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IEA Wind TCP Task 34

IEA Wind White Paper
Cumulative Effects Analysis for Wind Energy Development: Current Practices, Challenges, and Opportunities

Technical Report

IEA Wind White Paper Cumulative Effects Analysis for Wind Energy Development: Current Practices, Challenges, and Opportunities

Prepared for the
International Energy Agency Wind Implementing Agreement
by Task 34, also known as WREN (Working Together to Resolve Environmental Effects of Wind Energy)

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Executive Summary

The increasing global deployment of wind energy has given rise to concerns about potential adverse effects on certain wildlife species and habitats. The United States and European nations use environmental impact assessments (EIAs) to evaluate the environmental effects of wind energy and inform wind energy planning, siting, and operational processes. A key component of the EIA is the cumulative effects analysis/assessment (CEA). CEAs consider the effects of a proposed development in the context of past, present, and future developments, as well as other (non-wind) activities. However, practitioners worldwide have struggled to implement cost-effective and consistent processes for CEAs. Further, there is no widely accepted scientific methodology to assess cumulative effects. As wind energy deployment continues to expand, developing a consistent and scientifically based approach to CEAs may provide greater comparability across assessments and more cost-effective mitigation options during siting, operations, and decommissioning/repowering, while minimizing regulatory hurdles.

The current research highlights the need to develop recommended practices and consistent terminology, collect and disseminate baseline data, and integrate regional and project-level analyses to streamline CEAs. The challenges described in this report affect costs and timelines for wind energy deployment, and the current conclusions from CEAs may not accurately capture the real cumulative impact on species and ecosystems. In addition, there is a growing need for confidence in CEA analysis. Pursuing further research and updating current practices to align with the current recommended practices provide opportunities to address these challenges.

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IEA Wind Technology Collaboration Programme

DESCRIPTION OF IEA:
The International Energy Agency (IEA) is an intergovernmental organization that works to shape a secure and sustainable future for all, through our focus on all fuels and all technologies, and our analysis and policy advice to governments and industry around the world.

The Technology Collaboration Program (TCP) is a multilateral mechanism established by the IEA with a belief that the future of energy security and sustainability starts with global collaboration. The programme is made up of thousands of experts across government, academia and industry in 55 countries dedicated to advancing common research and the application of specific energy technologies.

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1 Introduction

1.1 Task 34-Working Together to Resolve the Environmental Effects of Wind Energy (WREN)

In October 2012, The International Energy Agency Wind Technical Collaborative Program (TCP) initiated Task 34, known as WREN—Working Together to Resolve Environmental Effects of Wind Energy. The scope of WREN is to facilitate an international collaboration that advances global understanding of the environmental effects of land-based wind (LBW) and offshore wind (OSW) energy development and creates a shared global knowledge base for recommended practices for monitoring, research, and mitigation. The goals of WREN align with the International Energy Agency's mission toward environmental awareness and the Technical Collaboration Program's 2019–2024 strategic objectives, specifically to 1) lower the cost of LBW and OSW energy, 2) facilitate wind energy deployment through social support and environmental compatibility, and 3) foster collaborative research and exchange of best practices and data. Outreach for WREN is aimed primarily toward key stakeholder groups within regulatory agencies, the wind energy industry, conservation organizations, and researchers.

1.2 Background

Increased wind energy development has given rise to concerns about potential cumulative adverse effects on certain species, species groups, and habitats (Snyder 2009; May et al. 2019). Adverse effects, including those on wildlife from wind turbines, are a function of three factors: stressors, receptor vulnerability, and risk exposure. Stressors are components of a project that cause risk to wildlife. Each phase of development, including preconstruction, construction, operation, and decommissioning, creates potential stressors that can affect the surrounding environment and wildlife. This includes noise generated during construction, collision with spinning turbine blades, or disturbance or collision with vehicles or vessels. Receptors are the vulnerable species or ecosystems in the project impact zone (i.e., the geographic scope of project impacts) that are adversely affected by the stressor(s). The extent and magnitude to which a receptor interacts with an identified stressor determines the receptor vulnerability. Finally, risk exposure is the frequency and duration of an interaction a species has with a stressor (Goodale and Milman 2016).

