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Underground Utility Safety: Protecting Lives, Infrastructure, and the Future Beneath Our Feet

In the modern world, much of what keeps our cities alive lies out of sight. Beneath our roads, fields, and sidewalks runs a complex web of underground utilities—gas pipelines, water mains, electrical conduits, telecommunications cables, and sewerage systems—that power our homes, transport our waste, and sustain our lives. Yet, the very invisibility that makes these networks convenient also makes them dangerous. When excavation, maintenance, or construction activities are undertaken without proper safety measures, the consequences can be catastrophic.

This editorial explores the importance of underground utility safety, the regulations designed to protect both infrastructure and people, the role of technology in mitigating risks, and the cultural change needed across industries to ensure the ground beneath our feet remains safe for generations to come.

The Hidden Danger Beneath Our Feet

Every year, thousands of incidents occur involving accidental damage to underground utilities. Whether caused by excavation crews, landscapers, or even routine maintenance operations, these incidents can result in injuries, fatalities, service outages, property damage, and costly repairs. The U.S. Common Ground Alliance (CGA) reports that hundreds of thousands of “dig-ins”—instances where underground facilities are damaged—take place annually. Many of these are entirely preventable.

The root cause of most of these incidents is a lack of awareness or failure to follow established safety proto-

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cols. Workers might assume that utilities run deeper than they do, or that their project is too small to cause harm. In other cases, outdated maps, unregistered lines, or miscommunication between agencies and contractors lead to errors.

The consequences of a single mistake can be severe. Accidentally rupturing a gas line can cause explosions or fires. Damaging electrical conduits can lead to electrocution. Cutting fiber optic cables can disrupt telecommunications and emergency services for entire regions. And while the economic cost of such accidents runs into billions annually, the human cost—lives lost or permanently changed—is incalculable.

Regulations and Standards: Building a Framework for Safety

Recognizing these dangers, governments and industry organizations have developed an array of regulations, standards, and best practices to reduce underground utility damage. In the United States, the 811 “Call Before You Dig” program is a cornerstone of national prevention efforts. This system requires anyone planning to dig to contact a local one-call center, which then coordinates with utility operators to mark underground lines before work begins. Similar systems exist globally. The UK operates the “Dial Before You Dig” service, while many Asian and European nations have developed their own national frameworks. These programs share a simple but powerful principle: prevention begins with communication.

Beyond calling and marking services, international standards such as ASCE 38-22 (in the U.S.) or PAS 128 (in the UK) establish processes for mapping and documenting subsurface utilities during design and construction. These standards categorize the quality and accuracy of utility data, helping engineers understand how reliable their information is before breaking ground.

Regulatory enforcement also plays a crucial role. Agencies often impose fines or penalties for failing to follow safety procedures or for neglecting to notify one-call centers prior to excavation. However, penalties alone are insufficient. A holistic safety approach requires education, training, and collaboration—turning regulations into routine behavior rather than bureaucratic obligations.

Technology: The New Frontier in Underground Safety

While regulations form the backbone of safety practices, technology provides the tools to make them stronger, smarter, and more efficient. Over the past decade, the field of underground utility detection and mapping has undergone a quiet revolution. Traditional paper maps and guesswork have given way to advanced geospatial tools, ground-penetrating radar (GPR), electromagnetic (EM) locators, and GPS-based digital mapping systems.

1. Ground-Penetrating Radar (GPR) and EM Locators

GPR sends electromagnetic waves into the ground and measures reflections from various subsurface objects. It can locate non-metallic utilities such as plastic water pipes that older systems cannot detect. EM locators, on the other hand, excel at finding metallic conductors, making the two technologies complementary. When used together, they provide a more complete, three-dimensional view of underground environments.

2. Geographic Information Systems (GIS) and Digital Twin Technology

Modern GIS software allows for detailed digital mapping of underground networks, integrating data from multiple utilities and field surveys. Combined with digital twin technology—virtual replicas of physical infrastructure—cities can simulate construction projects before they start, identifying conflict points and potential hazards well in advance.

3. Artificial Intelligence and Machine Learning

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AI-driven analysis is transforming utility detection. Algorithms can now interpret radar scans and sub-surface imaging data more accurately than human operators alone. Over time, these systems learn from previous results to improve detection accuracy, reduce false readings, and generate predictive models of where unregistered utilities may exist.

Imagine a construction worker looking through AR-enabled glasses and seeing, in real-time, the exact location of underground cables beneath their feet. This is no longer a futuristic fantasy. AR overlays and wearable devices are being adopted in field operations, providing intuitive, hands-free safety guidance in real conditions.

