Innovating Highway Design for Environmental and Community Benefit

Design & Development Report

September, 2022
ACKNOWLEDGEMENTS

AUTHORS

Ben Stapleton, USGBC-LA Executive Director
Colin Mangham, USGBC-LA Net Zero Accelerator Director
Heather Cruz, USGBC-LA Green Building Corps
Cheng Peng, USGBC-LA Green Building Corps
Pars Parikh, USGBC-LA Program Coordinator

SPECIAL THANKS

LA County Metropolitan Transportation Authority
California Department of Transportation (Caltrans) District 7
Cumming Management Group
# TABLE OF CONTENTS

**Executive Summary** ................................................................. 4

**Innovation Workshop Insights** ................................................ 6
- Aims ....................................................................................... 6
- Key Objectives ................................................................. 7
- Order of Events ............................................................... 8
- Participant Engagement .................................................. 10
- Sample Dialogue ............................................................. 11
  - Select Links Shared ...................................................... 14
- Workshop Key Takeaways & Action Items ..................... 15

**Highway Innovation Market Landscape Overview** ................... 17
- Materials ............................................................................ 18
  - Concrete and Cement .................................................. 21
  - Steel and Iron .............................................................. 23
  - Asphalt .......................................................................... 25
- Landscaping ..................................................................... 27
  - Trellis ............................................................................ 28
  - Recreation ..................................................................... 30
  - Parks .............................................................................. 31
  - Native Plants (& Roadside Landscape) .......................... 32
  - Urban Agriculture ...................................................... 36
  - Gardens .......................................................................... 37
# TABLE OF CONTENTS

**Integrated Infrastructure**

Data Infrastructure ............................... 38

**Electrical** ........................................... 39

Charging Stations ..................................... 39
Energy Storage ........................................ 40
  Energy storage systems (ESS) technologies ...................................................... 42
Data Infrastructure .................................... 43

**Renewable Energy** ................................. 44

Solar Energy .......................................... 45
  Photovoltaic Noise Barriers ............................ 45
Wind Energy .......................................... 45

**Environmental Mitigation** ...................... 46

Noise ....................................................... 47
  Noise Walls ........................................... 47
  Quieter Pavements ................................. 48
Air Pollution .......................................... 49
Stormwater ............................................ 50
Multi-Modal Systems ............................... 52
In this study, USGBC-LA set out to reimagine how highways could be developed to reduce environmental impacts as well increase resilience and equity in the communities they touch. Using sustainability as the guiding principle, USGBC-LA leveraged innovation to explore ways to approach the highway development process to create positive impacts across the environment, equity, and resilience for the communities LA Metro impacts.

This was conducted in three phases with the initial phase involving market research to identify some of the best examples from around the world as well as technology innovations that leverage highway infrastructure for community benefit. During the second phase of the study, USGBC-LA interviewed industry and community leaders for their recommendations, including those in the architectural, engineering, and construction sectors who develop highway projects. In the final phase, USGBC-LA, in collaboration with the LA County Metropolitan Transportation Authority (LA Metro) and Caltrans hosted a special, invite-only workshop where we together reimagined how highways could be developed to reduce environmental impacts as well increase resilience and equity in neighboring communities.

Over the course of our work we divided this research and information into five categories: Materials, Landscaping, Integrated Infrastructure, Renewable Energy, and Environmental Mitigation. With materials, for example, the goal was to assess the market landscape of new and existing technology around materials used in highway construction (concrete, steel, pavement, cabling, etc.) to determine which materials could have a net zero or net negative carbon footprint as part of future projects.

In the workshop we endeavored to explore specific concepts around breakthrough pilot opportunities related to ancillary improvements required for highway development, including landscaping, sensor systems, electrical infrastructure and more, to see how they can be leveraged for positive environmental, equity, and resiliency impacts for local communities.
RECOMMENDATIONS

There are several key strategic initiatives we recommend in the near term to ensure that momentum is maintained in moving innovation this work forward:

- Metro & Caltrans Designating Specific Highways or Corridors as Innovation Zones for deployment of strategies and technologies to reduce environmental impact and enhance community benefits.

- Establishing a joint task force that meets monthly or quarterly between Metro, Caltrans, and a select set of community partners to review projects for opportunities to implement innovation.

- Setting standards for procurement that include embodied carbon calculations for concrete, structural steel, and asphalt.

- Creating guidelines and a toolkit for improved use of highway adjacent space for improved community and environmental impact, ensuring that co-benefits are a requirement.
Aims

USGBC-LA, in collaboration with the LA County Metropolitan Transportation Authority and Caltrans, developed and hosted an invite-only workshop in which participants were to reimagine how highways could be developed to reduce environmental impacts as well increase resilience and equity in the communities they touch.

In this facilitated workshop we engaged diverse stakeholders in what was effectively a design charrette, which began with an interactive market landscape discussion on innovation across highway design, construction, and maintenance. We then explored local opportunities to reduce highway related environmental and community impacts. And then closed the session by bringing all the pieces together to collectively design the highway of the future for LA and beyond.

What follows are the stated objectives going into and accomplished by the workshop, the order of events as they took place, and some key takeaways and action steps.
Key Objectives

- Highlight the opportunity to create more positive impact with highway design and development with construction and currently planned projects.

- Identify and engage relevant stakeholders to reimagine the process of highway design, construction, and maintenance.

- Assess the market landscape of new and existing technology around materials used in highway construction (concrete, steel, pavement, cabling, etc.) to determine which materials could have a net zero or net negative carbon footprint as part of future projects.

- Explore specific concepts around breakthrough pilot opportunities related to ancillary improvements required for highway development, including landscaping, sensor systems, electrical infrastructure and more, to see how they can be leveraged for positive environmental, equity, and resiliency impacts for local communities.

- Surface key opportunities and challenges to the integration and implementation of multiple innovations in the Highway of the Future, as well as potential unintended systemic impacts.
INNOVATION WORKSHOP INSIGHTS

Order of Events

8:00 AM – Welcome Remarks
Heather Repenning, Executive Officer, Sustainability Policy, Los Angeles Metro & Godson Okereke, Deputy District Director for Maintenance, Caltrans District 7

8:10 AM – Workshop Framing
Ben Stapleton, Executive Director, USGBC-LA

- What is the opportunity we have in LA to reimagine our highways? What is practical?
- How do we engage with local communities to create the positive change needed to make this possible?

8:15 AM – Roundtable Introductions

- Establish who is in the room and what role each person plays in this discussion
- Identify any specific stakeholders missing from this conversation

8:30 AM – Highways Innovation Landscape Overview
Colin Mangham, Director, Net Zero Accelerator, USGBC-LA

- What makes LA ideal to reimagine highways for environmental and community benefits?
- What does the global landscape of innovation in highway design and development look like? What specific technologies present opportunities for LA?
- Group work leveraging an interactive Mural board for sourcing innovations for projects here in LA
INNOVATION WORKSHOP INSIGHTS

Order of Events

9:15 AM – Breakthrough Pilots
Becky Feldman Edwards, Event Manager & Corporate Sustainability Lead, USGBC-LA

- What stories and examples can be shared about successes or failures of the integration of innovation from around the world?
- Breakouts + Small Group Discussions focused on: Materials, Landscape, Renewables, Integrated Infrastructure, Mitigation (air quality, noise, runoff), and Multi-Modal Systems.

10:15 AM – Assembling the Highway of the Future
Ben Stapleton, Executive Director, USGBC-LA

- How do these innovations come together in the real world? What are the next steps to make this highway of the future a reality?

10:50 AM – Next Steps & Closing Remarks
Ben Stapleton, Executive Director of USGBC-LA, Heather Repenning, Executive Officer, Sustainability Policy, Los Angeles Metro & Barbara Marquez, Deputy District Director for Sustainability & Innovation, Caltrans District 7

- Timeline of the Reimaging Highways Project
- Closing Remarks

11:00 AM – Networking
INNOVATION WORKSHOP INSIGHTS

Participant Engagement

To facilitate discussion we used Mural boards, post-it note styled collaborative spaces where participants could present, organize, and prioritize ideas, challenges, and opportunities.

1. Define your problem statement
   - What is the opportunity we have in LA to reimagine our highways? What is practical?
   - How do we engage local communities to create the positive change needed to make this possible?
   - Who isn’t here that should be? Who needs to be a part of this journey?

