Urban Green Infrastructure Permitted Interaction Group (UGI PIG) to the Greenhouse Gas Sequestration Task Force

WHAT IS GREEN INFRASTRUCTURE?

Green infrastructure is any practice that uses or replicates natural systems to achieve a desired outcome. This includes green roofs, bioswales and rain gardens. Green roofs replicate meadows to retain water and restore habitats on the top of buildings. Green infrastructure does not exclusively mean vegetation. Permeable surfaces are considered green infrastructure as well, because they handle rainfall the same way natural landscapes do. Green infrastructure looks to nature for advice, restoring and replicating ecological systems to create human benefits.

Green infrastructure can take many forms — from big networks of protected natural areas to green roofs in cities — but all types of green infrastructure employ nature to provide natural benefits such as clean air or reliable flows of clean water.

Conventional engineering approaches have immediate benefits — concrete breakwaters reduce wave energy, for example — but can be costly to install and maintain. Moreover, they can impair the environment — for example, dams can upset the migration of fish living in channels downstream. The challenge is strategically combining the two.

With green infrastructure, water is a resource. It is valuable for keeping landscapes and waterways healthy. With green infrastructure, climate challenges are reframed as opportunities. Green infrastructure not only reduces the load on aging grey infrastructure, but also provides opportunities to nourish plants and provide drinking water.

Every infrastructure project is an opportunity to equally prioritize the conservation of nature and the provision of natural critical services to communities. A combined green-gray approach can be greater than either strategy applied alone.

Infrastructure upgrades are necessary to maintain the social, economic, and environmental health of a community and present a unique opportunity to integrate green infrastructure elements into the gray - "Greening the Gray". Implementing projects in public spaces provides additional benefits and gives communities the opportunity to showcase the aesthetic appeal of green infrastructure practices and provide a visual demonstration of how they can function. This real-life context allows residents, businesses, and local governments to experience the multiple benefits and values of green infrastructure practices including more walkable streets, traffic calming, green public spaces, shade, and enhanced foot traffic in retail areas. Communities can then use the experience gained from the design, installation, and maintenance of green infrastructure projects to help tailor regulations and incentive programs to make green infrastructure easier to implement in the future.

How does Green Infrastructure Improve Climate Resiliency?

Manages Flood Risk

High-intensity storms and hurricanes are expected to become more frequent in Hawaiʻi and intense as global temperatures continue to rise. As a result, the risk of flooding is likely to increase dramatically. Green infrastructure can help manage both localized and riverine floods by absorbing rainfall, preventing water from overwhelming pipe networks, and pooling in streets or basements. Green infrastructure, open space preservation, and floodplain management can complement gray infrastructure approaches by reducing the volume of stormwater that flows into streams and rivers, protecting floodplain functions and reducing infrastructure and property damage.

Builds Resiliency to Drought

Fragile local water supplies are being stressed by decreased precipitation associated with climate change. When a storm event occurs, rain falling on roofs, parking lots, streets, and other hard surfaces runs directly into city storm drains or water bodies. The Hawaiian Islands are losing valuable water that could be used or stored for use when it is needed most. Green infrastructure can help replenish groundwater reserves, relieving stress on local water supplies, and reducing the need to import potable water.

Reduces the Urban Heat Island Effect

Urban heat islands occur when cities replace natural land cover with dense concentrations of pavement, buildings, and other surfaces that absorb and retain heat. This effect increases energy costs (e.g., for air conditioning), air pollution, and heat-related illness and mortality. Extreme heat events often affect our most vulnerable populations first. Trees, green roofs, and vegetation can help reduce urban heat island effects by shading building surfaces, deflecting solar radiation, and releasing moisture into the atmosphere.

Decreases Building Energy Demands

Trees and vegetative cover can lower ambient air temperatures in urban areas through shading, windbreak, and evapotranspiration. The result is lower demand for the energy needed to provide air conditioning. Green roofs can greatly reduce the amount of energy needed to keep the temperature of a building comfortable year-round by insulating against extensive heat loss in the winter and heat absorption in the summer. A National Research Council of Canada study found that an extensive green roof reduced daily energy demand for air conditioning in the summer by over 75%.

Improves Coastal Resiliency

Coastal areas are particularly vulnerable to the effects of climate change. Sea-level rise and heavy storms can cause erosion and flooding of sensitive coastal areas and destroy natural habitat. Climbing global temperatures will result in continued sea level rise, amplified storm surges, and more frequent and intense storms that will continue to erode the shoreline and damage property and infrastructure. Living shorelines can be created using plants, reefs, sand, and natural barriers to reduce erosion and flooding.

Ultimately, the advantages of green infrastructure projects are two-fold: they can mitigate the production of GHG emissions and also provide extra resilience against the effects of global warming.

