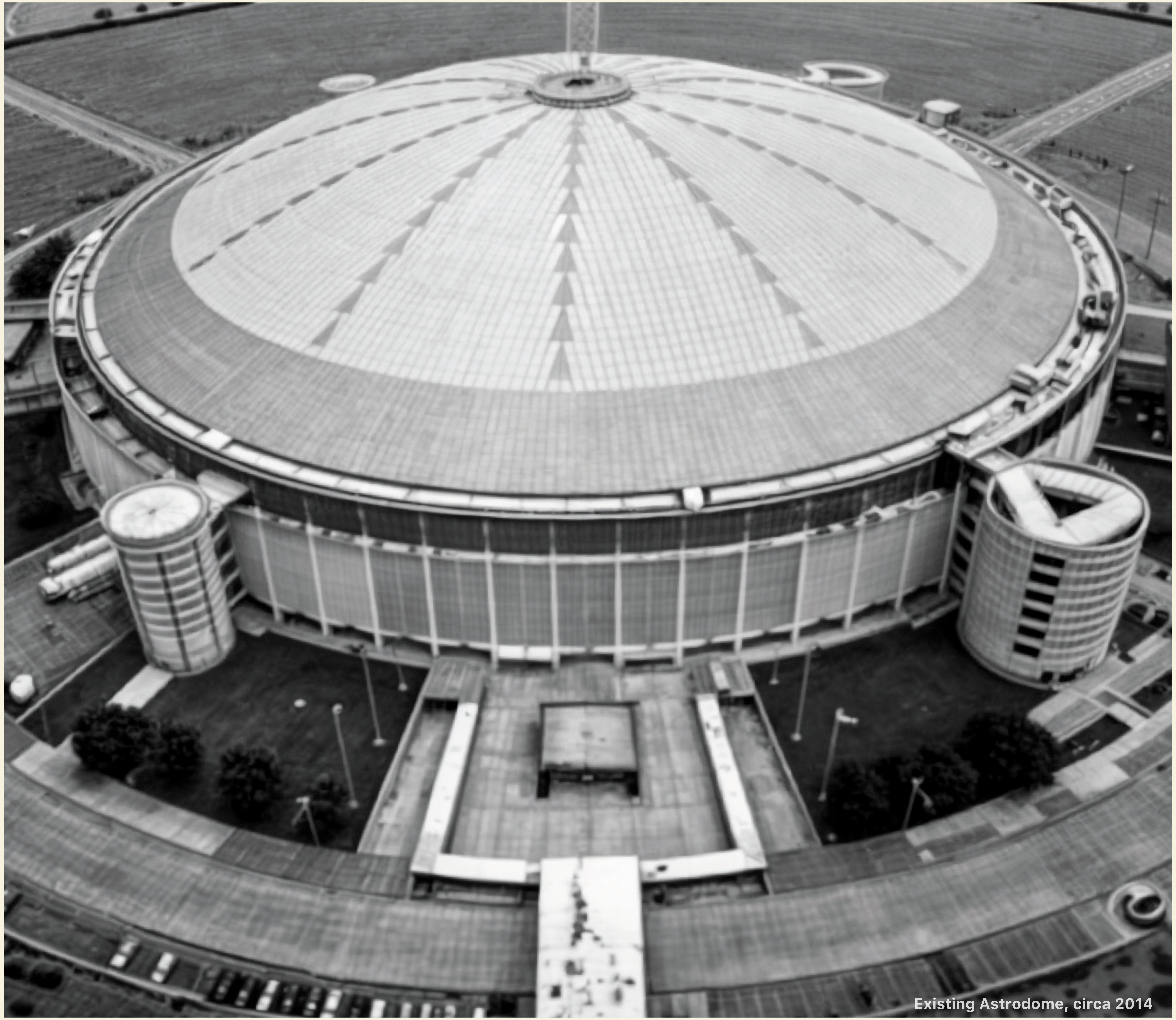
Carbon Impact of Astrodome Preservation & Repositioning

NOVEMBER 2024

ASTRODOME CONSERVANCY

Gensler



Existing Astrodome, circa 2014

Reimagined Astrodome Design by Gensler

Introduction

Executive Summary

Preserving the Astrodome with a dual focus on cultural legacy and environmental sustainability will create a balance between the past and the future, demonstrating that cultural preservation and carbon reduction can work together to shape a more sustainable, culturally rich world for generations to come.

This study evaluates the carbon footprint associated with preserving the Astrodome compared to demolishing it and constructing a new, in-kind building. This analysis considers existing embodied carbon, upfront embodied carbon (carbon emissions from material production, transportation, and construction), carbon associated with demolition, and operational carbon (emissions from energy use during the building's lifecycle).

Preserving and repositioning the Astrodome will have a 76% lower carbon impact compared to replacing it with a new, in-kind building. Repositioning the landmark for new functions will further enhance its value, extending its lifecycle, and making it more adaptable to modern needs while preserving its historic significance.

Existing Astrodome, circa 1962

Understanding Whole Building Carbon

WHOLE LIFE CARBON = **EXISTING EMBODIED CARBON** + **UPFRONT EMBODIED CARBON** + **OPERATIONAL CARBON** + **DEMOLITION CARBON**

EXISTING EMBODIED CARBON

The Astrodome today, a 60-year old landmark structure

Embodied emissions associated with the historical materials and construction practices already in place, including the embodied carbon from materials used throughout the building's life

UPFRONT EMBODIED CARBON

Renovation & Repositioning of the Astrodome to a mixed-use entertainment facility

Emissions resulting from any renovations or new construction activities added to the existing structure, including impacts from materials, labor, and transportation

OPERATIONAL CARBON

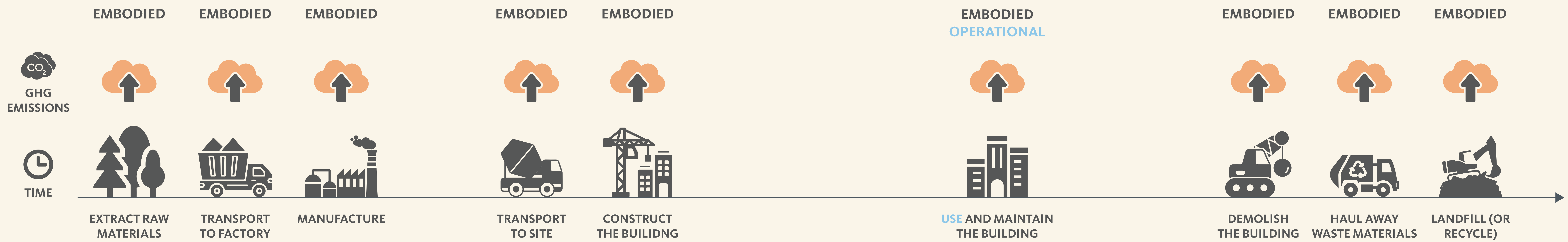
Operations going forward, projected for a 60-year lifecycle

Emissions from energy use during the building's occupancy, which may be influenced by the energy efficiency of both the existing and new elements

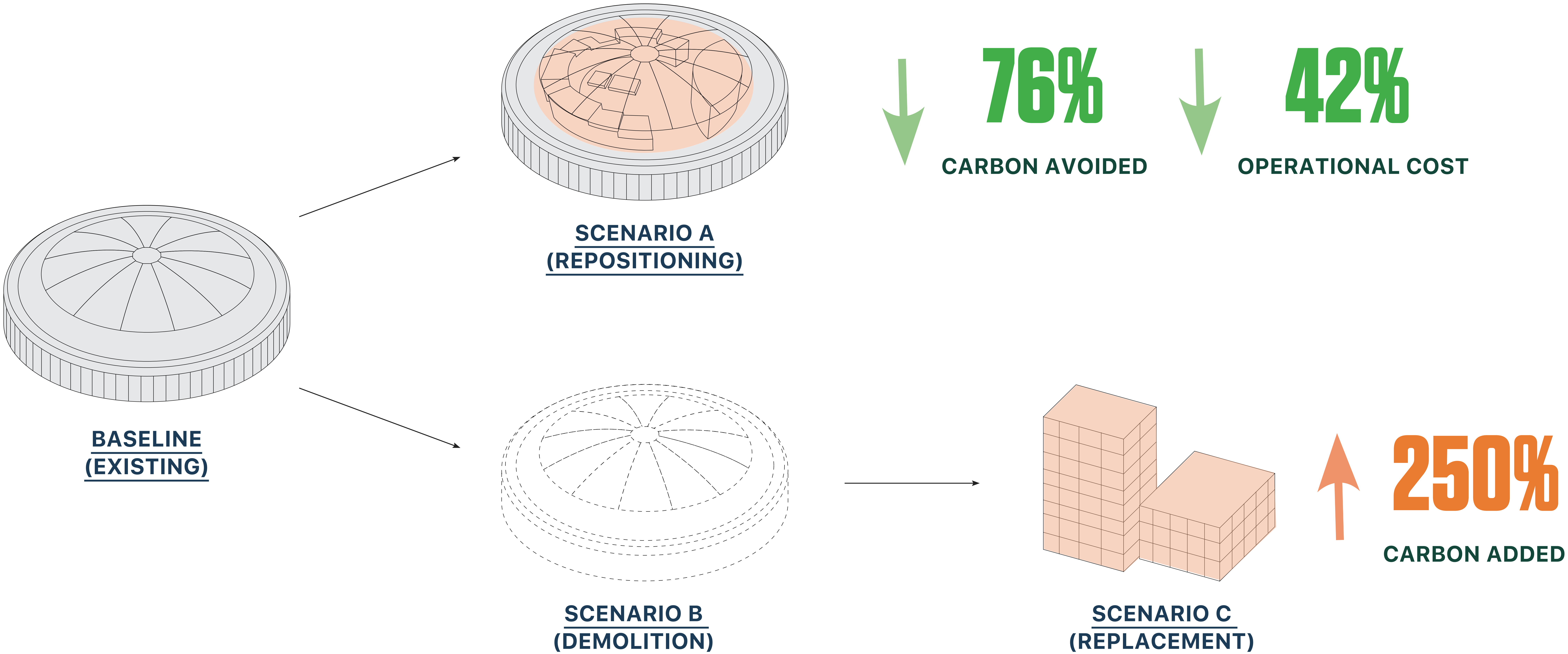
DEMOLITION CARBON

Demolition of current Astrodome, returning it to a flat surface

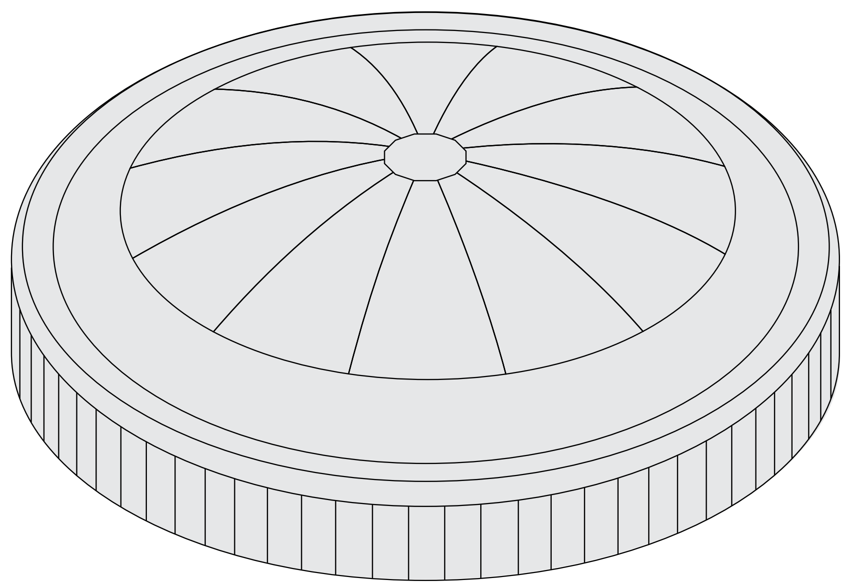
Refers to the greenhouse gas emissions associated with the demolition of a building including energy use for equipment and machinery, transportation of debris, disposal, and landfilling or processing for recycling or reuse