2. Brainstorm – The Landscape for Highway Innovation
   - Materials
   - Landscape
   - Renewables
   - Integrated Infrastructure
   - Mitigation
   - Multi-Modal Systems

3. Breakouts – How do we breakthrough in California?
   - Materials
   - Landscape
   - Renewables
   - Integrated Infrastructure
   - Mitigation
   - Multi-Modal Systems

4. Let’s Build the Highway of the Future

5. Prioritize
Sample Dialogue

Following are some highlights of the focus and spirit of the dialogue between participants reimagining highways in real-time:

“In the scope of redesigning or improving on existing [highways], please keep in mind to enhance all the nearby neighborhoods.” ~ Charles Favors, CBF Xeriscape Landscape Architect

“Absolutely correct, Charles! We want to think about how highways could support the communities they touch in greater ways through enhancing resilience, providing emergency resources, green space, and more….” ~ Ben Stapleton, USGBC-LA

“Also need to look at whether microplastics would come off due to wear of plastic (or tire crumb aggregate) based pavements.” ~ Eric Strecker, Terraphase Engineering

“The CA state Climate Action Plan for Transportation Infrastructure (CAPTI) includes piloting a Highways to Boulevards conversion program.” ~ Bryn Lindblad, Climate Resolve

“I support Walker and Bryn’s comments about removing or converting unneeded highways to increase public space while reducing the burden of maintenance … extra priority given to removing or converting in underserved communities or those historically negatively impacted by infrastructure development.” ~ Anthony Kane, Institute for Sustainable Infrastructure

“One of the main points from our conversations was how unused or adjacent unused highway space could be converted to urban green space to support community health, biodiversity, and more.” ~ Ben Stapleton, USGBC-LA

“Caltrans adopting Portland lime will push the entire California construction market towards utilizing low carbon concrete. The impact of that decision is even bigger than just the public infrastructure projects. That’s how we are seeing innovative materials get market entry.” ~ Heather Repenning, LA Metro Sustainability
“For greening highways, roadside vegetation can improve or worsen local air pollution. EPA has a guide to the vegetation characteristics needed for air quality benefits (link below).”
~ Rich Baldauf, US EPA

“What about the availability and access to lithium?” ~ Debra Scacco, Air / Artist / Researcher

“Supply chain and weight of batteries are areas of concern. We could bring the charging to the vehicle rather than the vehicle to the charging to get battery size down and eliminate range anxiety (link to Aspire below).”
~ Laura Rogers, The Ray

“Rather than a methodology to indicate what highways might not be ‘needed’, consider framing the analysis as to what are the true costs and benefits of our highways. What are the health impacts to the communities adjacent to highways and how much time does a solo vehicle driver save on a daily commute at the cost of people’s health?” ~ Sam Morrissey, Urban Movement Labs

“Not entirely joking, but induction charging in areas prone to significant traffic might offer a positive to counter the negative.” ~ Anthony Kane, Institute for Sustainable Infrastructure

“We put in the FasTrak [The Toll Roads] over 3 to 4 years, we could have a dedicated EV charging lane that Angelenos could pay for.” ~ Christine Marez, Cumming

“I would also encourage everyone to broaden horizons when thinking of EVs, which should encompass transit vehicles, electric bikes, e-scooters, etc. These induction charging approaches could and should support (and potentially prioritize) these moves of single occupancy vehicles (SOVs).” ~ Tony Dang, Caltrans

“Caltrans could pilot induction charging to benefit bikes and transit on non-freeway highways, for example on SR-72 in Whittier.” ~ Julio Perucho, LA Metro, Roads & Highways
“A common theme seems to be reimagining highway infrastructure for multiple resiliency aspects instead of just serving the fossil fuel/car industry. Would be cool to pilot a highway diet/retrofit project in a formerly redlined community that doesn’t just reduce the negative but improves the positive. Great way to get investment dollars to people that need it the most. Maybe in a community like Wilmington, that’s already bombarded by highway pollution, port pollution, and petrochemical infrastructure.”
~ Kathleen Hetrick, Carbon Leadership Forum

“Would be great to do a community workshop in a place like that to see what they might want from their freeway if we gave them options.” ~ Ben Stapleton, USGBC-LA

“We can get Physicians for Social Responsibility [PSR-LA] to host, or Communities for a Better Environment. They are already doing so much. We could all take an electric bus–powered toxic tour. :)
~ Kathleen Hetrick, Carbon Leadership Forum

“Caltrans requires maintenance agreements with local jurisdictions if Cities want landscaping choices within the Caltrans R/W that are more than a reduced maintenance planting palette. Are there opportunities to include community non-profit groups to be part of those maintenance agreements?”
~ Julio Perucho, LA Metro, Roads & Highways

“Ben, you are right about integrating broadband proliferation into new infrastructure development! This “dig once” effort is part of a SCAG report on broadband and reduced VMT which is about to be published … That is a very good point [Kathleen, re: “dig once” benefits including way less carbon emissions from construction equipment]! ~ Hilary Norton, CTC & FASTLinkDTLA

“Less air pollution, less carbon emissions, less sound pollution, less money!”
~ Kathleen Hetrick, Carbon Leadership Forum

“There’s a Japanese philosophy called ‘kintsugi’ that comes to mind here. It’s basically to embrace the imperfect. If for example, you break a bowl, you put it back together. You certainly don’t throw it out. And you don’t hide the history of the repair … in fact, you accentuate it, you fill the cracks with gold. I like to think about this when we talk about reuse, repair, repurpose, and maintenance of this infrastructure … as we beautify and level it all up for the next generation.” ~ Colin Mangham, USGBC-LA Net Zero Accelerator
INNOVATION WORKSHOP INSIGHTS

Select Links Shared

- LA Metro – Sustainability
- Caltrans – Sustainability
- Caltrans Approves Use of Low-Carbon Cement to Help Combat Climate Change
- Using Meadows to Sequester More Carbon
- What Is Biomimicry
- Biomimicry Resources in Los Angeles
- Ask Nature Database
- Constructing Roadside Vegetation Barriers to Improve Near-Road Air Quality
- The Ray – Let’s Drive the Future
- Aspire is Eliminating Range and Charging as Barriers to Electric Vehicle Use
- US DOT Sustainable Highways (INVEST Self Evaluation)
- 3M Connected Roads
- Detroit Gets First US Public EV Inductive Road Pilot
- Physicians for Social Responsibility (PSR-LA)
- Communities for a Better Environment
- CTC – California Environmental Quality Act (CEQA)
INNOVATION WORKSHOP INSIGHTS

Workshop Key Takeaways & Action Items

We were appreciative of everyone’s active participation and were able to cover a lot of ground and set the stage for the important journey ahead. As we left it, our overarching next step is to extend and increase collaboration with our colleagues at Caltrans, LA Metro, and LA County to determine the best next steps to turn some of our conversation into action.

Some things we together envisioned:

- Deeper dives on promising technologies and solutions
- Pilot opportunities to stress-test and validate innovative approaches
- Assessing and prioritizing innovative technologies ready for deployment
- Leveraging past/present Net Zero Accelerator companies to accomplish the above
- Workshops, Town Halls, and Webinars to get to actionable details and milestones
- Identify projects for Reconnecting Communities funding in the Infrastructure Bill
- Ensuring that any key stakeholders absent from our conversations join us
The goal of our research was to identify innovative technologies and approaches to highway construction and expansion as well as look for technologies or approaches that impart positive environmental, equity, and/or resilience impact.
Materials

While highway infrastructure has evolved over time, the current challenge of accomplishing a net zero or net negative carbon footprint anchors on advancements in the building blocks and their ingredients: concrete and cement, steel and iron, and asphalt. A reflection of its strength and durability, concrete is actually the earth’s second-most-consumed product. For many of the same reasons, steel is also highly coveted with an estimated 22% of global steel consumption going toward infrastructure, second to the 39% consumed by buildings.

The City of Los Angeles recognized this and became the first municipality to adopt the Buy Clean California Act, which necessitates reducing emissions from construction materials. Furthermore, Caltrans recently approved the use of low-carbon cement that can mitigate potentially 28,000 tons of carbon dioxide a year. Thereafter, on May 27th, the LA City Council doubled down and passed a motion to require new commercial and residential buildings to be zero-carbon.
While this paper does not examine buildings, those structures incorporate many of the same materials utilized in highway construction. In other words, traction in the built environment helps foster growth within the materials markets. Although carbon is emitted at multiple points during production, a majority of emissions come from operating at high temperatures. For materials, strategies to reduce emissions generally involve one of these areas: modifications in the production process; reduction in materials; carbon sequestration; and using low-carbon heat sources.

- Reviewing the manufacturing process to ensure the best equipment and technology is utilized can reduce emissions.
  - Research has demonstrated that utilizing heat exchangers, fortifying the plant’s insulation, and upgrading boilers, can reduce energy consumption by 26%, 10%, and 25%, respectively.

