January 31, 2022

Via Federal eRulemaking Portal

U.S. Environmental Protection Agency
EPA Docket Center, Docket ID No. EPA-HQ-OAR-2021-0317
1200 Pennsylvania Avenue NW
Washington, DC 20460

Re: *Qnergy's Comments to the U.S. Environmental Protection Agency's Proposed Standards of Performance for New, Reconstructed, and Modified Sources and Emissions Guidelines for Existing Sources: Oil and Natural Gas Sector Climate Review*

Qnergy submits these comments to the U.S. Environmental Protection Agency ("EPA" or the "Agency") at the docket identified above in relation to its proposed standards of performance for new, reconstructed, and modified sources and emissions guidelines for existing sources (the "Proposed Rule"). In this comment letter, Qnergy focuses primarily on EPA's proposed best system of emission reductions ("BSER") and proposed standards of performance for greenhouse gases ("GHGs") and volatile organic compounds ("VOCs"), specifically as they relate to emissions from pneumatic controllers and pumps. Qnergy supports EPA's efforts to reduce methane and VOC emissions in a cost-effective manner that reflects the significant technological advancements that companies like Qnergy have made possible in recent years.

This comment letter introduces EPA to Qnergy and its revolutionary power generation technology and compressed air pneumatics solutions. Qnergy technologies demonstrate that the emissions reductions EPA has proposed are achievable, feasible, cost effective and available now for commercial deployment throughout the natural gas industry on production sites, *i.e.*, well pads (upstream), and pipelines (midstream). About 90% of Qnergy installations are "off-grid" units that provide the primary power to a site for automation, cathodic protection, and air compression. In about 10% of the remaining installations, Qnergy technology provides power as a back-up to the grid.

As described in greater detail throughout this letter, Qnergy:

- Generally supports EPA's proposed BSER and standards of performance;[1]
- Requests that EPA expressly prohibit the use of diesel and other conventional internal combustion engines ("ICE") to generate power to run zero-emissions controllers; and
- Requests that EPA expressly recognize in the BSER and proposed standards of performance for pneumatic and non-pneumatic devices alike (such as storage vessels' well casings and equipment at processing plants) the availability of and emissions reductions

[1] *See* Tables 2 and 3 of the Proposed Rule at 63118-63121.

achievable through technology like Qnergy's that meets EPA's proposed standards of performance for zero-emissions controllers and a natural gas emission rate of zero.

Qnergy also responds to several of EPA's requests for information from the Proposed Rule, including (consistent with Qnergy's request above) presenting its alternative technologies which would enable EPA to exclude conventional ICEs—which emit VOCs (such as formaldehyde) and appreciable amounts of carbon monoxide ("CO") and nitrogen oxides ("NOx")—from the possible solutions permissible under EPA's forthcoming rule.

Qnergy commends EPA's efforts to reduce methane emissions and supports the finalization of stringent BSER and standards of performance for pneumatic devices that reflect the greatest degree of emissions reductions possible. This approach advances the United States' commitment to reduce methane emissions across the globe by 30% from 2020 levels by 2030 and furthers domestic energy policy objectives.

I. Qnergy and its products

Launched in 2018, Qnergy is a U.S. company based in Ogden, Utah. It produces the most reliable standalone power generator in the distributed energy market. Qnergy's generators use free-piston Stirling engines and potentially any heat source to produce tens of thousands of hours of uninterrupted operation without the need for lubrication, maintenance, or repair. The National Aeronautics and Space Administration ("NASA") recognized this engine design as the most reliable heat engine technology "in history."[2]

Qnergy operates a 50,000-square foot factory in Ogden, Utah, with a capacity to produce more than 6,000 engines per year. This facility's current capacity is capable of meeting the demand of the U.S. natural gas supply chain. Outside of Utah, we operate a sales office in Calgary, Canada. Since the launch of our power generators in 2018, Qnergy is growing quickly, increasing in size 100% year over year, and we expect to grow from 65 to 100 employees by the end of 2022. Qnergy has built strong partnerships with many key players in the natural gas industry.

Of relevance to the Proposed Rule, Qnergy produces compressed air pneumatic systems ("CAP3") to displace methane and VOC emissions from pneumatic devices. Qnergy has developed an application allowing its Stirling generators to power CAP3, even when grid power is not available. CAP3 leverages the reliability of Qnergy's power generators to drive compressors that replace methane emissions from pneumatic devices with clean, dry instrument air. This revolutionary technology offers a low-emission alternative to the gas-powered pneumatic devices currently used throughout the natural gas industry, particularly in the upstream sector.

[2] Michael Cole, *It Keeps Going and Going: Stirling Engine Test Sets Long-Duration Record at NASA Glenn*, SPACEFLIGHT INSIDER (July 30, 2018), https://www.spaceflightinsider.com/space-centers/glenn-research-center/it-keeps-going-and-going-stirling-engine-test-sets-long-duration-record-at-nasa-glenn/.

Based on a range of capacities and operating conditions, each Qnergy CAP3 system can abate between 500 and 5,000 tons of carbon dioxide ("CO_2") equivalent per year. Qnergy's CAP3 system meets EPA's proposed standards of performance for zero-emissions controllers and a natural gas emission rate of zero both on and off the grid.[3] Our internal testing has demonstrated that Qnergy technology not only eliminates "bleeding" natural gas at well sites effectively, but it does so at the lowest emissions abatement costs of any pneumatic technology.[4]

Qnergy offers a range of CAP3 products, including large walk-in shelters with auxiliary equipment space, weather-proof reach-in enclosures, compact cabinets, grid-powered skids, and skids that work in areas where no grid connections or back-up power sources are available. These systems operate in virtually any environment, including offshore platforms, hurricane-prone regions, sandstorm-prone deserts, arctic temperatures, and other remote areas with harsh environmental and climatic conditions. The systems provide real-time measurement and reporting of instrument air supply as a proxy for abated methane and has proven to be useful in identifying methane leaks. Qnergy stands by its products and offers constant support for its customers to ensure that their systems are working properly and reducing emissions as intended.

Qnergy continues to expand the commercialization of its technology to decarbonize the natural gas supply chain. To date, Qnergy has worked with its growing base of over 80 customers in the industry to install over 600 systems in wide-ranging environments from shore to shore throughout the United States (including Alaska), Canada, and Mexico. For example, we have been fortunate to partner with customers like TotalEnergies to reduce methane emissions from venting by thousands of tons a year over the next decade as we help them build low-emission sites.[5] TotalEnergies and many other multinational and regional customers have made serious climate and methane reduction commitments in recent years that depend on our technology. Recognizing the integral role Qnergy technology plays in reshaping the industry, Qnergy recently raised capital from the Oil & Gas Climate Initiative to accelerate deployment of its methane mitigation systems throughout the world, with a focus on the natural gas exploration, production, and transport markets.[6]

II. Qnergy's technology advances the goals and statutory objectives EPA seeks to fulfill through the Proposed Rule

[3] When operating off the grid, the CAP3 system produces only negligible emissions of CO and NOx (ten- to a hundred-fold less than ICEs) from the Stirling engine's power generation, which EPA recognizes as only "secondary impacts from the use of instrument air systems" that still allow pneumatic devices to meet the proposed emission rate of zero. Proposed Rule at 63208.

[4] *See* Appendix A for more information about Qnergy's technology and its uses and Appendix E for our internal abatement cost data. Appendix E contains Confidential Business Information ("CBI").

[5] *United States: TotalEnergies and Qnergy deploy an innovative technology to reduce methane emissions on the Barnett field*, TOTALENERGIES (Oct. 11, 2021), https://totalenergies.com/media/news/press-releases/united-states-totalenergies-and-qnergy-deploy-innovative-technology.

[6] *Qnergy closes $16 million series C funding round, led by OGCI Climate investments*, QNERGY (Nov. 16, 2021), https://www.qnergy.com/qnergy-closes-16-million-series-c-funding-round-led-by-ogci-climate-investments/.

The Clean Air Act assigns EPA the unique responsibility and authority to regulate harmful air pollutants emitted by the natural gas industry.[7] To fulfill this responsibility, EPA promulgates rules that limit emissions of harmful pollutants like methane and VOCs through emissions guidelines premised on the BSER.[8] EPA uses the BSER to develop standards of performance for pollution sources, which States may incorporate into plans that impose regulatory requirements to reduce emissions.[9] As the Agency recognizes in the Proposed Rule, technology is key to monitoring, minimizing, and even eliminating emissions throughout the natural gas supply chain from wellhead to commerce. Some innovative technologies already are being deployed throughout the industry to reduce emissions, such as the use of advanced leak detection and repair technology. In other areas, more progress is necessary to lower costs and further drive emissions reductions without creating unintended environmental harm from the use of substitution technology, such as ICEs powered by conventional fuel sources.

