Hexatronic

Whitepaper

Micro Cabling Systems – Driving the future of fiber optic long-distance networks

Introduction – A shift in long-distance network design

Imagine a world where building fiber networks is faster and cheaper, with a substantial reduction of the environmental footprint. That world is here, thanks to new high-performance micro cabling systems. Traditional fiber deployment methods, while reliable, are gradually outpaced by the demands of modern data traffic needs. This whitepaper introduces the need for a new transport network design approach that embraces agility, scalability, and environmental responsibility.

Historical context and basic design

The foundation of modern telecommunications relies heavily on robust and high-capacity fiber optic networks. These networks, often categorized into access, metro, and transport segments, are critical for delivering high-speed data across various applications, from Fiber to the Home (FTTH) and 5G infrastructure to inter-city and international long-haul connections.

Historically, installing fiber optic cables primarily involved conventional methods, such as pulling or jetting large, heavy cables into equally large conduits. While effective for their time, these traditional approaches are increasingly challenged by the continuous demand for reduced total cost of ownership, enhanced network flexibility, greater scalability, and a diminished environmental impact.

The telecommunications industry, driven by relentless innovation and the escalating need for bandwidth and cost optimization, has rapidly emerged and adopted micro cabling systems over the past decade. This technological shift represents a paradigm change in network deployment, moving away from physically larger, more rigid cable structures towards smaller, more flexible, and installation-optimized solutions.

Hexatronic, a key innovator in this space, has developed the Viper series of micro cables. These cables combine cutting-edge air-blown installation performance with the latest generations of optical fibers, enabling the benefits of micro cabling with the performance of traditional cables for long-distance networks. The advancements are not merely incremental improvements but fundamentally alter the network infrastructure's economics and environmental footprint.

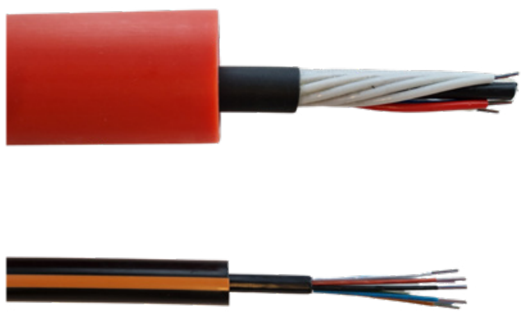

Figure 1. Traditional cable in duct (top) and micro cable in microduct (bottom).

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Peter Lo Curzio is the Deputy Chief Technical Officer for Hexatronic and has 30 years of experience in fiber optic technology. Starting at Ericsson R&D, he pioneered fiber optic access networks and has vast experience in virtually all areas related to fiber access. Peter is a specialist in passive fiber network systems and FTTH and has been instrumental in developing new fiber solutions with a reduced environmental impact.

Time to focus on facts

Sometimes we stick to the way we've always done things. It feels safe, and after all, it has worked before. But even as society and technology continue to evolve, adopting new solutions can be difficult. Often, it's not because the solutions are wrong – but because change makes us uncertain. This paper presents key facts on why Hexatronic's Viper micro cabling systems offer a strong alternative to traditional methods—delivering cost savings, flexibility, and sustainability for long-distance transport networks today and tomorrow.

Micro cabling isn't just a theory—it's a proven solution. From bustling metro areas to rural access networks and long-distance connections, these systems have demonstrated technical maturity and ecosystem readiness. With success stories spanning continents, micro cables have evolved into a trusted technology, supported by a robust supply chain and installation expertise.

Key aspects behind the value of micro cabling

A detailed understanding of the Total Cost of Ownership (TCO), breaking down how micro cabling significantly reduces both upfront capital investment (CAPEX) and ongoing operational expenses (OPEX).

An exploration of the enhanced performance and reliability offered by advanced micro cable designs, optical fiber technologies, and stringent quality assurance processes.

An examination of the scalability and flexibility that micro cabling systems bring to network design. Future-proofing is crucial for adapting to evolving bandwidth demands and technological advancements.

An assessment of the substantial environmental benefits, particularly in terms of reduced material consumption and lower carbon dioxide emissions (CO_2e) associated with manufacturing, transportation, and installation.

Traditional vs. micro cabling: A comparison

The fundamental objective of any fiber optic cabling system is to securely and efficiently transport optical signals over distances. However, the methods and implications of achieving this objective vary significantly between traditional and micro cabling technologies. Understanding these differences is crucial for appreciating the value proposition of modern micro cabling solutions, particularly for high-capacity transport networks.

Installation environment – Conduits vs. microducts

Traditional cabling deploys large-diameter cables (requiring 40-110 mm [1¼”-4”] conduits of PVC or HDPE) pulled or jetted underground as protective pathways. In contrast, micro cabling uses smaller, lighter cables in 14-20 mm microducts, optimized for air-blown installation to enable flexible, scalable networks.

