# Greener Connections

## Understanding the Environmental Impacts of Fiber and Copper Communications Networks

RAMBOLL

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Our company mission is to create sustainable societies where people and nature flourish.

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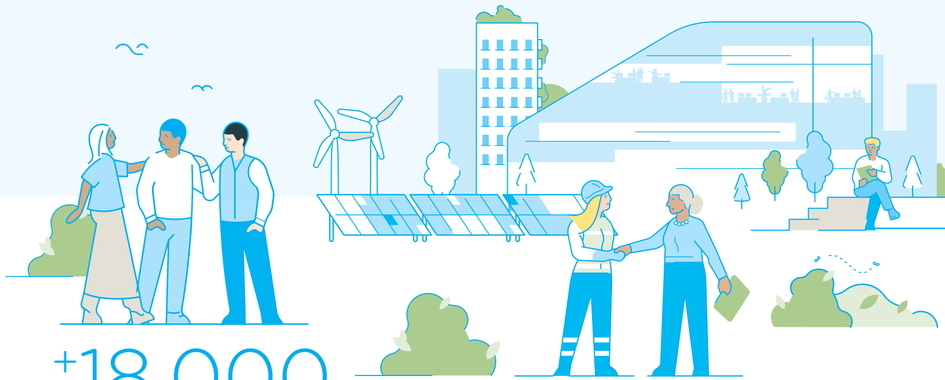


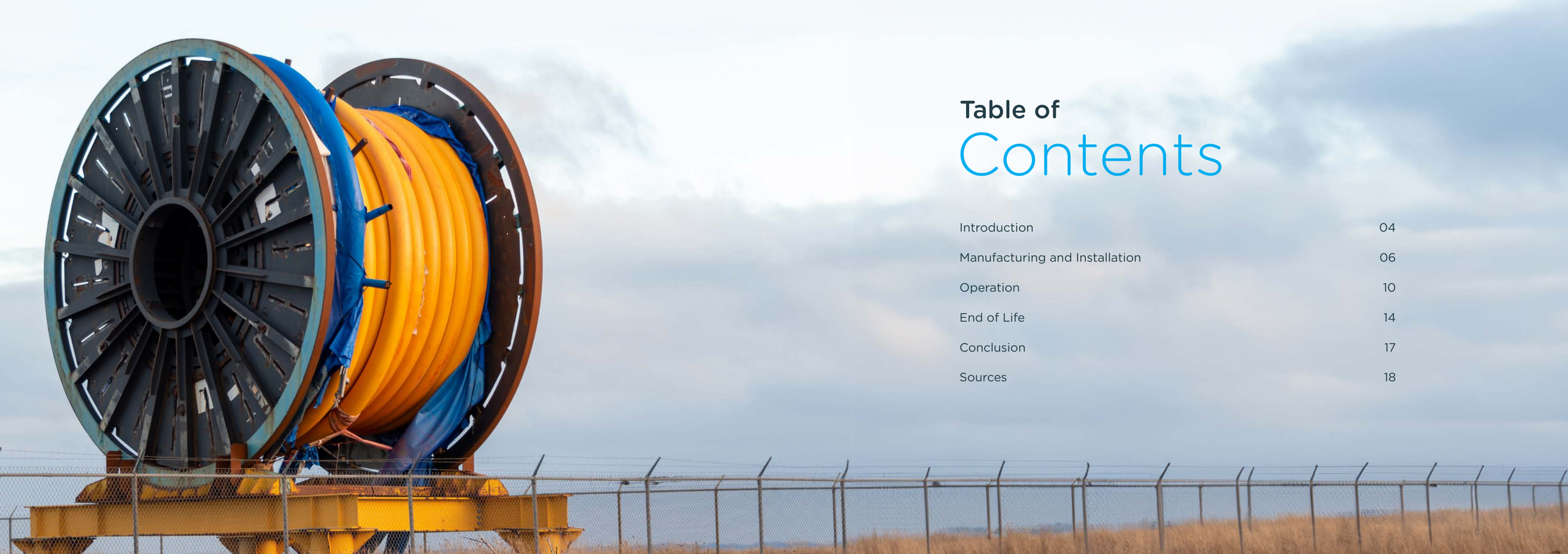
## +18,000

We are a diverse organization with more than 18,000 bright minds who deliver standalone and multidisciplinary solutions to clients and partners.

