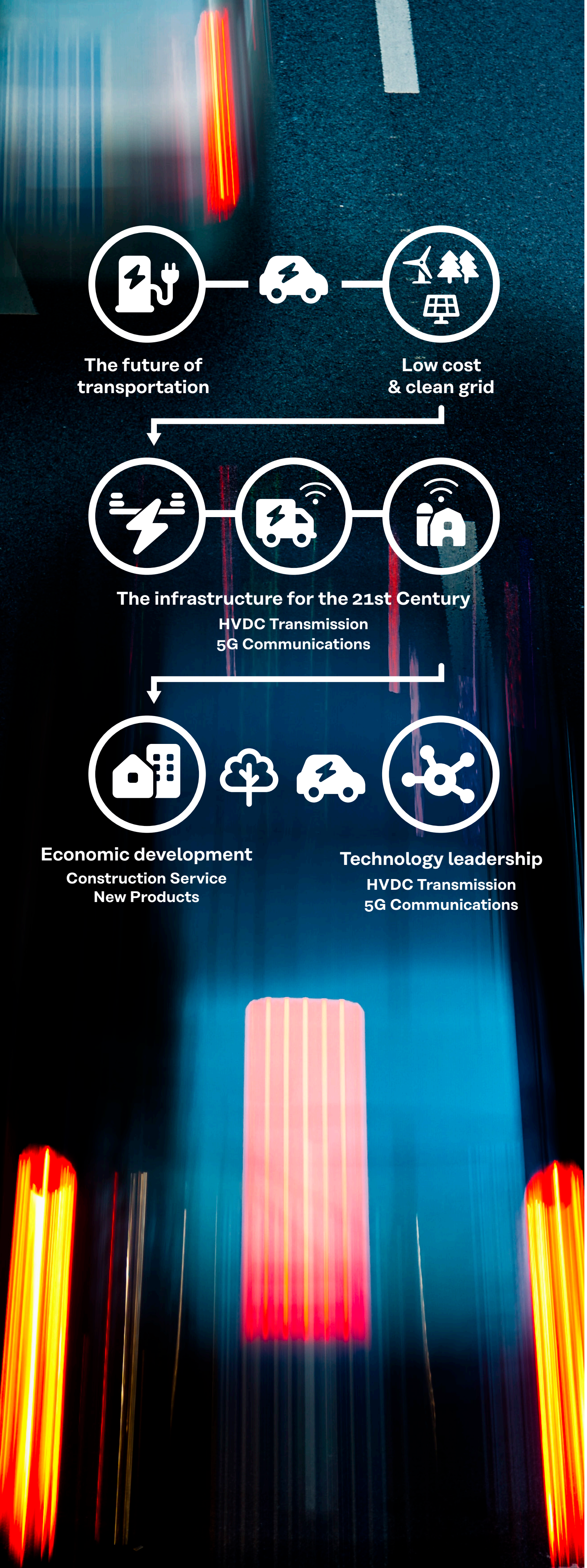
NextGen Highways Feasibility Study for the Minnesota Department of Transportation

Buried High-Voltage Direct Current Transmission



Project Team and Project Leads

This white paper was produced by NGI Consulting, The Ray, Great Plains Institute, Satterfield Consulting, Tracy Warren and 5 Lakes Energy.

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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.

The Ray is a 501(c)(3) nonprofit charity and net-zero highway testbed, located on 18 miles of Interstate 85 between LaGrange, Georgia and the Georgia-Alabama state line. The stretch of interstate was named in memory of Ray C. Anderson (1934-2011), a Georgia native recognized as a leader in green business when he challenged his company, Interface, Inc., to pursue a zero environmental footprint. "The Ray Highway" testbed is paving the way for a zero carbon, zero waste, zero death highway system to build a safer and more prosperous future for all.

Learn more at theray.org

Study Supporters

The Minnesota Department of Transportation (MnDOT) was critical to the development of this report. The Project Team thanks each member of the NextGen Highways work group for the time and expertise they contributed. The Project Team further thanks Tim Sexton for his support of the initiative and offers a special thanks to Jessica Oh, MnDOT's project lead, without whom this project would not have been successful.

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Feasibility Study Documents

To maximize readability of this Feasibility Study while at the same time providing the required deep dives, the Feasibility Study findings are distributed across the series of documents described below.

Throughout this Feasibility Study we will use special links to flag the opportunity for interested readers to dive deeper via information in the other Feasibility Study documents.

Overview of Relevant Projects

Content: Compilation of 1-2 page summaries of relevant projects

Overview of Federal and State Policy

Content: Compilation of 1-page summaries of related federal and state policies (Federal Highway Administration, Wisconsin, New Hampshire, & Maine)

Related Issue Overviews

Content: Brief white papers on key topics discussed in the Feasibility Study

- Introduction to Buried High-Voltage Direct Current (HVDC) Transmission for DOTs
- Minnesota's Energy Future
- Review of Interregional Transmission Studies
- Transmission Overview for MnDOT

Lessons from Wisconsin

Content: Documents related to how the Wisconsin Department of Transportation (WisDOT) and the Public Service Commission of Wisconsin (PSCW) work together to site transmission in highway right-of-way

- Introduction to Permitting Transmission in WisDOT Right-of-Way
- Wisconsin 2003 Act 89
- Wisconsin DOT Utility Accommodation Policy (2020)
- Cooperative Agreement between WisDOT and PSCW Regarding New Electric Transmission Lines (2009)
- Utility Constructability Report for Badger Coulee Transmission Line (2013)
- Badger Coulee Transmission Line Final Environmental Impact Statement (2014)
- Wisconsin DOT Permit for Utility to Construct, Operate and Maintain Utility Facilities on Highway Right-of-Way (2016)

Table of Contents

Executive Summary

Abstract

The NextGen Highways Team worked with an internal working group at the Minnesota Department of Transportation (MnDOT) to investigate the opportunities and barriers associated with locating buried high-voltage direct current (HVDC) transmission and fiber within the highway right-of-way (ROW). This Feasibility Study reviewed applicable policy, regulation, and projects; analyzed MnDOT-specific concerns; examined HVDC transmission line requirements; assessed buried HVDC cost and benefits; and broadly evaluated typical highway ROW design for suitability of HVDC transmission line siting. The findings from this study demonstrate that buried HVDC transmission is cost-effective and can be feasibly sited in interstate and highway ROW after making appropriate consideration for existing and future transportation system needs. While the team identified challenges over the course of this study, none of those challenges appear to pose barriers that cannot be overcome.

The NextGen Highways Vision for Integrated Infrastructure

NextGen Highways are highways where electric and communications infrastructure are strategically co-located in the highway right-of-way.

NextGen Highways would accomplish the following:

- **build for our transportation future** by integrating electric and communications infrastructure into our existing transportation infrastructure
- **enable a clean energy economy** by building the transmission needed to affordably achieve 100 percent clean energy and by ensuring the electric grid can be rapidly strengthened in transportation corridors to support electric vehicle charging needs
- **unleash economic development** by removing barriers that are currently holding back a trillion dollars of private investment that would create new jobs, services, and technologies
- **strengthen national security** by constructing an energy and communications backbone that is hardened against everything from severe weather events to cyberattack

improve equity by remedying the enduring air quality impacts of the interstate system, which disproportionately affect low-income communities and Black, Indigenous and people of color communities, and by increasing broadband access in rural and urban communities

Purpose and Need

Hundreds of billions of dollars are now being invested in electric, connected, and autonomous vehicles.[1] To fully support these vehicles, our existing transportation infrastructure will need to evolve to incorporate electric and communications infrastructure. This evolution is required to power these vehicles and the communications infrastructure to support their connected and autonomous functionality. In short, our existing transportation, communications and electric infrastructure will need to become integrated.[2]

From the perspective of a state department of transportation (DOT), there are several key challenges and opportunities related to the future of transportation and integrated infrastructure:

Challenge	Opportunity
Transportation electrification of fleets will require extensive electric upgrades in highway corridors	Enable the required electric grid upgrades by providing electric utilities with highway ROW access for buried transmission or distribution
Transportation decarbonization requires electrification and grid decarbonization	Enable the construction of the long-distance transmission lines needed for cost-effective grid decarbonization to benefit transportation
Reducing vehicle miles traveled	Improve broadband access using DOT ROW such that remote work, online learning, and some professional services (e.g. telehealth) can help reduce the number of vehicle miles traveled
Maximizing the positive impacts and mitigating the negative impacts of the highway system to adjacent communities	Use the transportation system to (1) deliver community benefits (e.g., broadband); (2) reduce air pollution (by supporting the electric grid investments needed to accelerate the transition to EVs); and (3) reduce the private land acquisition needed to accommodate new transmission

[1] The future of mobility is at our doorstep

[2] Our Transportation Future: Industries Collide

Federal policy and funding for integrated infrastructure has just started to emerge. In April 2021, the White House announced a coordinated set of actions by the US Department of Energy and the US Department of Transportation that would encourage the development of "Clean Energy and Connectivity" projects along the nation's highway system.[3]

Study Background and Scope

In June 2020, MnDOT established a Sustainable Transportation Advisory Council (STAC) to help MnDOT reduce transportation carbon emissions. As part of its first set of recommendations to MnDOT in December 2020, the STAC recommended that MnDOT examine the value of NextGen Highways.[4] The STAC's recommendations included asking MnDOT to update its utility accommodation policy and initiate a multi-stakeholder process focused on NextGen Highways.

In its April 2021 response to the STAC recommendations, MnDOT committed to working with the NextGen Highways Team and other stakeholders to clarify opportunities and challenges to co-locate broadband and electric transmission in interstate and highway ROW.[5]

From June through December 2021, the NextGen Highways Team and associated partners worked with an internal working group at MnDOT to investigate the opportunities and barriers associated with locating buried HVDC transmission and fiber within highway ROW. The key findings from this analysis, which focuses on buried HVDC transmission, and next steps are presented below.

Items addressed in this Feasibility Study include:

- Policy review
  - Review of federal policy and funding related to integrated infrastructure
  - Review of Minnesota and MnDOT policies, plans, and regulations
  - Review of key policies in select other states
- Project review
  - Review of relevant projects in the US and Europe
- Analysis of MnDOT concerns
  - Covered 14 different topic areas: safety, highway expansion and maintenance, planning and siting, permitting, and license fees
- Buried HVDC transmission—introduction for DOTs
  - Introduction to system design and footprint, safety, construction techniques, maintenance requirements, and potential impacts on existing infrastructure and the environment
- Buried HVDC transmission—requirements
  - Planning, siting, permitting, construction, maintenance, and future relocation

[3] FACT SHEET: Biden Administration Advances Expansion & Modernization of the Electric Grid Our Transportation Future: Industries Collide

[4] Sustainable Transportation Advisory Council (STAC) Recommendations to MnDOT

[5] MnDOT Response: 2020 Sustainable Transportation Advisory Council Recommendations

- Buried HVDC transmission—cost and benefits
    - Cost comparison: buried HVDC vs. overhead AC
    - Grid reliability and resiliency benefits
    - Societal value of accelerated permitting and siting
- Broad assessment of feasibility

MnDOT Findings

The MnDOT Work Group and NextGen Highways team identified areas where further study and resolution of specific issues are required for MnDOT to consider supporting longitudinal siting of buried HVDC transmission and fiber in interstate ROW. Utility siting in uncontrolled highway ROW is already allowed in Minnesota. A more detailed evaluation of these topics is provided in Part 1a and Part 1b of this report.

Table 1. Considerations for longitudinal siting of HVDC transmission and fiber in the interstate right-of-way

Topic	Description
Current MN Policy	Longitudinal utility installation is ***not*** allowed in Minnesota Interstate and other Controlled Access Highways. MnDOT, Minnesota Public Utilities Commission (MN PUC), and the Minnesota Department of Commerce (Commerce) already coordinate to site proposed transmission lines just outside the ROW. This process can be built upon for siting transmission in ROW. A Dig Once policy has been enacted for broadband conduit.
Regulatory Landscape Outside of MN	Some states (WI, NH, ME) allow longitudinal siting of transmission lines in the highway and interstate ROW. The Federal Highway Administration (FHWA) is encouraging state DOTs to allow co-location of fiber, electrical transmission and distribution, and renewable energy in the highway and interstate ROW.[6]
Safety	Safety features for HVDC lines include the following: (1) burying underground, (2) surface and subsurface markings, (3) restricted access, (4) thick cable insulation, (5) conduit, (6) cable shield ground points, and (7) adherence to MnDOT's Utility Accommodation Manual (UAM) for permitting, construction, environmental restoration, and traffic control.
Policy/Plan Alignment	There is significant alignment between the NextGen Highways vision and Minnesota and MnDOT's existing goals, policies, and strategic plans.
Overhead Infrastructure & HVDC Converter Stations	A buried HVDC transmission line would not have any aboveground infrastructure located in the ROW. Associated HVDC converter stations would be placed well outside of the ROW.

[6] State DOTs Leveraging Alternative Uses of the Highway Right-of-Way Guidance

Topic	Description
Potential HVDC Operational Impacts on Existing Infrastructure	Buried HVDC transmission lines do not induce currents or create voltage potentials, do not affect nearby communication infrastructure or equipment, and do not corrode adjacent metal pipes. HVDC converter stations could interfere with communication infrastructure but are designed not to via the use of a faraday cage.
Environmental Impacts	Buried HVDC transmission lines have significantly less impact on the environment than overhead transmission lines. Transmission lines would be subject to environmental requirements in MnDOT's Utility Accommodation Policy and MN PUC's transmission siting process.
Future Highway Maintenance & Construction	MnDOT must be able to maintain and expand the highway ROW as needed to serve Minnesota's transportation needs. Non-transportation infrastructure must not unreasonably impede highway maintenance and expansion.
Planning & Siting Utilities in the ROW	When siting a buried HVDC transmission line or major fiber line, the goal is to place it where it won't have to move (for as long as possible). Increased density of utilities in urban areas and the difficulty of accurately locating existing utilities have led to operational challenges. There is a need for more integrated planning.
Transmission Permitting	MnDOT has jurisdiction in its ROW and must approve any transmission project. MnDOT has a transmission permitting process for utility crossings that can be built upon for siting transmission in ROWs.
Transmission Construction	Construction methods, traffic impacts, and safety considerations all must be accounted for and mitigated.
Transmission Maintenance	Access to highway ROW presents both safety and security concerns. Modern HVDC transmission lines require minimal maintenance (namely, annual visual inspections). No new security vulnerabilities for MnDOT have been identified.
Future Utility Relocation Responsibilities and Costs	State statute specifies that MnDOT is responsible for all utility relocation costs for utilities located in the interstate ROW. This is contrary to the assignment of relocation costs to the utility for highway ROW in Minnesota and contrary to the policies of many other states. The assignment of utility relocation costs to MnDOT is a barrier to the use of interstate ROW for buried transmission or buried fiber.
Permit Fees and Utility Leasing Fees	MnDOT does not currently charge permit fees or utility license fees for use of its ROW. This poses a financial concern for MnDOT as transmission and fiber build-out in the ROW would increase the amount of required coordination between MnDOT and utilities, consequently requiring more internal MnDOT resources.

Topic	Description
Communications Infrastructure	There are strong parallels between buried fiber and transmission for siting and construction in an existing ROW. Minnesota IT Services (MNIT) can barter existing fiber with the private sector. This exchange of fiber resources has reduced public network costs and benefited private sector companies in the network services they provide across the state.

Recommended Next Steps in Minnesota

Based on the findings noted above, the following are recommended next steps to further evaluate and advance the NextGen Highways vision in Minnesota.

Table 2: Recommended next steps to advance NextGen Highways in Minnesota

Topic(s)	Description
MN Policy & Permitting	The NextGen Highways Team and MnDOT review Wisconsin's laws, policies, and processes that have enabled the location of overhead AC transmission and fiber in interstate and highway ROW. MnDOT, with support from the NextGen Highways Team, examines how to remove barriers that exist in state statute, MnDOT rules, and MnDOT's utility accommodation policy (e.g., assignment of interstate utility relocation costs to MnDOT). This would include the engagement of other state agencies such as Commerce and MN PUC. The NextGen Highways Team and MnDOT further evaluate potential impacts on vegetation, noxious weeds, wetlands, slope stabilizers, stormwater management, cultural resources, and tribal lands.
Transmission: Construction, Maintenance, and Relocation	The NextGen Highways Team and MnDOT further investigate transmission construction, maintenance, and relocation processes, taking lessons from project "Constructability Reports" and maintenance agreements in Wisconsin and incorporating knowledge specific to buried HVDC transmission lines.
Planning and Siting	The NextGen Highways Team, with support from MnDOT, conducts a GIS review of the suitability of MnDOT's ROW for buried HVDC transmission and fiber. The NextGen Highways Team, with support from MnDOT, conducts a high-level evaluation of a buried HVDC transmission and fiber project in an interstate or highway corridor that would address known transmission needs (e.g., needs identified by MISO's long-range transmission planning process). MnDOT, with support from the NextGen Highways Team, examines potential to reduce existing process barriers (e.g., challenges with the current utility locate process).

Topic(s)	Description
Communications Infrastructure	The NextGen Highways Team and MnDOT expand the focus of the work to include fiber and communications infrastructure and support MnDOT as it seeks to clarify (1) its fiber needs to support connected and autonomous vehicles, and (2) fiber needs to support improved broadband access in communities across the state.
Stakeholder Engagement	The NextGen Highways Team and MnDOT engage a greater number of stakeholders outside of MnDOT (e.g., state agencies, utilities, tribes, communities, cities, and companies).

National Findings

The following findings demonstrate that buried HVDC transmission is cost-effective and can be sited in interstate and highway ROW through appropriate consideration of transportation system needs.

1. Transmission and fiber have been and are being sited in interstate and highway ROW across the United States.
2. Much of the interstate is suitable for buried HVDC transmission and fiber, but certain areas require special considerations or routing outside of the interstate ROW.
3. Buried HVDC transmission can be compatible with interstate and highway ROW.
4. Buried HVDC transmission is comparable in cost to overhead AC transmission while providing additional reliability and resilience benefits.
5. Together, DOT ROW and buried HVDC transmission can deliver billions of dollars in societal benefits.
6. Buried HVDC transmission supports transportation decarbonization.
7. Wisconsin has the playbook for siting transmission in DOT ROW.

National Recommendations

State DOTs should:

- Site and build fiber in a way that allows for buried HVDC transmission to be co-located at a later date
- Develop and invest in their relationship with utilities, public utilities commissions, and other state agencies with transmission siting jurisdiction
- Determine the amount of operational funding required to support the co-location of electric and communications infrastructure in their ROW

Utilities and energy developers should:

- Develop and invest in their relationship with state DOTs
- Evaluate how highway ROW (if made available) could enable the various grid investments needed to support electric vehicle charging
- Evaluate how planned regional and interregional transmission lines could benefit from highway ROW (if made available)

Governors should consider:

- Supporting and facilitating the implementation of Wisconsin's co-location playbook
- Working with their DOT, utilities, and legislature to remove any statutory barriers in state law
- Evaluating options to provide their DOT with operational funding to support the co-location of electric and communications infrastructure in the ROW

Next Step for NextGen Highways

Given the positive findings from this Feasibility Study, the NextGen Highways Team is planning to launch a NextGen Highways Coalition to support the co-location of buried fiber and transmission in highway and interstate ROW.

The NextGen Highways Coalition will do the following:

- Facilitate conversations between state DOTs, utilities, and governors
- Facilitate conversations between state DOTs, utilities, and technology vendors
- Review states' highway ROW siting and permitting regulations, identify barriers to co-location, and work with stakeholders to overcome barriers
- Share insights and best practices across states
- Provide a platform through which tribes, communities, nonprofits, cities, and companies can understand the required transformation of the national highway system
- Foster public/private partnerships to build out the required infrastructure

Interested parties can email morgan@buildngi.com and laura@theray.org for more information.

Conclusion

The findings from this study demonstrate that buried HVDC transmission can be cost-effective and that there is the potential to be sited in Interstate and highway ROW after making appropriate consideration of existing and future transportation system needs. Next steps are proposed to address the challenges identified over the course of this study.

Buried fiber in the interstate and highway ROW shares many of the same challenges as buried HVDC transmission. Given the ability of state DOTs to co-locate buried fiber and HVDC transmission, it makes sense for them to consider the potential for future accommodation of buried HVDC transmission when installing fiber in interstate and highway ROW.

Feasibility Study Documents

Results from the Feasibility Study are distributed across a series of documents. The primary document is the Study Report. Additional documents include an Overview of Relevant Projects, an Overview of Federal and State Policy, Overviews of Related Issues (a series of documents), and Lessons from Wisconsin (a series of documents). These additional documents are flagged from within the Study Report and provide interested readers an opportunity to dive deeper into an issue than practical within the Study Report.