Pneumatic devices particularly are ripe for progress. Historically, these devices have produced significant GHG emissions across the natural gas industry. Pneumatic devices activate valves and pumps, mainly for process control and chemical injection and, while doing so, vent spent gas (*i.e.*, methane) directly into the air. On an individual basis, each pneumatic device emits relatively small amounts of methane; on a collective basis, the millions of bleeding pneumatic devices in the global natural gas supply chain constitute one of the largest sources of methane emissions. Indeed, according to the International Energy Agency, emissions from bleeding pneumatic devices constitute about 15% of the global greenhouse gas emissions of the oil and gas value chain.[10]

To maximize emissions reductions from pneumatic devices in a cost-effective manner, EPA regulations must recognize in the BSER and standards of performance the role of innovative technologies such as Qnergy's CAP3 technology, which virtually eliminates methane emissions from pneumatic devices and provides system monitoring to ensure effective and continuous emission control. Qnergy respectfully submits to EPA that the CAP3 system's performance can raise the bar for pneumatic controllers and pumps. It can serve as a basis for the BSER, as demonstrated by an increasing reliance by leading companies in the industry[11] because of CAP3's elimination of methane emissions, commercial availability, lowest possible abatement costs [redacted], and overall environmental performance (*e.g.*, lower CO_2 equivalent emissions

[7] Reorganization Plan No. 3 of 1970.

[8] 42 U.S.C. § 7411(a), (b).

[9] 42 U.S.C. § 7411(c).

[10] *Reducing Methane Emissions: Best Practice Guide Pneumatic Devices*, METHANE GUIDING PRINCIPLES (Nov. 2019), https://methaneguidingprinciples.org/wp-content/uploads/2019/11/Reducing-Methane-Emissions-Synopsis-Pneumatic-Devices.pdf.

[11] Qnergy's technology is well known, and accepted, throughout the industry. Over 80 customers—including regional, national, and global natural gas leaders—have chosen to use Qnergy technology in the field to reduce emissions. Appendix B provides a partial list of active users among U.S. natural gas producers. Additional users can be found in the attached presentation in Appendix D. All of these materials contain CBI.

and only negligible emissions of non-GHGs or VOCs).[12] This already widespread and increasing deployment throughout the industry demonstrates that the CAP3 technology is practical, cost-effective, and capable of continuing to transform the industry.

Furthermore, Qnergy's technology targets natural gas facilities, which often are located in remote settings or in or near environmental justice communities. In addition to reducing global climate pollutants, CAP3 reduces local air pollution and mitigates environmental injustice, all while producing only minimal noise emissions.[13]

Additionally, Qnergy will continue to leverage its existing customer relationships to generate investments and drive greater market penetration, while building on its strategic partnerships with research and governmental institutions (*e.g.*, NASA, Idaho National Laboratory) to find ways to improve this technology.[14] Eventually, Qnergy plans to expand its Stirling-engine-powered clean energy technology to other sources that EPA and other federal agencies regulate or support (*e.g.*, biogas, telecommunications, electric-vehicle charging stations, residential and commercial power generation).

Qnergy's overarching goal is to enable all natural gas producers to minimize methane emissions from pneumatic devices through the increased availability of our technology, which will play a critical role in helping EPA fulfill its statutory obligation to mitigate harmful air pollution. By ensuring that the final rule's BSER and standards of performance reflect technology such as Qnergy's CAP3, EPA will achieve the greatest possible reductions in emissions through achievable, cost-effective technology.

III. Qnergy supports the Proposed Rule and encourages EPA to promulgate the most stringent emissions reduction standards possible

EPA's proposed BSER and standards of performance are supported by federal law. Section 111(a)(1) of the Clean Air Act requires EPA to impose performance standards that reflect "the degree of emission limitation achievable through the application of the best system of emission reduction which (taking into account the cost of achieving such reduction and any non-air quality health and environmental impact and energy requirement) the Administrator determines has been

[12] *See* Appendices C, D, and E for more information based on our internal testing and data collection efforts. These appendices contain CBI.

[13] It is possible to have a conversation without raising one's voice in the immediate vicinity of an actively operating CAP3 system, thereby protecting workers and local communities from excess noise pollution and minimizing disruption to nearby wildlife.

[14] In Alberta, Canada, where Qnergy has been operating for two years in the gas pneumatic space, the government (having become familiar with the technology's performance) considers Stirling engines as an "alternative energy" source. *See* "Quantification Protocol for Greenhouse Gas Emission Reductions from Pneumatic Devices", page 8, https://open.alberta.ca/dataset/9f28037a-df38-403a-ac3c-51ed3a53d605/resource/bd3c728a-5cec-42bb-bb9b-f1846cc6d22a/download/aep-quantification-protocol-for-greenhouse-gas-emission-reductions-from-pneumatic-devices-versio.pdf ("Alternative electricity includes solar, wind, biomass, microturbine, waste pressure, waste heat, solid oxide fuel cell and Stirling engine power sources").

adequately demonstrated."[15] Through Qnergy's technology, the industry has demonstrated the ability to reduce emissions from pneumatic controllers and pumps to the degree identified in the Proposed Rule. This technology should form the basis of the proposed BSER for pneumatic controllers and pumps.

Qnergy supports the significant steps EPA is taking to reduce emissions of methane, a key driver of global climate change, which impacts everyday American life and the economy. If finalized, EPA's proposed updates to its regulations would strengthen and expand the current requirements under Section 111(b) of the Clean Air Act for methane emissions from new, modified, and reconstructed facilities, including facilities not currently regulated, and for emissions from existing, or "designated," facilities. In particular, Qnergy supports EPA's most stringent proposed BSER for both pneumatic controllers and pneumatic pumps: zero-emissions controllers and a natural gas emission rate of zero, respectively.[16]

Our testing shows that Qnergy's CAP3 product produces no methane or VOC emissions while providing compressed air to power pneumatic devices. Other power generation technologies—such as those that operate with ICE-powered generators using natural gas or diesel—should not form the basis for the BSER because these systems leak methane due to incomplete combustion. This is a phenomenon known as "methane slip,"[17] and a similar phenomenon is known to occur with respect to VOCs.[18] These emissions are contrary to the purpose of EPA's performance standards and undermine the Clean Air Act's goals. In Appendix E (which contains CBI), Qnergy provides its internal data demonstrating the different emission profiles between its Stirling engine generators and a typical gas-powered ICE. This data shows that, although Qnergy's Stirling engines do emit small quantities of GHGs (like most energy generators), these emissions are, as EPA observes in the Proposed Rule, "minimal, and no other secondary impacts are expected."[19] By contrast, ICE-powered generators generate appreciable emissions, including formaldehyde. Because Qnergy's CAP3 systems allow pneumatic controllers to reach a VOC and methane emission rate of zero and pneumatic pumps to reach a natural gas emission rate of zero, they represent a significant improvement over traditional gas-powered engines that may be used to operate pneumatic devices. EPA's final rule should expressly prohibit the use of ICEs as a means to satisfy the BSER and standards of performance.

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[15] 42 U.S.C. § 7411(a)(1).

[16] Proposed Rule at 63118-63121.

[17] "Equipment that uses natural gas as a fuel is generally designed to have at least 98% combustion efficiency (that is, at least 98% of the gas will be burned), so some methane is released as unburned gas. This is known as methane slip. Even though methane slip is generally a small percentage of the fuel used, in operations that use a significant amount of energy, methane slip can be a major source of emissions." *Reducing Methane Emissions: Best Practice Guide Pneumatic Devices*, METHANE GUIDING PRINCIPLES (Nov. 2019), https://methaneguidingprinciples.org/wp-content/uploads/2019/11/Reducing-Methane-Emissions-Synopsis-Pneumatic-Devices.pdf.

[18] Appendix D describes our internal testing on the environmental performance of Qnergy's generators compared to ICE generators. This appendix contains CBI.

[19] Proposed Rule at 63208. Based on our internal data, Qnergy's technology can achieve up to or greater than 99% emission control. *See* Appendix E for more information. This appendix contains CBI.

Additionally, Qnergy submits that as a result of its technology, the Agency can promulgate a performance standard that pushes the industry toward at least 95 percent control of emissions from pneumatic pumps in the production and transmission and storage segments. As noted above, Qnergy's CAP3 technology allows pneumatic devices to achieve emission rates of zero. Less stringent emissions standards would not necessarily reflect the "best" system of emissions reduction, undermining the Agency's goals and statutory obligation.

Even when not connected to the grid, Qnergy's off-grid-capable CAP3 technology is not only sustainable, but also dependable. For example, when Hurricane Ida passed directly over more than 100 Qnergy systems, Qnergy's customers did not report any power loss, unlike most others in the region. This technology is critical for achieving methane and VOC emissions reductions from pneumatic controllers and pumps located at sites that lack on-site power and experience harsh environmental conditions (*e.g.*, in Alaska).[20]

Qnergy also notes that its technology can replace all controller types, regardless of whether they are continuous bleed natural gas driven or intermittent natural gas driven. With zero- or near-zero-emissions technology that uses compressed air available, the natural gas bleed rate becomes irrelevant.

IV. Responses to EPA's requests for comment

In this section, Qnergy provides responses to other EPA specific requests for comment.

