1. Request for Information – Project Title	Lifecycle Greenhouse Gas Emissions from Energy Use for the State of Vermont
2. Name of Firm	Eastern Research Group, Inc. (ERG)
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5. Date of Submission	March 4, 2022

Lifecycle Greenhouse Gas Emissions from Energy Use for the State of Vermont

ERG appreciates the opportunity to present its capabilities for the request for information titled *'Seeking Availability of Environmental Consultants with Expertise in analysis of Lifecycle Greenhouse Gas (GHG) Emissions from Energy Use for The State of Vermont'.* Vermont is assessing expanding its greenhouse gas emissions inventory (GHGEI) to account for impacts beyond its border such as the upstream impacts from production and supply of energy resources used in state. ERG brings unique qualifications related to conducting both consumption-based GHG emissions inventories (CBEI) and upstream fuel cycle accounting for energy sector GHGEIs, as described in the subsequent sections. Our response is organized as follows:

Part 1: Response to Statement of Need
Part 2: Brief Description of Expertise with Similar Projects and Clients
Part 3: List of Qualifications as it Pertains to this Project

Part 1: Response to Statement of Need

1. *Please detail your qualifications and experience with conducting lifecycle GHG emissions analyses for national or sub-national jurisdictions.*

- We recently supported New York State in including out-of-state energy fuel life cycle emissions in its updated GHG inventory. New York State's 2019 Climate Leadership and Community Protection Act requires accounting for GHG emissions associated with the extraction and transmission of fossil fuels imported into the state for consumption. This requirement necessitates using upstream fuel life cycle factor data—a requirement unique for GHG inventories. We developed customized and regionally-explicit time series models for upstream fossil-fuel extraction, processing and distribution that occur outside of New York, but which result from consumption of fuels within New York. To generate the results, we used both national and region-specific, bottom-up models (including many we support ourselves, such as the Argonne National Laboratory GREET model and models for National Energy Technology Laboratory (NETL)). We developed technical report documentation and interactive inventory tables for the state to use in its public-facing emissions inventory reporting process and presented the method during a public webinar.

- We are one of the primary technical contributors in developing and updating EPA's US Environmentally Extended Input-Output (USEEIO) Model, a widely used, tool for assessing supply chain GHG emissions across all commodities and sectors in the economy.[1] For

[1] USEEIO model description available at: https://www.epa.gov/land-research/us-environmentally-extended-input-output-useeio-models

example, this model was used to develop EPA's dataset for Supply Chain GHG Emission Factors for US Industries and Commodities. Additionally, USEEIO is widely used by commercial organizations (e.g., Amazon, General Motors) for Scope 3 GHG reporting. USEEIO provides a national perspective aimed at supporting governmental agencies in reporting supply chain impacts by sector. ERG is currently working with the EPA and northeastern states to develop CBEIs tailored to the consumption patterns and emissions of specific states using USEEIO.

2. ***Please define and explain the term "lifecycle" and "upstream" for purposes of a GHG emissions analysis.***

- **Lifecycle:** the comprehensive scope of processes, from raw material extraction through combustion, that defines a fuel's production and use; intermediary processes may include processing, transmission, and/or distribution of fuels.
- **Upstream:** activities that proceed the final step of a process or product under analysis; for the purposes of a fuel-based GHG emissions analysis, this would include all steps preceding the combustion of fuels (i.e., raw material extraction, processing, transmission and/or distribution) within the analysis' defined geographic region, regardless of whether these upstream steps take place outside or inside the geographic boundary of the analysis.

ISO 14040/44 standards can also be referenced for specific LCA terminology definitions.

