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Sarah Moore, Project Manager
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U.S. Department of Energy
1000 Independence Ave SW
Washington, D.C. 20585

Re: Comments by Clean Energy Group regarding Notice of Intent to Prepare an Environmental Impact Statement (EIS) for the Appalachian Hydrogen Hub; Department of Energy (DOE) Docket DOE-HQ-2024-0082.

Dear Ms. Moore,

Clean Energy Group (CEG), a national nonprofit organization that works to provide innovative technical, economic and policy solutions to enable communities to participate equitably in the clean energy transition, is pleased to provide these comments in response to the Department of Energy's (DOE) notice of intent to prepare an Environmental Impact Statement (EIS) for the Appalachian Hydrogen Hub also known as the Appalachian Regional Clean Hydrogen Hub (ARCH2). These comments reflect the position of CEG and do not necessarily reflect the positions of CEG's partner organizations or funders.

For the past four years, CEG has worked extensively with environmental justice and community-based partners on hydrogen issues. Through its national Hydrogen Information and Public Education initiative, CEG is working to counter misinformation regarding hydrogen by developing a repository of research and information on the viability of issues related to the production and use of hydrogen. In addition, through this initiative, CEG supports the work of frontline organizations to understand and critically evaluate how hydrogen production may benefit or harm their communities.

The development of the Appalachian Hydrogen Hub and the scope of this environmental impact statement will have wide ranging implications for the evaluation of federally funded hydrogen projects moving forward. Ensuring that the environmental impact of ARCH2 is accurately evaluated is crucial in developing a hydrogen economy that supports, rather than hinders, vital decarbonization efforts, and minimizes harm to environmental justice communities. An analysis of the chemical properties of hydrogen and how it interacts with surrounding materials and the atmosphere, as well as an examination of production methods and end uses proposed by ARCH2, will be necessary in determining the best path forward for this regional hub.

EIS Comment Deadline

First and foremost, we urge DOE to extend the deadline for comments on the proposed scope of the EIS by another 60 days. ARCH2 has provided limited information on the scope and locations of the proposed projects, leading to a lack of community knowledge and awareness of the potential environmental impact of the development of this hub. Extending the comment period would allow more time for crucial information to be released that would inform community engagement and education around the environmental impact statement.

All three in person scoping meetings for this EIS process have been cancelled, one scheduled for February 5th in Pennsylvania, one scheduled for February 12th in Ohio, and one scheduled for February 13th in West Virginia. These meetings would have provided an opportunity for community members to provide input, an important step in the process. Extending the deadline for comments would be a step in the right direction to ensure that all voices be heard and incorporated into the scope.

Hydrogen's Global Warming Potential

While hydrogen does not produce carbon dioxide (CO2) when combusted, the rapid expansion of a hydrogen economy could still exacerbate global warming. Hydrogen interacts with the atmosphere in four main ways: 1) it extends the lifetime of methane in the atmosphere; 2) it increases the production of ozone; 3) it increases the production of stratospheric water; and 4) it alters the production of certain aerosols. These atmospheric effects culminate in an extreme global warming potential, nearly 12 times that of CO2 over 100 years after release. When looking at a time scale of 20 years, hydrogen contributes to climate warming 35 times more than CO2.[1] Venting hydrogen is part of standard industry safety practices during the production, transportation, and storage of this gas, and understanding the effects of introducing hydrogen into the atmosphere through these practices is imperative to analyzing the climate impacts of increased hydrogen production and use through the Pacific Northwest Hydrogen Hub.

In addition to purposeful venting of hydrogen into the atmosphere, hydrogen will be introduced into the atmosphere through unintentional leakage. Due to its small molecular size and low density, hydrogen gas is highly prone to leakage. While exact data on leakage is limited, many models have pointed to the necessity for leakage rates to be kept at a minimum as hydrogen production and use increases to mitigate the climate warming effects.[2] Leak detection for hydrogen is a nascent technology, still being developed and refined, and relying on this limited data could underestimate the true climate warming effects of hydrogen production and use.[3]

ARCH2 has stated that it plans to produce 1,500 metric tons per day (mtpd) of hydrogen.[4] The impact of intentional and unintentional release of hydrogen into the atmosphere through industry standard venting and inevitable leakage while producing and offtaking this 1,500 mtpd of hydrogen could have far reaching consequences for the climate and must be included in the scope of the EIS.

