Electric Truck Guidance Report Series

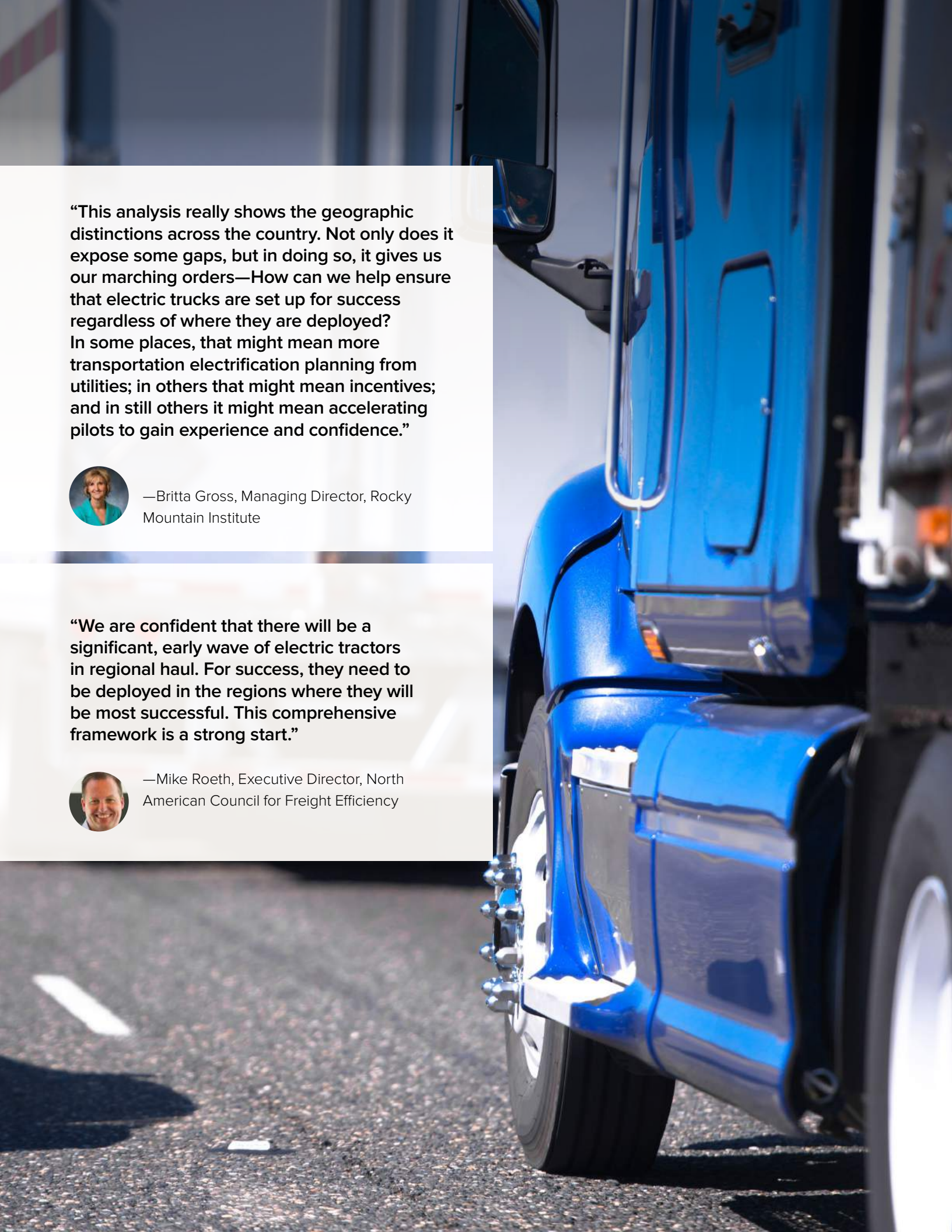
HIGH-POTENTIAL REGIONS FOR ELECTRIC TRUCK DEPLOYMENTS

BY JESSIE LUND AND MIKE ROETH

NACFE
NORTH AMERICAN COUNCIL FOR FREIGHT EFFICIENCY

IN PARTNERSHIP WITH

ROCKY MOUNTAIN INSTITUTE



“This analysis really shows the geographic distinctions across the country. Not only does it expose some gaps, but in doing so, it gives us our marching orders—How can we help ensure that electric trucks are set up for success regardless of where they are deployed? In some places, that might mean more transportation electrification planning from utilities; in others that might mean incentives; and in still others it might mean accelerating pilots to gain experience and confidence.”

—Britta Gross, Managing Director, Rocky Mountain Institute

“We are confident that there will be a significant, early wave of electric tractors in regional haul. For success, they need to be deployed in the regions where they will be most successful. This comprehensive framework is a strong start.”

—Mike Roeth, Executive Director, North American Council for Freight Efficiency

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The ongoing assistance from fleets, manufacturers, utilities, governments, non-governmental organizations, academia, and others for our work guiding the future of electric trucks.

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Rocky Mountain Institute (RMI)—an independent nonprofit founded in 1982—transforms global energy use to create a clean, prosperous, and secure low-carbon future. It engages businesses, communities, institutions, and entrepreneurs to accelerate the adoption of market-based solutions that cost-effectively shift from fossil fuels to efficiency and renewables. RMI has offices in Basalt and Boulder, Colorado; New York City; Oakland, California; Washington, D.C.; and Beijing. **www.rmi.org**

ABOUT NACFE

The North American Council for Freight Efficiency (NACFE) works to drive the development and adoption of efficiency enhancing, environmentally beneficial, and cost-effective technologies, services, and operational practices in the movement of goods across North America. NACFE provides independent, unbiased research, including Confidence Reports on available technologies and Guidance Reports on emerging ones, which highlight the benefits and consequences of each, and deliver decision-making tools for fleets, manufacturers, and others. NACFE partners with Rocky Mountain Institute (RMI) on a variety of projects including the Run on Less fuel efficiency demonstration series, electric trucks, emissions reductions, and low-carbon supply chains. **www.nacfe.org**

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EXECUTIVE SUMMARY

Regional haul heavy-duty trucking operations are good candidates for electrification due to the segment's relatively short-haul nature and return-to-base operations. Many early electric truck deployments have taken place in California, due to the state's supportive policies and incentives as well as its milder climate and terrain, which make it ideal for operating battery electric trucks. As the market matures, fleets, utilities, manufacturers, policymakers, charging companies, and other industry stakeholders are seeking assistance to prioritize regions outside California for future deployments of this technology.

If deployments are done strategically, they are more likely to be successful, which not only benefits first-movers, but also catalyzes further deployments, thereby benefitting the industry as a whole and speeding adoption of this technology.

This report proposes a three-part framework that the industry can use to prioritize regions for electric truck deployments:

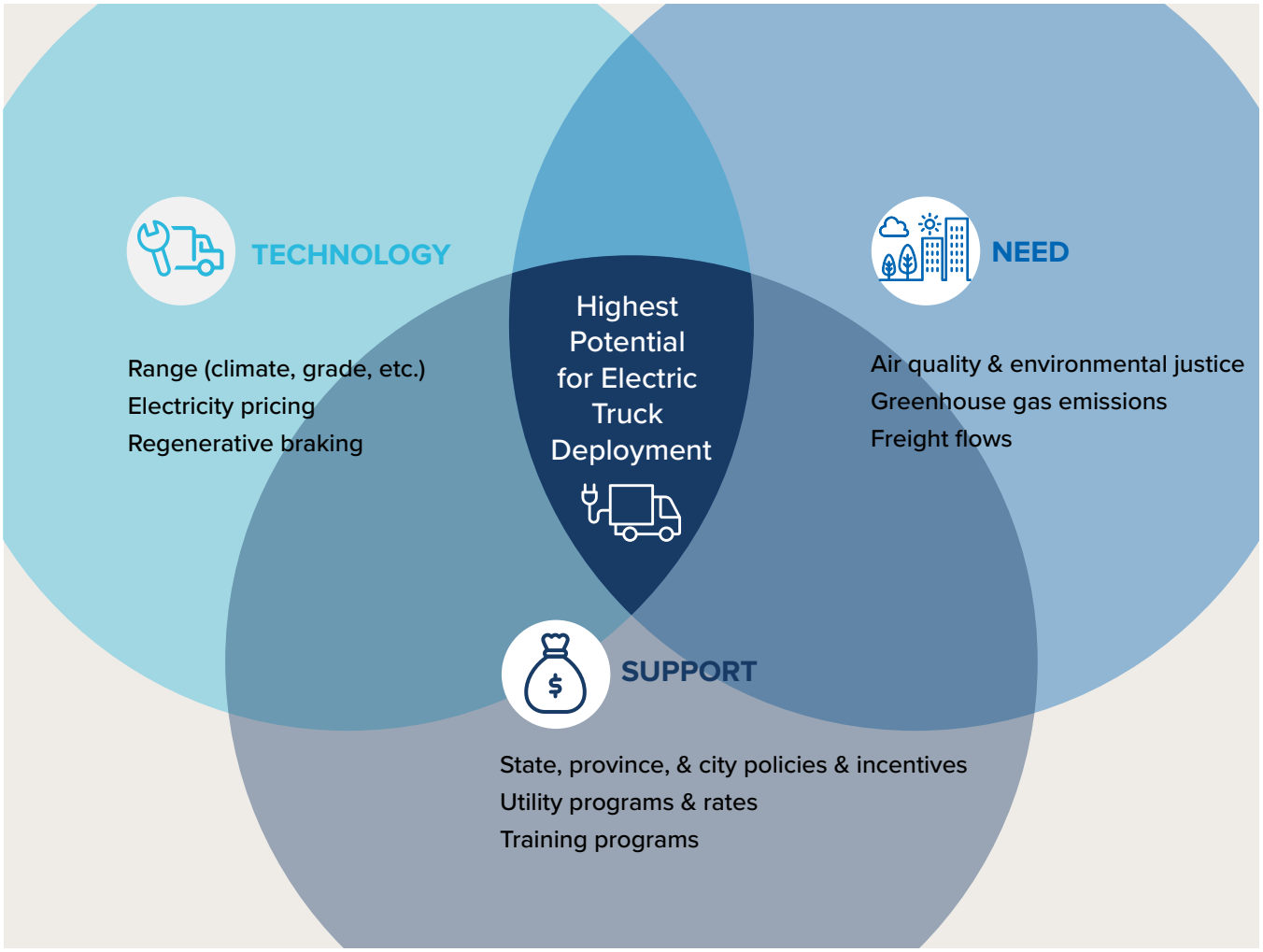
- **Technology** – Identify the regions that are most favorable to the unique attributes of the technology itself.
- **Need** – Identify the regions that exhibit the greatest need for the technology.
- **Support** – Identify the regions that provide the most support for the technology.