- Seeking less carbon intensive sources of energy such as decarbonized electricity, natural gas, biomass, etc.
  - Coal has nearly twice the carbon density per unit of energy as compared to natural gas. However, results can vary depending on the method by which natural gas is extracted.

- Recycling materials to reduce the harvest of virgin materials.

- RubbleMaster offers asphalt and concrete crushing and aggregate processing equipment and technology to facilitate the recycling of materials.

- Research suggests that asphalt and non-permeable concrete can reach peak surface temperatures of 120°F–150°F. To reduce the urban heat island effect, the EPA recommends installing cool pavements. Net Zero Accelerator (NZA) alumnus ePave offers a non-toxic solution that can be applied to concrete, metal, and asphalt to improve its solar reflectance, extend its lifespan, and reduce surface temperatures by nearly 30 degrees.
Materials Sector Overview from Innovating Highway Design Workshop

**Materials**

**Opportunities**

- Reduce Aggregate Base (50%)
- Smoother Surfaces for Bikes as Well
- Industry Leadership if bring this to scale in LA
- Advocacy of EPDs & Embodied Carbon Impacts
- Use aggregate base to help manage stormwater (it may also don’t reduce, but add a purpose. Does not require poisons pavement side inlets.
- Rubberized Asphalt (recycled tire material) also reduces noise
- "Living Labs" designated for testing / prototyping

**Barriers**

- Habit / Disruption
- Understanding of Embodied Carbon and its impacts
- Current design requirements (Fed/State/Local)
- Potential toxicity issues with use of tire crumb rubber that is exposed to stormwater
- Time scale, validating new approaches takes time
- Barriers for large wildlife like bears, lions, coyote,
According to the International Energy Agency, from 2015–2020 the carbon intensity of cement production increased 1.8% year. That is a sharp contradiction to the necessary 3% annual declines required to meet net zero by 2050. Shortcomings are crippling, and as a result, organizations such as Global Cement and Concrete Association, Climate Group, World GBC, and WBCSD have formed multinational initiatives such as 2050 Climate Ambition and ConcreteZero in an effort to bring people and organizations together and stimulate progress. Striving for carbon neutral concrete by 2050, the initiatives comprise a cohort of companies representing more than 40% of global production. Initiatives such as these drive demand, prompting the concrete manufacturers to respond, and meet the needs of their customers.
CRH: Targeting the year 2050, CRH’s umbrella goal is to reach net zero carbon throughout the cement and concrete value chain.
- CRH played an instrumental role in Québec Ministry of Transport’s first carbon-neutral infrastructure project, the Turcot Interchange. With more than 45 bridges, and the intersection of three highways, neutralizing the Turcot Interchange’s carbon emissions required planting 70,000 grasses, perennials, shrubs, trees, and vines.

CEMEX:
- Developed their first net-zero CO2 concrete called Vertua. Through reduction and offsetting efforts, the Vertua Ultra neutralizes the carbon footprint. Their concrete is being utilized in projects worldwide.
- Working in conjunction with Carbon Upcycling Technologies, a member of USGBC-LA’s Net Zero Accelerator cohort, to develop the “first commercial-scale cement additive plant that combines CO2 sequestration and waste glass.”

CarbonCure:
- Their technology empowers all concrete manufacturers with the ability to inject carbon dioxide into concrete during mixing.
- They have saved nearly 200,000 tons of carbon dioxide and delivered roughly 2.7 million truckloads of concrete.

CarbonBuilt:
- Headquartered in Los Angeles, their Reversa technology embeds carbon dioxide into concrete during the curing process.

Aquipor Technologies, Inc.
- With their technology, they are able to offer concrete that is permeable, and better yet, doesn’t require highly polluting cement plants. Instead, the concrete is formed with industrial by-products.
- Here is a video demonstrating how their concrete responds to water compared to traditional concrete.
Steel and Iron

Where you’ll find concrete, you’ll likely also find steel. And where you’ll find steel, you’ll definitely find carbon because more than two-thirds of steel production utilizes a coal-derived substance, coke, as the reductant for iron ore. All in, manufacturing one ton of steel emits about 4,000 pounds of carbon dioxide. The International Energy Agency reports the production of iron and steel contributes 2.6 billion tons—about 7% of the world’s carbon dioxide emissions.
The key to reducing carbon emissions begins with substituting coke with a compound or process that is capable of reducing the iron ore. Some alternatives currently being explored:

- **Hydrogen and carbon monoxide**: A method known as direct reduced iron (DRI) and emissions were reduced by nearly 61%.
- **Only hydrogen**: Estimates suggest this approach would net a 97% reduction, down to about only 50 kilograms of carbon dioxide per ton of steel, and is being explored in Australia, China, and Europe.
- **Electrolysis**: Both the world’s largest publicly traded manufacturer, ArcelorMittal, and Boston Metal are exploring this.

Another strategy is to utilize alternative furnaces fueled by renewable energy.

- Currently, steel is produced via:
  - an integrated blast furnace (BF)/basic oxygen furnace (BOF) where coal is the reductant. This is the most common with about 70% of production.
  - an electric arc furnace (EAF) where natural gas-based DRI or steel scrap are the reductants. This furnace accounts for about 29% of production.
- Market forces influencing the price of energy generally dictate how steel is produced in that region. For example, in Europe coal-dependent processes are dominant, while in North America natural gas-dependent processes are big.

Overall, most technologies are attempting to incorporate a combination of both. For example, using an electric arc furnace fueled by renewable energy. Plus, hydrogen is sourced from the electrolysis of water. According to McKinsey, this method is established as a nearly emission-free process of producing steel.

Depending on the source of energy, steel can be recycled economically with an electric arc furnace netting a 20%-25% reduction in emissions.
The development of high quality low temperature binders and mixes produces substantial savings in energy and production costs.

The European Asphalt Pavement Association (EAPA) is the only trade association that exclusively represents the interests of the asphalt producer/contractor on the national level with Congress, government agencies, and other national trade and business organizations.

- Asphalt by definition is a mixture of aggregates, binder and filler, used for roads, parking zones, railway tracks, and a number of other urban areas. Aggregates used for asphalt mixtures could be crushed rock, sand, gravel or slags.
- Today, certain waste and by-products, such as construction and demolition debris, are being used as aggregates, which increases the sustainability of asphalt. In order to bind the aggregates into a cohesive mixture a binder is used. Most commonly, bitumen is used as a binder, although now, a series of bio-based binders are also under development with the aim of minimizing the environmental impact of the roads.

Research is currently investigating pavement sustainability and the myriad of technologies that exist in the web of asphalt potentiality including: Recycled Asphalt Pavement, Bio-binders of asphalt, asphalt cement, warm mix asphalt, tack coat, rubberized asphalt (RA), and polymer modified asphalt (PMA).

- Bio-binders are a form of recycled or “reclaimed” asphalt pavement (RAP) and consist mostly of biomass from plant or organic waste products with equivalent qualities to conventional asphalt. The biological additives, notably vegetable oils, work well with adding RAPs, boosting bitumen flow and fusion properties and are environmentally friendly.
An additional option for wet or dry modification of asphalt mixes is Rubberized Asphalt (RA) or Rubber Modified Asphalt (RMA). RA is recycled crumb rubber from scrap tyres that contains up to 54% natural and synthetic rubber. This solution merges with addressing the surplus of tire waste that exists in our landfills today.

An alternative to asphalt are cool pavements, which are already being experimentally implemented into many parts of Los Angeles, Boston, and Phoenix.

- According to the MIT Concrete Sustainability Hub, typical paving surfaces like traditional asphalt absorb more radiation and emit more heat due to their darker surface and have a “low albedo”; albedo being what measures surface reflectivity. Cool pavements, however, have brighter materials that reflect more than three times as much radiation, and air temperatures drop due to emitting less heat.
- A recent study by MIT CSHub researchers found that this cool pavement technology could not only cut greenhouse gas emissions by 3 percent in Boston and 6% in Phoenix, but it could also aid in lowering air temperatures by up to 1.7° C (3° F) and 2.1° C (3.7° F).
HIGHWAY INNOVATION MARKET LANDSCAPE OVERVIEW

Landscaping

Landscaping Sector Overview from Innovating Highway Design Workshop

<table>
<thead>
<tr>
<th>Landscape Opportunities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adding more vegetation to urban areas</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Barriers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abandonment</td>
</tr>
</tbody>
</table>
Trellis walls or vertical gardens are created near highways around the world. In Mexico City, 1,000 highway bridge pillars are being turned into vertical gardens by Via Verde. Their plants are of high resistance, low water consumption, and good drainage, and are suitable for the light and shadow conditions offered by the columns, which can bring better air quality, less noise, more thermic regulation, and less stress to citizens. The patent vertical structure can be installed independently, not harming the existing pillars. The gardens are also equipped with automated, monitored, and remote-controlled irrigation systems, which can be controlled by phone apps.
Vegetative barriers prevent pollution from spilling into adjacent neighborhoods.