Figure 1. Heavy seas engulf the Block Island Wind Farm, Rhode Island USA. ***Photo by Dennis Schroeder NREL, 40389.***

To assess the potential effect of an activity within an area or industry in combination with past, present, and future effects, cumulative effects analyses/assessments (CEAs) are conducted. CEAs are one component of environmental impact assessments (EIAs) (Judd et al. 2015). CEAs can be considered for either a single wind farm or for a species across wind farms (May et al. 2020). The international community organizes cumulative effects pathways in three ways:

- Additive: the cumulative effect is equal to the sum of the individual effects
- Synergistic: the cumulative effect is greater than the sum of the individual effects
- Antagonistic or countervailing: the cumulative effect is less than the sum of its individual effects (Goodale and Milman 2019).

For LBW energy development, the impacts of preconstruction activities in the project area are often negligible. During the construction phase, noise, habitat loss, disturbance, and/or increased traffic may impact local wildlife (e.g., prairie grouse). However, the primary focus of CEAs is the operational phase and the direct impact of bird and bat collisions (Allison et al. 2019). For OSW energy, receptors such as marine mammals, fish, sea turtles, and seabirds may be impacted by the various activities associated with wind farm development and operations, including geotechnical site surveys during preconstruction, pile driving and increased boat traffic during construction, and the presence of infrastructure throughout operations (Goodale and Milman 2016). Currently, there are few empirical studies assessing collision impact to birds and bats at operating OSW sites, but collision risk models are often used to predict wind-turbine-related bird mortality (Madsen and Cook 2016), and opportunities exist for further implementation offshore.

Given the proposed footprints of future LBW and OSW energy developments, the potential environmental effects are an important consideration. CEAs play a key role in appropriately assessing stressors, receptors, and exposure for a specific project site and region. The purpose of this report is to describe the commonalities and differences in terms, policy, and research across regions, summarize the challenges, and highlight opportunities related to cumulative effects research.

2 Cumulative Effects Guidance

2.1 Definition

In the United States, the Council on Environmental Quality (CEQ) previously defined cumulative effects as the "impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (federal or nonfederal) or person undertakes such other actions. Cumulative impacts can result from individually minor, but collectively significant, actions taking place over time" (CEQ 1997). In 2020, the CEQ published a final rule that amended regulations for the National Environmental Policy Act (1969) and removed references to direct, indirect, and cumulative effects (Federal Register 2020).

The European Union identified cumulative effects processes that are consistent with relevant directives in the recently updated guidance document on wind energy developments and nature legislation (European Commission 2020). One approach outlined in this document is the Common Environmental Affects Framework (CEAF), developed within the North Seas Energy Cooperation (NSEC), a voluntary cooperation of 11 countries bordering the North Sea, to enhance offshore renewable energy development. CEAF provides a toolbox for considering the ecological impacts from OSW (https://northseaportal.eu/), and represents collaboration underpinned by a political declaration. It defines cumulative effects as "impacts that result from incremental changes caused by other past, present or reasonably foreseeable actions together with the project" (CEAF 2019).

Outside of the United States and European nations, the International Finance Corporation (IFC)—the private sector arm of the World Bank—produced CEA guidance for the private sector in emerging markets (IFC 2013). Although this guidance is not legislatively mandated, it can affect which projects are able to secure financing. The handbook highlights why CEAs are important, the process for implementation, and how to overcome challenges.

2.2 Legislative Instruments

In 2020, the CEQ final ruling removed the requirement to conduct a CEA and required federal agencies to develop new or revised procedures to align with the final rule (Federal Register 2020). No other regulations are impacted by this change. Thus, other federal legislation in the United States may require a CEA, including the Endangered Species Act (1973), Coastal Zone Management Act (1972), Clean Water Act (1972), Clean Air Act (1963), and Marine Mammal Protection Act (1972). Depending on the project jurisdiction, state policies may also require a CEA. For example, for an OSW project in California, the California Environmental Quality Act and the California Coastal Act also have specific requirements for CEAs (Willsteed et al. 2018).

Cumulative impact assessments in the European Union are required by the Environmental Impact Assessment Directive (Directive 2014/52/EU), the Strategic Environmental Assessment (Directive 2001/42/EC), and the Marine Strategy Framework Directive (Directive 2008/56/EC) (Willsteed et al. 2018). Individual countries may also have legislation that involves additional or complementary CEA requirements to move a project forward.