"In considering where to deploy electric trucks, there's a lot to think about—everything from charging infrastructure to which climates the technology operates the best in to where the most funding and incentives are available. This framework helps not just fleets, but utilities, OEMs, policymakers, and others think through the many considerations to ensure that wherever they deploy electric trucks, they're a success."

–Patrick Browne, Director of Global Sustainability, UPS

EXHIBIT ES-1

Framework for Identifying and Prioritizing High-Potential Regions for Electric Truck Deployments

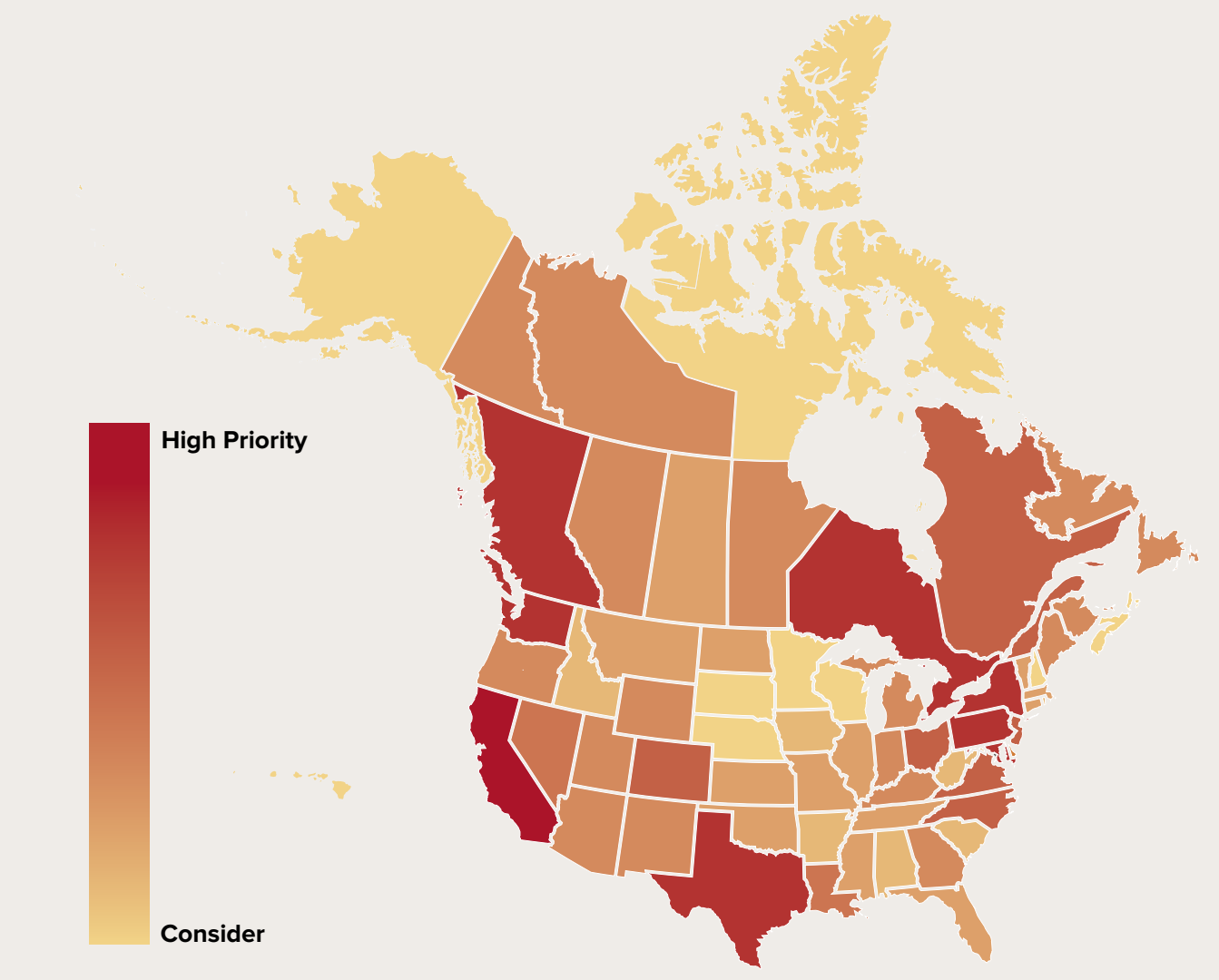


In evaluating each of these criteria, fleets should consider not only which regions are best suited for electric trucks, but also which represent the strongest competitive advantage over diesel trucks.

This report also presents an initial analysis of where these three criteria come together to create a "hotspot" for near-term regional haul electric truck deployment. Regions are rated based on these criteria, resulting in a "heatmap" of electric truck potential by state, which distinguishes between regions fleets should consider to those that are the highest priority for electric truck deployments.

EXHIBIT ES-2

Heatmap of High-Potential Regions for Electric Truck Deployments



The aim of this analysis is to initiate a data-informed dialogue about which regions have the highest potential for successful regional haul electric truck deployments and why, and to spur feedback from the industry. This analysis is meant to represent one perspective of a snapshot in time, as the data is continuously changing.

Regions favorable for electric truck deployments are found across North America. The regions with the highest potential for electric truck deployments include both Northern and Southern California, the Texas Triangle, Cascadia (stretching from Portland, Oregon through Seattle and into Vancouver, Canada), the Colorado Front Range, the Northeast United States, the Greater Toronto Area, and Greater Montreal. Fleet owners with trucks operating regional haul routes of approximately 230 miles/370 kilometers or less per shift or per day in these high-priority regions should immediately begin planning for electric truck deployments—even if only on a pilot scale. It can take over a year to build out charging infrastructure and acquire vehicles, so it makes sense to start today. Those that act fast are least likely to experience challenges with grid infrastructure that is already maxed out by other nearby fleets.

"We are at the early stages of freight electrification, and while the future is electric, it requires everyone including the fleet, the utility, the OEM, the charging supplier, the permitting jurisdiction, and potential funding providers to all come together. As fleets are getting started they should make sure to pick the right location to ensure the greatest opportunity for success."

—Ben Prochazka, National Director, Electrification Coalition

1 INTRODUCTION

California is undeniably leading the continent when it comes to reducing emissions from medium- and heavy-duty commercial vehicles. The vast majority of the zero-emission trucks on the road in North America today have been deployed in the Golden State, and many of the fleets with pre-orders for electric trucks going into production in the next few years have plans to operate them in this region as well. California's milder climate and terrain are ideally suited for operating electric trucks, and the business case for the technology is bolstered by the state's many incentives—and now requirements.

California recently made history as it became the first state to require zero-emission trucks be sold via its **Advanced Clean Truck (ACT) rule**, which will require truck makers to sell an increasing number of clean, zero-emission trucks in the state—from 5% of Class 7/8 tractors in 2024 to 40% by 2035. Given the state's high volume of freight movement (California is home to the country's two biggest ports), its commitment to reducing greenhouse gas (GHG) emissions, the large share of those emissions that come from freight, and additional air quality concerns, the decision to regulate emissions from commercial vehicles should come as no surprise. However, questions remain about what this transition will look like and how quickly it will take place.

