Qnergy

December 29, 2022

Via Federal eRulemaking Portal: *a-and-r-docket@epa.gov*

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*

To whom it may concern:

Qnergy, Inc. ("**Qnergy**") appreciates the opportunity to comment on the supplemental proposal to the U.S. Environmental Protection Agency ("**EPA**") *Standards of Performance for New, Reconstructed, and Modified Sources and Emissions Guidelines for Existing Sources: Oil and Natural Gas Sector Climate Review (Federal Register, Vol. 87, No. 233 / Tuesday, December 6, 2022), 40 CFR 60* (the "**Proposed Rule**"), and respectfully submits the following comments which supplement the comment letter sent by Qnergy to EPA January 31, 2022 with respect to the November 2021 proposed rules (the "**Original Comment Letter**"). The current letter refers to the standard and BSER for Pneumatic Controllers and related request for information by EPA in the Proposed Rule (the "**Pneumatic Controllers Request for Information**").

I. ABOUT QNERGY

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."[1]

Qnergy operates a 95,000-square foot factory in Ogden, Utah, with a capacity to produce

[1]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/itkeeps-going-and-going-stirling-engine-test-sets-long-duration-record-at-nasa-glenn/.

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. Since the launch of our power generators in 2018, Qnergy is growing quickly, increasing in size 70% (CAGR) year over year in the last 4 years, doubling the number of employees from 2018 to 2022. Qnergy has built strong partnerships with many key players in the natural gas industry.

II. THE TECHNOLOGY

Qnergy is proud to be the only company with a low-maintenance commercial power generator based on a linear 'Free Piston' Stirling Engine with no rotating parts, meaning no need for lubrication and maintenance. The engine is designed to operate on unrefined methane from natural gas fields and biogas. The technology was developed and is manufactured in the United States. More than a thousand units have already been successfully deployed in the U.S. and Canada. In essence, Qnergy's line of instrument air systems, also called Compressed Air Pneumatics ("**CAP**") systems turn unrefined methane to Instrument Air with minimal emissions and should be utilized as part of the best system of emission reductions in the pneumatic controller sector ("**BSER**").

Qnergy has already deployed more instrument air packages in the U.S. natural gas sector than any other company and is considered to be the market leader in off-grid solutions in the 1-12 scfm range. Based on a range of capacities and operating conditions, each Qnergy CAP3 system can abate between 500 and 5,000 tons of carbon dioxide equivalent per year ("**CO2e**"). 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.[2] 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, as discussed in the Original Comment Letter.[3] TotalEnergies commented on the deployment of Qnergy instrument air systems, stating that:

> *"During a successful pilot project at the Barnett site in March 2021, Qnergy's technology proved to be reliable, simple to install and easy to operate, allowing to eliminate up to 98% of the methane venting emissions related to instruments using natural gas."*[4]

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[2] 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.

[3] See, Original Comment Letter, Appendix A and E.

[4] https://totalenergies.com/media/news/press-releases/united-states-totalenergies-and-qnergy-deploy-innovative-technology. (Qnergy already deployed the one hundred units mentioned in the press release and is in the process of deploying the next (larger) order. For more information, see: www.qnergy.com. For more information on Qnergy's CAP instrument air products see **Appendix A.**)

One of the U.S. largest natural gas operators abated the emissions of 9,000 pneumatic controllers in 2022, using Qnergy's CAP system (the press release is expected in February '23).

Qnergy applauds the EPA's efforts to eliminate methane and volatile organic compounds ("VOCs") emissions in a cost-effective manner that reflects the significant technological advancements that companies like Qnergy have made possible in recent years, while providing the industry with clarity and consistency. Qnergy further supports EPA's direct regulation of methane for both new and existing sources in the oil and gas industry and welcomes the innovative approach allowing for new and emerging technologies to detect, monitor, and mitigate methane emissions. ***Qnergy has reviewed the Proposed Rule, and respectfully submits that the deployment data, actual measurements and field experience in this letter demonstrate that the Proposed Rule can be implemented without disruption or material cost to the energy industry*** and does not believe additional extensions to the comment period are warranted.

The purpose of these comments is to answer specific requests for information and provide EPA with additional information in response to the supplemental notice based on actual deployments of zero methane emission instrument air systems.

III. GENERAL COMMENTS TO PROPOSED RULE

Qnergy supports the requirement that "pneumatic controller affected facility will be defined as the collection of all the natural gas-driven controllers at a site, and will be designed and operated with a methane emission rate of zero, where zero methane emission instrument air systems will be considered BSER."

This letter provides information that supports the above statement as well as the technical and economic viability of the Proposed Rule, as currently written. It is based on actual measurements, deployment data and field experience and responds to EPA's Pneumatic Controllers Request for Information and comments on provisions of the Proposed Rule and relevant comment letters where Qnergy's experience may be dispositive. Please note that Qnergy is sharing proprietary pricing data under CBI.

Qnergy requests EPA to clarify explicitly that instrument air systems with zero methane emissions in the power generation stage are considered BSER for pneumatic controllers applications.