A. Zero-emitting, Low-bleed, and Intermittent Pneumatic Controllers

The Proposed Rule would require all new and existing pneumatic controllers at production, processing, and transmission and storage facilities to have zero methane and VOC emissions, with the exception of sites in Alaska that do not have power. The Proposed Rule also would regulate emissions from intermittent vent pneumatic controllers for the first time. With respect to these proposals, the Agency first requested information on other potential control options that could demonstrate compliance with a standard of zero-emitting pneumatic controllers.[21]

Qnergy requests that EPA formally consider our technology as a control option that demonstrates compliance with its proposed zero-emissions standards for the purpose of compliance with the forthcoming rule. Qnergy's CAP3 products do not emit methane or VOCs (including toxic VOCs like formaldehyde) and therefore should enable our customers to achieve a methane/VOC or natural gas emission rate of zero. Although the Stirling engine generators used to power the CAP3 produce some CO_2 equivalent emissions and trace amounts of other non-methane and non-VOC emissions (*e.g.*, CO and NO_x) when operating independently from the grid, these emissions are

[20] Proposed Rule at 63118-63121. *See also* Appendix D, slides 13-14, for a demonstration of how Qnergy's technology works in extreme weather conditions. This appendix contains CBI.

[21] Proposed Rule at 63202-63209.

significantly lower when compared to applicable industry benchmarks (*e.g.*, gas-powered ICEs) and federal and some California emissions standards for generators in other applications outside of the oil and gas industry.[22] Qnergy notes that EPA recognizes in the Proposed Rule the potential for such "minimal" emissions that are "indirect, variable, and dependent on the electrical supply used to power the compressor."[23] Accordingly, Qnergy respectfully submits that its CAP3 systems, even when powered by a Stirling engine, meet the proposed zero-emissions standards.

EPA also requested information on specific functional needs that would require a low-bleed or intermittent controller.[24] Qnergy's CAP3 technology can be applied to all pneumatic controller types, eliminating the need to vent natural gas to the atmosphere. While low-bleed and intermittent controllers are prevalent in the industry today, Qnergy submits that these controller types produce emissions that the industry is capable of eliminating. Simply put, there is little need for these controller types when a feasible, cost-effective alternative with no bleeding is available.

Qnergy has developed multiple configurations to cover the spectrum of possible well-pad pneumatic emissions, spanning from a minimum of one small "CAP3-nano" providing 1 scfm to a single pad in a low-bleed site up to a double "CAP3-M" providing 24 scfm to a 16-well pad. The different CAP3 configurations are presented in Appendices D and E (which contain CBI). Again, Qnergy maintains that no specific functional needs require a low-bleed or intermittent controller that vents natural gas into the atmosphere, and so we support EPA's promulgation in the final rule of standards of performance that move the industry toward pneumatic devices that operate without methane and VOC emissions.

B. Use of Diesel or ICE Generators

The Proposed Rule recognizes that ICE-based generators used to power pneumatic controllers produce formaldehyde emissions and can result in so-called "secondary impacts." For this reason, EPA does not intend for diesel generators to power zero-emissions controllers. In particular, the Agency solicits comment on whether owners and operators would use diesel generators to generate power to run zero-emission controllers.[25]

ICE generators typically are cheaper to purchase than lower emitting generators, and so some owners and operators may be inclined to purchase them to power pneumatic devices. However, ICE generators require higher maintenance costs compared to Qnergy technologies.[26] Qnergy supports EPA's proposal for BSER and corresponding standards of performance to prohibit the use of such generators, as they are not only unnecessary, but would contravene the emissions

[22] *See* Appendix E for Qnergy's internal emissions test data and Generac emissions data. This appendix contains CBI.

[23] Proposed Rule at 63208.

[24] Proposed Rule at 63179, 63207.

[25] Proposed Rule at 63207.

[26] *See* Appendix E for a total cost of ownership analysis for the "CAP3-F" configuration. Appendix E also contains an Excel model (in this case for the "CAP3-M" configuration) based on our internal testing. This appendix contains CBI.

reductions the Proposed Rule seeks to implement. By adopting technology like CAP3, oil and gas owners and operators can minimize overall emissions and completely eliminate methane and VOC emissions from pneumatic devices, at a lower total cost of ownership. The forthcoming rule should expressly recognize this and prohibit the use of ICE-powered generators as a power source for pneumatic devices.

C. Requirements for Grid-tied Pneumatic Pumps

EPA also requested comment on whether it is technically feasible to require the use of zero-emitting pneumatic pumps at new and existing facilities with access to electric power or solar power.[27] Qnergy's CAP3 systems can work on and off the grid and with both renewable and non-renewable energy sources.[28] All of Qnergy's CAP3 systems can be connected either to Qnergy's generators (which are the most reliable power source available on site) or to any other source of power (including grid power), when it exists. This technology is reasonably affordable and already has been deployed at a number of sites across the country. Because Qnergy has demonstrated that it is technically feasible to require the use of zero-emissions pneumatic pumps at facilities with or without access to electric or solar power, it requests that EPA base its BSER on the understanding that any facilities with access to electric or solar power incorporate zero-emissions pneumatic pumps.

V. Conclusion

Qnergy's technology achieves demonstrable emissions reductions for pneumatic devices at the lowest abatement cost in the industry, and so should form the basis for EPA's BSER and performance standards for pneumatic controllers and pumps. While Qnergy continues to research and develop new applications for its revolutionary technology, it currently provides applications for pneumatic devices, well pad automation, and pipelines (through cathodic protection) that are compatible with all natural gas facilities that use these devices. As Qnergy attracts greater demand and investments, we can continue to provide our emissions-saving solutions at a reasonable cost to the industry, helping the country's operators meet climate goals while maintaining economic viability. Upon EPA' request, Qnergy is willing to share confidential pricing information with the Agency as well as anonymized user data and benchmarks on air consumption across the industry.

Qnergy supports the Proposed Rule and EPA's efforts to promulgate defensible performance standards for the natural gas industry that reflect available, cost-effective abatement technology. As noted throughout this letter, Qnergy urges EPA to adopt the strongest performance standards possible to continue to push the industry to develop and improve innovative technologies that help it meet the Clean Air Act's goals. In particular, Qnergy believes these goals can be best furthered through:

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[27] Proposed Rule at 63227.

[28] Note that the "CAP3G" configuration is the variation of this technology capable of being powered by the grid.

- Adoption of the proposed BSER and standards of performance identified in the Proposed Rule for pneumatic and non-pneumatic devices;
- Formal recognition of technology such as Qnergy's in forming the basis for the proposed BSER and standards of performance for pneumatic pumps and controllers and some non-pneumatic devices, as applicable; and
- Exclusion of technologies from the BSER that emit appreciable amounts of VOCs, CO, and NOx, such as those powered by ICEs (regardless of whether operated by natural gas or diesel).

As these technological advancements become integral components of EPA's standards of performance and States' implementing regulations, Qnergy stands ready to assist the natural gas industry in meeting the significant, but attainable, emissions reduction challenges that lie ahead while helping the country meet its climate goals and maintain an adequate energy supply. Qnergy appreciates EPA's attention and welcomes the opportunity for further dialogue regarding our technology and the ways it can promote the important statutory goals EPA seeks to fulfill with this rulemaking.

Please do not hesitate to contact me with any questions.

Best regards,

Ory Zik
Chief Executive Officer
Qnergy
300 W 12th St., Ogden, UT 84404
Office: 617-943-3215
Email: ory.zik@qnergy.com

Appendix A: General Information about Qnergy's Technology

Free Piston Stirling Engine. The original Stirling engine was invented by Robert Stirling in 1816. It is also called external combustion engine because heat energy is applied to the outside of the device. Like a steam engine or internal combustion engine, a Stirling engine converts heat energy to mechanical energy (work) by repeating a series of basic operations, known as its cycle. Stirling engines use pistons but the engine itself is sealed to the atmosphere.

The engine operates using the Stirling cycle, which can theoretically reach the maximal thermal efficiency known as Carnot efficiency. The efficiency achieved in practice is less due to pressure and thermal losses in the engine. The Stirling cycle operates on a closed regenerative thermodynamic cycle, with cyclic compression and expansion of a working fluid at different temperature and pressure levels.

The heat is transferred to the engine's working gas through the walls of the primary heater. The engine is a completely closed system. The working gas (which may be air or an inert gas such as helium or hydrogen) forces the pistons in the engine to move, compressing and expanding the working fluid, thus producing mechanical energy that can be used to drive a generator and produce electricity.

The original Stirling Engine evolved into what is known as the kinematic Stirling engines where manual linkages like cranks are used to move the working fluid inside the engine. Despite the superior theoretical efficiency, the kinematic Stirling engine did not gain significant commercial traction over the conventional internal combustion engines.

The Stirling engine was modified to the FPSE in the early 1960s with a design that reduces the number of moving parts and nearly eliminates friction and wear altogether. FPSE use pressure variations in the working fluid to drive a linear alternator. In the FPSE the moving parts have no side load thanks to the lack of connecting rods, which enables a long operating life without the need for lubrication. In FPSE the mechanical dynamics and the thermodynamics are highly coupled, making designing a FPSE more complicated than designing a kinematic Stirling engine. The FPSE can operate very quietly, since off-axis motions and forces are eliminated, hence resulting vibrations to the engine are in the axial direction and may be easily isolated.