Beyond being driven by policy, the transition to electric trucks will also be dictated by market forces. As the technology proves a positive return on investment, demand among fleets will rise. In many cases, electric trucks already make economic sense, especially when paired with incentives. Between "hard costs"—such as purchase price, maintenance expenses, and electricity prices—and "soft costs"—such as driver attraction and retention and environmental branding—total cost of ownership of electric trucks can be on par or even cheaper than diesel vehicles. And economies of scale as more models go into production will help bring costs down as well. According to engineering,

procurement, and construction company **Black and Veatch**, "Soon the cost of not electrifying fleets will outweigh today's cost of investment. Businesses that do not electrify will be at a competitive disadvantage."

While it's certain that **the trucking industry's long-term future is zero-emission vehicles**, the sort of operations and geographies these trucks are best suited for—particularly in the short-term—is less certain. Zero-emission vehicles include both battery electric and fuel cell electric vehicles, but this report focuses on battery electric for regional haul. This is because the North American Council for Freight Efficiency (NACFE) and Rocky Mountain Institute (RMI), through our extensive work on electric trucks and regional haul, have discovered that **regional trucking operations are well suited to be early adopters of battery electric trucks**, given the segment's relatively short-haul nature and return-to-base operations.

Relatively short routes are well-suited to the range of electric trucks currently on the market, and return-to-base operations make charging infrastructure development—which is frequently cited as one of the **top barriers to electric truck adoption**—relatively straightforward. (Fuel cell electric vehicles face similar infrastructure issues—but with hydrogen—that also fit well with return-to-base operations where the infrastructure is near or at the base of operations, though they are likely better suited to longer haul applications.) Therefore, we expect that regional haul applications will account for a majority of the heavy-duty battery electric truck sales over the next decade, which are estimated to be as high as **13%** in the United States.

However, outside of California, where do regional haul electric trucks make the most sense? Beyond policy and incentives, which have arguably been driving zero-emission truck deployments to date, what other factors should fleets be considering in developing electrification plans?

To help answer these questions, NACFE and RMI have developed the following framework for evaluating high-potential regions for electric truck deployments. The framework includes considerations such as the unique attributes of the technology, the need for the technology, and support for adoption. Our hope is that this framework helps fleets, utilities, policymakers, manufacturers, charging companies, investors, and other industry stakeholders better plan for the future and ensure the success of electric truck investments. We anticipate this framework will be particularly valuable for:

- Fleets with geographically dispersed operations trying to determine where to prioritize electric trucks;
- Utilities trying to understand the diverse considerations surrounding electric trucks; and
- Policymakers looking to encourage more freight vehicle electrification.

This paper also includes an initial analysis, which was conducted using the framework, to determine favorable "hot spots" for electrification.

A NOTE ON REGIONS VS. CORRIDORS:

In the initial stages of electric truck adoption, regional planning is more critical than corridors. There is a lot of talk about "corridors" in the light-duty electric vehicle (EV) world, where installing charging stations along highly trafficked roads is considered a critical piece of the puzzle to incentivizing EV adoption. As the thinking goes, this charging infrastructure is necessary to help alleviate the "range anxiety" of drivers who worry about depleting their vehicle's battery while out and about. This is particularly important for drivers who want to be able to travel far from home and for those who don't have access to charging at home.

As such, many corridor groups have sprung up across the country to advocate for charging infrastructure buildout along key travel routes in their area, often with a focus on DC fast chargers (DCFCs). Current DCFCs are able to charge most light-duty vehicles in under an hour, which is considered a reasonable rest stop for travelers, particularly when stations are located next to restaurants and retail shops.

However, the size of medium- and heavy-duty vehicle batteries combined with the power levels of existing public chargers makes the prospect of charging on the road unpalatable for many fleets and drivers. Many of these drivers get paid by the mile and are therefore not keen to wait at a station for hours while their truck charges. Availability of public chargers is also a concern, as is privacy and safety.

For all of these reasons, we believe that electric truck deployments are prime for regional haul operations that return to base each shift or each day. This is in large part because these vehicles tend to have sufficient dwell time at their depot or base, which means fleets can build out private infrastructure "behind the fence" at these locations to charge their vehicles. Not only are these chargers reliably available when needed, but they also allow the fleet to more directly control the timing of charging (depending on operational needs, utility rates, and even renewable electricity availability). Private infrastructure of this sort can also be combined with on-site electricity generation, storage, and/or demand management if beneficial (to help mitigate utility demand charges, for example).

Because the charging to support these regional operations is expected to be done primarily at fleets' home-bases for the near future, less emphasis is placed on public charging networks and therefore on corridors. Rather, the focus of any public charging infrastructure for medium- and heavy-duty electric vehicles for the next several years should be on extraordinary circumstances and/or redundancy in emergency situations.

However, this doesn't mean that fleets shouldn't prioritize certain geographies over others for electric truck deployments, when given the choice. On the contrary, and as we explain in this report, there are plenty of regional attributes to consider when prioritizing locations for electric truck deployments and infrastructure investment—especially for regional haul. Because most (but not all) of these distinctions are made at a regional level, rather than focused on specific roadways, we have designed the framework below to evaluate priority regions rather than corridors.

2 FRAMEWORK

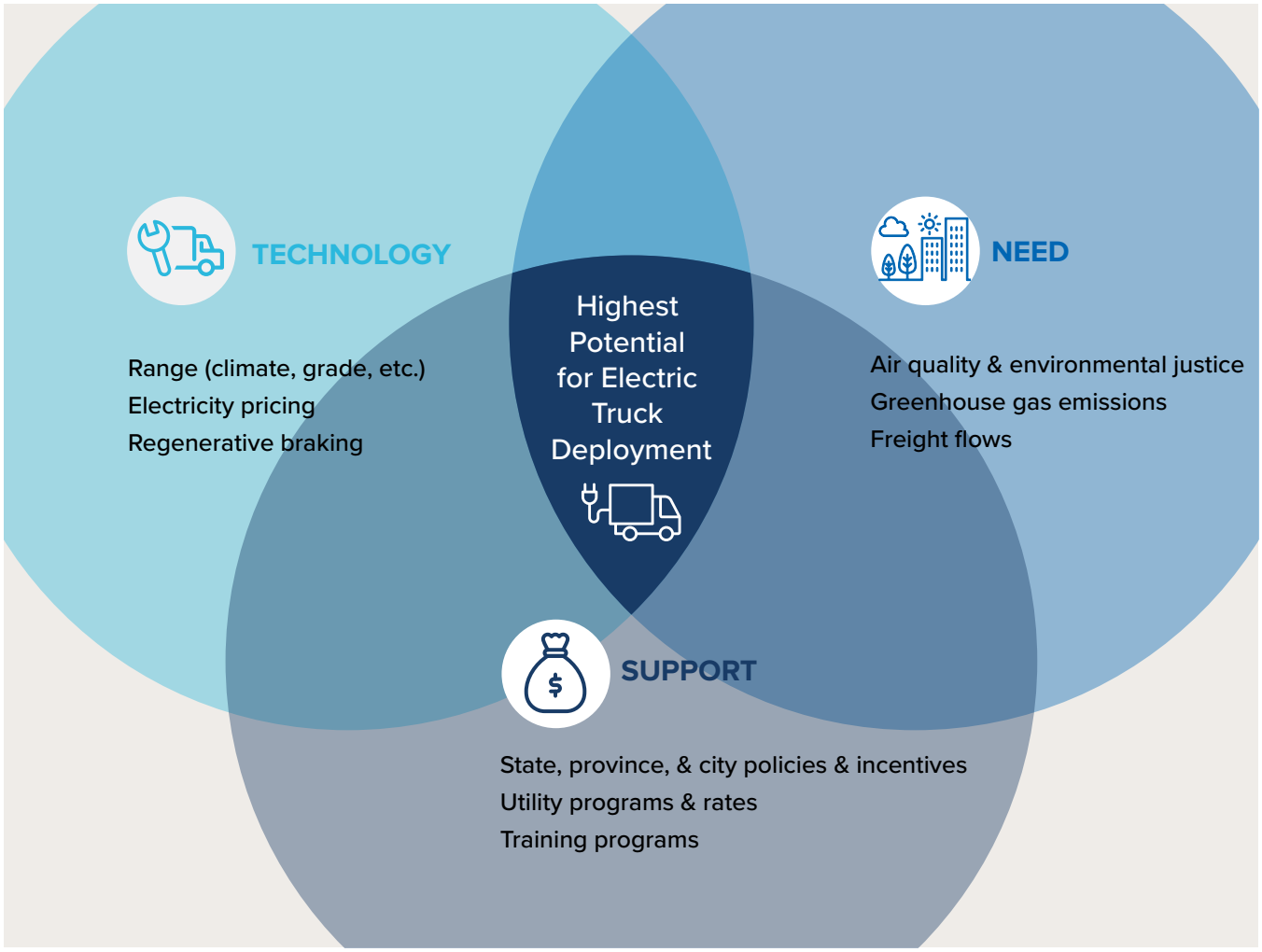
The framework outlined below can be used to determine high priority regions of the United States and Canada for electric truck deployments. The framework is made up of three overarching categories of considerations:

- Technology
- Need
- Support

Note that the framework is designed to evaluate not only where electric trucks are best suited, but also where they are most likely to have a competitive advantage over diesel trucks.

