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The Center for Public Policy and the Social Sciences

Policy Research Shop

THE NORTHERN PASS PROJECT

An Analysis of Transmission Line Undergrounding

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Natural Resources

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TABLE OF CONTENTS

EXECUTIVE SUMMARY	1
1. CASE STUDIES	1
1.1 LONG-TERM DEVELOPMENT: CALIFORNIA	1
1.2 RAPID DEVELOPMENT: SWEDEN	2
1.3 RECENT DEVELOPMENT: NEW ZEALAND	2
2. UNDERGROUNDING ANALYSIS	2
2.1 SYSTEM DESIGN	3
2.2 CONSTRUCTION AND CONVERSION COSTS	3
2.3 GRID RELIABILITY AND OUTAGES	4
2.4 MAINTENANCE AND REPAIR	4
3. ECONOMIC IMPACT	4
3.1 IMPACT ON JOB CREATION	6
3.2 IMPACT ON ENERGY COSTS	7
3.3 IMPACT ON LONG-TERM GROWTH	8
4. ENVIRONMENTAL IMPACT	8
4.1 MAINTENANCE OF RIGHT-OF-WAY	9
4.2 WILDLIFE	9
4.3 HEAT DISSIPATION	9
4.3 OTHER CONCERNS	9
5. PUBLIC OPINION REGARDING NORTHERN PASS	10
6. CONCLUSION	10
REFERENCES	111



EXECUTIVE SUMMARY

The Northern Pass Project is a proposal for a transmission line route that is designed to deliver electricity from Québec to the New England area. The \$1.4 billion project will transmit Canadian hydroelectric power to the New England grid via 187 miles of transmission line, including 32.25 miles of new overhead right-of-way and 7.75 miles of new underground right-of-way in northern New Hampshire.¹ The project, expected to be in service by mid-2017, has been a source of great controversy among electrical worker unions, environmental groups, and state officeholders. The Policy Research Shop is tasked with evaluating the benefits and costs of undergrounding all new right-of-ways on the Northern Pass route—from both economic and environmental perspectives.

1. CASE STUDIES

In analyzing the impact of a massive infrastructure project such as the proposed Northern Pass, it is important to first consider the policy implications of similar projects or proposals that exist in other parts of the world. The undergrounding of transmission cables has been considered as early as the mid-1800s in Germany—meanwhile, urban centers such as New York City ceased constructing overhead cables by the end of the 19th century. Furthermore, revamped power grids in nations such as Singapore and the Netherlands are now 100 percent underground; Belgium completely banned overhead power lines in 1992 and new policies in France are transitioning over a quarter of the nation's transmission lines underground.² This proliferation of undergrounding has spread in the past century and, less than a decade ago, the ratio of underground to overhead cables neared 40 percent, 17 percent, and nine percent in Europe, North America, and Asia respectively.³ Nonetheless, the transition is ongoing and has had a distinct impact on various regions.

1.1 Long-Term Development: California

The most notable long-term undergrounding effort in recent decades has occurred in San Diego, California. Since the 1960s, the city has buried over 570 miles of line as part of a project that is now over 60 percent complete.⁴ Through its Undergrounding Utilities Program, the government is currently relocating approximately fifteen miles of overhead utility lines to underground each year.⁵ In conjunction with compensation from state funds, San Diego's plan for undergrounding utilities is primarily funded through a residential electricity surcharge approved by the California Public Utilities Commission in December 2002.⁶ Approximately \$54 million each year is invested in infrastructure through undergrounding efforts—less than four percent of what the total cost of the Northern Pass transmission project entails.