3. ***Based upon your definition of "lifecycle" and "upstream" in (2), do you foresee any issues in focusing on either lifecycle or upstream emissions solely related to Vermont's energy supply (including but not limited to electricity including renewable, hydro, solar, wind and nuclear generation; liquid fuels for transportation and heating including biofuels, gaseous fuels including renewable fuels, and solid fuels including wood) versus a more comprehensive consumption based or lifecycle analysis of the energy emissions impact of goods and services?***

The boundaries and data sources used as well as the level of effort will vary based on the approach employed. ERG has expertise in both CBEI and developing upstream emissions for a state's energy sector. Either approach is feasible. There are three possible options to consider:

- **Conducting comprehensive consumption-based LCA:** this approach typically uses environmentally extended input-output (EEIO) data coupled with statewide spend information to determine the life cycle impacts of all goods and processes consumed in the state.
- **Energy sector upstream fuel cycle accounting:** similar to our support for the New York State energy sector GHGEI, this approach typically relies on detailed bottom-up process models to determine the impacts of fuel extraction, processing, and distribution that occur outside of the state but relate to energy consumed in the state. Energy sector upstream emissions are particularly important to capture, especially as they relate to methane emissions that occur in the fossil fuel supply chain.

- **Hybrid approach:** this approach would use detailed process models to capture the impacts of the energy sector, which often can dominate GHGEIs, and then use an EEIO to capture impacts from other types of goods (e.g., food, clothes) consumed in Vermont.

All approaches are valid, but have a different level of coverage. An energy sector upstream approach has been employed by other states and captures impacts from a dominate source of GHGs.

4. *Please identify any other states, provinces, or nations that have undertaken a similar jurisdiction-wide energy-related lifecycle or upstream GHG emissions analysis that might serve as a useful guide to Vermont's efforts.*

- The State of New York passed the Climate Leadership and Community Protection Act in 2019 which requires the accounting for GHG emissions associated with the extraction and transmission of fossil fuels imported into the state for consumption. ERG lifecycle staff supported this effort. ERG's methodology for developing upstream fuel life cycle factor data is documented in a public-facing file that can be found on the website of the New York State Energy and Research Development Authority (NYSERDA): https://www.dec.ny.gov/docs/administration_pdf/energyghgerg.pdf
- Both the State of Oregon and the State of Minnesota developed consumption-based GHG emissions inventories (CBEI) which estimate worldwide supply chain emissions associated with satisfying in-state consumption.

5. *Please provide a list of recommended software, datasets, methodologies, protocols, etc. that would be required to perform a lifecycle or upstream GHG emissions analysis for Vermont.*

	Source	Description
Datasets	United States Greenhouse Gas Inventory (US GHGI)	Annual data on natural gas activity factors and emissions
	United States Energy Information Administration (US EIA)	Annual data on natural gas activity factors and emissions
	US GHGI	Annual data on changes in underground coal mine methane emissions over time
	US EIA	Annual data on coal origin source for coal received by power plants
	US EIA	Annual data on coal distribution transport modes
	US EIA	Annual data on petroleum imports and domestic, interstate movement

<table>
<tr><th></th><th>Source</th><th>Description</th></tr>
<tr><td rowspan="2"></td><td>EPA's supply chain GHG factors for U.S. industries and commodities</td><td>Provides GHG supply chain emission factors to use with economic data</td></tr>
<tr><td>Federal LCA Commons</td><td>Repository of publicly available federal and non-federal (e.g., through USLCI database) datasets for modeling supply chain impacts of commodity materials and energy processes</td></tr>
<tr><td rowspan="4">Software/Models</td><td>USEEIO Model</td><td>EPA's EEIO model used to determine the full supply chain impacts of all sectors and commodities in the economy</td></tr>
<tr><td>openLCA/National Energy Technology Laboratory (NETL) natural gas model</td><td>1. Assesses GHG emissions from natural gas extraction, processing, transmission, and distribution from U.S. natural gas basins
2. Underlying data sourced from GHGI and Greenhouse Gas Reporting Program</td></tr>
<tr><td>openLCA/National Energy Technology Laboratory (NETL) coal extraction and processing model</td><td>1. Profiles coal extraction through coal cleaning for U.S. production basins
2. Underlying data on coal production and coal mine methane emissions source from EIA and EPA</td></tr>
<tr><td>The Greenhouse Gases, Regulated Emissions, and Energy Use in Technologies (GREET) Model by Argonne National Laboratory</td><td>Contains data on upstream petroleum fuel cycle emission factors and domestic and international shares of crude oil</td></tr>
<tr><td>Methodologies</td><td colspan="2">A CBEI could take an approach using an EEIO method. Process models (described above) could be used for a detailed assessment of the energy sector. The following methodologies relate to specific considerations for energy supply process modeling:
1. Adjusting static openLCA natural gas and coal models to represent changes in fuel activity data over time
2. Adjusting for undercounting of methane emissions from bottom-up emissions (e.g., include comparison to satellite emissions data)</td></tr>
<tr><td>Protocols</td><td colspan="2">LCA and carbon footprint methodologies are further outlined in ISO 14040/44 and 14067</td></tr>
</table>