EXHIBIT 1

Framework for Identifying and Prioritizing High-Potential Regions for Electric Truck Deployments



TECHNOLOGY

To assess where electric trucks make the most sense to deploy, one must first appreciate the unique characteristics of the technology itself. This includes implications for range and benefits compared with diesel vehicles related to regenerative braking and electricity as a "fuel."

Range

The average range of the **battery electric trucks expected to be on the market within the next three years** is 286 miles/460 kilometers. Though it's unclear if the manufacturer-stated ranges assume that the full battery capacity of the vehicle is usable or if it takes into consideration the fact that most manufacturers

don't want to allow the batteries to drop below a 20% state of charge. Therefore, to be conservative, we assume an actual, real world max range of approximately 229 miles/368 kilometers. NACFE **defines regional haul duty cycles** as:

- **A-B-A**, where the truck goes out to the same location and returns to base, doing this once or several times in a driving shift.
  - includes shuttles, dedicated, and dedicated fast-turn duty cycles
- **Hub-and-spoke**, which is like A-B-A, but has different B locations over a day, week, or month.
- **A-B-C-D-A,** where there are multiple pick-ups and deliveries over the course of the route with the vehicle still returning to the same base.
  - includes city, diminishing load, and milk run duty cycles

This means that locations with a prevalence of out-and-back, A-B-A type "shuttle" routes of less than 114 miles/183 kilometers each way would be prime candidates for the technology. Similarly, hub-and-spoke and A-B-C-D-A type routes under 230 miles/370 kilometers per shift or day may also be a good match for the technology. Electric trucks may also be well-positioned for fleets with dedicated A-B-A routes under 230 miles/370 kilometers each way, assuming the truck spends sufficient time at point B, since fleets could hypothetically install charging infrastructure at both the depot and the destination facility, provided a compelling business case exists and that utilization of the infrastructure would be high enough to justify the costs.

Routes at the outer ranges of these distances would likely need to be located in relatively flat geographies, since steep grades require more power to climb, thereby reducing the manufacturer-provided vehicle ranges, which tend to be based on ideal conditions (e.g., empty trailer, flat or downhill grades, etc.). Telematics systems and data trackers, paired with elevation data, can be used to determine where "hot spots" exist with many routes typically falling within this range. RMI and NACFE are actively collaborating with Geotab and others to identify these "hot spots." These ranges are specific to the state of the technology today, though it should be noted that we expect the range of electric trucks to increase over time, as battery technology improves and prices come down.

Fleets should also consider prioritizing regions with more temperate climates, as extreme weather can negatively impact battery performance. Extreme weather can also result in more auxiliary loads related to driver comfort, such as heating and cooling the cab, which increases electricity demand on the battery and therefore also decreases range. **Data** shows that EVs maximize their range when operating in 70°F/21°C weather, with range decreasing as temperature increases or decreases. Prolonged exposure to high temperatures has also been found to accelerate the rate of battery degradation, which is another reason fleets may prioritize temperate climates for electric truck deployments.

Regenerative Braking

Another unique attribute of electric truck technology to consider is regenerative braking. This feature is an energy recovery mechanism that uses the vehicle's motor as a generator to capture and store its otherwise-lost kinetic energy when braking. This gives electric trucks a fuel efficiency advantage over traditional internal combustion engine vehicles in some environments because it makes the inefficient process of braking less wasteful. However, the experience of EV operators to date is that the benefits of regenerative braking are very situational.

Energy recovery is typically optimized in more smooth, consistent, somewhat slow braking events, which allow the energy to be recovered rather than lost as heat to the friction of the brakes. In addition, the process of capturing the energy and putting it into the batteries can vary significantly from vehicle to vehicle, depending on the efficiency of the generator (motor), inverter, and wiring. However, even in situations where energy is not very efficiently recovered, fleets may still benefit due to the reduced wear (and therefore maintenance) on brakes while slowing.

Terrain also impacts the effectiveness of regenerative braking. For example, an on-highway truck spending most of its time at speed on a flat grade through Kansas may not have much regenerative braking opportunity. Conversely, that same truck running a route down the Rockies into Grand Junction, Colorado, may be able to use regenerative braking nearly constantly to regulate speed while continuously charging the battery.

In addition to these performance benefits from regenerative braking, electric trucks also have an advantage over diesel counterparts in high-traffic conditions because they do not "idle" the same way internal combustion trucks do. In other words, while the truck may still be expending energy in order to power auxiliary loads, there is no motor that requires energy to run while the truck is stopped. Therefore, fleets with trucks operating in and around regions known for particularly bad congestion, such as **Boston, Chicago, Philadelphia, New York, DC, and LA**, make prime candidates for replacing diesel trucks with electric models.

And because regional haul routes tend to involve more highway than urban driving, *corridors* with high congestion levels, such as I-5 and US-101 in California and the Brooklyn Queens Expressway and I-95 in New York, should also be prioritized. These congestion-heavy corridors tend to be near population centers, making the technological hotspot coincide with the public health and environmental justice hotspot (described in detail in the *Needs* section below).

Electricity as a "Fuel"

The most obvious technological difference between electric and diesel trucks is the fuel source. In fact, one of the biggest selling points of electric vehicles is how much cheaper (and less volatile) their energy source—electricity—is compared to diesel. For example, while the **average retail fuel price** of diesel in the United States was US$2.71 per gasoline gallon equivalent (GGE) in January 2020, the average price of electricity was US$1.19 per GGE. (And that's based on residential electricity rates, which tend to be more expensive than rates for commercial and industrial customers, so the savings for commercial fleets are likely even higher.)

Diesel prices certainly vary across the continent, but the price of electricity varies even more widely state by state, province by province, and utility provider by provider, with the **average commercial retail price** in April 2020 ranging from 7.53 cents per kilowatt-hour (kWh) in Oklahoma to 16.67 cents/kWh—more than double—in Vermont. (Prices are even higher in Alaska and Hawaii.) While fleets with geographically diverse operations may be tempted to prioritize electric truck deployments in regions with the lowest electricity prices, the metric that should truly be used for evaluation is which locations have the biggest savings potential *compared to diesel fuel*.

When considering deployments of electric trucks, fleets should be sure to understand the expenses they'll face for charging, including not only the electricity itself, but also the cost of the charger, software, and installation (if the fleet chooses to own the electric vehicle supply equipment [EVSE]) or the markup for these expenses and an administrative fee (if the fleet chooses to procure electricity via a charging-as-a-service model).

In addition to the cost savings themselves, fleets can also expect less volatile prices by switching to electricity since prices are highly regulated and less subject to market fluctuations than diesel. That said, it is important to note that electricity bills include more than volumetric charges by kilowatt-hour and can also include additional fees such as demand charges and time-of-use (TOU) rates. Therefore, fleets should carefully review the full tariff structure in each of their operating areas.

Fleets may also want to prioritize deployments in areas where the local utility has put a moratorium on demand charges, such as is the case in Southern California Edison's (SCE) territory, or proposed replacing them with some sort of subscription rate, as has been proposed by Pacific Gas and Electric (PG&E).

Fleets should be aware that demand charges will likely be more of a challenge for small deployments in which the charge cannot be spread over multiple vehicles; for fleets with operations that require multiple trucks to charge at the same time; for fleets that do not actively manage demand or that may accidentally charge multiple trucks at the same time; and for quick-turn operations that necessitate fast charging, which requires higher power levels. They may also wish to prioritize regions where TOU rates are not mandated or do not conflict with the necessary charging times of vehicles given their operational patterns.

NEED

In determining where to prioritize regional haul electric truck deployments, fleets should consider not only which regions play to the unique strengths of the technology itself, but also where there is the biggest need for this technology. Where is there potential to do the most good and have the biggest impact?

Air Quality

Heavy-duty internal combustion vehicles are the **largest contributor to mobile source emissions of nitrogen oxides (NOx)**. These emissions negatively impact human health and also react with volatile organic compounds in the presence of sunlight to form ozone. In fact, heavy-duty trucks are expected to be one of the largest mobile source contributors to ozone in 2025. In California, for example, as much as **70% of smog-causing pollution and 80% of particulate matter** come from diesel trucks, even though they make up just 7% of the state's 30 million registered vehicles.

