America's Backbone:

The importance of steel and its evolving demand

ALLIANCE FOR INNOVATION AND INFRASTRUCTURE

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Executive Summary

Steel is ubiquitous in our economy. It upholds our entire built environment and facilitates the very necessities we depend on most: food, water, shelter, waste; and it is involved in every good and service from the basics to luxury. Not only does steel comprise our built environment in unfathomable quantities, but it is demanded every year. While much of this can be met with recycling, a great amount and weight of steel is required every year to build the new products we depend on. As policymakers, advocates, and industry leaders seek to transition the economy toward electrification, to incorporate greater use of wind and solar infrastructure, and turn the vehicle fleet over to a primarily battery-electric transportation fleet, the demand will only increase.

In fact, renewables are a steel-heavy investment that in turn require increased steel investments in new high-voltage transmission cables and towers. If these are to be used to facilitate centralized green hydrogen production and carbon management solutions, still more steel will be demanded for pipelines to move hydrogen and carbon dioxide around the country. Finally, an electrified economy utilizing a growing share of electric vehicles (EVs) will require huge amounts of high-quality steel for automakers and charging infrastructure. These economic changes will necessitate production readiness, stable supply chains, innovative technological advancement, and quality that can also meet consumers economically.

Consider how steel is evolving to meet our needs. The average weight of an electric vehicle surpasses comparable internal combustion engine vehicles due to heavy batteries and other components. To address this, the automotive industry has turned to innovation for different high-quality steel products. This underscores a unique feature that future market forces and public policy are each driving towards - the need for more, and innovative types of steel across different applications, technologies, infrastructure, and supporting assets.

Steel is so fundamental, it is not only a linchpin for energy security, economic health, national defense, and environmental goals, but it is required for basic life. It must be accessible in a high-quality and reliable form, with resilient supply chains, and at a low or competitive cost. Ensuring the domestic steel industry is equipped for the organic and policy-driven changes to come is of national importance.

The United States domestic steel industry is currently in a state of renewal after years of decline. Plans for future green expansion have revived interest in American steel, heralding innovations for decarbonization and expanding production. Recent events have further highlighted how important steel is.

The Biden-Harris Administration is poised to block the acquisition of the United States Steel Corporation by Nippon Steel Corporation of Japan. This policy move has captivated the attention of American politicians and industry leaders. Opinions on the merger have been hyper-politicized in a tense election year, with facts and reasoning contending with patriotic fervor.

Under the terms of the sale, U.S. Steel would keep its name and operations, while sharing resources and research. U.S. Steel and Nippon are still pushing for the deal to be approved, but bipartisan opposition has halted momentum.

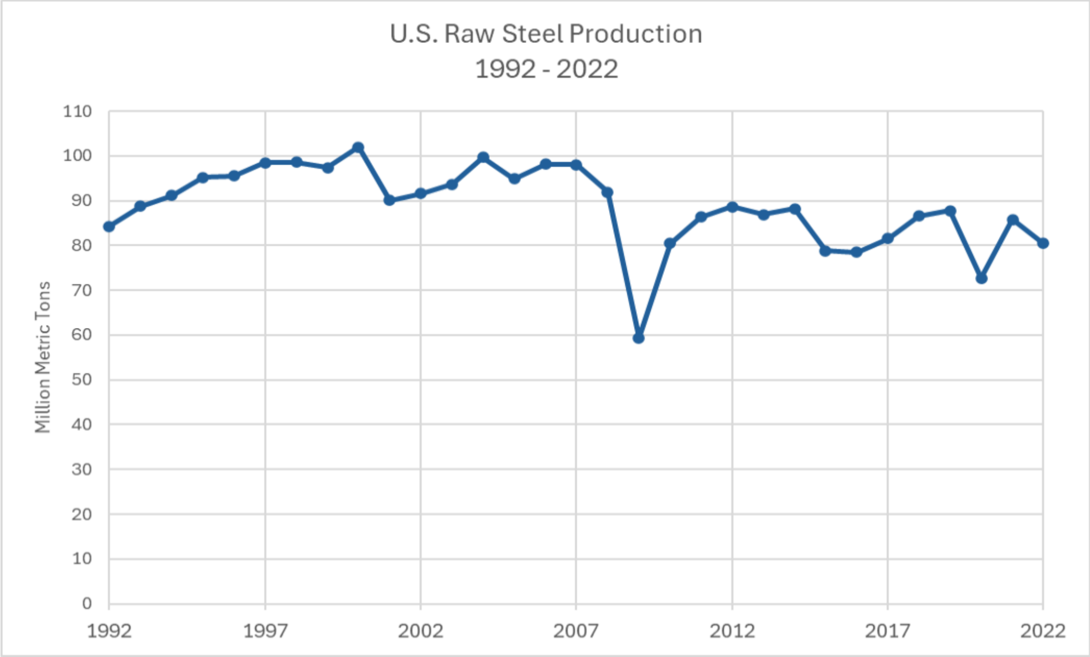
The opposition to the merger is surely well-intentioned, but ultimately flawed. Arguments that Nippon Steel purchasing an American steel company threatens national security ignore the fact that Japan is a close and longstanding ally and trade partner. The United Steelworkers union opposed the deal due to worries that its workers will not be protected, despite Nippon promising to honor all agreements. On the other side, an anticipated tenfold increase in Research and Development (R&D) spending by Nippon would keep U.S. Steel ahead of the competition on innovation and technological advances.

By highlighting the enduring necessity of steel, the steel-intense plans policymakers are advancing, and evolving need and application for innovation in the industry, this paper provides an approach that policymakers and industry leaders should consider when examining policy changes. Steel is ubiquitous in our infrastructure and society. Failing to understand steel's importance can result in serious damage now or in the future.

