BEFORE THE PUBLIC SERVICE COMMISSION OF THE STATE OF MISSOURI

In the Matter of the Establishment of a Working Case for the Review and Consideration of Promulgating a Rule Consistent with Section 386.895	))))	Case Number GW-2022-0060

COMMENTS OF ENVIRONMENTAL DEFENSE FUND

Environmental Defense Fund (EDF) appreciates this opportunity to provide comments to the Missouri Public Service Commission.

EDF is a national environmental nonprofit organization whose mission is to preserve the natural systems on which all life depends. Guided by science and economics, EDF finds practical and lasting solutions to the most serious environmental problems. EDF has a strong interest in minimizing the natural gas utility industry's significant contribution to climate change and other environmental and environmental justice problems, and in ensuring an equitable clean energy transition. EDF addresses certain identified questions from the Commission's Order as indicated below.

Renewable Natural Gas Program – Question 1

Should the Commission adopt separate rules regarding renewable natural gas (RNG) for biogas, hydrogen, and gas derived from waste CO2? Please explain your reasoning.

EDF Comment:

With regard to cost recovery, there should be one rule and one standard for assessing whether investments are prudent, just, and reasonable. EDF addresses that standard below in Question 4. Other safety and operational aspects of such facilities may require separate rules.

Renewable Natural Gas Program – Question 2

Are there, or should there be, separate classifications of RNG facilities based upon feed stock (i.e. agricultural applications, landfill collection, etc.)? If so, how should those be defined?

EDF Comment:

Safety and operational aspects of such facilities may require separate rules, but the standard for cost recovery of such facilities should be uniform, as discussed in Question 4 below.

Renewable Natural Gas Program - Question 3

Subsection 386.895.2, RSMo, states, in part: The commission shall adopt rules for gas corporations to offer a voluntary renewable natural gas program.

a. Does this statute authorize, but not require, a program applicable to customers who volunteer to participate?

b. Does this statute authorize, but not require, that utilities offer a program to generally inject biogas into the gas supply, the costs of which are borne by all customers of that utility whether or not a given customer volunteers to participate?

EDF Comment:

The language of the statute, by itself, and construed with other relevant statutes, leads to the answer that the statute authorizes, but does not require, utilities to offer a program, and that participation in the program, including payment for the costs of the program, is voluntary for the customer on an opt-in basis.

In construing the statute, one must first look to its language. Section 1.090 RSMo.

The relevant language provides that "[T]he commission shall adopt rules for gas corporations to offer a voluntary renewable natural gas program." The word "shall" denotes something that is mandatory, and applies only to the Commission, i.e., requiring it to do a rule making.

Section 393.130, RSMo, provides that gas utilities "shall furnish and provide such service instrumentalities and facilities as shall be safe and adequate and, in all respects, just and

reasonable." This is the primary mandatory requirement for a gas utility in the Missouri statutes, and the statute uses the term "shall" to indicate the mandatory nature of the obligation. Subsection 386.895.2 RSMo, contains no language requiring a utility to have a program as part of its safe and adequate service, rather, the Legislature used the traditional mandatory language obligating only the Commission to act in the form of a rule making. The lack of mandatory language applying to the utilities indicates a different legislative intent, i.e., voluntary action by the utilities. EDF suggests it would be inappropriate to infer a mandatory requirement where none exists in the clear reading of the language. Thus, EDF submits that the correct construction of the language is that the utility is authorized, but not required, to provide a renewable natural gas program to its customers.

EDF further submits that the statutory language, "voluntary renewable natural gas program," applies to customer participation, indicating that no customer is required to participate or pay the costs of such a program unless they voluntarily do so on an opt-in basis.

Renewable Natural Gas Program – Question 4

Subsection 386.895.5, RSMo, allows recovery of prudent, just, and reasonable qualified investment costs.

a. What factors should the Commission consider in determining prudence?

b. How will prudence be demonstrated prior to recovery?

c. Should prudence be determined in the rate adjustment mechanism (RAM) case, rate case, or some other or combination of cases?

d. How will prudence be determined for a voluntary program that is likely more costly than the traditional alternative and without a state or federal supply mandate?

e. What factors should the Commission consider in determining the justness?

f. Should justness be determined prior to recovery?

g. Should justness be determined in the RAM case, rate case, or some other or combination of cases?

