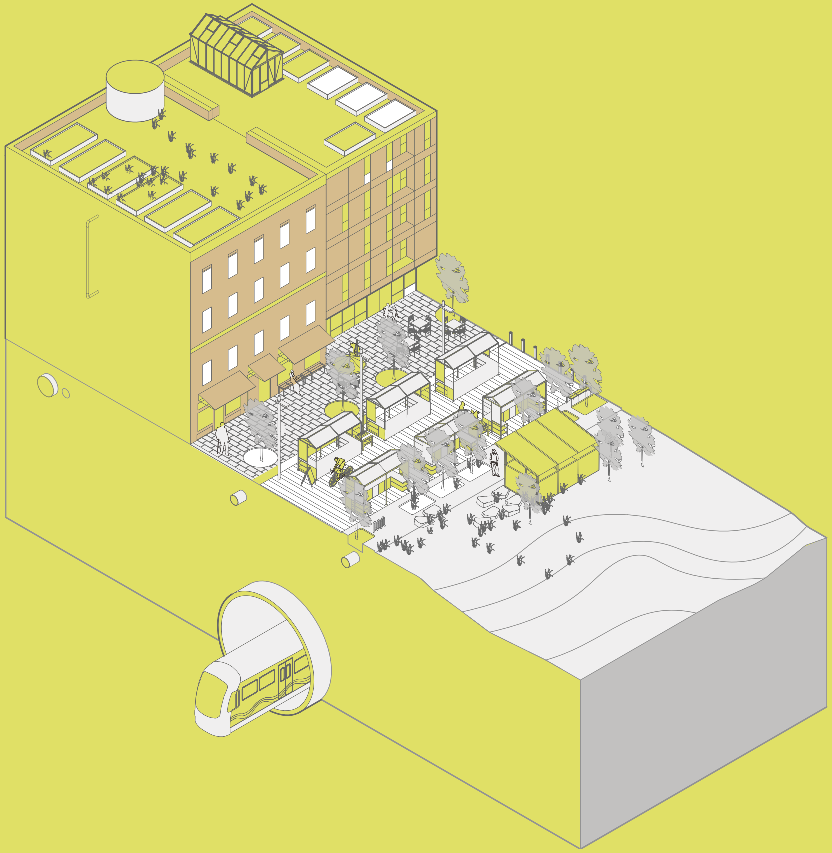

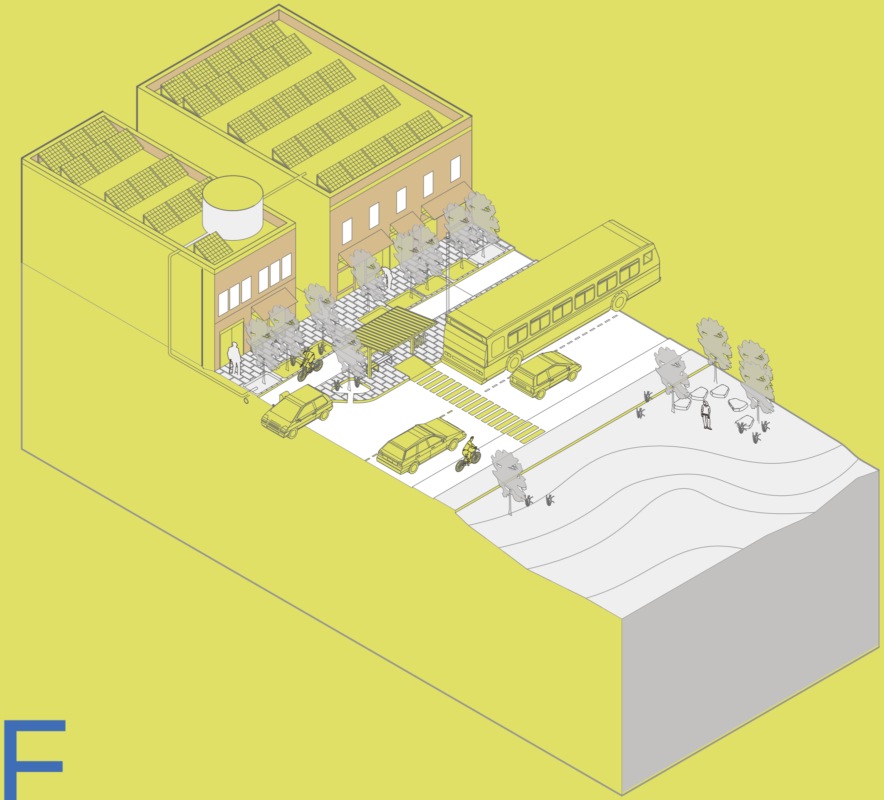

# DESIGNING THE **CLIMATE RESPONSIBLE** CITY

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+ Vaughn Rinner - PLA, FASLA

# DESIGNING THE **CLIMATE RESPONSIBLE** CITY

# Foreword

**Solutions to our planet's climate crisis must be applied in every sector,** with particular emphasis given to immediate reduction in atmospheric greenhouse gases. Planners and designers of the built environment may be fully aware of the urgent need to reduce greenhouse gas emissions and sequester carbon, but opportunities and appropriate approaches and tools that will be most effective for the urban realm are not always discernible.

Our 2022 UW Green Futures Lab Interns Erin Irby and Sarah Lukins have brilliantly worked to unpack and illustrate how we can decarbonize material and energy flows through urban design practices, shifting from linear to circular-flow thinking and actions. This guide begins by providing frameworks for decoupling carbon emissions through inputs, metabolic processes and outputs, and then compellingly illustrates possible design practices related to energy, water, transportation, food systems, and green spaces. Through informed thinking and decisive interventions, planners and urban designers can indeed be instrumental in deploying much-needed solutions to protect our planet's fragile climate.

We are profoundly grateful to the Scan Design Foundation for funding this guide, and hope that it will inform, catalyze and support the important work of designers across urban contexts.

Please do download the booklet and supporting material from the UW Green Futures website: www.greenfutures.washington.edu, and use it to create Climate Responsible Cities!

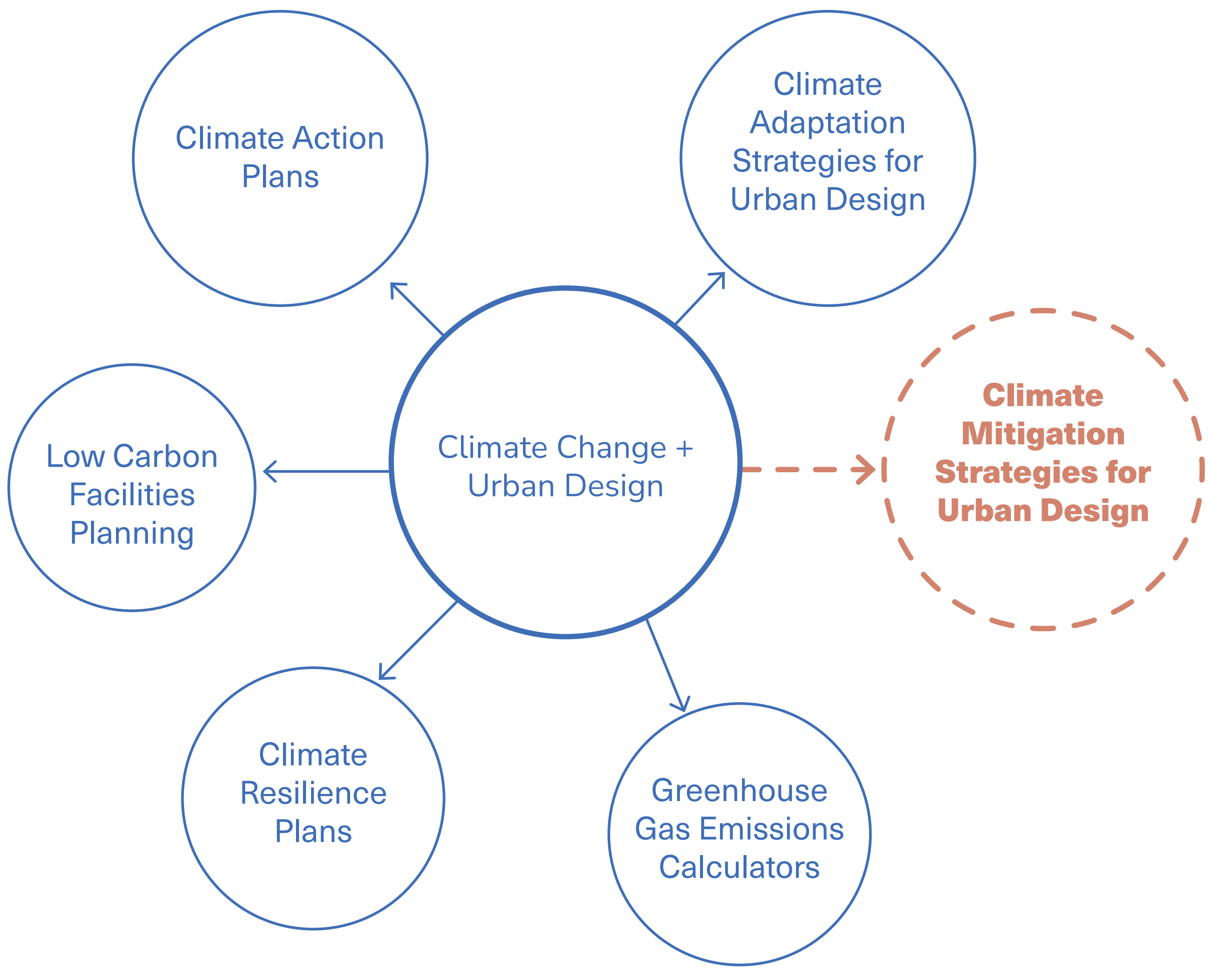
**Nancy Rottle**

Director, UW Green Futures Lab

*Professor Emeritus, UW Department of Landscape Architecture*

# Table of Contents

# Why Focus on Urban Design + Climate Mitigation?



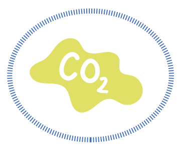
# Introduction

Cities consume over 78% of the world's energy and produce over 60% of global greenhouse gas (GHG) emissions. For this reason, cities and urban areas more broadly are critical in mitigating, or reducing the severity of, global climate change. Urban designers can be part of the needed solution by implementing design strategies that reduce greenhouse gas emissions and sequester carbon at multiple scales. In this guide, we will focus on design actions centered on parcel, neighborhood and district scales -- the scales where urban designers usually work -- and suggest design strategies that can be implemented.

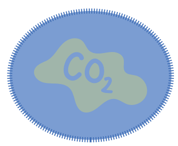
As urban designers, we must help to decouple CO2 and other GHG emissions from the creation and maintenance of the built environment, and from the everyday lives of people who live in urban places. Our collective carbon footprint (the amount of carbon emissions we produce) is implicated in every system we interact with. For instance, how do we get to the places we need to go? What volume of GHG emissions are produced by city services like providing fresh water and sewage disposal? How are materials (which represent embodied GHG emissions) disposed of or reused? The urban form and its materials can significantly impact how these processes happen. Changes to urban form can increase resource efficiency by decreasing the distances that goods, materials and people need to traverse, incentivizing low emissions behavior and changing resource flows so that less carbon-intensive products are required, and less waste is produced. This is exciting because the work is inherently holistic; solutions cannot happen in isolation, but rely on a series of interdependencies between people, industries, government and other sectors.

Understanding and identifying where to center emissions reduction and sequestration efforts is inherently challenging. Urban systems are of course embedded within much larger economic systems and resource flows beyond the purview of urban design. For this guide, we use a materials flow analysis framework to help understand potential design intervention points at feasible scales, and suggest alternative design actions based upon two different energy contexts in which urban designers may work, to achieve climate-positive outcomes for the climate responsible city.

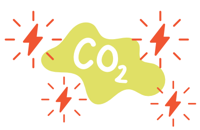
# Key Definitions




**Carbon Sequestration:** The process of capturing and storing atmospheric carbon dioxide



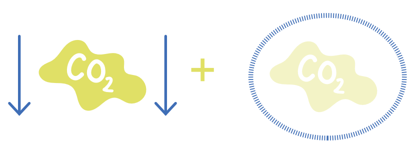

**Carbon Sink:** Anything that absorbs more carbon from the atmosphere than it releases; e.g. soil retains carbon in undigested organic material



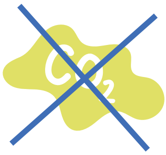

**Carbon Intensity:** Measure of carbon dioxide and greenhouse gases produced per unit of electricity and/or dollar of GDP



**Climate Responsible Design:** Design of the built environment that not only minimizes GHG emissions but also maximizes carbon sequestration and spurs positive behavior and policy change at multiple scales.




**Climate Mitigation:** Climate Mitigation = Greenhouse Gas Emissions Reduction + Carbon Sequestration

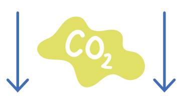



**Decouple:** Taking fossil fuels out of the equation by reducing or eliminating the release of carbon dioxide/GHG by opting for transformations that rely on alternative forms of energy and/or don't produce GHG as a byproduct

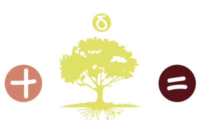

**Embodied Carbon:** Refers to the greenhouse gas emissions arising from the manufacturing, transportation, installation, maintenance, and disposal of materials. E.g. re-using existing buildings and streetscapes (versus building new ones) can lower the overall carbon footprint of a project.




**Greenhouse Gases (GHGs):** Gases in Earth's atmosphere that trap heat (water vapor, carbon dioxide, methane, ozone, nitrous oxide, chlorofluorocarbons)




**Greenhouse Gas Emissions Reduction:** Efforts to reduce or prevent emissions of greenhouse gases that cause atmospheric warming



**Material Flow Analysis (MFA):** MFA includes the comprehensive measurement of the content input and output flows into space at a time specified framework.

**Urban Heat Island (UHI):** Phenomenon where urban areas are significantly warmer than surrounding areas due to the density of surfaces that absorb and retain heat and heat-generating processes in urban areas.

# FRAMEWORK

# Carbon Decoupling: 101

## Material and Energy Flows

Removing carbon dioxide and other greenhouse gases as an output from urban systems requires a diverse array of strategies. In this chapter, we introduce our framework which uses a material flow analysis to investigate where designers can intercede to create lower carbon intense spaces and processes. In considering where designers can intervene, we look at two sets of flows: material flows and energy flows. Metabolic processes require both - material to transform, and energy to produce the transformation. To that end, to decouple carbon, or decarbonize, we can change the type of materials that enter our urban systems and we can change the type of energy that we use to catalyze those transformations (product manufacture is an example of a transformation, where raw goods are transformed into functional products - using energy to produce a higher level of organization).

Similar to organisms, urban systems consist of a series of nested systems all with their own manifold metabolic processes. Depending on where we are located within the system, we can make choices about what materials enter our site and what energy is used for transformations (inputs), the configuration of the space to facilitate efficient transformations (metabolism) and what happens to the products and byproducts of those transformations (outputs).

Within urban systems, in terms of energy use, this means removing fossil fuels from our energy diet and replacing them with renewable energy sources as well as removing opportunities for energy loss. In terms of material use, this means keeping materials in circulation within the system which eliminates many of the energy intensive transformations raw materials must undergo before they can be used for their intended purpose (all transformations that happen before arriving and functioning on site contribute to embodied carbon).

In addition, our urban systems should maximize the number of transformations that sequester carbon (i.e. use atmospheric carbon as an input). To the right is an example of one such metabolic process - the transformation of carbon dioxide, sunlight, water and nutrients into plant tissue (trapping atmospheric carbon).

