Next Generation Highways

CO-LOCATING THE TRANSPORT OF VEHICLES, ENERGY, AND INFORMATION

FUTURE OF TRANSPORTATION

LOW COST & CLEAN GRID

INFRASSTRUCTURE FOR THE 21ST CENTURY

ECONOMIC DEVELOPMENT

TECHNOLOGY LEADERSHIP

NGI Consulting | September 2020
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NGI Consulting is based in Seattle, WA and is focused on helping cities, corporations, and states envision a path towards next-generation infrastructure. For more information, contact morgan@buildngi.com.


A. Preface

The United States is facing a unique moment in time that will define the economic, environmental, and social health of our country for decades to come. To rise to this challenge, we need to make investments that drive economic recovery, reduce greenhouse gas emissions, modernize our infrastructure, incentivize technology leadership, and facilitate equity. NextGen Highways are one such investment.

**NextGen Highways are highways where electric transmission lines and broadband/5G communications infrastructure are strategically colocated along the highway right-of-way.** Colocating this infrastructure is essential to fully and efficiently facilitate the electric sector’s transition to renewable energy and the transportation sector’s transition to zero-emission vehicles. In addition, colocating broadband/5G infrastructure along the highway right-of-way will help reduce the digital divide facing rural communities.

NextGen Highways would:

- Modernize our transportation, power, and communications infrastructure
- Dramatically reduce greenhouse gas emissions
- Ensure US technology leadership in high-voltage direct current power transmission, electric vehicle transportation and 5G communications
- Improve air quality and reduce noise pollution in disadvantaged communities
- Create hundreds of thousands of construction and trade jobs

Importantly, NextGen Highways would align the efforts of a number of different stakeholders and policy makers.

Transmission advocates have been looking to develop inter-regional transmission.¹ Clean transportation advocates have been looking to enable charging and fueling infrastructure in transportation corridors.² Autonomous and connected vehicle advocates have been looking to pilot communications infrastructure.³ Environmental and social justice advocates have been seeking to improve air quality in the most heavily affected regions, which are often transportation corridors.⁴ And broadband advocates have been seeking to utilize the highway right-of-way, particularly in rural areas.⁵

**This white paper lays out the NextGen Highways concept. It details the possible benefits, provides motivational context, and addresses some of the questions that arise. The goal is to initiate a more thorough stakeholder examination of the NextGen Highways concept and to facilitate the cooperation and investment needed to put this concept into action.**

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¹ https://acore.org/macro-grid-initiative/
² https://laincubator.org/tepstimulus/
³ https://westcoastcleantransit.com/
⁴ https://www.engadget.com/cavne-michigan-corridor-221520625.html
⁵ https://www.sierraclub.org/articles/2020/05/bold-clean-transportation-stimulus-for-jobs-health-and-climate
B. What are NextGen Highways?

NextGen Highways are highways where the highway right-of-way is used for the strategic colocation of underground (and some overhead) power transmission, electric vehicle charging capacity and broadband/5G communications infrastructure. They are an extension of how the transportation right-of-way is used in dense urban cores where power, telecommunications, water, sewer, and gas infrastructure are collocated beneath major streets.

While conceptually simple, there are historical reasons that power infrastructure has not utilized the highway right-of-way. One major reason is that underground AC transmission is inefficient over long distances and overhead power transmission poles represent a safety risk to vehicles that depart the roadway at highway speeds. Another historical reason is the challenge to accurately document, and later find, underground infrastructure. NextGen Highways take advantage of recent technological advances—underground HVDC power transmission and digital representations of the built environment—to overcome these historical barriers to the colocation of vehicles, energy, and information within a single right-of-way.

As proposed in this paper, NextGen Highways will:

1. Use a portion of the federal interstate right-of-way to construct transmission facilities, including a national underground HVDC transmission grid
2. Strengthen the electric grid in key transportation corridors, thereby increasing the grid’s capacity to support zero-emission medium and heavy-duty vehicles
3. Deploy broadband and 5G communications infrastructure in parallel with the above
C. Why NextGen Highways?

NextGen Highways will be the platform upon which the future of transportation, energy, and information are built. NextGen Highways will enable decarbonization of the power and transportation sectors, support environmental equity, create hundreds of thousands of jobs and lead to the development of new technologies and services that can be exported globally.