Introduction

Steel is not a naturally occurring metal, but a highly versatile alloy. It is produced by blending iron with carbon, and humans have been using it for millennia. Various steel forms and mixtures produce a diverse range of steel alloys, but this report will treat "steel" as a relative monolith and include different blends and qualities together for the purpose of demonstrating the enormous demand for steel in the economy. As the report progresses, we will delve into aspects such as quality and cost, but leave the details to architects and engineers. Our discussion will center on the total demand of steel, its uses, the impact of public policy frameworks, and the market forces that will impact or be impacted by changes in conditions.

Current estimates suggest there are well over four billion metric tons of steel in our built environment.[1] The steel stock can be found in the automotive fleet already on the road, the buildings around us, and the various other infrastructure components you see and that are hidden from the public eye. While this quantity of steel is difficult to conceptualize, even more is demanded and consumed every year.



Aii Figure 1: 30-year trend in domestic steel production (source: USGS Iron and Steel Statistics)

Since the 2008 recession, the U.S. consumption of steel has held relatively consistently around 100 million metric tons per year, while the nationwide steel production has averaged around 85 million metric tons.[2] Between 70 and 90 percent of annual steel consumption was produced domestically during this period, while eight to 14 percent was exported.[3]

The U.S. primarily imports steel from Mexico and Canada. Other smaller sources of steel imports include Brazil, Japan, South Korea, Russia, and Germany. Despite producing more than 50 percent of all steel worldwide, China accounted for only two percent of all imports from 2010 to 2021.[4] International steel from outside Canada and Mexico are subject to significant tariffs and quotas by the U.S. government. These trade restrictions have protected domestic steel manufacturers, who may not otherwise be competitive, but the rules have also harmed steel-consuming industries who face high costs and demand large quantities of steel.[5]

In addition to raw steel and iron, the U.S. also imports steel in the form of intermediate, semi-finished, and finished products. A 2019 report highlighted that millions of tons of steel enter the U.S. through these channels, and much of it is ultimately recycled along with domestically produced steel.[6]

The U.S. steel sector has also tended to focus on higher-quality steel products such as lightweight automotive steel. Domestic steel exported at an average of $1,570 per ton in 2021, while imported steel cost an average of $1,171 per ton.[7]

Aii Figure 2: 30-year trend in steel scrap (source: USGS Iron and Steel Scrap Statistics and Information)

Domestic consumption of steel scrap has been decreasing steadily since around 2000, with a noticeable drop during the 2008 recession. Meanwhile, steel scrap exports have been steadily increasing for the past two decades, signifying that the U.S. has more steel scrap than it consumes.

The U.S. also uses significant amounts of recycled steel for overall production. Of the 85.8 million metric tons of steel produced in the U.S. in 2021, 69.23 percent (or 59.39 MMT) was from steel scrap.[8] The 2022 steel recycling rates for appliances, rebar, and packaging were 88 percent, 71 percent, and 70 percent respectively.[9] Construction steel has a remarkable 98 percent recycling rate, and automobile steel recycling is close to a hundred percent. Overall, the scrap recycling rate for the entire United States has been between 80 and 90 percent over the past decade, according to the United States Geological Survey (USGS). The U.S. actually has exported around 30 percent of domestic scrap in recent years.

Recycled steel is generally considered to be of slightly poorer quality than steel produced from iron ore, or "virgin steel" that may be produced for specific purposes.[10] This is due to impurities and trace metals remaining from the recycling process. Nevertheless, recycled steel is suitable for most applications, and is the most common source of steel overall. Some industries that deal with higher-quality steel or certain types of steel may prefer virgin steel, such as automakers and aerospace manufacturers.[11] However, for most applications, recycled steel is adequate.[12] In particular, recycled steel can be used for wind turbines and solar farms.[13,14] Recycled steel is regularly used in construction, bridges, and more.[15]

Recycling is the primary method of steel production in the U.S., leading to a significant reduction in iron ore mining. In 2021, only 47.5 million metric tons of iron ore were mined – down from 63.1 million metric tons in 2000.[16] According to the USGS, 98 percent of all iron ore is used for steelmaking, and it takes roughly 1.6 metric tons of iron ore to produce one ton of steel.[17] The U.S. exports around 30 percent of its raw iron production, considerably more than for finished steel products. The overwhelming majority of iron ore in the U.S. comes from Minnesota and Michigan, where several large mines supply virtually the entire non-recycled steel industry.[18]

Historically, the Great Lakes region has been the largest originator of steel, with over 50 percent of steel production located there in 2022.[19] However, recent data shows that the Southern U.S. has also been a major producer of steel, with other regions also supporting smaller steel operations.[20] There has been a gradual shift from traditional integrated steel mills to mini-mills, which can have lower labor and energy costs.[21] Mini mills often work with scrap metal, using Electric Arc Furnaces (EAF) rather than coke ovens and Basic Oxygen Furnaces (BOF) used by traditional mills.

Aii Figure 3: Steel Manufacturing Jobs in the U.S. 1987 - 2032 (source: Bureau of Labor Statistics)

The U.S. Steel industry has been in a steady decline since 1990, as production and profits have decreased significantly. In 1990, there were 187,300 jobs in the U.S. Steel industry, compared to just 83,600 in 2023.[22] The U.S. government projects an annual decrease of about 0.7 percent in employment in the steel industry between 2022 and 2032, shown in red above.[23]

Stagnation in domestic steel production lines up with a report from 2013 estimating a steady decline in steel production among developed nations.[24] The report, titled “Steel all over the world: Estimating in-use stocks of iron for 200 countries,” predicts a decrease in new steel production over time as the economy becomes saturated with older steel stock and products are built to last longer. Steel is so recyclable that the overall stock has been increasing to the point where mining new ore is not as necessary. The rate of loss to landfills and waste is essentially equal to the newly produced steel not derived from recycling. In fact, many developed nations underestimate the amount of steel being recycled, leading to overproduction that resulted in a massive contraction of the industry since 1990. Per capita, the United States has comparable steel stocks to other developed nations.