3 Cumulative Effects Process and Analysis

3.1 Process Summary

The following sections provide a summary of the CEA process and components. Prior guidance for the United States and existing guidance for the European Union note that the following elements of a CEA process may not happen in sequence but may occur in tandem, depending on the availability of data and project context.

1. *Scoping*

   Scoping a CEA requires identifying the significant cumulative effects of a proposed project, determining the geographical boundaries, and classifying the temporal bounds. To appropriately determine the cumulative effects analysis scope, it is necessary to identify past, present, and reasonably foreseeable activities (NYSERDA 2017). When assessing cumulative effects, all activities—public and private—should be included in the analysis (BOEM 2020). Geographic scoping, or determining the appropriate geographic boundaries for a CEA, varies depending on the project's size and potential impact. For example, the geographic scope may depend on the level of analysis, whether regional or project-based, and the ecologically determined scales for the specific species affected by the potential project (CEAF 2019). To properly account for the temporal and geographical boundaries, it is crucial to systematically determine not only the past and current impacts, but also potential future events that may affect the proposed project or regional development.

2. *Stressors, Receptors, and Baselines*

   <u>Identify Stressors</u>

   In addition to determining the specific stressors from wind energy development, the CEA process calls on practitioners to determine how those stressors will interact with other past, present, or future stressors (OSPAR 2019). In the context of wind energy, common stressors include additional traffic or human disturbance, dredging, underwater noise, infrastructure, and turbine blades (Goodale and Milman, 2016).

   <u>Identify Receptors</u>

   In a CEA, focusing on the species that may be the most vulnerable is the best use of the finite resources and time afforded to EIAs (Foley et al. 2017). Typical characteristics of vulnerable species may include the potential for co-occurrence with the impactful activities, either temporally (e.g., at a critical life stage or seasonal event) or geographically (e.g., in an ecologically important area), or any specific behaviors that may increase exposure. Referring to similar projects can assist in assessing the potential impact of a stressor on a receptor.

Identify Baselines

In the context of wind energy development, a baseline "describes the state of the receptor prior to the implementation" and may factor in existing stressors (e.g., nearby development or climate change) (Goodale and Milman 2016). Identifying baselines is a difficult aspect of the CEA process. The uncertainty around the spatiotemporal aspects of a species' abundance, distribution, behavior, and movement patterns make baseline determinations challenging and costly (Willsteed et al. 2018). Baseline determinations can also be difficult when there is limited data specific to a particular location or species. However, it is crucial to determine baselines to understand the impact of a project on a species or a region. Baselines should be determined for each identified vulnerable receptor.

3. *Analysis*

In the United States, prior guidance offered a host of evaluation tools and methodologies that could be implemented depending on the project and context. These methods included questionnaires, interviews, and panels to gather expert information; checklists, matrices, networks and systems diagrams, modeling, trends analysis, and overlay mapping with GIS (CEQ 1997). However, due to the complexity and breadth of data that are needed to effectively conduct a CEA, new and dynamic models that provide consistency and quantitative results have been developed (Halpern et al. 2018). Examples of evolving evaluation methodologies include experimental methods, meta-analysis, single-species modeling, qualitative modeling, and multi-species modeling.

3.2 Analysis Model Example: Cumulative Exposure Model

Increased need for CEAs for the wind energy industry is driving the development and adoption of new evaluation methods and models (Goodale and Milman 2019). The Cumulative Exposure (CE) Model is specific to OSW and illustrates the need for and value in creating these types of evaluation tools. The model has five steps:

1. Establish the suitability layer (i.e., where it makes sense to build OSW farms).
2. Create a species distribution map.
3. Join wildlife layers and siting factors (i.e., combine steps one and two).
4. Produce the siting scenarios that would best address each receptor and stressor pathway.
5. Provide two outputs: a cumulative exposure curve and a cumulative exposure index.

The value of this model is not only the quantification and definition of an OSW specific process and corresponding information, but also its broad usability in various ecological scenarios, including intensity and length of exposure.

