HEI energy

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A Health Effects Institute Affiliate

Cumulative Impact Assessment for Unconventional Oil and Gas Development Communities

HEI Energy

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This Research Brief is part of a series of periodic updates on the literature about potential human exposures and health effects associated with unconventional oil and gas development (UOGD) in the United States

Trusted Science, Clean Environment, Better Health

Cumulative Impact Assessment for Unconventional Oil and Gas Development Communities

Health Effects Institute Energy

Boston, MA

TRUSTED SCIENCE, CLEAN ENVIRONMENT, BETTER HEALTH

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About HEI Energy

The Health Effects Institute (HEI) Energy is a national research program formed to identify and conduct high-priority research on potential population exposures and health effects from development of oil and natural gas from shale and other unconventional resources across the United States. HEI Energy supports community exposure research in multiple regions. To enable exposure research planning, HEI Energy conducts periodic reviews of the relevant scientific literature. Once initial research is completed, HEI Energy will assess the results to identify additional exposure research priorities and, where feasible and appropriate, health research needs for funding in subsequent years.

The scientific review and research provided by HEI Energy will contribute high-quality and credible science that supports decisions about how best to protect public health. To achieve this goal, HEI Energy has put into place a governance structure that mirrors the one successfully employed for nearly forty years by its parent organization, the Health Effects Institute, with several critical features:

- HEI Energy receives joint funding from the US Environmental Protection Agency under a contract that funds HEI Energy exclusively and from the oil and natural gas industry.
- HEI Energy's independent Board of Directors consists of leaders in science and policy who are committed to fostering the public–private partnership that is central to the organization.
- HEI Energy's research program is governed independently by individuals having no direct ties to, or interests in, sponsor organizations.
- HEI Energy's Research Committee consists of members who are internationally recognized experts in one or more subject areas relevant to the Committee's work, have demonstrated their ability to conduct and review scientific research impartially, and have been vetted to avoid conflicts of interest.
- All research undergoes rigorous peer review by HEI Energy's Review Committee.
- HEI Energy staff and committees engage in open and extensive stakeholder engagement before, during, and after research, and communicate all results in the context of other relevant research.
- HEI Energy makes publicly available all literature reviews and original research that it funds and provides summaries written for a general audience,
- Without advocating policy positions, HEI Energy provides impartial science, targeted to make better-informed decisions.

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Abstract

Many studies and review articles describe the chemical and nonchemical stressors that can affect communities living near unconventional oil and gas development (UOGD). This Research Brief summarizes a scoping review of the peer-reviewed and gray literature that assesses or describes what is known about the cumulative impact of these stressors and methods for assessing cumulative impacts experienced by UOGD communities.

The scoping review revealed a variety of analytical frameworks and decision contexts for conducting cumulative impact assessments (CIAs) alongside a variety of methods that can be used to assess cumulative impacts. Few studies specifically analyzed cumulative impacts in UOGD communities, and more broadly, the literature did not include generally accepted standardized guidance for conducting such assessments. Moreover, questions remain related to both theoretical and methodological aspects of CIA.

Along with an educational webinar series on the topic of CIA, this Research Brief represents an important preliminary step to understanding what is known about cumulative impacts and how to conduct a CIA of UOGD communities.

Introduction

Motivation for This Research Brief

The term "cumulative impacts" refers to the "totality of exposures to combinations of chemical and nonchemical stressors and their effects on health, well-being, and quality of life outcomes" (US EPA 2022). Communities living near UOGD are exposed to multiple chemical and nonchemical stressors from the built, natural, and social environments that may directly and indirectly affect health. These stressors include chemicals released into air or water, noise and light, psychosocial stress, land use changes, traffic congestion, or other impacts to community health and well-being. Other factors experienced by these communities can be beneficial, such as increased employment, income, and overall economic development for the region. Environmental justice (EJ) advocates, government agencies, and researchers have highlighted the need to assess cumulative impacts to better capture the full range and character of impacts experienced by people who are exposed to many types of stressors (Morello-Frosch et al. 2011; Sadd et al. 2011; Baptista et al. 2022; US EPA 2022; Bakkensen et al. 2024; Tulve et al. 2024). Addressing this need should include capturing the cumulative impacts experienced by people who currently live in proximity to, or who could live in proximity to, UOGD activities.

Although current studies have summarized or evaluated stressors separately or individually (e.g., Allshouse et al. 2019), no summaries exist to our knowledge that have synthesized the cumulative impacts of multiple stressors related to UOGD activities. Moreover, there is no standardized guidance for how to conduct or design a CIA for communities experiencing oil and gas extraction and production operations in the United States. To advance the practice of cumulative impact assessment, HEI Energy is conducting a special project that aims to produce an initial design for a CIA for a UOGD community in the United States. Within the context of UOGD research, HEI Energy is well-positioned to synthesize what is already known from the program's currently funded research and what has been learned about the adverse and beneficial impacts on communities over the past two decades. The design will identify and prioritize impacts that are most important for understanding and addressing the health and well-being of people living in communities affected by oil and gas development. More broadly, amid a shifting US energy landscape, this design provides an opportunity to use the experience of UOGD activities to crystallize collective aspirations for an energy transition that maximizes health benefits while minimizing unintended adverse health consequences. As a first step of this larger project, this Research Brief (see Box 1) summarizes the results of a scoping review of the peer-reviewed and gray literature that contributes to the current understanding of cumulative impacts and CIA methods with a focus on the experience of UOGD communities; it does not provide an analysis of the literature.

Box 1: HEI Energy's Research Brief Series

To support HEI Energy's ongoing research and strategic research planning, HEI staff regularly survey relevant scientific literature and make the search results publicly available at our online Literature Hub. Occasionally, staff summarize new literature on timely topics in Research Briefs. These documents provide summaries but not analyses of the literature with the singular goal of keeping HEI's staff and expert committees apprised of scientific developments. This document is the latest in the series of Research Briefs, all of which are freely available on our website.

Overview of Cumulative Impact Assessment

The notion of cumulative impacts has been discussed across multiple disciplines and contexts. Consideration of cumulative impacts has been an integral component in the field of environmental impact assessment (EIA) since the 1970s, most prominently as a requirement of cumulative effects analysis under the National Environmental Protection Act (NEPA) (CEQ Regulations for Implementing the Procedural Provisions of NEPA 1978) and under similar state-level regulations such as the California Environmental Quality Act (CEQA). The notion of cumulative impacts has been linked with the notion of cumulative risk in the context of health risk assessment (Faust 2010; US EPA 2022). Cumulative risk is understood to encompass the combined risks of exposures to multiple environmental stressors to human health (US EPA 2003). In practice, the assessment of cumulative risk refers to either the assessment of chemical mixtures typically with similar modes of toxic action or the assessment of combined effects from a mixture of chemical and nonchemical stressors (Sexton 2012; Payne-Sturges et al. 2021). Acknowledgment and analysis of cumulative impacts has also been a central focus of the EJ movement in highlighting the need to capture the lived experiences of communities exposed to the combined effects of chemical and nonchemical stressors (also referred to as cumulative burden). The inequity in exposures experienced by many communities, including historically marginalized communities, is amplified by the array of multiple and overlapping chemical and nonchemical stressors that characterize the local environment. Advocacy efforts by the EJ movement have in large part spurred recent efforts to consider cumulative impacts in environmental policymaking (Payne-Sturges et al. 2021; Lam et al. 2022).

The US Environmental Protection Agency (EPA) has highlighted CIA as one means in addressing environmental injustice. For example, EPA recently charged the National Academies of Sciences, Engineering, and Medicine (NASEM) with exploring the state of the science of CIA and its application at the community, state, and national levels.[1] The agency also recently released several funding opportunities that focus explicitly on cumulative impacts research. HEI's Community Health and Environmental Research Initiatives program also recently released a funding opportunity focusing on CIA for decision-making. In 2023, President Biden issued Executive Order 14096, which states that the federal government should analyze all federal activities for their potential adverse health and environmental effects related to cumulative impacts (88 FR 25251). Furthermore, several states have developed policies,

[1] Available: *https://www.nationalacademies.org/our-work/state-of-the-science-and-the-future-of-cumulative-impact-assessment*

analytical tools, or guidance that include consideration of cumulative impacts (Environmental Justice Clinic 2024). For example, methodologies for analyzing cumulative impacts have been promulgated by California and New Jersey for over a decade (NJ DEP 2009; Adams and Denton 2010; Alexeeff et al. 2012).

Numerous studies identify multiple chemical and nonchemical stressors in UOGD communities (HEI Energy Research Committee 2020), some of which assess exposures experienced by historically marginalized communities (e.g., Cushing et al. 2021; Proville et al. 2022; Berberian et al. 2023). Much of this work focuses on the "boom" cycle of UOGD activities (Klasic et al. 2022). The evolving energy landscape has highlighted the need for evaluation of cumulative impacts over both the "boom" and "bust" cycles of UOGD activities (Mayfield et al. 2019). No standardized methods for analyzing cumulative impacts currently exist, however, and open questions remain for how to conduct CIAs. Some of these questions relate to varied understanding of cumulative impacts and what is meant by the words "cumulative" and "impacts." Other questions relate to understanding the interrelationships between chemical and nonchemical stressors, data availability, how best to incorporate communities' lived experiences, and approaches for translating cumulative impacts research to inform policy.

Approach to Scoping Review

As defined in HEI (2020), UOGD refers to the onshore development and production of oil and gas from shale and other unconventional, or low permeability, geologic formations. UOGD includes operations associated with the extraction and production of oil and natural gas (HEI Energy Research Committee 2020). This scoping review of the literature focused on communities located near UOGD.

This scoping review of the literature was guided by the following question:

What is known about cumulative impacts and how to conduct a cumulative impact assessment of UOGD communities?