4. Augmented Reality (AR) and Wearables

Collectively, these technological innovations not only enhance worker safety but also improve project efficiency, reduce costs, and minimize service disruptions.

The Human Element: Training, Culture, and Accountability

Even with the best technology and regulations, underground utility safety ultimately depends on people. The individuals operating machinery, marking lines, and supervising projects must be trained, vigilant, and empowered to make safety their first priority.

One of the major cultural challenges in the construction and utilities industries is the pressure to meet deadlines and budgets. In such environments, safety checks are sometimes seen as delays rather than essential procedures. This cultural mindset must change. A truly safety-oriented organization recognizes that skipping precautions for short-term gain invites long-term disaster.

Comprehensive training programs are essential—not only for field workers but also for supervisors, engineers, and contractors. Training should encompass:



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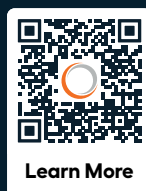
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Moreover, safety should not be compartmentalized within one team or department. Effective organizations make underground utility safety a shared responsibility, embedded in every stage of the project—from design to planning to final inspection.

Accountability also matters. Many incidents occur because errors go unreported, or minor near-misses are dismissed as inconsequential. Encouraging transparent reporting and non-punitive safety feedback loops creates a culture of continuous learning. When people feel safe to speak up about potential hazards, risks can be addressed before disasters occur.

Case Studies: Lessons Written in the Dirt

Examining real-world incidents underscores the value of underground utility safety.

1. The 2010 San Bruno Gas Explosion (California, U.S.)

In 2010, a natural gas pipeline operated by PG&E exploded in San Bruno, California, killing eight people and destroying dozens of homes. The subsequent investigation revealed failures in pipeline maintenance, recordkeeping, and oversight. This tragedy illustrated that underground safety is not only about locating utilities before digging—it is about maintaining and monitoring them throughout their lifecycle.

2. Fiber Optic Outages in Urban Renewal Projects

In many city redevelopment projects across Europe and Asia, poorly coordinated excavation schedules have led to repeated fiber optic cable cuts, crippling

Internet and emergency services. These incidents have highlighted the need for integrated digital platforms where utilities share data in real time, ensuring everyone knows what lies beneath each site before work begins.

3. Innovative Success: The Singapore Model

Singapore has become a global leader in underground utility safety and management through its Digital Underground Project, which uses 3D mapping and data integration to visualize subsurface assets. By requiring utilities to submit standardized digital data before construction, Singapore minimizes inter-agency conflicts and ensures safety compliance citywide.

Each of these cases—whether tragic or successful—teaches us that underground safety requires vision, coordination, and continuous improvement.

Environmental and Sustainability Dimensions

Beyond safety and economics, underground utility management intersects with environmental stewardship. Damaging utility lines can cause leaks of oil, gas, or sewage, contaminating soil and groundwater. These spills not only harm ecosystems but also create long-term health hazards for nearby communities.

Safe utility practices, on the other hand, promote sustainability. Accurate mapping and responsible excavation minimize waste, reduce rework, and extend the lifespan of infrastructure. Furthermore, as cities transition to smart grids, renewable energy systems, and electric vehicle infrastructure, the density of underground utilities will increase dramatically. Without a robust safety framework, the environmental and economic risk will grow exponentially.

Sustainability also entails reducing the carbon footprint of maintenance operations. By using advanced detection tools and digital planning, crews can perform more targeted excavations—reducing



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Collaboration and Communication: The Nexus of Safety

Effective underground utility safety depends on collaboration among all stakeholders—government agencies, utility owners, contractors, engineers, and the public. Fragmented communication is a major threat; when each party works in isolation, vital information is lost.

To counter this, industry leaders are advocating for shared utility databases and integrated project platforms. These systems allow real-time data exchange so everyone involved in a project has access to the most current and accurate information. Cloud-based tools can synchronize updates across maps, inspection logs, and maintenance records, ensuring that outdated data does not lead to dangerous oversights.

However, collaboration extends beyond digital connectivity—it also means cultural cooperation. When contractors and utility companies work with mutual transparency and trust, mistakes decline. Building strong partnerships between the public and private sectors—through safety campaigns, accreditation programs, and joint training initiatives—amplifies the collective commitment to safety.

