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Consideration of Environmental Justice in EPA's Regulatory Analyses: A Review and Assessment

Emma DeAngeli, Richard Morgenstern, Burçin Ünel, and Ann Wolverton[1,2]

Abstract: Increasingly, the US Environmental Protection Agency (EPA) conducts environmental justice (EJ) assessments as part of its regulatory analyses for new rules. We inventory and evaluate the available EJ analyses for the EPA's 68 economically significant final rules issued between 2012 and 2024. We find that three-quarters (53) of these rules include an EJ analysis, and 45 of these analyses are at least partially quantitative. The proportion of rules that include an EJ analysis increased from about 60 percent in 2012 to more than 90 percent within the past three years. While many of the quantitative EJ analyses examined only baseline issues, some of the more recent assessments have used more nuanced methods to assess differences in vulnerability, cumulative impacts, and climate risk. Three EJ analyses consider the incidence of costs across population groups. While recognizing the different budget, data, and modeling constraints across EPA program offices, we emphasize the need to consider EJ at the early stages

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[2] The views expressed in this paper are those of the authors and do not necessarily represent the views or policies of the EPA.

of the analytical process. We also discuss important gaps in data and methods that are key to examining the underlying heterogeneity in concentrations and health risks, EJ impacts of regulatory options, regulatory costs, and net benefits across demographic groups.[3]

Keywords: regulatory analysis, environmental justice, distribution

[3] We thank Vasundhara Gaur, Peiley Lau, Jason Schwartz, and Margaret Walls for their comments on this paper. We acknowledge both the Smith Richardson Foundation and the EFI Foundation for funding the Resources for the Future authors in the creation of this paper.

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1. Introduction

Under Executive Order (EO) 12866, the Office of Management and Budget (OMB) reviews regulatory analyses conducted in support of federal rulemaking. In this role, the OMB has long directed federal agencies to evaluate both the economic efficiency and distributional implications of its regulatory policies.[4] In practice, however, the emphasis has traditionally been on improving and expanding the quantification of aggregate benefits and costs (i.e., efficiency).[5]

At the US Environmental Protection Agency (EPA), for instance, regulatory analyses often estimate the impacts of a regulatory action on small businesses, workers, or employment, but we found no examples where the EPA included a quantitative analysis of how costs *and* benefits are distributed across households, a finding confirmed by other recent reviews.[6] Cecot and Hahn (2022) report that "virtually no agency prepares a distributional analysis that could help determine whether a proposed regulation, on net, advantages or disadvantages a particular group or whether an alternative could generate a preferred distributional outcome" (2022, 99). Looking across federal agencies, Revesz and Ünel (2022) find that the distribution of costs is

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[4] EO 12866 (1993) acknowledges the potential role of factors such as those related to the economy, environment, public health, and safety; distributive impacts; and equity. The importance of these factors is reaffirmed in subsequent orders. EO 13563 (2011) states that "where appropriate and permitted by law, each agency may consider (and discuss qualitatively) values that are difficult or impossible to quantify, including equity, human dignity, fairness, and distributive impacts to support decision-making." EO 14094 (2023) states that "regulatory analysis, as practicable and appropriate, shall recognize distributive impacts and equity, to the extent permitted by law."
[5] Echoing widely held views that the transfer of benefits across demographic groups is best accomplished via taxes as opposed to regulatory policy, early approaches to the analysis of environmental regulations generally ignored distributional issues and focused on traditional economic efficiency concerns—namely, the aggregate benefits and costs of regulation (Arrow et al. 1996).
[6] A recent exception that is not included in these reviews is an evaluation of the distribution of social costs across households based on income that was conducted by the EPA for the Greenhouse Gas Standards and Guidelines for Fossil Fuel-Fired Power Plants, promulgated in 2024. See https://www.epa.gov/stationary-sources-air-pollution/greenhouse-gas-standards-and-guidelines-fossil-fuel-fired-power for more information.

rarely assessed, and when such distributions are estimated, they are “truncated, inconsistent or inadequate” (2022, 4). Similar findings are reported in Robinson et al. (2016).

Recently, attention has turned to the importance of conducting distributional and, more specifically, environmental justice (EJ) analysis.[7] Revised guidance from the OMB (2023) on conducting regulatory analysis strongly encourages distributional analysis when practical, including evaluating the impacts of each proposed regulatory option. EO 14096 (2023) calls on federal agencies to identify, analyze, and address EJ concerns—the potential for disproportionate and adverse human health or environmental effects of federal programs, policies, and activities in specific communities or for populations of concern (e.g., low income, people of color, Tribes).[8] Further, it expands on earlier directives (e.g., EO 12898) by encouraging consideration of the impacts of climate change, cumulative impacts, historic inequities, and systematic barriers to accessing federal policies and programs.[9] The EPA is also in the process of updating its 2016 guidance on how to conduct EJ analysis for rulemakings to reflect this renewed emphasis and recent scientific and analytical advances (EPA 2023a).

Environmental justice as defined by EO 14096 also focuses on procedural justice—the just treatment and meaningful involvement of all people in agency decisionmaking.[10] While an

[7] Evidence of exposure to pollution and associated health effects that differ by race, ethnicity, and income has greatly expanded over the years, revealing major disparities for pollutants such as lead and particulate matter (see EPA 2023a and Banzhaf et al. 2019 for recent reviews).
[8] Exec. Order No. 14096, 3 CFR 88 FR 25251 (2023), https://www.federalregister.gov/documents/2023/04/26/2023-08955/revitalizing-our-nations-commitment-to-environmental-justice-for-all
[9] Exec. Order No. 12898, 3 CFR 59 FR 7629 (1994), https://www.federalregister.gov/documents/1994/02/16/94-3685/federal-actions-to-address-environmental-justice-in-minority-populations-and-low-income-populations.
[10] Specifically, EJ is defined as “the just treatment and meaningful involvement of all people, regardless of income, race, color, national origin, Tribal affiliation, or disability in agency decision-making and other Federal activities that affect human health and the environment so that people are fully protected from disproportionate and adverse human health and environmental effects (including risks) and hazards” (EO 14096).

evaluation of processes put in place by the EPA to enhance meaningful involvement is beyond the scope of this paper, this concept interacts with EJ analysis in two ways. First, it is important for the analysis to clearly lay out key assumptions, methods, and results so they are transparent and easy for nonspecialists to understand. Second, it may be appropriate for agencies to ask for more public input regarding health outcomes of concern, the ways in which individuals might be exposed to environmental pollutants, or data sources that could improve EJ analysis (EPA 2016). We return to this point in Section 6.

This paper reviews all the EJ analyses conducted by the EPA for economically significant final rules promulgated since 2012.[11] We selected 2012 as a reasonable starting point, given activity to raise the profile of environmental justice, and EJ analysis in particular, at the end of the first Obama administration.[12] We consider the breadth and quality of the EJ analyses, including the extent to which they go beyond baseline characterizations to explicitly consider the impacts of regulatory options. Given the recent emphasis on cumulative impacts, we also examine the extent to which the EPA's EJ analyses consider costressors, copollutants, or the potential for local hot spots. Finally, we build on earlier work (e.g., Wolverton 2023) by taking a closer look at the way EJ analyses have evolved over time, with a particular emphasis on recent examples, given the Biden administration's focus on environmental justice.