Study Preface: A Changing Transportation Landscape

The Future of Transportation Requires Integrated Infrastructure

Hundreds of billions of dollars are now being invested in electric, connected, and autonomous vehicles.[7] Our existing transportation infrastructure will need to evolve to incorporate the electric infrastructure to power these vehicles and the communications infrastructure to support their connected and autonomous functionality. In short, our existing infrastructure will need to become integrated.[8]

From the perspective of a state department of transportation (DOT), there are several key challenges and opportunities related to the future of transportation and integrated infrastructure:

Challenge	Opportunity
Transportation electrification of fleets will require extensive electric upgrades in highway corridors	Enable the required electric grid upgrades by providing electric utilities with ROW access for buried transmission and/or distribution
Transportation decarbonization requires electrification *and* grid decarbonization	Enable the construction of the long-distance transmission lines needed for cost-effective grid decarbonization
Reducing vehicle miles traveled	Improve broadband access using DOT ROW such that remote work, online learning, and some professional services (e.g. telehealth) can help reduce the number of vehicle miles traveled
Maximizing the positive impacts and mitigating the negative impacts of the highway system to adjacent communities	Use the transportation system to (1) deliver community benefits (e.g., broadband); (2) reduce air pollution (by supporting the electric grid investments needed to accelerate the transition to EVs); and (3) reduce the need for new transmission ROW

[7] State DOTs Leveraging Alternative Uses of the Highway Right-of-Way Guidance

[8] Our Transportation Future: Industries Collide

Federal Policy and Funding for Integrated Infrastructure

Federal policy and funding for integrated infrastructure has just started to emerge. In April 2021, the White House announced a coordinated set of actions by the US Department of Energy and the US Department of Transportation that would encourage the development of "Clean Energy and Connectivity" projects along the United States highway system.[9] These and related actions include the following:

FHWA Guidance Memo (April 2021)

Clarified that highway ROW "can be leveraged by State DOTs for pressing public needs relating to climate change, equitable communications access, and energy reliability." Examples of projects listed include energy generation, electrical transmission and distribution projects, broadband projects, vegetation management, inductive charging in travel lanes, and alternative fueling facilities.[10]

DOE Loan Program Announcement (April 2021)

Announced that the Loan Program Office is seeking applications for up to $5 billion in loan guarantees to support innovative transmission projects. This includes high-voltage direct current (HVDC) systems, transmission to connect offshore wind, and facilities sited along rail and highway routes.[11]

Investment in Infrastructure and Jobs Act (IIJA) (November 2021)

Made undergrounding of public utility infrastructure eligible under the National Highway Performance Program if carried out in conjunction with an eligible project.[12]

FHWA Rulemaking (December 2021)

FHWA amended its regulations governing the accommodation of utilities to implement requirements of the Consolidated Appropriations Act of 2018 for broadband infrastructure deployment.[13]

For more information, please see the Overview of Federal and State Policy document.

An Expanding Definition of Transportation

Coincidental with the growing recognition of the need for integrated infrastructure, DOTs are increasingly taking or being asked to take an expanded view on the definition of transportation.

As the following excerpt from the Wisconsin Department of Transportation (WisDOT) guide to utility coordination shows, WisDOT is open to the accommodation of utility infrastructure in its interstate and highway ROW and understands it has a role to play in helping to minimize costs for the general public:

> The 1979 Edition of the Random House Dictionary of the English Language defines transportation as "the business of conveying people, goods, etc." WisDOT is charged with providing an efficient, safe, and economical transportation system for the people and goods in the state of Wisconsin.

[9] FACT SHEET: Biden Administration Advances Expansion & Modernization of the Electric Grid

[10] State DOTs Leveraging Alternative Uses of the Highway Right-of-Way Guidance

[11] Loans Will Support Projects to Widen Clean Electricity Reach and Enhance Grid Reliability

[12] FACT SHEET: Biden Administration Advances Expansion & Modernization of the Electric Grid

[13] Federal Highway Administration 23 CFR § 645

> The funding for our work comes largely from State and Federal taxes, which are paid by the general public. A utility company's primary source of revenue is the rates paid by the consumers, which are, in effect, the general public. In order to reduce the total cost to the general public, the designer must plan the proposed work so that the cost of relocating utility facilities, and the cost of the highway project are minimized. This provides a facility with the lowest overall transportation cost.[14]

Similarly, in Utah, HB 333 proposes to transfer Utah's Broadband Center—responsible for expanding broadband access and usage across Utah—to the Utah Department of Transportation.[15]

In Texas, Senate Bill 507 ruled for the Texas Transportation Commission to establish an accommodation process that authorizes broadband-only providers to use the state highway ROW for creating, maintaining, making additions to, and relocating both new and existing broadband facility installations in the ROW.[16]

Finally, in the words of one staff member from the Minnesota Department of Transportation (MnDOT):

"Teleworking has proven itself a way of transportation; [I] now consider this a transportation issue."

The NextGen Highways Vision for Integrated Infrastructure

NextGen Highways are highways where electric and communications infrastructure are strategically co-located in the highway right-of-way.

NextGen Highways would accomplish the following:

- **build for our transportation future** by integrating electric and communications infrastructure into our existing transportation infrastructure
- **enable a clean energy economy** by building the transmission needed to affordably achieve 100 percent clean energy and by ensuring the electric grid can be rapidly strengthened in transportation corridors to support electric vehicle charging needs
- **unleash economic development** by removing barriers that are currently holding back a trillion dollars of private investment that would create new jobs, services, and technologies
- **strengthen national security** by constructing an energy and communications backbone that is hardened against everything from severe weather events to cyberattack
- **improve equity** by remedying the enduring air quality impacts of the interstate system, which disproportionately affect low-income communities and Black, Indigenous and people of color communities, and by increasing broadband access in rural and urban communities

[14] Wisconsin Department of Transportation Guide to Utility Accommodation, Chapter 1

[15] Utah State Legislature, H.B. 333, Economic and Workforce Development Amendments

[16] Texas Senate, SB 507, Legislative Session 87(R)

As illustrated in figure 1, showing a reimagined interstate corridor, **NextGen Highways would create an energy and communications backbone that would drive economic development in rural and urban areas.**

Figure 1. A reimagined interstate corridor where energy and communications infrastructure support economic development and increase resilience.

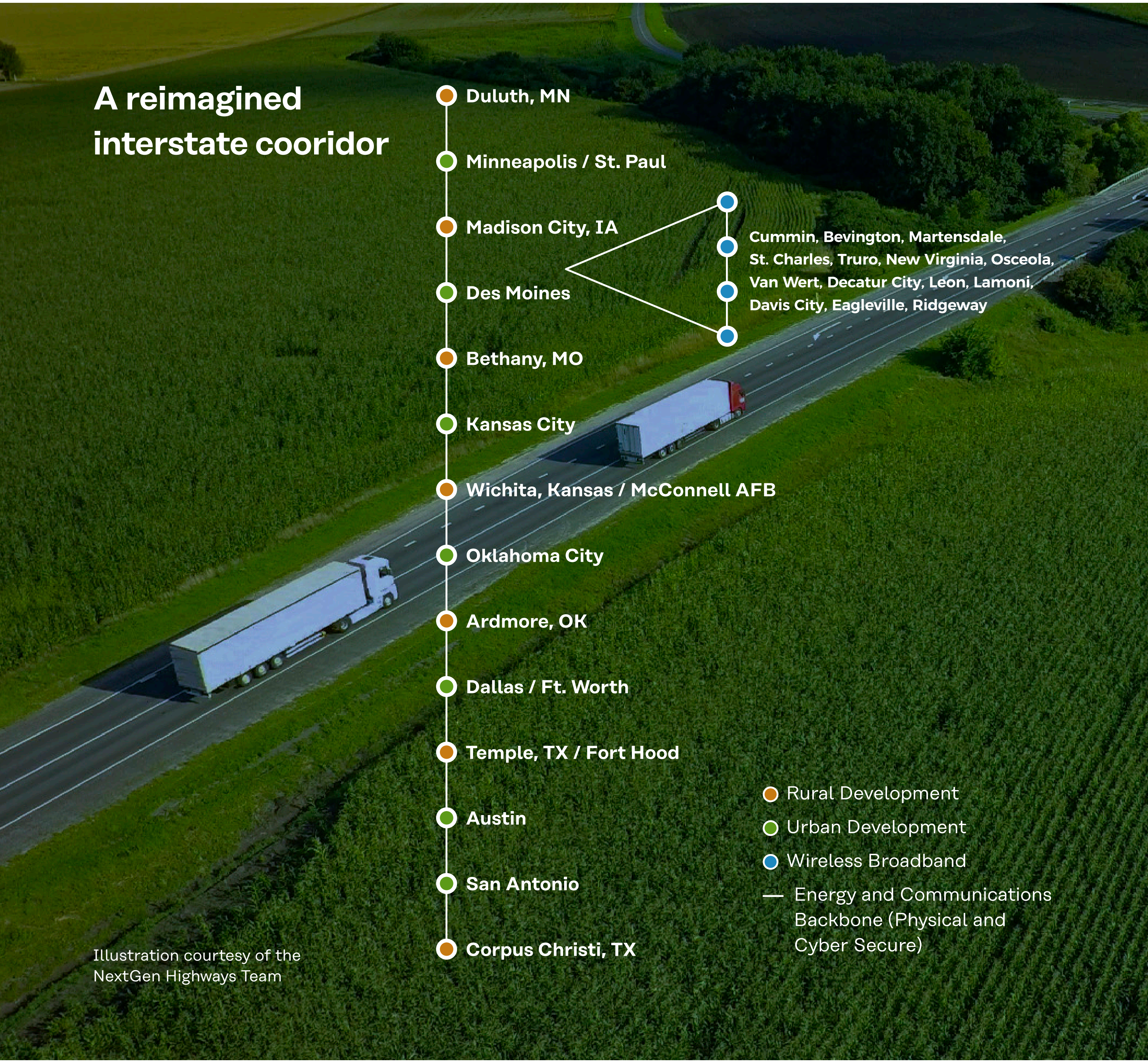
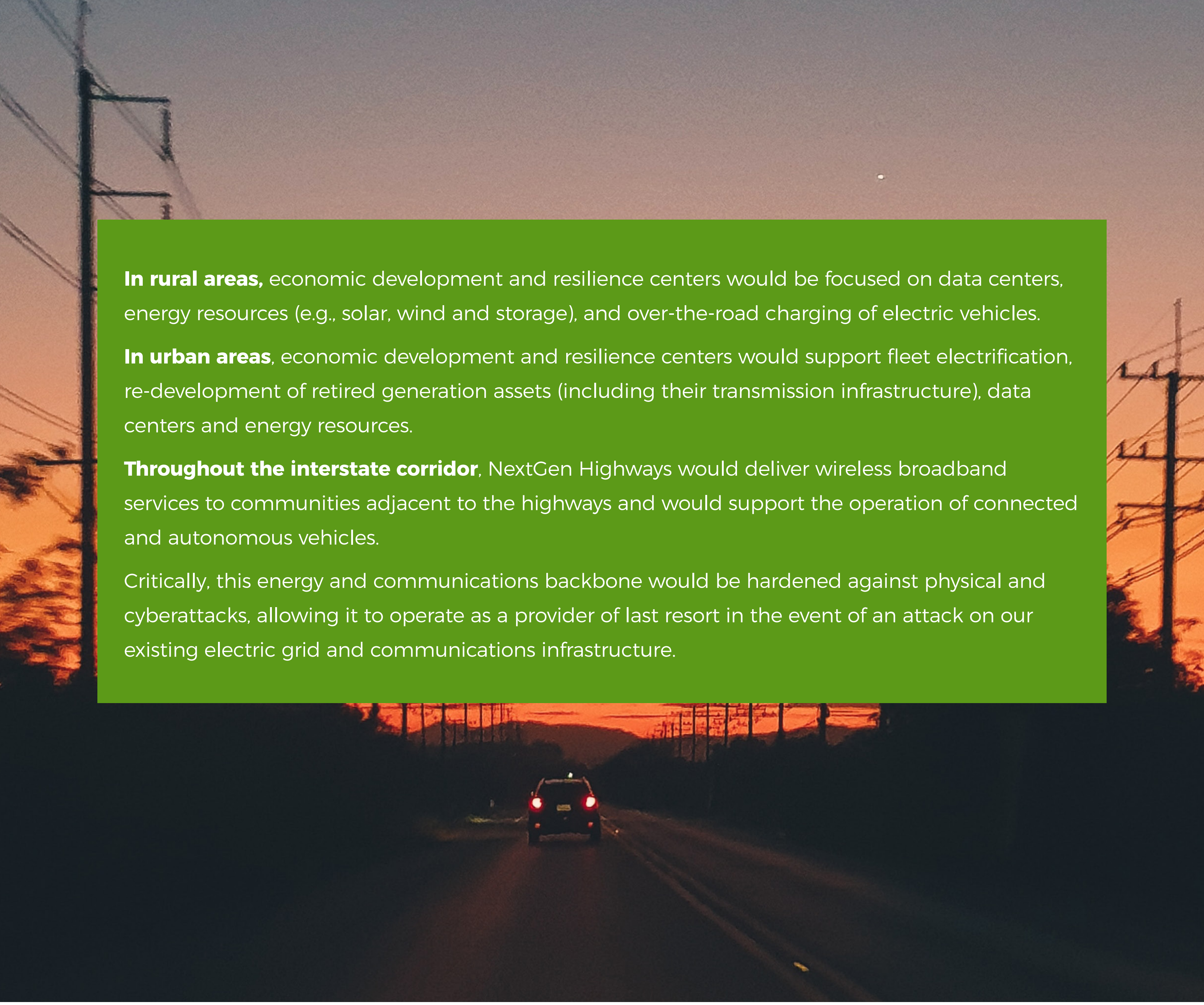


Illustration courtesy of the NextGen Highways Team



In rural areas, economic development and resilience centers would be focused on data centers, energy resources (e.g., solar, wind and storage), and over-the-road charging of electric vehicles.

In urban areas, economic development and resilience centers would support fleet electrification, re-development of retired generation assets (including their transmission infrastructure), data centers and energy resources.

Throughout the interstate corridor, NextGen Highways would deliver wireless broadband services to communities adjacent to the highways and would support the operation of connected and autonomous vehicles.

Critically, this energy and communications backbone would be hardened against physical and cyberattacks, allowing it to operate as a provider of last resort in the event of an attack on our existing electric grid and communications infrastructure.

For more information on the NextGen Highways concept, please see the NextGen Highways white paper.[17]

[17] NextGen Highways: Co-locating the Transport of Vehicles, Energy and Information

Study Introduction: Why the Focus on Buried HVDC Transmission?

Study Background and Scope

Study Background

In June 2020, MnDOT established a Sustainable Transportation Advisory Council (STAC) to help the agency reduce transportation carbon emissions. As part of its first set of recommendations to MnDOT, the STAC recommended that MnDOT examine the value of NextGen Highways.[18] The STAC's recommendation included asking MnDOT to update its utility accommodation policy and initiate a multi-stakeholder process focused on NextGen Highways.[19]

In its response to the STAC recommendations, MnDOT committed to working with the NextGen Highways Team and other stakeholders to clarify opportunities and challenges to co-locate broadband and electric transmission in interstate and highway ROW.[20]

MnDOT chose to participate in the further evaluation of NextGen Highways as it saw the potential for greater utilization of the ROW to support a number of internal and state goals: transportation electrification; electric grid decarbonization; preparing for connected and autonomous vehicles; increasing broadband access; and grid reliability and security. Each of these is an envisioned component of NextGen Highways.[21]

Study Scope

This Feasibility Study is the first product resulting from MnDOT's further evaluation of the NextGen Highways vision. The study was focused on examining the feasibility of allowing a utility to install a new type of transmission technology—buried HVDC transmission within the highway ROW.

The overarching goal of the Feasibility Study was to determine whether the potential for locating buried HVDC transmission in MnDOT ROW was sufficiently promising to merit further investigation.

Secondary study goals included the following:

- identification of co-location barriers and opportunities for further study
- survey of allowed ROW uses in other US states
- clarification of buried HVDC transmission costs and benefits

Notably, the Feasibility Study consists of two parts. The first part of the study focused on evaluating MnDOT's specific questions surrounding the potential installation of buried HVDC transmission in its interstate and highway ROW. The key result from part one was the identification of MnDOT-specific barriers and opportunities related to the potential installation of buried HVDC transmission in MnDOT ROW.

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[18] Sustainable Transportation Advisory Council (STAC) recommendations to MnDOT

[19] NGI Consulting presented the NextGen Highways vision and 2020 white paper to the STAC in October 2020

[20] MnDOT Response: 2020 Sustainable Transportation Advisory Council Recommendations

[21] NextGen Highways: Co-locating the Transport of Vehicles, Energy, and Information

The second part of the study had a broader focus. It included examining allowed utility access to DOT ROW in other states and investigating the cost and benefits of buried HVDC transmission. The key result from the second part was a clear understanding of existing precedent in other states and a rough sense of the economic feasibility of installing buried HVDC transmission in highway ROW.

Why Start with Buried HVDC Transmission?

The reason to start with a focus on buried HVDC transmission is simple: it is a transmission technology that can be and is being sited within existing transportation ROW. As such, there is a need for MnDOT and other state DOTs to be aware of this new type of utility that may seek accommodation in interstate or highway ROW through a state DOT's existing utility accommodation policy.

Proposed projects in the US and Europe provide clear examples of transmission developers combining buried HVDC transmission technology with existing transportation rights-of-way. The proposed project examples in the US are the SOO Green HVDC Link, Clean Path NY, and Champlain Hudson Power Expressway. In Europe, the examples are the SuedLink, SuedOstLink, and Italy-France Interconnector.

Figure 2 shows four buried HVDC cables that have been sited within the A-32 motorway as part of the Italy-France Interconnector. Notably, this project required amending the highway code. It was one of the first times that underground transmission was longitudinally sited in a motorway in France.[22]

Figure 2. Buried HVDC cables in highway ROW (Italy-France Interconnector)

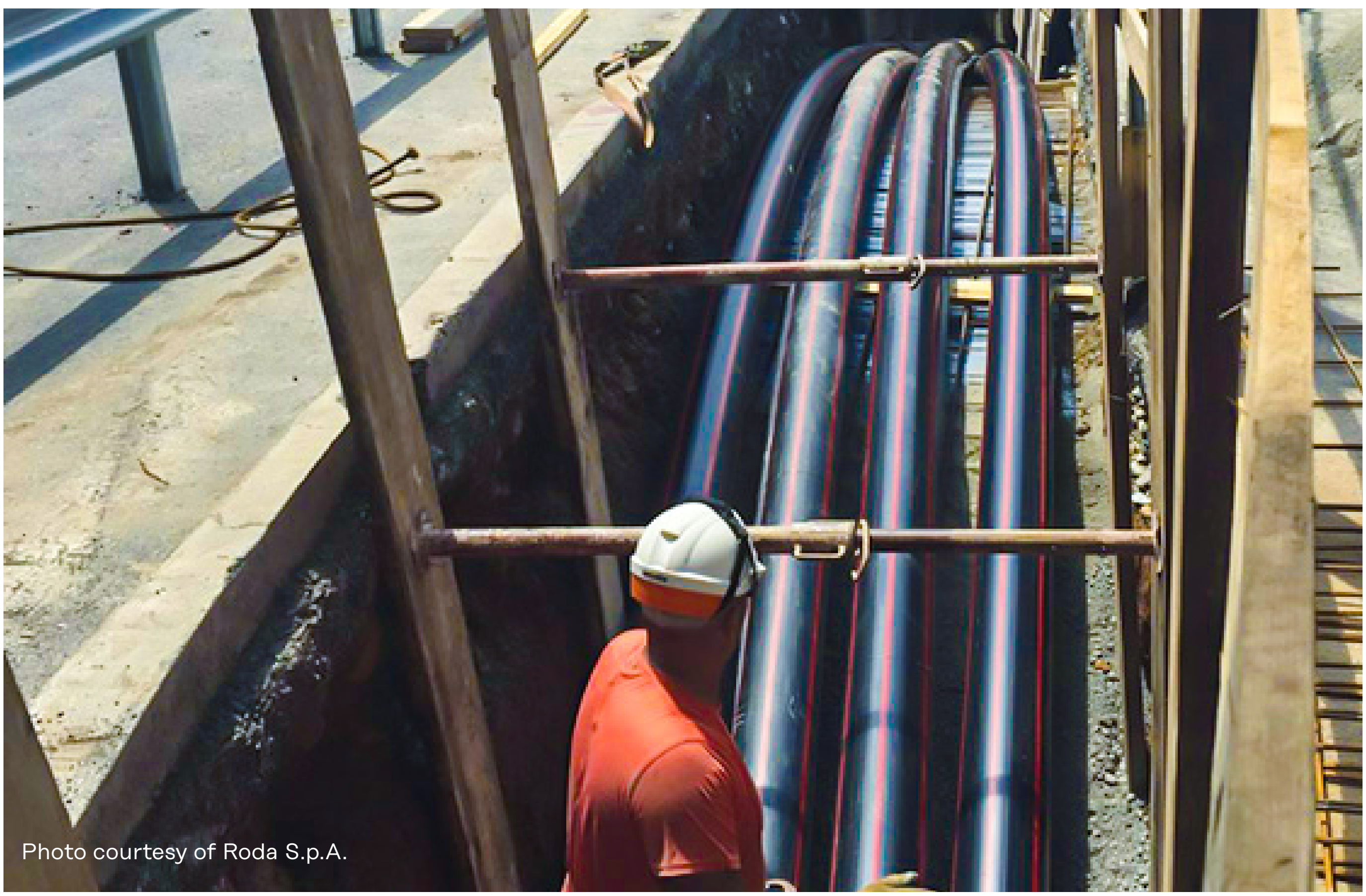

Photo courtesy of Roda S.p.A.