EDF Comment:

In order to recover costs associated with any RNG blending into its distribution system, the utility must show that such activity is consistent with safe and adequate service, including consideration of cost, environmental, and community impacts. Such activity should also be shown to yield a net reduction in climate pollution at a cost that is reasonable compared to other potential societal expenditures designed to yield climate benefits. RNG includes biogas (commonly known as biomethane) and hydrogen. 386.895.1.(6), RSMo. Each presents various issues and challenges to meeting the foregoing standards, as discussed below.

ISSUES INVOLVED IN DETERMINING WHETHER A PARTICULAR USE OF BIOGAS IS PRUDENT, JUST, AND REASONABLE

Biogas, as defined in the statute, is a mixture of carbon dioxide and hydrocarbons, primarily methane gas, released from the biological decomposition of organic materials. 386.895.1.(1), RSMo. Biogas combustion releases CO2 and local pollution at the same rates as natural gas combustion since both are comprised mostly of methane. Thus, the benefits of biogas, if any, result from benefits upstream of the distribution system and burner tip.

Biogas may or may not result in climate benefits depending on the source. Biogas is typically emitted from sources such as landfills, lagoons, and animal-feeding operations. Capturing and using this biogas can be beneficial because it can yield a net reduction in methane emissions, even if there is some leakage. But if new biogas is generated, for example, from wood product wastes or purpose-grown crops, subsequent leakage of that new biogenic methane would increase overall atmospheric methane concentrations and be counterproductive to addressing climate change.[1]

[1] Joe Rudek & Stefan Schwietzke, *Not All Biogas is Created Equal*, EDF ENERGY EXCHANGE (Apr. 15, 2019), https://blogs.edf.org/energyexchange/2019/04/15/not-all-biogas-is-created-equal/.

For a biogas source to provide a genuine climate benefit, the fuel must result in a net reduction in methane emissions. To provide a net reduction in methane emissions, biogas production and use must not result in new or excess methane emissions relative to current waste management practices. But this is unlikely, and gasifying organic sources of biogas would likely result in more net climate pollution due to methane leakage during production, processing, transportation, and end-use applications, due in part to leakage throughout the existing gas supply chain, discussed further below.[2] Similarly, a study from Lawrence Livermore Laboratory found that organic sources such as forest biomass and agricultural residue are not viable source materials for biogas because they would not yield a net reduction in climate pollution.[3]

EDF notes that biogas may have a particular role to play in hard-to-electrify sectors -- especially if the facility using the biogas is in the proximity of the biogas source, thus presenting fewer opportunities for pipeline leakage. Such sectors could include making materials (plastics, steel, and cement) and long-haul transport (heavy-duty trucking, shipping, and aviation).[4]

ISSUES INVOLVED IN DETERMINING WHETHER A PARTICULAR USE OF HYDROGEN IS PRUDENT, JUST, AND REASONABLE

With respect to hydrogen, this fuel has around one third the energy density per unit volume as natural gas, which means its energy yield is lower than natural gas and more of the gas blend will be required to deliver the same energy content to customers. For example, a 20% hydrogen blend means that 15% more natural gas and hydrogen by volume will be needed to deliver the

[2] Mark Omara & Joe Rudek, *Careful Accounting is Critical to Assessing the Climate Benefits of Biomethane*, EDF ENERGY EXCHANGE (Mar. 24, 2021), https://blogs.edf.org/energyexchange/2021/03/24/careful-accounting-is-critical-to-assessing-the-climate-benefits-of-biomethane/.

[3] Sarah E. Baker et al., *Getting to Neutral: Options for Negative Carbon Emissions in California*, LAWRENCE LIVERMORE NAT'L LAB., LLNL-TR-796100 (Jan. 2020), at Fig. 15, https://www.osti.gov/biblio/1597217.

