FUTURE STREETS

LEVERAGING AUTONOMOUS SHARED VEHICLES FOR GREATER COMMUNITY HEALTH, EQUITY, LIVABILITY AND PROSPERITY

AUGUST 2021

TABLE OF CONTENT


Alley Street

INTRODUCTION

AUTONOMOUS VEHICLE TRANSFORMATION

A little more than hundred years ago, we took an animal out of our transportation system – horses – and replaced them with the much greater horsepower of automobiles and trucks, which were safer than dealing with horses, cheaper than stabling horses, and cleaner at least in terms of the pollution that horse manure created. A hundred years later, we are in the process of removing another animal from our transportation system – people – for much the same reason. Self-driving or autonomous vehicles (AV's) are safer, cheaper, and cleaner than driven cars and trucks and they will become a major part of how most of us move around in the next decade or two.

Safer than current cars and trucks, AV's utilize systems – radar, lidar, and other sensors – long used in the aerospace industry. These technologies have evolved to such an extent that they are now very effective in preventing collisions, as we know from airline accidents, which are almost always the result of pilot error during takeoff or landing. With well over 90% of car accidents caused by driver error, bringing these aerospace technologies into ground-based vehicles will greatly reduce injuries and deaths on our roads.

Cheaper than owning a car or truck, AV's are part of a shift in the auto industry toward the provision of mobility services, where companies will make vehicles and instead of selling them to us, they will offer us mobility on-demand. It remains to be seen whether mobility services follow a fee-for-service model like the current ride-sharing companies, or a subscriber-based model as some car companies have begun to do, or an advertiser-based model, which would make the ride itself free. But whatever model becomes most common, all would offer us mobility at a much lower cost than what it takes to own and operate a car or truck now.

Cleaner than most of the cars and trucks we drive, AV's will be powered by electricity or possibly fuel cells, which will greatly reduce air and noise pollution. And the reason for this is simple. If the car companies are going to own and operate the vehicles as part of their mobility services, they want technology that is inexpensively operated and easily maintained, which is the case for electric cars and trucks.

While many people affirm their love of cars – as many people did their horses a hundred years ago – the fact that AV's are overwhelmingly safer, cheaper, and cleaner makes the economics of the autonomous vehicle, mobility service revolution in our transportation system unstoppable. This does not mean that driven vehicles will disappear. Like the riding of horses, the driving of automobiles will continue to occur, mostly in rural areas for reasons of safety and liability. Driving cars will also become what it once was at the beginning of the 20th century: an expensive hobby. The expense will come largely from high insurance rates, which increase as the insured pool of high-risk drivers shrinks as more people switch to mobility services. And like stabling horses, storing cars will typically happen outside of urban and suburban areas. Eventually, drivers will be banned from metropolitan areas except for the police and other emergency personnel, who will be able to continue driving vehicles in the city, just as they are allowed to ride horses there.

The transition from a horse-drawn transportation system to a horse-powered one took roughly two decades in the early 20th century, where old photos show almost no cars on urban streets in the early 1900's and almost no horse-drawn vehicles there by the early 1920's. The transition from driven vehicles to AV's may take that long – or less time, given the greater speed with which the 21st economy operates and the significant profits that car companies will realize as they shift from being goods-producing to service-providing businesses.

AUTONOMOUS VEHICLE INFRASTRUCTURE

What changed in the early 20th century was not just the type of vehicles on our roads, but the nature of the roads themselves. As cities, suburbs, and small towns went from accommodating horses and horse-drawn vehicles to accommodating drivers and driven vehicles, roads went from having a primarily dirt and gravel surface to having a surface of pavers - cobbles or paving bricks - and eventually continuous pavement of concrete or asphalt. The hydrology of our road system also changed in the transition from horses to cars, as we went from pervious surfaces, with swales or ditches handling major rain events, to impervious surfaces, with curbs and gutters channeling stormwater to below-grade sewers and eventually to our waterways.

AV's will involve an equally dramatic change in our roadway infrastructure. Unlike drivers who tend to wander within their lanes as they drive and so require a continuously paved road surface to accommodate that movement, AV's maintain the same path, with little or no wander as they move down a roadway. Research by the Minnesota Department of Transportation has shown that the precision of AV's movement leads to repetitive wear on the road surface, rutting softer materials like gravel or asphalt relatively quickly. Most of the research on AV's has assumed that roads themselves will not change, but the work documented in this publication has assumed the opposite. AV's will require a different kind of road than those built for driven vehicles and we need to understand that difference, especially now, as the U.S. invests in the repair and upgrade of its transportation infrastructure to stimulate the economy and to repair or replace roads and bridges in poor condition.

AUTONOMOUS VEHICLE PUBLIC REALM

AV-ready roads will likely combine aspects of both the horse-drawn carriage road, with its pervious surface, and the horse-powered car or truck road, with its impervious surface. To handle the repetitive wear of precisely guided AV's, roads will need to have wear-resistant tracks or grade beams with high-strength concrete to ensure greater longevity. Those tracks, which accommodate the AV's tires, will constitute only about 10-33% of the road surface. The remainder of the road can then have a pervious surface, which in turn will allow stormwater to percolate into the road bed and recharge the aquifers below. This in turn will enable cities to abandon their expensive and environmentally damaging stormwater sewer system, a savings that can perhaps be used to help pay for AV infrastructure. For large storm events, former surface parking lots – many of which will no longer be needed as the demand for parking greatly diminishes in a mobility service future – can become constructed wetlands and retention ponds that can hold large amounts of rain water when necessary.

The drawings on the following pages show the work that the staff and students of the Minnesota Design Center have done to illustrate the nature of AV-ready alleys, local streets, collector streets, and arterial streets. We illustrate the pervious and impervious materials and their composition in AV-ready streets and the phases of work as we transition from streets designed to accommodate drivers to ones designed to handle AV's. We also show the elements of an AV-ready street and the zones within the public right away for AV's, bikes, scooters, and pedestrians, as well as the green infrastructure and street planting possible in these streets.

With each street type, we provide an overview of the existing condition and its AV alternative, with calculations related to planting, stormwater retention, heat island effects, and material costs. We also show cross-sections through each street type to indicate the below-grade conditions of AV-ready streets and how they compare to what we do now. In all cases, the AV-ready streets outperform existing ones in several areas: carbon sequestration, stormwater runoff, heat-island mitigation, and material costs. And while we do not calculate the savings that come from abandoning the storm sewer system, that too will be a considerable amount of money.

CONCLUSION

The full transition of our streets and roads from the accommodation of horses to cars took longer than the transition to the vehicles themselves: many rural areas still have dirt or gravel roads over one hundred years after the shift in our transportation system. The transition of our current road infrastructure to one that is AV-ready will likely take a long time to evolve as well. Which is why we need to begin now. The auto industry is moving rapidly to an AV-based, mobility service business model and once these vehicles become common, their negative impacts on our roads will quickly become apparent. With major investments in transportation-related infrastructure underway or about to begin in many nations around the world, we need to stop putting in 20th century streets, based on out-of-date assumptions about street design and vehicle needs, and start installing AV-ready streets in preparation for what is to come. We hope the material in this publication will help communities move in that direction.

Thomas Fisher
Director

RESEARCH TEAM

THOMAS FISHER
Minnesota Design Center
Director and Co-Principal

JOSEPH HANG
Minnesota Design Center
Senior Research Associate

JAVKHLAN "JAVA" NYAMJAV
Minnesota Design Center
Research Associate

CHON FAI "CHARLIE" KUOK
Minnesota Design Center
Research Associate

MATHIAS HUGHEY
Minnesota Design Center
Research Associate

JOSEPH FAVOUR
University of Minnesota: College of Design
Head of Landscape Architecture

BRUCE JACOBSON
Bruce Jacobson Landscape Architecture
Landscape Architect and MDC Affiliate

CREDITS

The work was funded as part of a National Science Foundation Smart and Connected Communities grant # 1831140, Leveraging Autonomous Shared Vehicles for Greater Community Health, Equity, Livability, and Prosperity (HELP). Support also came from the Dayton Hudson Foundation funds at the University of Minnesota Foundation.

DESIGNING FOR FUTURE STREETS


Local Street
Right-of-Way

RESEARCH ASSUMPTIONS

POLICY ASSUSMPTIONS

Autonomous Vehicles (AV's) will:

- offer a safer, cleaner, and cheaper alternative to cars
- become prevalent by 2040 as driven cars are banned from metropolitan streets
- rely upon on-demand platforms that people can use to access mobility
- be part of a mobility-as-a-service (MaaS) model, reducing transportation costs
- largely eliminate the need for parking as vehicles remain in continuous operation
- greatly reduce the number of vehicles on the road as they increase in efficiency
- respond to people on-demand, challenging fixed schedule transit systems

PUBLIC REALM

AV-ready streets will:

- have concrete, grade-beam tracks and pervious, planted surfaces
- have fewer and narrower lanes than those today, allowing more space for people
- be equipped with real-time information, and integrated sensor technologies
- become places for neighborhood gatherings and community destinations
- accommodate diverse modes of transportation as travel lanes decrease in width
- provide space for community uses never possible on busy streets before

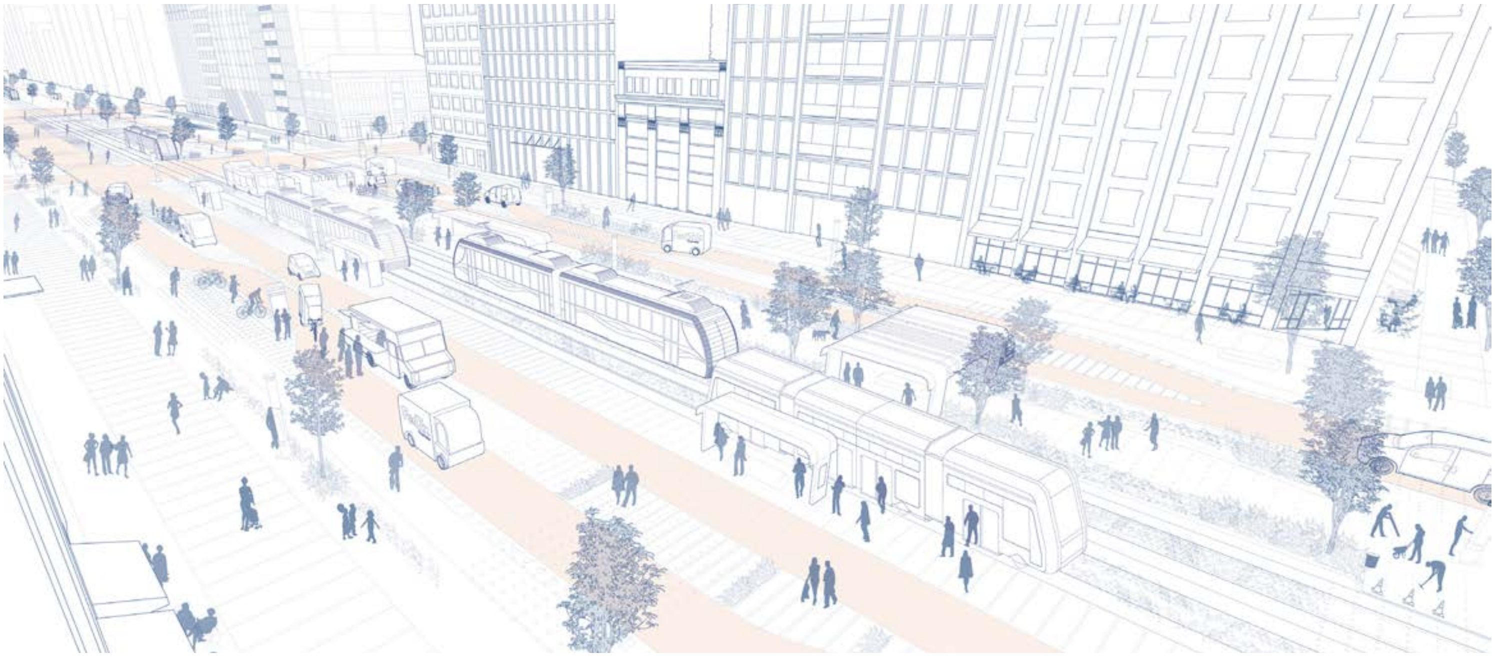
CLIMATE CHANGE

AV's will:

- help reduce heat Island effects, as streets become healthier and shadier
- help reduce carbon emissions because of the electric drivetrain on cars
- handle much of the first-mile/last-mile need with on-demand services
- reduce stormwater run-off as streets become more pervious
- increase green space as well as the storage capacity of major storm events

1

3



2

4

5

(1 - Google's Autonomous Vehicle, 2 - NACTO's Blueprint for Autonomous Urbanism, 3- MDC's Future Streets, 4 - Boulder, Colorado, 5 - Detroit, Michigan)

STREET TYPES

AL **ALLEY** (20' - 0", typical)
Service and rear access streets, typically found in urban areas and residential neighborhoods.

LO **LOCAL** (40' - 0", typical)
Residential streets with pedestrian sidewalk and street parking on both sides.

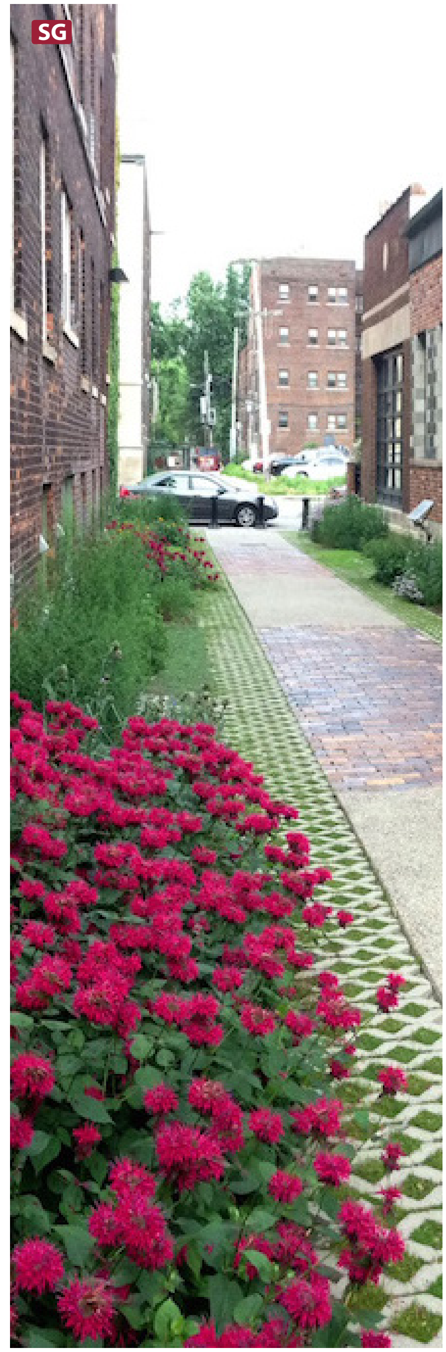
CO **COLLECTOR** (60' - 0", typical)
Streets connecting residential streets to commercial and industrial areas. Surface parking lots, street parking, public transportations (multi-modal transitways), shared bicycle lanes, and wider pedestrian sidewalks are often found adjacent to collector streets.

AR **ARTERIAL** (80' - 0", typical)
Streets connecting high volume traffic (interstates, highways, boulevards) to and from urban areas/downtowns. Surface parking lots, street parking, parking ramps, public transportations (multi-modal transitways), shared and dedicated bicycle lanes, and wider pedestrian sidewalks are often found adjacent to arterial streets.

SG **SHARED GREEN** (varies)
Streets that incorporate Green Infrastructure (Green and Blue strategies) to reduce and manage stormwater. These strategies are meant to improve water quality, reduce runoff and heat island effect, restore native ecosystem, provide public space, and preserve natural landscape in urban areas.

AL

LO



(Alley, Local, Collector, and Arterial Streets - Minneapolis, Minnesota, Shared Green Street - Detroit, Michigan)

STREET MATERIALS
ASSEMBLY AND COMPOSITION

AC **ASPHALT CONCRETE PAVEMENT**

BA **BASE AGGREGATE** (ROCK)

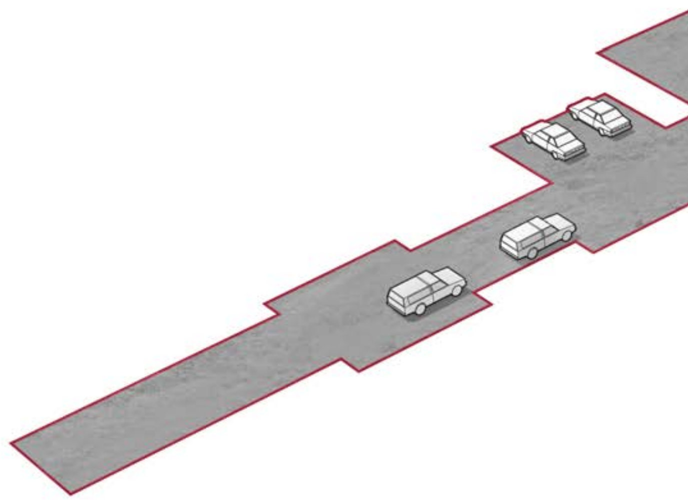
CA **COARSE AGGREGATE**
(Recycled Asphalt Concrete Pavement)

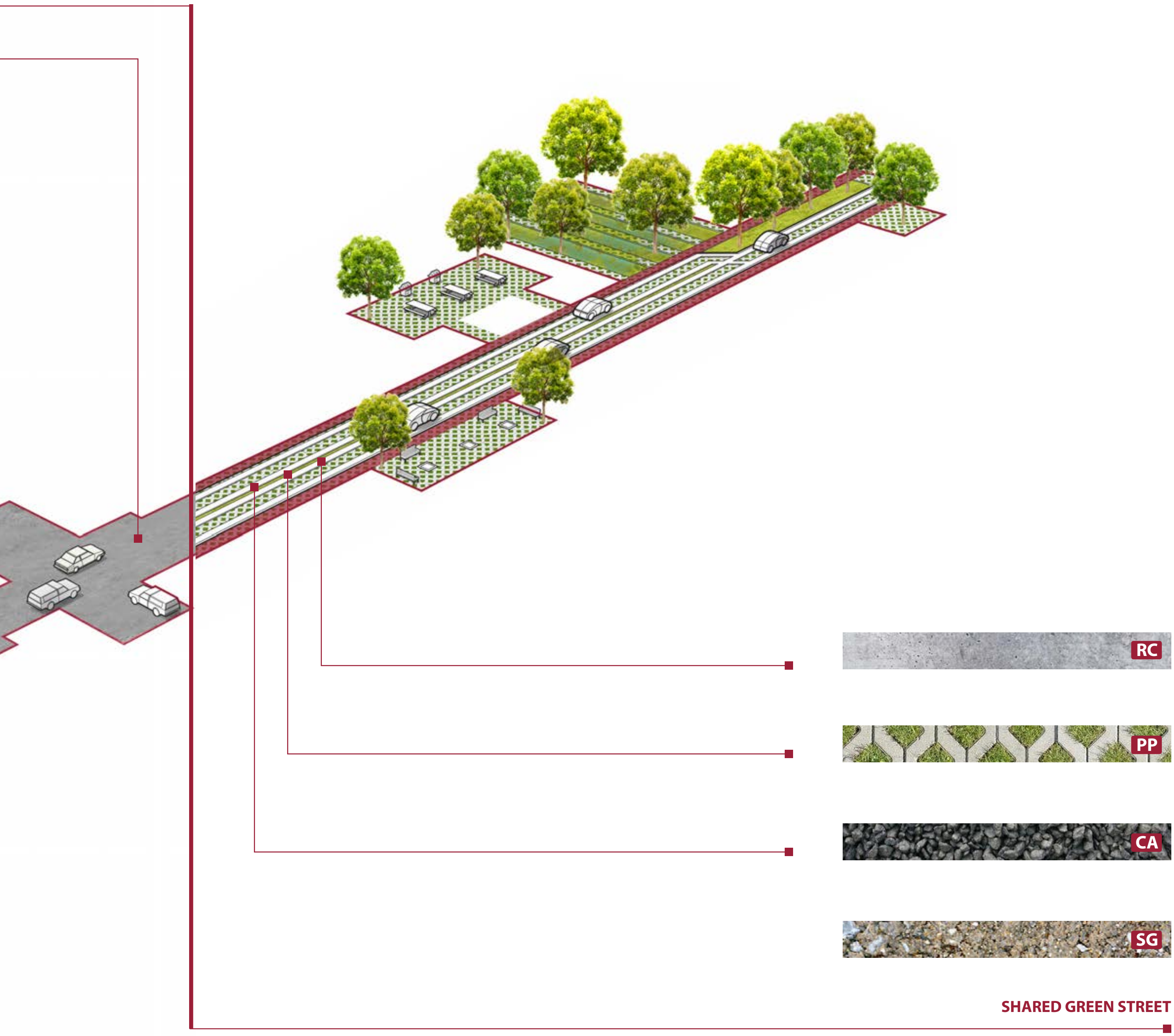
PP **PERMEABLE PAVERS/ PLANTING SOIL**
(See Green Infrastructure and Street Planting)

RC **REINFORCED CONCRETE** (AV TRACKS)
(Sloped Edges and Heated)
2' - 0" wide, 6' - 0" OC

SG **SUB-GRADE**

EXISTING STREET




RC
PP
CA
SG
SHARED GREEN STREET

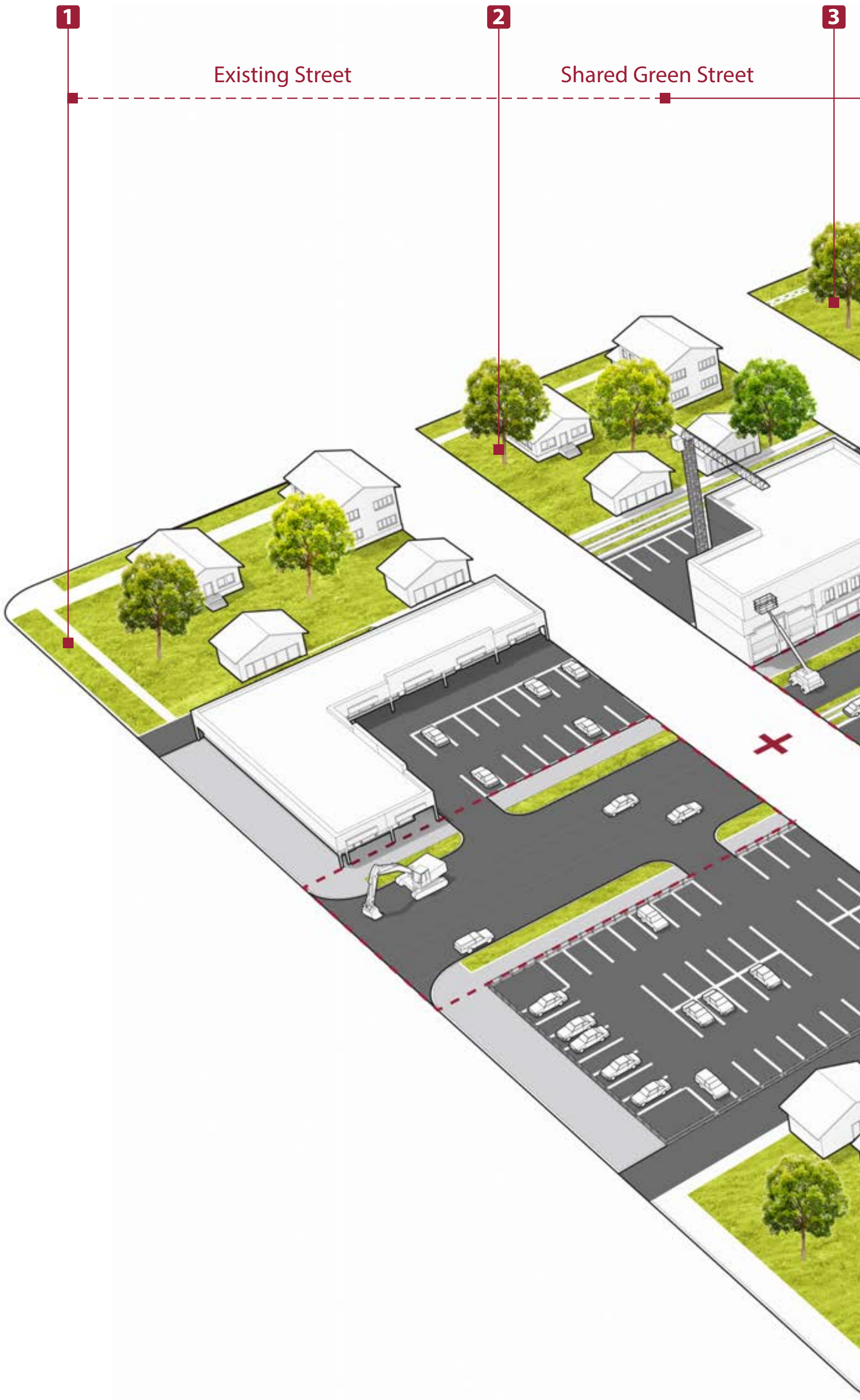
STREET PHASES
TRANSITION

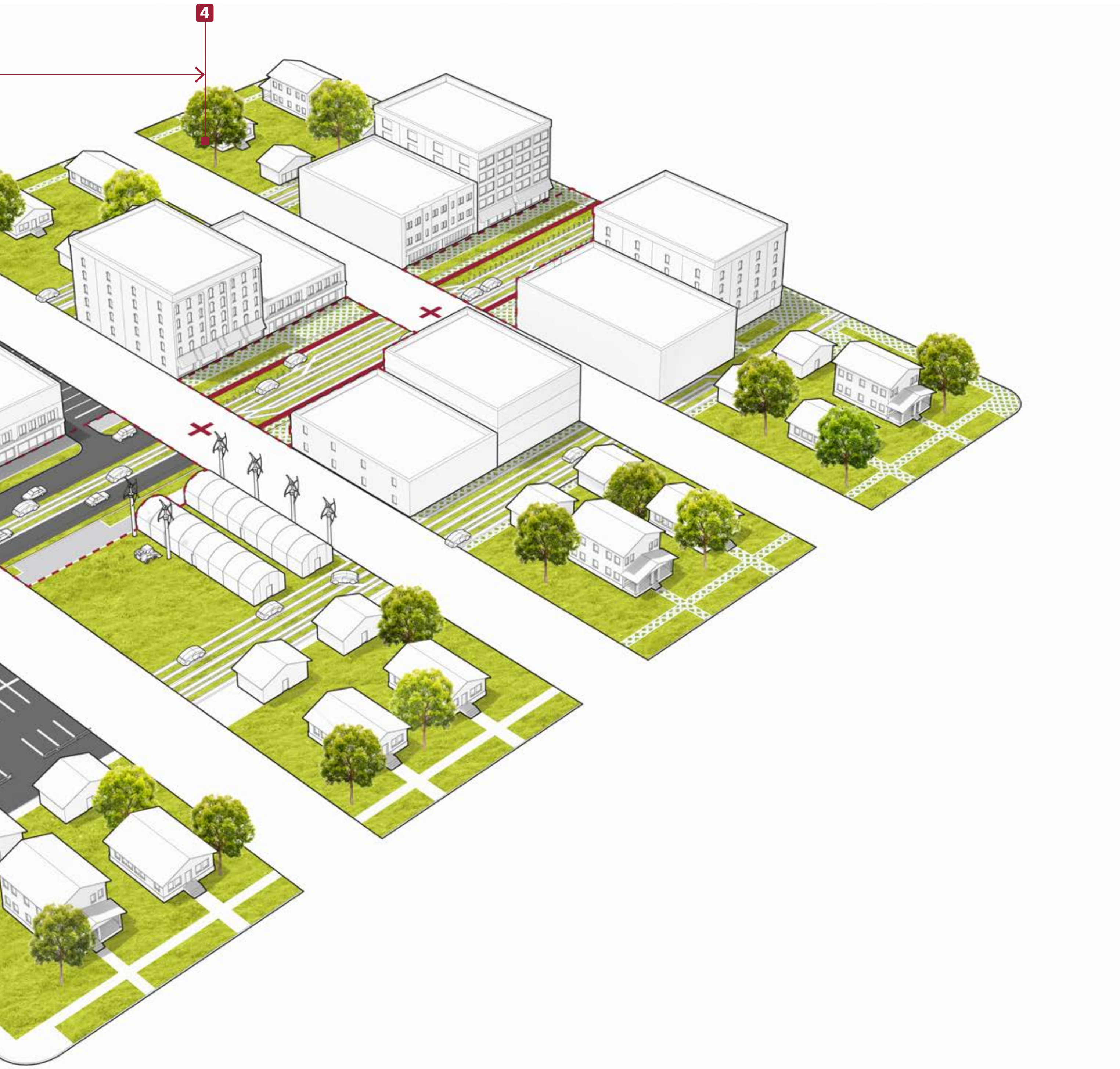
1 In the first-phase of transitioning from driver-oriented to AV-ready streets and from car-oriented parking requirements to a future of mobility services involves assessing the location of below-ground utilities and the amount of surface paving materials that can be reused as part of the new construction. With 30% of the land area in most municipalities devoted to the movement and parking of cars, the amount of material available for reuse will be substantial.

2 In the second phase, the streets become a hybrid of both driven vehicles and AV's, each with their own dedicated lanes in order to avoid accidents in which drivers run into AV's – and almost never the other way around. This phase also begins to see mobility services rendering surface parking lots superfluous as that land gets repurposed as stormwater retention ponds, urban greenhouses, solar or wind farms, and other uses of benefit to communities.

3 By the third phase, the AV-ready streets are in place, with concrete grade-beam tracks for the AV's and pervious paving or planted medians covering the remainder of the road surface. Reused concrete and asphalt from the previous streets form the aggregate base and subsurface for the new roads. Also, new development begins to fill in where surface parking lots formerly stood, increasing the tax base of the municipality.

4 By the fourth phase, the transition to fully automated streets is complete. Driven cars are no longer allows on urban and suburban streets because of the hazard they create for both AV's as well as bicyclists and pedestrians. Meanwhile, dedicated bike lanes have been created on most streets to encourage self-propelled transportation, and sidewalks have become much wider as the number and width of AV lanes have decreased.

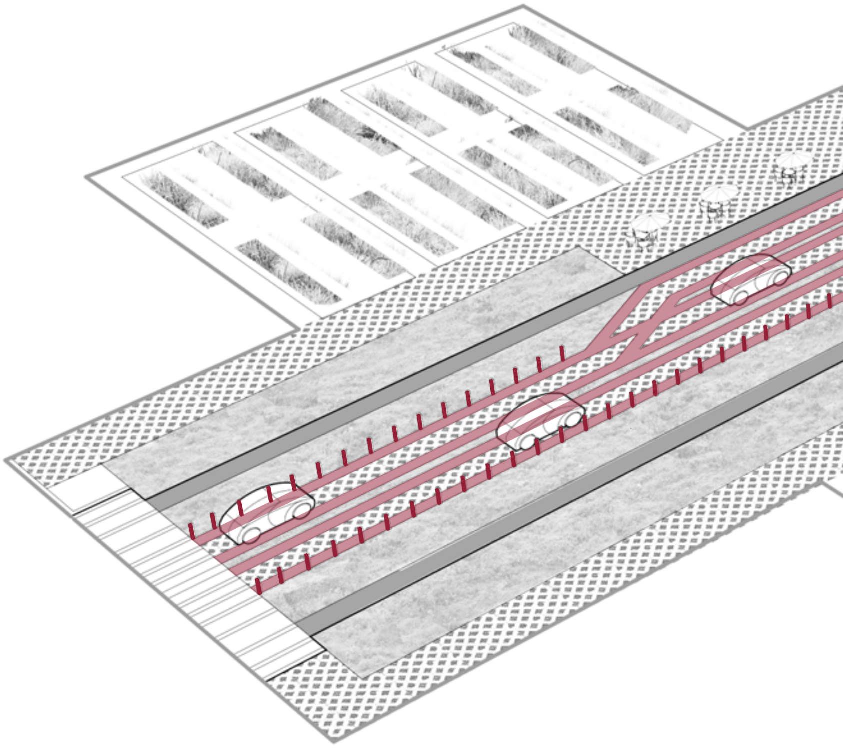


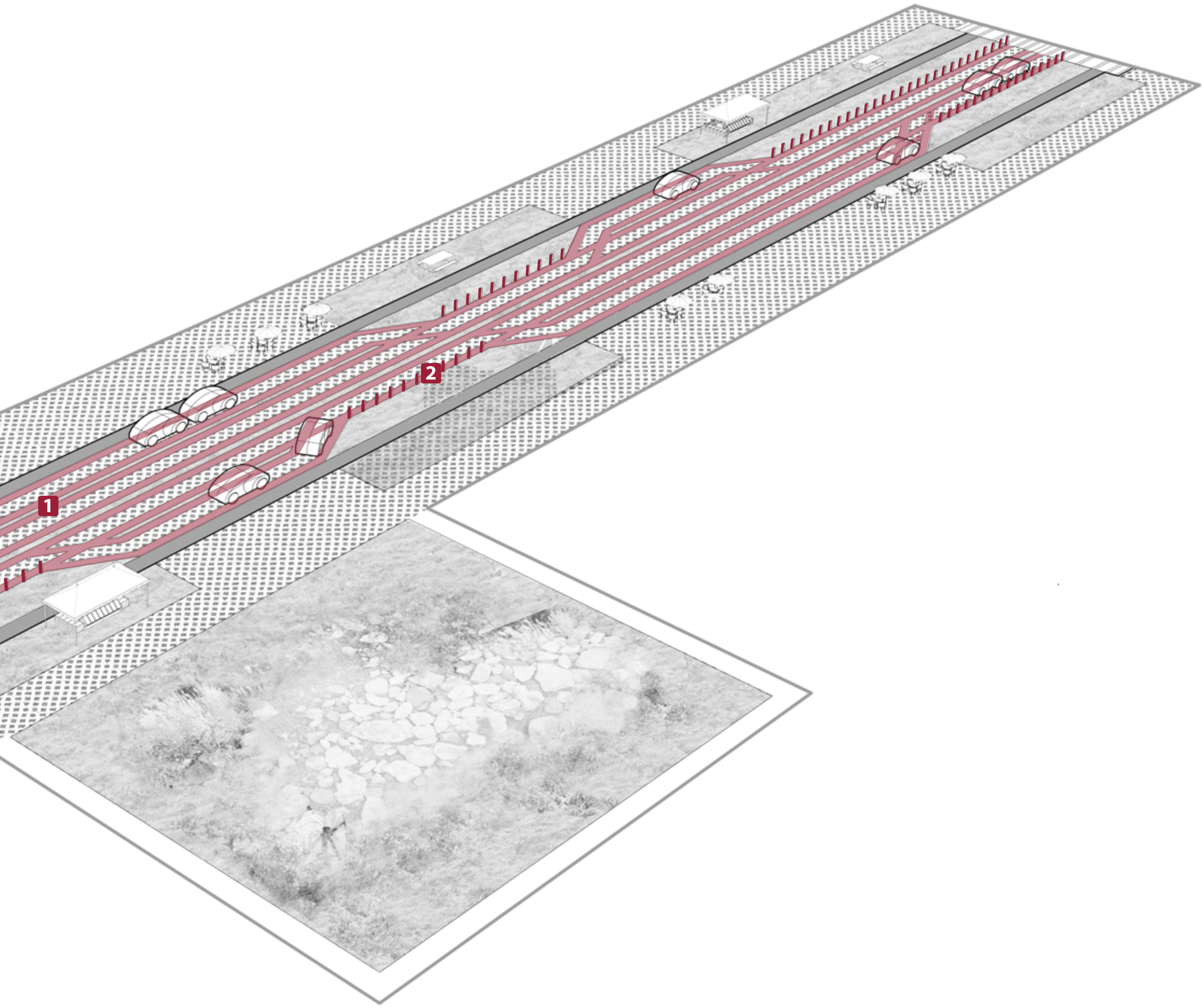

4

STREET ELEMENTS
TECHNOLOGIES

1 **AV TRACKS**
AV tracks are designed to collect and store regenerative energy from braking and idling AVs and produce generative energy from moving AVs. The energy generated can be used to heat the concrete slab tracks, to power the street bollards, and/or provide access to charging stations in public spaces along the shared green street.