First, bundles of small tubes or microducts are laid in the ground. These multi-way microducts come in various standardized sizes, often containing color-coded cells, and are manufactured from tough but flexible materials. Second, at a later stage, lightweight optical micro cables are ”blown” (or ”jetted”) through these predefined microduct pathways using compressed air. This methodology allows for speeds of up to 150 m per minute (~500 feet per minute) for cable installation.

Physical characteristics

Traditional cables typically have a larger diameter and greater weight than micro cables.

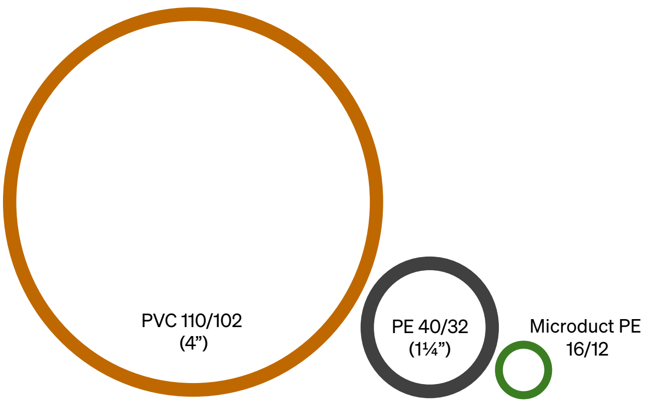

Figure 2. Comparison of traditional conduits and microducts.

For example, a conventional 432-fiber cable can be approximately 18 mm, requiring a conduit with an inner diameter of 32 mm (1.25 inches) or larger. This substantial physical size directly translates into higher material consumption for the cable and surrounding conduit infrastructure.

Figure 3. 192-fiber traditional cable vs. 192-fiber Viper Micro Cable.

Micro cables, such as Hexatronic’s Viper series, are designed to be super slim and lightweight. A 432-fiber micro cable is as small as 8.8 mm in diameter. This minimal size significantly reduces the amount of plastic consumed in production, leading to 4 to 6 times lower volume and weight than traditional cables.

Figure 4. Comparison of drum handling of a reel for standard cable and micro cable.

The physical characteristics of micro cables enable easier handling. Micro cables’ lightweight nature and flexible design, including features like robust inner tubes that resist kinking, make them more durable and easier to handle during installation, minimizing installation cost and CAPEX.

Total Cost of Ownership (TCO) - A paradigm shift with micro cabling

Let's talk numbers. Micro cabling systems reduce costs in materials, labor, and maintenance. They also improve safety, ease of handling, and reduce environmental impact while providing reliable performance and scalability for long-haul applications.

What affects the TCO?

The Total Cost of Ownership (TCO) is crucial for evaluating fiber optic networks. While many focus solely on the upfront material cost, Hexatronic emphasizes that a thorough understanding of TCO reveals that installation and maintenance costs overwhelmingly dominate the overall investment in a fiber optic network over its lifetime. Micro cabling systems, like Hexatronic's Viper series, are designed to minimize TCO by optimizing labor-intensive aspects.

The installation process for traditional cables is typically highly labor-intensive. These cables' sheer size and weight, combined with the need to pull them through conduits, often require larger installation teams and significant physical effort. This contributes to the high labor cost percentage (typically 80-85%) in a network's installation budget, overshadowing material costs (15-20%).

On the other hand, the design of micro cables and microducts is inherently installation-optimized, designed to minimize the installation cost.

Fastest installation - Longest blowing distances

This is arguably one of the most important factors in lowering the total cost. Traditional cables often cannot be blown or pulled for very long distances, forcing network planners to incur extra costs for numerous manholes and the associated setup times for blowing cables in shorter sections. Hexatronic's installation-optimized Viper micro cables offer 25-50% better installation speed and distance than comparable cables on the market. This gives not just one, but two significant benefits that affect the total cost:

- Shorter cable installation time and lower installation cost
- Fewer manholes are needed, faster installation, and lower cost

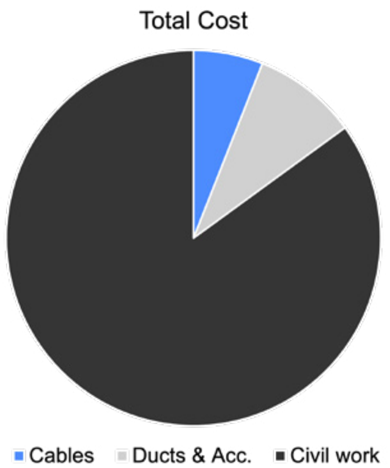

Figure 5. Typical cost distribution in a fiber installation project.