[22] [Savoie-Piémont: 190 km of European Solidarity from Chambéry to Turin]

It is worth noting that buried HVDC projects often combine a number of different types of ROW (existing and new): existing highway, railway, and waterway ROWs are commonly used. As one example, the proposed SOO Green HVDC link uses both highway and railway ROW despite being known predominantly for its use of railway ROW.

For two-page project summaries for each of the buried HVDC projects referenced above, please see the Overview of Relevant Projects document.

Buried HVDC Transmission Also Matters to DOTs

As a final note, buried HVDC transmission doesn't just matter to the electric utility industry – it also matters to the transportation industry.

Buried HVDC transmission matters to DOTs and the transportation industry because it will directly support transportation electrification and decarbonization. The three different ways that buried HVDC transmission will do this are described in detail in Finding #6: Buried HVDC transmission supports transportation decarbonization.

Buried HVDC Transmission: A Brief Introduction for DOTs

In seeking to understand the feasibility of locating buried HVDC transmission within interstate and highway ROW, MnDOT had a number of questions related to the following areas:

- system design and footprint
- safety
- transmission construction techniques
- transmission maintenance requirements
- potential impact on existing infrastructure and devices
- environmental impacts

The NextGen Highways team investigated these questions and produced an Introduction to Buried High-Voltage Direct Current (HVDC) Transmission for DOTs document that discusses each of the areas above to help MnDOT (and other state DOTs) evaluate the compatibility of buried HVDC transmission within highway and interstate ROW. Notably, the NextGen Highways team's investigation and projects under development in Europe suggest that buried HVDC transmission can be compatible with interstate and highway ROW.[23]

Key takeaways from the Introduction to Buried High-Voltage Direct Current (HVDC) Transmission for DOTs document are presented below for each of the areas identified above.

System Design and Footprint

There are three primary components of a buried HVDC transmission line. The conductor, or cable, is buried below grade and requires a 5-foot ROW for construction. Conductor sections are connected approximately every half mile inside joint vaults, which are typically 40 feet long, 10 feet wide, and 8 feet tall and buried fully below grade. Lastly, converter stations are above ground but located fully outside the highway ROW. These primary components and their relative locations are shown in figure 3.

[23] As discussed in Finding #2, there are certain areas where it will not be practical to site buried HVDC transmission in the interstate or highway ROW. But the existence of specific constraints doesn't prevent the broader use of the interstate and highway ROW.

Figure 3. Schematic of buried HVDC transmission line in highway right-of-way

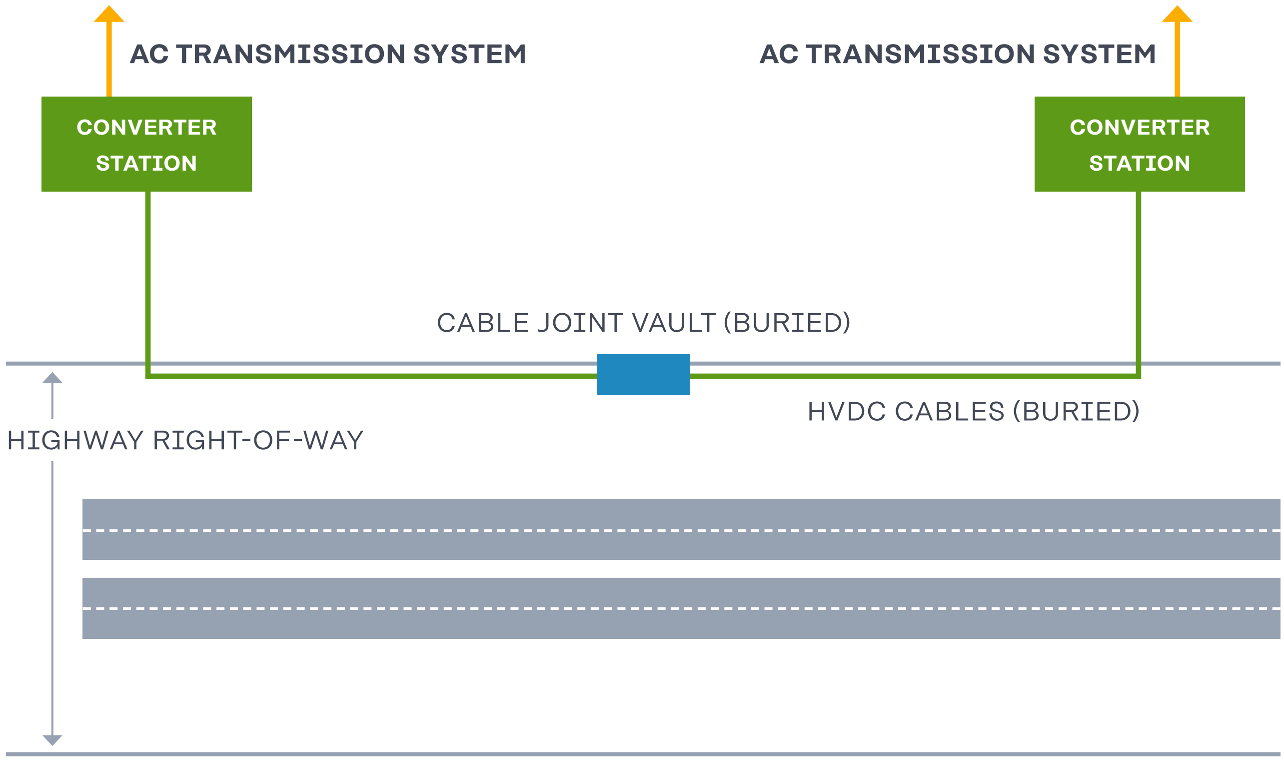

Figure developed by the NextGen Highways Team

Figure 4 provides a cross-section view of one buried cable design. It shows that while the transmission cable requires a 5-foot wide ROW, the cables are about 5 inches in diameter. This leaves space for co-location with other utilities (i.e., fiber optic cables) within the same 5-foot ROW.

Figure 4. Cross-section of a buried HVDC cable

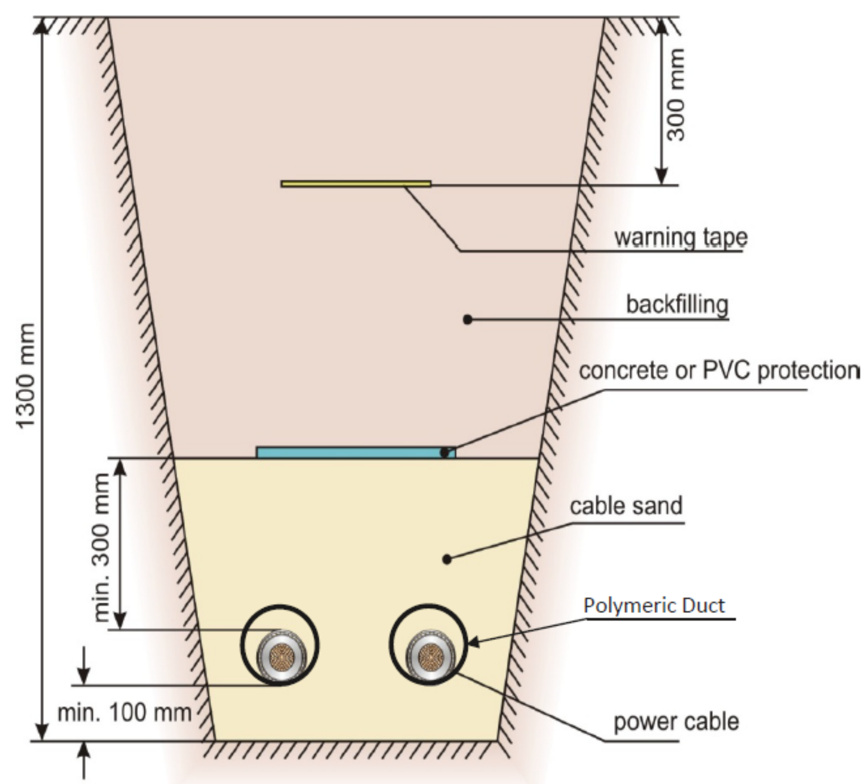

Figure courtesy of Southwire

Buried HVDC transmission safety considerations

Safety is a key concern for both project developers and DOTs for any utility infrastructure in the highway ROW. Several protection schemes are put in place along the entire length of the buried cable. A warning tape is laid down approximately one foot below grade along the entire length of the cable path. Below this warning tape, approximately three feet deep and one foot above the cables, a concrete or PVC proactive layer is placed to mitigate and protect against dig-in risk. Then, depending on the design choices of the specific project, additional protection can be implemented around the cables.

One example of a design with additional protection is the buried duct installation (see figure 4), in which a polymeric duct is placed in the trench along the length of the line. Then the cable is pulled through that duct. This provides additional protection for the cable and has the added benefit of providing additional security against theft during construction and protection against dig-ins after construction is complete.

Lastly, a duct bank system can be employed, encapsulating the cable ducts into a concrete bank. This system provides additional protection against dig-ins compared to the direct buried cable or buried duct approaches.

Buried HVDC Transmission Construction

During construction, a number of techniques can be employed to efficiently and safely lay cable and associated protective equipment. In open or rural areas, open trenches can be dug to lay cables in, then buried with native or thermal backfill, depending on the specific project design needs. In more confined areas or those with obstacles like waterways or other communications or transportation infrastructure, specialized equipment can be used to simultaneously dig the trench, lay the cable, and cover it with backfill. Where needed, horizontal drilling techniques can be employed to tunnel under waterways or avoid disturbing the surface of the ROW.

Buried HVDC Transmission Maintenance

Modern HVDC transmission line designs require minimal ongoing maintenance over their expected 40-year useful life. Modern cables use cross-linked polyethylene insulation that does not require any cooling oil or oil pumping stations to maintain safe operation. Transmission line operators may elect to perform visual inspections of the cable joint vaults annually. Any other equipment that would need regular maintenance is located outside the highway ROW.

Impact on Existing Utilities and Infrastructure in the Highway ROW

Buried HVDC transmission lines have minimal impact on surrounding infrastructure. Unlike AC transmission lines, DC transmission lines do not produce a time-varying electromagnetic field and, therefore, cannot induce currents or create voltage potentials on adjacent metal structures.

Additionally, corrosion concerns are mitigated by newer buried HVDC cable designs (buried bi-poles with a metallic return) that ensure that there are no appreciable leakage currents (i.e., voltage bleed) that could cause corrosion of adjacent metal pipes.

Importantly, buried HVDC transmission has no detrimental impact on communications equipment. The cables consist of conductive wires surrounded by an insulative polymer coating that prevents the ionization of air adjacent to the transmission line. The ionization of air—known as corona noise or corona discharge—is what produces the potential for radio communications interference (and the audible noise) associated with overhead transmission lines. In addition to the cables themselves, converter stations could also potentially interfere with communications infrastructure. However, they are designed not to via enclosure within a faraday cage.

For additional detailed information on HVDC transmission construction, operation, maintenance and safety, please see the Introduction to Buried High-Voltage Direct Current (HVDC) Transmission for DOTs document.

Part 1a: MnDOT Key Findings

MnDOT's vision is that "Minnesota's multimodal transportation system maximizes the health of people, the environment and our economy." MnDOT's mission is to "plan, build, operate and maintain a safe, accessible, efficient and reliable multimodal transportation system that connects people to destinations and markets throughout the state, regionally and around the world."

To accomplish its vision and mission, MnDOT must retain its ability to maintain and expand the transportation system as needed to best serve Minnesotans. This includes being able to adapt the system to meet the needs of electric, connected, and autonomous vehicles. MnDOT can accommodate non-transportation infrastructure as long as it does not unreasonably impede highway maintenance and expansion.

Areas of Analysis

After receiving an introduction to the NextGen Highways vision, the MnDOT Work Group and NextGen Highways Team worked to identify areas where study and/or resolution of specific issues would be required to enable MnDOT to support the location of buried HVDC transmission and fiber in interstate and highway ROW.

Relevant Background Areas:

- current policy and regulatory landscape
- MNIT and experience with connecting Minnesota

Buried HVDC Transmission & NextGen Highways Areas:

- safety
- alignment with MnDOT's and Minnesota's policies and plans
- overhead infrastructure & location of HVDC converter stations
- potential impacts on existing infrastructure
- environmental impacts
- highway construction
- highway maintenance
- planning and siting utilities in the highway ROW
- transmission permitting
- transmission construction
- transmission maintenance
- future utility relocation responsibilities & costs
- covering MnDOT's costs to support: permit fees and utility leasing fees
- communications infrastructure: fiber, intelligent transportation system, connected and automated vehicles, and broadband

A Snapshot of MnDOT Concerns

Safety

How can maintenance work be done in the vicinity of buried transmission lines?

Highway Expansion

How do we preserve ROW for future expansion?

Current Policy Environment

What are the considerations for changing the longstanding prohibition on longitudinal lines in controlled access highways?

Relocation Cost

How is the cost of relocation of a transmission line paid for?

Adjacent Infrastructure

Are there impacts on existing utilities?

Jurisdictional authority

How would MnDOT's jurisdictional authority of the ROW impact the transmission siting and approval process conducted by Commerce and MN PUC?

Key Findings

After much discussion and additional study for each identified area, the NextGen Highways team and MnDOT determined that some topic areas are relatively simple to address, some are a bit more challenging, and some require additional study. The recurring themes were safety, existing policy and regulation, process, planning, integrated coordination, and resources required to execute the NextGen Highways vision. Each topic presented both opportunities and challenges. While some of the challenges need further analysis, none appear to pose a barrier that cannot be overcome.

A summary of key findings, including opportunities and challenges for each, is presented in the table below, followed by a detailed discussion for each topic.

Table 3: Findings, opportunities and challenges

<table>
<tr><th>Topic</th><th colspan="2">Key Findings</th></tr>
<tr><td rowspan="4">Current MN Policy</td><td colspan="2">Findings</td></tr>
<tr><td colspan="2">Longitudinal utility installation is not allowed in Minnesota interstate and other controlled access highways.
MnDOT, MN PUC, and Commerce already coordinate to site proposed transmission lines just outside the ROW. This process can be built upon for siting transmission in ROW.
A Dig Once policy has been enacted for broadband conduit.</td></tr>
<tr><td>Opportunities</td><td>Challenges</td></tr>
<tr><td>MnDOT has existing policies, procedures, and relationships for permitting utilities in the ROW that can be used as a starting point.</td><td>Both MnDOT policy (its Utility Accommodation Manual) and Minnesota legislation will need to be revised.</td></tr>
<tr><td rowspan="4">Regulatory Landscape Outside of MN</td><td colspan="2">Findings</td></tr>
<tr><td colspan="2">Some states (WI, NH, ME) allow longitudinal siting of transmission lines in the highway and interstate ROW.
The Federal Highway Administration (FHWA) is encouraging state DOTs to allow co-location of fiber, electrical transmission and distribution, and renewable energy in the highway and interstate ROW.[24]</td></tr>
<tr><td>Opportunities</td><td>Challenges</td></tr>
<tr><td>A few states have built transmission in the ROW. Their experience, policies, and procedures can serve as examples to build upon. FHWA's support signals a willingness to remove barriers.</td><td>Many states still do not allow longitudinal siting of utilities in the transportation ROW.</td></tr>
</table>

[24] State DOTs Leveraging Alternative Uses of the Highway Right-of-Way Guidance

<table>
<tr><th>Topic</th><th colspan="2">Key Findings</th></tr>
<tr><td rowspan="4">MNIT - Connecting Minnesota</td><td colspan="2">Findings</td></tr>
<tr><td colspan="2">MNIT is the information technology agency for Minnesota's executive branch, responsible for providing IT and enterprise services to agency partners.
Connecting Minnesota was a public-private partnership to deploy fiber in the I-94 corridor. The private partner went bankrupt, and the State of Minnesota took over responsibility for the project.</td></tr>
<tr><td>Opportunities</td><td>Challenges</td></tr>
<tr><td>MNIT and MnDOT's partnership supports ITS[25] and TSMO[26] needs in the Twin Cities metro region, utilizing highway ROW. This can be expanded to other corridors, such as the I-35 corridor between the Twin Cities and Duluth.</td><td>While the Connecting Minnesota fiber line has been a net positive for Minnesota, there are many within MnDOT who remember the various stresses related to the bankruptcy of the private company, subsequent legal challenges and concerns in the telecom industry that the Connecting Minnesota project produced.</td></tr>
<tr><td rowspan="4">Safety</td><td colspan="2">Findings</td></tr>
<tr><td colspan="2">Safety features for HVDC lines include the following (1) burying underground, (2) surface and subsurface markings, (3) restricted access, (4) thick cable insulation, (5) conduit, (6) cable shield ground points, and (7) adherence to MnDOT's utility accommodation manual for permitting, construction, and environmental restoration traffic control.</td></tr>
<tr><td colspan="2">Opportunities</td></tr>
<tr><td colspan="2">MnDOT and public utilities both share safety as a top priority.</td></tr>
</table>

[25] Intelligent transportation systems (ITS) encompass a broad range of wireless and wire line communications-based information and electronics technologies. ITS improves transportation safety and mobility and enhances American productivity through the integration of advanced communications technologies into the transportation infrastructure and in vehicles; [US DOT Intelligent Transportation Systems FAQ]

[26] Transportation Systems Management and Operations (TSMO) means an integrated set of strategies to optimize the performance of existing infrastructure through the implementation of multimodal and intermodal, cross-jurisdictional systems, services, and projects designed to preserve capacity and improve security, safety, and reliability of the transportation system; [(23 USC 101 (a) (32))]

<table>
<tr><th>Topic</th><th colspan="2">Key Findings</th></tr>
<tr><td rowspan="6">Policy/Plan Alignment</td><td colspan="2">Findings</td></tr>
<tr><td colspan="2">There is significant alignment between the NextGen Highways vision and MN and MnDOT's existing goals, policies, and strategic plans.</td></tr>
<tr><td>Opportunities</td><td>Challenges</td></tr>
<tr><td>Build on shared values, including (1) climate and extreme weather resilience, (2) efficiency in land use and the transportation system, (3) increasing renewable energy generation, and (4) innovation.</td><td>Quantifying the specific benefits that NextGen Highways can be expected to bring to MnDOT.</td></tr>
<tr><td rowspan="4">Overhead Infrastructure & HVDC Converter Stations</td><td colspan="2">Findings</td></tr>
<tr><td colspan="2">A buried HVDC transmission line would not have any aboveground infrastructure located in the ROW. Associated HVDC converter stations would be placed well outside of the ROW.</td></tr>
<tr><td colspan="2">Opportunities</td></tr>
<tr><td colspan="2">Burying HVDC transmission lines and siting converter stations outside of the ROW removes collision hazard concerns.</td></tr>
<tr><td rowspan="4">Potential HVDC Operational Impacts on Existing Infrastructure</td><td colspan="2">Findings</td></tr>
<tr><td colspan="2">Buried HVDC transmission lines do not induce currents or create voltage potentials, do not affect nearby communication infrastructure, and do not corrode adjacent metal pipes. HVDC converter stations could interfere with communication infrastructure but are designed not to via the use of a faraday cage.</td></tr>
<tr><td>Opportunities</td><td>Challenges</td></tr>
<tr><td>New HVDC technology eliminates impacts that were of concern for previous technologies and can also be co-located in the same trench as fiber.</td><td>Different types of utilities may require minimum spacing even if there are no impacts from the buried HVDC transmission lines.</td></tr>
</table>

