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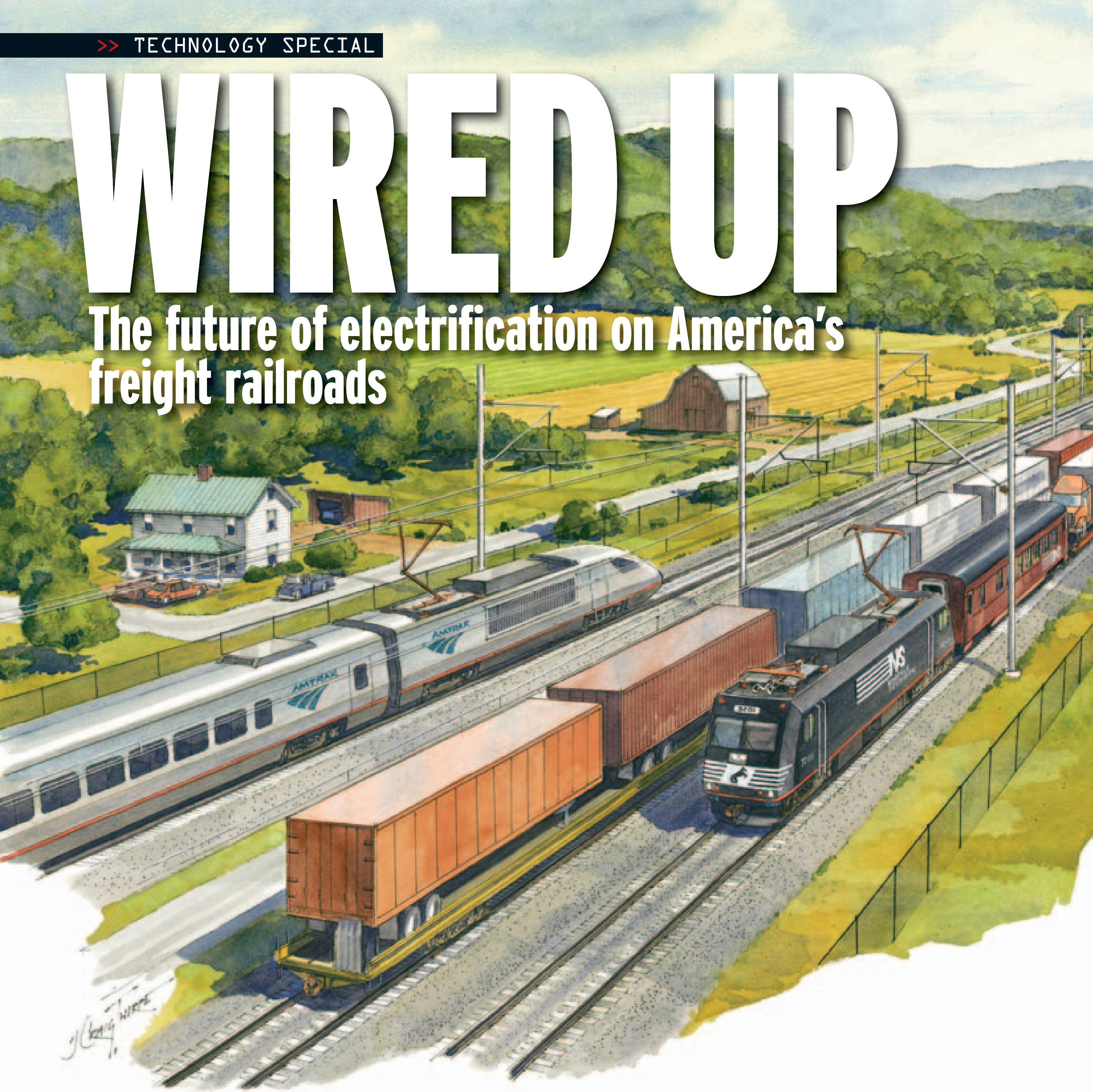
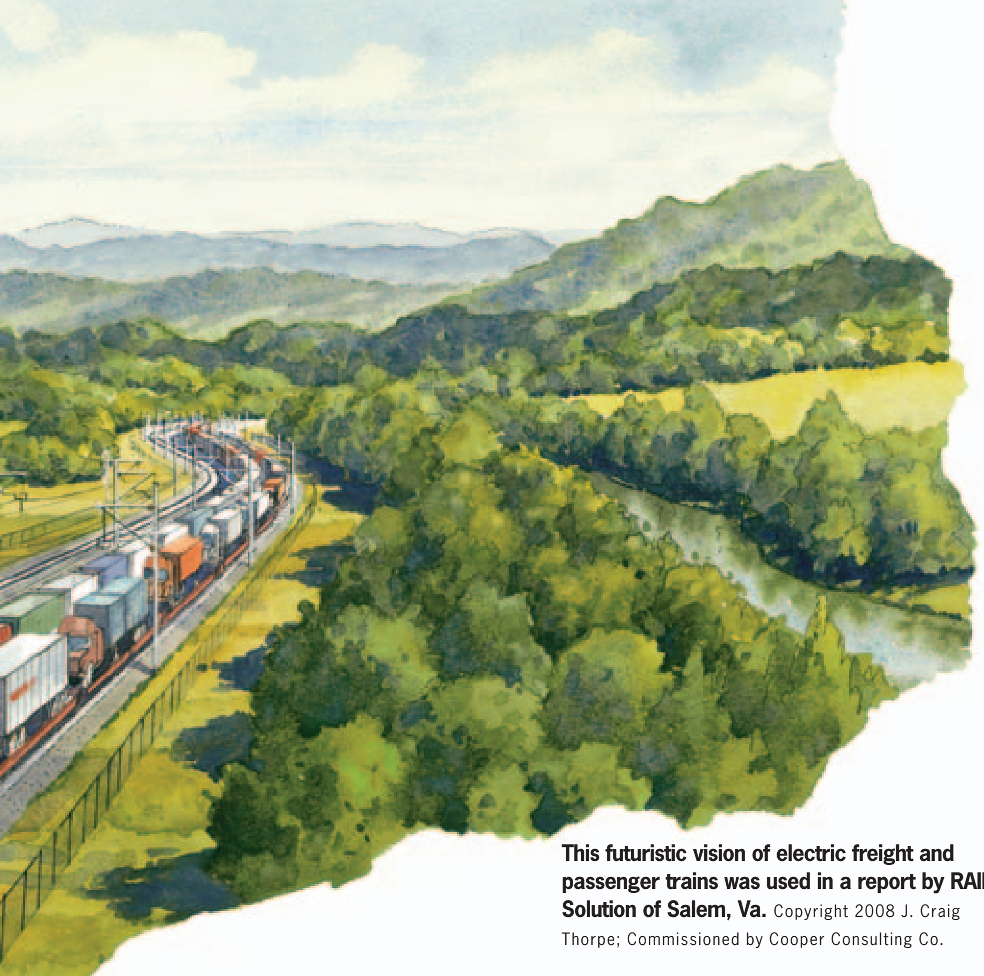
WIRED UP