Hydrogen Safety

Hydrogen's chemical properties increase the safety risks from leaks and ignition. Hydrogen has a wide ignition range and burns hotter than the most utilized and studied flammable gas, methane. When it

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[1] Sand, Maria, Ragnhild Bieltvedt Skeie, Marit Sandstad, Srinath Krishnan, Gunnar Myhre, Hannah Bryant, Richard Derwent, et al. "A Multi-Model Assessment of the Global Warming Potential of Hydrogen." Communications Earth & Environment 4, no. 1 (June 7, 2023): 203. https://doi.org/10.1038/s43247-023-00857-8.

[2] Bertagni, Matteo B., Stephen W. Pacala, Fabien Paulot, and Amilcare Porporato. "Risk of the Hydrogen Economy for Atmospheric Methane." Nature Communications 13, no. 1 (December 13, 2022): 7706. https://doi.org/10.1038/s41467-022-35419-7; Ocko, I. B., and S. P. Hamburg. "Climate Consequences of Hydrogen Emissions." Atmospheric Chemistry and Physics 22, no. 14 (2022): 9349–68. https://doi.org/10.5194/acp-22-9349-2022.

[3] Qanbar, Mohammed W., and Zekai Hong. "A Review of Hydrogen Leak Detection Regulations and Technologies." Energies 17, no. 16 (August 15, 2024): 4059. https://doi.org/10.3390/en17164059.

[4] Office of Clean Energy Demonstrations, "Appalachian Hydrogen Hub (ARCH2) Awardee Fact Sheet," September 2024. H2Hubs Appalachian Factsheet Booklet_update.pdf

ignites, hydrogen flames are invisible during the daytime.[5] Additionally, there are no commercially available odorants for hydrogen, an odorless gas, that could aid crucial leak detection, especially around workers and customers.[6] The properties of hydrogen flames paired with inadequate leak detection technology make the production and transportation of this gas of particular concern.

ARCH2 has proposed the use of hydrogen combustion for power generation.[7] When combusted, hydrogen produces on average six times as much NOx as methane.[8] NOx pollution is a public health hazard that does significant damage to the respiratory system over time. Many frontline communities located near existing heavily polluting power plants or existing oil and gas production sites have developed serious health disparities due to overexposure to NOx. These impacts are not limited to areas where production or combustion takes place, and adverse health impacts are seen even when NOx emissions are within permitted limits.

Existing NOx emissions control technologies, such as using a catalytic reaction, diluting the fuel mix with water or steam, or using newer low-NOx technology such as a dry low NOx (DLN) combustion system, are not equipped to handle higher blends of hydrogen and natural gas. During a pilot hydrogen blending demonstration at NYPA's Brentwood facility, NOx emissions increased as much as 24 percent as the fraction of hydrogen increased. To keep NOx emissions within permitted limits, the plant had to significantly increase water consumption.[9] At best, in newer turbines developed to successfully combust 100 percent hydrogen while deploying NOx emissions control technologies, NOx emissions remain like that of a newer natural gas plant.[10] Environmental justice communities are already seeing adverse health impacts from NOx emissions at these levels, and introducing a new source of NOx emissions could have devastating effects.

When combusting hydrogen in gas turbines, special consideration must be made to the interaction of hydrogen with typical turbine materials. Hydrogen corrodes metals through a process called hydrogen embrittlement (HE), where hydrogen diffuses into the alloy and combines with carbon to form methane, which then creates crack in the metal. Exposure to hydrogen can result in a decreased resistance to fracture and an exacerbation of the existing flaws in steel and other types of metal.[11] The nickel-based