Policy Recommendations: Strengthening the Foundations

To enhance underground utility safety globally, several policy directions merit attention:

1. **Mandatory Data Sharing:** Governments should require utility operators to contribute accurate information about the location and condition of their assets to centralized databases.
2. **Nationwide Standards for Subsurface Information:** Standardizing mapping and classification systems ensures consistency across regions.
3. **Technological Incentives:** Tax breaks or funding

could encourage adoption of GPR, GIS, and digital twin technologies.

4. **Continuous Education and Certification:** Mandating recurring safety training for contractors promotes long-term competency.
5. **Enhanced Public Awareness:** Just as 811 campaigns educate professionals, public education ensures homeowners and small businesses understand the importance of “calling before you dig.”
6. **Incident Transparency:** Publishing annual reports of underground strikes promotes accountability and helps identify trends and common errors.

These measures are not merely bureaucratic. They are practical steps toward saving lives, preserving infrastructure, and ensuring economic resilience.

The Road Ahead: Safety as a Shared Future

Underground utility safety is not a static goal but a continuous mission. As our societies expand and our technologies evolve, the subsurface environment will become increasingly crowded with cables, pipes, and networks serving advanced urban systems. The pressure to build faster—driven by urbanization and population growth—will only intensify the risks.

The future demands a proactive rather than reactive approach. This means not only improving detection and prevention but also designing cities that account for underground complexity from the outset. Comprehensive subsurface planning should become an integral part of urban design, infrastructure funding, and environmental policy.

Beyond the technical sphere lies an ethical dimension: protecting the unseen workers who toil below the surface. These individuals face daily risks so that the rest of us may enjoy uninterrupted power, clean water, and communication. Ensuring their safety is a moral responsibility shared by engineers, policymakers, and citizens alike.

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Conclusion: From the Ground Up

Underground utility safety is far more than a procedural requirement—it is the foundation of a safe, resilient, and sustainable society. Every pipe, cable, and conduit beneath our feet represents not just infrastructure, but human lives connected through technology and necessity.

The ultimate goal should be a future where every excavation is informed by accurate data, every worker is properly trained, every organization communicates transparently, and every community values the unseen systems that keep modern life running. Achieving this vision requires investment, innovation, and above all, a commitment to collaboration.

The challenge is immense—but the reward is greater. A world that respects the safety of what lies underground is one that builds its progress on solid ground. •





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Electric Boilers Hasten Europe's Clean Energy Transformation



At the forefront of the EU's transition, Finland accelerates its clean energy agenda by deploying high-efficiency electrode boilers across critical heat networks

Across Europe, high-voltage electrode boilers are quietly becoming a key part of the continent's clean energy transition. In countries like Finland, these systems are being deployed to support decarbonization goals, reduce emissions from heating networks, and help stabilize power grids increasingly powered by variable renewable sources. As the EU advances its Green Deal and REPowerEU initiatives, technologies like high-voltage electrode boilers provide a practical way to convert surplus renewable electricity into useful heat while supporting the shift away from fossil fuels.

Finland, in particular, has set one of the most advanced climate policies in the region, committing to carbon neutrality by 2035. Part of the European Union since 1995, the country has established interim emission reduction targets of 60% by 2030, 80% by 2040, and 90–95% by 2050, all relative to 1990 levels.

Like other EU members, Finland is striving to take advantage of financial and policy incentives such as the Recovery and Resilience Facility (RRF), a major EU funding program launched after the pandemic to promote electrification, renewable energy deployment, and resilience. The program is allocating approximately €672.5 billion to EU member states, distributed



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Like all EU member states, Finland must fully implement all RRF-funded initiatives by the program deadline of August 2026.

To meet its ambitious goals on schedule, Finland is directing a significant portion of the approximately €500 million it has already received toward modernizing its energy infrastructure, with a particular emphasis on the deployment of high-efficiency electric boilers.

Modern high-output electrode boilers are CE-marked systems designed to generate steam or hot water using high-voltage electricity, with output capacities reaching up to 60 MW and steam production pressures as high as 32 barg. These systems deliver zero emissions at the point of use, offer full modulation from zero to 100 percent output, and feature flexible configurations—including jet-type and immersed electrode designs—suitable for both new installations and retrofit projects in industrial and district heating applications.

“Electrode boilers are being installed across district heating networks to help decarbonize thermal energy production, offset fossil-fueled heat sources, and absorb excess electricity during periods of high renewable output. Their integration not only supports emissions reduction but also strengthens grid stability, making them a strategic investment in Finland’s broader path to carbon neutrality,” says Juha Mäntynen, Vice President of CT Industrial Oy (CTI), a Finland-based CleanTech provider specializing in turnkey, zero-emission, high-efficiency energy systems—including high-voltage electrode boilers—for industrial and district heating applications across 19 European countries.