Types of Green Infrastructure for the State of Hawaiʻi to Explore

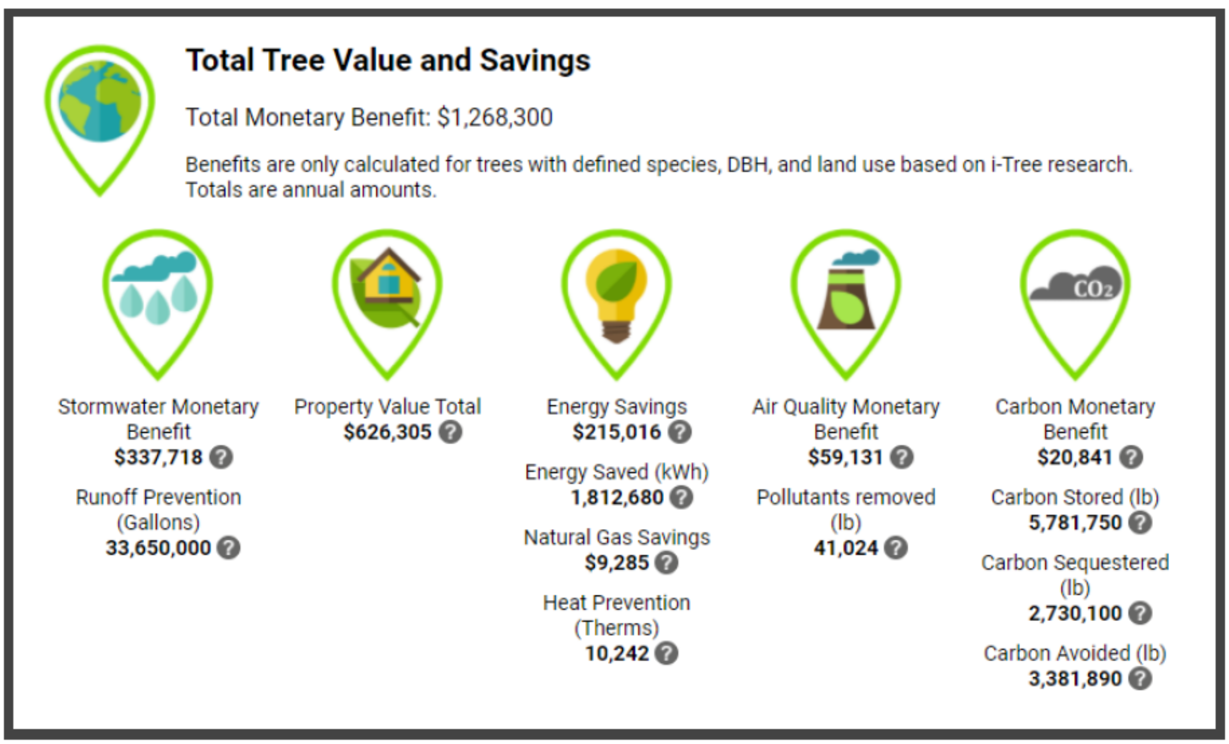
Green Infrastructure Through Urban Tree Canopy

The tree and its canopy are a driving force behind numerous environmental, social, and economic benefits that we rely on every day. On average, the bigger the tree canopy, the bigger the benefits. Trees sequester carbon in their trunks, remove particulate matter from the air, clean stormwater run-off by removing harmful chemicals, cool ambient air by up to 10 degrees on hot days, shelter wildlife, and they create a sense of place. Research also shows that communities that plant trees together grow together- improving social ties and trust among neighbors and communities.

Sequestration Capacity of Urban Trees

We do not have yet have the research on this to report about the statewide capacity of urban trees to sequester carbon, but we do have some information:

Citizen Foresters inventoried 21,311 municipal (street & park) trees in communities across Oahu (from East, South and Central Oahu), and using software that utilizes the iTree platform. These trees sequester 2,730,100 lbs of carbon and provide $1,286,300 monetary benefits annually.



Economic Value of Urban Trees

Based on a 2007 Municipal Forest Resource Analysis, for every $1 spent on tree care, Honolulu's trees provide $3 in benefits (5). At the time of the analysis there were an estimated 235,800 municipal trees, 60% as street trees and the remainder in city parks. These trees provide the following benefits: 1) electricity saved – $8/tree/year; 2) carbon dioxide storage – 25,529 tons; 3) net carbon dioxide removal – 3,340 tons carbon dioxide/year, valued at $22,314; 4) stormwater runoff management – 35 million gallons/year, valued at $350,104. Trees are one of the few pieces of City infrastructure that accrues value over time.

Consumer surveys have shown that preference ratings increase with the presence of trees in the commercial streetscape. In contrast to areas without trees, shoppers indicated that they shopped more often 62 and longer in well-landscaped business districts, and were willing to pay more for goods and services (Wolf 1999). In Honolulu, monkeypod trees along streets effectively added $1,043, annually, to the value of an adjacent home, condominium, or business property (834 ft2 × $1.25/ft2 = $1,043)(https://smarttreespacific.org/wp-content/uploads/STRATUM-HNL_MFRA_web.pdf)

The Intergovernmental Panel on Climate Change recognizes that storing carbon in trees and soil is one of the pathways that will limit warming to 1.5 C. Warming of 1.5 C will disrupt social and economic activities around the world.

Climate resiliency benefits of urban trees include water retention, ambient temperature reduction, water and air filtration, habitat for wildlife, and more.

Trees can greatly reduce heat severity (urban heat islands) across the urban landscape where other environmental factors are not in play. Surfaces shaded by trees are 20-45°F lower than unshaded surfaces, and the air around trees can be 2-9°F cooler[1]. With global temperatures set to rise, trees are needed more than ever in our urban spaces to keep heat severity down and limit heat related illnesses and hospitalizations.

Trees can promote enhanced stormwater management and water quality: Vegetation reduces runoff and improves water quality by absorbing and filtering rainwater.

