life. Finally, the widespread adoption of green roofs may provide significant, indirect net benefits to the community.	
Ultra Low water toilets ★	**Effectiveness**: Toilets account for almost half of a typical building's water consumption. Ultra low water toilets reduce water use to 1.28 gallons/flush (or dual-flush with average flush rates less than 1.1	For more information, see pg 136 of the Greening Federal Facilities document. There are a number of high-efficiency toilet options, including

Mitigation Strategy	Overview	Implementation
	gallons per flush). The actual effectiveness of GHG emissions reductions depends on how much energy is saved per gallon of water saved. **Cost**: New, low-flow toilets typically cost $100-$400/toilet[ciii] and low-flow urinals cost $70-$900 (high-end models have electronic sensor and automatic flush).[civ] Costs do not include installation costs. **Additional Information**: Older toilets, manufactured before 1992 when the Energy Policy Act mandated water efficient toilets, use up to 3.5 gallons per flush. Replacing these toilets with WaterSense labeled toilets could save nearly 2 billion gallons per day across the country. Switching to high-efficiency toilets can save a family of four, on average, $2,000 in water bills over the lifetime of the toilets.[cv]	dual flush technology. Dual flush toilets have two flush volumes-a full flush for solids and a reduced flush for liquids only. Select toilets with 1.28 gallons per flush or less (or dual-flush with average flush rate less than 1.1 gallons per flush). Select urinals with 0.5 gallon or less per flush. Before purchasing, explore the Maximum Performance Website to determine the most appropriate toilet for your facility. This site allows you to search products both by efficiency (gallons per flush) and effectiveness (grams per flush).
Grey water onsite	**Effectiveness**: Gray water reuse is an increasingly accepted practice to (1) provide irrigation water and some fertilizer to landscapes, (2) reduce wastewater loads to sewage systems, (3) improve the effectiveness of on-site wastewater disposal, and (4) reduce pressure on limited potable water resources in some communities, especially during drought crises.[cvi] The objective is to reduce the quantity of new water required by operations, and reduce or eliminate the use of potable water for applications where it is not needed. Gray water systems can reclaim up to 80% of domestic wastewater for use in the garden, saving each household up to 40,000 gallons of water per year. Gray water systems also save money, reduce load on sewage infrastructure, recharge local groundwater, and save energy. Through energy savings and reduced sewage treatment loads reusing gray water can significantly reduce GHG emissions. **Cost**: The cost of gray water systems varies on how simple or complex the plumbing is, how large the yard is, and who is doing the installation. For low-tech systems much of the work is digging mulch basins and digging trenches to bury pipe. Average costs for a low-tech system range from $1000 to $3000. High-end residential systems that include a sand filter to drip irrigation are between $5,000 and $10,000 depending on complexity of the plumbing and if there is a	For more information, see pg 153 of the Greening Federal Facilities document.

Mitigation Strategy	Overview	Implementation
	compatible existing drip irrigation system. **Additional Information**: Gray water is usually defined as water from showers, bathtubs, bathroom sinks, washing machines, and drinking fountains. It may also include condensation pan water from refrigeration equipment and air-conditioners, hot tub drainwater, pond and fountain drainwater, and cistern drainwater. Gray water systems are currently not approved by King County code, but may be in the future.	
Dry composting toilets	**Effectiveness**: Composting toilets have been an established technology for more than 30 years, and recent advances have made them easy to use and similar in look and feel to regular toilets. As they require little to no water, composting toilet systems can provide a solution to sanitation and environmental problems in unsewered, rural, and suburban areas. A DCT typically requires a continuously operating fan that consumes only about 2 watts of electricity. By comparison, a normal electric light bulb consumes about 60 watts. Overall, the greenhouse gas emissions from a flush toilet would be vastly greater than from the electricity required to run a 2-watt fan. **Cost**: DCTs typically have a higher initial cost than a conventional toilet however they have longer life cycle costs than septic and sewerage systems. Composting toilets will continue to save money over the years on water costs, while also producing humus, a valuable soil additive. **Additional Information**: A feasibility study found that a DCT system (including road transport) has potential to be slightly lower in energy use than conventional sewerage. This benefit will increase where there is considerable pumping lift in the sewerage system and where the sewage treatment plant does not generate any of its own energy. However, depending on the source of power and gas used to ventilate and heat the DCT, it may use more energy than a sewerage system. In terms of GHG reductions DCT's effectiveness is highly dependent on the sources of power used.[cvii]	For more information, see pgs 136 to 137 of the Greening Federal Facilities document.
Use permeable pavements	**Effectiveness**: Pervious pavements can indirectly help reduce energy consumption, air pollution, and GHG emissions through reductions in energy and	Effective stormwater management practices should be incorporated into any new development.

Mitigation Strategy	Overview	Implementation
	materials for stormwater facility construction, maintenance and operation, and through reduced solar heat gain that contributes to the urban heat island effect. **Cost**: The cost of permeable pavement varies by region, the contractor, the time of year, materials chosen, accessibility of the site, local availability of materials, underlying soils, size of the project, expected traffic, and the desired life of the pavement. **Additional Information**: The greatest overall value of pervious pavements results when multiple benefits, such as improved stormwater management and water quality are factored into the evaluation. These additional benefits include: *Reduced stormwater runoff and improved water quality:* Permeable pavements allow stormwater to soak into the pavement and soil, reducing runoff and filtering pollutants. They also lower the temperature of runoff, resulting in less thermal shock to aquatic life in the waterways into which stormwater drains. *Lower tire noise:* The open pores of permeable pavements can reduce tire noise by two to eight decibels and keep noise levels below 75 decibels. *Enhanced safety:* Permeable roadway pavements can improve safety by reducing water spray from moving vehicles and increasing traction through better water drainage.	Minimize the size of parking lots and the width of roadways. When possible, use porous paving, such as porous asphalt, porous concrete, modular block pavers, and specialized grass-paving systems to allow for greater stormwater infiltration.[cviii]
Reduce impermeable surfaces in site design	**Effectiveness**: Reducing the amount of impermeable surfaces in site design helps to preserve native vegetation and soils and maintain natural drainage patterns. Most disturbances to a site, including grading (which compacts soils) and removal or disturbance of vegetation, will increase stormwater flows by reducing the ability of soils to infiltrate rainwater. Site design that mimics natural hydrologic processes reduces stormwater and pollutant loads and resultant infrastructure requirements such as detention ponds and stormwater treatment facilities. As climate change produces more extreme storm events and communities struggle to adapt to more frequent extreme flooding events, these benefits will increase in value. In addition, porous materials can significantly reduce the heat gain of pavements from the sun.	Minimize the size of parking lots and the width of roadways. Separate impervious surfaces with turf, gravel, or vegetation to increase infiltration.