IV. GENERAL COMMENTS ON THE NATIONWIDE IMPACT

Qnergy asserts that the industry[5] can adopt a proven technology to abate methane emissions at minimal to no cost. The difference between 'low-cost' to 'no-cost' depends on the value assigned to the saved natural gas. Qnergy's position is based on field experience with respect to cost and

[5] Qnergy refers to 'industry' as gas production sites of two wells and above. Small (1 well per site) installations are not included in our current scope of supply and thus we do not have installation data to share with respect to these sites.

per unit abatement capacity.

The nationwide impact will amount to abating about 1.2 M tpy of methane at a cost of about $300M per year across the U.S. industry. This result assumes zero value of natural gas. When the value of natural gas is considered, the abatement cost to the industry ranges from about $190M at $2 per MMBtu of natural gas to a net gain at $6 per MMBtu with a crossover at $5 per MMBtu. The detailed derivation and sources of data are provided in **Appendix B.** The summary table of sensitivity of cost to natural gas prices is given below:

Abatement cost as a function of Natural Gas Price				
Natural gas price ($/MMBtu)	0	2	4	6
Nationwide abatement cost ($/yr)	[redacted]	[redacted]	[redacted]	[redacted]
Abatement cost ($/tCH4)	[redacted]	[redacted]	[redacted]	[redacted]

Table 1

The abatement cost is as low as [redacted] at zero value of natural gas. At a reasonable value of [redacted], the abatement cost is about [redacted].

The same information is presented in the following chart with a crossover to profit at about $5/MMBTU of natural gas.

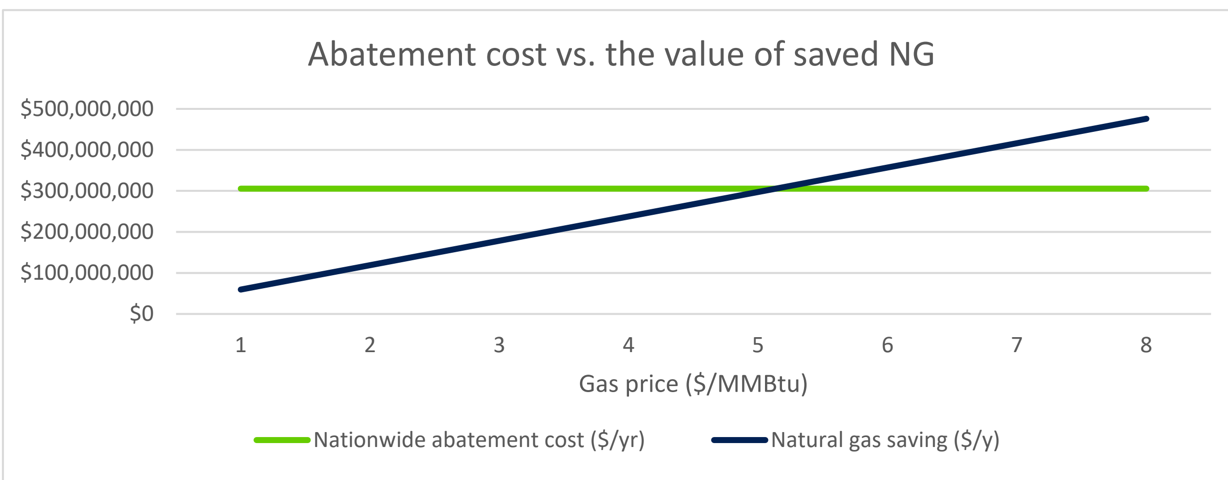

Figure 1

The overwhelming conclusion is that the industry can abate methane through pneumatic controller at a significantly lower cost than published, based on actual experience across the US. The data is based on successful installations across all US climate zones. The following map shows Qnergy's installations across North America. It should serve to remove any concerns about performance in different climates.