The Hawaiʻi Tree Canopy Viewer is (due in June 2022) will provide a statewide geospatial interactive dataset and platform. It also includes socioeconomic and demographic data to allow tree canopy data and human wellbeing data to be considered in context. It was derived using the Canopy layer, 2010 Census Tract Boundaries, and the Carbon Assessment Land Cover dataset compiled by USGS. Urban developed areas were queried out out of Land Cover dataset to embody residential areas, commercial areas, roads, freeways, etc. Canopy was clipped around 2010 census tracts as a boundary layer, and then clipped to examine urban areas.

RECOMMENDATIONS TO INCREASE CANOPY:

Planting

To ensure successful plantings, mandate conditions that allow trees to grow — adequate space and air. Tree roots and therefore tree canopy is inhibited by soil compaction, which can be addressed through design. Ensure that trees have the necessary uncompacted soil volume to allow large canopy trees to reach maturity and deliver cooling, shade, and carbon sequestration benefits. This can be accomplished in myriad ways. One example of not providing for such is the "concrete tree box" in Drawing G-5B, which fails to recognize if you want large canopy trees (See: J. Urban, "Bringing Order to the Technical Dysfunction within the Urban Forest", Journal of Arboriculture 18(2): March 1992). Trees where soils have been compacted to construction engineering standards (>90% compaction) roots cannot penetrate and will surface to damage sidewalks, asphalt and other built improvements. This soil restriction also results in shorter-lived, poorly structured, sometimes unstable and unhealthy trees.

Examples of problems when tree roots are not given enough space to expand:

The cost of repair and replacement will exceed the higher upfront cost of providing a suitable environment when first developed.

While it will cost more up front to provide adequate soil volume for trees that thrive and provide the desired functional benefits, the long-term, measurable financial benefits of lower maintenance cost, elimination of multiple removal and replacement actions, and other quantifiable benefits/value creation will significantly offset the initial costs and create a positive return on investment. The average street tree planted without sufficient soil volume needs to be replaced much more frequently and dies before it grows large enough to provide significant ecological and financial benefits. A tree planted with sufficient soil volume that will live much longer and provide many more benefits.

Planting trees in sylva cells, a patented modular suspended pavement system that holds unlimited amounts of lightly compacted soil while supporting traffic loads beneath paving, is another upfront cost that pays for itself many times over.

Table 1 and Figures 1-4 below show our methodology and results in more detail.

Lifecycle Costs and Benefits over 50 years	Tree Without Silva Cells: Estimated Lifespan 13 years	Notes for Tree Without Silva Cells	Tree With Silva Cells: Estimated Lifespan 50+ Years	Notes for Tree With Silva Cells
Installation Costs	$4,000	Estimated at $1,000 per tree, installed 4 times over a 50 year study period	$14,000	Estimated at $14,000 per tree, installed 1 time over a 50 year study period
Total Benefits	$2,717.66	Includes savings from reduced building energy costs, stormwater interception, increased property values, and the net value of carbon sequestration in the tree.[1]	$41,769	Includes savings from reduced building energy costs, stormwater intercep-tion, increased property values, the net value of carbon sequestration in the tree,[1] bioretention,[3] and stormwater utility fee credit.[4]
Total Maintenance Costs	$1,211.95	Includes estimated costs for pruning, pest and disease control, infrastructure repair, irrigation, cleanup, liability and legal costs, and administration costs.[2]	$2,341.75	Includes estimated costs for pruning, pest and disease control, infrastructure repair, irrigation, cleanup, liability and legal costs, adminis-tration costs[2] and bioretention maintenance.
Removal Costs	$600	Estimated at $200 per tree, 3 times over a 50 year study period	$0	Removal Costs
Net Lifecycle Cost	**$3,094.29**		**$-25,427.25**	

Table 1: Urban Tree Lifecycle Costs and Benefits for a 50 Year Study Period, Based on Typical Costs and Benefits for Minneapolis, MN

Source for Table 1 above:
https://www.deeproot.com/silvapdfs/resources/articles/LifecycleCostAnalysis.pdf

Another option is to reduce the number of trees planted, and instead make large planters or reserve lawns with trees that are spaced further apart for larger canopy trees to grow in groves versus rows.

Rather than requiring x number of trees per linear feet of frontage or x number of trees per x number of parking stalls, think in terms of canopy cover which can promote trees with larger canopy rather than just number of trees. Not all trees are equal. For example see: https://www.cityofsacramento.org/Public-Works/Maintenance-Services/Trees/Permits-Ordinances) . Similarly, an example from Los Angeles, California has an incorporation of point system to determine new development's impacts and required landscaping prerequisites, which specifies "trees shall be located in such a manner and be of such a size that the trees are capable of producing an overhead canopy that will shade at least 50 percent of the parking stall area in summer after 10 years growth when the sun is at its zenith at local solar time at the summer solstice.”

Planting specifications for tree planting should include ground cover in order to protect tree roots and to prevent erosion. Ground cover shall consist of mulch, low-lying non-invasive vegetation, and other similar landscaping materials.