Figure 1. Benefits of NextGen Highways.

NextGen Highways will be the largest infrastructure project in 50 years. They are an investment in America’s continued prosperity and global leadership. Critically, they will:

- Strengthen the grid, increase grid resiliency, and reduce energy costs
- Expand the number of locations where clean energy generation assets can be built
- Enable electric vehicle charging and hydrogen fueling stations to be rapidly scaled to support transportation electrification goals
- Improve air and noise quality in our communities, especially in low/moderate income and minority communities which are often adjacent to major highway corridors
- Deploy the 5G and broadband infrastructure needed to reduce the digital divide between rural and urban areas and to support the continued digitalization of our economy
- Deploy the 5.9GHz infrastructure to enable connected and autonomous vehicles
- Create construction jobs, trade jobs, and professional service jobs of all types
D. NextGen Highways and Power Transmission

1. A National HVDC Transmission Grid

The National Renewable Energy Lab’s (NREL) Interconnection Seam Study\(^7\)\(^8\) investigated the benefits from the construction of a national high-voltage direct current (HVDC) grid that would strengthen ties between the electric grids serving the eastern and western United States. Importantly, the ‘Seams Study’ found that, for every dollar invested in a national HVDC grid, American households and businesses would receive one-to-two dollars of net benefits through lower electricity costs. Additionally, a national HVDC grid would allow for higher penetrations of renewable energy (as high as 85%) and would increase grid resiliency during unique weather events, such as the August 2020 heat wave that led to rolling blackouts in California.

Figure 2 illustrates how select parts of the existing federal highway system align well with the HVDC grid identified by the Seams Study. The black lines in the figure represent the hypothetical HVDC grid that was studied by NREL. The dark blue lines represent the parts of the existing federal highway system that could be used for the construction of a nearly equivalent HVDC grid. As can be seen, there is a strong overlap between the two. Note, the gray, yellow, orange, and red lines represent alternating current (AC) transmission capacity that would be needed to support the national HVDC grid contemplated in the NREL Study.

Figure 2. Alignment of existing federal highway system with the national HVDC grid evaluated in NREL’s Interconnection Seam Study. This figure is modified from Figure 5 of a paper describing NREL’s Interconnection Seam Study.\(^7\)

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\(^7\) https://www.nrel.gov/analysis/seams.html
While a national HVDC grid could be constructed without utilizing the existing right-of-way of the federal highway system, doing so would require using land that has not already been disturbed, which would pose challenging environmental, land-use and community resistance issues. More importantly, it would not adequately prepare for the electrification of transportation.

2. The Broad Need for Transmission

The gray, yellow, orange and red lines in Figure 2 are indicative of the broad need for transmission investments across the United States. Here again, existing transportation infrastructure (federal interstates and major state highways) can be used to support the development of new transmission. For example, I-80 aligns well with red lines in Iowa, Illinois and northern Indiana. I-94 aligns well with the yellow lines through North Dakota, Minnesota and I-94, SR-29, and I-43 align well with the yellow and orange lines through Wisconsin. And I-40 aligns well with orange and red lines in Oklahoma and Arkansas.

When considering the need for transmission development, it is worth highlighting how transmission constraints are already impacting the build out of renewables across the United States. At each stage in the renewable development process, a significant fraction of renewable capacity becomes non-viable due to transmission constraints. A good example of this is the most recent general interconnection process for Midcontinental Independent System Operator’s (MISO). At the start of the process, there were 5000 MW of renewables approved for interconnection and the estimated transmission upgrade costs were $10-100 million dollars. At the end of the general interconnection process only 250 MW of renewables were moving forward, and the estimated transmission upgrade costs were $100 million, as shown in Table 1.9 By the National Resources Defense Council’s estimate, only 7% of the renewable projects in MISO’s interconnection queue can be accommodated.