The motion in the FPSE is linear and the piston is suspended on flexures, giving rise to the name Free Piston Stirling Engine. The engine is contactless (i.e. no contact between moving parts, fully sealed and requires no lubrication or oil change). Since the FPSE have no manual linkages, both the reliability and life expectancy of the engine are increased as there is nearly no wear in the system. The FPSE construct allows us to build systems that are, always-on and can serve as a source of reliable primary and/or standby power. Among the benefits attributed to FPSE beside high reliability, low emissions and fuel flexibility. In the last few decades Qnergy and its predecessors improved the FPSE technology in term of manufacturability, cost and power density.

Electronic controller firmware and hardware. We have developed and are manufacturing an electronic control board which we call Qnergy Electronic Control ("QEC"). The QEC is responsible for the health and the operation of the engine. Among other functions, the QEC verifies the stroke of the engine, ensuring that at any given time the engine is cooled by water and does not over stroke.

From the electrical standpoint, the QEC converts the Stirling Engine AC power to DC power. It also uses our firmware to accurately follow customers' electrical loads. In addition, the QEC has a bidirectional battery interface which enables the QEC to charge its DC buses during startup. This allows the QEC to provide AC auxiliary power to a system when the engine is not providing power.

System. The engine + controller are the 'muscle' and 'brain' of our products. But there is still a need for a body to have a full product. This is the system. It includes the engine and controller but also a Coolant Loop, Heat Rejection Unit, Local User Interface and Control ("LUI") and more.

Remote monitoring of generators and compressors. Our PowerGen units are connected to a cloud-based IoT platform and a database server. Data is pushed constantly to monitor performance and provide early alerts, which are created for

faults or any other abnormalities. Systems typically communicate via an amplified cellular signal. We can also provide a satellite option in remote locations where cell signal is unavailable. For CAP customers we enable methane abatement monitoring that enables quantifying their emissions for internal or reporting purposes such as carbon credits.

For additional information, *see* the presentation to EPA in Appendix D, which contains CBI.

CONFIDENTIAL BUSINESS INFORMATION

Appendix B: Partial List of Active Users

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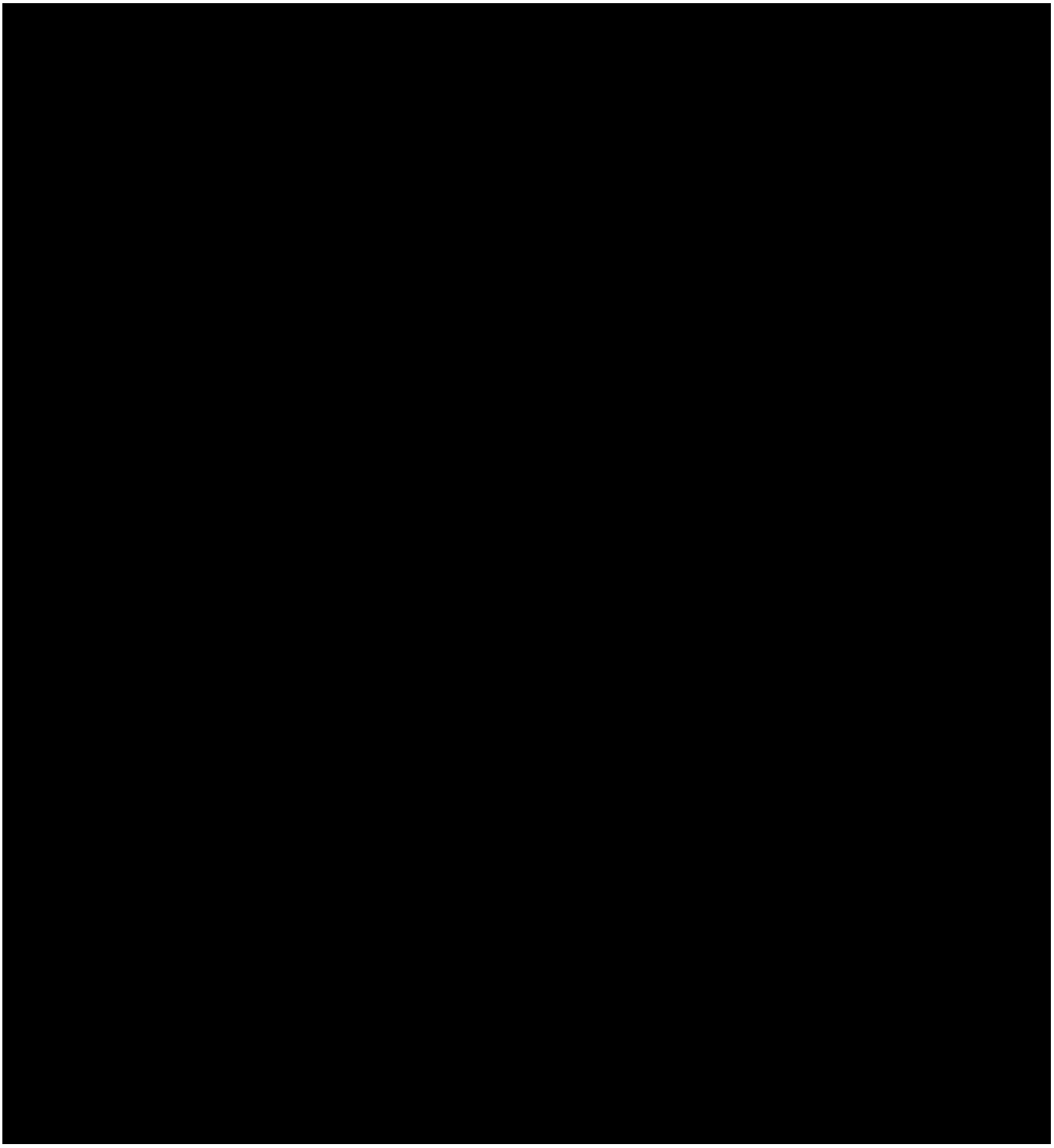
Appendix C: Environmental Performance (based on Qnergy's internal testing)



CONFIDENTIAL BUSINESS INFORMATION

Appendix D: Confidential Presentation to EPA

Qnergy

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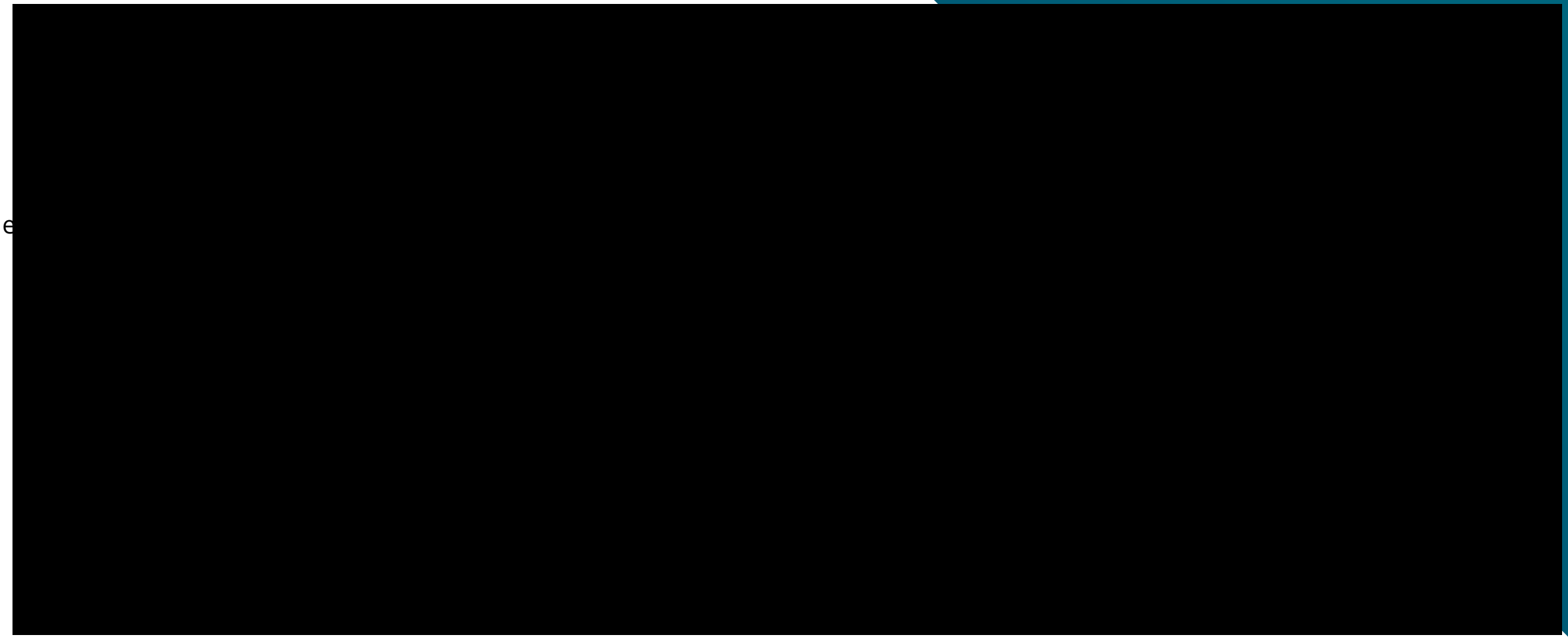
Executive Summary



