



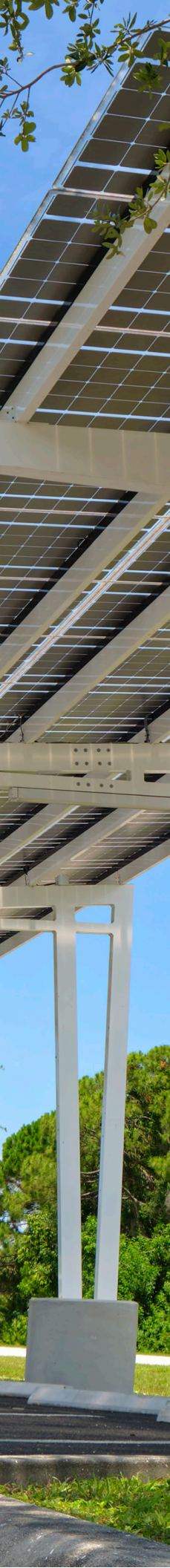
National Association of
State Energy Officials



Integrating Smart Surfaces in Transportation

A Smart Surfaces Primer for State and Territory Energy Offices





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Introduction

As State and Territory Energy Offices work to support a more reliable, resilient, and affordable energy system, Smart Surfaces—which include technologies such as cool roofs and pavements, rooftop and canopy solar, green roofs, permeable pavements, and trees—provide a cost-effective opportunity to reduce peak electricity demand and cut energy bills for households and businesses. In addition to their energy benefits, Smart Surfaces can also mitigate extreme heat and manage stormwater, helping protect critical infrastructure and improve public health and quality of life. By incorporating Smart Surfaces into transportation planning and implementation, State Energy Offices can simultaneously address multiple priorities including energy demand reduction, public health, energy affordability, and enhanced traffic and pedestrian safety. Through strategic collaboration with state Departments of Transportation (DOTs) and other stakeholders, State Energy Offices can accelerate the deployment of these technologies across transportation networks. This primer, part of a series of Smart Surfaces resources developed for State Energy Offices, explores how State Energy Offices can support the implementation of Smart Surfaces into transportation infrastructure.

Benefits of Smart Surfaces in Transportation

Energy Demand and Grid Benefits

By reducing pressure on the electric system during extreme heat events, Smart Surfaces can contribute to grid stability and resilience. In densely developed areas, dark, impervious surfaces used for transportation infrastructure (such as asphalt and concrete) absorb and retain heat. This dynamic exacerbates urban heat islands, which can raise city-wide ambient temperatures by one to seven degrees Fahrenheit⁵ and significantly increase cooling demand. Some neighborhoods in cities, in particular in low-income communities that have seen historic underinvestment in tree planting and green infrastructure, can be up to 20 degrees Fahrenheit hotter than rural areas.^{6,7} Smart Surfaces can reduce these temperature spikes, offering an important tool to mitigate cooling energy loads, especially during peak demand periods. Additionally, energy generation technologies, such as solar canopies installed over parking lots, bus shelters, and other transportation infrastructure, can help offset transportation-related energy demand, including for nearby facilities or electric vehicle charging. These systems also provide shade that reduces human heat exposure.

Energy Affordability

Smart Surfaces can also contribute to cooling efficiency for drivers and greater energy affordability for neighborhoods in proximity to transportation infrastructure. Cool and reflective pavements lower ambient temperatures and mitigate urban heat island effects, which can reduce the need for air conditioning in surrounding buildings. This is especially important in low-income areas where cooling costs place a disproportionate burden on residents.

By mitigating peak energy loads and reducing strain on the electric grid, Smart Surfaces help

WHAT ARE SMART SURFACES?

“Smart Surfaces” is a term coined by the Smart Surfaces Coalitionⁱ and includes a variety of surface infrastructure interventions and technologies that help enhance local resilience, reduce energy costs, and lower peak demand.