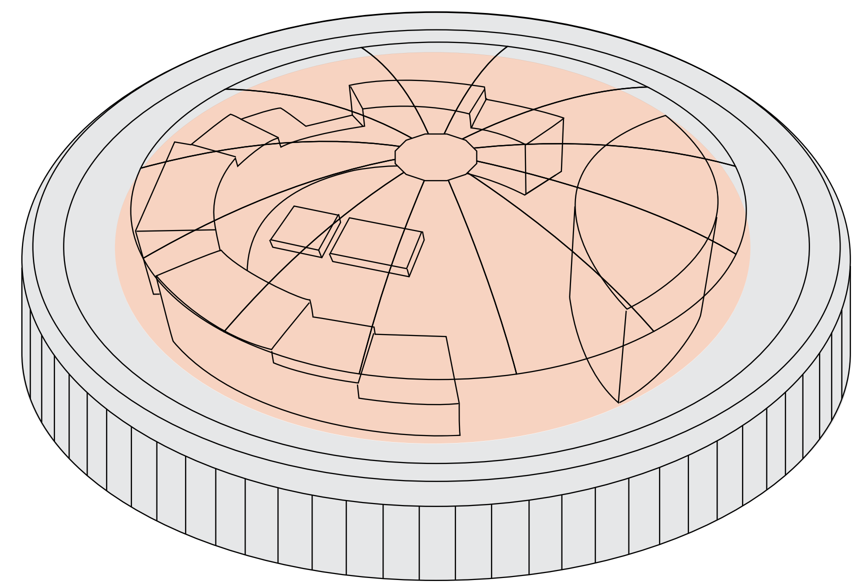


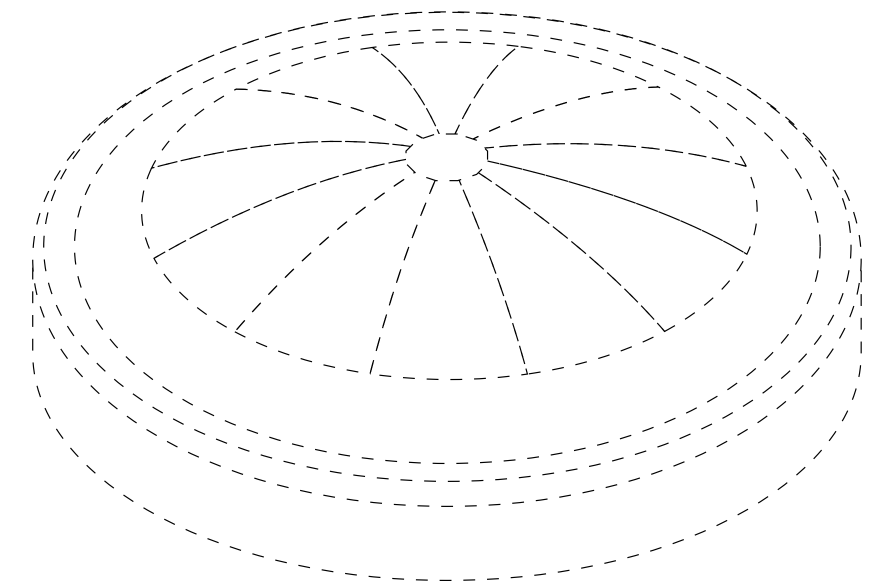
Study Scenarios

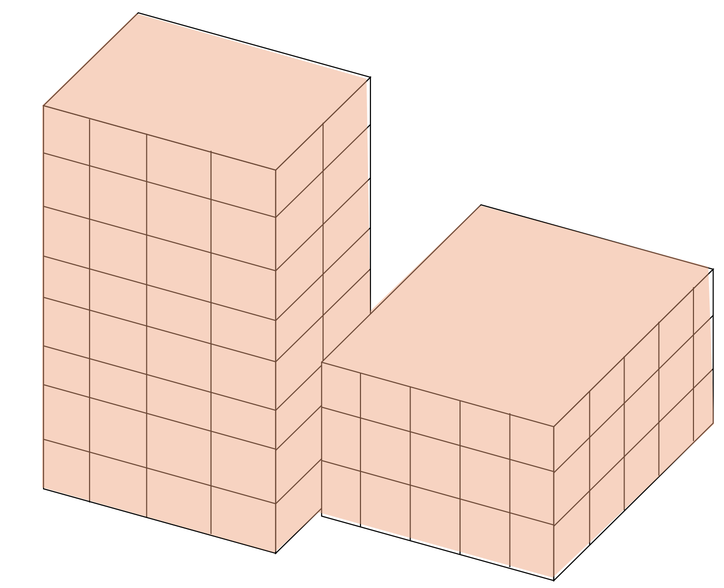


Assumptions









	BASELINE (EXISTING)	SCENARIO A (REPOSITIONING)	SCENARIO B (DEMOLITION)	SCENARIO C (REPLACEMENT)
Area (sqft)	490,025	490,025	716,158 (New) + 490,025 (Existing) = 1,206,183	1,206,183
Structure Type	Existing Steel and Concrete	Existing Steel and Concrete	Steel, Concrete and Timber	Standard Steel and Concrete
Carbon Addition	N/A	Yes, Complete Demolition Carbon	Yes, Upfront + Operational + Minor Demolition Carbon	Yes, Upfront + Operational + Complete Demolition Carbon
Energy Use Intensity (kBtu/ft2)	N/A	N/A	33	45
Renewables	No	No	Yes, 80% On-site Solar	Yes
Description	No change to existing	Demolition includes removing all structure, returning site to flat grade	Includes utilizing existing structure with upgrades and repurpose of the Astrodome w/ site improvements	Includes demolition, clearing the site, new construction and site improvements

Key Metrics

OPERATIONAL COST REDUCED

42%

BY REPOSITIONING FROM BASELINE

CARBON AVOIDED BY REPOSITIONING IS

76%

OF THE TOTAL REPLACEMENT CARBON

SOCIAL COST OF CARBON FOR REPLACEMENT IS

85%

OF THE TOTAL CONSTRUCTION COST OF REPOSITIONING

Index of Terms

EMBODIED CARBON

Embodied carbon accounts for the total greenhouse gas (GHG) emissions throughout the lifecycle of building materials and construction processes. It is expressed in common unit kg CO_2-equivalent (kg CO_2e).

UPFRONT EMBODIED CARBON

Upfront Embodied Carbon refers to the new added greenhouse gas emissions associated with the materials, construction, and manufacturing processes of a building or infrastructure project before it becomes operational.

RENEWABLE ENERGY

Energy obtained from sources that are naturally replenished, such as solar, wind, hydro, biomass, and geothermal energy. It has a lower environmental impact compared to fossil fuels.

OPERATIONAL CARBON

The greenhouse gas emissions produced by the ongoing operation of a building or facility, including energy consumption, waste management, and other operational activities.

MT CO_2e

MT CO_2e stands for Metric Tons of Carbon Dioxide Equivalent. It is a unit of measurement used to compare the emissions of various greenhouse gases based on their global warming potential (GWP).

CRADLE-TO-GATE

An LCA approach that assesses the lifecycle of a product from raw material extraction (cradle) to the point it leaves the manufacturing gate (before it reaches the consumer).

GLOBAL WARMING POTENTIAL (GWP)

GWP is a measure used to compare the relative ability of different greenhouse gases (GHGs) to trap heat in the atmosphere over a specific period of time, typically 20 to 60 years.

ENERGY USE INTENSITY (EUI)

EUI is a measure of a building's energy efficiency, expressed as the amount of energy consumed per unit of area over a specified time period. It is typically represented in terms of kWh/sq ft/year.

SOCIAL COST OF CARBON (SCC)

SCC is an economic estimate representing the total cost to society caused by emitting one additional ton of carbon dioxide into the atmosphere, essentially measuring the economic damages associated with climate change caused by that single ton of carbon emissions.

Astrodome, Past & Future

WHY IT MATTERS

Economic | Environmental | Legacy

Economic Benefits

REDUCE OPERATIONAL COST

Modernizing and replacing energy systems will enhance efficiency, leading to reduced energy consumption and lower operational costs. It will add integration with renewable energies and help incorporate advanced monitoring and control technologies, ultimately providing better data for decision-making and optimizing operations.

REVENUE GENERATION

Entertainment, hospitality, commercial, and retail spaces will support existing uses and tenants at NRG Park, while providing a unique destination for visitors to Houston.

YEAR-ROUND DESTINATION

The Astrodome will be the centerpiece of NRG Park, providing a year-round destination for millions of visitors for years to come.

LOWEST SOCIAL COST OF CARBON

Construction cost of repurposing the Astrodome is significantly less than that of the social cost of carbon of a new, in-kind structure. The "social cost of carbon" (SCC) is an economic estimate representing the total cost to society caused by emitting one additional ton of carbon dioxide into the atmosphere, essentially measuring the economic damages associated with climate change caused by that single ton of carbon emissions. The existing Astrodome provides a one-of-a-kind experience and preserves a storied legacy for Houston and Texas.

Existing Astrodome, circa 1980

Environmental Benefits

STRUCTURAL RESILIENCE

Retrofitting will upgrade materials to more resilient options and reinforce existing elements, enhancing the building's ability to withstand environmental stress and multiple new uses. The existing freespan space would not be feasible to replicate in new, modern construction.

FUTURE PROOFING

Integrating energy-efficient systems (HVAC, insulation, lighting) and smart building technologies will enhance operational efficiency, improve occupant comfort, and ensure adaptability to the many proposed new uses for the Astrodome.