Inputs → Metabolism → Outputs

**RAW MATERIALS**
**ENERGY**
→ **MEDIATOR** →
**PRODUCTS**
**BYPRODUCTS (WASTE)**

**Strategies:** choose inputs with lower embodied carbon

**Example:** using cross laminated timber instead of conventional steel and concrete construction

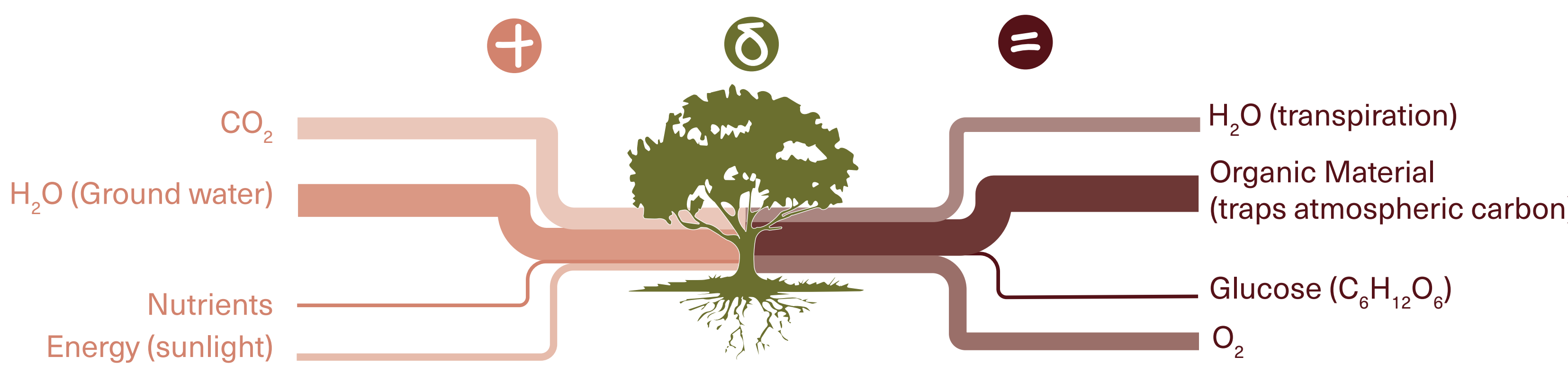
**Strategies:** higher efficiency metabolism (requires less input or renewable input for equivalent output)

**Example:** building dense housing to more efficiently administer services

**Strategies:** byproducts become inputs in other systems

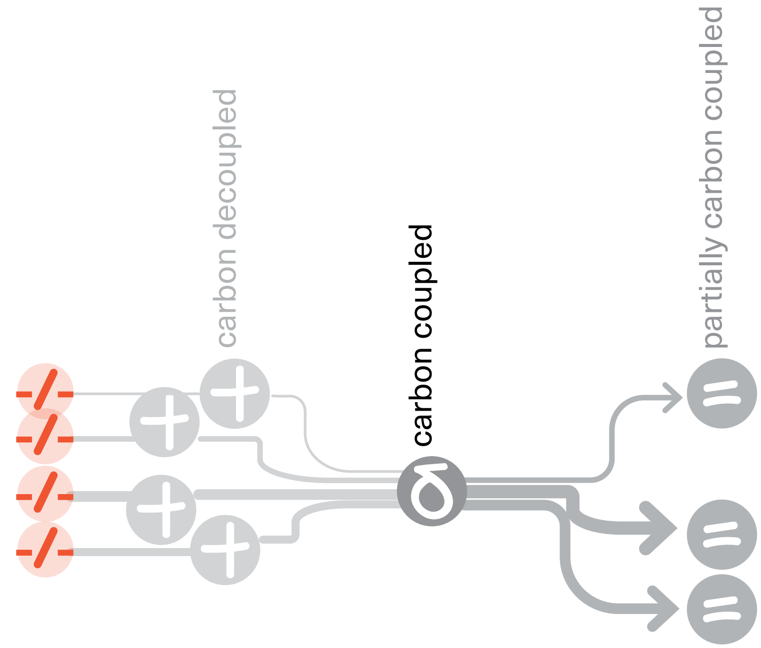
**Example:** heat is a byproduct of many industrial processes. Heat can be captured using a cross-current exchanger for use in district heating

## TREE: MATERIAL FLOW ANALYSIS



# Opportunities for Carbon Decoupling within a Metabolic Process

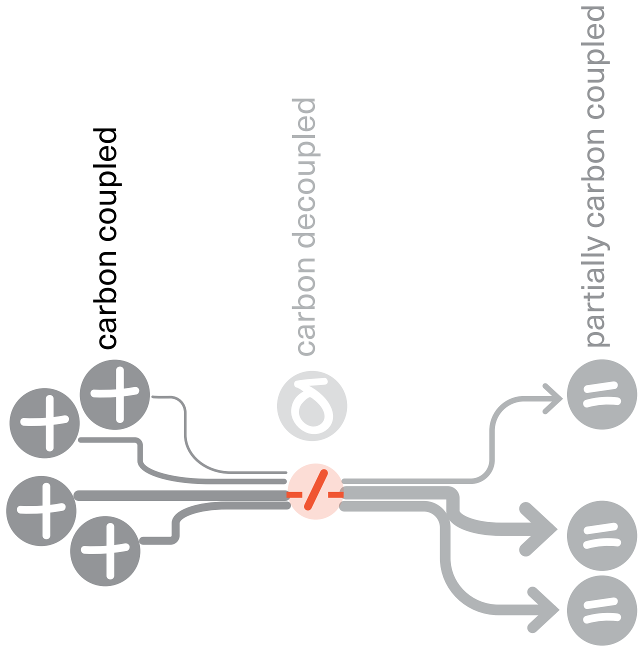
## Decoupling Opportunities




### Decoupling **Inputs**

+ Substitute renewable inputs for nonrenewable inputs including substituting renewable energy for fossil fuels
+ Choose inputs with low or no embodied carbon
+ Choose durable inputs (with a long lifecycle)


GHG decoupling opportunity

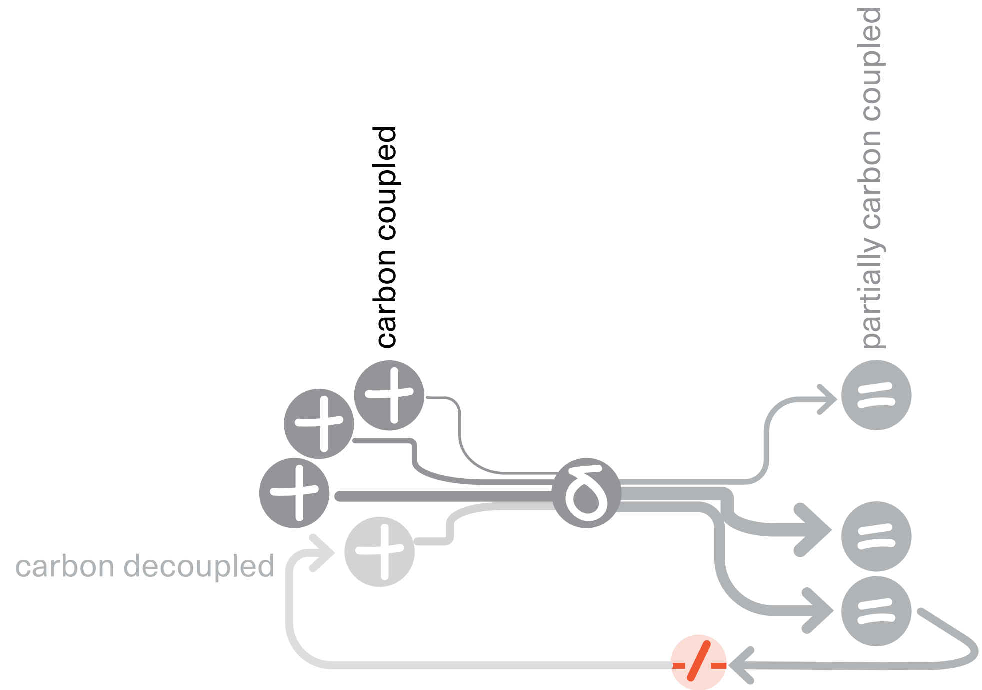



## Decoupling **Metabolism**

δ Build metabolic processes that efficiently transform inputs

δ Shrink metabolic processes so inputs have less distance to travel - Eg Density, colocation

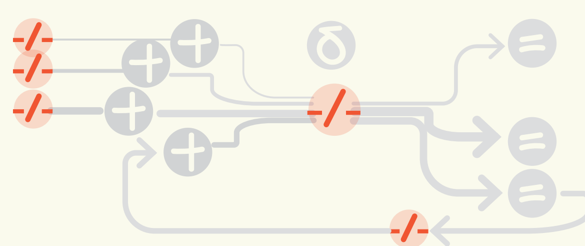
δ Improve insulation so that less energy is lost from the system (both thermal and electric) during transformations




## Decoupling **Outputs**

= Reuse or recycle outputs alleviating the need for high embodied carbon inputs (reuse, recycle in that order)

= Use biproducts (secondary outputs) produced by metabolic processes as inputs for other metabolic processes rather than allowing biproducts to become waste and pollution



All these decoupling strategies combined can create a fully carbon decoupled metabolic process.

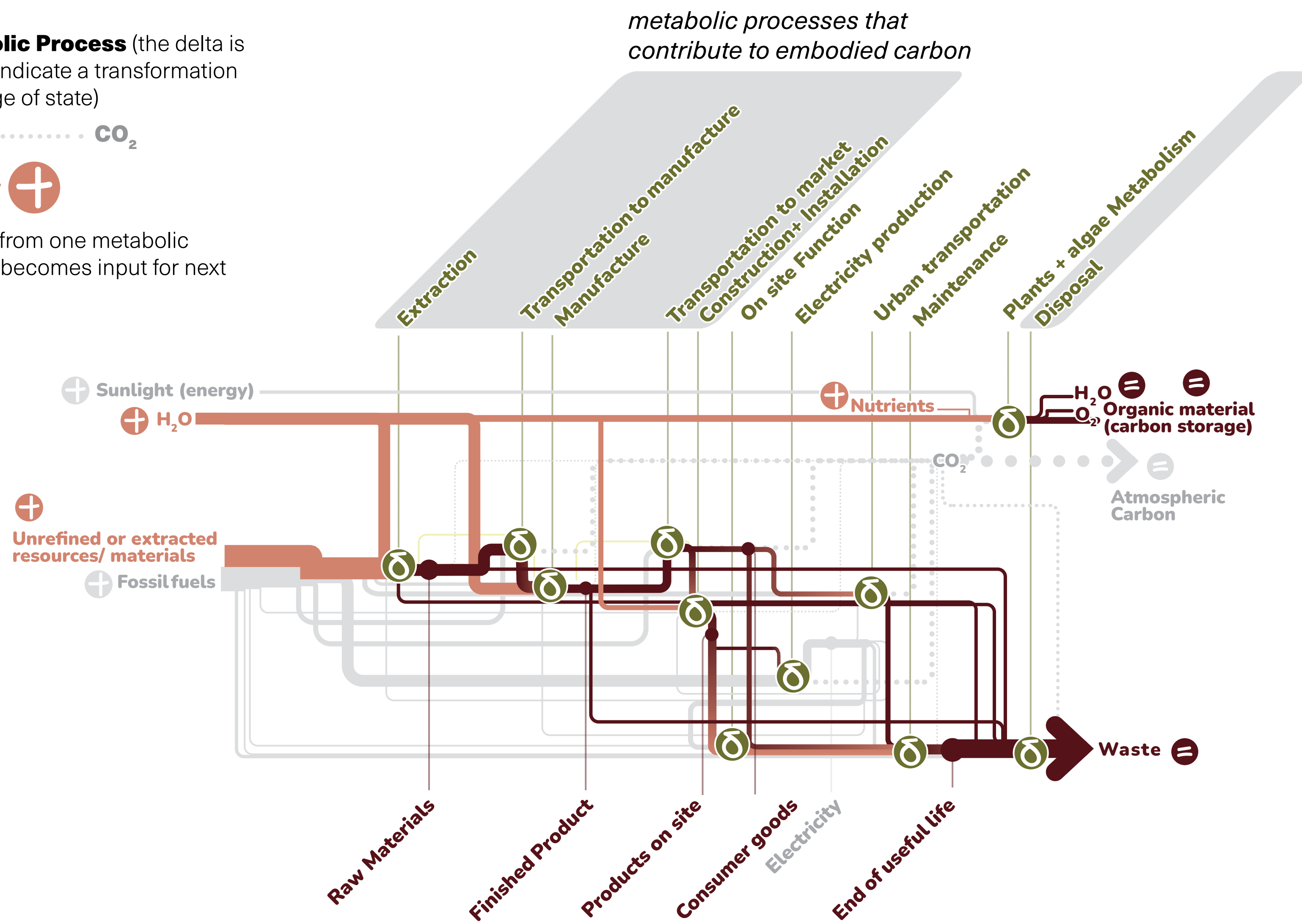
Many decoupled metabolic processes combined can produce a carbon decoupled system (visualized as the circular system on pages 17 & 19).

# Material Flow Analysis: Linear system (high carbon intensity)

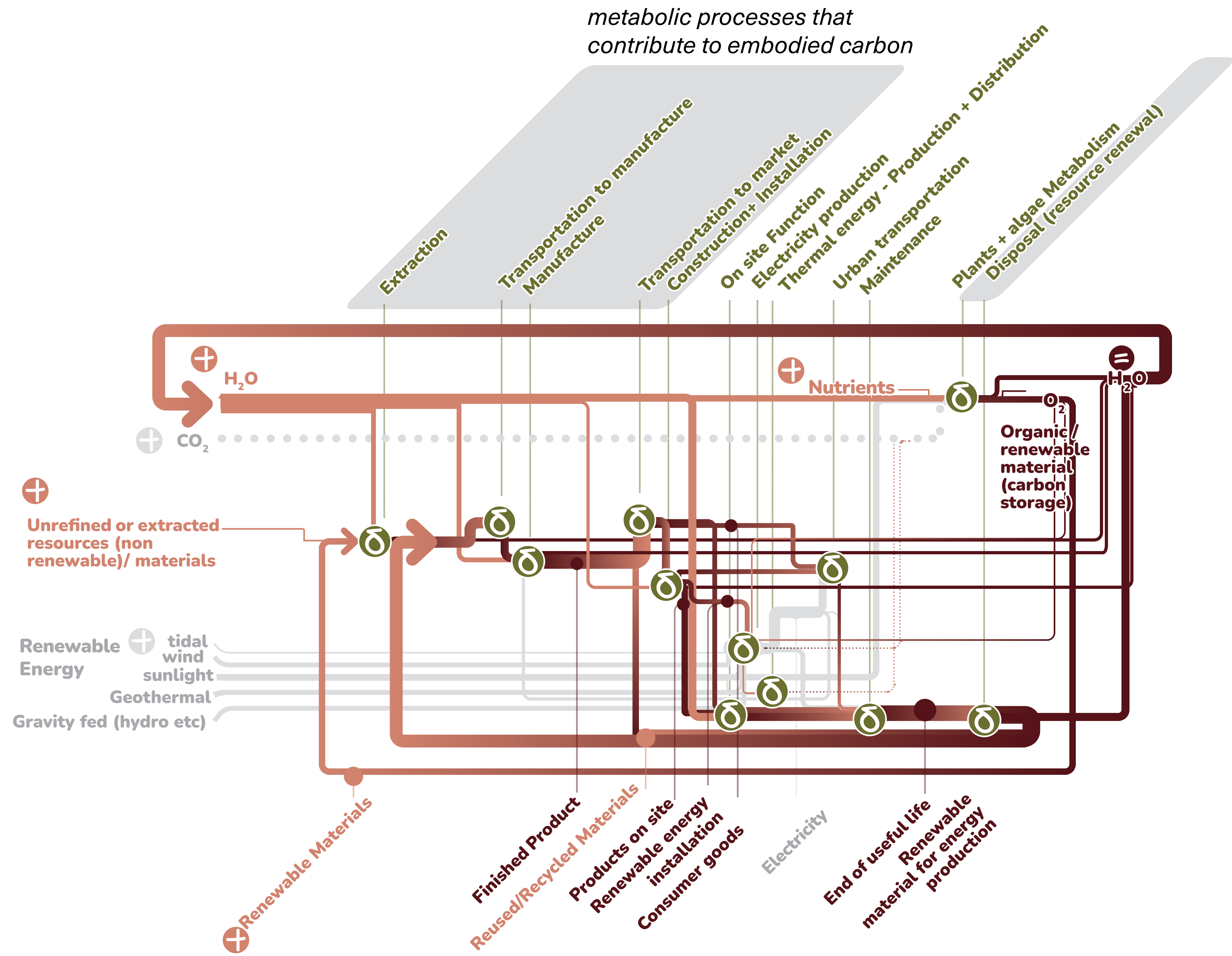
**Metabolic Process** (the delta is used to indicate a transformation or change of state)