Our review identifies important trends in EJ analysis and highlights analytical and

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[11] EO 12866 creates a category, colloquially referred to as "economically significant" rules, including any rule that has "an annual effect on the economy of $100 million or more or adversely affect in a material way the economy, a sector of the economy, productivity, competition, jobs, the environment, public health or safety, or State, local, or tribal governments or communities." EO 14094 amended the threshold to $200 million in April 2023.

[12] EJ was made an EPA national priority in 2010. The EPA then released *Plan EJ 2014* in September 2011, a roadmap for integrating EJ into all its programs, policies, and activities, including the intention to develop technical guidance on how to assess EJ concerns for rulemakings (EPA 2011).

procedural gaps to be addressed in further improvements. We offer recommendations for how to improve future EJ analyses but leave to others the normative question of how distributional and EJ concerns should be considered in decisionmaking alongside other information, such as the aggregate net benefits of the regulations.

Following this brief introduction, Section 2 summarizes the main components of the EPA's regulatory and EJ analyses and delineates how they differ from distributional analysis. Section 3 presents the main findings from our review of EPA EJ analyses since 2012, including general characteristics and key trends. Section 4 describes the various methods and characteristics of EPA EJ analyses. Section 5 provides examples of recent EJ analyses that showcase new analytical areas or methods. Finally, Section 6 concludes by offering recommendations for improving future EJ analyses at the EPA.

2. Regulatory, Distributional, and EJ Analyses

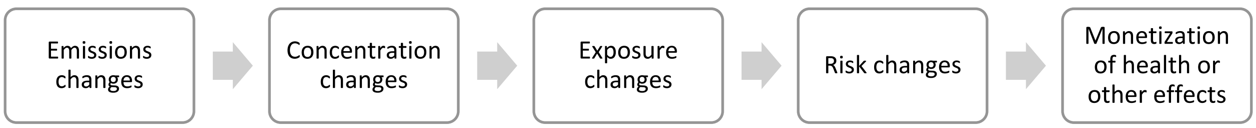
The purpose of a regulatory analysis is to "anticipate and evaluate the likely consequences of" a regulatory action (OMB 2023, 2). While this analysis may evaluate a variety of economic and environmental impacts, OMB (2023) identifies benefit-cost analysis, which characterizes aggregate welfare via a measure of net benefits, as the primary tool for evaluating these effects. As a result, agencies typically invest most heavily in data and methods to improve the quantification and monetization of benefits and costs to calculate aggregate net benefits; this generates data and results that are useful inputs for other types of analyses.

A typical regulatory analysis has five steps, as shown in Figure 1: identifying the need for a new regulatory action; determining baseline conditions without a regulatory action; identifying multiple regulatory options; assessing the costs and benefits of each of these regulatory options relative to the baseline; and summarizing the analysis (OMB 2023). Each step comes with its own analytical challenges. For example, specifying the baseline requires defensible data and methods for characterizing current and future environmental and economic conditions absent new regulation. Later steps in the assessment of costs and benefits can also be demanding and are often hindered by the unavailability of appropriate data and limited modeling capabilities.

Figure 1. Main Steps of a Regulatory Analysis

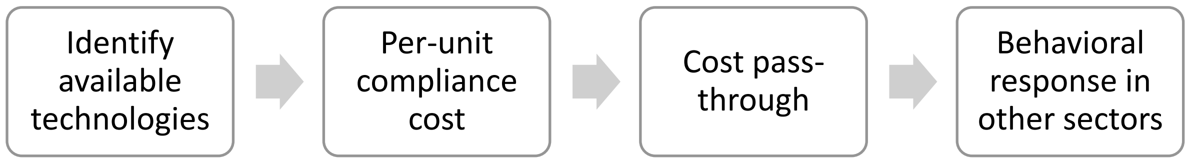
Understanding the health and other benefits of a typical pollution-control regulatory action issued by the EPA requires analysts to first identify how a given regulatory option affects emissions/discharges at the sources subject to the regulation (Figure 2). Next, analysts need to model how these changes in emissions/discharges translate into changes in pollutant concentrations. This step requires an understanding of where emissions travel; the rate at which they dissipate, mix, or chemically change form; and who is likely to be exposed to them (i.e., fate and transport). Analysts then use peer-reviewed scientific evidence to model specific exposure pathways and how changes in exposure result in changes in the risk of a given health or environmental impact. This relationship is often mapped out over a range of potential exposure levels via a dose-response or concentration-response function. When feasible, health and environmental effects are translated into monetary terms to facilitate aggregation across benefit categories and a comparison with costs. In many cases, limited data or modeling challenges the EPA's ability to identify where changes in concentrations might occur, the main pathways for exposure, and how these changes lead to impacts on human health and the environment—often not observed until many years after the initial exposure.

Figure 2. Steps to Estimate Aggregate Benefits from an Environmental Regulation



To estimate the aggregate costs of a regulatory option, analysts often rely on an engineering-based approach to identify available technologies that reduce emissions/discharges and estimate the fixed and variable costs for installing and operating them (Figure 3). Unit- or plant-level costs are estimated by applying these technologies to each regulated source, which are then aggregated. Note that aggregate compliance costs do not necessarily translate into total costs to society, as behavioral responses by producers and consumers may mitigate some of the cost impacts. However, data and methods for estimating pass-through and behavioral responses, including credible estimates of demand and supply elasticities and the market power present in different markets, are often limited.

Figure 3. Steps to Estimate Aggregate Costs of an Environmental Regulation



In contrast to benefit-cost analysis, two other types of regulatory analysis—distributional and EJ analyses—focus on understanding how the aggregate effects of regulation are distributed among specific population groups. However, while the goals of the EJ and distributional analyses overlap, they also differ in several important ways. First, the focus of EJ analysis is on specific sociodemographic characteristics that may correlate with higher exposure or increased vulnerability, such as race, ethnicity, and income. In contrast, distributional analysis focuses on the incidence of costs and benefits across broader categories such as households, businesses, or workers.[13] Second, the EOs that guide the conduct of EJ analysis are focused primarily on the precursors to monetized benefits, specifically, health and environmental effects.[14] Welfare impacts are not typically included in EJ analyses. Third, costs are not consistently considered in EJ analyses, and there are ongoing debates about whether and how they should be considered.[15] Finally, an EJ analysis emphasizes how existing and historical conditions might contribute to the vulnerability of already heavily burdened communities and populations. This is evidenced by the expansion of the analytical goals of an EJ analysis to consider cumulative impacts, historical inequities, and systemic barriers to accessing federal programs.

[13] These analyses respond to many different executive order and statutory requirements. See chapter 2 of EPA (2010) for a list of the main ones.
[14] For example, EO 14096 focuses on the identification and analysis of "disproportionate and adverse human health and environmental effects."
[15] For instance, some public comments received on the EPA's revision of its technical guidance for evaluating EJ in regulatory analysis emphasize the importance of considering costs, while others state that costs should not be part of the EJ analysis. See Docket ID No. EPA-HQ-OA-2013-0320.