And while vehicles have gotten much cleaner in recent decades—so much so that it now takes over 70 current model year trucks to match the emissions of a single truck from early 2002—there is still plenty of room for improvement, particularly in areas considered in "nonattainment" with National Ambient Air Quality Standards. These regions struggling with air pollution have the most immediate benefits to gain by transitioning to zero-emission vehicles. Fleets should prioritize deployments in these pollutant nonattainment areas, particularly those with large populations.

Equity and Environmental Justice

Focusing on high-pollutant areas not only benefits public health, but it also helps to advance equity and environmental justice. Historically disadvantaged communities are more likely to be located near truck-traffic corridors and therefore more likely to breathe toxic vehicle emissions. Thus, they are **disproportionality impacted by air and carbon pollution** and more likely to experience higher rates of asthma, lung and heart disease, and chronic bronchitis. Researchers estimate that **over 9,460 premature deaths** in the United States alone are linked to diesel emissions each year. This inequity has particularly disastrous impacts during a health crisis like COVID-19. In fact, **research from Harvard** shows that an increase of one unit of fine particulate pollution is associated with an 8% death rate increase among COVID-19 patients.

Greenhouse Gas Emissions and Climate Action

In addition to eliminating tailpipe air pollutants such as NOx, ozone, and particulate matter, electric trucks also dramatically reduce GHG emissions compared with diesel trucks. According to the **EIA**, freight trucks currently account for about 21% of the US transportation sector's energy-related carbon dioxide emissions and over 7% of all energy-related carbon dioxide emissions. As such, many states, provinces, cities, and businesses are realizing that they can't meet their ambitious climate and sustainability goals without tackling emissions from freight movement, and electric trucks are one of the most promising ways to reduce emissions from heavy-duty transportation. And although **electric delivery trucks already offer significant reductions in life-cycle global warming emissions in all regions of the United States**, the exact impact this technology has on emissions depends on the energy mix of the local electricity grid.

In other words, although electric trucks have no tailpipe emissions, they do still generate emissions upstream at the power plant used to generate the electricity. And how electricity is generated varies from region to region, with some areas boasting a large supply from clean, renewable sources like wind and solar while others still rely more heavily on fossil fuels like coal and gas. Therefore, fleets may want to prioritize near-term electric truck deployments in regions with cleaner electricity grids since this is where the technology will immediately support the largest reduction in GHG emissions. This is particularly true for fleets with climate and/or sustainability goals.

In the long term, the GHG emissions benefits of electric trucks across the continent are expected to grow as states, provinces, cities, utilities, and businesses switch to more economic and less polluting electricity sources. This is great news for fleets, as their investments in electric trucks will continue to get cleaner as they age.

An additional reason to prioritize electric truck deployments in regions with high renewable energy generation is that, depending on when and where they are charged, these vehicles can help better utilize renewable resources by avoiding having to curtail them, thereby improving their economics. While these sorts of grid benefits are difficult for fleets to capture, they are an important consideration as policymakers work to green the grid and help bring more renewables online.

It should also be noted that end of life pathways for batteries (including reuse, repurposing [second life], materials recovery [recycling], and disposal) are an ongoing challenge for the industry, particularly when it comes to life-cycle greenhouse gas emissions. Even when recycled, salvaging is only partially effective at harvesting useful materials and can often be complicated, energy-intensive, and costly. Furthermore, access to and mining of cobalt remains a **geopolitical, human rights, and environmental concern**. For these reasons, fleets with ambitious climate and/or sustainability goals may eventually wish to prioritize regions with local battery recycling facilities. These do not yet exist at any appreciable scale in North America. However, California is working to **promote EV battery recycling**, so fleets can expect facilities to be developed in that region in the coming years.

Freight Flow

In prioritizing regions for electric truck deployments, fleets may also want to consider the level of freight movement—both currently and that expected in the future. According to the US Department of Transportation, nationwide **freight movement in the United States is expected to increase by nearly 50% by 2045** compared with a 2012 baseline. And **regional haul operations in particular are growing**.

While freight activity may be a sort of proxy for the air pollution and GHG emissions challenges mentioned above, it also highlights where freight movement is concentrated and therefore where fleets are most likely to influence their peers and help the industry as a whole move forward. That is, as electric trucks are deployed in a particular region, additional fleets will become more familiar with this technology due to increased visibility on the road and at local industry events and may therefore be more likely to deploy it themselves. This phenomenon, known as the "contagion effect," "social diffusion effect," or "seeding" has been experienced by many industries, including **rooftop solar**.

The good news here is that regions with high levels of freight activity—those most in need of electric trucks—are more likely to experience this phenomenon. Therefore, fleets that deploy electric trucks in these regions are more likely to catalyze this social diffusion, thereby increasing their impact. And not only does this diffusion help support electric truck deployments where it is most needed, but it also increases the likelihood that supply chains and complementary service industries (such as charging, maintenance, etc.) build up in these regions, thereby benefitting the fleets themselves.

Fleets may also want to prioritize regions with high levels of freight activity since long term, these regions may be most likely to require expensive grid upgrades to meet the increasing electricity demand from increasing deployments of electric trucks. Therefore, fleets that invest in deployments in these regions early are less likely to experience costly infrastructure upgrades or backlogs in the future.

SUPPORT

Finally, and perhaps most importantly, fleets should consider where electric trucks have the most support when determining where to prioritize their deployment. Support can include government mandates, various incentive programs, and even personnel trained to work with these vehicles.

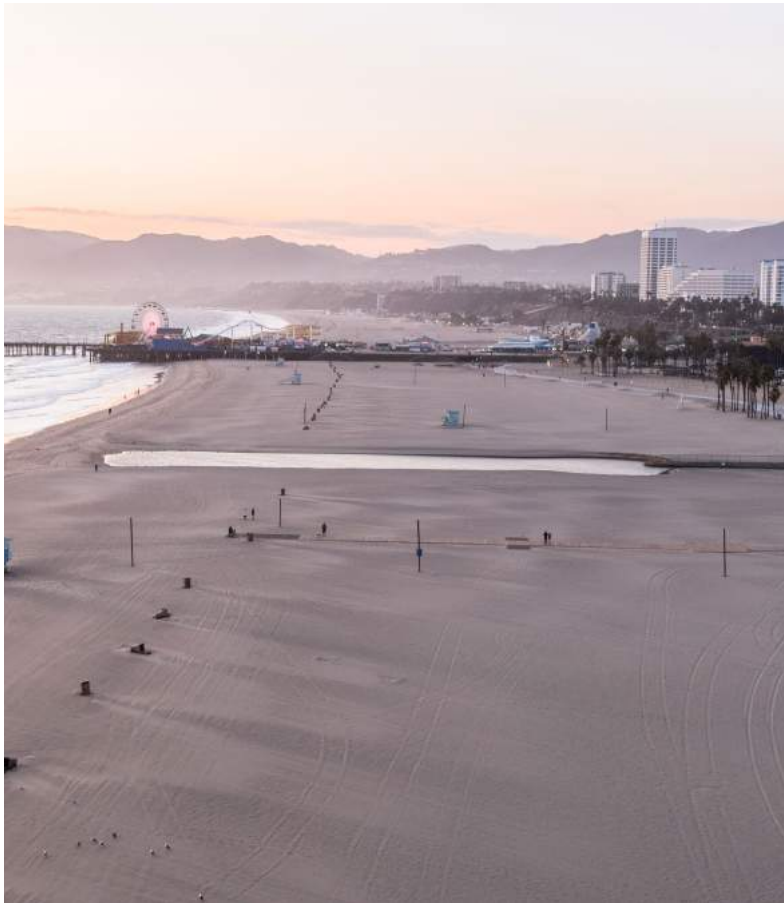
Mandates

The most obvious regions fleets will want to target for electrification are regions that have implemented zero-emission vehicle mandates. For example, California's recently passed **ACT rule** requires an increasing percentage of truck sales in the state to be zero-emission—a move that is expected to **save at least US$7 billion over the next 20 years**. Experts also anticipate the rule will remove more than 17 million metric tons of carbon dioxide and 60,000 tons of hazardous nitrogen oxides from the atmosphere and prevent more than 900 premature deaths, delivering at least US$9 billion in public health benefits.

While this rule is focused on truck maker sales rather than fleet purchases, the California Air Resources Board (CARB) is considering a **complementary regulation** that would require larger fleets in the state to transition to electric trucks year over year. Although California may be the only state with these sorts of mandates on the books or officially under consideration, it is **in talks with seven states and the District of Columbia** to cooperate on electric trucks.