Although the City of San Diego has made great progress with converting to underground power lines since 1970, approximately a thousand miles of overhead utility lines remain to be buried. Long-term estimates state that nearly all residential areas across San Diego will be completed within the next half-century. Figure 1⁷ provides an overview of the number, length, and cost of all active projects as of Q4 2012.⁸



SUMMARY OF ALL ACTIVE PROJECTS

	NO. OF PROJECTS	LENGTH (MILES)	ESTIMATE	CUSTOMERS
IN CONSTRUCTION	40	67.0	\$ 162,883,827	7,942
IN DESIGN	36	43.0	\$ 116,893,216	5,263
AWAITING PUBLIC HEARING	19	24.5	\$ 66,296,373	3,146
TOTAL ALL ACTIVE PROJECTS	95	134.5	\$ 346,073,416	16,351

Figure 1. City of San Diego, Utilities Undergrounding Program Active Projects

1.2 Rapid Development: Sweden

In comparison with the gradual undergrounding transition in California, Sweden’s progress has grown rapidly over the past decade. Last January, Sweden’s national grid operator, Svenska Kraftnät, granted an order worth upwards of \$160 million for the installation of a new high-voltage underground cable system.⁹ Created in 1992, Svenska Kraftnät is a state-owned public utility that owns 20 percent of the Nord Pool Spot, which runs the largest market for electrical energy in the world. ABB, the global power and automation technology group, will lead the charge in revamping the nation’s infrastructure for the South-West Link power transmission project in southern Sweden. The revamped underground cable system will facilitate the transport of 660 megawatts of electrical power across 192 kilometers between Barkeryd and Hurva.¹⁰

This link is part of a larger \$1.1 billion project that spans the E6, Sweden’s main highway. The purpose of the infrastructure overhaul is to strengthen the national power grid, improve reliability, and increase transmission capacity in the southern country between Norway and Sweden. The project will also support government plans for the construction and integration of large-scale wind farms across southern Sweden.

1.3 Recent Development: New Zealand

The majority of New Zealand’s electricity is generated from power stations located in remote areas of the South Island, while most consumption occurs in the Upper North Island. High voltage transmission lines carry power from generation plants to major substations in urban areas, where local line companies distribute electricity to residents and businesses. While new lines have been undergrounded in urban areas, much of New Zealand’s power grid remains overhead. The expense of undergrounding these transmission lines costs about \$750 per meter, with an estimated overall cost of \$4 billion for transitioning all 400 kilometers of urban lines.¹¹ This price is a result of greater costs for insulation, equipment, and protection.

While New Zealand is unable to fund a complete undergrounding effort, economists have called for the beneficiaries of such projects to aid in bearing the cost. These beneficiaries, mainly



landowners, residents, and retailers, have invested over \$40 million into such programs since 2000.¹² One major example of such an effort was the Highbrook Development project, in which Highbrook entered an agreement to pay for the undergrounding and realignment of existing transmission lines. The project involved cabling nearly 3 kilometers of 110 kilovolt lines and realigning another 2.6 kilometers of 220 kilovolt line on overhead monopolies. Current undergrounding efforts include the North Auckland and Northland Grid Upgrade Project. Commissioned in 2013, the project's estimated cost of \$415 million will account for the removal of 33 overhead towers and the addition of 37 kilometers of underground cabling.¹³

2. UNDERGROUNDING ANALYSIS

Weighing the output of these case studies, their results support claims that the process of undergrounding comes with variable trade-offs. Differences in construction materials, building techniques, and maintenance needs are responsible for huge disparities in per mileage cost for overhead and buried lines. The frequency and duration of power outages also varies across the two systems of overhead versus underground transmission lines.

