

Electrification: Connecting the Pieces in the Broader View

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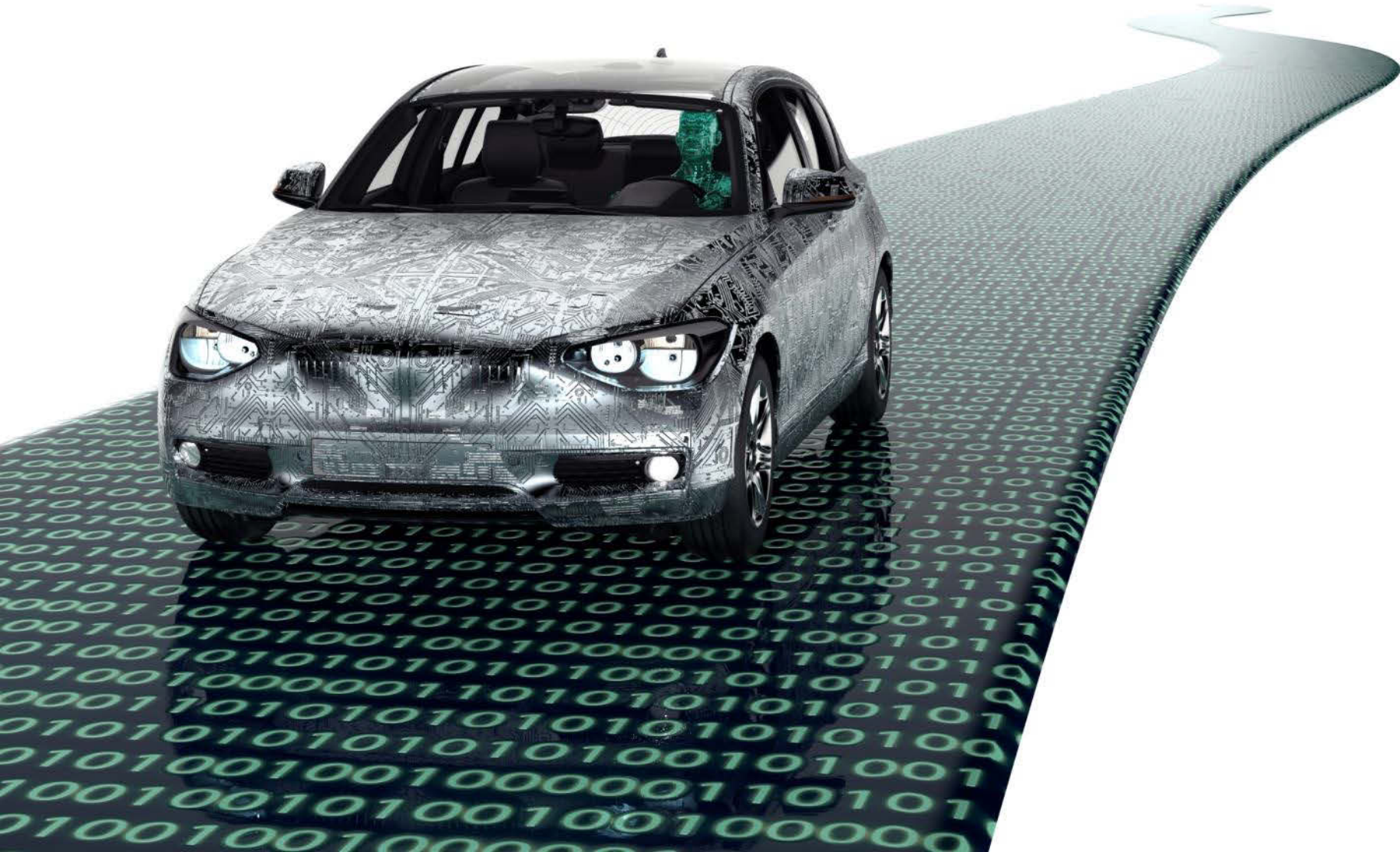
Connectivity is becoming ubiquitous.



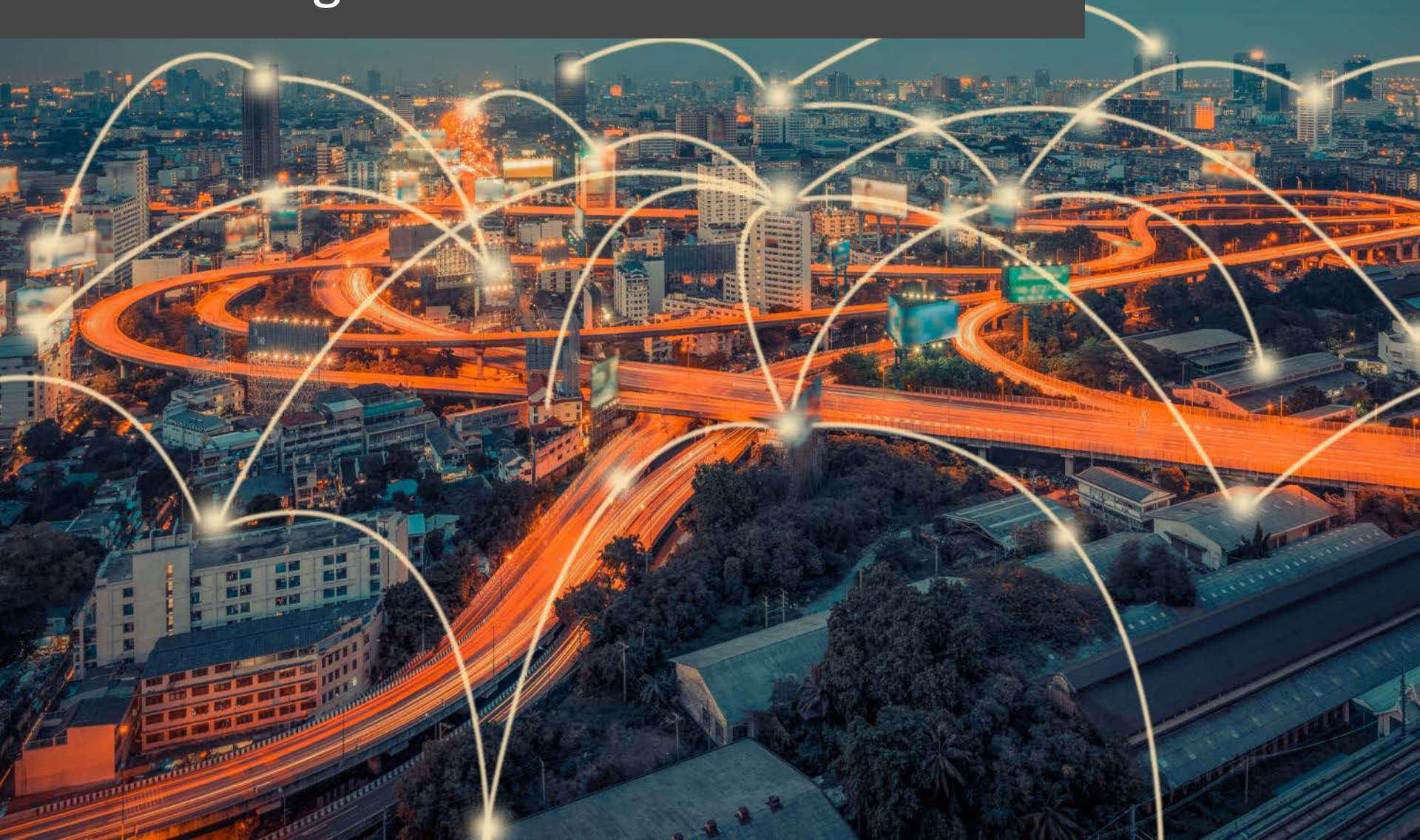
Automation technology is advancing rapidly.