Grid Stabilization

In the EU’s broader decarbonization effort, high-voltage electrode boilers play a critical role in appli-

cations requiring rapid load absorption and grid stabilization, according to Mäntynen.

Electrode boilers are particularly important for maintaining grid balance as renewable energy production expands. Because wind and solar generation can fluctuate rapidly, the grid requires technologies that can respond just as quickly. Electrode boilers meet this need by adjusting their electricity consumption almost instantly, allowing them to absorb excess power during periods of oversupply. This makes it easier to integrate variable renewable sources without overloading the grid or wasting clean energy.

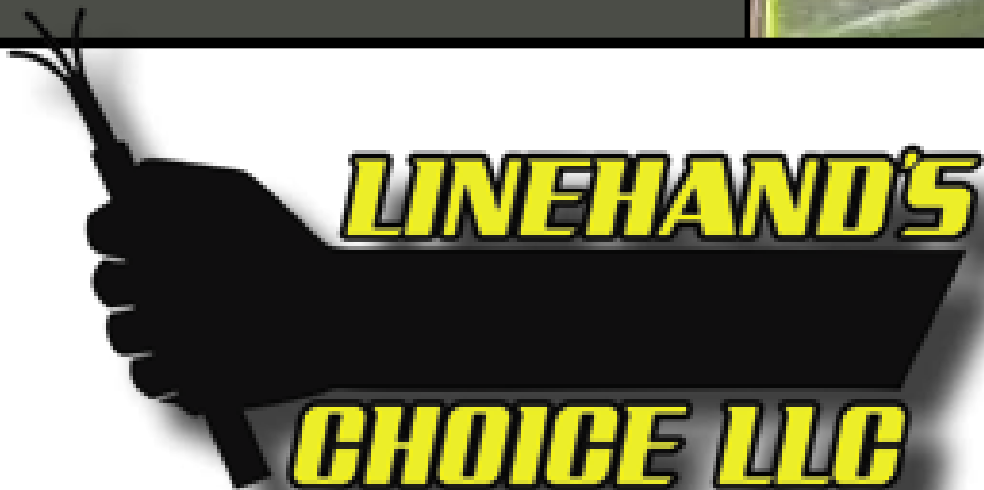
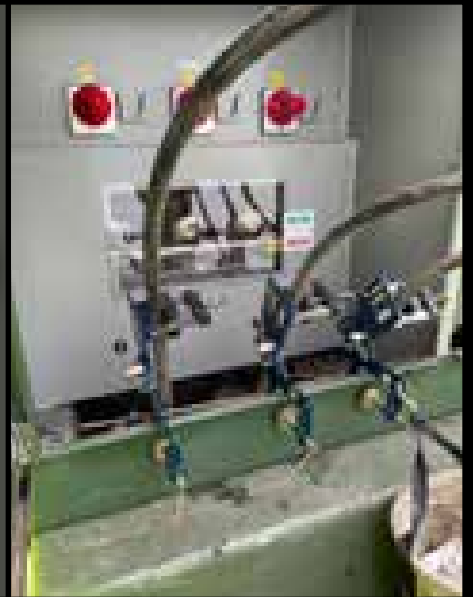
This is a key consideration for Finland, given its substantial investments in renewable energy over the past 15 years. By the end of 2023, Finland had approximately 1,600 operational wind turbines with a combined capacity of nearly 7,000 megawatts, including over 1,200 MW added that year alone. Wind has become Finland’s second-largest electricity source, generating roughly 19.8 terawatt-hours in 2024—enough to supply 24–25% of national electricity demand. The country also makes significant investments in heat recovery, heat pumps (air to heat), offshore wind, solar, and nuclear energy.

The Reserve Market and Negative Prices

As renewable energy production grows across Europe, instances of negative electricity pricing are occurring more frequently. This creates a financial opportunity for energy consumers who participate in the reserve market, allowing them to generate revenue by absorbing excess power. Electrode boilers are instrumental in leveraging this trend, enabling rapid, demand-responsive operation that aligns with market conditions.

According to Mäntynen, when wind production exceeds demand, surplus electricity causes prices to drop sharply—sometimes becoming negative. He explains that a negative electricity price means that electricity producers are paying people to take

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electricity off the grid, instead of customers paying for electricity.