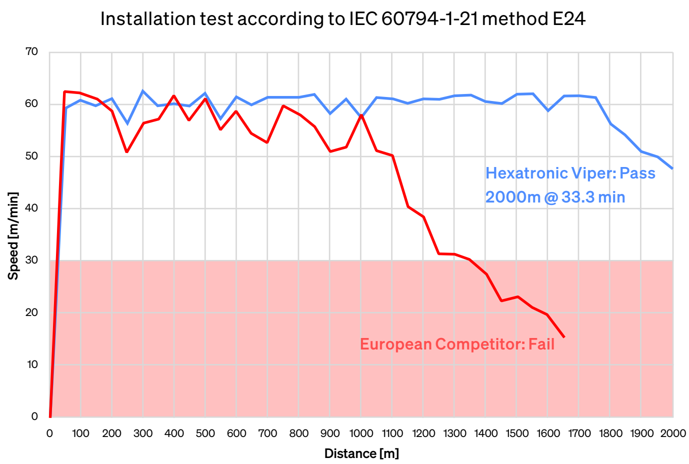

Figure 6. Hexatronic Viper installation speed test compared to traditional cable.


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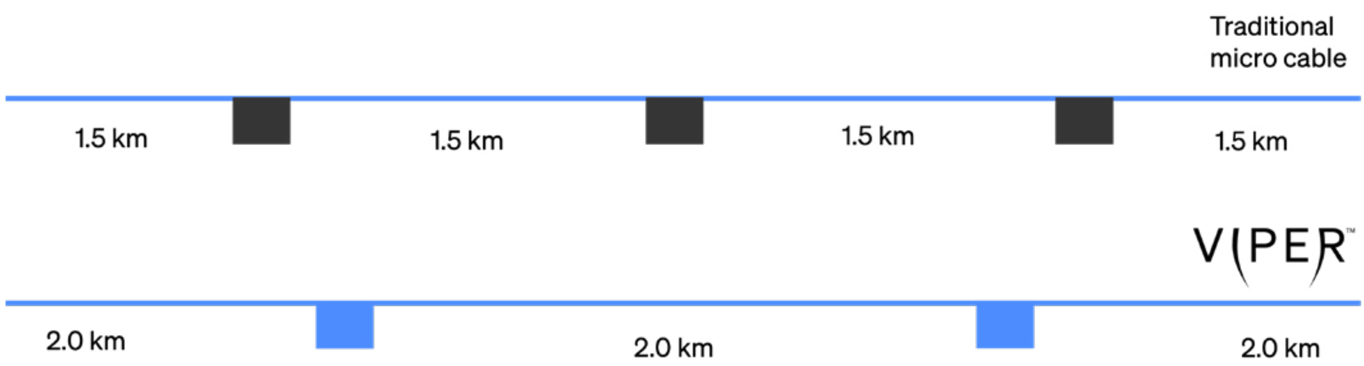


Figure 7. Manhole distance, traditional vs. Viper Micro Cable.

Shorter cable installation time and lower installation cost: Hexatronic has demonstrated exceptional blowing performance in real-world scenarios, with successful customer trials achieving typical blowing distances regularly exceeding 3000 meters, reaching up to 6000 meters with center blowing (2 × 3000 m), or up to 12 km (4 × 3000 m) in cascade, or sectional blowing. This ability to blow cables over such extensive distances without intermediate splice points or manholes profoundly impacts labor requirements and equipment usage, directly translating into substantial cost savings. Furthermore, blown-in fiber cables can be installed at up to 500 feet per minute (~150 m/min), further accelerating deployment and reducing labor hours.

Fewer manholes: Longer runs with traditional cables often necessitate more frequent manholes or access points for splicing cable sections together or facilitating circuit redirection. Each splice point adds to installation time and cost, and more importantly, introduces potential points of optical loss, reducing overall system reliability. Fewer manholes are needed, resulting in faster installation and lower cost. As illustrated above, a 33% increase in blowing performance can reduce the number of manholes by 33%, drastically cutting total expenses.

In addition, traditional cables require larger manholes to accommodate excess cable length, which increases installation cost. Micro cables can be installed in small compartments that are lower in cost and faster to install.

Figure 9. The Viper Den – A miniature manhole for micro cable installations.