2.1 System Design

Although there are several types of buried power lines, most lines consist of one or more copper cables surrounded by insulation and covered in a steel outer coating.¹⁴ The cables are placed in underground trenches that periodically open into concrete vaults, which are used for splicing lines and accessing the lines for maintenance.¹⁵ Trenches are generally dug four to eight feet deep to keep cables below the frost line, which ends at around three feet.¹⁶ The trenches are often covered with concrete slabs and are always marked with warning signs to identify the high-voltage lines and prohibit digging.¹⁷

For the New Hampshire section of the Northern Pass, a 300 kV high-voltage direct current (HVDC) transmission line will run 153 miles from Canada to Franklin, NH, where it will be converted to a 345 kV alternating current line.¹⁸ The AC line will then run 34 miles to Deerfield, NH.¹⁹ As such, the project is certainly feasible, as HVDC is often used to transmit power for long distances underground, including undersea.²⁰

2.2 Construction and Conversion Costs

Installation of new underground lines is widely reported to cost 10 times as much as installation of overhead lines.²¹ According to a 2012 study by the Edison Electric Institute, construction of new overhead transmission lines in rural areas costs about \$174,000 per mile, while rural underground lines cost about \$1,400,000 per mile.²²

Conversion of existing overhead lines to underground lines is also costly. The same EEI study reports that the cost of converting overhead transmission lines in rural areas is about \$1.1 million per mile.²³ However, it is unlikely that the Northern Pass will convert existing overhead lines in northern New Hampshire to underground lines. The existing lines between the Canadian border



and the location of the proposed converter in Franklin are AC lines, as opposed to the HVDC lines the Northern Pass Project would use.²⁴

2.3 Grid Reliability and Outages

There are several reasons that communities choose to bury power lines. In densely populated cities, power lines may be buried simply because there is insufficient overhead space for the lines. In cities and suburbs alike, power lines are buried for aesthetic purposes.²⁵ However, burying power lines can also significantly improve grid reliability by reducing the number of power outages due to weather-related causes. More than 40 percent of power outages in the U.S. are caused by adverse weather conditions, including fallen branches, heavy winds, lightning strikes, and ice buildup.²⁶ In 2012, 31 percent of New Hampshire's 26 outages were caused by weather, seven percent were caused by animals, and 23 percent were caused by vehicular accidents.²⁷ Thus, 61 percent of New Hampshire's outages were caused by factors unique to above-ground lines. Although underground lines are not impervious to adverse weather—flooding, for example, can also damage underground lines—buried lines are significantly less vulnerable to weather-related outages.²⁸

Reducing the number of power outages has wide economic benefits. A 2002 study from the University of California—Berkeley estimated that an hour-long power outage costs each affected resident \$2.70, each commercial customer \$886, and each industrial customer \$4,227 in inconvenience, damage to equipment, or spoilage of goods.²⁹

2.4 Maintenance and Repair

However, although burying lines decreases weather-related outages, when outages do occur, it takes longer to repair buried lines than overhead lines. Buried lines are better protected from the elements, but insulation deterioration due to underground stresses and loading pressures can create faults in the lines.³⁰ Because the lines cannot be inspected visually, it is more difficult to identify the location of failure.³¹ Once the location is identified, the line must be dug up before it can be repaired.³² If replacement parts or cable is needed, additional time delays accumulate. The companies that produce underground power materials are mostly based in Europe, so receiving necessary components may also add to the time.³³ Although delays vary according to cable type, the typical minimum duration of a buried-line outage is about eight days.³⁴ In contrast, outages on overhead lines can be identified and repaired very quickly and generally last a day at most.³⁵

Thus, there is a trade-off inherent to buried power lines: power outages are less frequent but longer lasting. Longer-duration outages also translate into increased cost due to additional labor and specialty materials. Additionally, the lifespan of an underground cable is only 50-70 percent as long as the lifespan of an overhead cable, depending on cable type and site conditions.³⁶ However, even given its shorter lifespan, buried cable generally lasts at least 50 years, and its lifespan is continually lengthening with improved technology.³⁷

3. ECONOMIC IMPACT

In June 2013, Northern Pass officials revealed a new route that consisted of 147 miles of existing right-of-way and 40 miles of new right-of-way running through the North Country. This revised route abandons \$40 million in prior land purchases to reduce its number of private property hosts from 187 down to 31 and builds along existing state and local roadways. It also strategically places 7.5 miles of buried line priced at \$200 million.³⁸ In analyzing the economic tradeoffs associated with burying the additional 32.5 miles of new right-of-way prior to the established I-93 corridor, several endogenous factors specific to this case must be taken into account.