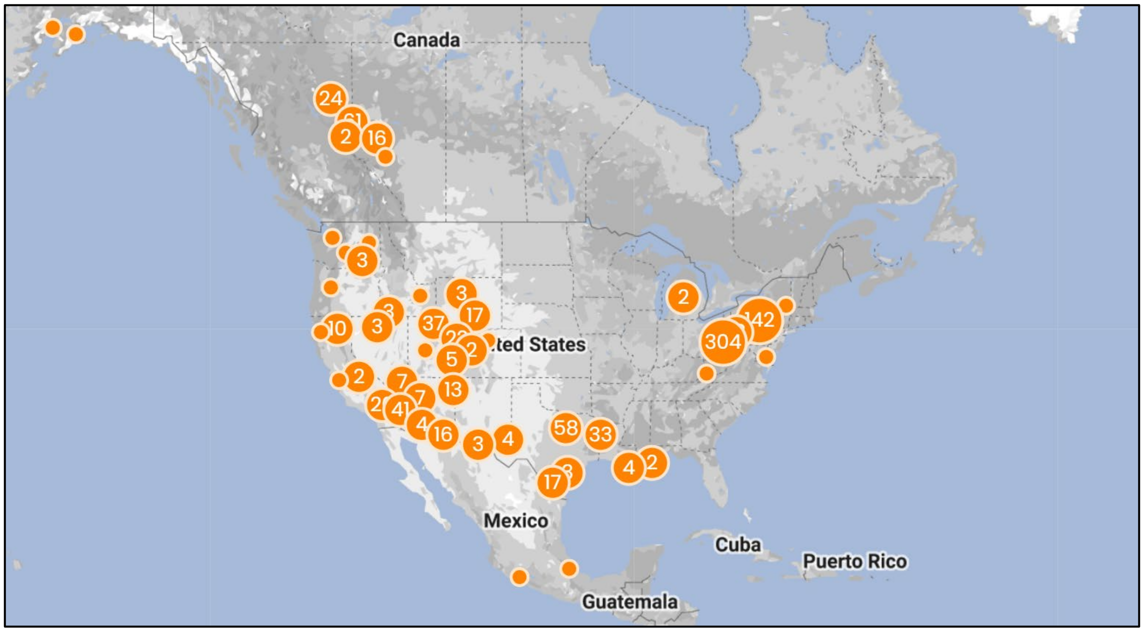

Figure 2

V. SPECIFIC COMMENTS TO PROPOSED RULE AND SUBMITTED COMMENT LETTERS

(a) <u>Definition of Affected Facility</u>

i. EPA REQUEST: *"Now that the EPA is proposing in this supplemental proposal to define the affected facility as the collection of natural gas-driven continuous bleed and intermittent vent controllers at a site, the EPA solicits comment on the proposed changed definition."*[6]

ii. QNERGY POSITION: Qnergy supports the proposed definition and does not believe that this is unclear or will have an adverse effect on operations. The replacement of methane based Pneumatic systems at all "Affected Facilities" with instrument air technology can be accomplished without an adverse economic impact to the industry.

iii. DISCUSSION: The most effective zero-emissions measures for pneumatic controllers are site-wide solutions. In general, a compressed air system installed at a site would be used to power all the pneumatic controllers at the site, rather than a separate system for each controller. Qnergy routinely replaces methane emissions in entire sites that contain a plurality of continuous and intermittent controllers. Methane emission in those sites is

[6] <u>See</u> Proposed Rule at page 186.

typically replaced with one instrument air system, leading to a complete elimination of methane venting.

Replacing instrument gas with instrument air means that the downstream leaks are also eliminated. These leaks become irrelevant because all the leaks are of clean dry air. In those circumstances the discussion of the replacement of high bleed with low bleed becomes irrelevant as well.

Qnergy does not believe that meeting the requirements of the Proposed Rule, in light of the proven deployment of hundreds of systems utilizing Qnergy's technology, will result in any cost increase to the industry, further, as demonstrated by actual deployment data, there is an economic gain to the operator by not venting the gas, given the current price of natural gas. Both of these statements are supported below.

(b) 100% reduction of methane emissions

i. EPA REQUIREMENT: *"to require that each pneumatic controller affected facility be designed and operated with a methane emission rate of zero"*[7]

ii. QNERGY POSITION: Qnergy supports this rule and, as discussed in this letter, utilizing instrument air technologies, can be accomplished without an adverse economic impact to the industry.

iii. DISCUSSION: Once natural gas is replaced with instrument air, the only remaining methane source is the methane that is emitted directly from the generator due to incomplete combustion. However, this can be eliminated using commercial and affordable technology.

For example, using the Stirling Generator (PG5650) provides a complete one hundred percent methane destruction, as measured by various third party organizations and also published_[8] by CanERIC, the Canada Emission Reduction Innovation Consortium of researchers and end-users dedicated to developing, validating, and employing technologies for critically needed, novel, high-performance, and cost-effective technologies to address the global emissions reduction challenge.

For a detailed evaluation and raw data see **Appendix C**.

(c) Other Secondary Impacts: CO, NOx, CO2

i. EPA COMMENT: *"Secondary impacts from these options, particularly from the use of instrument air systems, are indirect, variable, and dependent on the electrical supply used to power the compressor. As discussed above, this would result in an increase in electricity needs and minimal emission increases. As discussed above, the use of a generator to power*

[7] See Proposed Rule at 244.

[8] https://qnergy.com/2022/11/03/independent-testing-proves-qnergys-technology-delivers-useful-power-with-100-efficiency-of-methane-destruction/

an instrument air system will result in emissions of two criteria pollutants – CO and CO2. However, the comparison in the CO2 equivalent emissions shows that even with the secondary emissions from the generator, there is a substantial reduction in CO2 equivalent emissions."[9]

ii. QNERGY POSITION: ***Qnergy supports this statement. Specifically, the Stirling Generator emits negligible levels of CO and NOx as verified through third party analysis***.