<table>
<thead>
<tr>
<th>Interconnection Stage</th>
<th>Renewable Capacity</th>
<th>Est. Transmission Upgrade Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approved for Interconnection</td>
<td>5000 MW</td>
<td>$10-100 M</td>
</tr>
<tr>
<td>Technical Studies</td>
<td>1500 MW</td>
<td>$100’s of M</td>
</tr>
<tr>
<td>Moving Forward</td>
<td>250 MW</td>
<td>$100 M</td>
</tr>
</tbody>
</table>

Transmission constraints also increase land costs for renewable projects by limiting the number of available interconnection locations to connect these projects to the grid. This scarcity in viable interconnection locations creates competition for scarce land, which in turn significantly increases land costs.10

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9 https://energynews.us/2020/01/10/midwest/as-bottleneck-stymies-projects-midwest-groups-call-for-transmission-reforms/
10 Conversations author had with members of sPower at Solar Power International in September 2019
3. Use of the Highway Right-of-Way for Power Transmission

According to the United States Government Accountability Office, “currently, federal statutes, as well as federal and state guidance, encourage the collection of new transmission lines along existing transportation and other rights of way”\(^\text{11}\).

Despite supportive federal policy there have been several historic barriers to colocating new transmission within the highway right of way. One barrier has been the concern for vehicle safety associated with the risk of vehicles colliding with overhead transmission poles. Another barrier has been the potential need to move existing transmission infrastructure when a highway is expanded or altered. Finally, colocating transmission in highway corridors has been hampered by inconsistent highway right-of-way policies among different states. Though some states encourage the use of the highway right-of-way for transmission, other states prohibit all utilities (electric, gas, communications) from following the highway right-of-way.

As envisioned, NextGen Highways would address the safety concern (and additional aesthetic concerns) by making greater use of underground transmission and by ensuring the well-planned strategic placement of above-ground lines in coordination with transportation authorities. Specifically, NextGen Highways would utilize underground HVDC transmission lines for the construction of a national transmission grid and would utilize underground transmission lines (AC or DC) in urban areas. For AC transmission lines outside of urban areas, NextGen Highways would either locate the transmission support structures sufficiently far from travel lanes or follow the highway on private land as close to the highway right-of-way as possible, as has been successfully done for a number of CapX 2020 projects in Minnesota and Wisconsin\(^\text{12}\).

Coordinated planning between transportation and energy agencies – which is a prerequisite for NextGen Highways – would address the safety and other concerns that have thus far discouraged colocation of transmission lines in highway corridors. Further coordination among states could address the inter-state inconsistencies that might otherwise impede the development of NextGen Highways.

Finally, as discussed in the next section, having new transmission lines follow the highway right-of-way in key transportation corridors is an obvious way to cost-effectively support transportation electrification, especially for medium and heavy-duty vehicles.

\(^{11}\) https://www.gao.gov/assets/100/95342.pdf
\(^{12}\) http://www.capx2020.com/
E. NextGen Highways and Transportation Electrification

1. Transportation Electrification Requires Grid Investments in Transportation Corridors

Transportation electrification will lead to electric grid constraints in both rural and urban areas. The West Coast Clean Transit Corridor study\textsuperscript{13} found that the electric grid cannot support the charging of heavy-duty electric vehicles along Interstate-5. The study also found that the electric grid cannot support the charging of medium-duty electric vehicles in rural areas along Interstate-5. Similarly, a 2019 Rocky Mountain Institute study with Seattle City Light revealed that transit electrification will require increasing the substation capacity for at least nine of the eleven substations that serve bus depots in Seattle City Light’s service territory.\textsuperscript{14} The study also found that the electrification of private fleets would likely require an increase in feeder capacity for roughly half of the feeders serving major trucking corridors.

Figure 3, from the Rocky Mountain Institute study, puts the charging challenge in perspective. A single mega-charger for a Class 8 truck will draw the same amount of power as 1,200 homes. In greater perspective, an electrified future a truck stop in a rural area could be asked to deliver 10,000-30,000 homes worth of power using an electric grid that was built for the truck stop and a few dozen adjacent homes and businesses. For this reason utilities and transmission developers have already started to think about building new transmission lines to serve such truck stops.\textsuperscript{15}

\emph{Figure 3. Power requirements to charge heavy-duty trucks. Infographic is taken from Rocky Mountain Institute’s transportation electrification study for Seattle City Light.}\textsuperscript{14}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{power_requirements}
\caption{Power requirements to charge heavy-duty trucks.}
\end{figure}