Despite this trend, the demand for steel is expected to rise to meet the growing energy needs, projected to exceed 5 trillion kWh by 2050.[25] Steel is crucial not only for traditional and renewable energy technologies on the generation side, but facilitating transmission infrastructure is also highly reliant upon steel. It is possible that a significant and premature policy shift will challenge the expectation of the saturation model[26] and force policymakers to confront critical tradeoffs while recognizing economic realities. To fulfill the vision of the future, many key factors must be aligned in the short term to unlock the potential for long-term growth.

While the increased demand for steel will likely be slow from year to year, and depend upon the magnitude of policy shifts, the steel industry requires long-term investments to be in position to achieve the larger milestones. It is unlikely to be nimble enough to slowly ramp up to a fundamental energy and infrastructure transition without strategic investments, partnerships, and innovation. Only by evaluating future political and industry goals over extended periods can we understand how steel demand and its integration into the built environment will manifest.

What Uses Steel: *Modern life requires steel.*

Steel made this report possible. It was used in the computer you're reading this on, as well as in the trucks, boats, and trains that transport the products and materials making up every part of our homes and workplaces. Steel was used in the power lines that carry electricity to every home and business in America. Steel is the backbone of our modern economy, and such a valuable resource deserves special consideration for the future. The USGS estimates that iron and steel comprise about 95 percent of all metal tonnage produced annually in the U.S. and globally.[27]

Transportation and infrastructure are the two primary consumers of steel worldwide, with energy projects also being significant users. Household appliances and smaller products also use large amounts of steel. More indirectly, it is impossible to go through modern life without encountering something that uses steel or requires steel to be made, transported, or sold.

Transportation:

The basic components of passenger and commercial vehicles utilizing steel include "car frames, door panels, support beams, exhaust pipes and mufflers."[28] While personal vehicles are the primary consumers of steel in transportation, substantial quantities are also used in shipbuilding, railroad cars, and airplanes.

In the automotive industry, steel plays a crucial role. According to the Bureau of Transportation Statistics, the average American "light-duty vehicle," which includes most passenger vehicles like sedans, SUVs, and non-commercial trucks, contains about 2,133 pounds of steel.[29] This adds to approximately 250 million metric tons of steel in the vehicles driven by Americans every day.

Rail transportation, which moves over 1.45 billion metric tons of freight in the U.S. every year, is completely dependent on steel.[30] Railways, railcars, and locomotives all depend upon huge amounts of steel. Railroad tracks in the U.S. contain over 13.6 million metric tons of steel, not including the numerous bridges, signs, and rail stations.

While steel is also used in commercial airplanes, most modern aircraft are primarily made of aluminum to reduce weight. Nonetheless, an estimated 2,868 metric tons of steel are present in the U.S. airliner fleet.

Vehicles are not the only products that require steel in the transportation sector. Intermodal containers, commonly found on cargo-ships, freight trains, and at dockyards are made entirely from steel. A TEU (twenty foot equivalent unit) intermodal container weighs approximately 4,410 pounds, and there are tens of millions scattered across the globe. Estimates to the total number of intermodal containers vary widely, but there may be more than 114 million metric tons of steel used in the containers that are crucial for global trade. The largest cargo ships, capable of carrying up to 24,000 TEUs, are constructed from massive steel plates and are about 70% steel by weight.[31] The U.S. merchant fleet, comprising 337 ships, contains around 5.9 million metric tons of steel.

Military:

Rough estimates on the amount of steel used in basic military hardware indicate that the U.S. Military is a significant consumer of steel.[32] Information is not widely available on how the U.S. Department of Defense sources all of its requisite steel, but most of it is believed to come from domestic suppliers.[33,34] A 2021 Trump Administration rule currently necessitates that 95 percent of construction materials made of iron or steel manufactured for the military must be domestically produced.[35]

In your Household:

Almost every part of your household contains steel, from the walls that surround you to the laptop on your desk. Homes in the U.S. often have wooden frames, but steel nails and screws hold it together. Doorknobs, pipes, and fastenings are all commonly made of steel, and some homes are even beginning to use lightweight steel frames as an alternative to wood. The electricity used to power all the devices, lighting, and air-conditioning rely on steel-framed transmission infrastructure to deliver the electricity to you.

Household appliances are some of the steel objects that we interact with the most. Nearly all households in America contain an oven, which is around 80 percent steel by weight, or around 145 pounds of steel. A refrigerator, dishwasher, washing machine, and dryer contains a combined 495 pounds of steel on average. Stovetop burners also utilize steel, not to mention the thousands of pounds in steel pipes used for any natural gas appliance. Many bed frames also utilize steel, meaning you may have started your day already relying on this versatile material.

Steel is not just present in the items you own; it is essential to almost everything you interact with. Factories, farms, and hand tools all depend on steel.

Construction:

Almost half of all steel used in the United States, approximately 46 percent, is allocated to construction and infrastructure, comprising the largest of any sector by far.[36] Construction uses for steel include building frames, reinforced concrete, bridges, pipelines, transmission towers, and more. Millions of tons of steel are used every year in new construction, and billions of tons are already in use, present in every building, roadway, and home. Construction is where the most steel stock is utilized, but accurately measuring it is nearly impossible.

Hand tools, power tools, work trucks, tractors, trailers, and excavators all use different quantities and types of steel. On job sites, much more steel can be found, from small uses like temporary fencing to major uses, including the foundation and support components that become major infrastructure projects. The cranes and other heavy equipment use steel and also help place steel into final structures.