To identify literature that would answer this question, we built a search phrase that included the same oil and gas terms that were used in the HEI Energy Research Committee's survey of the UOGD exposure literature (HEI Energy Research Committee 2020). To the search phrase we added the terms "cumulative impact," "cumulative impact assessment," "cumulative effect," "cumulative exposure," "community benefit," and "community impact." Although we also included the terms "cumulative risk" and "cumulative risk assessment" in the search phrase, we ultimately excluded the majority of documents using these terms because of their limited focus on single chemicals or chemical mixtures. We expected the volume of literature related to CIA and UOGD communities to be small and were aware that much of the cumulative impacts and CIA literature is found in gray literature. Thus, we supplemented the literature search with manual hand searching and consultation with external experts. The results of this search did not reveal any guidance for how to conduct a CIA for a UOGD community. Therefore, we also manually added publications related to CIA more broadly to understand what existing guidance said about how to conduct a CIA. Overall, the literature search included peer-reviewed and gray literature published between January 1, 1997, and March 31, 2024.

The steps in our scoping review of the literature are outlined in Table 1. The formal search phrase returned 8,360 publications. Publication titles and abstracts were screened to identify eligibility. We considered publications related to cumulative impacts research or assessment of cumulative impacts in the context of UOGD as eligible for this scoping review (n = 8). We excluded publications that focused on cumulative risk (i.e., single or multiple chemical stressors only), dietary exposures, psychological development, and toxicology. HEI Energy's Cumulative Impact Assessment Design special project is focused on people's health and well-being; thus, we also excluded studies on cumulative impacts for ecosystem health and ecology only. We additionally excluded studies on UOGD communities that did not focus on cumulative or multiple impacts. Our supplemental manual search yielded an additional 11 publications related to cumulative impacts and UOGD. Finally, we manually included 15 publications that contribute to our understanding of CIA more broadly. Throughout the search, we prioritized literature from the United States and Canada but also included one publication focused on cumulative impacts and UOGD in Australia and two publications focused on other regions because they provided specific guidance on how to conduct a CIA.

In this Research Brief, we summarize 33 publications. Of these, eight publications were included from our search phrase and 25 were manually added. The discussion of this literature is organized following a basic conceptual model for the steps in a CIA that was described throughout many guidance documents in the literature (Figure 1).

Table 1. Search and selection for scoping review of the literature on understanding cumulative impacts and CIA in the context of UOGD communities

Identification	**Potentially useful literature related to cumulative impacts research and CIA in the context of UOGD communities**: *n* = 8,360
Exclusion Criteria	**Excluded publications**: *n* = 8,352 • Cumulative risk related to chemicals or chemical mixtures • Dietary exposure assessment • Psychological development studies • Mechanisms of toxicity • Toxicological studies • Cumulative impacts and ecology/marine ecology only • UOGD not related to cumulative impacts or CIA (e.g., single stressor only)
Included	**From search phrase**: *n* = 8 • Cumulative impacts or CIA and UOGD • Community impacts and UOGD • Multiple stressors and UOGD **From manual searching**: *n* = 25 • Cumulative impacts or CIA and UOGD • Community impacts and UOGD • Multiple stressors and UOGD • CIA guidance • Cumulative impact analysis methodologies • CIA policies in the United States • Recommendations for cumulative impacts research
Total	**Total**: *n* = 33

Figure 1. Conceptual model for the overarching steps in a cumulative impact assessment.

The literature included in this scoping review refers to assessment of cumulative risk, cumulative effects, and cumulative impacts. Although conceptually similar, each term is generally informed by a specific decision context and has subtle nuances in its definition (Box 2). EPA considers cumulative risk assessment to be distinct from CIA (US EPA 2022). CIA and cumulative effect assessment (CEA), however, are more often considered interchangeable throughout the literature (e.g., Blakley 2021). Hereafter, we refer to cumulative impacts in the text for simplicity.

Box 2: Defining Cumulative Impacts, Cumulative Risk, and Cumulative Effects

EPA (2022) defined cumulative impacts as "the totality of exposures to combinations of chemical and nonchemical stressors and their effects on health, well-being, and quality of life outcomes" and stated that these impacts "include contemporary exposures to multiple stressors as well as exposures throughout a person's lifetime," and CIA as "a process of evaluating both quantitative and qualitative data representing cumulative impacts to inform a decision."

Cumulative effects, as defined under NEPA, are "effects on the environment that result from the incremental effects of the action when added to the effects of other past, present, and reasonably foreseeable actions regardless of what agency (federal or nonfederal) or person undertakes such other actions. Cumulative effects can result from actions with individually minor but collectively significant effects taking place over a period of time" (40 CFR 1508.1). Most of the guidance publications that appear in this scoping review reflect guidance pertaining to how to conduct CEA.

As initially delineated in the Council on Environmental Quality (CEQ) 1978 Regulations for Implementing the Procedural Provisions of NEPA, effects and impacts were referred to similarly. In recent revisions to CEQ's implementing regulations for NEPA, CEQ noted that the field of environmental justice often uses the term cumulative impacts, rather than cumulative effects (89 FR 35442). In reference to EJ in the revisions, CEQ has proposed using the term "cumulative impacts" rather than "cumulative effects." CEQ stated that "cumulative impacts" more precisely captures the aggregate effect of multiple stressors and exposures on individuals, communities, or populations within the realm of EJ. CEQ has underscored that the evolving science behind cumulative impacts necessitates differentiation from the broader concept of cumulative effects as delineated in NEPA regulations. However, CEQ has refrained from establishing a formal regulatory definition of "cumulative impacts," noting the evolving nature of this field (89 FR 35442).

(Continues on next page)

Box 2: Defining Cumulative Impacts, Cumulative Risk, and Cumulative Effects
(Continued)

EPA (2003) defined cumulative risk as "the combined risks from aggregate exposures to multiple agents or stressors" and cumulative risk assessment as "an analysis, characterization, and possible quantification of the combined risks to health or the environment from multiple agents or stressors." Although this framework denotes the applicability of cumulative risk assessment (CRA) to a range of decisions, CRA follows a specific methodology to estimate a probability of harm arising from exposure to [multiple] hazards (US EPA 2003).

Results of Scoping Review

The results of this scoping review are organized according to a basic conceptual model for the steps in a CIA (see Figure 1). First, we discuss the analytical frameworks, or steps, to outline a CIA as described in the reviewed literature. We next discuss the decision contexts in which CIA can be conducted. Finally, we discuss the scoping, analysis, and management steps that can form part of a CIA for a UOGD community.

Throughout, this section refers to UOGD literature that describes multiple chemical and nonchemical stressors in UOGD communities, with some specifically assessing historically marginalized communities (e.g., Cushing et al. 2021; Proville et al. 2022; Berberian et al. 2023). Much of this work focuses on the "boom" cycle of UOGD activities (Klasic et al. 2022), and some have called for the evaluation of cumulative impacts over both the "boom" and "bust" cycles of UOGD activities (Mayfield et al. 2019).

Analytical frameworks

The following section discusses steps for CIA described in the reviewed literature. We refer to these steps as frameworks. Each of the analytical frameworks are necessarily influenced by, and derivative of, the decision context in which CIA occurs. Table 2 outlines the major steps in the CIA analytical frameworks that are documented in the literature reviewed here.

Table 2. Frameworks for CIA that appear in this scoping review

Frameworks for CIA that appear in this scoping review		
Title	**Author Year**	**Analytical Framework Steps**
Considering Cumulative Effects under the National Environmental Policy Act	CEQ 1997	EIA framework 1. Scoping 2. Describing the affected environment 3. Determining the environmental consequences
Cumulative Effects Assessment Practitioners Guide; Assessing Cumulative Environmental Effects Under the Canadian Environmental Assessment Act, 2012: Interim Technical Guidance	CEAA 1999; CEAA 2018	CEA framework 1. Scoping 2. Analysis of effects 3. Identification of mitigation 4. Evaluation of significance 5. Follow-up
Good Practice Handbook Cumulative Impact Assessment and Management: Guidance for the Private Sector in Emerging Markets	IFC 2013	Rapid CIA framework

Frameworks for CIA that appear in this scoping review		
Title	**Author Year**	**Analytical Framework Steps**
		1. Scoping phase 1 – valued environmental and social components,[2] spatial and temporal boundaries 2. Scoping phase 2 – other activities and environmental drivers 3. Establish information on baseline status of valued environmental components 4. Assess cumulative impacts on valued environmental components 5. Assess significance of predicted cumulative impacts 6. Management of cumulative impacts – design and implementation
Cumulative Environmental Impact Assessment Industry Guide	Kaveney et al. 2015	CIA framework 1. Scoping 2. Data and information gathering 3. Analysis and review 4. Consultation 5. Finalization 6. Implementation
Introduction: Foundations and challenges in cumulative impact assessment	Blakley 2021	CEA framework 1. Scoping 2. "Retrospective" analysis 3. "Prospective" analysis 4. Significance determination 5. Mitigation and management

Many of the guidance publications outline similar steps for CIA that reflect the process for conducting a CIA as practiced in the field of impact assessment. The framework outlined by CEQ (1997) corresponds to the three overarching steps of an EIA: (1) scoping; (2) describing the affected environment; and (3) determining the environmental consequences. Within each step, the guidelines ascribe a set of principles for assessing cumulative impacts. Within the scoping step of an EIA, CEQ noted four principles for analyzing cumulative impacts: (1) include past, present, and future actions; (2) include all federal, nonfederal, and private actions; (3) focus on each affected resource, ecosystem, and human community; and (4) focus on truly meaningful effects (CEQ 1997). In comparison, the guidance provided by the Canadian Environmental Assessment Agency (CEAA) outlined five overarching steps in conducting a CIA that clearly distinguish mitigation, significance determination, and management as separate components in the framework. The International Finance Corporation (IFC 2013) further parsed out scoping in a CIA into multiple steps that distinguish between the identification of valued environmental components, such as the addition of a pollutant to the relevant environment, and the identification of stressors that may affect the selected valued environmental components. Kaveney et al. (2015) included a

[2] Valued environmental and social components are defined in IFC (2013) as environmental and social attributes that are considered important in assessing risks, including physical features, ecosystem services, natural processes, social conditions, and cultural aspects. CEAA (1999) define valued environmental components as components of the natural and human world considered valuable by participants in a public review process.

step for data and information gathering between the scoping and analysis steps in a CIA. In contrast, in the framework outlined in Blakley (2021), these processes are not separated in the scoping step, but the analysis step distinguishes between "retrospective" and "prospective" analysis of the impacts of interest. Most of the frameworks reviewed here include a management step that includes strategies to address cumulative impacts. Here Kaveney et al. (2015) specifically designated consultation and finalization steps that include discussion of the results of the analysis step with the public and key participants prior to the management step of a CIA.