Convenience & ROI insure continued growth, that



...will create tremendous **opportunities**
to change our lives for the better



But they also present a number of
unknown consequences.



Drivers already travel a total of **3.2 trillion miles**

& businesses transport **\$10 billion of freight**


across U.S. roads each year.





Transportation uses **70%** of petroleum,

24% is imported.

A woman with dark hair, wearing a light blue button-down shirt and a necklace, is smiling as she refuels a silver car. She is holding a yellow gas nozzle. The background is a blurred green landscape, suggesting an outdoor gas station setting.

The typical American **spends >\$9,000**
on transportation each year.



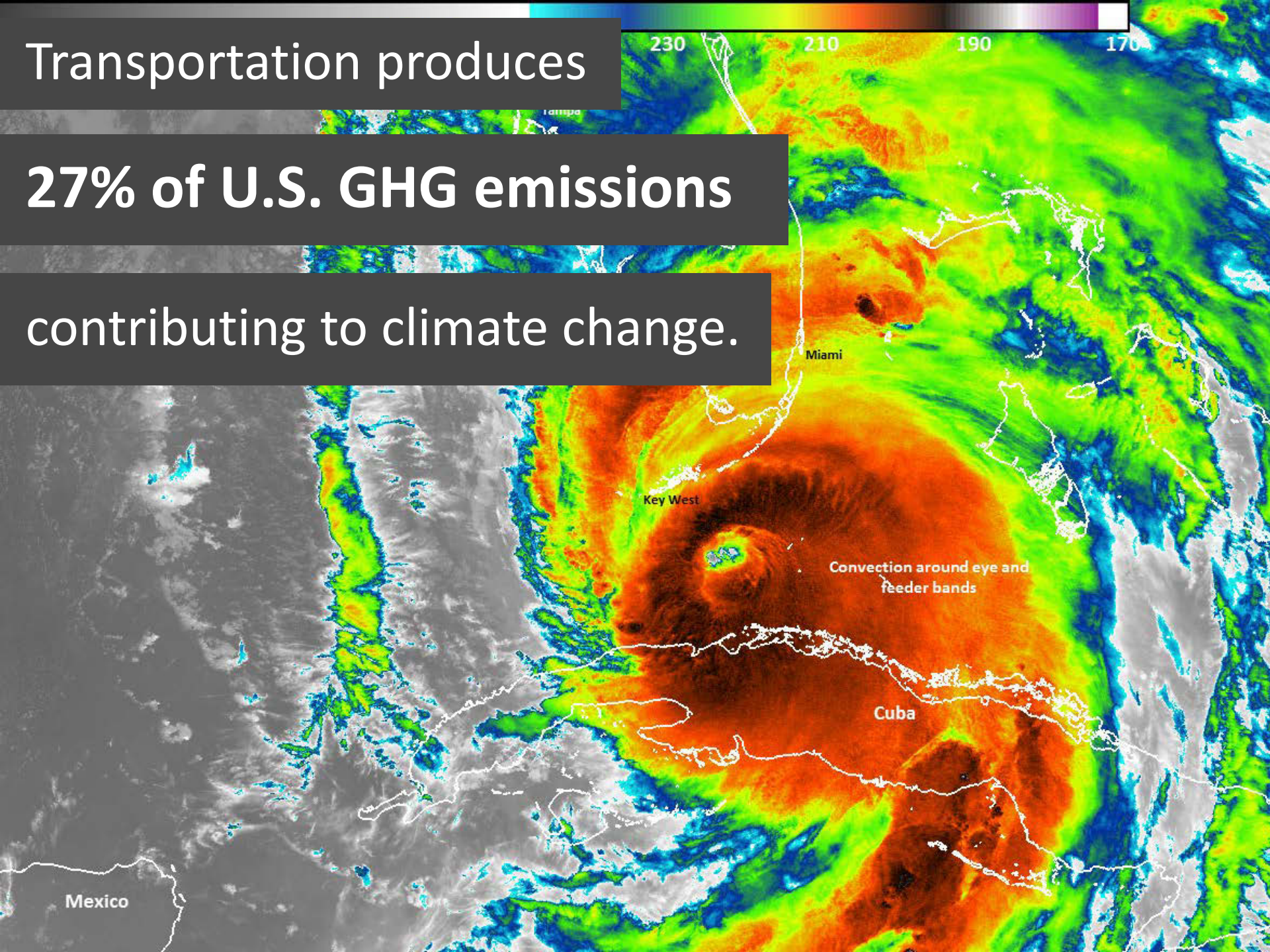
Vehicle emissions impact


air quality, visibility, and health.

Transportation produces

27% of U.S. GHG emissions

contributing to climate change.