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[5] Martin, Paul, Ilissa B. Ocko, Sofia Esquivel-Elizondo, Roland Kupers, David Cebon, Tom Baxter, and Steven P. Hamburg. "A Review of Challenges with Using the Natural Gas System for Hydrogen." Energy Science & Engineering 12, no. 10 (October 2024): 3995–4009. https://doi.org/10.1002/ese3.1861.
[6] Ibid.
[7] Office of Clean Energy Demonstrations, "Appalachian Hydrogen Hub (ARCH2) Awardee Fact Sheet," September 2024. H2Hubs Appalachian Factsheet Booklet_update.pdf
[8] Cellek, Mehmet Salih, and Ali Pınarbaşı. "Investigations on Performance and Emission Characteristics of an Industrial Low Swirl Burner While Burning Natural Gas, Methane, Hydrogen-Enriched Natural Gas and Hydrogen as Fuels." International Journal of Hydrogen Energy 43, no. 2 (January 11, 2018): 1194–1207. https://doi.org/10.1016/j.ijhydene.2017.05.107
[9] Low Carbon Resource Initiatives, "Hydrogen Cofiring Demonstration at New York Power Authority's Brentwood Site: GE LM6000 Gas Turbine." Technical brief. 2022 LCRI-PG LCRI Program. EPRI, September 15, 2022. https://restservice.epri.com/publicdownload/000000003002025166/0/Product
[10] Kawasaki Heavy Industries, Ltd. "World's First Successful Technology Verification of 100 percent Hydrogen Fueled Gas Turbine Operation with Dry Low NOx Combustion Technology Improving Power Generation Performances to Realize a Hydrogen Society," July 21, 2020. https://global.kawasaki.com/news_200721-1e.pdf
[11] Raju, Arun SK, and Alfredo Martinez-Morales. "Hydrogen Blending Impacts Study." Prepared by: University of California, Riverside. Prepared for: The California Public Utilities Commission. https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M493/K760/493760600.PDF

alloy that typically comprise gas turbine blades are particularly susceptible.[12] Corrosion of these components due to the introduction of hydrogen could result in safety failures and a decrease in turbine durability.

For decades the Appalachian region has been the site of energy extraction processes like coal mining and natural gas fracking that have exposed residents to extreme levels of air and water pollution, and introducing new sources of air pollution through hydrogen combustion for power generation would have grave implications for one of America's most impoverished regions.

Blue Hydrogen Production

ARCH2 intends to produce the majority of the 1,500 mtpd of hydrogen through fossil fuels paired with carbon capture and storage (CCS), also known as blue hydrogen. Fugitive methane emissions during the production of blue hydrogen greatly increase its greenhouse gas footprint, and in some cases, it produces more greenhouse gas emissions than natural gas use.[13] The production of blue hydrogen is also very water intensive, consuming more than 1.5 million gallons of water for an average plant.[14]

CCS is a technology that has not been proven at scale as existing CCS projects do not meet their target CO2 capture goals, and estimates of emissions reductions are inflated.[15] Additionally, CCS projects employ carbon dioxide pipelines that lead to long term storage. These pipelines can leak and even rupture, emitting climate warming gases and potentially poison surrounding residents as seen in the Satartia, MI pipeline rupture.[16] Instead of evaluating target claims, DOE must evaluate the realistic emissions from blue hydrogen production at the Appalachian hydrogen hub.

In order to produce blue hydrogen, ARCH2 will need a steady supply of fossil fuels. Appalachia is a center for much of the nation's fracking industry, and decades of air and water pollution has contributed to the severe health disparities present in the area. The region's hydrogen hub will perpetuate these harms through its proliferation of blue hydrogen. The cumulative effects of decades of harm coupled with a new demand for fossil fuels must be evaluated as the hub moves forward.[17]

The societal, health, and climate implications of fracking and fossil fuel extraction must be included in any evaluation of this hub. We urge the DOE to analyze the effects of the fracking and fossil fuel

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[12] Zhang, Zhichao, Jurriaan Peeters, Vera Popovich, and Can Ayas. "Combined Effects of Stress and Temperature on Hydrogen Diffusion in Non-Hydride Forming Alloys Applied in Gas Turbines." International Journal of Hydrogen Energy 47, no. 71 (August 19, 2022): 30687–706. https://doi.org/10.1016/j.ijhydene.2022.07.006.
[13] Howarth, Robert W., and Mark Z. Jacobson. "How Green Is Blue Hydrogen?" *Energy Science & Engineering* 9, no. 10 (2021): 1676–87. https://doi.org/10.1002/ese3.956.