$CO_2$

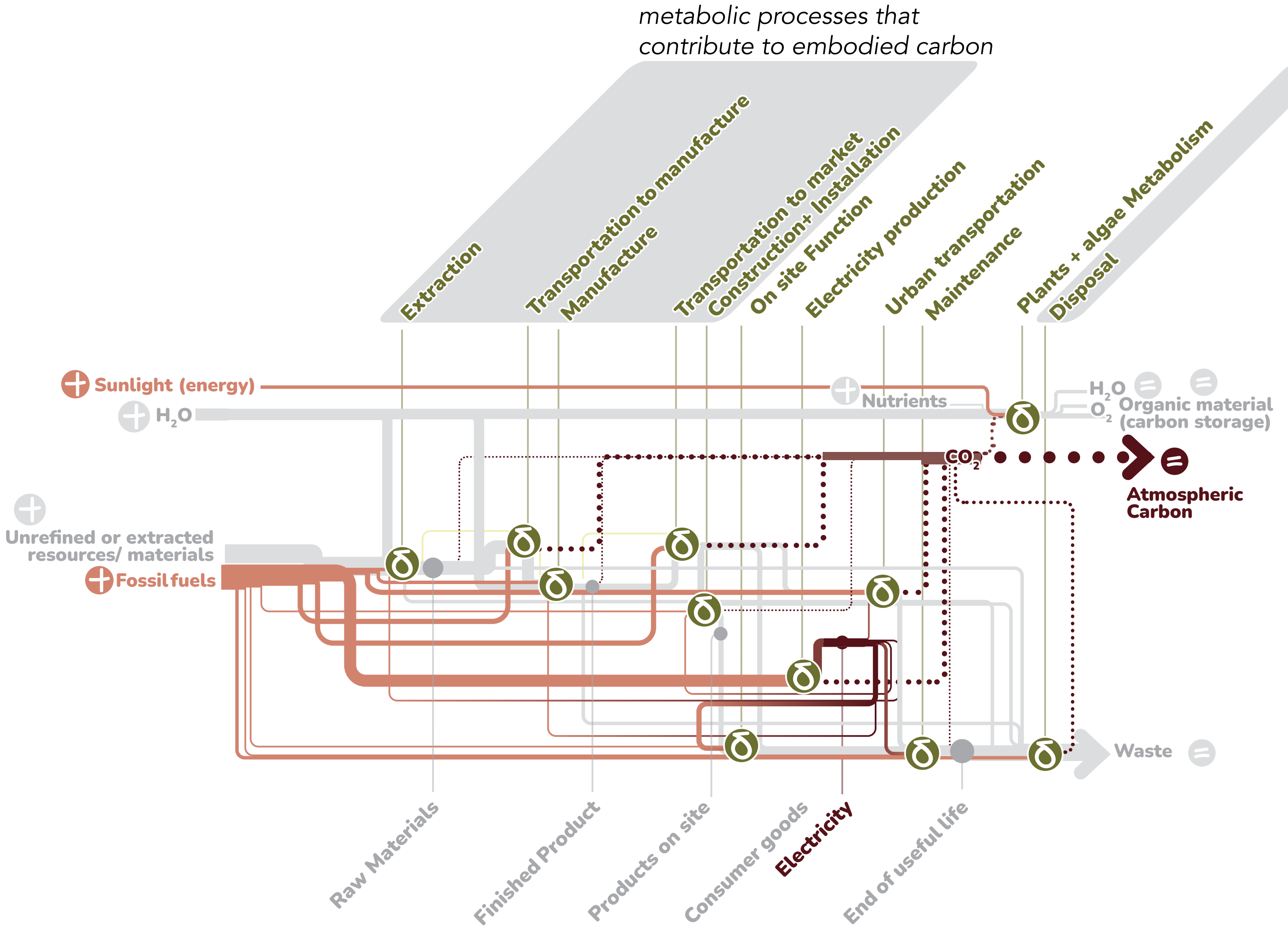
**Output** from one metabolic process becomes input for next process



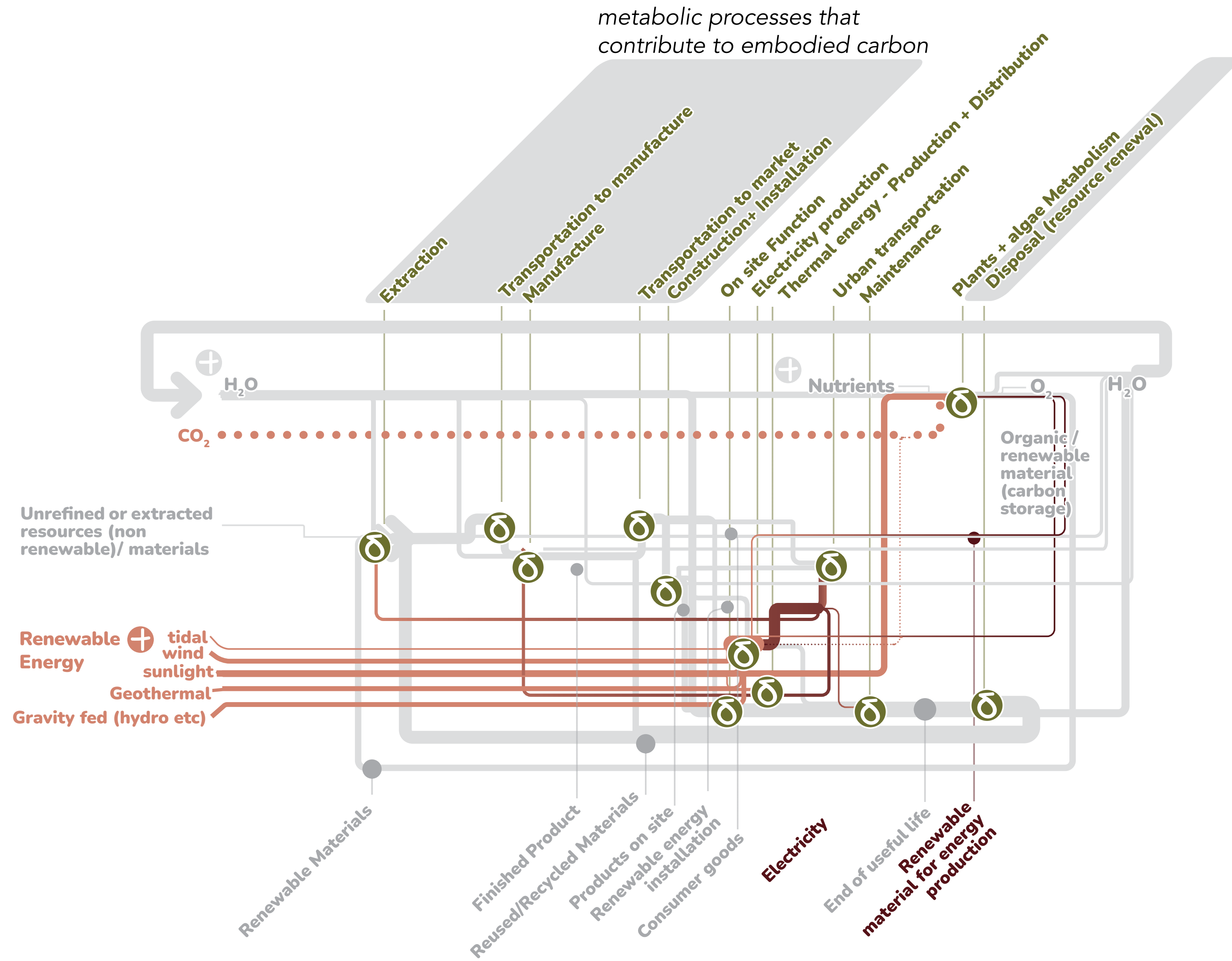
# Material Flow Analysis: Circular system (low carbon intensity)



# Energy Flow Analysis: Linear system (high carbon intensity)



# Energy Flow Analysis: Circular system (low carbon intensity)

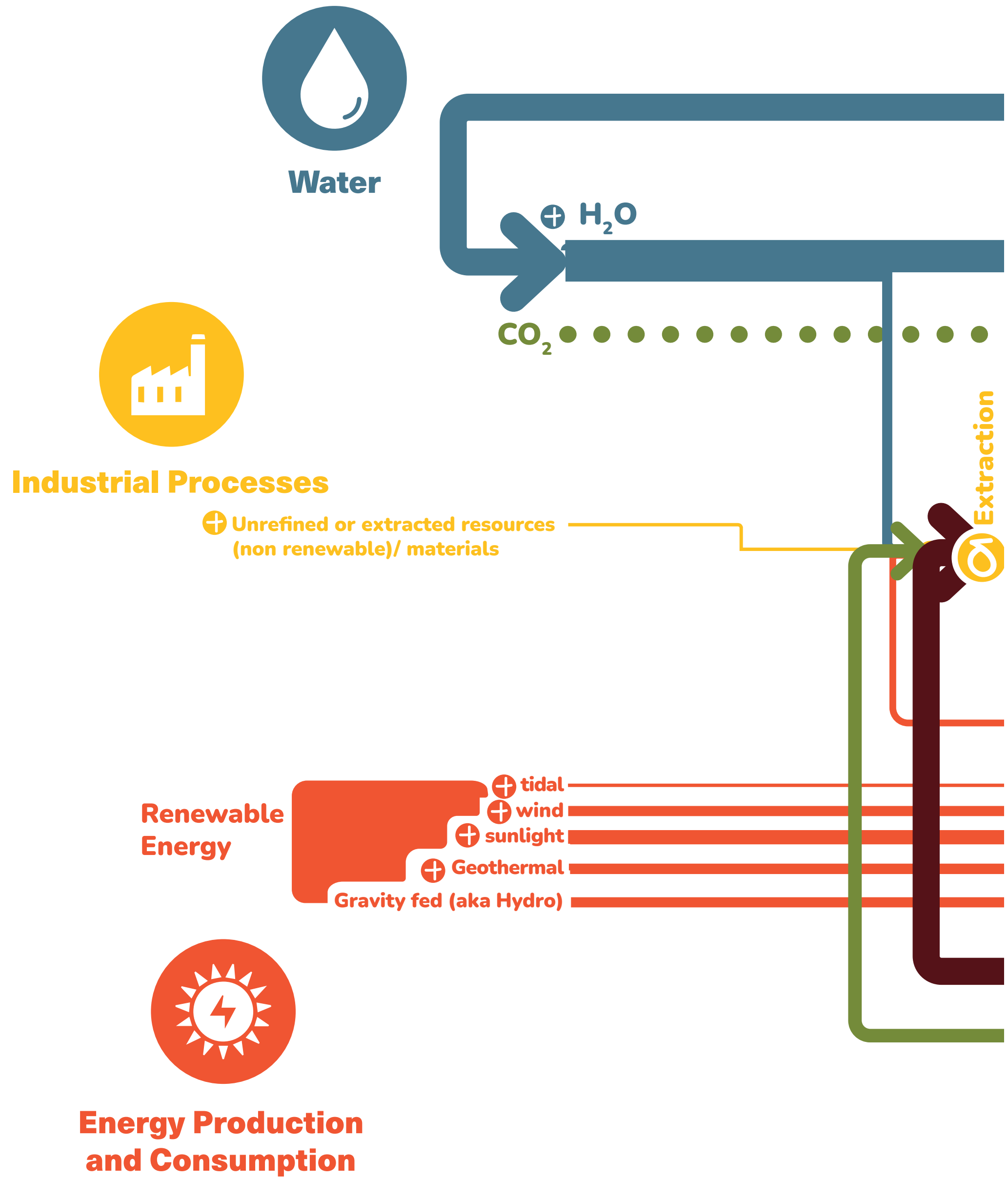


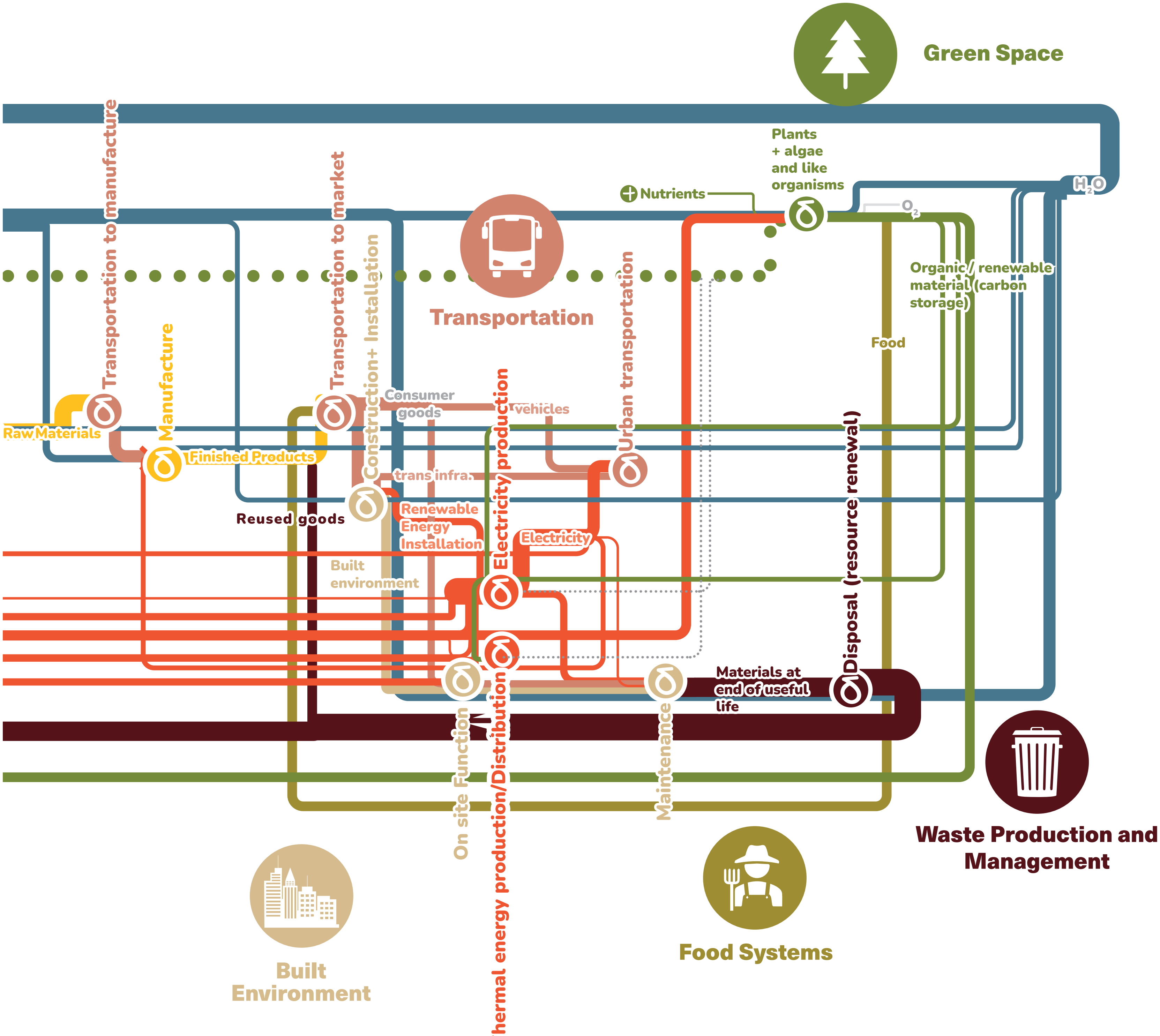

*Note: These are hypothetical systems - quantities of different materials and energy sources vary as well as the transformations (metabolism) they undergo.*

# Systems in Urban Environments

All urban systems require energy and materials to maintain quality of life. For the purposes of this guide, we will touch on eight subsystems that provide the materials and energy that an urban system needs in order to function. The optimum size and geography for these subsystems is contingent on the location of the urban system. For instance, the energy subsystem that services San Francisco might function most efficiently capturing solar energy in the San Fernando Valley and transmitting it large distances back to the city. This is an equation of how efficiently solar can be harvested balanced against the embodied carbon of the electricity infrastructure and the amount of energy lost in transmitting the electricity from the solar installation to the city.