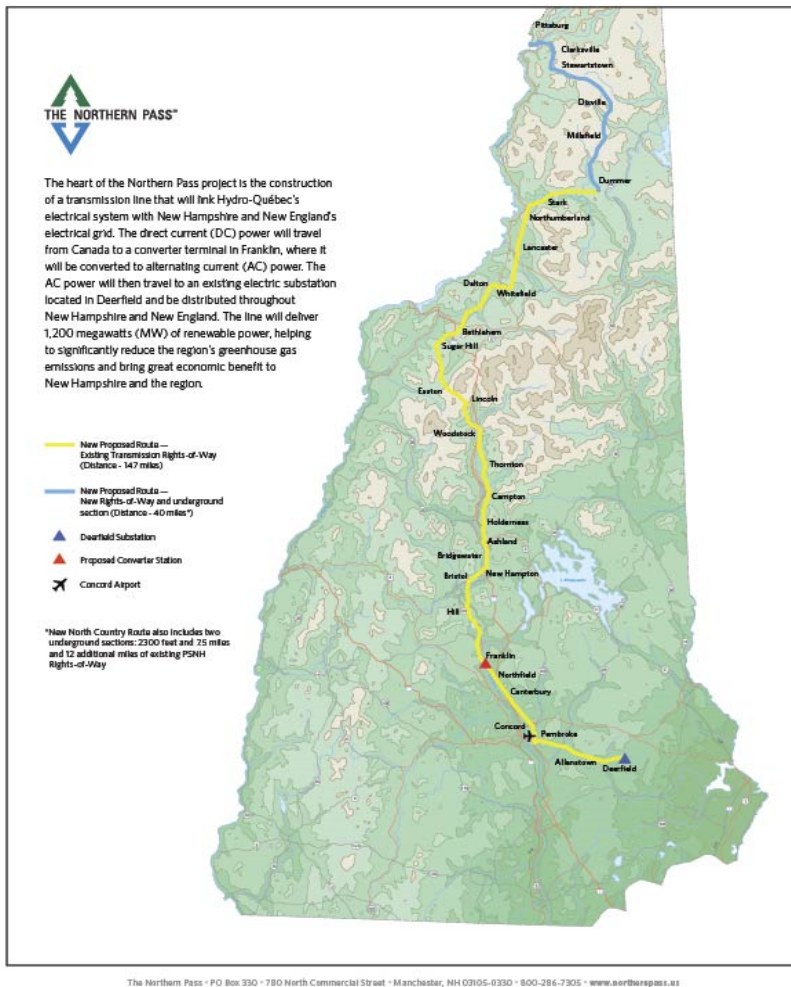


Figure 2. Northern Pass Transmission Line Route Proposal, August 2013

First and foremost, it is important to recognize that unlike comparable transmission line projects, the Northern Pass line will be entirely private-funded by Northeast Utilities and Hydro-Quebec. In addition to \$40 million in land purchases along its proposed route, the most recent projection places the cost of construction at \$1.4 billion.³⁹ David Long, who now heads the Northern Pass effort in New Hampshire, recently stated in October 2013 that the private firms sponsoring the line would be unable to pay to bury the entire length and a 50 percent increase in costs would render the project “uneconomic.”⁴⁰



Second, the northern New Hampshire terrain has been the source of vigorous debate regarding whether it is suitable for long-distance undergrounding. This project is often compared against the Champlain Hudson Power Express (CHPE) project, which includes 333 miles of buried transmission line. However, of this length, roughly 196 miles of line ran underwater through Lake Champlain and the Hudson/Harlem Rivers while the remaining 137 miles ran under existing railroad right-of-way.⁴¹ Concurrently, the 25-cent-per-kilowatt-hour retail electric rates in New York City available to the Champlain-Hudson Express are incomparable to the 6-cent-per-kilowatt-hour wholesale electric rates in New England available to the Northern Pass.⁴²