6. ***Are there other software, datasets, methodologies, protocols available? If so, please describe the rationale for your recommended selections.***

- In addition to the openLCA models described above, the Argonne National Laboratory GREET model includes life cycle emission factors for natural gas and coal. The GREET model is a well-established and highly regarded tool for life cycle applications. However for a regionally explicit fuel cycle analysis we would recommend the datasets above as the GREET model does not enable parameterization for basin-specific natural gas characteristics, nor does it explicitly account for the full range of sources of emissions within the gas supply chain. As for coal, the GREET model does not account for differences across mine basins or mine types.
- Alternative models for estimating emissions from petroleum are the Oil Production Greenhouse gas Emissions Estimator (OPGEE) extraction model and Petroleum Refinery Life Cycle Inventory Model (PRELIM) for refining. These models have been leveraged in developing the GREET model; however, using these models on their own requires extensive input data that may be unavailable for the specific crude assays consumed in Vermont.

7. ***Would any of the components you recommend require specialized training of staff, purchase of software licensing or subscriptions, purchase of specialized hardware, an ongoing need for consultant services, etc.? If so, please elaborate.***

- No; ERG has access to all necessary datasets and software and has staff specialized in use of these software.
- The datasets and models we recommend are all open-source, which will reduce cost and allow for full transparency in data and methodology.

8. ***Please describe the tasks and estimate the anticipated number of person hours required to produce a lifecycle or upstream analysis for a single calendar year, and whether a similar level of effort would be required annually in future years to compile a comparable analysis.***

- The level of effort will vary based on the approach taken (see question #3). For an energy sector life cycle approach, we estimate the first year of the work would require 1500-2000 labor hours or approximately one to 1.5 full time person equivalents for the year.
- ERG anticipates that updating the analysis in future years would require a lower level of effort as compared to developing the initial inventory. The initial inventory could be structured to accommodate future additions of data; therefore, the level of effort for future years would be primarily focused on procuring and inputting data into the initial inventory structure.

9. ***Do data of sufficient detail exist to describe the diverse and variable nature of Vermont's energy imports with reasonable accuracy for a given year?***

- Based off ERG's previous experience developing emission factors for energy imports for the State of New York, sufficiently detailed data exist to account for upstream life cycle emissions from various fuel imports into the state, although some assumptions supported by peer-reviewed literature may have to be made to fill in any data gaps and back cast emission factors. Upstream fuel cycle information exists at the average U.S. level, and ERG also brings expertise in developing spatially explicit upstream fuel cycle emission factors based on final demand. See notes on example fuel-specific data below:
    - Natural Gas
        - openLCA NETL natural gas model assesses GHG emissions from natural gas extraction, processing, transmission, and distribution from domestic natural gas basins; is representative of 2016 activity and emissions data, but contains parameters that can be adjusted to account for changes in emissions over time, as well as other parameters specific to a Vermont context.
        - Assumptions will have to be made about which natural gas basins Vermont sources its consumed gas from.
    - Coal
        - openLCA NETL coal model profiles coal extraction through coal cleaning
            - Underlying data on coal mine methane emissions over time can be adjusted.
        - EIA data exist for determining coal source and transport to Vermont.
    - Petroleum
        - GREET contains annual data on petroleum fuel cycle emission factors and domestic and international share of crude oil.

10. ***Please identify the time lags in the availability of the underlying data for a lifecycle or upstream GHG emissions analysis (e.g., when would sufficient data to conduct an analysis for calendar year 2021 become available and is this later than data availability for the current inventory approach?).***

In general, estimates of fuel cycle emissions or upstream emission factors are not expected to vary substantially from one year to the next. Activity, or consumption data, is much more significant for developing a time series emissions inventory. With that being said, data to support the development of upstream emissions generally are updated at the same frequency as other emissions data sources used in the current inventory approach. Some models or data sources used to characterize the emissions from upstream production are not updated annually.