Both distributional and EJ analysis follow steps similar to those in Figure 1, including characterizing the baseline and the incremental effects of regulatory options, whether expressed as health and environmental effects or as costs and benefits. However, the dual challenges of characterizing the baseline and then analyzing the incremental impacts of the regulatory options on specific groups are particularly daunting, as one needs to differentiate impacts across populations of interest. Further, for distributional analysis, there are often challenges in distinguishing compliance costs from true cost incidence across households, as the extent to which initial burdens are passed on in the form of higher prices can be difficult to estimate. In addition, one needs to understand how the households will respond: Will they stop buying a particular good or switch to an alternative? The way in which higher costs are passed on to households (e.g., via changes in prices of goods or returns to capital), as well as the nature of existing regulatory structures, can also affect incidence. For example, how much a household ultimately pays for its electricity, water, or other utilities depends on the rate structure in place locally as well as the availability and use of income-based support programs.

In addition, because an EJ analysis requires understanding how a regulatory option will affect the health and environment of certain communities that are not uniformly distributed throughout the population, the analysis needs to be conducted at a spatially granular level. To provide more nuanced analysis of the effects of exposure and risk changes, this level of granularity often requires even more detailed data than an aggregate benefit-cost analysis may need on forecast changes in pollution/discharges, fate and transport, unique exposure pathways, and potentially differentiated dose-response functions.[16] Thus, even when a regulatory action includes a relatively complete aggregate benefit-cost analysis, analysts might still lack the data and methods needed to conduct a comparably sophisticated EJ or distributional analysis.

3. Historical Trends in the EPA's EJ Analyses

Building on Wolverton (2023), we examine the available EJ analyses for the 68 economically significant final rules promulgated by the EPA between January 2012 and July 2024 (see Appendix 1 for a complete list). We focus on economically significant rules because they are subject to the requirements for regulatory analysis under EO 12866, and recently revised OMB guidance emphasizes that such analysis should include consideration of distributional effects, including on population groups that may be defined on the basis of specific demographic characteristics. To identify the economically significant final rules promulgated by the EPA over our study period, we relied mainly on a searchable OMB database of all regulatory packages reviewed under EO 12866.[17] We verified this list via internally maintained information at the EPA.

We found it more challenging than anticipated to locate the EJ analyses associated with each rulemaking. Ultimately, we searched in several locations, such as the EPA's website, the docket for each rule (which typically includes the regulatory analysis and technical support documents), and the preambles of individual rulemakings. While the EJ analysis could often be

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[16] The role that exposure to other chemical and nonchemical stressors plays is an important evolving aspect of characterizing the dose-response relationship. Not only do some groups have higher levels of exposure, but their response may also vary based on prior exposure to other chemical and nonchemical stressors.
[17] The OMB's database can be accessed at https://www.reginfo.gov.

found in the regulatory analysis, naming conventions were not standardized across rules.[18]

Overall, we find that more than three-quarters (53) of the 68 economically significant final rules reviewed include an EJ analysis. The proportion of rules that include an EJ analysis varies by presidential administration and EPA program office. The rigor and depth of the EJ analyses also vary. Some are strictly qualitative, others evaluate only the baseline, and still others assess one or more regulatory options. We also find that the ability to evaluate the impact of regulatory options seems to correlate with whether exposure or risk (or both) was modeled for the aggregate benefit-cost analysis. We summarize these key differences in Sections 3.1–3.3.

3.1. Differences Across Presidential Administrations and EPA Program Offices

Figure 4 characterizes these EJ analyses by EPA program office and presidential administration. The height of each column reflects the total number of economically significant final rules promulgated within a specific period. The gray area at the top of each column indicates the subset of rules without an EJ analysis, while the other colors indicate the number of rules that included an EJ analysis within a specific EPA program office. First, we observe that the proportion of economically significant final rules that include an EJ analysis varies by presidential administration. It was 68 percent under the Obama administration (2012–16), dipping to 58 percent under the Trump administration (2017–20), and then increasing to 96 percent under the Biden administration (2021–24).[19]

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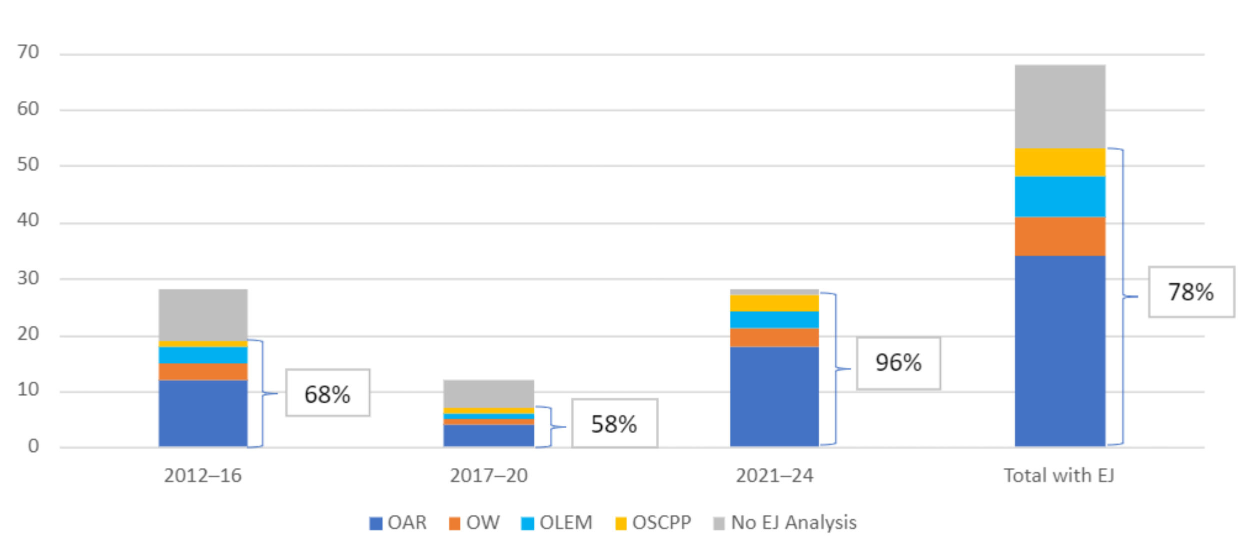
[18] This was not a straightforward exercise, given different practices and naming conventions across EPA offices and specific types of rules. Search terms included "environmental justice," "demographic," and "socioeconomic."
[19] Rules promulgated during the last year of the first Obama administration (2012) are grouped with the second Obama administration for analytical purposes. During the last five years of the Obama administration (2012–16), the EPA promulgated 28 economically significant rules; during the Trump administration (2017–20), it promulgated 12; and during the Biden administration (2021–24), it promulgated 28.