2 **SMART BOLLARDS**
In addition to physically separating AV traffics from pedestrians, smart bollards are integrated with advanced technologies making rides safers and more comfortable. Bollards are wired with motion sensor technology that indicate /signalize when on-coming traffic/movement (an AV, a cyclist, and/or small vehicle) is approaching and/or departing as well as when a pedestrian is crossing the shared green street, walking along the sidewalk, and/or standing in the middle of the sharfed green street. These smart bollards alert by-standers if there is an emergency near-by or if physical assistance is requested or needed. The diagram below highlights other features that can be found in a smart bollard.

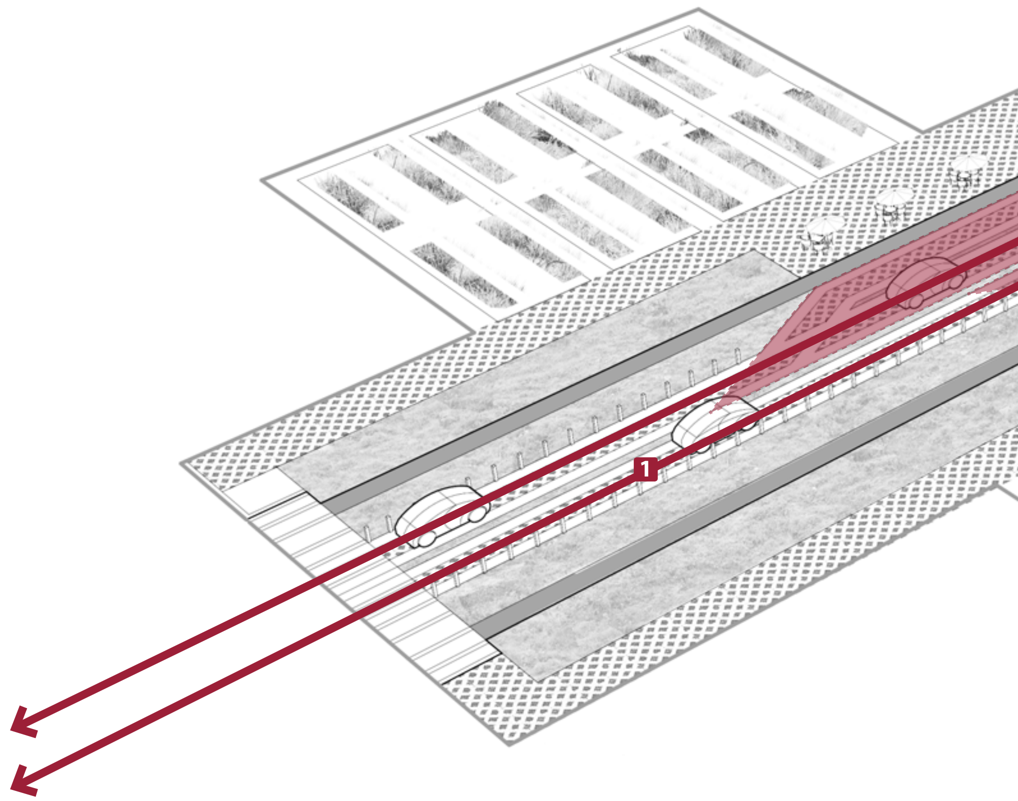


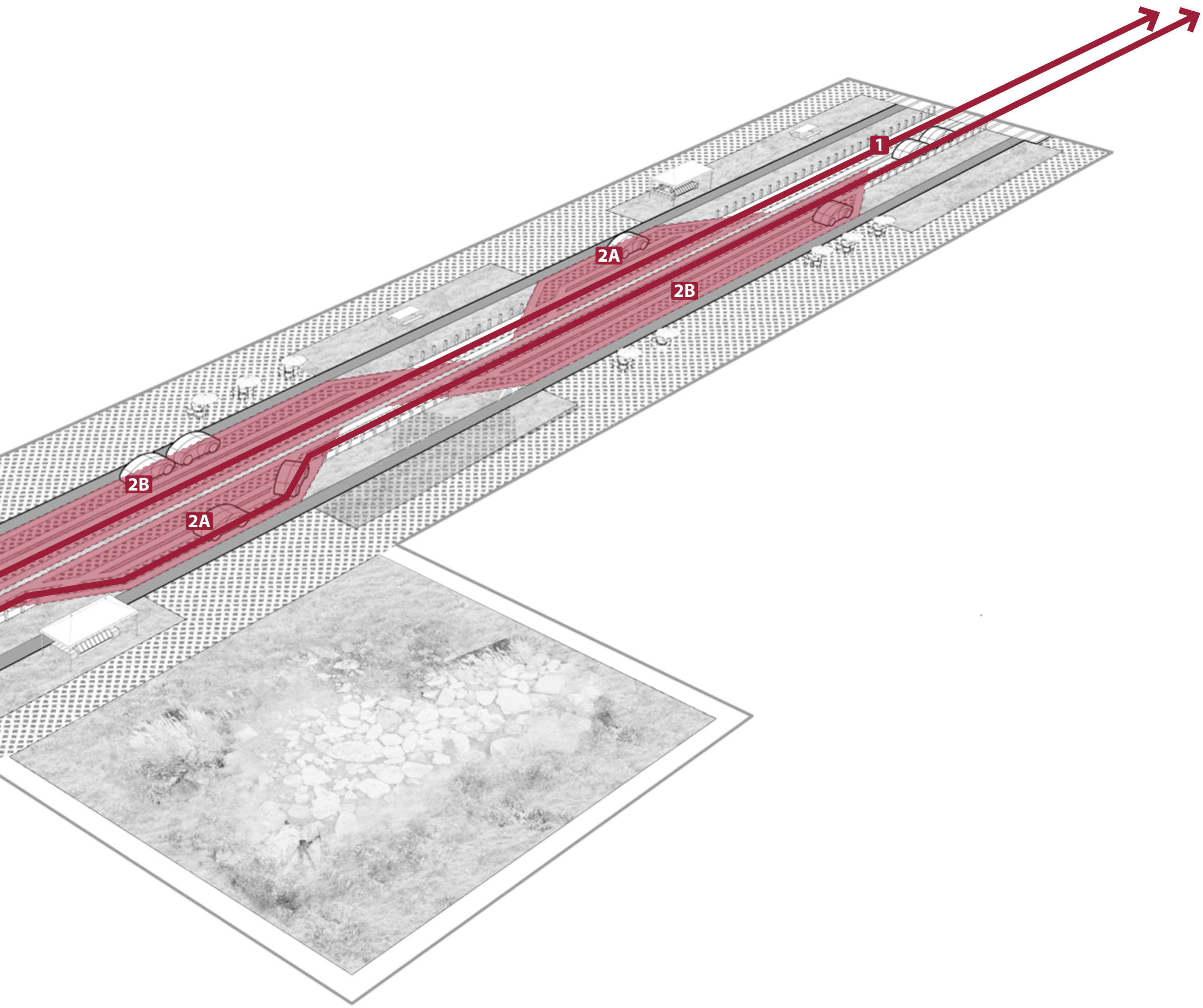

1
2

STREET ZONES
AUTONOMOUS VEHICLE

1 **AV TRACKS**
Two primary AV tracks (6'-0" OC) run parallel in the center of the shared green street; These tracks branch off at designated Pick-up/ Drop-off Areas along the shared green street's edges. AV tracks run in both directions, unless due to congestion or scheduled disruption, AV may run in the same direction.

2 **AV PICK-UP/ DROP-OFF ZONE**
There are two Pick-up/ Drop-off Areas on each side of the shared green street. The smaller designated area is dedicated for the quick pick-up and drop-off of individuals (**A**). The larger designated area is dedicated for the quick pick-up and drop-off of individuals, pick-up and drop-offs that require additional time and/or assistance, and for multi-users - Public Transportation (**B**).



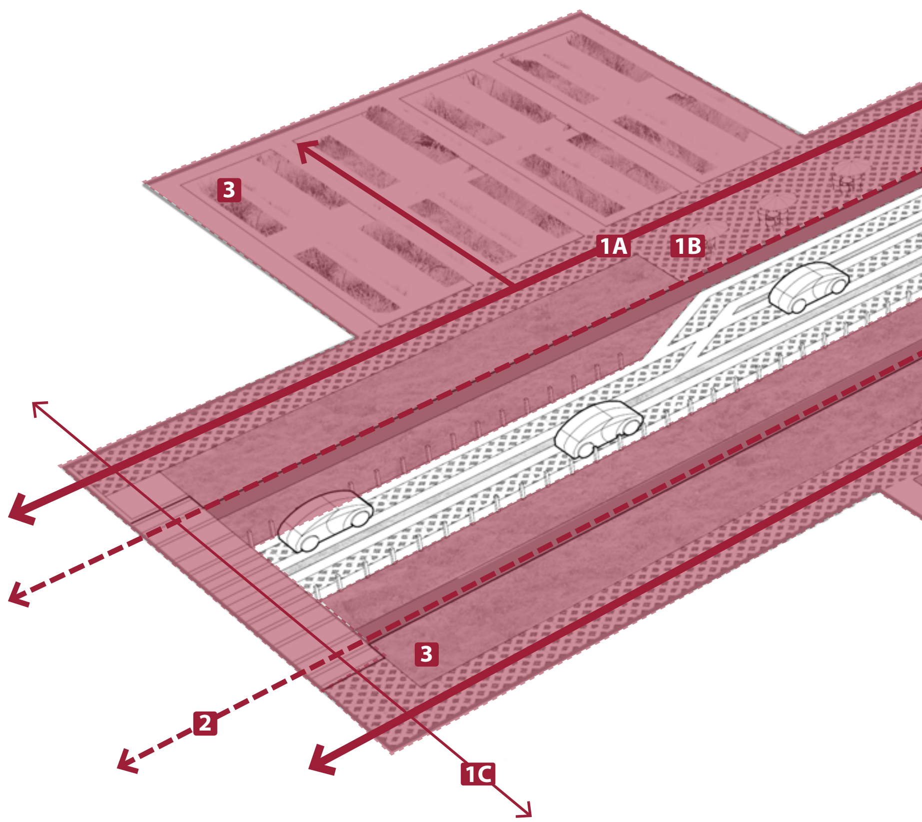

1
2A
2B
2B
2A

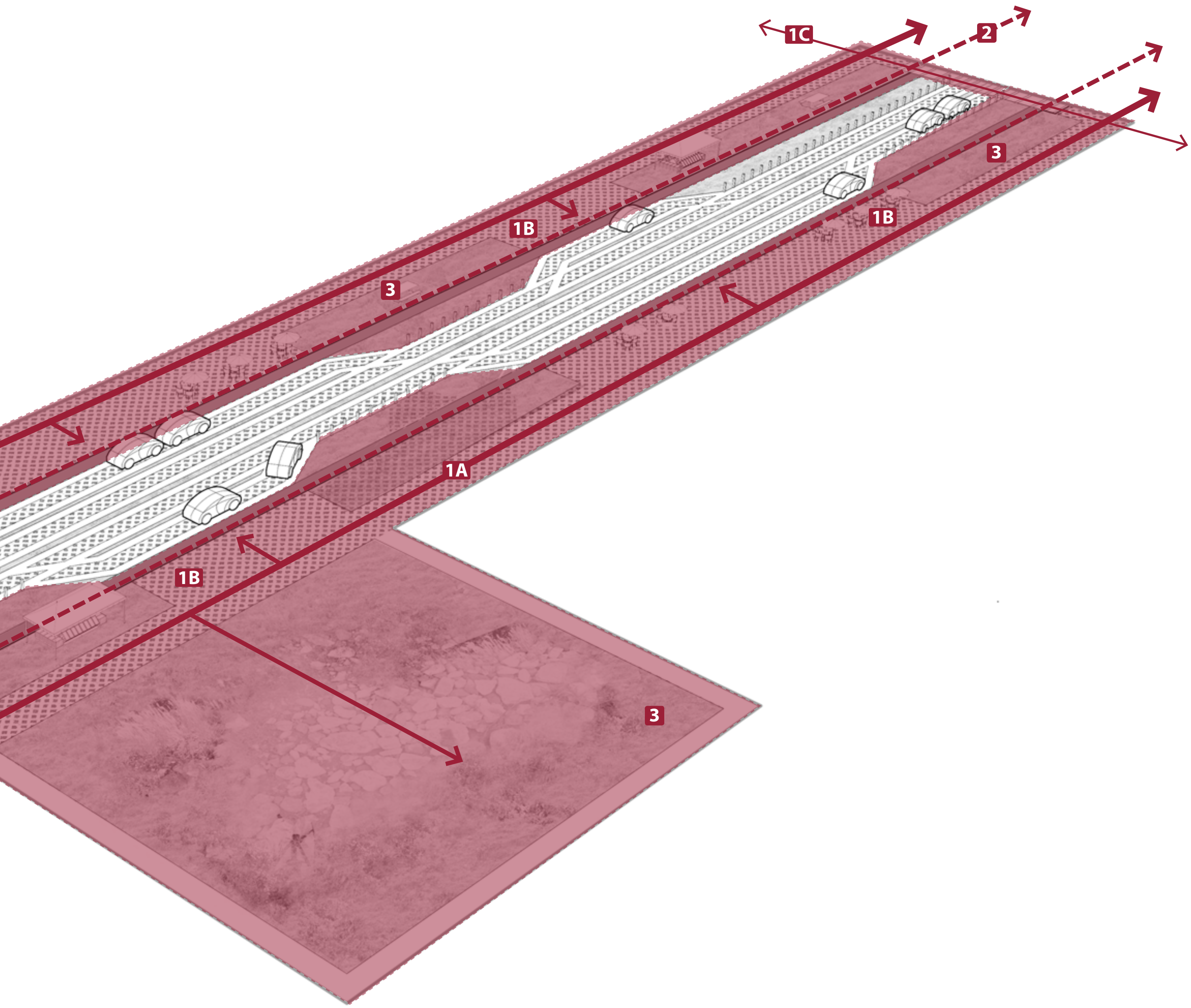
STREET ZONES
PEDESTRIAN AND PUBLIC REALM

1 **PEDESTRIAN ZONE**
A shared green street consists of three primary pedestrian zones: Pedestrian Sidewalk (**A**), Pedestrian Waiting Area (**B**), and Pedestrian Crosswalk (**C**). These areas are located along the perimeter of the shared green street and are designated for pedestrians only and/or pedestrian operated small vehicles.

2 **DEDICATED BICYCLE LANE AND/OR DEDICATED SMALL VEHICLE LANE**
These lanes are located on the outer edge of the shared green street. All shared green streets have dedicated bicycle lanes and are apart of a larger and more extensive bicycle network. As the shared green streets widen, some shared green streets will have both dedicated bicycle lanes and dedicated small vehicle lanes.

3 **FLEXIBLE GREEN SPACE**
Under-utilized, unused, and/or available spaces adjacent to pedestrian sidewalk can be converted into productive and active green spaces or passive Green Infrastructure.




1C
2
3
1B
1B
3
1A
1B
3

STREET SYSTEMS
GREEN INFRASTRUCTURE

BR **BIORETENTION (RAIN GARDEN)**
The narrower vehicular right-of-way of AV-ready streets allows for the installation of bioretention areas between the road and sidewalk, allowing stormwater to recharge the aquifer and to support the growth of street trees that provide shade for pedestrians, while lowering the heat island effect.

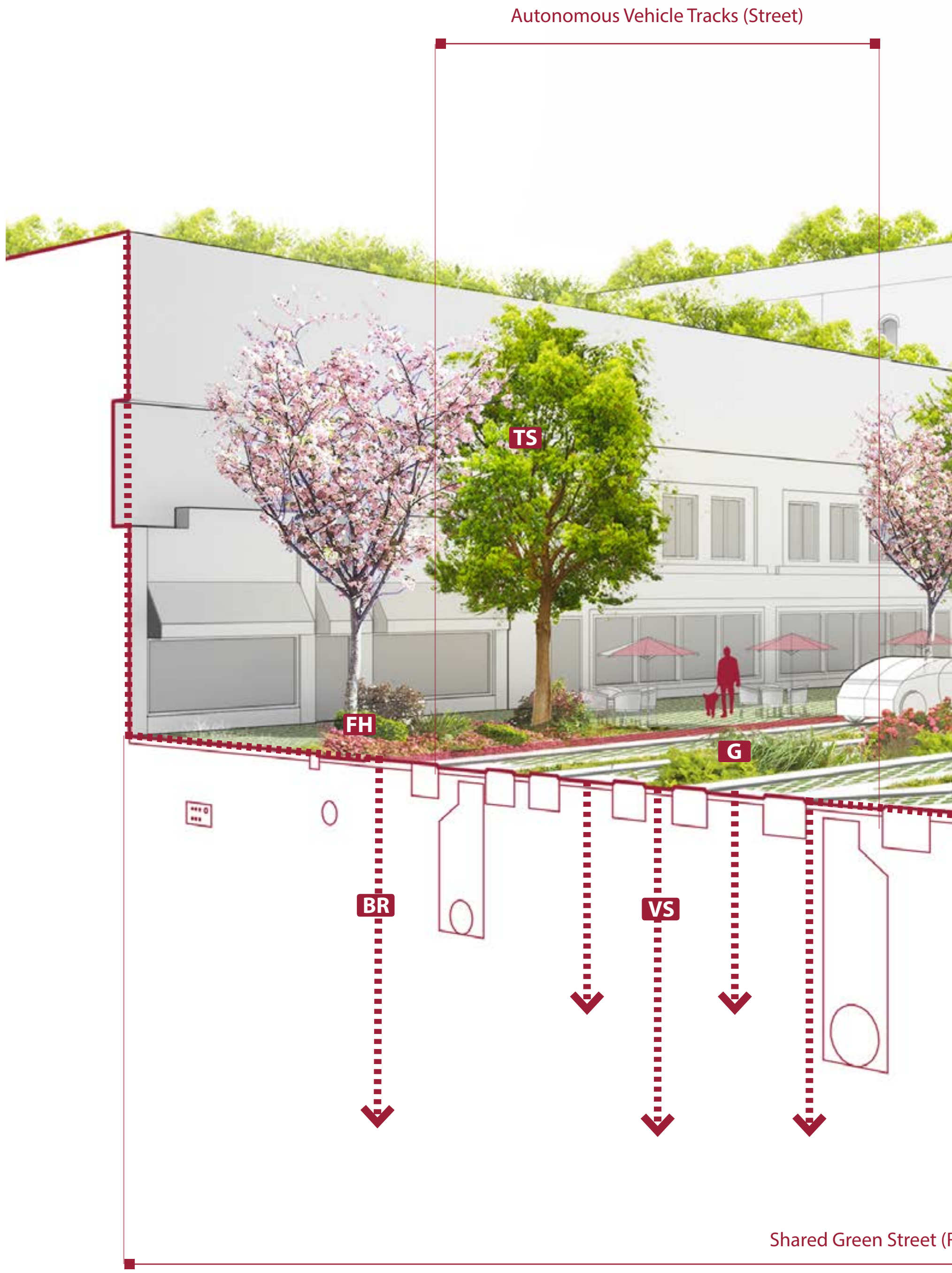
IT **INFILTRATION TRENCH**
The rain gardens and pervious paving of the road and sidewalks allow the capture of stormwater in retention basins below ground and enabling it to percolate back into the soil. Infiltration trenches can also nourish the roots of trees and other street planting, while filtering out pollutants from the roadways.

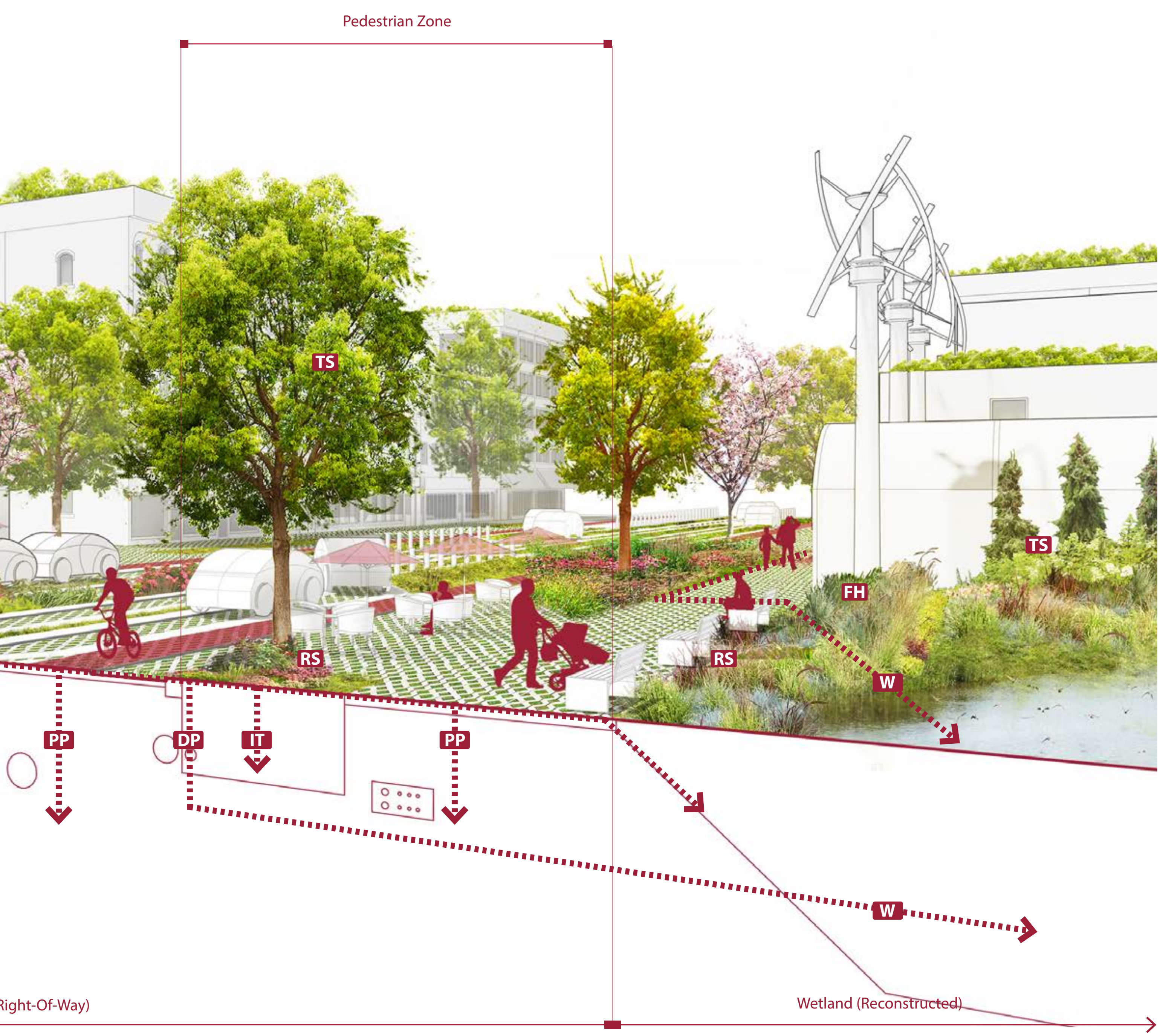
PP **PERMEABLE PAVEMENT**
A range of permeable pavement is possible now that the AV's follow their own, dedicated concrete tracks. And once the curb-and-gutter stormwater system is abandoned, the installation of permeable pavement allows for a continuous surface, with different types of pavers demarcating vehicular, bike, and pedestrian zones.

VS **VEGETATIVE SWALE**
One of the greatest challenges for AV-ready streets is the control of pedestrians crossing at will along a street, knowing that the AV will not strike them. Vegetative swales in the middle of the road can discourage crossings and funnel pedestrians to a few places along a block where crossings are allowed.

W **WETLAND**
The replacement of former surface parking with constructed wetlands has several benefits: it provides green space and diverse habitat, it reduces heat island effects, and it absorbs excess runoff during large storm events. The wetlands serve in lieu of the stormwater sewers, offering more environmental benefit at a much lower cost.

TS
FH
RS
G
SUGGESTED PLANTS
(See Street Planting - Native Plants)





Pedestrian Zone
TS
TS
FH
RS
RS
W
PP
DP
IT
PP
W
Right-Of-Way)
Wetland (Reconstructed)

STREET SYSTEMS
NATIVE PLANTS

TS TREES AND SHRUBS
Restoring the urban tree canopy and providing continuous shade to sidewalks makes trees an essential part of AV-ready streets. The type of tree and shrub will depend upon the climate and maintenance requirements of each native specimen.

FH FORBS AND HERBS
The greater space that AV's allow for activities other than vehicular movement provides opportunities, for example, to plant edible species and to think about the street accommodating urban gardens.

RS RUSHES AND SEDGES
These plant types can tolerate extreme conditions sometimes found along urban and suburban streets. Sedges do well on green roofs and rushes can thrive in rain gardens and wetlands, where other plants cannot.

G GRASSES
Native grasses are among the heartiest plants to install along AV-ready streets. Their deep roots make them able to tolerate long periods without rain and they require very little maintenance once they are established.

Alder (Alnus spp.)
40'-0" - 80'-0"

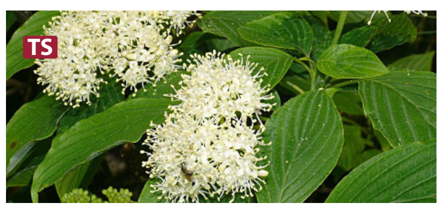
American Hazelnut (Corylus americana)
6'-0" - 15'-0"

Hackberry (Celtis occidentalis)
40'-0" - 60'-0"

Red Osier Dogwood (Cornus sericea L.)
6'-0" - 12'-0"

Alleghany Serviceberry (Amelanchier laevis)
15'-0" - 30'-0"

Downy Arrow-wood (Viburnum rafinesquianum)
6'-0" - 10'-0"



Pagoda Dogwood (Cornus alternifolia)
15'-0" - 25'-0"

Black Chokeberry (Aronia melanocarpa)
3'-0" - 8'-0"

Nannyberry (Viburnum lentago)
15'-0" - 20'-0"

Northern Bush Honeysuckle (Diervilla lonicera)
3'-0" - 5'-0"

Prairie Blazing Star (Liatris pycnostachya)
4'-0"/ Perennial

Cutleaf Coneflower (Rudbeckia laciniata)
3'-0" - 10'-0"/ Perennial

Flat-Topped Aster (Doellingeria umbellata)
2'-0" - 7'-0"/ Perennial

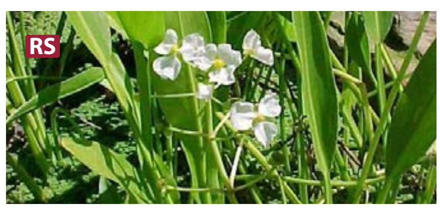
Anise Hyssop (Agastache foeniculum)
2'-0" - 4'-0"/ Perennial

Swamp/ Marsh Milkweed (Asclepias incarnata)
1'-0" - 4'-0"/ Perennial

Hard-stem Bulrush (Schoenoplectus acutus)
3'-0" - 9'-0"/Perennial

Woolgrass (Scirpus cyperinus)
3'-0" - 6'-0"/ Perennial

Bottlebrush Grass (Elymus hystrix)
2'-0" - 4'-0"/ Perennial



Common Arrowhead (Sagittaria latifolia)
1"0" - 4'-0"/ Perennial

Awl-Fruited Sedge (Carex stipata)
1'-0" - 3'-0"/ Perennial

Big Bluestem (Andropogon gerardii)
4-0" - 8'-0"/ Perennial

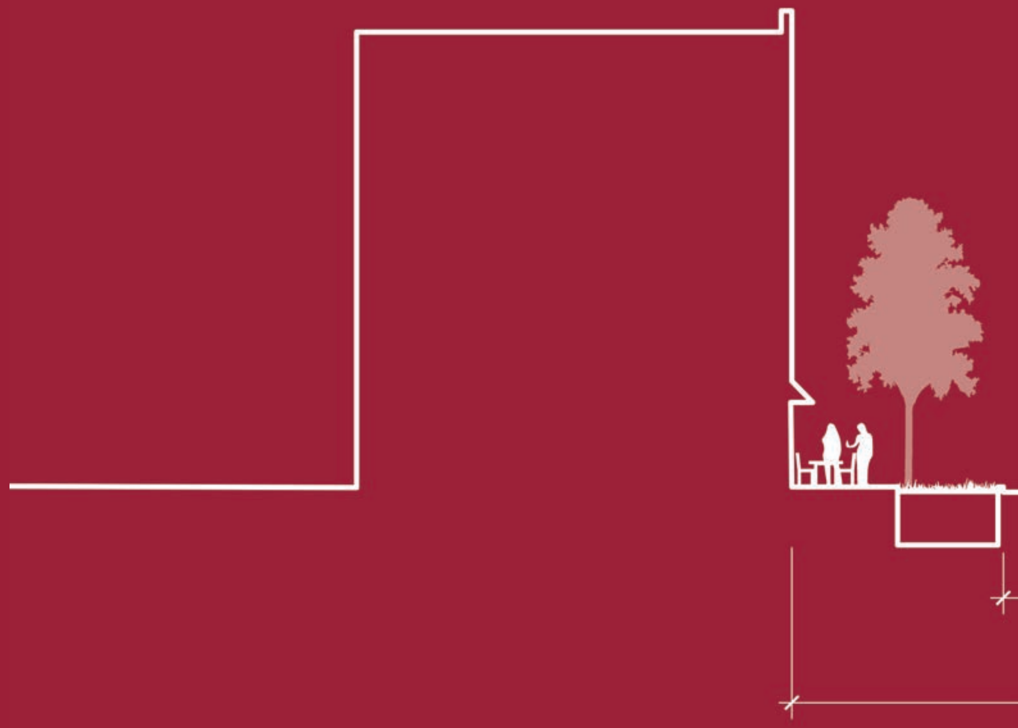
Indiangrass (Sorghastrum nutans)
3'-0" - 8'-0"/ Perennial

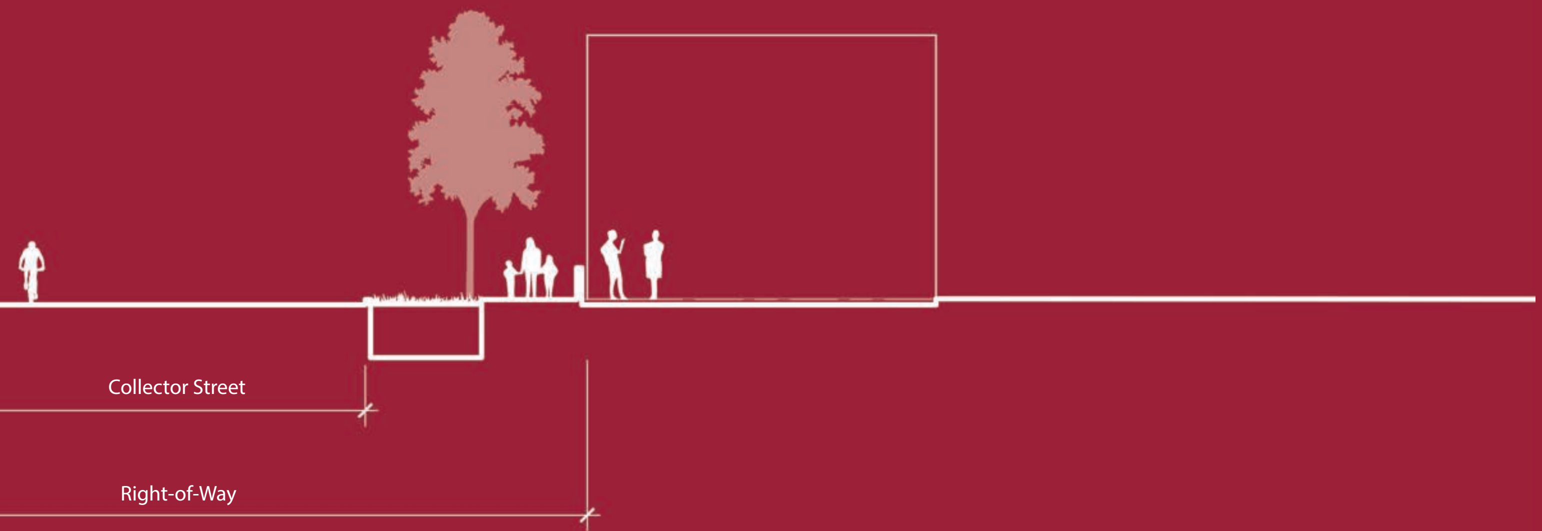
Switchgrass (Panicum virgatum)
3'-0" - 6'-0"/ Perennial