Data	Availability
US GHGI annual data on natural gas activity factors and emissions	• Data for 2021 expected to be available in early 2023 • In a scenario where the State of Vermont would be interested in conducting a 2021 inventory before these data are released, and extrapolation of the trends in changes in data over the past few years could be made for 2021
US EIA annual data on natural gas gross withdrawals and production	Finalized data for 2021 are expected to be available in late 2022; however, the EIA does release estimates of 2021 data beforehand (currently unavailable)
US GHGI annual data on changes in underground coal mine methane emissions	Data for 2021 expected to be available in 2023
EIA annual data on coal origin source for coal received by power plants	Release of 2021 data expected in late 2022
EIA annual data on coal distribution transport modes	Estimates for 2021 data expected to be available in late 2023
EIA annual data on petroleum imports and domestic, interstate movement	Data for 2021 expected to be available in early 2023
GREET data on upstream petroleum fuel cycle emission factors	Data for 2021 expected to be available in late 2022

11. Please describe any methodological challenges, limitations, data gaps, etc. that are likely to be encountered during the preparation of a statewide lifecycle GHG analysis related to energy use. In addition, please state your opinion regarding the feasibility and usefulness of conducting a comparable analysis for historical years, including the baseline years 2005 and 1990.

- To conduct a comparable analysis for historical years, including the baseline years of 2005 and 1990, more assumptions around data may have to be made in comparison to more recent years, but detailed data do exist around production amounts and emissions for different fuels. The usefulness of conducting a comparative analysis to the baseline years is that it can serve as a benchmark to (1) inform to what extent Vermont has reduced its state-wide GHG emissions over time and (2) help the State gauge where it stands on meeting future GHG reduction goals.
- Methodological challenges with natural gas fuel cycle
    - A body of peer-reviewed literature has recently emerged highlighting the potential for bottom-up natural gas methane inventories to be underestimating actual emissions, when compared to bottom-up measurements. The majority of public data on natural gas supply chain emissions which would inform this analysis is from bottom-up inventories, so one challenge would be developing an approach to reconcile this discrepancy.

- Another challenge is assigning natural gas consumed in Vermont to specific production basins, due to the intermixing of natural gas in the transmission network post-processing. Addressing this challenge would require a literature search for any published data that could inform to which basins Vermont gas could be assigned.

12. Please describe if / how this analysis might inform or interact with Vermont's existing annual statewide GHG emissions inventory.

- As it pertains to natural gas for commercial or residential use, if Vermont's existing GHG inventory contains data on natural gas in-state transmission and distribution emissions, this information could supplement the out-of-state upstream piece from this analysis to help complete a comprehensive well-to-burner fuel cycle emission factor.
- In general, the upstream fuel cycle accounting approach handles emissions that occur outside of the state. This allows the upstream emissions to be used in conjunction with the current inventory approach.
- Upstream fuel cycle energy factors can also be applied to electricity imports to the state.

13. Do you have recommendations that would maximize the usefulness of this analysis to policymakers? Specifically: what aspects or components should be included or excluded in the analysis to facilitate effective prioritization and development of GHG emissions reduction actions. Should this analysis be periodically repeatable, and if so on what periodic basis should the analysis be conducted?

- An upstream fuel cycle analysis is especially relevant for policymakers seeking to drive emissions reductions in states that are net energy importers such as Vermont. A full life cycle comparison is necessary to understand the GHG implications for policy choices that may involve prioritizing some fuel sources over others.
- Calculated emissions factors for upstream fuels are not expected to vary substantially from one year to the next. However, updating those factors with the latest understanding from the scientific literature, especially during fuel extraction and processing, is paramount to maintaining updated inventory estimates. As a result, we would recommend reviewing the upstream emissions factors and updating the models behind them on a periodic basis, e.g., every three years. Annual inventory estimates can still be calculated using the existing emissions factors based on annual updates to consumption estimates.

14. Please provide any additional relevant information you believe is key to conducting this analysis.

All relevant information provided in response to the other questions.

15. Please indicate your availability and capacity to provide assistance to the ANR over the time period of XXXX to YYYY.