\textsuperscript{13} https://westcoastcleantransit.com/
\textsuperscript{14} https://rmi.org/insight/seattle-city-light/
\textsuperscript{15} Conversations NGI Consulting had with transmission operators and utility regulators in April and May 2020
2. NextGen Highways will Proactively Strengthen the Grid in Transportation Corridors

In addition to facilitating the construction of a national HVDC grid, NextGen Highways could proactively provide the required grid upgrades in both urban and rural areas. Figure 4 shows active and planned highway construction in the Los Angeles metropolitan area. With knowledge of the transmission grid, the map reveals what could have been a large opportunity to support transportation electrification. Recent and planned improvements for the I-5 and I-710 freeways could have connected a significant source of power (the DC Pacific Intertie at the northern end of the highlighted segment of the I-5 freeway) with a major transportation electrification and air pollution target (the Port of Los Angeles and the Port of Long Beach at the southern end of the I-710 freeway).

Figure 4. A Missed Opportunity: recent and planned highway construction in Los Angeles could have been used to build transmission from the DC Pacific Intertie to the I-710 corridor and the Ports of Los Angeles and Long Beach. The figure is modified from a figure in The Press Enterprise.

Similarly, NextGen Highways offer opportunities for planned transmission projects in more rural areas. An example is the Energy Gateway Project, which is depicted in Figure 5. The Energy Gateway project is a typical transmission project for the largely rural areas of Idaho, Utah, and Wyoming. The proposed route (grey lines in the Figure 5) seeks to avoid urban areas and, as a result, lies far from the major highways in the area (I-80, I-84, and I-15). By comparison, transmission developed along I-80, I-15, and I-84 (green lines in the figure below) would move generation to key load pockets and strengthen the grid along the interstate at the same time.

3. **NextGen Highways are a Transportation Electrification Platform**

NextGen Highways will construct a strong and modern electric grid in key transportation corridors. This platform will enable electric vehicle chargers, hydrogen generation stations, or even wireless chargers to be more rapidly connected to the grid without expensive and time-consuming transmission upgrades. As a result, NextGen Highways will enable public-private partnerships where the public sector provides the platform and the private sector determines which technologies to deploy and when to deploy them. Critically, this platform will enable rapid scaling while being technology neutral.

Figure 6. NextGen Highways will provide the power platform upon which electric vehicle chargers, hydrogen stations, or even wireless charging lanes can be rapidly connected to the grid.

There are many ways to power an electric drivetrain...

...but they all require a strong grid.

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17 Figure created using Google Maps and published information on the Energy Gateway project from: https://www.pacificorp.com/transmission/transmission-projects/energy-gateway.html
4. NextGen Highways Account for the Development of DC Power Conversion Technologies

Historically, DC power conversion (converting DC power from one voltage to another) required converting DC power to AC power, transforming the voltage, and then re-converting to DC power for the end-use. Consequently, DC transmission in the highway right-of-way has been assumed not to be beneficial for providing local sources of DC power (e.g., for the DC fast-charging stations that are beneficial for light-duty electric vehicles and critical for medium and heavy-duty electric vehicles).

However, DC power conversion and DC power systems are in a period of rapid development. Advancements have been driven by commercial needs in Europe (the build out of a DC grid) and enabled by new device designs and new materials (silicon carbide and gallium nitride semiconductors). ARPA-E’s BREAKERS\textsuperscript{18} program and its CIRCUITS\textsuperscript{19} program have also contributed to the rapid development.

Notably, the International Council on Large Electric Systems (CIGRE) has been studying means of achieving power system DC-to-DC Converters since 2017 through an international working group B4-76 entitled: DC-DC converters in HVDC Grids and for connections to HVDC systems. The CIGRE study is expected to be released in 2021 and will include DC transformer configurations from very high voltage (e.g., 500 kV) down to lower voltages that would be suitable for fast charging of electric trucks and electric vehicles. Notably, these DC transformer configurations can be achieved with technologies available today. China already has one operational configuration and others in production. Additionally, many new DC transformer configurations are being developed, including one internationally patented out of the US Patent Office of a joint US and Canadian development.\textsuperscript{20}

As such, the potential for directly connecting DC fast chargers to DC transmission exists and may enable NextGen Highways to significantly reduce the grid investments required to support transportation electrification.