Other publications reviewed in this brief do not necessarily outline a series of steps for CIA, but instead discuss frameworks with which to assess or analyze cumulative impacts and support CIA. Zeise and Blumenfeld (2021), NJ DEP (2023), Lam et al. (2022) and Baptista et al. (2022) outlined conceptually similar frameworks for cumulative impacts that are based on community cocreated methodologies to capture and visualize the multiple burdens experienced by communities. The methodologies outlined in these publications are also termed cumulative impacts analysis and are described in more detail in the Scoping and Analysis sections of this brief.

EPA (2022) developed a categorical approach to support cumulative impacts research within the Office of Research Development. EPA's approach consists of four components, including establishing the decision context, addressing the scientific considerations for meeting partners' needs, engaging and involving the community in each phase of the process, and translating scientific results to empower action (US EPA 2022). Beausoleil et al. (2022) discuss the integration of components of Indigenous community-based monitoring (ICBM) in a conceptual model of a pressure- or stressor-pathway and response continuum for the oil sands region of Canada. Haggerty et al. (2018b) evaluate the use of an iterative public health planning process known as Mobilizing Action through Planning and Partnerships (MAPP) as a framework for assessing impacts in a UOGD community in Montana. MAPP focuses on public health planning at the community scale through a process that includes needs assessments, data collection, and participatory meetings to prioritize public health issues, as well as identification of ways to address them (Haggerty et al. 2018b).

Separately, several publications discuss theoretical constructs with which to conceptualize cumulative impacts. The concept of the Total Environment, developed by EPA, provides one such theoretical approach that describes the various interrelationships between "characteristics, activities and behaviors, and stressors from the built, natural, and social environments" (Tulve et al. 2024). The concept of "impact geographies" as proposed in Haggerty et al. (2018a) is another example specific to UOGD communities. An impact geography is a "spatially bounded area that features a distinct constellation of historical, physiographic, economic, and cultural factors that influence the nature of oil and gas development and the character and magnitude of its impacts on local people, ecologies, and landscapes," emphasizing the attachment between development impacts and geographical contexts (Haggerty et al. 2018a). Another example specific to UOGD communities is the conceptual model based on allostatic load that is outlined in Adgate et al. (2014), which describes community and individual level chemical and nonchemical stressors and impacts and their relationship with individual psychosocial stress.

Decision Context

Throughout the literature surveyed for this scoping review, it was clear that consideration of cumulative impacts and the methods for any CIA depend on the decision context the assessment will inform. EPA (2022) notes that CIA has and can inform a variety of national, state, and local regulatory decisions, including permitting, enforcement actions, and land use and zoning ordinances. It can also serve other purposes such as raising awareness and educating community members and policymakers. At the national level, one decision context for CIA is the requirement for "cumulative effects analysis" under NEPA. NEPA establishes a framework under which federal agencies are required to analyze environmental impacts and cumulative impacts of proposed projects before they are undertaken (Ma et al. 2009). In its 1997 guidelines publication, CEQ provides a framework of nine principles for addressing cumulative impacts in environmental assessments and environmental impact assessments required under NEPA. CEQ (1997) emphasizes that most federal agencies have developed their own guidance for analyzing cumulative impacts to satisfy the NEPA process. A similar decision context exists for Canada under the 2012 Canadian Environmental Assessment Act (CEAA 2018). In addition, Executive Order 14096 directs all US federal agencies to identify, analyze, and address cumulative impacts across federal activities (88 FR 25251).

The practice of strategic environmental assessment in Canada and of strategic assessment in Australia both include consideration of cumulative impacts in the broader sense of programs or policies (Kaveney et al. 2015; Blakley and Russell 2022). Another policy-oriented decision context is that outlined in IFC (2013), which proposes a framework for rapid cumulative impact assessment as part of the organization's Policy on Environmental and Social Sustainability. Regional assessments (RAs) are also an example of a slightly different decision context that occur in Canada (Blakley 2021; Blakley and Russell 2022). NASEM (2003) is an example of an assessment aimed at informing long-term decision-making that is not tied to a specific regulation. In this study, Congress charged the National Academies to establish an expert committee to review information about oil and gas activities on Alaska's North Slope for known and probable cumulative impacts of such activities (NASEM 2003).

In the United States, CIA is required in some state environmental review processes, akin to the NEPA framework (Ma et al. 2009). In addition, efforts by EJ advocates in the United States have motivated several states to introduce or pass legislation that includes consideration of cumulative impacts in permitting decisions by using geospatial mapping tools to identify cumulative impacts (Baptista et al. 2022; Environmental Justice Clinic 2024). For example, S232, enacted in New Jersey, requires the Department of Environmental Protection to consider cumulative impacts on overburdened communities when evaluating permit applications (N.J.S.A. § 13:1D-157). The geospatial EJMAP tool outlined in NJ DEP (2023) supports the analysis required under the adopted regulations that implement this act.

Several publications included in this scoping review do not discuss cumulative impacts as part of a specific decision context but rather in the context of UOGD communities for the purpose of awareness and education (e.g., Adgate et al. 2014; Yap et al. 2016; Krupnick et al. 2017; Klasic et al. 2022). However, the community impacts and analytical methods outlined in those publications could be illustrative of various components of a CIA (i.e., scoping, analysis).

Although the CIA frameworks and decision contexts that appear in the literature reviewed here feature variations among the steps in a CIA, there are three general phases that appear in each: scoping, analysis, and management. As discussed earlier, these steps largely reflect CIA as conducted in the field of impact assessment; however, other methodologies for analyzing cumulative impacts (e.g., as discussed in Baptista et al. (2022) and Lam et al. (2022)) are integrated throughout the following sections as applicable. In each of the sections that follow, we discuss these generalized CIA steps in more detail, including the various methods that might be used in each, and examples of where they have been or could be applied to the UOGD context.

Scoping

The guidance publications included in this review describe the scoping step of a CIA as the step that defines the breadth of the assessment (CEQ 1997; CEAA 1999; IFC 2013; Kaveney et al. 2015; CEAA 2018). Several publications note that scoping is the most critical step for a successful CIA as it sets the foundation for the analysis and management steps that follow (IFC 2013; Kaveney et al. 2015). It also necessarily requires a clear definition and understanding of cumulative impacts (Ma et al. 2009; Blakley and Russell 2022). Multiple authors note that the key feature of the scoping process is identifying the issues or impacts of concern and the selection of what will be evaluated in the assessment. Much of the guidance on how to conduct a CIA described a process of linking the identified issues of concern with the resulting "environmental components," "valued environmental components," or "valued components" to assess (e.g., CEAA 1999; IFC 2013; Kaveney et al. 2015; CEAA 2018). For example, if the impact of concern is asthma within a community (i.e., the effects of air pollutant exposures on health), one component to assess is air quality (CEAA 1999). To preclude a narrow focus on environmental issues and for simplicity, we use the term "components" hereafter in this brief. Somewhat differently, publications that outline methods for cumulative impacts analysis begin "scoping" by identifying a range of exposures (or components) that affect individuals and communities (Zeise and Blumenfeld 2021; Lam et al. 2022; NJ DEP 2023).

In addition to issue identification and selection of components, several guidance publications discuss the following additional elements in the scoping step: establishment of the geographic and temporal boundaries of the components of interest (and for the analysis moving forward) and identification of other factors, aside from the project or activity being evaluated, that affect the components (CEQ 1997; CEAA 1999; Kaveney et al. 2015; CEAA 2018). IFC (2013) described this latter element as the identification of the totality of stressors or other drivers that would affect the components of interest. Using the prior example of air quality, other factors that would affect air quality include other industrial activities in the community or extreme weather events. CEAA (1999) noted that the elements within the scoping step of a CIA can proceed sequentially but in practice often proceed concurrently. Another important feature of the scoping process that appeared in several publications is the solicitation of input from interested parties, community members, or individuals (CEAA 1999; IFC 2013).

Community Engagement

Several publications highlight community engagement as an important element for effective and meaningful CIA (Yap et al. 2016; US EPA 2022; Tulve et al. 2024). Lam et al. (2022) underscored the efforts of communities in calling for the development of cumulative impact tools and approaches. Other publications discussed the value of input from communities to help to identify the impacts to be assessed (CEQ 1997; CEAA 1990). For example, Uhlmann et al. (2014) discussed the role of community and populations in prioritizing and selecting indicators to assess impacts. More broadly, IFC (2013) stated that identification of important participants in the CIA process should occur early in the scoping phase and that those participants should be updated and included as needed as the overall process proceeds. IFC (2013) noted that best practice consists of an open, participatory, transparent, and meaningful consultation with affected communities and other relevant interested participants. Other publications further emphasized that CIAs should be developed and applied with a focus on community engagement for solutions (Tulve et al. 2024). Tulve et al. (2024) also called for community-based participatory science in the context of using CIAs to inform decision-making to address environmental inequities. EPA (2022) cited community involvement in decision-making and community involvement in the evaluation of community needs as important considerations when designing a CIA. CEAA (2018) further highlighted the role of community input and knowledge throughout the CIA process, for example, in providing baseline data for analysis, in using anecdotal information to evaluate historical trends, and in determining thresholds and significance of cumulative impacts.

The literature reviewed included several examples that highlight the role of community engagement in CIA. Lam et al. (2022) described a community cocreated methodology for analyzing cumulative impacts that was developed and applied to the cities of Chicago and Newark. The MAPP process evaluated in Haggerty et al. (2018b) for use in a UOGD community was grounded in community engagement: quality of life assessments were conducted using surveys, interviews, and photography to capture communities' lived experiences. That process subsequently informed a formal "Quality of Life Profile" that was discussed at community open houses to identify and prioritize community needs in physical, environmental health, and social health. In Lawe et al. (2005), a request for the review of monitoring initiatives in the oil sands region of Canada as part of cumulative impact management in the area resulted in the recommendation of a community-based monitoring program based on a nationally recognized model to better reflect the value base of all area residents in managing decisions concerning cumulative impacts.