The future of electrification on America's freight railroads



Once an electrification pioneer, America threw in its lot with the diesel and never looked back. Could recent social and economic forces prompt a string of catenary from sea to shining sea?

by Scott Lothes



This futuristic vision of electric freight and passenger trains was used in a report by RAIL Solution of Salem, Va. Copyright 2008 J. Craig Thorpe; Commissioned by Cooper Consulting Co.

In 1939, the United States was the global leader in railway electrification, with more than 20 percent of the world's mileage. Seventy years later, electrification is a non-factor on virtually all U.S. railroads outside the Northeast Corridor. How did this happen? The heady projects from the early 20th century that propelled the U.S. to world leader were built on predictions that their "white-coal" technology would replace steam power nationwide. Then came the Great Depression, World War II, and diesels. One by one, electric railroads switched off the juice and took down their wires. The last holdout, Conrail, quit mainline electric freight operations in 1981.

When oil prices spiked in 2008, American interest in rail electrification surged to a level not seen since the energy crisis of the 1970s. Industry managers and consultants began revisiting both the completed projects and stillborn proposals of decades past. In a July 2008 interview with Trains, BNSF Railway President Matt Rose confirmed that his company is studying electrification for its principal routes. Norfolk Southern Chief Marketing Officer Donald W. Seale told the *Journal of Commerce* his company is exploring electrification as a byproduct of new high speed rail corridors. Other Class I railroads are almost certainly doing the same, yet so far, none are stringing wires. Meanwhile, Russia, China, and India are investing billions in freight railroad electrification and becoming the new world leaders. The recent dip in oil prices and downturn in traffic may have cooled some of electrification's fervor, but other factors are emerging that could drive an American resurgence just as strongly as high oil prices.

>>IN 2008, AMERICAN INTEREST IN RAIL ELECTRIFICATION SURGED TO A LEVEL NOT SEEN SINCE THE ENERGY CRISIS OF THE 1970S.

From world leader to non-player

The earliest mainline electrifications occurred in congested tunnels where railroads had no choice but to electrify. Steam simply could not move the necessary tonnage through Baltimore's Howard Street Tunnel, over Washington's Cascade Mountains, or under Michigan's Detroit and St. Clair rivers. In each case, the railroad involved electrified only the minimum amount of trackage necessary. The new technology performed admirably, even remarkably, but required exorbitant initial costs to string wires and build new locomotives and servicing facilities. These arrangements worked well in the steam era, but diesels changed the equation.

In his authoritative book on the subject, "When the Steam Railroads Electrified," William D. Middleton notes that the electrics' cost advantage in tunnels was no longer enough to justify the expense of operating and maintaining separate fleets of power over such short distances. In every case, improving tunnel ventilation to allow diesel run-throughs proved cheaper than maintaining short electric districts.

Tunnel electrifications paved the way for larger projects. Both the Virginian Railway and the Milwaukee Road strung wire over their steepest mountain districts, where electrics held the greatest advantage over steam. In 1925, the Virginian electrified 134 miles of main line, including 14 miles of 2 percent grade against loaded coal trains out of Mullens, W.Va. Where three Mallets had taken 2½ hours to heft a 5,500-ton train to the summit, two box-cab electrics whisked a 6,050-ton train up the grade in an hour.

Ten years earlier, electricity had proved superior to steam in nearly every way when the Milwaukee Road began energizing its main line through the Rocky Mountains. By 1919, the Milwaukee had added a second electric district in Washington's Cascade Mountains. At a combined length of 645 route-miles, the Milwaukee's two installations formed the longest electrification in the world. Middleton wrote it "captured the public fancy as had few other comparable engineering achievements … there was something wondrous about trains that preserved dwindling reserves of coal and oil by taking their energy from the 'white coal' of rushing mountain streams … and frugally returned electricity to the wires by the magic of regenerative braking." The railroad's 59 electric locomotives moved a volume of freight in 1923 that would have required 167 steam locomotives, Middleton notes, saving $1.2 million a year in operating costs.

Both the Milwaukee and Virginian electrifications survived after their roads dieselized — if only for a time.

The Virginian studied de-electrifying in the 1950s, but research instead led management to upgrade its distribution system and buy 12 new General Electric engines. What killed the electrification was the Virginian's 1959 merger with the Norfolk & Western. The N&W was a much larger system and, as with electrified tunnels, the Virginian's installation became an anomaly, requiring specialized equipment confined to a limited area. (Decades earlier, N&W had electrified its own Appalachian route, then forsook it for a non-electrified line relocation.) Furthermore, Virginian-originated coal found new markets and routings with the N&W, many of which bypassed the 2 percent climb out of Mullens, denying the electrification its most advantageous territory. Diesels performed well enough to handle the remaining traffic, and the wires came down in 1962.

The situation on the Milwaukee Road was more complex. Hamstrung by the 215-

Three GE-built EL-C electrics lead a Virginian coal train east near Clarks Gap, W.Va., on Sept. 9, 1960. Built in 1956-57, the EL-Cs outlived Virginian's electrification. Harold Cavanaugh

mile gap between its electric districts, which required separate fleets of motive power, the Milwaukee Road also considered de-electrifying after World War II, but ultimately kept the power on. Electrification ended almost inexplicably during a global oil crisis that made diesels twice as expensive to operate as electrics. Cash-strapped for much of its existence, the Milwaukee never made the major upgrades that would have been necessary to modernize its electrification. Its directors had set their sights on merging with another railroad, and they deferred maintenance to pump up the road's finances. That decision proved disastrous, ultimately to the entire railroad, but first to the electrification, which ended in the Cascades in 1972 and completely in 1974.