- ERG's life cycle experts have availability over the next calendar year (e.g., April 1, 2022 to March 31, 2023) to support the level of effort described in the response to question #8. We have a staff of approximately 20 life cycle experts on hand and access to a broader team of approximately 450 consultants able to provide technical research support as needed.

Part 2: Brief Description of Expertise with Similar Projects and Clients

The table below highlights projects of similar or related scope ERG has or is currently supporting.

Project Title, Client	Description
Technical Support for New York State's GHG Inventory, New York State Energy Research and Development Authority (NYSERDA)	New York State's 2019 Climate Leadership and Community Protection Act requires accounting of GHG emissions associated with the generation of electricity imported into the state and the extraction and transmission of fossil fuels imported into the state. This requirement necessitates using upstream fuel cycle factor data—a requirement novel for GHG inventories. ERG coupled its expertise in GHG inventories and LCA to support NYSERDA's recent GHG inventory effort. For the NYSERDA GHG inventory, ERG developed customized fuel cycle models for natural gas, petroleum, and coal. The models identify the geographic locations for fuel extraction, processing, and distribution relevant to New York. We used regionally explicit bottom-up models, such as those we support for the National Energy Technology Laboratory, as well as national models we support, such as Argonne's Greenhouse Gases, Regulated Emissions, and Energy Use in Technologies (GREET) tool. We conducted additional sensitivity analyses using top-down GHG emission satellite data across the fuel cycle.
Regional Life Cycle Assessment Tool for U.S. Electricity, EPA and NETL	In coordination with EPA and NETL, ERG supported development of the ElectricityLCI (https://www.epa.gov/sciencematters/researchers-develop-regional-lifecycle-assessment-tool-electricity-use), a system that provides a more precise estimate of the entire life cycle of electricity grid impacts at the national, state, and regional levels than currently available electricity inventory data. If a user knows the location of electricity consumption, the model automatically determines which upstream fuel processing datasets to use, such as the mix of natural gas basins and transportation distances. ERG built the system to automatically update and harmonize electricity generation facility data from publicly available government databases. ERG also accounted for the distribution of electricity, including transmission losses, and imports and exports of electricity at the regional level. The open-source ElectricityLCI datasets are available on the Federal LCA Commons (https://www.lcacommons.gov/), and provide a spatially explicit electricity tool for diverse organizations interested in understanding the environmental impacts, including GHG emissions, of the electricity supply chain in the United States.
U.S. Environmentally Extended Input-Output (USEEIO) Model for Consumption-Based Inventories, EPA	ERG helped EPA develop the environmental release information for USEEIO model (https://www.epa.gov/land-research/us-environmentally-extended-input-output-useeio-models). This model uses a life cycle approach to determine high-level impacts of sectors in the U.S. economy across the full supply chain. Impact categories relate to environmental impact potential (including GHGs), resource use, waste generated, and economic and social considerations. The USEEIO model serves as an engine behind EPA's Sustainable Materials Management Prioritization Tools, which comprise interfaces that deliver impact results for supply chains of purchased goods and services from national (e.g., governments, academic institutions) or organizational (e.g., CEOs, procurement and sustainability professionals) perspectives. The USEEIO also is widely used for statewide consumption-based inventories and organizational Scope 3 GHG accounting, given its coverage of all sectors in the economy. ERG is currently working with EPA and

Project Title, Client	Description
	northeastern states to develop state-level consumption-based GHG emissions inventory using the USEEIO as the engine.
Technical Support for GREET model, Argonne National Laboratory	ERG actively contributes data development for Argonne National Laboratory Greenhouse Gases, Regulated Emissions, and Energy Use in Technologies (GREET) Model, which is widely used by public and private organizations for understanding and reporting the supply chain impacts of specific fuels. Specifically, ERG developed GHG results for the following products in GREET: cement and concrete, petrochemicals via steam cracking of natural gas liquids, H2 from steam methane reforming, and petroleum refining. ERG also provides technical programming support for the GREET model.