As a construction and infrastructure example most people interact with on a daily basis, bridges and overpasses are reinforced structures that would not be possible without steel. There are 621,000 bridges in the United States according to the USDOT, with a total bridge area of 403,488,432 square meters.[37] A conservative estimate of 220 pounds of steel per square meter means that there is about 40 million metric tons of steel embedded in the nation's bridges.

Energy Projects:

Pipelines are a major steel application in infrastructure. It is estimated that around 368 million metric tons of steel are used in natural gas and hazardous liquid pipelines, which is equivalent to more than four years of modern U.S. steel production.[38] Steel is also a necessary component of many low-carbon initiatives, and is used extensively in wind turbines, solar panels, and transmission infrastructure. Steel used in renewable energy projects will continue to increase over the coming decades.[39]

Solar panels can use up to 45.4 metric tons of steel per MW, not including the increased amount of transmission infrastructure needed. Wind turbines use even more steel, requiring over 100 metric tons of steel per MW. The installed wind and solar capacity for 2023 was 251,536.79 MW, using around 21.6 million metric tons of steel.[40]

Estimates put the current steel stock for coal, natural gas, and nuclear power plants at roughly 7.5 million metric tons, 680,000 metric tons, and 3.8 million metric tons, respectively. At first it appears that natural gas uses very little steel despite contributing about 60 percent of the electricity in the U.S., but this calculation did not include natural gas pipelines.

These figures provide a snapshot of steel's role in the modern world and highlight potential stress points for the future. Market developments and public policy that nudges or require certain projects - like transportation or energy infrastructure - will require steel. Policy choices favoring specific types of energy will likely drive further steel requirements. The time horizons for those projects will also intersect with permitting and environmental studies, market factors and supply chains, and more. It is incumbent on policymakers and industry leaders to acquaint themselves with a wide enough view of industry realities and policy preferences - and how they intersect and implicate other issues or create unintended consequences.

What is the Future Demand

Next year

The year 2025 is already accounted for on corporate balance sheets, federal appropriations, and much more. The demand is a basic continuation of current market conditions, but sudden changes could still influence overall demand. Drawing from industry reports, the demand for steel next year is expected to remain consistent with the current year or increase marginally.[41, 42]

To accomplish this, current suppliers are already making or recycling steel. Orders have been placed, and new demand will be met with short-term contracts. This context informs policy discussions and debate over mergers, domestic industry, tariffs, and more. With demand potentially increasing in the first year of this analysis, it is vital that the industry be supported and infused with capital, technology, and the strategy needed to meet demand when major public policies begin taking effect that dial up demand considerably.

Five Years

This time horizon is already in play but has the opportunity to change. Currently, the stalled U.S. Steel - Nippon Steel merger is the biggest topic in the domestic steel market. We discuss the acquisition in more detail later in the report, but the blocking of this deal could significantly impact the domestic steel industry and the economy at large. U.S. Steel will likely try and find a new owner.

Predicting the future demand or production of steel is challenging due to the number of factors at play. Trade is critical for the industry, and sudden changes in supply chains can have massive changes in demand and production. For example, a 2015 report from PwC, one of the largest accounting firms in the world, faltered on 2025 steel demand predictions.[43] The report correctly identified China as having demand roughly equal to the rest of the world put together, but massively overestimated overall demand. The report estimates NAFTA countries as having a 215 million metric ton steel demand in 2025, but in 2024 it was actually around 135 million metric tons.

More recent reports forecasting into 2030 and beyond believe that steel demand will increase gradually.[44,45] However, every prediction should be approached with caution, as unexpected developments, like the 2020 pandemic, can arise without warning. Recession, extreme weather events, wars, and other disruptions can upend any careful forecasting.
The five-year timeline is where the automotive industry is likely to be relevant, as well as general construction, appliances, and energy. Organic market changes may demand more steel or demand more innovative applications of steel. It is also possible that policy changes will directly impact market forces on a five-year timeline - either by directly requiring certain things or by implication, which leads market players to prepare for a policy even if it is not in place yet.

Mergers may be critical for this timeline, but deals struck today will certainly make an impact moving forward. Delays or interruptions to planned bolstering of the steel industry may critically undermine the ability to enact larger-scale and longer-term goals. Projections accuracy may vary, but current policy and needs are trending towards a gradual increase in production.

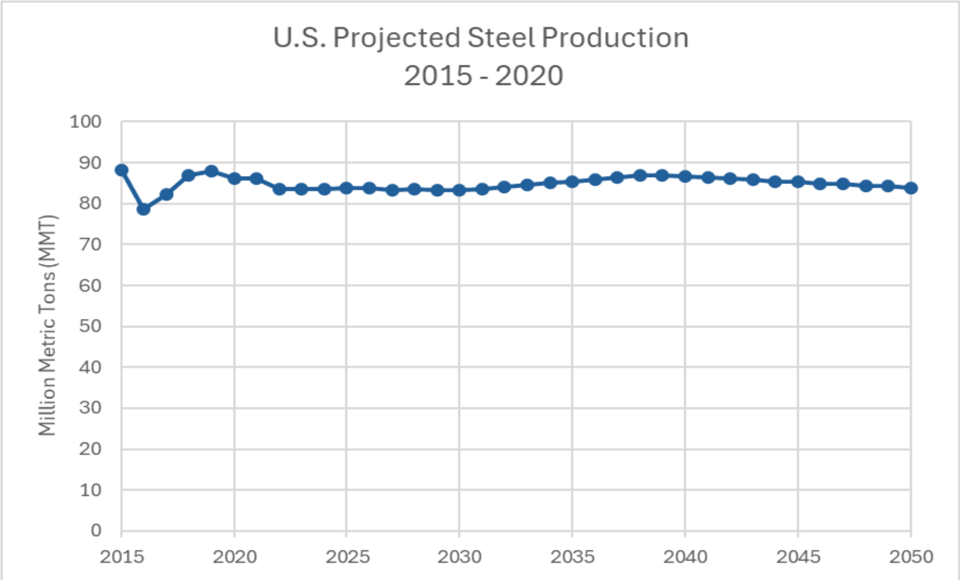
25 Years

The steel outlook for 25 years or more will depend upon the state of clean-energy initiatives being considered and promoted by policymakers as well as voluntary industry leadership and consumer-led market demand. Various plans, such as "Net Zero by 2050," "Net Zero America," and the "Green New Deal," outline ambitious goals for reducing carbon emissions. These plans may vary by feasibility and timescale, but they all require massive changes to infrastructure and are being pushed forward in policy, academia, and industry regardless of the readiness of industry resources or economic realities. These conceptual plans may appear well-defined, but are all on the 25 year timeline, necessitating flexibility.