[4] U.S. DEP'T ENERGY, *DOE National Clean Hydrogen Strategy and Roadmap* (Sept. 2022), at 39, https://www.hydrogen.energy.gov/pdfs/clean-hydrogen-strategy-roadmap.pdf.

same energy content as 100% natural gas methane. This means that natural gas greenhouse gas emissions are only reduced by 5% with a 20% hydrogen blend. Smaller blends, therefore, such as 3%, will have fairly negligible reductions in greenhouse gas emissions.

Hydrogen itself is a climate-warming gas that can often leak more easily than natural gas.[5] Research shows that hydrogen/natural gas blends can leak either at the same rate or faster from pipelines compared to traditional natural gas, depending on the type of leakage. Because of its lower viscosity and smaller molecular size, hydrogen is expected to leak more easily (1.3 to 3 times faster) than natural gas based on fundamental fluid dynamic theories.[6] However, recent experimental studies reveal different leak behaviors through different leakage pathways. One study conducted by researchers at UC Irvine suggests that hydrogen and methane would leak at a similar rate if the gas mixtures are leaked through the joints and fittings of a low pressure distribution pipeline.[7]

Another study conducted by researchers at UC Riverside suggests that hydrogen/natural gas blends would leak faster than natural gas itself and the leak rate increases as the proportion of hydrogen increases, if the gas mixtures are leaked through cracks or pinholes.[8] Overall, leakage of hydrogen blends will occur at least at the same rate of traditional natural gas, and likely faster. However, hydrogen's warming effects per mass are around two to three times lower than methane's

[5] Lara Williams, *There's a Cleaner Way to Heat Your Home, and It's Not Hydrogen*, Bloomberg Opinion (corrected Feb. 26, 2023), https://www.bloomberg.com/opinion/articles/2023-02-23/climate-change-hydrogen-isn-t-the-cleanest-way-to-heat-our-homes.

[6] M.R. Swain, *A Comparison of H2, CH4 and C3H8 Fuel Leakage in Residential Settings*,17 INT'L J. HYDROGEN ENERGY 807 (1992), https://doi.org/10.1016/0360-3199(92)90025-R.

[7] Alejandra Hormaza Mejia, *Hydrogen Leaks at the Same Rate as Natural Gas in Typical Low- Pressure Gas Infrastructure*, 45 INT'L J. HYDROGEN ENERGY 8810 (2020), https://www.sciencedirect.com/science/article/abs/pii/S0360319919347275.

[8] Arun SK Reju, Hydrogen Blending Impacts Study, CAL. PUB. UTIL. COMM. (July 18, 2022), https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M493/K760/493760600.PDF.

in both the near- and long-term.[9] A simple calculation reveals that if hydrogen leaks at the same rate as natural gas—a conservative estimate—a 20% hydrogen blend would only reduce the warming effects of gas leakage by 6%; if hydrogen leaks at three times the rate as natural gas, warming effects would be reduced by 4% (see Exhibit A, attached). Smaller blends would yield even less benefits. Thus, leakage of hydrogen and hydrogen/natural gas blends warrants further investigation before any large-scale blending occurs.

EDF further notes that hydrogen production is energy intensive. Given that there currently are not scalable sources of natural hydrogen, the fuel must be produced from larger molecules, such as water. However, this process is energy intensive and requires a clean energy source—such as renewables—in order to be considered a decarbonization strategy.[10] Electrolytic hydrogen that is produced from fossil-fueled power is far less likely to be beneficial, potentially creating harmful emissions impacts. Furthermore, hydrogen produced using a renewable source that would otherwise have been used for another purpose; for example, wind and solar that would power the grid but are diverted instead to hydrogen production, can similarly increase emissions elsewhere in the energy system as the grid must rely on a greater proportion of fossil fuels since renewable energy is instead used for hydrogen production.

While the foregoing discussion indicates there may be substantial issues in using of hydrogen in distribution systems, clean hydrogen has potential to help decarbonize hard-to-

[9] Sand et al. 2023; IPCC AR6 WGI 2021 Chapter 7.