And in July 2020, 15 states and the District of Columbia, which collectively account for **almost half of the US economy and nearly 40% of goods moved by truck** (by value), signed an **MOU** that set goals of 30% zero-emission medium- and heavy-duty vehicle sales by 2030 and 100% by 2050. The MOU committed these jurisdictions to develop an action plan to "identify barriers and propose solutions to support widespread electrification of medium- and heavy-duty vehicles." The MOU cites California's ACT rule as a strategy that will be considered for inclusion in this action plan. As such, fleets can anticipate more statewide zero-emission mandates in the coming years.

Some local jurisdictions are also mandating zero-emission commercial vehicles. Multiple European cities have already banned or eliminated internal combustion vehicles in city centers, and Santa Monica, California, is bringing this trend to the United States. The city recently announced plans for the **country's first zero-emission delivery zone**, which would require every good delivered in the region to be transported in a zero-emission vehicle (ZEV). The city is currently developing a pilot project, which includes a one-square-mile area of the city's downtown corridor.



State/Province Incentives

In addition to the mandates mentioned above, many states and provinces have developed incentive policies and voluntary programs to help encourage electric truck adoption. While total cost of ownership analyses indicate that electric trucks may already be cheaper than diesel counterparts over the life of the vehicle, many fleets—particularly smaller fleets and owner-operators—still struggle with the higher initial purchase price of these electric vehicles, which can cost, on average, **twice as much** as a diesel fuel alternative. In fact, this high upfront purchase price is the **most commonly cited barrier** for fleets considering electric truck adoption.

Technological developments—particularly around battery density and costs—are helping to reduce this premium, and economies of scale due to growing demand are expected to further address this issue. Policymakers are also helping by directing public and electric utility funding to help reduce the high upfront costs associated with electric trucks and their requisite charging infrastructure, the price of which is also a frequently cited barrier among fleets considering electric truck deployments.

Some programs exist at the federal level, such as the US Federal Transit Administration's Low or No Emission Program or Canada's Zero-Emission Vehicle Infrastructure Program. However, particularly in the United States, **most federal dollars are usually reserved for research and development and pilot projects, while state and local funds focus on vehicles and infrastructure**, including funding from the VW Settlement (i.e., Environmental Mitigation Trust). Not all states have finalized their plans for this funding yet and not all VW mitigation fund plans include funding for medium- and heavy-duty vehicles. However, there is already over US$300 million available from 38 states' VW settlement plans that can be used for zero-emission trucks. That said, public funding varies drastically by region, with some jurisdictions committing significant budgets to support electric truck adoption while others have done little or nothing.

In addition to VW funding, some states are passing additional innovative incentive programs to support electric truck deployments. The most popular of these state programs have been voucher incentives such as California's **Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project** (HVIP) and **On-Road Heavy-Duty Voucher Incentive Program** (VIP) and New York's **Truck Voucher Incentive Program**, all of which help cover the incremental cost between a new diesel-powered truck and a new battery-powered vehicle of the same type and class.

Voucher programs have been proven to be among the **most effective policies** for incentivizing clean trucks because of their ease of use and administration. These voucher programs have been so successful at the state level that the National Zero-Emission Truck Coalition—a group of America's biggest truck equipment manufacturers, suppliers, and key stakeholders, such as Cummins, Daimler, PACCAR, Eaton, Tesla, and Rivian along with CALSTART and the Environmental Defense Fund—recently **called for a national point-of-sale incentive program** to support the production and deployment of zero-emission trucks in the United States.

Some states and provinces also offer electric truck incentives beyond vouchers, including other types of grants or rebates, income tax credits, sales tax exemptions, and loans. These include British Columbia's Specialty Use Vehicle Incentive (SUVI) program and Québec's Écocamionnage program. Additionally, though not designed to directly cover the cost of the vehicle, some states have created low-carbon fuel markets to help incentivize fleets to transition to low- or zero-emission technologies. These include California's **Low Carbon Fuel Standard** and Oregon's **Clean Fuels Program**. Canada is in the process of developing a nationwide **Clean Fuel Standard**. Fleets should consider all state and

province incentives available to them when prioritizing regions for electric truck deployments.

While some states and provinces don't yet have official programs or incentives for zero-emission heavy-duty trucks in place, many are beginning to consider these sorts of options. For example, in April 2020, Colorado released a **new EV Plan**—the first from the state to include a goal for electrifying medium- and heavy-duty vehicles. Three months later, the state **announced a public process to work with the industry and community stakeholders to develop a broad set of strategies to reduce emissions from heavy-duty vehicles**. The plan is for state agencies to work with the Colorado Motor Carriers Association to develop these strategies collaboratively. If they haven't already, fleets should consider joining their local trucking association and participating in these sorts of collaborative task forces to help shape the strategies and ensure that their voices are heard.

City Incentives

Local governments have also made incentives available for electric trucks. For example, New York City launched its **Clean Trucks Program** in June 2020. The program utilizes state VW Settlement funds to make **thousands of dollars** available for fleets operating in or near industrial business zones to replace older diesel trucks with cleaner trucks including electric models.

The City of Chicago also implemented an incentive program known as **Drive Clean Chicago**, which successfully incentivized the purchase of over 280 Class 2–8 hybrid and electric vehicles before program funds ran out in 2017. Cities are also finding innovative ways—beyond financial incentives—to support medium- and heavy-duty vehicle electrification. For example, Chicago recently developed **Commercial Electric Vehicle Readiness Guidelines** to help commercial developers plan to incorporate EV charging infrastructure readiness for medium- and heavy-duty fleets into projects. Because it is **significantly cheaper to install the infrastructure for electrification in new construction than it is to retrofit existing structures**, these guidelines can help fleets save significant money when it comes time to install chargers.

Regardless of your location, local Clean Cities Coalition leads may be able to help identify funding opportunities specific to your region.

Utility Programs

In addition to incentive programs managed directly by states, provinces, and cities, policymakers have also directed electric utility funding to help reduce the high upfront costs associated with electric trucks and charging infrastructure. In total, **over US$711 million** in utility funds has been approved across ten utilities: Pacific Gas and Electric (PG&E), San Diego Gas and Electric (SDG&E), and Southern California Edison (SCE), in California; Rocky Mountain Power in Utah; and Central Hudson Gas & Electric Corporation, Consolidated Edison (ConEdison), National Grid, New York State Electric & Gas Corporation (NYSEG), Orange and Rockland Utilities, and Rochester Gas and Electric Corporation (RG&E) in New York. This funding has been approved primarily to cover the equipment and construction costs associated with grid upgrades required to support new charging stations, also known as "make-ready" infrastructure.

These expenses can include new power lines, transformers, meters, conduit, and even electrical panels and switchgear. These sorts of make-ready infrastructure programs include SCE's **Charge Ready Transport** (CRT), PG&E's **EV Fleet**, and SDG&E's **Power Your Drive for Fleets**, which together plan to support charging for at least 17,990 electric medium- and heavy-duty vehicles at over 1,870 sites across California. SCE has **already broken ground** on some of its CRT infrastructure projects, even amid the COVID-19 pandemic.

It makes sense for utilities to focus on charging infrastructure for fleets since they **can bring large amounts of demand online quickly**. Therefore, it came as little surprise when New York recently approved a **US$701 million make-ready EV charging infrastructure program**, part of which will require the state's investor-owned utilities (including Central Hudson, NYSEG, National Grid, O&R, and RG&E) to develop medium- and heavy-duty fleet make-ready pilot program implementation plans. The directive also requires the utilities to create a "Fleet Assessment Service" that includes site feasibility and rate analysis, tailored to each depot location.

This will aide fleet owners in identifying cost- and time-saving synergies and help them understand all available rate options as well as a "reasonably

certain range of expected costs based on charging behavior." This service may also help fleets better understand where excess grid capacity exists and where minimal service upgrades would need to be made—information that many have struggled to ascertain previously.

In addition to utility programs that provide direct investments to support infrastructure buildout, fleets should also consider differences between utilities having to do with electricity tariffs. That is, fleets should understand whether their local utility offers or requires TOU electricity rates or demand charges and how these may impact their costs to charge their vehicles. For example, Con Ed, through its statewide **SmartCharge NY** program, seeks to incentivize electric trucks and off-peak charging by offering much lower electricity rates to fleets that are able to charge their vehicles during "off-peak" hours. Fleets that plan to charge in the evenings should certainly prioritize electric truck deployments in regions that offer TOU rates.

Some utilities are also beginning to plan for public charging to support medium- and heavy-duty electric trucks. This is the case along the Pacific Coast, where the **West Coast Clean Transit Corridor Initiative** (WCCTCI)—a collaboration among nine electric utilities and two agencies representing more than two dozen municipal utilities (including Los Angeles Department of Water & Power, Northern California Power Agency, PG&E, Pacific Power, Portland General Electric, Puget Sound Energy, Sacramento Municipal Utility District, SDG&E, Seattle City Light, SCE, and Southern California Public Power Authority)—commissioned a study on building out charging infrastructure along 1,300 miles of I-5 to support medium- and heavy-duty electric trucks through Washington, Oregon, and California, from the Mexican to the Canadian border. WCCTCI expects this plan to be a **template for other states**.