Steel, by far the most commonly used metal, is critical for infrastructure and the economy at large. Every so-called *green plan* runs through steel and will require a healthy and thriving domestic industry to be achieved.

The Princeton Net Zero America report is an informative study that demonstrates what it would take to achieve net zero emissions by 2050 in five different scenarios, as well as a control timeline with no new policies. Each scenario requires huge infrastructure spending and policy changes, with annualized costs of over a trillion dollars. Even the control group includes significant economic spending.

Regarding steel, the Princeton Net Zero America project relies upon Energy Information Administration (EIA) projections of steel production through 2050, and concludes that even in a net-zero scenario, overall steel production will not increase.[46] However, they conclude that the way steel is made will have to change to meet the goal of net zero by 2050, with Basic Oxygen Furnaces (BOF) being replaced by Electric Arc Furnaces (EAF), which are mainly used for steel recycling today. The report proposes phasing out BOF furnaces as they reach the end of their operational life but does not alter the overall production levels of steel.



Aii Figure 4: US Projected Steel production (source: EIA)

This graph above shows the projected steel production in the EIA reference case from their 2019 Annual Energy Outlook report. It may seem counterintuitive for a report about changing our entire energy infrastructure to suggest that our steel production will not require an increase, but that is because of our saturated steel stock. Additionally, different models predict different production levels.

The Net Zero Industry project puts together three scenarios that all show annual steel demand in the United States increasing to between roughly 100 and 120 metric tons by 2050.[47] Similar to other reports, it advocates for a decrease in BOF steelmaking, at least without carbon capture and storage (CCS) technologies.

For steel production, hydrogen is often cited by advocates as being a better, cleaner alternative for gas-powered furnaces. However, a report by Aii on process heating explains how any changes to heating infrastructure will have serious challenges to overcome.[48] Hydrogen in industry and energy is a yet unproven technology, and will require vast amounts of clean energy to be carbon-neutral, if using a centralized electrolysis process.[49] Should policies incentivize *green hydrogen* as a primary energy source, this would necessitate increased steel production due to the need for more clean energy and battery capacity, as well as new transmission infrastructure, production facilities, storage tanks, pipelines, and specialized tank cars for transportation.

The varied "net zero" reports represent a somewhat fractured landscape in which to analyze the future of steel. Despite uncertainties in exact steel requirements, it is clear that steel will be absolutely indispensable to our economy moving forward. Even without any kind of "Net Zero" plan, the need for more transmission infrastructure to supply our ever growing desire for more electricity will require vast amounts of steel.[50] Furthermore, policy changes for energy infrastructure will not decrease the demand for steel in regular applications such as building construction, automaking, machinery, and appliances.

The "Net Zero" reports may not specifically warrant a dramatic rise in overall steel production, but there is no question that the policy changes sought would still demand large amounts of steel to complete. Some basic calculations can give insight to the amount of steel that may be needed for the ambitious goals in these reports.

The Princeton Net Zero America study estimates that wind capacity could range from 410 GW to 3,250 GW and solar capacity from 160 GW to 2,770 GW by 2050.[51] Wind turbines require approximately 115 metric tons of steel per MW, and solar requires about 41.7 tons per MW. Using this we can calculate rough estimates for the minimum and maximum amount of steel needed exclusively for renewable energy sources by 2050, excluding transmission infrastructure and energy storage.

Energy Source	Metric Tons per MW	Total MW Installed (Projections)	Total Steel Required (Million Metric Tons)
Lower Scenario			
Wind	115	410,000	47.2
Solar	47.13	160,000	6.7
Total			53.8
Higher Scenario			
Wind	115	3,250,000	373.8
Solar	47.13	2,770,000	115.6
Total			489.3

Aii Figure 5: Approximate Steel Use per MW.[52]

On the lower end, the amount of steel required is still significant, as 54 million metric tons is more than half of current annual domestic production. Even though this demand might be spread over 25 years, delays in environmental and regulatory permitting means most projects do not begin for multiple years, forming a demand bubble potentially a decade from now where enormous quantities of steel may all be demanded at one time to fulfill dozens (to thousands[53]) of energy projects that had been waiting in the queue all the while. Renewable energy sources have a typical lifespan of 25 to 30 years, meaning that the vast majority of currently installed renewables will not last until 2050, necessitating further steel production.

The highest estimate, drawn from the most ambitious scenario, would necessitate a serious increase in production. At current production rates, it would take a little more than six years to produce 489.3 million metric tons of steel, meaning that over a quarter of all steel for the next 25 years would need to be used for renewable energy alone. These basic calculations do not account for transmission infrastructure, end-of-life renewable components, or offshore wind installations, all of which would require additional steel.

The extreme estimates underscore the critical role steel will play in the future, even if they are based on less realistic electrification scenarios.