Mitigation Strategy	Overview	Implementation
	Pervious and open grid materials such as pavers, stone, blocks and interlocking concrete pavements with high-albedo reflective material reduce heat absorption from the sun and result in lower emitted heat. That has related benefits in reduced energy use for cooling and associated GHG emissions. **Cost**: Reduced impermeable surface reduces stormwater management costs, heat island effects (increased ambient temperatures on sunny days), and leaves more land for other productive uses, including farming and wildlife habitat. In general, more compact development that minimizes impermeable surfaces tends to reduce per capita infrastructure and transportation costs. **Additional Information**: Preserving large, contiguous areas of open space better protects ecosystems that may be under pressure from the changing climate as well as protecting areas that serve as important carbon sinks. Preserving original topography is generally recommended, though recontouring land, if planned and done carefully, can also improve infiltration in some cases.	
Avoid curbs where pedestrian safety is not an issue	**Effectiveness**: When there are no curbs, rainwater runs off driveways, sidewalks, and roads and goes directly into the ground. Directing runoff to natural areas promotes improved water quality and provides infiltration and recharge of streams, wetlands and aquifers. While the effect is indirect related to GHG emissions, using the natural landscape to treat and infiltrate stormwater reduces the number of constructed facilities required for that purpose which in turn reduces GHGs associated with the materials, operations and maintenance of such facilities. **Cost**: Eliminating curbs can produce savings on infrastructure and storm conveyance costs as water is dispersed throughout the site with the purpose of managing water in an evenly distributed manner.	Avoid designing curbed streets where possible as they concentrate pollutants and stormwater instead of dispersing them, which makes use of the natural landscape to treat and store runoff.

Food Facility Waste Management Practices

Mitigation Strategy	Overview	Implementation
Compost at all onsite food facilities ★	**Effectiveness**: The net GHG emissions from composting are lower than landfilling for food discards (composting avoids CH_4 emissions). Food scraps are a major source of methane emissions from landfills. Meaningful and direct emission reductions from alternative management of food scraps are obtainable. Food scraps are the single largest volume of material, by weight, disposed in landfills in Washington.[cix] **Cost**: Food scrap composting delivers emissions reductions and offers potential cost savings. Compost produced by food scraps offers several additional benefits during its use, including reducing or eliminating the need for chemical fertilizers, improving soil porosity and water retention, facilitating reforestation and habitat restoration, and promoting higher yields of agricultural crops. **Additional Information**: GHG emissions reductions can also be achieved by diverting food scraps to anaerobic digestion. In Washington, Cedar Grove Composting is seeking a permit to use anaerobic digestion to convert food and yard scraps into biogas to produce electricity and natural gas.[cx]	Composting is a living, dynamic process, thus the maintenance of an onsite composting system requires more attention and training than standard recycling and disposal alternatives. Thus, an on-site food waste composting program may entail locating and acquiring other ingredients such as shredded paper, wood shavings, or wood chips, some of which may have to come from off site. Compost facilities can be problematic if not operated optimally. This can lead to emissions of VOCs, as well as odor and vector issues, undermining community support. Best practices have been developed by the U.S. Composting Council under a grant from the EPA that suggest how to minimize odor and other potential issues through proper aeration, feedstock management, carbon/nitrogen balance and covering rows with finished compost (Christiansen 2009).
Partner with a local company to pick up used cooking oils and convert to biodiesel	**Effectiveness**: Biodiesel is an ester that can be made from a variety of vegetable oils and animal fats. Roughly 30 million gallons (113.5 million liters) of U.S. biodiesel are produced annually; most of that is used in a 20% blend with conventional diesel fuel. The benefits of using biodiesel to displace fossil fuels can include reduced air pollution, reduced greenhouse gas emissions, and conservation of limited fossil fuels. Avoiding fats, oils, and greases in wastewater treatment systems increases efficiency, saving process energy and reduces GHG emissions. **Cost:** Used cooking oil is generally available for free. Having reliable sources of cooking oil can be difficult. Biofuel price fluctuates with the petroleum supply and price. **Additional Information**: Rhode Island passed legislation that makes it mandatory (as of Jan. 1, 2012) for restaurants to recycle used cooking oil. In California cities like	For more information, see pg 128-129 of the Greening Federal Facilities document.

Mitigation Strategy	Overview	Implementation
	San Bruno, San Carlos and San Mateo, mandatory recycling of used cooking oil from restaurants has been the case for some time.	

Solid Waste Treatment: Landfill Methane Capture and Management Practices

Mitigation Strategy	Overview	Implementation
Implement an active landfill gas extraction system ★	**Effectiveness**: Greater than 90% reduction in methane emissions, however, partial systems and less efficient systems may only reduce emissions by 20%. **Cost**: \$1500-2250 per kW energy produced; Cost savings of \$2/tCO2-eq* with onsite electrical generation. A town of 50,000 people landfilling a total of 30,000 tons per year could install a landfill gas recovery system with electricity generation and reduce emissions by about 13,500 MTCE per year.[cxi] **Additional Information**: The implementation of an active landfill gas extraction system using vertical wells or horizontal collectors is the single most important mitigation measure to reduce emissions. Intensive field studies of the CH_4 mass balance at cells with a variety of design and management practices have shown that >90% recovery can be achieved at cells with final cover and an efficient gas extraction system.[cxii]	Install complete gas extraction system with early implementation of gas recovery to achieve the highest emission reductions. For more information about measures that improve overall gas collection, see IPCC 600-601. For more information about how to determine the GHG emissions of different waste management practices, see EPA's Climate Change – Waste webpage.
Use thick, compost-amended biocovers on landfills engineered to optimize oxidation ★	**Effectiveness**: Under optimal conditions, compost covers can practically eliminate CH_4 emissions; however, effectiveness depends on the thickness, physical properties, moisture content, and temperature of the cover. Oxidation rates in conventional landfill biocovers may be as high as 166–240 g CH_4 m^2/day-1 and greater than 1000 g m^2/day-1 in thick, compost amended covers engineered to optimize oxidation. Landfill biocovers can thus attain very high rates of CH_4 oxidation.[cxiii] **Cost**: Biocovers offer a relatively low-cost and effective way to optimize the biological	Biocover design includes an underlying coarse-grained gas distribution layer to provide more uniform fluxes to the biocover above. This technique works best in northern temperate climates.