Issue Identification

"Issue identification," as described in the scoping step of a CIA across several publications, consists of several elements, which are outlined in Figure 2. After identifying the issues or impacts of concern, authors described a process of identifying components for CIA. Indicators that reflect the state of the selected components that will be measured or monitored should also be identified (CEQ 1997; CEA 1999; IFC 2013; Kaveney et al. 2015). Figure 2 provides an illustrative example using effects of air pollutant exposures on health as one identified issue of concern. Kaveney et al. (2015) further proposed selecting "sensitive receptors" that are the ultimate recipients of the impact of concern before identifying potential indicators to measure. Using the same example of air quality as a component of interest, the "sensitive receptors" might include residential neighborhoods or schools near the project or activity being evaluated (Kaveney et al. 2015). Components need not be environmental or physical in nature. Blakley (2021) described components as biophysical or sociocultural, while CEAA (1999) noted that components may be selected for economic, social, environmental, aesthetic, or ethical reasons. More generally, several authors noted that the process of issue identification necessitates consideration of cause-and-effect relationships for the issues of interest in order to identify components and indicators (CEAA 1999; CEAA 2018).

Several methods that can be used for issue identification appear throughout the publications reviewed. Literature reviews can be used to identify issues or impacts of concern (e.g., Yap et al. 2016; Mayer 2017; Buse et al. 2019; Haggerty et al. 2018a). Baptista et al. (2022) highlighted the development of various mapping tools for identifying communities that experience "multiple stressors" or "cumulative burdens," such as EPA's EJ Screen, CEQ's Climate & Economic Justice Screening Tool (CEJST), or any number of state-level tools (i.e., California's CalEnviroScreen, Washington State Environmental Health Disparities Map), which can be helpful in scoping issues of concern. Other screening and mapping tools are more broadly discussed in their utility for gathering baseline information in the Analysis section of this brief. Other sources of information that can be used for all elements of issue identification include scientific literature, legislation, environmental assessments, technical reports, checklists, regional studies, baseline studies, surveys, and input from the public, Indigenous groups, and other interested parties (CEQ 1997; CEAA 1999; Kaveney et al. 2015; CEAA 2018). For consideration of cause-and-effect relationships between an action and a component, CEAA (1999) recommended the use of interaction matrices, while CEAA (2018) highlighted the value of using a source-pathway-receptor model, which can describe the relationship between the project or activity of concern, other activities, and the component of interest.

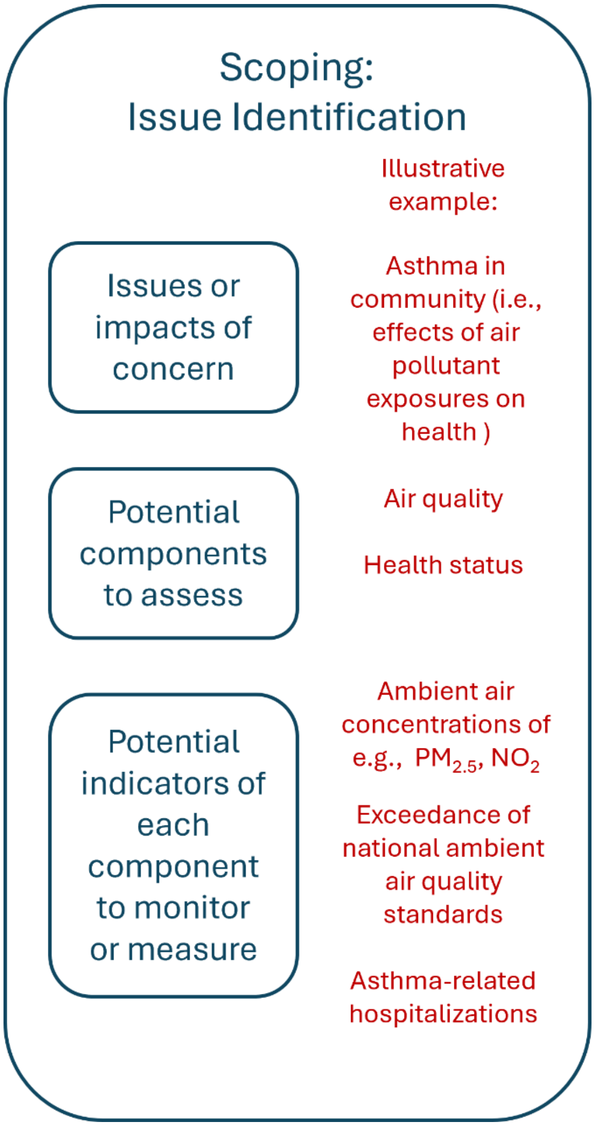

Figure 2. Elements involved in "issue identification" during the scoping step of a CIA as described in multiple publications, accompanied by a simplified illustrative example that focuses on two potential components. In reality, if the impact of concern were asthma, multiple components might be assessed beyond air quality or health status contingent on identification of other influences (e.g., housing quality).

Several studies provided abundant information applicable to issue identification (and scoping more broadly) for a CIA in the context of UOGD (Adgate et al. 2014; Uhlmann et al. 2014; HEI Special Scientific Committee on Unconventional Oil and Gas Development in the Appalachian Basin 2015; Gislason and Andersen 2016; Yap et al. 2016; Mayer 2017; Haggerty et al. 2018a; Mayfield et al. 2019; Klasic et al. 2022). To explore the prioritization of indicators as part of the issue identification process, Uhlmann et al. (2014) used the concept of the "indicator industry," which describes the set of criteria for selecting indicators in UOGD contexts in such a way that satisfies industry, community, and government priorities. Through a review of literature on the UOGD "indicator industry," 16 sets of indicators were identified and organized into impact themes, which were reflected in five capital categories: financial capital, natural capital, manufactured capital, human skills, and social capital (Uhlmann et al. 2014).

Rather than components, some studies used the more widely recognized terms chemical and nonchemical stressors (e.g., Adgate et al. 2014, Zeise and Blumenfeld 2021; NJ DEP 2023), while others referred to community impacts (Mayer 2017; Mayfield et al. 2019; Klasic et al. 2022). Adgate et al. (2014) identified air pollutants, ground and surface water contamination, truck traffic and noise pollution, accidents, and psychosocial stress associated with community change as the important components to assess for UOGD communities. This process of component selection was informed using a variation of a source-pathway-receptor conceptual model (Adgate et al. 2014). Buse et al. (2019) focused more broadly by categorizing the issues of interest into four groups through a literature review: (1) environmental; (2) infrastructure and services; (3) policy, regulation, and participation in decision-making; and (4) socioeconomic. They then identified several components to assess in each group, for example, earthquakes, water quality, and noise within the environmental impact grouping (Buse et al. 2019). Beausoleil et al. (2022) identified access to land, water, and traditional territories, as well as the health of the ecosystem as the primary issues of concern for Indigenous communities in the oil sands region of Canada. Using a source-pathway-receptor model, the authors linked air quality and water quality to those issues of concern (Beausoleil et al. 2022).

Geographic and Temporal Boundaries

Following issue identification, guidance publications described the next step in scoping of a CIA as the identification of geographic and temporal boundaries for the assessment based on the components selected. IFC (2013) outlined a general "rule of thumb" for determining geographic and temporal boundaries for CIA analyses, which includes consideration of the spatial area that may be directly affected by UOGD activities, the resources within that spatial area, whether the components selected extend beyond the boundaries first identified, the time frame expected for the complete life cycle of the activity or project of concern, and the extent to which the issues of concern extend beyond that time frame. CEQ (1997) proposed the concept of a "project impact zone" to help to determine appropriate geographic boundaries for a CIA, while CEAA (1999; 2018) described a similar concept as the "zone of influence" for a project or activity. Several authors highlighted the use of professional judgment and adaptive approaches as basic tenets of setting appropriate geographic and temporal boundaries for CIA (IFC 2013; CEAA 2018).

One example for this step appears in NASEM (2003), which considered all issues associated with oil and gas development on the North Slope of Alaska for its CIA process with the components selected broadly encompassing the physical, biological, and human systems in the region. The spatial domain considered was the land of the North Slope of Alaska and its adjacent marine waters, while the temporal domain spanned 1965 to 2025 or, in some cases, 2050.

Identification of Other Influences

The final element of the scoping step of a CIA described in the reviewed literature involves identifying influences or actions that will affect the components selected or characterizing of the components' responses to stress and change (CEQ 1997; CEAA 1999; IFC 2013; CEAA 2018, Kaveney et al. 2015). This step encompasses consideration of past, present, and foreseeable future influences or actions that will affect a component (CEQ 1997; CEAA 1999). It also includes consideration of any other relevant external social or environmental drivers (e.g., floods, wildfires, human migration) (IFC 2013). Both IFC (2013) and Kaveney et al. (2015) noted the usefulness of determining whether a set of actions will cause similar effects on the component of interest. In the context of UOGD activities, potential actions to be considered can include all those associated with UOGD extraction and production, including well pad operations and associated activities and facilities such as compressors, processing facilities, gathering flowlines, and development-related waste management (HEI Energy Research Committee 2020). Other influences that can be considered include local terrain and meteorology (CEAA 1999).

Another example that appears in NASEM (2003) identified the following other influences that affect subsistence activities: the Inupiaq culture has a nutritional and cultural relationship with the bowhead whale, whose migratory patterns are altered with noise from exploratory drilling, thereby forcing subsistence hunters to travel farther from home to hunt whales. The potential for a major oil spill was also identified as another action that would affect bowhead whales and, consequently, Inupiaq subsistence activities (NASEM 2003). Buse et al. (2019) described the response of property value (component of interest) in relation to UOGD and found that many studies point toward reductions in property value related to proximity to drilling because of factors such as road noise, risk of groundwater contamination, and potential for induced seismicity.