To the right key systems are delineated within the circular system diagram. Later in the guide, specific site scale interventions are detailed based on these systems. As is evident in this diagram, systems overlap in many places.

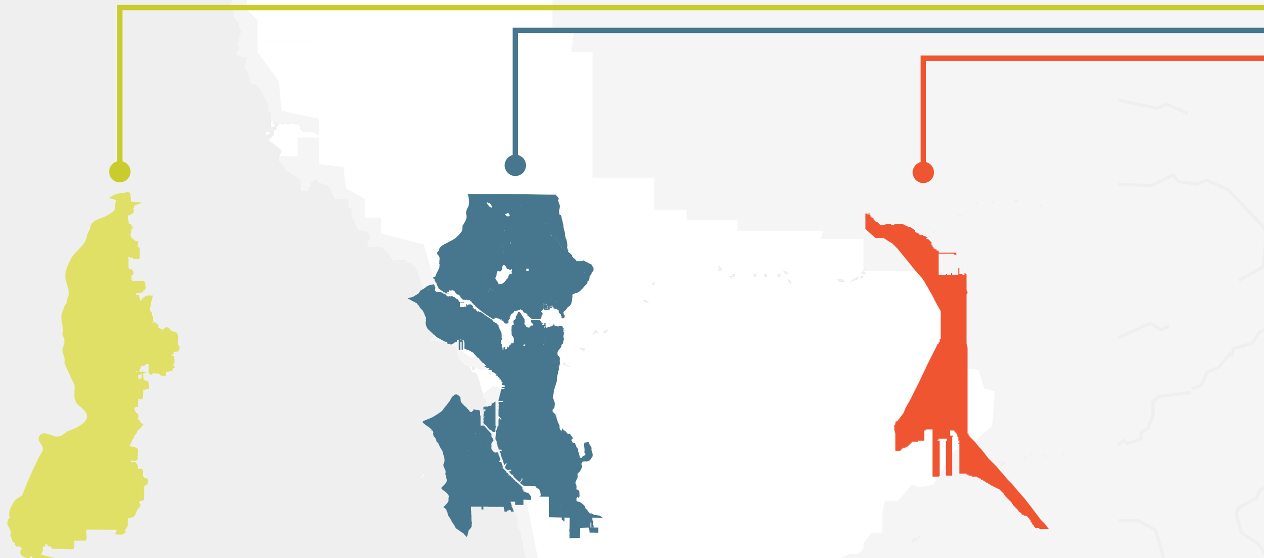



Green Space
Plants
+ algae
and like
organisms
Nutrients
$H_2O$
$O_2$
Organic / renewable
material (carbon
storage)
Food
Transportation
Transportation to manufacture
Raw Materials
Manufacture
Finished Products
Transportation to market
Construction+ Installation
Consumer
goods
vehicles
Urban transportation
trans infra.
Reused goods
Renewable
Energy
Installation
Electricity production
Electricity
Built
environment
Thermal energy production/Distribution
On site Function
Maintenance
Materials at
end of useful
life
Disposal (resource renewal)
Waste Production and
Management
Food Systems
Built
Environment

# Climate Responsible Strategies at Nested Scales

Not all design strategies make sense at every scale. There are optimized placements of climate responsible strategies, at appropriate scales, that collectively contribute to climate mitigation and adaptation.

A look at Sound Transit's regional network illustrates the various climate responsible strategies potentially employed at nested scales. At the regional level, policy and design focused on land use patterns, infrastructure, and energy production is most effective.



## REGION

*Sound Transit Service*

Area (>1000 sq mi; >50 cities; Population: 2.86 million)

+ Scaled renewable energy production
+ EV charging infrastructure
δ Transit oriented development
δ Urban growth boundaries
δ Smart grid
= Increased access to low carbon equiv. transit modes
= Strategic land use
= Large scale recycling and industrial reuse

## MUNICIPALITY

*Seattle, Washington*

(84 sq mi; Population: >700,000)

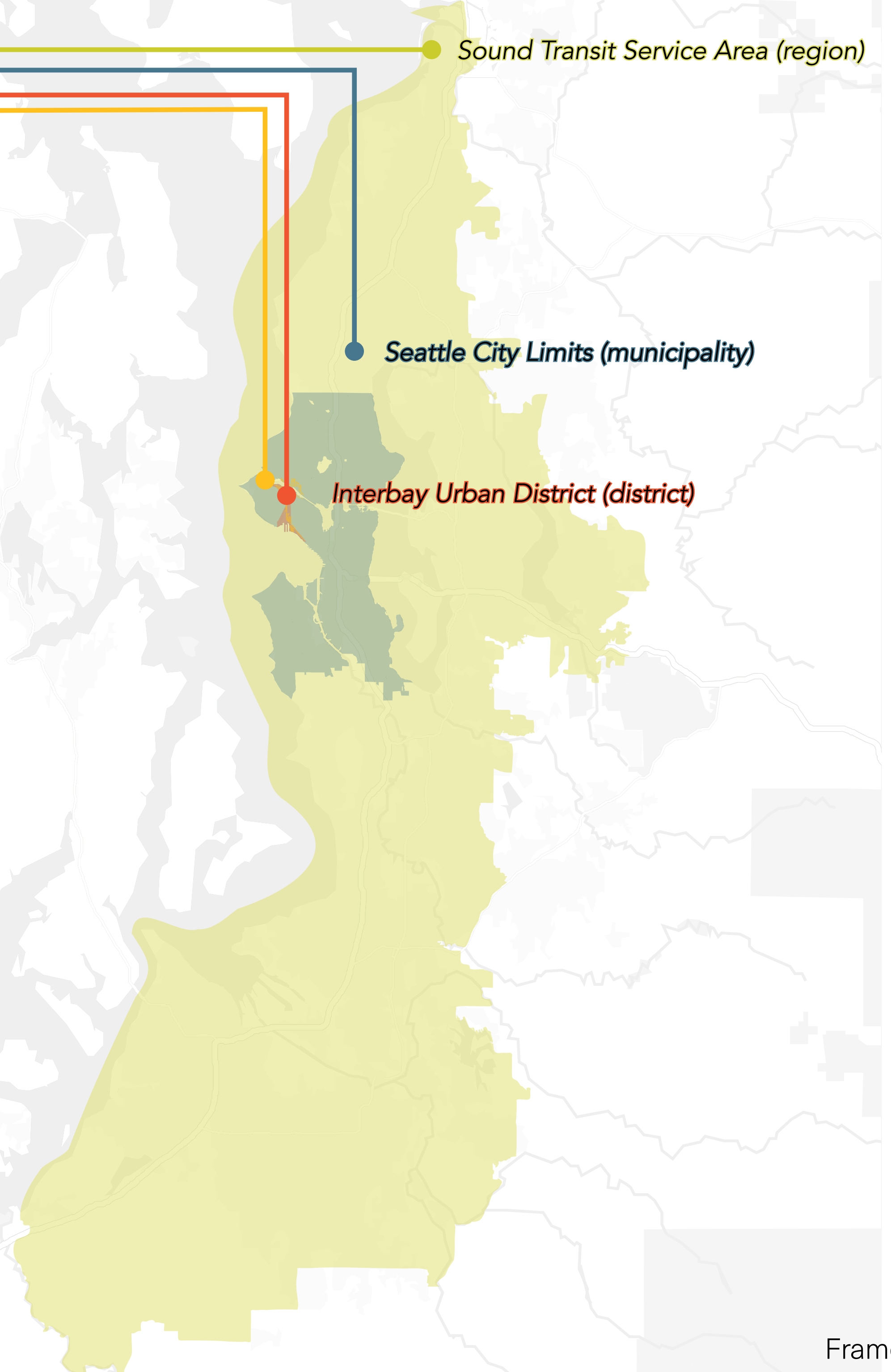
+ Community funded renewable energy installation
+ EV charging infrastructure
+ Co-located complimentary businesses
+ Green corridors and enhanced urban tree canopy coverage
δ Transit oriented development
δ Urban Clusters
δ Increased housing diversity
δ Active transport enhancement
δ Updated building code neighborhoods
= Increased access to low carbon transit modes
= Circular city

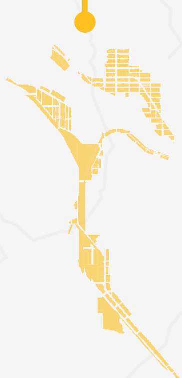
## SUB AREA

*Interbay*

(1.4 sq mi; >5,000 people)

+ District heating and cooling
+ Methane capture
+ Urban agriculture
δ High density mixed use development
δ Energy storage
δ Amenities clusters
= Increased access to low carbon equiv. transit modes
= Circular compost system
= Water reuse / Stormwater management
= Biochar production



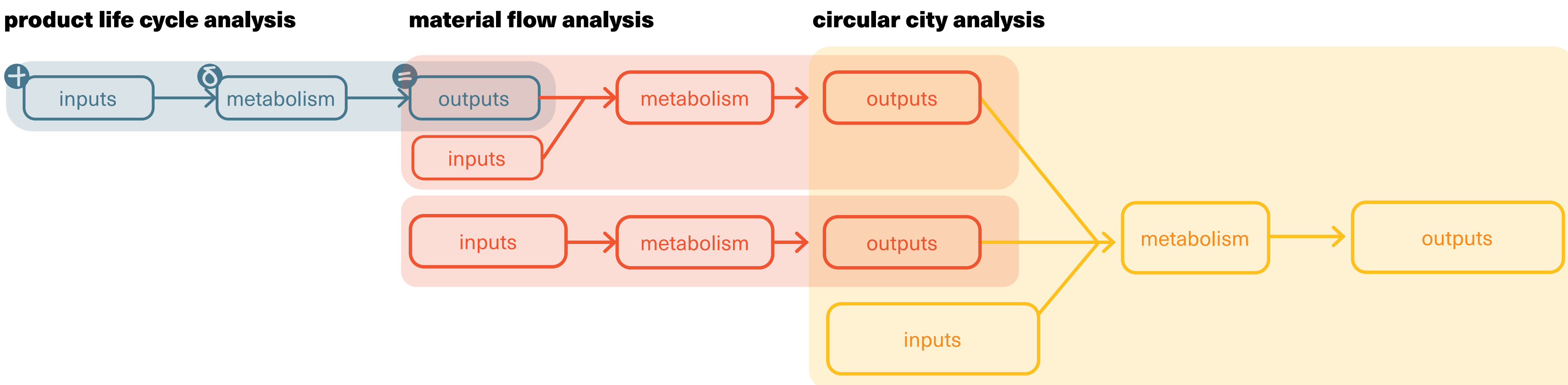
# PARCELS

*Vary in size and use based on zoning requirements*

+ Low embodied carbon materials for construction
+ Small renewable energy installations
δ On site energy storage
δ Efficient building and appliances
δ Maximize units
δ Housing orientation
= Adaptive reuse
= Water reuse / Stormwater management
= Reusing demolition or recycled materials

# Strategies at Nested Scales

*Nested Systems (scale and time)*




Assessing carbon intensity for urban systems is incredibly challenging - it requires quantifying the embodied carbon of everything entering the system as well as all greenhouse gas emissions that happen within the system and all carbon emissions when waste leaves the system. This is particularly challenging given the lack of transparency in global supply chains. For this reason, many third party organizations have formed to quantify different scales of material flows from the most granular level of product lifecycle analysis to much larger systems analysis (like a circular city analysis). Of course products and their lifecycle analysis are embedded in larger scale metabolic processes.

At smaller scales - like at the site scale - it is easier to quantify flows on the level of individual product inputs. At the city level, greater abstraction is required.

# Systems and Tools for Impact at Nested Scales

| | Certification or Calculator | Governing Body | Focus | Year Developed | Engaged Stakeholders |
|---|---|---|---|---|---|
| CARBON CONSCIENCE | Calculator | Sasaki | Quantifying embodied and operational carbon for site and early-phase design decisions | 2021-2022 | Design + Planning Firm; Local Communities; Business + Industry |
| THE Sustainable SITES Initiative | Certification | Green Business Certification Inc. | Nature positive landscape design; complementary with LEED | 2006-2014 | Design + Planning Firm; Governing Body; Local Communities; Business + Industry; Non profit + NGOs |
| climatepositive design | Calculator | Climate Positive Design | Quantifying carbon footprint of landscape design projects | 2019 | Design + Planning Firm; Governing Body; Local Communities; Business + Industry |
| U.S. GREEN BUILDING COUNCIL LEED USGBC | Certification | U.S. Green Building Council | Green building rating system; includes parameters for landscape design and can be combined with SITES | 1993-1998 | Design + Planning Firm; Governing Body; Business + Industry; Non profit + NGOs |
| CERTIFIED cradle to cradle | Certification | Cradle to Cradle Products Innovation Institute | Circular product certification program | 2002-2012 | Design + Planning Firm; Local Communities; Business + Industry |

Design + Planning Firm | Governing Body | Local Communities | Business + Industry | Non profit + NGOs

# DESIGN STRATEGIES

# Urban Design Strategies for Climate Protection

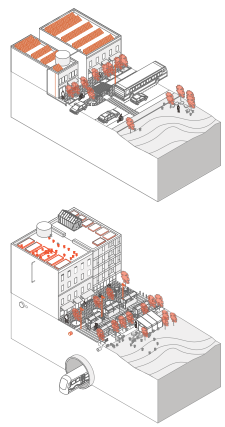
At all stages of the design process, there are trade-offs. Design is already a balancing act of creative ideas, community desires, client demands, key performance indicators, timelines, material availability, contractor technical skills, and more. It is therefore critical that, as designers of the built environment, we illuminate the co-benefits of climate responsible and positive design strategies.

The goal of this guide is to promote thinking about urban design and climate protection through urban systems as well as give clear pathways for action via climate responsible design strategies at the site scale in urban environments. This guide is not a comprehensive list of design strategies for climate protection, nor does it encompass the rigorous quantification of climate impacts of design strategies.

For this work, we chose five key systems where urban designers can typically have the biggest impact on reducing green house gas emissions. However, through material choices, and thoughtful lifecycle analysis, designers can also impact site scale end of life waste production, and industrial systems upstream.