Mitigation Strategy	Overview	Implementation
	methane oxidation in the cover material. **Additional Information**: Laboratory experiments have documented that a very high methane oxidation rate can be obtained in bio-covers, thereby reducing the methane emission significantly. The biological methane oxidation transforms methane into carbon dioxide, and since methane has a 21 times stronger global warming potential than carbon dioxide, a significant reduction in emissions contributing to climate change is obtained.	
Design passive or active methanotrophic biofilters	**Effectiveness**: Microbial oxidation of methane (CH_4) may serve as an inexpensive technique for reducing fugitive methane emissions. Laboratory experiments have shown the potential to apply passive or active methanotrophic biofilters to treat low-volume CH_4 releases. **Cost**: Reported ranges of capital, operational, and maintenance costs indicate the cost of an equivalent ton of CO_2 removal using methanotrophic biofilters is $90-$910 ($2,070-$20,900 per ton of methane), depending on the influent concentration of methane and if heating is required.[cxiv] **Additional Information**: The use of methanotrophic biofilters for controlling methane emissions is technically feasible and, provided that either the costs of biofilter construction and operation are reduced or the value of CO2 credits is increased, can also be economically attractive.	Works best as an addition to biocovers.

Solid Waste Treatment: Incineration and Other Thermal Processes

Mitigation Strategy	Overview	Implementation
Incinerate waste (with energy recovery)	**Effectiveness**: When waste is incinerated, the energy recovery displaces electricity generated by utilities by burning fossil fuels (thus reducing GHG emissions from the utility sector), and landfill CH_4 emissions are avoided. Landfill CH_4 can also be flared or utilized for its energy potential.	For best results, use moving grate boilers to allow mass burning of waste with diverse properties, low steam pressures and temperatures to avoid corrosion, and extensive flue gas cleaning. End uses for recovered energy

Mitigation Strategy	Overview	Implementation
	When used for its energy potential, landfill CH_4 displaces fossil fuels, as with municipal solid waste (MSW) combustion. Incinerating waste can generate 41GJ electrical energy and 110 million FG thermal energy. **Cost**: Greater than \$370/tCO_2-eq* The maximum amount of energy recoverable through MSW incineration depends primarily on the lower calorific value of the waste, but also on the system applied for energy recovery. It is most efficient when both electricity and steam/heat are produced, and the yield is lowest when only electricity is generated and the surplus heat is cooled away. **Additional Information**: Incinerators and landfills manage a mixed waste stream; therefore, net emissions are determined more by technology factors (e.g., the efficiency of landfill gas collection systems and incinerator energy conversion) than by material specificity.[cxv]	through waste conversion processes depend on the local energy market conditions, including: • Existing infrastructure for energy distribution—for example, the availability of a power grid and district heating network • Annual energy consumption pattern (the energy output from MSW incineration plants is relatively constant) • Prices of the various types of energy and possible agreements with the consumer(s).
Incinerate waste (without energy recovery)	**Effectiveness**: The net GHG emissions from incinerating mixed MSW are lower than landfilling mixed MSW (under national average conditions for landfill gas recovery). Estimates suggest 90% less emissions than landfills. **Cost**: \$87-140/ton of waste. MSW incineration plants tend to be among the most expensive solid waste management options, and they require highly skilled personnel and careful maintenance. **Additional Information**: Air pollution control remains a major problem in the implementation of incineration of solid waste disposal. In the United States, the cost of best available technology for the incineration facility may be as high as 35 % of the facility cost.[cxvi]	For best results, use moving grate boilers to allow mass burning of waste with diverse properties, low steam pressures and temperatures to avoid corrosion, and extensive flue gas cleaning.
Produce refuse derived fuel (RDF)	**Effectiveness**: Refuse derived fuel pre-treats the waste stream to remove non-carbonaceous materials, such as metal and glass—for example. RDF can reduce the mass of waste and avoid GHG emissions except for the small contribution from fossil carbon. This technology offers some benefits in terms of reduced furnace size and improved energy efficiency. However, the front end processing that shreds and mixes the wastes is demanding	Refuse derived fuel is a fuel produced by shredding and dehydrating municipal solid waste (MSW) in a converter. RDF can be produced from MSW through a number of different processes consisting in general of: ▪ Separation at source; ▪ Sorting or mechanical separation; ▪ Size reduction (shredding,

Mitigation Strategy	Overview	Implementation
	and expensive.[cxvii] **Cost**: The cost and energy required to process MSW into RDF and the amount of energy used to operate RDF combustion facilities can be difficult to quantify and can vary among facilities on a daily, seasonal, and annual basis.	chipping and milling); ▪ Separation and screening; ▪ Blending; ▪ Drying and pelletising; ▪ Packaging; and ▪ Storage. Typically, the waste material is screened to remove the recyclable fraction (e.g. metals), the inert fractions (such as glass) and separate the fine wet putrescible fraction (e.g. food and garden waste) containing high moisture and high ash material before being pulverized.
Process waste through industrial co-combustion, including cement kilns	**Effectiveness**: Co-combustion is defined as simultaneous combustion of different fuels in the same boiler. It achieves emission reductions by replacing fossil fuel with MSW waste. Industrial co-combustion in cement kilns can substitute fossil fuels with burning of waste or biomass. Cement kilns are well suited for waste-combustion because of their high process temperature and because the clinker product and limestone feedstock act as gas cleaning agents. Used tires, wood, plastics, chemicals and other types of waste are co-combusted in cement kilns in large quantities in Europe. Plants in Belgium, France, Germany, the Netherlands and Switzerland have reached average substitution rates of from 35% to more than 70%. Some individual plants have even achieved 100% substitution using appropriate waste materials. However, very high substitution rates can only be accomplished if a tailored pre-treatment and surveillance system is in place. Municipal solid waste, for example, needs to be pre-treated to obtain homogeneous calorific values and feed characteristics.[cxviii] **Cost**: Burning waste fuels in cement kilns utilizes pre-existing kiln infrastructure and energy demand, and therefore avoids considerable energy, resource and economic costs.	Burning alternative fuels in dedicated facilities or cement kilns has potential environmental impacts, such as harmful emissions, that need to be appropriately managed. In general, wastes with high heavy metals content, sulphur and halogen but also with a low colorific value should not be burned in a cement kiln.
Use wood products that would otherwise accumulate in landfills as a fuel	**Effectiveness**: Approximately 30 teragrams per year of forest products currently enter landfills. Overall, wood waste accounts for about 17% of the total waste received at MSW landfills in the United States. Use of this wood for fuel would offset 1.2% of U.S. fossil fuel use, lower emissions of	Wood waste can be utilized as a fuel to displace fossil fuels through a number of different processes consisting in general of: ▪ Separation at source; or ▪ Recycling through commingled collection;