CEQ (1997) described a completed scoping process as consisting of a list of components to be assessed with associated geographic and temporal boundaries, and a list of other actions that affect each component. These guidelines, along with several other publications, also noted that data needs and availability related to the issues identified and selected components should be evaluated during the scoping phase before proceeding to analysis (CEQ 1997; CEAA 1999; IFC 2013; CEAA 2018). In the approach outlined in Lam et al. (2022), issue identification is not described as a formal step in analyzing cumulative impacts. Instead, this approach consists of identifying all chemical and nonchemical stressors that affect individuals and communities. In this scoping process, indicators that reflect stressor (or component) exposures are identified and selected reflecting stressor (or component) exposures, as well as population characteristics that might modify vulnerability to such components, subject to data availability.

Analysis

The analysis step of a CIA is described as building on the results of the scoping step to provide the overall assessment of cumulative impacts (CEAA 2018). The assessment of cumulative impacts can be retrospective or prospective, depending on the decision context. Although the literature reviewed pertaining to general guidance for conducting a CIA differed somewhat on the order of steps for analysis of cumulative impacts, three common elements appeared throughout several publications: definition and description of baseline information, analysis of cumulative impacts, and determination of significance of cumulative impacts (CEQ 1997; CEAA 1999; IFC 2013; Kaveney et al. 2015; CEAA 2018). Other publications described a slightly different process for analysis that includes some combination of identification of indicators and assessment of cumulative impacts (Zeise and Blumenfeld 2021; Lam et al. 2022; NJ DEP 2023). NJ DEP (2023) additionally includes a determination of a point of comparison in the methodology described.

Baseline Assessment

To analyze the cumulative impacts of a project or activities based on selected components and associated indicators, several authors cited the need for collection of baseline information to provide a point of reference and information on trends (CEQ 1997; CEAA 1999; Kaveney et al. 2015). Lack of baseline data for evaluating trends in affected populations and environmental media has been cited as a significant driver of uncertainty in assessing impacts of UOGD on communities (Adgate et al. 2014). IFC (2013) described the availability of data relevant to the selected components as “critical” to the success of a CIA and simultaneously highlighted the importance of defining the methods that will be used to determine baseline conditions of components early in the CIA process. In some cases, gaps in available data might require the collection of new data for a baseline assessment or the use of models to generate baseline conditions (IFC 2013; CEAA 2018). Other referenced sources of information that can help to establish baseline conditions include government reports, NGO reports, community health surveys, prior assessments, community knowledge, or information from “controls” or areas with the same components that are exposed to differing levels of impact (IFC 2013). Although the scoping step in a CIA describes consideration and identification of available baseline data, many guidance publications state that baseline assessment constitutes the "formal" step of collecting and analyzing baseline and historical data on the selected components and associated indicators (IFC 2013; CEAA 1999). CEAA (2018) described desired characteristics of baseline information as including (1) detailed data for selected components within the previously identified spatial and temporal boundaries; (2) natural variability, drivers of change, and historical shifts for selected components; (3) trends or spatial patterns in quantity, quality, value, or use of components; (4) current condition of the component in the context of relevant indicators; and (5) data or perspectives applicable to baseline conditions of selected components obtained through community knowledge where appropriate.

As an example, the Colorado Energy and Carbon Management Commission produced a report with baseline information to support ongoing evaluation and assessment of potential cumulative impacts as required under a recent state regulation.[3] The report evaluated data for oil and gas development plans and associated oil and gas locations that had been approved in the 2022 calendar year, including baseline information on water quality, land use, wildlife, air quality, and trends in greenhouse gas emissions and ozone (Colorado Oil and Gas Conservation Commission 2023).

Assessment of Cumulative Impacts

CEQ (1997) notes that the baseline assessment provides the reference and historical context needed to evaluate cumulative impacts. Throughout the literature reviewed for this Research Brief, no single methodology is prescribed as the most appropriate or preferred method for assessing cumulative impacts (CEA 1997; CEAA 1999; IFC 2013; Kaveney et al. 2015; CEAA 2018, Blakley 2021; Blakley and Russell 2022). Instead, as expressed in CEAA (1999), "the practitioner must select an appropriate approach or assessment 'tool' from a collection or 'toolbox' of approaches." Table 3 depicts the various methods used in the analysis (as well as scoping) steps in a CIA as cited in the publications included this scoping review. IFC (2013) broadly categorized the methods used for cumulative impact analysis as impact models, numerical models, spatial analysis using geographical information systems (GIS), and indicator-based approaches.

Table 3. Methods for assessing cumulative impacts that appear in this scoping review

Methods for assessing cumulative impacts that appear in this scoping review		
Title	**Author Year**	**Methods Referenced for Assessing Cumulative Impacts**
Considering Cumulative Effects under the National Environmental Policy Act	CEQ 1997	• Matrices, networks, and systems diagrams (for cause-and-effect relationships) • Modeling, trends analysis (to establish appropriate baselines or project future cumulative effects) • Overlay mapping and GIS (to set boundaries and analyze parameters) • Ecosystem analysis

[3] Malin (2020) notes that the Colorado Oil and Gas Conservation Commission, now known as the Colorado Energy and Carbon Management Commission, is positioned as an entity purposed with both encouraging oil and gas development and protecting the public. This paper discusses friction in protecting development and serving community concerns and cites instances wherein community members express concern over the representativeness of the Commission's findings.

Methods for assessing cumulative impacts that appear in this scoping review		
Title	**Author Year**	**Methods Referenced for Assessing Cumulative Impacts**
		• Economic impact analysis (establishes a region of influence and models the economic effects to determine significance of effects) • Social impact analysis (focuses on key social variables and projects future effects using social analysis techniques such as linear trend projections and simulation modeling)
Cumulative Effects Assessment Practitioners Guide; Assessing Cumulative Environmental Effects Under the Canadian Environmental Assessment Act, 2012: Interim Technical Guidance	CEAA 1999; CEAA 2018	• Questionnaires and interviews • Checklists and matrices • Trend analysis • Impact models • Spatial analysis with GIS • Indicators and indices • Conceptual and numerical models
Good Practice Handbook Cumulative Impact Assessment and Management: Guidance for the Private Sector in Emerging Markets	IFC 2013	• Conceptual modeling, pathways, network analysis • Cost-benefit analysis • Decision support systems • GIS analysis • Habitat modeling • Indicators and indices • Landscape modeling • Population viability analysis • Quantitative and/or simulation modeling • Scenario analysis • Sustainability appraisal • Thresholds • Visual amenity analysis
Cumulative Environmental Impact Assessment Industry Guide	Kaveney et al. 2015	• Detailed surveys • Interaction matrices • Impact models • Spatial analysis with GIS • Numerical models • Expert opinion
Tracing the Flow of Oil and Gas: A Spatial and Temporal Analysis of Environmental Justice in Coastal Louisiana from 1980 to 2010	Hemmerling et al. 2021	• Geospatial analysis • Industrial hazardousness of place model
CalEnviroScreen 4.0	Zeise and Blumenfeld 2021	• Indicators, rankings • Geospatial mapping
Understanding the Evolution of Cumulative Impacts Definitions and Policies in the US	Baptista et al. 2022	• Geospatial mapping • Indicators and indices

Methods for assessing cumulative impacts that appear in this scoping review		
Title	**Author Year**	**Methods Referenced for Assessing Cumulative Impacts**
International Progress in Cumulative Effects Assessment: A Review of Academic Literature 2008–2018	Blakley and Russell 2022	• Linear response models • Quantitative vulnerability scores • Expert judgment
Seeing the Whole: Using Cumulative Impacts Analysis to Advance Environmental Justice	Lam et al. 2022	• Indicators and rankings • Geospatial mapping
Guidance Document for Environmental Justice: New Rule N.J.A.C. 7:1C and Online Mapping Tool	NJ DEP 2023	• Indicators • Spatial analysis • Geospatial mapping • Comparative analysis
Cumulative Impacts in Environmental Justice: Insights from Economics and Policy	Bakkensen et al. 2024	• Rankings, thresholds, or indices • Decomposition methods to analyze cumulative impact indices • Cost-benefit analysis • Hedonic methods • Quasi-experimental approaches
Challenges and Opportunities for Research supporting Cumulative Impact Assessments at the United States Environmental Protection Agency's Office of Research and Development	Tulve et al. 2024	• Exposomal studies (biomarkers, allostatic load) • Participatory science • Interdisciplinary systems-based approaches

Like context-setting, assessment of cumulative impacts can require consideration of the future condition of components from past, present, and reasonably foreseeable future actions (to the extent possible) (CEQ 1997; CEAA 1999; IFC 2013; CEAA 2018; Blakley 2021). Another element described in multiple publications is the characterization of potential additive, countervailing, masking, or synergistic effects (IFC 2013; Kaveney et al. 2015; CEAA 2018). For example, an additive effect can be described as equal to the sum of individual effects, while a synergistic effect can be described as the total effect being greater than the sum of the individual effects (IFC 2013).

CEQ (1997) described the elements of cumulative impacts analysis as reliant on identifying cause-and-effect relationships between activities and resources, ecosystems, and human communities. To identify cause-and-effect relationships, both CEQ (1997) and CEAA (1999) specifically highlighted pathway diagrams and matrices, while CEAA (2018) and Beausoleil et al. (2022) proposed the use of a source-pathway-receptor model as described in the Scoping section of this brief. CEQ (1997) additionally noted that qualitative evaluation methods can be used if cause-and-effect relationships cannot be quantified or are not necessary to characterize consequences. In such methods, the magnitude of effects may be categorized into classes (e.g., low, medium, high), or a descriptive narrative of the types of potential effects that may occur can be provided.

Comparison of effects using reference cases or models (quantitative, qualitative, or mixed methods) is another overarching approach posited to assess cumulative impacts (CEAA 2018). EPA (2022) and Tulve et al. (2024), meanwhile, did not explicitly discuss methods for assessing cumulative impacts but emphasized the role of, for example, epidemiological, toxicological, and economic methods to support

CIA. In practice, Ma et al. (2009) showed that among 38 states surveyed for their study, mixed methods (i.e., the use of both quantitative and qualitative methodologies) were predominantly used in state-level CIA analyses. Mixed-methods approaches were also highlighted as crucial to disentangle complex causal processes that connect UOGD activities with quality-of-life impacts (Mayer 2017).