SITE RESTORATION

The redesign will include efforts to reimagine the immediately adjacent site — improve drainage, manage stormwater runoff, provide green spaces for comfort and respite, improve air quality — enhancing ecological health. Incorporating native plants and sustainable landscaping will boost biodiversity and create enhanced natural habitats around the structure to the benefit of NRG Park patrons and tenants.

REUSE/REPURPOSE/REPOSITION

The utilization of this historic structure will reimagine a cherished landmark unique to Houston, create a destination for visitors to our region, and onboard an economic engine to attract investment to NRG Park and the surrounding area.

Landmark Preservation Benefits

CULTURAL VALUE

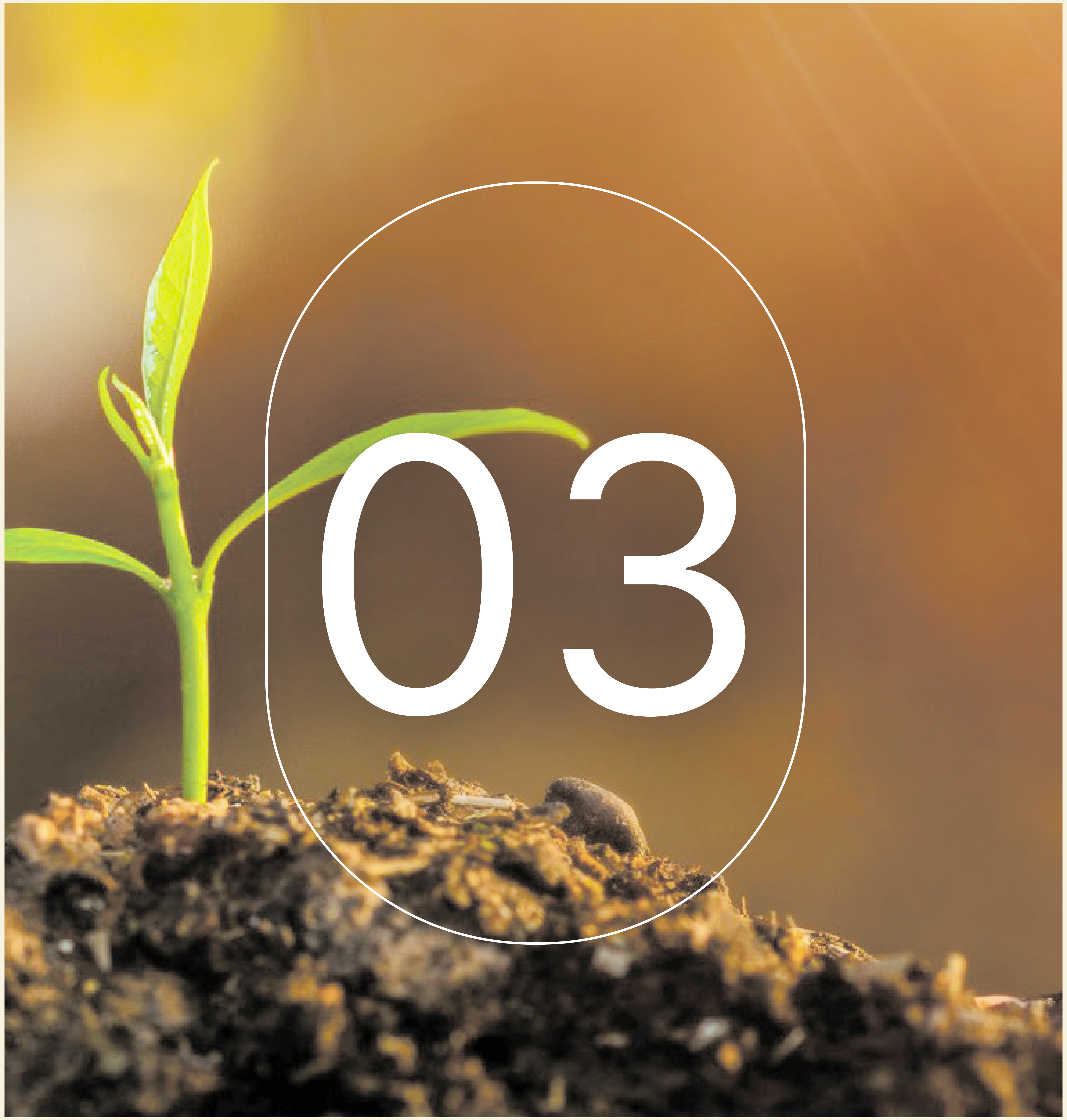
The Astrodome symbolizes Houston and Harris County's history and architectural heritage, and fosters a sense of identity, continuity, and pride. Preserving it fosters a connection to the past, helping future generations appreciate their cultural roots of innovation and "can do" spirit.

COMMUNITY VALUE

A repositioned Astrodome will foster community interaction and engagement through programmed events and activities year-round. It will be a destination for Houstonians and visitors, in addition to expanding the user experience for existing tenants and their patrons.

CARBON VALUE

The redesigned space will lower the lifecycle carbon of the existing structure by leveraging the significant embodied carbon already present and adding the least upfront embodied carbon, thereby reducing long-term operational carbon emissions.



Results and Impact

Tools & Softwares Used

CARE TOOL

The CARE (Carbon Avoided Retrofit Estimator) Tool estimates the operational and embodied carbon emissions associated with reusing and upgrading an existing building or replacing it with new construction.

CARE helps with **absolute carbon values** of carbon emissions using built-in embodied and operational carbon assumptions.

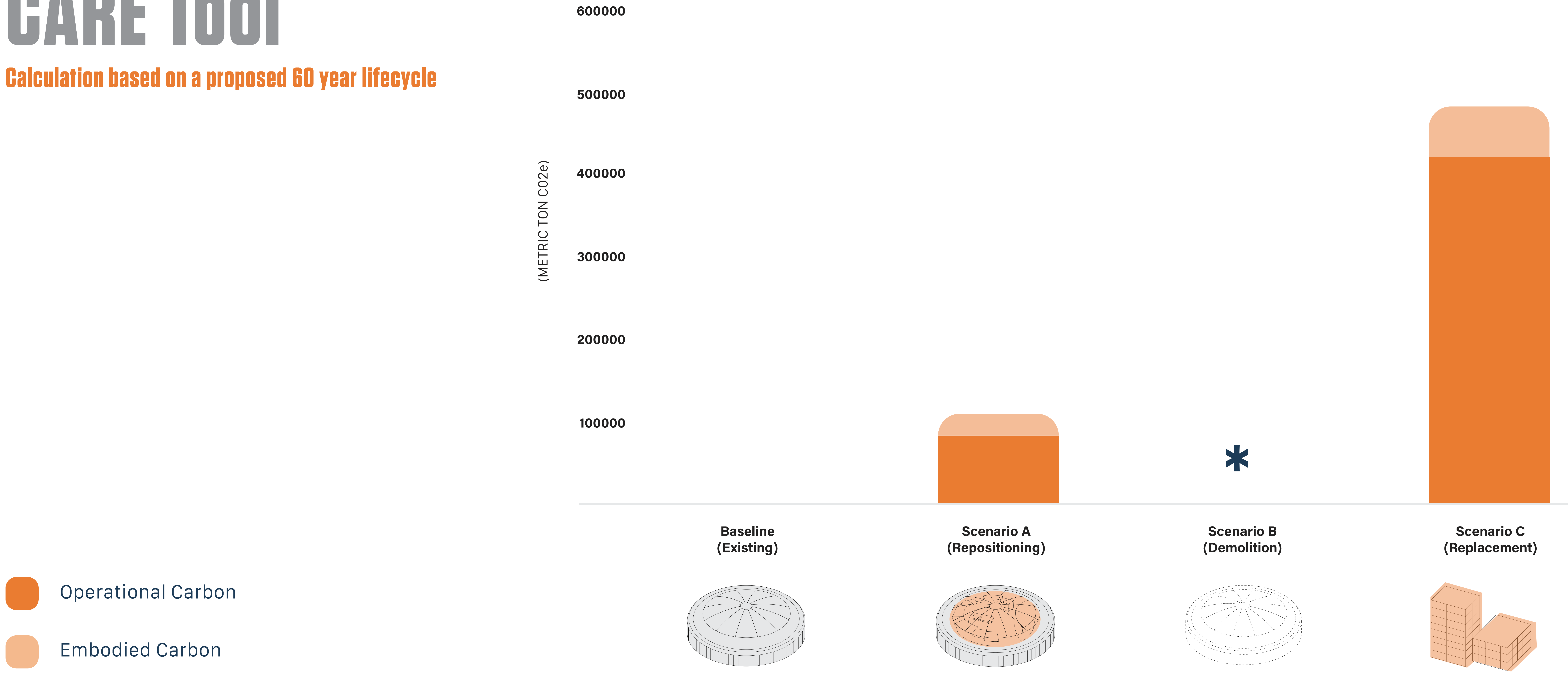
ONECLICK LCA

OneClick LCA is a powerful tool that simplifies the life cycle assessment process, making it easier for the industries to evaluate and improve the environmental performance of their existing or new projects.