[10] Falko Ueckerdt, *Potential and Risks of Hydrogen-based E-fuels in Climate Change Mitigation*, 11 NATURE CLIMATE CHANGE 384 (2021), https://www.nature.com/articles/s41558-021-01032-7.

electrify sectors. This would include making materials (such as plastics, steel, and cement) and long-haul transport (such as heavy-duty trucking, shipping, and aviation).[11]

CONSIDERATION IN RATE CASE PREFERRED

It is with the foregoing issues in mind that the Commission should proceed with a rule regarding reviewing the costs for RNG investment and expenditures to see if they are prudent, just, and reasonable. The Commission will need to review the issues presented by RNG deployment to determine if the deployment is consistent with safe and adequate service, and yields a net reduction in climate pollution at a cost that is reasonable compared to other potential expenditures designed to yield climate benefits.

EDF submits that a rate case should be the preferred forum to review investment and expenditures to see if they are prudent, just, and reasonable. A rate case has a broader scope than a RAM proceeding thereby providing a more thorough review of comparison between other investments, plans and programs. Furthermore, while there are exceptions, a rate case typically has procedural schedules and participation by parties more consistent with a review of these complex issues.

Renewable Natural Gas Program – Question 5

What should be included as the minimum filing requirements for a RNG application?

a. Should all applications include a demonstration that each Tartan criteria has been met?

EDF Comment:

The Commission has traditionally applied five factors when considering whether to approve a certificate of public convenience and necessity (CPCN). These factors are known as the Tartan criteria first established in the case, *In Re Intercon Gas, Inc*., 30 Mo P.S.C. (N.S.) 554, 561

[11] U.S. DEP'T ENERGY, *DOE National Clean Hydrogen Strategy and Roadmap* (Sept. 2022), at 39, https://www.hydrogen.energy.gov/pdfs/clean-hydrogen-strategy-roadmap.pdf.

(1991). The applicant has the burden of proving: 1) there is a need for the project; 2) the applicant is qualified to undertake the project; 3) the applicant has the financial ability to undertake the project; 4) the project is financially feasible; and 5.) the project is in the public interest. *In re Tartan Energy Co*., L.C., 3 Mo.P.S.C.3d 173, Case No. GA-94-127, 1994 WL 762882 (Sept. 16, 1994).

In the instant case, the Commission is proposing a rulemaking for future applications of RNG (biogas and hydrogen). EDF submits that it is appropriate to require alternative fuel applications to follow the traditional Tartan factors. Following these criterion are particularly important since the blending of RNG is a relatively new concept that utilities are beginning to undertake. When an applicant is applying for a CPCN, these factors are the foundation on which the Commission relies when making their decision. While these factors foster more transparency in the application process, facilitating an earlier understanding of whether a project is likely to be used and useful, whether its associated costs are likely to be prudent and reasonable, and whether it is in the public interest. These criterion are equally important when considering an RNG blending project, and thus should similarly be mandatory filing requirements.

Additional principles that the Commission should consider when evaluating an application are (1) accountability, (2) equity and inclusivity, (3) reduction of greenhouse gas (GHG) emissions, and (4) cost-effectiveness as compared to other supply and demand-side alternatives to achieve similar outcomes. Definitions of these terms in this context are as follows.

1. Accountability - a clear demonstration of how the project will continually be used and useful and in the public interest, considering reasonable forecasts.

2. Equity and Inclusivity - creating benefits for historically under-served communities or those with higher total energy burdens as a share of income. Projects should also be inclusive from the start and reflect interests and priorities of participants.

3. Reduction of GHG emissions - projects that they could provide substantial and cost-effective emissions reductions in the context of a future, largely or entirely decarbonized gas system.

4. Cost-effectiveness: there are numerous supply- and demand-side options for meeting gas system needs at lower emissions than traditional investments in the natural gas system and continued or increased natural gas use; for example, weatherization and energy efficiency. An analysis of potential alternatives should be included to demonstrate the reasonableness of undertaking an RNG blending project.