Cool Pavements

Cool pavement, also referred to as reflective pavement, reflects a higher percentage of sunlight than typical asphalt pavement. Due to the higher reflective value, cool pavement stays cooler throughout the day and reduces the urban heat island effect and thus peak demand. There is no specific reflectivity value that a pavement must have to be labeled as “cool.” Rather, it is a relative category that may differ among jurisdictions with different definitions, requirements, or incentive thresholds.ⁱⁱ Cool pavement can be applied on roads or parking lots, although the materials for different applications may vary.

Permeable Pavements

Permeable pavement allows for the infiltration and temporary capture of water unlike typical impervious concrete or asphalt pavement. Permeable pavements reduce stormwater runoff, leading to increased flood prevention and lower water treatment costs, thereby saving energy. When specced properly with lighter colored materials, permeable pavements also reflect more sunlight and thus help mitigate urban heat island effects.

Trees and Green Stormwater Infrastructure

Trees and green stormwater infrastructure (such as bioswales, urban meadows, and rain gardens) can help manage stormwater, improve air quality, and mitigate extreme heat events by reducing the temperature of surrounding air, pavement, and building surfaces. For example, shade from trees can lower street-level temperatures by more than five degrees Fahrenheit.¹

ⁱ The [Smart Surfaces Coalition](#) is a 501(c)(3) organization committed to the rapid, cost-effective global adoption of Smart Surfaces to enable cities to thrive despite climate threats, save cities billions of dollars, create jobs, decrease heat, reduce flood risk, mitigate climate change, and improve city livability, health, and equity.

ⁱⁱ Although there is no common definition of cool pavement, a target solar reflectance of 0.30 or higher is a good starting point for policymakers and developers to consider.

limit rate increases tied to extreme weather events and infrastructure stress. Solar panels can also reduce energy costs for public facilities and, when paired with storage, improve long-term affordability and resilience for transit systems.

Health, Comfort, and Safety Benefits

Smart Surfaces create safer, cooler public spaces that enhance pedestrian comfort and decrease public health costs associated with extreme heat, flooding, and poor air quality. As a result, Smart Surfaces can decrease heat-related illnesses and respiratory problems, particularly for vulnerable populations that rely on public transportation. An analysis published in the NIH National Library of Medicine from researchers in Shanghai showed that for every 1.8 degree Fahrenheit increase in ambient temperature, there was a 1.78 percent increase in emergency department visits.⁸ Installing Smart Surfaces, such as cool and permeable pavements, green stormwater infrastructure, and trees can help lower ambient temperatures and improve associated health outcomes.

Reflective pavements improve visibility, especially at night,⁹ while also increasing the longevity of roads, keeping them well maintained and lowering the risk of cracks and potholes that could lead to vehicle damage and off-road collisions. Traffic calming measures that physically slow vehicles or narrow the visual field of drivers can incorporate green infrastructure elements like curb extensions with rain gardens, larger bioswale green corridors, protected bike and bus lanes with solar reflective coatings, and rain garden medians and roundabouts to meet dual goals of improving pedestrian comfort and safety by reducing both injuries and fatalities. Communities also benefit financially from reduced cooling costs and decreased surface maintenance needs. Cool pavements can extend the life of transportation infrastructure by reducing thermal stress,¹⁰ while permeable paving can reduce winter maintenance costs by decreasing ice formation.

Cool Roofs

Similar to cool pavements, cool roofs reflect a higher percentage of sunlight away from the roof, leading to cooler temperatures on the roof surface and in the building. On a hot sunny day, cool roofs can stay more than 50 degrees Fahrenheit cooler than conventional dark roofs.² Because of their cooling effect, cool roofs can reduce air conditioning needs and lower energy costs in the summer. Studies show that retrofitting 80 percent of commercial building roof area in the U.S. with cool roofs would yield net annual cooling energy cost savings of \$735 million.³ In addition, cool roofs may experience less wear and tear due to reduced temperature fluctuation, which can lower maintenance costs and extend roof lifespan.