OneClick LCA includes **Upfront Embodied carbon** (A1-A5), **Operational Carbon**(B1-B7), and **End-of-life carbon** (C-D) which helps understand both- **Carbon Avoided and Whole building absolute carbon values.**

Total Impact - CARE Tool

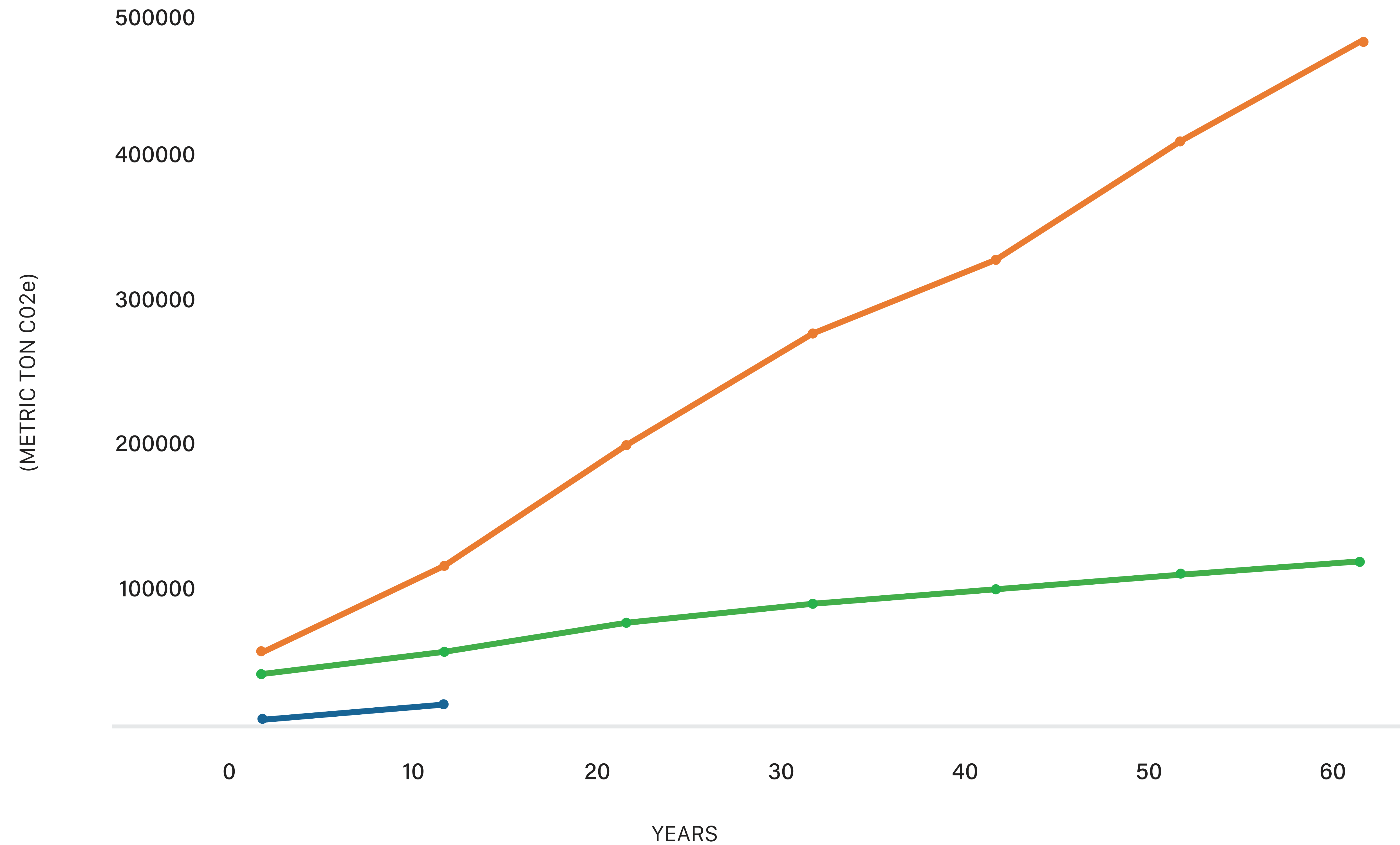
Calculation based on a proposed 60 year lifecycle



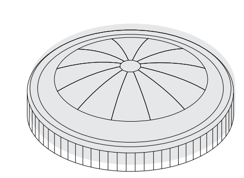
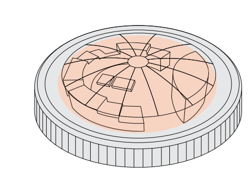
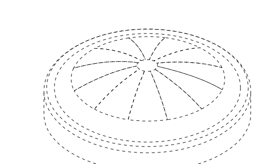
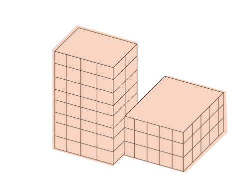
* Tool does not calculate emissions associated with demolition

Total Impact - CARE Tool

Calculation based on a proposed 60 year lifecycle



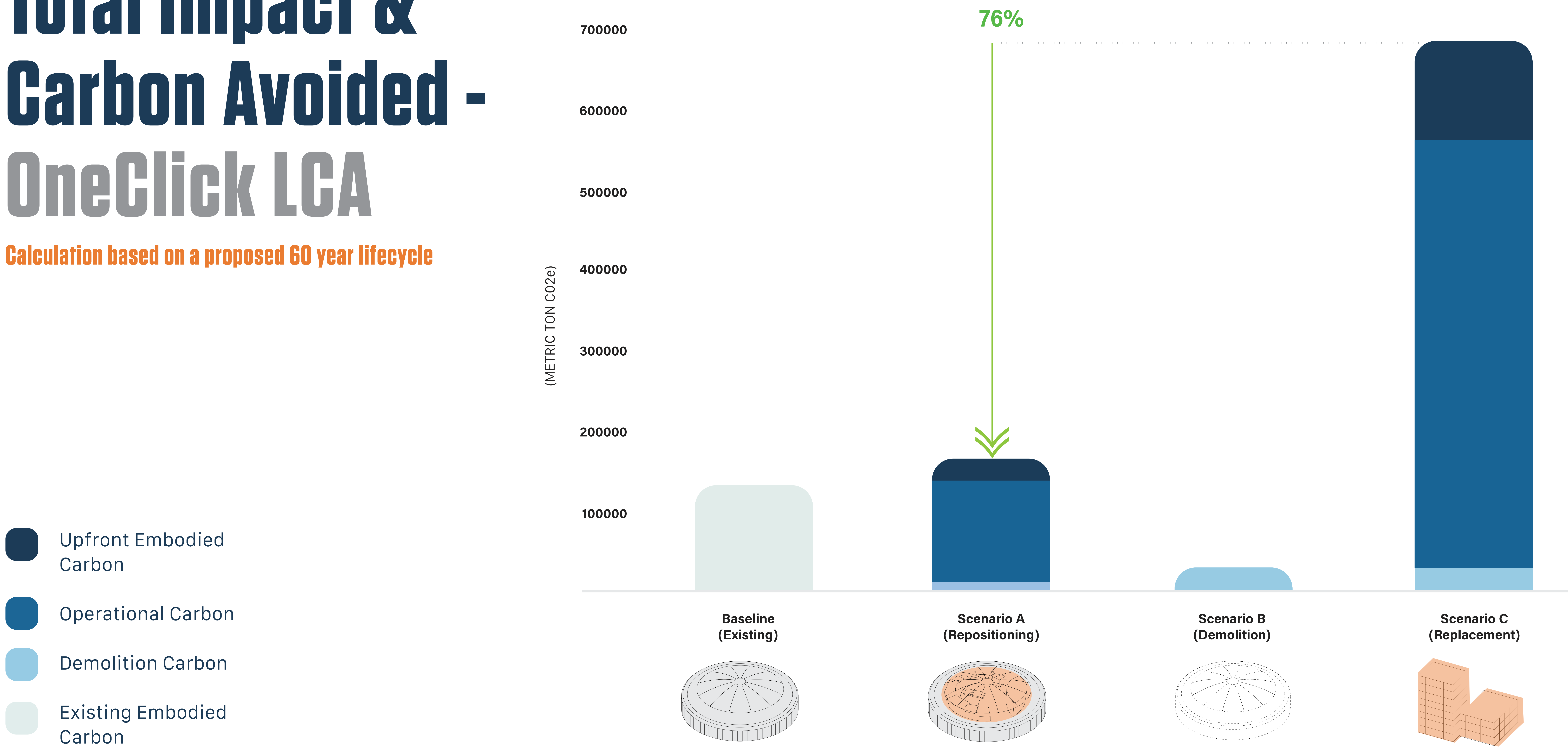
Scenario C (Replacement)
Scenario A (Repositioning)
Baseline (Existing)

	 Baseline (Existing)	 Scenario A (Repositioning)	 Scenario B (Demolition)*	 Scenario C (Replacement)
Embodied Carbon	N/A	32,179	-	52,666
Operational Carbon	N/A	90,306	-	430,815
Total Carbon	**N/A**	**122,484**	**-**	**483,481**

* Tool does not calculate emissions associated with demolition

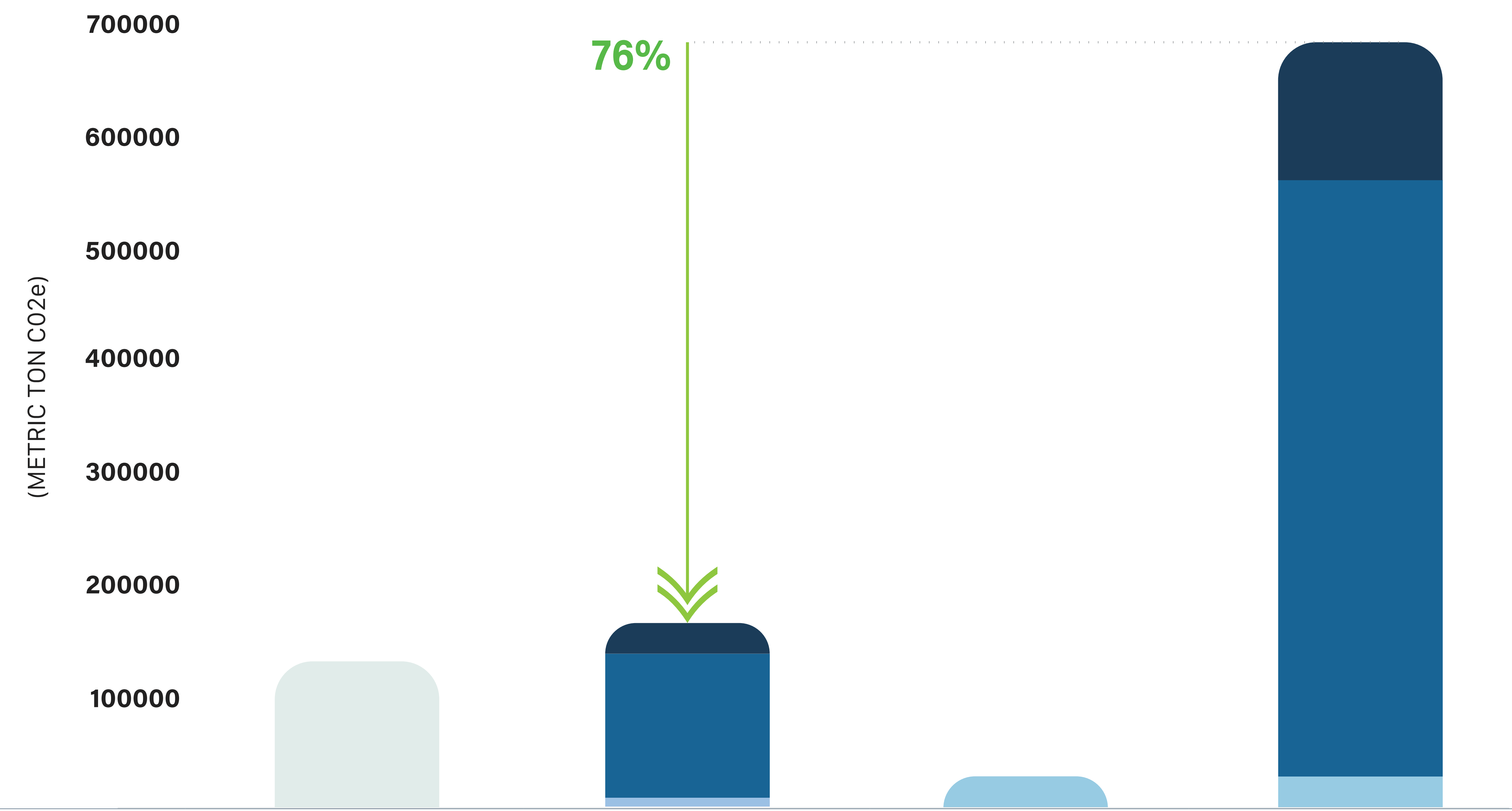
Total Impact & Carbon Avoided - OneClick LCA