Figure 4. Count of Rules with EJ Analyses by EPA Program Office and Administration



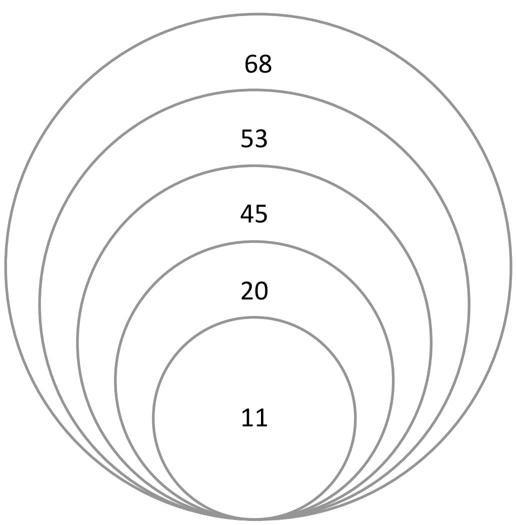
Second, we observe that the Office of Air and Radiation (OAR) conducted more EJ analyses than any other program office between 2012 and 2024 (34 in total), but this office also promulgated more economically significant rules over this period (47 in total). The Office of Land and Emergency Management (OLEM) and Office of Chemical Safety and Pollution Prevention (OCSPP) promulgated 7 and 5 economically significant rules, respectively, between 2012 and 2024, with all of them including an EJ analysis. The Office of Water (OW) conducted an EJ analysis for 7 of its 9 economically significant rules over this period.

3.2. Differences in How the EJ Analyses Assess Effects

We consider whether the EJ analyses assess effects only qualitatively, evaluate them only in the baseline, or characterize them across regulatory options. Per OMB guidance, regulatory analysis strives to quantitatively assess the effects of a rule. Likewise, when EPA analysts are able to quantify and characterize how EJ implications vary across regulatory options, EJ concerns are put on a more level playing field with quantified information on how aggregate benefits, aggregate costs, and other economic impacts vary by regulatory option. Importantly, even if an EJ analysis identifies differences in baseline pollution exposure across population groups, this does not mean that those most exposed will necessarily benefit from a rule that reduces the overall level of pollution. While this inference is likely correct on average, such a conclusion requires explicit quantitative analysis of the regulatory options to establish the degree to which it holds for specific population groups of concern.

Of the 53 rules with an EJ analysis, 45 include some level of quantitative assessment (Figure 5). Of the 45 rules with a quantitative EJ analysis, 25 characterize only baseline conditions. Of the remaining 20 rules, those with an EJ analysis that characterizes one or more regulatory option, 9 examine a single regulatory option, while 11 analyze multiple regulatory options.[20]

Figure 5. EPA EJ Analyses for Economically Significant Final Rules, 2012–24



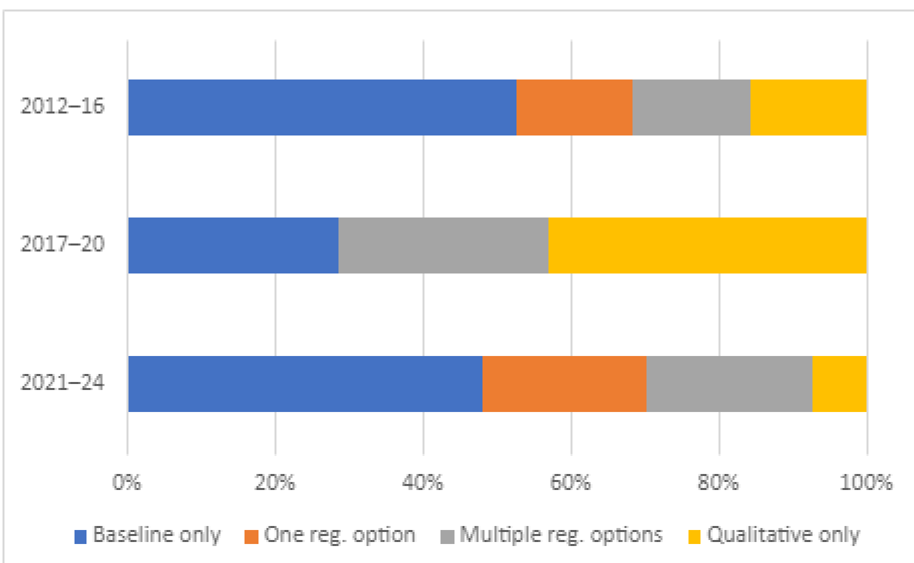
Characteristic	**Count (%)**
Economically significant final rules	68 (100%)
Rules with an EJ analysis	53 (78%)
Rules with a quantitative EJ analysis	45 (66%)
Rules with an EJ analysis that analyzed a regulatory option	20 (29%)
Rules with an EJ analysis that analyzed multiple regulatory options	11 (16%)

[20] Note that in a few instances, the EPA analyzes multiple regulatory options for the proposal but evaluates only the preferred option in the final rule, reflected in the tabulations presented here.

The remainder of the rules with an EJ analysis, 8 in total, consist of only qualitative discussion and do not rely on structured qualitative approaches such as case studies or focus groups. While 7 of these describe why risk, exposure, or health outcomes may vary by population group, only 3 include a review of evidence from the published literature, and only 3 discuss possible unique pathways or costressors that might contribute to differential exposure or vulnerability.

Figure 6 shows that the proportion of EJ analyses with only a qualitative discussion was markedly higher during the Trump administration (2017–20) than during other administrations. However, when a quantitative analysis was conducted during this time period, the EJ analysis was more likely to characterize multiple regulatory options than in analyses conducted during other administrations.

Figure 6. Quantitative vs. Qualitative EPA EJ Analyses by Administration



3.3. Differences in What the EJ Analyses Model

A further metric of quality is whether the quantified EJ analyses went beyond a proximity-based approach to more accurately characterize the nature of exposure, risk of health effects, or costs. A proximity-based approach compares the people living near affected facilities with a comparison group, often the total US population, broken out by sociodemographic characteristics. It therefore assumes that people living near the affected facilities are all equally exposed to what is being emitted, while those farther away are not exposed.

More refined exposure analysis requires fate and transport modeling to better understand where a pollutant travels after it is emitted by a source and therefore the volume (or concentration) of pollution to which individuals living nearby are likely exposed. How changes in concentrations translate into risk of a given health effect requires further modeling. Risk modeling accounts for factors such as likely pathways for exposure and the effect of underlying vulnerabilities, such as exposure to other chemical or nonchemical stressors or preexisting health conditions.

The challenges of characterizing exposure and risk vary considerably across media (e.g., air, water) and often are not specific to the EJ analysis, as discussed in Section 2. Our analysis shows that the number of quantitative EJ analyses that characterize exposure or risk of health effects has increased over time (Table 1). However, the number of quantitative analyses also varies substantially across administrations, though the proportion of quantitative EJ analyses that model exposure does not follow a consistent trend. All EPA EJ analyses that quantify exposure under the Obama and Trump administrations also quantify health effects. A little less than half do so under the Biden administration, though many more economically significant rules are being promulgated relative to prior administrations. While the reason for this drop-off is unknown, a stated explanation for stopping short of disaggregating changes in health effects by demographic group is uncertainty in estimating how differences in expected changes in concentrations across demographic groups translate into stratified health effects (EPA 2023b).