Slender Wheatgrass (Elymus trachycaulus)
1'-0" - 3'-0"/ Perennial

Sideoats Grama (Bouteloua curtipendula)
2'-0"/ Perennial

FUTURE STREETS



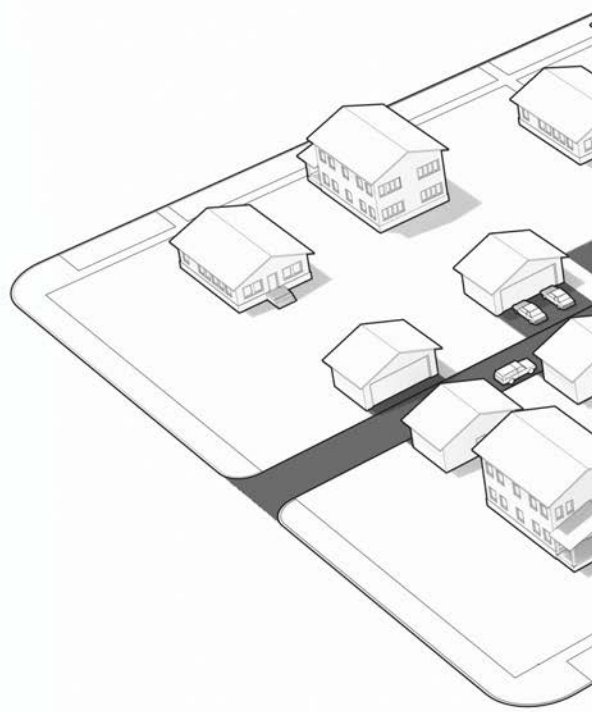

Collector Street
Right-of-Way

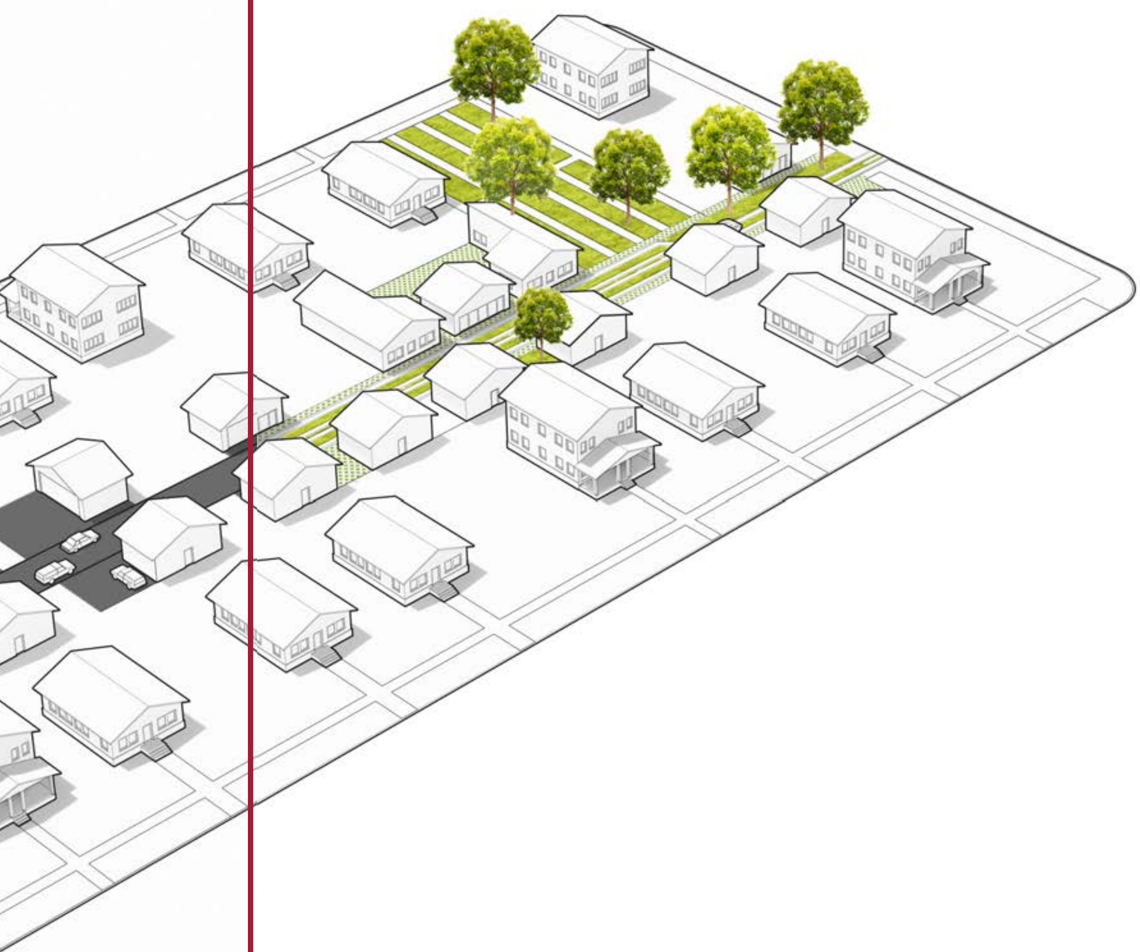
ALLEY STREET

EXISTING
In cities served by alleys, these infrastructure corridors – typically 20 to 25 feet wide – rarely get the attention or maintenance of other streets. While some alleys are dirt or surfaced with gravel, most have asphalt paving, with garages and surface parking spaces along them. Trash and recycling bins as well as utility lines dominate the alley landscape, with few trees or other planting except what might exist in adjacent back yards. In some cities, the alleys are publicly owned and in others, they are privately owned as easements private property, making property owners responsible for their upkeep and repair.

SHARED GREEN STREET (FUTURE)
In the near future, car companies will begin providing us with mobility for a fee or as part of a subscription or advertiser service. The emergence of these mobility services will have a dramatic impact on the nature and role of alleys. Most of the garages along alleys, for example, will be available for uses other than storing vehicles, uses that might include accessory dwelling units, production workshops, business start-up space, and childcare facilities among many other possibilities. The alley itself will also become greener, with AV tracks and the rest of the right-of-way having pervious pavement. Open lots might become space for urban agriculture or wetlands and former driveways might become places to plant trees to shade the pedestrian-oriented activities there. In addition to trash and recycling bins, the alleys might also have containers for the secure delivery of packages.

EXISTING ALLEY STREET
- Area: 12,000 SF (20' x 600')
- Impervious Surface: 12,000 SF (100%)
- Pervious Surface: 0 SF (0%)





SHARED GREEN STREET

✚ Area: 12,000 SF (20' x 600')
✚ Impervious Surface: 5,400 SF (45%)
✚ Pervious Surface: 6,600 SF (55%)

ALLEY STREET

PLANTING
- Area: 0 SF
- Tree: 0
- Carbon Sequestration: 0 LB/ YR

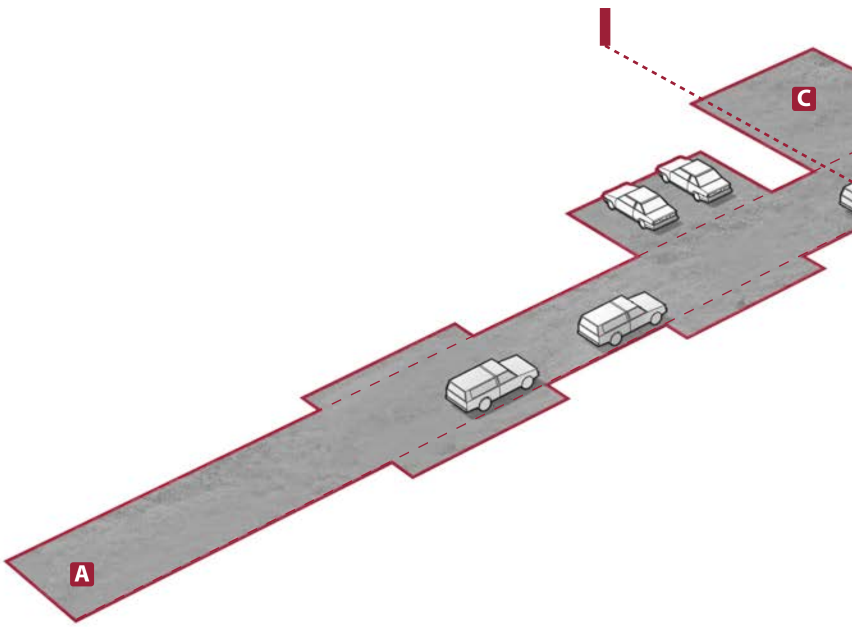
STORMWATER
(Stormwater calculations are based on a 10-year rainfall event in Minnesota)
- Volume: 30,576 CF
- Reserve: 0 CF
- Difference: -30,576 CF
- Runoff is captured off site

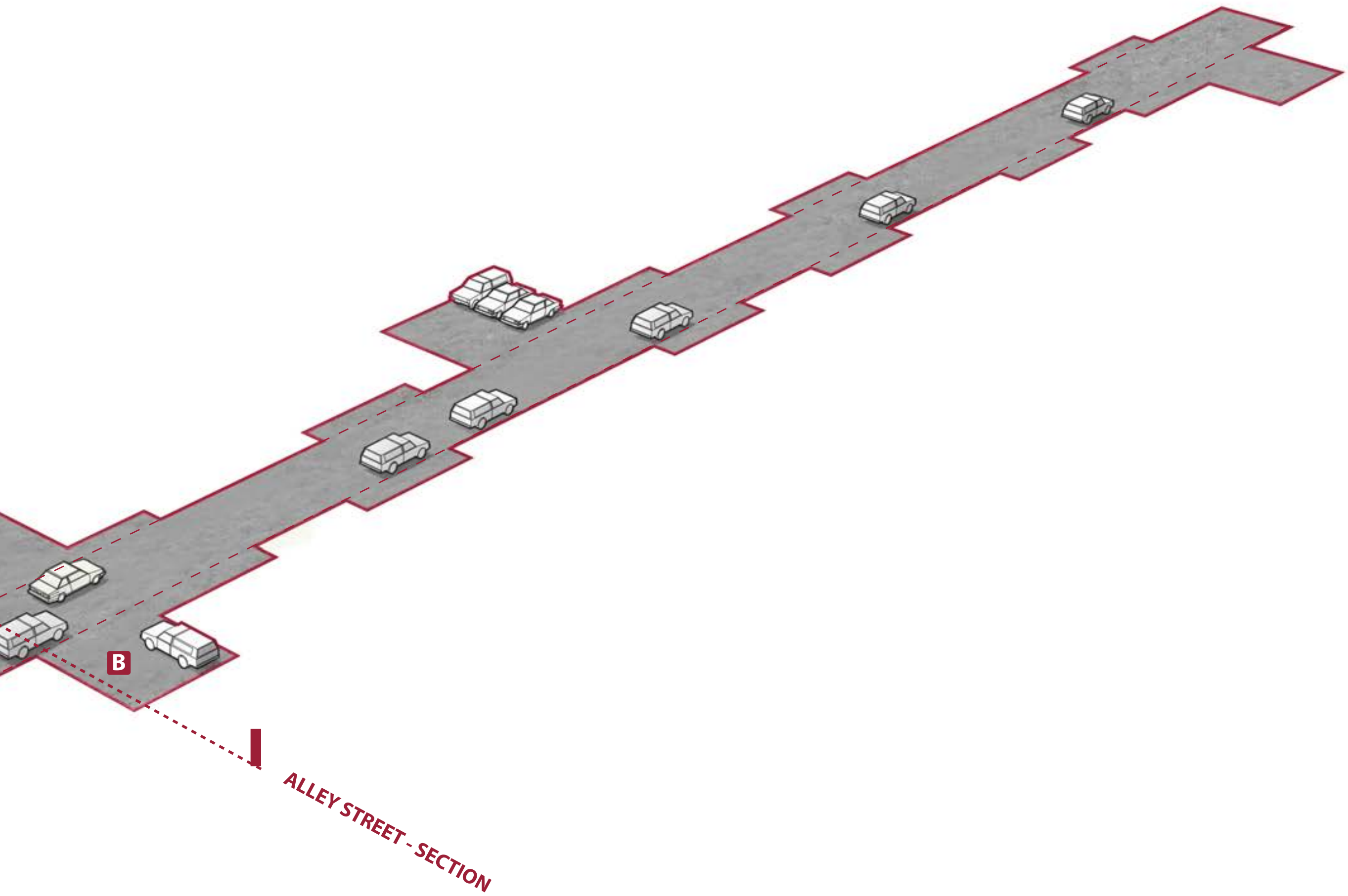
HEAT ISLAND INDEX
- Heat is absorbed
- Temperature increased

MATERIAL COST
(Material cost does not include labor)
- Impervious: 12,000 SF (100%)
- Cost: $178,025.40

PROGRAMS
A Existing Alley Street
B Alley Surface Parking
C Residential Driveway

– – Street Boundary




B
ALLEY STREET - SECTION

ALLEY STREET

PLANTING
- Area: 0 SF
- Tree: 0
- Carbon Sequestration: 0 LB/ YR

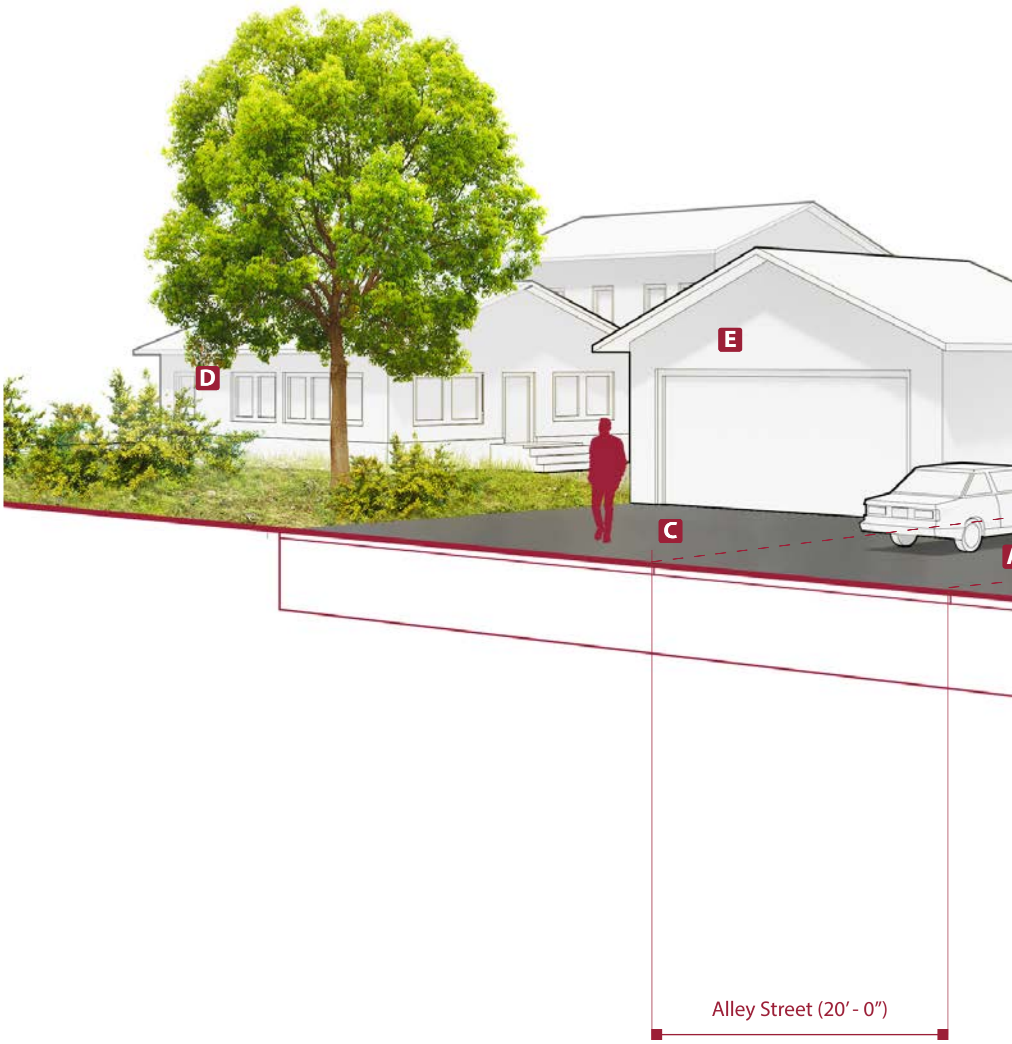
STORMWATER
(Stormwater calculations are based on a 10-year rainfall event in Minnesota)
- Volume: 30,576 CF
- Reserve: 0 CF
- Difference: -30,576 CF
- Runoff is captured off site

HEAT ISLAND INDEX
- Heat is absorbed
- Temperature increased

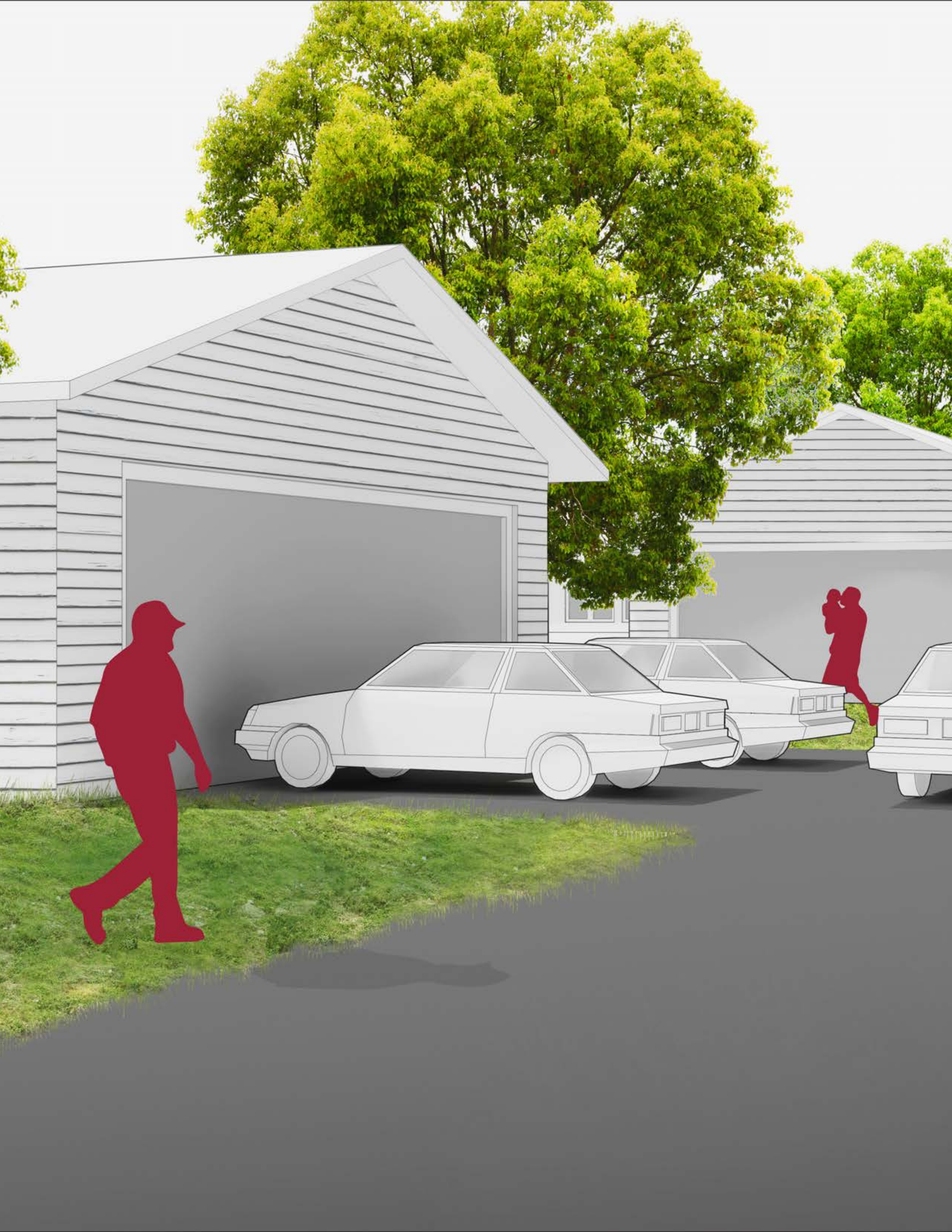
MATERIAL COST
(Material cost does not include labor)
- Impervious: 12,000 SF (100%)
- Cost: $178,025.40

PROGRAMS
A Existing Alley Street
B Alley Surface Parking
C Residential Driveway
D Single Family Residential
E Detached Garage

– – Street Boundary




A
B



SHARED GREEN STREET
ALLEY STREET (FUTURE)

PLANTING
- Area: 2,522 SF
- Tree: 12 (20'-0" OC)
- Carbon Sequestration: 7,128 LB/ YR

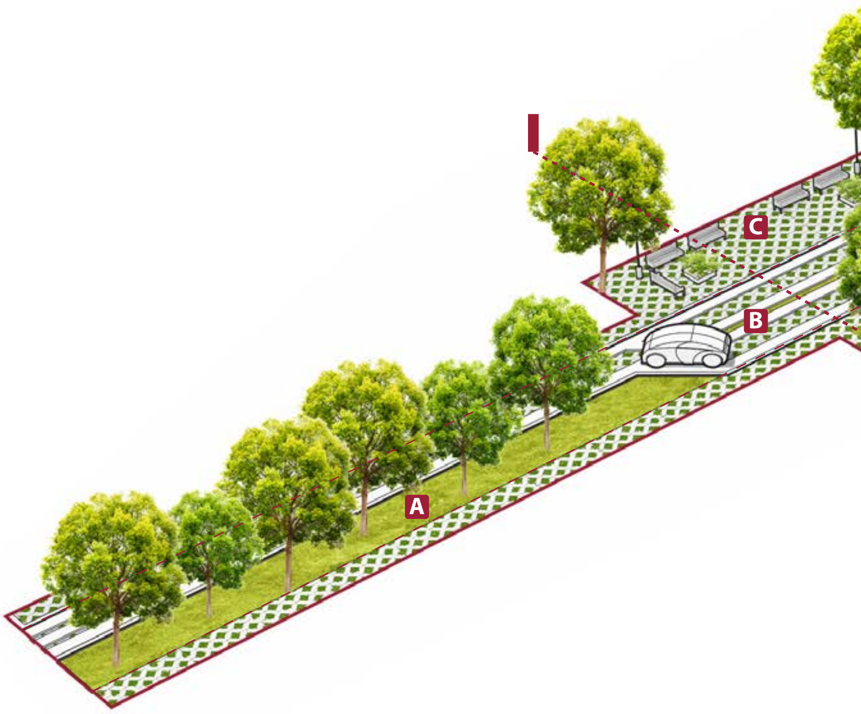
STORMWATER
(Stormwater calculations are based on a 10-year rainfall event in Minnesota)
- Volume: 30,576 CF
- Reserve: 13,200 CF
- Difference: -17,375 CF
- Runoff is captured on site
- Permeable Pavement and Infiltration Trenches can accommodate for 57% of the runoff
- Vegetative swale and Bioretention can accommodate for additional runoff

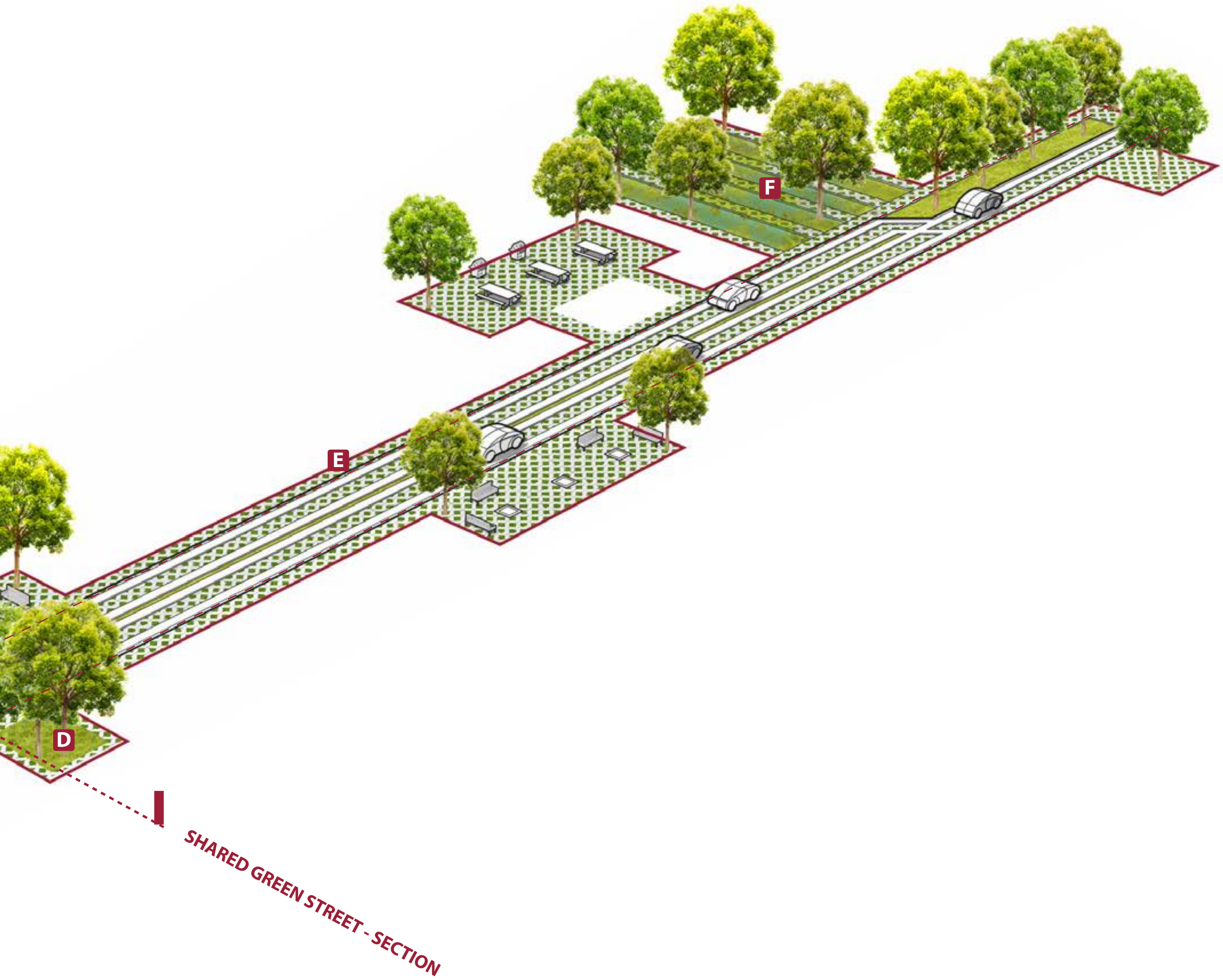
HEAT ISLAND INDEX
- Heat is reflected
- Temperature is reduced by 8 degrees; Trees and Planting Areas provide additional cooling and shading

MATERIAL COST
(Material cost does not include labor)
- Impervious: 5,400 SF (45%)
- Pervious: 6,600 SF (55%)
- Cost: $238,258.72
- Cost increased by $60,233.32 (134%); Although the cost increased significantly, the Alley Street becomes more inviting, active, and livable

PROGRAMS
A Linear Park/ Neighbothood Plaza
B Autonomous Vehicle Tracks
C Shared Communal Space/ Court Yard
D Vegetative Swale and Infiltration Trench
E Shared Pedestrian/ Bicycle Sidewalk
F Bioretention and Wetland

– – Street Boundary





F
E
D
SHARED GREEN STREET - SECTION

SHARED GREEN STREET
ALLEY STREET (FUTURE)

PLANTING
- Area: 2,522 SF
- Tree: 12 (20'-0" OC)
- Carbon Sequestration: 7,128 LB/ YR

STORMWATER
(Stormwater calculations are based on a 10-year rainfall event in Minnesota)
- Volume: 30,576 CF
- Reserve: 13,200 CF
- Difference: -17,375 CF
- Runoff is captured on site
- Permeable Pavement and Infiltration Trenches can accommodate for 57% of the runoff
- Vegetative swale and Bioretention can accommodate for additional runoff

HEAT ISLAND INDEX
- Heat is reflected
- Temperature is reduced by 8 degrees; Trees and Planting Areas provide additional cooling and shading

MATERIAL COST
(Material cost does not include labor)
- Impervious: 5,400 SF (45%)
- Pervious: 6,600 SF (55%)
- Cost: $238,258.72
- Cost increased by $60,233.32 (134%); Although the cost increased significantly, the Alley Street becomes more inviting, active, and livable

PROGRAMS
A Autonomous Vehicle Tracks
B Shared Communal Space/ Court Yard
C Vegetative Swale and Infiltration Trench
D Receiving and Delivery Post
E Shared Pedestrian/ Bicycle Sidewalk
F Bioretention and Wetland
G Single Family Residential
H Adaptive Reuse Structure

-- Street Boundary

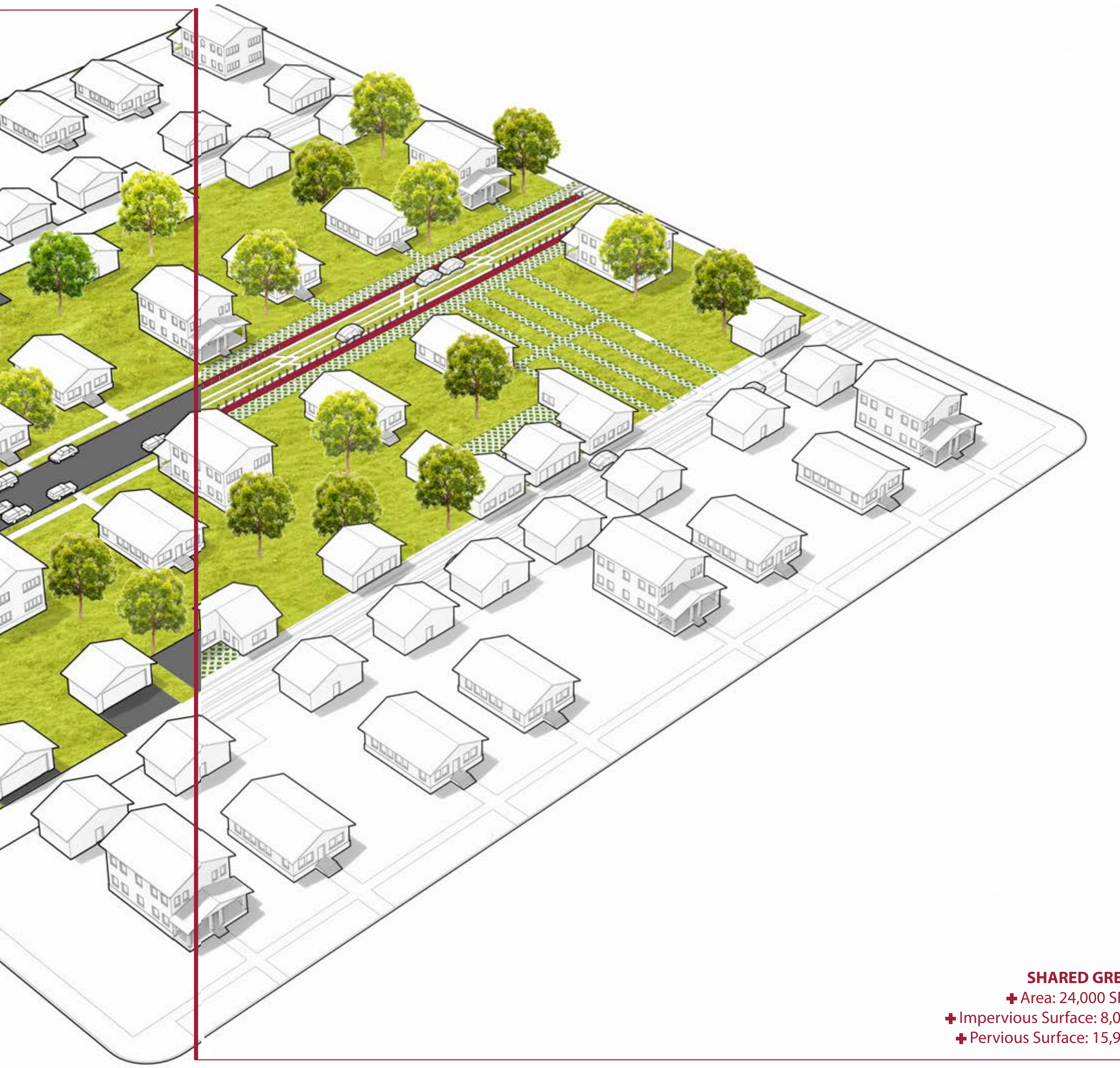

F
G

LOCAL STREET

EXISTING
Local streets constitute the largest number of roadways in cities and suburbs and they are typically underutilized in terms of the traffic they handle and the parking they provide. Except in the densest neighborhoods, local streets often have few cars and ample parking space, and they show the excess capacity that exists in our transportation infrastructure, especially when serving properties that also have rear alleys. The excessive width of many local streets taxes the budgets of municipalities that must maintain and repaved them, and it also reduces the amount of space in the public right-of-way for other uses.

SHARED GREEN STREET (FUTURE)
When AV's become the dominant mode of vehicular transportation, local streets will change in several ways. These streets will only need one pair of tracks in each direction, with planting or pervious pavers in lanes that need only be eight-feet wide. This will allow for space to drop off and pick up people and packages, once on-street parking disappears. Dedicated bike lanes can also be installed in the space formerly occupied by parked cars. The narrowing of the right-of-way devoted to vehicles will provide more space for pedestrians. Some cities may also decide to reduce the amount of infrastructure they have to maintain by ceding some local streets to the adjacent property owners, who can use the right-of-way for non-transportation uses like community gardens, wetlands, and play space.