\textsuperscript{18} https://arpa-e.energy.gov/technologies/programs/breakers
\textsuperscript{19} https://arpa-e.energy.gov/technologies/programs/circuits
\textsuperscript{20} The author thanks Dennis Woodford at Electranix Corporation for the information in this paragraph.
F. NextGen Highways & Digitalization of the Economy

The digitalization of the US and global economy is a clear trend that will continue with time. Individuals, communities, and companies will increasingly require access to the digital economy to utilize and deliver public and private services, from banking to health care to logistics. For these reasons there is a growing concern around the digital divide in both rural and urban areas. The ramifications of this digital divide have been rapidly amplified by the current pandemic as many users are now completely reliant upon a strong internet connection for work, education, health care, and simply connecting with family and friends.

NextGen Highways can help facilitate the deployment of broadband and 5G infrastructure. According to staff at the Western Governors’ Association, half the costs of new broadband infrastructure are soft costs, such as land-acquisition, that are unrelated to physical construction. By combining siting and permitting with the construction of other infrastructure (highways and/or power transmission), NextGen Highways will reduce deployment costs and generally facilitate deployment of broadband infrastructure. As it relates to 5G infrastructure, highways and wireless communication infrastructure are increasingly inseparable. Highway users increasingly rely upon strong wireless connections to guide them where they are going and to connect with the world around them. Similarly, vehicles are increasingly reliant on wireless connections and, in the future, automotive manufacturers and departments of transportation (DOTs) are likely to rely on 5.9GHz infrastructure to support partial and/or full autonomous vehicle capabilities.
G. NextGen Highways Increase Grid Resiliency

Whether it is the resilience of the grid to a physical attack, a cyber-attack or a climate event, our economy is increasingly dependent on an operational electric grid. Importantly, this is a trend that will only continue with the increasing electrification of our economy in order to reduce greenhouse gas emissions.

A national HVDC grid deployed as part of a NextGen Highway system would increase grid resiliency and climate resiliency in two important ways. First, it would deliver tremendous value in the event of a large-scale grid outage (i.e., the 2003 outage in the northeast United States.) This is because a national HVDC grid can be used to deliver black-start services. Black-start services are the specific services required to re-energize the grid after a large-scale outage. Second, it would allow load and generation to be averaged over a much larger part of the country. This would offer significant value as extreme climate events lead to large load events and/or reduced generation events that can result in a lack of generation. As an example, California experienced rolling blackouts in mid-August 2020. These rolling blackouts were due to hot weather over most of the western US that led to high loads and insufficient generation. If a national HVDC grid leveraging NextGen Highways had existed, additional generation resources in the central and eastern US could have been used to prevent California’s rolling blackouts.

Additionally, NextGen Highways can help deliver an ‘all hazards’ approach to grid resiliency by increasing the relatively small amount of underground transmission that currently exists. Underground transmission has a greater resilience than overhead transmission to a number of severe weather events (e.g., tornadoes and hurricanes). Additionally, underground transmission can remain energized without risk of starting a wildfire – critically important in western states. As such, it is a natural complement to overhead transmission which has a greater resilience to severe flooding events. Having both overhead and underground transmission ensures that the grid can operate (at least partially) in any type of severe weather event.

Similarly, both overhead and underground transmission collocated with highways are vulnerable to direct attacks and cyber-attacks. However, the vulnerabilities are different due to the different types of accessibility: open-air in remote areas and below-ground in accessible areas, respectively. As such, a grid with both types of transmission would likely offer greater overall resiliency in the event of either direct attacks or cyber-attacks.
H. NextGen Highways are Affordable

When discussing NextGen Highways, the higher costs of underground transmission receive significant attention but are not in and of themselves prohibitive for strategic projects that deliver multiple value streams.

A frequent pushback for underground transmission is that it costs too much. Commonly quoted numbers are 5-10X cost increases for underground AC transmission in urban cores and 2-4X cost increases for underground DC transmission. However, the following example reveals how NextGen Highways could be deployed using underground transmission with a minimal impact on electric rates (assuming consumers were to bear the full cost without any federal funding). In the NREL Seams Study, $80 billion of transmission investment was needed to build a national HVDC grid and build/strengthen AC transmission.7

For this high-level illustration, we will assume transmission investments for NextGen Highways, if they were overhead, would also cost $80 billion. This is a rough assumption but is likely accurate within a factor of two. Next assume a 3X overall cost increase for this transmission to be built underground. This is based on a roughly equal blend of underground AC and DC transmission and that cost increases at or below the low-end of the ranges above can be achieved by utilizing:

- the existing right-of-way;
- construction coordinated with highway upgrades;
- economies of scale for underground transmission lines;
- shared environmental analysis and permitting costs;
- and an expedited permitting timeline via the national environmental policy act (NEPA), since NextGen Highways would be a federal project on already disturbed land.