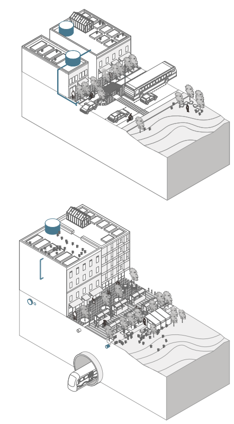
***** *These strategies double as both climate mitigation and adaptation. Win-win!*

## ENERGY



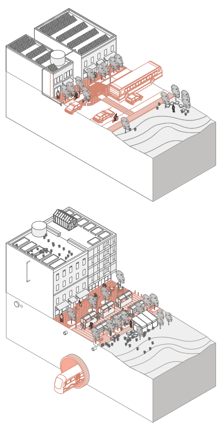
- Solar Generated Hot Water
- Street Trees*
- Cool Pavement*
- Optimized Electric Landscape Fixtures Photovoltaic (PV) Solar Panels
- Low Embodied Carbon Materials
- Underground Utilities
- Green Roof*
- Connection to District Heating and Cooling
- Energy Efficient Fixtures

## WATER



- Green Roof*
- Interpretive Signage
- Climate Adaptive Plantings*
- Cisterns
- Gravity Fed Drip Irrigation
- Bioretention Facilities*
- Healthy Soil Strategy*
- Mulch*
- Permeable Paving
- Gray Water Reuse

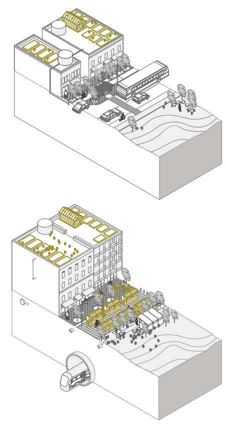
## TRANSPORTATION



- Active Transportation Infrastructure
- Bicycle Parking; Bike Sharing Location
- Electric Vehicle Charging
- Devoted Public Transit Space
- Pedestrian Amenities
- Highly Efficient Public Transit
- Moveable Streetscape Bollards

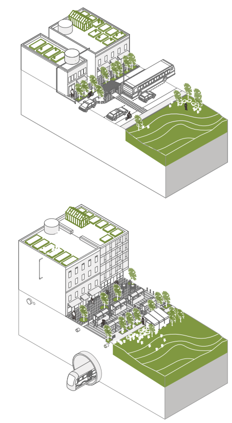
***Active transportation:*** *Human-powered movement that prioritizes physical activity, reduces reliance on motorized vehicles, and promotes health, sustainability, and community livability.*

## FOOD SYSTEMS



- Community Rooftop Garden*
- Farmers' Markets
- Food Trucks
- Urban Orchard/Food Forest*
- Food Recovery Network*
- Community Garden*
- Public Space = Local Food Scene*

## GREEN SPACE



- Alternatives to Mowed Turf
- Green Roof*
- On-Site Ecological Maintenance*
- Climate Adaptive Trees*
- Climate Demonstration Garden*
- Healthy Soil Strategy*
- Street Trees*
- Shared Greenway

*Systems not included in this design strategy work: Industry, Buildings, Waste*

# High and Low Carbon Intensity Contexts


### **High Carbon** Intensity Context

A high carbon context represents an extreme urban environment characterized by significant greenhouse gas emissions resulting from carbon-intensive practices, heavy reliance on fossil fuels, inefficient energy consumption patterns, and limited circular material use and economy.

### **Low Carbon** Intensity Context

A low carbon context signifies an ideal urban environment where greenhouse gas emissions are significantly reduced through sustainable morphology, renewable energy sources, energy efficiency measures, circular material use, and a focus on carbon mitigation.

All design choices should be informed by larger systems thinking. Regional context, in terms of land use and resource availability have huge consequences for how we should approach design at the district or site scale. It is, therefore, critical to consider how design strategies complement, accelerate, or augment existing carbon equations based on the nested scales explored on pages 20 and 21. Because design strategies at the site scale are so contingent on the larger scale systems they are embedded within, this chapter explores two possible scenarios at either end of the carbon intensity spectrum. The best use of public space from a greenhouse gas mitigation perspective is very different in each scenario.



## **High Carbon** Intensity Context

Houston, the fourth-largest city in the United States, serves as an example of a high carbon urban context. Known for its sprawling urban landscape and heavy reliance on the oil and gas industry, Houston faces significant challenges in reducing its carbon emissions. The city's extensive transportation network, industrial activities, and energy consumption contribute to its high carbon footprint.

**Houston, TX** *Carol Highsmith*

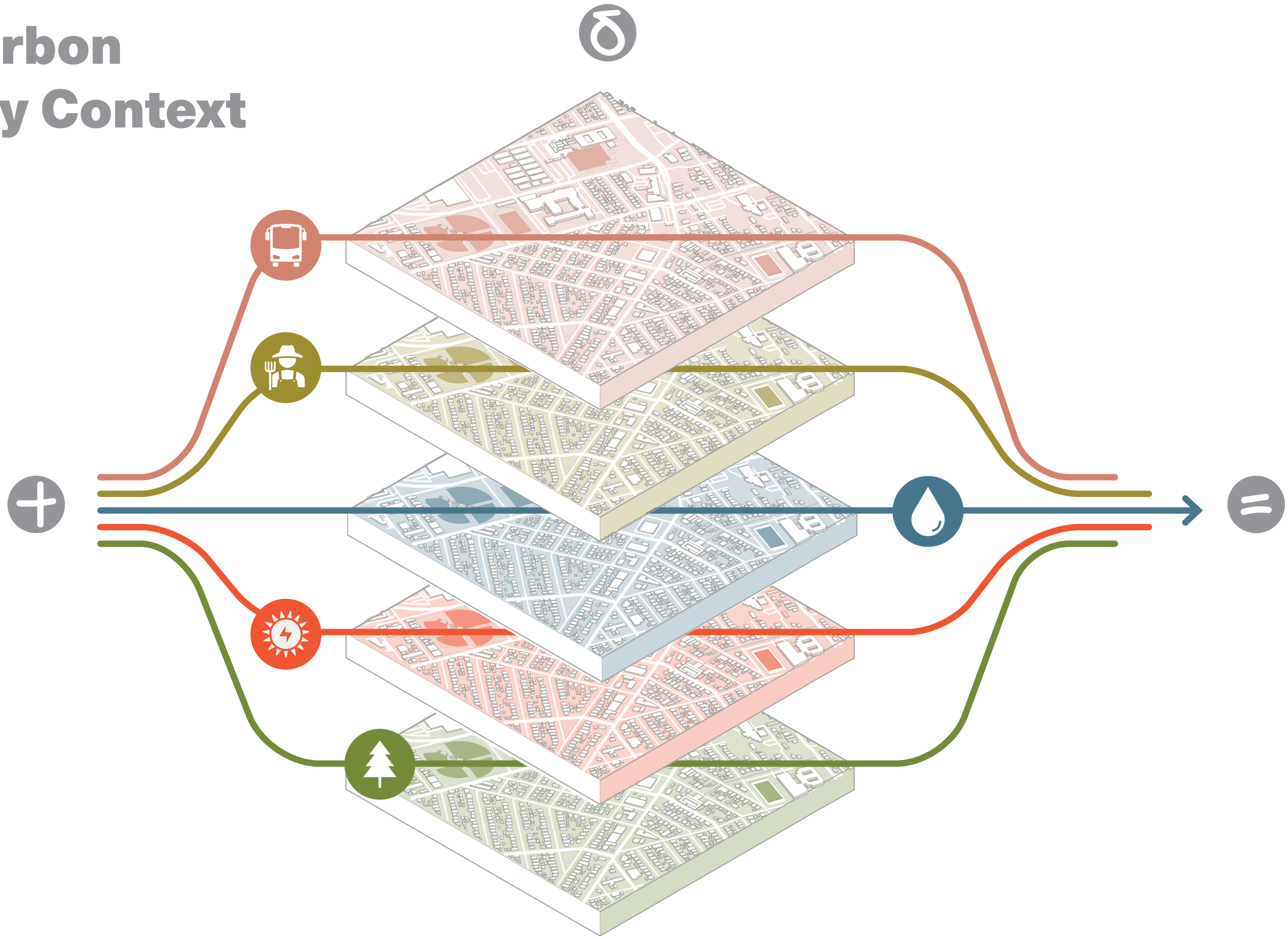


## **Low Carbon** Intensity Context

Copenhagen is a leading example of a low carbon urban context. Copenhagen's well-planned built morphology, with pedestrian-friendly streets, extensive bike lanes, and sustainable building designs, play a crucial role in shaping its low carbon context and fostering a sustainable and livable city.

**Copenhagen, DK** *Brookings Institute*

# High Carbon Intensity Context



## Inputs from Outside the Urban System

Regional highway and road network, no regional railroad or light rail networks.

Electricity generation is from fossil fuel combustion transmitted over long distances.

Fresh water is sourced and piped long distances.

Highly processed food from industrial scale mono-cultures.

Building and consumer products are produced from primary materials sourced all over the world.

## Metabolism within the Urban System

Most green space is on single family lots and is non-contiguous.

Water is not retained and used within the district.

Old energy grid cannot receive energy from small scale energy installations and loses significant energy during energy transmission.

Road network and buses are the only realistic option for transit powered by fossil fuels.

Sprawling residential with diffuse amenities.

## Outputs from the Urban System

GHGs produced from fossil fuel powered single occupancy vehicles and freight vehicles.

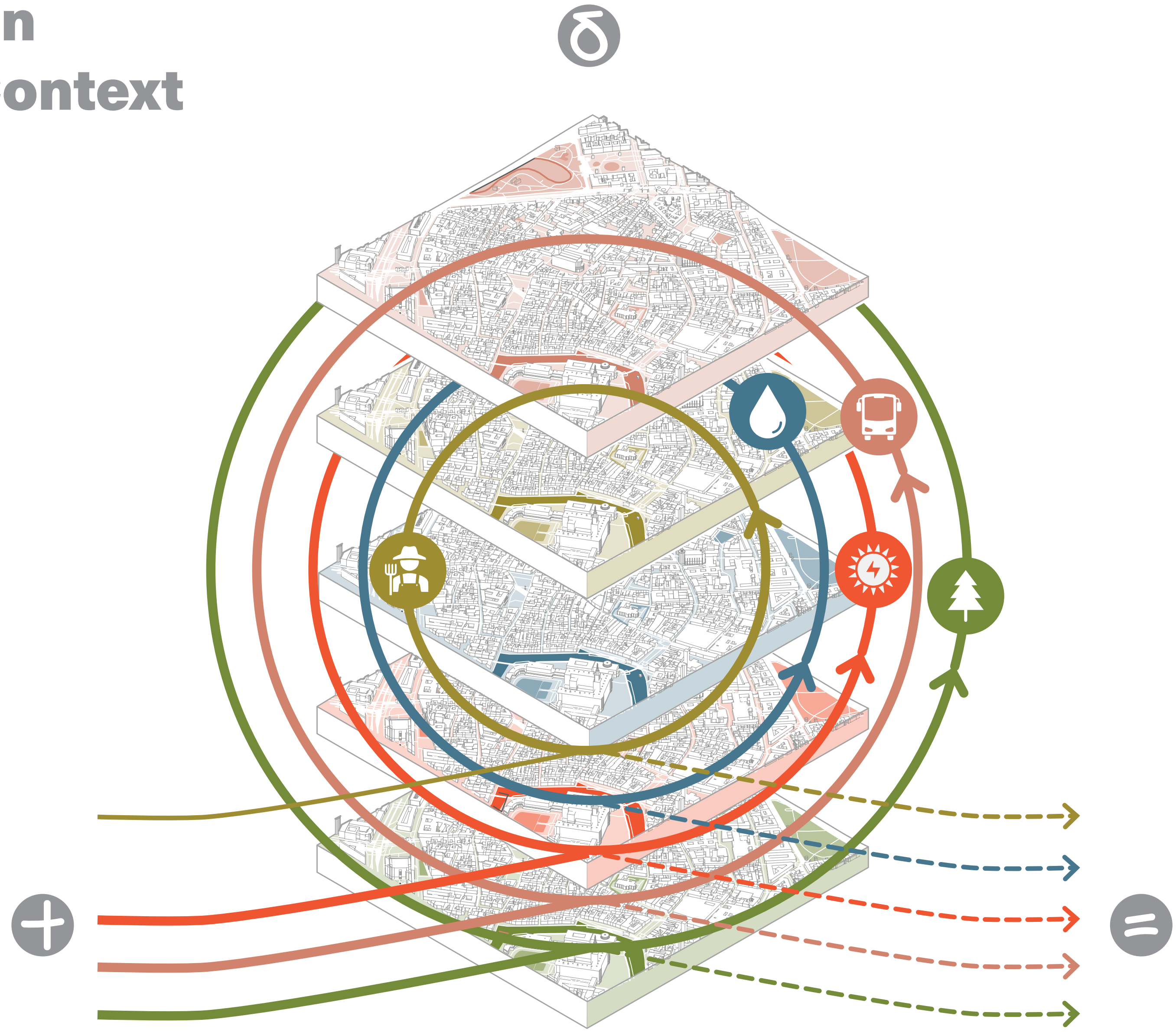
Unfiltered runoff carries pollutants downstream and can cause flooding and stress aquatic ecological communities.

Waste from products that are single use or quickly obsolete, no system for resource recovery, waste is transported to landfills

In the **high carbon intensity context**, sprawl is the defining urban form. This has many high carbon consequences. First is the reliance on a high volume of redundant infrastructure that serves a low volume of customers. The sourcing, construction, maintenance and retirement of all this redundant infrastructure represents huge quantities of embodied carbon (imagine a single large water main serving an entire apartment building of 30 units vs 30 single family homes each requiring their own separate hook up to a significantly longer water main - we're looking at huge pipe savings!).

Secondly, because of the prohibitive distances caused by sprawl, residents must drive to access work, school, healthcare, food and other essential amenities. Everyday goods are transported into the system by fossil fuel powered freight vehicles and waste is transported out, releasing green house gases yet again. Land use is dominated by single family housing meaning that community resources must be used to convince land owners to act in unison to further low carbon goals including installing renewable energy, detaining and reusing water on site,  and limiting peak electricity use.

# Low Carbon Intensity Context



## Inputs from Outside the Urban System

Regional low carbon transportation network connects dense urban clusters.

Land use decisions at the regional scale prioritize renewable energy installations in high yield locations. Regional smart grid utilizes a diverse and flexible fuel mix and loses very little energy in transmission.

Land use decisions at the regional scale preserve high quality farmland, which not only provides local food, but sequesters carbon in the soil.

Green space forms contiguous, undisturbed habitat that supports many ecological communities and sequesters carbon in organic material above and below ground.

Building and consumer products are sourced and produced as locally as possible from renewable materials and through resource recovery.

## Metabolism within the Urban System

Urban street canopy mitigates urban heat island effect, bioretention areas collect and clean stormwater, soil strategy sequesters carbon

Water is collected from roofs and used for systems within buildings that do not require potable water such as toilets and irrigation systems.

Small renewable energy installations provide electricity and hot water to buildings while energy efficient fixtures and appliances minimize energy use. Utilities incentivizes energy usage during peak production times.

In areas of highest density, pedestrians and bikers take over the right of way. High capacity transit is moved below ground to enhance the public realm.

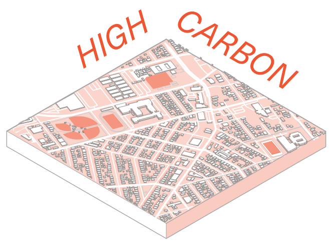
Mid rise density built from renewable materials minimizes embodied carbon, tight building envelopes prevent energy leakage. Adaptive reuse is prioritized.

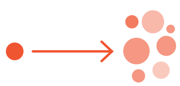
## Outputs from the Urban System

Green systems sequester carbon, removing atmospheric $CO^2$

In the **low carbon intensity context**, mid rise density is the defining urban form. City residents can work, shop and recreate within convenient walking, biking, or rolling distance of their homes thereby lessening the need for single occupancy vehicles. Urban life is defined by share economies where high energy intensity systems such as building heating and cooling function at an extremely efficient district scale. Public space operates as an extension of the home, lessening the need for large units.

Material flows are circular so that the system produces very little waste. Instead, materials and goods are built to last. This diminishes the need for replacement. When goods are replaced, they can be re-metabolized or reused in new industrial processes. Land use prioritizes energy and food production in highest yield locations. Water is harvested efficiently within the district, and local water resources are not depleted.