Third, instead of reflecting economies of scale, the costs associated with undergrounding are projected to increase due to intensified engineering requirements associated with burying long tracts of direct current line.⁴³ Ignoring topographical differences, projections based on burial costs associated with the CHPE place the cost of burying an additional 32.5 miles at around \$416 million (at \$12.8 million per mile).⁴⁴ If the \$200 million attributed to the 7.5-mile tract of buried line is interpreted as a result of topographical differences, the burial cost of the additional 32.5 miles would jump to around \$868 million (at \$26.7 million per mile).⁴⁵ These figures likely reflect a combination of higher insulation, equipment, and protection costs.

3.1 Impact on Job Creation

When considering the Northern Pass Project's impact on state job creation, it is essential to distinguish between short-term and long-term positions. Drawing laborers, operators, suppliers, and technicians from a varied range of construction and electrical sectors, the Northern Pass Project is expected to produce around 1,200 jobs during a construction period slated to last from three to four years.⁴⁶ These numbers are derived from extended RIMS II and REMI multiplier modeling, which indicates that there would approximately be a split between direct job creation and indirect or induced job creation.⁴⁷ It is worthwhile to note that burying the additional 32.5 miles of new right-of-way will prolong the project's construction time and similarly extend the span for which New Hampshire workers will remain employed in the construction industry.⁴⁸

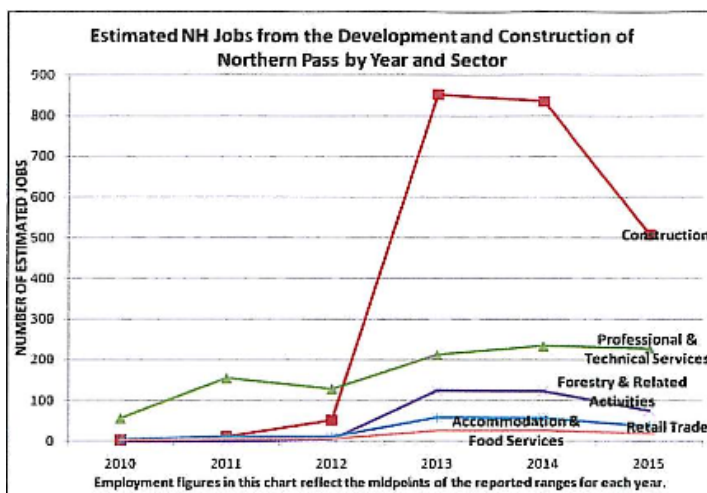


Figure 3. Northern Pass Job Creation by Sector



As for the question of whether New Hampshire workers are qualified to undertake many of the construction jobs during the Northern Pass' construction period, the response from labor unions across the region have been largely positive. Starting as early as September 2012, union chapters such as the Local 104 of the International Brotherhood of Electrical Workers have already begun offering New Hampshire workers a series of training programs on the construction of high-voltage power lines.⁴⁹ Although these jobs are primarily temporary positions, a number of hires will be retained for maintenance operations leading well past construction.

3.2 Impact on Energy Costs

Following the adoption of hydraulic fracturing methods in 2009, the dramatic increase in natural gas supplies caused electric prices to drop across New England – the result being that older coal and oil-fired plants became uneconomical to run except during peak periods on the ISO New England (NE-ISO) grid.⁵⁰ However, the National Grid, one of two leading electric utilities serving Greater Boston, recently had to announce an 18 percent electric bill raise due to a 40 percent raise in its own cost of generating electricity; meanwhile, NStar, the other major electric utility, has since announced an over 20 percent price bump starting in January.⁵¹ Generation spikes driven by “cold weather, unscheduled plant outages, and pipeline restrictions” inflate the futures market for natural gas and causes energy prices to rise due to increased volatility.⁵²