Mitigation Strategy	Overview	Implementation
	methane, and extend the life of landfills.[cxix] Oven-dry wood produces about 9,000 Btu/lb when burned, and it can be converted to liquid or gaseous fuel. When wood is used to displace high sulfur bituminous coal, sulfur emissions can be reduced by more than 80%. Additionally, using wood waste frees up landfill space, contributes to sequestering of carbon, reduces carbon dioxide emissions from processing virgin material, and contributes to sustainable use of natural resources. **Cost**: The value of wood used for biomass fuel varies depending on market conditions but is generally much lower than when it is used for reuse as lumber or feedstock for engineered wood products. **Additional Information**: Much processed lumber currently ends up as biomass fuel, and is not recycled back into wood products. This prevents the emission of methane from wood waste anaerobically decomposing in landfills, and can replace the need for fossil fuels, but produces its own carbon emissions, and does not offer the benefit of reducing the impact of manufacturing of new wood products that recycling does.	▪ Sorting or mechanical separation; ▪ Size reduction (shredding, hogging); ▪ Separation and screening; ▪ Direct shipment and use in local wood-fired boilers; or ▪ Through pelletizing, packaging and sale to residential users of pellet stoves. Typically, the waste material is screened to remove contaminants (e.g. plastics, gypsum, paper), the inert fractions (such as glass).
Use pyrolysis to treat waste	**Effectiveness**: The advantage of pyrolysis over normal waste-to-energy incineration is that pyrolysis produces a liquid fuel that can be stored and used in a number of applications (similar to biodiesel), whereas waste-to-energy produces only electricity for immediate consumption. **Cost**: Variable - pyrolysis is a simple technology capable of processing a wide variety of feedstocks to produce syngases, a bio-oil, bio-chemicals, and charcoal. **Additional Information**: Although the basic concepts of the process have been validated, the performance data for an emerging technology have not been evaluated according to methods approved by EPA and adhering to EPA quality assurance/quality control standards. Performance data are currently available only for vendors. Also, existing data are limited in scope and quantity/quality and are frequently of a proprietary nature.	Pyrolysis is a form of incineration that chemically decomposes organic materials by heat in the absence of oxygen. Pyrolysis is less proven in operation than mass burn incineration and generally recommended for smaller scale operations. Pyrolysis can be used to produce a bio-oil that can be used to power ethanol, biodiesel or other local industries facilities. It also can produce a charcoal. The charcoal is incorporated into the soil to promote fertility and organic matter through synergistic processes between the soil, soil organisms, the roots of plants, water, and the CO_2 and nitrogen in the atmosphere.

Mitigation Strategy	Overview	Implementation
Use gasification to treat waste	**Effectiveness**: Gasification is a more efficient and cleaner way to extract heat energy than burning biomass. Biomass is heated in an oxygen-starved environment, which breaks down the biomass into its chemical constituents and produces biogas. This biogas can then be used as fuel in a high-efficiency gas turbine. Sophisticated gasification combined cycle systems include a gas-turbine topping cycle and a steam-turbine bottoming cycle to achieve efficiencies nearly double those of direct combustion (37% vs. 20%). **Cost**: Costs vary depending on feedstocks and unit costs are high. **Additional Information**: Gasification uses heat, pressure, and steam to convert any raw material that contains carbon into synthesis gas - a gaseous mixture composed primarily of carbon monoxide (CO) and hydrogen (H_2), which can then be used to create electricity, chemicals, pure hydrogen, and liquid transportation fuels.	Gasification is less proven in operation than mass burn incineration and generally recommended for smaller scale operations. For more information, see pgs 128-129 of the Greening Federal Facilities document.

Solid Waste Treatment: Composting and Other Biological Processes

Mitigation Strategy	Overview	Implementation
Compost residential and commercial yard and food waste	**Effectiveness**: Diversion of food scraps from landfills offers the greatest quantity of GHG emissions reductions. Food scraps are responsible for a large share of methane emissions generated by landfills, and while landfill emissions comprise only a small portion of life-cycle emissions attributable to goods and food, they nonetheless represent a real opportunity for emissions reduction. This is largely due to the large quantities of food that is wasted and sent to landfills.[cxx] **Cost**: Food scrap composting not only delivers emissions reductions, it offers potential cost savings as well. Seattle Public Utilities estimates that its program costs about 20% less per load than landfilling. In 2009, this translated into a savings of approximately $250,000. Preventing that waste is a huge opportunity for emissions reductions and cost savings for	Best applied to source separated waste fractions—food and yard waste need to be separated. Particularly appropriate for drier feedstocks. GHG emissions reductions can also be achieved by managing food scraps through alternative composting methods (such as static aerated piles or enclosed systems) and by anaerobic digestion. When anaerobically digested, food scraps can also be used as an alternative energy source. The methane generated during decomposition can be captured and converted to a natural gas

