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Statement of
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# Hearing on Senate Bill 5

## Committee on Natural Resources and Energy
## Vermont State Senate

## February 8, 2023

My name is Robert Howarth. I am an Earth systems scientist with a B.A. from Amherst College and a Ph.D. from MIT and the Woods Hole Oceanographic Institution. I have been a tenured faculty member at Cornell University in Ithaca, NY since 1985 and an endowed professor at Cornell since 1993 (*the David R. Atkinson Professor of Ecology & Environmental Biology*). I have also served as an Adjunct Senior Scientist in the Ecosystems Center of the Marine Biological Lab in Woods Hole, MA for the past 23 years. For decades, I have worked on the consequences of global climate change, on emissions of methane from the oil & gas industry as a driver of climate change, on the production and use of hydrogen, and on alternative energy policies. I have published over 200 peer-reviewed papers, and these have been cited more than 79,000 times in other peer-reviewed literature, making me one of the most highly cited environmental scientists in the world.

Throughout my career, I have been engaged in energy and environmental policy, and I have given briefings and testimony at the White House, at the U.S. Congress and to committees of the US Senate, to the Canadian Senate, to the European Parliament, to the Irish Parliament, to the Senate and Assembly of the State of New York, and in New York courts. I have served on many committees of the US National Academy of Sciences and the International Council of Science, having chaired several of these. Currently, I am one of 22 members of the New York State Climate Action Council, which is the body charged by law with the development of the implementation blueprint ("Scoping Plan") for New York's progressive climate law, the Climate Leadership & Community Protection Act of 2019.

Today, I want to address the proposal that "clean heat credits" be given by the State of Vermont for green hydrogen and for renewable natural gas. In my professional opinion, it would be unwise for Vermont to encourage the use of either hydrogen or renewable natural gas for heating of homes and commercial buildings. These uses were debated extensively by the New York Climate Action Council and its advisory panels and sub-groups over the past 2 to 3 years. In our final Scoping Plan from the Council (passed by a strong 19-3 vote on December 19, 2022), the Council fully rejected the use of hydrogen for heating homes, and put aside the issue of RNG saying it needed further study. Renewable natural gas was certainly not endorsed, though, and I note that renewable natural gas is not mentioned at all in the Executive Summary of the Scoping Plan.

Let me first address renewable natural gas (RNG). RNG is made by processing biogas, making a fuel that is composed mostly of methane and that can be mixed with fossil natural gas in gas pipeline systems. Biogas is a mixture of methane and carbon dioxide as well as other impurities that is produced from anaerobic digesters (including some wastewater treatment plans as well as farm-based systems using manure) and can be captured from landfills. The biogas can itself be used as a fuel, for instance to

generate electricity or heating, but biogas is not suitable for use in pipeline distribution systems. In the final Scoping Plan for the New York Climate Action Council, we specified that whenever possible, biogas should be used directly at the site of production, and preferably used in fuel cells rather burned to generate electricity. Our plan further stated that the use of biogas as biogas was to be preferred to processing it into RNG. There are two reasons for this: 1) it takes energy to process biogas into RNG, and so this is inherently inefficient and increases greenhouse gas emissions; and 2) the latest peer-reviewed science shows that methane emissions from processing biogas into RNG can be substantial, as shown in a review paper published last year (see: Bakkaloglu, Cooper, and Hawkes. 2022. Methane emissions along biomethane and biogas supply chains are underestimated. *One Earth* 5: 724-736, doi:10.1016/j.oneear.2022.05.012). Converting biogas into renewable natural gas is wasteful and further contributes to greenhouse gas emissions, with no benefit other than to allow the gas to be pumped into the traditional fossil gas distribution systems.

Please let me note that Vermont Gas Systems currently has contracted to buy RNG from the Seneca Meadows Landfill in central-western New York State, with an expectation of a significant increase in purchase in coming years. This gas is not actually delivered to Vermont, nor will it ever be: rather, the gas enters a general pipeline system moving gas to the west, away from Vermont. Vermont Gas Systems apparently gets financial credits for this scheme through trading mechanisms established by the California Air Resources Board (CARB). The CARB's policy on RNG is based on old, out-of-date science. They simply are wrong that there is any greenhouse-gas benefit from using RNG, and in fact the use of RNG may lead to greenhouse gas emissions that exceed those from using fossil natural gas. The State of New York will now be discouraging the production of RNG such as that from Seneca Meadows Landfill, based on the Climate Action Council's final Scoping Plan. I respectfully ask that the State of Vermont not encourage a policy that runs counter to the policy of New York, and do so based just on paper credits without even any actual delivery of any RNG to Vermont. California started a bad policy in this area, and one that we in New York hope to reverse at least within our State. This issue is close to my heart, as I live only 40 miles from the Seneca Meadows Landfill, the largest active landfill still active in New York, and an environmental travesty with a height of 28 feet over 400 acres. I hate to think that Vermont citizens who buy gas from Vermont Gas Systems will continue to contribute to our environmental problems in the Finger Lakes of New York.