These additional principles are as important as the Tartan factors, particularly given the rapidly evolving understanding of the use of alternative fuels in the natural gas distribution system. The nascency of the alternative fuel landscape in Missouri further underscores the need for additional filing requirements, as well as for continuous review of the standards once the projects are better understood. While the approval of a project will likely provide evidence for and inform the ratemaking process, approval through this process should not be considered a decision on ratemaking or cost recovery.

Renewable Natural Gas Program – Question 7

What credits or certificates should be used to track volumes of RNG generated?

a. Are there current certification/crediting processes already in use, or should a certification specific to Missouri be developed? Please provide as much detailed information as possible regarding the certification/crediting process currently in use.

b. Please describe the current or proposed certification process, how ownership of credits is derived, and existing markets for RNG credits.

c. Do RNG credits expire? If so, please provide citations to regulations of the various credits including timeline from development of a credit to expiration.

d. Which entities will be credited with the renewable attributes (i.e. credits) of RNG within an Investor Owned Utility RNG program? Will those renewable attributes be transferrable?

e. What entity will be responsible for running and tracking the RNG credit system?

f. How should sales/transfers of RNG credits be handled?

i. What mechanism is appropriate to return those revenues to ratepayers or participants?

g. Should RNG credits expire? If so, when?

EDF Comment:

Whether Missouri creates its own certification/crediting process or adopts one being used elsewhere (see e.g. the TotalGreen program offered by Northern Illinois Gas Company d/b/a Nicor Gas, see Illinois Commerce Commission Docket No. 21-0098, Final Order of November 18, 2021 at 118-126), accountability and transparency are essential for any attribute-based program.[12] The Commission should require the Company to identify the types of projects that are providing environmental credits. This is for basic consumer information and protection, transparency, accountability, and administrative efficiency. Despite credits and registries that may change over time, the Company should provide in its proposal specific details and examples of the type, size and location of facilities from which the credits originate, and the specific credit activities. These are basic levels of service description and transparency the Company should provide, even at the proposal stage, to inform the Commission's review and approval of the proposal. Credits should not be accepted from Companies that cannot meet this proposed standard.

Additionality is an essential element of a credit program. An activity that becomes required in the future will no longer qualify as additional. A credit in a registry that is additional today may lose its additionality in the future if there are changes to regulations and law. It is incumbent on the program, registry, and credit provider to document and verify that credits remain additional as the regulatory and policy landscape evolve. Otherwise, future developments could render the program worthless, without stakeholders being aware of the deficiency.

[12] Order available at: https://icc.illinois.gov/docket/P2021-0098/documents/317918/files/553459.pdf .

Considering what credits should be used to track volumes of RNG generated will depend on the Company's estimate and plan to reduce emissions during the extraction, production, and delivery of gas, including fugitive and combustion emissions.

Renewable Natural Gas Program – Question 8

Please provide detailed explanations of the economics of current RNG facilities.

a. What are the primary revenue streams that support these facilities?

i. Please provide detailed estimates, with citations to the extent possible, of the market value of various products.

b. What equipment is necessary to construct a RNG facility by fuel source type?

c. What are the ongoing costs of processing RNG to natural gas (NG) pipeline quality by fuel type?

i. Are there incremental investments/replacements necessary over the life of the facility? Please provide detailed explanations, timelines, and cost estimates for those investments.

d. What are the approximate costs for constructing a RNG facility by fuel source type?

e. Is RNG typically stored on-site, and if so, what is a typical storage amount based upon peak monthly production?

f. Provide estimates for the cost of pipeline or distribution system interconnection based upon various distances from RNG facilities.

g. Provide detailed explanations for RNG production quantities by feed stock type.

i. How does production from RNG facilities change based on variations from normal weather (i.e. colder than normal, warmer than normal, various precipitation levels, etc.)? Do those changes vary by feed stock?

ii. What is the typical variation for gas production (upper bound, lower bound, and confidence intervals if available)?

iii. How do various agricultural feed stocks impact RNG production (i.e. poultry, cattle, swine, vegetative, combination, etc.)?

h. What safety/security measures need to be installed at RNG facilities and what are the approximate costs for each measure based on facility size?

i. Should a RAM include any tax incentives? Why or why not?