Calculation based on a proposed 60 year lifecycle



Total Impact & Carbon Avoided - OneClick LCA

Calculation based on a proposed 60 year lifecycle

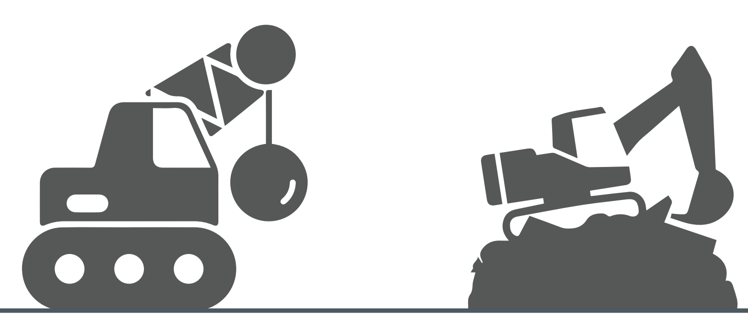


	Existing Embodied Carbon	Scenario A (Repositioning)	Scenario B (Demolition)	Scenario C (Replacement)
Upfront Embodied Carbon	N/A	27,222	N/A	122,848
Operational Carbon	N/A	132,740	N/A	532,755
Demolition Carbon	N/A	6,027	30,140	Scenario B
Existing Embodied Carbon	130,922	N/A	N/A	N/A
Total Carbon Added	**130,922**	**165,990**	**30,140**	**685,743**

- Upfront Embodied Carbon Added
- Operational Carbon
- Demolition Carbon
- Existing Embodied Carbon

Demolition Carbon

	Assumptions	Quantity	Units
Total weight of concrete	Concrete weighs approximately 2.4 tons/ m^3	326,345	Tons
Total weight of steel reinforcements	Steel reinforcement in a typical concrete building is about 100-120 kg/m^3 of concrete	14,957	Tons
Total weight of steel @ the Astrodome	12.5 pounds per square foot as an average	2,835	Tons
Total weight of materials		**344,137**	**Tons**
Diesel usage for concrete	Heavy demolition equipment consumes about **3.5 - 6.5 gallons** of diesel per ton	1,631,728	Gallons
Diesel usage for steel	Heavy demolition equipment consumes about **3.5 - 6.5 gallons** of diesel per ton	88,966	Gallons
CO_2 emissions from fuel for concrete demolition and crushing	Diesel combustion produces approximately **10.21 kg of CO_2 per gallon**	16,660	MT CO_2
CO_2 emissions from fuel for steel demolition	Diesel combustion produces approximately **10.21 kg of CO_2 per gallon**	910	MT CO_2
CO_2 emissions from fuel for recycling steel	Diesel combustion produces approximately **10.21 kg of CO_2 per gallon**	7,925	MT CO_2
Number of trucks/trips required	Assuming each truck can carry approximately **20 tons** of material	17,207	Trips
Total miles	Assuming an average 100-mile round trip for each load of material	1,720,700	Miles
CO_2 emissions from transportation	Trucks emit 2.7 kg of CO_2 per mile	4,645	MT CO_2
Total Demolition Carbon		**30,140**	**MT CO_2**



Total Cost Impact

Calculation based on a proposed 60 year lifecycle

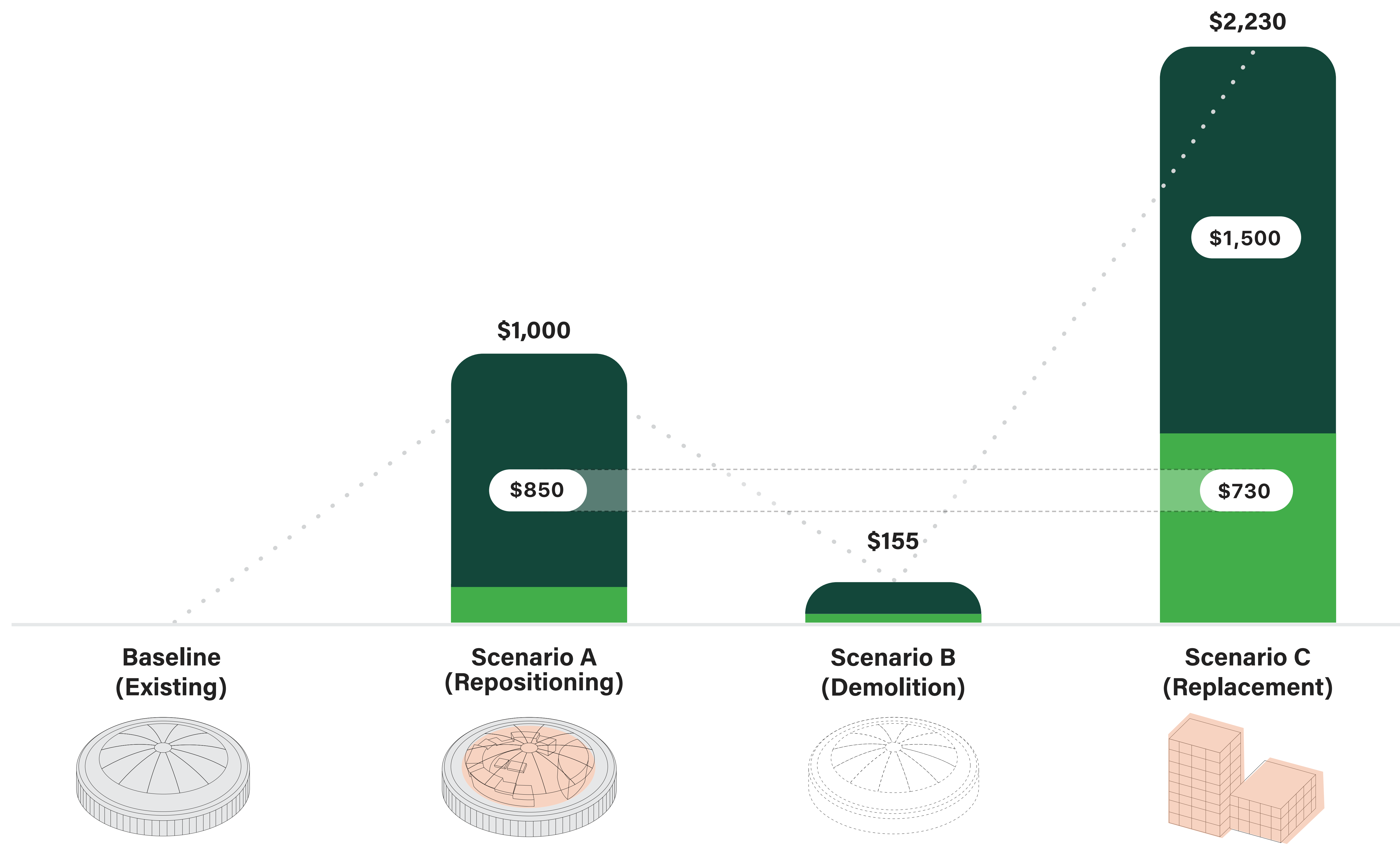
SOCIAL COST OF CARBON (SCC)

The "social cost of carbon" (SCC) is an economic estimate representing the total cost to society caused by emitting one additional ton of carbon dioxide into the atmosphere, essentially measuring the economic damages associated with climate change caused by that single ton of carbon emissions.

Social cost of carbon for 686,000 metric ton of CO2 emissions added by replacement

686,000 MTCO2 X $1,065* ~ $730 MILLION

- Construction Cost + Soft Costs (in Millions)
- Health Impacts - Social Cost of Carbon SCC (in Millions)
- Total Cost (in Millions)



* Source: National Bureau of Economic research https://www.nber.org/papers/w32450?utm_campaign=ntwh&utm_medium=email&utm_source=ntwg1

Key Findings

Key Takeaways

CULTURE & THE FUTURE MATTERS

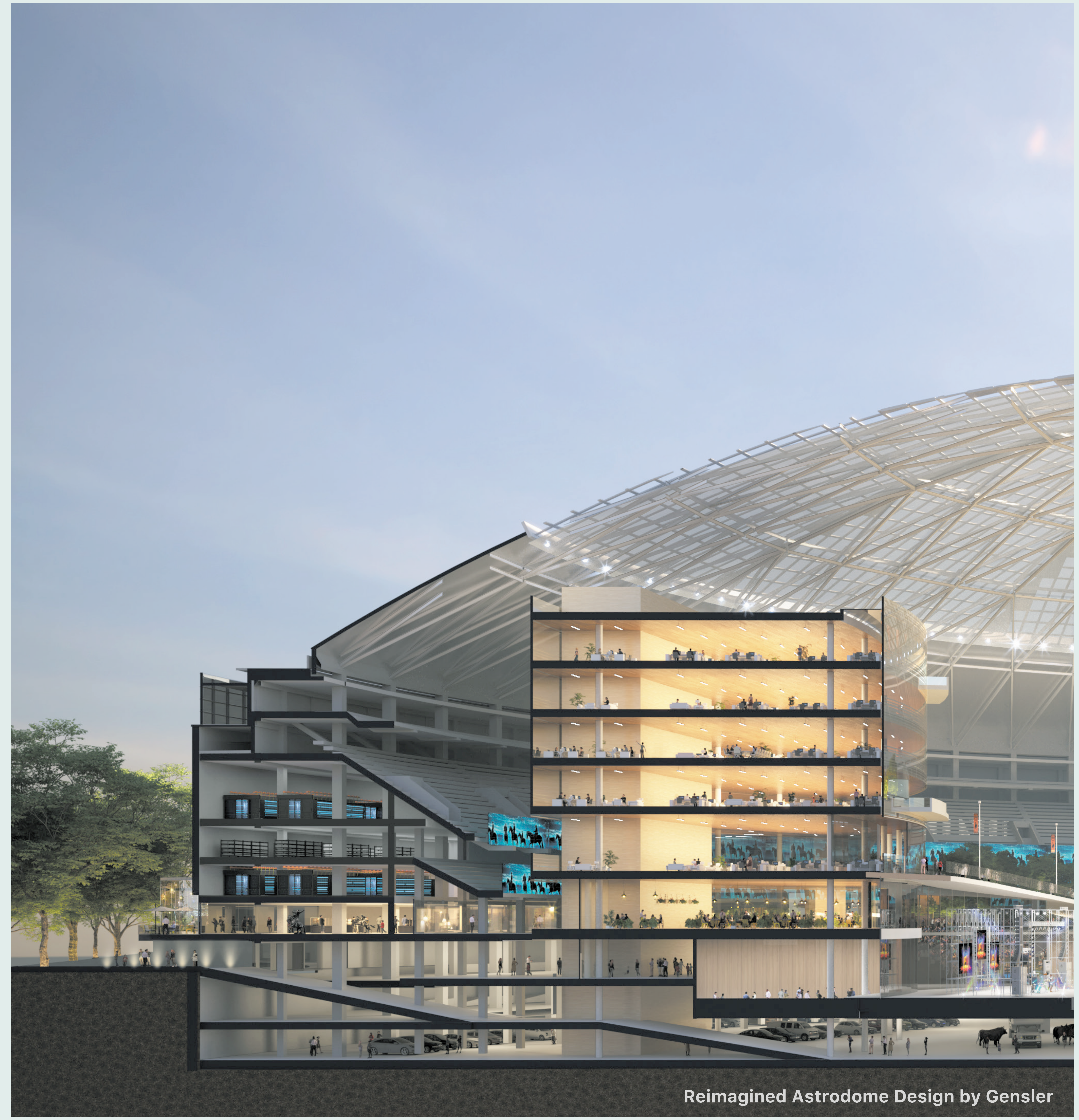
Preserving the Astrodome with a dual focus on cultural legacy and environmental sustainability creates a balance between the past and the future, demonstrating that cultural preservation and carbon reduction can work together to shape a more sustainable, culturally rich world for generations to come. **The redesign illustrates cultural conservation and environmental responsibility while preserving a significant, iconic landmark and its history.**