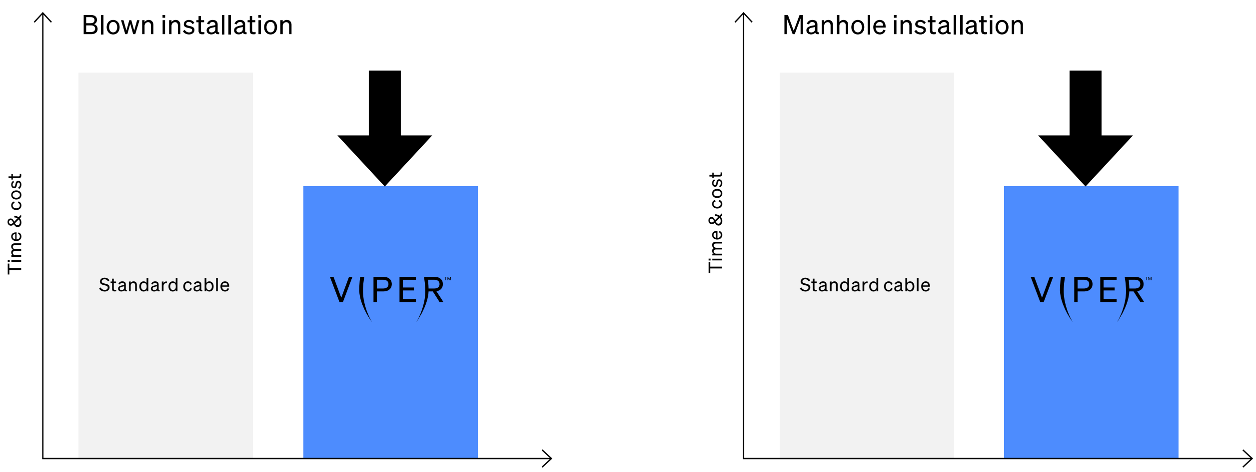


Figure 8. Typical savings acheived with micro cables.

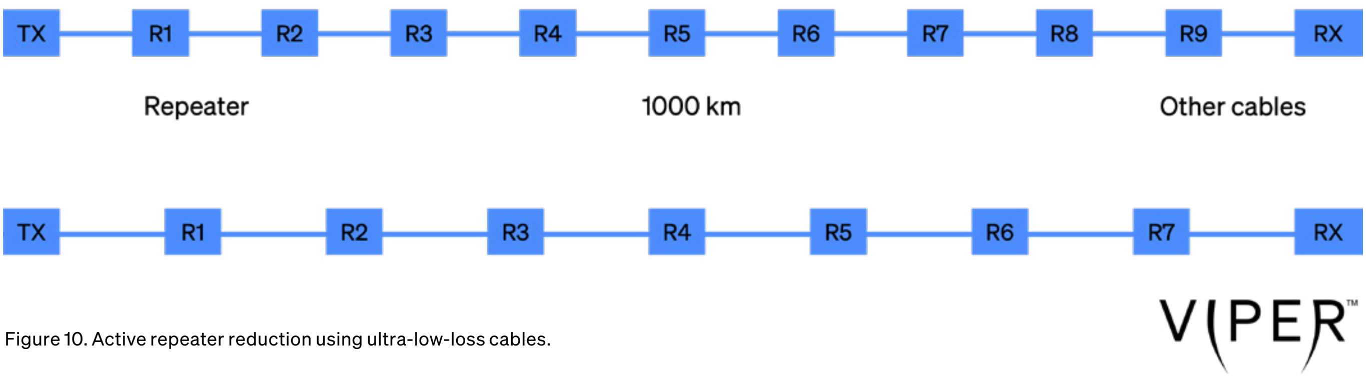


Figure 10. Active repeater reduction using ultra-low-loss cables.

Best Optical Performance – Fewer repeaters and lower cost

A trade-off between data rate and transmission distance fundamentally limits the transmission capacity of an optical link. As the bit rate increases, so does the required optical signal-to-noise ratio (OSNR) for error-free detection. However, OSNR inevitably degrades over distance due to several factors:

- **Fiber attenuation** – the gradual loss of optical power as light propagates through the fiber.
- **Chromatic dispersion** – the spreading of optical pulses as different wavelengths travel at slightly different speeds, which blurs the signal.
- **Non-linear effects** – signal distortions caused by the interaction of high-power optical signals with the fiber medium itself.
- **Amplifier noise** – the noise accumulation each time an optical amplifier boosts the signal.

Over long distances, these impairments cause the signal to become too weak or distorted to detect reliably. To overcome this, optical amplifiers (e.g., Erbium-Doped Fiber Amplifiers, EDFAs) are placed periodically along the link to boost signal power, or active regenerators are used to fully detect, clean, and retransmit the data. Regeneration (often called ”3R” – re-amplify, re-shape, re-time) is particularly costly, since it requires complex active equipment that must be powered, maintained, and eventually replaced. In addition, regeneration sites are typically housed in costly In-Line Amplifier Huts (ILA Huts) that are prefabricated and expensive to deploy.

By deploying ultra-low-loss fiber optic cables, the attenuation per kilometer is reduced, meaning the signal can travel farther before falling below the OSNR threshold. This increases the spacing between amplifiers or repeaters, minimizing the number of active sites required. The result is a network with a lower total cost of ownership, higher reliability, and reduced environmental footprint over its lifetime.

Hexatronic Viper cables achieve low attenuation (e.g., 0.18 dB/km for G.657A1/G.652D and 0.17 dB/km for G.654 at 1550 nm), reducing the need for repeaters in long-distance or dark fiber networks. Our analysis shows that a 0.03 dB/km improvement can save 30 dB over 1000 km, potentially cutting transmission costs by 10-20% through fewer repeaters.