EDF Comment:

The economics of natural gas and alternative fuels like biomethane/renewable natural gas are changing rapidly as technology, markets, and policies evolve. There are a multitude of options for natural gas utilities to respond to these changes, and those options are not only natural gas, blending of natural gas with hydrogen, or biogas. As other programs are being developed and proposed, regular reevaluation of the rules approved in this process will be necessary to make sure that they are still reasonable in light of the rapidly changing landscape. What is economic today, or next year, may not be economical the year following. Otherwise, the Commission risks long-term approval of costs that create an undue cost burden for customers, sacrifice reliability, or leave vulnerable communities behind.

Renewable Natural Gas Program – Question 9

Pipeline quality limits - questions for operators of natural gas transmission and distribution systems:

a. Heating Value

i. What is the range of heating values of the natural gas your system currently receives? Please provide numerical values and specify the units (e.g. 950 to 1,200 BTU/dry standard cubic foot, at STP).

ii. In your opinion, what is an acceptable range of heating values if renewable natural gas is substituted for or blended with the natural
gas delivered to your system? (If different from the range for the natural gas your system currently receives, please explain the reason(s) for the differences.)

b. Water Vapor

i. What is the maximum limit for water vapor in the natural gas currently delivered to your system? Please provide a numerical value and specify the units (e.g. 7 pounds of water vapor per MMcf).

ii. In your opinion, what is a reasonable maximum limit for water vapor content if renewable natural gas is substituted for or blended with the natural gas delivered to your system? (If different from the limit for the natural gas your system currently receives, please explain the reason(s) for the differences.)

c. Impurities

i. What are the maximum limits for the following listed impurities in the gas currently delivered to your system? Please provide a numerical value and specify the units (e.g. 1.0 grain of hydrogen sulfide per 100 cf).

1. Hydrogen sulfide
2. Total Sulfur
3. Oxygen
4. Liquid hydrocarbons
5. Carbon dioxide
6. Hydrogen
7. Active bacteria or bacterial agents
8. Hazardous or toxic substances
9. Other

ii. In your opinion, what are reasonable maximum limits for impurities if renewable natural gas is substituted for or blended with the natural gas delivered to your system? (If different from the limits for impurities in the natural gas your system currently receives, please explain the reason(s) for the differences.)

1. Hydrogen sulfide
2. Total Sulfur
3. Oxygen
4. Liquid hydrocarbons
5. Carbon dioxide
6. Hydrogen
7. Active bacteria or bacterial agents
8. Hazardous or toxic substances
9. Other

d. Do you have any additional suggestions related to gas quality limits if renewable natural gas is?

EDF Comment:

There is not a clear consensus regarding to what extent hydrogen can be safely blended into existing gas distribution systems, and there is likely significant variability depending on pipeline material, age, and other factors. capacity of in-line compressors, and compatibility with end-use appliances like cooktop burners and heating furnaces. Until there is a scientific consensus on safe hydrogen blending limit, large-scale hydrogen blending into gas distribution systems should not be pursued.

Renewable Natural Gas Program - Question 11

What differences exist between interconnection at the LDC level versus interstate pipeline level?

EDF Comment:

EDF submits that purchases of or investments in RNG – whether it is injected directly into the LDC or procured from an interstate pipeline – are the same. In either case, the costs of the RNG use must be prudent, just, and reasonable, as addressed in Question 4 above.

Renewable Natural Gas Program – Question 12

Do you have any further comments regarding specific topics that should be considered in the context of an RNG rule? Please provide as much information as possible and citations for supportive information, if available.

EDF Comment:

While this rulemaking is focused on biogas and hydrogen blending, the future of the gas system and viable decarbonization pathways is rapidly evolving. Technological, market, and policy shifts are driving change nationwide. The Commission should be mindful of this backdrop in considering rules for Biogas and hydrogen blending. For example, the trend toward electrification is being accelerated by the federal Inflation Reduction Act. In contrast, hydrogen is a relatively new alternative, but production is energy intensive and there are currently no scalable sources of natural hydrogen, as addressed in Question 4 above. . Leading economy-wide decarbonization analyses identify building electrification as the primary, most cost-effective pathway to reduce GHG emissions from the building sector and identify[13] Against this backdrop, the Commission should consider the extent to which the rules approved in this process support long-term benefits.