Electric short lines

Freight electrification most recently has been confined to short lines, many of them single-commodity carriers (see page 28). The poster child for this is the Black Mesa & Lake Powell, an isolated coal-hauler in northeastern Arizona that has been entirely electric from its outset. The 78-mile line was built in the early 1970s with the world's first 50,000-volt system, using electricity readily available from the generating station for which it hauls coal, rather than trucking millions of gallons of diesel fuel for hundreds of miles. The pioneer for this type of railroading was Montana's Butte, Anaconda & Pacific, whose 1913 electrification helped foster the Milwaukee Road's subsequent installation. For more than half a century, the BA&P operated a 26-mile electrified main line, hauling more than a dozen daily trains of copper ore (hydroelectric plants generated the power used by the BA&P). Only when a new smelter opened in Butte, eliminating the vast majority of the road's traffic, did electric operations cease.

Pennsylvania's great electrification

Perhaps the most applicable example of what U.S. electrification might look like in the future is also arguably the most successful of the past: the Pennsylvania Railroad's project of the 1930s. When full electric operations commenced between New York and Washington in 1935, the Pennsylvania boasted one of the most state-of-the-art railroad corridors in the world: a multiple-track main line with frequent crossovers shared by freight, intercity passenger, and suburban commuter trains. It was remarkably similar to the busy main lines of Europe and Asia today, but it might never have been built had the Pennsylvania not been able to carry the project through the Great Depression.

The PRR began experimenting with electrification on suburban branch lines in the first decade of the 20th century, electrified its New York terminal trackage in 1910, and relieved severe congestion at Philadelphia's Broad Street Station by electrifying some of the busiest commuter routes in 1913-1915.

As early as 1913, Pennsylvania had considered heavy-haul, mainline electrification. Early studies looked at the route over the Allegheny Mountains, but by the mid-1920s, the focus had shifted to the East Coast, a route that, according to author Michael Bezilla, "carried freight and passenger traffic of a density unmatched by any other line in North America." The cities along what is today's Northeast Corridor were part of a bustling industrial center in the 1920s. Along with hundreds of passenger trains, PRR's Washington-New York main line carried several dozen freight trains every day. (North of New York, the New Haven Railroad served this corridor on its own electrified freight and passenger route to New Haven, Conn.) Even with a main line that was four tracks wide in places, the PRR's managers were concerned over the corridor's future capacity.

By 1929, Pennsylvania had decided to electrify its route between New York and Washington at an estimated cost of $175 million. While the stock market crash of that year killed many railroad infrastructure projects, the Pennsylvania's directors, led by President William Wallace Atterbury, chose to move forward with their plans.

By electrifying its East Coast main line during the height of the Great Depression, the Pennsylvania Railroad obtained both labor and material at bargain prices, pumped millions of dollars and some 45 million man-hours into the struggling economy, and obtained low-interest federal loans to finance more than half the project. By 1938, wires had extended to Harrisburg, Pa., adding another $50 million to the price tag. With 656 route-miles under catenary, PRR accounted for one-third of all U.S. electrification and nearly 10 percent of the world's total, Middleton notes.

Tested almost immediately by unprecedented traffic volumes during World War II, the electrified lines played a major role in helping the railroad handle a system-wide doubling of freight traffic and quadrupling of passenger traffic between 1939 and 1944.

Fast-forward to 1958, with diesels performing admirably in place of steam and its fleet of electric locomotives more than 20 years old, the PRR hired three different consulting firms to perform economic studies of electric versus diesel traction. A 1959 statement issued by the PRR revealed that all three studies "unequivocally proclaimed the superiority of the electrification."