Companies that participate in reserve markets can earn considerable revenue by consuming excess electricity to balance the grid.

The reserve electricity market—also known as the ancillary services or balancing market—is essential for maintaining grid stability by compensating producers and consumers who can quickly adjust power generation or consumption. This market ensures reliable system frequency and reduces blackout risks by responding to sudden shifts in supply and demand. Technologies like electrode boilers are particularly valuable in this context, as they can rapidly absorb excess electricity or shut off on demand, making them effective tools for balancing the grid in real time.

“Under favorable conditions, an electric boiler can pay for itself within a year or less. For example, last year the average price paid for reserve market electricity consumption was three thousand (3000) euros per megawatt-hour. A 50-megawatt boiler operating for one hour could earn approximately 150,000 euros,” says Mäntynen.

Thermal Power and District Heating

Thermal power and district heating are also critical to Europe’s energy infrastructure, supplying consistent heat to millions of homes and businesses while supporting grid reliability. These systems play a key role in energy security, especially in colder regions and during peak demand periods.

Finland operates one of the most advanced district heating networks globally, spanning over 16,000 kilometers of underground insulated piping and serving approximately half the population, particularly in urban areas. The system distributes hot water—typically heated between 65°C and 115°C, depending on outdoor temperatures—and returns it at 40°C to

60°C, with minimal heat loss of just 8–9%.

While the network historically relied on coal, peat and wood chips, it is now undergoing a major transition toward renewable and low-carbon energy sources. Many cities are phasing out biomass-fired plants in favor of modern technologies such as electrode boilers.

Relatively cheap electricity prices and taxation benefits have made Finland an attractive location for large data centers operated by companies like Google and Microsoft. Data centers produce a large amount of waste heat from cooling processors, and this waste energy has been used to heat cities in Finland.

“Heat pumps generate base energy from data centers, while electrode boilers increase the district heating water temperature to reach the required temperature level for city needs,” says Mäntynen.

To accelerate deployment, CTI has teamed up with Acme Engineering to expand electrode boiler implementation across Finland and other European markets.

Acme’s products are distinguished by their wide range of designs and technical flexibility. The portfolio includes the jet boiler, capable of handling higher pressures with zero to 100 percent modulating capacity, and the immersed electrode boiler, which can be configured for either hot water or steam applications. Additionally, the OEM offers a horizontal hot water boiler design that is particularly well-suited for retrofit projects. A variety of voltage options are available to meet different regional requirements.

Today, CTI partners with Acme to provide high-voltage electrode boilers to the European market under the ACME-CTI brand. CTI manufactures and delivers electrode electric boilers for steam and hot water production, serving both the energy and process

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industries. These systems are based on proven electrode boiler technology developed by ACME and are CE marked in compliance with standards established by the European classification society. Boiler design and production meet the requirements of EN 13445 and EN 12593. CTI oversees the complete delivery process of the electric boiler system, from initial planning through installation with ongoing support also available.

Together, CTI and Acme form a highly nimble and technically capable partnership, offering customized solutions, rapid modifications to existing equipment, and a high degree of responsiveness to customer requirements.

“Acme is a small, agile company, allowing it to quote, make decisions, and adapt to customer needs much faster than larger, more bureaucratic boiler manufacturers,” says Mäntynen.

As demand for clean energy solutions ramps up, a significant milestone was achieved when CTI successfully lifted the first European ACME-CTI electrode boiler in September 2024. In June 2025, operating in Jepua, the 10 MW jet-type electrode boiler will soon generate 28 barg of steam for heating applications in industrial processes. The delivery scope includes also the demineralized water system, feed water system, and blowdown system, with automation integrated into the customer's existing boiler setup, all turnkey delivered.

Even more recently, CTI installed a 15 MW electric boiler and feed water tank in the industrial area in Honkajoki. A new 15 MW electric boiler was also installed in connection with the Vatajankoski biomass boiler plant, which will increase the production of inexpensive and non-combustible steam.

The high-voltage electrode boiler manufactured by CTI will produce steam for use by Vatajankoski Oy. In the future, it will also be possible to store energy

produced by an electric boiler in a heat accumulator, which will later be installed next to the plant. Heat from the accumulator will also be supplied to the Honkajoki Oy (producer for high-quality renewable raw materials for animal nutrition, biofuels and fertilizers).

Currently, CTI is heavily engaged in the process industry sector, which is expected to be a major area of future growth for electrode boiler applications. At present, CTI has nine turnkey projects underway.