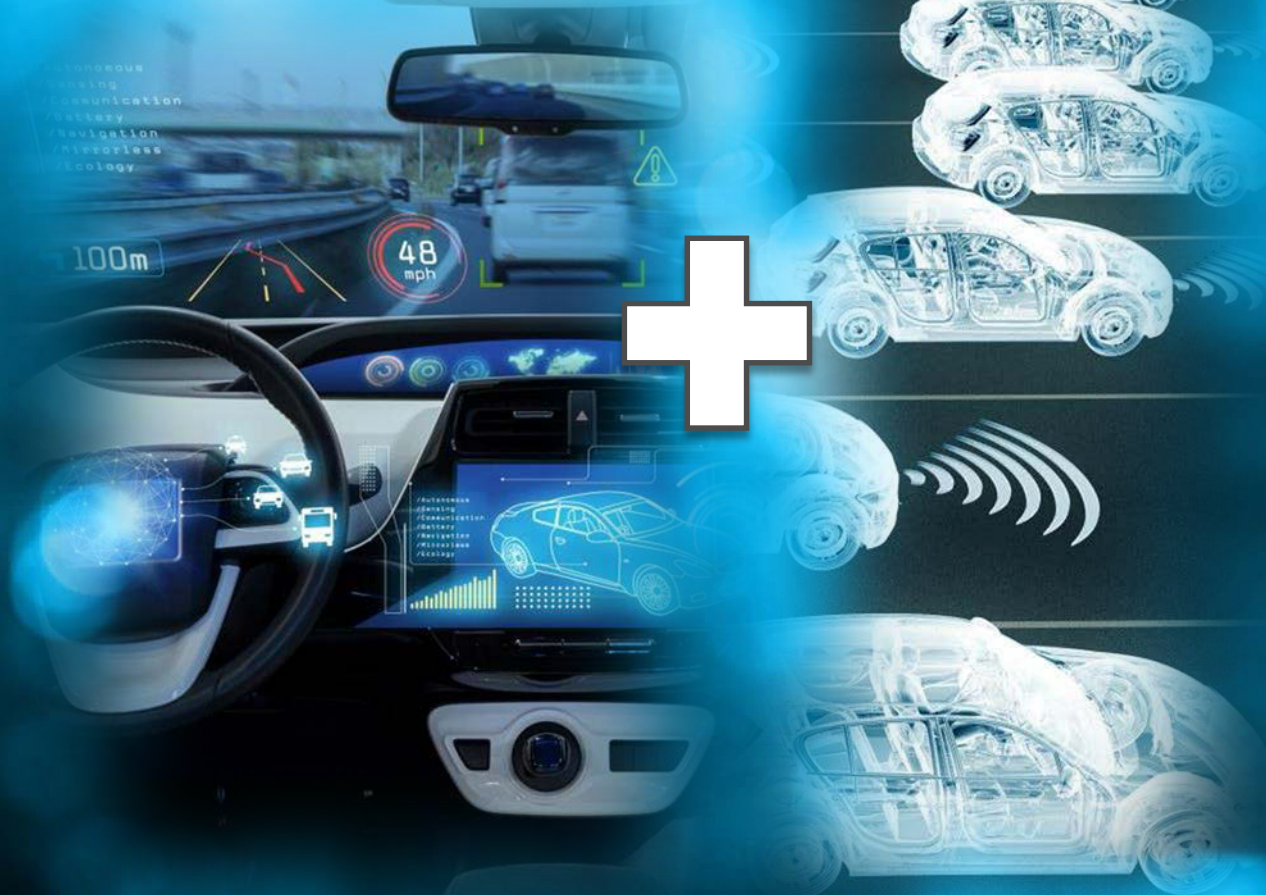


An aerial photograph of a city skyline, likely Los Angeles, viewed from a hillside. The foreground shows dry, brownish vegetation. The middle ground is filled with a dense urban landscape, including numerous buildings and a prominent highway. The background features a hazy city skyline with several tall skyscrapers under a bright, overcast sky.

We have to reduce CO₂ emissions
at least 80% by 2050.

Automation

Connectivity



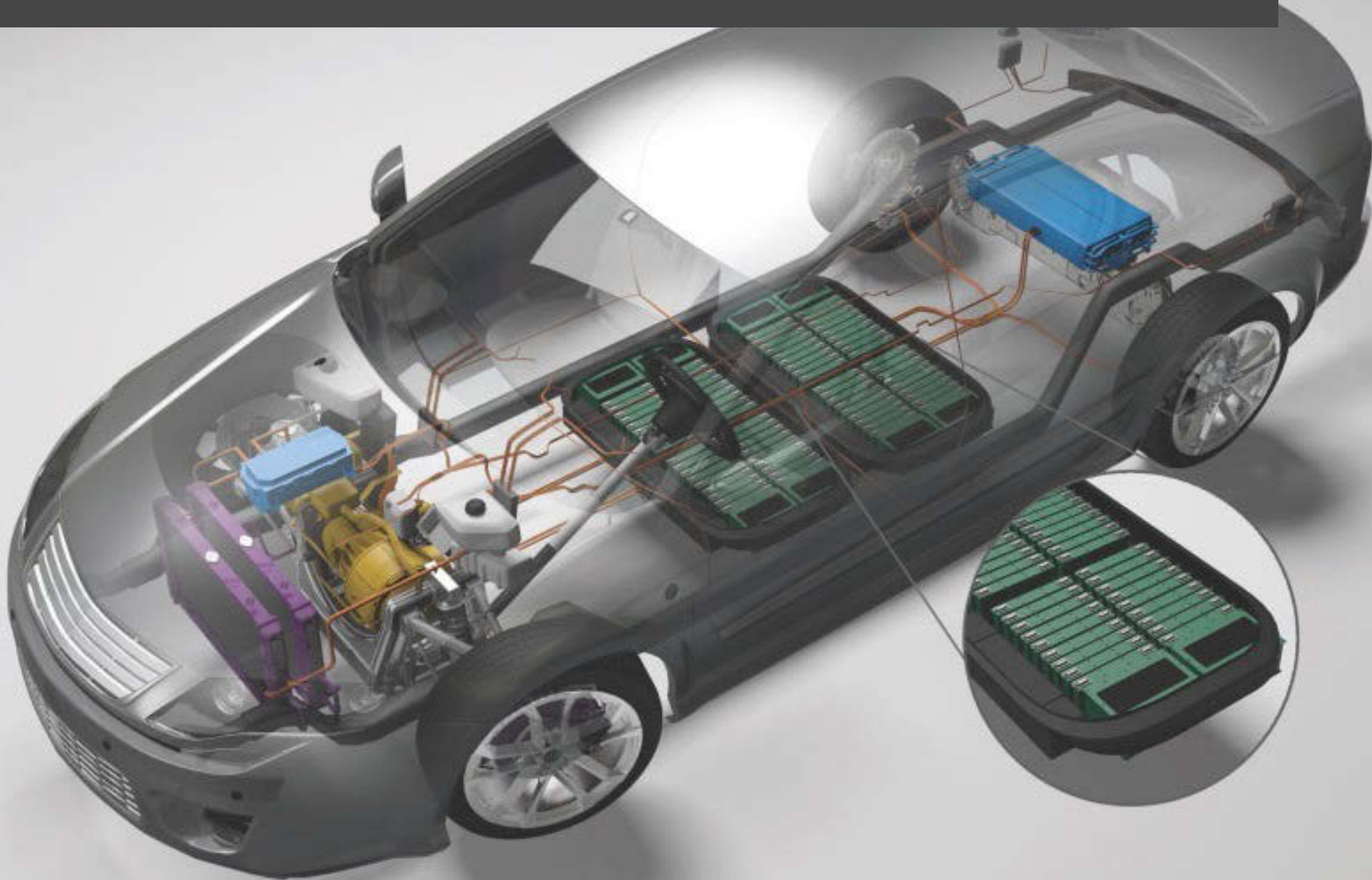
= more travel, more emissions

Connectivity + Automation + Electrification
= improved mobility and fewer emissions...