EXISTING LOCAL STREET
- Area: 24,000 SF (40' x 600')
- Impervious Surface: 24,000 SF (100%)
- Pervious Surface: 0 SF (0%)



SHARED GREEN STREET

- Area: 24,000 SF (40’ x 600’)
- Impervious Surface: 8,053 SF (33%)
- Pervious Surface: 15,947 SF (67%)

LOCAL STREET

PLANTING
- Area: 0 SF
- Tree: 0
- Carbon Sequestration: 0 LB/ YR

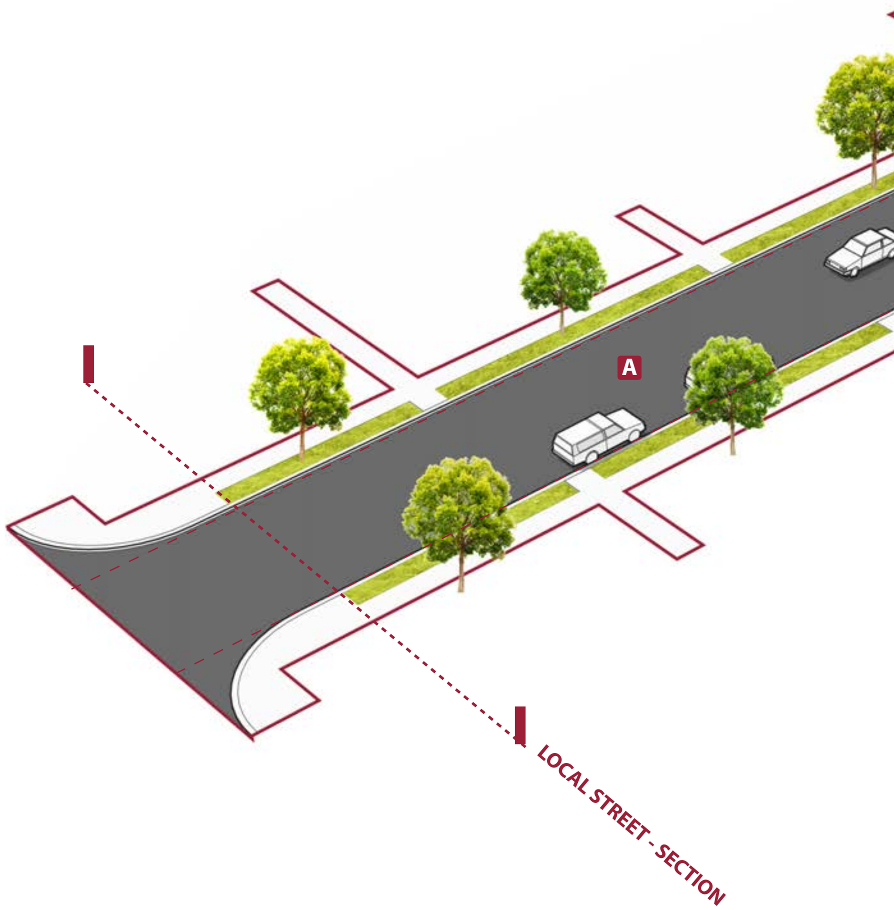
STORMWATER
(Stormwater calculations are based on a 10-year rainfall event in Minnesota)
- Volume: 34,652.8 CF
- Reserve: 0 CF
- Difference: - 34,652.8 CF
- Runoff is captured on site; Redirected to the Stormwater Drainage System below and discharged and/or stored off site

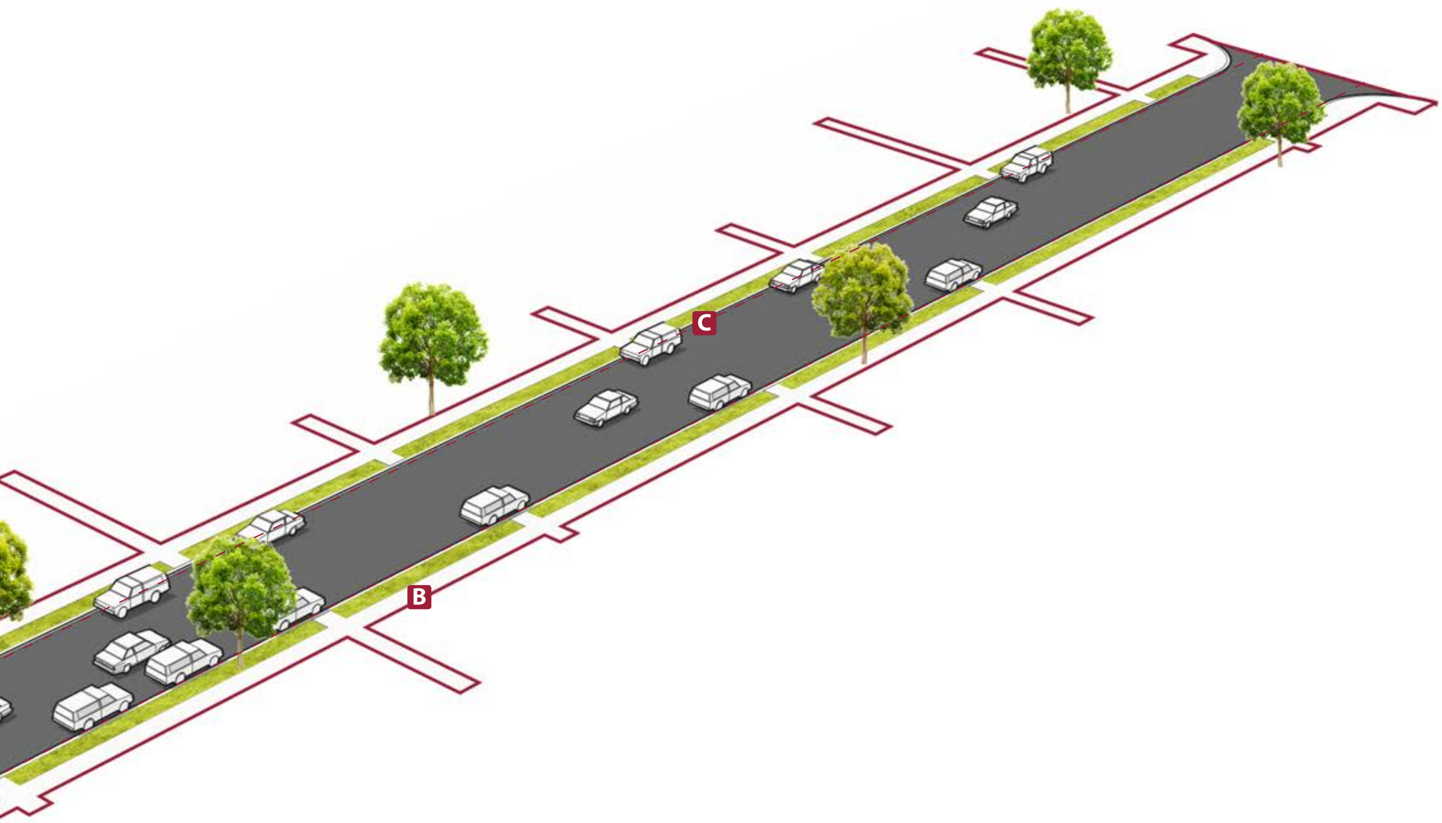
HEAT ISLAND INDEX
- Heat is absorbed
- Temperature increased

MATERIAL COST
(Material cost does not include labor)
- Impervious: 24,000 SF (100%)
- Cost: $1,030,039.92

PROGRAMS
A Existing Local Street
B Pedestrian Sidewalk
C Local/ Residential Street Parking

– – Street Boundary




C
B

LOCAL STREET

PLANTING
- Area: 0 SF
- Tree: 0
- Carbon Sequestration: 0 LB/ YR

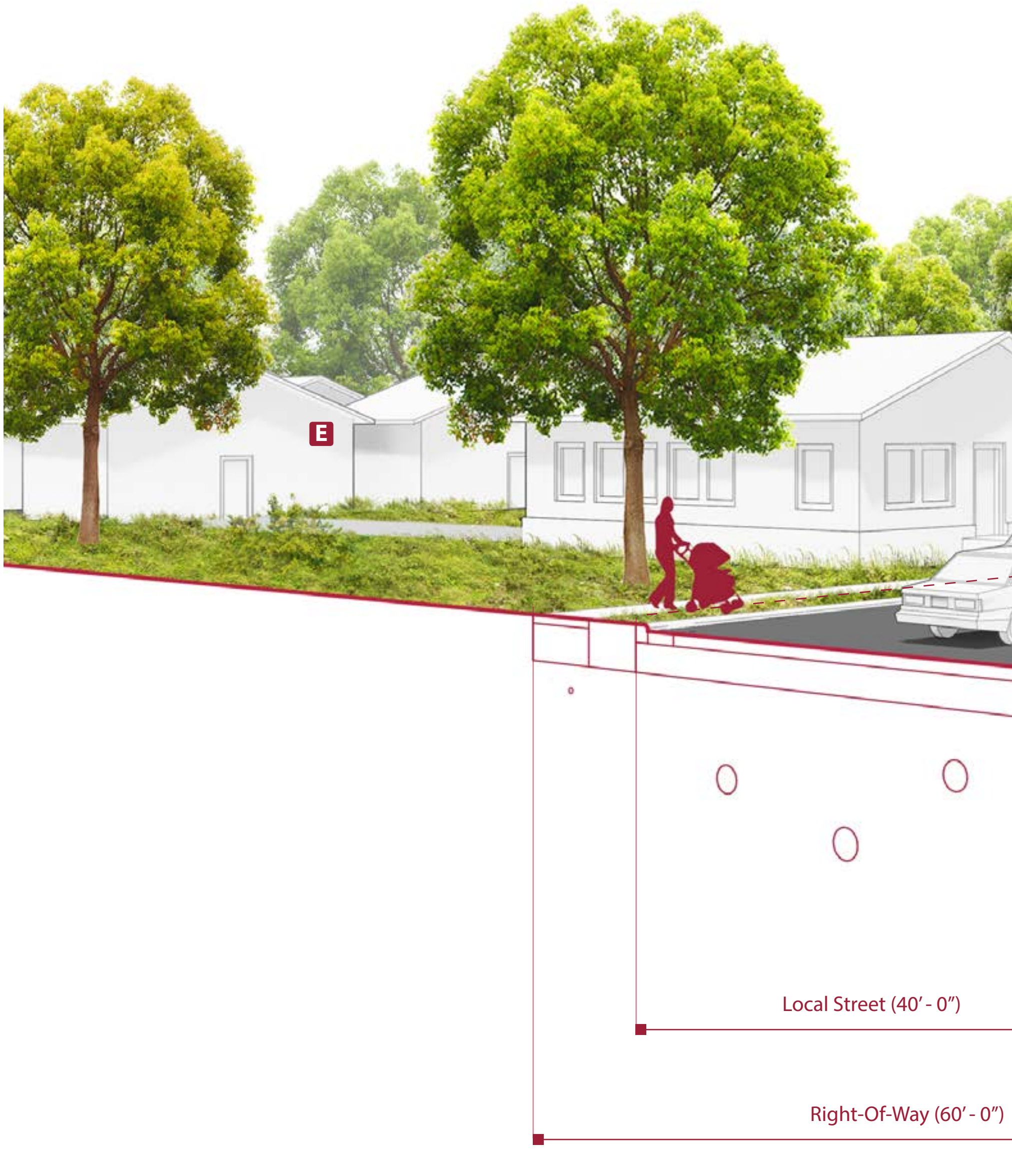
STORMWATER
(Stormwater calculations are based on a 10-year rainfall event in Minnesota)
- Volume: 34,652.8 CF
- Reserve: 0 CF
- Difference: - 34,652.8 CF
- Runoff is captured on site; Redirected to the Stormwater Drainage System below and discharged and/or stored off site

HEAT ISLAND INDEX
- Heat is absorbed
- Temperature increased

MATERIAL COST
(Material cost does not include labor)
- Impervious: 24,000 SF (100%)
- Cost: $1,030,039.92

PROGRAMS
A Existing Local Street
B Pedestrian Sidewalk
C Local/ Residential Street Parking
D Single Family Residential
E Detached Garage

– – Street Boundary




D
A
B
C

SHARED GREEN STREET

LOCAL STREET (FUTURE)

PLANTING

- Area: 15,947 SF
- Tree: 44
- Carbon Sequestration: 28,058 LB/ YR

STORMWATER

(Stormwater calculations are based on a 10-year rainfall event in Minnesota)

- Volume: 34,652.8 CF
- Reserve: 41,360 CF
- Difference: +6,707.48 CF
- Runoff is captured on site
- Permeable Pavement and Infiltration Trenches can accommodate for 100% of the runoff
- Vegetative swale and Bioretention can accommodate for additional runoff
- Stormwater Drainage System can be capped and/or decommissioned based on calculations

HEAT ISLAND INDEX

- Heat is reflected
- Temperature is reduced by 15 degrees; Trees and Planting Areas provide additional cooling and shading

MATERIAL COST

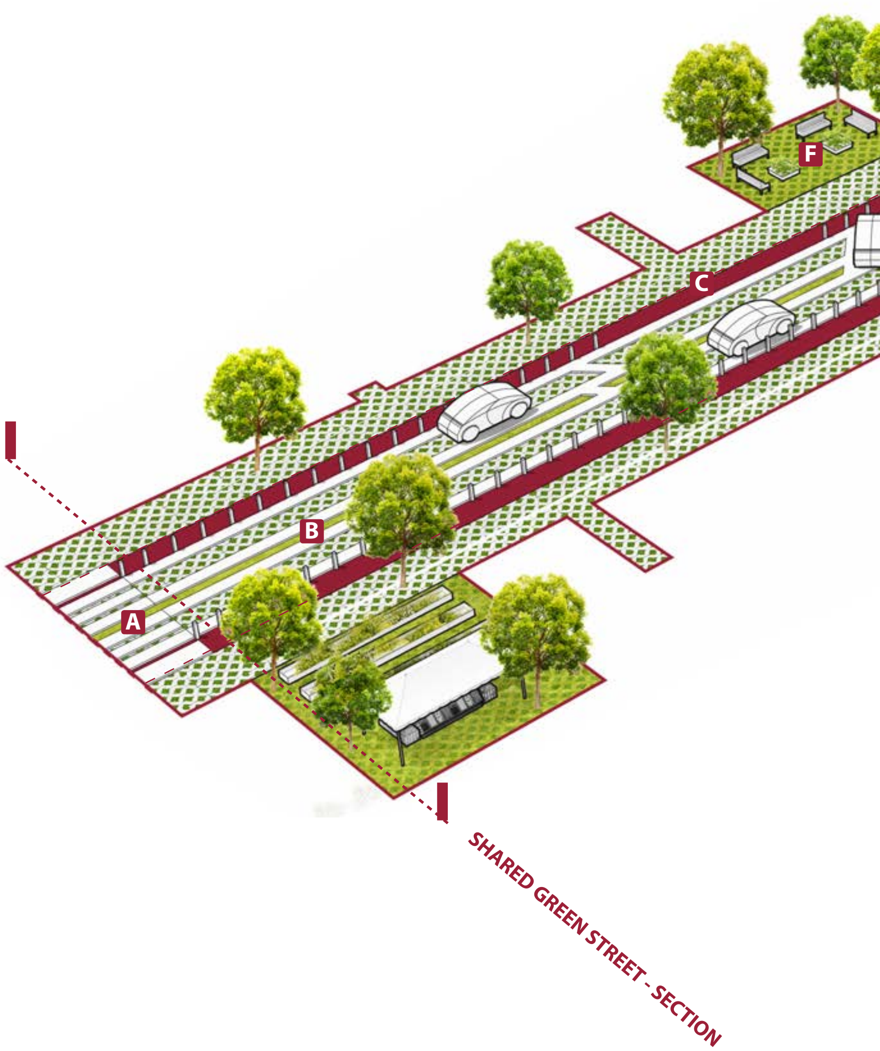
(Material cost does not include labor)

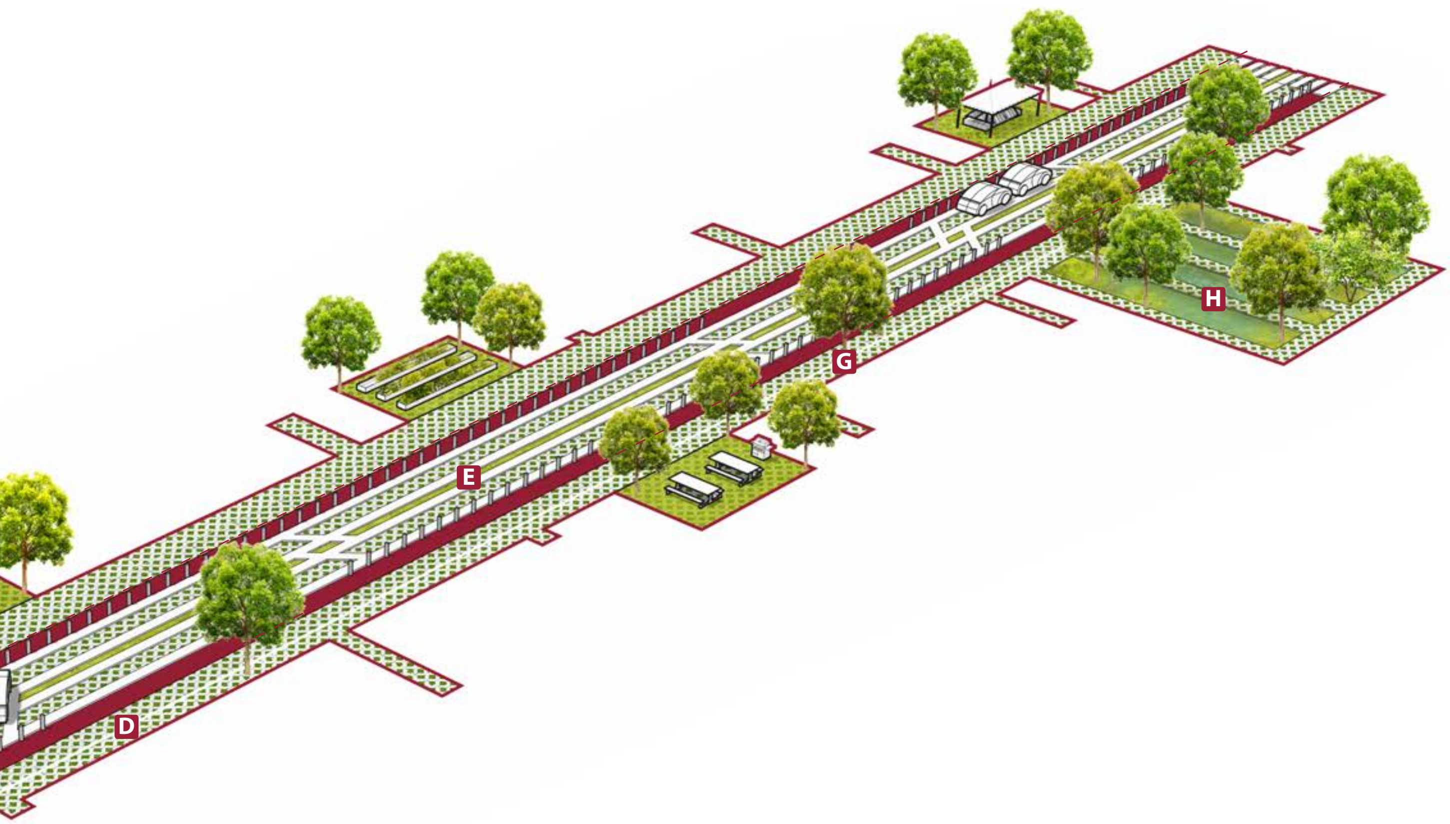
- Impervious: 8,053 SF (33%)
- Pervious: 15,947 SF (67%)
- Cost: $425,642.29
- Cost decreased by $604,397.63 (41%)

PROGRAMS

A Pedestrian Crosswalk
B Autonomous Vehicle Tracks
C Dedicated Bicycle/ Small Vehicle Lane
D Dedicated Pedestrian Sidewalk
E Pick-up/ Drop-off Zone
F Shared Communal Space/ Front Yard
G Vegetative Swale and Infiltration Trench
H Bioretention and Wetland

– – Street Boundary





D
E
G
H

SHARED GREEN STREET
LOCAL STREET (FUTURE)

PLANTING
- Area: 15,947 SF
- Tree: 44
- Carbon Sequestration: 28,058 LB/ YR

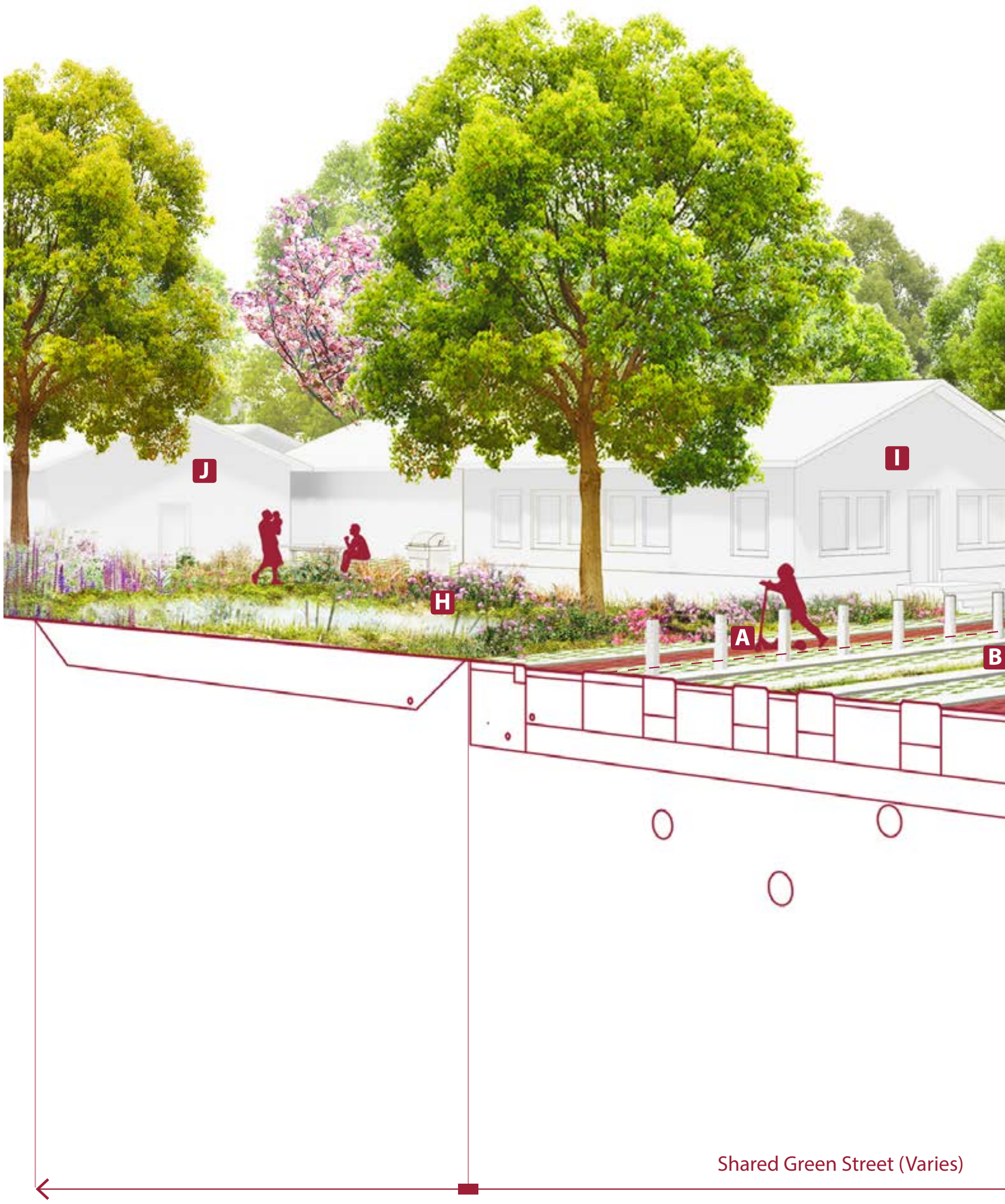
STORMWATER
(Stormwater calculations are based on a 10-year rainfall event in Minnesota)
- Volume: 34,652.8 CF
- Reserve: 41,360 CF
- Difference: +6,707.48 CF
- Runoff is captured on site
- Permeable Pavement and Infiltration Trenches can accommodate for 100% of the runoff
- Vegetative swale and Bioretention can accommodate for additional runoff
- Stormwater Drainage System can be capped and/or decommissioned based on calculations

HEAT ISLAND INDEX
- Heat is reflected
- Temperature is reduced by 15 degrees; Trees and Planting Areas provide additional cooling and shading

MATERIAL COST
(Material cost does not include labor)
- Impervious: 8,053 SF (33%)
- Pervious: 15,947 SF (67%)
- Cost: $425,642.29
- Cost decreased by $604,397.63 (41%)

PROGRAMS
A Smart Street Technology
B Autonomous Vehicle Tracks
C Dedicated Bicycle/ Small Vehicle Lane
D Dedicated Pedestrian Sidewalk
E Pick-up/ Drop-off Zone
F Shared Communal Space/ Front Yard
G Vegetative Swale and Infiltration Trench
H Bioretention and Wetland
I Single Family Residential
J Detached Garage

- - Street Boundary



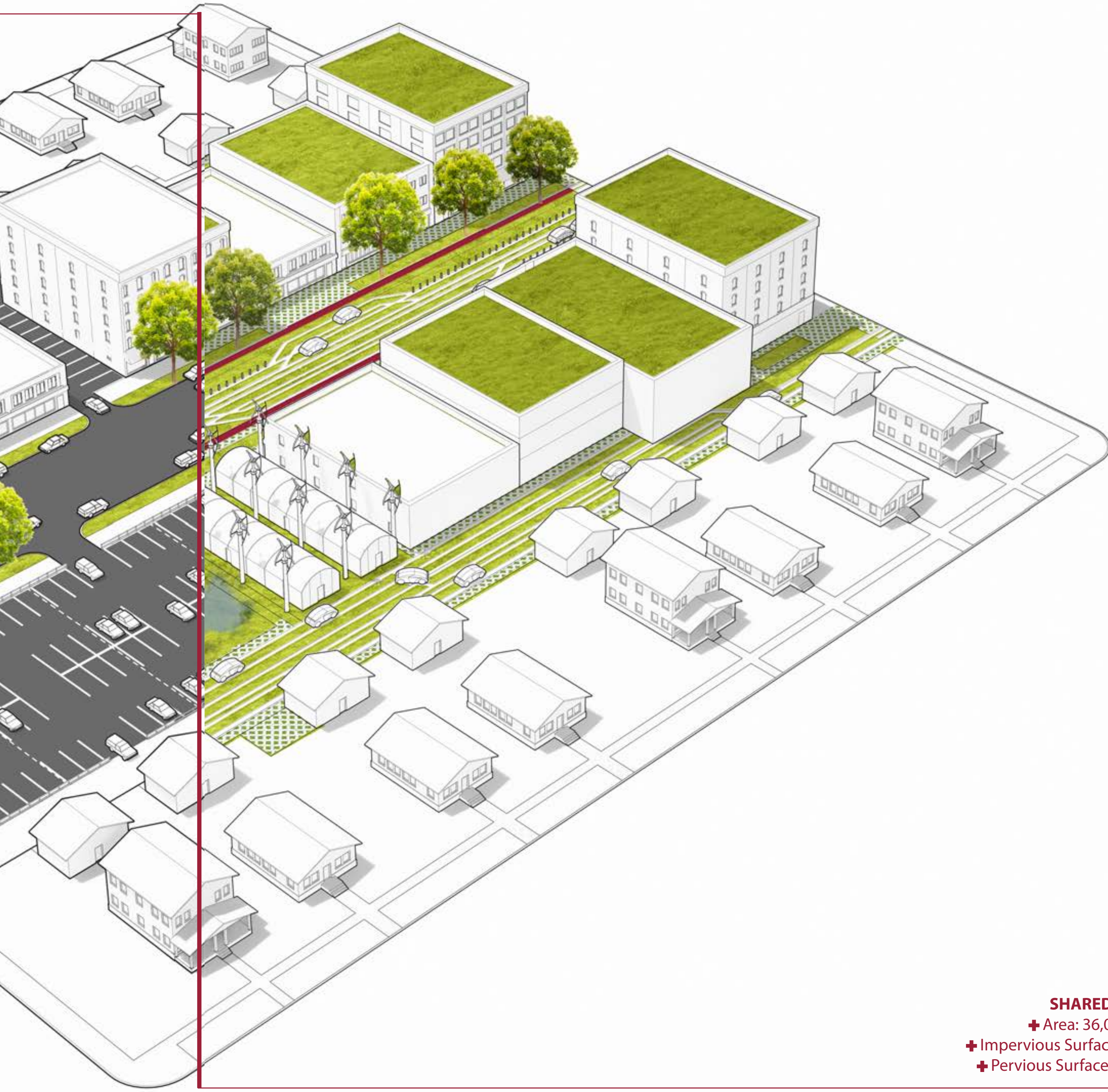

E
G
C
D
F

COLLECTOR STREET

EXISTING
Collector streets often have multiple pass lanes and parking lanes on one or both sides of the street, taking up most of the right-of-way and making it difficult for other modes of transportation – bikes, scooters, pedestrians – to use or cross the street. Because collector streets typically have commercial uses along them, most have extensive amounts of parking in lots or ramps on adjacent private property. The amount of pavement along collector streets greatly increases the heat island effect, and the amount of impervious surface increases runoff and water pollution.

SHARED GREEN STREET (FUTURE)
AV's will substantially alter collector streets. The number of lanes will decrease, since AV's can operate safely when much closer together than driven vehicles, and so they can move the same number of people in much less space. As part of mobility services, AV's also will not need parking, since they will drop off passengers and move on to their next call, much as taxis and ride sharing vehicles do now. That allows former on-street parking spaces to be used for dropping off and picking up passengers or for other, pedestrian-oriented uses. The additional space in the right-of-way also allows for dedicated bike lanes, a denser tree canopy, rain gardens, and other sidewalk-oriented activities in place of parked vehicles. Surface parking lots can also be used for urban agriculture, solar and wind farms, or new infill development, whose green roofs can further decrease heat islands and increase animal habitat.