The use of indicators and indices also appear throughout the publications included in this review. Many geospatial mapping tools identify EJ communities (e.g., EPA's EJScreen), and a growing number include a quantitative calculation or a qualitative description of cumulative impacts (Zeise and Blumenfeld 2021; Baptista et al. 2022; Lam et al. 2022; NJ DEP 2023; Bakkensen et al. 2024; Environmental Justice Clinic 2024). One of the most widely cited indices is California's CalEnviroScreen tool, which utilizes an index-based scoring approach (Baptista et al. 2022; Bakkensen et al. 2024; Tulve et al. 2024). In brief, the tool uses a set of indicators to characterize pollution burden and population characteristics at the census tract level, which are ultimately assigned relative scores based on percentiles and averaged to produce a score for components in the categories of pollution burden and sociodemographic characteristics. An overall cumulative score is then calculated by multiplying the pollution burden and population characteristics scores (Zeise and Blumenfeld 2021). CalEnviroScreen has been used in conjunction with spatial analyses to identify communities experiencing cumulative burdens from chemical and nonchemical stressors (i.e., multiple selected components), including those in proximity to conventional[4] oil and gas operations (e.g., Chan et al. 2023). The tool described in NJ DEP (2023) combines an indicator approach with comparative analysis and geospatial mapping to quantify and visualize the total number of cumulative adverse stressors in a community. Related cumulative impacts analysis methodologies continue to be developed that assess cumulative impacts by examining a list of stressors and determining which of the stressors show a "disproportionate" or "adverse" burden within the community in question (Environmental Justice Clinic 2024) — rather than by calculating a total cumulative impacts score used to rank communities.

Specific to the context of UOGD communities, some of the publications reviewed demonstrate quantitative and qualitative approaches for assessing cumulative impacts. For example, Mayfield et al. (2019) estimated cumulative impacts from UOGD activities (spanning pre-production to end use) in the Appalachian basin on the selected components of air quality, climate change, and employment. The team separately modeled selected indicators for each component using a combination of process-level emissions inventories, reduced complexity source-receptor air quality and climate change models, and empirical, regression-based employment models. Estimates of impacts of each component were produced in physical units (e.g., premature mortality, global mean temperature change). Tradeoffs between different impacts were then assessed. For example, they reported that air quality and employment impacts improve after drilling activities peak but that climate impacts worsen for another decade, all else being equal. In addition, the authors translated air quality, employment, and climate change into monetized impacts for use in a cost-benefit analysis (Mayfield et al. 2019). Hemmerling et al. (2021) combined geospatial analysis with an industrial hazardousness of place model to assess cumulative impacts of UOGD in Louisiana. That approach produced a decile ranking of cumulative hazards for Louisiana parishes and described how this ranking changed over time (Hemmerling et al. 2021).

Other examples include NASEM (2003) and Gislason and Andersen (2016); both provided qualitative assessment of cumulative impacts. Using judgment from an expert committee and a literature review, NASEM (2003) determined the magnitude of impacts of oil and gas activities on Alaska's North Slope and whether they were accumulating or interacting with other identified components. Gislason and

[4] In contrast to UOGD, conventional oil and gas development produces crude oil and natural gas using a well drilled into a geologic formation in which the reservoir and fluid characteristics permit the oil and natural gas to readily flow to the wellbore (*https://www.heienergy.org/term/conventional-oil-and-gas-development*).

Andersen (2016) similarly used literature reviews to provide a qualitative description of cumulative impacts of intensive resource extraction in the Blueberry River First Nation territory in Canada, which was organized along different dimensions of interest (i.e., environment and health, health and social justice).

Some publications also discuss quantification or description of uncertainty as an element of CIA (CEQ 1997; CEAA 1999; IFC 2013; Kaveney et al. 2015; CEAA 2018). These publications reflect the CIA frameworks prevalent in the field of impact assessment that contrast with the cumulative impact frameworks proposed by EJ groups and community groups, which do not rely on including uncertainty quantification (e.g., as described in Baptista et al. (2022) and Lam et al. (2022)). In the guidance publications that do discuss uncertainty estimation, scenario analysis describes possible alternatives that might take place and lead to several possible past or future conditions (IFC 2013; CEAA 2018). EPA (2022) also discussed uncertainty analysis in CIA in order to consider potentially changing baseline conditions. EPA noted that the EPA Guidelines for Human Exposure Assessment (2019) provides a resource for quantitative and qualitative methods to integrate uncertainty throughout analyses of cumulative impacts.

Significance of Cumulative Impacts

Several authors outlined the next element in the analysis step of a CIA as a determination of the magnitude and significance of cumulative impacts on components (CEQ 1997; Blakley 2021). Again, other authors did not focus on selected components, but rather on all manner of chemical and nonchemical stressors that affect an individual or community (Lam et al. 2022). This step, or series of steps, is cited as one of the most challenging (CEAA 1999; IFC 20135). Specific thresholds and methods are lacking to help to decide the magnitude and significance of cumulative impacts (CEAA 1999; IFC 2013; Baptista et al. 2022; Blakley and Russell 2022). CEAA (1999) and IFC (2013) underscored that, because there is not always an objective technique to determine thresholds, in practice such determinations happen using professional judgment. Baptista et al. (2022) also pointed out that what constitutes significant, unreasonable, or cumulative is a normative question subject to debate.

Kaveney et al. (2015) indicated that significance should be determined by the degree to which components are moved toward a threshold rather than by the amount of change to a component attributable to a project or activity. CEQ (1997) suggested thresholds be designated at levels reflecting a component's condition beyond which positive or negative change would lead to significant degradation or enhancement of the component. CEQ (1997) also noted that often this process requires an evaluation of the history of the component to assess whether past degradation might place it near such a condition. CEQ (1997) and IFC (2013) suggested that the significance of cumulative impacts be determined based on context and intensity (defined by magnitude, geographic extent, duration, and frequency of effects). Thresholds and criteria are also described as quantitative (e.g., as in economic impact modeling) or qualitative (e.g., perception of community members on fish population health) (CEQ 1997; Beausoleil et al. 2022).

Despite challenges to defining magnitude and significance, the literature reviewed does include some examples of practice. In the survey of state-level practitioners described by Ma et al. (2009), the authors found that 14 state programs use formal criteria to determine the significance of predicted cumulative impacts. An example from the state of New York is highlighted in which cumulative impacts are considered significant if they cause a sizable change in the use or intensity of use of agricultural land, open space, or recreational resources (Ma et al. 2009). In California, the California Environmental Protection Agency designates census tracts within the highest 25% of overall cumulative scores from CalEnviroScreen as "disadvantaged" communities, which is intended to be used by state decision-makers to identify communities in need of resources to address pollution burdens and negative health effects (Zeise and Blumenfeld 2021; Baptista et al. 2022). In New Jersey, comparative analysis is used to determine whether stressors present within a community are considered “adverse”, and the total number of cumulative adverse stressors are quantified to inform permitting decisions (Baptista et al. 2022; NJ DEP 2023).

Management

Some guidance documents include management of cumulative impacts as the final step in a CIA (CEQ 1997; IFC 2013; Kaveney et al. 2015; Blakley 2021). This step is only applicable when a project or activity is determined to proceed or continue. The step differs from the frameworks for cumulative impact assessment posited in, for example, Lam et al. (2022) which do not include a management step. The guidance literature that discusses this step differs in whether mitigation is included in this step of a CIA or whether mitigation of cumulative impacts takes place as part of an iterative process between the analysis and management steps (CEAA 1999; IFC 2013; CEAA 2018). Other publications refer to mitigation and management as complementary measures (CEQ 1997; Kaveney et al. 2015; Blakley 2021). Blakley (2021) described mitigation, management, and follow-up as critical elements of a CIA that include identification and implementation of strategies to control, minimize, or prevent adverse effects of cumulative impacts that collectively comprise “cumulative effects management.” CEQ (1997) also discussed monitoring as the last step in determining cumulative impacts that can help to address uncertainty in the assessment.

Regardless of the process’s steps, mitigating effects can be considered a first step in managing cumulative impacts. Both CEAA (1999) and Kaveney et al. (2015) stated that mitigating local effects is the best approach to reducing cumulative impacts. CEQ (1997) suggested that effective mitigation strategies for each component are based on identifying which of the cause-and-effect pathways results in the greatest effect, although what constitutes “greatest” is again subject to determination of significance. Management strategies can then be designed to address those cumulative impacts deemed most important (IFC 2013).

Blakley (2021) outlined an ideal management plan as one that (1) considers ecological boundaries; (2) establishes management targets and response triggers; (3) takes an adaptive management approach; (4) engages affected interests in management programs and activities; and (5) clearly defines roles and responsibilities for implementation, monitoring, and feedback over the long term. IFC (2013) further provided examples of strategies that can be used to manage cumulative impacts effectively, including project design changes, adaptive management approaches for mitigation, collaborative engagement in other regional cumulative impact management strategies, and participation in regional monitoring programs. Kaveney et al. (2015) and CEAA (1999; 2018) also cited long-term and regionally based mitigation and monitoring as best practice.

Several publications specifically discussed management of cumulative impacts in UOGD communities, drawing on examples from the oil sands region of Alberta, Canada (Lawe et al.; 2005; Beausoleil et al. 2022; Dubé et al. 2022). Dubé et al. (2022) provided an overview of environmental monitoring in the region, highlighting scope, governance, and inclusion of Indigenous perspectives as distinct challenges for the series of ambient regional monitoring programs that have been implemented in the region. Lawe et al. (2005) discussed groundwater as a specific component of interest to the Mikisew Cree First Nation. The authors set forth meaningful input, transparency, and authenticity as cornerstones of an effective monitoring process. Moreover, community-based monitoring is suggested as a way to improve monitoring initiatives in the region to address cumulative impacts (Lawe et al. 2005). Similarly, Beausoleil et al. (2022) highlighted the value of Indigenous community-based monitoring and provided examples that focus on ecosystem responses to cumulative impacts, noting that environmental monitoring strategies are enhanced by examining relationships between physical and chemical stressors and culturally relevant indicators.