<table>
<tr><th>Topic</th><th colspan="2">Key Findings</th></tr>
<tr><td rowspan="4">Environmental Impacts</td><td colspan="2">Findings</td></tr>
<tr><td colspan="2">Buried HVDC transmission lines have significantly less impact on the environment than overhead transmission lines.
Transmission lines would be subject to environmental requirements in MnDOT's Utility Accommodation Policy and MN PUC's transmission siting process.</td></tr>
<tr><td>Opportunities</td><td>Challenges</td></tr>
<tr><td>Burying HVDC transmission lines allows the land aboveground to be restored to a natural habitat.</td><td>Historically, site restoration has not been accomplished after projects. In addition, with ever-increasing extreme weather events, stormwater infrastructure designed for infiltration will compete for space in the ROW.</td></tr>
<tr><td rowspan="4">Future Highway Maintenance & Construction</td><td colspan="2">Findings</td></tr>
<tr><td colspan="2">MnDOT must be able to maintain and expand the highway ROW as needed to serve the State of Minnesota's transportation needs. Non-transportation infrastructure must not unreasonably impede highway maintenance and expansion.</td></tr>
<tr><td>Opportunities</td><td>Challenges</td></tr>
<tr><td>There are successful examples in the US where a state DOT was able to work with the transmission operators to plan and site a transmission line in interstate ROW while accounting for highway maintenance and expansion needs. Looking to WisDOT's experience with the Badger Coulee transmission line in the I-90/I-94 ROW can illuminate best practices.</td><td>A deeper understanding and assessment is needed to determine feasibility and best practices for a project that would impact MnDOT ROW.</td></tr>
</table>

Topic	Key Findings	
Planning & Siting Utilities in the ROW	**Findings**	
	When siting a buried HVDC transmission line or major fiber line, the goal is to place it where it won't have to move (for as long as possible). Increased density of utilities in urban areas and the difficulty of accurately locating existing utilities have led to operational challenges. There is a need for more integrated planning.	
	Opportunities	**Challenges**
	Multiple departments within MnDOT agreed with the need for more integrated planning. An entity (MnDOT or a private partner) could create multi-utility duct banks that support fiber, transmission, and other utilities (e.g., water, gas).	Need additional information on the siting and digging limitations around existing infrastructure and for the proposed buried HVDC transmission. Finding solutions that address the different needs for multiple types of utilities.
Transmission Permitting	**Findings**	
	MnDOT has jurisdiction in its ROW and must provide its approval for any transmission project in its ROW in coordination with Commerce and MN PUC. MnDOT does not allow longitudinal transmission installations in interstate ROW today but does allow for utility crossings and transmission siting adjacent to interstate ROW. MnDOT's existing transmission permitting process can be built upon for siting transmission in highway and interstate ROWs.	
	Opportunities	**Challenges**
	MnDOT can build on its existing utility accommodation policy to incorporate transmission and emerging technologies to support clean energy and connectivity projects, including electric vehicle charging infrastructure, transmission, solar, and expanded fiber policies.	MnDOT has a single staff member who is deeply engaged with MN PUC's transmission siting process. Knowledge of MN PUC's transmission siting process is limited outside of this person.

<table>
<tr><th>Topic</th><th colspan="2">Key Findings</th></tr>
<tr><td rowspan="5">Transmission Construction</td><td colspan="2">Findings</td></tr>
<tr><td colspan="2">Construction methods, traffic impacts, and safety considerations all must be accounted for and mitigated.</td></tr>
<tr><td>Opportunities</td><td>Challenges</td></tr>
<tr><td>The Badger Coulee project in Wisconsin provides an example process to follow. The project included regular meetings between WisDOT and American Transmission Company (the transmission line developer), Constructability Reports, a work zone traffic control plan, permitting for construction, and maintenance.</td><td>The Badger Coulee project is an overhead transmission line in the ROW. An underground project may have meaningful differences that will need to be analyzed and mitigated.</td></tr>
<tr></tr>
<tr><td rowspan="4">Transmission Maintenance</td><td colspan="2">Findings</td></tr>
<tr><td colspan="2">Access to highway ROW presents both safety and security concerns. Modern HVDC transmission lines require minimal maintenance (namely, annual visual inspections). No new security vulnerabilities for MnDOT have been identified.</td></tr>
<tr><td>Opportunities</td><td>Challenges</td></tr>
<tr><td>Siting of cable joint bays where they can be safely accessed, possibly outside of the ROW.</td><td>Requires a greater degree of trust and collaboration than currently exists between MnDOT and utilities..</td></tr>
<tr><td rowspan="4">Future Utility Relocation Responsibilities and Costs</td><td colspan="2">Findings</td></tr>
<tr><td colspan="2">State statute specifies that MnDOT is responsible for all utility relocation costs for utilities located in the interstate ROW. This is contrary to the assignment of relocation costs to the utility for highway ROW in Minnesota and contrary to the policies of many other states. The assignment of utility relocation costs to MnDOT is a barrier to the use of interstate ROW for buried transmission or buried fiber.</td></tr>
<tr><td>Opportunities</td><td>Challenges</td></tr>
<tr><td>WisDOT's model requires utilities to pay for relocation and can be used as a guide. Utilities are accustomed to paying relocation costs throughout most of the US. Planned outage of the line for maintenance can enable consistent coordination between MnDOT and the utility.</td><td>Legislative change is needed to transfer cost allocation from MnDOT to the utility. The utility locate process has been difficult due to unresponsiveness from the utilities, inaccuracies for locates, and after-hours work for MnDOT staff.</td></tr>
</table>

<table>
<tr><th>Topic</th><th colspan="2">Key Findings</th></tr>
<tr><td rowspan="5">Permit Fees and Utility Leasing Fees</td><td colspan="2">Findings</td></tr>
<tr><td colspan="2">MnDOT does not currently charge permit fees or utility license fees for use of its ROW. This poses a financial concern for MnDOT as transmission and fiber build-out in the ROW would increase the amount of required coordination between MnDOT and utilities, consequently requiring more internal MnDOT resources.</td></tr>
<tr><td>Opportunities</td><td>Challenges</td></tr>
<tr><td>Many DOTs across the US have permitting and license fee programs that can be evaluated for potential application to a MnDOT program.</td><td>MnDOT does not charge permit or utility license fees to support staff resources needed for utility coordination and planning.</td></tr>
<tr></tr>
<tr><td rowspan="4">Communications Infrastructure</td><td colspan="2">Findings</td></tr>
<tr><td colspan="2">There are strong parallels between buried fiber and transmission for siting and construction in an existing ROW.
MNIT can barter existing fiber with the private sector. This exchange of fiber resources has reduced public network costs and benefited private sector companies in the network services they provide across the state.</td></tr>
<tr><td>Opportunities</td><td>Challenges</td></tr>
<tr><td>There is internal interest in having MnDOT senior leadership decide what MnDOT's role should be in the construction and ownership of additional fiber infrastructure to support greater broadband access and reduce VMT.
Fiber supports future connected and autonomous vehicles and intelligent transportation system needs.</td><td>New fiber deployment may generate political opposition from existing broadband providers.
Quantifying the amount of new fiber needed to (1) meet broadband needs and (2) meet future connected and autonomous vehicles and intelligent transportation system needs.</td></tr>
</table>

Recommended Next Steps

Table 4: Recommended next steps in Minnesota

Topic	Description
MN Policy & Permitting	The NextGen Highways Team and MnDOT review Wisconsin's laws, policies, and processes that have enabled the location of overhead AC transmission and fiber in interstate and highway ROW. MnDOT, with support from the NextGen Highways Team, examines how to remove barriers that exist in state statute, MnDOT rules, and MnDOT's utility accommodation policy (e.g., assignment of interstate utility relocation costs to MnDOT). This would include the engagement of other state agencies such as Commerce and MN PUC. The NextGen Highways Team and MnDOT further evaluate potential impacts on vegetation, noxious weeds, wetlands, slope stabilizers, stormwater management, cultural resources, and tribal lands.
Transmission: Construction, Maintenance, and Relocation	The NextGen Highways Team and MnDOT further investigate transmission construction, maintenance, and relocation processes, taking lessons from project "Constructability Reports" and maintenance agreements in Wisconsin and incorporating knowledge specific to buried HVDC transmission lines.
Planning and Siting	The NextGen Highways Team, with support from MnDOT, conducts a GIS review of the suitability of MnDOT's ROW for buried HVDC transmission and fiber. The NextGen Highways Team, with support from MnDOT, conducts a high-level evaluation of a buried HVDC transmission and fiber project in an interstate or highway corridor that would address known transmission needs (e.g., needs identified by MISO's long-range transmission planning process). MnDOT, with support from the NextGen Highways Team, examines potential to reduce existing process barriers (e.g., challenges with the current utility locate process).
Communications Infrastructure	The NextGen Highways Team and MnDOT expand the focus of the work to include fiber and communications infrastructure and support MnDOT as it seeks to clarify (1) its fiber needs to support connected and autonomous vehicles, and (2) fiber needs to support improved broadband access in communities across the state.
Stakeholder Engagement	The NextGen Highways Team and MnDOT engage a greater number of stakeholders outside of MnDOT (e.g., state agencies, utilities, tribes, communities, cities, and companies).

Part 1b: MnDOT In-Depth Findings

This section of the report provides a detailed discussion for each of the 16 topic areas identified by MnDOT where study and/or resolution is required to enable MnDOT to support the location of buried HVDC transmission and fiber in interstate and highway ROW.

Current Policy and Regulatory Landscape

Current Policy - Longitudinal Utility Installations

Minnesota statutes and rules require utility owners to obtain a permit from MnDOT to install, alter, or maintain utility facilities on trunk highway ROW. MnDOT evaluates the technical aspects of how accommodation of the utility facility will be accomplished. For example, MnDOT would evaluate how and where a utility facility may be located so as not to interfere with other utility facilities or the safety of the traveling public.

Through MnDOT's Utility Accommodation Policy, MnDOT allows the deployment of both transmission and fiber in highway and non-interstate corridors. However, for MnDOT's controlled access corridors – namely the interstate – MnDOT requires utility facilities along interstate highways to be located outside the control-of-access lines, except as outlined in the rules. MnDOT posts a list of Minnesota's controlled access freeway locations online.[27]

Longitudinal Utility Installation

Longitudinal utility installations are not allowed in the interstate and other controlled access highways. Longitudinal utility installations are allowed in uncontrolled access highways (e.g., state and US highways).

MnDOT's Utility Accommodation Manual specifies that the utility facility shall not interfere or impair the safety, design, construction, operation, maintenance, stability, or future expansion of the highway. The Utility Accommodation Manual further specifies that new longitudinal installations on highways without full or partial access control shall be located on uniform alignment as near as practicable to the ROW line and outside the clear zone.

In the context of buried HVDC transmission, the interstate corridors are of significant interest since they represent a national network and connect the country's major urban centers, which are also the country's major energy load centers.

An allowance of transmission in interstate ROW would require an expansion of MnDOT's Utility Accommodation Manual in consultation with and approval from the FHWA MN Division office. MnDOT's Utility Accommodation Section III and the Utility Accommodation on Highway ROW Policy

[27] MnDOT Trunk Highway Freeway Design and Special Condition Road Sections – No Parallel Installations

apply in certain situations for projects subject to the requirements of 23 CFR § 645.209(g), such as projects within local road and street ROW where federal-aid funds are used. To satisfy the requirements of 23 CFR § 645.209(g), a local agency may exercise its authority to manage utility accommodation pursuant to Minn. Stat. § 237.163, subd. 2(b).

Current Policy - Dig Once

Minnesota enacted a Dig Once policy in 2013 when it created the Office of Broadband Development.[28] According to state law, the Office of Broadband Development "shall, in collaboration with the Department of Transportation and private entities, encourage and coordinate 'dig once' efforts for the planning, relocation, installation, or improvement of broadband conduit within the right-of-way in conjunction with any current or planned construction, including, but not limited to, trunk highways and bridges."[29]

MnDOT and its district offices convene annual utility coordination meetings to inform utilities of MnDOT's upcoming construction plans.

Further investigation is needed to understand the degree to which the State of Minnesota's Dig Once policy facilitates the deployment of fiber and, in turn, increases broadband access across the state.

Current Policy - Transmission Siting

Minnesota's statutory siting guidance for high-voltage transmission lines requires "the evaluation of potential routes that would use or parallel existing railroad and highway rights-of-way."[30] The statute makes it clear that this preference for co-location stems from a desire to reduce environmental and societal impacts.

As a result of this statute, MnDOT, MN PUC, Commerce have coordinated on the siting of high-voltage overhead transmission lines just outside of the highway ROW. Notably, there are high-voltage transmission lines adjacent to I-90, I-94, and MN-52.

Regulatory Landscape

MnDOT is interested in understanding how Minnesota's policies compare with federal policy and policies in other states. The NextGen Highways team is in the process of conducting a review of the regulatory landscape. Initial findings reveal that some states (WI, NH, and ME) allow for transmission siting in interstate and highway ROW. The initial findings also show that the FHWA is actively encouraging state DOTs to open interstate and highway ROW to fiber, electrical transmission and distribution, renewable energy generation, and broadband projects.

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[28] Minnesota Statute 116J.391 Coordination of Broadband Infrastructure Development

[29] Article 14 of the Minnesota constitution established the state's trunk highway system. Trunk highways in Minnesota that are part of the federal-aid system are also subject to federal statutory and regulatory requirements. For a list of Minnesota's trunk highways see List of State Highways in Minnesota

[30] Minnesota Statute 216E.03 Designating Sites and Routes

Regulatory Landscape

See Finding #1 - Transmission and fiber have been and are being sited in interstate and highway ROW across the United States for an introduction to key federal and state policies related to the co-location of transmission in interstate and highway ROW. For a deeper discussion of these federal and state policies, see the Overview of Federal and State Policy document.

MNIT and Experience with Connecting Minnesota

MNIT

Created in 2011, Minnesota IT Services (MNIT) is the information technology agency for Minnesota's executive branch. The agency provides IT services to agency partners and, separately, enterprise services paid for by agency customers. MNIT, in partnership with the Minnesota Department of Employment and Economic Development and Commerce, make up the governor's broadband subcabinet, responsible for collaborating on state government-wide broadband policies.

MNIT also supports local cities and counties. MNIT directly supports towns, counties, and truck stops proximal to MNIT's fiber. Additionally, MNIT has provided fiber lighting services to community organizations in exchange for a nominal one-time fee.

MnDOT, MNIT, and the Minnesota Department of Employment and Economic Development are completing a 10-year investment plan for fiber optic deployment that will support connected and autonomous vehicle needs and broadband needs. As part of this planning, MNIT has met with the private telecommunications industry to understand its broadband expansion goals. As it relates to this network, MNIT and MnDOT have identified a need to build fiber in the I-35 corridor between the Twin Cities and Duluth.

As a final note, MNIT does not receive legislative dollars from the state. The agencies supported by MNIT pay for the cost of its services. Notably, MNIT is audited by the federal government, and any over-collection of funds must be returned to the federal government; otherwise, they face penalties. While not overly problematic, this requirement nonetheless introduces some concerns about any activities that generate revenue.

Experience with Connecting Minnesota

Twenty years ago, Minnesota allowed for the deployment of a major fiber line spanning the length of the I-94 corridor in the state (from Lakeland to Moorhead). A private company initiated this project, known as "Connecting Minnesota," and received special legislative approval to use the interstate ROW, but then later entered bankruptcy. The state had to take on the fiber build-out and operations, except for an AT&T-owned portion of the line between Plymouth and St. Cloud.

While this fiber project has been a net positive for Minnesota, there are many within MnDOT who remember the various stresses related to the bankruptcy, subsequent legal challenges, and concerns in the telecom industry that the Connecting Minnesota project produced.

Safety

Safety is the number one priority for MnDOT – just as it is for other state DOTs. The safety of the traveling public, as well as the safety of DOT employees and contractors working on the highway ROW enters into essentially every decision made by MnDOT.[31] Fortunately, safety is also the number one priority for the electric utility industry. In this way, MnDOT and public utilities have a shared priority and vision.

MnDOT raised a number of questions related to safety. Brief answers to these questions are provided here, and more detailed answers can be found in the Introduction to Buried High-Voltage Direct Current (HVDC) Transmission for DOTs.

Q. Is there any aboveground infrastructure that would need to be sited within the highway ROW?

No. The transmission cables and the cable joint bays are buried, and the converter stations would not be sited within the highway ROW.

Q. How is the transmission line protected from accidental contact (e.g., protection from damage by a backhoe)?

Several safety measures aim to prevent buried transmission lines from being accidentally exposed:

- restricting access to the interstate ROW
- surface markings/warnings
- subsurface marking
- subsurface protection
- conduit
- cable insulation

Q. What would happen if a backhoe or other construction equipment were to contact the line?

The transmission cable has a strong and thick layer of insulation. As such, simply touching the line while operational would not be problematic. For construction equipment to produce a dangerous line fault, it would have to either (2) pinch the cable against something hard and immovable (e.g., a large rock) or (2) exert enough force on the cable that it snapped into two pieces. Scraping against the cable would initially just displace the cable within the soil. If an operational line were to be severed, a line fault would occur that could be dangerous to personnel working in the immediate vicinity.

Q. What would happen if there were a line fault?[32]

The line would safely ground itself to the earth via the cable shield ground points. The cable shield ground points are buried in the earth every 1-3 miles.

[31] The priority MnDOT gives safety cannot be overstated. One member of MnDOT half-joked that if they could just remove the cars from the roads then the highway system could be as safe as they wanted it to be.

[32] A line fault not associated with mechanical severance.

Q. What safety considerations are associated with the construction of the line?

Construction-related safety considerations are well-documented in *MnDOT Utility Accommodation and Coordination Manual* Section VII, Construction and Maintenance Requirements and Traffic Control requirements.[33] Construction requirements are outlined in *Minnesota Manual on Uniform Traffic Control Devices*[34] and include the use of appropriate traffic control devices and a traffic control plan.

Q. Are there any health effects from the standard operation of the line?

No. The magnetic field directly above the line is roughly twice the strength of the earth's magnetic field and well below the safety thresholds (including those for pacemakers). Ten feet from the line the magnetic field is one-tenth the strength of the earth's magnetic field.

Alignment with MnDOT's and Minnesota's Policies and Plans

The State of Minnesota and MnDOT each have goals, policies, and strategic plans that support their missions. To ascertain the overlap between the NextGen Highways vision and these existing documents, the NextGen Highways Team reviewed 15 key documents identified by MnDOT (see table 5).[35]

A review of these documents indicated significant alignment between the NextGen Highways vision and the State of Minnesota's and MnDOT's existing goals, policies, and strategic plans. Notable areas of alignment included accessibility, broadband, carbon reduction and climate resilience, connected and autonomous vehicles, equity, innovation, partnerships, and transportation electrification – including for medium-duty and heavy-duty fleets.

The following table provides a snapshot of the alignment between the NextGen Highways vision and existing missions, goals, policies, and plans of the state and MnDOT.

[33] MN DOT Utility Accommodation and Coordination Manual

[34] Minnesota Manual on Uniform Traffic Control Devices

[35] A full list of documents considered during this study can be found in Appendix A: Existing Plans, Policies, Practices, and Projects that Informed This Work.

Table 5. Comparison of MnDOT's and Minnesota's policies and plans and NextGen Highways vision[36]

Notes:

- **Dark green:** NextGen Highways concepts or close synonyms mentioned by name.
- **Light green:** NextGen Highways concepts mentioned (e.g., climate and extreme weather resilience, efficient transportation system and land use, and increasing renewable energy).
- **Gray:** Alignment with NextGen Highways vision may exist.
- **Light Gray:** No alignment.