In this **high carbon intensity** context:

At the district scale, priorities to mitigate climate change include:

- Reducing electricity use
- Small community led renewable installations in high yield locations like rooftops

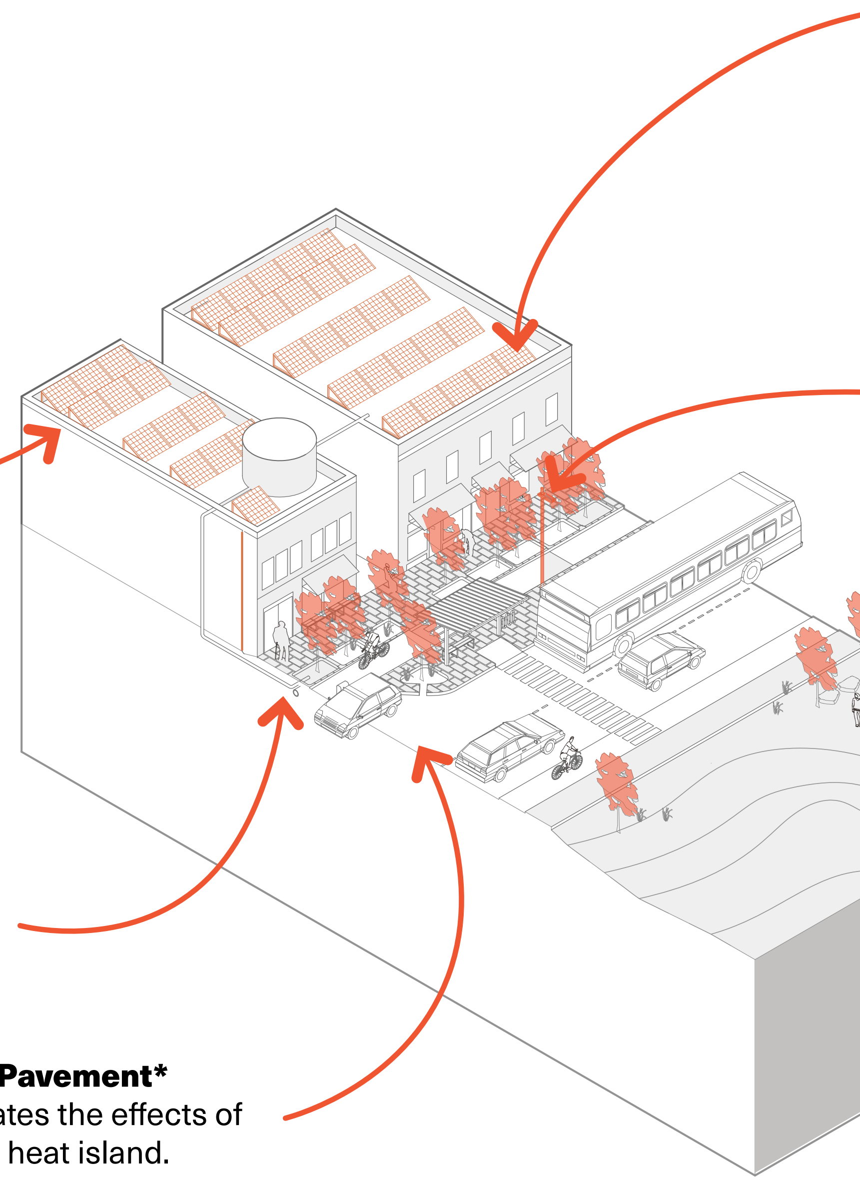
Urban design scale strategies include:

- High efficiency or renewable energy site appliances and fixtures

**Solar Generated Hot Water**
Thermal energy produced on building rooftops is used to produce hot water and reduces energy demands within building.

**Street Trees***
Mature street trees can reduce the need for highly energy inefficient air conditioning by lowering the ambient temperature of the streetscape.

**Cool Pavement***
Mitigates the effects of urban heat island.



**Photovoltaic (PV) Solar Panels**
Legible climate strategies such as solar panels provide accessible actions for homeowners, businesses, and community members to incorporate at the site scale. Renewable energy installations in public space act as demonstration projects that can inspire more widespread adoption on privately owned properties.

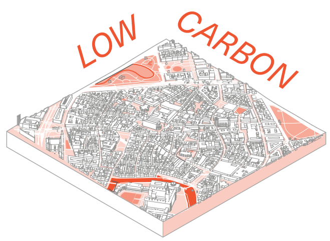
**Optimized Electric Landscape Fixtures**
Incentives given for using electricity during peak renewable energy production times. Street lights and other electric fixtures are only used when required based on occupancy and/or are responsive to changing daylight hours. These fixtures can also utilize and/or produce local renewable energy via microsolar or wind turbine installations for self sufficiency.

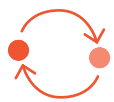
**Daramou House Green Roof**

*Sydney, Australia*

By combining a green roof with photovoltaic solar panels, this projects provides a multi-functional and carbon friendly rooftop. Plantings optimize solar efficiency by cooling the roof, and the solar arrays provide critical shade for the rooftop plantings.

# DESIGN INTERVENTIONS
*at the site scale*

In this **low carbon intensity** context:

At the district scale, priorities to mitigate climate change include:

- Reducing carbon emissions from material and transportation sources
- Energy Efficient building envelopes
- Passive house or similar requirements

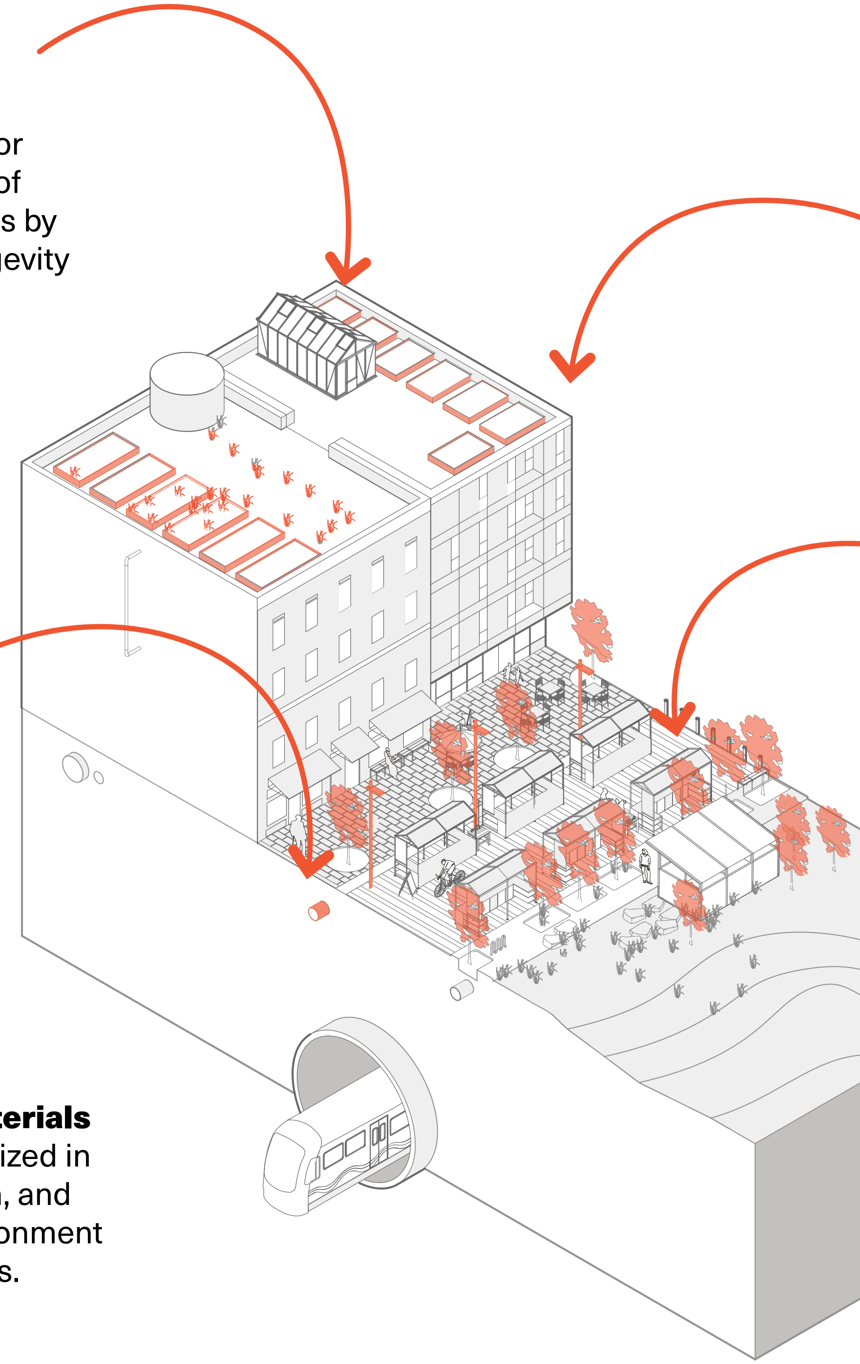
Urban design scale priorities include:

- Cooling the streets and improving the pedestrian experience
- Removing the need for additional energy inputs

**Green Roof***
Without the need for on-site renewable energy generation, this space can be prioritized for community use. The green roof reduces building energy needs by increasing insulation and longevity of the roof structure

**Underground Utilities**
By prioritizing the pedestrian experience and increasing energy resilience, buried utilities offer climate protection when compared to potentially vulnerable above-ground energy lines, and make way for abundant street trees.

**Low Embodied Carbon Materials**
Energy consumption is minimized in the production, transportation, and construction of the built environment via innovative material sources.



**Connection to District Heating and Cooling**
Centralized, district scale plants efficiently convey thermal energy to structures and thereby remove the need for redundant and energy inefficient heating, ventilation and air conditioning (HVAC) systems.

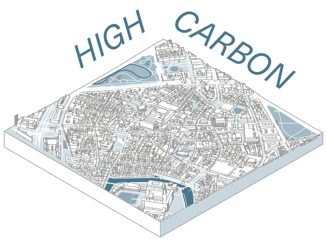
**Energy Efficient Fixtures**
Public amenities such as lighting, bathrooms, water fountains, and "trash" collection require very little or no electricity for daily use.

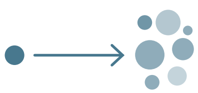
# DESIGN INTERVENTIONS
*at the site scale*

**Dutch Kills Green, Queens Plaza**

New York City, NY, US

By carving out impermeable pavement from the urban environment and using the reclaimed concrete on site, the Dutch Kills Green project drastically reduces energy required for material production, decreases the amount of fossil fuels used to transport demolition waste, sequesters carbon through abundant plantings, and improves pedestrian safety in a bustling neighborhood.

In this **high carbon intensity** context:

Priorities include:

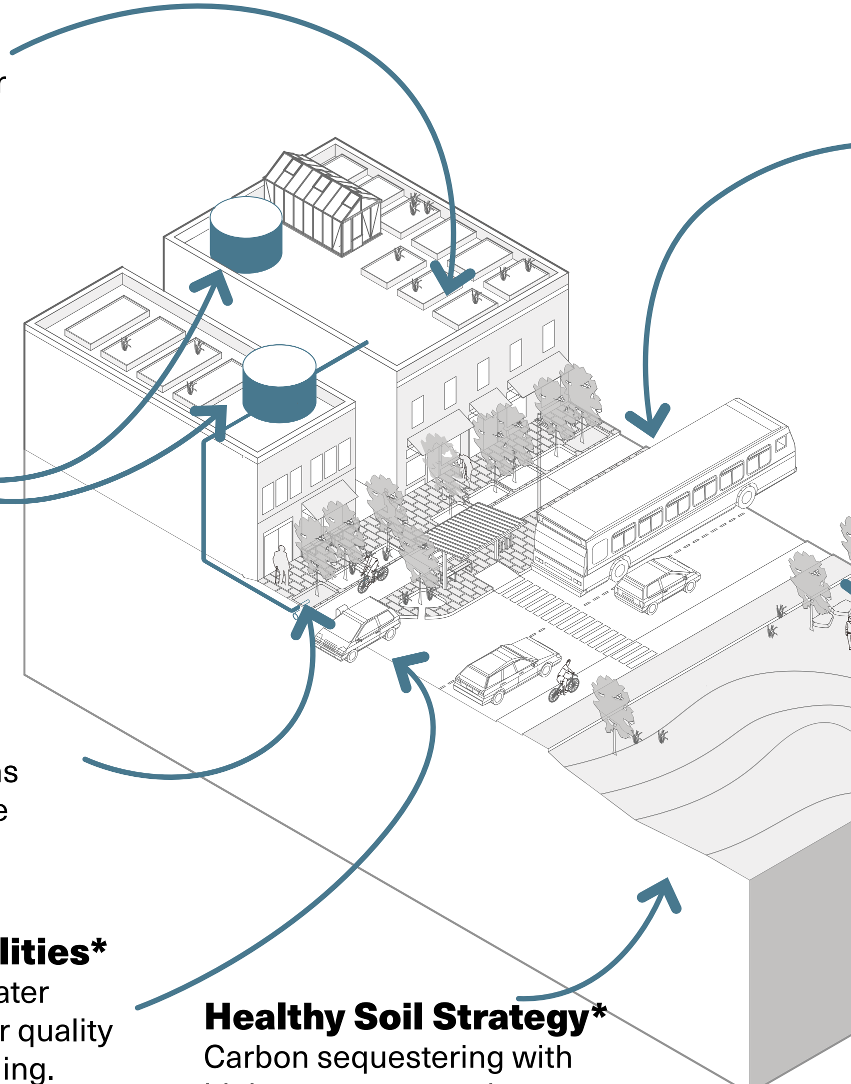
- Efficiently using potable water
- Reducing the need for pumping and treating water
- Reducing fossil fuel-powered maintenance of green infrastructure
- Increasing local community care and knowledge

Design strategies include:

- Incorporating on-site water treatment, storage, and use

**Green Roof***
Intercepts rainwater and helps prevent flooding.

**Cisterns***
Rainwater captured from adjacent rooftops can be used for gravity fed systems and reduces the need for pumping freshwater and helps delay or meter the amount of stormwater released.



**Gravity Fed Drip Irrigation**
By using water collected on-site, this strategy lessens the need for freshwater use in planting areas and helps prevent flooding.

**Bioretention Facilities***
Natural green stormwater systems improve water quality and help prevent flooding.

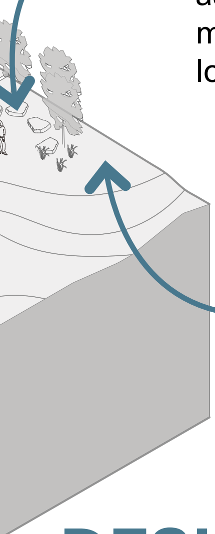
**Healthy Soil Strategy***
Carbon sequestering with high water storage due to abundance of organic material.

## Interpretive Signage

Helps illuminate the positive effects of green stormwater infrastructure and can help encourage private property owners to implement strategies on their properties.

## Climate Adaptive Plantings*

Drought and flood tolerant plant choices, in comparison with highly intensive plant choices, can reduce water use as well as emissions related to maintenance and increase the longevity of natural systems.



## Mulch*

Supports water retention and natural weed suppression

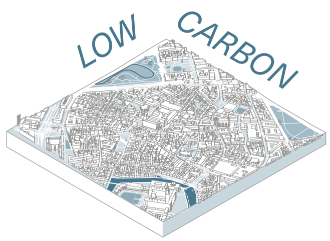
# DESIGN INTERVENTIONS

*at the site scale*

**South Los Angeles Wetland Park**

Los Angeles, California, U.S.

Developed on a brownfield remediation site, this multifaceted project provides critical green space, habitat, and stormwater filtration while also generating nearly all of the energy it consumes via solar lighting.