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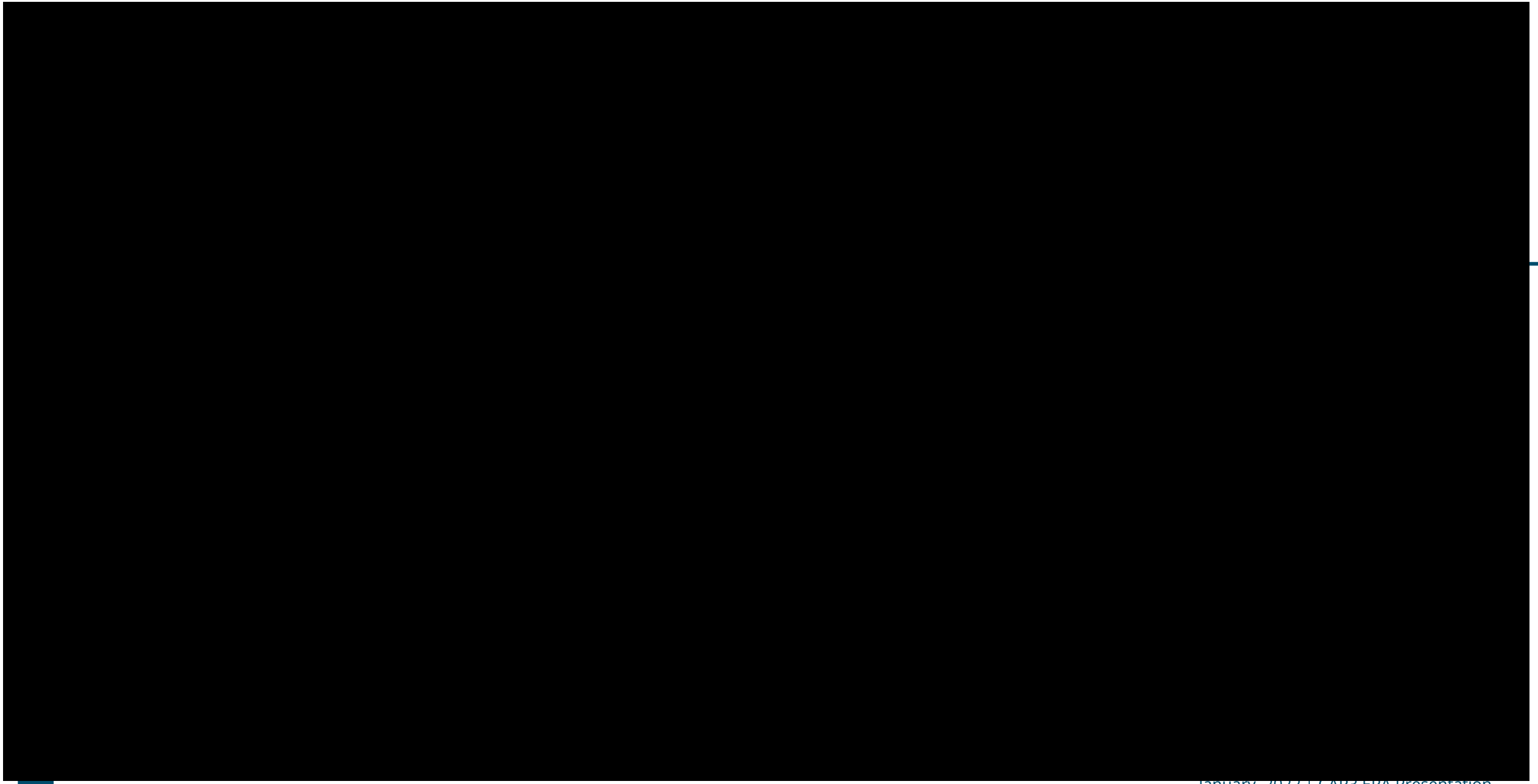
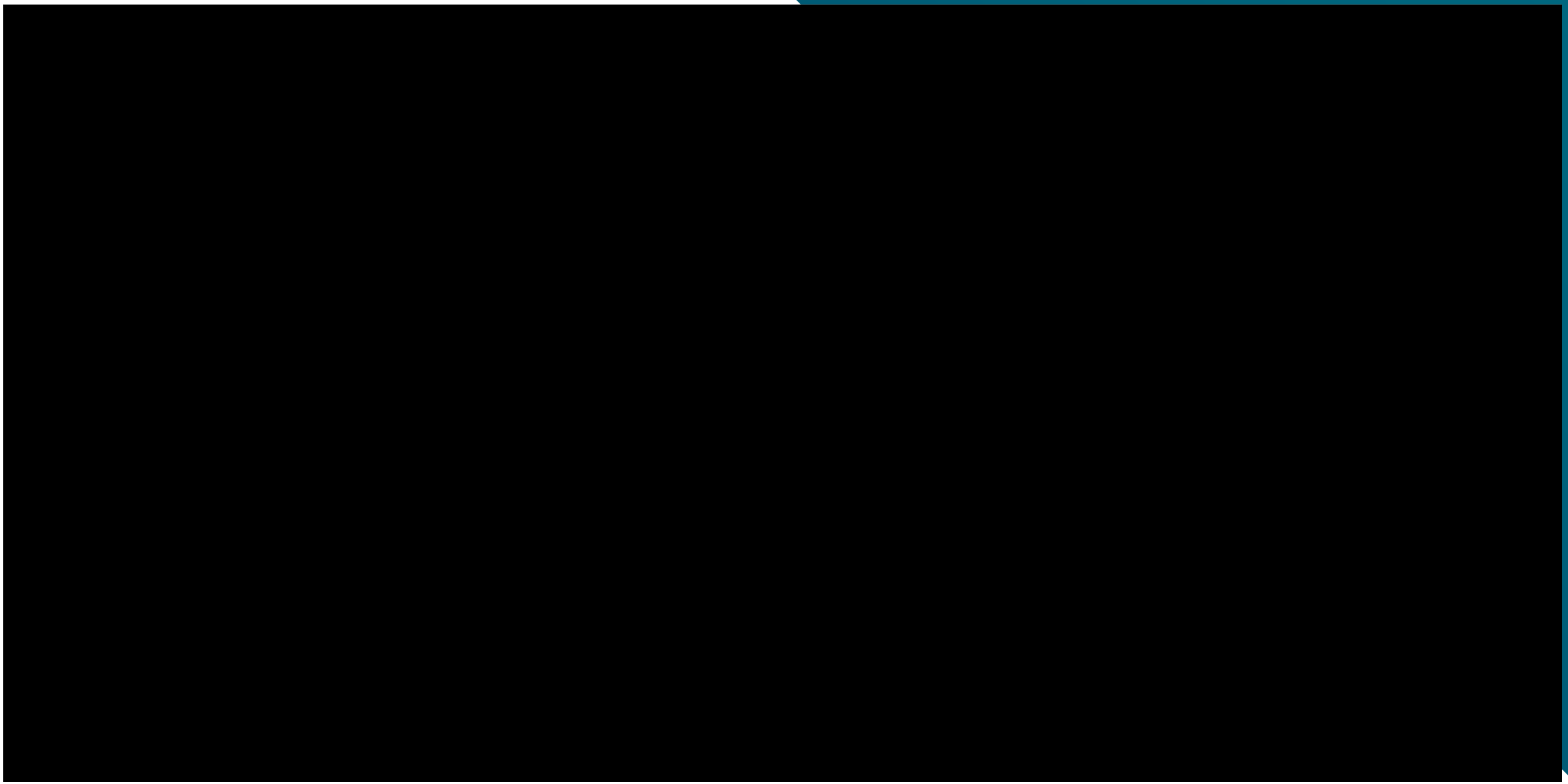
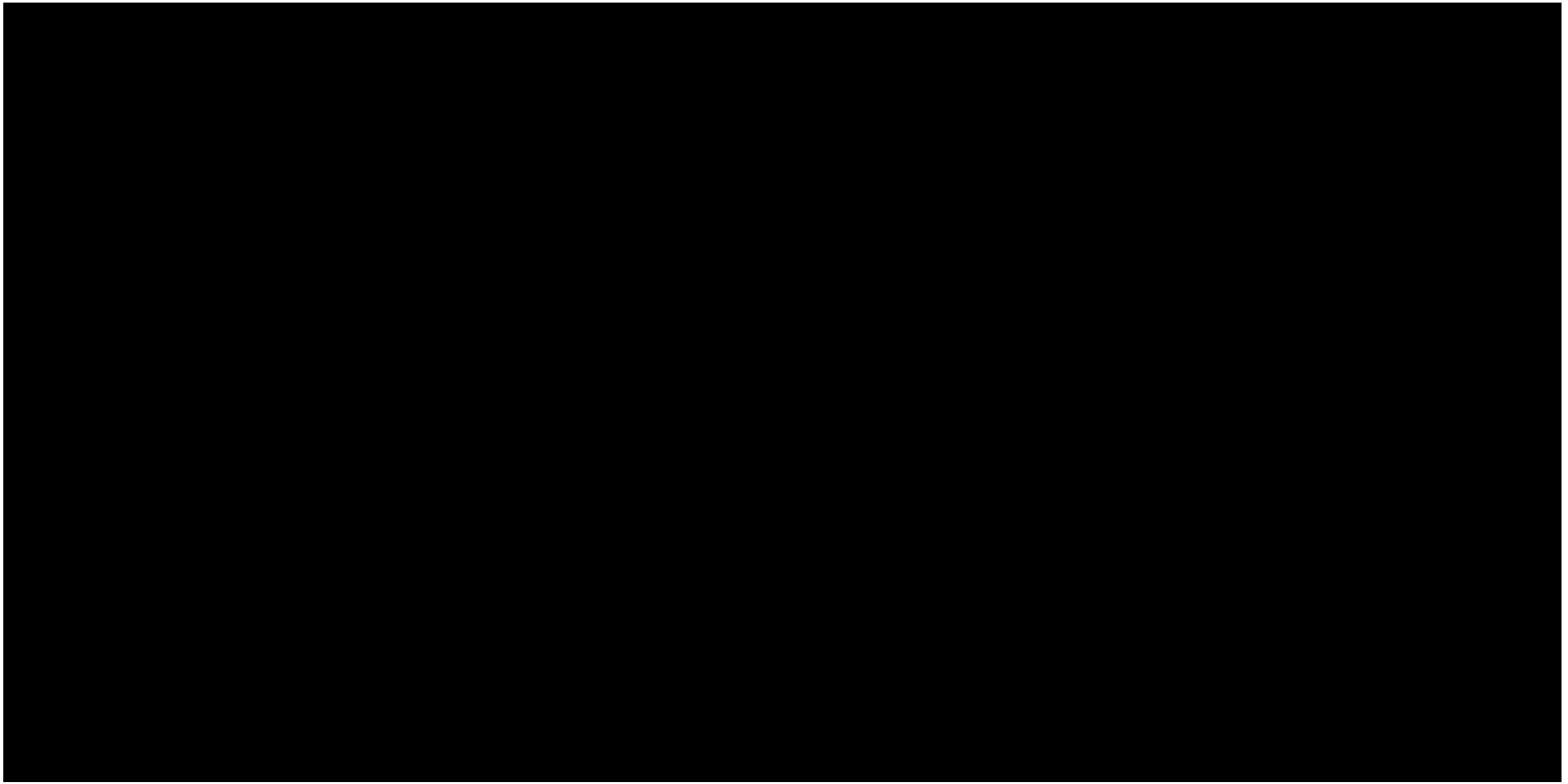
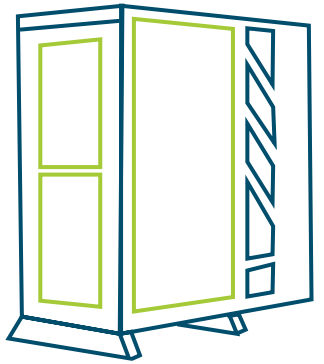