This upward trend in regional energy costs is directly impacted by New Hampshire's growing reliance on natural gas, which now accounts for 19 percent of the state's energy consumption, and the transmission congestion produced by New England's pipeline constraints.⁵³ Meanwhile, the approaching retirement of many coal and oil-fired plants will create an electrical generation shortage that would exacerbate brownouts during high-use months in the winter and summer.⁵⁴ This deficit will become widely apparent during high demand periods since natural gas is difficult to store and plants are generally only able to carry the minimum reserve margin even during cold winter months.

In mid-2012, the PA Consulting Group was commissioned by the New England Power Generators Association to write a report reexamining expected energy price changes from the completion of the Northern Pass line. PA Consulting Group's “Electricity Market Impacts of the Northern Pass Transmission Project” utilizes a report prepared for Northern Pass Transmission LLC in 2010 by the Charles River Associates (CRA) as well as more recent projections on long-term gas prices from the US Department of Energy (DOE).⁵⁵ The following analysis combines qualitative and quantitative analysis to provide an overview of the Northern Pass' expected impact on price volatility.

The primary difference is that the recent surge in domestic natural gas production from shale reserves has dramatically transformed the future outlook for natural gas supplies. The Energy Information Agency's 2012 Annual Energy Outlook (AEO) places projected natural gas prices at a full \$2/mmBtu below the prices that the Charles River Associates report relied on.⁵⁶ Consequently, this results in lower expected revenues for the Northern Pass' private backers as well as smaller expected reductions in customer costs in the New England energy market—



roughly half the Charles River Associates' estimate based on AEO 2010 gas price projections. Assuming hydropower is bid into the market at a zero price, the Northern Pass line would reduce wholesale prices by approximately \$1/MWh, representing an annual reduction of \$152 million in 2024.⁵⁷ This represents an over 50 percent drop from the cost reduction projections made by CRA.⁵⁸

While other grid interties with Ontario, New York, New England, and New Brunswick already allow the project backers to deliver all surplus energy, the Northern Pass line would shift power sales to higher-priced locales along the line. In addition, several exogenous variables, such as an expansion of transfer capacity for the Champlain-Hudson Power Express or a reduction of Ontario's net export capacity due to coal plant closures, present the risk of a dip in import supply.⁵⁹ The study acknowledges that it does not take into account costs and revenues considered in a comprehensive analysis but does provide a stark outlook for the economic hurdles that the Northern Pass line will face in the wake of the shale revolution. An early study by Gallagher, Callahan, and Gartrell estimated New Hampshire's wholesale savings on energy costs at \$23 million per year upon completion – rising to \$37 million per year within ten years.⁶⁰

3.3 Impact on Long-Term Growth

To start with the claims that the Northern Pass line hurts property values by diminishing the natural beauty of New Hampshire, properties in direct sight of towers on the proposed route will be subjected to some depreciation in value but overall property values increase as a result of the improved utility service at lower costs.⁶¹ Likewise, estimates for additional tax revenue place the total sum of state and local property taxes at \$25 million annually – money that will be funneled back into the system as investments into education funding.⁶² Broken down, local and county property taxes account for \$15.1 and \$2.4 million respectively while state education payments account for \$7.2 million annually.

In terms of projected future job creation, the net positives for the economy and businesses are expected to generate around 200 jobs a year once the line is completed. For instance, the Greater Manchester Chamber of Commerce cited reduced energy costs, improved regional fuel diversity, and the environmental benefits of renewable energy as key drivers in its support of the project. The Greater Nashua Chamber of Commerce, which also endorsed Northern Pass, cited the project's wholesale prices as evidence that it will have a net positive impact on business costs. Overall, economic output in New Hampshire is estimated to increase by an average of \$74-\$91 million as a result of the project.