Only plant Coconuts in areas where they can be allowed to produce fruit that can be used. Stop prematurely removing coconuts and overpruning the palms. These trees are healthier (and likely sequester more carbon) when they are not overpruned constantly. In addition, they are vital food sources that promote community resilience. Their nuts should not be discarded. As a substitute, plant other palms (eg native *Pritchardia spp* or loulu) in areas with people and personal properties in order to reduce maintenance expenses and to avoid litigious concerns. (See documentary produced by National Association of State Foresters: https://www.stateforesters.org/newsroom/nasfs-newest-short-film-highlights-the-cultural-significance-of-the-tropical-worlds-tree-of-life/

Establish a diverse urban forest. Learn lessons from the devastation of Asian Longhorn Beetle and Emerald Ash Borer which decimated urban forests on the continent that were strongly monotypic. Biodiversity brings resilience. Monkey pod trees provide much urban tree canopy but if they were targeted by a pest, the consequences to the urban forest would be significant.

Consider practices such as those in Portland Parks and Recreation Urban Forestry tree planting program. It offers residents of priority neighborhoods free trees planted in the right-of-way adjacent to their property. After planting, the trees receive free establishment care, including regular watering and mulch, for 3 years.

Preservation of Existing Canopy

Proper pruning following American National Standards Institute A300 standards for urban forestry management. No lion-tailing, lollipopping, or topping should be permitted.

Per Senate Bill 105 (from 1975) pertaining to Environmental Quality, each County is to have an Arborist Advisory Committee to identify Exceptional Trees and to "Recommend to the City Council appropriate protective ordinances, regulations and procedures." Require each county to have an active Arborist Advisory Committee as legislated. Currently, not all are active.

Currently, regulated trees are municipal (county) trees, trees in special districts of Honolulu, Exceptional Trees, and potential risk trees. Most urban tree canopy exists on private property, so this misses a huge opportunity. Establish a tree code that protects large canopy trees on private property. Let's homeowners easily remove problem trees (those that are dead, dying, diseased, dangerous, nuisance species, or too close to buildings) with the provision that a new tree of a similar size and potential be replanted to replace the one being removed.

Tree replacement policy - wood for wood, not “stem for stem”. When a tree is removed, the recommendation is to replace inches of diameter at standard height (DSH)

During excavations, when it becomes necessary to expose or cut tree roots that are greater than one (1) inch in diameter or are within the PRZ of any tree, the contractor has a duty to protect the roots in accordance with City and MPRB policies and specifications.

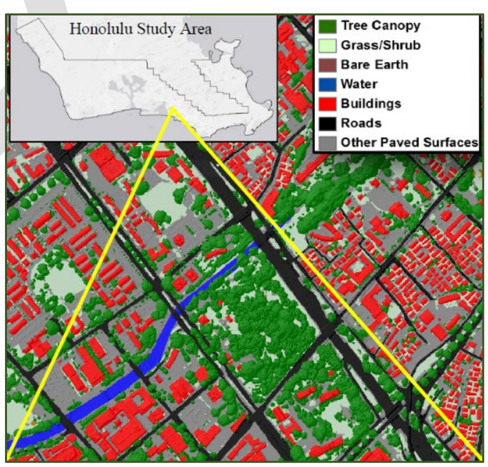
Tree Canopy Goals to Promote Growth

Throughout the United States, cities are setting urban tree canopy (UTC) goals in an effort to mitigate rising temperatures, improve safety, reduce stormwater runoff, etc. These goals are often adopted into urban forestry management plans as percentage goals that are realized over an extended period of time.

Based on research conducted by American Forests in 1997, a baseline of 40% UTC was the standard goal. More recently, a leading urban forester researcher, Cecil Konijnendijk van den Bosch, recommends every neighborhood have 30% minimum UTC (https://iucnurbanalliance.org/promoting-health-and-wellbeing-through-urban-forests-introducing-the-3-30-300-rule/). Due to the diverse conditions across cities and regions, urban forestry researchers (i.e., Greg McPherson) advocate for cities to consider four factors when setting UTC goals: ratio of impervious to pervious surfaces, climate, existing ordinances, and land type.

Cities have used these guidelines and modified them to fit their conditions. For example, Portland has made an exception to impervious surfaces that are sidewalks, parking lots and the airport, and have implemented projected population growth to come to their 33.3% UTC goal by 2035 goal. Los Angeles sets additional percent benchmarks for different land use types to come to their 25% UTC goal by 2040. Phoenix has put an emphasis on resourceful water management due to their desert climate in their urban forestry management plan to achieve a UTC goal of 25% by 2030. Lastly, in Seattle, the size and species of tree as well as land use type to work towards 30% UTC by 2037.

Research focused on Honolulu County (Vermont Spatial Analysis Lab Tree Canopy Assessment Team 2017 https://dlnr.hawaii.gov/forestry/files/2020/04/Tree-Canopy-Report-Honolulu-2016.pdf.) has explored existing and possible tree canopy, land deemed not suitable (Impervious surfaces such as buildings), possible tree canopy impervious surfaces, and possible tree canopy vegetation (parks, grassy areas, shrubs, etc.) This study's ultimate goal was to give a comprehensive idea of areas that can possibly be utilized for tree plantings. Factors such as analysis of parks, zoning districts, council districts, urban vs. non urban, coastal elevation zones, and a tree canopy opportunity index were considered. For the study geography, approximately 20% of the urban area has tree canopy, another 30% exists as vegetation where tree canopy could potentially exist, and about 20% of the area exists as impervious surfaces (e.g., asphalt or concrete, excludes roads and buildings) that could potentially be retrofitted to support tree canopy.