We find only three instances (all occurring at the end of the Biden administration) where quantitative EJ analyses examine how costs of the regulatory options are distributed across population groups.[21] This is not surprising, given that the directives for EJ analysis under EOs 12898 and 14096 focus on characterizing health and environmental effects and risks. See Section 5 for discussion of a recent example.

Table 1. EPA's Quantitative EJ Analyses That Characterize Exposure, Risk of Health Effects, or Costs

Year range	**Total quantitative EJ analyses**	**Number (percentage) of EJ analyses that quantify exposure**	**Number (percentage) of EJ analyses that quantify exposure and health effects**	**Number (percentage) of EJ analyses that quantify costs**
2012–16	16	6 (38%)	6 (38%)	0 (0%)
2017–20	4	3 (75%)	3 (75%)	0 (0%)
2021–24	25	13 (52%)	6 (24%)	3 (12%)

[21] The rules are the Volume Requirements for 2023 and Beyond Under the Renewable Fuel Standard Program, the Per- and Polyfluoroalkyl Substances National Primary Drinking Water Regulation, and the Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category.

4. Methods and Key Characteristics of EPA EJ Analyses

This section extends the broad overview presented in Section 3 by investigating the methods used in the EPA's EJ analyses. We first look at the characteristics of the rules without an EJ analysis or with only a qualitative assessment, then turn to the rules with a quantitative EJ analysis.

4.1. Rules with a Qualitative or No EJ Analysis

Of the EPA's economically significant rules during the 2012–24 time period, 15 lack an EJ analysis, and 8 include only a qualitative analysis. Around half of these analyses are associated with rules issued in the early years (2012–16) of our dataset. To understand whether these rules have any distinguishing characteristics versus rules with quantitative EJ analysis, we consider several possible explanations (Table 2). First, we note that the agency's technical guidance on evaluating EJ in regulatory analyses was not issued until mid-2016, which may have limited the EPA staff's ability to conduct EJ analyses before that date (EPA 2016). The evidence is suggestive in this regard: 43 percent of the rules promulgated between 2012 and 2016 lack an EJ analysis or include only a qualitative assessment, while this is true of only 30 percent of the rules promulgated in the 2017–24 period.

Another possible explanation for the lack of an EJ analysis is that the rule was expected to have no or few EJ implications. Of the 15 economically significant final rules without an EJ analysis, 7 (47 percent) state that they do not need a regulatory analysis—let alone an EJ analysis—because they are not expected to affect the level of protection to human health or the environment under existing programs (though they may impose costs). Five of these 7 rules affirm or modify annual volumetric standards under the Renewable Fuel Standard (RFS)

Program, which conducted a detailed regulatory analysis (though no EJ analysis) when originally promulgated in 2010.

Table 2. Possible Explanations for the Lack of a Quantitative EJ Analysis

Possible explanation	Characteristics
More rules promulgated before the EPA finalized its technical guidance in 2016 lack a quantitative EJ analysis.	Suggestive evidence: During 2012–16, 43% had a qualitative or no EJ analysis; during 2017–24, 30% (i.e., fewer) had a qualitative or no EJ analysis.
Rules for which an EJ concern is less obvious do not conduct an EJ analysis.	Likely evidence: 47% of rules with no EJ analysis state that they did not change the level of protection to human health and the environment.
Statutory or judicial deadlines limited the conduct of a quantitative EJ analysis.	Contrary evidence: For rules with no deadlines, 44% had a qualitative or no EJ analysis, whereas for rules with deadlines, 17% had a qualitative or no EJ analysis.
A quantitative EJ analysis could not be conducted because of inherent complexities and data limitations.	Likely evidence: 25% of rules with a qualitative or no EJ analysis cite this as a reason why it was not possible to quantify effects.

Still another possible explanation is that statutory or judicial deadlines resulted in time to conduct an EJ analysis. However, in our review, we do not find that these deadlines were a factor in limiting EJ analyses. Specifically, 23 rules in our sample had deadlines, but only 4 of them (17 percent) lack a quantitative EJ analysis, perhaps signaling that these rules underwent greater scrutiny and attention, incentivizing the agency to conduct higher-quality EJ analyses. In contrast, of the remaining 45 economically significant final rules, which did not have statutory or judicial deadlines, 23 (51 percent) lack a quantitative EJ analysis.

Further, it is possible that inherent modeling complexities and data limitations are major factors in the EPA's ability to conduct quantitative EJ analysis. We find that 25 percent of the rules with a qualitative or no EJ analysis cite analytical challenges as a limiting factor for the analysis. Several rules note that information was unavailable on the specific location of polluting sources (e.g., underground storage tanks; internal combustion engines; new, reconstructed, or modified oil and natural gas wells). These challenges also apply to estimating benefits more generally. For example, two rules without an EJ analysis and one rule with a qualitative-only EJ analysis relate to varying interpretations of what constitutes Waters of the US (WOTUS) for the purposes of regulation under the Clean Water Act. Quantifying the benefits and costs for these rules is challenging because uncertainty about which water bodies would be affected introduces uncertainty into identifying the specific communities affected.

4.2. Rules with a Quantitative EJ analysis

Of the 68 rules we studied, 45 have some form of quantitative EJ analysis. In reviewing them, our goal is to understand whether certain distinguishing characteristics of rules allow for higher-quality EJ analysis. For this assessment, we pose and answer several questions:

- What characteristics distinguish rules with EJ analyses that assess one or more regulatory options from those that only analyze the baseline?
- In what situations do the EJ analyses characterize differences in exposure or risk of health effects?
- What common sources and types of demographic characteristics are included in EJ analyses?
- How are comparison groups and spatial buffers determined?

4.2.1. What characteristics distinguish rules with EJ analyses that assess one or more regulatory options from those that only analyze the baseline?

An assessment of baseline conditions is rarely sufficient to understand the EJ implications of regulatory policy, yet of the 45 economically significant EPA final rules with a quantitative EJ analysis, more than half (25 rules) are limited to a baseline-only analysis. While the EPA often observes the limitations of conducting a baseline-only assessment, many such analyses do not specify what prevented them from evaluating one or more regulatory options. In a few cases, rules cite a lack of information about which emissions sources would be affected or uncertainty in how they would respond.

In contrast, all 20 of the quantitative EJ analyses that went beyond a baseline-only characterization relied on exposure or risk modeling to do so. Among these, 45 percent (9 of 20) characterize only the preferred regulatory option (in addition to the baseline). Most of these single-option EJ analyses characterize changes in particulate matter or ozone concentrations. Because modeling these changes is often a time- and resource-intensive exercise,[22] the decision not to evaluate multiple options may have been determined by the extent to which modeling was conducted across multiple options in the aggregate benefit-cost analysis.[23]

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[22] For example, the Community Multiscale Air Quality model simulates key processes (i.e., emissions, transport, chemistry, and deposition) affecting primary and secondary (formed by atmospheric processes) particulate matter at a 12 × 12 km grid scale, granular enough to be highly resource- and time-intensive.