Mitigation Strategy	Overview	Implementation
	individuals and governments alike. **Additional Information**: The Climate Action Reserve, North America's largest carbon offset registry, issued an Organic Waste Digestion Protocol in 2009 and recently established an Organic Waste Composting Protocol. These protocols set standards for the quantification and verification of GHG emissions reductions from composting and anaerobic digestion projects. Projects adhering to the protocol and listed by the Reserve are eligible to sell carbon offset credits (CRTs), generated from the projects. Revenue from CRT sales can help support private investment in composting and anaerobic digestion.[cxxi]	equivalent fuel, or used to power a turbine to generate electricity.[cxxii]
Use anaerobic digestion to treat waste ★	**Effectiveness**: Anaerobic digestion of organic matter generates methane from municipal sewage treatment plants, livestock manure tanks, source-separated residential and commercial food wastes, and other nutrient-rich organic matter, which can then be burned as fuel, **Cost**: GHG emissions from controlled biological treatment are small in comparison to uncontrolled CH_4 emissions from landfills without gas recovery. The advantages of biological treatment over landfilling are reduced volume and more rapid waste stabilization. Depending on quality, the residual solids can be recycled as fertilizer or soil amendments, used as a CH_4-oxidizing biocovers on landfills, or landfilled at reduced volumes with lower CH_4 emissions.[cxxiii] **Additional Information**: In the EU, the future landfilling of organic waste is being phased out via Council Directive 1999/31/EC, This directive requires that, by 2016, the mass of biodegradable organic waste annually landfilled must be reduced 65% relative to landfilled waste in 1995. As a result, increasing quantities of post-consumer waste are now being diverted to reduce the organic carbon content using anaerobic digestion or partial aerobic composting. In Gronigen, Holland, a biomass digester system digests the organic component of municipal solid waste to generate 2.5 MW of electricity.[cxxiv]	Best applied to source separated waste fractions—food and yard waste need to be separated. Particularly appropriate for wet waste. Also, resulting biogas from anaerobic digestion can be used for process heating, onsite electrical generation and other uses. Several facilities are using this technique to produce CH_4 from mixed waste, which is then used to fuel energy recovery. The approach generates CH_4 more quickly and captures it more completely than in a landfill environment, and thus, from a GHG perspective, offers a potentially attractive waste management option.[cxxv]
Use Mechanical Biological Treatment	**Effectiveness**: Compared with landfilling, MBT can theoretically reduce CH_4 generation by as much as 90%.[cxxvi] In practice, reductions are smaller and	MBT is where mixed waste is subjected to a series of mechanical and biological operations to reduce volume and achieve partial

Mitigation Strategy	Overview	Implementation
(MBT)	dependent on the specific MBT processes employed. Can produce useful secondary materials such as compost provided there is quality control on material inputs and operations. **Cost**: $18-156 per ton of waste $32/ton of waste for open window operations; $46/ton of waste for in-vessel processes **Additional Information** Can emit N_2O and CH_4 under reduced aeration or anaerobic conditions.	stabilization of the organic carbon. Typically, mechanical operations (sorting, shredding, crushing) first produce a series of waste fractions for recycling or for subsequent treatment (including combustion or secondary biological processes). The biological steps consist of either aerobic composting or anaerobic digestion.

Wastewater treatment: Low Emissions Treatment Processes

Mitigation Strategy	Overview	Implementation
Activated sludge treatment	**Effectiveness**: Conventional activated sludge wastewater treatment facilities consume more energy than they can recover through anaerobic digestion of sludge. Activated sludge treatment produces a large amount of GHG emissions as a result of biomass sequestration and energy consumption in the aeration stage. Separation of black water and grey water can reduce the overall energy requirements for treatment. Pretreatment or limitation of industrial wastes is often necessary to limit excessive pollutant loads to municipal systems, especially when wastewaters are contaminated with heavy metals. **Cost**: Publicly-owned wastewater treatment plants in the U.S. consume an estimated 21 billion kilowatt hours (kWh) per year. This electricity consumption is equivalent to 12.7 million metric tons of CO_2 emitted per year, based on the U.S. EPA estimated national average of 0.603 kg CO_2/kWh delivered.[cxxvii]	Activated sludge treatment is considered the conventional method for large-scale treatment of sewage. Options for sludge treatment include stabilization, thickening, dewatering, anaerobic digestion, agricultural reuse, drying and incineration. Imported power for mechanical aeration of wastewater is the dominant source of GHG emissions at wastewater treatment facilities.[cxxviii]
Trickling filters	**Effectiveness**: TFs use a simple, reliable biological process and are very effective in treating high concentrations of organics depending on the type of medium used. All varieties of sewage trickling filters have a low and sometimes intermittent power consumption. TFs can be used for small scale on-site septic systems as well as for waste from industrial processes. **Cost:**	Trickling filters (TFs) are used to remove organic matter from wastewater. The TF is an aerobic treatment system that utilizes microorganisms attached to a medium to remove organic matter from wastewater.

Mitigation Strategy	Overview	Implementation
	TF can be somewhat more expensive than traditional septic tank-leach field systems, however their use allows for better treatment, a reduction in size of disposal area, less excavation, and higher density land development. Estimated energy use is 750-1500 kWh/MG.	
Anaerobic or facultative lagoons	**Effectiveness**: Facultative lagoons are the most common form of aquatic treatment-lagoon technology currently in use. Facultative lagoons are frequently used to treat municipal and industrial wastewater in the US. The water layer near the surface is aerobic while the bottom layer, which includes sludge deposits, is anaerobic and constitutes the facultative zone. **Cost**: Cost information for facultative lagoons varies significantly. Construction costs include cost of the land, excavation, grading, berm construction, and inlet and outlet structures. If the soil is permeable, an additional cost for lining the lagoon should be considered. Estimated energy use is 500-1000 kWh/MG. **Additional Information**: Moderately effective in removing settleable solids, BOD, pathogens, fecal coliform, and ammonia. Easy to operate. Requires little energy, with systems designed to operate with gravity flow. The quantity of removed material will be relatively small compared to other secondary treatment processes.	Note that in cold climates, low temperatures and ice formation will limit process efficiency during the winter. Odors may be a problem in the spring and fall during periods of excessive algal blooms and unfavorable weather conditions.
Anaerobic digestion	**Effectiveness**: Anaerobic digestion is a series of processes in which microorganisms break down biodegradable material in the absence of oxygen. It is used for industrial or domestic purposes to manage waste and/or to release energy. Anaerobic digestion is widely used as a source of renewable energy. The process produces a biogas, consisting of methane, carbon dioxide and traces of other pollutant gases. This biogas can be used directly as cooking fuel, in combined heat and power gas engines or upgraded to natural gas-quality biomethane. The use of biogas as a fuel helps to replace fossil fuels. The nutrient-rich digestate that is produced can be used as fertilizer. **Cost**: The main power loads for anaerobic digesters are from mixers, blowers and sludge/hot water	The technical expertise required to maintain industrial-scale anaerobic digesters, coupled with high capital costs and low process efficiencies, had limited the level of its industrial application as a waste treatment technology.