(Source: U.S. Forest Service Tree Canopy Report: Honolulu, Hawaiʻi 96813)

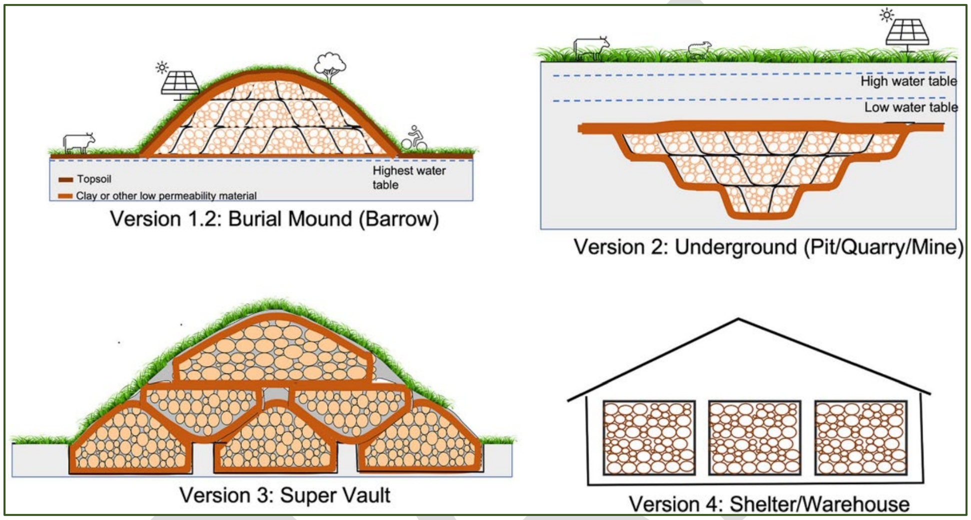
This level of analysis would be appropriate to conduct with updated data for all counties to create UTC goals.

In 2018, the City Council of Honolulu passed a resolution 18-55 that set a UTC goal of at least 35% by 2035. Whether this is attainable depends on how canopy is assessed. Currently elementary school districts in Honolulu have UTC ranging from 3% in around Puʻuhale Elementary School (Kalihi Kai) to 40% around Sunset Beach Elementary (Haleiwa), with urban areas of Oʻahu having a total UTC of 14,748 acres (17% of urban acres) as of 2020. Given the speed at which trees grow, it is not clear if Honolulu is on track to meet the goal. Below is a breakdown of UTC percent ranges by county (Title I schools are bolded):

County	Urban Tree Canopy Cover Acres	Lowest UTC by Elementary School District Acres	Highest UTC by Elementary School District Acres
Hawaiʻi County	19,826 acres (33%)	**Kealakehe Elementary (15%), Waimea Elementary (15%),** de Silva Elementary (16%)	**Mountain View Elementary (63%), Hoʻokena Elementary (63%), Pāhoa Elementary (53%)**
Honolulu County	14,748 acres (17%)	**Puʻuhale Elementary (3%),** Nimitz Elementary (4%), **Kaʻiulani Elementary (5%), Fern Elementary (5%), Honowai Elementary (5%)**	Sunset Beach Elementary (40%), **Lincoln Elementary (40%),** Maunawili Elementary (35%), **Waiāhole Elementary (35%), Waimānalo Elementary (34%)**
Kauaʻi County	7,048 acres (31%)	**ʻEleʻele Elementary (18%), Wilcox Elementary (24%)**	Niʻihau Elementary (53%), **Kīlauea Elementary (40%)**
Maui County	9,783 acres (26%)	**Kahului Elementary (7%), Lihikai Elementary (11%),** Puʻu Kukui Elementary (12%)	**Hāna Elementary (53%), Haʻikū Elementary (48%), Kilohana Elementary (47%)**

Urban Biomass Storage

Long-term carbon storage in an urban environment is especially important to have a meaningful impact on net carbon sequestration in urban areas. Wood harvesting and storage (WHS) is a hybrid Nature-Engineering combination method to combat climate change by harvesting wood sustainably and storing it semi-permanently for carbon sequestration. Storing wood in many environments is possible, leading to different versions of Wood Vault: (1) Burial Mound (Tumulus or Barrow), (2) Underground (Pit, Quarry, or Mine), (3) Super Vault, (4) Shelter, (5) AquaOpen or AquaVault with wood submerged under water, (6) DesertOpen or DesertVault in dry regions, (7) FreezeVault in cold regions such as Antarctica. Smaller sizes are also possible, named Baby Vault.



(Source: Zeng and Hausmann, 2022)

Wood Vault is a centralized storage facility that collects wood from a variety of sources such as urban natural wood residuals (woody yard trimmings, natural wood residuals), wood from storm damage, wood from forest thinning, construction and demolition debris, wood harvested in sustainably managed forests. The buried biomass is sealed off from oxygen with clay or other low-permeability material and embedded in a subterranean environment that will prevent decomposition semi-permanently. After full closure of a Wood Vault, the land can be utilized for recreation, agriculture, solar farm, or agrivoltaics.

Urban Green Infrastructure for the Built Environment

Urban Heat Island Effect

A city's many miles of hot, dark pavement absorb and radiate heat into the surrounding atmosphere at far a greater rate than a natural landscape would. Known as the urban heat island effect, this phenomenon can significantly increase ambient air temperatures. The EPA estimates that the average air temperature of a city with one million people or more can be 1.8 °F to 5.4 °F (1 to 3 °C) warmer than surrounding areas. Higher temperatures reduce air quality by increasing ground-level ozone (also known as smog). In Los Angeles, for example, a 1-degree temperature increase alone makes the air roughly 3 percent smoggier. Green roofs, green streets, and other forms of green infrastructure help improve air quality and reduce smog through their use of vegetation. Plants not only provide shade but also absorb pollutants such as carbon dioxide (CO2)—delivering valuable carbon sequestration—and help reduce air temperatures through evaporation and evapotranspiration.