Transmission infrastructure will be just as crucial for an energy transition as the generators themselves. Wind and solar projects often incur higher transmission costs compared to traditional fossil fuel generators, as they are more likely to be located in rural areas.[54] A 60 percent expansion of the current transmission grid will be required by 2030, and it may need to triple by 2050.[55] In fact, transmission infrastructure may become the bottleneck for energy infrastructure, with huge queue times for project approval increasing in recent years.[56]

The interconnection queue for new energy projects increased to an average of 3.7 years between 2011 and 2021, contributing to the historically low amount of new high-voltage transmission installed. Renewable energy projects that are thoroughly planned and permitted today will likely not be ready for construction for several years. Significant reform is needed to improve and streamline this process.

Transmission towers are particularly steel-intensive. The cables are made of specific composite alloys that contain steel, and larger structures are made entirely of steel. Tower size varies significantly by the terrain and voltage, which can range between 69kV and 765 kV. Accurate measures of steel composition range from 2.7 metric tons for the smaller towers up to 70 metric tons for larger high-voltage and long-distance transmission towers.[57] Based on U.S. Department of Energy (DOE) estimates, the need for new transmission towers will increase considerably. At a minimum, the large transmission towers will be needed for wind and solar projects, which are often located remotely.

The need for brand new transmission towers can be limited by reconductoring current towers, but the DOE estimates that for a clean grid, 54,500 GW-miles of new transmission line is needed.[58] GW-miles is a metric created by the DOE for the report and does not have a direct equivalent to miles or voltage. However, The Princeton Study predicts that the added high-voltage transmission by 2050 will be between 151,736 and 1,308,971 GW-km, depending on the scenario.[59] Approximately 13 to 25 million metric tons of steel would be needed for transmission towers, depending on the Princeton Net-Zero scenario and the type of transmission towers deployed.[60] This estimation is extremely rough, and does not account for difficult terrain or other transmission infrastructure other than towers. Additionally, a range of values exists, with shorter and higher-voltage transmission towers providing more GW-miles than longer, lower voltage towers.

Aii expects that the demand for steel will increase steadily in the coming years. The deployment of renewable energy sources and electrification initiatives will not only necessitate an increase in production, but also a need for more innovative applications of steel. Rapid advancements in technology will require the steel industry to adapt and innovate swiftly. Continued research and development will be crucial for sustaining a robust and competitive domestic steel sector.

Aligning Market Realities and Policy Visions

Are policymakers considering all the factors? The sheer quantity and significance of steel in the economy already is difficult to conceptualize. Even as policymakers use planes, trains, and automobiles to get to the capital regularly and pass by billboards, dumpsters, and street signs on their way, they may overlook the steel all around them. If that’s the case, it is additionally likely they are not adequately equipped to consider the increase in demand for steel inherent to the strategies they may wish to pursue, subsidize, pilot, or reform.

Shifting the country toward renewables, electrification, and other low-carbon paths requires steel-intensive investments. That naturally means policymakers must be prepared to invest in steel itself and strengthen the domestic steel industry. The easiest way to do that is allow the market to function and voluntary transactions to take their course without government interference. This way no deadweight loss is created by government interference, and it costs appropriators nothing – sparing the resources they need to pour into their preferred energy and infrastructure projects. Moreover, by allowing a merger to advance, policymakers can make their greatest impact in setting the stage for an industry capable of delivering on their priorities and promises.

In August of 2023, United States Steel Corporation announced it was accepting acquisition proposals.[61] Once the most valuable company in the world, U.S. Steel is now just the third biggest steel producer in the United States. In December 2023, U.S. Steel announced that Japanese-owned Nippon Steel Corporation had put forward the most attractive bid, and would purchase U.S. Steel for $14.9 billion.[62] Under the deal, U.S. Steel would keep its name and headquarters, but have access to Nippon Steel's extensive technology and resources. The sale to a foreign competitor immediately sparked conflicting opinions in the media and political world. With tensions heightened in an election year, the intense opposition from union workers and politicians ultimately brought President Biden to the point of blocking the merger in September.

In 1916, U.S. Steel became the first ever company to be valued at over $1 billion, but the company is no longer the economic powerhouse it once was.[63] U.S. Steel has struggled to remain profitable in recent years, recording losses as often as profits.[64] Large steel mills have been idled or downsized to avoid further losses. Today, U.S. Steel accounts for about 10 percent of domestic production and ranks as the 24th largest producer in the world.[65, 66]

After announcing its intention to seek a sale, U.S. Steel was first approached by domestic competitor Cleveland Cliffs.[67,68] U.S. Steel rejected a $7.3 billion offer, despite being supported by the United Steelworkers union.[69] If Cleveland Cliffs succeeded, they would control virtually all of the domestic raw-iron production. Eventually that bid was overshadowed by Nippon Steel's offer of $14.9 billion.[70]

Nippon Steel was a more attractive buyer to U.S. Steel for reasons beyond just shareholder value. The Japanese company is the fourth largest steel producer in the world, and its size would be an asset in a volatile market.[71] Nippon's strength and capital makes it easier to increase or decrease production based on market conditions. American steel companies have been idling steel plants for years due to decreased demand. Currently, U.S. Steel spends about $40 million annually on R&D, compared to more than $400 million by Nippon Steel.[72,73] Innovation and new technology is absolutely critical for the health of older industries. This is especially true as sustainability and decarbonization goals that all require steel also require that the steel be adaptable to new uses and innovative applications.

The U.S. domestic steel industry has recently struggled to compete against lower cost foreign labor, and has been slow to modernize.[74] Partnering with a successful international competitor could be good for an industry that has been on the decline in America. Nippon Steel also recently announced its plans to invest an additional $1.3 billion into two U.S. Steel mills, on top of the $1.4 billion already planned through 2026.[75] The considerable R&D resources of Nippon Steel could be leveraged to help American steelworkers, while meeting market demand and policymaker priorities in the future.