[13] *Net Zero by 2050: A Roadmap for the Global Energy Sector*, INT'L ENERGY AGENCY, Part 2.5.5, Part 3.7 (revised Oct. 2021), https://www.iea.org/reports/net-zero-by-2050; Jan Rosenow, *Is Heating Homes with Hydrogen All But a Pipe Dream? An Evidence Review*, 6 JOULE 2225 (2022), https://doi.org/10.1016/j.joule.2022.08.015.

The Commission must prioritize safety, climate benefits, and cost effectiveness, to carefully assess mixing hydrogen into existing gas pipeline systems. There are significant research studies that illustrate the risk associated with biogas and hydrogen. Therefore, the Commission should encourage companies to utilize the most cost-effective and safe decarbonization strategies, not just the two choices or biogas and hydrogen. Further, the Commission should encourage companies to engage the community for their feedback. Transparency and accountability are paramount, ratepayers and stakeholders feedback should be taken into consideration.

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Respectfully submitted,

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Comparison of Climate-Warming Emissions per Unit Energy Delivered: Natural Gas (Methane) v. Hydrogen/Methane Mix

	Unit	**100% Natural Gas**	**20% Hydrogen / 80% Natural Gas**		
		Methane	**Methane**	**Hydrogen**	
		Methane has 1% leakage rate	**Methane has 1% leakage rate**	**Hydrogen has 1% leak rate (same as methane)**	**Hydrogen has 3% leak rate (three times as methane)**
Proportion of gas by volume	Fraction	1	0.8	0.2	
Volume of gas required to deliver same energy content as 100% natural gas (assuming 1 m^3 of 100% natural gas yields 1 unit of energy delivered)[a]	m^3	1	0.92	0.23	
Resulting increase in volume of gas	%	0	15	15	
Mass of gas for delivering 1 unit of energy[b]	kg	0.67	0.62	0.02	
Emissions from leakage	kg	0.01	0.01	0.0002	0.0006
Emissions in CO_2e-20[c]	kg CO_2e-20	0.55	0.51	0.01	0.02
Emissions in CO_2e-100[d]	kg CO_2e-100	0.2	0.18	0.002	0.007
	100% natural gas	**80/20% mix same leak rate**	***Reduction in emissions from mix***	**80/20% mix 3* leak rate**	***Reduction in emissions from mix***
Total emissions from delivering 1 unit of energy (kg CO_2e-20)	0.55	0.52	*6%*	0.53	*4%*
Total emissions from delivering 1 unit of energy (kg CO_2e-100)	0.2	0.187	*7%*	0.192	*4%*

[a] Energy content of methane (natural gas): 39.8 MJ/m^3; energy content of hydrogen: 12.7 MJ/m^3

[b] Mass per volume of methane (natural gas): 0.668 kg/m^3; mass per volume of hydrogen: 0.08375 kg/m^3

[c] CO_2e20 refers to carbon dioxide equivalence using global warming potentials with 20-year time horizon; fossil methane GWP-20 = 83 (IPCC AR6 WGI 2021) and hydrogen GWP-20 = 37 (Sand et al. 2023)

[d] CO_2e100 refers to carbon dioxide equivalence using global warming potentials with 100-year time horizon; fossil methane GWP-100 = 30 (IPCC AR6 WGI 2021) and hydrogen GWP-100 = 11.5 (Sand et al. 2023)

Note: rounding may yield inconsistent summations in the table relative to raw data.

Certificate of Service

The undersigned certifies I have caused a true and correct copy of the foregoing to be served on the General Counsel of the Staff of the Missouri Public Service Commission and the Office of Public Counsel by email on this 18th day of September, 2023.

Martin C. Rothfelder