[23] We find that in 4 of the 6 cases where the EJ analysis characterizes the distribution of ozone or PM concentrations only for the preferred option, air quality modeling was conducted only for the preferred option in the benefit-cost analysis. For the Oil and Natural Gas Sector: New Source Performance Standards and National Emission Standards for Hazardous Air Pollutants rule, the benefit-cost analysis provides an estimate of hazardous air pollutant emissions reductions for the preferred option but does not quantify or monetize any benefits for the rule.

4.2.2. In what situations do the EJ analyses characterize differences in exposure or risk of health effects?

The most common technique in EPA EJ analyses to characterize differences in exposure is a proximity-based approach, which uses a set distance around emitting sources to compare the average demographic characteristics of individuals living near these sources (within the set distance) and those living farther away. Of the 45 quantitative EJ analyses in our sample, about three-quarters (33 of 45) include a proximity analysis. Of these, two-thirds (21 of 33) are baseline-only analyses, all but 3 of which relied on this approach.

Half (22) of the 45 quantitative EJ analyses in our sample relied on more complex exposure modeling to characterize changes in concentrations. A smaller subset (15) of analyses also quantify changes in health effects across demographic groups. The EPA's ability to conduct this type of assessment for the EJ analysis likely relates to the extent to which exposure or risk modeling was conducted for the aggregate benefit-cost analysis and whether the modeling outputs spatially disaggregate information. For example, the Hazard Standards and Clearance Levels for Lead in Paint, Dust and Soil limit dust-lead in older housing stock to reduce exposure of children with elevated blood lead levels. To characterize changes in dust-lead, blood lead levels, and avoided IQ losses in affected children for the benefit-cost analysis, the EPA relied on multiple sources of information and models. Because the data on housing stock and blood lead levels used in the benefit-cost analysis also include demographic information for exposed individuals, the EPA was able to evaluate how these effects vary by race, ethnicity, and income for the EJ analysis. In contrast, while the National Primary Drinking Water Regulations: Lead and Copper Rule Improvements (LCRI) rule quantifies aggregate avoided IQ decrements from replacing lead pipes for drinking water in its benefit analysis, information on the location of leaded pipes across the United States was limited, which thus limited analysts' ability to assess which populations of concern may be exposed in the EJ analysis.

Even when it was not possible to characterize changes in concentrations or health effects from one or more regulatory options, 7 of the 25 baseline-only EJ analyses provide information on demographic characteristics for subsets of communities based on aspects of the regulated sources that correlated with higher concentrations or risk and therefore often faced more stringent regulatory requirements. For example, the EJ analysis for the Accidental Release Prevention/Risk Management Plans rule compares average demographics near facilities with and without a history of accidents, since the regulation imposes additional requirements on facilities that have had a prior accident.[24]

4.2.3. What common sources and types of demographic characteristics are included in EJ analyses?

Most (35 of 45) quantitative EJ analyses use the five-year American Community Survey (ACS) or the US Decennial Census as their main source of demographic data. Both datasets are nationally representative and available at a disaggregated spatial scale. The EPA's EJ screening tool, EJScreen, also relies on ACS data. Another source of demographic data for quantitative EJ analyses is the US Census Bureau's American Housing Survey, which is useful when the hazards being regulated are correlated with specific housing characteristics (e.g., lead in paint, formaldehyde in wood products). Finally, in addition to other sources of demographic information, a small number of quantitative EJ analyses rely on geographically disaggregated

[24] Eight rules also reported results for individual facilities subject to regulatory requirements under the rule.

projections of future demographic trends produced by Woods and Poole (2015).[25]

Given that EO 12898 and EO 14096 call out the importance of advancing environmental justice for all, regardless of race, ethnicity, or income, it is not surprising that these characteristics are commonly included in a quantitative EJ analysis. While race and ethnicity categories are defined by OMB for federal statistical surveys such as those administered by the US Census Bureau, the way they are aggregated and reported differs across EJ analyses. In particular, 9 of the rules with quantitative EJ analyses report findings for only an aggregate non-White category (e.g., minority or people of color). The remaining quantitative 36 EJ analyses report results for more specific race and ethnic categories, although not consistently. While there is no specific federal definition for "low-income," the two most common ways of defining the term in EPA quantitative EJ analyses are income below the poverty threshold and income twice below the poverty threshold, both of which are ACS variables.

Three-quarters (36 of 45) of the quantitative EJ analyses also include one or more characteristics associated with some other aspect of increased vulnerability to pollution exposure. These include age (children or older adults), recreational and subsistence fishing, linguistic isolation, and level of education (e.g., less than high school). Consideration of these categories is sometimes explicitly justified by concern about unique exposure pathways (e.g., lead exposure due to hand-to-mouth behavior in children or mercury exposure through elevated fish consumption for recreational or subsistence fishers) or barriers to accessing environmental risk

[25] For more information on Woods and Poole (2015), consult the "Demographic Data" section of the Final Regulatory Impact Analysis for the Particulate Matter Reconsideration rule at https://www.epa.gov/system/files/documents/2024-02/naaqs_pm_reconsideration_ria_final.pdf.

information (e.g., educational attainment or linguistic isolation), though this is not always the case. A few EJ analyses also include cross-tabulations, such as fishers by race and ethnicity.

4.2.4. How are comparison groups and spatial buffers determined?

To evaluate differences in effects across population groups, a comparison population group is needed. The comparison group for EJ analyses conducted for EPA national rulemakings is typically defined as the national average, which 43 of the 45 quantitative EJ analyses used. Nine of these analyses also evaluate the implications of the rule for specific states or regions. In some cases, state-level analysis was conducted to reflect potential variation in state and local conditions and regulatory stringency (e.g., the Steam Electric Power Generating Effluent Guidelines and Steam Electric Reconsideration Rule). In other cases, the rule is regionally focused (e.g., Federal Implementation Plan for Oil and Natural Gas Sources on the Uintah and Ouray Indian Reservation). In these cases, the relevant state or regional average is typically reported as the comparison group.

A few EJ analyses departed from using the national average as the comparison group by also examining effects for those exposed to relatively high baseline concentrations or risks. For example, the National Emissions Standards for Hazardous Air Pollutants for Ethylene Oxide Commercial Sterilization Facilities rule presents information for several cancer risk bins that allows comparisons not only with the national mean but also across risk bins (for other examples, see Section 5). Five of the 45 quantitative EJ analyses also use the rural national average as a comparison group to ensure that effects in rural communities are not masked by including those in affected urban areas.

Finally, all 33 EJ analyses that relied on a proximity-based approach include information about the size of geospatial buffers used to designate communities close to an affected facility. However, rarely do these rules justify the choice of a specific buffer (e.g., how the selected distance related to the fate and transport of the regulated pollutant). About one-third of the proximity analyses use only one buffer distance, ranging from 1 to 50 miles. The remainder use multiple buffer distances. Additionally, the approach to apportioning demographic data to these buffers is not routinely specified. When specified, drawing buffers from the centroid of a regulated source is by far the most common approach.