IF well-integrated with renewable energy generation and an
appropriately designed urban environment

More **electric vehicles** are coming to market,

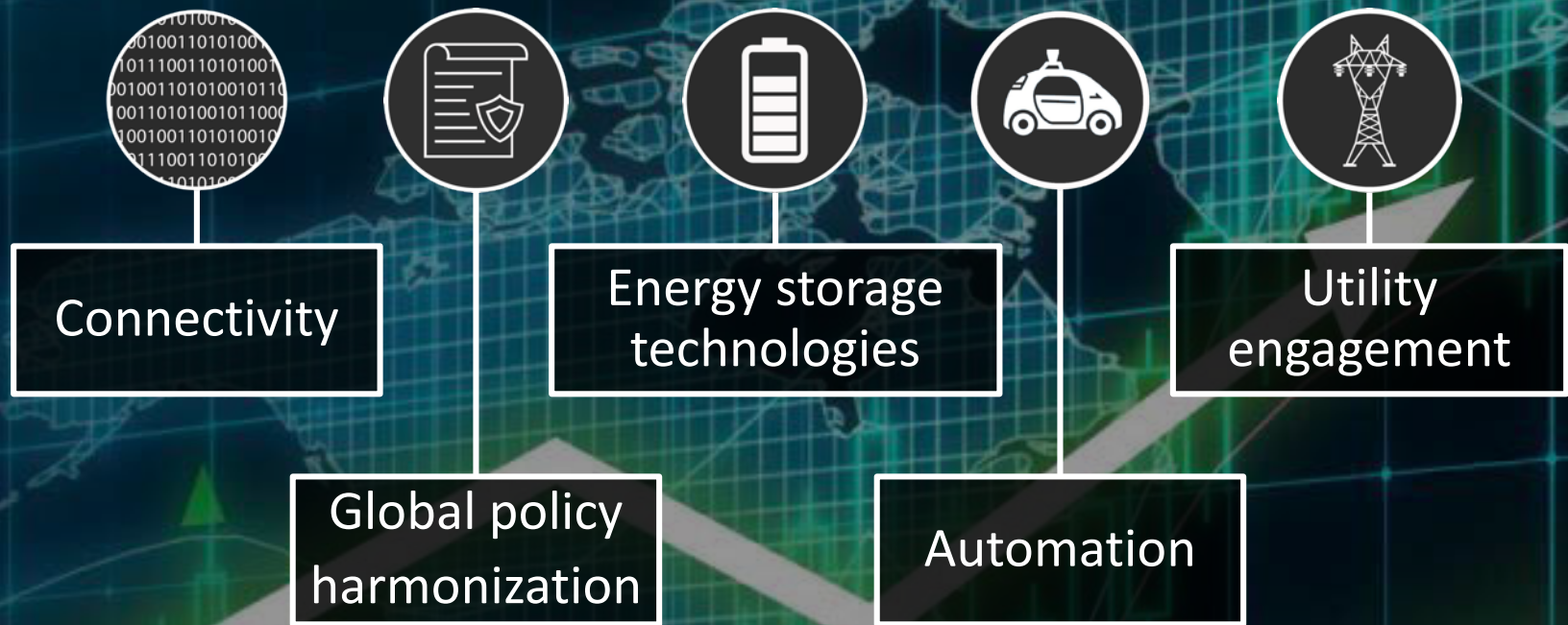


... but it's no longer *just* about the vehicle

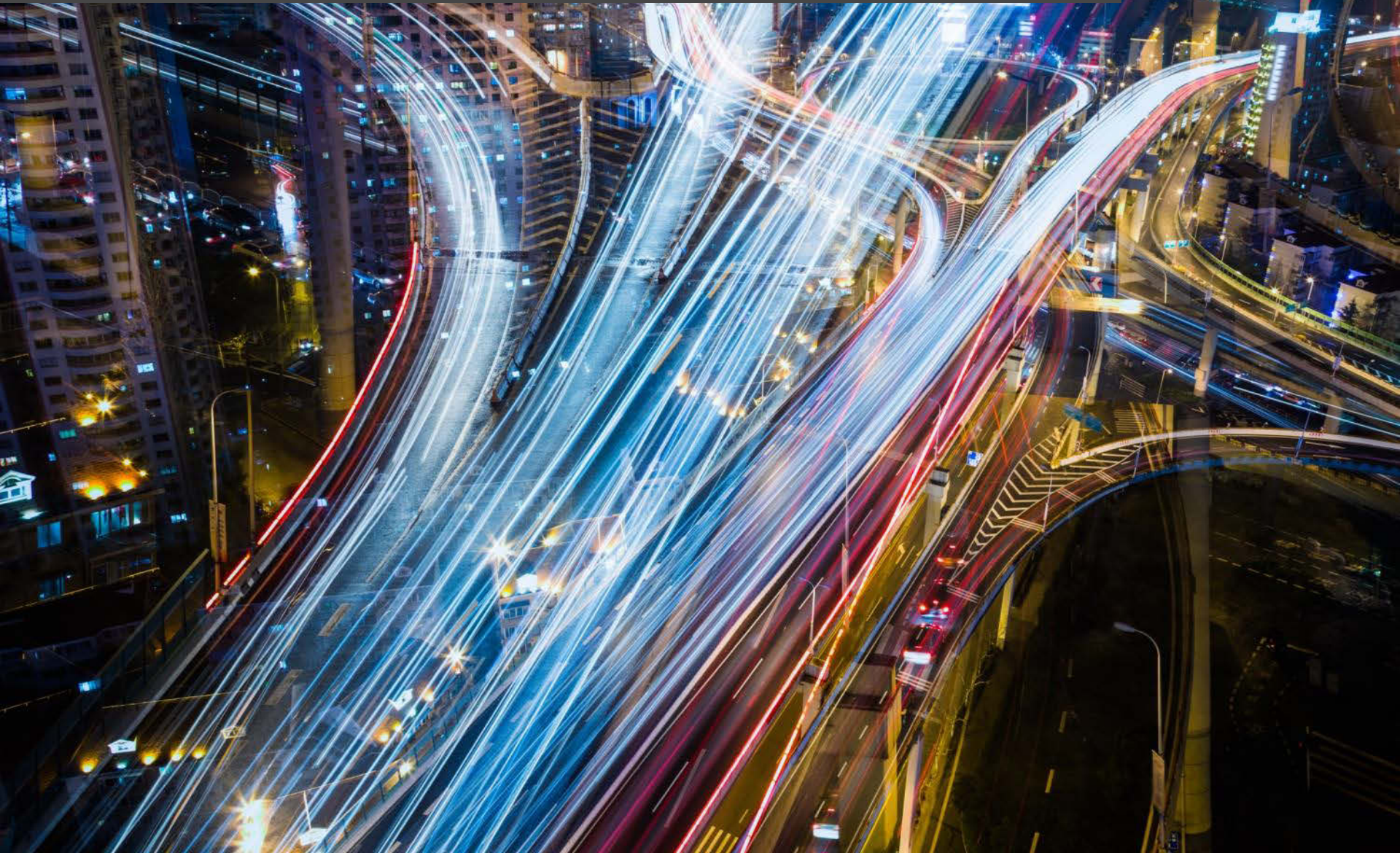
Future mobility represents a
complex systems optimization problem