Despite the numerous advantages U.S. Steel and its shareholders saw in the sale, political pressure have halted the merger. Politicians from both parties across the rust belt have criticized the deal from the outset, and ultimately want to stop it for good. Despite promises by Nippon to honor all current contracts, the United Steelworkers union has expressed concern that the acquisition could lead to layoffs if there was a "significant downturn in business conditions."[76] Lingering frustrations over Nippon Steel previously outcompeting American steelmakers may also have fueled opposition.

Unions have wielded tremendous political power in recent election years, especially as U.S. Steel is headquartered in Pennsylvania, a crucial swing-state. Former president Trump had already vowed to block the deal if elected again, and his running mate JD Vance argued that the sale would threaten national security.[77] President Biden as well as current Vice President and 2024 Democratic Nominee Kamala Harris also came out against the merger, seeking to ally themselves with the United Steelworkers union.[78]

With the Biden-Harris Administration's formal announcement to block the deal pending, the future of U.S. Steel remains uncertain. However, the assertion that the sale represents a national security threat is not likely to go over well with Japan.[79] Nippon Steel hails from a close ally of the United States, not an unpredictable foreign government. Moreover, Japan is a fierce rival of China, the biggest economic security threat to the United States. The acquisition could revitalize a company that has recorded net losses for nine of the past 15 years.[80] Given U.S. Steel's recent production cuts and plant closures, Nippon Steel's promise to not lay off workers or close any facilities could be a relief to the approximately 22,000 employees.

In the days leading up to the Biden-Harris Administration's formal interjection on the deal, U.S. Steel CEO David Burritt attempted to rally support for the deal, warning that the company could close its historic Mon Valley mill and leave Pennsylvania altogether. "If that mill [Mon Valley] won't make it to the next decade, why would we stay [in Pennsylvania]," Burritt said.[81,82] The announcement was heavily criticized by some politicians, but the company may have to sell off assets to stay afloat.[83,84] Whatever the case, Cleveland Cliffs or other American companies are unlikely to match the huge investments promised by Nippon, potentially necessitating mill closures.

An uncertain future for the United States Steel Corporation is dangerous and could jeopardize the critically important steel supply for the United States. If U.S. Steel reduced or stopped production, it may necessitate increased imports of foreign steel or else put strain on the construction and automotive industries. Considering the amount of steel we use on a daily basis, an unexpected drop of even a few percent in overall production could have serious economic consequences, possibly limiting new development. As policymakers specifically push the economy toward ever higher steel-dependent energy and sustainability strategies, further tension may be created between market activity and public policy. U.S. Steel sought a buyer for a reason. Preventing the Nippon Steel acquisition may pose more risk than letting the free-market process play out.

Conclusion

Steel will be as critical as ever for the future, whether further major policy changes are made or not. As a foundation pillar of our society, steel is essential. It holds up our buildings, gets us to work on time, helps generate our power, and is integral in our high quality of life.

The push for decarbonization will necessarily increase demand and consumption of steel, requiring careful consideration when making changes to policy. Steel will also be crucial for new transmission infrastructure, which may become the limiting factor for any national decarbonization plan without proper reform. Not only will the demand for steel continue to evolve, but so will the new and innovative applications of steel. In the modern age, steel production is a high-tech industry and must work hand-in-hand with manufacturers and developers for the specifications needed for the dynamic projects of the future. Fresh changes may be required to breathe new life into a domestic sector that has often been slow to adapt.

This report is intended to emphasize the strategic importance of steel for the nation and for the future. As the foundation of the modern economy, steel requires careful management and consideration. Policymakers must understand its importance to any major electrification build outs or decarbonization projects, and its direct relation to industries that employ millions of Americans. If demand for steel increases, it could have major impacts on the wider economy such as increasing construction costs and harming automakers. Even well-intentioned protectionist measures can cause headaches for consumers and other industries.

Industry leaders and policymakers will continue to argue the merits and timelines for decarbonization strategies and economic policy, but they must never lose sight of the monumental importance of steel. Market activity that bolsters the steel market is essential for national objectives. Policy decisions that frustrate the ability to strengthen the steel sector while simultaneously striving for a steel-supported future must be reevaluated.

Appendix A:

Steel Intensity of Transmission Infrastructure

Transmission Tower type	**Weight in Steel (Metric Tons)**
Single Circuit 500 Kv transmission pole*	15.92
Single Circuit 500 Kv transmission tower*	12.25
Double Circuit 345 kV transmission tower*	16.33
HDVC 500 kV transmission pole*	9.95
HDVC 500 kV transmission tower*	7.65
Average	**12.42**

*tangent structures only

Transmission line additions by 2050				
Princeton Study Scenario	**Reference**	**E+**	**E+RE-**	**E+RE+**
Added HV transmission vs. 2020 (for wind and solar) - Base all (GW-km)	151,736	672,869	306,145	1,308,971
Added HV transmission vs. 2020 (for wind and solar) - Base all (TW-km)	151.7	672.9	306.1	1309.0
Added HV transmission vs. 2020 (for wind and solar) - Base all (TW-mile)	94.3	418.1	190.2	813.4
Approximate Distances for Different Line Types				
Approximate Distance with new HVDC 500 kV HV Transmission (miles)	31,114	137,973	62,776	268,408
Approximate Distance with new double-circuit 345 kV HV Transmission, OR Single circuit 500 kV (miles)	63,171	280,128	127,454	544,949

Theoretical Steel Use for different Transmission Line Types				
Steel required for HVDC 500 kV transmission tower lines* (metric tons)	1,190,784	5,280,499	2,402,545	10,272,460
Steel required for HVDC 500 kV transmission pole lines* (metric tons)	1,548,055	6,864,805	3,123,380	13,354,503
Steel required for Double Circuit 345 kV transmission tower lines* (metric tons)	5,157,659	22,871,494	10,406,177	44,493,241
Steel Required for Single circuit 500 kV transmission tower lines* (metric tons)	3,868,245	17,153,621	7,804,633	33,369,932
Steel Required for Single circuit 500 kV transmission pole lines* (metric tons)	5,028,718	22,299,707	10,146,022	43,380,911
Average of different transmission lines	**3,358,692**	**14,894,025**	**6,776,551**	**28,974,209**

*tangent structures only

Assumes 5 towers per mile.