5. Recent Innovative Examples

This section examines how heightened attention to EJ under the Biden administration may have led to refinements and innovations in the analytical approaches to EJ analysis. We selected 10 rules issued between 2021 and 2024 to illustrate some of the novel features and approaches included in recent EJ analyses. While we make no claim as to the representativeness of this sample, we include rules from each of the EPA program offices that promulgate rules to reflect a variety of regulatory contexts and modeling environments.

Table 3 identifies seven innovative issues that these recent EJ analyses address. Overall, we find evidence of the EPA's efforts to address several issues called out in EO 14096, including cumulative impacts, differential vulnerability, climate risks, and access to environmental benefits. We also see evidence of efforts to expand consideration of costs in a few EJ analyses. Finally, we note instances where the EPA has developed specific case studies in the absence of national-level data. While we identify the relevant rules in each case, we direct the reader to the individual EJ analyses for more detail.

Table 3. Novel Features and Approaches in EJ Analyses for Recent EPA Rules

Issue addressed	Novel feature or approach	Rules
Reflect cumulative impacts	Other pollution sources not regulated by the rule emitted in the same location	SOCMI, Chrysotile asbestos, LCRI, HFC phasedown
	Past environmental compliance of regulated sources	Chrysotile asbestos, HFC phasedown
	Measure of past discriminatory land use siting	PM NAAQS, Oil & gas GHG
Consider differential vulnerability	Race/ethnicity-specific dose-response function	PM NAAQS
	Unique pathway via worker exposure	Chrysotile asbestos, Oil & gas GHG
	Prevalence of preexisting health conditions and social stressors	Chrysotile asbestos, Oil & gas GHG, PM NAAQS
Quantify climate risk for EJ	Risk of flooding from climate change in areas with vulnerable populations	Legacy CCR
Consider differential access to environmental benefits	Qualitative discussion based on evidence in literature	Dust-lead hazard and clearance, LCRI
Consider effects away from the mean	Demographics for upper portion of exposure distribution	HD NO_x, LCRI, PM NAAQS, SOCMI
Consider cost incidence	Increased cost of service as a proportion of income	PFAS NPDWS
	Qualitative discussion	Oil & gas GHG
Case study approach to identify and fill data gaps	Community-specific quantitative assessment	LCRI

Note: **Chrysotile asbestos** = Chrysotile Asbestos: Part I, Regulation of Certain Conditions of Use Under the Toxic Substances Control Act; **Dust-lead hazard and clearance** = Reconsideration of the Dust-Lead Hazard Standards and Dust-Lead Post Abatement Clearance Levels (proposal); **LCRI** = National Primary Drinking Water Regulations: Lead and Copper Rule Improvements (proposal); **Legacy CCR** = Legacy Coal Combustion Residuals Surface Impoundments and Management Units; **HD NO_x** = Control of Air Pollution from New Motor Vehicles: Heavy-Duty Engine and Vehicle Standards; **HFC Phasedown** = Phasedown of Hydrofluorocarbons: Allowance Allocation Methodology for 2024 and Later Years; **Oil & gas GHG** = Standards of Performance for New, Reconstructed, and Modified Sources and Emissions Guidelines for Existing Sources: Oil and Natural Gas Sector Climate Review; **PFAS NPDWS** = Per- and Polyfluoroalkyl Substances National Primary Drinking Water Regulation; **PM NAAQS** = Review of the National Ambient Air Quality Standards for Particulate Matter; **SOCMI** = New Source Performance Standards for the Synthetic Organic Chemical Manufacturing Industry and National Emission Standards for Hazardous Air Pollutants for the Synthetic Organic Chemical Manufacturing Industry and Group I & II Polymers and Resins Industry.

5.1. Cumulative Impacts

Five recent rules in this sample evaluate some aspect of cumulative impacts in their EJ analysis, though their approaches to defining "cumulative impacts" differ. Four rules consider the role of other sources of pollution in contributing to cumulative exposure or risk. This ranges from modeling estimated cancer risks from exposure to all air toxics emitted from the regulated facilities, and not just those covered by the rule (e.g., SOCMI), to examining the number of other polluting facilities and the estimated cancer risk from exposure to hazardous air pollutants for communities within a specified distance of the regulated facility (e.g., Chrysotile asbestos and HFC phasedown). It also includes consideration of indicators for possible exposure to other sources of the regulated contaminant as part of the EJ analysis (e.g., LCRI).

In addition, several of the recent rules evaluate the extent to which regulated sources had a history of noncompliance with a major environmental statute, such as the Clean Air Act, Clean Water Act, or Resource Conversation and Recovery Act (e.g., HFC phasedown, Chrysotile asbestos), or include an indicator for historical redlining. Finally, several EJ analyses examine whether past discriminatory land use siting practices were associated with emissions concentrations (e.g., PM NAAQS, Oil & gas GHG).

5.2. Differential Vulnerability

Three recent rules in our sample consider aspects of increased vulnerability of specific population groups to the effects of pollution. For example, the EJ analysis for the PM NAAQS rule relied on concentration-response functions from the published literature, which finds causal evidence of higher premature mortality rates from a given level of exposure to fine particulate matter among older Black adults than among older White adults. In other cases, the agency relied on aggregate reduced-form approaches by examining the association between a population group's average access to health insurance, lifespan, or employment status in a specific location and average PM or ozone concentrations (e.g., PM NAAQS, Oil & gas GHG).

While the EPA has long considered the EJ implications of unique pathways for children (e.g., higher exposure to lead dust due to hand-to-mouth behavior) and fishers (e.g., higher exposure to mercury and other heavy metals due to higher fish consumption), 2 of the 10 recent rules examine the extent to which the demographics of workers in regulated facilities differ from those for the industry or the nation as a whole (e.g., Chrysotile asbestos, Oil & gas GHG).

5.3. Climate-Related Risks

Several EJ analyses include a qualitative discussion of the evidence that people of color and low-income individuals are more vulnerable to the effects of climate change and less able to adapt to or recover from these effects. Within our sample of recent EJ analyses, the Legacy CCR rule examines the risk to unlined coal ash surface impoundments from climate-related flooding and the extent to which those impoundments at greatest risk are in communities of color or with low-income populations.

5.4. Differential Access to Environmental Benefits

EO 14096 also highlights that advancing EJ goals may require removing barriers to accessing the benefits of environmental programs and policies. Two recent rules, Dust-lead hazard and clearance and LCRI, qualitatively discuss possible barriers. The Dust-lead hazard and clearance rule discusses and reviews the available literature on the possibility that additional cleaning requirements might induce landlords to exit the public housing program, which might further limit the availability of low-cost housing. If this reduction in low-cost housing stock occurs, it could inadvertently push some families into housing stock with even greater levels of deterioration, potentially exposing children to even higher levels of lead dust.[26] The LCRI rule discusses the role of financial and nonfinancial barriers (e.g., time and hassle costs, lack of trust, greater difficulty obtaining owners' permission for rental units) to inspection and replacement of lead service lines among renters and low-income households, noting that even when local water utilities cover the entire cost of replacement, it can still be difficult to induce uptake. It also describes several state-initiated approaches to overcoming such barriers.