## 2040

We are a responsible company, committed to reaching net-zero GHG emissions across scopes 1, 2 and 3 by 2040, in alignment with the SBTi Corporate Net-Zero Standard.

**Note:**
This study was commissioned by USTelecom – The Broadband Association, the nation's leading trade association representing service providers and suppliers for the telecom industry. USTelecom members provide a full array of services, including broadband, voice, data, and video over wireline and wireless networks. Its diverse member base ranges from large publicly traded communications corporations to local and regional companies and cooperatives, serving consumers and business around the world.



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# Introduction

Today, being connected is essential. Having access to high-speed internet and communication channels allows businesses to run efficiently, supports innovation and growth, promotes inclusion, increases education, and much more.

When telephone networks were first deployed over 100 years ago, the best technology available was copper. Today, fiber optic lines have significantly increased connectivity speeds. The global fiber optic market is currently a $15-billion industry and is projected to double in size by 2030.[1] These advances in fiber-based technologies have unleashed a torrent of network upgrades throughout the US. However, federal and state requirements put in place many decades ago for copper networks stand in the way of even more fiber deployment.

This means telecommunication providers are simultaneously building out new fiber optic and other infrastructure to meet growing demand while still maintaining antiquated copper infrastructure.[2] Requiring providers continue to maintain copper infrastructure not only prevents the country from realizing the benefits from transitioning to modern networks but also undermines the objectives of the U.S. government to facilitate robust, high speed digital internet connectivity.[3] Compared to copper lines, fiber optic lines have higher bandwidths, faster speeds, better security and higher resilience and durability.[4] Deployment of faster fiber optic infrastructure has also been linked to higher employment rates and increased usage of digital social services.[5]

Many studies have explored the economic and other societal impacts of the transition to high-speed, fiber-based broadband networks. This report aims to better understand an important additional dimension to this transition – the environmental impacts of the copper to fiber transition.

Information and communication technology (ICT) already produces over 2% of global carbon emissions[6] and, given the size of these networks, any decision made around retiring or continuing to maintain the existing copper infrastructure is likely to have environmental implications. This paper specifically focuses on the environmental impacts, including carbon emissions emitted and effects to environment and biodiversity, of maintaining copper-based infrastructure versus installing new fiber optic infrastructure*.

In this study, we found that installing new fiber optic infrastructure shows clear environmental benefits in the long term versus maintaining copper infrastructure. Once in operation, fiber optic lines use less energy, take up less space, require less maintenance and will need to be replaced less frequently than their copper counterparts.

Aspects of this subject have already been studied by various manufacturers, providers, and researchers, including lifecycle assessments (LCAs) of both fiber optic and copper lines. In addition to reviewing publicly available research, we reviewed documented case studies on switching from copper to fiber optic infrastructure and spoke with industry experts in the telecommunications space to understand the impacts they are seeing with fiber optic and copper infrastructure. We have synthesized insights across these sources in this study to outline the benefits and drawbacks of each type of infrastructure.

* Although other advanced digital technologies, such as wireless or satellite, are part of modern communication networks, this paper does not consider the environmental impacts of these options. This paper is also not a full lifecycle assessment (LCA) or an engineering analysis of these infrastructure options. In addition, this paper does not address the environmental impacts of any specific project, as they will vary significantly project-to-project.

# Manufacturing and Installation

Installing new fiber optic infrastructure and maintaining existing copper infrastructure, including repair and replacement, require obtaining materials, manufacturing lines, and installing them. All of these activities can have environmental impacts, including generating greenhouse gas (GHG) emissions and environmental consequences from mining and installation activities. When considering the scenario of maintaining copper-based infrastructure versus installing new fiber optic infrastructure, we found that, the absolute impact in the manufacturing and installation stage in the short term will likely be higher for fiber due to the amount of installation needed to build out new infrastructure. However, in the long term, once the infrastructure is installed, fiber optics lines will have a lower manufacturing and installing impact per unit compared to copper lines.