As mentioned earlier, the focus of this report is on return-to-base operations, where charging would likely be privately owned and located behind the fence of the depot. However, we understand that fleets focused on resiliency may wish to prioritize regions where local utilities are planning for this sort of publicly accessible charging infrastructure that can be used in an emergency by fleets that invest in electric truck technology and find they're usually able to charge at their depot but occasionally need (or appreciate the redundancy of) additional charging options.

Public charging can also help support fleets that can't or don't want to own their own charging infrastructure (e.g., due to real estate challenges where fleets lease their facility and can't agree with their landlord on infrastructure investments and/or when fleets are planning to move facilities in short- to medium-term and don't want to invest in infrastructure at their current facility).

Fleets may also want to consider which utilities have (or are in the process of developing) transportation electrification plans (TEPs). States requiring utilities to develop these plans was **one of the top EV trends of 2019**. And while not all TEPs include plans for electrifying medium- and heavy-duty vehicles, the existence of a TEP can offer a good indication that these utilities are the most likely to have thought through vehicle electrification, to be prepared to work with fleets on charging infrastructure projects, and to have rate structures designed to support EV charging. And just because a utility might not have a commercial vehicle electrification program (yet!) doesn't mean it hasn't given it some thought, even if its strategy may not be as sophisticated as those that have progressed to the comprehensive plan and/or program stage.

Training

Finally, fleets may also want to consider where they are most likely to be able to find trained staff to drive, manage, and service electric trucks. This is why the **Volvo LIGHTS** demonstration project is partnering with local colleges such as Rio Hondo College and San Bernardino Valley College, which are both designing maintenance technician training programs to support workforce development in the region. This sort of workforce development is necessary to support the burgeoning electric truck market, which **requires technicians with an understanding of high voltage environments**.

OTHER CONSIDERATIONS

Due to geographical variations in density, certain regions (e.g., the Northeast United States) have more routes with shorter distances, while others (e.g., the South) tend to have more routes with longer distances. We did not account for this in this analysis because while these trends are broadly true, it really depends on the unique operations of the fleet. For example, some may run long regional routes in the Northeast and others may run relatively short routes in the South.

Though not included in this framework because not unique to regions or corridors, fleets should also consider their unique duty cycles, including dwell time per day, when determining where electric trucks are best suited to replace diesel models. More information on these considerations can be found in previous **electric truck guidance reports** and in NACFE's ***Run On Less Regional* report**.

Finally, while we did not include explicit consideration of economic development potential in this analysis, many regions are interested in pursuing trucking electrification to help attract distribution or manufacturing centers as well as build up local supply chains.

3 ANALYSIS

Using the above framework, we completed an initial analysis of US and Canadian regions. Due to the availability of data, as well as significant distinctions at the policy level, we collected and analyzed data at the state and provincial level. Therefore, some indicators mentioned above that are unique to smaller scales—such as city policies, utility programs, traffic congestion along certain corridors, and grades along routes—were not considered in this initial analysis. This is not intended to imply that these factors are not important. Rather, this reflects the scope and scale of the analysis. An overview of how we conducted the analysis is included below, and a more detailed description of the analytical methodology, including metrics and data sources, can be found in a separate Technical Appendix.

For this initial analysis, we selected a minimum of two indicators for each category for which data was available:

EXHIBIT 2

Indicators Examined by Category

Technology

Climate

- Where is the climate most conducive to electric trucks?
- Where is extreme heat and cold—which reduce range by adding auxiliary power loads and decreasing battery performance—less frequent?

Electricity Pricing

- Where are volumetric charges for electricity the cheapest and where do they have the biggest potential for savings compared with diesel prices?

Need

Air Quality

- Where is air quality the worst, particularly with respect to ozone?
- How many people in each of these regions are negatively impacted by this pollution?

Life-cycle GHG Emissions Benefits

- Where is the generation mix of the electricity grid the cleanest?
- Where do electric trucks represent the biggest opportunity for reducing greenhouse gas emissions, compared with diesel vehicles?

Freight Flow

- Where is the most freight being moved?

Support

Supportive Policies and Incentives

- Where are legislative and regulatory conditions most favorable?
- Where have they approved policies and incentives such as grants, rebates, income tax credits, and financing options?

Expressed Interest

- Where have policymakers expressed interest in supporting electric truck deployments?
- Where are states and provinces most committed to a successful transition to electric heavy-duty vehicles?

Funding Availability

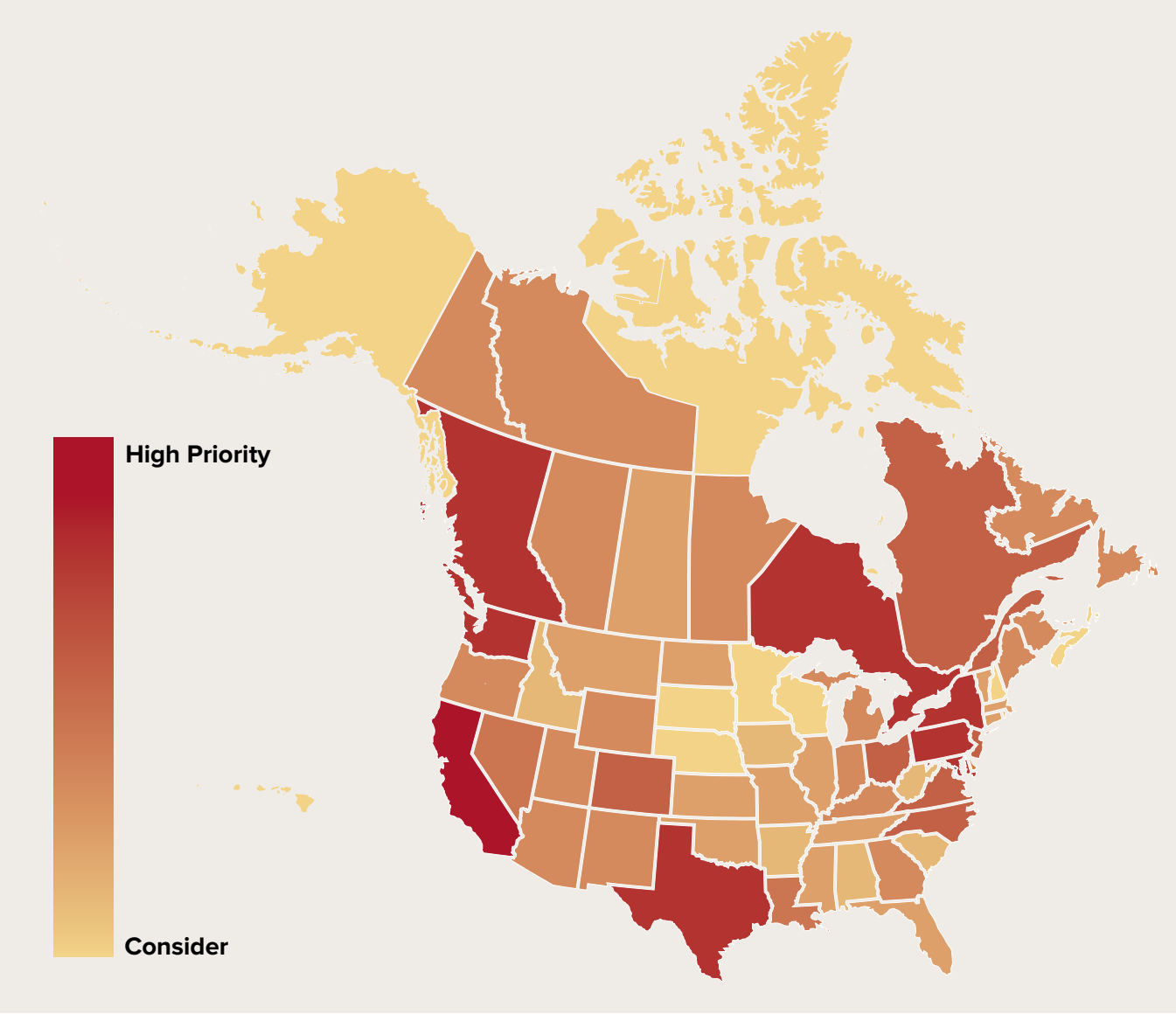
- Where has funding been set aside or made available to support electric truck deployments?
- Where have utility “make-ready” programs been approved to help with funding for charging infrastructure?

We collected and analyzed data for each of these indicators for each state and province. For each indicator, each state and province received a score depending on how favorable the data was. The scores for each indicator were then summed to give each state and province a total score for prioritization. All indicators were weighted evenly.