	Accessibility and/or Broadband	Burying Transmission	EV Charging Infra-structure	Carbon Reduction, Climate Resillience	Innovation	External Partnerships
MnDOTs Vision Minnesota GO	Vision, Guiding Principles	Vision, Guiding Principles	Vision, Guiding Principles	Vision	Vision	Guiding Principles
MN SHIP Plan Overview	Investment Categories	Investment Categories	Investment Categories	Transportation Influences, Investment Categories	Transportation Influences	Investment Direction and Project Selection, Investment Categories
SMTP Executive Summary	Objective	Objective	Objective	Objective	Objective	Objective
Sustainable Transporta-tion Advisory Council	Goals, Recom-mendations	Recommenda-tions, Goals*	Charter, Recommenda-tions, Goals*	Goals, Recom-mendations	Recommenda-tions	Charter, Goals, Recommenda-tions
MnDOT Response: STAC 2020	Recommenda-tions	Recommenda-tions	Recommenda-tions	Introduction	Introduction	Introduction, Recommenda-tions
MnDOT Pathways to Decarboniz-ing Transpor-tation	Executive Summary	Executive Summary	Website Homepage, Executive Summary	Website Homepage	Executive Summary Background	Website Homepage, Executive Summary
Sustainabil-ity & Public Health 2020 Strategic Plan	Vision, Strate-gic Goals	Mission, Vision, Guiding Statues, Strategic Goals	Mission, Vision, Strate-gic Goals	Mission, Vision, Strate-gic Goals	Mission, Vision, Princi-ples, Strategic Goals*	Mission, Principles, Strategic Goals

[36] MnDOT is updating its Statewide Multimodal Transportation Plan (SMTP). The updated SMTP will reflect an increased focus on climate change and equity, further increasing the already strong alignment that exists between the SMTP and the NextGen Highways vision.

	Accessibility and/or Broadband	Burying Transmission	EV Charging Infra-structure	Carbon Reduction, Climate Resillience	Innovation	External Partnerships
MnDOT CAV Strategic Plan	Focus Areas, Key Themes, Goals*	Focus Areas, Goals	Focus Areas, Goals, State-wide Vision	Goals	Key Themes	Focus Areas, Key Themes
MnDOT Fiber Policy	Fiber Optic Infrastructure	Supports Dig-once Practice			Fiber Optic Infrastructure	Policy Statement
Regional EV Midwest Coalition MOU	Background Objectives, Activities	Objectives, Activities	Background Objectives	Background Objectives, Activities	Objectives, Activities	Objectives
Climate Change Executive Order (19-37)	Comprehen-sive Equity	Weather Resilience, 100% Clean Energy*	Clean Energy	Goals	Subcabinet Duties	Public Engagement
Our Minne-sota Climate Legislative Priorities for 2021	Invest in Rural Communities	Resilience, Homegrown Energy	Homegrown Energy	Throughout, Resilience		
Governer's Task Force on Broadband 2020 Report	Pupose	Recommenda-tion 4	Additional Consideration 5		Throughout	OBD Duties
Dig-Once Policy	Throughout, Subd 2 (d)	Subd 2(a), (c), (d), Subd 3				Sub 2 (a)
MNIT 2020 Strategic Plan	Goals, Guiding Principles*				Goals	Goals

Through the collaboration between the NextGen Highways Team and MnDOT working group, several critical questions emerged regarding the benefits to Minnesota from buried HVDC transmission and how those benefits align with MnDOT's goals. Members of MnDOT asked the following questions.

Q. How would transmission lines in the highway ROW benefit transportation electrification?

Transmission lines (AC or DC, buried or overhead) benefit transportation electrification by providing the power for electric vehicle charging in or proximal to the highway ROW. This allows travelers to quickly and easily access charging infrastructure, a critical attribute for driving electric vehicle adoption. Co-location of transmission in the ROW practices system stewardship by helping to get the most out of investments and adapting to changing needs in the transportation system, which is one of the objectives of the 2017 Statewide Multimodal Transportation Plan.

Q. How would transmission lines in the highway ROW benefit intelligent transportation systems (ITS) and connected and autonomous vehicles (CAV)?

Buried HVDC transmission does not directly support ITS and CAV. However, buried electrical distribution (AC or DC) in the highway ROW will support these applications by powering the communications and edge computing required for ITS and CAV.

Q. How would buried HVDC transmission lines in the highway ROW align with the State of Minnesota's and MnDOT's goals?

Buried HVDC transmission lines in the highway ROW align with many of the goals and values listed in the plans identified in the preceding table. These goals and values include:

- climate and extreme weather resilience
- efficiency in land use and the transportation system
- increasing renewable energy generation
- innovation

Burying transmission lines reduces their exposure to (and potential damage from) extreme weather events while allowing for multiple uses of ROW land. Using the highway ROW allows for expeditious permitting of new transmission, thereby removing a key decarbonization roadblock (the timely build-out of new transmission). HVDC transmission (and their converter stations) offer unique functionality that increases grid reliability and allows for higher penetrations of renewable energy on the grid.

Finally, many of these strategic plans also value new solutions, flexibility, and adapting to change, all of which embody a broad view of serving the state's transportation needs. Burying HVDC transmission lines can be seen as a first step in preparing for the infrastructure needed to serve the state's transportation future, as envisioned by the Minnesota GO guiding principles.

Overhead Infrastructure and Location of HVDC Converter Stations

Two major points of concern for MnDOT were the possibility for overhead infrastructure associated with the buried HVDC transmission lines and the location of the HVDC converter stations.

Overhead infrastructure is a major concern for state DOTs because of the collision hazard immovable objects represent for vehicles departing the interstate at highway speeds. MnDOT wanted to confirm that there was no overhead infrastructure associated with a buried HVDC transmission line (e.g., electrical substations) that would need to be sited within the interstate ROW. Similarly, MnDOT wanted to confirm that the HVDC converter stations would also not be sited within the interstate ROW.

A buried HVDC transmission line would not have any aboveground infrastructure in the interstate ROW. The associated HVDC converter stations are aboveground and would be placed well outside of the interstate ROW. The exact distance from which converter stations will be located outside the interstate ROW will vary based on the specific design requirements and constraints of each individual buried HVDC transmission project.

For additional detail on design and construction requirements for buried HVDC transmission within a highway ROW, please see the Introduction to Buried High-Voltage Direct Current (HVDC) Transmission for DOTs document.

Potential Impacts to Existing Infrastructure from Operation of the Buried HVDC Transmission

Given the infrastructure that has been deployed in or near the highway ROW, MnDOT wanted to understand the potential for buried HVDC transmission to impact existing infrastructure. Such existing infrastructure includes radio communications devices, fiber optic cables, pipelines, and electric transmission and distribution lines.

In particular, members of MnDOT asked the following questions.

Q. Does buried HVDC transmission create currents or voltage potentials on adjacent metal structures?

No. DC transmission lines, unlike alternating current (AC) transmission lines, do not produce a time-varying electromagnetic field. As such, HVDC transmission cannot induce currents or create voltage potentials through capacitive effects on adjacent metal structures.

Q. Does buried HVDC transmission affect nearby communication infrastructure?

No. Buried HVDC transmission cables consist of conductive wires surrounded by an insulative polymer coating. The insulator coating serves multiple purposes, including preventing the ionization of air adjacent to the transmission line. The ionization of air—known as corona noise or corona discharge—is what produces the potential for radio communications interference (and the audible noise) associated with overhead transmission lines. (Overhead transmission lines do not have an insulative coating.)

Q. Do HVDC converter stations affect nearby communication infrastructure?

No. HVDC converter stations could interfere with communication infrastructure but are designed not to. Additionally, newer voltage-source converter station designs produce significantly less communication interference (before the use of mitigating measures) than previous load-commutated converter designs.

Q. Does buried HVDC transmission corrode adjacent metal pipes?

No. Newer buried HVDC cable designs (buried bi-poles with a metallic return) will not corrode adjacent metal structures. The bi-pole design with a metallic return ensures that there are no appreciable leakage currents (i.e., voltage bleed) that could cause corrosion of adjacent metal pipes.

Environmental Impacts

Broadly speaking, one of the advantages of buried HVDC transmission lines is that they have significantly fewer environmental impacts than overhead transmission lines, especially when the lines are buried in an existing ROW. Compared to overhead transmission lines, buried transmission lines:

- require far less ROW (approximately 10 feet in comparison with 200 feet)
- do not impact the viewshed, and
- do not pose an electrocution risk to birds or a collision risk to small aircraft.

In the context of environmental impacts on the interstate ROW, MnDOT wanted to know the following:

- Will buried HVDC transmission heat the surrounding soil? If yes, what impacts will this have?
- How will buried HVDC transmission impact existing environmental programs?
- How can MnDOT ensure site restoration work is completed according to contract agreements?
- Will vegetation and wetlands be impacted?
- What are the impacts to slope stabilizers?
- What are the cultural resource impacts and tribal impacts?

Heating of the Surrounding Soil

Soil temperatures adjacent to the transmission line will increase by roughly one-degree centigrade. It is worth noting that soil temperature is carefully studied during the design process to ensure the safe operation of the buried HVDC transmission cable.

Existing Environmental Programs

MnDOT has a number of existing environmental programs (e.g., creation of pollinator habitat, the Monarch Highway) that could be impacted by the construction of buried HVDC transmission lines. The NextGen Highways Team fully expects that these impacts are manageable but acknowledges that further investigation would be beneficial.

Site Restoration

Per contract agreements, MnDOT expects utilities to conduct post-construction landscaping and vegetation management work. From MnDOT's perspective, this site restoration work is often not completed. This creates a challenge for MnDOT as they do not have any enforceable accountability measures. MnDOT also lacks the resources to take on the additional work generated by the installation of utilities within the highway ROW.

Impacts on Vegetation, Noxious Weeds, Wetlands, Slope Stabilizers, Stormwater Management, Cultural Resources, and Tribes

Potential impacts on vegetation, noxious weeds, wetlands, slope stabilizers, stormwater management, cultural resources, and tribes will be project-specific and go beyond the level of depth covered in this Feasibility Study. They have, however, been identified as topics for investigation in future work.

Potential Next Steps:

- MnDOT and the NextGen Highways team further evaluate the potential for impact to existing environmental programs.
- The NextGen Highways team conducts further study on vegetation, noxious weeds, wetlands, slope stabilizers, stormwater management, cultural resource, and tribal impacts in Phase 2.
- MnDOT shares with the NextGen Highways team its existing GIS data sets to be incorporated into a GIS review of the suitability of MnDOT's ROW for buried HVDC transmission and fiber.
- MnDOT determines (1) the most common contract shortcomings, (1) whether contract shortcomings are broadly true or isolated to a few utilities, and (3) what options it has to improve contract adherence.

Highway Construction

MnDOT must be able to alter, update and expand the highway ROW as needed to serve Minnesota's transportation needs. As such, it is critical that the addition of non-vehicle transportation infrastructure to the highway ROW not unduly impede highway construction activities.

Fully assessing the impacts on future highway construction from the addition of buried HVDC transmission to the interstate ROW was beyond the scope of this Feasibility Study and is one of the recommended next steps.

Yet there are successful examples where a state DOT was able to work with transmission operators to plan and site a transmission line in interstate ROW while accounting for future highway construction needs.

WisDOT has been able to take highway expansion and maintenance concerns into account when siting overhead AC transmission lines in highway and interstate ROW. As one example, WisDOT worked with American Transmission Company (ATC) and Xcel Energy to site the Badger Coulee transmission line within the I-90/I-94 ROW. See the Overview of Relevant Projects document for more information on the Badger Coulee transmission line.

For the Badger Coulee project, ATC and Xcel Energy worked with WisDOT early in their development process to identify a rough corridor in which the transmission line could be sited. Then, during the final siting process, WisDOT documented where highway maintenance, upgrades, and expansion would impact the proposed siting of the transmission line. To see examples of the siting guidance that WisDOT provided to ATC and Xcel Energy, please see the Lessons from Wisconsin's experience utilizing a highway ROW subsection of this Study Report.

Potential Next Steps

- MnDOT and the NextGen Highways Team review Wisconsin's laws, policies, and processes that have enabled the location of overhead AC transmission and fiber in interstate and highway ROW.
- The NextGen Highways Team enables MnDOT (and other DOTs) to visualize how transmission infrastructure has been sited in highway and interstate ROWs in Wisconsin.

- The NextGen Highways Team, with support from MnDOT, conducts a high-level evaluation of a buried HVDC transmission and fiber project in an interstate or highway corridor that would address a known transmission need (e.g., a need identified by MISO's long-range transmission planning process).
- MnDOT and MN PUC set up a Cooperative Agreement (analogous to the one in Wisconsin), with support from the NextGen Highways Team where needed.

Highway Maintenance

MnDOT conducts a number of activities to preserve the interstate corridor, meet transportation needs, and ensure safety. These activities can span from keeping roadways clear through mowing and snow or debris removal to maintaining highway conditions by repairing potholes and painting road striping to overseeing sign installations, drainage and ditch clearances, and utility coordination. While such activities are important to be aware of, none were identified that would prohibit the installation of buried HVDC transmission and fiber in highway and interstate ROW.

Potential Next Steps

- The NextGen Highways Team and MnDOT glean insights into any highway maintenance impacts that have been observed by WisDOT and other state DOTs that allow for the presence of utilities in highway and interstate ROW.

Planning and Siting Utilities in the Highway ROW

Planning

A key realization that emerged while discussing how to incorporate utilities in the ROW was a desire for MnDOT senior leadership to decide what MnDOT's role should be in the construction and ownership of additional fiber infrastructure to support greater broadband access. This desire stemmed from MnDOT's recent commitment to reducing vehicle miles traveled and from the realization that teleworking has proven itself as a means of transportation.[37] As such, broadband and associated fiber deployment is now a transportation issue.

Discussing this second realization further raised the obvious parallel between the existing transportation system (where MnDOT owns the highway but not the cars using it) and the potential deployment of conduit or conduit plus fiber by MnDOT, where MnDOT would own the mechanism of transportation but not the transported data. Or, more simply, should MnDOT take responsibility for creating another transportation surface? Notably, this "dumb infrastructure" model has already been proposed to promote competition and innovation in vehicle-to-infrastructure technology and infrastructure while minimizing the use of regulator resources and public funding of networks.[38]

A second realization that emerged was a need for more integrated planning. Notably, this was a need that already exists today. MnDOT uses a significant amount of fiber in the Twin Cities metropolitan region to support its intelligent transportation system infrastructure. While discussing

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[37] In Big Move, MnDOT Sets Goal to Reduce Vehicle Miles Traveled

[38] Smart Cities, Dumb Infrastructure: Policy-Induced Competition in Vehicle-to-Infrastructure Systems

this existing infrastructure and the possibility of adding additional infrastructure, multiple departments within MnDOT agreed on the need to include additional infrastructure considerations at a higher level of planning than has been historically included. For example, stormwater mitigation has been and will continue to be a critical area of focus and concern for MnDOT. Stormwater infrastructure designed for increased infiltration and storage requires more space and flexibility. It could compete with fiber, especially in urban areas.

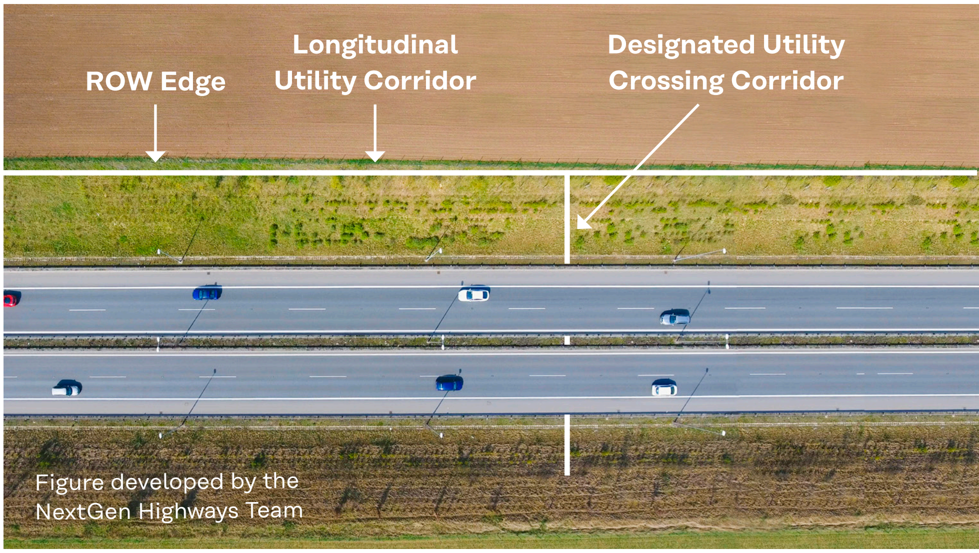
A final realization was that utilities in the ROW have proliferated significantly in urban areas and are resulting in operational challenges. In the words of another state DOT, "utilities in the ROW have begun to resemble spaghetti." This increased density of utilities, combined with the challenge of obtaining accurate utility location information (see next section), is leading in part to the 20 or so unintentional backhoe-induced fiber failures that occur each year. Recently, MnDOT experienced an issue with CenturyLink that produced a major stoppage in MnDOT's work.

In the context of these planning conversations, two potential solutions were identified:

- An entity (MnDOT or a private partner) could create multi-utility duct banks that support fiber, transmission, and other utilities (e.g., water, gas). See figure 6.
    - Prefabricated concrete ducts that support multiple utility types are a relatively new product (e.g., Forterra's Red-e-Duct[39] product, see figure 5).
- MnDOT could project future capital projects in the 50-year timeframe utilizing the State Transportation Improvement Plan,[40] Capital Highway Investment Plan,[41] Minnesota State Highway Investment Plan[42] and Minnesota GO[43] plans and identify areas where longitudinal utility installations would be challenging without an entity (DOT or utility) acquiring new ROW.

Figure 5. Forterra's Red-e-Duct product

Figure 6. Schematic of designed utility corridors



39 Red-e-Duct

40 MnDOT State Transportation Improvement Plan

41 MnDOT 10-Year Capital Highway Investment Plan

42 Minnesota State Highway Investment Plan (2018-2037)

43 Crafting a Vision for Generations

Siting

MnDOT's questions and concerns related to the siting of the transmission line within the highway ROW included the following:

- How closely can adjacent transportation infrastructure (e.g., a sign foundation, bridges, footings, culverts, etc.) be placed near the buried transmission and fiber lines?
- What restrictions on digging will exist once the transmission and fiber lines have been placed (e.g., hand digging within two feet)?
- What are the restrictions on digging around existing utility infrastructure?
- There is incomplete information regarding existing utility infrastructure within the ROW.
    - MnDOT's GIS viewer[44] is a two-dimensional dataset that doesn't contain depth data; as such, there is an ongoing need to determine depth data for utility infrastructure.
    - MnDOT lacks easy access to as-built data for utility infrastructure in the ROW.

Potential Next Steps:

- The NextGen Highways Team develops an understanding of the siting and digging limitations adjacent to buried transmission and fiber lines.
- The NextGen Highways Team and MnDOT evaluate the potential increase in the electrical and communications infrastructure in and around the highway ROW.
- The NextGen Highways Team and MnDOT evaluate the potential impact of buried transmission lines on gravity flow stormwater systems.
- The NextGen Highways Team and MnDOT evaluate ways to visualize transmission within the highway ROW prior to construction.
- The NextGen Highways Team, with support from MnDOT, conducts a high-level GIS review of the suitability of MnDOT's ROW for buried HVDC transmission and fiber.

Transmission Permitting

ROW Jurisdiction

An early question of MnDOT was which state agency (MnDOT or MN PUC) has jurisdiction in MnDOT's ROW. MN PUC and MnDOT quickly determined that MnDOT has jurisdiction in its own ROW (see the Overview of Federal and State Policy document). The need to answer this question is indicative of the relatively small degree of interaction that exists today between MnDOT and MN PUC.

MN PUC: Transmission Permitting

In Minnesota, MN PUC and Commerce are responsible for the siting and permitting of proposed transmission projects. As part of this process, MnDOT's opinion is solicited when transmission projects would involve the use of MnDOT ROW. MnDOT participates during routing and siting proceedings, informing the PUC on the compatibility of routes under consideration with MN DOT rules or

[44] Georilla

policies. MnDOT's permitting process begins after MN PUC has approved a transmission project's proposed route.

When siting a transmission project, MN PUC and Commerce are aware of MnDOT's restrictions on the use of highway ROW, including MnDOT's prohibition of longitudinal utility deployments within interstate and other controlled access ROW. The PUC and Commerce rely on MnDOT guidance in their evaluation of potential routes.

MnDOT has a single staff member who is deeply engaged with MN PUC's transmission siting process. This staff member has a strong working relationship with their counterparts at MN PUC and Commerce. Knowledge of MN PUC's siting process is highly limited with MnDOT outside of this individual.

MnDOT: Transmission Permitting

As previously noted, MnDOT does not allow for longitudinal utility installations in controlled access highways (namely the interstate). However, MnDOT does allow for utility crossings of controlled access highways and for longitudinal installations and utility crossings in its uncontrolled access highways.

MnDOT's transmission permitting process for utility crossings is an internal process. The process includes many of the same types of reviews within MN PUC's transmission siting process.

An unresolved question for MnDOT was whether its existing permitting process would need adjustments to support a buried HVDC transmission line located in interstate ROW. Similarly, there was an unresolved question of whether the existing opportunities for utilities to conduct pre-permitting discussions with MnDOT would be sufficient for a buried HVDC transmission line. To help address these unresolved questions, members of MnDOT were interested in obtaining information on the practices and policies Wisconsin uses to enable the permitting of longitudinal transmission in interstate ROW.