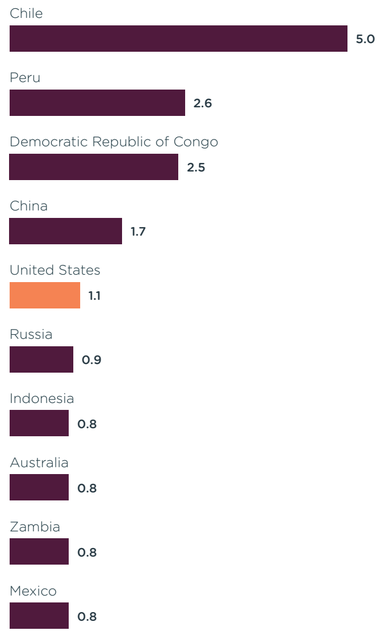
**Mining and processing copper has significant environmental impacts**

For copper lines, the biggest impact in materials comes from copper, which requires significant energy to mine and process. Raw material acquisition can account for over 60% of copper's total lifecycle energy demand, depending on the ore grade and the type of copper line.[12,13] Copper mining has also been linked to other significant environmental impacts, such as deforestation[14] and water pollution.[15]

In addition, the US produces only 5% of the world's copper supply[18], so copper is often imported from other countries. Importing materials has a higher environmental impact, due to emissions generated from transportation, and some of the countries where copper is imported from have questionable track records when it comes to key environmental issues.[16,17] Over half of the world's copper comes from South America (Chile and Peru), Africa (Democratic Republic of Congo), and Asia (China) and as the demand for this metal rises, driven by EV and power infrastructure growth, U.S. providers may need to further rely on foreign sources to supply even more copper. In addition, industry experts have noted that copper lines in the US are getting harder to source, as many manufacturers are no longer making them. This scarcity may also force providers to look overseas for copper lines.

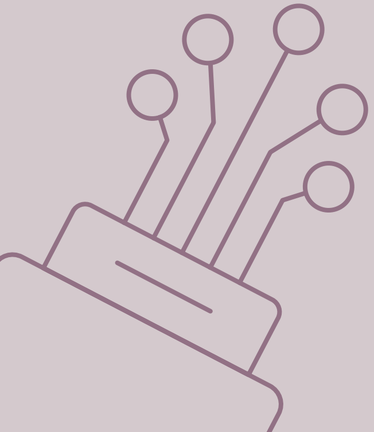
Although copper is often recycled and does not always require virgin materials (see later section on "End of Life"), secondary copper isn't sufficient to meet demand. The World Bank Group determined that "even a 100 percent end-of-life recycling rate would only reduce the demand for copper from primary sources by 26 percent by 2050."[19] Given this, it's clear that maintaining existing copper infrastructure would likely require some amount of primary copper in the future for the repair and replacement of lines.

**2023 Copper production**
(million metric tons)



# 50%

of raw material environmental impact for fiber optic comes from silica



### Mining and processing silica has less environmental impact than mining copper

According to Corning's lifecycle assessment of its fiber optic lines, silica accounts for 50% of the raw material impact.[7] For the most part, silica is sourced from quartz, which more reliably produces the high-purity silica required for these lines, but in some cases, silica can also come from sand. Depending on the raw material used, fiber optic lines can have different environmental impacts:

- Quartz requires open pit mining, which typically has less impact than copper mining but can still disturb ecosystems, and 90% of the quartz used in the US is imported from China,[20] which has a poor track record on certain environmental issues.[21]
- Sand acquisition has fewer environmental impacts and can be sourced more locally, since the US is a leading producer of sand and gravel, thanks to its use in hydraulic fracturing.[20]

For either source of silica, these mining activities have less environmental impact than copper mining.