4. ENVIRONMENTAL IMPACT

It is difficult to quantify more specific environmental consequences of buried power lines based on case studies because most buried power lines are in urban areas; the environmental impact of rural power lines remains a subject of considerable debate. We attempt to quantify many of the more arbitrary segments of environmental and scenic damage by analyzing visual impact assessments to gain a better idea of the impact on the state's \$3 billion tourism industry.



4.1 Maintenance of Right-of-Way

In both overhead and underground power lines, the right-of-way must be cleared and maintained to prevent interference with the lines. Trees near overhead lines must be felled or pruned to prevent foliage from touching the lines, although small trees that grow to be less than 12 feet tall may be allowed to remain in the right-of-way.⁶³ The area around underground lines must also remain clear, both to allow maintenance vehicles access and to prevent roots from disrupting the buried trenches. Additionally, both overhead and underground lines require access roads. These adverse effects, however, can be mitigated by carefully selecting the line's location. Sharing a corridor with a highway, for example, can reduce the environmental footprint of the power line, as the highway already provides access to the line and partial clearing of trees and shrubs.⁶⁴

4.2 Wildlife

Underground lines are safer for birds, especially large raptors. Large birds can be electrocuted when they perch on overhead power lines and connect conductors with their wings.⁶⁵ That said, these events are relatively rare in New Hampshire. For example, no eagles were electrocuted in New Hampshire between 1970 and 1997.⁶⁶

Indeed, some environmentalists argue that the right-of-way associated with overhead lines can bring beneficial diversity to ecosystems. The wild berries and small shrubs that thrive in the open right-of-ways can become habitats for small birds and mammals.⁶⁷ It is however unclear whether these benefits would translate to buried lines in rural areas, as many buried lines are covered with concrete slabs or patio blocks. There has also been little study of the effects of buried power lines on the bugs and mammals that dwell underground.

4.3 Heat Dissipation

Heat dissipation is of negligible concern in overhead lines, which are surrounded by air. To avoid overheating, underground cables use special materials such as circulating fluid or gas to draw heat from the conductors and into the surrounding soil. The heat then dissipates through the ground. The type of soil determines the efficiency of the heat conduction, and if the native soil is not sufficiently conductive, special backfill material may be placed around the line to better dissipate heat through the ground.⁶⁸ Adding foreign materials to the ground may disrupt the surrounding environment

The heat produced by the high-voltage power lines causes the surrounding soil to increase a few degrees in temperature.⁶⁹ The dissipated heat is not enough to disturb plants, although it may cause seeds to germinate prematurely.⁷⁰

4.3 Other Concerns

Erosion can be a problem in rural areas with buried power lines, due to the concrete slabs and the cleared right-of-ways. Special construction techniques must be used to minimize mixing soil



layers.⁷¹ However, it is also possible that in a densely wooded area, environmental impacts such as erosion will be localized and relatively insignificant in comparison to the larger forest.⁷² Ultimately, constructing either overhead or underground lines will disturb the environment, but as of now there is very little data quantifying these effects.

5. PUBLIC OPINION REGARDING NORTHERN PASS

For the past two years, the Rockefeller Center's New Hampshire State of the State Poll has included questions regarding support for and opposition to the Northern Pass Project. In April of 2013, 424 registered voters responded to the poll; in April of 2014, 412 registered voters participated in the poll. According to the poll results, New Hampshire registered voters remain divided over whether the Northern Pass Project should be built between Canada and New Hampshire.⁷³ However, support for the project increased somewhat from 30 percent in 2013 to 40 percent this year. Opposition remained relatively stable, increasing from 31 percent in 2013 to 34 percent in 2014. Respondents who are unsure dropped from 39 percent to 26 percent. The figure below provides the breakdown of responses by partisan identification.