(d) <u>Cost Effectiveness of Generators</u>

i. EPA REQUEST: *"The EPA is specifically requesting more detailed information on the use of generators at sites without access to the grid to power pneumatic controllers, primarily to power instrument air systems. The EPA is also interested in receiving more information on the costs associated with this equipment"*[10]

ii. QNERGY POSITION: ***Qnergy asserts that the pricing presented in Table 24 in the EPA supplement document are about 50% higher than the actual prices of instrument air packages.***

iii. QNERGY DISCUSSION: Qnergy has already deployed about a thousand PG5650 generators in off-grid natural gas locations in the U.S. and Canada. The levelized cost of electricity (LCOE) of these systems is in the range of [redacted]. Our oldest deployed system has been operating continuously for 5 years (more than 42,000 of maintenance free engine operation, which is by far the best in class) and is longer than any other company in this industry globally.

According to EIA[11], the average price of electricity the U.S. is also \$0.12/kWh, while the average industrial price is about \$0.093/kWh. Based on discussions with customers, the price of electricity in remote locations, is typically higher than the average. ***The conclusion is quite striking: unlike what one might assume, using a Stirling Generator, off-grid power for instrument air applications is at the same range as grid power.***[12]

A comparison table is provided below. The details are provided in **Appendix D**.

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[9] Proposed Rule at 224.
[10] Proposed Rule at 204.
[11] https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_5_6_a
[12] The cost analysis and price list of instrument air packages are provided in Appendix C and are classified as CBI. The calculation does not include the price of gas since in this well sites application, the gas that is used to power the generator would otherwise be vented. It is a negligible fraction of the gas that would be otherwise vented.

DIFFERENCE (%)	TCI[13]	TAC
Instrument Air System - Grid		
Small System	[redacted]	[redacted]
Medium System	[redacted]	[redacted]
Large System	[redacted]	[redacted]
Instrument Air System – Natural Gas Generator		
Small System	[redacted]	[redacted]
Medium System	[redacted]	[redacted]
Large System	[redacted]	[redacted]

Table 2

(e) <u>Supply Chain Disruptions</u>

i. EPA COMMENT: *"owners and operators have already experienced delays of several months in acquiring equipment to retrofit facilities to instrument air, all prior to the EPA proposal, and that the increased demand for that equipment given proposed rule requirements would only exacerbate the challenges associated with acquiring that equipment."*[14]

ii. QNERGY DISCUSSION: Qnergy and other U.S. companies are investing significant resources in on-shoring their supply chain to guarantee on-time delivery of methane mitigation products. Qnergy already expanded its production capacity by 60% to meet the surging demand with the goal to provide lead time of six weeks or less. Qnergy expects that the Inflation Reduction Act and other government programs will promote U.S. methane mitigation technologies.

(f) <u>Backup Systems</u>

i. EPA REQUEST: *"The EPA is concerned that allowing these backup systems would result in a potential loophole that would enable owners or operators to continue to use natural gas-driven controllers in routine situations. Therefore, the EPA is interested in how the use of these systems could be narrowly defined and how a clear distinction could be drawn between the allowed use of these backup systems and violations of the zero emissions standard."*[15]

ii. QNERGY POSITION: ***Qnergy believes that there is no need for backup systems.***

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[13] Using EPA's definitions: TCI = Total capital investment includes capital cost of equipment plus engineering and installation costs; TAC = Total annual costs including capital recovery (at 7 percent interest and 15-year equipment life) and operation and maintenance costs.
[14] See Proposed Rule at 227.
[15] See Proposed Rule at 198.

iii. QNERGY DISCUSSION: Operators can use proven cost effective instrument air packages that have compressor redundancy i.e., if one compressor is malfunctioning the other will still operate. The built-in redundancy eliminates the need for backup systems.

(g) <u>Use not Lose</u>

i. EPA REQUEST: *"First, we are soliciting information that describes specific situations where owners and operators have utilized this option to use, rather than lose, the valuable natural gas emitted from pneumatic controllers. We are interested in the specific processes and equipment needed, as well as their costs."*[16]

ii. QNERGY POSITION: ***Replacing instrument gas with instrument air means that methane emissions is eliminated and nearly all the otherwise vented gas is used instead of wasted***.

iii. QNERGY DISCUSSION: Emission reduction happens 'naturally' because instrument gas is replaced by instrument air. The saved gas has a significant economic value – rendering venting mitigation profitable.

(h) <u>Site Economics</u>

i. EPA COMMENT: *"The EPA notes that the cost effectiveness values for the smallest model plant, which includes 1 high-bleed, 1 low-bleed, and 2 intermittent vent controllers, were $181 and $238 per ton of methane reduced for electric controllers and solar controllers, respectively. These cost effectiveness values are well within the ranges considered to be reasonable by the EPA."*[17]

ii. QNERGY DISCUSSION: Qnergy's typical installations are medium facilities with 16 controllers and above and about 2scfm (about 22 tpy of methane) the mitigation cost at these facilities is [redacted].[18] **Appendix E** shows that at $4/MMBtu of natural gas, a 9 scfm site is highly profitable, where the operator enjoys about $13,000 of net profit each year (about $135 profit from each ton of abated methane). ***At 6 scfm and $2/MMBtu the operator breaks even while offsetting the whole site entire emissions.***