Electric freight operations eventually ended under Conrail, owing primarily to the drastic decline in freight volumes throughout the Northeast and a shift of the remaining traffic onto non-electrified routes that had little or no passenger service. As recently as 1979, Conrail had investigated electrifying its main line over the Alleghenies to Pittsburgh. That study favored electrification as a long-term investment, but the initial capital outlay was too high. Without the new wire, however, Conrail's freight electrification had become a familiar anomaly, too small a part of a larger system to warrant its continued operation.

>>BY ELECTRIFYING DURING THE HEIGHT OF THE GREAT DEPRESSION, THE PRR OBTAINED BOTH LABOR AND MATERIAL AT BARGAIN PRICES.

In typical fashion, a Milwaukee Road Little Joe electric teams up with two run-through GP40s and an FP45 hauling freight east over St. Paul Pass, Idaho, in 1970. George W. Hamlin collection

The passenger legacy of the Pennsylvania electrification is, of course, another story. With the creation of Conrail in 1976, Amtrak acquired both the PRR main line from Washington to New York, and the New Haven line from New York to Boston. In 2000, Amtrak realized a long-standing goal by electrifying the remaining leg between New Haven and Boston. It's safe to say that business in the Northeast could not function without the corridor's fast, frequent rail passenger service, and that would not have been possible without the PRR's determination to electrify in the 1930s.

Worldwide

As American railroads de-energized after World War II, electrification increased in much of the rest of the world, fueled by national policies and government investment. While U.S. railroads increasingly became tailored for long-distance, heavy-haul freight, Europe and Japan focused on running fast, frequent passenger trains. These systems have limited value as examples of how U.S. electrification might re-emerge. Instead, the recent railway electrifications in Russia and China offer more applicable comparisons. The vast distances and natural resources of mainland Asia present similar challenges to those faced by U.S. freight railroads.

Russia

It's 5,771 miles from Moscow to Vladivostok, Russia, via the famed Trans-Siberian route, and since 2002, every mile has been electrified. In the U.S., that would be enough to electrify the ex-New York Central from New York to Chicago, the ex-Great Northern from St. Paul, Minn., to Seattle, and the ex-Santa Fe from Chicago to Los Angeles, and still have a few hundred miles left over.

Russia is second only to the U.S. in the size of its railway system, with 53,000 route-miles (vs. 140,000 in the U.S.), and it operates the most electrified trackage in the world: more than 25,000 miles. The Russian system carries staggering amounts of freight and passengers, accounting for nearly 80 percent of all transportation in the world's largest country. On average, one mile of track in Russia handles about 90 percent more ton-miles than a mile of track in the

Two Conrail E44s bring a freight north on the former PRR raceway at Havre de Grace, Md., on Dec. 31, 1976. This train is bound for Enola Yard near Harrisburg, Pa. David C. Warner

Recent U.S. electrification projects have been limited to passenger rail expansions and closed-loop freight lines linking coal loadouts and power plants. A coal train on the Black Mesa & Lake Powell rolls behind GE-built E60Cs on Sept. 9, 2000. Scott A. Hartley