In summary, using the above assumptions it would cost an additional $240 billion to build NextGen Highways using underground transmission. Yet, this additional cost has a small effect on electricity prices when spread out over a large volume of electricity and many years. US electricity usage was 4,000 billion kWh in 2018 and transmission is a 50-year-plus asset. As a result, the additional cost for underground transmission would only increase electrical rates for residential and commercial ratepayers by ~2%.21

However, the above societal cost increase does not take into account that NextGen Highways will meaningfully increase the rate of transportation electrification. As such, NextGen Highways will deliver a significant societal benefit from greatly reducing transportation-sector greenhouse gas emissions. Assuming NextGen Highways led to a 20% absolute increase in transportation electrification over a 20-year period, NextGen Highways would deliver $310 billion of societal benefits based solely on the carbon-reduction impact, using a social cost of carbon of $50 per metric ton.

The above analysis suggests that underground transmission and, consequently, NextGen Highways are affordable and have the potential to deliver net benefits when considering multiple value streams.

21 Assumes residential and commercial ratepayers pay $0.10/kWh today and spreads the investment over a thirty-year period. Thirty years, instead of the fifty-year asset lifetime, is used to roughly account for the time-value of money.
I. NextGen Highways Aligns with Existing Policy Goals

The following is a partial list of existing policy goals that align with NextGen Highways:

Creating a National HVDC Grid:

– CLEAN Future Act and the Moving Forward Act:
  • Federal Energy Regulatory Committee (FERC) should require effective interregional planning

– Macro-Grid Initiative22:
  • A fully planned and integrated nationwide transmission system
  • An expanded nationwide and eastern grid with a focus on the regions of MISO, PJM and SPP

– House Select Committee on the Climate Crisis – Climate Crisis Action Plan:
  • “Congress should provide financial support for priority HVDC transmission lines, such as through an ITC. Where feasible, the priority HVDC transmission lines should be buried to ensure resilience to climate change impacts.”

Using the Highway Right-of-Way for Transmission Deployment:

– House Select Committee on the Climate Crisis – Climate Crisis Action Plan:
  • “… FERC should identify where it would be possible to use existing rights of way, such as for railroads and interstate highways.”

Using the Highway Right-of-Way for Broadband Deployment23:

– Nationwide Dig Once Act of 2020:
  • Establishes a process for states to notify broadband providers of federally funded highway construction that may present opportunities for coordinating installation of broadband infrastructure;
  • Requires the installation of broadband conduit if a provider has not committed to deploy conduit as part of a federally funded construction project; and
  • Establishes a task force co-chaired by the U.S. Secretary of Transportation and the National Telecommunications and Information Administrator to consider and propose methods to fund the nationwide dig once policy.

– Federal Highway Administration (FHWA) Proposed Rule - 23 CFR Part 64524:
  • FHWA proposes to amend its regulations governing the accommodation of utilities on the right-of-way (ROW) of Federal-aid or direct Federal highway projects to implement requirements of the Consolidated Appropriations Act, 2018. The requirements aim to facilitate the installation of broadband infrastructure.

Investing in EV Charging in Highway Corridors:

– FAST ACT:
  • “Designate national electric vehicle charging and hydrogen, propane, and natural gas fueling corridors that identify the near- and long-term need for, and location of, electric vehicle charging infrastructure, hydrogen fueling infrastructure, hydrogen fueling infrastructure.”

22 https://acore.org/macro-grid-initiative/

23 Eleven states (AZ, CA, IL, GA, MD, ME, MN, NC, NV, UT, WV) have already passed ‘Dig-Once’ legislation that supports the use of the highway right-of-way for new broadband development.

propane fueling infrastructure, and natural gas fueling infrastructure at strategic locations along major national highways."