(i) <u>Reliability of Solar Generation</u>

i. COMMENT LETTER DISCUSSION: *One commenter stated that while the EPA suggested the use of onsite solar generation paired with battery storage as an alternative to grid electricity, such systems are currently "uncommon, unreliable, and will likely increase the frequency of facility upsets, which will increase safety risks such as*

[16] See Proposed Rule at 207.
[17] See Proposed Rule at 225.
[18] The calculation is presented to EPA as CBI in Appendix D.

overpressure events and spills."[19]

ii. *"As the EPA also indicated in the November 2021 proposal, there are Canadian provinces that have successfully implemented non-emitting controller regulations"* [20]

iii. QNERGY DISCUSSION: Qnergy has observed that the intermittency and sensitivity to weather conditions of solar generation, in addition to low availability during the winter, especially in high latitudes, limit adoption. Qnergy has installed more than a hundred instrument air units in Alberta and British Columbia, which meet the relevant zero emission requirements. However, despite many attempts, solar generation have not seen a broad adoption in Canada. Qnergy itself has considered commercializing a solar solution for small sites and concluded that it is applicable only for powering single controllers but not as a broad instrument air solution.

(j) <u>Is instrument air only at the pilot stage?</u>

i. COMMENT LETTER DISCUSSION: A Comment letter to the EPA stated that, "*while there may be some pilot projects within the industry, it has not been demonstrated that reliable turnkey packages are available on a widescale basis.*"[21]

ii. QNERGY POSITION: With hundreds of installations – in the broader perspective of instrument air, ***the industry has long passed the pilot stage***.

(k) <u>BSER - adequately demonstrated</u>

i. EPA COMMENT: *"Under CAA Section 111(b), EPA must show that a BSER determination has been "adequately demonstrated." The EPA concludes that zero-emission pneumatic controller systems that do not use natural gas meet this standard at sites both with and without access to electricity."*[22]

ii. QNERGY POSITION: ***Qnergy agrees with the BSER definition***.

iii. QNERGY DISCUSSION: Qnergy confirms that it has already installed hundreds of units. This fact alone should remove any remaining doubt with respect to adequate demonstration of the technology, application and its cost effectiveness.

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[19] See Proposed Rule at 209.
[20] See Proposed Rule at 211.
[21] See Proposed Rule at 209.
[22] See Proposed Rule at 212.

(l) BSER – secondary impact

i. EPA COMMENT: *"These total CO2e would represent a more than 90 percent reduction in the CO2e emissions when compared to the uncontrolled methane emissions from natural gas driven controllers."*[23]

ii. QNERGY POSITION: ***The emission reduction is close to 99.6% as can be seen from the following table***:

Abatement	
Compressor size (HP)	5
Air supply (scfm)	9
Air consumption (scf/y)	4,730,400
Gas Equivalency Ratio / GEF	1.2977
% CH4	94%
Density of Methane (kg/scf)	0.01889
Avoided Methane (tpy)	109
GHG Emissions	
CO2 (tpy)	9.4
CH4 (tpy)	0.00091
N2O (tpy)	0.00045
Summary GHG impact (tCO2e/y)	9.6
Net	
Abatement (tCO2e/y)	(2,715)
Percent CO2e emission reduction	99.6%

Table 3

Conversion factors used are 25x for CH4 and 298 x for N2O.

iii. QNERGY DISCUSSION: With respect to the size of compressors and generators - Qnergy provides instrument air packages with rocking piston compressors that are as small as 1HP. Qnergy's 5HP compressors (both scroll and screw) are driven by the PG5650 (5.6 kW Stirling generator). Qnergy released triplet packages of more than 16kW (3 x PG5650) to power large compressors.

(m) BSER – size mismatch

i. EPA COMMENT: *"The EPA recognizes that if owners and operators elect to comply by installing and operating a generator, there will be secondary emissions generated from the fuel combustion. However, we also point out that, for a site with 100 controllers (a size*

[23] See Proposed Rule at 213.

cited by the commenter requiring a large instrument air system), these secondary emissions would represent approximately a 77 percent decrease in CO2 equivalent emissions and a 96 percent decrease in VOC emissions from a site with 25 low bleed and 75 intermittent bleed controllers."[24]

ii. QNERGY POSITION: ***Qnergy believes that the EPA's values are too conservative***.

iii. QNERGY DISCUSSION: A 100 controller site, as mentioned in the EPA example, will consume nearly 12 scfm of instrument air, as can be seen in the following table:

Well pad with 100 controllers - air consumption			
	High bleed	Low bleed	Intermittent
Emissions (scf whole gas/hr)	21.2	6.8	8.8
Methane emission rate (scfm)	0.30	0.10	0.12
Number of controllers	0	25	75
Site summary	0.0	2.4	9.2
Total air (scfm)	**11.6**		

Table 4

The instrument air system will abate about 126 tpy of methane, as can be seen in the following table:

Parameter	**Value**
Air supply (scfm)	11.6
I/A consumption (scf/yr)	6,107,472
Gas Equivalency Ratio / GEF	1.2977
% CH4	94%
Density of Methane (kg/scf)	0.01889
Abated methane (tpy)	**157**

Table 5

The abatement efficiency is very similar to the 99% or higher as discussed above. The emissions are 10-30 tCO2e per year and the abatement 120 tons of methane, which is equivalent to nearly four thousand tCO2e per year.