Mitigation Strategy	Overview	Implementation
	recirculation. Opportunities for energy savings are from efficient pumps, use of timer controls and reduced power input for mixing/cogeneration. **Additional Information**: Anaerobic digestion facilities have been recognized by the United Nations Development Programme as one of the most useful decentralized sources of energy supply, as they are less capital-intensive than large power plants.	
Constructed wetlands	**Effectiveness**: Constructed wetlands are generally very successful at polishing the treated wastewater effluent from lagoons. These systems have also been used with more traditional, engineered primary treatment technologies such as Imhoff tanks, septic tanks, and primary clarifiers. Their main advantage is to provide additional treatment beyond secondary treatment where required. Constructed wetlands typically remove up to 70% of solids and bacteria. **Cost**: • Minimal capital cost • Low operation and maintenance requirements and costs **Additional Information**: In recent years, constructed wetlands have been utilized in two designs: systems using surface water flows and systems using subsurface flows. Both systems utilize the roots of plants to provide substrate for the growth of attached bacteria which utilize the nutrients present in the effluents and for the transfer of oxygen. Bacteria do the bulk of the work in these systems, although there is some nitrogen and other nutrient uptake by the plants.	Requires periodic removal of excess plant material. Best used in areas where suitable native plants are available.
Sludge treatment such as stabilization, thickening, dewatering, agricultural reuse, drying, and incineration	**Effectiveness**: The use of composted sludge as a soil conditioner in agriculture and horticulture recycles carbon, nitrogen and phosphorus (and other elements essential for plant growth). Heavy metals and some toxic chemicals are difficult to remove from sludge; either the limitation of industrial inputs or wastewater pretreatment is needed for agricultural use of sludges. Lower quality uses for sludge may include mine site rehabilitation, highway landscaping, or landfill cover (including biocovers). **Cost**:	Sludges (or biosolids) are the product of most wastewater treatment systems. Some sludges are landfilled, but this practice may result in increased volatile siloxanes and H_2S in the landfill gas. Treated wastewater can either be re-used or discharged, but re-use is the most desirable option for agricultural and horticultural irrigation, fish aquaculture, artificial recharge of aquifers, or industrial applications.

Mitigation Strategy	Overview	Implementation
	Systematic studies of GHG-reduction potentials and costs for sludge treatment systems are generally unavailable.	
Separation of black and grey water in wastewater treatment	**Effectiveness**: Gray water collection involves separating grey water from all other sources of wastewater in a building, which are designated as blackwater. Black water sources include wastewater from toilets, urinals, dishwashers and kitchen sinks. Gray water reuse is an increasingly accepted practice to (1) provide irrigation water and some fertilizer to landscapes, (2) reduce wastewater loads to sewage systems, (3) improve the effectiveness of on-site wastewater disposal, and (4) reduce pressure on limited potable water resources in some communities, especially during drought crises. **Cost**: The separation of black water and gray water results in decreased costs and lower pollution levels. Separating grey and black water reduces waste discharged to sewage treatment plants allowing for more efficient treatment and energy savings. **Additional Information**: In some parts of the country, grey water can be used for below-ground irrigation. Because pathogens may be present, it should not be used for aboveground irrigation or on fruits and vegetables for human consumption.	A maintenance program for grey water systems should be planned for and include (1) inspecting the system for leaks and blockages, (2) cleaning or replacing any filters bimonthly or as recommended by the manufacturer or designer, (3) periodically flushing the entire system if called for by the manufacturer or designer, and (4) regularly inspecting the ground being irrigated to make sure that not too much water is being delivered (in which case, gray water should be shunted into the sewage line). For more information, see pgs 144-145 of the Greening Federal Facilities document.

Transportation

Construction

Mitigation Strategy	Overview	Implementation
Limit idling time for construction vehicles[cxxix]	**Effectiveness**: Depends on the size, efficiency, and fuel type of the vehicle. Regardless, this strategy is highly cost-effective. **Cost**: According to the EPA SmartWay program, idling costs the truck owner the price of almost one gallon of fuel each hour, so savings can be significant. Cost for implementation may be as simple as creating signage and communication strategies to the crew. **Additional Information**: Further information, as well as anti-idling signage and other resources, are available from the Puget Sound Clean Air Agency.	During contract negotiations, require that construction companies limit if not eliminate idling time for their construction vehicles. Emphasize that doing so will save them money, as fuel will not be consumed unnecessarily. The Puget Sound Clean Air Agency will provide anti-idling signage and other resources, if certain site conditions are met.
Use alternate fueled vehicles for transport of persons and materials to and from the construction site[cxxx]	**Effectiveness**: Depends on how many vehicles are used, how far they are traveling, weight of vehicles and goods, and fuel type. Biodiesel blends reduce criteria air pollutants (CAPs), and have been shown to reduce GHGs by up to 75%, depending on the blend.[cxxxi] Compressed Natural Gas vehicles also reduce CAPs, and reduce GHG emissions by up to 25%.[cxxxii] **Cost**: Depends on the type of alternative fuel used; biodiesel blends are typically more expensive than gasoline or diesel fuel, but Compressed Natural Gas (CNG) is typically less expensive.[cxxxiii] **Additional Information**: More information is available at the US Dept of Energy's Alternative Fuels & Advanced Vehicles Data Center.	Include language about alternative fueled vehicles in bid language and contract with construction companies that use alternate fueled vehicles.
Provide worker housing near construction sites[cxxxiv]	**Effectiveness**: Depends on the number of workers that participate, how far they would be traveling to the construction site otherwise, and what mode they would be traveling to the construction site. **Cost**: Expensive, but depends on the number of	Temporary worker housing is available through specialty vendors, and does not have to be built on site for every project.

Mitigation Strategy	Overview	Implementation
	workers.	
Promote carpooling	**Effectiveness**: Depends on the number of workers that participate, how far they would be traveling to the construction site, and what mode they would normally use to travel to the construction site. **Cost**: Save on fuel costs for drivers, which can serve as an incentive to carpool. **Additional Information**: Workers who want to carpool can use resources such as: RideshareOnline King County Ridematch	Project managers or construction companies may want to set up a carpool or ride sharing system for specific projects, in addition to resources available through King County.