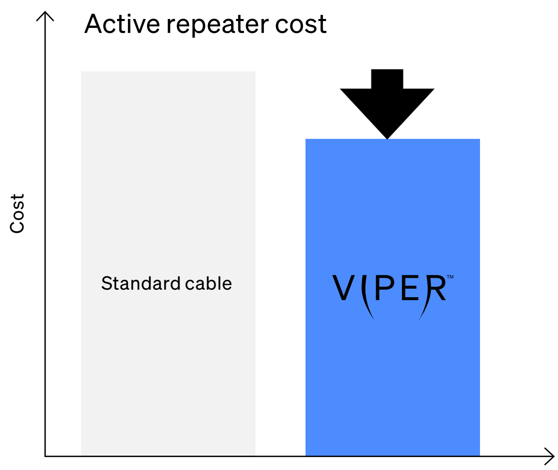


Figure 11. Typical active repeater savings when using ultra-low-loss Hexatronic Viper Micro Cable.

Scalability challenges

Micro cabling systems provide unparalleled network flexibility and future scalability. The pre-installation of multi-way microduct assemblies means that optical fiber cables can be installed incrementally, adapting to actual end-user demand rather than committing to full capacity upfront. This allows for easy network upgrades by blowing in higher fiber counts or switching to different fiber types as technology evolves or demand increases. The system design often includes spare ducts for future cable installations, offering built-in multi-pathway flexibility.

While traditional conduits can be designed to accommodate multiple cables, achieving future scalability often means laying down additional conduits upfront or using innerduct systems like MaxCell fabric to compartmentalize larger conduits. Even with such systems, the physical footprint and material requirements remain substantial. For instance, while seemingly efficient, accommodating a future capacity equivalent to four 288-fiber cables in a 4-inch conduit using MaxCell fabric still results in a significantly higher overall cost than a micro cabling solution for the same capacity.

Let's examine two case studies that illustrate the above. For comparison purposes, the cost is shown as X USD/m for micro cabling systems. The figures in the case studies are drawn from real-life projects with customers worldwide. Interested in the full calculation? Contact Hexatronic for more insights.

Case study 1

Cost, initial 288-fiber capacity, expandable

A 288-fiber micro cable has a diameter of just 7.5mm and can be installed in a 4-way 16/12mm (OD/ID) microduct bundle. This setup leaves three microducts available for future installations, providing built-in scalability.

To achieve the same initial capacity and future expansion capability with traditional cabling, an 18mm diameter traditional 288-fiber cable would require at least a 1.25-inch conduit, and then three more 1.25-inch conduits would need to be installed for equivalent future capacity.

When material and installation costs are compared, the traditional cable system would cost 58% more than the micro cable option. This significant difference highlights the inefficiency of traditional methods when future growth is considered.

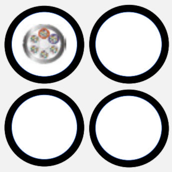
Type	Cost
4×16/12 mm Microduct assembly and micro cables 	X USD/m
4×40 mm (1¼") Conduit with traditional cables 	1.58X USD/m +58%

Table 1. Initial 288-fiber capacity with upgrade path - Comparison of 4×16/12 mm microduct assembly with micro cables and 4×40 mm conduits with traditional cables.

Case study 2

Cost, high capacity 1,152 fibers

This scenario explores using large 4-inch conduits with MaxCell fabric innerducts in a traditional system, allowing four 288-fiber cables to be installed in a single conduit, for a total capacity of 1,152 fibers.

Even in this optimized traditional scenario, a traditional system providing the same 1,152-fiber capacity is still 61% more expensive than a micro cabling system. This demonstrates that micro cabling retains a substantial cost advantage even with attempts to maximize capacity in traditional conduits.

Type	Cost
4×16/12 mm Microduct assembly and micro cables 	X USD/m
110/102 mm (4") Conduit with MaxCell and traditional cables 	1.61X USD/m +61%

Table 2. 1152-fiber capacity - Comparison of 4×16/12 mm microduct assembly with micro cables and a 100 mm (3½") Conduit with MaxCell and traditional cables.

Performance and reliability of micro cable systems

Beyond economic advantages, fiber optic cables' technical performance and inherent reliability are paramount for ensuring a stable and efficient transport network. Hexatronic's Viper micro cableseries and microducts are engineered to deliver superior performance and robustness, ensuring long-term network integrity even in demanding conditions.

Superior pipe stiffness of reduced-diameter microducts

Pipe stiffness is a crucial mechanical property defining a duct's deformation resistance under external loads. A higher pipe stiffness indicates a more robust and resilient conduit, capable of withstanding the rigors of installation and long-term environmental stresses. Counterintuitively, microducts with reduced diameters exhibit significantly higher pipe stiffness compared to traditional, larger ducts, making them inherently stronger and more reliable.

An approximate relationship exists between the pipe stiffness, the Standard Dimension Ratio (SDR), and the material's elasticity module. The SDR is the ratio between the pipe's outside diameter and wall thickness. The figure below illustrates this relation. This phenomenon is also verified in physical tests.