Green Roofs

Green roofs, also known as vegetative roofs, contain weather-tolerant plants and are typically installed on low-slope roofs. The vegetation on roofs reduces how much sunlight is absorbed by the building, saving energy used for heating and cooling, and reduces stormwater runoff.

Cool Walls

Like cool roofs, cool walls reflect more sunlight than non-cool walls. As with cool pavements, there is no set definition of a reflectivity threshold for cool walls; however, an initial solar reflectance of 0.40-0.50 or higher is a good starting point for policymakers and developers to consider. Cool walls can reduce the cooling needs of a building by keeping it cooler during hot summer days and thus reducing electricity consumption and stress on the grid. Researchers estimate that cool walls can shave up to 8.3 percent off monthly energy bills for single-family homes in warm U.S. climate zones.⁴

Solar Panels

Incorporating solar panels on building roofs, walls, and above parking lots and bus stops can provide shade for buildings and pedestrians while also generating clean electricity for the grid.

Real-World Examples

Cool Pavements: Pacoima, California

In the summer of 2022, the Pacoima neighborhood in Los Angeles, California launched a cool pavement program through a public-private partnership between GAF Materials Corporation and the City of Los Angeles called the “Cool Community Project.” To increase surface reflectivity and reduce heat absorption, 660,000 square feet of street and recreational surfaces in Pacoima were painted with a cool pavement coating made up of a water-based epoxy that has more than six times the solar reflectance as new asphalt.¹¹ Within the first year of the program, ambient air temperatures around the cool pavement regions were reduced by 1.5 degrees Fahrenheit on sunny days and up to 3.5 degrees Fahrenheit during extreme heat events.¹² Through the addition of this reflective pavement coating, Pacoima was able to reduce urban heat island effects, contribute to greater energy affordability and resilience during heatwaves, while simultaneously enhancing pedestrian comfort and safety.

Solar Canopies: Rhode Island

Through a public-private partnership with Kearsarge Energy, the University of Rhode Island installed solar canopies over 300 parking spaces at a commuter park-and-ride facility, financed through a third-party ownership model leveraging tax equity and virtual net metering.¹³ This solar carport system generates approximately 2 million kWh of electricity annually, enough to power more than 250 homes, while providing shade¹⁴ for commuters’ vehicles. By installing solar generation infrastructure over existing paved surfaces, the project also helps mitigate the urban heat island effect and serves as a model for efficient land use and sustainable transportation integration.

Green and Complete Streets: Cleveland Heights, Ohio

Cleveland Heights, Ohio, has integrated Smart Surface strategies through its award-winning Complete and Green Streets Policy which their city council passed in June of 2022.¹⁵ Ranked first in the nation by the National Complete Streets Coalition in 2018, the policy applies to all transportation projects citywide and emphasizes flexibility to meet site-specific needs. A key feature of the policy is its requirement for green stormwater infrastructure, which reduces runoff, alleviates strain on the city’s aging sewer system, and improves water quality. The green stormwater infrastructure requirement also helps reduce urban heat island and flood risk, enhance resilience, and lower energy demand associated with stormwater pumping and treatment. Additionally, by promoting traffic calming, multimodal design, and pedestrian safety improvements, Cleveland Heights supports more walkable and safer neighborhoods, which further reduces vehicle reliance and associated emissions.



Photo courtesy of Rhode Island Office of Energy Resources

Navigating Funding Pathways and Resources

State-Specific Approaches and Cross-Agency Collaboration

State Energy Offices can leverage state-specific funding opportunities to support Smart Surfaces in transportation. As an example, Washington State's \$17 billion Move Ahead Washington transportation package created an Interagency EV Coordinating Council (IEVCC) comprising the State Energy Office, State DOT, and other agencies.¹⁶ This council provides recommendations that reduce emissions, preserve infrastructure, and develop a statewide transportation electrification strategy. Entities like the IEVCC can lay out the groundwork for statewide transportation strategies to include Smart Surface technologies and are an example of an innovative state funding outcome.