Carbon Dioxide Mineralization in Concrete

In recent years innovative carbon sequestration technologies are being developed. One such technological innovation is introducing recycled CO_2 into fresh concrete to reduce its carbon footprint without compromising performance. Once injected, the CO_2 undergoes a mineralization process and becomes permanently embedded. The Highways Division of HDOT requires that all structural concrete placed in highways projects on Oahu use technologies to reduce the embodied carbon footprint of concrete. The first choice is to utilize carbon dioxide mineralization, a technology that the DOT has successfully and cost-effectively employed on a number of projects. Other methods to reduce the cement content such as use of supplementary cementitious materials (SCMs) or admixtures such as C-S-H nanoparticle-based strength-enhancing admixture (CSH-SEA) or equivalent may also be used to reduce the embodied carbon footprint. These methods and techniques could be used by other State and county agencies.

Green streets

A form of sustainable road design, green streets combine various green infrastructure practices to more effectively manage stormwater. Whereas typical roads direct runoff into storm drains, green streets use permeable pavement, bioswales, planter boxes, and other stormwater management techniques to capture, absorb, and filter rainfall where it lands, slashing the amount of runoff that reaches waterways and improving the quality of what does.
In addition to providing an economical alternative to costly new investments in sewer system infrastructure, green streets can improve air quality, provide shade, enhance the safety of pedestrians and bicyclists, and beautify neighborhoods. When green streets incorporate additional elements such as energy-efficient lighting, recycled or locally sourced materials, and improved space for walking, running, biking, or public transportation, they are referred to as "complete streets".

Urban Green Building: LEED Certified Buildings, LEED Certified Neighborhoods

Green building projects aim to reduce the environmental impact of buildings over their lifespan by targeting water-saving and energy-efficient initiatives such as smart meters and LED lighting. Enabling investment in more energy-efficient and low-carbon transport solutions can help to reduce the transportation sector's greenhouse gas (GHG) emissions—which are currently the second-highest of any sector.

Green building designs and certification systems, such as LEED, certified by the U.S. Green Building Council, drives building and development project teams to improve energy efficiency by investing in green infrastructure that provides shading and wind protection. For example, green roofs add insulation and extend the lifetime of roof materials, reducing both energy demand and life cycle material costs. Reduced building footprints preserve land for high-performing sites that can use permeable surfaces, catchment systems and water-efficient landscaping to reproduce natural conditions.

Another green building system extends beyond the individual building footprint, to the certify the green building design of the entire neighborhood area. LEED for Neighborhood Development advocates incorporating green infrastructure into buildings, landscapes and the many connecting spaces between, which accentuates the importance of green infrastructure at different scales throughout cities.

LEED for Neighborhood Development recognizes green infrastructure as a tool for creating complete and livable communities, which limit resource use and automobile dependence.

Urban Green Buildings: Parking Garages and Parksmart

One specific green building design mechanism for garages and parking facilities is Parksmart, which addresses an often overlooked facet of the built environment: parking infrastructure. Parking structures often include large, dark, impervious surfaces, which make them a significant source of polluted runoff and a local heat island.

Parksmart recognizes projects that use green infrastructure, including green roofs, green walls and permeable pavers, to mediate these ecological challenges and to transform parking structures into community assets. Additionally, by encouraging carpooling, car sharing, bicycling, and alternative fuel vehicles, Parksmart helps expand more sustainable transportation choices. These green parking lots use green infrastructure to curb rainfall runoff, green parking lots often feature permeable pavement, vegetated areas around or within their perimeter, and shade trees that can help reduce the urban heat island effect.

Green roofs

A living landscape of vegetation (think hardy grasses, succulents, and wildflowers), green roofs provide a verdant oasis for birds, butterflies, and the people who have access to them. By providing an extra layer of insulation to a home or building, green roofs slash cooling- and heating-related energy usage and costs. Whereas a conventionally dark roof basically bakes on a hot summer day (transmitting the heat it absorbs to the building below), a green roof can remain cooler than the ambient air temperature around it. For a one-story building, this can lead to a reduction in average daily cooling costs of more than 75 percent. Keeping cool generates other pluses, too: According to one study, blanketing half of Toronto's available roof space in green roofs would lower ambient air temperatures citywide by as much as 3.8 °F.

Green roofs sequester rain and carbon pollution as well. The water that is released from a green roof is released slowly, reducing the amount of runoff that rushes into a watershed all at once, which curbs flooding and erosion. The vegetation found on green roofs also captures CO_2, which gets stored in plants and soil.

Downspout Disconnection

Even a few inches of rain falling on a house can result in thousands of gallons of stormwater runoff. Often channeled into storm drains by gutters and downspouts, this runoff increases the risk of sewer system overflows. Downspout disconnection is the practice of redirecting rooftop runoff from storm drains to a pervious surface, such as a lawn, or to rain barrels or cisterns, which capture and hold the water for later use. Downspout disconnection can also significantly reduce the amount of stormwater that municipalities must manage.