MnDOT Permitting Concerns

Some specific concerns arose regarding the potential to change MnDOT's longstanding prohibition on the longitudinal installation of utilities in interstate ROW. A brief Q&A for key concerns is provided here:

Q. What happens if we hit maximum utility capacity? How is utility access to a finite quantity of ROW determined?

There are different ways this could be addressed, from a first-come-first-served policy to having MN PUC adjudicate access. To start answering this question, the NextGen Highways Team recommends engaging the relevant state and industry stakeholders.

Q. How many requests might they receive from other utilities (e.g., fiber)? Would they be able to support this increase in requests?

The NextGen Highways Team recommends that MnDOT engage relevant state and industry stakeholders to identify the potential number of requests and to consult with other states who have already opened their interstate ROW for transmission and fiber installations, such as Wisconsin. Once MnDOT has developed an understanding of the potential increase in requests, it will be better positioned to assess the resources that would be required to support such an increase.

Q. Who would own the transmission lines? And would the owner have the ability to take land?

The transmission lines would be owned by a public utility with the power to take land (if needed). Note, independent transmission developers (e.g., LS Power) would register as a public utility in the State of Minnesota if they were to win a competitively-bid transmission project from MISO.

Environmental Permitting

MnDOT's transmission permitting process includes reviews of impacts on cultural resources, tribal areas, wetlands, and federally-regulated waters, among other natural resources. MnDOT desires to understand better the environmental permits that could be required (e.g., US Army Corps of Engineers 404 permit).

Potential Next Steps

- NextGen Highways Team obtains information from Wisconsin on the practices and policies used to enable transmission permitting in interstate ROW.
- NextGen Highways Team obtains information from Wisconsin on the number of transmission and fiber projects permitted in interstate ROW and an estimate of the resources required to support that permitting.
- NextGen Highways Team and MnDOT engage state, industry, and tribal stakeholders for their input on managing the finite space within interstate ROW and the potential increase in permit requests.
- With support from MnDOT, the NextGen Highways Team investigates and summarizes the likely environmental permits required.

Transmission Construction

The process of constructing buried HVDC transmission lines produced a series of questions from MnDOT regarding construction methods, traffic impacts, and safety considerations. Key areas of concern included the following:

- Non-highway access to the construction area (i.e., use of secondary access)
- Temporary traffic impacts such as the need for shoulder or lane closures that could cause significant interstate impacts
- Potential impacts on the safety of the traveling public

In Wisconsin, transmission developers prepare and submit Constructability Reports to WisDOT for review and approval before any transmission project construction that would use highway ROW.[45] These reports address the above issues and others in detail.

In speaking with WisDOT and ATC regarding the construction process, the following observations were shared:

- **The utility and WisDOT will have met multiple times over a two- to three-year period prior to project application submission**

[45] For example, see the "Constructability Report" by American Transmission Company and Xcel Energy, produced for Wisconsin's Badger Coulee project

- "ATC and WisDOT met for months leading up to the permit application to determine what details needed to be included. We continued to meet monthly during construction to review/discuss construction progress and determine if any enhancements to the traffic control plan were needed. All meetings were facilitated by an independent engineering firm that had both WisDOT and ATC as clients." David Hollenberger, American Transmission Company, Manager, Real Estate[46]

- **WisDOT requires the utility to prepare a Constructability Report during the application process and WisDOT reviews and comments on the Constructability Report**
  - The purpose of the Constructability Report is to identify issues such as routing and siting constraints, proposed construction access, and traffic impacts for review by WisDOT.
  - The transmission applicants request WisDOT's concurrence that the preliminary alignments along the highways discussed within the report are permissible. This concurrence is subject to developing a memorandum of understanding outlining major conditions for state trunk highway (STH) occupation, supplemental permit provisions, and other items for discussion and resolution before a draft environmental impact statement submittal (e.g., possible alignment shifts, especially through interchange areas).
  - The Constructability Report for the Badger Coulee transmission.[47]
- **WisDOT, in consultation with the utility, sets certain conditions for construction as part of the permit to construction, such as the following examples:**
  - Utility construction occurs anytime, sunrise to sunset, Monday thru Friday.
  - Weekend work must be prior approved and may be required for traffic stops and slowdowns when traffic counts are low (e.g., Sunday mornings on the interstate).
  - Work is typically restricted on major holidays (for example, no lane or shoulder closures starting noon Friday before the Memorial Day or Labor Day weekend and ending 6:00 AM Tuesday morning).
  - On the Badger Coulee Transmission Line Project, WisDOT did not allow construction in the Wisconsin Dells area between Memorial Day and Labor Day because of high volume vacation traffic.
- **WisDOT requires the utility to develop comprehensive work zone traffic control plans**
  - When lane closures were required on the Badger Coulee project, which were infrequent, they were typically in six-hour increments at night or early morning.
  - If traffic stops were required (rarely), they were done in five-minute increments, and ATC paid for State Patrol costs.

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[46] Interview conducted in October 2021

[47] Badger Coulee Constructability Report

- **WisDOT permits must be acquired for maintenance work**
  - Regarding highway access, WisDOT prefers access via private property first or from side roads, then driving along the ROW line.
  - Direct highway access is also allowed when other access is not available.
  - Access points must be called out on the permit application, and a proper work zone traffic control plan must be provided for each.

Potential Next Steps:

- The NextGen Highways team and MnDOT review the Constructability Reports from Wisconsin.
- The NextGen Highways team evaluates how the buried HVDC transmission construction processes would meaningfully differ from the overhead construction process in Wisconsin.
- The NextGen Highways team provides MnDOT with an analysis of the likely issues and mitigation methods related to the construction of buried HVDC transmission in MnDOT's ROW.

Transmission Maintenance

Access to the highway ROW is a major concern to MnDOT. Activity in the ROW is a distraction to drivers traveling at high speed, and any vehicles in the ROW represent potential collision hazards for vehicles that depart the travel lanes. Each of these presents a safety concern to MnDOT. Highway ROW access is also a concern for MnDOT for security reasons.

Given MnDOT's safety and security concerns regarding highway access, MnDOT asked the following questions:

Q. How often will buried HVDC transmission lines require maintenance that requires highway access?

Modern buried HVDC transmission cables require minimal maintenance over their forty-year design life. These cables use cross-linked polyethylene insulation that, unlike older designs, does not require any cooling oil or oil pumping stations to maintain safe operation. Transmission line operators may elect to perform visual inspections of the cable joint vaults annually. Any other components of the buried HVDC transmission line that would need regular maintenance would be located outside the highway ROW (namely, the converter stations).

Q. Will additional access points through fencing for access-controlled ROWs be required for transmission maintenance?

Potentially. The answer will be project dependent. As with any ROW access event, the electric utility will be required to coordinate with the DOT to mitigate any safety and security risks.

Q. Are there any additional security or terrorist threats that should be considered beyond typical MnDOT infrastructure?

Additional threats have not been identified, but this topic requires further investigation. This will be best addressed with utility partners in future work.

Future Utility Relocation Responsibilities & Costs

Utility relocation is the process of moving utility infrastructure in or adjacent to the highway ROW to accommodate the expansion of the highway ROW or the alteration of the highway travel lanes.

As discussed earlier, the goal when siting a buried HVDC transmission line or major fiber line should be to place it where it won't have to move and can be designed around. However, MnDOT's historical experience with the Connecting Minnesota fiber line in the I-94 corridor suggests that the line will have to be moved every few years to accommodate highway maintenance and expansion in and around the Twin Cities metro area. For fiber, this generally results in a 10-12 hour outage for which planning is required.

Depending on a number of factors – including whether the buried HVDC transmission route selected utilized highway ROW in the Twin Cities metro area – it is possible that relocation events for a buried HVDC transmission line could be less than those experienced by Connecting Minnesota. Nonetheless, this is an important issue for MnDOT since they may bear the cost of utility relocation within the highway ROW if those needs come to fruition.

Operational Costs

MnDOT incurs operating costs (associated with 1-2 full-time employees) when supporting the utility relocation process. Before allowing an increase in the number of utilities sited in the interstate and highway ROW, MnDOT would like to ensure that it has the required operational funding to support the eventual need for utility relocations. When considering the full nature of this concern, it is worth noting that operational funding at MnDOT (and other state DOTs) is much harder to obtain than capital funding. As such, operational funding is quite precious.

Relocation Cost Allocation

In Minnesota, the entity responsible for the costs of relocation is determined by the location of the infrastructure. For most MnDOT ROW, MnDOT is responsible for all relocation costs for utility infrastructure when relocation is required to go outside of the highway ROW, while the relevant utility(ies) is responsible for relocation costs of infrastructure located within the highway ROW. However, for interstate ROW, MnDOT is also responsible for utility relocation costs for utilities sited within interstate ROW.[48] Given the potentially large costs associated with relocating a buried HVDC transmission line sited within the interstate ROW, MnDOT needs to understand how potential relocation costs would be paid for.

It is worth noting that relocation costs are paid for by the utility in Wisconsin for all WisDOT ROW (i.e., there is no exception for interstate ROW, as there is in Minnesota) in accordance with Wisconsin Administrative Code.[49]

[48] MN Statute §161.46 subdivision 2, and §161.45; MN Rule 8810.3300

[49] Wisconsin Administrative Code, Chapter 220 "Utility Facilities Relocation"

Planning for Relocation

MnDOT would like to understand whether its existing utility relocation process will work for buried HVDC transmission lines. MnDOT would also like to better understand how utilities would plan for the relocation of a buried HVDC transmission line. With regards to the utility downtime associated with relocation, it is worth noting that HVDC transmission lines are offline for 1-2 weeks per year as the converter stations[50] undergo routine maintenance. This is similar to other energy infrastructure that is offline for multiple weeks per year for maintenance, such as, coal, gas, and nuclear plants. This planned outage period may enable coordination between MnDOT and the utility to align utility relocation work with planned converter station maintenance to minimize impacts on electric customers.

Utility Location Process

As part of the utility relocation process, MnDOT first has to locate the existing utilities in the ROW. This is referred to as the utility locate process. Discussions of the utility relocation process revealed challenges with the existing utility locate process:

- Significant improvements could be made in utility responsiveness and accuracy for locates.
- The number of utility locates required means that staff is working into the night during construction months.
- Utility locates reportedly cost MnDOT hundreds of thousands of dollars on an annual basis.

Establishing dedicated utility corridors within the ROW is one of the potential solutions identified in this report's Planning and Siting Utilities in the Highway ROW subsection.

Potential Next Steps

- Address MnDOT's significant concerns about the cost of relocation of transmission in interstate ROW through (1) conducting additional analysis, either by MnDOT, the NextGen Highways team, or both, on the allocation of relocation costs, and (2) conducting additional ROW valuation analysis in Phase II in partnership with other relevant state agencies.
- MnDOT could enumerate additional transmission relocation protocols for all parties in its Utility Accommodation Policy.
- MnDOT, with support from the NextGen Highways team, addresses relocation process barriers (e.g., ease of obtaining locational information for existing utilities within the interstate ROW).
- Initiate a conversation between MnDOT and Minnesota utilities regarding the relocation process.
- Form a joint committee with MnDOT and utility representatives to develop a set of business practices for relocation and related activities (such as transmission and highway maintenance).

[50] Note that converter stations will be located outside the highway ROW in all cases and will therefore have no impact on traffic or other activities occurring within the ROW.

Covering MnDOT's Costs to Support: Permit Fees and Utility Leasing Fees

The build-out of transmission and fiber in the highway and interstate ROW as envisioned by NextGen Highways would increase the amount of coordination and planning required between MnDOT and utilities.

While this increased coordination and planning is not in itself problematic, MnDOT does need to have the resources to support it. This is problematic because MnDOT does not currently have a mechanism to generate the operational funds required to support the increased coordination and planning that would be required. Specifically, MnDOT does not charge permit fees or utility license fees when providing access to the public ROW.

The rationale behind not charging for utility access to the public ROW is that any such charges would be passed on to Minnesotans via their electricity bills. At the same time, operational funding is hard to come by at MnDOT, just as it is at other state DOTs. The lack of permit fees or utility license fees thus leads to a legitimate concern that MnDOT may not have the resources required for the increased utility coordination and planning necessary to support the NextGen Highways vision. A concern that has already been partially validated by operational resource constraints related to maintaining the existing Connecting Minnesota fiber line.

For reference, the NextGen Highways team has loosely estimated that the additional costs are on the order of a few hundred thousand dollars per year, which would translate to low tens of millions of dollars in cost over the 40-year lifetime of a buried HVDC transmission line.

Potential Next Steps:

- NextGen Highways team and MnDOT evaluate the quantity of additional resources required to support the NextGen Highways vision, drawing on WisDOT's experience.
- NextGen Highways Team conducts a national review of state DOT permit fees and utility license fees.
- MnDOT, with support from the NextGen Highways team, evaluates what would be required to add a permit fee or utility license fee.

Communications Infrastructure: Fiber, ITS, CAV, and Broadband

The topic of fiber repeatedly arose during the Feasibility Study, despite the study's focus on buried HVDC transmission. This was not entirely unexpected, given the strong parallels between buried fiber and buried transmission and the full scope of the NextGen Highways vision.

The most prominent issue for MNIT and MnDOT is the potential for new fiber deployment to disadvantage existing broadband providers, generating political opposition to new fiber deployment.

MNIT knows that, on the whole, its existing fiber and ability to barter that fiber has been valuable to the telecommunications industry in Minnesota. MNIT has bartered with many different companies, including Charter, Spectrum, Zayo, CNS, and Emerald 2. As a result of this bartering, MNIT believes it has helped increase competition and reduce access costs across Minnesota. However, MNIT also knows that this increased competition can disrupt existing power balances and that there are those who will be threatened by the expansion of fiber resources in Minnesota.

As MnDOT looks to develop the connectivity infrastructure it requires to support future CAV and ITS needs while also supporting Minnesota's broadband goals, the following questions will need to be addressed:

- How much additional fiber and other communications infrastructure is needed, and for what uses?
- Is MNIT's existing bartering authority sufficient to enable effective and efficient public-private partnerships, or would it help if MnDOT additionally had resource sharing and/or bartering authority with private industry?
- Are there opportunities to align MnDOT's two different fiber accommodation policies? MnDOT utilizes its utility accommodation policy for private fiber and a separate policy for state fiber projects.[51]

Potential Next Steps

- The NextGen Highways Team and MnDOT analyze the fiber and other communications infrastructure required for future transportation needs (e.g., CAV and ITS needs).
- The NextGen Highways Team and MnDOT evaluate the ability for MNIT and MnDOT to site new fiber such that buried HVDC transmission could be sited adjacently in the future.

[51] Fiber Optic Infrastructure and RTMC Network Access #DM008.

Part 2: National Findings

The following findings demonstrate that buried HVDC transmission is cost-effective and can be sited in interstate and highway ROW through appropriate consideration of transportation system needs.

Summary of Findings

1. Transmission and fiber have been and are being sited in interstate and highway ROW across the United States.
2. Much of the interstate is suitable for buried HVDC transmission and fiber, but certain areas require special considerations or routing outside of the interstate ROW.
3. Buried HVDC transmission can be compatible with interstate and highway ROW.
4. Buried HVDC transmission is comparable in cost to overhead AC transmission while providing additional reliability and resilience benefits.
5. Together, DOT ROW and buried HVDC transmission can deliver billions of dollars in societal benefits.
6. Buried HVDC transmission supports transportation decarbonization.
7. Wisconsin has the playbook for siting transmission in DOT ROW.

Finding #1: Transmission and fiber have been and are being sited in interstate and highway ROW across the United States

Each state sets its own specific utility accommodation rules documented in a utility accommodation plan or utility accommodation manual. These rules are then approved by FHWA. In all states, the DOT retains authority over the use of highway ROW. While many state DOTs allow longitudinal utility installations along uncontrolled access highways, most do not allow longitudinal utility installations along controlled access highways (i.e., interstates). Occasionally, longitudinal utility installations may be allowed along controlled access highways with special approval.

In recent years, a few state DOTs have removed barriers to longitudinal utility installations along controlled access highways for broadband and electric transmission to support greater societal needs. In April 2021, FHWA also removed barriers to longitudinal siting and issued guidance encouraging state DOTs to accommodate broadband and electric transmission projects in the highway ROW for "pressing public needs relating to climate change, equitable communications access, and energy reliability."[52]

States are Expanding Broadband Access by Deploying Fiber Using Highway ROW

Several states are now deploying fiber – or taking steps to enable future fiber projects – in highway rights-of-way. Other states are exploring policy changes so they can follow suit. Many states acknowledge future communication needs and the advent of autonomous and connected vehicles in their plans. Many state DOTs receive substantial financial benefits from public-private partnerships, a trend expected to grow with the $65 billion of federal funding for broadband in the IIJA.

[52] State DOTs Leveraging Alternative Uses of the Highway Right-of-Way Guidance

Some States Have Revised Utility Accommodation Policies to Allow for Transmission Projects

The dominant growth of wind, solar, and geothermal energy resources is increasing demand for transmission to connect these assets to the grid.[53] States are exploring policy changes that will enable siting transmission in highway ROW. Declining costs of buried HVDC transmission cable will likely accelerate this trend.

Policy and Project Highlights - Fiber

- **North Carolina** is installing 300 miles of fiber optic cable along Interstate 95 and US 70 to expand access to broadband and telecommunication access.[54]
- The **Pennsylvania** Turnpike Commission is deploying 220 miles of fiber to support the commission's communications needs, enable the transition to automated tolling, and support the expected growth of ITS devices and automated vehicles.[55]
- **Utah** DOT partnered with industry to install more than 100 miles of conduit and fiber on UDOT ROW that supports UDOT's communications needs and will enable expanding broadband service to underserved communities.[56]
- The **Arizona** DOT started construction on a fiber optic conduit along a 46-mile stretch of I-17 from Flagstaff to Sedona. The agency is partnering with the Arizona Commerce Authority to increase broadband availability by providing access to ROW along the four main interstates in Arizona.[57]

Several states are developing broadband plans and making the necessary policy changes to facilitate fiber deployment using highway ROWs, including **Wyoming**[58], **Washington**[59], **California**[60], and **Ohio**[61].

See Overview of Relevant Projects for greater detail.

Policy and Project Highlights - Transmission:

- In 2003 **Wisconsin** passed a law establishing existing highway ROW as a priority siting corridor for new transmission lines, second only to existing transmission corridors. Since then, the state has sited several transmission projects using highway ROW.
- In 2010 **Maine** passed a law designating energy corridors for the development of transmission and other energy infrastructure along specific highway and pipeline rights-of-way. Developers can apply to build pipelines, transmission lines, or other energy infrastructure along Interstate-95 and two other state-owned corridors.

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[53] Solar and wind have represented the overwhelming majority of new generation capacity added to the US electric grid in recent years.

[54] I-95/US 70 Improvements: Innovative Technology and Rural Mobility Improvements

[55] Fiber Optic Network Will Boost Connectivity, Support Safety, and Mobility Along our Roadway

[56] How a State Agency Can Drive Fiber Development

[57] ADOT begins first project to bring broadband internet to rural Arizona communities

[58] WyoLink and Broadband in Highway Rights-Of-Way

[59] Broadband Access to State Right-of-Way

[60] Caltrans Broadband Partnership Opportunity Map

[61] The Ohio Broadband Strategy

- In 2016 **New Hampshire** passed a law that laid the groundwork for co-locating transmission infrastructure and highways. The law designated portions of I-89, I-93, I-95, and NH Route 101 as energy infrastructure corridors.

Additional details on these state policies can be found in the Overview of Federal and State Policy document.

Finding #2: Much of the interstate is suitable for buried HVDC transmission and fiber, but certain areas require special considerations or routing outside of the interstate ROW.