(n) Clarity with Respect to Instrument Air with Zero Methane Emissions as BSER

i. EPA COMMENT: *"we have determined that BSER for pneumatic controllers is use of one of the several types of controllers that have zero methane and VOC emissions"*[25]

[24] See Proposed Rule at 214.
[25] See Proposed Rule at 215.

ii. QNERGY POSITION: ***Qnergy requests EPA to clarify explicitly that instrument air systems with zero methane emissions in the power generation stage are considered BSER for pneumatic controllers applications***.

iii. QNERGY DISCUSSION: The EPA has used the following language: "*controllers that have zero methane and VOC emissions"* throughout the proposed rule. By definition, the controllers emit the gas that is fed into them. If the gas is air, then the controllers have clearly zero methane and VOC emissions.

Appendix A: Examples of Commercial Zero Methane Emission Instrument Air Packages

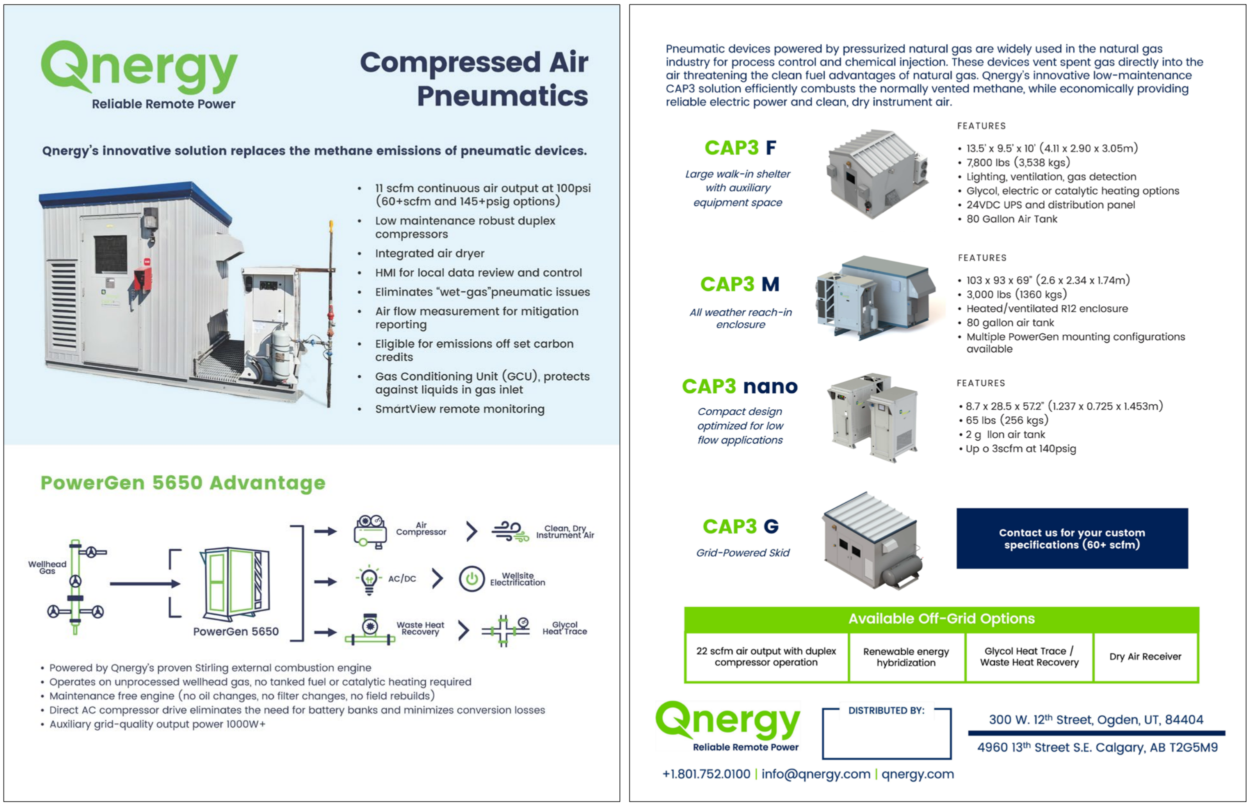

Figure 3

Additional information can be found on Qnergy's website: https://qnergy.com/compressed-air-pneumatics/.