Transmission line additions by 2050				
Princeton Study Scenario	**Reference**	**E+**	**E+RE-**	**E+RE+**
Added HV transmission vs. 2020 (for wind and solar) - Base all (GW-km)	151,736	672,869	306,145	1,308,971
Added HV transmission vs. 2020 (for wind and solar) - Base all (TW-km)	151.7	672.9	306.1	1309.0
Added HV transmission vs. 2020 (for wind and solar) - Base all (TW-mile)	94.3	418.1	190.2	813.4
Total Towers	235,711	1,045,253	475,574	2,033,392
Approximate Steel Use in transmission towers/poles (metric tons)	**2,927,656**	**12,982,608**	**5,906,886**	**25,255,818**

Assumes 5 towers per mile.

Assumes 500 miles of HV transmission per TW-mile

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The Alliance for Innovation and Infrastructure (Aii) is an independent, national research and educational organization that explores the intersection of economics, law, and public policy in the areas of climate, damage prevention, energy, infrastructure, innovation, technology, and transportation.

Aii is a think tank consisting of two non-profits: the National Infrastructure Safety Foundation (NISF), a 501(c)(4) social welfare organization, and the Public Institute for Facility Safety (PIFS), a 501(c)(3) educational organization. Both non-profits are legally governed by volunteer boards of directors. These work in conjunction with the Alliance's own volunteer Advisory Council.

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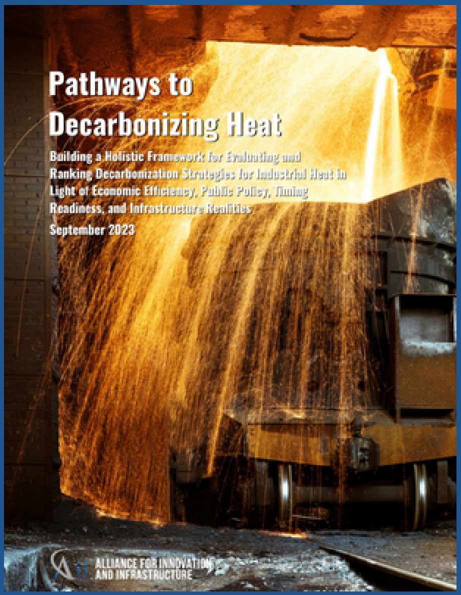

ALLIANCE FOR INNOVATION AND INFRASTRUCTURE

America's Top Infrastructure Challenges

A look at the costs and impacts of the most pressing infrastructure issues facing society

For years, American infrastructure has required substantial maintenance and investment. The problems run deeper than repairing potholes or storm walls. In some cases, systemic flaws in funding have led to chronic underspending on maintenance. For some, regulatory barriers hinder market forces from resolving an issue. Elsewhere, new regulation may be needed to remedy vulnerabilities impacting large populations and communities.

This policy brief surveys five of the top infrastructure challenges facing America today. While unranked, these five issues all stand out as urgent challenges draining the U.S. economy, harming communities, and degrading critical infrastructure. To help understand the scale and scope of these issues, we stack up their estimated costs, present the number of people impacted, and discuss the implications for other systems.

How does Aii define infrastructure?

Infrastructure: the physical systems and structures that facilitate transportation, transmission, distribution, and storage for people, resources, energy, information, and goods.

While often referred to rhetorically as infrastructure, many systems are not truly infrastructure. These may include software, healthcare, or climate policy, which are not physical systems not primarily intended for transportation, transmission, or storage. They often rely on infrastructure, such as roads, bridges, telecommunications cables, electrical distribution, and more to carry out their objectives. Other examples, like *digital infrastructure* – when not referring to the hard components that make Internet or computer networks function – help paint a picture of the way software can organize, analyze, store, or distribute information, yet serves as an analogy, not an example, of infrastructure.

Rhetorical and metaphorical uses of infrastructure actual serve to emphasize how critical real infrastructure is. Many plans and policies group additional topics into a broad infrastructure tent to highlight the criticality of infrastructure to other systems. This importance is why proper attention must be paid to these challenges today. Regardless of who builds and pays for it, the underlying physical systems and structures – *infrastructure* – is what makes most modern service and movement possible.

The five top U.S. infrastructure challenges:

- Road and Bridge Infrastructure
- Damage Prevention
- Infrastructure Resilience
- Electrical Grid Modernization
- Cybersecurity

We assess these by presenting estimated economic and human impacts, systemic barriers to improvement, and potential innovative solutions.

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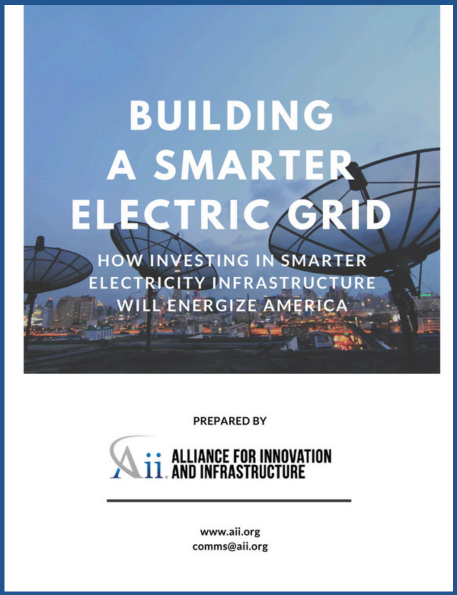

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