EXISTING COLLECTOR STREET
- Area: 36,000 SF (60' x 600')
- Impervious Surface: 36,000 SF (100%)
- Pervious Surface: 0 SF (0%)



SHARED GREEN STREET

✚ Area: 36,000 SF (60' x 600')
✚ Impervious Surface: 9,674 SF (27%)
✚ Pervious Surface: 26,326 SF (73%)

COLLECTOR STREET

PLANTING
- Area: 0 SF
- Tree: 0
- Carbon Sequestration: 0 LB/ YR

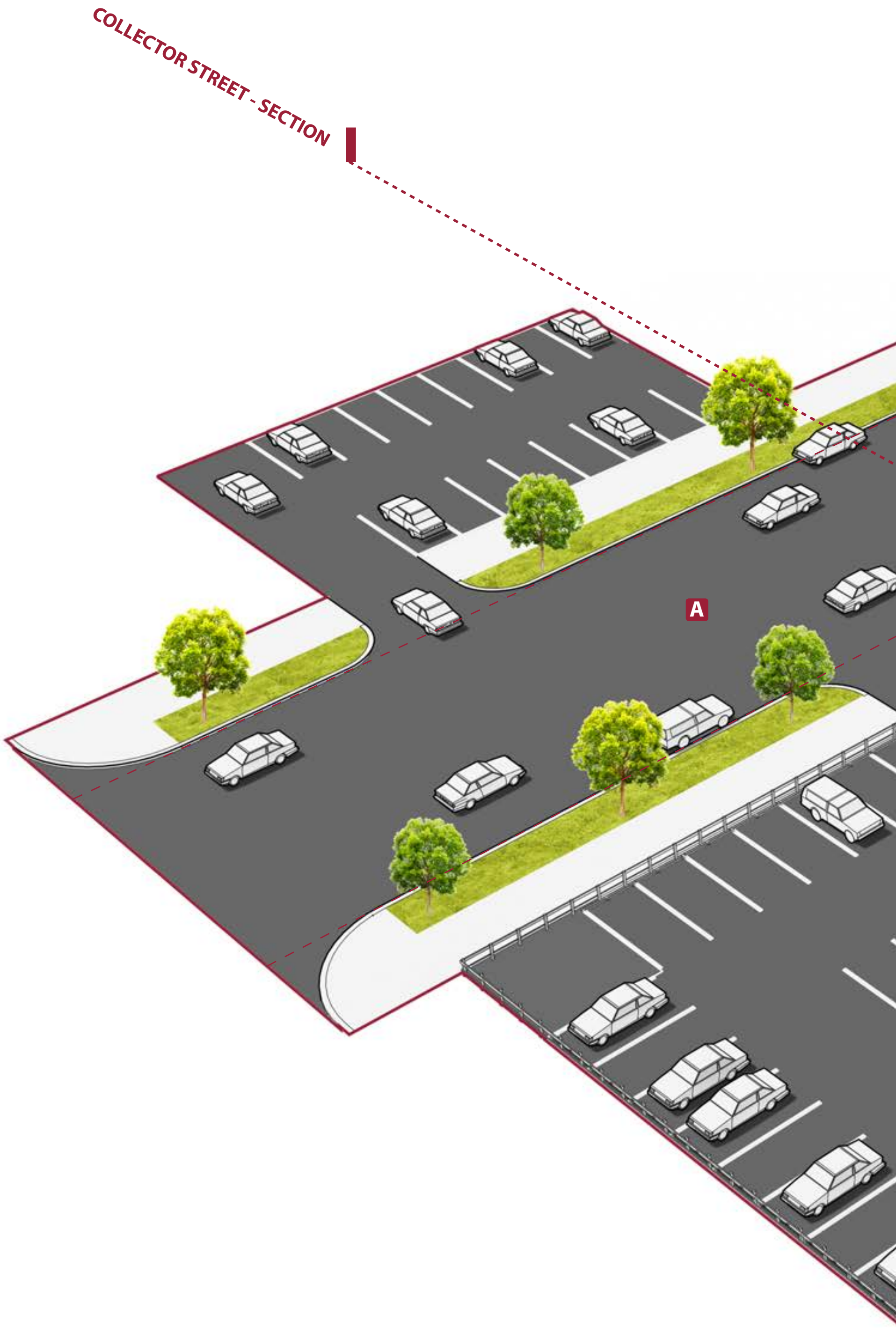
STORMWATER
(Stormwater calculations are based on a 10-year rainfall event in Minnesota)
- Volume: 56,738.5 CF
- Reserve: 0 CF
- Difference: - 56,738.5 CF
- Runoff is captured on site; Redirected to the Stormwater Drainage System below and discharged and/or stored off site

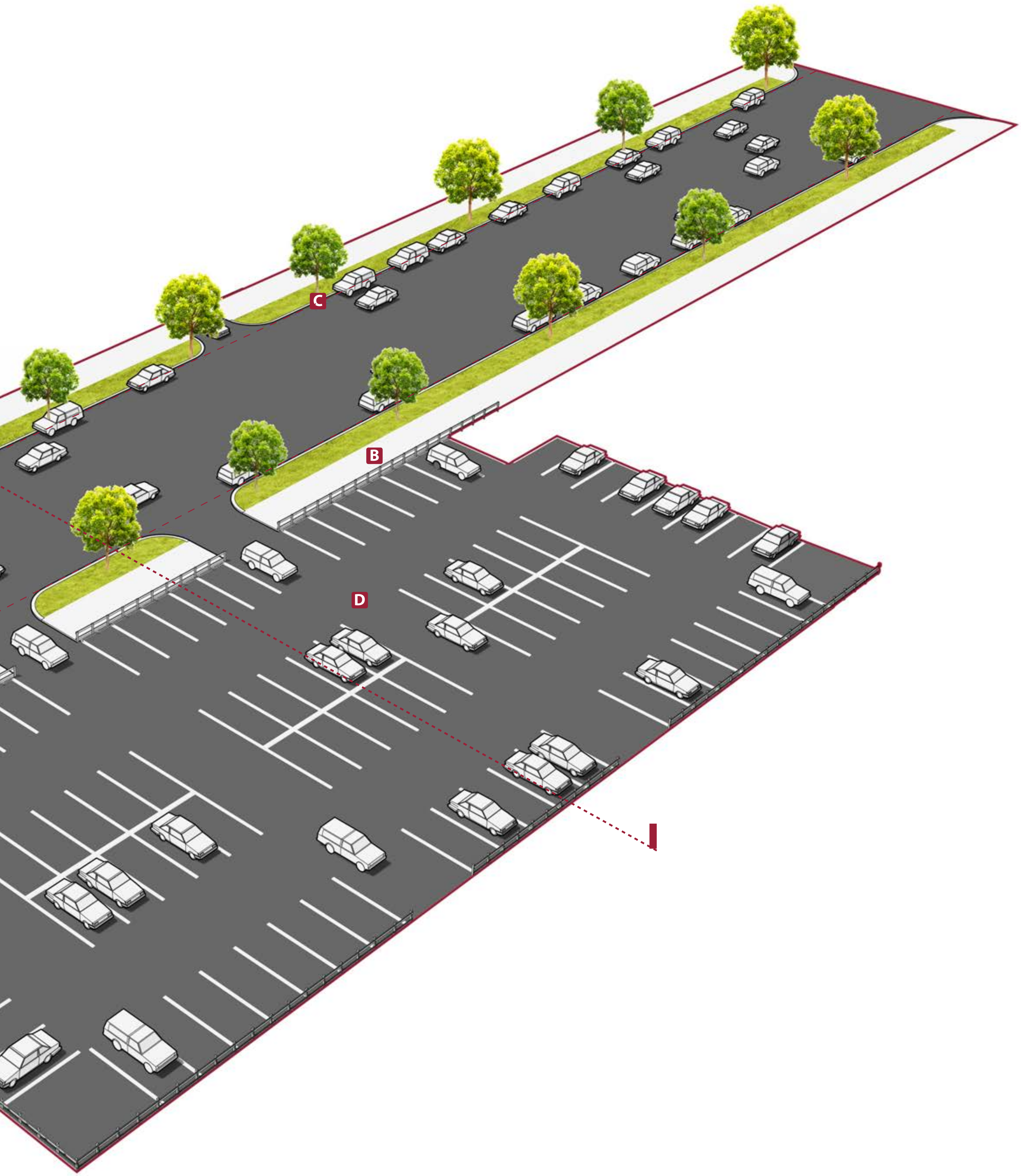
HEAT ISLAND INDEX
- Heat is absorbed
- Temperature increased

MATERIAL COST
(Material cost does not include labor)
- Impervious: 36,000 SF (100%)
- Cost: $1,208,065.32

PROGRAMS
A Existing Collector Street
B Pedestrian Sidewalk
C Collector/ Street Parking
D Surface Parking Lot

- - Street Boundary




C
B
D

COLLECTOR STREET

PLANTING
- Area: 0 SF
- Tree: 0
- Carbon Sequestration: 0 LB/ YR

STORMWATER
(Stormwater calculations are based on a 10-year rainfall event in Minnesota)
- Volume: 56,738.5 CF
- Reserve: 0 CF
- Difference: - 56,738.5 CF
- Runoff is captured on site; Redirected to the Stormwater Drainage System below and discharged and/or stored off site

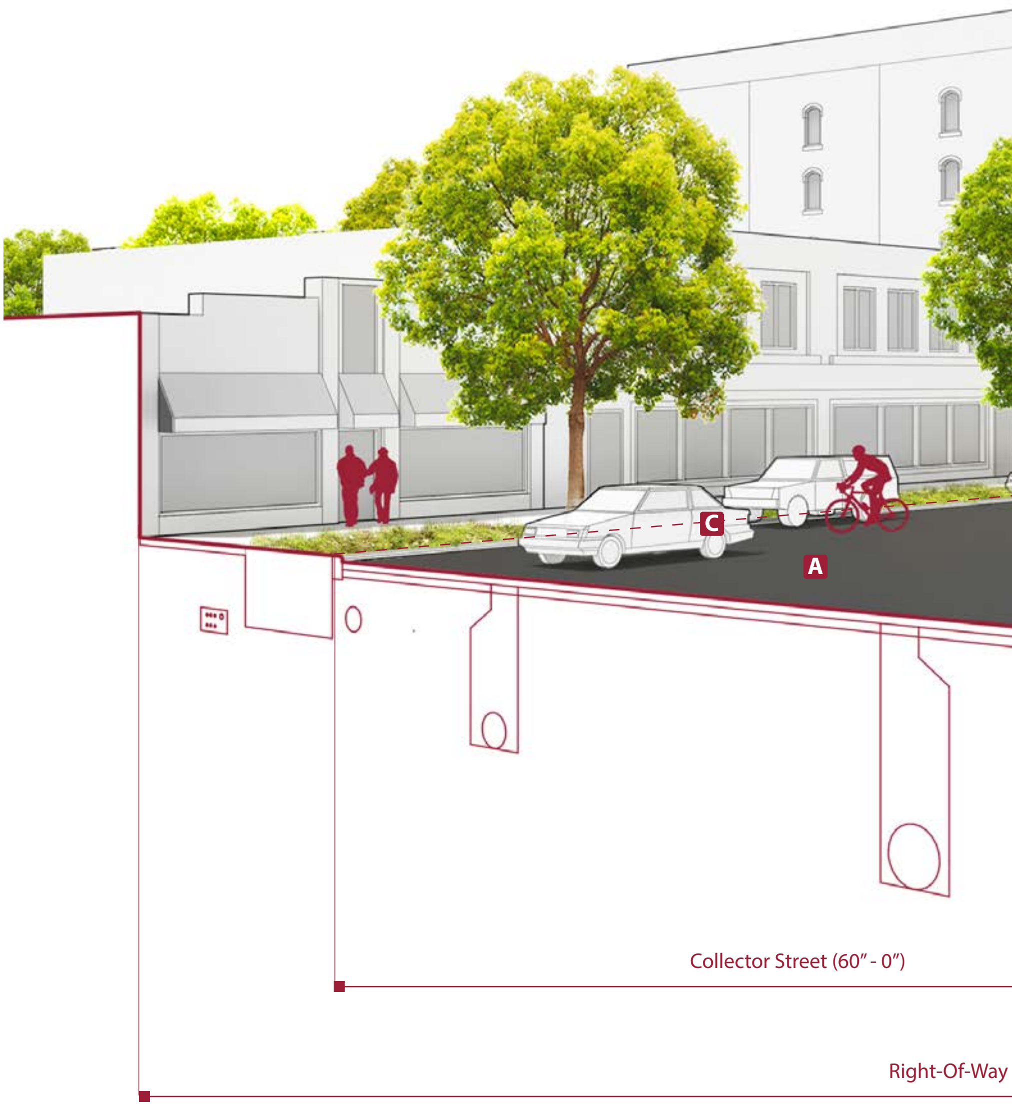
HEAT ISLAND INDEX
- Heat is absorbed
- Temperature increased

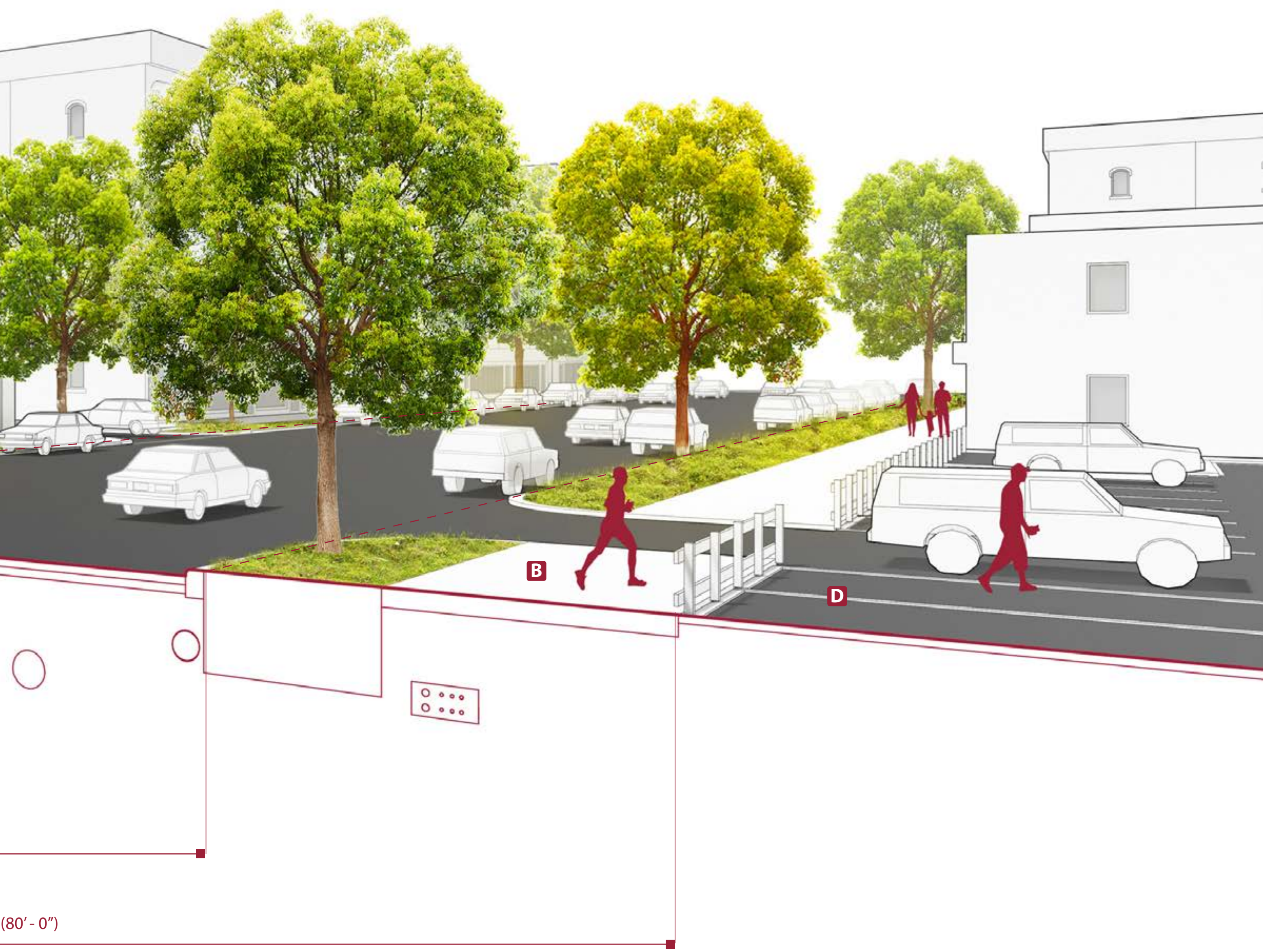
MATERIAL COST
(Material cost does not include labor)
- Impervious: 36,000 SF (100%)
- Cost: $1,208,065.32

PROGRAMS

A Existing Collector Street
B Pedestrian Sidewalk
C Collector/ Street Parking
D Surface Parking Lot

- - Street Boundary




B
D
(80' - 0")

SHARED GREEN STREET
COLLECTOR STREET (FUTURE)

PLANTING
- Area: 26,326 SF
- Tree: 35
- Carbon Sequestration: 22,420 LB/ YR

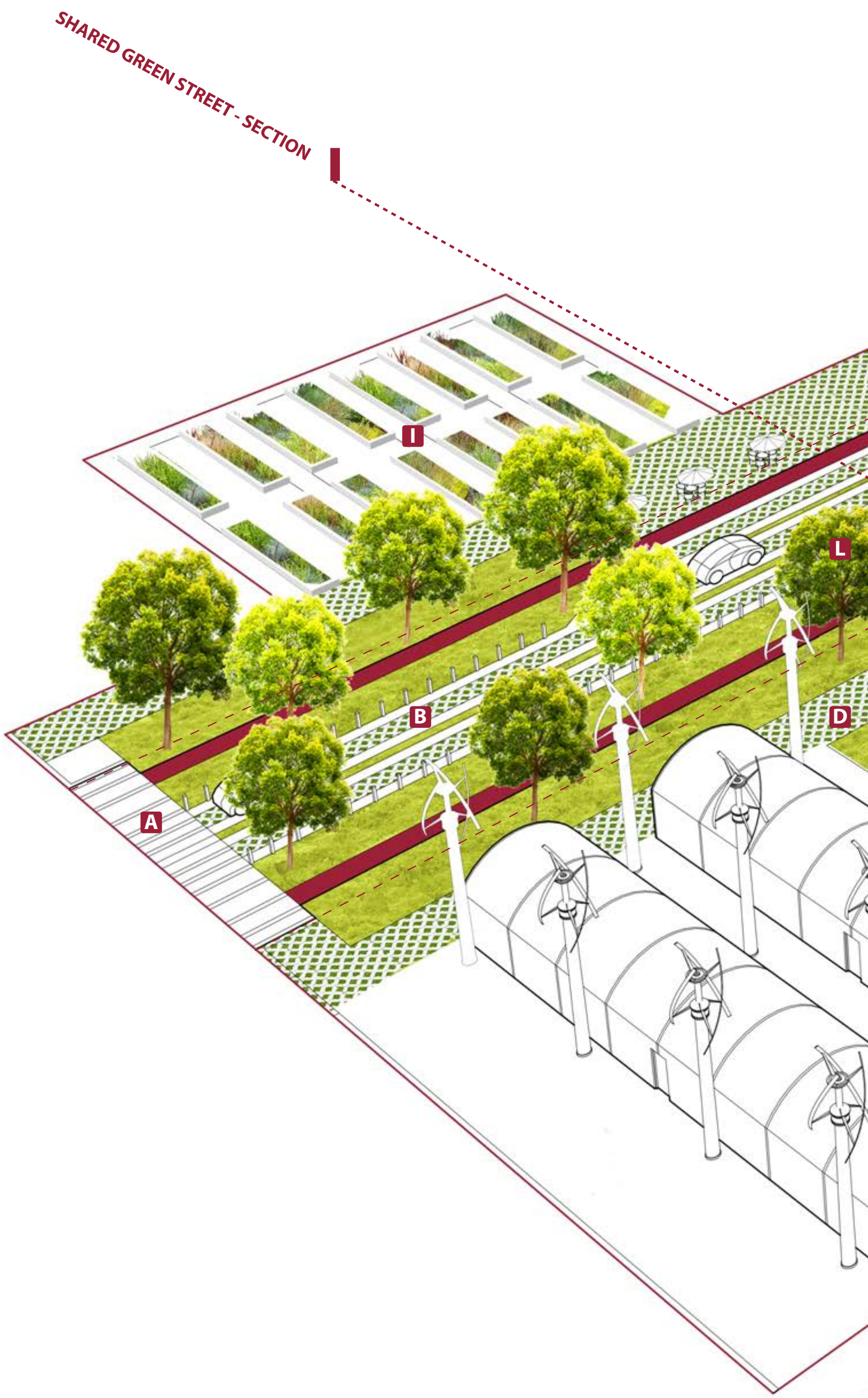
STORMWATER
(Stormwater calculations are based on a 10-year rainfall event in Minnesota)
- Volume: 56,738.5 CF
- Reserve: 47,960.3 CF
- Difference: - 8,778.22 CF
- Runoff is captured on site
- Permeable Pavement and Infiltration Trenches can accommodate for 84% of the runoff; Green Roof helps with rainfall
- Vegetative swale and Bioretention can accommodate for the remaining runoff

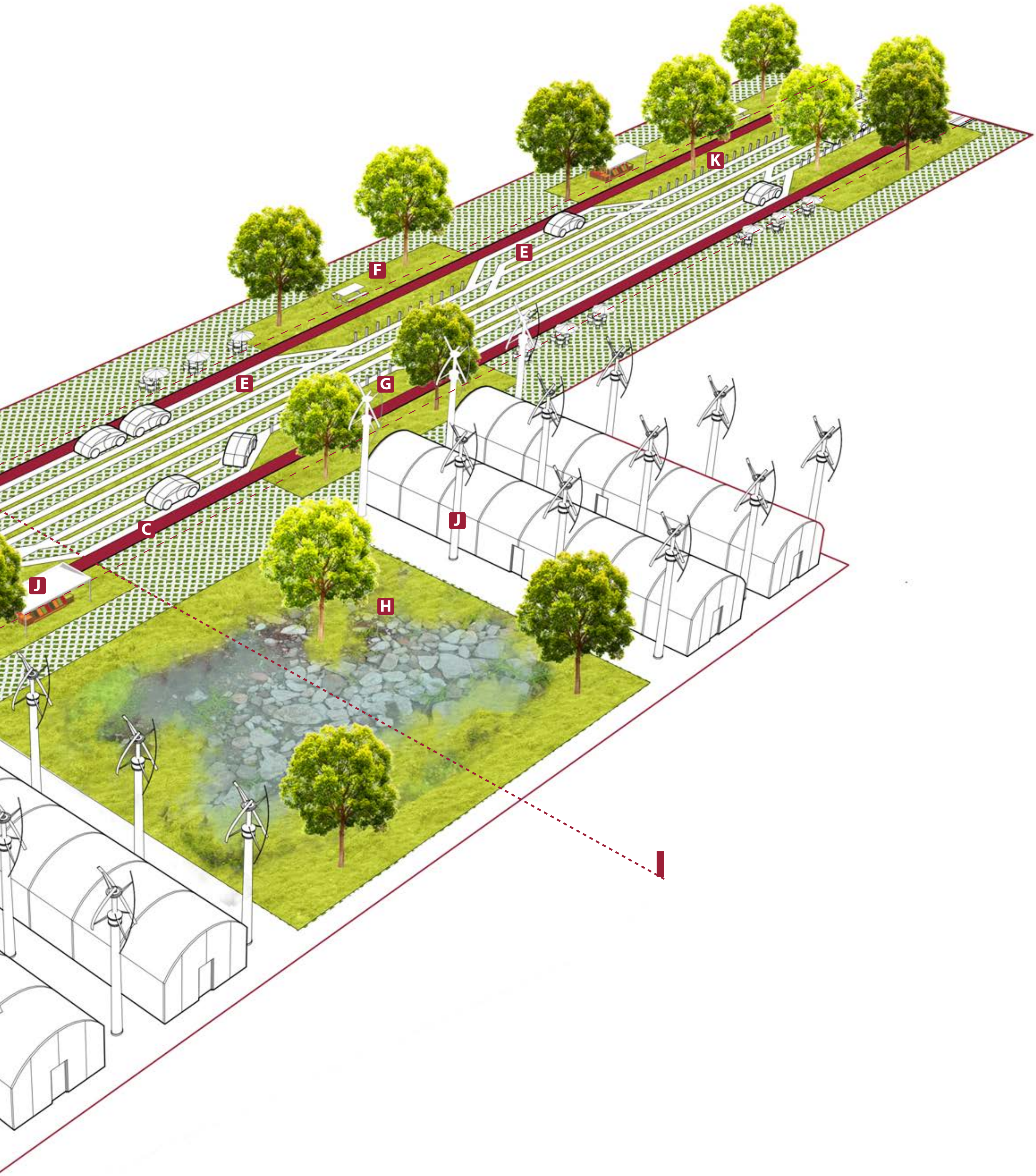
HEAT ISLAND INDEX
- Heat is reflected
- Temperature is reduced by 8 degrees; Trees and Planting Areas provide additional cooling and shading
- Sun's ray can be collected, stored, and use

MATERIAL COST
(Material cost does not include labor)
- Impervious: 9,674 SF (27%)
- Pervious: 26,326 SF (73%)
- Cost: $697,764.84
- Cost decreased by $510,300.48 (58%)
- Saving can be used to fund neighborhood's projects and initiatives to create a more resilient community

PROGRAMS
A Pedestrian Crosswalk
B Autonomous Vehicle Tracks
C Dedicated Bicycle/ Small Vehicle Lane
D Dedicated Pedestrian Sidewalk
E Pick-up/ Drop-off Zone
F Shared Communal Space
G Vegetative Swale and Infiltration Trench
H Bioretention and Wetland
I Agricultural Farm
J Wind and Solar Farm
K Smart Street Technology

– – Street Boundary




K
E
F
E
G
C
J
J
H

SHARED GREEN STREET
COLLECTOR STREET (FUTURE)

PLANTING
- Area: 26,326 SF
- Tree: 35
- Carbon Sequestration: 22,420 LB/ YR

STORMWATER
(Stormwater calculations are based on a 10-year rainfall event in Minnesota)
- Volume: 56,738.5 CF
- Reserve: 47,960.3 CF
- Difference: - 8,778.22 CF
- Runoff is captured on site
- Permeable Pavement and Infiltration Trenches can accommodate for 84% of the runoff; Green Roof helps with rainfall
- Vegetative swale and Bioretention can accommodate for the remaining runoff

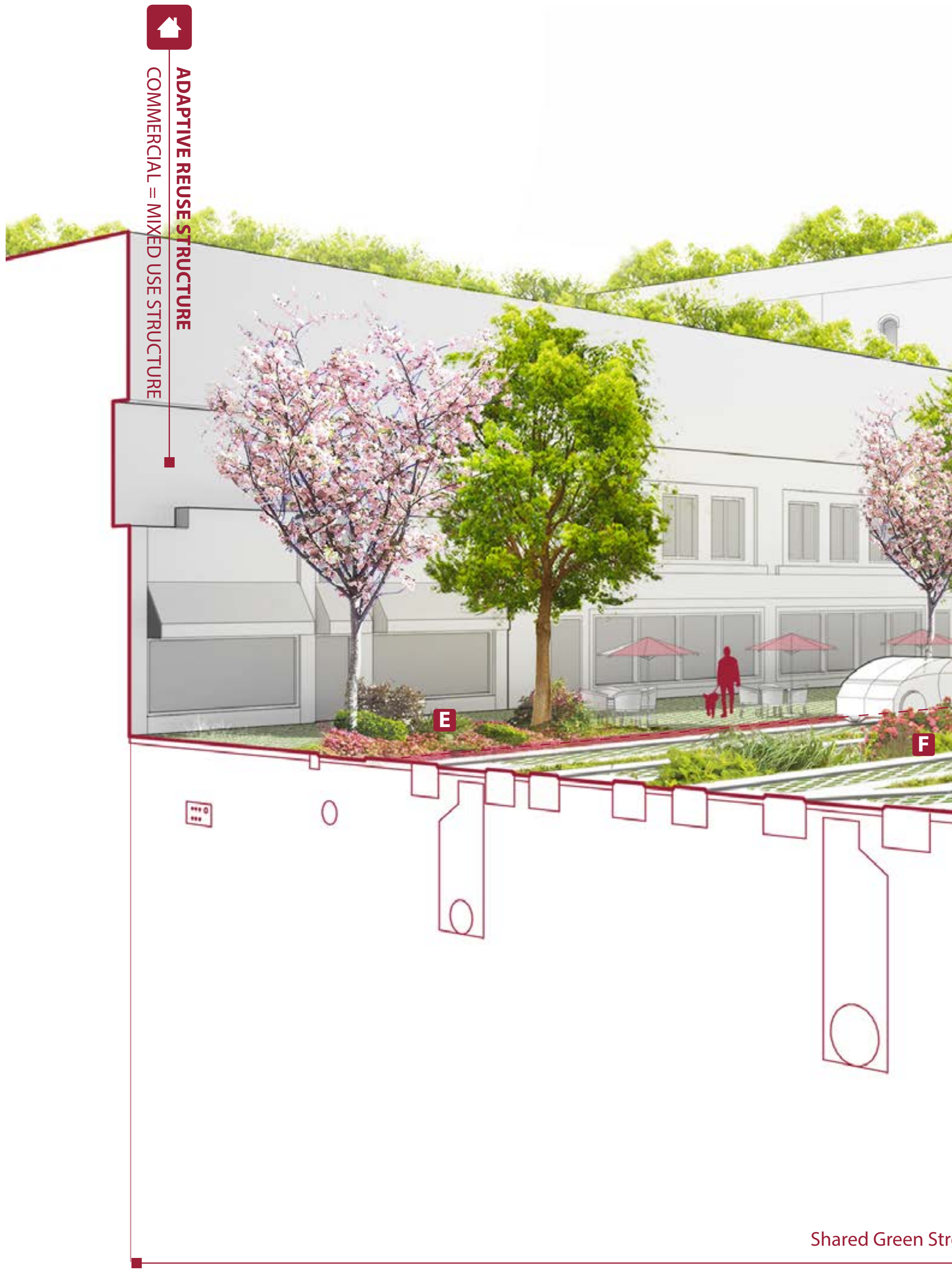
HEAT ISLAND INDEX
- Heat is reflected
- Temperature is reduced by 8 degrees; Trees and Planting Areas provide additional cooling and shading
- Sun's ray can be collected, stored, and use

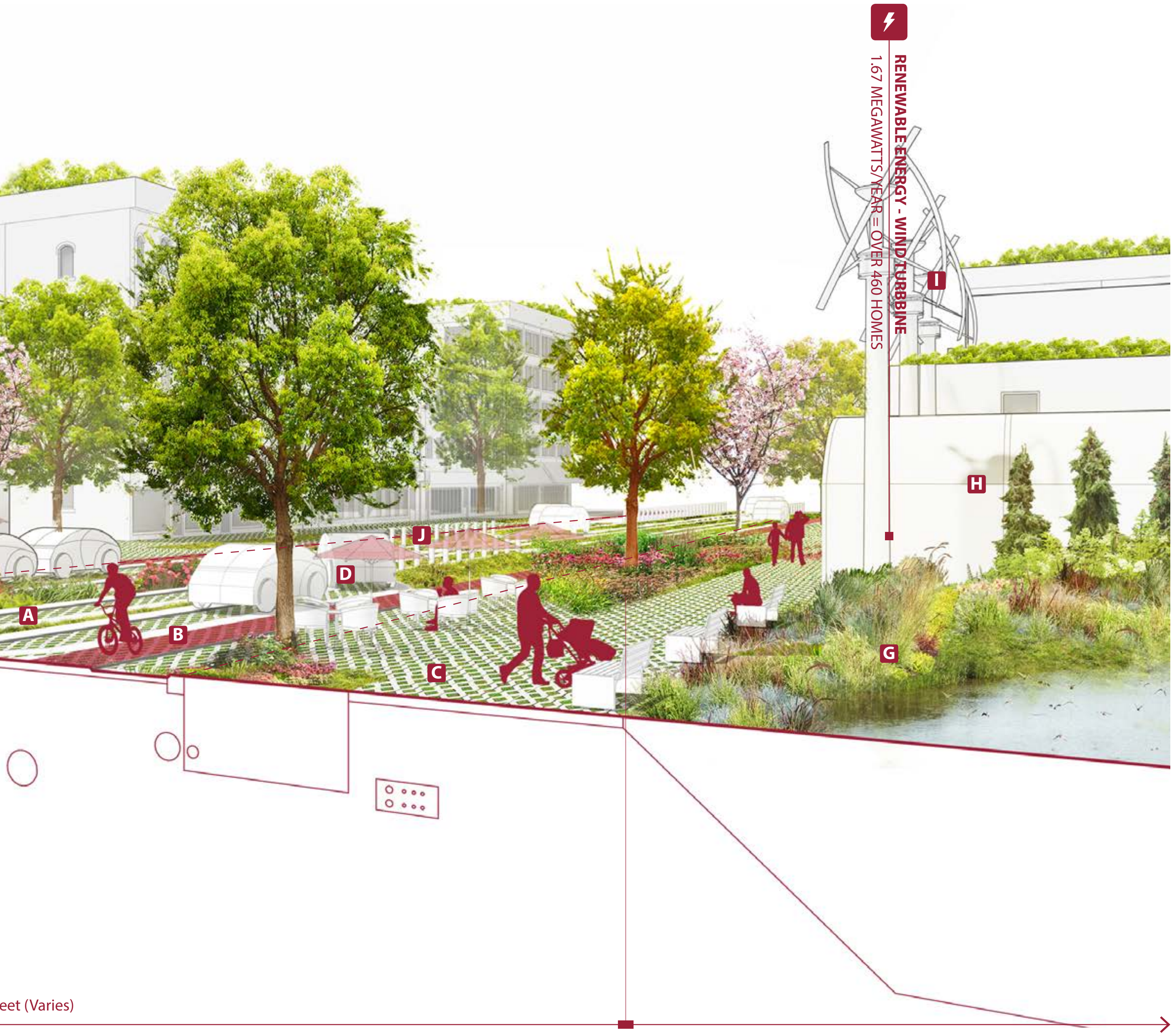
MATERIAL COST
(Material cost does not include labor)
- Impervious: 9,674 SF (27%)
- Pervious: 26,326 SF (73%)
- Cost: $697,764.84
- Cost decreased by $510,300.48 (58%)
- Saving can be used to fund neighborhood's projects and initiatives to create a more resilient community

PROGRAMS

A Autonomous Vehicle Tracks
B Dedicated Bicycle/ Small Vehicle Lane
C Dedicated Pedestrian Sidewalk
D Pick-up/ Drop-off Zone
E Shared Communal Space
F Vegetative Swale and Infiltration Trench
G Bioretention and Wetland
H Agricultural Farm
I Wind and Solar Farm
J Smart Street Technology

-- Street Boundary



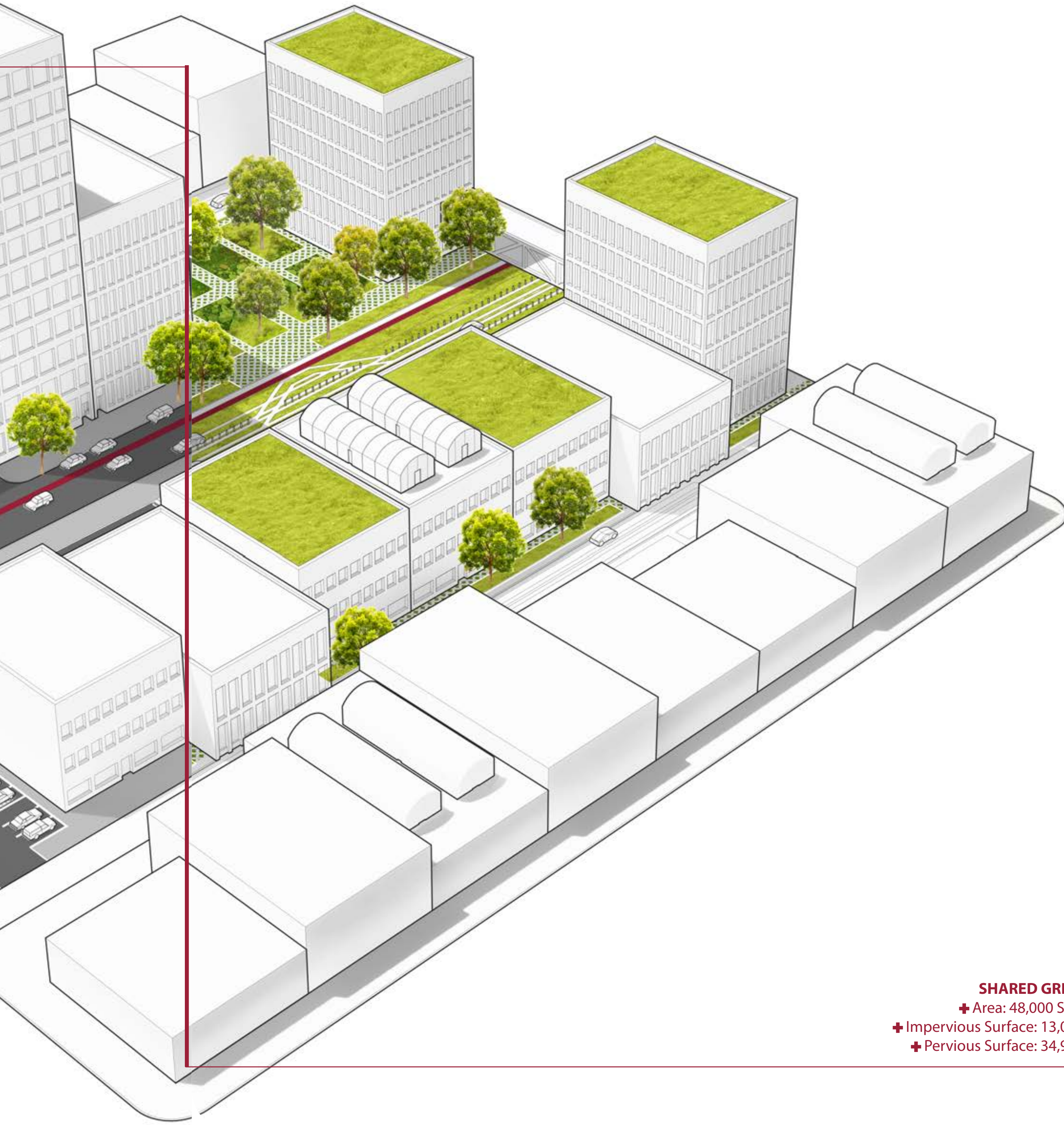

RENEWABLE ENERGY - WIND TURBINE
1.67 MEGAWATTS/YEAR = OVER 460 HOMES
A
B
C
D
G
H
I
J
eet (Varies)

ARTERIAL STREET

EXISTING
Arterial streets gather the traffic from local and collector streets and concentrate vehicles in what are often very wide roadways, with more than one travel lane in each direction and often with turn lanes and on-street parking as well. As arterial streets move through downtowns or dense commercial corridors, surface parking and structured parking ramps also abound. Although street trees often exist along arterial streets, the heat radiating off of the impervious surfaces – as well as the heat from building air-conditioning units – makes these streets among the warmest in any municipality.