In this **low carbon intensity** context:

Priorities include:

- Eliminating unnecessary use of potable water
- Reducing stormwater runoff
- Using clean greywater close to collection location
- Reducing the need for pumping and treating water

Design strategies include:

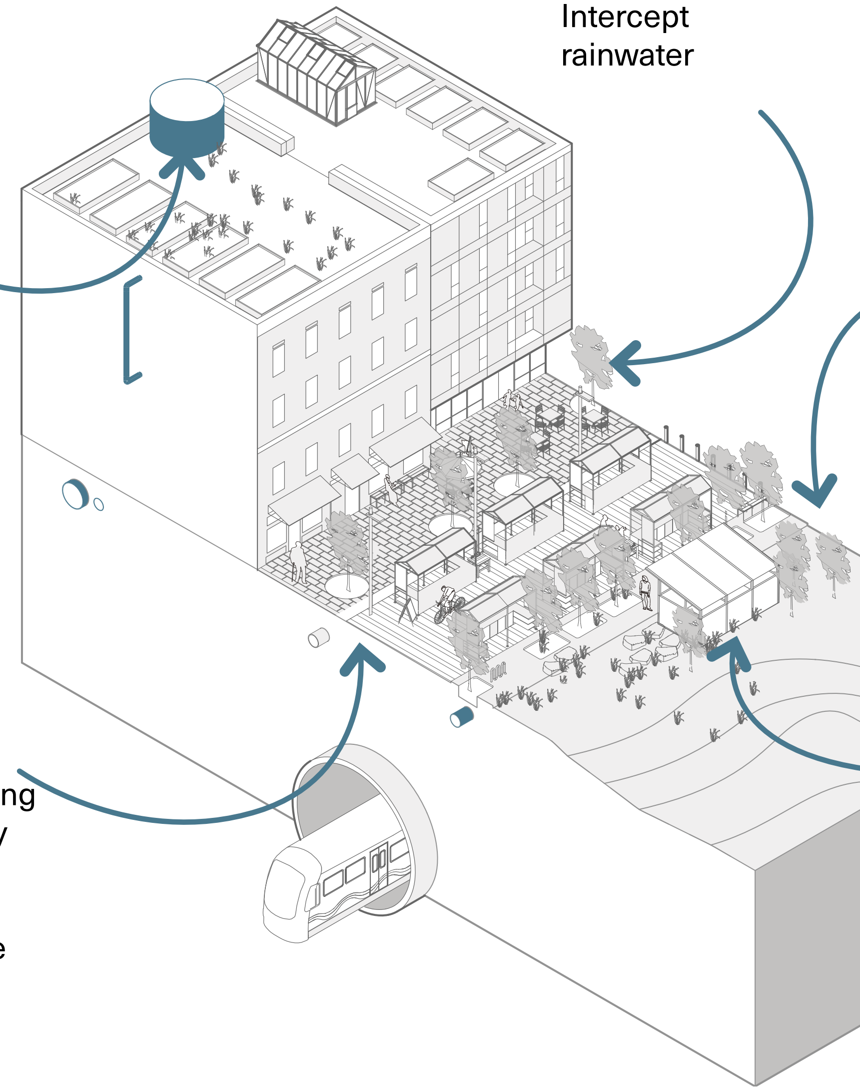
- Bioswales
- Soil strategies that retain water

**Cisterns***
Capture and utilize rainwater on site and add redundant water sources.

**Street Trees***
Intercept rainwater

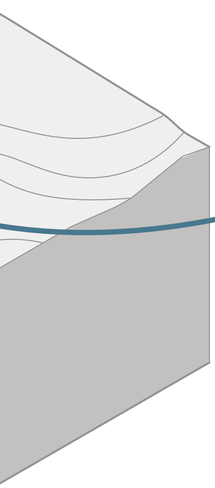
**Gray Water Reuse**
***Gray water generated from buildings is treated and used in buildings for toilets or irrigation.***

**Permeable Paving**
Keeps water on site and allows infiltration removing volume from high energy municipal waste and stormwater processing. Additionally, restores the water table.



**Rain Garden***
Adaptable plantings in biochar media to sequester carbon and filter pollutants. Routine maintenance ensures function and aesthetics.

**Gravity Fed Drip Irrigation**
Utilizes cleaned greywater from district scale infrastructure.



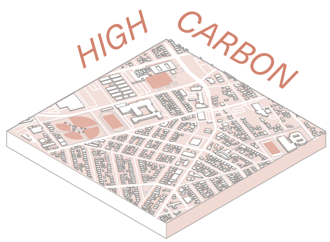
# DESIGN INTERVENTIONS
*at the site scale*

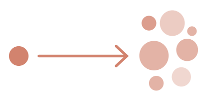
**Bridget Joyce Square Community Rain Park**

London, England

This public park and stormwater filtration powerhouse not only adds lush greenery to a once paved over part of London, but it also serves as a transformative pedestrian safety amenity to an area near an elementary school and playgrounds once riddled by aggressive vehicular traffic.

# TRANSPORTATION



In this **high carbon intensity** context:

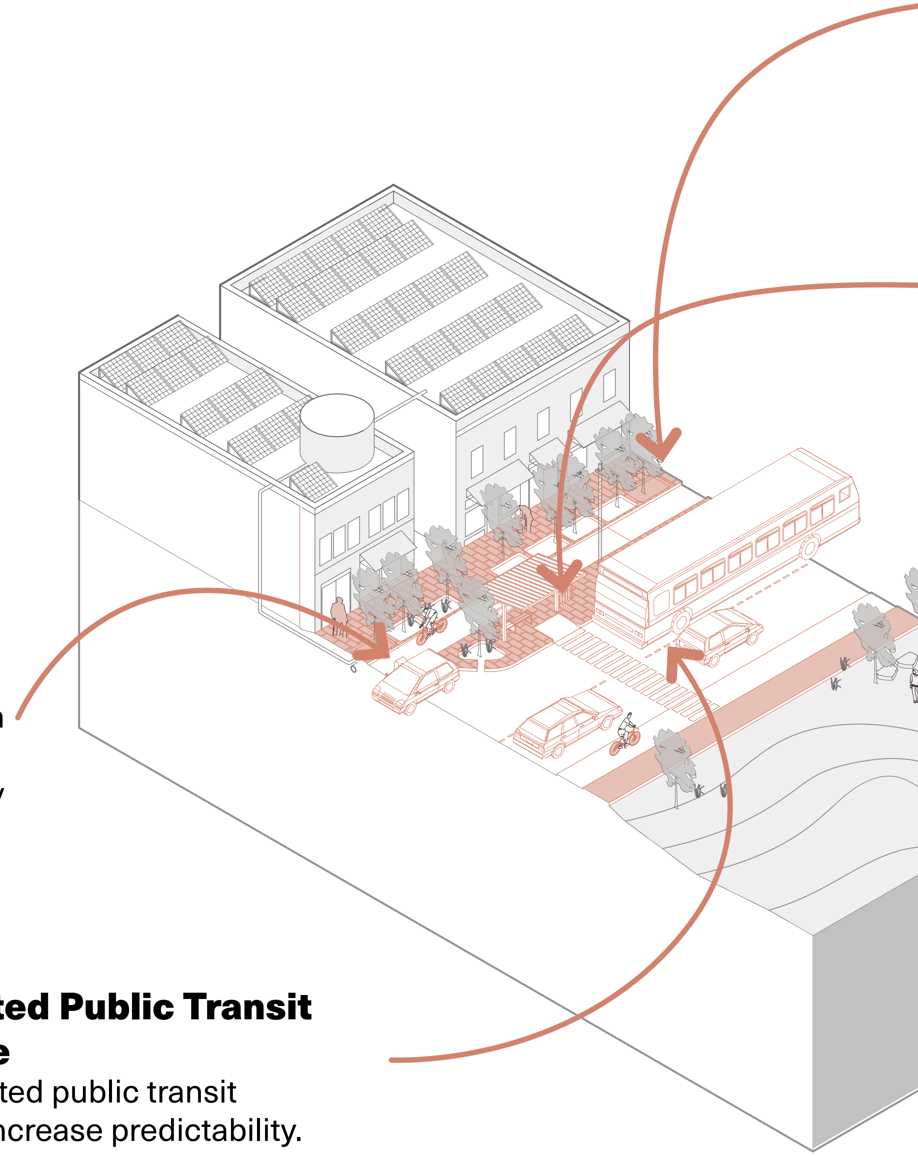
Priorities include:

- Reducing single occupancy vehicle (SOV) use and vehicular congestion
- Supporting electrification of existing transportation networks

Design strategies include:

- Streetscape improvements
- Amenities for cyclists, pedestrians, and transit users along key transit corridors

**Electric Vehicle Charging**
EV charging run from on site renewable energy installations uses locally produced energy and supports lower carbon transportation options.



**Devoted Public Transit Space**
Dedicated public transit lanes increase predictability. Comfortable and protected transit stops improve transit use experience and encourage climate friendly transportation choices.

**Active Transportation Infrastructure**
Bike lanes and sidewalks installed in key locations around high density and commercial zones increase lower carbon transportation options.

**Bicycle Parking; Bike Sharing Location**
Provides convenience and access for bicyclists.

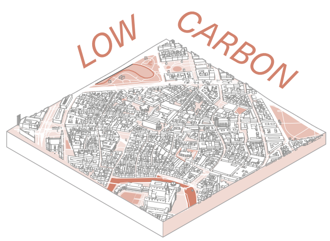
**Eje Ambiental, Transmilenio (Bus Rapid Transit) Station**

Bogota, Colombia

By increasing the frequency, reach, and comfort of Bogota's BRT system, the city is reducing emissions, improving air quality, and getting closer to citywide climate goals while serving all of its citizens.

## DESIGN INTERVENTIONS
*at the site scale*

# TRANSPORTATION




In this **low carbon intensity** context:

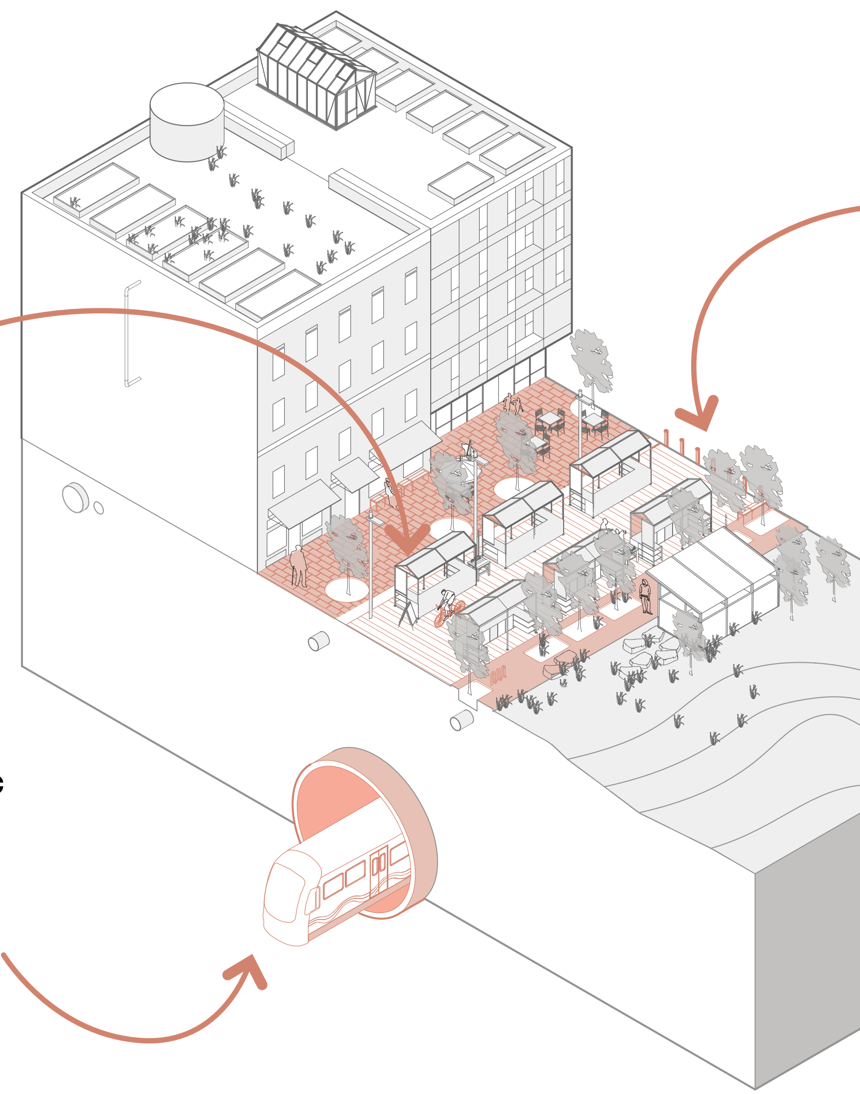
Priorities include:

- Highly connected active transit network at street level
- Highly efficient public transit network below ground

Design strategies include:

- Making a delightful public realm that prioritizes people with diverse programming

**Pedestrian Amenities**
Benches, lighting, public restrooms, shelters and drinking fountains increase comfort and accessibility for navigating public space.



**Highly Efficient Public Transit**
Underground transit opens up the public realm to people oriented programming while moving high volumes of riders predictably and frequently.

**Moveable Streetscape Bollards (Car Impediments)**
Multifunctional structures support pedestrian safety and clearly delineate and support a car-free public realm. Freight vehicles can access businesses during low pedestrian volume times.

**Bicycle Parking; Bike Sharing Location**
Provides convenience and access for bicyclists.

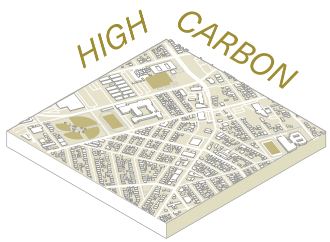
# DESIGN INTERVENTIONS
*at the site scale*

**Lille Langebro (Little Long Bridge)**

Copenhagen, Denmark

Pedestrian and bicycle bridges provide critical connections for citywide mobility. By linking popular waterfront destinations, Lille Langebro makes the biking experience even more pleasant and encourages carbon-friendly transportation choices.

# FOOD SYSTEMS




In this **high carbon intensity** context:

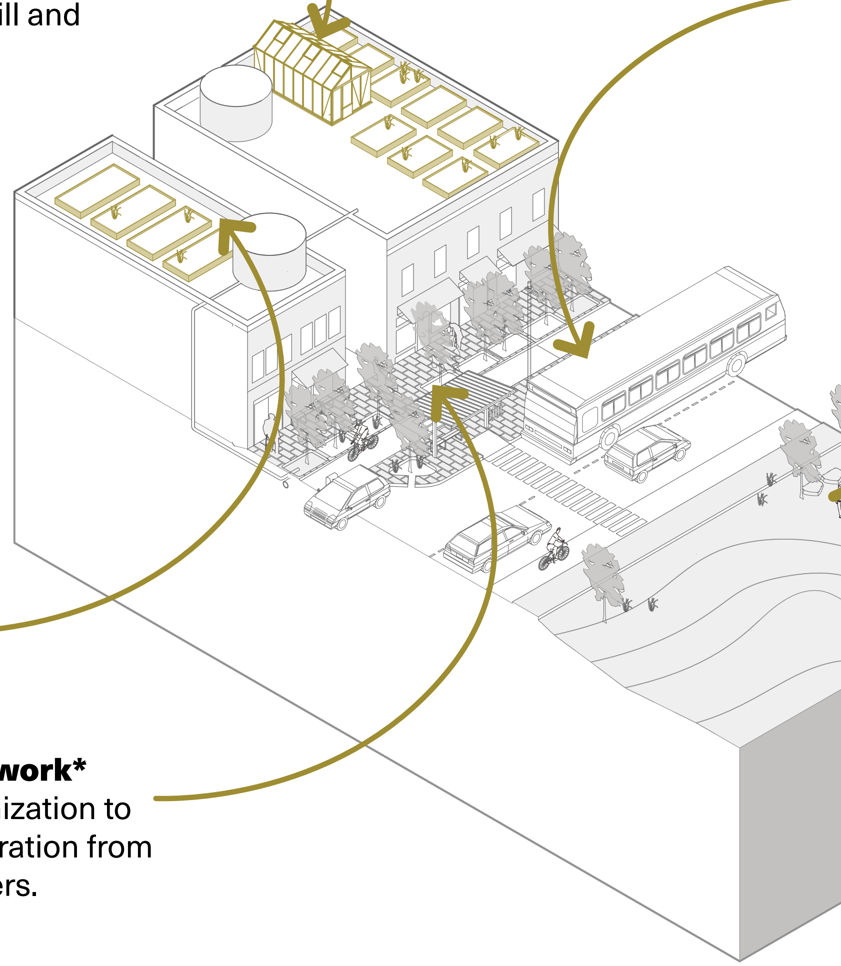
Priorities include:

- Growing food on site to improve food access and decrease the need for highly processed and transported food

Design strategies include:

- Rooftop gardens
- Demonstration gardens and "P-Patches" in public space

**Community Rooftop Garden***
Growing space for community members offers local food production and on-site composting which diverts food waste from the landfill and enriches soil.



**Urban Orchard/Food Forest***
Edible street trees can provide gleaning opportunities.

**Food Recovery Network***
Community run organization to collect food near expiration from restaurants and grocers.

**Food Trucks**
Mobile food trucks create opportunities for small businesses with low upfront capital investment. Existing ample surface parking can be leveraged to increase local food security.