### Fiber optic lines require less material than copper lines per unit length

It's also critical to consider the amount of material required, not just the type of material. Manufacturing new fiber optic lines will initially require more materials than maintaining existing copper infrastructure (which only needs new materials when copper lines require repair or replacement). However, it should be noted that fiber optic lines are also smaller (thinner than a human hair) and lighter (up to 40x lighter than copper, according to industry experts), since they use ultra-thin glass fiber optic lines to transmit data instead of bulkier copper ones. As a result, fiber optic lines use less overall material than copper lines per unit length.

### Fiber optic lines have a smaller carbon footprint overall than copper lines (on a per unit basis)

Upfront emissions related to fiber optic and copper lines include all emissions before the operation of the lines, including the acquisition of raw materials (such as mining), the manufacturing of these materials into finished products, and the installation of the infrastructure. Most upfront emissions from copper lines come from copper acquisition; the manufacturing stages of copper lines only account for about 20% of upfront emissions.[19] In contrast, the manufacturing of fiber optic lines (an electricity intensive process) accounts for 70-80% of the total upfront GHG emissions of fiber optic lines.[7]

Although sources of emissions differ between the two materials, when both raw materials and manufacturing are considered, fiber optic lines still have a much lower carbon footprint than copper lines. Corning estimated that the total carbon footprint of one pair of copper lines was 6x higher than one optical fiber.[7] The smaller carbon footprint of fiber optic lines is even more significant when considering fiber optic lines are capable of transmitting up to 2,000x more data / second.[7] In addition, as manufacturers move toward renewable electricity (e.g. Corning has committed to increasing the use of renewable energy by 400% by 2030[22]), the carbon footprint of manufacturing fiber optic lines will continue to decrease.

### Installing fiber optic infrastructure can be done more quickly than installing replacement copper, reducing environmental impacts during installation

Fiber optic lines can be installed above ground ("aerial" installations) or underground. Aerial installations are typically done when there is existing infrastructure (e.g. poles) or when the terrain is not suitable for underground installations and do not disturb the soil. Furthermore, as fiber optic lines are getting lighter, they are becoming self-supporting, which means they do not require additional wire strands to be installed alongside the fiber optic lines. This translates to faster installation times, which means less energy usage and fewer emissions from the equipment used for installation.

Underground fiber optic installations, on the other hand, can be more disruptive to ecosystems and wildlife, as well as require energy to power equipment and transport installation crews, similar to aerial installations. However, because fiber optic lines are smaller and thinner, many fibers can be placed in the same duct, requiring less digging to provide more capability and bandwidth than copper lines can provide.

In addition, because of their size, fiber optic lines can take advantage of an underground installation technique called "microtrenching." Using this technique, trenches for lines can be 3-10x smaller and lines can be installed up to 10x faster[23], reducing the impact to the ecosystem and requiring fewer crews for installation, which translates to fewer emissions overall. In addition, many fiber optic installations today are being planned with other infrastructure projects, such as road repair or construction, or can be installed in existing ducts, which can further reduce incremental impacts from the installation of new fiber optic infrastructure.

Finally, deploying fiber optic lines can also simplify the installation of equipment for customers. Newer technologies like fiber optic lines can be easier to connect, allowing customers to self-install equipment. This reduces the volume of technician installations and their resulting fleet emissions. One provider noted that from 2021 to 2023, customer self-installations saved technicians 21.8 million miles in travel.

# Operation

Once new fiber optic lines are installed and begin operating, they have clear advantages over existing copper lines. Compared to the existing copper infrastructure, new fiber optic infrastructure:

1. Requires less energy to operate
2. Has smaller physical space requirements
3. Needs less maintenance

### Fiber optic lines use less energy than copper lines

The operation of fiber optic lines requires significantly less energy, both on a per length and per unit of data transferred basis, than copper lines. This reduction in energy comes from two key benefits fiber optic lines offer:

- Higher efficiencies in transmission of data
- Reduced energy demand and cooling loads in the network, thanks to the use of passive components (which do not consume power continuously, unlike copper lines, which are powered) and fewer connections overall in the network (i.e. fewer electronic components)