Vegetated walls can support roadside environment management. The PYRAWALL® developed by GeoSolutions is a wrap-face vegetated solution that can produce reinforced soil mass to protect the site from erosion and provide Vegetated Best Management Practice Solution for NPDES Storm Water Compliance. It is also designed to be flexible, durable, and permeable for building vegetated wall faces with good sustainable and aesthetic potential.

Slope Retention Systems can also play an essential role in roadside landscape construction and maintenance. The Engineered Earth Armoring System designed by ARMORMAX® can lock the soil in place and protect the roadside against erosion. In the meantime, it can filter sediments and pollutants to improve the water quality of nearby sites. Its web-shaped structure can also reinforce vegetation on the ground, aiding more beautiful and sustainable design.
Create more wildlife crossings and freeway caps with landscaping. Some of the caps are made into soccer fields and landscapes with retaining walls along the freeways. E.g., Aubrey Davis Park was built in Mercer Island, Washington, which encompassed 90+ acres and a 2.8-mile-long recreation and transportation corridor. It was built above the I-90 highway, and was the first example of a recreational park built on top of a freeway anywhere in the world. It protects the residents from seeing, hearing, or smelling freeway traffic. More similar projects are abundant in history.

source: Mercer Island Reporter
Implement new and maintain existing BMPs for stormwater runoff. Utilize this water for irrigating the plants. Landscape designers can consider partnering with local or state parks. E.g., Ocean Park Boulevard Green Streets Project includes parkway / stormwater biofilter swales and infiltration areas, and a drip irrigation system. By utilizing subsurface infiltration, space is preserved for development or green spaces above, runoff is reduced or eliminated, and groundwater recharge can occur. A similar project is the Culver Median Stormwater Regional Project for stormwater capture and reuse for the landscape above the system. Although the project is for a regular driveway instead of a highway, the idea can be used as a reference.

Spaces set aside on highways, places where there were no parks before, can be used to build parks and urban green spaces. We can also consider converting unused highways into urban parks (similar to the Quarry Garden below).
Native Plants (& Roadside Landscape)

- Grow plants along freeways or in at-risk neighborhoods for bioremediation and contaminants holding. Extract them for other uses. E.g., according to Caltrans Roadside Management Toolbox: native plants, plants can survive on naturally occurring rainfall and soil nutrients. They need less maintenance and few irrigation requirements.

- Planting native vegetation with proper landscape design can help stabilize steep slopes and minimize erosion. Caltrans’ Roadside Erosion Control and Management Studies came to the conclusion that jute netting and 0.5 inches of compost reduced sediment loss by over 99% compared to bare soil, between which the jute netting yielded more runoff than compost. They also developed a Caltrans Highway Planting Database and Specification Tool called trans PLANT for landscape experts working on erosion control, biofilters, or other highway plantings. A few erosion guides for developers are also created by Caltrans and Erosion Control Technology Council, from data collection to potential assessment, management practice selection, and sustainable vegetation selection.
• Systems like vegetated infiltration swale is a nice feature to improve water quality and ecology along the highway. E.g., a project (Page 62) along the Intercounty Connector (ICC) near Washington D.C. was implemented for roadside revegetation. Besides its massive trees and plants, its swale helps infiltrate stormwater, is also blended to accommodate plant growth, and is equipped with a slow-release underdrain system to help stabilize water temperature and maintain healthy aquatic species habitat.

• Planting proper vegetation can help preserve endangered plant and wildlife species, mitigating the negative impact of highway construction on nature. The State Route 76 (SR-76) Project at the intersection of Interstate 5 and the Interstate 15 (I-5 and I-15) corridors in northern San Diego County includes an Environmental Mitigation Program (EMP), which provides $850 million to protect, preserve, and restore habitats, which has successfully preserved 236 acres of freshwater wetlands and 1356 acres of upland vegetation so far (more introduction, Page 66). Steep slopes created by the construction of Sylvan Pass (Page 67) at Yellowstone National Park led to difficulties for wildlife to cross. Planting gentle vegetation slopes assists their crossing and provides a safe living environment for them.
The growing concept of The Complete Highway reminds us of the importance of roadside conservation and highway landscape. The George Washington Parkway is designed with a great amount of green space. Its first segment, The Mount Vernon Memorial Highway, is the first comprehensive demonstration of modern arterial highway development, including widened streets, parking spaces, and attractive landscape spots with great historical significance.

George Washington Parkway

Creating various road landscapes can help improve traffic safety. According to a research on the impact of roadside landscape on driving behavior, two ‘Black-Spots’ (high-risk accident locations) at Southern Expressway were analyzed regarding some of their spatial characteristics of road landscapes. It was found that if the solidity and degree of enclosure, differentiation of forms, and proportion/scale of roadside are always similar, monotonous landscapes would be created, which would lead to driver fatigue or hypo-vigilance. It highlights the importance of creating rich spatial characteristics of road landscapes during design and construction processes.

Innovative street designs can take advantage of traditional road facilities to boost sustainability. The NE Siskiyou Green Street at Portland turns curb extensions into a series of mini-dams. Stormwater would run into, be stored in those dams, and be used for plant irrigation until these dams reach their storage capacity. Then the water would overflow into the next dam. The street as a whole can manage 225,000 gallons of stormwater runoff every year, which helps ease the burden of the existing sewage system, protect pedestrians and form a beautiful road landscape.
Since we have plenty of spaces that are not used wisely along highways or parkways, there are great opportunities to build food forests on those spaces. Tisdale Food Forest (video) was built along the L.L. Tisdale Parkway in Tulsa, Oklahoma in 2015. It has been serving local residents for years on food security, noise reduction, beautification, stormwater purification, job offer, and education in a place with food deserts, especially during COVID-19 pandemic. It includes edible vegetables, nitrogen fixing trees and shrubs, and native plants and flowers.

Source: https://edibletulsa.ediblecommunities.com/things-to-do/roadside-attraction
Different types of native plants can be arranged properly to reduce costs and save resources while beautifying the environment. E.g., sustainable designs are used at The Pete V. Domenici Courthouse Sustainable Landscape Renovation in Albuquerque, New Mexico. Specifically, its courtyard uses drought-tolerant plants, among which 79 percent of them are native. The plants are arranged according to their water needs, that drought-tolerant plants occupy the higher ground, and wet plants are placed at the base. The design helps save water in its drought environment and attracts various urban wildlife.

In Shanghai, China, a 10-acre abandoned rock quarry with dangerous landform was transformed into an ecological public garden called Quarry Garden. The park includes a deep quarry pool, a biocoenosis lake with plants along its edges, multiple fences, gardens, and footpaths. It takes advantage of the negative environmental impact of mining and, in turn, makes it a place with nature and culture. It also reminds us of the potential of turning abandoned highways and their hard-to-utilize landforms into parks and gardens.
Integrated Infrastructure

**Opportunities**
- Allocate dedicated corridor
- Inductive charging for goods movement
- Utilize FastTrack, HOVS as good movements corridors
- Encourage public transit; alternative types of transit (train, bus, biking) to dec congestion
- Offer reimbursements for alternative transport
- Education

**Barriers**
- Comingling of goods movement with automobiles
- Costs of dedicated corridor
- Lack of understanding or knowledge around public transit
- Multiple agencies, silos for different aspects of highways
A 2020 technological review on Electric vehicles standards, charging infrastructure, and impact on grid integration states that with the advancement of EV technology, charging infrastructure and grid integration facilities, EV popularity is expected to increase significantly in the next decade. Therefore, further technological advancements such as the suitable smart charging infrastructure, reliable communication systems, and coordinated charging system to quantify the impacts on the power grid are essential to ensure maximum benefits from EVs with distributed generators.

Plug-in electric vehicles (PEVs) have proved to provide a cleaner alternative that not only reduces GHG emissions, but also provides local air quality, noise reduction, and national security benefits. PEVs are an integral component in the suite of technologies that will help meet the United States’ commitments under the Paris Agreement—an ambitious 26 percent to 28 percent reduction in GHG emissions by 2025, compared with 2005 levels.