CAP3

[redacted]



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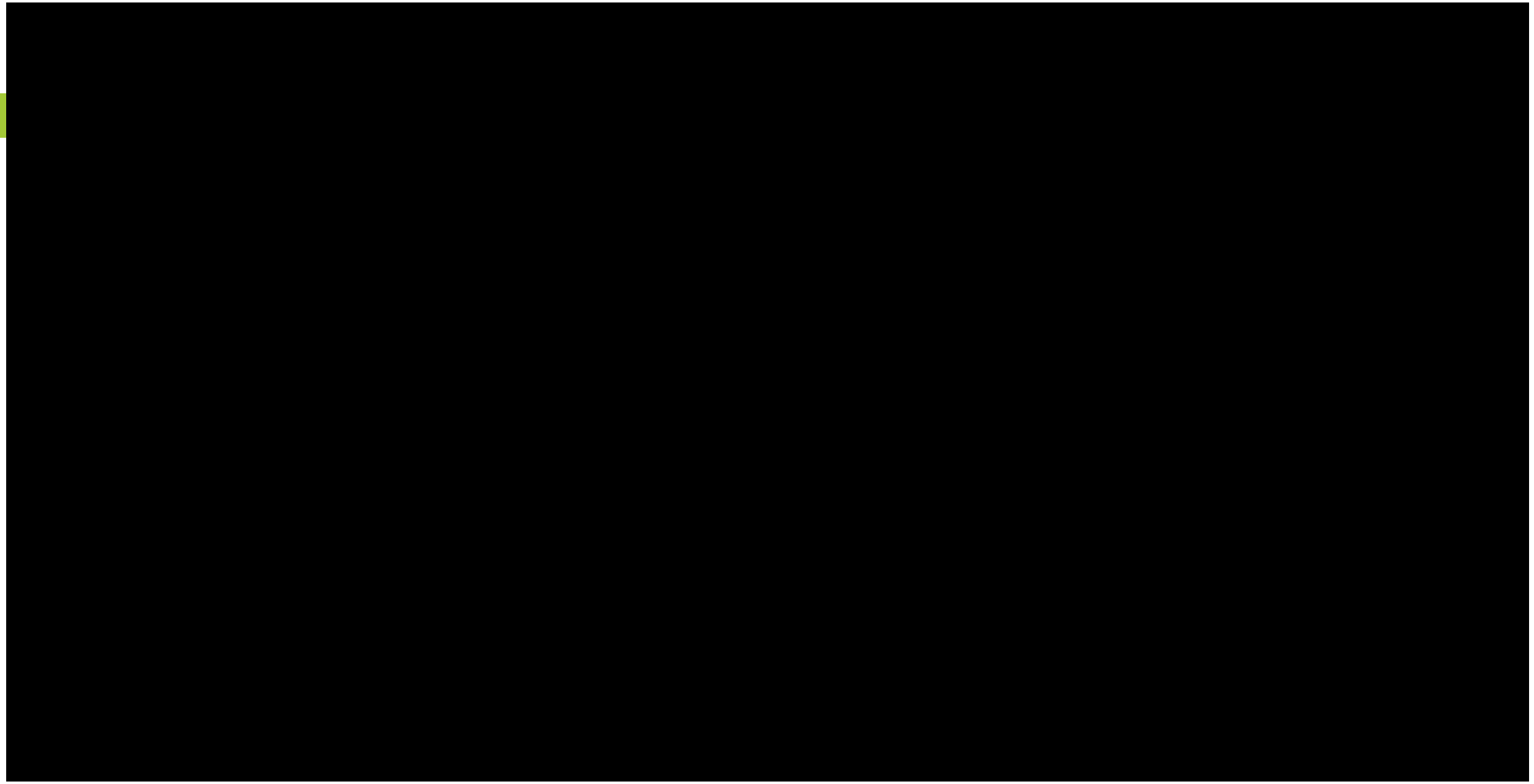