Although the exact improvement varies based on the specific type of fiber optic line and copper line being compared, studies have shown that fiber optic lines use less energy than their copper equivalents:

- A study conducted in New Zealand in 2021 found that fiber optic lines used at least 30-40% less energy than copper[10]
- A study conducted in Italy in 2022 showed that fiber optic lines can use over 54% less energy during operation compared to copper[9]
- A lifecycle assessment conducted in Spain in 2022 determined that fiber optic lines used 80% less energy than copper when considering energy usage per access point, and up to 95% less energy when considering energy usage per petabyte of data transmitted[8]

US providers that have retired parts of their copper infrastructure and begun to use fiber optic lines have seen dramatic reductions in energy usage and significant savings in energy costs:

- In Verizon's 2023 sustainability report, the company notes that its "fiber-delivered broadband services are at least 100 times more efficient on a kilowatt hour (kWh) per gigabyte basis than copper-delivered broadband services."[24]
- Frontier was able to reduce electricity usage by almost 31 million kWh in 2023 alone by switching from copper to fiber[25], equivalent to the annual electricity usage of almost 3,000 households.[26]
- AT&T estimates that neighborhoods that have switched from copper to fiber optic lines have reduced energy consumption by 70%.[27]

As fiber optic technology continues to improve, this efficiency advantage, and subsequent energy cost savings, are likely to grow.

### Fiber optic infrastructure requires less real estate than copper infrastructure

In addition to reducing energy usage, using fiber optic lines can also reduce the amount of infrastructure and real estate a company requires. Fiber optic lines allow for fewer physical connection points, thanks to their ability to transmit signals over greater distances without degradation and because of the reduced cooling and power needs in their lines.

These space reductions can be significant. When Verizon switched over their infrastructure in one location in New York, the company was able to reduce its physical presence from 13 floors to just two with fiber.[28] On a larger scale, the UK estimates that its current copper infrastructure requires over 6,000 connection points. Retiring this infrastructure and switching to fiber optic would reduce the number of connections by 70%.[29]

Reducing the physical space fiber optic networks occupy frees up these spaces for other uses, which can in turn reduce the demand for new buildings, reducing emissions from these activities. Furthermore, minimizing the amount of land needed for human activities helps to maintain or improve biodiversity and to protect valuable natural resources.

### Fiber optic infrastructure requires less real estate than copper infrastructure

Finally, fiber optic lines have another environmental advantage over copper lines beyond reduced energy usage and smaller physical footprints: increased reliability and resilience. This translates to fewer environmental impacts associated with maintenance. Examples of these impacts include:

- Reduced emissions from replacement of lines (less new material extraction and energy for manufacturing)
- Lower emissions from less maintenance crew travel to sites
- Fewer ecosystem disruptions from digging up lines

When Verizon switched over to fiber optic in New York, it saw a 60% reduction in maintenance, including a reduction in truck rolls required in the area, and estimated that its new infrastructure provided up to 90% better reliability over its previous copper infrastructure.[28]

So why do fiber optics lines require less maintenance? These lines have a few key characteristics that contribute to their resilience:

- They are more durable – fiber optic lines are able to withstand 100-200 pounds of pressure[30,31] compared to copper, which can withstand around 25 pounds of pressure[32]
- They are less susceptible to weather / climate-related events, such as flooding[33]
- They have fewer exchanges, resulting in fewer points of failure

In addition to needing to occur less often, maintenance of fiber optic lines is often easier and faster than copper line maintenance, which generally means less fuel spent traveling to sites and less energy used by repair equipment.

Many providers are already deploying fiber optic facilities to reduce their maintenance demands or increase their network resilience to natural disasters. Both Verizon and AT&T have begun upgrading to fiber optic lines in locations prone to flooding, and cities like Seattle are using fiber optics for service to public buildings in order to make the city more resilient to natural disasters.[33] As climate-related disasters become more frequent, the importance of network resilience will continue to grow and become an essential part of developing sustainable infrastructure, adding to the public policy case for accelerating the transition from copper to fiber networks.