Other potential state-level approaches include creating dedicated funding streams for Smart Surfaces within existing energy or transportation programs and developing technical assistance

programs to help local governments with implementation. State Energy Offices can work with state DOTs to incorporate Smart Surfaces requirements into state transportation design standards and provide incentives for local governments to adopt Smart Surfaces in their transportation plans.

In order to achieve this, cross-agency collaboration is essential. State Energy Offices can work toward establishing formal partnerships with state DOTs, environmental agencies, and public health departments to coordinate planning, funding, and implementation efforts for the successful deployment of Smart Surface technologies into transportation programs. These partnerships can help overcome institutional barriers and ensure that Smart Surfaces are incorporated into routine transportation planning and design processes.

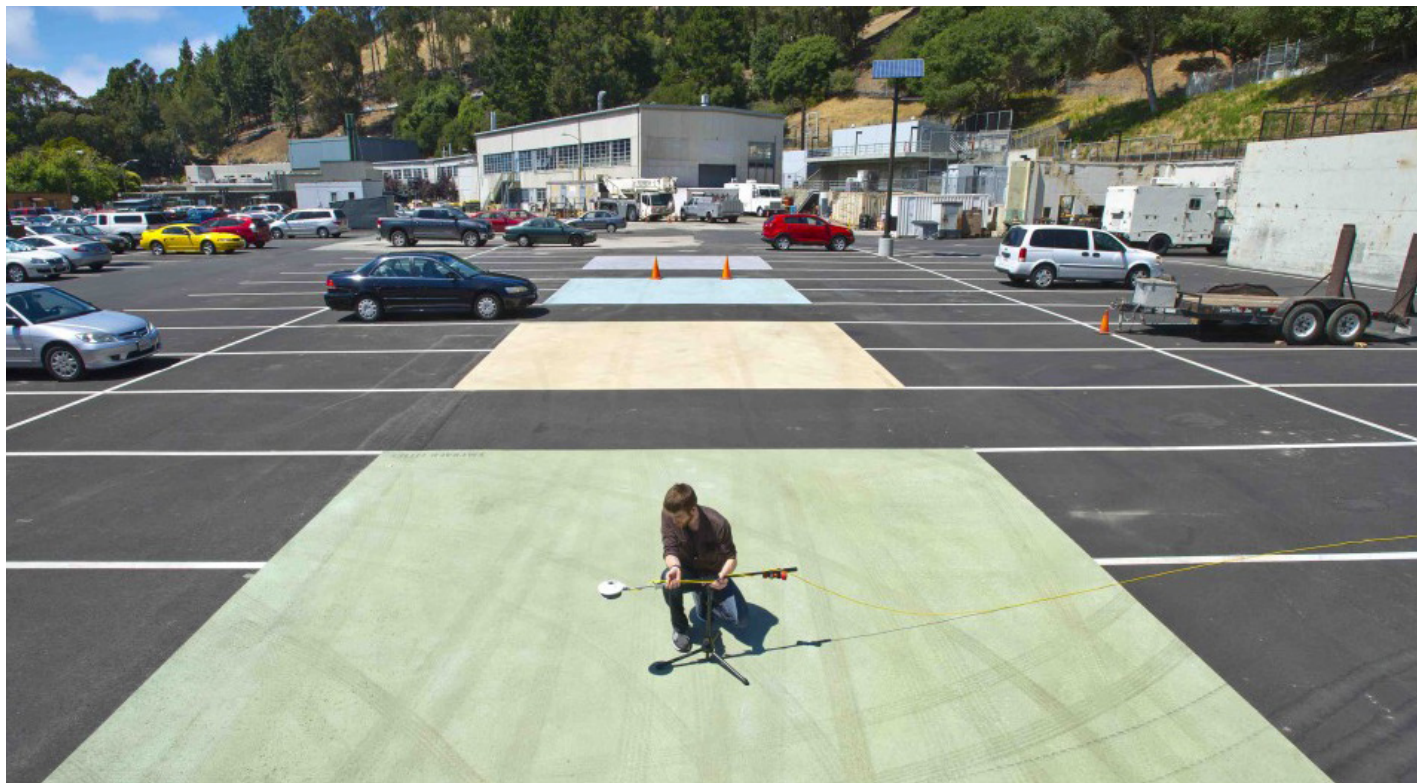


Photo courtesy of U.S. Department of Energy-Science/Public domain

Federal Funding Mechanisms

The Better Utilizing Investments to Leverage Development (BUILD) program, established by the Infrastructure Investment and Jobs Act, provides funding for infrastructure projects in urban and rural communities, with an emphasis on surface transportation.¹⁷ Grants can be used for “planning or constructing surface transportation infrastructure projects that will improve safety; environmental sustainability; quality of life; mobility and community connectivity; economic competitiveness and opportunity including tourism; state of good repair; partnership and collaboration; and innovation.”¹⁸ State DOTs could potentially use grant funding to repave roads with permeable or reflective pavement or install green infrastructure along roadways. State Energy Offices could collaborate with state DOTs to integrate solar canopies onto bus stops, sidewalks, and parking spaces, as well as introducing rooftop solar on transit centers and EV charging infrastructure.

The Promoting Resilient Operations for Transformative, Efficient, and Cost-Saving Transportation (PROTECT) Program funds improvements to the resilience of transportation infrastructure to natural disasters and extreme weather events.¹⁹ Smart Surfaces, including permeable and reflective pavements, tree canopies, and green stormwater infrastructure, are eligible for funding under this program. While future funding rounds for PROTECT have been paused, State Energy Offices can collaborate with state DOTs on the implementation of existing projects to ensure that resilience efforts funded by PROTECT also align with state energy goals. For example, they might partner on funding a microgrid system to power a transit bus depot with Smart Surface elements including solar panels and tree canopies, enhancing both transportation energy resilience and energy efficiency.