In a case study on the financial feasibility of high-power fast charging stations in San Diego California, it was found through the Electric Infrastructure Financial Analysis Tool (E-FAST) that the breakeven recharging prices for financial viability of the proposed fast charging stations (at a 10% discount rate) in San Diego, vary from 35 to 50 cents per kWh. The results also show that bundling energy storage and photovoltaics with direct current fast charging stations (DCFC) leads to a strong business case with higher profitability indices and internal rates of return (above 10 percent).
Energy storage is crucial for our around the clock urbanized societies as it maintains supply and demand with a smart grid network. It also holds out high hopes for electric vehicles, over a billion of which are expected to be on roads by 2050, along with a 70% electrification of passenger transport, according to a recent report by IRENA.

More and more states, cities, and companies are starting to embrace energy storage as an essential bridge in their renewables agendas.

New York plans to allocate $400 million for the deployment of 3 GW energy storage by 2030, while many other cities are developing their own energy storage roadmaps and embracing energy storage innovations.

In a 2020 report conducted by Renewable and Sustainable Energy Reviews, the following table demonstrates a series of advantages that were found on Electric Vehicle Grid Integration:
## Advantages

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Description/method</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Power management</strong></td>
<td>• By using scheduled charging/discharging, better power management can be achieved.</td>
</tr>
<tr>
<td></td>
<td>• Peak load demand can be met by scheduling discharging during peak hours.</td>
</tr>
<tr>
<td><strong>Power quality improvement</strong> [74,204,205]</td>
<td>• Voltage surge caused by uncontrolled DER (Distributed Energy Resource) penetration can be solved by controlled EVGI (Electric vehicle grid integration).</td>
</tr>
<tr>
<td></td>
<td>• Voltage flickers can be smoothed out.</td>
</tr>
<tr>
<td></td>
<td>• Reactive power can be injected when required.</td>
</tr>
<tr>
<td></td>
<td>• Harmonics injected by uncontrolled DER can be reduced.</td>
</tr>
<tr>
<td></td>
<td>• Voltage imbalance can be solved by distributing power flow through phases.</td>
</tr>
<tr>
<td><strong>Regulation</strong> [206,207]</td>
<td>• Frequency regulation by correcting grid frequency deviation.</td>
</tr>
<tr>
<td></td>
<td>• Voltage regulation by supplying/absorbing reactive power.</td>
</tr>
<tr>
<td></td>
<td>• Power flow balance by storing excess power.</td>
</tr>
<tr>
<td></td>
<td>• Ramping power absorption.</td>
</tr>
<tr>
<td></td>
<td>• Stability improvement of isolated electric networks.</td>
</tr>
<tr>
<td><strong>Renewable energy support</strong> [209]</td>
<td>• The uncertainty in renewable energy can be suppressed by operating EVs as energy storage.</td>
</tr>
<tr>
<td></td>
<td>• Using EVs as a renewable energy buffer can reduce emission as well as save money.</td>
</tr>
</tbody>
</table>
The figure on the right illustrates a summary of several energy storage technologies that may be employed in power systems. Photovoltaic panels, wind farms, electronic converters, and storage systems with barriers are some examples of the addition of new values with respect to both generation and loads of power systems.

Energy storage can be done directly, through the electricity accumulation in supercapacitors, or indirectly by either an electrochemical process such as batteries, or mechanically, as flywheels. All these technologies are constantly evolving and are the subject of research aimed primarily to reduce production costs, increase their storage capacity, and reduce the environmental impacts.

Additionally, the types of power used in EV charging involves either AC or DC power supplies. AC charging has different voltage and frequency levels based on the power system of a concerned country. In terms of the voltage levels, AC charging can be divided into Levels 1, 2 and 3 charging, where level 3 has the highest charging voltage.

- The Levels 1 and 2 charging facilities can be installed in a private location while setting up of Level 3 charging facilities, involving separate wiring and transformer, requires permission from utility providers and are usually built in public charging stations. At the same voltage level, DC charging is faster and usually has a high charging power capacity.
- The latest DC fast charging (DCFC) technology can fully charge an EV within as low as 20 min.
Data Infrastructure

- Smart pavement technology ([video here](video here))
- Electric vehicle grid integration
- Technology such as wireless networking through Smart Pavement is an example of an approach to delivering an integrated network of seamless expansion and densification of transforming the road into a sustainable digital infrastructure. It’s not only pavement that builds quickly and lasts longer than traditional asphalt or concrete pavement but it requires less maintenance and provides a range of services such as EV charging and traffic sensors, the [diagram](diagram) is Integrated Roadways visual of their next generation technology.
**Renewable Energy**

Right-Of-Way (ROW) areas or roadside lands have considerable potential for renewable energy infrastructure as they are clear, accessible lands owned by Departments of Transportation (DOTs).

---

### Renewables Sector Overview from Innovating Highway Design Workshop

**Renewables**

**Opportunities**

- Integrated Solar (sound walls, pavement, roadside)
- Wind microturbines
- Stormwater microturbines
- Solar shading
- Energy storage
- Capital set aside for renewables and charging could be leveraged for highways
- Power for lighting, for EV charging
- Emergency areas provide power and other access

**Barriers**

- Aesthetics and vandalism of panels
- Integrated energy storage was a challenge
- Panel cleaning and maintenance
- Policy around power procurement
Solar Energy

Photovoltaic Noise Barriers
Highway photovoltaic noise barriers (PVNBs) are the combination of noise barrier systems and photovoltaic systems that can produce renewable energy in addition to mitigating highway traffic noise. According to this report, noise barriers can be designed to produce power without compromising their ability to safely reduce noise and in some cases, their performance was improved. Considering the approximately 3000 linear miles of noise barriers in the US and based on estimates from this study, there is a potential of at least 400 Gigawatt hours (GWh) solar energy production annually.

Wind Energy

According to this report, a project studied the potential of wind energy generation along North Carolina highways. Anemometers were installed along three heavily trafficked highways to simulate the potential for traffic-generated turbulence required for wind energy generation. The findings showed that there is considerable potential for electricity generation from harvesting traffic-generated turbulence. According to this report, the current cost of energy generation by wind energy exceeds solar energy generation, however it’s expected that larger-scale deployment of Vertical Axis Wind Turbine technology will reduce the costs in the future.
## Environmental Mitigation

### Mitigation Sector Overview from Innovating Highway Design Workshop

<table>
<thead>
<tr>
<th>Opportunities</th>
<th>Barriers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orange County management of storm water</td>
<td>Integration of organizations</td>
</tr>
<tr>
<td>Other agencies may be the best group to action some items</td>
<td>Lack of flexibility in planning</td>
</tr>
<tr>
<td>Up-front planning to prevent need for mitigation</td>
<td>Need to involve contractors</td>
</tr>
<tr>
<td>Engage maintenance contractors up-front</td>
<td>LA Metro hand over to Caltrans for maintenance</td>
</tr>
<tr>
<td>Strategies to Reduce Vehicle Miles Traveled</td>
<td>Often there is more resources for building mitigation than for maintaining it (ordinances that authorize capital funds, but disallow maintenance funds)</td>
</tr>
<tr>
<td>Planning communities to reduce need for car travel</td>
<td>Multiple agencies, silos for different aspects of highways</td>
</tr>
<tr>
<td>Create more opportunities to work remotely or in local office</td>
<td>Connect water supply/groundwater management agencies to transportation agencies to improve water supply carefully</td>
</tr>
</tbody>
</table>
According to the U.S Department of Transportation Federal Highway Administration in their 2017 report on Highway Renewable Energy: Photovoltaic Noise Barriers, a highway noise barrier is a physical obstruction constructed between the highway noise source and the noise sensitive receptor(s) that attenuates the noise level near the receptor, as measured in decibels (dB).

- Noise barriers include stand-alone walls, berms, and combination berm/wall systems and are constructed from diverse materials, such as earth, wood, concrete, and metal, among others. They reduce noise by reflecting it back across the highway or forcing it to take a longer path over and around the barrier.
- Although they do not block all noise completely, noise barriers typically reduce overall noise levels by 5 to 10 dB, effectively cutting the loudness of traffic noise by up to one half.
- The PVNB (pictured) represents the combination of noise barrier systems with PV systems that use solar cells to convert light energy directly into electricity. Photo source: TNC Consulting
Quieter Pavements

- According to the U.S. Department of Transportation Volpe Center in 2017, the National Park Service has 5,500 miles of publicly accessible paved roads in the national parks due to anthropogenic noise in the parks caused by traveling vehicles in the area.
  - By using pavement wearing courses that are designed to help reduce noise, emissions can be significantly reduced since the road-tire interface is the primary source of noise emitted by automobiles at speeds greater than approximately 20 miles per hour.
- A 2018 report on Quieter Pavement: Acoustic Measurement and Performance by CalTrans found in the figure above, the typical highway noise source breakdown for light vehicles under non accelerating conditions, indicating that tire-pavement interaction contributes 78% of the overall traffic noise from light vehicles at highway speeds.
Various studies show that proximity to highways and other transportation facilities and exposure to near-road air pollution can lead to adverse health conditions.