[14] Lewis, Eric, Shannon McNaul, Matthew Jamieson, Megan Henriksen, H. Matthews, Liam Walsh, Jadon Grove, Travis Shultz, Timothy Skone, and Robert Stevens. "Comparison of Commercial, State-of-the-Art, Fossil-Based Hydrogen Production Technologies," April 12, 2022. https://doi.org/10.2172/1862910.
[15] Institute for Energy Economics and Financial Analysis. "Carbon Capture and Storage: An Unproven Technology." Accessed March 3, 2025. https://ieefa.org/ccs.
[16] Ramirez-Franco, Juanpablo. "The Nation's First Commercial Carbon Sequestration Plant Is in Illinois. It Leaks.," *NPR Illinois.* October 21, 2024. https://www.nprillinois.org/illinois/2024-10-21/the-nations-first-commercial-carbon-sequestration-plant-is-in-illinois-it-leaks; Simon, Julia. "The U.S. Is Expanding CO2 Pipelines. One Poisoned Town Wants You to Know Its Story." *NPR*, September 25, 2023, sec. Climate. https://www.npr.org/2023/05/21/1172679786/carbon-capture-carbon-dioxide-pipeline.
[17] Payne, Elizabeth E. "The Human Impact: Mining and Fracking in Appalachia." *Appalachian Voices* (blog), August 23, 2017. https://appvoices.org/2017/08/22/the-human-impact-mining-and-fracking-in-appalachia/; Ohio River Valley Institute. "Repairing the Damage from the Fossil Fuel Industry." Accessed March 3, 2025. https://ohiorivervalleyinstitute.org/repairing-the-damage/.

extraction needed to produce the feedstock for blue hydrogen projects including air and water pollution, emissions from extraction and leakage, and well as the historic impacts of the fracking industry on nearby communities.

Hydrogen Liquefaction, Storage and Transport

Development plans proposed for ARCHES include the production, storage, and transport of liquid hydrogen.[18] Hydrogen liquefaction is a very energy intensive process. Hydrogen transforms into a liquid from a gas at –253 degrees Celsius, a much lower temperature than other liquid fuels, so more energy is needed for the conversion and to maintain the liquid state of hydrogen. To convert ~12,000L of gaseous hydrogen into ~14L liquid hydrogen (both equaling 1kg), around 13.8 kWh of energy is used.[19]

Storing and transporting liquid hydrogen provides novel issues. Through the duration of time that the liquid hydrogen is stored and transported, one to five percent of the liquid will evaporate into gas per day. Allowing this expanded hydrogen gas to remain in storage containers with liquid hydrogen would lead to explosions, so it is industry practice to vent this hydrogen gas into the atmosphere.[20] This extensive venting practice will have major implications for the climate due to hydrogen's global warming effects and must be taken into consideration during an environmental evaluation.

Hydrogen Blending

One of the projects currently identified for ARCH2 includes blending hydrogen into natural gas pipelines. As previously discussed, hydrogen creates cracks in steel and iron pipelines through hydrogen embrittlement (HE) and permeates through plastic pipelines, increasing the risk of hydrogen accumulation and explosion as well as leakage of hydrogen and methane into the atmosphere. A recent report done for the Pipeline Safety Trust fully details the safety hazards present when blending hydrogen with natural gas, including the corrosion of pipelines leading to potential rupture, hydrogen's increased flammability and wide ignition range compared to natural gas, and the lack of safety assessment tools available for hydrogen.[21] Leaks from natural gas pipelines are consistently undercounted and injecting hydrogen into these pipelines would only increase the leakage rates for both hydrogen and methane.[22]

In addition to the safety hazards of blending extremely flammable hydrogen gas with natural gas into the natural gas pipelines, the health implications of combusting hydrogen in end-use appliances like furnaces and stoves must be evaluated. As previously described, burning hydrogen results in six times more

[18] Office of Clean Energy Demonstrations, "Appalachian Hydrogen Hub (ARCH2) Awardee Fact Sheet," September 2024. H2Hubs Appalachian Factsheet Booklet_update.pdf

[19] Zhang, Tongtong, Joao Uratani, Yixuan Huang, Lejin Xu, Steve Griffiths, and Yulong Ding. "Hydrogen Liquefaction and Storage: Recent Progress and Perspectives." Renewable and Sustainable Energy Reviews 176 (April 1, 2023): 113204. https://doi.org/10.1016/j.rser.2023.113204.

[20] Ibid.