SHARED GREEN STREET (FUTURE)
The changes that AV's and mobility services will bring to arterial streets will be among the most striking. The number of lanes will decrease significantly, given the efficiency with which AV's move large numbers of people, and turn lanes will largely disappear, since AV's sense the movement of everything around them and respond without the need of signals. Indeed, traffic signals will only be needed to control pedestrian crossings, which can occur at various points along a block, not just at intersections. In a mobility service future, parking ramps will no longer be needed for the storage of vehicles and will likely get converted to uses, such as housing or hydroponic food production. Meanwhile, surface parking lots will offer space for infill development, increasing density and while improving the efficiency of mobility services and growing a city's tax base, which will, in turn, help pay for the AV infrastructure that makes all of this possible.

EXISTING ARTERIAL STREET
- Area: 48,000 SF (80' x 600')
- Impervious Surface: 48,000 SF (100%)
- Pervious Surface: 0 SF (0%)



SHARED GREEN STREET

✚ Area: 48,000 SF (80' x 600')
✚ Impervious Surface: 13,055 SF (27%)
✚ Pervious Surface: 34,945 SF (73%)

ARTERIAL STREET

PLANTING
- Area: 0 SF
- Tree: 0
- Carbon Sequestration: 0 LB/ YR

STORMWATER
(Stormwater calculations are based on a 10-year rainfall event in Minnesota)
- Volume: 77,160.3 CF
- Reserve: 0 CF
- Difference: - 77,160.3 CF
- Runoff is captured on site; Redirected to the Stormwater Drainage System below and discharged and/or stored off site

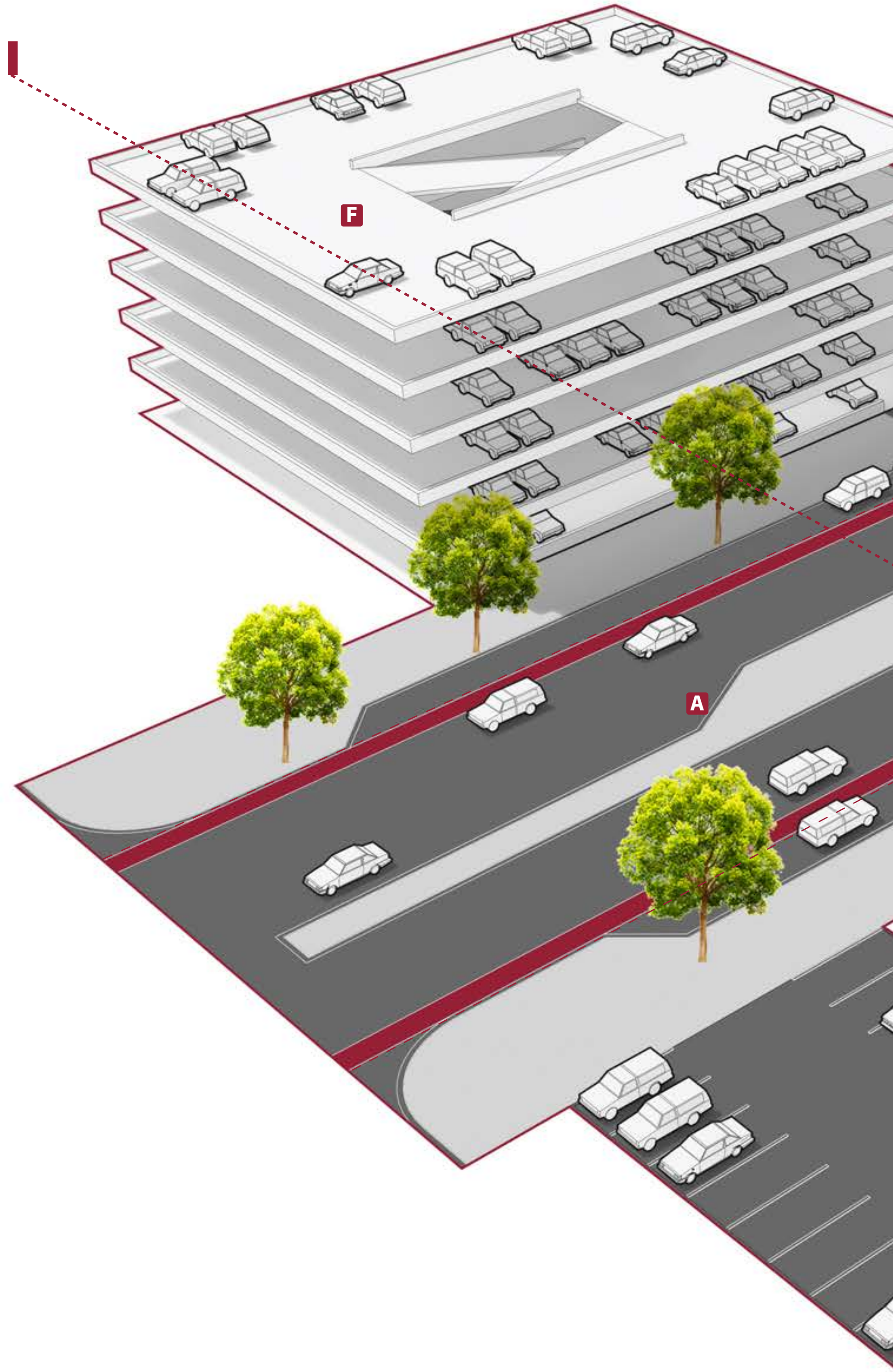
HEAT ISLAND INDEX
- Heat is absorbed
- Temperature increased

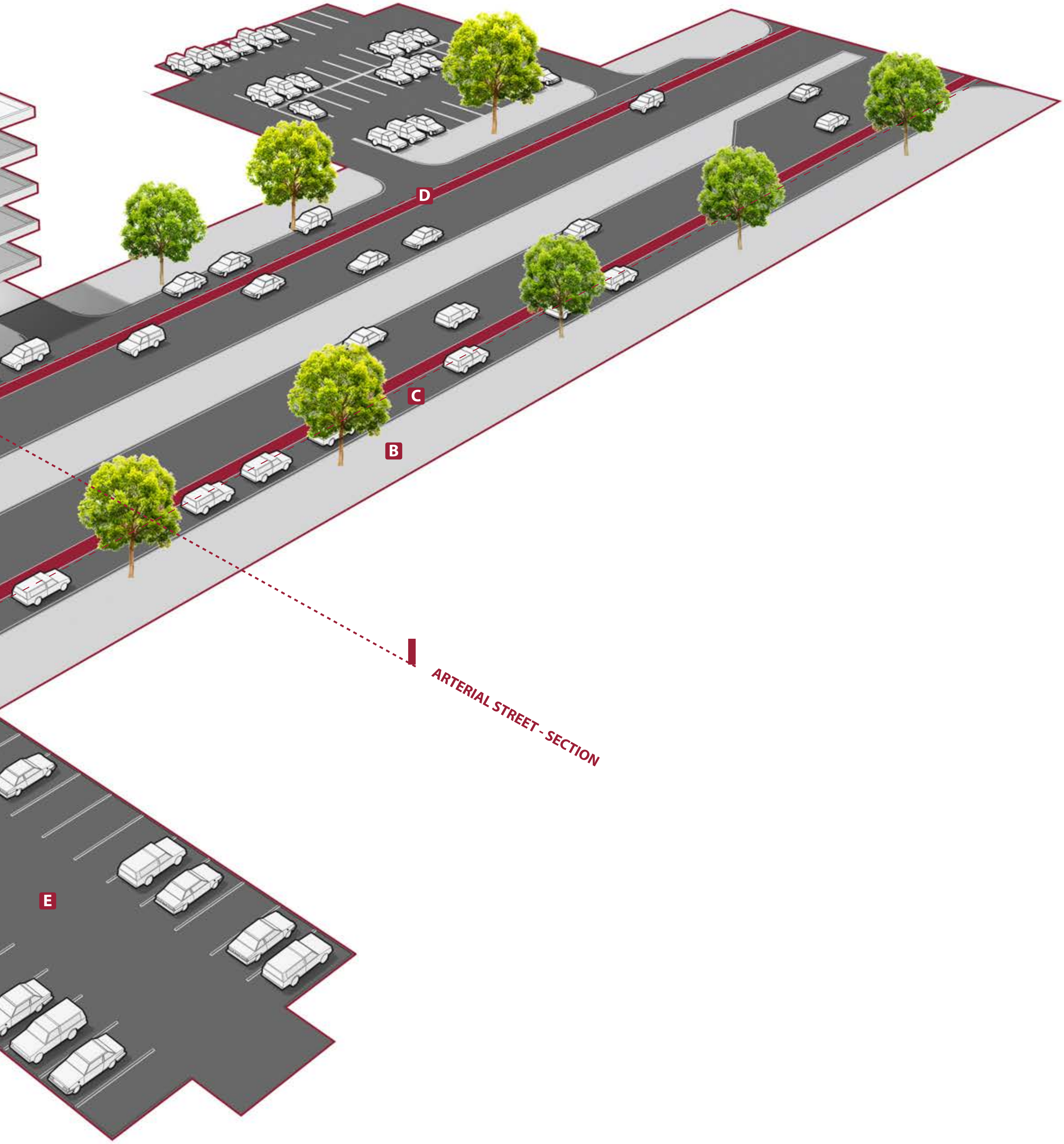
MATERIAL COST
(Material cost does not include labor)
- Impervious: 48,000 SF (100%)
- Cost: $1,386,090.72

PROGRAMS

A Existing Arterial Street
B Pedestrian Sidewalk
C Arterial/ Street Parking
D Dedicated Bicycle Lane
E Surface Parking Lot
F Parking Ramp

– – Street Boundary




D
C
B
E
ARTERIAL STREET - SECTION

ARTERIAL STREET

PLANTING
- Area: 0 SF
- Tree: 0
- Carbon Sequestration: 0 LB/ YR

STORMWATER
(Stormwater calculations are based on a 10-year rainfall event in Minnesota)
- Volume: 77,160.3 CF
- Reserve: 0 CF
- Difference: - 77,160.3 CF
- Runoff is captured on site; Redirected to the Stormwater Drainage System below and discharged and/or stored off site

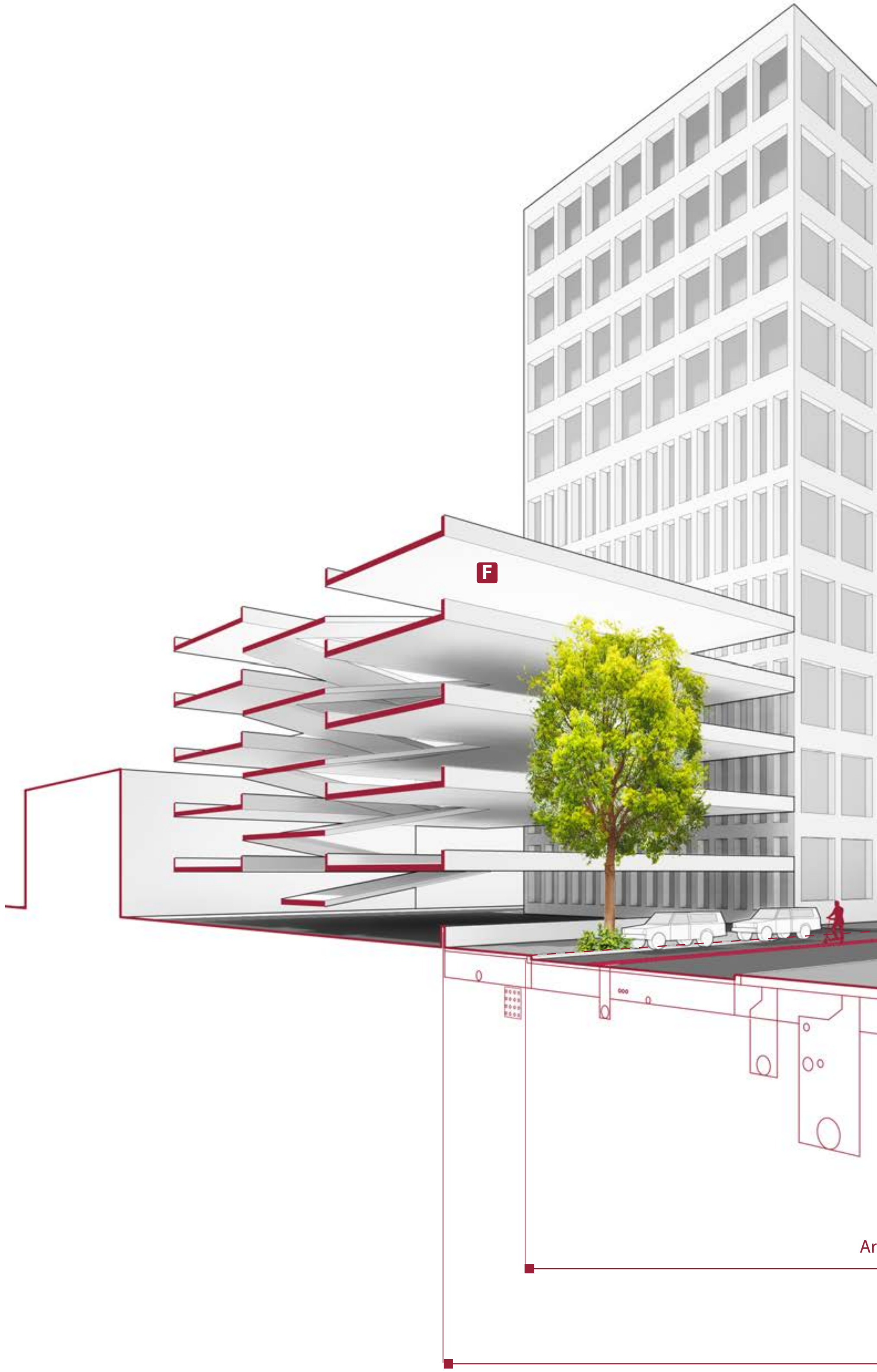
HEAT ISLAND INDEX
- Heat is absorbed
- Temperature increased

MATERIAL COST
(Material cost does not include labor)
- Impervious: 48,000 SF (100%)
- Cost: $1,386,090.72

PROGRAMS

A Existing Arterial Street
B Pedestrian Sidewalk
C Arterial/ Street Parking
D Dedicated Bicycle Lane
E Surface Parking Lot
F Parking Ramp

- - Street Boundary




E
A
D
C
B
terial Street (80' - 0")
Right-Of-Way (100' - 0")

SHARED GREEN STREET

ARTERIAL STREET (FUTURE)

PLANTING
- Area: 34,945 SF
- Tree: 50
- Carbon Sequestration: 32,788.8 LB

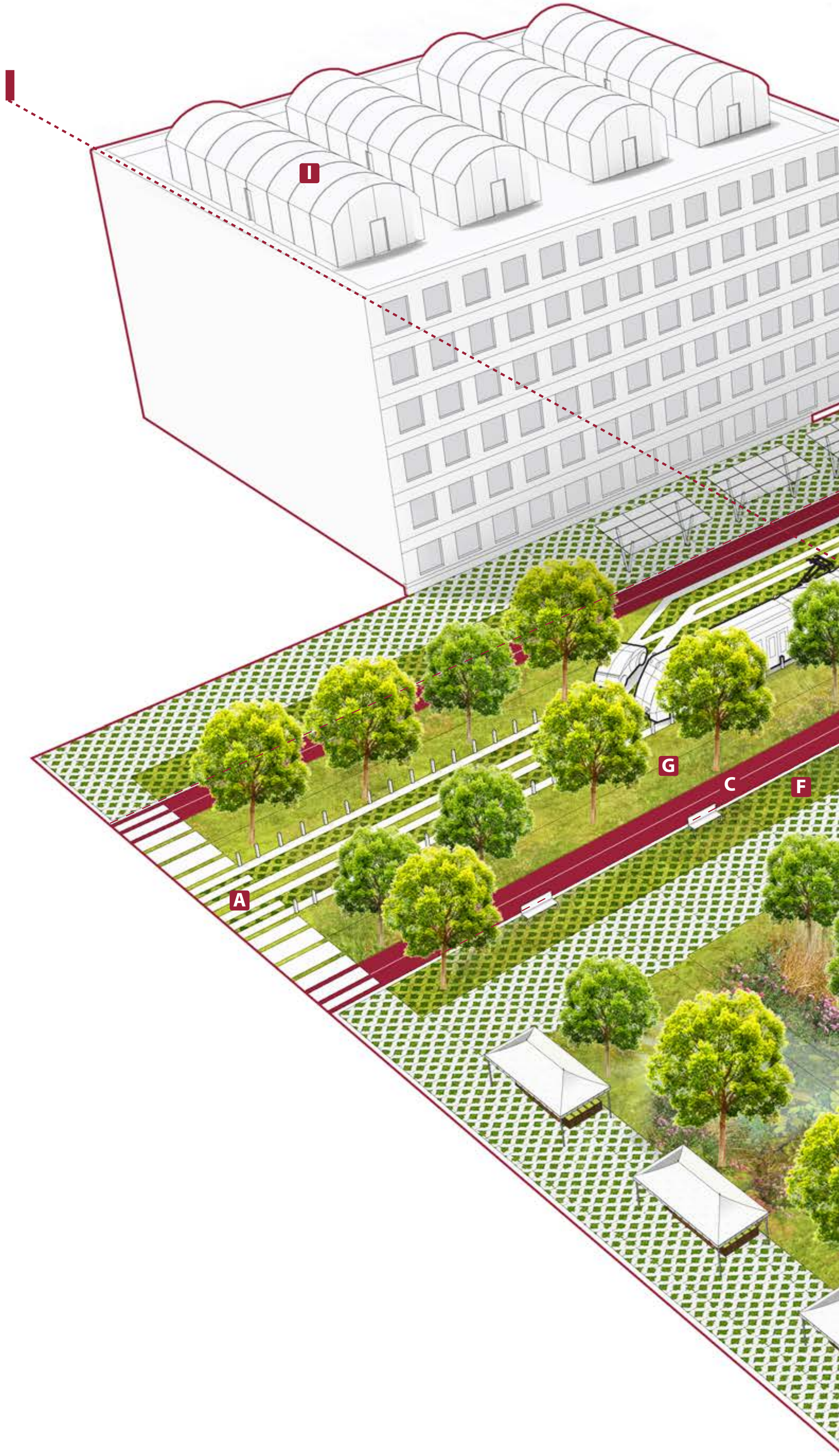
STORMWATER
(Stormwater calculations are based on a 10-year rainfall event in Minnesota)
- Volume: 77,160.3 CF
- Reserve: 69,960.3 CF
- Difference: - 7,200 CF
- Runoff is captured on site
- Permeable Pavement and Infiltration Trenches can accommodate for 90% of the runoff; Green Roof helps with rainfall
- Vegetative swale and Bioretention can accommodate for the remaining runoff

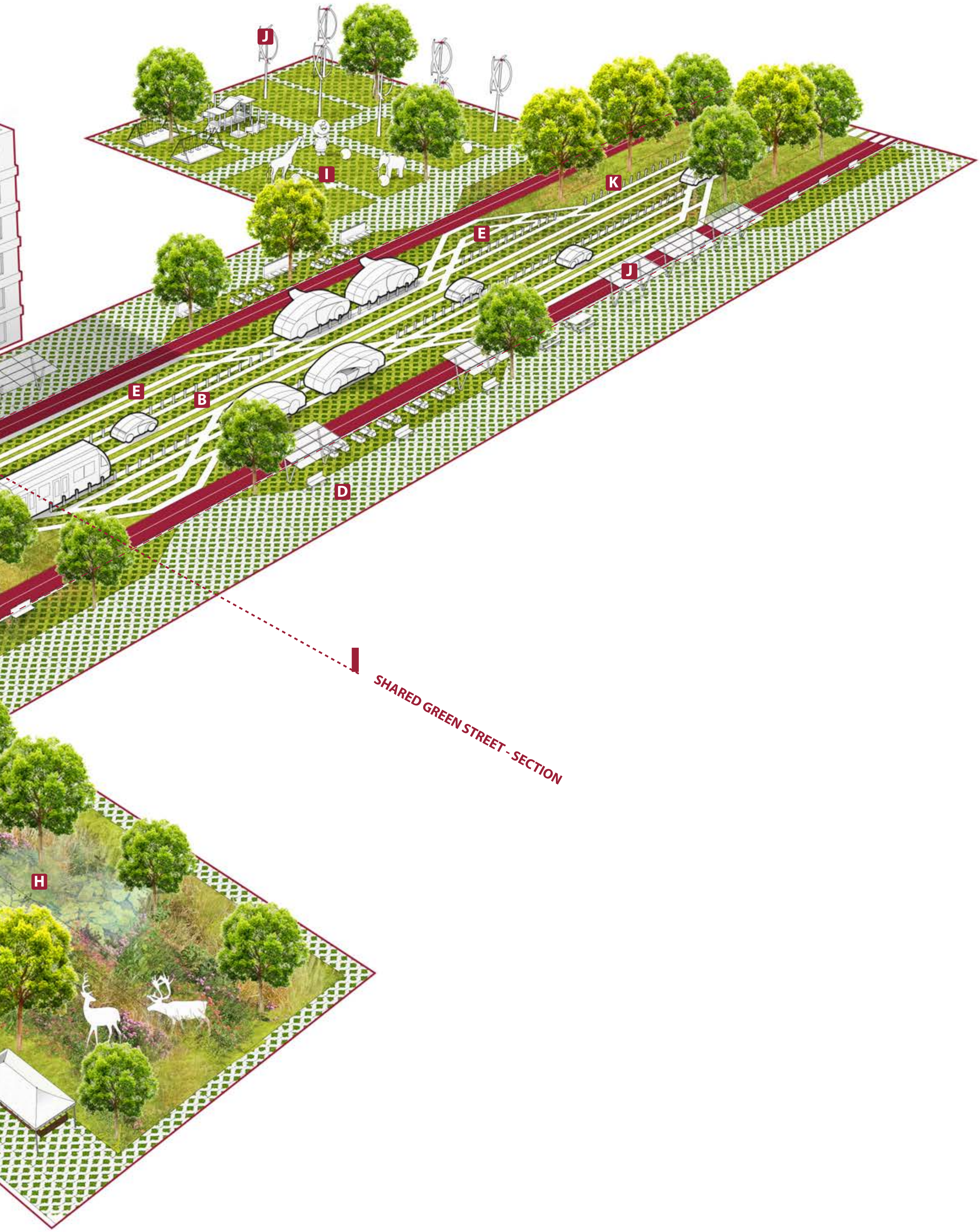
HEAT ISLAND INDEX
- Heat is reflected
- Temperature is reduced by 9 degrees; Trees and Planting Areas provide additional cooling and shading
- Sun's ray can be collected, stored, and use

MATERIAL COST
(Material cost does not include labor)
- Impervious: 13,055 SF (27%)
- Pervious: 34,945 SF (73%)
- Cost: $911,286.67
- Cost decreased by $474,804.05
- (66%)
- Saving can be used to fund neighborhood's projects and initiatives to create a more resilient community

PROGRAMS
A Pedestrian Block Crossing
B Autonomous Vehicle Tracks
C Dedicated Bicycle/ Small Vehicle Lane
D Dedicated Pedestrian Sidewalk
E Pick-up/ Drop-off Zone
F Shared Communal Space
G Vegetative Swale and Infiltration Trench
H Bioretention and Wetland
I Agricultural Farm
J Wind and Solar Farm
K Smart Street Technology

– – Street Boundary




J
I
K
E
J
E
B
D
SHARED GREEN STREET - SECTION
H

SHARED GREEN STREET
ARTERIAL STREET (FUTURE)

PLANTING
- Area: 34,945 SF
- Tree: 50
- Carbon Sequestration: 32,788.8 LB

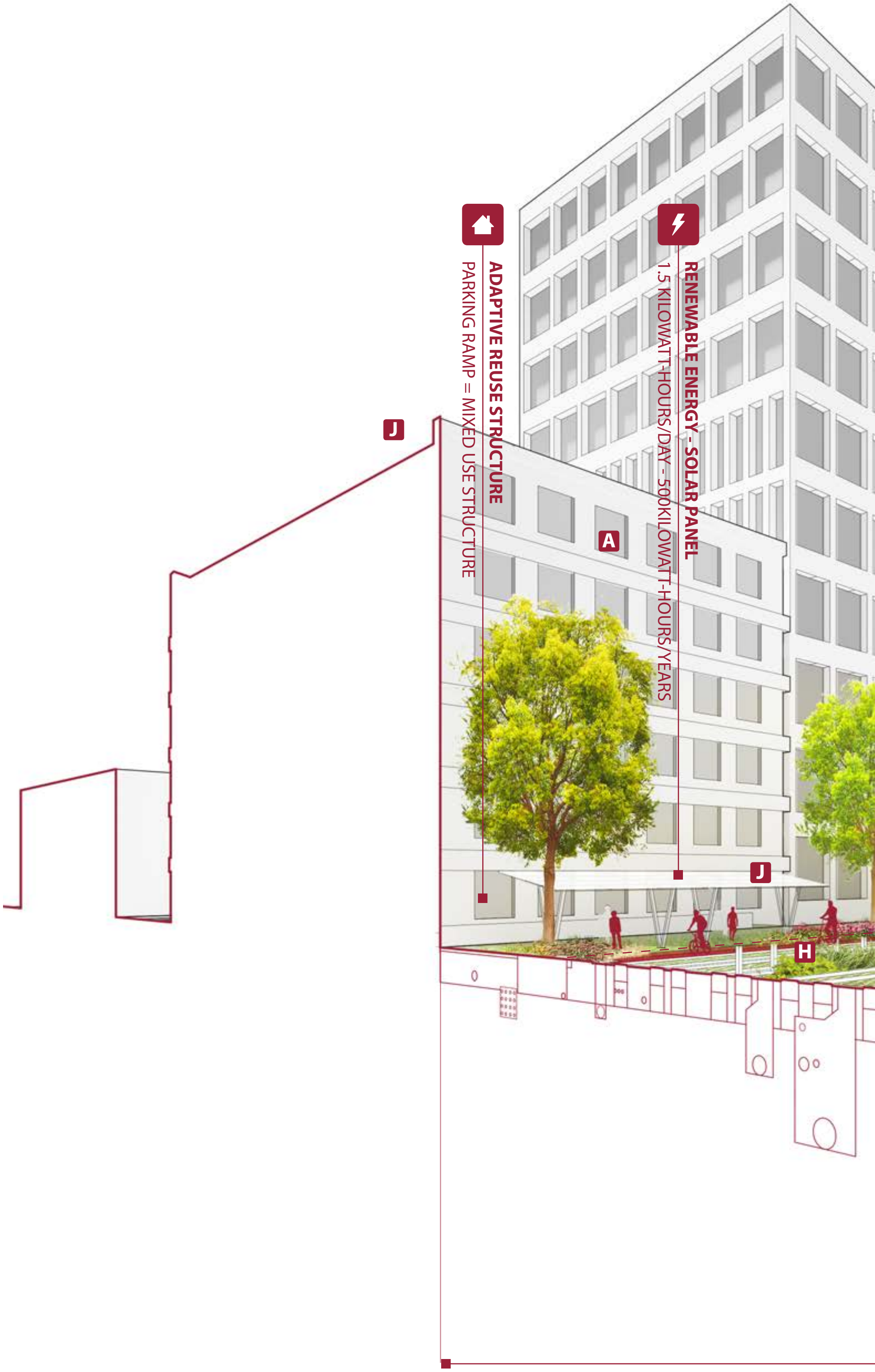
STORMWATER
(Stormwater calculations are based on a 10-year rainfall event in Minnesota)
- Volume: 77,160.3 CF
- Reserve: 69,960.3 CF
- Difference: - 7,200 CF
- Runoff is captured on site
- Permeable Pavement and Infiltration Trenches can accommodate for 90% of the runoff; Green Roof helps with rainfall
- Vegetative swale and Bioretention can accommodate for the remaining runoff

HEAT ISLAND INDEX
- Heat is reflected
- Temperature is reduced by 9 degrees; Trees and Planting Areas provide additional cooling and shading
- Sun's ray can be collected, stored, and use

MATERIAL COST
(Material cost does not include labor)
- Impervious: 13,055 SF (27%)
- Pervious: 34,945 SF (73%)
- Cost: $911,286.67
- Cost decreased by $474,804.05
- (66%)
- Saving can be used to fund neighborhood's projects and initiatives to create a more resilient community

PROGRAMS
A Adaptive Reuse Structure
B Autonomous Vehicle Tracks
C Dedicated Bicycle/ Small Vehicle Lane
D Dedicated Pedestrian Sidewalk
E Pick-up/ Drop-off Zone
F Shared Communal Space
G Vegetative Swale and Infiltration Trench
H Bioretention and Wetland
I Agricultural Farm
J Wind and Solar Farm
K Smart Street Technology

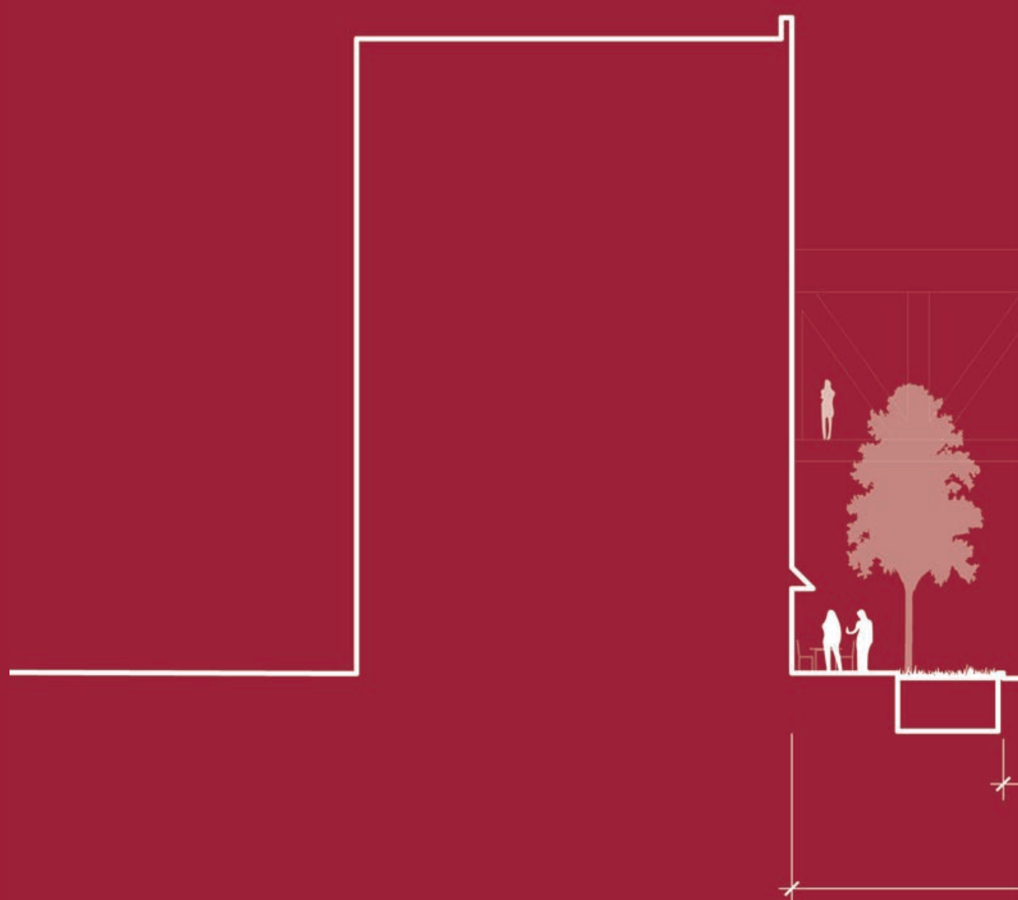
– – Street Boundary

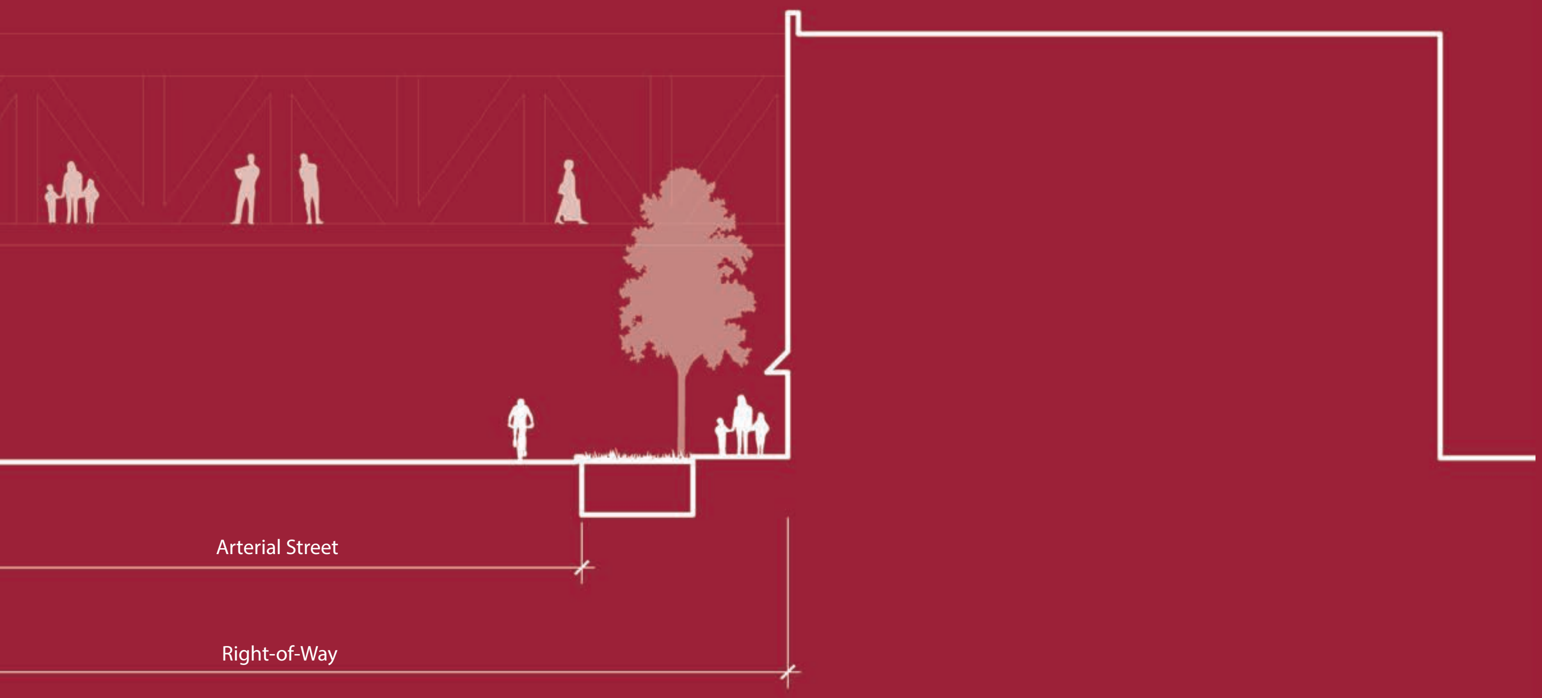


Shared Green Street

APPENDICES

CALCULATIONS
PROJECT DEVELOPMENT




Arterial Street
Right-of-Way

ALLEY CALCULATIONS

Alley Surfaces Calc

Total Area	Impervious Area	Plant Area (Tree)	Plant Area (native)	Pervious Paving	lengths (of tree s	(Trees if 20' on center)
	5413	2522	0	4065	110	6
						0
						0
12000	**5413**	**2522**	**0**	**4065**	**110**	**11**