These findings explicitly confirm that microducts possess significantly higher pipe stiffness. This enhanced stiffness directly translates into greater robustness, making microducts stronger and more reliable throughout their lifecycle, from manufacturing and transportation to installation and operation.

The superior mechanical integrity of these smaller microducts minimizes the risk of damage during installation, especially in challenging routes, and provides increased protection for the optical fibers contained within. This inherent strength and reliability are key benefits that allow for the efficient air-blown installation of micro cables, even in microducts with an inner diameter as small as 8 mm.

Superior fiber protection in cables

The Hexatronic Viper series of micro cables is specifically designed for all kinds of networks, including transport and long-haul networks. It combines state-of-the-art air-blown installation performance with the latest optical fiber generations. The design is a culmination of advancements in cable design, manufacturing, and optical fibers, allowing micro cables to offer key benefits without sacrificing mechanical or optical performance.

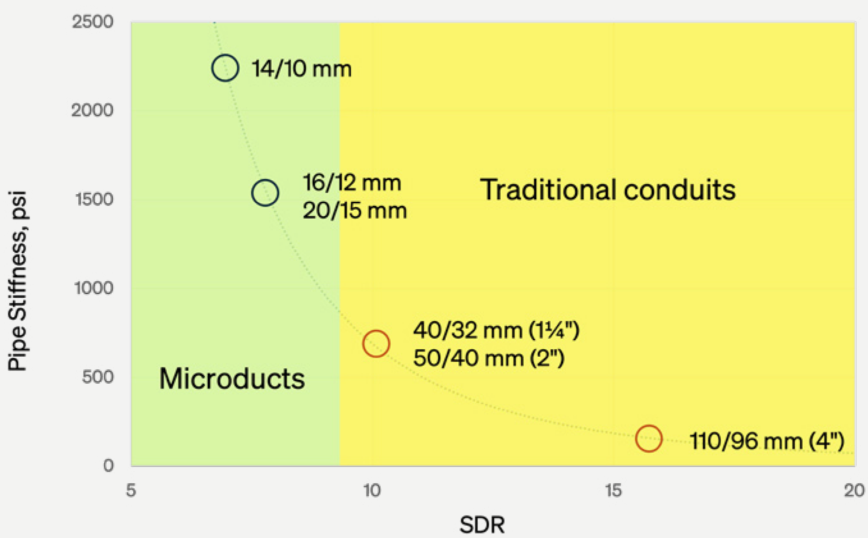


Figure 12. Pipe stiffness vs. SDR for HDPE ducts

Figure 13. Pipe stiffness test setup.

Key advantages of the Viper series

Extended temperature range: The unique cable design allows for an extended operational temperature range of -45 to +70°C (-49 to +158°F). This makes the Viper series suitable for deployment in various global environments where extreme heat and cold are significant concerns. The cable also maintains stability across this range for storage and handling.

Excellent bend performance: Viper micro cables demonstrate excellent bend performance, ≥70 mm (2.76”). Their small bending radius, down to 30 mm (1.18”), provides significant flexibility during installation, especially in challenging routes or confined spaces.

Superior impact resistance: The cables’ impact resistance exceeds IEC specifications 3 to 5 times. This robust characteristic further enhances their durability and minimizes the risk of damage during handling and installation, directly contributing to lower installation costs by reducing fiber breaks.

Environmental benefits:
A better choice for transport networks

With a growing focus on sustainability, infrastructure projects increasingly prioritize carbon footprints. Micro cabling reduces environmental impact compared to traditional methods by using less plastic (due to smaller sizes) and generating lower CO_2 emissions in production and transport—from raw materials to installation sites.

As shown earlier, traditional systems can produce up to 4x higher fuel use and CO_2 emissions than microduct solutions. Most concerning would be large 4-inch conduit and MaxCell solutions, which result in CO_2 emissions 15x greater than a microduct alternative. This highlights the environmental advantages of micro cabling.

Micro cabling represents a strategic shift towards more efficient, adaptable, and sustainable network deployment. While traditional methods fulfilled past requirements, micro cabling is designed to meet current and future transport networks' economic and performance demands, as well as environmental demands. Let's have a closer look.

Reduced Material Consumption

One of the most direct environmental advantages of micro cabling lies in its efficient use of raw materials, particularly plastics.

- **Diameter and volume reduction:** When compared with a micro cable, the traditional cable's diameter is typically 2 to 2.5 times larger. This seemingly small difference in diameter results in a disproportionately larger reduction in volume and weight. Specifically, a traditional cable can be 4 to 6 times greater in volume and weight than a micro cable. This significant reduction in physical mass directly translates to a considerable decrease in the amount of plastic materials used to produce both the cables and the necessary ducts or conduits.

- **Duct material savings:** The material savings are further amplified when considering the ducts. Traditional cables, due to their larger size, require much larger ducts than micro cables. This means that the entire system—cable and duct—consumes substantially less plastic material when a micro cabling solution is implemented. The total material consumption related to cables and ducts, being 4-6 times greater for traditional systems, is directly proportional to a much higher environmental impact.