Project Location

Mitigation Strategy	Overview	Implementation
Locate new buildings and other projects close to reliable and convenient public transit, prioritizing areas designated for transit-oriented development	**Effectiveness**: 0.4% to 1% reduction in emissions from vehicle travel.[cxxxv] **Cost** Depends on the site. May incur higher land purchase or construction costs in dense urban areas. **Additional Information**: There are number of resources on the GHG emissions benefits of building near existing transit infrastructure, such as: *Growing Cooler*, by Reid Ewing, et al The Victoria Transportation Policy Institute Smart Growth America	Locate project close to existing transit, bicycle, and pedestrian corridors. Setback distance between project and existing or planned adjacent uses is minimized or non-existent. Setback distance between different buildings on project site is minimized. Setback between project buildings and planned or existing sidewalks are minimized. Buildings are oriented towards existing or planned street frontage. Primary entrances to buildings are located along planned or existing public street frontage. Project provides bicycle access to any planned bicycle corridors. Project provides pedestrian access to any planned pedestrian corridor(s).[cxxxvi]
Locate buildings near high quality schools, daycare facilities, and affordable housing[cxxxvii]	**Effectiveness**: According to the Federal Highway Administration's (FHWA) National Household Travel Survey, 40% of daily automobile trips are 2 miles or less.[cxxxviii] The FHWA also found that work commuting constitutes only 15% of daily trips, with the rest divided between errands, shopping,	When deciding between sites, project manager should consider their proximity to amenities that employees need to minimize travel time and reduce automobile reliance to meet daily needs. LEED NC Sustainable Sites Credit 2 – Development Density and

Mitigation Strategy	Overview	Implementation
	and other activities. **Cost**: Depends on the site. May incur higher land purchase or construction costs in dense urban areas. **Additional Information**: There are number of resources on the GHG emissions benefits of building near existing amenities, such as: *Growing Cooler*, by Reid Ewing, et al The Victoria Transportation Policy Institute (VTPI) Smart Growth America An added benefit of locating workplaces near convenient amenities may be increased employee satisfaction, which can contribute to employee retention.	Connectivity provides detailed explanation of best practices for achieving connectivity and density.

Project Accessibility – Multiple Modes of Travel

Mitigation Strategy	Overview	Implementation
Only provide the minimum parking required by existing code ★	**Effectiveness**: 1-30% emissions reduction from reduced vehicle travel— Calculated by utilizing the Institute of Transportation Engineers (ITE) peak parking demand.[cxxxix] **Cost**: Depending on the type of parking, construction costs can range from about $5,000 (for a surface space) all the way to $35,000 (for a parking space in a structure) per space. Therefore, limiting parking generates a significant project savings.[cxl] VTPI provides an excel-based calculator to aid project managers in determining the lifecycle costs for parking. **Additional Information**: Additional information on the benefits of limiting parking, and more info on parking pricing, are available from VTPI.	Provide the minimum amount of parking required. Once land uses are determined, the trip reduction factor associated with this measure can be determined by utilizing the ITE parking generation publication. The reduction in trips can be computed as shown by the ratio of the difference between minimum parking required by code and ITE peak parking demand to ITE peak parking demand for the land uses multiplied by 50%.[cxli] Percent trip reduction = 50*[(Minimum parking required by code-ITE peak parking demand)/(ITE peak parking demand))]
Design buildings to be mixed use ★	**Effectiveness**: 0.05%-2% emissions reduction from reduced vehicle travel; .5% to 5% for onsite shops.[cxlii] **Cost**: Variable.	Project provides high-density office or mixed-use proximate to transit. Project must provide safe and convenient pedestrian and bicycle access to all transit stops within one-quarter mile.[cxliii] Project provides on-site shops and services for employees.

Mitigation Strategy	Overview	Implementation
Bicycle network	**Effectiveness**: Variable, depending on the number of employees and visitors that choose bicycling in lieu of driving to the project location, and what distances they are traveling. Can be a highly effective strategy when the project has visible bicycling infrastructure (bike racks, showers, signage) and bicycle commute programs in place. Effectiveness can be enhanced both by project design choices (infrastructure) as well as ongoing operational choices (bike commute programs and maintenance of bicycling infrastructure) that encourages employees and users of the building to travel safely via bicycle. **Cost**: $80.00-$100.00 per foot for 1,000 feet for a 5-foot wide lane. Costs for establishing bike to work programs for employees to bike to work can be minimal and draw on existing local resources in King County. **Additional Information**: Cascade Bicycle Club has a suite of employer resources for encouraging safe bicycle commuting for employees. Note that in addition to reducing GHG emissions, there are multiple co-benefits to this strategy, such as employee health and well-being. The Center for Disease Control notes that shifting from auto-dependent transportation modes to bicycling or pedestrian modes is the number one strategy to reduce inactivity-related diseases.[cxliv]	Project design includes: A comparable network that connects project uses to the existing offsite facility. A designated bicycle route connecting all units, onsite bicycle parking facilities, offsite bicycle facilities, site entrances, and primary building entrances to existing bike lanes within ½ mile Bicycle routes should: Connect to all streets contiguous with project site Have minimum conflicts with automobile parking and circulation facilities. All streets internal to the project wider than 75 ft have bicycle lanes on both sides.[cxlv] Look for opportunities to encourage multi-modal transportation, such as bike lanes that connect the project site to transit centers.
Pedestrian network	**Effectiveness**: Variable, depending on the number of employees and visitors that elect to travel to the project site by foot in lieu of automobile or bus, and the distances they are traveling. Encourages employees and users of the building to travel safely via foot. **Cost**: $110-$140 per foot for 1,000 feet of concrete sidewalk with drainage at the upper end. **Additional Information**: Note that in addition to reducing GHG emissions, there are multiple co-benefits to this strategy, such as employee health and well-being. The Center for Disease Control	The project provides a pedestrian access network that internally links all uses and connects to all existing/planned external streets and pedestrian facilities contiguous with the project site. Project design includes a designated pedestrian route interconnecting all internal uses, site entrances, primary building entrances, public facilities, and adjacent uses to existing external pedestrian facilities and streets. Route has minimal conflict with parking and automobile circulation facilities. Streets (with the exception of alleys) within the project have

Mitigation Strategy	Overview	Implementation
	notes that shifting from auto-dependent transportation modes to bicycling or pedestrian modes is the number one strategy to reduce inactivity-related diseases.[cxlvi]	sidewalks on both sides. All sidewalks internal and adjacent to project site are minimum of five feet wide. All sidewalks feature vertical curbs. Pedestrian facilities and improvements such as grade separation, wider sidewalks, and traffic calming are implemented wherever feasible to minimize pedestrian barriers. All site entrances provide pedestrian access.[cxlvii] Minimize pedestrian barriers—physical barriers such as walls, beams, landscaping, and slopes between residential and non-residential uses that impede bicycle or pedestrian circulation.[cxlviii]
Provide secure, dry places to store bicycles	**Effectiveness**: Encourages employees to travel via bicycle. **Cost**: $1200-$2950 ($700/bike on average)[cxlix]	Facilities should consist of a bicycle locker, locked room with standard racks and access limited to bicyclists only, or a standard rack in a location that is staffed and/or monitored by video surveillance 24 hours per day.[cl] Provide plentiful short and long-term bicycle parking to meet peak-season maximum demand.[cli]
Provide showers, changing rooms, and clothes locker facilities for employees	**Effectiveness**: Encourages employees to travel via bicycle and foot. **Cost**: Variable.	Provide plentiful short and long-term facilities to meet peak-season maximum demand, e.g. four lockers and one shower for every 80 employees.[clii]
Bike racks	**Effectiveness**: Encourages employees to travel via bicycle by providing a secure and easily accessible storage location. **Cost**: $70-$2000 ($70/bike on average)[cliii]	Provide plentiful short and long-term bicycle parking to meet peak-season maximum demand.[cliv] Ideally located racks within 200 yards of a building entrance.
Bus shelters	**Effectiveness**: 1-2% emissions reduction from reduced vehicle travel[clv] **Cost**: $15,000-$70,000[clvi] **Additional Information**: Provides safe and convenient bicycle and pedestrian access to transit stops. Provides essential transit stop improvements (i.e	Provide bus shelters at transit stops at the project site that include route information, benches and lighting.