3.3 Probability and Magnitude of Impacts

Determining the probability and magnitude of impacts will vary by potential stressor(s) in a project impact zone and the specific receptor(s) affected. Depending on the focus of the model or legislative driver, the probability and magnitude will differ. However, general principles can be applied, including focusing on valuable ecosystem components, exposure to stressors, ecosystem thresholds and indicators, and timeline of the effect. Historically, the significance of an action or project has been prescribed through expert opinion, but this approach lacks a transparent methodology for determining incremental effects of multiple stressors. Recently, there has been an increase in scientific processes and methods for determining significance. These approaches determine significance by overlaying the likelihood of impacts in the CEA process. Methods for determining probability and magnitude have been identified as components of the CEA process that could add value to CEA discussion and practice (Foley et al. 2017; Judd et al. 2015; Willsteed et al. 2018).

3.4 Mitigation: Avoidance, Minimization, and Compensation

Practitioners should be able to determine the most relevant mitigation factors for a project or development in a region based on the CEA analysis outcomes. Mitigation factors include avoidance, minimization, and compensation. Siting development away from vulnerable areas is often used as a means of avoiding impacts. Minimizing—using the outputs from a CEA evaluation to reduce the direct effects of a turbine or project design—is another option that planners use when determining where to site and how to operate a wind farm. Finally, when impacts cannot be avoided or minimized, compensating for the impact, or contributing to similar ecosystems to bring about "no net loss," can be considered, although this may not be possible for all receptors or locations (Goodale and Milman 2016; Blake et al. 2020; GoBe Consultants and Orsted 2020).

4 Challenges and Further Research

4.1 Scientific and Methodological Uncertainties

Many challenges remain in the CEA process. In some cases, these challenges can generate uncertainty, lack of confidence, increased costs, and project development delays. One challenge is improving confidence in the current scientific methodology and model outputs. Several evaluation methods exist, and strides have been made in improving model and evaluation outputs (May et al. 2020). However, the complexity and individualized nature of each CEA makes developing a standardized process challenging (Willsteed et al. 2018). Specific steps in the CEA evaluation process have been identified as needing further research to increase confidence in model fidelity (Masden et al. 2010). These include a standardized methodology for the determination of impact, identification of the most appropriate temporal and geographical scope for the assessment, and determination of the magnitude of the stressor. Additionally, further research is needed to evaluate how effective management measures are in reducing the risk of cumulative effects (Steltzenmüller et al. 2020). Unfortunately, current models and literature are concentrated in the academic space and will need to be disseminated and translated for practitioners.

4.1.1 State of the Research: Example Studies

Research at LBW and OSW farms provides an opportunity to advance both methodology and practice associated with CEAs. The following are a few examples to highlight recent LBW and OSW CEA research.

Land-Based Wind

Bastos et al. (2016) used a spatially explicit dynamic approach to assess the local and cumulative regional impacts of wind farms on skylarks (*Alauda arvensis*) in northern Portugal. A total of 123 wind farms were constructed by 2011, with an additional nine operational by 2014. The authors modeled the local collision mortality on the skylark population, determined the actual and future skylark breeding distribution across northern Portugal, and developed an emergent spatially explicit regional representation to capture the cumulative consequences. The simulations showed an increasing local impact on the breeding population directly affected by wind farms and a 4%–5% decrease in the distribution area for the breeding population within 15 years. When combined with mortality induced by all wind farms in the region, the regional cumulative impact increased from 1.2% to 3.7%.

Figure 2. Skylark soaring. Photo from IStock.com, 173833110.

Johnson and Erickson (2010) conducted a cumulative impacts analysis for the Columbia Plateau ecoregion of eastern Washington and Oregon in the United States. At the time, just over 4,000 MW were installed or under construction, with a future buildout of 6,700 MW expected. The CEA relied on mortality estimates from 16 wind energy facilities in the region and recent publications that estimated the breeding size of local bird species. Expected fatalities during the breeding season included 70 American kestrel, 44 red-tailed hawk, and 22 short-eared owls, which represented approximately 0.04%, 0.06%, and 0.10% of the breeding populations, respectively. The authors concluded that background mortality of these species is significantly greater, and the additional wind-energy-related mortality is likely insignificant from a population standpoint.