Second, let me address hydrogen. I am pleased to see that Vermont is apparently not favoring any hydrogen made from fossil natural gas, even if with carbon capture. In 2021 I published the first peer-reviewed analysis showing why that is a bad idea for climate when methane emissions are considered (see: Howarth and Jacobson. 2021. How green is blue hydrogen? *Energy Science and Engineering* 9: 1676-1687, doi: 10.1002/ese3.956).

The "clean heat credit" being considered in this bill by Vermont is for green hydrogen, that is hydrogen made from 100% renewable electricity using electrolysis to break water into hydrogen and oxygen. Green hydrogen has a far lower greenhouse gas impact than does the hydrogen made from fossil fuels, but it is still significant: hydrogen gas is the smallest molecule in the Universe, and as such is very hard to retain and keep from leaking. And while hydrogen is not itself a greenhouse gas, when more hydrogen is leaked to the atmosphere it does significantly increase global warming through prolonging the time methane stays in the atmosphere and adding more water vapor to the stratosphere (See: Ocko and Hamburg. 2022. Climate consequences of hydrogen emissions. *Environmental Science & Technology* 22: 9349–9368, doi.org/10.5194/acp-22-9349-2022).

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In addition to the role of hydrogen as an agent of global warming, there are many reasons not to put hydrogen into gas pipeline systems and use hydrogen for heating homes and commercial buildings. These are summarized in the table below which I produced for the New York State Climate Action

Council in my final statement accompanied my "yes" vote for our the Scoping Plan we adopted on December 19, 2022. That full statement is appended at the end of my testimony below and includes detailed referencing to support the table. These reasons against hydrogen include safety concerns, greenhouse gas emissions, inefficiencies, and high costs to consumers. With regard to safety, there is widespread recognition that most current pipelines designed and built to deliver fossil natural gas are simply not suitable for carrying hydrogen except at very low blends with the fossil gas. Exactly what level of blending is safe remains unknown, but based on a study they commissioned from the University of California at Riverside, the California PUC recommends that no more than 5% hydrogen be blended with 95% fossil natural gas (see: Pearl. 2022. Hydrogen blends higher than 5% raise leak, embrittlement risks for natural gas pipelines: California PUC. Utility Dive, https://www.utilitydive.com/news/hydrogen-blends-higher-than-5-percent-raise-leak-embrittlement-risks/627895/). With regard to inefficiencies, green hydrogen should be viewed as a precious and expensive resource made from renewable electricity, and using the electricity directly to heat homes with high-efficiency heat pumps generates 6 to 10 times more heat than does the green hydrogen can produce.

**Concerns with Blending Hydrogen into Gas Pipelines that Serve Homes & Apartments**

- Hydrogen is very leaky, much more so than methane, and hydrogen leakage from pipelines will contribute to global warming.
- Only small quantities of hydrogen can be blended with fossil gas in distribution pipelines, since hydrogen makes pipelines more brittle, potentially increasing methane emissions and leading to greater catastrophic risk.
- Most existing gas appliances in homes and apartments (furnaces, cooking stoves, water heaters, dryers) are not designed to burn hydrogen-methane blends, and increasing the hydrogen content can decrease the efficiency of combustion and lead to increased air pollution, particularly of nitrogen oxides.
- Most engineering studies indicate greatly increased risk of mixing more than 20% hydrogen into fossil gas systems, and the California Air Resources Board has concluded that no more than 5% hydrogen should be blended until further study shows higher amounts are sufficiently safe.
- The energy density of hydrogen is far less than for methane, so blending 20% hydrogen into a fossil-fuel distribution pipeline reduces the combustion emissions of carbon dioxide by only 7%.
- Hydrogen is significantly more expensive than fossil gas, and so blending any hydrogen into the distribution system increases costs.
- Using renewable electricity to produce green hydrogen which is then used to heat homes and apartments diverts this electricity from more efficient uses, such as using heat pumps. For the same quantity of electricity, a heat pump can deliver 6 to 10 times more heat in a home than could burning green hydrogen.
- Inefficient uses of renewable electricity drive up costs and slow the transition from fossil fuels, since renewable electricity will remain a relatively scarce and precious commodity for the next few decades.