In 2019 Highways England report, they conducted numerous studies that searched for air quality improvements. One study in particular looked at installing barriers alongside their highway network to help protect people and homes from pollution emitted by vehicles, by improving the way that pollutants disperse.

 Trials have already been run in the Netherlands and the USA. Although the results were not conclusive, they showed barriers had some potential to provide small reductions in NO2. They then decided to research several barrier options to see if they could reduce levels of NO2 behind the barrier.

 Although there were conflicting results, it was found that the 9m high barrier, compared to the 4-6m high barriers had a clear reduction in NO2 concentrations behind the barrier, compared to sections of the road without the barrier.
Stormwater

- According to this report, current stormwater management practices adopted by state departments of transportation (DOTs) mostly includes traditional gray infrastructure consisting of conventional piped drainage and water treatment systems.
  - Gray infrastructure is expensive and can lead to flooding and stormwater pollution resulting from improper design, construction and maintenance. Green Infrastructure (GI) and Low Impact Development (LID) (practices that use and conserve on-site natural resources to improve water quality) can be cost-effective and resilient alternatives to traditional gray infrastructure approaches.

- Findings from this study indicate that wet basins, bioretention areas and dry detention basins and infiltration basins are the most common green infrastructure stormwater management techniques adopted by the states.
Stormwater

- In a 2011 NRDC article “How Green Infrastructure Can Effectively Manage Stormwater Runoff from Roads and Highways” low impact development (LID) techniques include green infrastructure that replicates the natural functions of a landscape by integrating functions like storage, detention, infiltration, evaporation, and transpiration, or uptake by plants.
  - These techniques reduce the volume of runoff by capturing and managing rainwater where it falls
  - By rebuilding and rethinking road and highway design by incorporating green infrastructure, there is room for reduction in erosion, sedimentation, and harmful impacts on bodies of water.
  - Examples of green infrastructure for road projects include: Q Bioswales or grassed swales—grassy areas on the side of the road that convey drainage; they can be designed to promote pollutant removal and infiltration of runoff. Q Rain gardens—landscaping features planted with vegetation that collect, infiltrate, evaporate, and transpiration runoff. Q Wetlands—whether natural or engineered, wetlands perform many of these same functions. In fact, a single acre of wetland holding a foot of water stores up to 330,000 gallons of water and filters pollutants such as oil, sediments, and chemicals.
Multi-Modal Systems

While not initially explored in our scope of market innovation overview, it seems there are increasing opportunities to integrate multi-model systems into highway design, construction, and maintenance. It is recommended that this is explored further in future research.

Multi-Modal Sector Overview from Innovating Highway Design Workshop

<table>
<thead>
<tr>
<th>Opportunities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automation for bus/transit systems (e.g. speed enforcement)</td>
</tr>
<tr>
<td>Lane clearing technology - vehicle to vehicle communication</td>
</tr>
<tr>
<td>Add/Expand Express Lanes with a focus on dedicating revenue to transit</td>
</tr>
<tr>
<td>Look at the system as a whole, considering connection points at intersections</td>
</tr>
<tr>
<td>Add safety improvements for pedestrians / cyclists around on- and off-ramps</td>
</tr>
<tr>
<td>Strategies to reconnect communities that have been split by highways - need to evaluate best practices to do this effectively</td>
</tr>
<tr>
<td>Freeway caps</td>
</tr>
<tr>
<td>Welcome street vendors so pedestrian crossings are activated</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Barriers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customer experience (e.g. stations in the middle of the freeway are loud)</td>
</tr>
<tr>
<td>Rethinking highway use to incorporate other modes - and getting the public on board</td>
</tr>
<tr>
<td>Safety. Access (e.g. pedestrian pathways along freeways can feel isolated / sketchy)</td>
</tr>
<tr>
<td>Maintenance and safety enforcement of features</td>
</tr>
<tr>
<td>If spaces aren’t well used, they can feel unsafe</td>
</tr>
<tr>
<td>Need to address air quality issues in green spaces if we want to encourage people to use them</td>
</tr>
<tr>
<td>Stair-only access to bridges is an impediment to bikes and ADA</td>
</tr>
</tbody>
</table>
Thank You!

For taking the time to read our **Innovating Highway Design for Environmental and Community Benefit Report**

For more information please contact *Ben Stapleton* at ben@usgbc-la.org and *Colin Mangham* at colin@usgbc-la.org
APPENDIX

Expert Interview Summary and Insights

The expert interviews were conducted as part of the second phase of the project, following the market research on technology innovations for sustainable highway infrastructure. During this phase of the study, USGBC-LA interviewed industry experts including those in the architectural, engineering, and construction sectors who develop highway projects, as well as community leaders for insights and recommendations.
Expert Interview Summary and Insights

Terraphase Engineering Inc.: Eric Strecker, Principal Engineer
Response Type: Zoom Interview on 9/17/21

Interview Questions:

Q: How could highways or highway construction have a more positive impact on the environment?
A:

- **Coming up with strategies to address highway runoff, use both green and gray infrastructure.** Sometimes you’re in a location where the only thing you can do is gray. Ex: frontage of playa vista, Lincoln Blvd, and frontwater marsh - bioswales were added to pre-treat the water prior to entering the frontwater marsh considering that highway runoff is 2-4x dirtier than regular urban runoff.
- **Not just building something that is effective but also taking care of it. Swales need some attention.** 1) Come up with great concepts of design and construction management. 2) Make sure funding and resources are secured for inspections and maintenance work - above ground facilities are easier to inspect and detect need for maintenance.
- **Installing porous pavement can require extensive maintenance to keep its effectiveness.** They get clogged overtime and jet washing and vacuuming are needed. Would rather install an inlet and reintroduce the flow to the base that way. Focus on areas that will catch water. A side inlet would allow us to treat the water (sedimentation) as well.
- **Provide biological treatments** - Implementing vegetation on either side could provide separation from pedestrians and also install a bike lane. This could improve safety as well.
- In terms of widening a highway, a **retention system** needs to be created.
- **Media** - industrial chargers for effluent limits require media extras such as activated carbon, sand, etc. but stay away from compost. BMP database shows that some biofiltration systems are releasing more phosphorus than they keep and in some cases nitrate. Compost breaks down overtime and this can be seen in the dataset. Balancing costs and performance is a challenge. Another issue is putting in media mixtures and trying to get 2-6 inches of water which can clog easier. Would rather use a higher rate media and put in an outlet control to limit the rate. Don’t let the media govern the hydraulics. Want to keep the media porous so it has room to capture sediment before having to service it.
- **Innovation** - OPTIRTC - real time control for stormwater systems. It looks at what kind of incoming storm and how it is unfolding so you could make release rates to these systems. It’s more applicable to ponds or larger systems and generates longterm large datasets to adjust design and performance. It can also help to better prepare for floods or future storms.
- **Use sustainable materials** - Look into non-leaching non polluting materials such as zinc or treated wood.
- **Resources:** EPA Green Highways, NCHRP (technical), Green Building Hydrology Committee put together rating system for getting green building certifications
APPENDIX

Expert Interview Summary and Insights

Neo Pave – Founder/President – Sean Weaver
Response Type: Zoom Interview on 9/17/21

Interview Questions:
Q: How could highways or highway construction have a more positive impact on the environment?
A:

Using recycled materials while increasing performance and asphalt useful life. Neo Pave developed a technology that diverts 150,000 plastic bottles per lane mile from single-use, post-consumer waste into pavement. Multiple lab tests and in depth analysis proved performance and longer durability (2-3 times longer than conventional asphalt) and it claims to provide a 90% reduction in greenhouse gas emissions with zero leaching or negative impact on water, air, or soils when compared to conventional asphalt production and life cycle, with the possibility of designing highways to be recycled for 40-50 years. Caltrans has demonstrated interest in the new technology developed by Neo Pave, but more investments in special machinery need to be made. Neo Pave is working on finding strategic partners with interest in the circular economy to scale production.
APPENDIX

Expert Interview Summary and Insights

**ARUP - Principal - John Eddy**

**Response Type:** Emailed responses on 9/4/21 + Zoom Interview on 9/16/21

**Interview Questions:**

Q: How could highways or highway construction have a more positive impact on the environment?