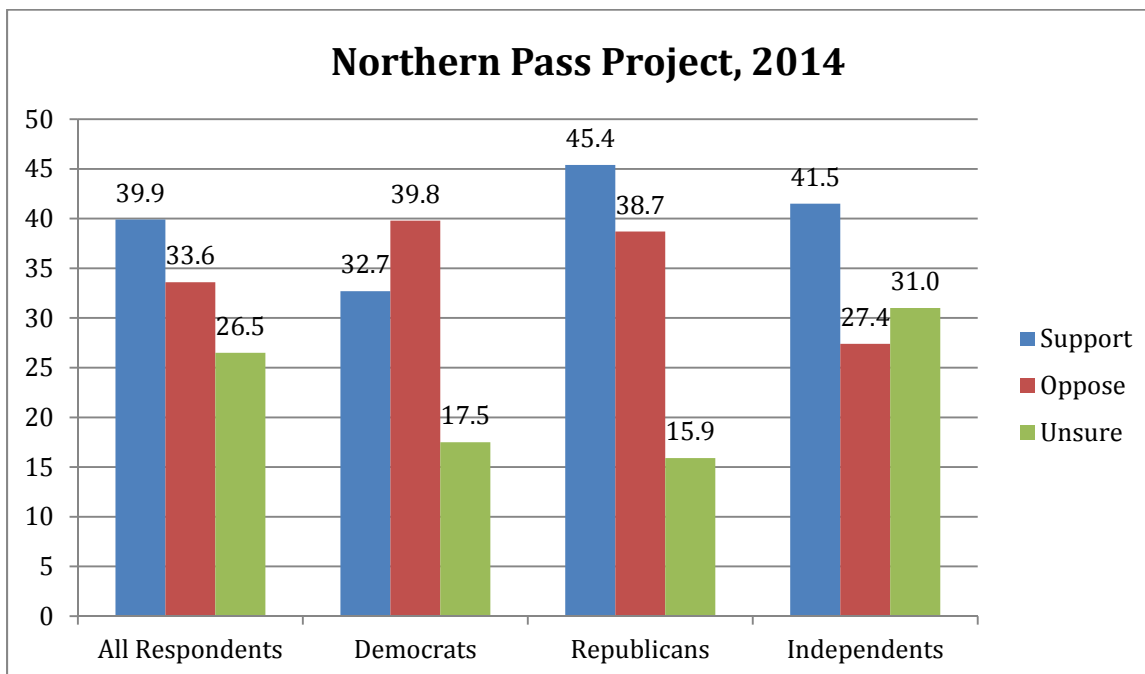


Figure 4. Opinion of Northern Pass Project in New Hampshire, by Party

6. CONCLUSION

As New Hampshire continues to consider the short and long term implications of the implementation of the Northern Pass project, the state is faced with the challenge of weighing the varied costs and benefits of a massive infrastructural undertaking. Through the evaluation of similar case studies and analysis of both economic and environmental impact, this report presents an objective analysis of all facets of the Northern Pass Project.



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- ⁶²*Ibid.*
- ⁶³“Powerlines as Habitat.” Northern Woodlands. Bodin, Madeline. (August 26, 2011).
- ⁶⁴Public Service Commission of Wisconsin. *Underground Electric Transmission Lines* (2011).
- ⁶⁵National Wildlife Health Center, U.S. Geological Survey. (1999.) *Field Manual of Wildlife Disease—General Field Procedures and Diseases of Birds*.
- ⁶⁶*Ibid.*
- ⁶⁷“Powerlines as Habitat.” Northern Woodlands. Bodin, Madeline. (August 26, 2011).
- ⁶⁸Public Service Commission of Wisconsin. *Underground Electric Transmission Lines* (2011).
- ⁶⁹*Ibid.*



⁷⁰Ibid.

⁷¹Ibid.

⁷²Friedland, Andrew (1 Nov. 2013). Interview.

⁷³Zachary Markovich and Jake Perkins, "2014 NH State of the State Poll," PRS Policy Brief 1314-06, Nelson A. Rockefeller Center for Public Policy and the Social Sciences, May 8, 2014, p.8.