Challenges in CIA Identified in the Reviewed Literature

One of the challenges in conducting CIAs cited throughout several publications pertains to data issues, including a lack of data, unrepresentative data, and inaccessible data (IFC 2013; Kaveney et al. 2015). EPA (2022) described a lack of historical pollution exposure data with which to assess trends and the difficulty of collecting data at the fine temporal and spatial scales needed to inform local and project- or activity-specific decisions. Several methods have been suggested to help fill data gaps, however, including the use of modeling techniques, participatory science, and other qualitative methods to gather information from communities themselves (CEAA 1999; CEAA 2018; US EPA 2022). A more notable challenge described by some authors stems not from the data on components or chemical and nonchemical stressors themselves but from a limited understanding of the causal- and inter-relationships between these elements and health and well-being (Tulve et al. 2024). Blakley (2021) noted that the practice of CIA has largely focused on biophysical or environmental cumulative impacts and on adverse rather than beneficial effects. The authors also noted limited exploration of social issues in CIA practice, for instance, self-assessed quality of life, distribution of benefits, and food security (Blakley 2021). In the context of UOGD communities, several publications similarly highlighted underrepresentation of socioeconomic, infrastructure, and social capital impacts in studies considering cumulative impacts and UOGD activities, in addition to a predominant focus on "boom-time" effects. (Buse et al. 2019; Klasic et al. 2022).

More broadly, Blakley and Russell (2022) reported that basic CIA terms and concepts are not well understood and that there is no standardized guidance on how to conduct a CIA, a finding that is underscored by our scoping review process and Ma et al. (2009). Moreover, as noted in the Analysis section above, thresholds for what cumulative impacts are considered significant remain unclear, which makes it difficult to use CIA outputs to guide policy or more generally in decision-making (CEAA 1999; IFC 2013; CEAA 2018; Baptista et al. 2022; Ma et al. 2009). It should also be noted, however, that other publications provide a clear conceptualization of cumulative impacts as capturing the lived experience of disproportionate burdens (Lam et al. 2022).

Methods to combine quantitative and qualitative data are also cited as an area of continued work (US EPA 2022; Tulve et al. 2024). Several authors highlighted a need for the continued development and use of mixed methods in the context of environmental decision-making (Blakley and Russell 2022; Tulve et al. 2024). The utility for mixed methods, alongside a need for longer-term studies, also appears in the context of cumulative impacts and UOGD activities (Yap et al. 2016; Mayer 2017; Buse et al. 2019; Klasic et al. 2022). Bakkensen et al. (2024) noted that although methods to identify cumulative impacts have relied on thoughtful statistical and theoretical foundations, there has been limited work on validating cumulative impact tools and indices. The authors attributed this observation to the fact that the real-world effects of cumulative impacts are challenging to evaluate using quantitative methods. They suggested the use of quasi-experiments to examine causal mechanisms underlying the cumulative impacts further.

In addition, as described in Blakley (2021), a better understanding of cumulative impacts on communities will partly depend on strengthening community engagement — an effort that includes greater inclusion of public perspectives and interdisciplinary science and integration of different types of knowledge (e.g., Indigenous knowledge and western knowledge) (Blakley and Russell 2022). It also necessitates a focus on meaningful partnerships, early and continued engagement with communities (US EPA 2022; Tulve et al. 2024), and a transformation of the way practitioners and researchers communicate with communities (Blakley and Russell 2022). The frameworks for analyzing cumulative impacts described in Baptista et al. (2022) and outlined in Lam et al. (2022) represent community cocreated methodologies that exemplify such community-engaged cumulative impacts work.

Summary and Next Steps

This Research Brief summarizes the results of a scoping review that assesses and describes what is known about cumulative impacts and methods for assessing cumulative impacts experienced by UOGD communities. The literature reviewed revealed several analytical frameworks and decision contexts for conducting CIA, alongside several methods that can be used to assess cumulative impacts. Overall, few studies specifically analyzed cumulative impacts in UOGD communities. More generally, there appears to be some consistency across many of the guidance publications regarding the steps included in a CIA, although this set of literature largely reflects the process for CIA as practiced in impact assessment, sometimes termed cumulative effects assessment. Other publications that described frameworks for analyzing cumulative impacts reflect the state of thinking about this topic as promulgated by EJ advocates (i.e., what is sometimes termed cumulative impacts analysis). The literature reviewed cited several challenges in CIA, both theoretical (definitions, concepts, and framing) and methodological (frameworks, data, methods for understanding chemical and nonchemical stressor relationships). However, regarding methods, we note that other authors have suggested that a variety of complex statistical techniques used in other disciplines already exist that may be useful for analyzing cumulative impacts but have hitherto not been used in this context (Huang et al. 2018). Nonetheless, the literature did not include generally accepted standardized guidance for conducting CIAs. This observation also applies in the specific context of UOGD communities.

The focus of this scoping review is specific to cumulative impacts for UOGD communities and how to conduct a CIA. Several categories of literature have important relevance for the topic of cumulative impacts, CIA methods, and UOGD communities that were not discussed in this Research Brief. For example, efforts at advancing EJ at the state level have produced several tools and methods for analyzing cumulative impacts. This brief includes some of this work, such as Baptista et al. (2022) and Lam et al. (2022), but many more examples exist and are more often found in cumulative impact policies and policy proposals. In addition, a burgeoning set of literature on community engagement provides important insights for the social and EJ aspects of CIA. Some of this literature pertains to best practices for community engagement (e.g., WE ACT for Environmental Justice 2022), and others are specific to the procedural justice and equity that influence meaningful community participation in CIA or related efforts (see, for example, Perry (2012), Willow and Wylie (2014), and Malin (2020)). Relatedly, a number of studies exist that report community perceptions and perspectives of the impacts of UOGD activities (e.g., McGranahan et al. 2017; see Tan et al. 2022 for a recent review). Yet another set of literature discusses community benefits plans and agreements, which are now required for some federal funding programs and could provide useful information for CIA (e.g., BW Research and CATF 2023; Rossi-Keen et al. 2024). Some literature related to methodologies are also relevant to CIA; one example includes a review of research methods in the context of UOGD (Fernando et al. 2014).

HEI Energy is developing a design for a CIA for a UOGD community in the United States, using locations where HEI Energy is currently funding research as example contexts. This design is intended to be a blueprint for identifying and prioritizing impacts, whether adverse or beneficial, that are most important for understanding and addressing the health and well-being of individuals and communities living near UOGD. In doing so, we hope to contribute to the growing body of work by many others, all with the goal of advancing the practice of assessing cumulative impacts. As this work proceeds, we will continue to follow related efforts by others on CIA.

References

40 CFR 1508.1. Definitions. Available: *https://www.ecfr.gov/current/title-40/chapter-V/subchapter-A/part-1508/section-1508.1* [accessed 7 August 2024].

88 FR 25251. Executive Order 14096 – Revitalizing Our Nation's Commitment to Environmental Justice for All. Available: *https://www.federalregister.gov/documents/2023/04/26/2023-08955/revitalizing-our-nations-commitment-to-environmental-justice-for-all* [accessed 11 September 2024].

89 FR 35442. National Environmental Policy Act Implementing Regulations Revisions Phase 2. Available: *https://www.federalregister.gov/documents/2024/05/01/2024-08792/national-environmental-policy-act-implementing-regulations-revisions-phase-2* [accessed 7 August 2024].

Adams LS, Denton JE. 2010. Cumulative Impacts: Building a Scientific Foundation. Sacramento, CA: California Office of Environmental Health Hazard Assessment (OEHHA).

Alexeeff GV, Faust JB, August LM, Milanes C, Randles K, Zeise L, et al. 2012. A screening method for assessing cumulative impacts. Int J Environ Res Public Health 9:648–659; doi:10.3390/ijerph9020648.

Adgate JL, Goldstein BD, McKenzie LM. 2014. Potential public health hazards, exposures and health effects from unconventional natural gas development. Environ Sci Tech 48:8307–20.

Allshouse WB, McKenzie LM, Barton K, Brindley S, Adgate JL. 2019. Community noise and air pollution exposure during the development of a multi-well oil and gas pad. Environ Sci Tech 53:7126–35; doi: 10.1021/acs.est.9b00052.

Bakkensen LA, Ma L, Muehlenbachs L, Benitez L. 2024. Cumulative impacts in environmental justice: Insights from economics and policy. Reg Sci Urban Econ 107:103993; doi:10.1016/j.regsciurbeco.2024.103993.

Baptista AI, Perovich A, Pulido-Velosa MF, Valencia E, Valdez M, Ventrella J. 2022. Understanding the Evolution of Cumulative Impacts Definitions and Policies in the U.S.New York, NY: the New School Tishman Environment and Design Center

Beausoleil D, Munkittrick K, Dubé MG, Wyatt F. 2022. Essential components and pathways for developing Indigenous community-based monitoring: Examples from the Canadian oil sands region. Integr Environ Assess and Manag 18:407–427; doi:10.1002/ieam.4485.

Berberian AG, Rempel J, Depsky N, Bangia K, Wang S, Cushing LJ. 2023. Race, racism, and drinking water contamination risk from oil and gas wells in Los Angeles County, 2020. Am J Public Health e1–e10; doi:10.2105/AJPH.2023.307374.

Blakley J., ed. 2021. Introduction: foundations, issues and contemporary challenges in cumulative impact assessment. In: Handbook of Cumulative Impact Assessment. Edward Elgar Publishing Limited: Cheltenham, UK.

Blakley J, Russell J. 2022. International progress in cumulative effects assessment: a review of academic literature 2008–2018. J Environ Plan Manag 65:186–215; doi:10.1080/09640568.2021.1882408.

Buse CG, Sax M, Nowak N, Jackson J, Fresco T, Fyfe T, et al. 2019. Locating community impacts of unconventional natural gas across the supply chain: a scoping review. The Extractive Industries and Society 6:620–629; doi:10.1016/j.exis.2019.03.002.

BW Research and Clean Air Task Force (CATF). 2023. Community Benefits: A Survey of Perspectives from Three Communities.

CEAA, ed. 1999. Cumulative effects assessment practitioners guide. Canadian Environmental Assessment Agency: Ottawa, Canada.