Major U.S. freight electrifications by type

1895 1915 1935 1955 1975 1995 2005

Type	Railroad	Installation location	Miles	Start-End (End of freight in parentheses where applicable)
TUNNELS	Baltimore & Ohio	Howard St. Tunnel, Baltimore, Md.	3.6	1895 1952
	Grand Trunk	St. Clair Tunnel, Port Huron, Mich.	4.2	1908 1958
	Great Northern	Cascade Tunnel, Washington	4.0	1909 1927
	New York Central	Detroit River Tunnel, Detroit, Mich.	4.5	1910 1953
	Boston & Maine	Hoosac Tunnel, North Adams, Mass.	7.9	1911 1946
	Pennsylvania	Hudson River Tunnel, New York	13	1910 1932
MOUNTAINS	Norfolk & Western	Iaeger-Bluefield, W.Va.; branches	56	1915-24 1950
	Milwaukee Road	Harlowton, Mont.-Avery, Idaho	438	1915-16 1974
	Milwaukee Road	Othello-Tacoma and Seattle, Wash.	225	1919-27 1972
	Virginian	Roanoke, Va.-Mullens, W.Va.	134	1925 1962
	Great Northern	Skykomish-Wenatchee, Wash.	73	1927-29 1956
MAIN LINE	New York Central	New York to Croton, N.Y.; branches	68	1906-31 (1959) Present
	New Haven	New York-New Haven, Conn.; branches	107	1907-25 (1969) Present
	Pennsylvania	New York-Washington-Harrisburg, Pa.; branches	656	1915-38 (1981) Present
	Long Island/NY Connecting	Port Morris-Bay Ridge and Sunnyside, N.Y.	21	1918-27 (1969) Present
LINE-HAUL SHORT LINES	Butte, Anaconda & Pacific	Butte-Anaconda, Mont.	37	1913 1967
	Kennecott Copper	Bingham Canyon, Utah	175	1926-47 1979-1981
	Detroit, Toledo & Ironton	Dearborn-Flat Rock, Mich.	16	1926 1930
	Muskingum Electric	Renrock, Ohio	15	1968 2002
	Black Mesa & Lake Powell	Black Mesa-Page, Ariz.	78	1973 Present
	Texas Utilities	Monticello, Texas; Martin Lake, Texas	32	1976 Present
	Navajo	Fruitland, N.M.	14	1983 Present
	Deseret-Western	Deserado Mine, Colo.-Bonanza, Utah	35	1984 Present

Source: William D. Middleton, "When the Steam Railroads Electrified, 2nd edition" (Indiana University Press, 2001), plus articles in TRAINS Magazine

United States. On the busiest segments of the Trans-Siberian, electric-hauled 100-car freight trains hurry by every 15 minutes. The line's eastern terminus, the port of Vladivostok, is an ice-free outlet to the Pacific, and the railway has virtually no overland competition. (The Trans-Siberian Highway is little more than a muddy path for the remote 1,000 miles near its center.)

Russia pays heavily to keep its trains rolling. Last year, the country unveiled a plan to invest $400 billion through 2030 on its rail system, with 40 percent of the funds coming from the railway, and roughly 30 percent each from the national government and private investors. The money will be used on modernization and expansion projects, including electrification. To put this investment in perspective, consider taking more than half of the $700 billion Wall Street bailout and spending it on American railroad infrastructure over the next five years.

In June 2009, an electric-hauled freight passes an intermodal yard under construction in Zhengzhou, a crossroads for China's main east-west and north-south rail lines. George W. Hamlin

China

China ranks second behind Russia, with 15,000 miles of electrified railways, nearly one-third of its total. China's railways move nearly three times more traffic per mile than U.S. lines. *Business Week* called its network "the busiest on the planet," handling one-fourth of the world's rail traffic on just 6 percent of the world's route-miles. Like Russia, China spends heavily on its national rail system. In 1998 alone, the country invested more than $6.5 billion in rail upgrades, including three major electrification projects, notes the *International Railway Journal*. Future plans call for 30,000 miles of electrification by 2020, or double the amount currently under wire, as part of a giant $248 billion rail expansion.

In the past 30 years, China's economy has grown seven times faster than its rail network, and the recent heavy investments in rail stem from an "urgent social demand" to keep all that commerce moving. China's manufacturing base historically was located along the coast, but the country's economic boom pushed industrialization inland, hence the need for good land transportation. While the nation is investing in both highways and railways, a combination of factors give an edge to rail. Two in particular — a growing demand for high speed passenger travel, and national energy goals — favor electrified railways.

Surprisingly, China's first electric railroad did not appear until 1961, and most installations went up after 1983, when the country's Ministry of Railways adopted a new policy making electric traction the preferred choice in railway development. From 1981 to 1995, the country electrified 300 miles per year, then in 2006, electrified nearly 2,500 miles, noted Li Shi-Wu at the International Conference on Transportation Engineering 2007. To illustrate electrification's benefits, Shi-Wu described the double-track, 1,400-mile trunk line linking Beijing in North China with Guangzhou in South China. Congested and approaching capacity in 1996, traffic swelled upon the completion of electrification in 2001, and now moves fluidly behind 13,000-hp HXD1 electric motors, which whisk 10,000-ton freight trains along at 75 mph. On one segment, passenger traffic jumped from 32 to 108 daily trains, Shi-Wu says, while annual freight traffic rose 71 percent, from 42 million to 72 million tons.