A futuristic, sleek car is shown from a side-front perspective, moving towards the right. The car is dark with glowing green highlights on its wheels and body. A bright, glowing green light source is visible in the distance, emitting a wide beam of light that illuminates the car and the surrounding space. The background is a dark, starry field with a grid of light lines, suggesting a digital or data-driven environment. The overall scene conveys a sense of advanced technology and complex systems.

A confluence of technology and policy drivers are transforming mobility



Integration delivers **maximum synergy.**





What does **electrification**
integration look like?

Four Elements of Sustainable Mobility



Movement of people



Movement of goods



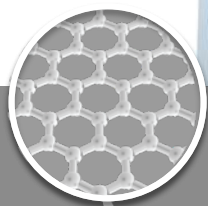
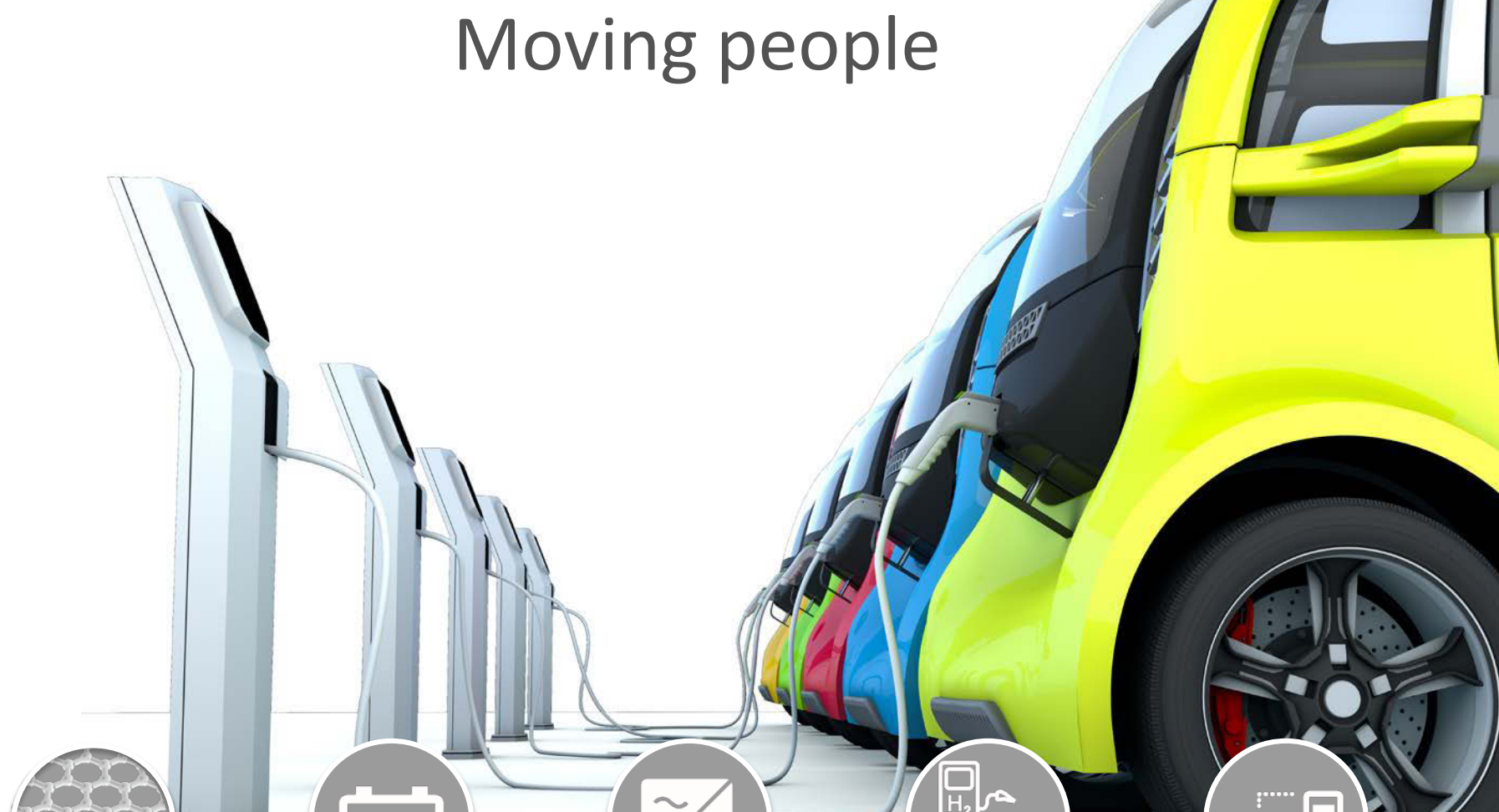
Powering mobility