CEAA. 2018. Assessing Cumulative Environmental Effects Under the Canadian Environmental Assessment Act, 2012: Interim Technical Guidance. Canadian Environmental Assessment Agency: Ottawa, Canada.

Chan M, Shamasunder B, Johnston JE. 2023. Social and environmental stressors of urban oil and gas facilities in Los Angeles County, California, 2020. Am J Public Health 113:1182–90; doi.org/10.2105/AJPH.2023.307360

CEQ. 1997. Considering Cumulative Effects under the National Environmental Policy Act.

CEQ. 1978. Regulations for Implementing the Procedural Provisions of NEPA. 40 CFR 1500-1508.

Colorado Oil and Gas Conservation Commission. 2023. Report on the Evaluation of Cumulative Impacts-Rule 904.a. Colorado Oil and Gas Conservation Commission: Denver, Colorado.

Cushing LJ, Chau K, Franklin M, Johnston JE. 2021. Up in smoke: characterizing the population exposed to flaring from unconventional oil and gas development in the contiguous US. Environ Res Lett 16:034032; doi:10.1088/1748-9326/abd3d4.

Dubé MG, Dunlop JM, Davidson C, Beausoleil DL, Hazewinkel RRO, Wyatt F. 2022. History, overview, and governance of environmental monitoring in the oil sands region of Alberta, Canada. Integr Envir Assess Manag 18:319–332; doi:10.1002/ieam.4490.

Environmental Justice Clinic. 2024. Environmental Justice Law and Policy Database. Vermont Law School. Available: *https://ejstatebystate.org/law-policy-database* [accessed 7 August 2024].

Faust JB. 2010. Perspectives on cumulative risks and impacts. Intl Journal of Toxicology 29: 58–64; doi: 10.1177/1091581809347387.

Gislason M, Andersen H. 2016. The interacting axes of environmental, health, and social justice cumulative impacts: a case study of the Blueberry River First Nations. Healthcare 4:78; doi:10.3390/healthcare4040078.

Haggerty JH, Kroepsch AC, Walsh KB, Smith KK, Bowen DW. 2018a. Geographies of Impact and the Impacts of Geography: Unconventional Oil and Gas in the American West. The Extractive Industries and Society 5:619–633; doi:https://doi.org/10.1016/j.exis.2018.07.002.

Haggerty JH, Smith K, Mastel T, Lapan J, Lachapelle P. 2018b. Assessing, monitoring, and addressing boomtown impacts in the US: evaluating an existing public health model. Impact Assessment and Project Appraisal 36:115–127; doi:10.1080/14615517.2017.1364022.

HEI Energy Research Committee. 2020. Human Exposure to Unconventional Oil and Gas Development: A Literature Survey for Research Planning. Communication 1. Boston, MA: Health Effects Institute.

HEI Special Scientific Committee on Unconventional Oil and Gas Development in the Appalachian Basin. 2015. Strategic Research Agenda on the Potential Impacts of 21st Century Oil and Natural Gas Development in the Appalachian Region and Beyond. Boston, MA: Health Effects Institute.

Hemmerling SA, DeMyers CA, Parfait J. 2021. Tracing the flow of oil and gas: a spatial and temporal analysis of environmental justice in coastal Louisiana from 1980 to 2010. Environmental Justice 14:134–145; doi:10.1089/env.2020.0052.

Huang H, Wang A, Morello-Frosch R, Lam J, Sirota M, Padula A, Woodruff TJ. 2018.Cumulative risk and impact modeling on environmental chemical and social stressors. Current environmental health reports 5:88-99; doi: 10.1007/s40572-018-0180-5.

IFC. 2013. Good Practice Handbook Cumulative Impact Assessment and Management: Guidance for the Private Sector in Emerging Markets.

Kaveney T, Kerswell A, Buick A. 2015. Cumulative Environmental Impact Assessment Industry Guide.

Klasic M, Schomburg M, Arnold G, York A, Baum M, Cherin M, et al. 2022. A review of community impacts of boom-bust cycles in unconventional oil and gas development. Energy Res Soc Sci 93:102843; doi:10.1016/j.erss.2022.102843.

Krupnick A, Echarte I, Zachary L, Raimi D. 2017. WHIMBY (What's Happening in My Backyard?): A Community Risk-Benefit Matrix of Unconventional Oil and Gas Development. Washington, DC: Resources for the Future.

Lam, Y, Bautista O, Wasserman K, Salazar P, Pino J, Lopez-Nuñez M. 2022. Seeing the Whole: Using Cumulative Impacts Analysis to Advance Environmental Justice. New York, NY: National Resources Defense Council.

Lawe LB, Wells J, Cree M. 2005. Cumulative effects assessment and EIA follow-up: a proposed community-based monitoring program in the Oil Sands Region, northeastern Alberta. Impact Assessment and Project Appraisal 23:205–209; doi:10.3152/147154605781765508.

Ma Z, Becker DR, Kilgore MA. 2009. Assessing cumulative impacts within state environmental review frameworks in the United States. Environ Impact Assess Rev 29:390–398; doi:10.1016/j.eiar.2009.03.004.

Malin SA. 2020. Depressed democracy, environmental injustice: exploring the negative mental health implications of unconventional oil and gas production in the United States. Energy Res Soc Sci 70:101720; doi: 10.1016/j.erss.2020.101720.

Mayer A. 2017. Quality of life and unconventional oil and gas development: towards a comprehensive impact model for host communities. The Extractive Industries and Society; doi:*https://doi.org/10.1016/j.exis.2017.10.009*.

Mayfield EN, Cohon JL, Muller NZ, Azevedo IML, Robinson AL. 2019. Cumulative environmental and employment impacts of the shale gas boom. Nat Sustain 2:1122–1131; doi:10.1038/s41893-019-0420-1.

McGranahan DA, Fernando FN, Kirkwood ML. 2017. Reflections on a boom: perceptions of energy development impacts in the Bakken oil patch inform environmental science & policy priorities. Sci Tot Environ 599:1993-2018; doi: 10.1016/j.scitotenv.2017.05.122.

Morello-Frosch R, Zuk M, Jerrett M, Shamasunder B, Kyle AD. 2011. Understanding the cumulative impacts of inequalities in environmental health: implications for policy. Health Aff 30:879-87; doi:10.1377/hlthaff.2011.0153.

NASEM. 2003. Cumulative Environmental Effects of Oil and Gas Activities on Alaska's North Slope. National Academies Press: Washington, DC.

NJ DEP. 2009. A Preliminary Screening Method to Estimate Cumulative Environmental Impacts. Trenton, NJ:NJ DEP.

NJ DEP. 2023. Guidance Document for Environmental Justice: New Rule N.J.A.C. 7:1C and Online Mapping Tool. Trenton, NJ: NJ DEP.

N.J.S.A. § 13:1D-157. An Act concerning the disproportionate environmental and public health impacts of pollution on overburdened communities, and supplementing Title 13 of the Revised Statutes.

Payne-Sturges DC, Sangaramoorthy T, Mittmann H. 2021. Framing environmental health decision-making: the struggle over cumulative impacts policy. Int J Environ Res Public Health 18:3947; doi:10.3390/ijerph18083947.

Perry SL. 2012. Development, land use, and collective trauma: the Marcellus shale gas boom in rural Pennsylvania. Cult Agric Food and Environ 2034:81–92; doi:10.1111/j.2153-9561.2012.01066.x

Proville J, Roberts KA, Peltz A, Watkins L, Trask E, Wiersma D. 2022. The demographic characteristics of populations living near oil and gas wells in the USA. Population and Environment 44:1–4.

Rossi-Keen D, Niebler M, Wolovich S. 2024. A Guide to Community Benefits in Southwestern Pennsylvania. FairShake Environmental Legal Services and RiverWise.

Sadd JL, Pastor M, Morello-Frosch R, Scoggins J, Jesdale B. 2011. Playing it safe: assessing cumulative impact and social vulnerability through an environmental justice screening method in the South Coast Air Basin, California. Int J Environ Res Public Health 8:1441–59; doi: 10.3390/ijerph8051441.

Sexton K. 2012. Cumulative risk assessment: an overview of methodological approaches for evaluating combined health effects from exposure to multiple environmental stressors. Int J Environ Res Public Health 9:370–90.

Tan H, Wong-Parodi G, Zhang S, Xu J. 2022. Public risk perceptions of shale gas development: A comprehensive review. Energy Research & Social Science 89:102548; doi:10.1016/j.erss.2022.102548.

Tulve NS, Geller AM, Hagerthey S, Julius SH, Lavoie ET, Mazur SL, et al. 2024. Challenges and opportunities for research supporting cumulative impact assessments at the United States environmental protection agency's office of research and development. Lancet Reg Health Am 30:100666; doi:10.1016/j.lana.2023.100666.

Uhlmann V, Rifkin W, Everingham JA, Head B, May K. 2014. Prioritising indicators of cumulative socio-economic impacts to characterise rapid development of onshore gas resources. The Extractive Industries and Society 1:189–99; doi: 10.1016/j.exis.2014.06.001

US EPA. 2003. Framework for Cumulative Risk Assessment. Washington, DC: EPA.

US EPA. 2019. Guidelines for Human Exposure Assessment. Washington, DC: EPA.

US EPA. 2022. Cumulative Impacts Research: Recommendations for EPA's Office of Research and Development. Washington, DC: EPA.

WE ACT for Environmental Justice. 2022. Community Engagement Brief: ensuring environmental justice communities participate in decision-making on the Justice 40 Initiative and beyond. New York, NY: WE ACT for Environmental Justice.

Willow AJ, Wylie S. 2014. Politics, ecology, and the new anthropology of energy: exploring the emerging frontiers of hydraulic fracking. J of Politi Ecol 21:222–36; doi: 10.2458/v21i1.21134

Yap NT. 2016. Unconventional shale gas development: challenges for environmental policy and EA practice. Impact Assessment and Project Appraisal 34:97–109; doi:10.1080/14615517.2016.1176405.

Zeise L, Blumenfeld J. 2021. CalEnviroScreen 4.0. Sacramento, CA: California Office of Environmental Health Hazard Assessment. Available: *https://oehha.ca.gov/calenviroscreen/report/calenviroscreen-40*