- **S.674 Clean Corridors Act of 2019:**
  - Directs the Department of Transportation to award $300 million in grants for ten years to certain governmental entities and planning organizations to install electric vehicle charging infrastructure and hydrogen fueling infrastructure along designated alternative fuel corridors

- **H.R. 5770 the Electric Vehicle Freedom Act:**
  - Would create a network of publicly available EV charging stations along public roads of the National Highway System

- **H.R.2 The Moving Forward Act:**
  - Section 1303 of the bill establishes a $350 million annual competitive grant program at DOT to deploy electric vehicle, hydrogen, and other fueling infrastructure, prioritizing projects that demonstrate the highest levels of carbon pollution reductions

### Investing in Broadband Infrastructure:

- **H.R.2 The Invest in America Act:**
  - Delivers affordable high-speed broadband Internet access to all parts of the country by investing $100 billion to promote competition for broadband internet infrastructure to unserved and underserved rural, suburban, and urban communities, prioritizing communities in persistent poverty and ensuring that broadband-related support is being administered in an efficient, technology-neutral, and financially sustainable manner.

### Investing in Transmission Infrastructure:

- **FERC Notice of Proposed Rule Making -170 FERC ¶ 61,204\textsuperscript{25}:**
  - Propose to focus on granting incentives based on the benefits to consumers of transmission infrastructure investment identified by Congress in FPA section 219: ensuring reliability and reducing the cost of delivered power by reducing transmission congestion.

### Expanding the Transmission Planning Process to better address Inter-regional Needs and Additional Benefits

- **House Select Committee on the Climate Crisis - Climate Crisis Action Plan:**
  - “Congress should direct FERC to conduct a rulemaking to require effective inter-regional planning in line with the principles outlined in the CLEAN Future Act and the Moving Forward Act. In addition, when the planning entities evaluate the multiple benefits of a proposed project, they should consider greenhouse gas emissions and national climate goals.”

\textsuperscript{25} https://cms.ferc.gov/sites/default/files/2020-05/20200320145741-RM20-10-000_1.pdf
J. Conclusion

NextGen Highways offer a unique opportunity to bring together different economic sectors to collaboratively modernize our transportation, energy, and communications infrastructure. The construction of NextGen Highways will create construction and trade jobs, enable a clean energy future, address the digital divide, increase environmental equity and advance our technology leadership in HVDC power transmission and 5G communication technologies – both of which can be exported globally.

Though questions remain and further investigation is needed, this paper has begun to address many of the key questions related to NextGen Highways.

Ultimately, whether we construct NextGen Highways is not a question of ‘can we?’ but a question of ‘will we?’. Will inertia and an unwillingness to embrace the unknown leave us tied to our established methods? Or are we willing to break the status quo and envision the possible?
NextGen Highways Author

Morgan Putnam, Ph.D., Principal at NGI Consulting

Morgan has spent 15 years advancing solar energy. Over the last six years, Morgan has worked closely with utilities to address the grid integration challenges that arise as the penetration of solar energy on the electrical grid increases. At the start of 2020, Morgan turned his attention to the grid integration challenges that will arise from transportation electrification. Morgan formed NGI Consulting to advance the NextGen Highways concept.

Morgan began his career as a solar cell scientist before working in consulting and new product development roles for a software-as-a-service company serving the solar and utility industries. Morgan has advanced the interconnection process for distributed solar assets, modeled high-penetration renewable futures, and led the MN Solar Pathways project. This work required building teams to address complex problems and securing both federal and corporate funding.

Morgan holds a Ph.D. in Chemical Engineering from Caltech. His thesis focused on the development of next-generation solar cells and led to a venture-backed startup. He also holds a bachelor’s degree in Chemical Engineering from Cornell University.