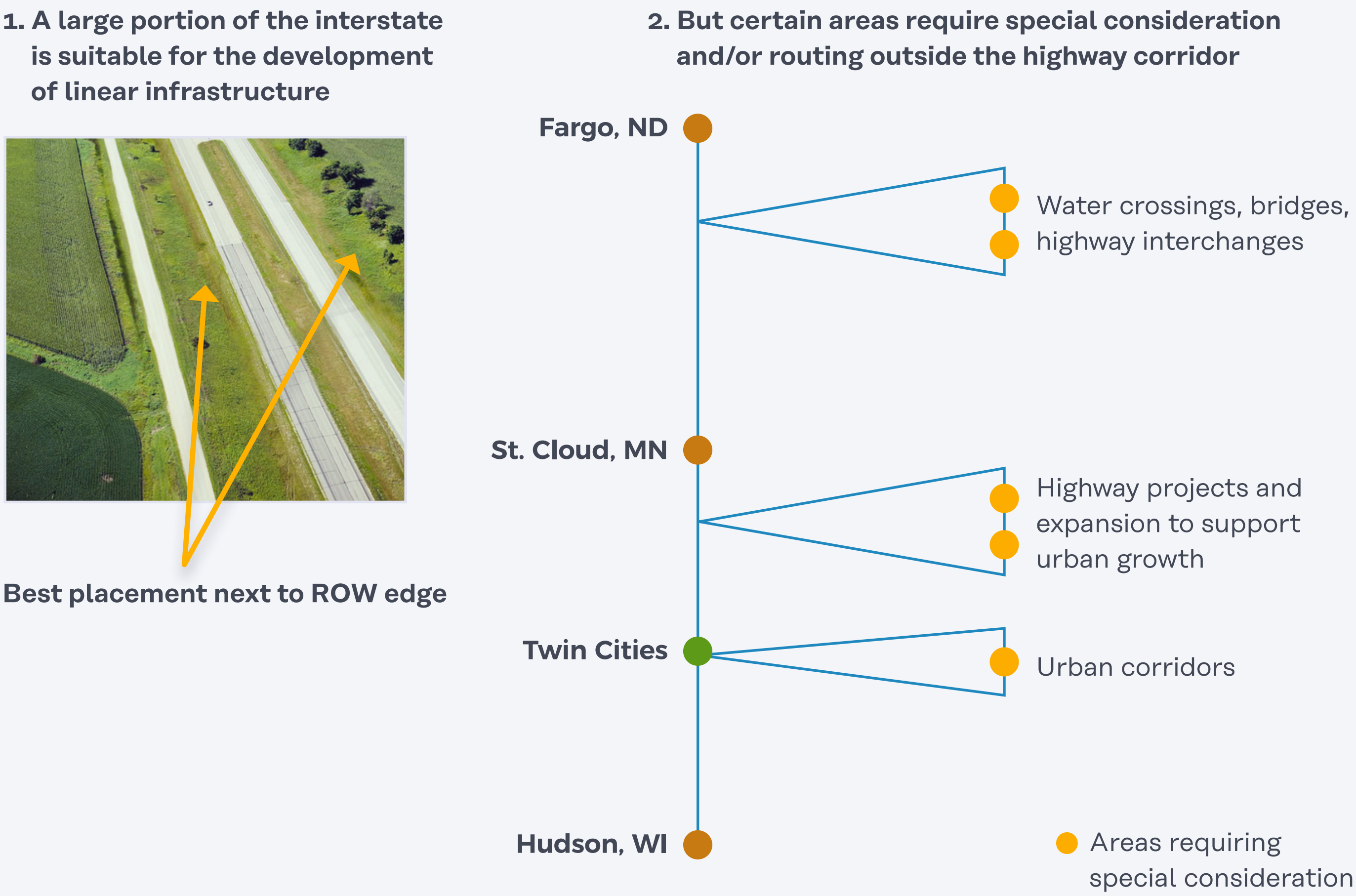
The development of transmission and fiber lines often requires the ability to acquire or lease significant lengths of ROW – this is especially true for interregional transmission. Utilities often prefer to use a ROW they have developed and own. However, obtaining new ROW is challenging and the optimal route is not always possible.[62] Access to a portion of existing ROW in interstate or highway could offer significant benefits in the development of new transmission and fiber lines. Existing ROW along interstate highways would be especially valuable for the interregional transmission lines needed to cost-effectively decarbonize the grid while improving its reliability and resilience.

If interstate and highway ROW were made available for transmission development, a typical transmission project would likely use a portion of the highway ROW while also using existing utility and rail ROWs. The transmission line would not be fully sited within the highway ROW alone. In these circumstances, siting of the transmission line within the ROW would be done in close collaboration with the existing ROW owner (e.g., the DOT) and would take into account current and future transportation needs.

While not all highway ROW is suitable or available for electric transmission (siting within urban corridors can be particularly challenging), ROW in rural areas can be suitable (see figure 7). In rural areas, the ROW is often 300 feet wide, and other utilities and land uses are not as competitive.

[62] A number of overhead interregional transmission projects have been successfully blocked by public opposition in recent years.

Figure 7. Utilizing a highway corridor



Key elements that require special consideration when determining the suitability of transmission siting in the interstate and highway ROW include impacts from or impacts on the following:

- Urban corridors
- Construction of new interchanges and bridges (primarily driven by safety upgrades and population growth through suburban expansion)
- Crossing bodies of water, bridges, and interchanges
- Stormwater systems and resilience/mitigation for increased stormwater due to climate change.

Urban Corridors

Urban corridors are particularly challenging locations to site utility infrastructure given the high percentage of the ROW dedicated to the travel lanes. Examples include the I-35W corridor just south of Minneapolis and the I-94 corridor between Minneapolis and St. Paul. Additionally, noise walls in urban areas present unique challenges given their proximity to the edge of the ROW and construction requirements.

Construction of New Interchanges and Bridges

Constructing new interchanges and bridges will likely create the largest operational challenges to siting transmission in the highway ROW. As urban areas grow, MnDOT needs to expand the highway infrastructure to accommodate the increased population. When MnDOT constructs new interchanges, bridges, travel lanes, etc., adjacent utilities may need relocation.

Crossing Bodies of Water, Bridges, and Interchanges

Siting linear utilities that cross bodies of water, bridges, and interchanges require additional planning to avoid or mitigate impacts on existing infrastructure and the environment. Bridges and interchanges require frequent routine and emergency maintenance and repair. Bodies of water have strict environmental protection requirements. Constructing and maintaining a transmission line near these areas must minimize its impact on the existing infrastructure and environment. It must also account for the inevitable future impact that maintaining, repairing, or expanding these areas can pose to the transmission line.

Stormwater Systems:

As Minnesota continues to experience more intense rain events at greater frequency, culverts and other elements of stormwater management systems will need to be redesigned. Nature based stormwater infiltration systems effectively manage increased quantity while providing better water quality treatment. However, these systems typically take up more space, which could impact siting of a transmission line.

The resounding consensus from a number of the MnDOT departments interviewed was that these transmission lines should be installed in a way that would minimize the potential for future movement. This would reduce relocation costs and planning efforts. Therefore, if these lines were allowed to be accommodated in the interstate or highway ROW, they should be located in areas where they would ideally never have to be moved. Preferably, they would also be located in areas with secondary access that can be used for maintenance needs.

Lessons from Wisconsin's Experience Utilizing Interstate ROW

The Badger Coulee project in Wisconsin provides a good example of how to account for future highway and maintenance needs during the transmission siting process. The project also shows how to avoid future relocation events. As discussed in the Badger Coulee Transmission Line Final Environmental Impact Statement, a significant portion of the transmission line is located longitudinally within WisDOT's ROW for I-90/I-94.[63] During the siting process for the Badger Coulee transmission line, WisDOT provided comments to the Public Service Commission of Wisconsin that:

- ensured WisDOT's future needs were met, and
- suggested changes to the siting of the transmission line to avoid the need for future line relocations to accommodate already planned upgrades within the I-90/I-94 corridor.

[63] Badger Coulee Transmission Line, Volume 1; Environmental Impact Statement

The following are three examples of how WisDOT worked with ATC to (1) identify areas where future highway maintenance and construction would be required and (2) site the transmission line in a location where the need for a future relocation event could be avoided where possible:

> "WisDOT opposes short jogs in transmission line ROW since it hampers its ability for future highway expansion. A more gradual shift is preferred to allow for smoother/easier transitions should horizontal curves need to be constructed to avoid relocation of transmission line structures. WisDOT is not opposed to its ROW being used for the transmission line ROW in this corridor. In addition, the same issues faced by the applicants regarding the inability to get approvals from USFWS to locate through its territory will likely be faced by WisDOT. Therefore, any expansion will need to be on the north side of the highway."

> "Since the existing bridges are next to each other, any expansion would likely include constructing a new structure on one side or the other. Should the east side be selected, the applicants' transmission line would have to be relocated if it was not located sufficiently away from the proposed new bridge site. … See attachment #3."

> "WisDOT is currently studying the corridor from the USH 12/STH 16 interchange to the I-39/STH 78 interchange on I-90/94 for major improvements and expansion. This includes improvements to all four interchanges in Wisconsin Dells and the major system interchange with I-39 south of Portage. No matter which transmission line alternative is selected, it is highly likely that the applicants' structures will have to be relocated to accommodate highway improvement and expansion. The WisDOT Southwest Region – Madison office has put together a summary of the proposed actions and parameters. See attachment #2."

For more information, see Appendix E of Vol 1 of the Final Environmental Impact Statement for the Badger Coulee Transmission Project.

Finding #3: Buried HVDC transmission can be compatible with interstate and highway ROW

The NextGen Highways Team's investigation, coupled with learnings from projects under development in Europe, demonstrates that buried HVDC transmission can be sited feasibly in interstate and highway ROW. Doing so requires close collaboration between the DOT and utility to ensure the project design accounts for existing and future transportation needs. As discussed in Finding #2, certain areas will not be practical to site buried HVDC transmission in the interstate or highway ROW. But the existence of specific constraints doesn't prevent the broader use of the interstate and highway ROW.

The NextGen Highways Team investigated the following topic areas and produced the Introduction to Buried High-Voltage Direct Current (HVDC) Transmission for DOTs document that discusses each area to help MnDOT (and other state DOTs) evaluate the compatibility of buried HVDC transmission within highway and interstate ROW:

- system design
- safety
- transmission construction techniques

- transmission maintenance requirements
- potential for impact on existing infrastructure and devices
- environmental impacts

Notably, buried HVDC cables would require a small fraction of the width of the interstate ROW (<5 percent in rural areas). Interstate highway ROW in rural areas is typically 300 feet wide, and buried HVDC transmission cables require a corridor that is 5 feet wide and 5 feet deep.

While the ROW required for buried HVDC cables is relatively modest, additional space may be required to meet offset requirements for other utilities in the interstate ROW and during construction for equipment. These additional space requirements will vary by project and need to be considered on a project-by-project basis.

Unresolved questions remain regarding the transmission construction process and what those impacts may be on the transportation system. There is also a need for careful consideration to minimize or altogether avoid impacting highway construction expansion as forecasted over a state DOT's long-range planning horizon. Future work will investigate these questions.

As a final note, many of the identified issues regarding buried HVDC impacts on the ROW are highly analogous to the impacts from fiber infrastructure. This is encouraging given the history of successfully siting fiber infrastructure in the interstate and highway ROW across the United States. As such, if fiber is possible, then buried HVDC transmission should also be possible, especially since co-location of the two is possible.

Finding #4: Buried HVDC transmission is comparable in cost to overhead AC transmission while providing additional reliability and resilience benefits

Transmission Cost Comparison

Buried HVDC transmission costs have declined and become competitive with traditional overhead AC transmission. The technology for buried HVDC transmission has matured, and the industry has gained experience designing and building projects across the world. Figure 8 compares transmission cost on a capacity-normalized basis (dollars per gigawatt-mile of transmission capacity) for a few representative transmission projects in the United States. The figure shows that buried HVDC projects are cost-competitive with overhead AC transmission projects.[64]

[64] The cost comparison presented includes all of the MISO Multi-Value Projects [Multi Value Project Portfolio Results and Analysis] that are over 100 miles long: 1-Brookings SD - SE Twin Cities; 2- Lakefield - Winnebago - Winco - Burt Area & Sheldon - Burt Area - Webster; 3- Winco - Lime Creek - Emery - Black Hawk - Hazleton; 4 - N. Lacrosse - N. Madison - Cardinal (i.e., Badger Coulee); 5 - Cardinal - Hickory Creek; 6- Big Stone South - Ellendale; 7- Maywood - Herleman - Meredosia - Ipava & Meredosia - Austin; 8 - Pana - Faraday - Kansas - Sugar Creek; and 9 - Reynolds - Burr Oak – Hiple. The buried HVDC projects included in the cost comparison were: 1 – SOO Green HVDC Link; 2 – Clean Path New York; and 3 – Champlain Hudson Power Expressway.

Figure 8. Transmission cost comparison: overhead AC and buried HVDC

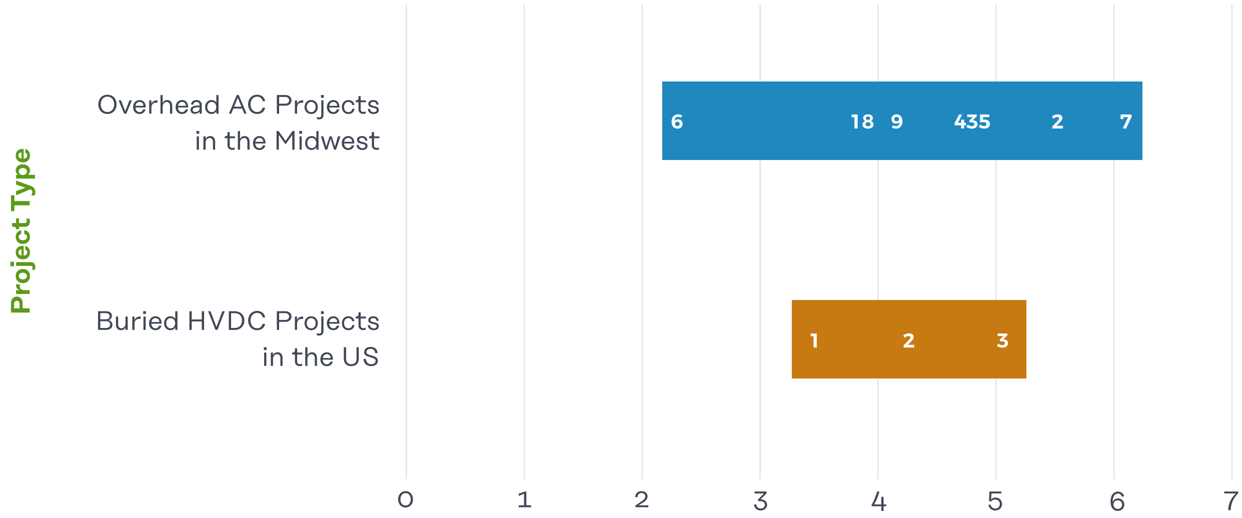


Figure developed by the NextGen Highways Team

Historically, utilities have discounted the use of underground transmission because buried AC line costs were often 7 to 10 times more costly than overhead lines. Today, some utilities will still cite those cost comparison numbers without considering the technological advances of HVDC cables and converter stations over the past decade.

The NextGen Highways Team researched the cost of buried HVDC transmission to facilitate a greater collective understanding of the recent cost declines and the difference in cost between overhead and underground transmission.

Notable takeaways from the NextGen Highways Team's research:

- Buried HVDC transmission is cost-competitive with traditional overhead AC transmission projects.
- Buried HVDC transmission is roughly 2-4 times the cost of overhead HVDC transmission.[65]
- Buried HVDC transmission costs fell over the last decade:
    - converter costs have fallen from $300 million per gigawatt (GW) per converter down to a conservatively estimated $200 million per GW per converter, and
    - installed cable costs have fallen from over $3 million per GW-mile to $1-2 million per GW-mile.

Benefits from Buried HVDC Transmission

When evaluating transmission projects, the utility regulatory process considers costs and benefits. Increasingly, there is a growing recognition of the need to include a greater number of benefits in the regulatory process.[66] This is especially true with regard to grid reliability,[67] grid resilience, and climate

[65] This assumes that the overhead HVDC transmission can be permitted and built. Over the last decade, a number of overhead HVDC transmission projects across the US were unable to be successfully built, including Northern Pass, New England Energy Connect (still active), Plains and Eastern, Grain Belt Express (still active).

[66] Brattle Transmission Planning and Cost-Benefit Analyses Presentation

[67] Report on Opportunities and Barriers to High-Voltage Transmission; Transmission Makes the Power System Resilient to Extreme Weather; Interconnections Seam Study

resilience benefits.[68] In the context of buried HVDC transmission, there are important benefits that should be considered:

- Grid reliability
- Grid and climate resilience
- Accelerated permitting timeline (as discussed in Finding #5)

Grid Reliability

In 2021, MISO issued its Renewable Integration Impact Assessment report.[69] The report identified grid reliability needs as renewable energy levels grow in the region. These needs included increased frequency and voltage support, particularly in areas of concentrated renewable generation development, and an expanded ability to move energy across the region daily to balance renewable generation and load.

HVDC technology can simultaneously address many of MISO's identified needs by providing voltage support, frequency regulation, and weak-grid support benefits. By doing so, HVDC transmission can improve the grid's overall operational efficiency and stability.

Grid and Climate Resilience

The simple fact that buried HVDC is underground results in electric grid resilience[70] that overhead transmission cannot achieve. Buried transmission can survive major weather-related disturbances such as hurricanes, tornadoes, and ice storms and doesn't require shutting off the grid during high fire risk periods. HVDC transmission also provides electricity grid resiliency because of services it can provide, such as "black start" capabilities that are critical to re-starting the electric grid after a blackout.

The following examples are recent significant weather and electric infrastructure events that demonstrate the risk associated with the overhead high-voltage electric system. Buried electric transmission in Louisiana during the two hurricanes would have avoided some of the negative impacts and economic hardship resulting from the storms.

Hurricane Laura (August 2020)

Hurricane Laura severely damaged the power grid in Louisiana and Texas. Nine of the nine transmission lines that deliver power into the Lake Charles area were out of service, with multiple transmission structures damaged beyond repair.

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[68] Accelerating Decarbonization of the U.S. Energy System; Transmission Planning for 100 Percent Clean Energy

[69] Renewable Integration Impact Assessment

[70] "Although the two terms [Grid Reliability and Grid Resilience] often are used interchangeably, they are not the same. Grid reliability is commonly defined as the ability of the electric power system to deliver electricity in the quantity and with the quality demanded by end-users. Resiliency is the ability for the electric power system to withstand and recover from extreme, damaging conditions, including weather and other natural disasters, as well as cyber and physical attacks. While the two are different, resilience directly impacts reliability." See Informing the Transmission Discussion for further discussion.

Hurricane Ida (August 2021)

Hurricane Ida devastated both Louisiana and Mississippi's power grids, knocking out electricity to more than 1 million customers, including all of New Orleans. All eight transmission lines that deliver power into New Orleans were out of service and multiple transmission structures were damaged beyond repair.

Kincade Fire (October-November 2019)

CalFire determined the Kincade Fire was caused when a jumper cable on a PG&E transmission tower broke in high winds, fell, and arced against the tower. The arc caused molten material to fall into vegetation and ignite below the tower. It took CalFire 15 days to contain the fire. The blaze burned more than 120 square miles and destroyed 374 buildings.

Figure 9. Damage from Hurricane Laura on overhead transmission

Photo from Entergy via Creative Commons.

Grid Reliability and Resilience Are Only Growing in Importance

As the nation continues to electrify and digitize the economy, the electric grid's reliability and resiliency are becoming more important every year. In 2021, Winter Storm Uri's impact to Texas electric grid and natural gas infrastructure foreshadowed what the severity of a major grid outage could look like in a fully electrified future. In Texas, the partial loss of the electric grid and natural gas infrastructure led to the loss of 210 lives and estimated financial losses between $80 billion to $130 billion.

Finding #5: Together, DOT ROW and buried HVDC transmission can deliver billions of dollars in societal benefits

By building a buried HVDC transmission system alongside our interstate network of roads and rail lines, the country can overhaul and expand the transmission network more quickly, cost-efficiently, and easily than developing a new ROW through private land. Benefits of this approach accrue to landowners, electric customers, and the grid itself.

Societal value from using the interstate and highway ROW: the NextGen Highways team estimates that using buried HVDC transmission in interstate and highway ROW can generate $150 billion of societal value by shaving five years (or more) off the permitting and siting timeline for interregional transmission projects.

Siting, permitting, and building a traditional overhead HVAC transmission line typically takes at least 10 years and often much longer because of challenges related to cost, environmental permitting, and siting on private land. Using highway and rail ROW means working with fewer property owners – potentially just a handful instead of many hundreds. It also largely removes the threat of eminent domain to take land from private owners.

As shown in table 6, shaving five years off of the permitting timeline for a single interregional transmission project can generate a billion dollars of societal value. Assuming a 2 gigawatt (GW) buried HVDC transmission line delivering 1 GW of renewable energy resources,[71] then 8,760 GW-hours of clean energy would be transmitted annually. Further assuming 0.5 tons of avoided carbon emissions per megawatt-hour (MWh) of energy,[72] then more than four million tons of carbon emissions would be avoided each year. Using a conservative value of $50 per ton for the avoided carbon emissions, the societal value of thee avoided emissions would more than $200 million annually. Thus, the five-year reduction in the transmission development timeline that the NextGen Highways Team believes is possible (for a typical interregional transmission project) would translate into $1 billion of societal value.