**Community Garden***
Utilizing small household plots can increase food security and decrease the need for importing fresh produce.

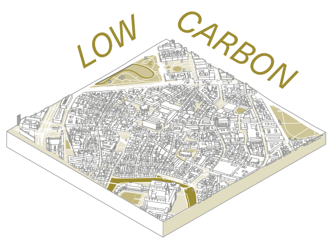
# DESIGN INTERVENTIONS
*at the site scale*

**Lak Si District Office Rooftop Garden**

Bangkok, Thailand

On the roof of the local government's office building, this rooftop garden now provides plentiful and nutritious produce for the local community and also serves as a teaching space for expanding urban agriculture, increasing food sovereignty, and ensuring climate resilience.

# FOOD SYSTEMS




In this **low carbon intensity** context:

Priorities include:

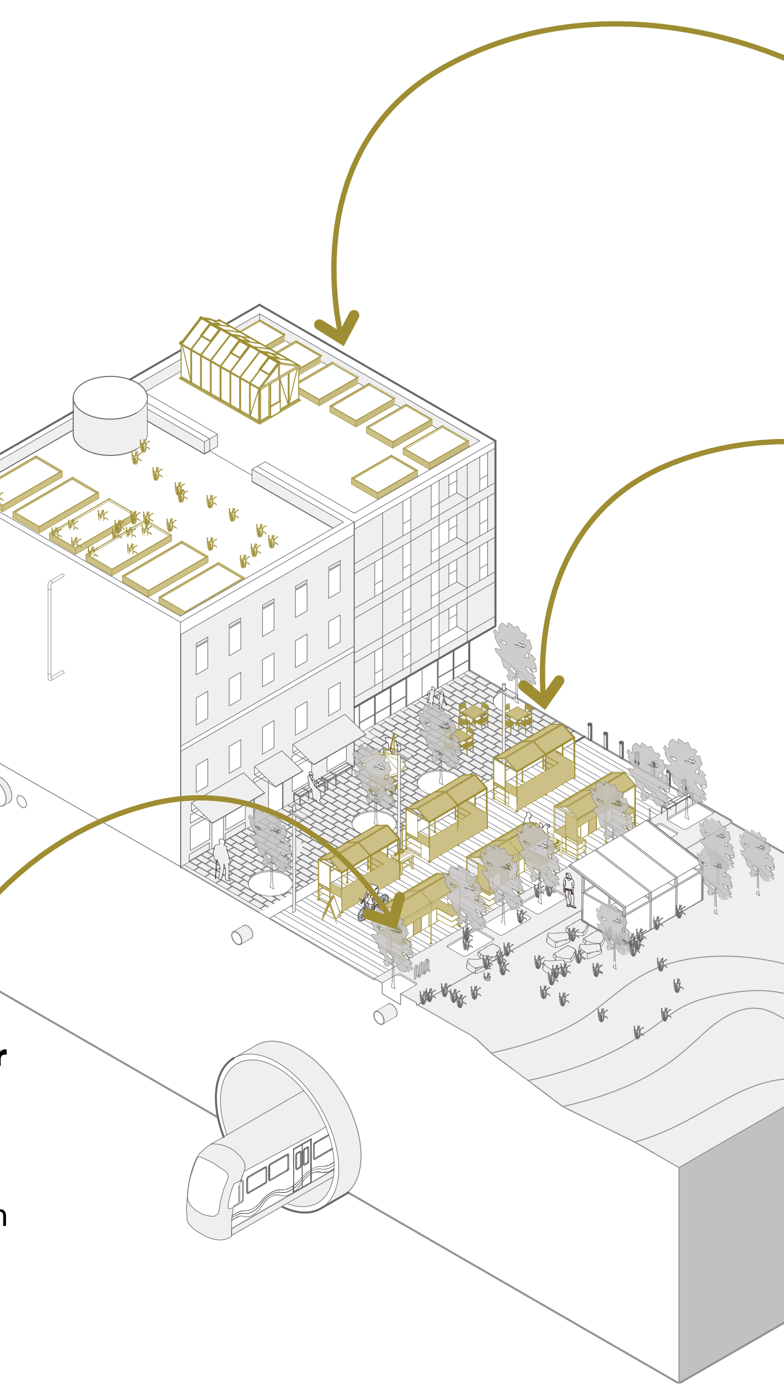
- Opening up public space to local food production and consumption
- Recovering food waste and composting locally

Design strategies include:

- Creating flexible public space with facilities for markets, gathering and sitting

**Community Orchard or Food Forest***

Some park space can be converted from low performing turf to carbon sequestering and food producing food forest.



**Rooftop used for Gardening***
Because renewable energy is being produced efficiently off site, rooftops can be devoted to community gardens and gathering space.

**Public Space = Local Food Scene***
Streets are easy to close for events and markets. Flexible seating provides places for people to rest and eat.

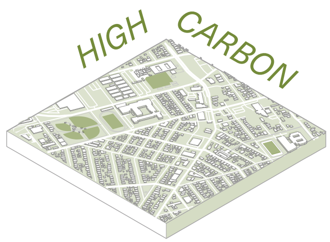
# DESIGN INTERVENTIONS
*at the site scale*

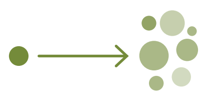
**Le Cours OASIS, Schoolyard Program**

Paris, France

By utilizing underused public space at local schools in central Paris, Le Cours OASIS program provides much-needed shaded green space for urban heat island mitigation, reduces the need for air conditioning by cooling the nearby air temperature, and promotes urban agriculture through ample vegetable and herb gardens for students and community members.

# GREEN SPACE



In this **high carbon intensity** context:

Priorities include:

- Educating the public about carbon sequestration and living systems
- Increasing the carbon storage of existing green spaces

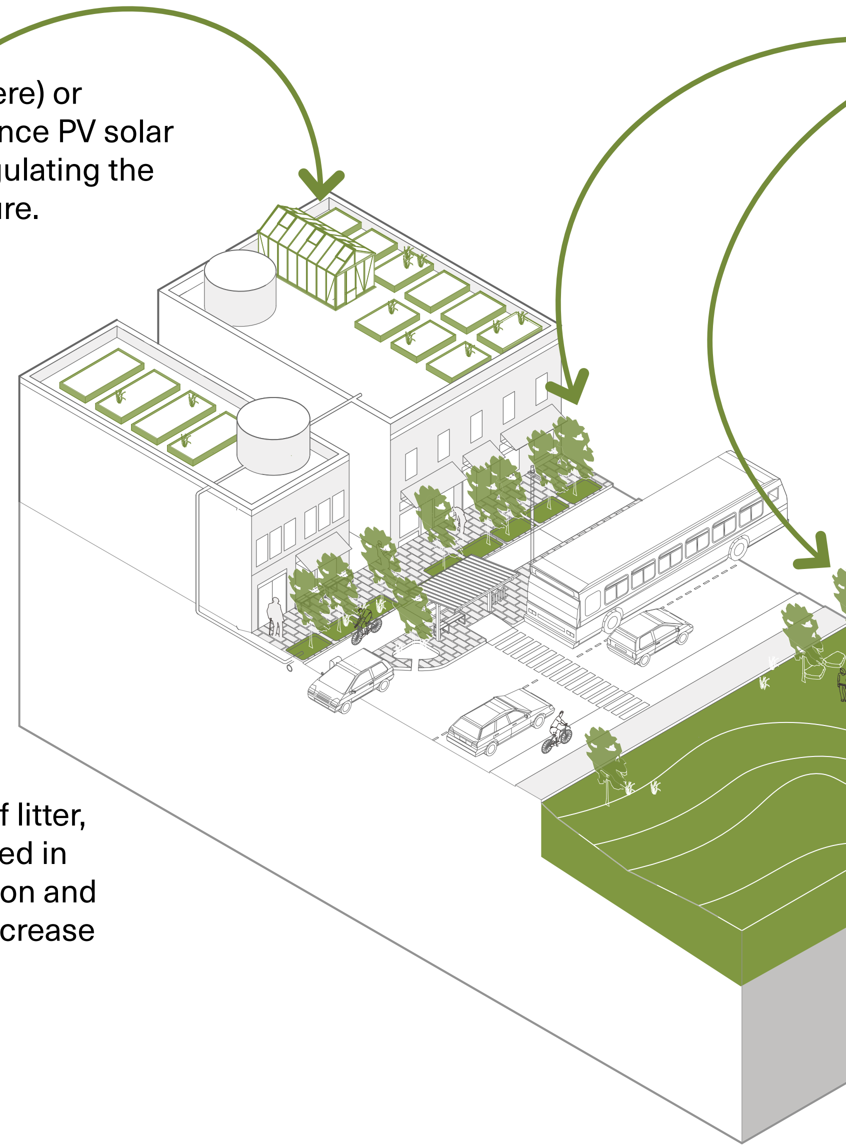
Design strategies include:

- Replacing turf with higher performing ecological communities
- Improving soil strategy to maximize carbon storage

**Green Roof***
Intensive (shown here) or extensive can enhance PV solar performance by regulating the rooftop's temperature.

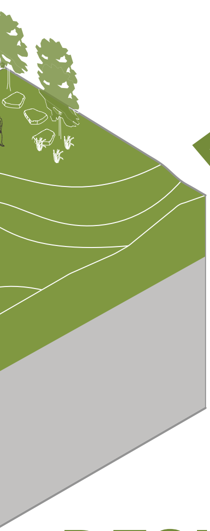
**Mulch***
Supports water retention and natural weed suppression

**On-Site Ecological Maintenance***
Leaving woody debris, leaf litter, snags removes carbon used in maintenance, transportation and waste disposal and can increase soil carbon storage.



**Climate Adaptive Plants***
Naturalized plant communities and trees support optimal carbon sequestration and are more resilient to the effects of climate change. Climate adaptive designs can create resilient pollinator pathways and enhance biodiversity.

**Climate Demonstration Garden***
Carbon sequestering demonstration garden features legible, climate adapted plant palette based on the local biome to showcase suitable plant choices.



**Healthy Soil Strategy***
Compost and biochar amendments can improve the site's soil, carbon storage, and nutrient availability for plantings.

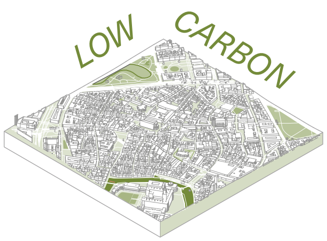
# DESIGN INTERVENTIONS
*at the site scale*

**Carbon Lane at Hyväntoivonpuisto (Park of Good Hope)**

Helsinki, Finland

Embedded within a larger linear park in the capital city, the Carbon Lane project is notable as both a community engagement process and demonstration project to test and showcase the use of biochar, a biomass byproduct and soil amendment that sequesters carbon, improves soil health, and can improve plant health.

# GREEN SPACE




In this **low carbon intensity** context:

Priorities include:

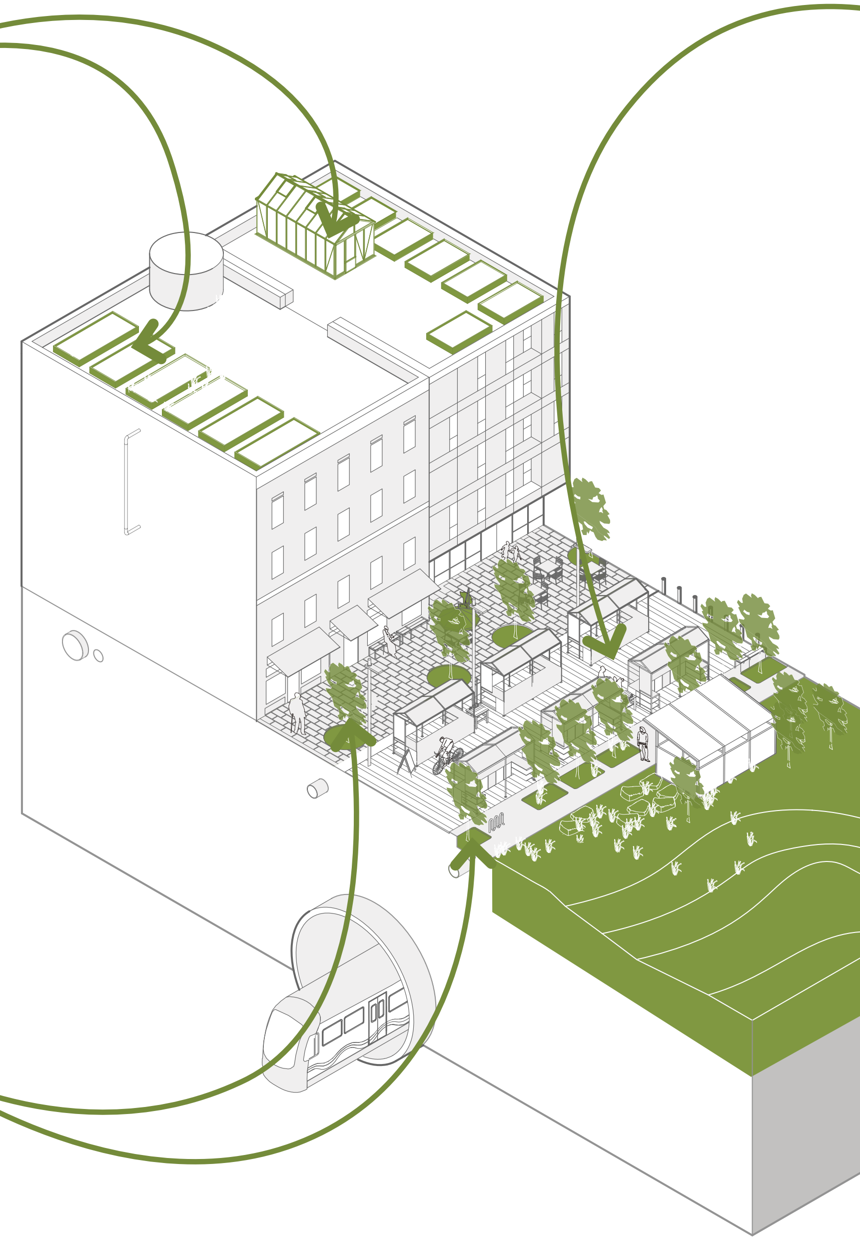
- Reducing paving or hardscapes
- Adding planting and permeable areas
- Supporting local biodiversity

Design strategies include:

- Choosing climate adapted and locally appropriate plant species

**Green Roof***
Intensive (shown here) or extensive can enhance PV solar performance by regulating rooftop temperature and provide insulation for buildings that lose heat through their rooftops. Intensive green roofs require significant structural support.

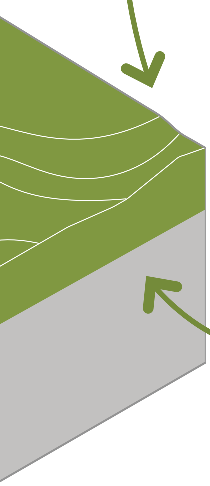
**Street Trees***
Well maintained and climate adapted tree species planted in Silva Cells or structural soil for optimal tree health.



**Shared Greenway**
Less room for cars means more room for green corridors. Single lane roads leave ample space for green stormwater infrastructure and other types of contiguous plantings like pollinator pathways.

**Alternatives to Mowed Turf**
These refer to different landscaping practices and strategies that can be used instead of maintaining large areas of regularly mowed grass. They can act as carbon sinks and reduce the urban heat island effect

**Healthy Soil***
Compost, biochar amendments, mulching and natural maintenance can improve the site's soil, carbon storage, and nutrient availability for plantings.



# DESIGN INTERVENTIONS
*at the site scale*

**Passeig de Sant Joan Boulevard**

Barcelona, Spain

Permeable, green space intertwined with a major transportation network cools the urban environment, offers pedestrians a pleasant place to rest, and creates easily accessible outdoor living rooms.

# RESOURCES + REFERENCES

# Image Sources

All graphics or images produced by the authors unless otherwise noted.

pg. 6 Key Definitions

Energy created by Alzam from the Noun Project

pg. 23; Understanding Impact at Nested Scales

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