Trees

Depth	Area	Cubic Ft Available	Number of Trees	CO2 (annual)	Intercept (gal/yea	$ value per tree	Max $ value
5	2522	12610	191	10126.21212	19106.06061	$ 13.00	**$ 2,483.79**
			113	12947.76786	25895.53571	$ 27.00	**$ 3,039.91**
			77	15070.4878	32601.46341	$ 45.00	**$ 3,460.06**
			58	16171.15741	36020.23148	$ 63.00	**$ 3,677.92**
			48	19300.03817	42691.10687	$ 84.00	**$ 4,042.90**
			41	21453.37662	47369.38312	$ 105.00	**$ 4,298.86**
			36	23082.71186	50831.83616	$ 126.00	**$ 4,488.31**
			32	23096.88776	56680.66327	$ 143.00	**$ 4,600.08**
			29	23137.88372	61495.74419	$ 160.00	**$ 4,692.09**
			27	23145.27778	65501.94444	$ 177.00	**$ 4,769.17**
			25	23858.12	71322.16	$ 196.00	**$ 4,943.12**
			24	24417.1161	76132.28464	$ 215.00	**$ 5,077.06**
		15-dbh tree	11	7128	15697	$ 126.00	**$ 1,386.00**

Stormwater Calc

Block Width (ft)	Block Length (ft)	Block Area (sq ft)	Block Area (Acres)	Total Block Area (ir	Total Block Area (Acres)
600.00	300.00	180000.00	4.13	192000.00	4.41
ROW Width	2nd ROW Width	ROW Length	2nd ROW Length (ft	ROW Area (sq ft) p	ROW Area (Acres)
20.00	0.00	600.00	0.00	12000.00	0.28
ROW Trench Depth (ft)	Capacity (cubic ft) Per Block	Column1	Column2	Column3	ROW % of Block
5.00	13200.00		0.00		0.06
Alley Width	Alley Length	Alley Area	Alley Area in Acres	Alley Capacity	ROW % Incl Alley
20.00	600.00	12000.00	0.28	13200.00	0.13

Block Type	% Impervious	Rv Runoff Coefficient	Rainfall (inches/24h	Runoff Volume (cu	Difference		
Residential	45.00%	0.455	1.25	9100	**4100.28**	90%	1.25
Residential	45.00%	0.455	2.8	20384	**-7183.72**	2-yr event	2.8
Residential	45.00%	0.455	4.2	30576	**-17375.72**	10-yr event	4.2
Residential	45.00%	0.455	6	43680	**-30479.72**	Flash Flood/100 yr	6
Residential	45.00%	0.455	7.4	53872	**-40671.72**	100	7.4
Residential	45.00%	0.455	10.5	76440	**-63239.72**	500	10.5

Cost Calc

ALLEY	**2003 per lin ft (20' ROW)**	**Typical block ft**	**Typical Block cost**	**SAV Block ft**	**SAV Block Cost**	
Paving Concrete 6" Sq ft	$ 10.00	0	$ -	5413	$ 54,130.00	
Paving asphalt	$ 5.00	12000.00	$ 60,000.00	0	$ -	
permeable paving	$ 6.00	0	$ -	4065	$ 24,390.00	
Base rock aggregate 4" sqft	$ 0.65	12000.00	$ 7,800.00	0.00	$ -	
subgrade 6" sqft	$ 5.00	12000.00	$ 60,000.00	12000.00	$ 60,000.00	
course aggregate	$ 3.00	0	$ -	12000.00	$ -	
Add on subgrade	$ 5.00	0	$ -	4065	$ 20,325.00	
Add on course	$ 3.00	0	$ -	4065	$ 12,195.00	
Storm drain 18" Concrete	$ 45.30	0	$ -	0		
Concrete Curb 6" 1' gutter	$ 21.90	0	$ -	0		
			$ 127,800.00		$ 171,040.00	$ 43,240.00
						133.8%
			Inflation adj		Inflation adj	
			$ 178,025.40		$ 238,258.72	$ 60,233.32
						134%

SIDEWALK AND LIGHTING WASH COST

Urban Heat Effect (estimate)

surface type	heat reduction	location heat reduction			
					*according to Y. Liu et al. exposure to moderate to extreme heat in the Twin Cities Metropolitan Area has an annual cost of $1,171,470,000,
agricultural fields	-6		-1.261	non-tree planting	(planted native area/total area) * -6f temp reduction
forests and surrounding areas	-9		-1.8915	tree planting area	(planted tree area/total area) * -9f temp reduction
tree shaded area	-18		-20.724	tree shading	((# of trees * square(20 ft radius canopy) = shaded area) / total area of block * -18f temp reduction
	Averge temperature reduction		-7.958833333		

LOCAL CALCULATIONS

Surfaces Calc

Total Area	Impervious Area	Plant Area (Tree)	Plant Area (native)	Pervious Paving	lengths (of tree space)	(Trees if 20' on center)
	8053	8445	0	7502	85	4
					208	10
					140	7
24000	**8053**	**8445**	**0**	**7502**	**433**	**43**

Trees

Depth	Area	Cubic Ft Available	Number of Trees	CO2 (annual)	Intercept (gal/year)	$ value per tree	Max $ value
5	8445	42225	640	33907.95455	63977.27273	$ 13.00	**$ 8,317.05**
			377	43356.02679	86712.05357	$ 27.00	**$ 10,179.24**
			257	50464.02439	109167.0732	$ 45.00	**$ 11,586.13**
			195	54149.65278	120614.9306	$ 63.00	**$ 12,315.63**
			161	64626.81298	142952.5763	$ 84.00	**$ 13,537.79**
			137	71837.33766	158617.9383	$ 105.00	**$ 14,394.89**
			119	77293.22034	170212.0763	$ 126.00	**$ 15,029.24**
			108	77340.68878	189797.0663	$ 143.00	**$ 15,403.51**
			98	77477.96512	205920.5233	$ 160.00	**$ 15,711.63**
			90	77502.72436	219335.4167	$ 177.00	**$ 15,969.71**
			84	79889.7	238824.6	$ 196.00	**$ 16,552.20**
			79	81761.51685	254931.4607	$ 215.00	**$ 17,000.70**
		15-dbh tree	43	28058.4	61789.1	$ 126.00	**$ 5,455.80**

Stormwater Calc

Block Width (ft)	Block Length (ft)	Block Area (sq ft)	Block Area (Acres)	Total Block Area (incl RO\	Total Block Area (Acres)
600.00	300.00	180000.00	4.13	217600.00	5.00
ROW Width	2nd ROW Width	ROW Length	2nd ROW Length (ft)	ROW Area (sq ft) per bloc	ROW Area (Acres)
40.00	40.00	340.00	600.00	37600.00	0.86
ROW Trench Depth (ft)	Capacity (cubic ft) Per Block	Column1	Column2	Column3	ROW % of Block
5.00	41360.00		0.00		0.17
Alley Width	Alley Length	Alley Area	Alley Area in Acres	Alley Capacity	ROW % Incl Alley
20.00	600.00	12000.00	0.28	13200.00	0.23

Block Type	% Impervious	Rv Runoff Coefficient	Rainfall (inches/24hr)	Runoff Volume (cubic ft)	Difference	total reserve
Residential	45.00%	0.455	1.25	10313.33333	**31046.94**	**41360.28**
Residential	45.00%	0.455	2.8	23101.86667	**18258.41**	**41360.28**
Residential	45.00%	0.455	4.2	34652.8	**6707.48**	**41360.28**
Residential	45.00%	0.455	6	49504	**-8143.72**	**41360.28**
Residential	45.00%	0.455	7.4	61054.93333	**-19694.66**	**41360.28**
Residential	45.00%	0.455	10.5	86632	**-45271.72**	**41360.28**

Cost Calc

LOCAL	**2003 sq ft (40' ROW)**	**Typical block ft**	**Typical Block cost**	**SAV Block ft**	**SAV Block Cost**	
Paving Concrete 6" Sq ft	$ 10.00	0	$ -	8053	$ 80,530.00	
Paving asphalt	$ 5.00	24000.00	$ 120,000.00	0	$ -	
permeable paving	$ 6.00	0	$ -	7502	$ 45,012.00	
Base rock aggregate 4" sqft	$ 0.65	24000.00	$ 15,600.00	0.00	$ -	
subgrade 6" sqft	$ 5.00	24000.00	$ 120,000.00	24000.00	$ 120,000.00	
course aggregate	$ 3.00	0	$ -	24000.00	$ -	
Add on subgrade	$ 5.00	0	$ -	7502	$ 37,510.00	
Add on course	$ 3.00	0	$ -	7502	$ 22,506.00	
Storm drain 18" Concrete	$ 45.30	7200.00	$ 326,160.00	0		
Concrete Curb 6" 1' gutter	$ 21.90	7200.00	$ 157,680.00	0		
			$ 739,440.00		$ 305,558.00	$ (433,882.00)
						41.3%
			Inflation adj		Inflation adj	
			$ 1,030,039.92		$ 425,642.29	$ (604,397.63)
						41%

SIDEWALK AND LIGHTING WASH COST

Urban Heat Effect (estimate)

surface type	heat reduction	location heat reduction		
agricultural fields	-6	-2.11125	non-tree planting	(planted native area/total area) * -6f temp reduction
forests and surrounding areas	-9	-3.166875	tree planting area	(planted tree area/total area) * -9f temp reduction
tree shaded area	-18	-40.7886	tree shading	((# of trees * square(20 ft radius canopy) * 3.14) = shaded area) / total area of block * -18f temp reduction
	Averge temperature reduction	-15.355575		

*according to Y. Liu et al. exposure to moderate to extreme heat in the Twin Cities Metropolitan Area has an annual cost of $1,171,470,000,

COLLECTOR CALCULATIONS

Surfaces Calc

Total Area	Impervious Area	Plant Area (Tree)	Plant Area (Lawn)	Pervious Paving	lengths (of tree space	(Trees if 20' on center)
	9674	6450	3864	16012	99	5
					93	5
					154	8
36000	**9674**	**6450**	**3864**	**16012**	**346**	**35**

Trees

Depth	Area	Cubic Ft Available	Number of Trees	CO2 (annual)	Intercept (gal/year)	$ value per tree	Max $ value
5	6450	32250	489	25897.72727	48863.63636	$ 13.00	**$ 6,352.27**
			288	33113.83929	66227.67857	$ 27.00	**$ 7,774.55**
			197	38542.68293	83378.04878	$ 45.00	**$ 8,849.09**
			149	41357.63889	92121.52778	$ 63.00	**$ 9,406.25**
			123	49359.73282	109182.2519	$ 84.00	**$ 10,339.69**
			105	54866.88312	121146.9156	$ 105.00	**$ 10,994.32**
			91	59033.89831	130002.1186	$ 126.00	**$ 11,478.81**
			82	59070.15306	144960.4592	$ 143.00	**$ 11,764.67**
			75	59175	157275	$ 160.00	**$ 12,000.00**
			69	59193.91026	167520.8333	$ 177.00	**$ 12,197.12**
			65	61017	182406	$ 196.00	**$ 12,642.00**
			60	62446.62921	194707.8652	$ 215.00	**$ 12,984.55**
		15-dbh tree	35	22420.8	49374.2	$ 126.00	**$ 4,359.60**

Stormwater Calc

Block Width (ft)	Block Length (ft)	Block Area (sq ft)	Block Area (Acres)	Total Block Area (incl RO\	Total Block Area (Acres)
600.00	300.00	180000.00	4.13	223600.00	5.13
ROW Width	2nd ROW Width	ROW Length	2nd ROW Length (ft)	ROW Area (sq ft) per blo(	ROW Area (Acres)
60.00	40.00	340.00	580.00	43600.00	1.00
ROW Trench Depth (ft)	Capacity (cubic ft) Per Block	Column1	Column2	Column3	ROW % of Block
5.00	47960.00		0.00		0.19
Alley Width	Alley Length	Alley Area	Alley Area in Acres	Alley Capacity	ROW % Incl Alley
20.00	600.00	12000.00	0.28	13200.00	0.25

Block Type	% Impervious	Rv Runoff Coefficient	Rainfall (inches/24hr)	Runoff Volume (cubic ft)	Difference	
Mixed Use	75.00%	0.725	1.25	16886.45833	**31073.82**	**47960.27548**
Mixed Use	75.00%	0.725	2.8	37825.66667	**10134.61**	**47960.27548**
Mixed Use	75.00%	0.725	4.2	56738.5	**-8778.22**	**47960.27548**
Mixed Use	75.00%	0.725	6	81055	**-33094.72**	**47960.27548**
Mixed Use	75.00%	0.725	7.4	99967.83333	**-52007.56**	**47960.27548**
Mixed Use	75.00%	0.725	10.5	141846.25	**-93885.97**	**47960.27548**

Cost Calc

COLLECTOR	**2003 sq ft (40' ROW)**	**Typical block ft**	**Typical Block cost**	**SAV Block ft**	**SAV Block Cost**	
Paving Concrete 6" Sq ft	$ 10.00	0	$ -	9674	$ 96,740.00	
Paving asphalt	$ 5.00	36000.00	$ 180,000.00	0	$ -	
permeable paving	$ 6.00	0	$ -	16012	$ 96,072.00	
Base rock aggregate 4" sqft	$ 0.65	36000.00	$ 23,400.00	0.00	$ -	
subgrade 6" sqft	$ 5.00	36000.00	$ 180,000.00	36000.00	$ 180,000.00	
course aggregate	$ 3.00	0	$ -	36000.00	$ -	
Add on subgrade	$ 5.00	0	$ -	16012	$ 80,060.00	
Add on course	$ 3.00	0	$ -	16012	$ 48,036.00	
Storm drain 18" Concrete	$ 45.30	7200.00	$ 326,160.00	0		
Concrete Curb 6" 1' gutter	$ 21.90	7200.00	$ 157,680.00	0		
			$ 867,240.00		$ 500,908.00	$ (366,332.00)
						57.8%
			Inflation adj		Inflation adj	
			$ 1,208,065.32		$ 697,764.84	$ (510,300.48)
						58%
			SIDEWALK AND LIGHTING WASH COST			

Urban Heat Effect (estimate)

surface type	heat reduction	location heat reduction		
				*according to Y. Liu et al. exposure to moderate to extreme heat in the Twin Cities Metropolitan Area has an annual cost of $1,171,470,000,
agricultural fields	-6	-1.719	non-tree planting	(planted native area/total area) * -6f temp reduction
forests and surrounding areas	-9	-1.6125	tree planting area	(planted tree area/total area) * -9f temp reduction
tree shaded area	-18	-21.7288	tree shading	((# of trees * square(20 ft radius canopy) * 3.14) = shaded area) / total area of block * -18f temp reduction
	Averge temperature reduction	-8.353433333		

ARTERIAL CALCULATIONS

Surfaces Calc

Total Area	Impervious Area	Plant Area (Tree)	Plant Area (Lawn)	Pervious Paving	lengths (of tree space	(Trees if 20' on center)
	13055	10810	9450	14685	154	8
					99	5
					154	8
					99	5
48000	**13055**	**10810**	**9450**	**14685**	**506**	**51**

Trees

Depth	Area	Cubic Ft Available	Number of Trees	CO2 (annual)	Intercept (gal/year)	$ value per tree	Max $ value
5	10810	54050	819	43403.78788	81893.93939	$ 13.00	**$ 10,646.21**
			483	55497.76786	110995.5357	$ 27.00	**$ 13,029.91**
			330	64596.34146	139739.0244	$ 45.00	**$ 14,830.79**
			250	69314.12037	154392.8241	$ 63.00	**$ 15,764.58**
			206	82725.38168	182986.0687	$ 84.00	**$ 17,329.01**
			175	91955.19481	203038.474	$ 105.00	**$ 18,426.14**
			153	98938.98305	217879.5198	$ 126.00	**$ 19,238.14**
			138	98999.7449	242949.2347	$ 143.00	**$ 19,717.22**
			126	99175.46512	263588.0233	$ 160.00	**$ 20,111.63**
			115	99207.15812	280759.7222	$ 177.00	**$ 20,441.99**
			108	102262.6	305706.8	$ 196.00	**$ 21,187.60**
			101	104658.6142	326324.3446	$ 215.00	**$ 21,761.70**
		15-dbh tree	51	32788.8	72206.2	$ 126.00	**$ 6,375.60**

Stormwater Calc

Block Width (ft)	Block Length (ft)	Block Area (sq ft)	Block Area (Acres)	Total Block Area (incl RO\	Total Block Area (Acres)
600.00	300.00	180000.00	4.13	243600.00	5.59
ROW Width	2nd ROW Width	ROW Length	2nd ROW Length (ft)	ROW Area (sq ft) per bloc	ROW Area (Acres)
80.00	60.00	360.00	580.00	63600.00	1.46
ROW Trench Depth (ft)	Capacity (cubic ft) Per Block	Column1	Column2	Column3	ROW % of Block
5.00	69960.00		0.00		0.26
Alley Width	Alley Length	Alley Area	Alley Area in Acres	Alley Capacity	ROW % Incl Alley
20.00	600.00	12000.00	0.28	13200.00	0.31

Block Type	% Impervious	Rv Runoff Coefficient	Rainfall (inches/24hr)	Runoff Volume (cubic ft)	Difference	
Urban	95.00%	0.905	1.25	22964.375	**46995.90**	**69960.27548**
Urban	95.00%	0.905	2.8	51440.2	**18520.08**	
Urban	95.00%	0.905	4.2	77160.3	**-7200.02**	
Urban	95.00%	0.905	6	110229	**-40268.72**	
Urban	95.00%	0.905	7.4	135949.1	**-65988.82**	
Urban	95.00%	0.905	10.5	192900.75	**-122940.47**	

Cost Calc

ARTERIAL	**2003 sq ft (40' ROW)**	**Typical block ft**	**Typical Block cost**	**SAV Block ft**	**SAV Block Cost**	
Paving Concrete 6" Sq ft	$ 10.00	0.00	$ -	13055	$ 130,550.00	
Paving asphalt	$ 5.00	48000.00	$ 240,000.00	0	$ -	
permeable paving	$ 6.00	0.00	$ -	20260	$ 121,560.00	
Base rock aggregate 4" sqft	$ 0.65	48000.00	$ 31,200.00	0.00	$ -	
subgrade 6" sqft	$ 5.00	48000.00	$ 240,000.00	48000.00	$ 240,000.00	
course aggregate	$ 3.00	0	$ -	48000.00	$ -	
Add on subgrade	$ 5.00	0	$ -	20260	$ 101,300.00	
Add on course	$ 3.00	0	$ -	20260	$ 60,780.00	
Storm drain 18" Concrete	$ 45.30	7200.00	$ 326,160.00	0		
Concrete Curb 6" 1' gutter	$ 21.90	7200.00	$ 157,680.00	0		
			$ 995,040.00		$ 654,190.00	$ (340,850.00)
						65.7%
			Inflation adj		Inflation adj	
			$ 1,386,090.72		$ 911,286.67	$ (474,804.05)
						66%

SIDEWALK AND LIGHTING WASH COST

0%

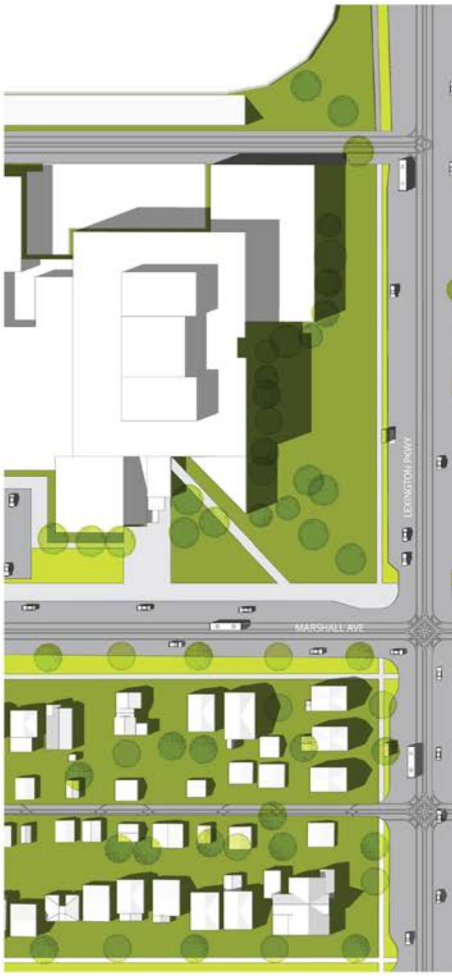
Urban Heat Effect (estimate)

surface type	heat reduction	location heat reduction		
				*according to Y. Liu et al. exposure to moderate to extreme heat in the Twin Cities Metropolitan Area has an annual cost of $1,171,470,000,
agricultural fields	-6	-1.18125	non-tree planting	(planted native area/total area) * -6f temp reduction
forests and surrounding areas	-9	-2.026875	tree planting area	(planted tree area/total area) * -9f temp reduction
tree shaded area	-18	-23.8326	tree shading	((# of trees * square(20 ft radius canopy)* 3.14) = shaded area) / total area of block * -18f temp reduction
	Averge temperature reduction	-9.013575		

PROJECT DEVELOPMENT

Existing (Yr 2018)

Transition (Yr 2025)

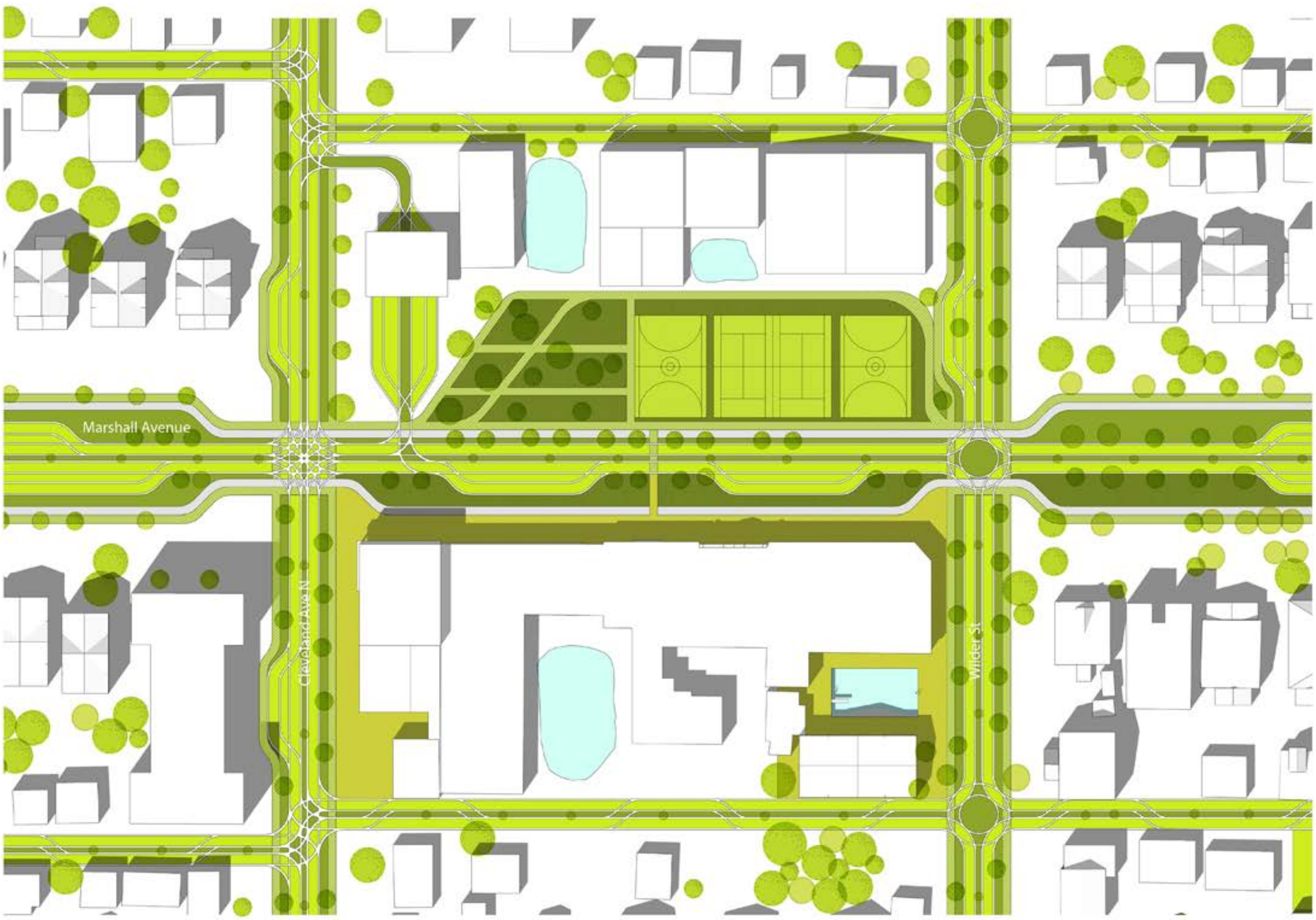


Proposed (Yr 2050)

PROJECT DEVELOPMENT

Existing (Yr 2018)

Proposed (Yr 2050)



PROJECT DEVELOPMENT

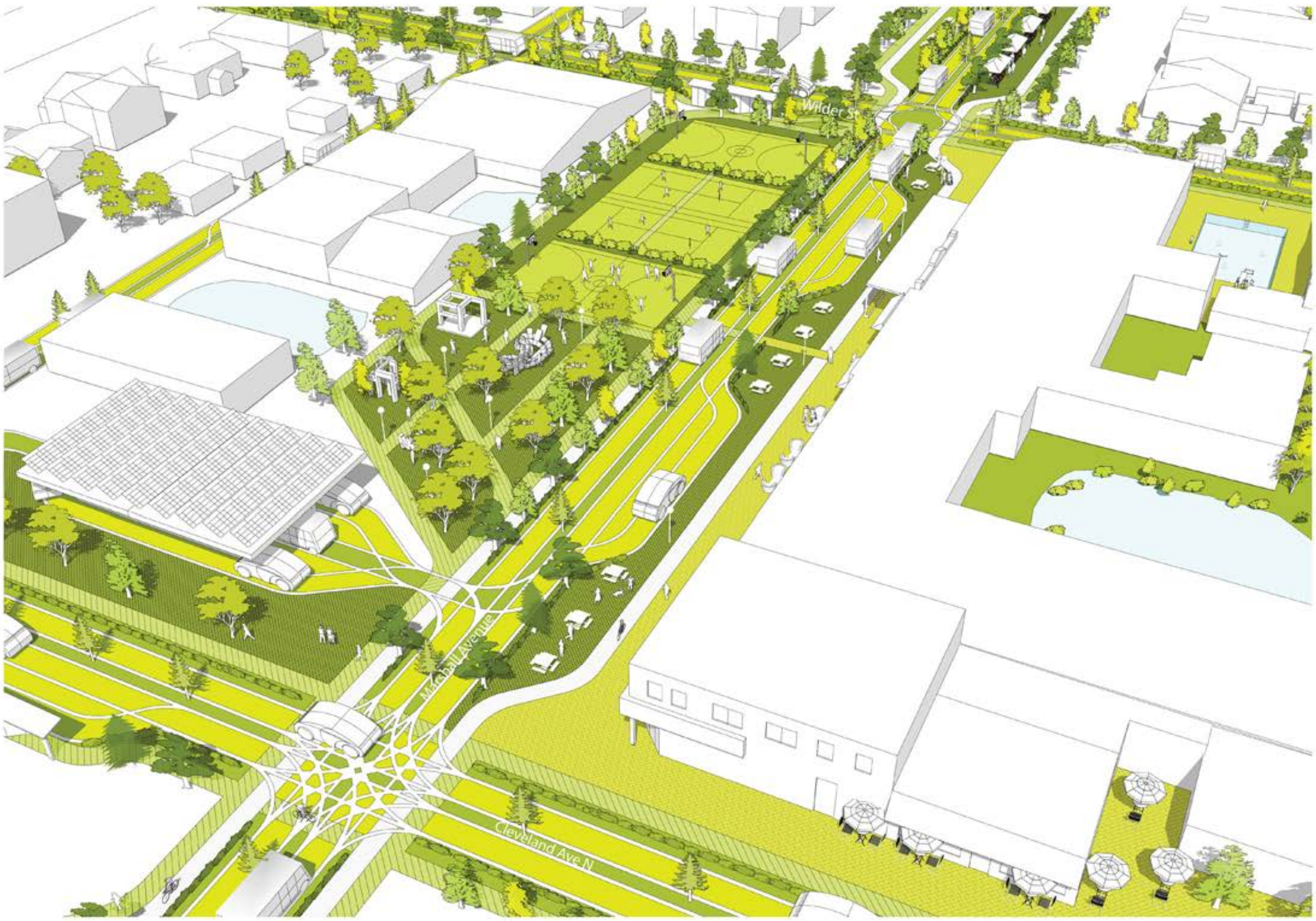
Existing (Yr 2018)

Proposed (Yr 2050)

PROJECT DEVELOPMENT

Existing (Yr 2018)

Proposed (Yr 2050)



PROJECT DEVELOPMENT

Existing (Yr 2018)

Proposed (Yr 2050)

PROJECT DEVELOPMENT

Existing (Yr 2018)

Proposed (Yr 2050)

PROJECT DEVELOPMENT

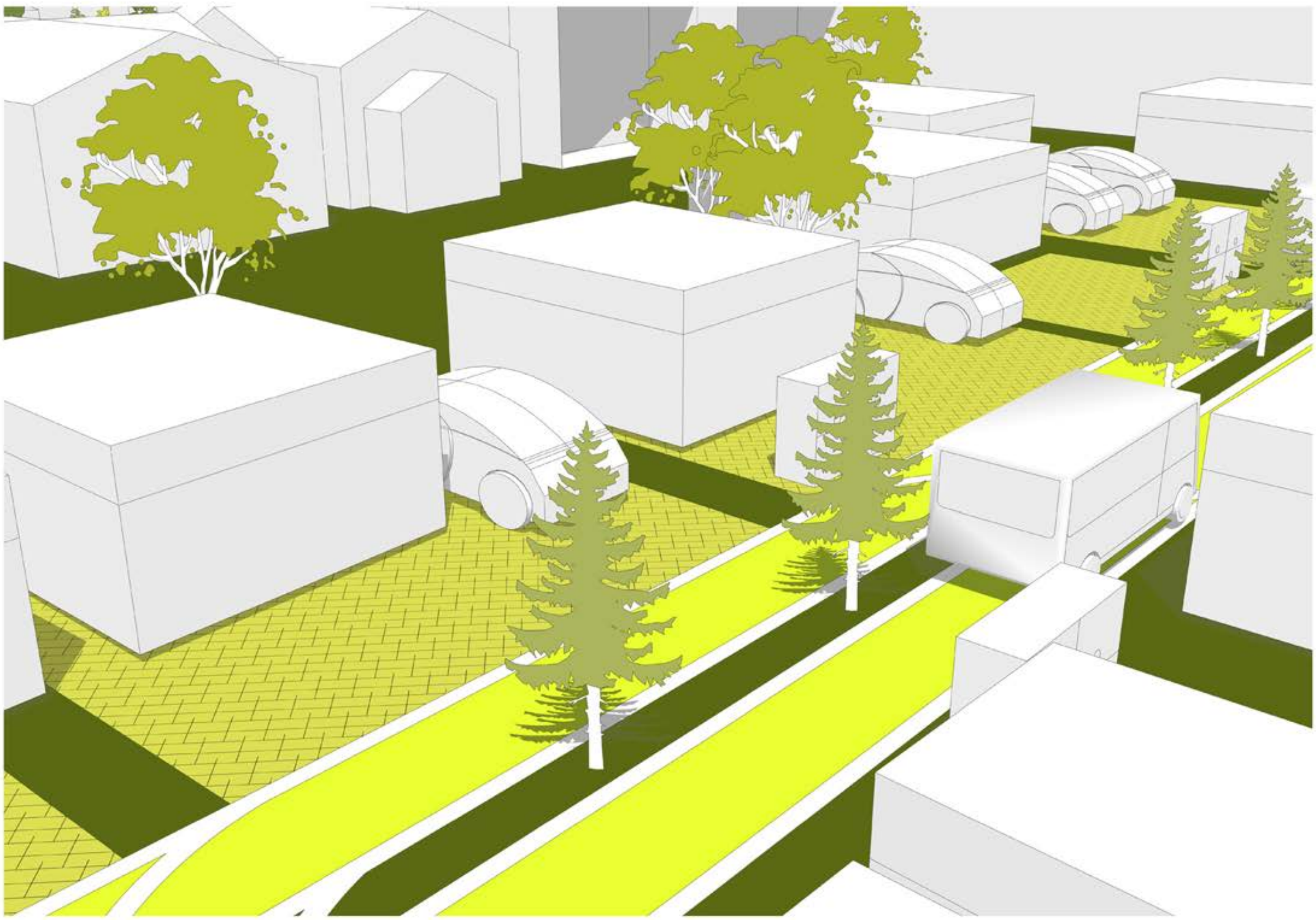
Existing (Yr 2018)

Proposed (Yr 2050)