Rainwater Harvesting

Beyond helping to rein in runoff, the capture, storage, and usage of rainfall (a practice known as rainwater harvesting) has the potential to meet 21 percent to 75 percent of a city's annual water needs, effectively supplying enough water for up to hundreds of thousands of residents, particularly for non-potable use. Rainwater harvesting (which typically uses cisterns or rain barrels to collect runoff from impervious surfaces like rooftops) provides a practical way to meet municipal water needs as climate change, population growth, and increased demand from industries such as agriculture and energy strain the water supplies of many regions.

Rain Gardens

Rain gardens—which can be used in a variety of settings from street medians to small yards—typically feature native shrubs, perennials, and grasses planted in a shallow basin. They are designed to trap and absorb rooftop, sidewalk, and street runoff. In addition to allowing rainfall to evapotranspire or slowly filter into the ground, rain gardens help recharge underground aquifers, keep stormwater from reaching waterways, provide habitat for wildlife, and can beautify a street or yard. They are hardworking, too: A typical rain garden is 30 percent more absorbent than a conventional lawn. In an analysis of Seattle area rain gardens, researchers estimated that each one can filter as many as 30,000 gallons of stormwater a year.

Planter boxes, a type of rain garden, are often used in the space between a sidewalk and street. They feature elevated sides and small openings that allow runoff to enter and be absorbed by vegetation and soil.

Bioswales

Long, relatively deep channels of native plants, grasses, flowers, and customized soils that run parallel to parking lots or roads, bioswales can handle large quantities of runoff from large impervious surfaces. Not only do they absorb and retain runoff from small storms, but they also filter and slow the release of water from heavier rains to sewers or surface waters, limiting floods and providing a first flush of pollutants.

Role of Green Infrastructure: Water Conservation, Resuse, and Recharge

As an alternative to traditional water management systems, green infrastructure offers a cost-effective solution to many water challenges, including how to handle flooding and stormwater pollution.

Stormwater runoff contributes to the frequency and severity of small-scale urban floods. Although localized flood events are not as damaging as catastrophic ones, they can create a greater overall economic burden because of their repetitive nature. In the United States, more than 30,000 properties have been flooded an average of five times each (with some homes getting inundated 30-plus times). The EPA estimates that annual flood damages, due in part to runoff, will increase by $750 million by century's end.

Green infrastructure prevents runoff by capturing rain where it falls, allowing it to filter into the earth (where it can replenish groundwater supplies), return to the atmosphere through evapotranspiration (when water evaporates directly from the land or plants), or be reused for another purpose, such as landscaping.

Green infrastructure improves water quality by decreasing the amount of stormwater that reaches waterways and by removing contaminants from the water that does. Soil and plants help capture and remove pollutants from stormwater in a variety of ways, including adsorption (when pollutants stick to soil or plants), filtration (when particulate matter gets trapped), plant uptake (when vegetation absorbs nutrients from the ground), and the decomposition of organic matter. These processes break down or capture many of the common pollutants found in runoff, from heavy metals to oil to bacteria.

More than half of the rain that falls in urban areas covered mostly by impervious surfaces ends up as runoff. Green infrastructure practices reduce runoff by capturing stormwater and allowing it to recharge groundwater supplies or be harvested for purposes like landscaping and toilet flushing. That reduces the demand on municipal water supplies. Green infrastructure promotes rainfall conservation using capture methods and infiltration techniques (for instance, bioswales, discussed below, absorb runoff that can recharge aquifers).

Green infrastructure is often far cheaper than more conventional water management strategies. Philadelphia found that its new green infrastructure plan will cost $1.2 billion over 25 years, compared with the $6 billion a gray infrastructure would have cost. The capital expenses associated with green infrastructure are often smaller—planting a rain garden to deal with drainage costs less than digging tunnels and installing pipes. But even when it isn't cheaper, green infrastructure still represents a good long-term bet. A Natural Resources Defense Council report found in 2013, that the life expectancy of a green roof is twice that of a regular roof, while the low maintenance costs of permeable pavement can make it a solid long-term investment.

Role of Building Codes: Energy Conservation

Urban green infrastructure will play a cental role in helping the state achieve its goal of a carbon-negative economy by 2045. To achieve that ambitious target, sequestration efforts must be paired with rapid emissions reduction efforts, including in the state's built environment. Building codes provide a power lever for guiding future planning and can help ensure that we are not constructing new buildings—which will stay in the building stock for decades—that are misaligned with our climate goals.

Most individuals spend a majority of their lives inside buildings. Yet buildings are often overlooked as important levers for influencing our safety, health, and economic and environmental quality of life. Not only can high-performing buildings lead to lower monthly utility bills, energy efficiency is also the cheapest, quickest, and cleanest way to accelerate Hawaiʻi's transition to 100% renewable energy.

Building codes have direct and indirect impacts on our wellbeing and quality of life. By establishing and regularly updating uniform state and county building codes, Hawaiʻi can ensure that building design, construction, and operation address society's most important concerns, including public health and safety, environmental protection, and consumer protection against costly monthly utility bills.