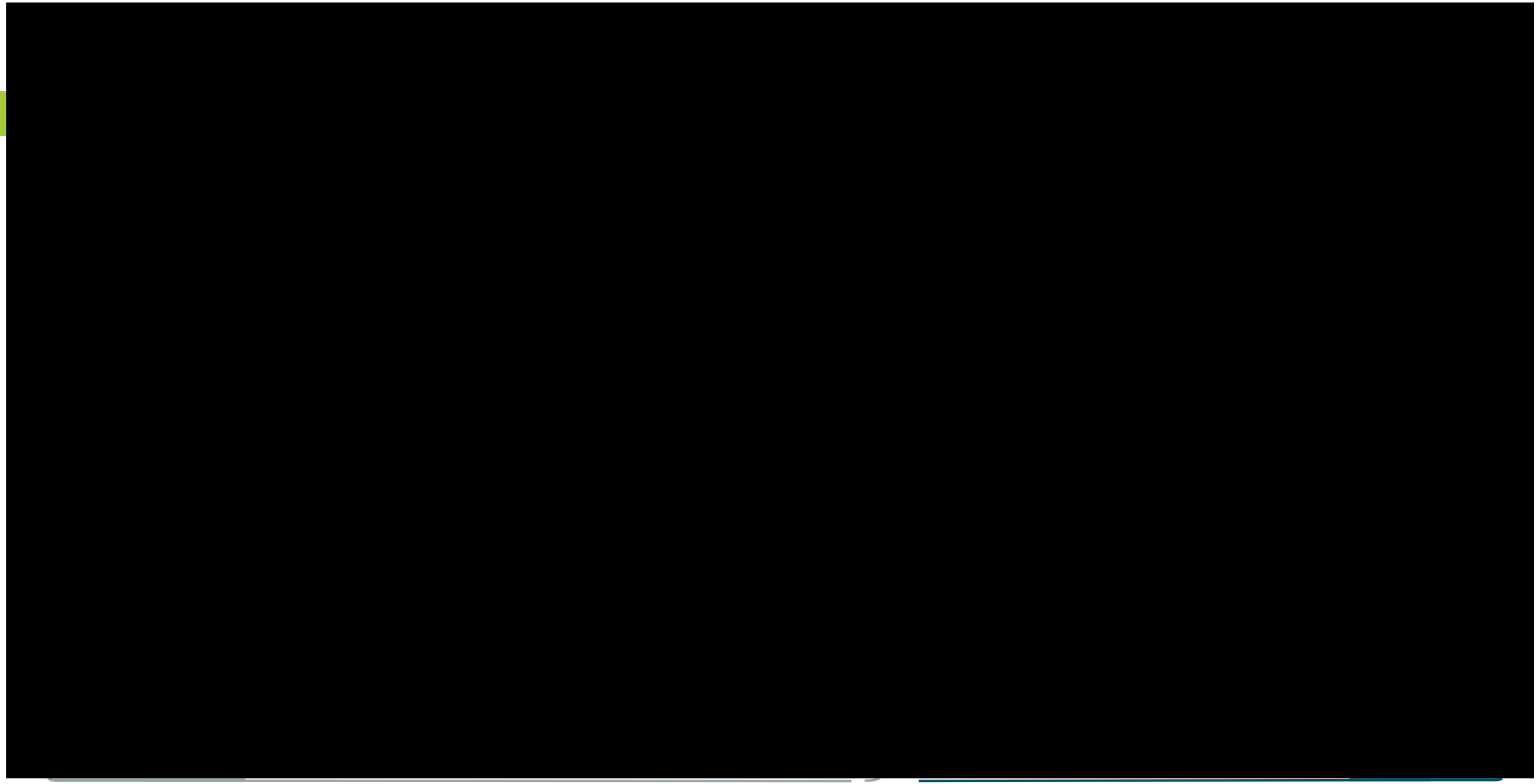

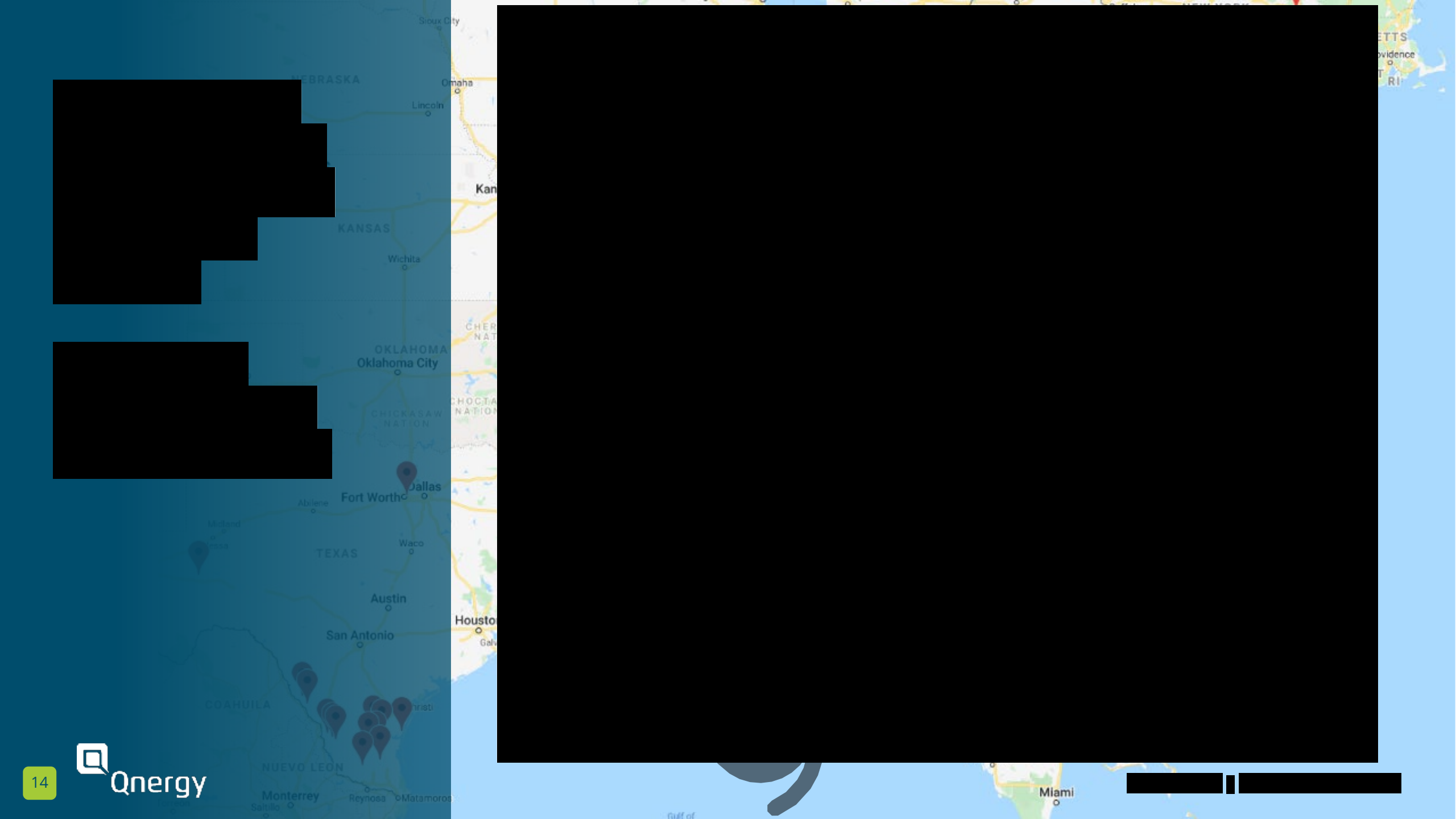
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Austin
San Antonio
COAHUILA
NUEVO LEON
Monterrey
Reynosa
Matamoros
Miami

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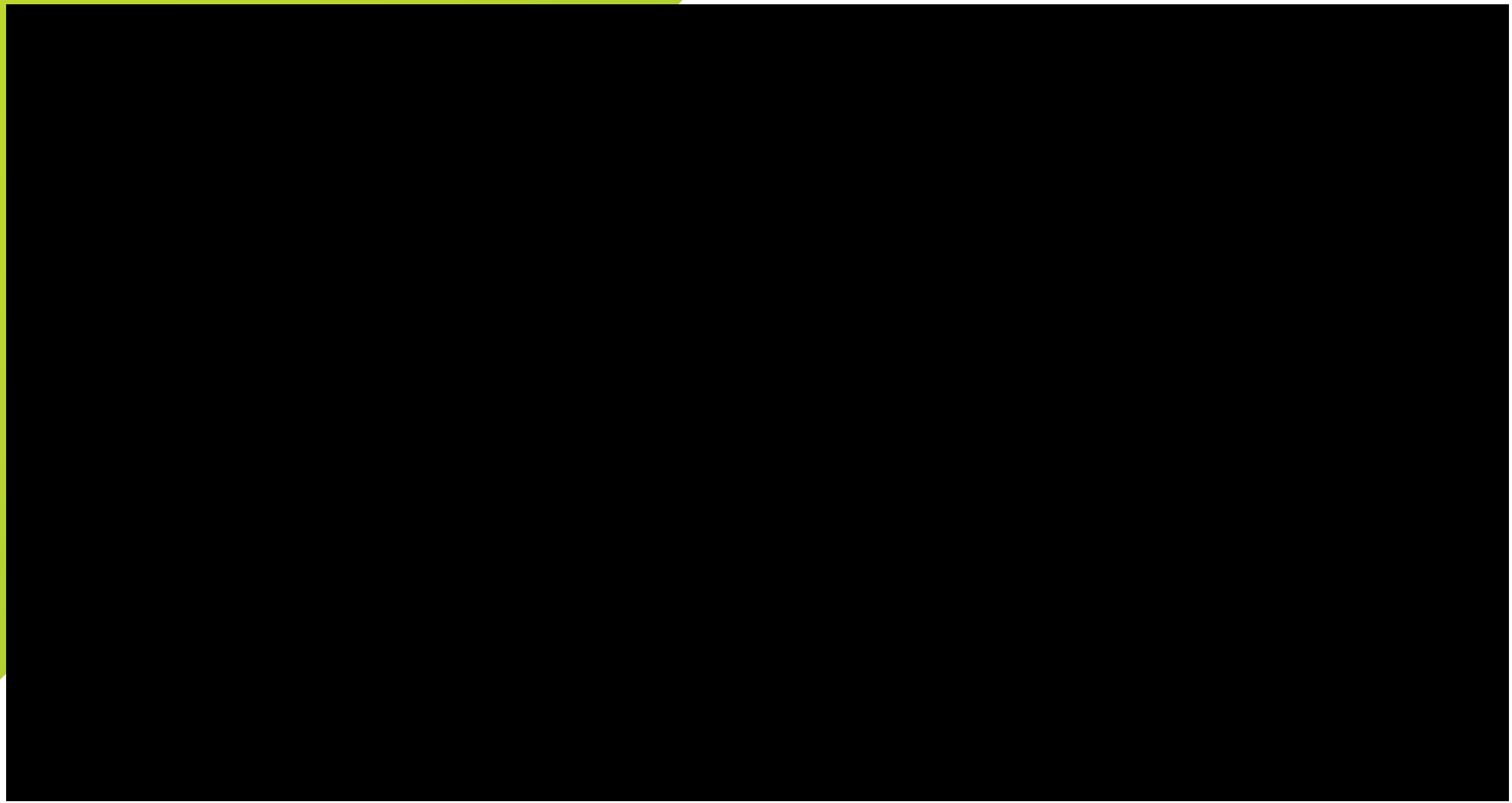