Of note, all independent studies have argued against using hydrogen for home heating, including peer-reviewed papers as well as reports from the International Energy Agency and the UN's Intergovernmental Panel on Climate Change (see: Rosenow. 2022. Is heating hydrogen with homes all

but a pipe dream? An evidence review. Joule. doi :10.1016/j.joule.2022.08.015). This includes 33 different studies as of today. Only studies funded by or carried out on behalf of industry groups with a vested interest in promoting hydrogen have ever suggested the use of hydrogen for heating. Based on this science, the New York State Climate Action Council strongly recommended against delivery of green hydrogen through the gas pipeline system to heat homes in our final Scoping Plan (see Chapter 18, https://climate.ny.gov/resources/scoping-plan/).

In conclusion, I urge the State of Vermont to not promote issue "clean heat credits" that would promote the use of renewable natural gas and hydrogen for home heating and use in gas delivery systems.

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Cornell University

and

**Member of the New York Climate Action Council**
by appointment of the Honorable Carl Heastie, Speaker of the Assembly

December 19, 2022

I fully support the Scoping Plan enacted today by the Climate Action Council, and I am honored and proud to have served on the Climate Action Council since its inception. I thank Speaker Carl Heastie and other members of the Assembly for this opportunity to have served. In my comments that follow, I speak as a member of the Council and as an Earth systems scientist and faculty member at Cornell University who has worked for over 40 years on issues of global change. My comments should not be construed as official positions taken by my employer, Cornell University.

Assembly Person Steven Englebright was hugely instrumental in the passage of the Climate Leadership & Community Protection Act that established the Climate Action Council. I thank him for his leadership on this, and particularly for his support of the progressive approach on greenhouse gas emissions that is a central part of the CLCPA. I originally proposed this to Assembly Person Englebright in 2016, and he enthusiastically endorsed and supported it through multiple versions of the bill that finally led to passage of the CLCPA in 2019. In this accounting for greenhouse gases, a major government for the first time ever fully endorsed the science demonstrating that methane emissions are a major contributor to global climate change and disruption. Further, in passing the CLCPA New York recognized that consumption of fossil fuels (and not simply geographic boundaries) is what matters in addressing the climate crisis. New York wisely banned the use of high-volume hydraulic fracturing ("fracking") to develop shale gas in our State. But since the time of that ban, the use of fossil natural gas has risen faster in our State than any other in the Union. Methane emissions from this use of shale gas are high, but much of that occurs outside of our boundaries in the nearby states of Pennsylvania, West Virginia, and Ohio. Through the CLCPA, the citizens of New York are taking responsibility for these out-of-state emission caused by our use of fossil fuels, particularly for fossil natural gas. The way to reduce these emissions is to rapidly reduce our use of fracked shale gas.

The Assembly and Senate specified in the CLCPA that many of the agency heads of New York's government be members of the Climate Actions Council, and also stated that the Council take input from a set of advisory panels. Both of these requirements led to the leadership of the State being heavily engaged and invested in the implementation of the CLCPA. And the panels brought in a large number of experts and key stakeholders who worked diligently to advise the Council on our Scoping Plan. The Plan benefitted immensely from their efforts and input, and all New Yorkers owe them our thanks.

In the well over one hundred meetings of the Council, advisory panels, and working groups since March of 2020, all viewpoints have been respectfully heard and debated. The tone set by our co-Chairs,

NYSERDA President Doreen Harris and DEC Commissioner Basil Seggos was a critical part of this. I thank them and all of the members of the Council for our sense of community through deliberations in which we often had major differences of opinion. I also thank the staff who contributed so much to the background information provided to the Council and to the drafting of our final report. A large number of individuals participated and contributed in major ways, but I want to particularly thank and acknowledge our Council Executive Director Sarah Osgood, Maureen Leddy and Jared Snyder from DEC, Carl Mas from NYSERDA, and Jessica Waldorf of DPS.