Part 3: List of Qualifications as it Pertains to this Project

Our staff include more than 450 environmental professionals focused on research areas relevant to the scope of work. We have a team of approximately 20 dedicated life cycle assessment professionals and our group 'Franklin Associates, A Division of ERG' includes staff involved in the original development of LCA methodology. We also serve as the U.S. training partner for openLCA, an open-source software for life cycle modeling. ERG staff also bring expertise in traditional territorial GHG emissions inventories and reporting. Below we have highlighted additional GHG inventory experience, which we can access for Vermont. We have also highlighted additional life cycle qualifications not already covered in Part 1 and Part 2.

Additional GHG Inventory Experience:

- ***GHG Reporting Program:*** ERG has supported EPA's national GHG Reporting Program (GHGRP) since its inception. In the rule development stage, we performed technical analyses of monitoring and reporting methods for several subparts. We also developed outreach materials, conducted training webinars, and created a web-based applicability tool to educate entities that might be required to report their emissions. ERG supports implementation by helping to analyze, verify, and publish reported data, with careful attention to redacting or aggregating data that could reveal confidential business information. We also integrate selected GHGRP data into EPA's national inventory.
- ***U.S. GHG Inventory:*** We have supported the development of EPA's Inventory of U.S. GHG Emissions and Sinks since 2000. ERG provides a wide range of expert support for compiling, tracking, and reporting the nation's annual inventory of GHG emissions:
    - ERG is EPA's primary technical contractor for developing the annual inventory for emissions from manure management (since 2000), enteric fermentation (since 2015), wastewater (since 2006), oil and gas systems (since 2012), industrial processes (2012–2016), coal mining (since 2000), and several land use sources (since 2015). Our technical experts obtain and compile data, maintain EPA's official data storage and calculation workbooks, conduct QC, and have helped EPA refine methods and incorporate new data sources over time.
    - ERG is currently helping EPA develop methods to generate state-level estimates of emissions from all major source categories.

- In addition to implementing Intergovernmental Panel on Climate Change (IPCC) guidelines in compiling EPA's inventory, ERG experts have served on the panels that contributed to the 2006 *IPCC Guidelines* and the 2019 *Refinement*.
- ERG designed and built the Data Explorer, a web-based system to provide user-friendly access to data from the national GHG inventory (https://cfpub.epa.gov/ghgdata/inventoryexplorer). ERG designed the Explorer to pull data from EPA's inventory database, using open-source JavaScript tools for graphs and on-the-fly calculations. The Explorer is open to the public, and EPA staff use it to answer questions and inform policy decisions.

Additional Life Cycle Qualifications:

- ***National Environmental Accounts for GHG Emissions from Industrial Sources:*** In collaboration with EPA, ERG has supported the development of national environmental accounts for U.S. industrial sectors, through the development of a publicly available python tool called the Flow Sector Attribution model (FLOWSA). ERG recently implemented the method to attribute national GHG emissions to industrial sectors through this tool, which will be integrated into the next release of the USEEIO model. ERG is also a partner in using this sector model to support the development of national physical flows accounts to align with the United Nations System of Environmental-Economic Accounting (SEEA) framework.
- ***Federal LCA Commons:*** ERG supports EPA, NETL, Argonne National Laboratory, and industry associations such as the American Chemistry Council (via NREL's USLCI database) in publishing datasets to the Federal LCA Commons, an interagency initiative to create an open source, federal life cycle database. We have created datasets for the Federal LCA Commons for process and transportation fuels, commodity chemicals, virgin and recycled plastics, material-converting operations, and more. This federal life cycle data source can be leveraged for determining supply chain impacts of key background processes such as commodity materials and energy production and generation systems.
- ***Application of Global Datasets:*** ERG recognizes the potential global nature of the Vermont supply chains, and we regularly create models to reflect specific geographies through use of location specific transport distances/modes and energy mixes. We have access to and use global databases for life cycle modeling. We are also familiar and routinely work with international open-source databases such as the Product Environmental Footprint (PEF) database and guidelines in Europe.
- ***Other Economic LCA Data and Tool Development:*** We have supported related EEIO efforts to determine supply chain emissions for other organizations and for broad sectors of the economy. For example, we have adapted use of the USEEIO to determine the supply chain impacts of power plant infrastructure for NETL. We also supported development of National Renewable Energy Laboratory's (NREL) economic LCA bioeconomy tool for determining the environmental impacts of the bioeconomy supply chain.