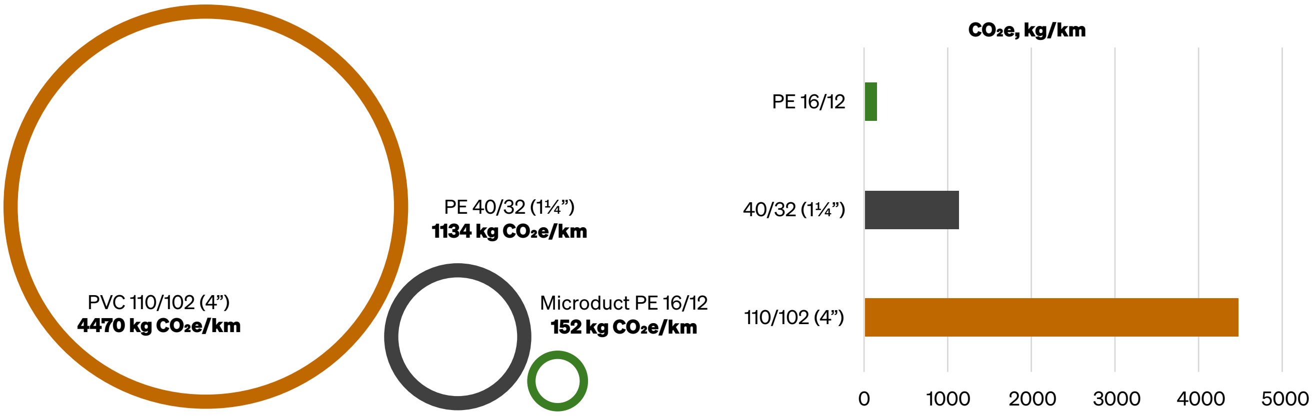


Figure 14. Calculated environmental impact of various duct sizes.

Lower CO_2 emissions from transport and handling

Beyond the manufacturing process, transporting materials and finished products represents a significant source of CO_2 emissions in network deployment. Micro cabling components' reduced volume and weight offer substantial advantages in reduced fuel consumption. This applies to every stage of the supply chain: from the delivery of plastic raw materials to the manufacturing plants, to the distribution of finished cables and ducts from production facilities to warehouses, and finally to the installation sites. Less weight and volume mean more products can be shipped per vehicle, reducing the number of transport trips and fuel burnt and CO_2 emitted. To study these effects, we go back to the two case studies in the previous chapter. The calculations are based on transport emission information from recognized databases. Again, if you want to follow the calculations, contact Hexatronic for a separate white paper elaborating on this matter.

Case study 1

Footprint, initial 288-fiber capacity, expandable

Comparing 4×40/32 mm (1¼") Traditional Conduits with a 4×16/12 mm Microduct Assembly: This comparison reveals that traditional cables/conduits can lead to up to 4 times (+300%) higher fuel consumption and CO_2 emissions than a microduct solution. This stark difference underscores the inefficiencies inherent in transporting bulkier traditional materials.

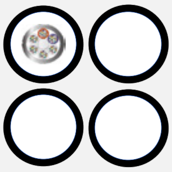
Type	Transport, handling, and CO_2e
4×16/12 mm Microduct assembly and micro cables 	0.87 kg CO_2e/100 km (3.1 lbs CO_2e/100 miles) 
4×40 mm (1¼") Conduit with traditional cables 	3.5 kg CO_2e/100 km (12.4 lbs CO_2e/100 miles) **+300%** 

Table 3. Initial 288-fiber capacity with upgrade path - Comparison of emissions from transport and handling

Case study 2

Footprint, high capacity 1,152 fibers

Comparing a 110/102 mm (4") conduit with MaxCell to microducts: Even optimized traditional setups yield 15x higher emissions (+1445%). This underscores the clear environmental edge of micro cabling for high-capacity needs.