RETROFITS & REUSE MATTERS

Energy efficiency retrofits are critical in reducing long-term emissions, structural retrofits extend the building's lifespan, and building reuse and low embodied carbon material choices offer immediate carbon savings - all while preserving architectural and cultural heritage. **The reimagination of the Astrodome provides a sustainable solution that balances the needs of the present and the future.**

REDUCING CARBON MATTERS

Along with meeting climate goals, repositioning the Astrodome will help to mitigate the long-term economic and social damages of climate change and can also promote climate justice and public health, a prime focus for Harris County. **The Astrodome will set an example of how cultural heritage can be preserved while contributing to broader climate objectives for the future.**



Reimagined Astrodome Design by Gensler

Key Metrics

OPERATIONAL COST REDUCED

42%

BY REPOSITIONING FROM BASELINE

CARBON AVOIDED BY REPOSITIONING IS

76%

OF THE TOTAL REPLACEMENT CARBON

SOCIAL COST OF CARBON FOR REPLACEMENT IS

85%

OF THE TOTAL CONSTRUCTION COST OF REPOSITIONING

Reimagined Astrodome Design by Gensler

LIFE CYCLE ASSESSMENT

Lifecycle Assessment (LCA) Overview

WHAT IS LCA?

Lifecycle Assessment is a standardized method to evaluate significant potential environmental impacts of materials and products. In this assessment, the proposed building design is compared to a baseline of the same size, energy performance, and functional requirements. Each change between the baseline and proposed design is quantified, and the potential maximum lifecycle savings is estimated.

IMPORTANCE OF LCA

Whole building LCA assesses all stages of a buildings life cycle — planning, design, construction, operation, maintenance, and demolition — providing a holistic view of its environmental impacts including Upfront Embodied Carbon, Operational Carbon and End-of-Life scenarios

DATABASE

For the purposes of this study, all LCA data was used from the OneClick LCA North America database in the OneClick LCA online platform. This selection allows for the creation of an ISO 14044-compliant LCA process with as comparable data as possible.

Scope and Methodology

LCA METHODOLOGY

Developed by the U.S. Environmental Protection Agency (EPA), TRACI provides a standardized approach to quantify and evaluate various environmental impacts. It offers a structured approach to LCA, emphasizing key environmental impact categories relevant to various industries and can be used for informed decision-making and improved sustainability practices.

LCA SCOPE

For the purposes of this study, entire structure, enclosure, and the Astrodome was assessed and analyzed. MEP systems and interior finishes were excluded from the scope of study. All scenarios are of comparable size, function, orientation, and operating energy performance.

LIMITATIONS

The assessment is limited to materials expected to have significant and known environmental impacts and are subject to limitations in included products, data collection, and the ability to reflect real-time or on-site nuances. The Carbon Leadership Forum recommends uncertainity of +/- 35% when using generic data.

LCA Stages

LIFE CYCLE STAGES

Materials (A1-A3) Construction drawings, bills of quantities, and building information models as available to the project team.

Material transport (A4) Specific transport distances are used for materials where supply is traced. For other materials, OneClick LCA's regional default distances and material-specific transport methods are applied for the assessment.

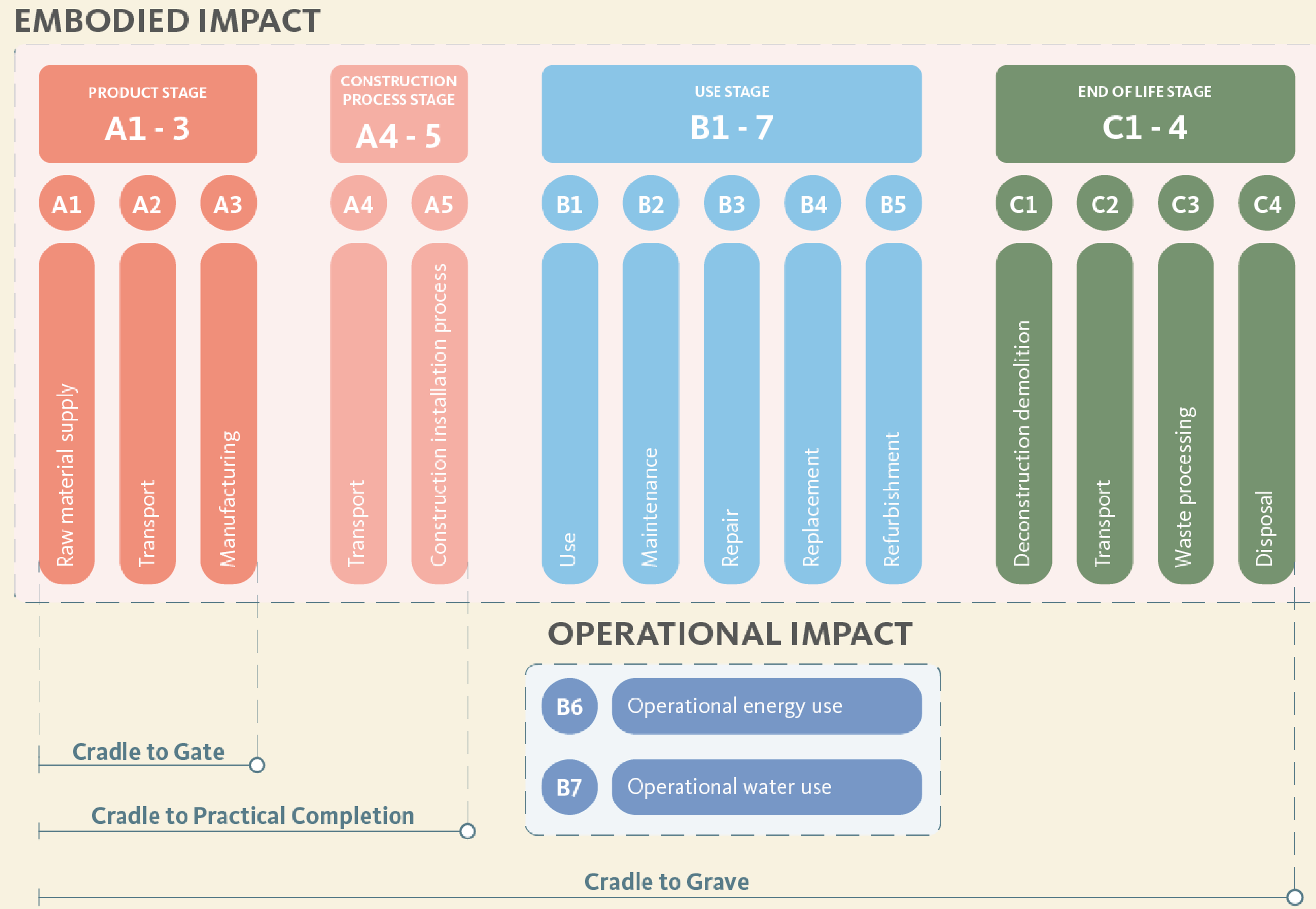
Construction (A5) The stage covering emissions and impacts from on-site construction activities, including material installation, energy use, waste generation, and its management.

Use phase of materials (B1-B5) Material repair rates and replacements at the end of service life are based on typical values for the material type. Replacements are assumed to apply in their entirety. Module B1 is not relevant as it applies to refrigerant fluids which are excluded; module B2 is not relevant as the materials in scope do not require any significant maintenance.

Use phase (B6) The stage covering emissions and impacts from operational energy use during a building's occupancy, including heating, cooling, lighting, ventilation, and other energy-related systems.

End-of-life (C1-C4) End-of-life impacts are based on OneClick LCA's scenarios which represent the typical end-of-life processing for each material type as applicable in the region where the project is located.

Beyond the system boundary (D) Not in the scope of this assessment.