This methodology produced the following "heatmap" of electric truck potential by state and province, which distinguishes between regions fleets should *consider* to those that are the *highest priority* for electric truck deployments.

EXHIBIT 3

Heatmap of High-Potential Regions for Electric Truck Deployments



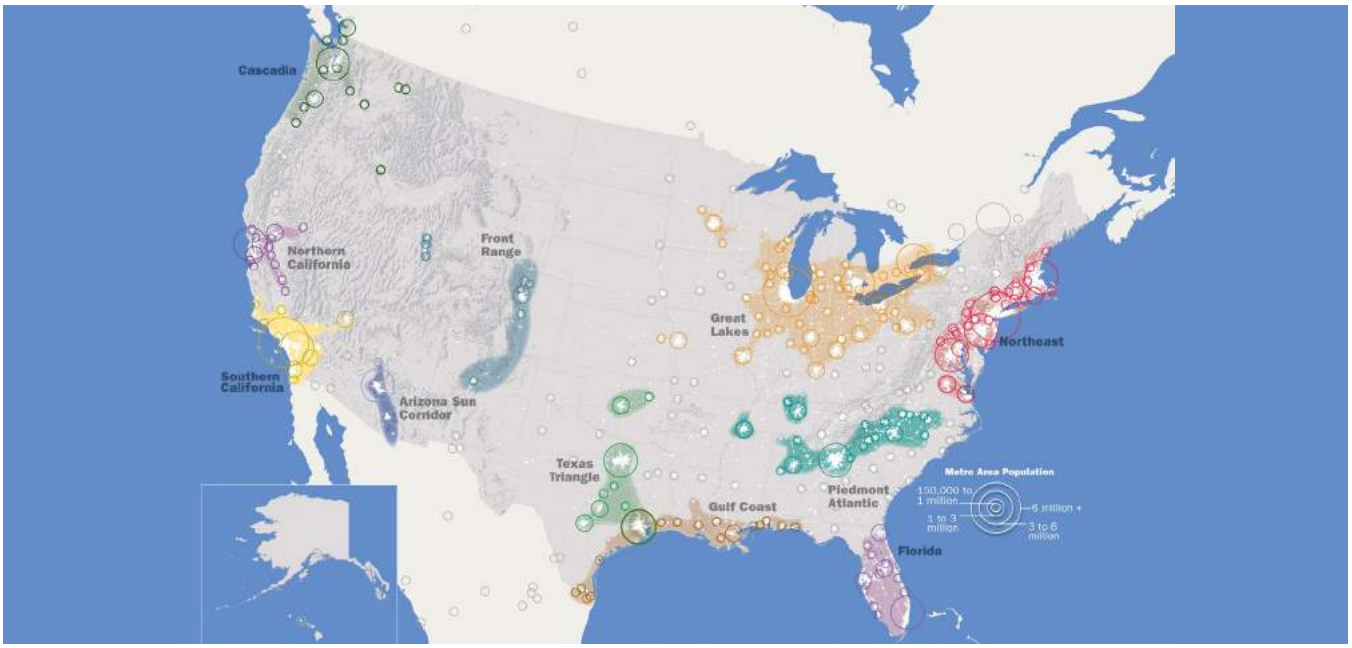
The authors note that this is an initial analysis using the regional prioritization framework. This is not a comprehensive look at every factor that influences regional potential for electric trucks, but rather, an initial attempt at answering this question of which regions exhibit the highest potential. The authors also note that this data is changing—sometimes rapidly—as has been the case with policy in particular. This analysis is meant to represent one perspective of a snapshot in time. We encourage any and all feedback from interested parties, including:

- What additional categories or indicators might we consider?
- Where might better or additional data be available?
- How might we think differently about "scoring" each indicator?
- Should we weight some indicators more heavily than others?
- At what other resolutions might we analyze this data (e.g., by utility territory, metropolitan area, US highway system, etc.)?

We are eager for feedback on the questions above and look forward to incorporating that feedback into future analyses. We also encourage fleets to develop their own methodology for assessing the indicators above across their operations. For example, while this analysis focused on distinctions between states and provinces due to data and funding availability at this level, fleets may want to assess these indicators at a scale as small as particular utility territories or as large as megaregions. The Regional Plan Association, for example, has defined **eleven emerging US megaregions** (Exhibit 4) that consist of interrelated population and employment centers that share common transportation networks. Fleets might consider focusing on these megaregions as they consider which regions hold the most promise for near-term electric truck deployments.

EXHIBIT 4

Emerging US Megaregions



Source: Regional Plan Association

4 FINDINGS

- Regions favorable for electric truck deployments are found across North America.
- The Northern California, Southern California, Texas Triangle, Cascadia, Colorado Front Range, Northeast United States, Greater Toronto, and Greater Montreal regions show particularly high potential.
- Many trucking operations are not confined to individual states or provinces, and as such, fleets should think about electric vehicle deployments at the regional level. The most important factor for geographic considerations is where the truck plans to charge, as this impacts electricity pricing and access to incentives—including those for make-ready infrastructure.
- Policies and incentives to support electric truck adoption vary drastically by region, with some jurisdictions committing significant budgets to robust incentive programs while others have done little or nothing to support electric truck adoption.
- Policymakers and advocates looking to increase adoption of medium- and heavy-duty vehicles in their regions should consider which of the framework criteria they can change. For example, while they can't change climate or topography of region, they can change supportive policies such as vehicle incentives, charging infrastructure, and utility rate structures.
- This analysis identifies the regions with the highest potential for regional haul electric trucks now. As the technology develops further, we expect even more regions to favor electric trucks.
- Fleets should work with policymakers, regulators, utilities, and other stakeholders in their region to collaboratively develop strategies to advance zero-emission trucks.

5 CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS:

- **Regional Focus** - While "corridors" tend to refer to specific high-traffic roadways that vehicles move through and along which infrastructure can be built out, "regions" refer to the overall regulatory, environmental, and market climate of particular areas. During the early stages of electric truck deployments, planning at the regional level is more important than that along specific corridors.

- **Holistic View** – In determining hotspots prime for regional haul electric trucks, the unique attributes of the technology, where it is most needed, and where it has the most support are all important components of a holistic regional assessment.

- **Highest Priority Regions** – Fleet owners with trucks operating regional haul routes of approximately 230 miles/370 kilometers or less per shift or per day in high priority regions should immediately begin planning for electric truck deployments—even if only on a pilot scale. It can take longer than a year to build out charging infrastructure and acquire vehicles, so it makes sense to start today. Those that act fast are least likely to experience challenges with grid infrastructure already being maxed out by other nearby fleets.

- **Competitive Advantage** – In deciding where to deploy electric vehicles, fleets should consider not only where electric trucks will fare well, but also where they have the strongest competitive advantage over diesel trucks.

RECOMMENDATIONS:

- **Support Deployments of Electric Trucks** – Collect real world data and lessons learned from initial deployments to refine both the framework and the analysis. As more electric trucks hit the road, fleets, utilities, OEMs, charging suppliers, policymakers, and other industry stakeholders will be able to learn from these initial deployments and use this information to better identify opportunities and overcome barriers for this technology.

- **Expand Analysis to Other Geographies** – Using the framework outlined above, conduct similar analyses for locations outside the United States and Canada. Priority considerations for additional analyses include China, the European Union, India, and Mexico.

- **Conduct Analysis at Smaller Scale** – Allow for more granular data relevant to smaller scale areas—such as utility territories, metropolitan areas, key trucking corridors, or census tracks—by performing analysis with more fine-grained resolution.

- **Share Results with Policymakers** – Present analysis and findings to policymakers to help inform plans for trucking electrification in their jurisdiction. Help identify opportunities and address challenges. Some indicators—such as climate and freight flow—are difficult or impossible to change, while policies are relatively adaptable. Enhancing regional policies to support electrification can create conditions for exponential growth in electric truck deployments which wouldn't otherwise be realized.

- **Analyze Economic Development Opportunities** – Conduct analysis of economic development opportunities for high-priority regions, including jobs, new supply chains, and local manufacturing.

ADDITIONAL RESOURCES

For more information on electric trucks and regional haul, please see the following reports from NACFE and RMI:

- **Electric Trucks: Where They Make Sense**
- **Medium-Duty Electric Trucks: Cost of Ownership**
- **Amping Up: Charging Infrastructure for Electric Trucks**
- **Viable Class 7/8 Electric, Hybrid, and Alternative Fuel Tractors**
- **More Regional Haul: An Opportunity for Trucking?**
- **Run On Less Regional Report**
- **Battery Electric Powertrains for Class 8 Regional Haul Freight Based on NACFE Run-On-Less**
- **Fuel Cell Electric Trucks: An Analysis of Hybrid Vehicle Specifications for Regional Freight Transport**
- **Defining Production**

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