Appendix B: Nationwide cost and abatement of the ruling (CBI)

Most of Qnergy's data refers to sites with 2 wells and above, which is the bulk of the issue from the emissions standpoint. Thus, the relevant number of wells is[26]:

Wells	**2 wells**	**3 wells**	**4 wells**	**5 wells**	**6 wells**	**≥7 wells**	**Total**
# of wells	[redacted]						
# of sites							

Table 6

[26] See tab TD_AD in supplementary material in Alvarez et. al., "Assessment of methane emissions from the U.S. oil and gas supply chain" SCIENCE, Vol 361, Issue 6398 (2018) https://www.science.org/doi/abs/10.1126/science.aar7204#supplementary-materials

Different sites have different airflow requirements. To estimate the cost and match to a per-site solution, the sites are grouped, and an estimation is provided in the following table:

Well Pad Size	**Small**	**Medium**	**Large**
Well Count	2-3	4-6	>7
Total Sites	[redacted]		
Cost			
TCI per site (on grid) [27]	[redacted]		
TAC per site (on-grid) [28]	[redacted]		
TCI per site (off grid) [29]	[redacted]		
TAC per site (off-grid) [30]	[redacted]		
Pct off grid [31]	[redacted]		
Weighted average TCI	[redacted]		
Weighted average TAC	[redacted]		
Product-fit [32]	[redacted]		
Nationwide TCI	[redacted]		
Nationwide TAC	[redacted]		
Methane Abatement			
Methane per site (tpy) [33]	[redacted]		
Methane abated per site size (tpy)	[redacted]		

Table 7

TOTAL methane abatement (tpy)	[redacted]

Table 8

Note that the total amount of methane emissions through Pneumatic Controllers as given by EPA[34] is significantly higher (about 2,000 ktpy)[35].

Part of the discrepancy was due to the fact that we have omitted the single well pads from the analysis.

[27] Qnergy Data shared in this document
[28] Qnergy Data shared in this document
[29] Qnergy Data shared in this document
[30] Qnergy Data shared in this document
[31] Survey conducted by Qnergy and a third party among U.S. operators across basins
[32] Qnergy's estimates based on deployment data
[33] Averages based on deployment data
[34] EPA, 2021b. Inventory of U.S. Greenhouse Gas Emissions and Sinks, 1990-2019. U.S. Environmental Protection Agency, 2021. https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks Additional Information, Methodology Annexes. Accessed 20 12 2022. https://www.epa.gov/ghgemissions/natural-gas-and-petroleum-systems-ghg-inventory-additionalinformation-1990-2019-ghg
[35] See also Figures 5, 6 in R. Kleinberg comments letter: https://www.regulations.gov/document/EPA-HQ-OAR-2021-0295-0001

In general, these data sources are based on self-reported information and thus are expected to have discrepancies. For example, a bottom-up analysis of the Pneumatic Devices component in EPA inventory [36] yields similar results to the above:

Emissions by application and bleed (ktpy)	Normal operations	Gathering and boosting	Transmission	Storage	TOTAL
Low Bleed	33.5	6.8	0.9	0.516	**41.8**
High Bleed	74.6	23.6	11.5	17.2	**126.9**
Intermittent Bleed	1,018.4	171	24.5	6.4	**1,220.3**
TOTAL	**1,126.5**	**201.4**	**36.9**	**24.1**	**1,388.9**

Table 9

The following table shows the cost to the industry of abating methane emissions when the value of natural gas is included. One can see a cross-over to positive abatement cost at natural gas cost of about $5 per MMBtu. The chart is presented in the text.

Value of saved gas								
Natural gas price ($/MMBtu)	1	2	3	4	5	6	7	8
Natural gas saving ($/y)	[redacted]							
Nationwide abatement cost ($/yr)								
Net cost to the industry ($/y)								

Table 10

[36] EPA, 2021b. Inventory of U.S. Greenhouse Gas Emissions and Sinks, 1990-2019. U.S. Environmental Protection Agency, 2021. https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks Additional Information, Methodology Annexes. Accessed 20 12 2022. https://www.epa.gov/ghgemissions/natural-gas-and-petroleum-systems-ghg-inventory-additionalinformation-1990-2019-ghg

Appendix C: Zero Methane Performance

Methane destruction – PowerGen SN833 had a natural gas fuel flow of order 3500g/hr at its rated power of 5.65kW exported to the user. This represents a fuel input flow (>95% methane) of ~>600 g/kW.hr of methane, and a measured CxHy hydrocarbon export of only <1.5mg/kW.hr. Combustion resulted in >99.998% (100%) methane destruction efficiency. Most of the hydrocarbon measurements were below the uncertainty threshold of the measuring equipment, so the destruction number is higher than what could be reported here.

Qnergy's January methane destruction test results were duplicated and confirmed by an experiment performed entirely independently from Qnergy participation, through a Canadian research group[37].

Technology	Flowrate	Inlet Gas Flow (m^3/d)	Exhaust Flow (m^3/d)	Inlet Methane (kg/h)	Outlet Methane (kg/h)	Methane destruction efficiency (%)
PowerGen 5650	Test 1	30.7	43.0	0.817	5.29E-05	99.99
	Test 4	117.2	74.1	3.13	0.000132	100.00
M1.5	Test 1	7.4	6.78	0.194	0.00994	94.86
	Test 3	13.8	9.12	0.366	0.00971	97.30
M5	Test 1	25.1	44.6	0.658	0.0568	91.36
	Test 4	41.4	105.5	1.08	0.131	87.90
EPOD 6XL	Test 2	65.5	56.3	1.70	0.051	96.95
	Test 5	81.1	53.1	2.02	0.042	97.99
C65	Test 1	223	686.4	5.81	0.00327	99.94
	Test 4	535	1223	14.2	0.000999	99.99
COREMO	Test 4	16.2	18.6	0.421	0.0069	98.37
	Test 4	15.1	22.0	0.394	0.0182	95.34