I further wish to acknowledge the incredible role that Prof. Mark Jacobson of Stanford has played in moving the entire world towards a carbon-free future, including New York State. A decade ago, Jacobson, I and others laid out a specific plan for New York (Jacobson et al. 2013). In that peer-reviewed analysis, we demonstrated that our State could rapidly move away from fossil fuels and instead be fueled completely by the power of the wind, the sun, and hydro. We further demonstrated that it could be done completely with technologies available at that time (a decade ago), that it could be cost effective, that it would be hugely beneficial for public health and energy security, and that it would stimulate a large increase in well-paying jobs. I have seen nothing in the past decade that would dissuade me from pushing for the same path forward. The economic arguments have only grown stronger, the climate crisis more severe. The fundamental arguments remain the same.

Our final Scoping Plan from the Climate Action implicitly endorses the vision of the Jacobson et al. paper and is quite clear: we can meet the goals of the CLCPA and we can and will do so in way that is affordable and that will benefit all New Yorkers. Our State will be stronger as this plan is implemented, the health and well being of our citizens improved. Economic uncertainties and vulnerabilities will be reduced. Energy security will be enhanced. Our plan is also clear that the #1 priorities are to continue to move towards wind, solar, and hydro as our source of electricity; to move rapidly towards beneficial electrification as a source of heating and cooling in our homes and commercial buildings; and to move rapidly towards beneficial electrification in our personal and commercial vehicles.

Although I strongly support our final Scoping Plan, I have some disappointments. Chief among these is the decision to postpone the dates by which the State will move away from fossil fuel use for construction of new homes and commercial buildings, which are now one year later than in our draft plan passed in December 2021. For single family homes, for example, our final Scoping Plan calls for the prohibition of fossil fuels in new construction in 2025, not the 2024 specified in the draft plan. The building sector is the largest single source of greenhouse gas emissions, as I discuss further in the next paragraph below. Therefore, the greatest priority for meeting the goals of the CLCPA should be to reduce emissions from the building sector. I urge the Assembly and Senate to act to mandate that the State move away from fossil fuels more quickly than called for in the Council's Scoping Plan., using the guidance from the December 2021 draft Scoping Plan.

Exactly how important are emissions from the building sector in New York State? The Scoping Plan states this sector is the single largest emitter, accounting for 32% of the total (closely trailed by transportation at 28%). However, I believe the Plan understates the importance of the building-sector emissions for two reasons. First, methane emissions from the operations of the fossil natural gas industry in New York are included as part of the "industry" sector in the Scoping Plan, whereas they should have been included in the building and electric sectors according to the accounting specified in the CLCPA (these emissions would not occur if the fossil natural gas were not being used in our buildings and electric power plants). Making this correction, the building sector is seen to contribute 36% of all emissions, followed by 28% for transportation, 14% for electricity, 12% for waste, 6% for agriculture, and only 4% for industry. Second, the greenhouse gas inventory for the State released by the DEC in December 2021 understates methane emissions from the use of fossil natural gas, in my professional

opinion, using an emission factor of 2.49% of gas production. The preponderance of peer-reviewed literature reviewed in my recent paper suggests the factor should be 4.8% (Howarth 2022), a value that is 1.9-times greater than that used by the DEC. Correcting by this factor, I estimate that the building sector is responsible for more than 40% of all greenhouse gas emissions in New York State.

The Scoping Plan strongly calls for beneficial electrification with heat pumps as the best way forward to reduce greenhouse gas emissions from the building sector in New York. I completely agree, but I feel the Plan could have made an even stronger case by including several recent papers and reports. Further, the Plan tends to favor air-sourced heat pumps over ground-sources heat pumps. While the initial cost of the air-sourced pumps is less, they have higher energy and maintenance costs. One recent study examining heat pumps for new home construction in the context of New York State concluded that ground-sourced heat pumps are actually less expensive when these energy and maintenance costs are included (Shron et al. 2022). This was true across the State, in both the coldest and warmest regions. The study also concluded that both air-sourced and ground-sourced heat pumps are almost always less expensive than building new homes heated by fossil natural gas or propane, although air-sourced heat pumps cannot quite out compete fossil natural gas (at average prices over the past decade) in the warmest part of the State, Long Island, according to this report. However, the Long Island Power Authority (2022) has produced a brochure arguing that air-sourced pumps are cost effective for new homes over fossil natural gas on Long Island. And of course the cost of fossil natural gas has increased dramatically since these studies were produced, and may well stay high indefinitely into the future according to many energy economists. If so, anyone building a new home in 2023 or 2024 using natural gas for heating will soon wish they had instead built a fossil-fuel-free home with heat pumps. Further, these costs are from the perspective of the new home owner. I have repeatedly urged in meetings of the Climate Action Council over the past 18 months that we consider the entire energy system when considering the question of heat pumps: ground-sourced heat pumps require far less electricity during peak winter heating times, meaning that encouraging their use over air-sourced pumps lessens the need for electricity storage and for total renewable generating capacity, which could benefit consumers immensely.