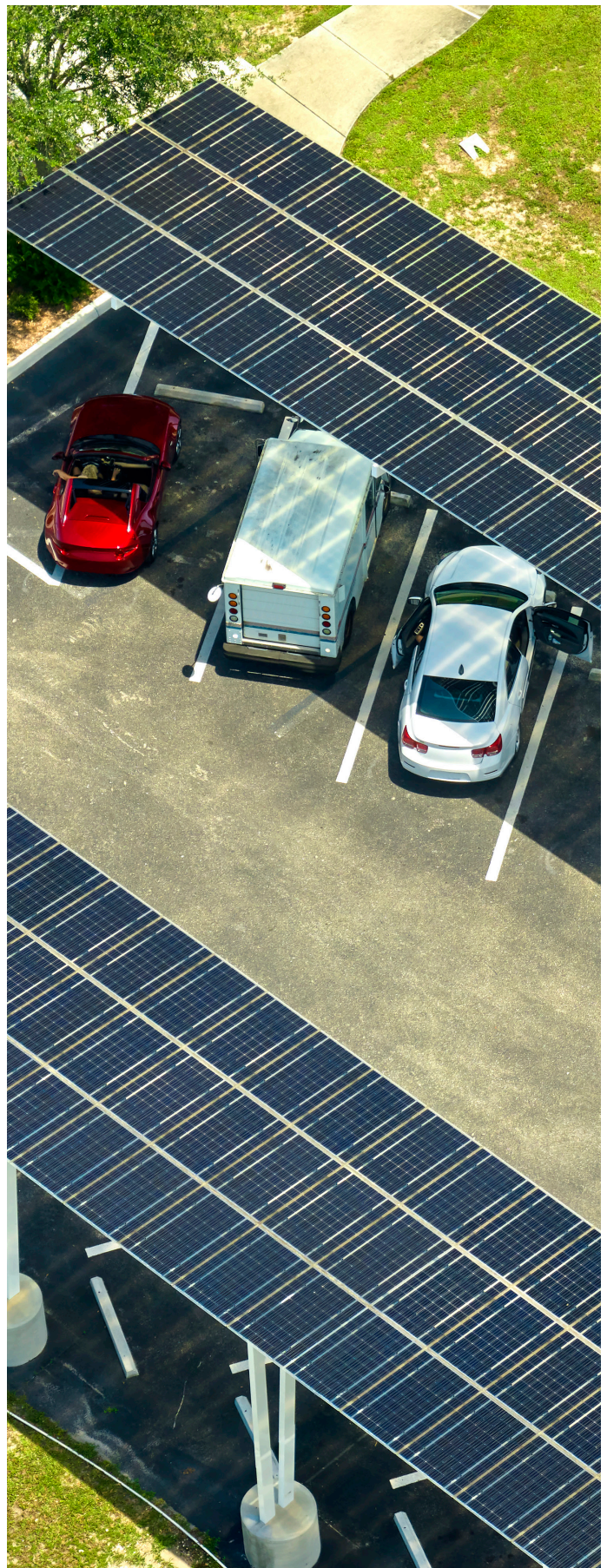


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Implementation Considerations

Planning and Design Integration

When implementing Smart Surfaces in transportation projects, several factors should be considered to maximize benefits. All urban areas would benefit from the comprehensive deployment of more reflective and permeable infrastructure; however, the climate zone and local conditions should guide the design and types of Smart Surface installations.

The specific location and context of transportation infrastructure is also important to consider. High-traffic pedestrian areas near transit stations may benefit most from cool pavements and shade trees, while parking lots and transit centers may be ideal for canopy and rooftop solar installations. State Energy Offices can work with state DOTs to develop context-sensitive guidelines for Smart Surfaces selection and design.

Maintenance requirements and lifecycle costs are also important considerations. Many Smart Surfaces have a *lower or comparable* first cost than conventional alternatives (e.g., many single-ply cool roofing technologies are less expensive than the non-cool alternatives, some cool pavement coating technologies have similar costs to asphalt emulsion-based sealants, and it is generally less expensive to build green infrastructure than to pave roads); however, for those solutions that may have higher upfront costs than conventional materials, the Smart Surface solution will provide significant lifecycle savings through reduced maintenance, extended service life, and energy and other benefits. State Energy Offices can share lifecycle cost analysis tools that account for these benefits with their transportation counterparts to help inform decision-making.



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Measuring and Communicating Benefits

To help educate energy and transportation stakeholders on how Smart Surfaces can be used to improve overall infrastructure planning and decision-making, State Energy Offices can develop metrics and evaluation frameworks to document their benefits. Key metrics might include:

- Energy savings (kWh) from reduced cooling demand in buildings
- Energy generation (kWh) from solar installations
- Peak demand reduction (kW) during extreme heat events
- Temperature reductions in urban environments
- Stormwater management capacity (gallons) of porous pavements
- Infrastructure lifecycle extensions (years) from reduced thermal stress
- Public health benefits from reduced heat exposure and improved air quality

By quantifying and communicating these benefits, State Energy Offices can advance their work to create safer, more efficient, and more affordable communities through the integration of Smart Surfaces into transportation planning and design. This information can also support the development of more accurate cost-benefit analyses that capture the full value of Smart Surfaces across various applications and environments.



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Additional Resources

- [Heat Island Reduction Solutions](#), U.S. Environmental Protection Agency.
- [Using Cool Pavements to Reduce Heat Islands](#), U.S. Environmental Protection Agency.
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- [Smart Surfaces Guidebook](#), Carnegie Mellon University Center for Building Performance and Diagnostics, 2022.
- [Smart Sidewalks Guide](#), Carnegie Mellon University Center for Building Performance and Diagnostics, Smart Surfaces Coalition, 2024.

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