LCA Impact Categories

GLOBAL WARMING POTENTIAL

ACIDIFICATION

EUTROPHICATION

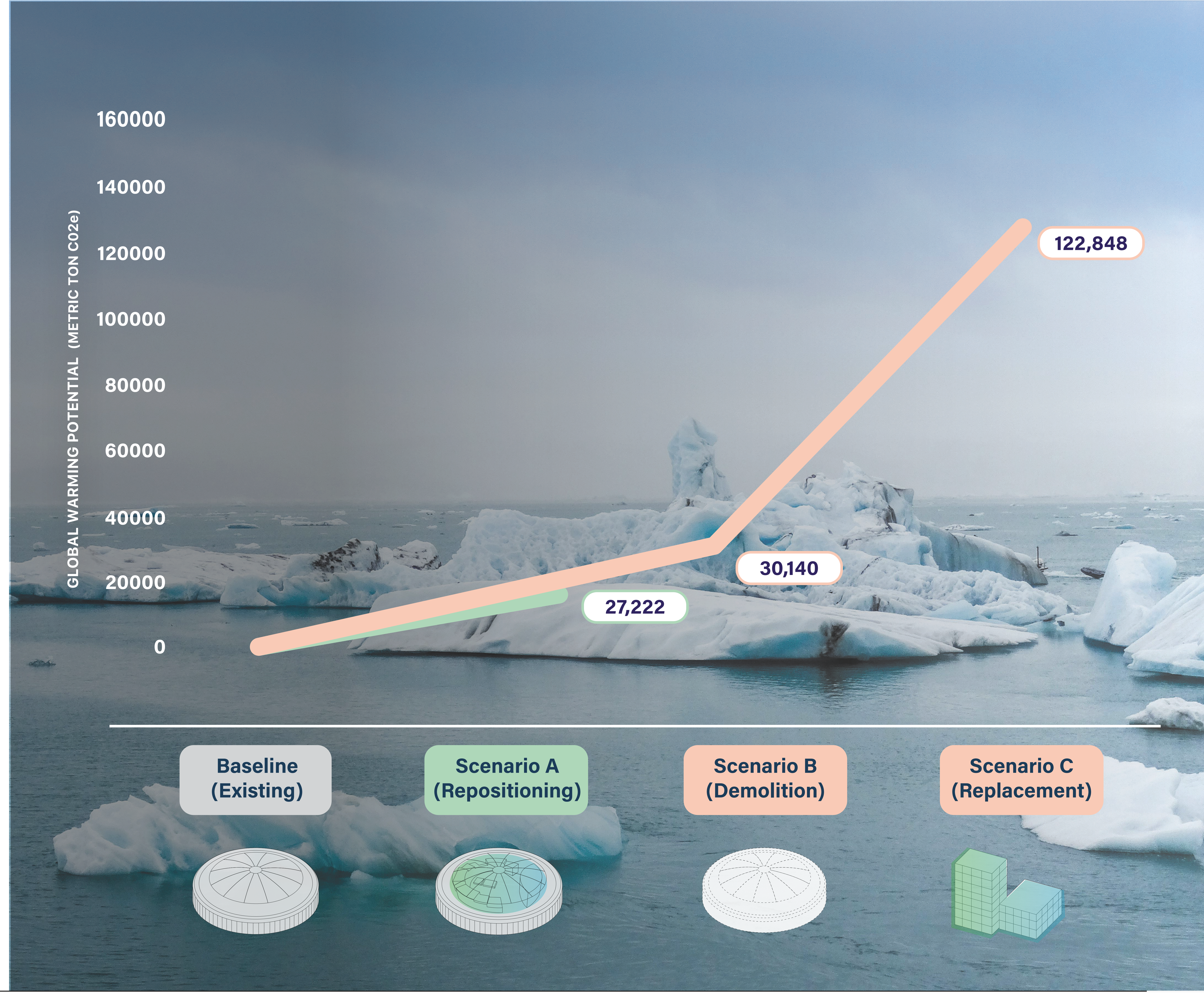
OZONE DEPLETION POTENTIAL

SMOG FORMATION POTENTIAL

RESOURCE DEPLETION

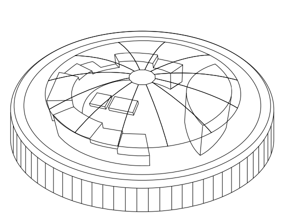
INTERPRETATIONS

Global Warming Potential



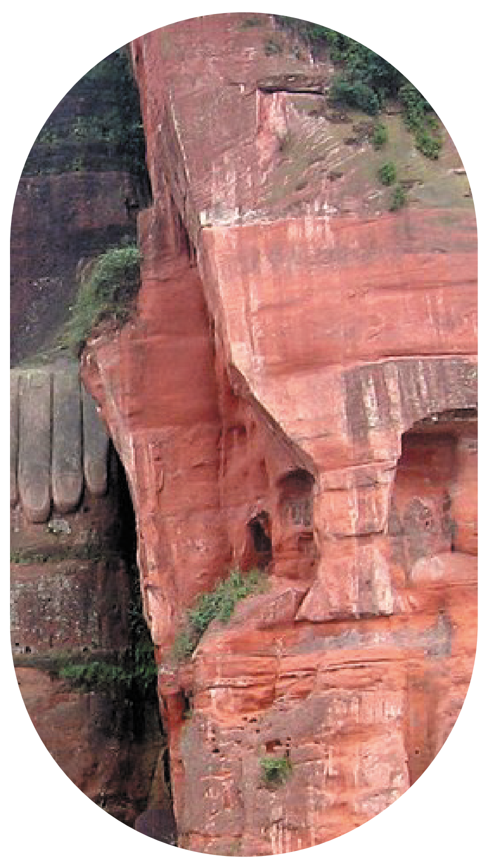
Global warming potential (GWP) measures the potential contribution of a product or activity to climate change, expressed in terms of carbon dioxide equivalents (CO2e).

GWP includes emissions from construction, energy use during the building's life, and disposal at the end.



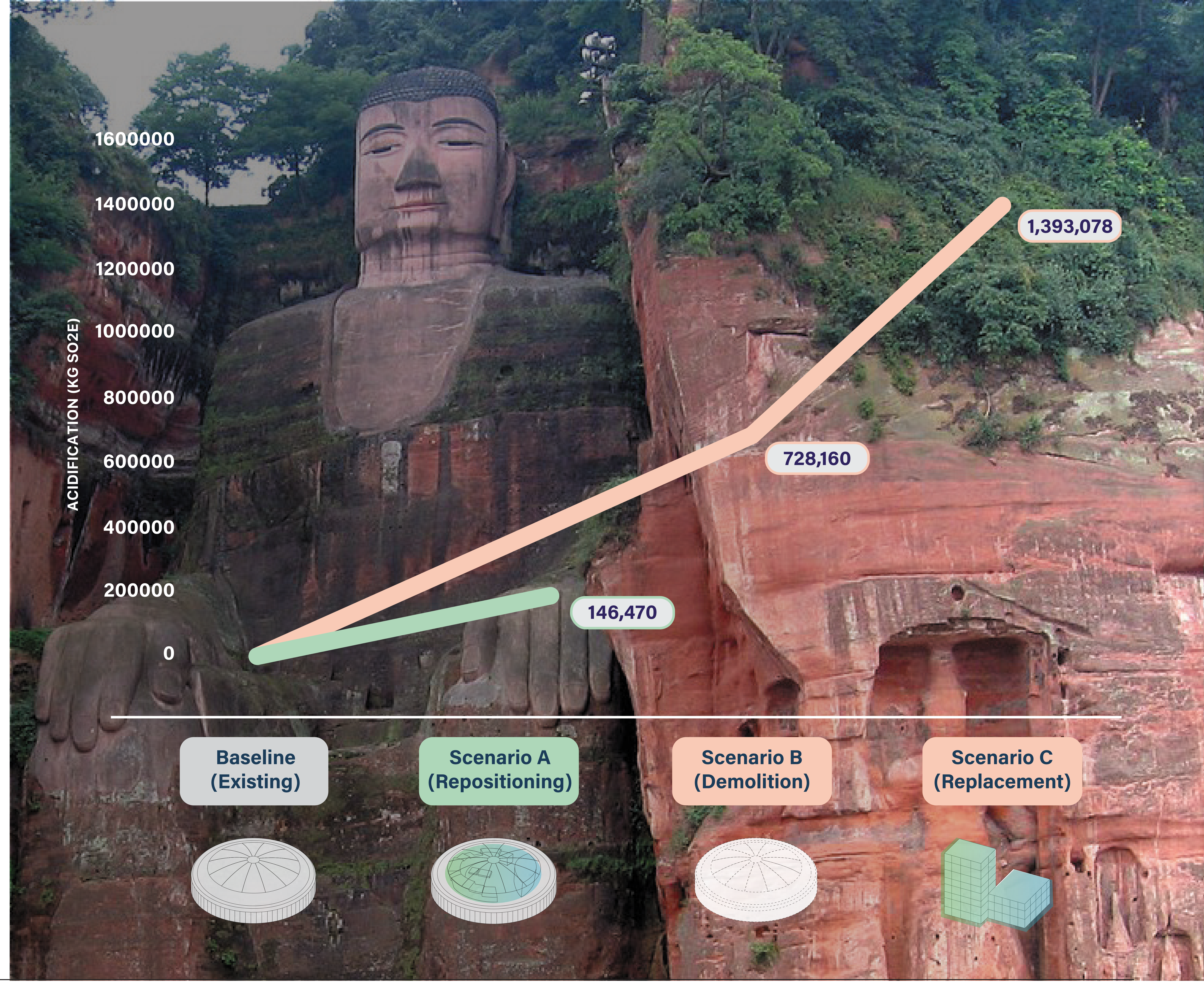
INTERPRETATIONS

Acidification



Acidification refers to the process by which water bodies, soil, or even the atmosphere become more acidic due to various pollutants.

Building materials contribute to an increase in acid rain through air pollution and improper waste disposal, leading to harmful effects on ecosystems, water quality, and soil health.