A:

- Electrify, use renewable electricity sources for vehicles, equipment, including tunnel boring machines which are massive power hogs.
- What part of the highway construction and maintenance supply chain can be electrified? Cement manufacturing? Asphalt production? Steel creation and manipulation?
- Plant shrubs and trees instead of building snow fences.
- More research and development of on-site or in-situ conditioning of existing soils and rock into durable subbase or even finished pavement.
- Water scarcity will require new pipelines. Share the r-o-w.
- Recycled materials
- Design, construct, maintain as a circular economy
- Adaptability and right-sizing. Reversible lanes as the norm to maximize lane capacity for lopsided commutes (reduces highway land and carbon footprint)

My focus is generally infrastructure and transportation. We did a paper on right-sizing highways, Creating more capability for transit systems. The electrification of the fleet will cause changes, less pollution. Can we take advantage of lighter electrical cars for right-sizing highways? Can we use freeways for neighborhood issues for water improvement, flood control? Use highways for solar power generation.

The DOT in Colorado studied the impact of solar on aging asphalt pavement, it needs to be shaded. Asplast introduces tons of oil products into the road, not a good idea. Concrete pavement is standard and codes are clear on recycling materials, but how does concrete pavement fall apart - big chunks? Risks need to be assessed.
Expert Interview Summary and Insights

ARUP - Principal - John Eddy
Response Type: Emailed responses on 9/4/21 + Zoom Interview on 9/16/21

Interview Questions:

Q: What is the bigger impact now?
A:

Important - what can be given back? Metro-like authority in San Francisco study shows unhealthy areas around the highways. Need to change the program. Electrification eliminates the problem with diesel particulate and helps developing around highways while fleets are getting cleaned up by electrification. Also, how can we rethink water corridors or telecom? Can we not bury the water and electric infrastructure? There are other routes in the city, not privately owned. Drilling technology can be less expensive and safer, making it easier to bury infrastructure.

Q: How could highways improve community resilience?
A:

- Sea level rise and flood protection (barriers).
- Integrating stormwater systems with surrounding communities and systems to alleviate flooding and help cleanse surface water before discharge into streams, rivers, lakes, and oceans.
- Livestock always seem to find high ground on roads and highways during flooding. If some highways aren’t evacuation routes, could they be a refuge for people?
- We are rebuilding bridges over rivers and typically reducing the bridge’s presence within the river’s hydraulic section. Can we use any of that extra hydraulic section to incorporate simple hydro-electric generation to provide for the highway power demands and beyond?
Expert Interview Summary and Insights

ARUP – Principal – John Eddy
Response Type: Emailed responses on 9/4/21 + Zoom Interview on 9/16/21

Interview Questions:

Q: How could highway design and construction be improved to address equity?
A:

- Removing highways in densely populated marginalized areas.
- Decking over or undergrounding in densely populated areas whenever possible to create open space and avoid creating barriers in communities.
- Job training from start (early planning) to finish (construction) and operations (maintenance) of a highway’s lifetime.
- Care in the placement of on and off ramps so as to not burden already marginalized communities. Convenience of an interchange in a community may actually be very inconvenient and even damaging.
- Better sound barriers and sound absorption rather than deflection to another receptor. A well designed highway (proper noise barriers as an example) can double as a buffer between communities and noise sources – heavy manufacturing, railyards, ports, etc.

Q: How could additional infrastructure be best integrated into highway design and construction?
A:

Multi-purposing of project elements has been a long passion and a pursuit. Using excess or orphaned land within the R-O-W for non-highway specific purposes - stormwater control, pollinator habitat, solar farms. Shifting the use of highway r-o-w as utility corridors into high gear as renewable energy sources are developed far from existing transmission corridors.
APPENDIX

Expert Interview Summary and Insights

BluePoint Planning and RAPID Climate Action Network – Principal – Mindy Craig
Response Type: Zoom Interview

Interview Questions:

Q: How could highways or highway construction have a more positive impact on the environment?
A:

We need to rethink our roadways completely. We have a traditional model, which focuses on building more car-centric roadways, making them wider and faster. This is not sustainable and cannot be part of a truly balanced and sustainable future. What more, highways represent a valuable infrastructure that is car dominated – how can they be reimagined then and any new construction to provide a more scaled and helpful mode of transportation? This would include transitioning lanes to rapid bus only and light rail. Where appropriate, these roadways can be repurposed to accommodate bikes, ebikes, and micro mobility personal vehicles.
Integrate new technologies such as electric roadway infrastructure to enable electric trucks and logistics vehicles to charge their vehicles as they drive for high volume, short distances.
Reduce single car-access and prioritize shared vehicles/transit, automated shared vehicles.
APPENDIX

Expert Interview Summary and Insights

BluePoint Planning and RAPID Climate Action Network – Principal – Mindy Craig
Response Type: Zoom Interview

Interview Questions:

Q: How could highways improve community resilience?
A:

Highways contribute to the heat island effect, create large amounts of runoff which will increase with more intense precipitation, and are becoming more and more vulnerable to extreme heat. Drivers on the roads are experiencing traffic and stalls while the temperatures soar into the 100s. Equally, highways create massive barriers when they are in urbanized areas, blocking human scale traffic, pedestrians and creating overall unsafe places with high levels of pollutants. Reimagining the storm water management system, moving away from impermeable hard scape, adding greenery, and vegetative barriers are important strategies. Consider the potential to have some solar shading in areas that are particularly hot that can have the dual benefit of generating electricity and shading roadways. Ensure that there are rest areas with shade and respite along longer stretches.

In some areas, it may be useful to consider how the roads would be used in an emergency evacuation - can it be converted to all one way traffic to allow large numbers of people to leave?

Q: How could highway design and construction be improved to address equity?
A:

Suggestions above would all address equity by creating more affordable modes of transportation. Creating a more robust transit network using existing roads would be a substantial benefit, especially in areas like the Bay Area or Los Angeles where long commutes are the norm. Providing affordable, reliable and robust transit and last mile connections for workers is essential. This would also reduce pollutants. Whenever possible transition truck goods to trains, and for those that cannot go via train, ensure that all logistics and truck traffic is electric or zero emissions. This is a critical element to reduce the impacts of pollution and poor air quality for disadvantaged communities.
Expert Interview Summary and Insights

**Carbon Cure – Co-founder –** Robert Niven

**Response Type:** Emailed responses on 9/14/21

**Interview Questions:**

Q: How could highways or highway construction have a more positive impact on the environment?

A:

By necessity, highways must be built from durable materials with long service lives and which are easy to maintain. Concrete has been the material of choice in many states due to its capacity to deliver on these needs. Choosing to use more durable materials such as concrete produces lower life-cycle emissions. These materials can also have lower solar reflectance values vs. alternative materials such as asphalt, reducing the heat island effect that leads to elevated temperatures in urban environments. Lower heat gain is beneficial to public health, and the importance of limiting urban heat islands will increase in importance if temperatures rise as the climate changes.

Concrete materials used for highway construction also have a unique capacity to sequester carbon dioxide. Carbon mineralization technologies (e.g. CarbonCure) for concrete are expected to have the largest potential for the reduction of emissions from the concrete and cement sector, accounting for 3.9 Mt of reductions by 2040 based on modeling conducted by Global Efficiency Intelligence in 2019. It is possible today to sequester CO2 in concrete at market price parity to traditional concrete mixes by using CO2 mineralization technologies. In this process, captured CO2 is introduced into the manufacturing of fresh concrete thereby improving its sustainability, material performance and production economics. The construction of highways and other transportation infrastructure requires very large volumes of concrete. Adopting green procurement and specification practices for highway construction can greatly accelerate the low-carbon transition of the entire cement and concrete industry, while offering immediate embodied CO2 reductions.
Expert Interview Summary and Insights

**Carbon Cure - Co-founder** - Robert Niven

**Response Type:** Emailed responses on 9/14/21

**Interview Questions:**

Q: What is the future of carbon capture technology in highway construction?

A:

Emissions from materials, called Embodied CO2 emissions, like concrete used in highway construction are a high-value target for action. Embodied CO2 emissions occur at the beginning of building lifecycles, meaning their impact is being felt in the near-term and, unlike Operating CO2 emissions from energy use, can not be mitigated after construction. Decarbonization of concrete will be heavily dependent on two core strategies: use of cement alternatives and carbon capture, utilization, and storage. Modeling conducted by the International Energy Agency and the Cement Sustainability Initiative (Technology Roadmap: Low-Carbon Transition in the Cement Industry, 2018) indicates that 48% of necessary emissions reductions in this sector must come from carbon capture and utilization. Concrete is the most immediate, scalable, and cost-effective use for captured carbon. Use of CO2 in the concrete and cement sector alone represents an opportunity valued at $400B annually and could realize annual CO2 reductions of 3 gigatons with continued investment in innovation. As the largest consumer of concrete, Government procurement yields the most influence in dictating the pace of deployment and innovation to attain these climate impacts available from carbon capture technologies.