Transformative technologies



Moving people



Adv.
Materials

Energy
storage

Power
electronics

Hydrogen/
biofuels

Device
Integration

Moving goods

HLT
HEAVY LOAD TRANSFER
US DOT 2874887
MC 964665
CA 484112



Adv.
Combustion

Hybridization

Biofuels

Hydrogen

Energy
storage

Powering mobility



Renewables



Grid
Integration



Buildings
integration



Cybersecurity



Extreme fast
charging

Transformative technologies



Autonomy

Connectivity

Wireless
charging

Big data/
analytics

Deep
learning

Integration at Four Levels



Materials



Devices

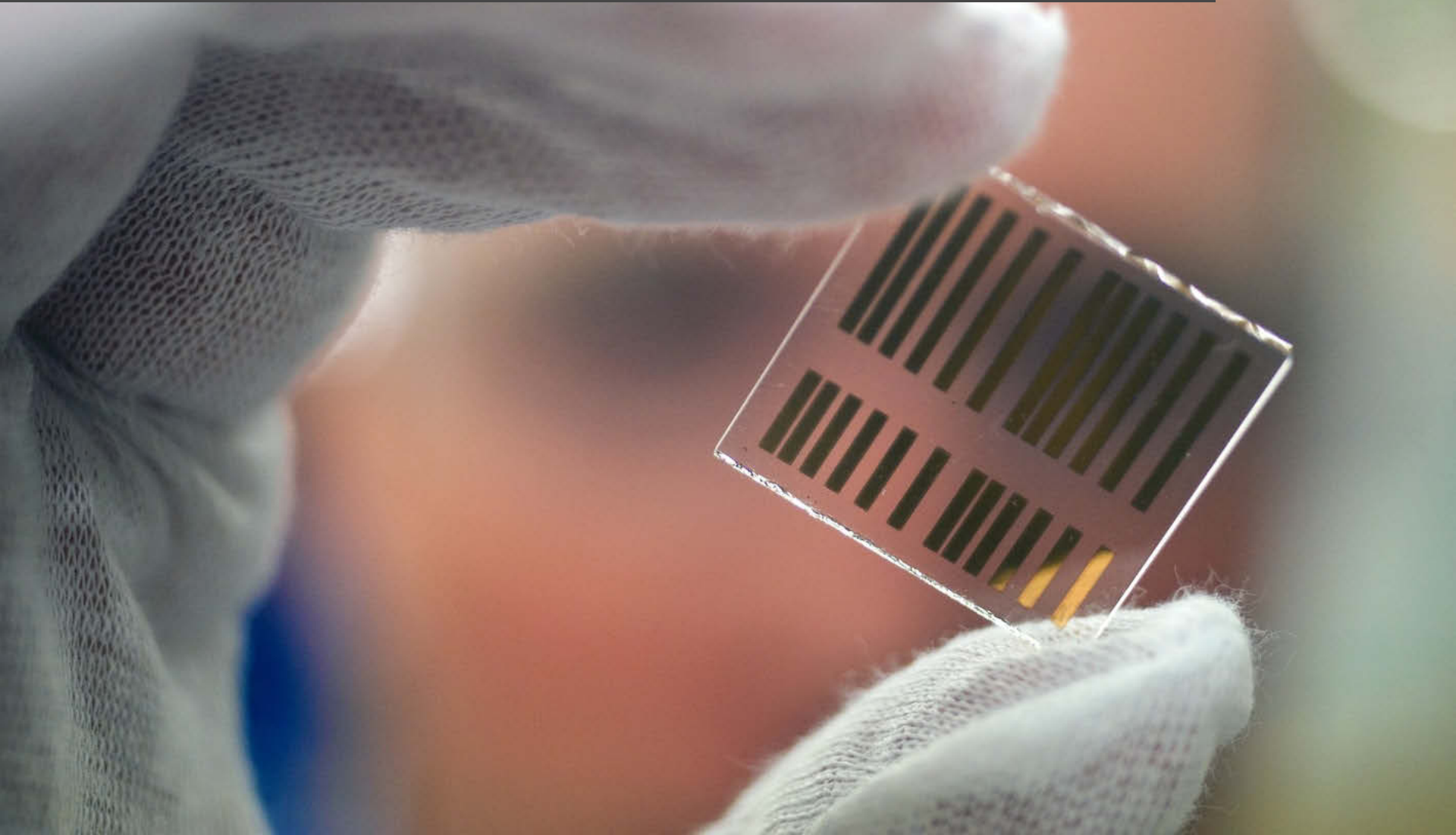


Ecosystems



Controls

Materials...



Devices...



Integration makes it possible to
optimize size, efficiency & performance.

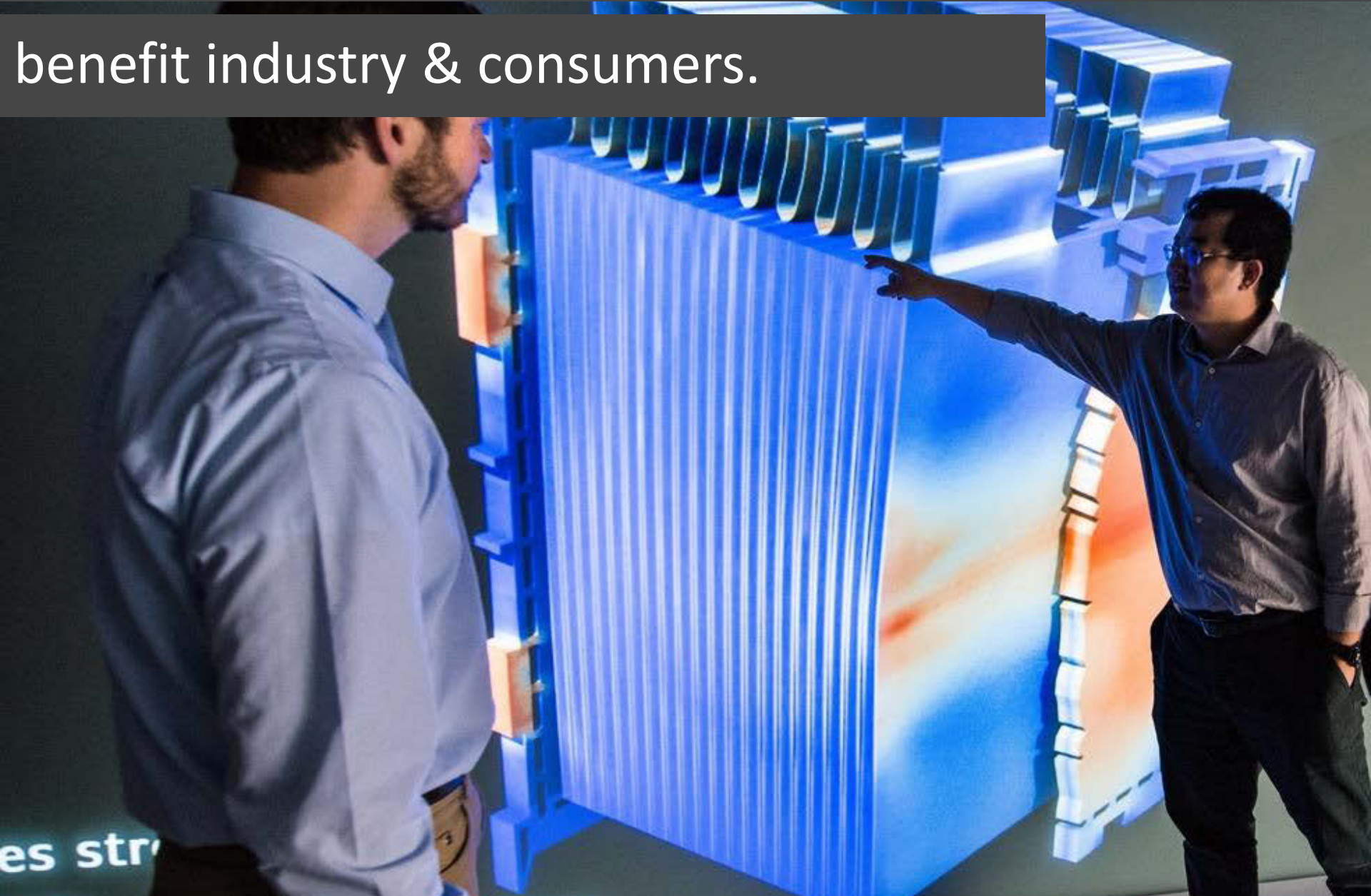


A man with glasses, wearing a blue short-sleeved button-down shirt and dark jeans, stands at an electric vehicle charging station. He is holding a white charging cable that is plugged into a red car. The car is parked under a large, modern charging canopy. The background shows a clear blue sky with some clouds and a grassy field. The overall scene is bright and sunny.