From an energy standpoint, researchers Zheng Wan and Xiang Liu, both at American universities, state that China's "ongoing electrification process has also helped significantly in energy conservation." In a study for the Transportation Research Board's 2009 conference, they report that China Railways reduced its energy consumption (per ton-mile) 60 percent from 1980 to 2007, a time period that coincides with its greatest electrification expansions.

Tripleheaded electric locomotives hustle a westbound freight across Russia's Trans-Siberian route on Dec. 13, 2007. In this remote part of the country, trains trump trucks. Eugene Sterlin

What's next for America?

During the oil crisis of the 1970s, Burlington Northern annual reports featured artist renditions of new Cascade Green electric locomotives, yet BN's electrification plans never came to fruition. Today, at least two Class I railroads have acknowledged they are investigating electrification. Amtrak President Joseph Boardman, in a 2008 interview in the *Pittsburgh Post-Gazette*, says he'd like to see electrified routes stretching from

Russia leads the world in electrified rail mileage. Two electrics haul a southbound freight on the main line between St. Petersburg and Murmansk on April 8, 2009. Eugene Sterlin

Maine to Florida and from the East Coast to Chicago. Could these ideas become reality?

The single most limiting factor of electrification is the tremendous initial cost. To achieve the full economic benefits, it is not enough to electrify Cajon Pass or in the Blue Mountains; railroads would have to electrify an entire, 2,000-mile transcontinental lane.

Or would they? Diesel-electric locomotives already use electric traction motors, but the power comes from the diesel engine instead of overhead wires. Could the locomotives simply bypass their diesel engines and draw power straight from the catenary, where it existed, then switch back to diesel outside electrified territory? Builder General Electric says such "dual-mode" locomotives are possible but that development would take at least three years, according to an April 2009 *Journal of Commerce* report.

>> IF THE FEDERAL GOVERNMENT DOES NOT INVEST IN RAIL IMPROVEMENTS, IT WILL PAY EVEN MORE IN HIGHWAY COSTS.

Even if dual-mode locomotives were available tomorrow, stringing catenary is prohibitively expensive, on the order of $1.5-2.5 million per track-mile, depending on terrain. (Widening interstates can cost 10 to 15 times more: $20 million per mile to expand I-25 in New Mexico and $32 million per mile to widen I-81 in Virginia, based on state DOT figures.) Recent studies peg the cost of electrifying the country's highest-density main lines (36,000 miles) at around $72 billion, notes Phillip Longman in the January 2009 issue of *Washington Monthly* magazine.

Researcher Alan Drake of the Millennium Institute, an environmental planning and consulting agency, advocates going even further by spending $250-500 billion to electrify all of America's intercity routes and upgrade 7,000-14,000 miles of main lines so passenger trains could run at 125 mph and freights up to 100 mph. Doing so, Drake says, has the potential to put 83 percent of today's truck traffic onto electrified rail lines.

"I'm taking twice the money the federal government spent on AIG just to build our railroads," Drake told attendees at the Transportation Research Board's 2009 meeting, where he presented his plan.

Who will pay for this? Russia and China have nationalized rail systems that can draw on their entire country's resources to fund infrastructure improvements. The same is true for railroads in Europe and Japan. Transportation researchers Zheng Wan and Xiang Liu, who have called for some deregulation of China's railways, concede that the high initial costs of railway projects do not favor private investors, and thus "the government remains the main entity or agent that should provide funds for further railway construction." American groups echo this sentiment, including the American Association of State Highway and Transportation Officials, which warns that if the federal government does not invest in rail improvements to meet rising traffic demands, it will pay even more in highway costs, traffic congestion, air pollution, and energy consumption.

The argument against private investment is based largely on operating costs, however, and does not consider capacity, which could prove more important for electrification, as Harvard professor John R. Stilgoe predicts in his book "Train Time: Railroads and the Imminent Reshaping of the United States Landscape." All other factors being equal, an electric railroad has significantly higher capacity than a diesel-powered line, as the electrics' faster acceleration and braking increases capacity by roughly 15 percent. Most U.S. main lines are not this congested, but a 2007 study sponsored by the Association of American Railroads predicts that by 2035, about half of the nation's principal rail lines will be at, near, or above capacity without significant infrastructure improvements. Curiously, electrification is mentioned nowhere in the AAR report.