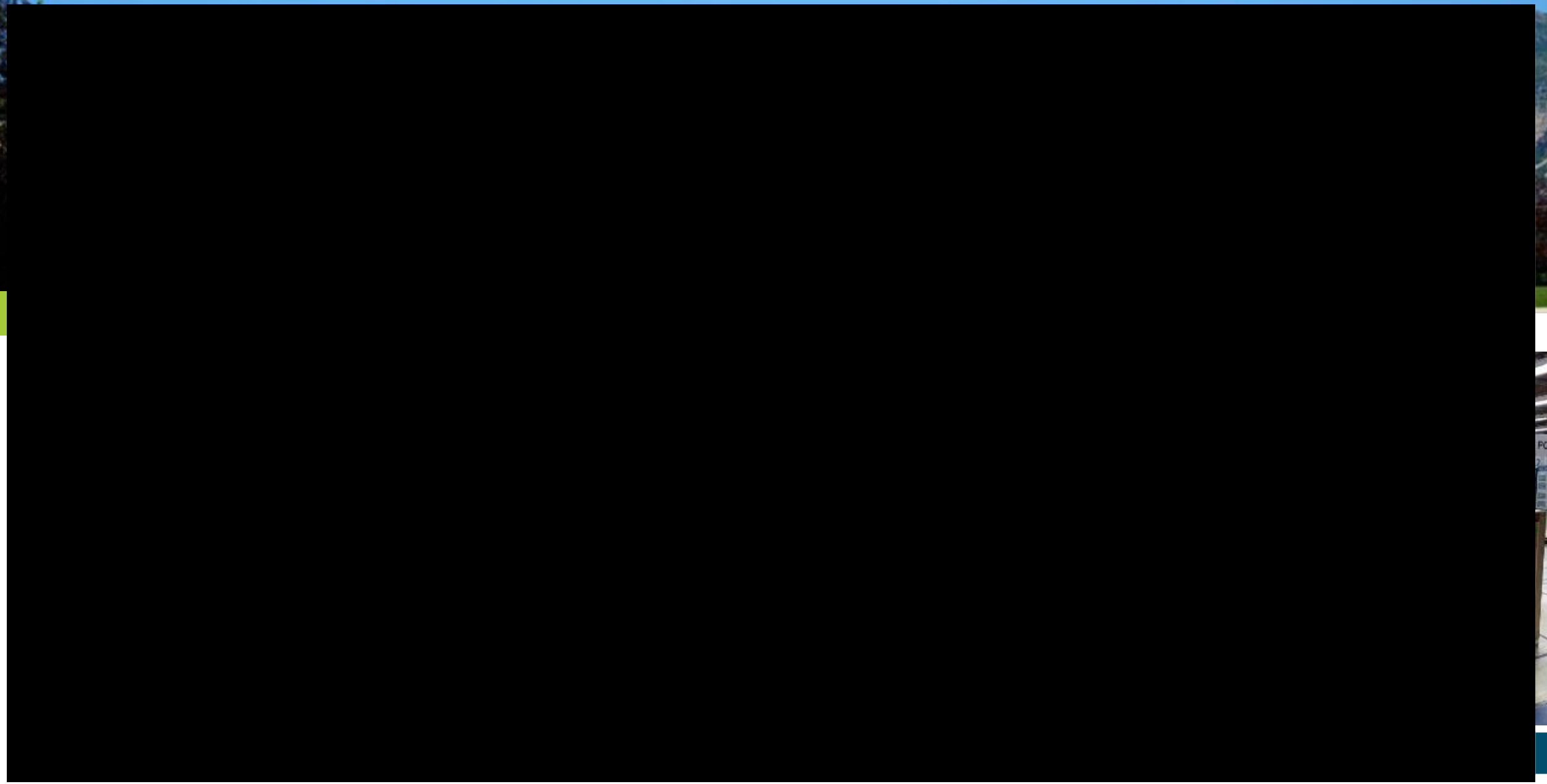

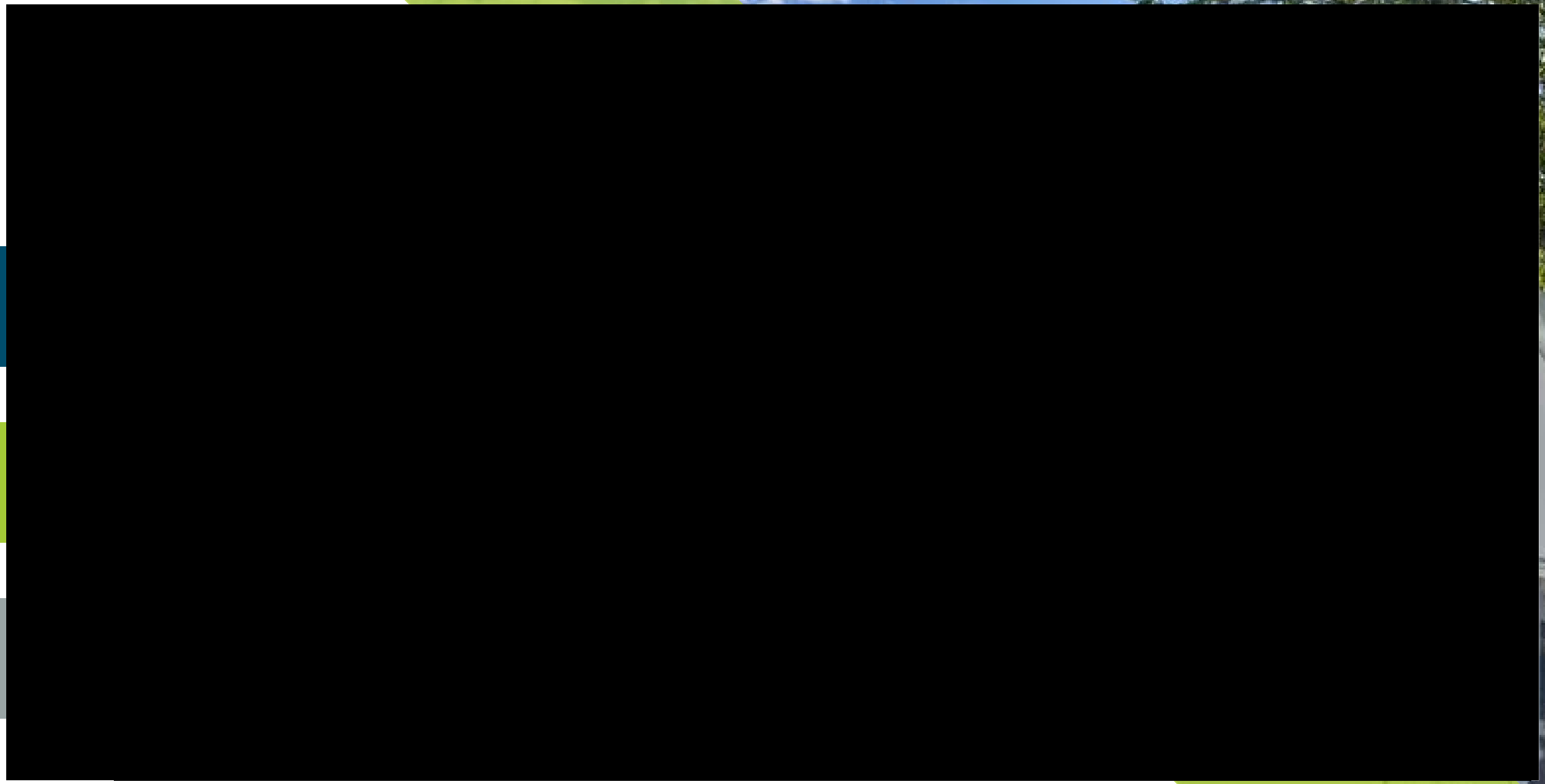

info@qnergy.com | qnergy.com
300 W. 12th Street, Ogden, UT 84404
4960 13th Street S.E., Calgary, Canada T2G5M9

CONFIDENTIAL BUSINESS INFORMATION

Appendix E: CAP3 Emission and Cost Data (based on Qnergy's internal testing)