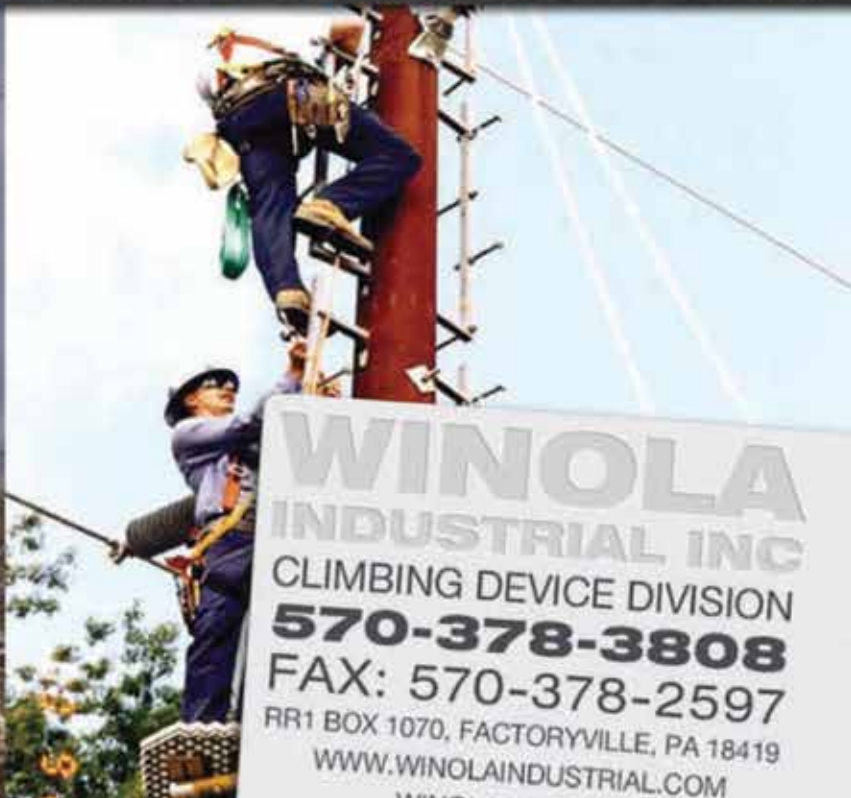
A notable recent development includes the signing of an additional order for two 50-megawatt boilers. These boilers are intended for a project in the city of Kajaani, located in central Finland. Originally, the plan was to supply heat solely for the city's district heating network. However, a new customer requirement emerged for a different temperature level than the city network typically demands.

CTI responded with an innovative proposal: using a single set of boilers to deliver two different thermal outputs without doubling the boiler capacity. By modifying the design to produce hotter water and then distributing it separately at two different temperature levels, CTI created a solution that met both needs simultaneously.

The European market for decarbonization technologies remains resilient, driven by sustained municipal investment in clean energy infrastructure aligned with long-term carbon reduction mandates. As demand continues to rise, high-voltage electrode boilers are poised to play a pivotal role by converting surplus renewable electricity into heat, supporting grid stability and emissions reduction efforts, and creating energy ecosystems that are agile during fuel price fluctuations.

www.acmeprod.com/high-voltage-electrode-steam-boiler/ •

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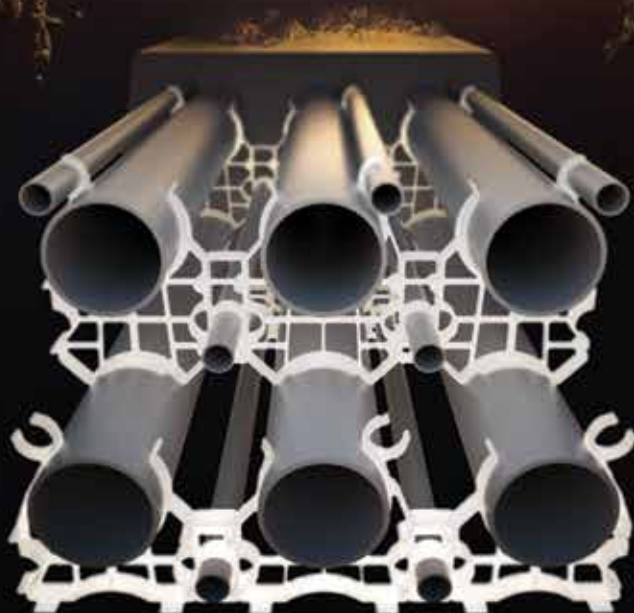
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