Q: Can every square foot of demolished concrete be recycled?

A:

Select markets (e.g. Singapore, parts of Europe) and practitioners have already demonstrated that all demolished concrete could be beneficially repurposed. Some processing would be appropriate (removal of reinforcing steel, for example) but the concrete can be crushed, graded and treated in a way that would make it appropriate for use as a fill material, a road base material or as a replacement for natural aggregate in concrete or asphalt.
Expert Interview Summary and Insights

Carbon Cure - Co-founder - Robert Niven
Response Type: Emailed responses on 9/14/21

Interview Questions:

Q: What are the other possible uses for crushed concrete besides base?
A:

Crushed concrete can be graded and treated for use as an aggregate to replace virgin aggregate. Such circular recycling is likely the best use of the material considering the economic value and limited supply of natural aggregate. Moreover, crushed concrete aggregates can be further upcycled by using new CO2 mineralization technologies to permanently sequester considerable volumes of CO2 and improve its material properties to be resold as a value-added aggregate replacement. CarbonCure and other technology companies are developing these technologies for commercial deployment in the near term. The CO2 mineralization of fresh concrete, crushed concrete aggregates and reclaimed concrete process water offers a complementary suite of climate solutions for highway construction which yields circular co-benefits for aggregate and water reuse which help to address the ongoing aggregate shortage and drought issues facing Southern California.

Q: What are the pollution consequences of onsite ready-mix sites?
A:

The adoption of the aforementioned suite of CO2 mineralization technologies is a Net Zero solution for CO2 emissions and water and solid wastes from onsite ready-mix sites. Once treated with CO2 mineralization technologies, the air, water and solid pollutants traditionally released from ready-mix plants become value-added feedstocks for new concrete production.
Expert Interview Summary and Insights

Carbon Cure - Co-founder - Robert Niven
Response Type: Emailed responses on 9/14/21

Interview Questions:

Q: Does the climate of the region contribute to the type/ process of concrete?
A:

The performance requirements of concrete can vary according to the climate.
- Concrete with reduced permeability may be preferred in an area where exposed to salt-laden air or de-icing salts.
- Concrete in areas with harsh winters will be designed to withstand freezing and thawing.
- Concrete in environments with an optimal relative humidity (around 50%) may be more susceptible to atmospheric carbonation thereby preferring the selection of lower w/c concrete.
- Precast concrete is more common in some areas due to speed of construction and resilience considerations.
APPENDIX

Expert Interview Summary and Insights

UC Davis - Dept. Environmental Science and Policy - James Thorne
Response Type: Emailed Response on 9/17/21

Interview Questions:

Q: How could highways or highway construction have a more positive impact on the environment?
A:

See some of the protocols in Caltrans D5 on Highway 101 for examples of fencing, jump outs, electromats, and culvert designs that can improve wildlife coexistence. Nancy Sieple (now retired from D5) was the lead, but the program is ongoing. Consider opportunities for carbon sequestration where it is possible to plant trees in the ROW in areas that have low wildfire risk. Consider opportunities to improve surface water retention from rainfall, in order to promote groundwater infiltration. In areas of specific geology (e.g. ultramafics) consider planting endemic species on interchanges and selected ROW. The ROW is actually owned/managed by Caltrans (for state highways, but perhaps analogous to local transportation). Therefore there are opportunities for management of those lands more directly.

Q: How could highways improve community resilience?
A:

Engage communities in extending resource management from ROW to private (and public) ownership lands that are adjacent. This is widely needed and somewhat in current practice with regards to wildfire risk reduction (e.g. Caltrans/USFS). But that model applies for many other risk factors (e.g. landslides) and potentially for beneficial as well.

Q: How could renewables be best integrated into highway design and construction?
A:

Transportation districts need to get to net zero emissions. Seek opportunities to plant trees for sequestration, move to hybrid and light-fuel motorized for construction purposes, change fleets over to electric powered first by solar on agency rooftops, promote multiple transportation options wherever possible, explore vibration- and solar-capture technologies for incorporation into bridges and road surfaces and conduct spatial assessments of where the highest opportunity areas are located.
Expert Interview Summary and Insights

**The Ray – Executive Director – Laura Rodgers and Deputy Director – Allie Kelly**

**Response Type:** Zoom interview 9/22/21

**Interview Questions:**

Q: How could highways or highway construction have a more positive impact on the environment?

A: 

Active with energy work. Things have to work as an ecosystem. Highways are a place with potential for energy production and natural habitats. Underground can be used for transmission lines, which are heavily needed. What else to consider:

- Why solar on the roadside? We can’t continue using farmland
- Rubber modified asphalt. Tires must be taken into consideration when discussing zero waste. Super hero binder for aggregates. “Rubber roads are climate roads”
- Curate roadside vegetation for slope retention, runoff, and improve soil quality. Make soil health relevant for DOTs.

Q: How could highways improve community resilience?

A: 

Loosen 1960s bills to commercialize national roads. Rest areas must be innovated to a cleaner future. Rest areas need to be part of the resilient future. It is important to marry the natural systems and infrastructure systems.
Expert Interview Summary and Insights

LA Cleantech Incubator – Artist – Creative Strategist – Debra Scacco
Response Type: Zoom interview on 9/22/21

Interview Questions:

Q: How could highways or highway construction have a more positive impact on the environment?
A:

Speaking and working with community members, and consider:
• Think 5 steps ahead and not as an isolation event
• How can highway displacement be positive? How does this connect with the design of highways? Space underneath freeways are design challenges.
• Can the design of freeways be done with biomimicry?
• Health must be taken into consideration when building highways.

Q: How could highways improve community resilience?
A:

Involve community members and involve them. Earn trust and build solutions around.
APPENDIX

Expert Interview Summary and Insights

DoT Sustainable Pavements Program Manager - Heather Dylla

Response Type: Zoom Interview on 9/22/21

Interview Questions:

Q: How could highways or highway construction have a more positive impact on the environment?
A:

More Life Cycle Analysis (LCA) data needs to be made publicly available and user-friendly. All highway materials can have more positive impacts but there is no benchmarking in place. LCA needs to be performed before thinking of NetZero. Savings can be found everywhere if everyone cares. Supporting Environmental Product Declarations (EPDs) and public data are key.
Expert Interview Summary and Insights

NAPA Director of Sustainable Pavements – Joseph Shacat
Response Type: Zoom Interview

Interview Questions:
Q: How could highways or highway construction have a more positive impact on the environment?
A: Calculate carbon footprint of asphalt material versus vehicle emissions. Vehicle emissions also depends on the smoothness of the road, so maintenance can be seen as an energy efficiency measure, Environmental Product Declaration (EPD) is the best method to calculate carbon emissions, but it has its limitations - only upfront emissions are calculated, not considering the performance of the pavement or its useful life. Activities to reduce emissions could be reflected in the EPDs. Design considerations should include full life cycle, pavement design and longevity of the pavement. Designing the pavement for less maintenance in the future can reduce life cycle impacts in LA. The issue with congestion related to maintenance is higher than the asphalt environmental impact. Specific requirements and limitations by agencies should move toward efficiency and novel materials. Broader implementation of the current technologies to add more recycled content for a balanced, performance-based mixed design, also including opportunities for bio-based materials. Another aspect: porous pavement and asphalt clearly demonstrated water quality improvement, but challenges and limitations are faced in mountainous areas.

Q: How could highways improve community resilience?
A: It’s an area with a lot of research going on: Resilience in transportation. In respect to climate change, different grades of asphalt must be selected accordingly based on increase in temperature. Roads can be adapted for the future.
Expert Interview Summary and Insights

NAPA Director of Sustainable Pavements - Joseph Shacat
Response Type: Zoom Interview

Interview Questions:
Q: How could highway design and construction be improved to address equity?
A:

First, gender equity can be improved. Very few women in the field and salaries are in despair. Support career path for women in asphalt.
More resilient, perpetual pavement, especially in flooding areas.
Health impacts on workers on the construction site needs to be addressed - asphalt fumes, crystal and silica exposure.
Manufacturers of the milling machines, emissions control, vacuum systems should be involved in the discussion.
Studies on the toxicity of the runoff needs to be performed.