Capacity of another kind could also play a role in freight railroad electrification: the capacity of the nation's power transmission

Top countries under wire

Nation	Electrified route-miles	Total rail miles	Percent electric
Russia	25,300	53,010	48
China	15,000	46,772	32
Germany	11,443	23,839	48
India	10,855	39,197	28
Japan	10,300	16,906	61
France	8,852	19,671	45
Poland	7,411	12,178	61
Italy	6,465	9,945	65
South Africa	5,537	12,941	43
Sweden	4,703	6,917	68

Sources: CIA Worldfact Book, The World Bank

A New Haven freight approaches New York's Harlem River Yard behind ex-Virginian EF-4 motors in May 1964. The city's ban on steam prompted New Haven to electrify. Harold Cavanaugh

network. The blackouts of 2003 in the Midwest and Northeast served as a solemn reminder of the precarious state of the national grid. Developing additional sources of alternative energy will require substantial improvements to transmission capacity, and BNSF's Rose is encouraging electric utilities to consider using his railroad's rights-of-way to locate new high-tension power lines (transmitting electricity produced by wind turbines or nuclear plants) in exchange for providing power to its trains.

Local governments also could become electrification catalysts. New York City's ban on steam locomotives in Manhattan, following a deadly 1902 train accident, essentially forced the New York Central and the New Haven railroads to electrify their routes into Grand Central Terminal. Chicago passed a law requiring Illinois Central to electrify its smoky lakefront commuter trackage by 1927. What might happen if, say, the city of Los Angeles or the entire state of California decided to ban diesel locomotive emissions?

Think it's far-fetched? In 2005, California signed a pollution reduction agreement with BNSF and Union Pacific that curbed locomotive idling, required idling reduction devices on California-based locomotives within three years, and mandated the use of ultra low sulfur diesel fuel (15 parts per million) at locomotive fueling facilities six years earlier than required by federal law. The railroads face stiff fines for non-compliance.

Beyond railroad operations, major electrification, coupled with significant renewable energy development, offers an attractive solution to energy, environmental, and national defense concerns. "The Environmental Protection Agency calculates that for distances of more than 1,000 miles, a system in which trucks haul containers only as far as the nearest railhead and then transfer them to a train produces a 65 percent reduction in both fuel use and greenhouse gas emissions," writes Phillip Longman in *Washington Monthly*. "As the volume of freight is expected to increase by 57 percent between 2000 and 2020, the potential economic and environmental benefits of such an intermodal system will go higher and higher."

Using dynamic simulation modeling, the Millennium Institute's Drake says his comprehensive plan for investing heavily in both railroad electrification and renewable energy over the next 20 years could see the U.S. increase its gross domestic product 13 percent, add 35 million jobs, reduce greenhouse gas emissions 38 percent, and reduce oil consumption 22 percent. Drake's vision for the future calls for separate freight and passenger rail corridors powered by electricity from renewable resources, integrated urban transit systems, and nearly all long-distance trucking transferred to double-stacked container trains.

"Under this non-oil policy," Drake told the Transportation Research Board, "you can be at the best of both worlds."

Will it happen?

Will wires come to a railroad near you? It's too early to say definitively, but America needs to consider and plan for the future of its transportation system. Although capital improvements have been scaled back, the long-term outlook for rail forecasts substantial growth. Oil supplies will continue to decline and environmental concerns will continue to grow. Rail offers numerous advantages, but will require substantial improvements and radical new thinking, especially to reclaim short-haul, small-volume freight shipments from trucking. These types of discussions are already occurring on the passenger side. At the very least, the plans for America's freight-hauling future should consider large-scale railroad electrification. I

Electrification has the potential to cut fuel and operating costs and boost capacity. But the upfront costs are huge. Eugene Sterlin

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>> America under catenary

Get more information about the evolution of U.S. railroad electrification at www.TrainsMag.com