These also are devices

Integration Materials to Devices

benefit industry & consumers.



es str

Integration involves **more than just**

vehicles & charging equipment.





...as well as feeding power to the **grid**.

Electric vehicles & renewable power sources

can be combined to improve **grid resiliency**.

The **ecosystem** encompasses

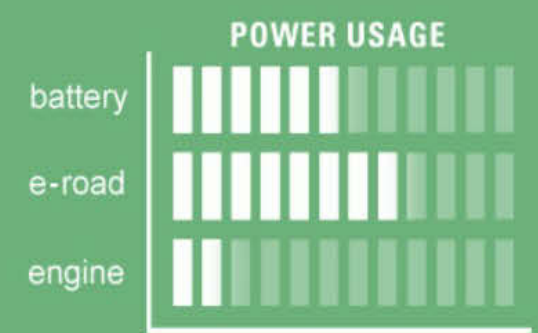
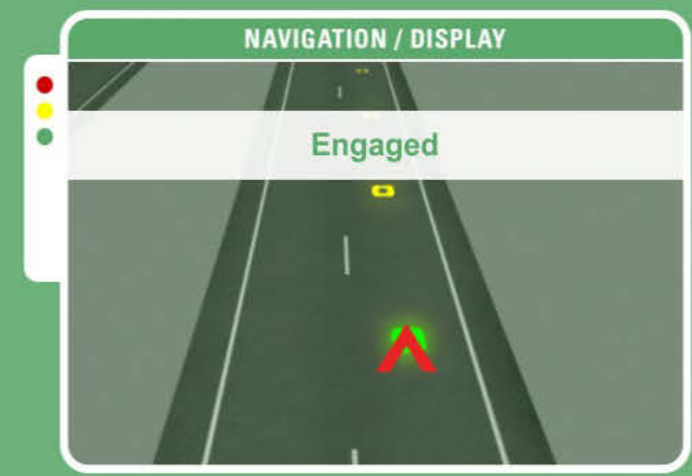
multiple types of vehicles, infrastructure,

communication, travel modes, and travelers.





Electric vehicles allow
immediate & direct connection
with other systems.

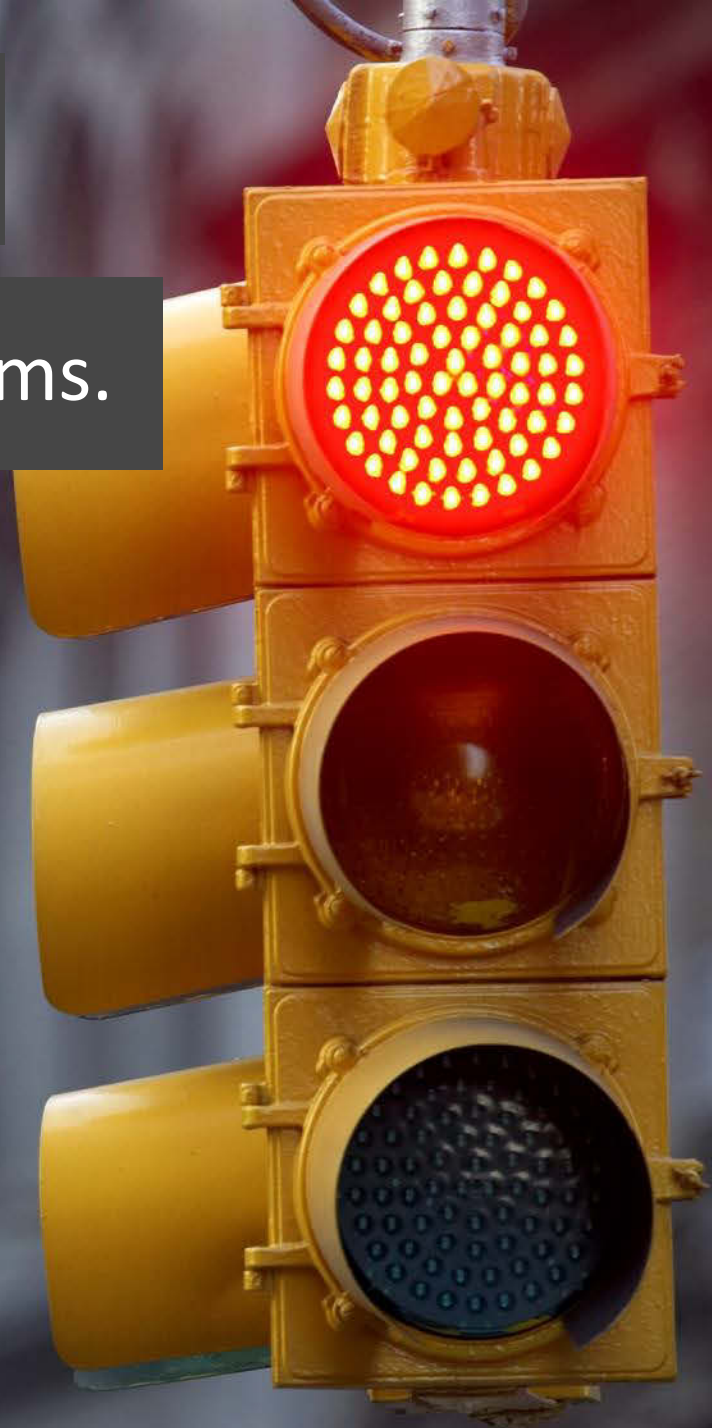


Sustainable mobility looks at transportation as
a network of travelers, services & environments
rather than just vehicles and roads



Higher-level controls can

synchronize multiple systems.