# End of Life

When considering the lifetime and end of life treatment of these materials, fiber optic lines are more likely to last longer than copper lines, thanks to their resilience to natural disasters and lower susceptibility to theft. However, copper lines are more likely to be recycled, given their high value and ability to be recycled and reused, limiting the impact when lines need replacement. It should be noted that most fiber optic lines have not yet reached the end of their useful life, so it is unclear how these lines will be treated at end of life in the future. Overall, though, the impacts from end-of-life disposal of either fiber optic[29] or copper lines[13] are small compared to the impacts from the development and installation of the lines and from the operation of the lines themselves.

### Fiber optic lines are more likely to last longer than copper lines

Some consider fiber optic lines to have longer lifespans than copper lines, thanks to a higher expected average lifespan[34,35] and the higher resilience of fiber optic lines to natural disasters. Others believe that there is no meaningful difference in lifespan between the two types of lines - fiber optic lines installed prior to 1986 are still in operation today and are still functioning well[7] and there are also copper lines functioning today that were installed over 100 years ago. That said, especially when considering the effects of climate-related disasters on copper lines (which are more susceptible to water damage than fiber optic lines) over the next 100 years, telecommunications providers might need to replace sections of copper lines up to 6-10 times compared to a fiber optic line that might need replacement 2-4 times.

In addition to considering copper's natural lifespan, it is also important to note that copper lines are more susceptible to theft than fiber optic lines and may not reach end of life before needing replacement. Although copper theft tracking tends to be localized, and therefore hard to track at a national level, the FBI identified this as a threat to critical U.S. infrastructure as early as 2008.[36] And thanks to high copper prices, incidents like the recent theft of copper lines from a telecommunications tower in Wisconsin[37] or the theft of copper from a cell phone tower in Texas[38] continue to occur. Given that prices are not expected to fall any time soon, replacements due to thefts may become more common, and shorten the effective lifespan of copper further.

### Copper lines are more recyclable, thanks to copper's properties and higher commodity value

As the International Copper Association notes, "copper is one of the few materials that can be recycled repeatedly without any loss of performance."[39] High copper prices and limited supply incentivize recovery and reuse, leading to a copper recycling rate of 33%[40] in the US and 40%[39] globally. One study noted that this recycling rate could be even higher if inefficiencies in collection, separation and processing were resolved.[12]

However, as previously discussed earlier in the paper (see "Manufacturing and Installation" section), even if all copper was recycled, it wouldn't be sufficient to meet projected global demand.

On the other hand, recycling and reusing fiber optic lines is more complicated. Although the lines can be recycled, and there are several companies that specialize in this, fiber optic lines need to be stripped down to individual components to properly recycle them. Given the complexity of the lines and the low value of the commodities, such as plastic and glass, there is little financial incentive to recycle them, and end-of-life fiber optic lines often still end up in landfills or incinerated.[41]

Some companies have found ways to "downcycle" and reuse old fiber optic lines in other materials. For example, AT&T was able convert its used fiber optic lines into roofing material. Downcycling means that new materials are still needed to replace fiber optic lines at end of life, so this solution is not as environmentally friendly as traditional recycling. However, it is expected that as more fiber optic lines start to reach end of life, providers will increase efforts around "downcycling," as well as recycling and reusing these lines.

# Conclusion

When considering the environmental impacts of deploying new fiber optic infrastructure versus continuing to maintain existing copper infrastructure, but are likely to have higher initial environmental impacts from manufacturing and installation compared to maintaining copper.

As the world increasingly relies on fast, reliable, and secure data transmission, the demand for fiber optic lines will continue to grow. For many experts in this field, it's a question of when, not if, copper infrastructure should be retired. To enable a faster transition to modernized networks, it will be critical for regulators to support providers working to retire existing copper infrastructure. Promoting investment in fiber optic infrastructure not only addresses current communication needs but also helps ensure a more efficient and sustainable network in the future.

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