[21] Accufacts Inc., "Report: Safety of Hydrogen Transportation by Gas Pipelines," Prepared for: Pipeline Safety Trust. November 28, 2022, Microsoft Word - 11-28-22 Final Accufacts Hydrogen Pipeline Report.docx

[22] Sherwin, Evan D., Jeffrey S. Rutherford, Zhan Zhang, Yuanlei Chen, Erin B. Wetherley, Petr V. Yakovlev, Elena S. F. Berman, et al. "US Oil and Gas System Emissions from Nearly One Million Aerial Site Measurements." *Nature* 627, no. 8003 (March 2024): 328–34. https://doi.org/10.1038/s41586-024-07117-5; Baird, Austin, Austin Glover, and Brian Ehrhart. "Review of Release Behavior of Hydrogen & Natural Gas Blends from Pipelines," Sandia National Laboratories. August 1, 2021. https://doi.org/10.2172/1817836.

nitrogen oxides (NOx) than natural gas. The increase of this harmful air pollutant would result in negative health impacts for natural gas customers as NOx emissions cause severe damage to respiratory systems.[23]

HE is an issue across the production, transportation, storage, and end use of hydrogen, regardless of its point of injection into the natural gas supply chain. Increased scrutiny must be paid to the types of metals and materials used throughout the hydrogen supply chain to prevent corrosion, decreased fracture resistance, and accelerated degradation of transportation and storage materials. ARCH2 has proposed dedicated hydrogen pipelines to transport the fuel to various end uses, and the development of hydrogen storage facilities, making it imperative that the materials used for this infrastructure are not susceptible to hydrogen embrittlement, lattice dilation, or permeation. Negative interactions with these materials could lead to increased leakage, hazardous explosions, and decreased infrastructure longevity.

Ammonia Production

Another intended end use of hydrogen proposed within the Appalachian hub is its use in the production of ammonia. Ammonia production exacerbates PM2.5 air pollution, frequently identified as the most harmful air pollutant, leading to chronic respiratory illnesses and premature death.[24] Ammonia breaks down into nitrogen dioxide, which in excess damages ecosystems and contributes to smog and acid rain.[25] Leakage estimates from the ammonia supply chain range from 2.6% to 6%, greatly increasing the prevalence of reactive nitrogen and the potential for health and ecosystem harm.[26]

The Environmental Impact Statement is an important step in evaluating the consequences of a fully developed ARCH2 hub. As the hydrogen economy proliferates, it is crucial that all environmental and social harms related to hydrogen production and use at ARCH2 be investigated. The impacts of the proposed projects for the Appalachian Hydrogen Hub do not start and end at the production of hydrogen. Impacts related to the production of the feedstock for hydrogen and relevant demand increases and the implications of the end uses proposed throughout this region must be included in a full evaluation.

In conclusion, CEG urges the DOE to analyze and evaluate impacts including but not limited to the global warming effects of venting and leaking hydrogen into the atmosphere, increased NOx emissions from hydrogen combustion, flammability of hydrogen, emissions and water use related to blue hydrogen production, hydrogen liquefaction, hydrogen blending, and the exacerbation of historic harms from fossil fuel production in the region. These issues could have grave consequences for the health and safety of Appalachians and broader decarbonization goals within the region, and the EIS is an opportunity to ensure the most just and effective path forward.

We would welcome a conversation to discuss these issues further if that is of interest.

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[23] Price, Doris, Rona Birnbaum, Richard Batiuk, Melissa McCullough, Roy Smith. "Nitrogen Oxides: Impacts on Public Health and the Environment", US Environmental Protection Agency. August 1997. D:I14NOXREPT.PDF | US EPA ARCHIVE DOCUMENT

[24] Wyer, Katie E., David B. Kelleghan, Victoria Blanes-Vidal, Günther Schauberger, and Thomas P. Curran. "Ammonia Emissions from Agriculture and Their Contribution to Fine Particulate Matter: A Review of Implications for Human Health." *Journal of Environmental Management* 323 (December 1, 2022): 116285. https://doi.org/10.1016/j.jenvman.2022.116285.

[25] Plautz, Jason "Ammonia, a Poorly Understood Smog Ingredient, Could Be Key to Limiting Deadly Pollution." *Science*, September 13, 2018. https://www.science.org/content/article/ammonia-poorly-understood-smog-ingredient-could-be-key-limiting-deadly-pollution.

[26] Virdis, Bernardino, and Jamin Wood. "Why Green Ammonia May Not Be That Green." *The Conversation*, April 27, 2023. http://theconversation.com/why-green-ammonia-may-not-be-that-green-204363.

Respectfully submitted,

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