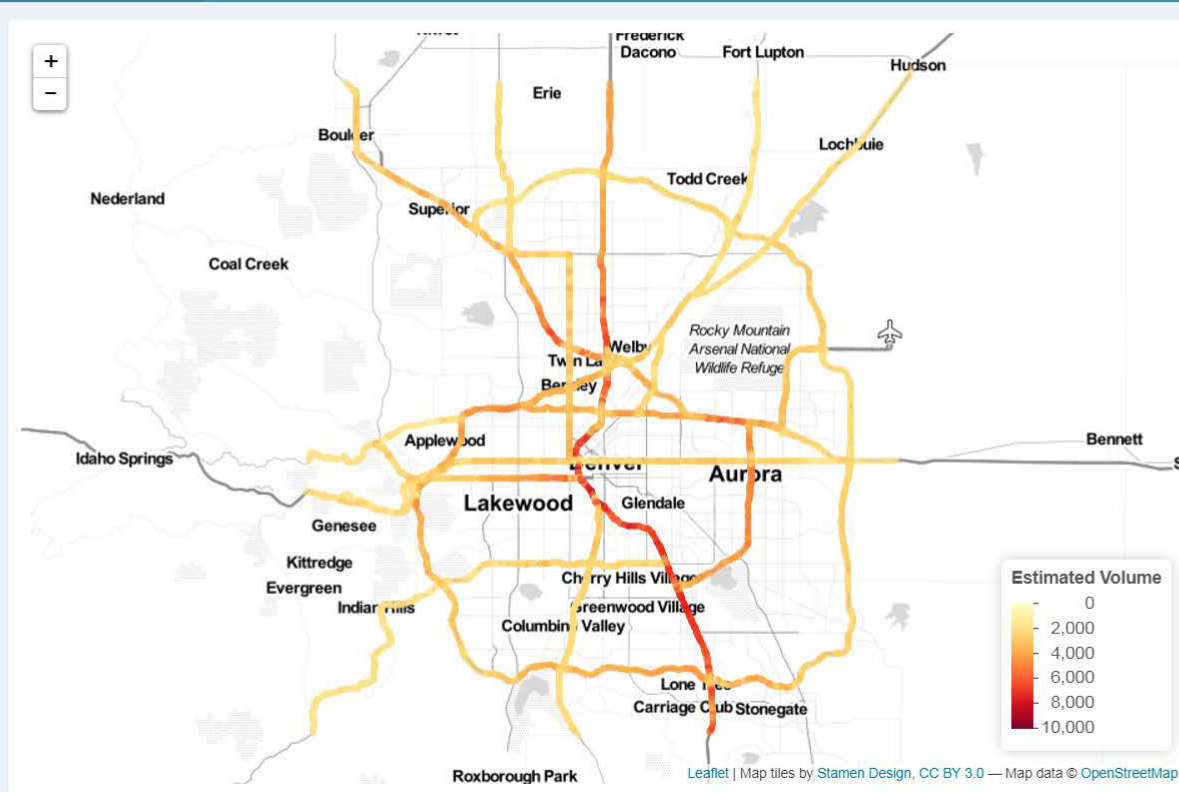
Apps act as supervisory control algorithms.

Real-time Traffic Volume Estimation



TMAS

Denver Area



Roads to be showed (FRC):

- 0
- 1
- 2

Select

Month



Day



Hour



Estimate

MAPE: 11%

Error to Capacity Ratio (ECR): 7%

Intelligent controls paired with wireless charging can
alleviate range anxiety.



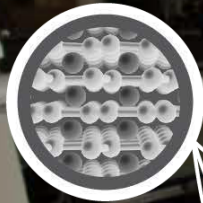


Electrification Challenges and Opportunities

Increase with larger vehicles.

Energy storage is central to electrical mobility systems integration

Electrochemical



Bio-molecular



Hydrogen



Thermal



Vehicles



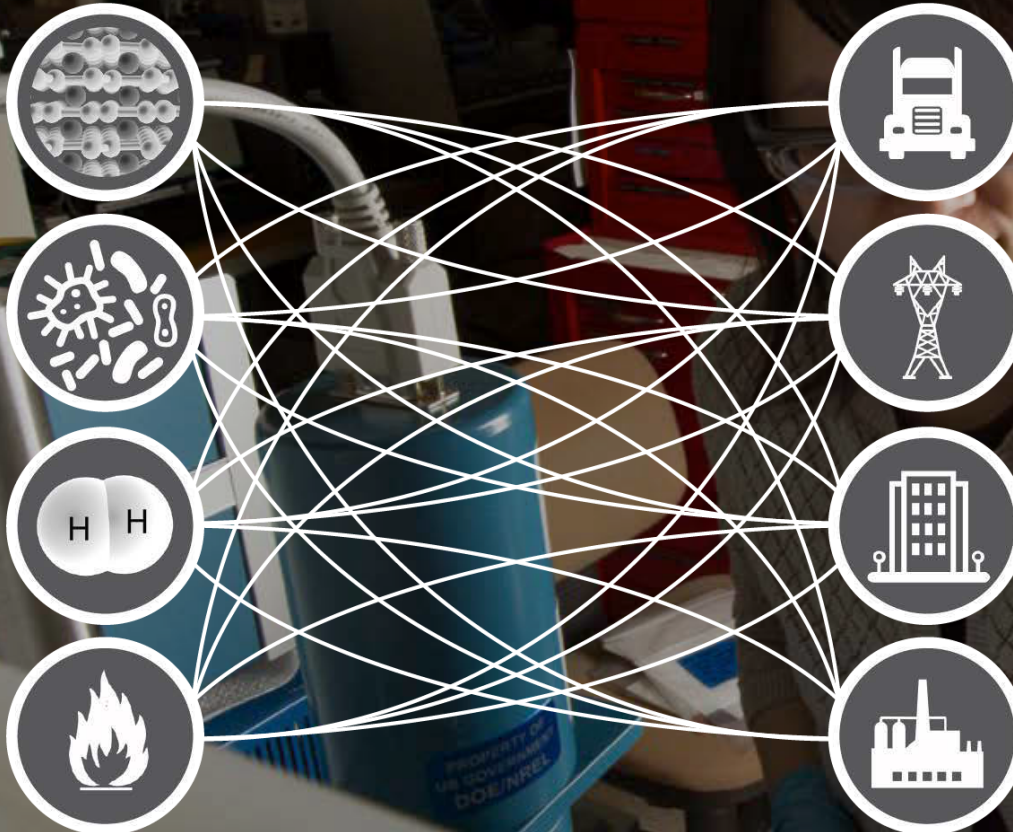
Grid



Buildings



Industry



Summary

Connectivity and electrification are here; automation is coming – they will transform the transportation eco-system.

Without integration, these transformations could magnify negative health, climate and economic problem.

With integration we have the chance to take advantage of the benefits AND mitigate the negative consequences.

But this will require careful connection of all of the pieces from materials up through controls to produce a transportation eco-system that is truly sustainable.

Thank you.
Questions?

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