May et al. (2020) presented an analysis and new methodology integrating CEA into the lifecycle assessments (LCA) framework to account for impacts across larger spatial scales. The methodology quantifies three impact pathways, which include habitat loss, disturbance, and collision impacts. The study focused on LBW wind development and the potentially disappeared fraction of species for the impact pathways. Across years and ecosystems, the effects of habitat loss and disturbance are consistently larger than the collision impact when considered cumulatively.

Offshore Wind

Goodale et al. (2019) assessed the cumulative exposure of seven seabird foraging guilds to three different OSW siting scenarios along the East Coast of the United States. The authors used a wind farm suitability layer of 450 GW and scenarios that factored in distance from shore, bathymetry, and wind speed. They developed seabird abundance data for 36 species using the National Oceanic and Atmospheric Administration survey data from 1978–2014. Results indicated that coastal guilds have the greatest likelihood of exposure regardless of siting decisions, whereas pelagic birds are exposed at high rates when projects are built in high-wind areas. No scenario reduced cumulative exposure for all guilds.

Brandt et al. (2016) conducted a study determining the effects of eight OSW projects on harbor porpoise abundance in the German Bight between 2009 and 2013. Using aerial survey data, passive acoustic porpoise detector data analyses, and the Population Consequences of Disturbance Model paired with pile driving data, this analysis aimed to understand the relationship between offshore wind construction noise and porpoise response. The study included both localized/small-scale cumulative effects and large-scale/regional cumulative effects analysis. The study indicated that prior to any piling or deterrence measures, porpoise activity was significantly decreased within a 10 km vicinity of all wind farm projects, likely due to the associated construction activities (e.g., increased vessel activity). However, these were short-term effects (1–2 days). The data collected at the larger scale did not indicate a population decline or change in distribution patterns over the five-year period.

Figure 3. Harbor porpoise. Photo from Ecomare.

In the United States, as interest in cumulative effects analysis and impacts grows, many state and regional entities are increasingly publishing assessments and reports to evaluate CEA in their jurisdictions, building on existing (often academic) research in the field. For example, the New York State Energy Research and Development Agency published the *New York State Offshore Wind Master Plan Consideration of Potential Cumulative Effects* in 2017. Through the lens of a theoretical project off the coast of New York, this effort summarizes process, modeling methods, and analysis for a CEA.

In Europe, several countries are developing similar evaluations and reports. For example, a French working group, ECUME, developed a methodological approach for CEA of OSW that will be tested at two sites located off the Normandy coast. ECUME also developed and applied a method to identify and prioritize critical stressors and impact pathways that should be considered in the impact assessment (Verling, et al., 2021). In the United Kingdom, the UK Centre for Ecology and Hydrology developed a Cumulative Effects Framework (CEF) co-funded by the European Maritime and Fisheries Fund (EMFF) and the Scottish government. The framework includes a data library, R package, and a user interface to develop a set of tools for the assessment of cumulative effects for key receptors (Mobbs 2021).

These examples of academic research and jurisdictional analysis demonstrate the interest in and direction of knowledge and process development for OSW CEA, as well as indicating the gaps and current interest in research and methodology development.

4.2 Data Availability and Quality

Data availability and collection responsibility also drive uncertainty in CEA outputs. The fidelity of any modeling or evaluation effort relies on data accuracy and availability (Halpern et al. 2018). Large amounts of specific data are needed to properly conduct a CEA for a project or region. Insufficient baseline environmental information, population data, and wildlife response data decrease the fidelity of many evaluation methods. Thus, data availability and quality remain central to efforts to improve CEAs (Judd et al. 2015).

The persistent lack of data may stem from the lack of defined responsibility for data collection and the limits to what developers and government agencies are capable of (Piper 2001). A further complication in gathering CEA data is that, once collected, the required data may not be available to the public, thus limiting the use of the data in subsequent studies. The variability in quantity and quality of data accessible to projects indicates the need for further research to better integrate uncertainty into CEAs to show the confidence in the conclusion/output. Additionally, research on data sharing structures and processes for the wind industry, such as the CEF tool, which integrates all available data into a single database, is needed.