Table 11

[37] CanERIC. (2022, October). Scoping Study for a Clean Combustion Technology Showdown. Retrieved from CANADA EMISSIONS REDUCTION INNOVATION NETWORK (CERIN) PUBLIC REPORT: http://www.cerinprojects.ca/projects/62b28b967f9ac0318b2c1ae7

Appendix D: Cost Effectiveness of Generators and Instrument Air Systems (CBI)

Assumptions	
Interest rate	7%
Project lifetimes (y)	15

Table 12

Off-grid Power Generation	
Generator (PG5650)	[redacted]
Installation	
Shipping and handling	
Capital Recovery Factor	
TCI	
Annual maintenance	
Annual cost	
Power (kW)	
Capacity factor	
Annual Power (kWh)	
Energy Cost ($/kWh)	

Table 13

Instrument Air			
	CAP3-nano	CAP3-V	CAP3-M
Flow level (scfm)	1-3	3-6	6-9
TCI	[redacted]		
Annual maintenance			
Annual cost			

Table 14

Appendix D (cont.)

EPA TABLE 24	**TCI**	**TAC**
Instrument Air System - Grid		
Small System	[redacted]	[redacted]
Medium System	[redacted]	[redacted]
Large System	[redacted]	[redacted]
Instrument Air System – Natural Gas Generator		
Small System	[redacted]	[redacted]
Medium System	[redacted]	[redacted]
Large System	[redacted]	[redacted]

Table 15

QNERGY PRICE LIST	**TCI**	**TAC**
Instrument Air System - Grid		
Small System	[redacted]	[redacted]
Medium System	[redacted]	[redacted]
Large System	[redacted]	[redacted]
Instrument Air System – Natural Gas Generator		
Small System	[redacted]	[redacted]
Medium System	[redacted]	[redacted]
Large System	[redacted]	[redacted]

Table 16

DIFFERENCE	**TCI**	**TAC**
Instrument Air System - Grid		
Small System	[redacted]	[redacted]
Medium System	[redacted]	[redacted]
Large System	[redacted]	[redacted]
Instrument Air System – Natural Gas Generator		
Small System	[redacted]	[redacted]
Medium System	[redacted]	[redacted]
Large System	[redacted]	[redacted]

Table 17

Appendix E: Site Economics (CBI)

Large site (9 scfm): At gas prices of $4 per MMBtu, a site that replace 9 scfm of gas with instrument air actually makes a profit. The project is profitable even at $2 per MMBtu.

Medium site economics			
	High bleed	Low bleed	Intermittent
Emissions (scf whole gas/hr)	21.2	6.8	8.8
Methane emission rate (scfm)	0.30	0.10	0.12
Number of controllers	5	40	30
Site summary (scfm)	**1.5**	**3.8**	**3.7**

Table 18

Total controllers	75
Total venting (scfm)	**9.0**

Table 19

Abatement	
Air supply (scfm)	9.0
Air consumption (scf/yr)	4,724,093
Gas Equivalency Ratio / GEF	1.2977
% CH4	84%
Density of Methane (kg/scf)	0.01889
Abated methane (tpy)	**97.3**

Table 20

Value of saved gas	
Price of natural gas ($/MMBtu)	[redacted]
Conversion (MMBtu/ scf)	
Natural gas (cf/y)	
Natural gas (MMBtyu/yr)	
Natural gas ($/y)	

Table 21

Mitigation cost	
Instrument Air System	[redacted]
Generator	
Gas saving	
Total annual cost	
Abatement cost ($/tCH4)	

Table 22

Small site (2 scfm): At 2 scfm and gas prices of $4 per MMBtu, a site that replace 9 scfm of gas with instrument air pays about.

Medium site economics			
	High bleed	Low bleed	Intermittent
Emissions (scf whole gas/hr)	21.2	6.8	8.8
Methane emission rate (scfm)	0.30	0.10	0.12
Number of controllers	2	8	5
Site summary (scfm)	**0.6**	**0.8**	**0.6**

Table 23

Total controllers	15
Total venting (scfm)	**2.0**

Table 24

Abatement	
Air supply (scfm)	2.0
Air consumption (scf/yr)	1,036,063
Gas Equivalency Ratio / GEF	1.2977
% CH4	84%
Density of Methane (kg/scf)	0.01889
Abated methane (tpy)	**21.3**

Table 25

Value of saved gas	
Price of natural gas ($/MMBtu)	[redacted]
Conversion (MMBtu/ scf)	
Natural gas (cf/y)	
Natural gas (MMBtyu/yr)	
Natural gas ($/y)	

Table 26

Mitigation cost	
Instrument Air System	[redacted]
Generator	
Gas saving	
Total annual cost	
Abatement cost ($/tCH4)	

Table 27