PROJECT DEVELOPMENT

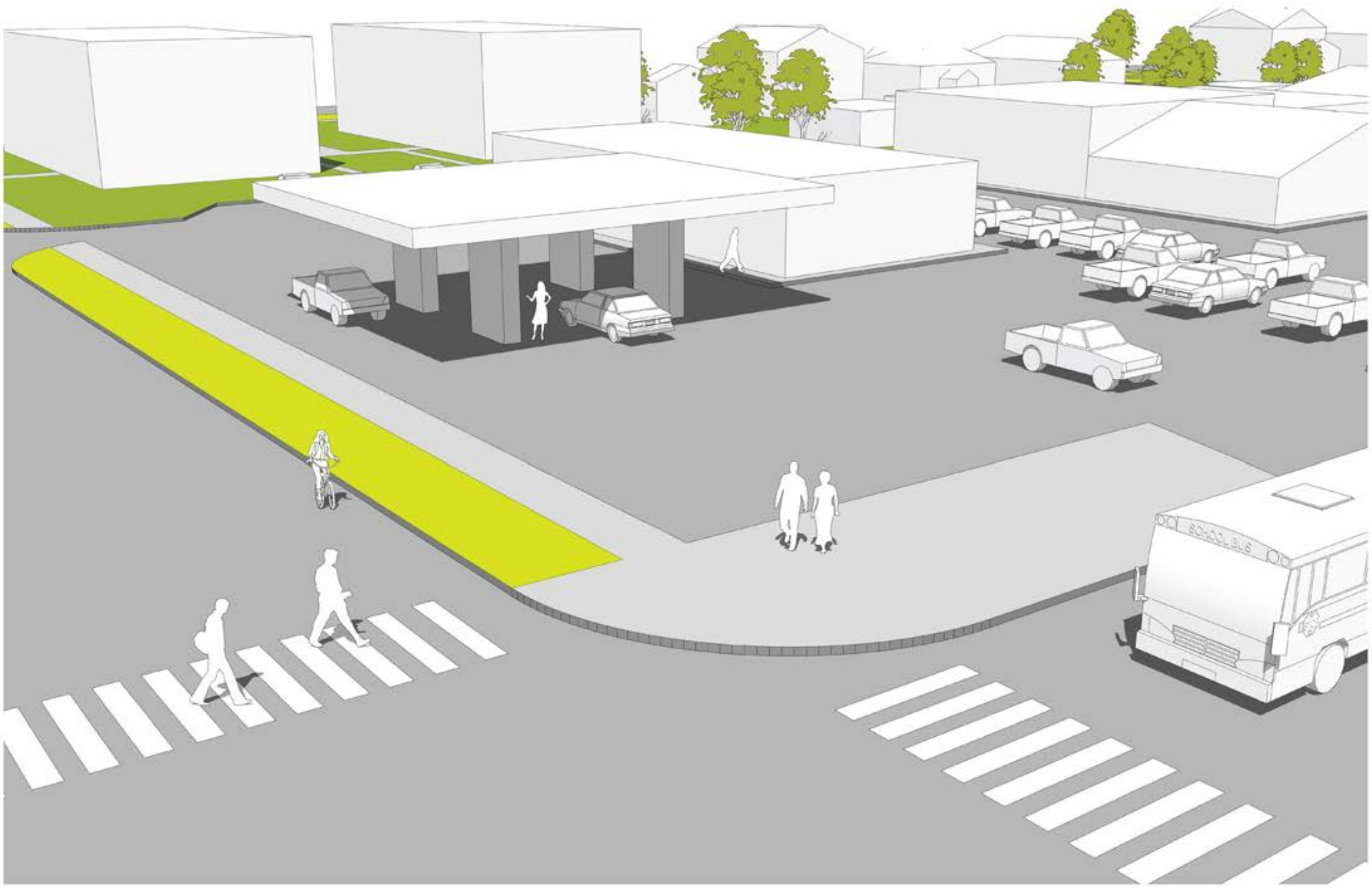
Existing (Yr 2018)

Proposed (Yr 2050)



PROJECT DEVELOPMENT

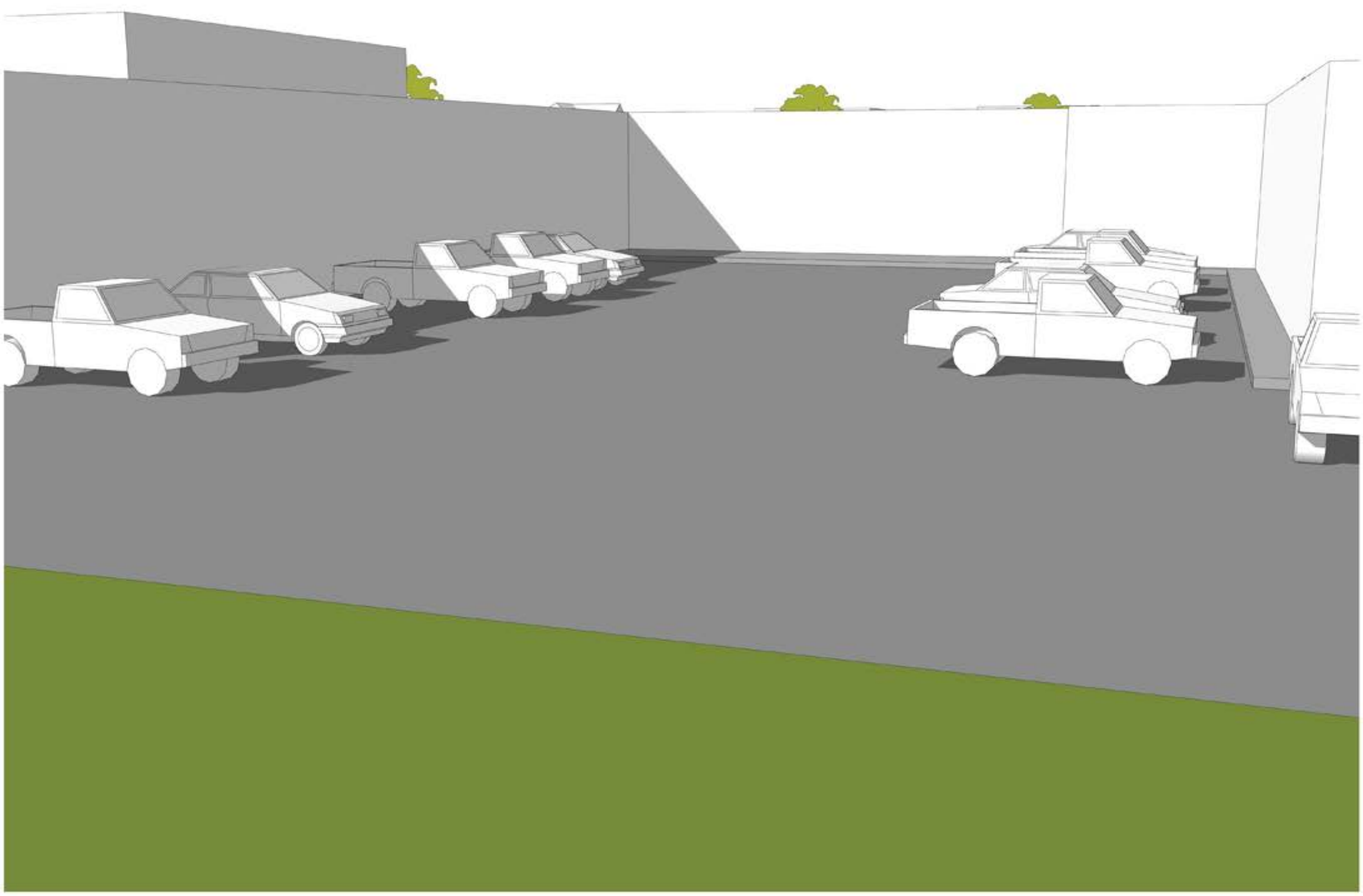
Existing (Yr 2018)



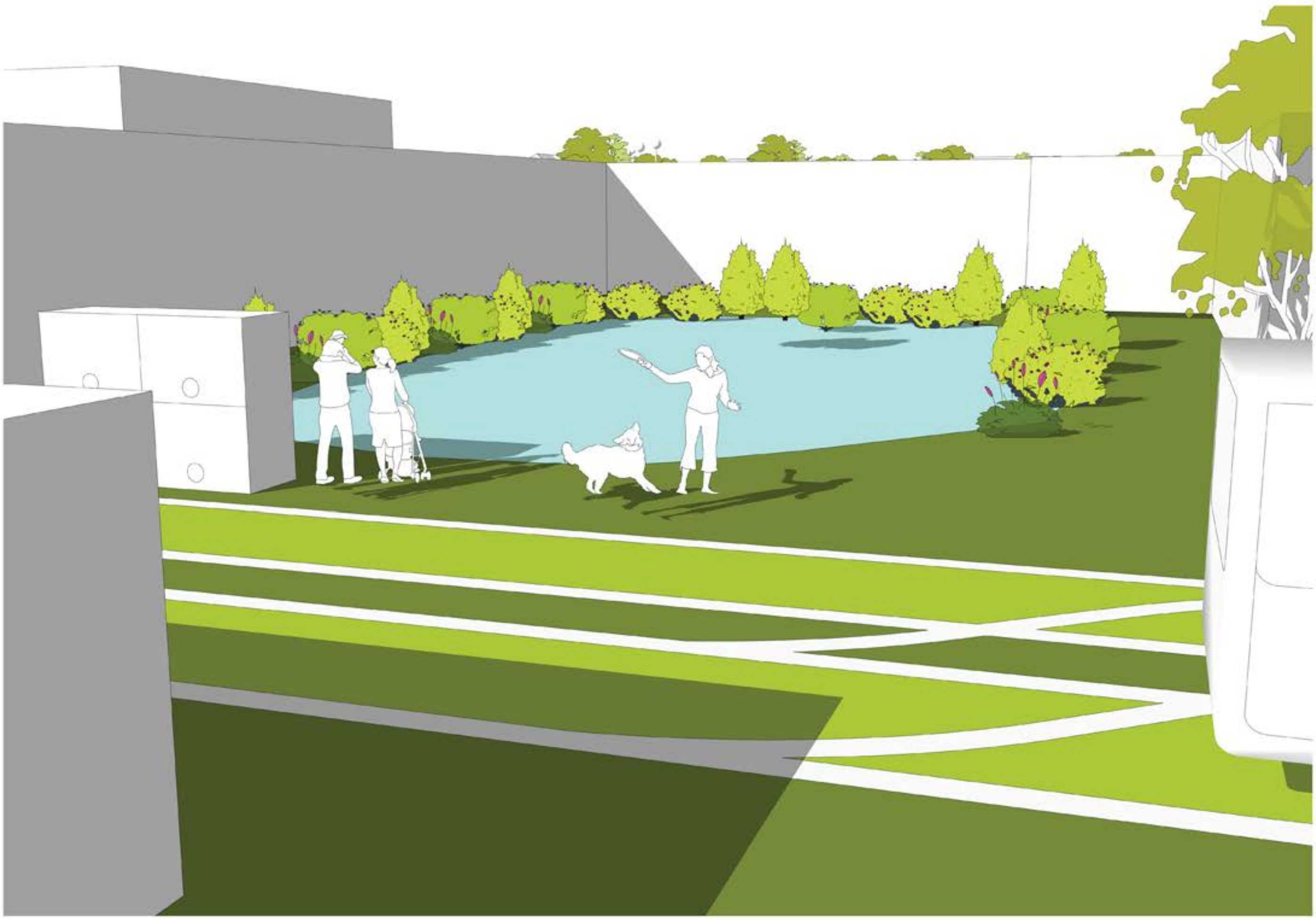
Proposed (Yr 2050)

PROJECT DEVELOPMENT

Existing (Yr 2018)

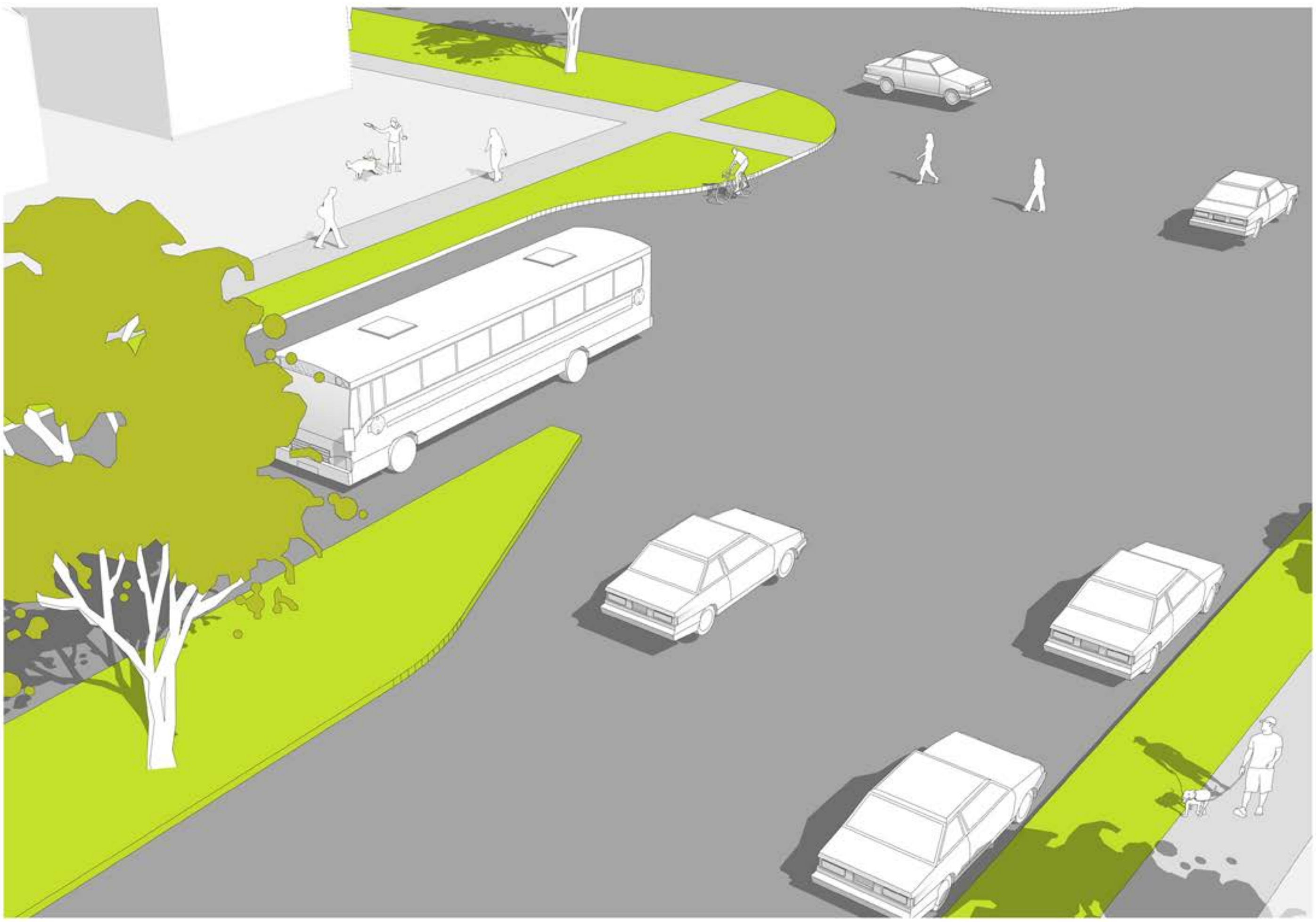


Proposed (Yr 2050)

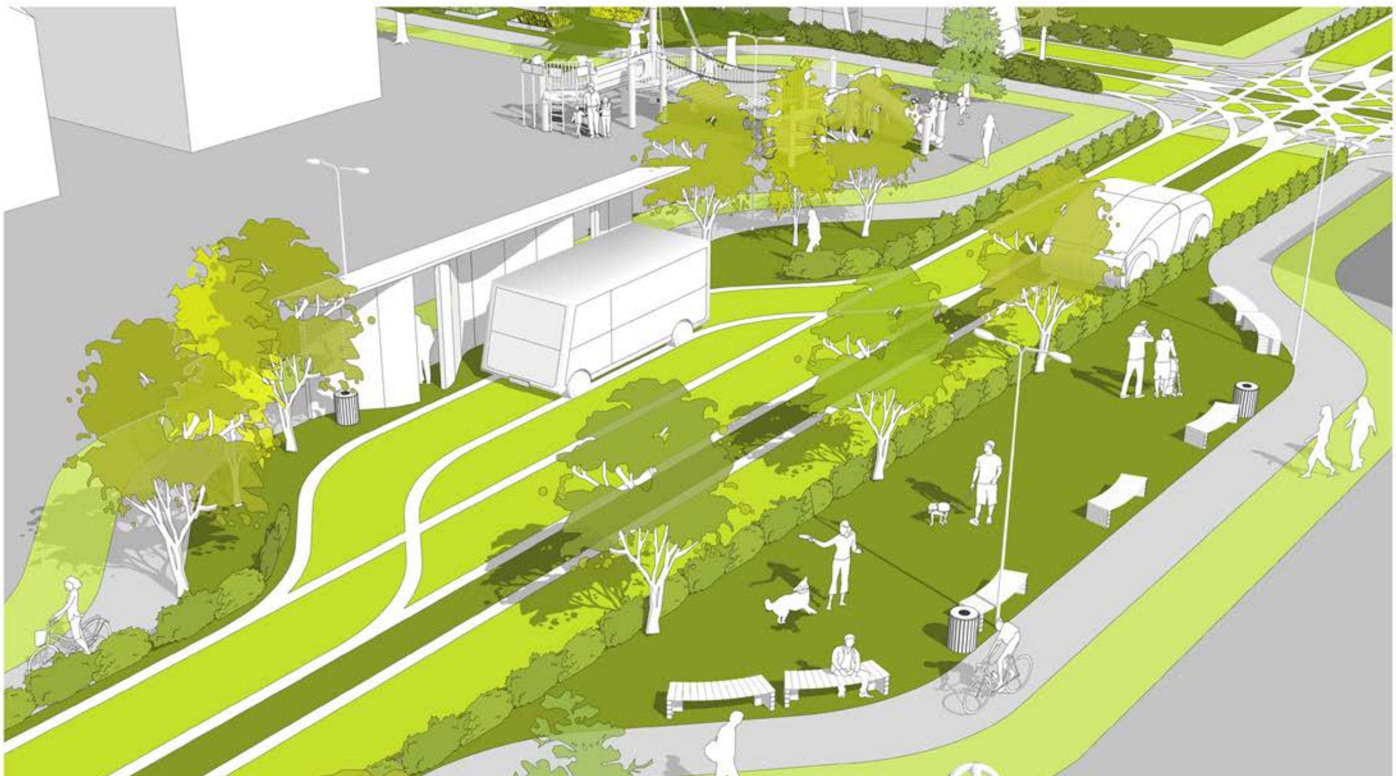


PROJECT DEVELOPMENT

Existing (Yr 2018)

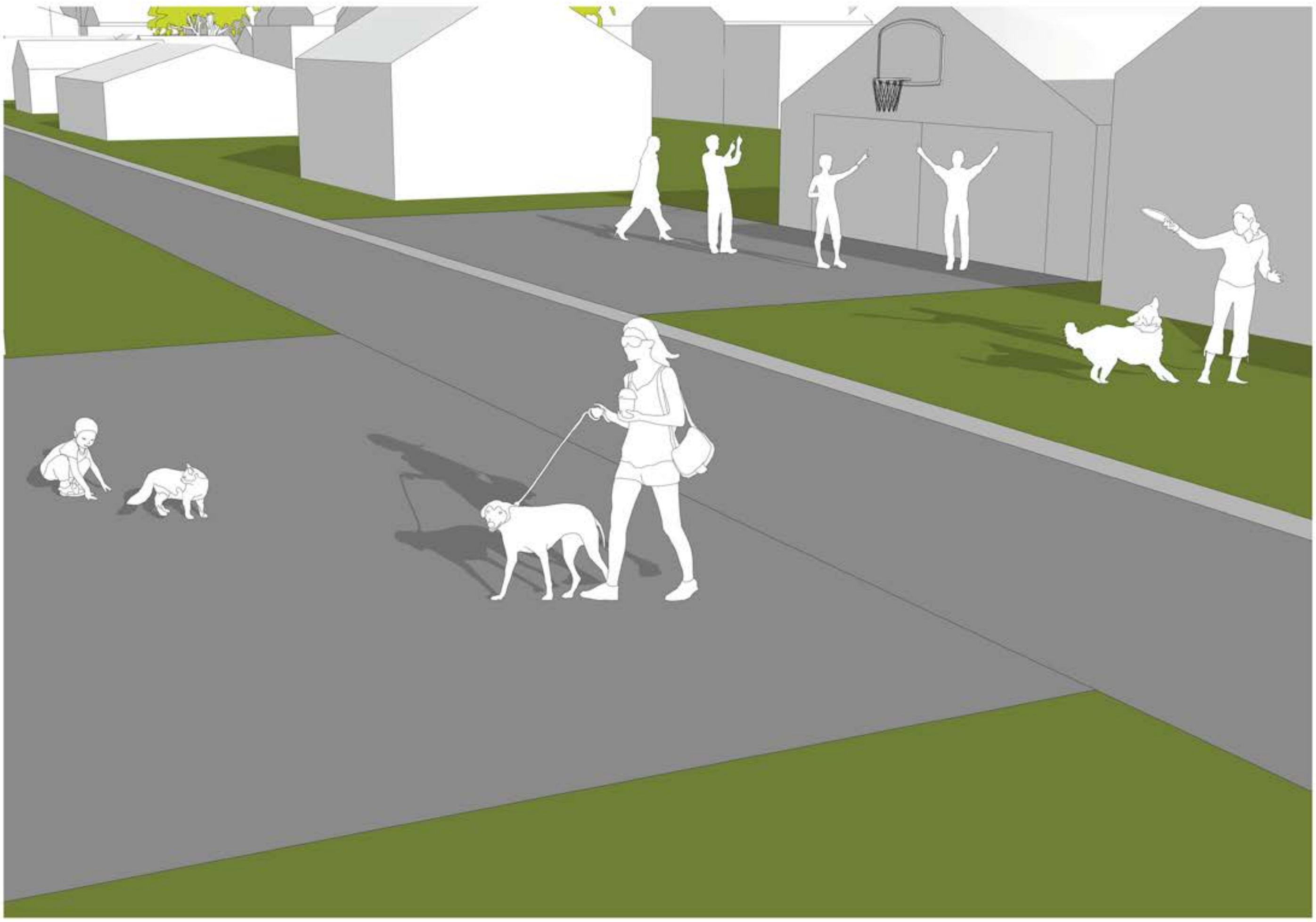


Proposed (Yr 2050)

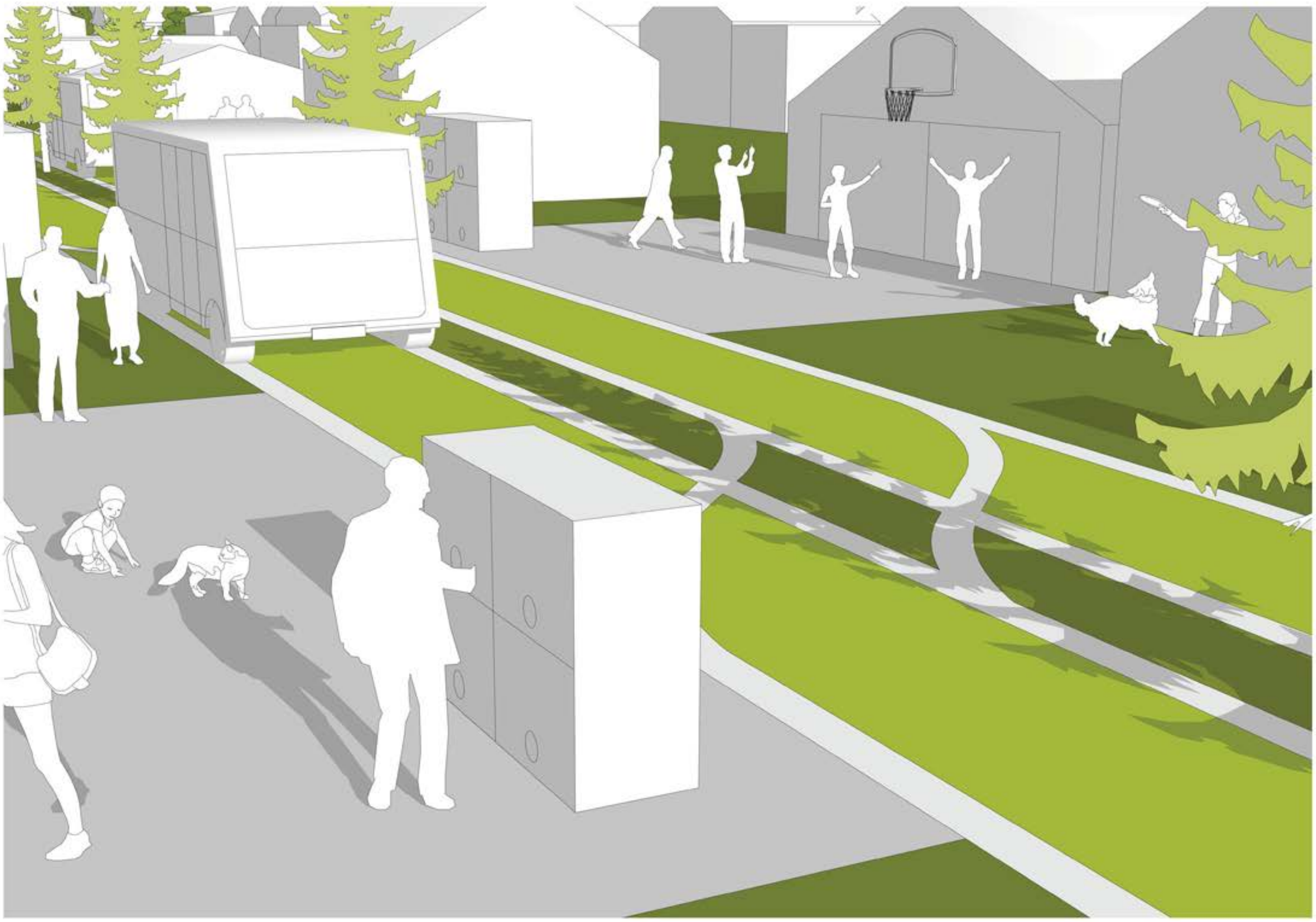


PROJECT DEVELOPMENT

Existing (Yr 2018)

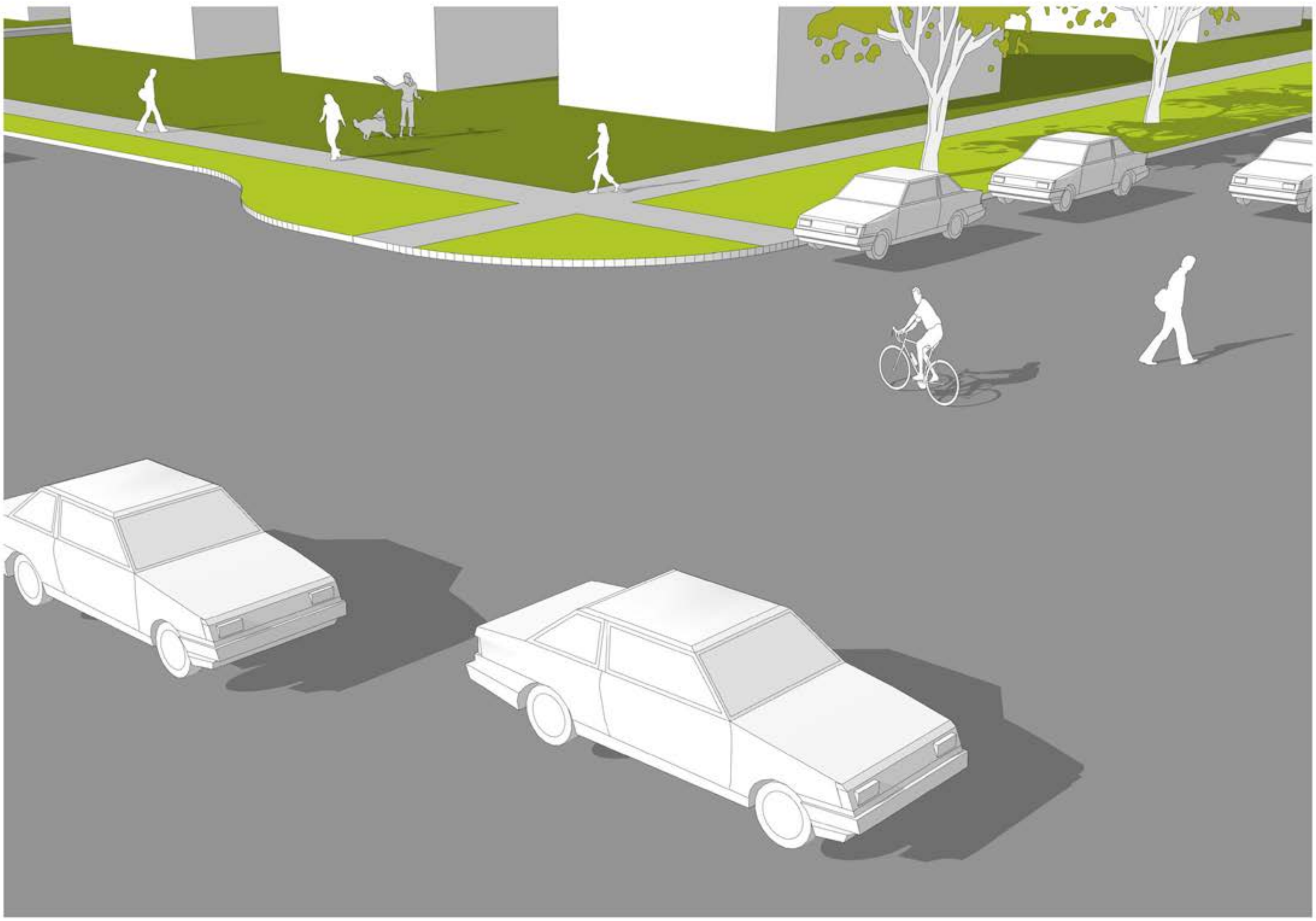


Proposed (Yr 2050)

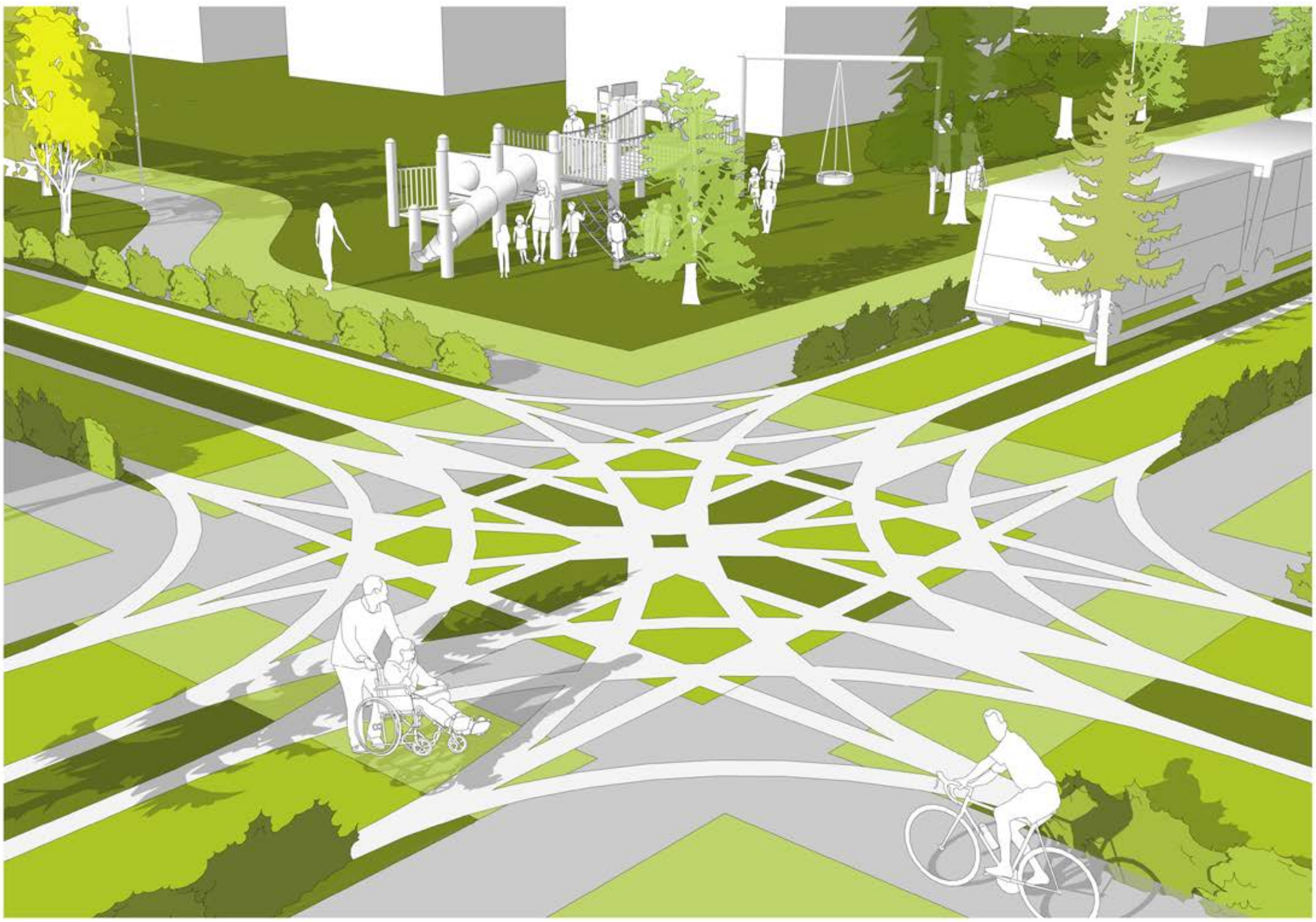


PROJECT DEVELOPMENT

Existing (Yr 2018)



Proposed (Yr 2050)



PROJECT DEVELOPMENT

Existing (Yr 2018)

Proposed (Yr 2050)

MINNESOTA DESIGN CENTER
COLLEGE OF DESIGN UNIVERSITY OF MINNESOTA
www.design.umn.edu/minnesota-design-center