One important code for achieving Hawaiʻi's carbon-negative goals is the energy conservation code. Hawaiʻi develops its energy building code based upon the International Energy Conservation Code (IECC). The International Code Council produces an updated version of the IECC through a democratic and deliberative process every three years. As noted by the Environmental and Energy Study Institute, "[t]he process of updating model codes every three years is optimal to ensure new technologies, materials and methods, as well as better approaches to health and safety, can be incorporated into the next generation of buildings with sufficient time for proof of performance."[1]

Hawaiʻi, however, has historically operated on a much slower timeline. Comparing code adoption processes across five jurisdictions (Hawaiʻi, California, Massachusetts, Vermont and Oregon), the following six best practices for timely code updates can be distilled:

1. **Timely State Code Updates**. Require the state code to be updated promptly when model codes are updated (e.g., within one year).
2. **Expert Review**. Require energy conservation expertise and sustainability expertise, on boards, commissions, or committees responsible for reviewing and approving code updates.
3. **Independent Cost-Benefit Analysis**. Utilize independent analyses of the cost-benefit impact of code updates.
4. **Integrated Efficiency & Energy/Climate Policy**. Integrate code updates with other energy planning, programs, and policies.
5. **Training & Other Resources.** Provide training, compliance tools, and other resources for local building inspectors.
6. **Stretch Codes.** Develop stretch codes, tied to incentive programs or to designated types of development.

The Hawaiʻi process embraces some, but not all, of these best practices. The energy code adoption process in Hawaiʻi can be improved by increasing the timeliness of code updates, implementing an independent cost-benefit analysis, more effectively integrating county code updates with other broader energy policies, and developing a stretch code with each code update.

[1] Vaughn, Ellen and Jim Turner, *The Value and Impact of Building Codes*, 2013, https://www.eesi.org/files/Value-and-Impact-of-Building-Codes.pdf.

Renewable Energy/Energy Efficiency: Co-benefits for Climate Resilience

In a recent report titled "Climate Change 2022: Mitigation of Climate Change," the UN Intergovernmental Panel on Climate Change (IPCC) emphasized that sequestration efforts must be paired with rapid gas (GHG) emissions reductions.[2] The report found that the global share of emissions that can be attributed to urban areas is increasing.[3] Furthermore, the report concluded that, "[u]rban areas can create opportunities to increase resource efficiency and significantly reduce GHG emissions through the systemic transition of infrastructure and urban form through low-emission development pathways towards net-zero emissions. Ambitious mitigation efforts for established, rapidly growing and emerging cities will encompass 1) reducing or changing energy and material consumption, 2) electrification, and 3) enhancing carbon uptake and storage in the urban environment."[4]

To reach Hawai'i's ambitious clean energy and climate goals at the pace and scale needed to avoid the worst impacts of climate change, Hawai'i must select decarbonization pathways that rebuild our economy, reach beyond the electricity sector, and ensure equity, access, and affordability. Hawai'i state policy should strive to achieve the following:

1. Identify and analyze opportunities for deep decarbonization

Hawai'i's ambitious clean energy and climate goals require more than decarbonizing the electricity sector. Current policies, programs, and incentives focus on specific sectors or industries creating uneven allocation of costs and benefits of economic transformation. By identifying and analyzing opportunities for deep decarbonization, Hawai'i can develop better policies, programs, and incentives that can help Hawai'i achieve multiple goals across the economy, such as energy production, housing, job creation, and economic diversification.

2. Significantly reduce transportation emissions

Hawai'i should fully transform to electrified transportation by design rather than default and codify urban planning requirements to encourage more sustainable models of transportation (e.g., biking, walking, and public transit). We can do this by setting a target for transitioning 100% of ground transportation in Hawai'i to zero emission vehicles by at least 2045, and optimizing the "whole-system" benefits of electrified transportation by expanding electric vehicle charging infrastructure—through policy, incentives, rebates, and/or other programs—particularly for those that do not have access to charging at home or at work, such as renters and residents in multi-unit housing.

3. Center equity, access, and affordability in energy and sustainability planning

Hawai'i's transition to clean energy should provide economic opportunities for residents, enhance social well-being, ensure equitable access to affordable energy, and contribute towards building more inclusive processes that remove barriers for community engagement. This includes supporting community-focused programs that increase access to financing for low- and moderate-income residents, and prioritize energy efficiency to reduce energy financial burdens.

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[2] *Climate Change 2022 Mitigation of Climate Change: Summary for Policymakers*, Working Group III Contribution to the Six Assessment Report, United Nations Intergovernmental Panel on Climate Change, https://report.ipcc.ch/ar6wg3/pdf/IPCC_AR6_WGIII_SummaryForPolicymakers.pdf.

[3] *Id.* at B.2.3.

[4] *Id.* at C.6.

4. Streamline and modernize state climate governance

Climate change policy development, analysis, and planning, and implementation in Hawaiʻi is currently done across multiple State and County government agencies and non-governmental organizations (NGOs), many of which were established before Hawaiʻi had a long-term vision for energy independence from fossil fuels. Streamlining and organizing these efforts into a more coordinated and cohesive structure will allow greater efficiency, stakeholder engagement, and impact, especially as Hawaiʻi positions itself for federal support.

5. Make Hawaiʻi a hub for carbon negative and sustainable technology innovation

To get ahead of critical climate change impacts, development of new technologies must be rapidly accelerated. A holistic decarbonization approach relies not only on advanced renewable energy generation, energy storage, and decarbonized transportation technologies, but also technologies to sequester or remove carbon dioxide from the ambient air. Hawaiʻi can drive job creation and attract of outside investment and funding by establishing itself as a center of RD&D for these carbon negative technologies, partnering with U.S. Department of Energy, other governmental agencies, academia, and industry.