Table 6. Societal Benefits from a Single 2 GW Buried HVDC Transmission Line.

Metric of Interest	Value	Assumption
Renewable Energy Transmitted	8,760 GW hours per year	2 GW line with 50% utilization
Avoided Carbon Emissions	4,380,000 tons per year	Baseline: 0.5 tons emitted per MWh
Value of Avoided Emissions	$219 million per year	$50 per ton of carbon
Reduction in Permitting Timeline	5 years	10+ years ⟶ 5 years
Societal Value of DOT ROW (for one line)	**$1,095,000,000**	5 years * $219 million/yr

[71] We conservatively assume that the line will not be loaded in excess of 50 percent of its capacity on average.

[72] This is the current emissions rate in the Midwest and many other parts of the country.

It is worth noting that a 2GW, 300 miles-long, buried HVDC transmission line would cost roughly $2.5 billion. As such, $1 billion of societal value would equate to 40 percent of the transmission line's cost.

Scaling the societal benefits from a single interregional transmission line to meet estimated interregional transmission needs yields about $150 billion of societal benefits from coupling buried HVDC transmission with our existing transportation ROW.[73]

Finally, building HVDC transmission alongside highways can support a broad array of electrification projects. These projects range from electrifying fleets in dense warehouse districts to installing over-the-road electric vehicle (EV) charging to the electrification of space and water heating in dense urban areas. This is described further in the next section.

Finding #6: Buried HVDC transmission supports transportation decarbonization

Buried HVDC transmission supports transportation decarbonization in three key ways:

1. Transportation decarbonization requires grid decarbonization, and grid decarbonization requires buried HVDC transmission.
2. With strategic guidance, the build-out of buried HVDC transmission will create economic development zones adjacent to HVDC converter stations. These economic development zones will be logical locations to site fleet and over-the-road EV charging infrastructure and data centers.
3. The advancement of solid-state converters and other advanced grid technology will enable EV charging to occur directly from medium and/or high-voltage DC systems.

How can HVDC transmission support transportation decarbonization?

Before discussing these three ways in detail, it is worth stating why many assume HVDC transmission is not relevant to transportation electrification: the cost of the HVDC converter stations.

HVDC converter stations are required to convert high-voltage DC power to high-voltage AC power. High-voltage AC power is then stepped down using a traditional AC transformer from the high voltage of a transmission line (e.g., 525 kV) to the lower voltage needed for electric vehicle charging (e.g., 1.5 kV for medium- and heavy-duty fleets). HVDC converter stations cost between $200 and $400 million, depending on their voltage and capacity.

Connecting to an HVDC transmission line is cost-prohibitive unless one is serving roughly 1,000 megawatts of electrical load. By comparison, the electric load from the electrification of fleets in a large warehouse district is hundreds of MW, and the load from EV charging along interstates will be tens of MW. This load discrepancy leads many to assume too quickly that HVDC transmission is not important to transportation decarbonization.

As illuminated by the following subsections, this is an oversimplified assumption that fails to account for the importance of (1) grid decarbonization, (2) economic development opportunities created by converter stations, and (3) technology advancement.

[73] Transmission Planning for 100% Clean Electricity

Transportation decarbonization requires grid decarbonization, and grid decarbonization requires buried HVDC transmission

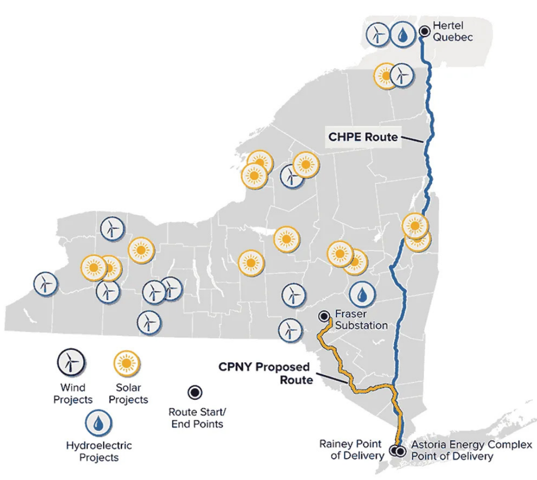
Transportation electrification must be coupled with grid decarbonization to achieve transportation decarbonization.

Unlike the US Interstate Highway System, the US power grid is composed of many discrete regions. Modeling study after modeling study has shown that connecting these regions is critical to cost-effective grid decarbonization.[74] It is also critical for grid reliability and resiliency (see the [Review of Interregional Transmission Studies] document).

Despite the importance of connecting the electric grid regions using interregional transmission lines,[75] project after project has failed in the US. Since 2014, the US has not built a single GW of interregional transmission capacity. Meanwhile, China, Europe, South America, and India have collectively built nearly 350 GW of interregional transmission capacity. Most recently, the construction of the New England Clean Energy Connect transmission line was stopped indefinitely by a public referendum in November 2021. This was an incredible result given that the New England Clean Energy Connect had already received the required regulatory approvals and was in the process of being built.

As seen in Europe and now in New York State, buried HVDC transmission is being used to build the interregional transmission required to cost-effectively and reliably decarbonize the electric grid. The transmission routes for four buried HVDC transmission projects currently under development/construction in New York[76] and Europe[77] are shown in figure 10.

Figure 10. Maps of Buried HVDC Transmission Projects in New York and Germany



Left figure courtesy of NYSERDA | Right figure developed by the NextGen Highways Team

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[74] The Value of Inter-Regional Coordination and Transmission in Decarbonizing the US Electricity System; Interconnections Seam Study;
Transmission Planning for 100% Clean Electricity

[75] Interregional transmission lines move power hundreds and even thousands of miles to connect different regions of the grid.

[76] New York State Department of Public Service Approves Buried HVDC Transmission Projects

[77] NKT Website

In the words of Cornelis Plet - a Principal Consultant with DNV and leading expert on HVDC transmission:

> ***"[Subsurface] HVDC technology enables economic transmission with low environmental and visual impact… enabling delivery of offshore wind power further inland, closer to load centers, and also enabling connections between different states and remote renewable energy resources."*** [78]

With strategic guidance, buried HVDC transmission systems will create economic development zones that include EV charging infrastructure

HVDC converter stations are a natural location for creating economic development zones. This is because customers adjacent to these converter stations will have direct access to the grid's cleanest and most reliable power. This will be especially true to the degree that the converter stations are connected to buried HVDC transmission lines. Data centers, logistics centers, and military assets (new or existing) are some of the obvious entities that should want to be close to an HVDC converter station.

Governors, mayors, and state and regional agencies have the opportunity to guide the siting of HVDC converter stations to maximize their economic and societal value. Specifically, elected officials and government staff can work to create economic development zones that serve multiple needs:

- on-boarding of clean generation
- serving new loads (data centers, over-the-road EV charging, and depot-based fleet charging)
- serving critical existing loads (downtown cores and military bases)
- improving grid economics and reliability

Such economic development zones will likely have the greatest value in rural areas. In rural areas, the development of multiple GW of clean energy can cover the cost of the converter stations. This will entice economic development in the form of data centers, logistics parks, over-the-road EV charging, and/or renewed investment in existing military assets. By guiding the siting of converter stations towards key transportation corridors – ideally spaced every 100-150 miles – elected officials and state agencies can ensure the public derives the greatest value possible from the build-out of HVDC transmission lines and their associated converter stations.

Furthermore, by linking the development of data centers, logistics parks, and/or the hardening of military assets to the development of renewable resources, economic development zones would tie land use to economic growth and might just start helping to repair our rural/urban divide.

The strategic creation of economic development zones will also deliver societal value in urban areas. A combination of loads, including depot-based fleet charging in dense warehouse districts, and a large value for grid reliability and resilience (from the large population and commercial activity) can cover the cost of the converter stations in urban areas.

[78] Offshore Wind: The key to unlocking the American transition to a clean, reliable and affordable energy future

The advancement of solid-state converters and other advanced grid technology will enable EV charging to occur directly from medium and/or high-voltage DC systems

Directly charging EVs from an HVDC transmission line will require significant advancement of solid-state power conversion technologies. Fortunately, the broadly recognized need for grid functionality, grid security, and grid reliability are resulting in the development of the required solid-state power conversion technologies.

In "Reimagining the Grid," Southern California Edison (SCE) did a laudable job of distilling future grid challenges, including those that will be faced in transportation corridors:

> ***"Sites with commercial EV fleets relying on fast charging will stress the existing distribution system's capacity within these corridors, and aggregate load from all EV charging in the region will push the capacity of the subtransmission system that links these corridors to the high-voltage transmission network."*** [79]

SCE's analysis considered future grid options for transportation corridors and specifically called out the potential value of medium- and high-voltage DC power:

> ***"...[for heavy-duty EV fleets], switching to a medium/high-voltage, DC-based system could be less costly than adding a traditional solution, including the transmission, sub-transmission and distribution level cable and transformer equipment required."***

> ***"This concept offers the potential to satisfy all the critical grid objectives noted above while minimizing land use in what typically are already dense transportation corridors."*** [80]

SCE was also quick to call out the primary challenge with powering EV fleets from a DC-based system:

> ***"this [grid] architecture has not been commercially deployed elsewhere yet, and to be implemented in the long term, it will require several critical technological components to be ready and available within the next couple of decades."*** [81]

In 2020, the US Department of Energy's Office of Electricity published the "Solid-State Power Substation Technology Roadmap."[82] This roadmap outlined the opportunities and challenges for solid-state power conversion technologies and identified key advancements expected in the next 5, 10, and 20 years.

Encouragingly, private companies are investing in solid-state power conversion technologies. In 2021, Amazon invested in Resilient Power—a provider of solid-state transformers to support the electrification of medium- and heavy-duty fleets. Also in 2021, Electranix announced its intentions to develop a way to support the charging of heavy-duty EVs directly from HVDC transmission lines. Last but not least,

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[79] Southern California Edison's Reimagining the Grid white paper

[80] Reimagining the Grid

[81] Reimagining the Grid

[82] OE Report: Solid State Power Substation Technology Roadmap

a major provider of grid infrastructure is rumored to be developing a way to charge heavy-duty EVs directly from an HVDC transmission line.[83]

The NextGen Highways team's opinion is that entities planning for the electrification of medium- and heavy-duty fleets should evaluate scenarios where charging occurs directly from transmission infrastructure located along interstate and highway ROW.

Finding #7: Wisconsin has the playbook for siting transmission in DOT ROW

Wisconsin state agencies, utilities, and regulators have successfully collaborated to place electric transmission infrastructure within and along state and interstate highway ROW over the last 20 years.

Wisconsin's Act 89, the Wisconsin Dept. of Transportation's (WisDOT) utility accommodation policy, and the Cooperative Agreement between WisDOT and the Public Service Commission of Wisconsin (PSCW) constitute a playbook that other states can benefit from when looking to accommodate transmission line projects within highway ROW. The NextGen Highways team has summarized that playbook below and developed the Introduction to Permitting Transmission in WisDOT ROW document for those interested in additional details and references.

In 2001, shortly after American Transmission Company (ATC) took over construction, maintenance, and operations of the transmission grid in much of Wisconsin, ATC and energy stakeholders realized that the state was in desperate need of transmission infrastructure development. Understanding the low likelihood of significant transmission development utilizing new ROW, ATC, regulators, and other stakeholders collaborated on minimizing potential impacts from new electric transmission.

The result was the 2003 Wisconsin Act 89. The law required that the following corridors be utilized in the following order of priority for the siting of new electric transmission facilities:

- existing utility corridors
- highway and railroad corridors
- recreational trails
- new corridors

After the passage of Act 89, the Wisconsin Department of Transportation (WisDOT) amended its utility accommodation policy to allow for the longitudinal installation of transmission lines in its interstate and highway ROW. Pursuant to federal requirements,[84] WisDOT's utility accommodation policy allows for the accommodation of electrical transmission infrastructure provided that it does not:

- Adversely affect the safety, efficiency, and aesthetics of the freeway
- Interfere with or impair the present use or future expansion of the freeway
- Rely on access for future maintenance directly from the freeway lanes or shoulder

[83] Despite widely-held beliefs that charging EVs from an HVDC transmission line must be prohibitively expensive, multiple companies are now developing the technology required to economically serve tens or hundreds of MWs of load from medium and high-voltage DC transmission lines. Such technology would be perfect for the needs of medium- and heavy-duty fleet electrification. As one example, see Tapping HVDC for Electrification of Rail and Heavy-Duty Transportation

[84] 23 CFR 645 subpart B, Federal Highway Administration

In 2009, as a result of Act 89, WisDOT's updated utility accommodation policy, and the development of new transmission infrastructure, WisDOT and PSCW entered into a cooperative agreement "to ensure that whenever practical, WisDOT and PSCW shall utilize existing transportation or transmission corridors instead of creating new corridors for electric transmission facilities."[85]

The Cooperative Agreement acknowledges Act 89 and WisDOT's utility accommodation policy. It notes that any potential conflicts between the agencies be resolved informally by primary agency contacts in a timely manner, consistent with the law and agency rules. The agreement also specifies measures to coordinate WisDOT and PSCW planning and review procedures in making respective regulatory decisions regarding the co-location of electric transmission facilities within transportation corridors, including highway and railroad ROW within the WisDOT jurisdiction.

If a route utilizing WisDOT ROW is selected as part of the project application, the utility must provide a constructability report[86] as part of the application to the PSCW. The utility drafts and submits the report to DOT for review and comment prior to including it in the application. The report typically includes a discussion of maintenance plans and roles and responsibilities of the utility and WisDOT.

The legislation, policy, and agreements described above have fostered a collaborative and trusting relationship between Wisconsin utilities and WisDOT and have resulted in the efficient, cost-effective, and successful siting of over 800 miles of transmission infrastructure in and along interstate and highway ROW in Wisconsin.

National Recommendations

State DOTs should:

- Site and build fiber in a way that allows for buried HVDC transmission to be co-located at a later date
- Develop and invest in their relationship with utilities, public utilities commissions, and other state agencies with transmission siting jurisdiction
- Determine the amount of operational funding required to support the co-location of electric and communications infrastructure in their ROW

Utilities and energy developers should:

- Develop and invest in their relationship with state DOTs
- Evaluate how highway ROW (if made available) could enable the various grid investments needed to support electric vehicle charging
- Evaluate how planned regional and interregional transmission lines could benefit from highway ROW (if made available)

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[85] Cooperative Agreement between the Wisconsin Department of Transportation and the Public Service Commission of Wisconsin Regarding New Electric Transmission Lines

[86] American Transmission Company and Xcel Energy Constructability Report

Governors should consider:

- Supporting and facilitating the implementation of Wisconsin's co-location playbook
- Working with their DOT, utilities, and legislature to remove any statutory barriers in state law
- Evaluating options to provide their DOT with operational funding to support the co-location of electric and communications infrastructure in the ROW

Next Step for NextGen Highways

Given the positive findings from this Feasibility Study, the NextGen Highways Team is planning to launch a NextGen Highways Coalition to support the co-location of buried fiber and transmission in highway and interstate ROW.

The NextGen Highways Coalition will do the following:

- Facilitate conversations between state DOTs, utilities, and governors
- Facilitate conversations between state DOTs, utilities, and technology vendors
- Review states' highway ROW siting and permitting regulations, identify barriers to co-location, and work with stakeholders to overcome barriers
- Share insights and best practices across states
- Provide a platform through which tribes, communities, nonprofits, cities, and companies can understand the required transformation of the national highway system
- Foster public/private partnerships to build out the required infrastructure

Interested parties can email morgan@buildngi.com and laura@theray.org for more information.

Conclusion

Across the country, state DOTs are assessing both their immediate and future needs. Many are planning how they can meet these needs using new federal infrastructure funding. The US Department of Transportation has provided clear guidance that it will prioritize projects that leverage these funds to bring other benefits to the state, such as expanded broadband and expanded electric transmission.

MnDOT is well-positioned to access these new funds. In this report, we have sought both to identify the many benefits of using highway ROW for other linear infrastructure and to address concerns and questions raised by MnDOT's experienced professional staff.

At a macro level, opening up interstate and highway ROW to communications and electric infrastructure will ensure Minnesota remains strong and competitive in a global economy by expanding robust broadband access and enabling clean energy development.

This infrastructure will also bring specific benefits for MnDOT. A modern highway system will need advanced communications. It will also need clean, reliable electric power as it prepares for the wave of autonomous vehicles and the needs of electric vehicles, including medium- and heavy-duty vehicle fast charging at scale. Projects in North Carolina and Pennsylvania, as mentioned above in Part 2, offer good examples of these synergies.

Coordinating with utilities to deploy buried HVDC transmission in the highway ROW offers several benefits, including increased resilience and significant carbon emissions reductions without changing the viewscape. Expanded transmission will be vital for electrifying transportation in the most cost-effective manner.

The traditional thorny issue of building linear infrastructure on private property can be mitigated with undergrounding the transmission along existing highway and rail corridors. Burying HVDC transmission can be done at a similar cost to conventional overhead AC transmission while providing critical reliability and resilience benefits. Furthermore, the potential for accelerated permitting timelines for buried transmission projects would be worth billions of dollars in avoided carbon emissions.

The findings from this study demonstrate that buried HVDC transmission is cost-effective and can be feasibly sited in interstate and highway ROW after making appropriate consideration of existing and future transportation system needs. While the study identified challenges, none appear to pose insurmountable barriers.

The NextGen Highways Team and MnDOT believe that this report will provide a solid foundation as MnDOT considers actively removing barriers to siting buried HVDC transmission in interstate and highway ROW in 2022.

Appendix A: Existing Plans, Policies, Practices, and Projects that Informed This Work

Various plans, policies, practices, and projects were reviewed and informed this Feasibility Study. The resources listed below were chosen based on their relevance of applying the NextGen Highways vision in Minnesota. Additional documents may be reviewed during future study.

Minnesota Statewide Strategic Documents

- Annual Report of the Governor's Task Force on Broadband (December 2020)
- Sec. 116J.391 Minnesota Statutes (Dig Once Policy, 2020)
- Climate Change Executive Order 19-37 (December 2019)
- Our Minnesota Climate, Legislative Priorities for 2021
- Minnesota IT Services (MNIT) 2020 Strategic Plan
- Statutory Siting Guidance for High Voltage Transmission Lines (HVTL) in MN

MnDOT Strategic Plans

- Minnesota GO
- Statewide Multimodal Transportation Plan (SMTP) (January 2017)
- Sustainable Transportation Advisory Council (STAC) Charter and Recommendations (2020)
- Sustainability and Public Health Division 2020 Strategic Plan
- CAV Strategic Plan
- Statewide ITS Plan
- MN Governor's Broadband Task Force 2020 Report

MnDOT Policies

- MnDOT Fiber Optic Infrastructure and RTMC Network Access Policy (August 2021)
- Minnesota Statutes § 161.45; 161.46, subd. 2; 237.163, subd. 2(b) (2021)
- Right of Way Manual (July 2018)
- Utility Accommodation Manual (March 2016)
- Minnesota Manual on Uniform Traffic Control Devices (MN MUTCD), Part 6 Temporary Traffic Control (December 2019)
- Minnesota Administrative Rules Part 8810.3300 (2012)

Wisconsin

- WisDOT and ATC successfully permitting transmission infrastructure in DOT ROW
- Act 89 in WI
- DOT Utility Accommodation Policy
- DOT and PSCW Cooperative Agreement on New Electric Transmission Lines

Transmission Projects in the US

- SOO Green HVDC Link: a buried HVDC transmission line from Iowa to Illinois that uses railroad and highway ROW
- Badger Coulee Transmission Line: an overhead AC transmission line in Wisconsin that uses highway ROW, including interstate ROW (I-94/I-90)
- Clean Path NY: a buried HVDC transmission line in New York that utilizes rail and road ROW and waterway
- Champlain Hudson Power Express: a buried HVDC transmission line in New York that utilizes rail and road ROW and waterway

Transmission Projects in Europe

- SuedLink: a buried HVDC transmission line in Germany
- SuedOst Link: a buried HVDC transmission line in Germany
- France-Italy Interconnection: a buried HVDC transmission line in France and Italy that utilizes highway ROW

MISO

- Long Range Transmission Plan

Federal

- FHWA, State DOTs Leveraging Alternative Uses of the Highway Right of Way Guidance (April 2021)
- FHWA Policy on Using Bipartisan Infrastructure Law Resources to Build a Better America (December 2021)