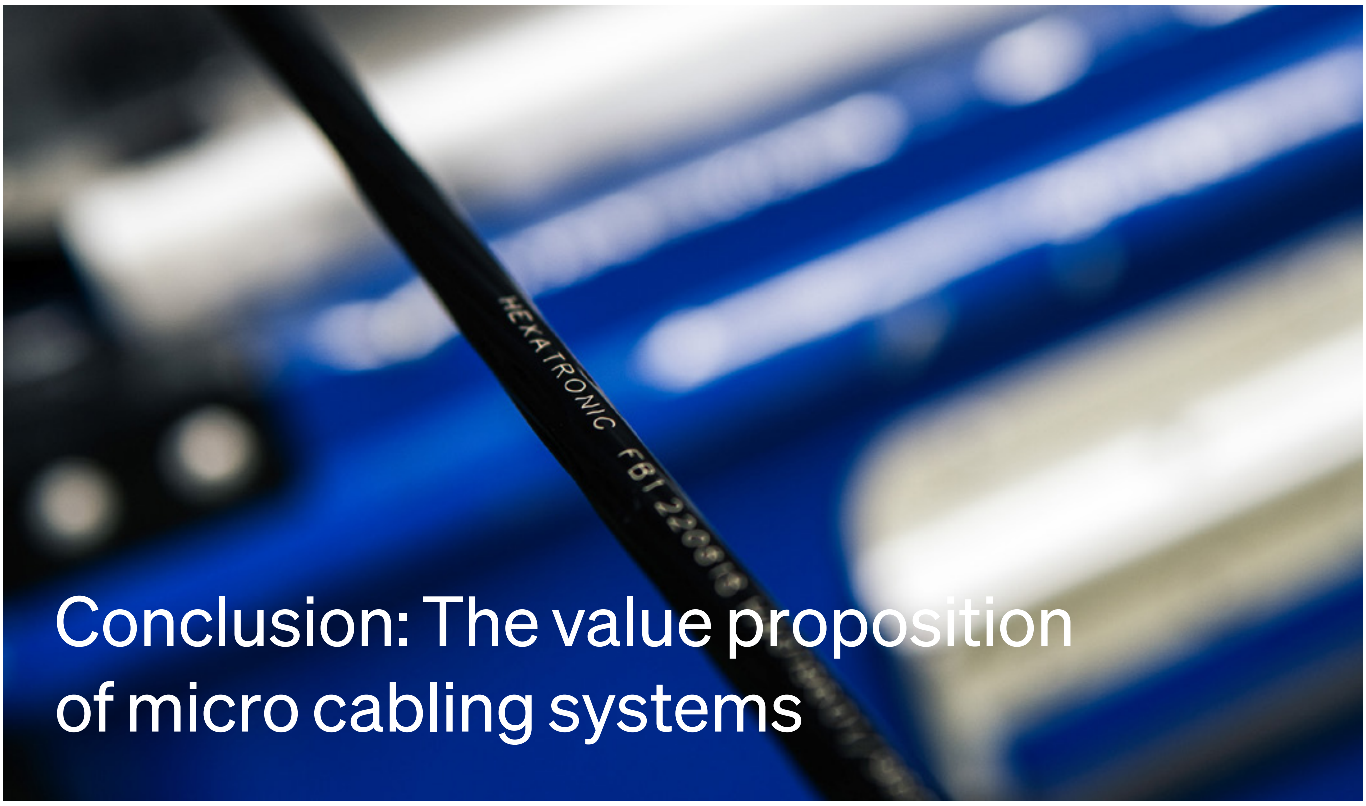
Type	Transport, handling, and CO_2e
4×16/12 mm Microduct assembly and micro cables 	0.87 kg CO_2e/100 km (3.1 lbs CO_2e/100 miles) 
110/102 mm (4") Conduit with MaxCell and traditional cables 	13.7 kg CO_2e/100 km (48.4 lbs CO_2e/100 miles) **+1445%** 

Table 4. 1152-fiber capacity - Comparison of emissions from transport and handling

Overall carbon footprint reduction

The cumulative effect of reduced material consumption and lower transportation emissions means that micro cabling systems have a substantially lower carbon footprint than traditional cabling. This makes micro cabling a much more environmentally friendly choice for building modern communication networks. The commitment to sustainability is evident in Hexatronic's approach, which integrates environmental considerations throughout its product design and supply chain.

In conclusion, the environmental benefits of micro cabling are not merely tangential advantages but core components of their overall value proposition. By choosing micro cabling solutions, network owners and operators can significantly reduce their environmental impact, contributing to global efforts to mitigate climate change while achieving economic efficiencies. The substantial reduction in plastic usage and CO_2 emissions makes a compelling case for micro cabling as the sustainable standard for future transport network deployments.



Conclusion: The value proposition of micro cabling systems

In a straightforward comparison, it is hard to argue for traditional cabling techniques in favor of air-blown micro cabling. Micro cabling systems have demonstrated their superiority in delivering the lowest total cost of ownership, the highest level of scalability and flexibility, and a significantly reduced environmental impact compared to conventional cabling methods. While blown fiber technology itself dates back to the 1980s, and is a mature technology in access and metro networks, continuous innovation, particularly by companies like Hexatronic, has refined micro cabling solutions to perfectly fulfill the needs of today's and tomorrow's transport, metro, and access networks.

Network owners and system installers globally strive for the lowest TCO and the highest level of network future-proofing. Micro cabling techniques were specifically developed to provide precisely this functionality, and their substantial cost benefits have now made them highly attractive for applications, including long-haul and data centers.

As demands grow and sustainability rises in priority, micro cabling offers a cost-effective, reliable, and smart option for future communication networks.

Connectivity creates opportunity. Hexatronic delivers future-ready fiber solutions for critical infrastructure, from telecom networks to rugged environments and data centers. Our systems are built to last, designed to scale, and supported by expert training and field services. In close collaboration with our customers, we shape solutions that strengthen communities and drive innovation in a connected world.

Hexatronic