Mitigation Strategy	Overview	Implementation
	shelters, route information, benches, and lighting).	
Pedestrian pathway through parking	**Effectiveness**: 1-4% emissions reduction from reduced vehicle travel[clvii] **Cost**: Low—clearly marking pedestrian pathways requires no new materials. However, costs could be higher if the number of parking spaces decreases as a result of pedestrian pathway, as the parking lot would generate less revenue. **Additional Information**: This strategy also improves pedestrian safety.	Provide a parking lot design that includes clearly marked and shaded pedestrian pathways between transit facilities and building entrances.[clviii]

Road Accessibility – Multiple Modes of Travel

Mitigation Strategy	Overview	Implementation
Implement street improvements that allow and promote bicycle and pedestrian accessibility ★	**Effectiveness**: A bicycle and pedestrian plan, when done regionally, can reduce emissions by 2-15%.[clix] Implementing these street improvements for road projects will likely have a similar impact, although on a smaller scale. This impact will be lower if surrounding areas lack similar or adequate infrastructure. **Cost**: Bicycle lanes: $80.00-$100.00 per foot for 1,000 feet for a 5-foot wide lane. Sidewalks: $110-$140 per foot for 1,000 feet of concrete sidewalk with drainage at the upper end.	Street improvements include: Bicycle lanes Multi-use paths Elevated sidewalks Separate bicycle lanes and sidewalks from roads with trees, grass patch, blockades, or stormwater rain gardens. Overpasses on busy roadways

Online Resources

Calculation Tools

King County Emissions Calculator
(no URL)

Simplified web-based calculator (WARM)

http://epa.gov/epawaste/conserve/tools/warm/Warm_Form.html

Downloadable Excel file (WARM)

http://epa.gov/epawaste/conserve/tools/warm/downloads/WARM.zip

Download URBEMIS
www.urbemis.com/software/Urbemis2007v9_4.html

URBEMIS User's Guide, FAQs, and other support
www.urbemis.com/support/FAQv9_2.html

CEQA Tools webpage
www.airquality.org/ceqa/index.shtml

Build Carbon Neutral Calculator
http://buildcarbonneutral.org/

Center for Urban Forestry Research Tree Carbon Calculator
www.fs.fed.us/ccrc/topics/urban-forests/ctcc/

Reforestation/Afforestation Project Carbon Online Estimator
http://ecoserver.env.duke.edu/RAPCOEv1/

Frameworks

King County LCCA Guide
http://your.kingcounty.gov/solidwaste/greenbuilding/documents/KC_LCCA_calculator-guide.pdf

National Institute of Building Sciences
www.nibs.org/

Whole Building Design Guide (Life-Cycle Costs Analysis)
www.wbdg.org/resources/lcca.php

Materials

King County Green Tools: Online Exchange
http://your.kingcounty.gov/solidwaste/exchange/building.asp

Seattle Public Utilities
www.seattle.gov/util/Services/Recycling/ReduceReuseExchange/BuildingMaterialSalvageandRecycling/index.htm

King County: Environmental Purchasing
www.kingcounty.gov/operations/procurement/Services/Environmental_Purchasing/Products.aspx

King County Green Tools: List of Distributors
http://your.kingcounty.gov/solidwaste/greenbuilding/links.asp#material

Home Depot Eco Options
http://www6.homedepot.com/ecooptions/index.html?cm_mmc=Thd_marketing-_-Eco_Options_Site_07-_-Vanity-_-Home

Amazon
www.amazon.com

Green Floors
www.greenfloors.com/HP_AD_Index.htm

Green Choice Adhesives
www.titebondgreenchoice.com/GC_products.htm

Eartheasy
www.eartheasy.com/live_nontoxic_paints.htm

EPA Green Roof Compendium
www.epa.gov/heatisland/resources/pdf/GreenRoofsCompendium.pdf

Concrete Thinker
http://concretethinker.org/solutions/Recycled-Content.aspx

Landscape Disturbance

King County Surface Water Design Manual, Appendix D: Erosion and Sediment Control Standards
your.kingcounty.gov/dnrp/library/water-and-land/stormwater/surface-water-design-manual/appendix-d.pdf

Stormwater Management Manual for Western Washington
www.ecy.wa.gov/programs/wq/

Low Impact Development Technical Guidance Manual for Puget Sound
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[cxliii] *Ibid.*

[cxliv] *Cascade Bicycle Club Education Foundation, Commuting Statistics. www.cbcef.org/bike-commuting-statistics.html*

[cxlv] *California Air Pollution Control Officers Association, CEQA and Climate Change: Evaluating and Addressing Greenhouse Gas Emissions from Projects Subject to the California Environmental Quality Act. 2008.*

[cxlvi] *Cascade Bicycle Club Education Foundation, Commuting Statistics. www.cbcef.org/bike-commuting-statistics.html*

Cascade Bicycle Club Education Foundation, Commuting Statistics

[cxlvii] *California Air Pollution Control Officers Association, CEQA and Climate Change: Evaluating and Addressing Greenhouse Gas Emissions from Projects Subject to the California Environmental Quality Act. 2008.*

[cxlviii] *Ibid.*

[cxlix] *Ibid.*

[cl] *Ibid.*

[cli] *Ibid.*

[clii] *Ibid.*

[cliii] *Ibid.*

[cliv] *Ibid.*

[clv] *Ibid.*

[clvi] *Ibid.*

[clvii] *Ibid.*

[clviii] *Ibid.*

[clix] *Ibid.*