Professional Highlights

- Co-led financial risk products for >300 MW of utility-scale solar.
- Created and led the MN Solar Pathways project. The project received national attention (e.g., The Interchange, Utility Dive, and CleanTechnica) for highlighting the value of overbuilding renewable capacity to address resource adequacy requirements during periods of low solar and low wind production.
- Developed the vision and partnerships needed to improve utility interconnection processes for distributed energy resources.
- Helped secure $5 million of DOE funding to improve the operational visibility and cyber security of distributed energy resources on the grid.
- Raised $5 million of funding from BP Ventures and Khosla Ventures for a solar cell startup company.
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- Corey Proctor (ITC Holdings)
- Pat Hayes (LS Power)
- Rolf Nordstrom (Great Plains Institute)
- Tim Sexton (Minnesota Department of Transportation)
- Jim MacInnes (Michigan Utility Consumer Participation Board)
- Mike Roeth (North American Council on Freight Efficiency)
- Ric O’Connell (Grid Lab)
- Jigar Shah (Generate)
- Allie Kelly (The Ray)
- Laura Rogers (The Ray)
- Dan Thiede (CERTS)
- Hans Detweiler (Clean Line Energy Partners)
- Dennis Woodford (Electranix)
- Daniel Cunningham (ARPA-E)
- Isik Kizilyalli (ARPA-E)
- Kevin Miller (Access Laser Company)
Appendix

K. NextGen Highways - Additional Considerations

NextGen Highways would require a much greater degree of coordination in the way we envision and plan for the transport of vehicles, electricity, and information. As such, there are unanswered questions that would need to be addressed. A few of the considerations and questions are called out below.

1. Maintenance and Repair

One additional consideration for NextGen Highways is maintenance and repair of both the highways and the underground transmission and communications infrastructure. In the context of NextGen Highways, it would be critical for the maintenance and repair of the power and communications infrastructure to be conducted without impeding traffic flow or safety. To that end two key questions are: 1) what design methods would enable maintenance and repair operations without impacting traffic flow or safety? and 2) where should the underground infrastructure be placed to enable highway maintenance and repair?

Notably, the above questions would need to be addressed in each state DOT’s utility accommodation plan. And, for efficiency, they might be first addressed with the American Association of State Highway and Transportation Officials (AASHTO), to whom the state DOTs look to for guidance on these types of questions.

2. Locational Identification of Underground Infrastructure

A second consideration is the ability for state DOTs, utilities, and other relevant agencies to precisely define the location of their underground infrastructure. In speaking with transmission operators, one existing challenge with underground infrastructure (power, sewer, water, fiber, etc.) is specifying its precise location. Historically, we have lacked the digital representation of our world to accurately track and share the location of underground infrastructure across multiple organizations. New technology is dramatically changing our capabilities in this regard. Notably, many utilities and almost all DOTs now use the GIS mapping software provided by ESRI26 to track their infrastructure. A key question to answer is: given today’s technology, are there substantial barriers to accurately recording and sharing the location of newly constructed underground infrastructure?

3. Public Safety

A third consideration is safety. As noted in the white paper, safety is a significant concern since these are high volume, high speed roadways. Fortunately, departments of transportation and utility operators share an overarching priority: the safety of their employees and the general public. As it relates to NextGen Highways, the key question to answer is: would co-locating new power transmission within the highway right-of-way meaningfully reduce public safety?

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4. Powering Large Truck Stops in Rural Areas

A fourth consideration is providing power for large truck stops in rural areas. As it relates to the Energy Gateway project discussed above, to provide power for large truck stops along I-15, I-80, and I-84 there would be a need to either build transmission line extensions (the red lines in Figure A1) or develop on-site generation capabilities. Both options would likely involve tens of millions of dollars of investment per truck stop, which is roughly $50-100 million dollars of investment in just this region of the country.

Figure A1. Top: Illustration of the transmission line extensions that could be required to support transportation electrification in rural areas. Bottom left and right: satellite images from Google of truck stops near Fort Bridger, Wyoming and Snowville, Utah.
5. Interference with Radio Communications Equipment

A fifth consideration is the interference with radio communications equipment. NextGen Highways are not expected to result in increased interference with radio communications equipment. There are a few reasons for this. First, power-line interference with radio communications equipment is an issue of decreasing impact. This is because the use of lower frequency radio communications (susceptible to power-line interference) has been replaced with higher frequency wireless communication (less impacted by power-line interference) and with broadband communication (not impacted by power-line interference). Second, power-line interference arises when electrical equipment is arcing, not when it is operating as intended. As such, it is in the utility’s best interest to address power-line interference as it is a sign of a larger problem. Lastly, the ground quickly attenuates power-line interference that would arise from buried utility infrastructure.