As a Council, we spent a disproportionate amount of time in debating what I believe are side issues such as renewable natural gas (RNG) and hydrogen for heating of homes. The oil & gas industry globally has pushed such ideas very heavily as a way to keep their massive fossil-gas pipelines system profitably in operation (Lowes and Cebon 2022). At the Climate Action Council, we have regularly heard suggestions that pipelines in the future can deliver hydrogen and RNG. I and others on the Council have pushed back with objective, scientifically based evidence. In the end, the Council fully rejected the use of hydrogen for heating homes, and somewhat put aside the issue of RNG saying it needed further study. I am pleased to say that RNG is not mentioned at all in the Executive Summary of the Scoping Plan, and hydrogen is mentioned only once, in this case appropriately in the context of its use with fuel cells (not combustion) in transportation (not home heating or use in pipelines).

While the Scoping Plan does not endorse the use of hydrogen for heating or in pipelines, it also does not fully explain the reasons for this decision. And in some places in the text, there is a suggestion for more research on hydrogen. In fact, there is a large amount of information that clearly demonstrates why hydrogen for delivery to homes for heating is a bad idea (Kurmayer 2021; Rosenow 2022; Pearl 2022; Prieto and Henchen 2022; Collins 2022; Lowes and Cebon 2022). There simply is no need for further research on this bad idea. Some of the major reasons for rejecting the use of hydrogen for heating for homes are outlined in the following table.

**Concerns with Blending Hydrogen into Gas Pipelines that Serve Homes & Apartments**

- Hydrogen is very leaky, much more so than methane, and hydrogen leakage from pipelines will contribute to global warming.
- Only small quantities of hydrogen can be blended with fossil gas in distribution pipelines, since hydrogen makes pipelines more brittle, potentially increasing methane emissions and leading to greater catastrophic risk.
- Most existing gas appliances in homes and apartments (furnaces, cooking stoves, water heaters, dryers) are not designed to burn hydrogen-methane blends, and increasing the hydrogen content can decrease the efficiency of combustion and lead to increased air pollution, particularly of nitrogen oxides.
- Most engineering studies indicate greatly increased risk of mixing more than 20% hydrogen into fossil gas systems, and the California Air Resources Board has concluded that no more than 5% hydrogen should be blended until further study shows higher amounts are sufficiently safe.
- The energy density of hydrogen is far less than for methane, so blending 20% hydrogen into a fossil-fuel distribution pipeline reduces the combustion emissions of carbon dioxide by only 7%.
- Hydrogen is significantly more expensive than fossil gas, and so blending any hydrogen into the distribution system increases costs.
- Using renewable electricity to produce green hydrogen which is then used to heat homes and apartments diverts this electricity from more efficient uses, such as using heat pumps. For the same quantity of electricity, a heat pump can deliver 6 to 10 times more heat in a home than could burning green hydrogen.
- Inefficient uses of renewable electricity drive up costs and slow the transition from fossil fuels, since renewable electricity will remain a relatively scarce and precious commodity for the next few decades.

As with hydrogen, the Scoping Plan does not endorse any widespread use of RNG. In fact, the Plan specifies that it is generally preferable to use biogas (the unrefined mixture of methane and carbon dioxide produced in anaerobic digesters and landfills) directly and at the site of production rather than refining the biogas to produce RNG. However, the Plan does not fully explain the strong science behind this conclusion. Briefly, it takes energy to refine RNG, and this comes either from fossil natural gas with the associated greenhouse gas emissions or from using some of the biogas to power the refining (resulting in a loss of some useful energy, and a lower overall efficiency of using the energy of the biogas). Further, biogas itself can have substantial methane emissions, and the refining of biogas into RNG can substantially increase these methane emissions (Bakkaloglu et al. 2022). In a memorandum I wrote to the Alternative Fuels Working Group of the Climate Action Council in July 2022, I calculated that using the CLCPA accounting methodology and mean emissions from the Bakkaloglu et al. study, methane emissions for RNG are 156 g $CO_2$-equivalents/MJ, or 1.7-times greater than the combined methane and carbon dioxide emissions for fossil natural gas. Unless these methane emissions can be greatly reduced, New York should clearly discourage the use of RNG.

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