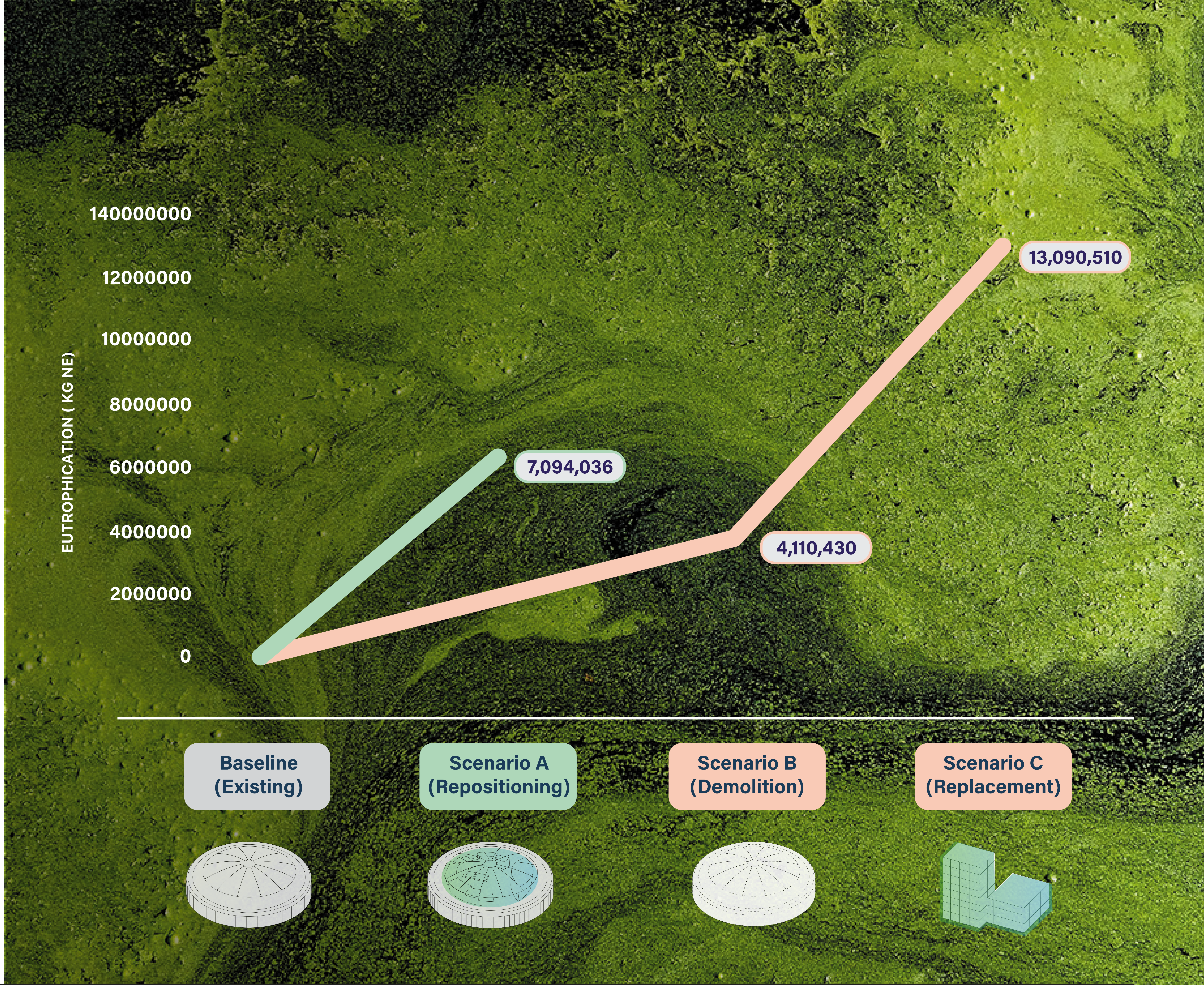


INTERPRETATIONS

Eutrophication

Eutrophication Potential (EP) is a nutrient overload in water that causes excessive algae growth, harms aquatic life, and leads to poor water, primarily due to the release of excess nitrogen (N) and phosphorus (P).

This looks at how nutrients from the building (from landscaping or runoff) can enter water bodies, causing excessive algae growth.

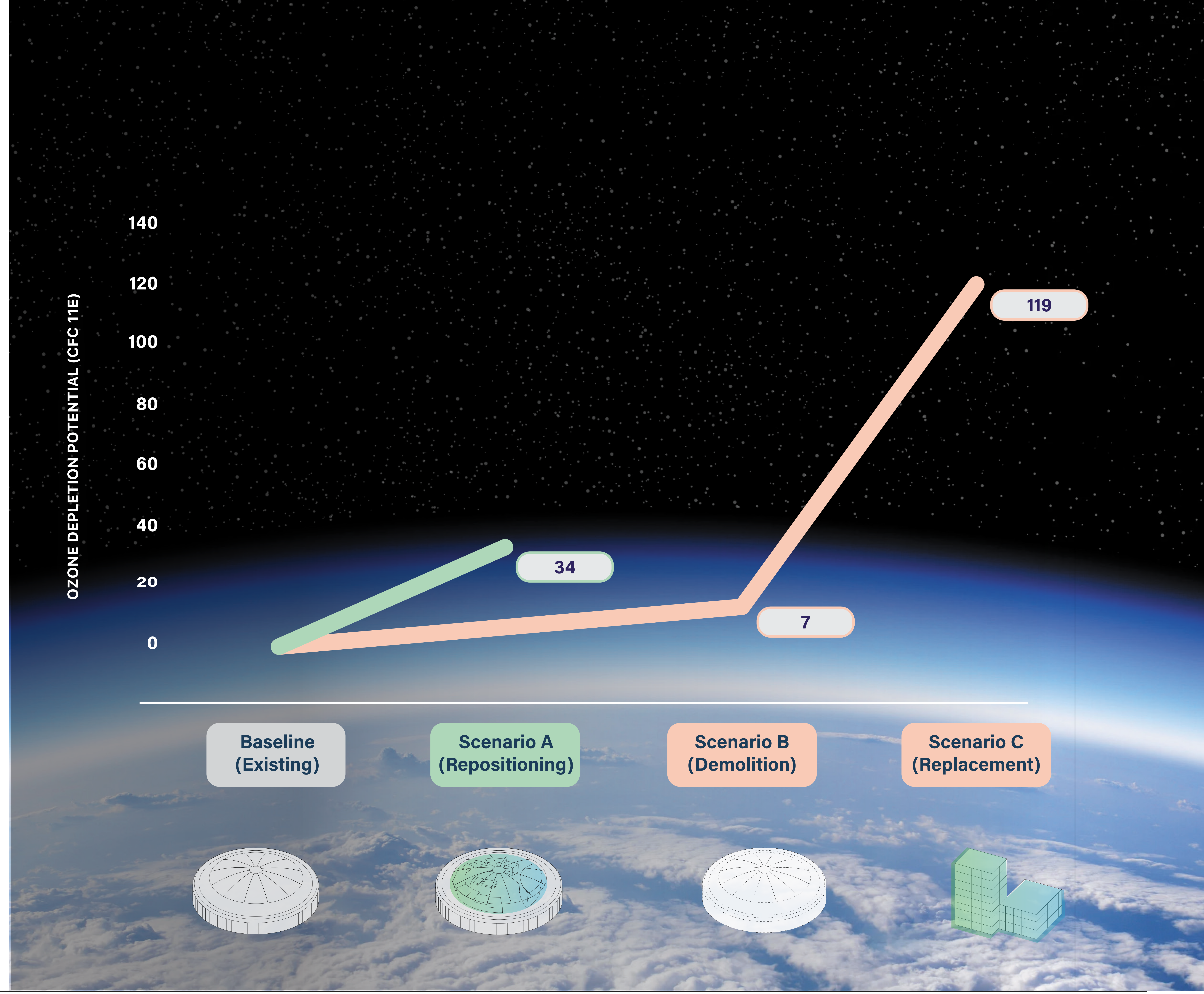


INTERPRETATIONS

Ozone Depletion Potential

This measures the potential of the building's materials and processes to harm the ozone layer, which protects us from harmful UV radiation.

Building materials contribute to ozone layer depletion by releasing harmful chemicals into the atmosphere. Choosing safer alternatives can help protect this crucial layer and reduce its thinning.



INTERPRETATIONS

Non-Renewable Energy

This evaluates the consumption of natural resources (like fossil fuels, metals, and water) throughout the building's lifecycle.

It helps us understand if we are using resources sustainably or depleting them faster than they can be replenished.

Our Team

SURYABALA SAH

Associate, Sustainability and Resilience Strategist

JERRY ALEXANDER

Principal, Co-Managing Director

KRISTOPHER STUART

Principal, Global Office Building Developer Practice Area Leader

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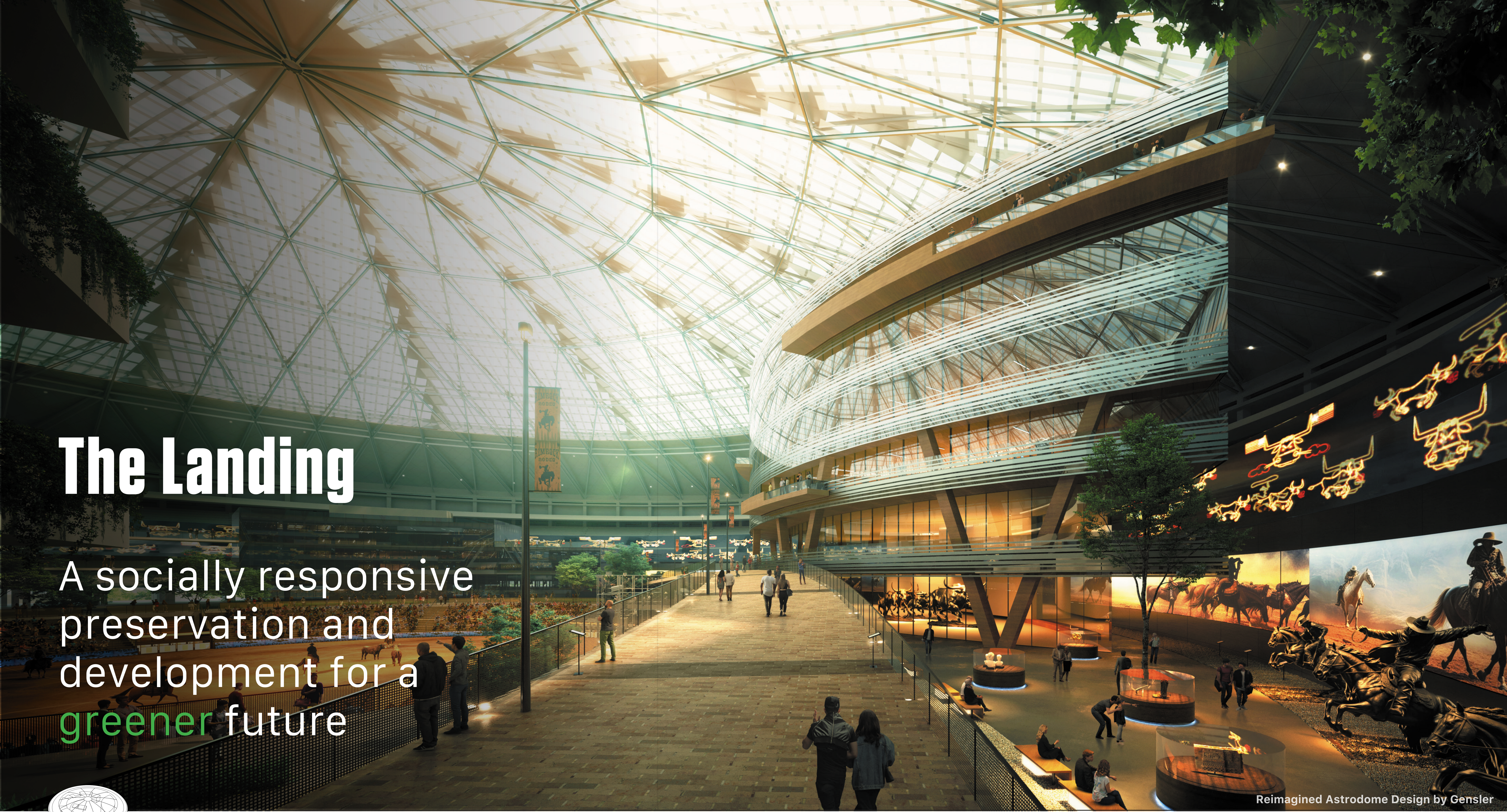
Principal, Global Resilience Research Leader



The Landing

A socially responsive preservation and development for a greener future

Reimagined Astrodome Design by Gensler