4.3 Project and Regional Analysis

Practitioners may conduct two types of CEAs: project-led and regional. These will inform either policy (governance and planning) or regulatory processes. An analysis is done at the project level, to gain the necessary permissions to proceed with the project, or at the regional level, to understand the total impact of an influx of development in a jurisdiction or biogeographical region (Willsteed et al. 2018). Developers primarily conduct project-level analysis and assessments. These studies tend to have a smaller geographic scope and time scale. For both regional and project-level analyses, there are financial and temporal constraints. In aggregate, project-level assessments can help collect the necessary data for determining baselines and conducting valid regional assessments (Goodale and Milman 2016). However, it is difficult for an isolated developer to assess the impacts of other activities (e.g., fishing, dredging) and future potential projects. Regional analyses, usually conducted by a government agency or nongovernmental organization, provide much-needed baseline information, and include a broad temporal and geographic scope. These types of analyses are essential in creating a more robust data repository for future assessments, but are done less frequently because of cost and uncertainty surrounding responsibility (Foley et al. 2017). Both project-level and regional assessments are important, and efforts to integrate the two assessments and bolster confidence in outputs is necessary.

4.4 Process and Consistency

Apart from scientific methodology and model fidelity, standardization of terms and process for CEAs is a persistent challenge. Inconsistent use of terms detracts from the communication of analysis conclusions and the transfer of knowledge between different interest groups (Judd et al. 2015; Foley et al. 2017). These inconsistencies can also drive variance in the scientific process (International Council for the Exploration of the Sea [ICES] 2019). The inconsistent use and definition of impacts has resulted in varied results and inconsistent determination of baselines, probability and magnitude of impacts, and spatial and temporal scopes (Foley et al. 2017).

Groups such as RenewableUK (formerly the British Wind Energy Association), a trade association for wind, wave, and tidal power technologies in the United Kingdom, have undertaken efforts to outline best practices, improve consistency, and add minimum information requirements to definitions for marine and OSW energy (RenewableUK 2019). The French Ministry of Environment is also currently leading a working group of experts on all ecosystem compartments to address cumulative effects (ECUME, Brignon et al. forthcoming). Organizations such as International Council for the Exploration of the Sea (ICES) have made similar efforts. However, terminology and process still differ. The reasons for these differences vary but are commonly traced to legislative inconsistency across jurisdictions (Judd et al. 2015). Depending on the specific laws in a country or region, standards for minimum information requirements differ, and analysis and designation of responsibility may vary dramatically. Consistency in terminology among CEAs is important for comparative purposes, both within and among jurisdictions.

5 Future Research and Recommended Practices

Figure 4. Golden Eagle flies at the National Wind Technology Center. ***Photo by Lee Jay Fingersh, NREL 35726.***

Standardization and improvement of CEA evaluation techniques and processes could decrease permitting, speed up the siting process, lower the levelized cost of energy, and increase confidence in the measures needed to protect vulnerable ecosystems threatened by wind energy development. In addition, more research is needed to evaluate the efficacy of these tools and assess cumulative effects associated with continued development. Bailey et al. (2014) outlined lessons learned for making CEAs more transparent and effective going forward, including:

1. Identify the area where biological effects may occur and determine the connectivity between populations and proposed development.
2. Determine whether impacts are biologically significant (i.e., have a population-level impact).
3. Measure responses to construction and operations to determine disturbance and avoidance responses.
4. Use data from other industries to inform risk assessments and effective mitigation measures.

Katsanevakis et al. (2020) suggest applying a comprehensive and transparent framework that embeds CEAs within a risk management process. Applying such a risk-based CEA framework can structure the associated complex analyses. They recommend a process consisting of risk identification (i.e., finding, recognizing, and describing risks), risk analysis (i.e., describing the risk of cumulative effects after accounting for the performance of existing management measures) and risk evaluation (i.e., comparing the results of risk analysis with the established risk criteria and benchmarks to determine the significance of the risk). These three steps can help reveal the likelihood of exceeding the acceptable risk of ecosystem state changes (Stelzenmüller et al. 2018).

In addition, developing recommended practices and consistent terminology, collecting and disseminating baseline data, and integrating regional and project-level analyses will help streamline CEAs. The challenges described herein affect costs and timelines for wind energy deployment, and the current conclusions from CEAs may not accurately capture the real cumulative impact on species and ecosystems. In addition, there is a growing need for confidence in CEA analysis. Pursuing further research and updating current practices to align with the current recommended practices provide opportunities to address these challenges.

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