5.5. Effects Away from the Mean

Presenting differences in average exposure or risk can mask information about those most at risk by including populations within each broad demographic category that may be less affected. Four of the recent rules in our sample used different approaches to examine the demographic characteristics of affected communities in the upper tail of the exposure distribution. For example, the HD NO_x rule compares the race and income characteristics of communities exposed to the highest baseline concentrations (top 5 percent) with the characteristics of those exposed to the rest of the distribution (the other 95 percent). The rule then examines changes in concentrations for the two groups under the preferred regulatory option. Another rule, LCRI, performed a similar demographic comparison based on quantiles of the concentration in the baseline.[27]

[26] The EJ analysis also identifies the types of public housing that might be affected by the regulatory requirements, noting that it is likely to be a small portion of the total.

[27] There are two other examples: The EJ analysis for the PM NAAQS rule presents a cumulative density function that shows how PM concentrations change over the entire distribution by race and ethnicity. The EJ analysis for the SOCMI rule characterizes the populations with cancer risks of ≥1 in 1 million, ≥50 in 1 million, and >100 in 1 million in the baseline and after meeting the regulatory requirements for communities near affected sources.

5.6. Cost Incidence

While several EJ analyses examine the distribution of quantified and even monetized health effects, few evaluate the distribution of costs. For example, if low-income households bear a larger relative share of the compliance costs that are passed on to consumers in the form of higher prices, they may experience net costs even after accounting for the benefits they gain from environmental improvements. Of the sample of recent rules, one uses information from the Consumer Expenditure Survey by income quintile and by race and ethnicity to show that low-income and Black and Hispanic households spend a greater proportion of their income on energy services, on average (Oil & gas GHG). Another rule estimates average annual population-weighted incremental household costs and examines how they vary by public water system size and the share of race and ethnicity within the population served (PFAS NPDWS).

5.7. Case Study Approach

The EPA recognizes that data are not always available at a sufficiently disaggregated scale to conduct an EJ analysis (EPA 2016). When only partial information is available, a case study approach may be appropriate. Within the sample of recent rules we examine, one rule (LCRI) notes that many water systems do not have a complete inventory of service line material, which means that the EPA could not conduct a national-level assessment of the extent to which lead service lines are in low-income communities or communities of color. To develop insights to inform the rule despite this data gap, the EPA examined baseline demographics for seven water system case studies with reasonably complete service line inventories for the EJ analysis.

6. Conclusions

The EPA has made substantial progress over the past decade in conducting EJ analysis as part of its regulatory assessments. Despite methodological and data challenges, more than three-quarters of the EPA's economically significant final rules promulgated since 2012 include some form of EJ analysis, a proportion that jumped to more than 9 out of 10 rules under the Biden administration. Increasingly, these EJ analyses are quantitative in nature. The instances where the EPA has not conducted EJ analysis of new rules during the 2021–24 period can largely be explained by the expectation that those rules would have little EJ impact or by the lack of data or modeling to estimate those impacts.

Substantial improvements in the quality of EJ analyses are also evident over time. For example, several recent EJ analyses have used refined methods to quantify health impacts or account for differential vulnerability among populations of concern, including differentiated dose-response functions and consideration of unique exposure pathways. The agency has also begun to address cumulative impacts, per EO 14096.

At the same time, more work is needed to delineate and prioritize data collection and modeling improvements, particularly to increase the proportion of EJ analyses that characterize the exposure and health implications of multiple regulatory options. The EPA program offices that carry out these analyses are generally well positioned to help with this prioritization. Identifying the gaps in data and methods that hinder conducting more and better EJ analysis can help guide future research efforts. Ideally, new regulations could include a detailed discussion of key gaps in the EJ analysis.

With clear progress principally on the benefits side of the ledger, the agency's work on evaluating the distribution of cost burdens has been much more limited. Only 3 of the 68 economically significant final rules promulgated by the EPA between 2012 and 2024 assess the impact of cost burdens on different demographic groups. Thus the fundamental challenge identified by Cecot and Hahn (2022) remains unaddressed: how to determine the *net* distributional impacts of a proposed regulation on a particular group and whether an alternative could generate a preferred *net* distributional outcome. Since the incidence of costs on different demographic groups is often difficult to estimate, further progress to fully understand the net impact of regulations on populations of concern will require substantial effort by the EPA as well as the broader research community.

In the remainder of this section, we outline several opportunities for improving the agency's EJ work. Many of these recommendations may apply to other federal agencies as well. The analytical improvements we enumerate are intended to provide food for thought for the academic community as it looks for ways for research to improve and inform federal rulemaking, while the procedural improvements are aimed at increasing transparency within the federal government.

6.1. Analytical Improvements

While the agency can and should continue to dig deeper into the existing literature to expand both the breadth and depth of its ongoing EJ analyses, including the distribution of costs, we identify three areas of high-priority research: gaining better understanding of the underlying heterogeneity among affected groups of health and environmental risks, improving methodologies for assessing cumulative impacts and risks, and improving methods for quantifying additional benefit and cost categories by demographic, economic, and other groups.

6.1.1. Gaining a better understanding of the underlying heterogeneity of health and environmental risks

While there is a general understanding in the literature that certain communities are affected more than others by a given level of exposure or are exposed to higher levels through unique exposure pathways, without a sufficient number of high-quality, peer-reviewed papers, the EPA cannot, as a standard practice, incorporate differentiated dose-response functions or include these exposure pathways in quantified health effects. Expanding the literature is an important step to being able to move beyond characterizing only the baseline and also evaluate the effects of regulatory options on specific population groups and communities.

Similarly, understanding differences in behavioral responses among communities is important for EJ analysis, as the observed correlation between pollution exposure and income or race is at least partially the result of spatial sorting. As Banzhaf et al. (2019) note, "The indirect effects of environmental improvements on housing (gentrification) and energy prices may be especially burdensome on the poor." However, the EPA has limited data to understand the dynamic responses to policy changes and future demographic movements. Understanding the heterogeneity in such behavioral responses is important to disaggregate the incidence of both benefits and costs among different groups.

6.1.2. Improving methodologies for assessing cumulative impacts and risks

Being able to analyze and quantify cumulative impacts is central to EJ analysis. Yet our analysis shows that there is no standard approach to analyzing cumulative impacts or even a common understanding of what constitutes a "cumulative" impact: whether it is the joint impacts of multiple pollutants, multiple policies, or covered and noncovered sources. Even more challenging is developing methods for integrating the role of chemical and nonchemical stressors into cumulative risk assessment. Improving the EPA's EJ analyses requires more guidance on methods to incorporate such impacts and more robust empirical studies on the subject.

6.1.3. Improving methods for quantifying more benefit and cost categories

Historically, the EPA's main emphasis when conducting EJ analyses for its rules has been on meeting the requirements set out in EO 12898 (and more recently, EO 14096), which calls for federal agencies to assess the potential for disproportionate and adverse human health or environmental effects. The importance of conducting distributional analysis noted in EO 12866 has been largely ignored. However, regulations can have broader economic and other impacts on communities with EJ concerns beyond just beneficial human health and environmental effects, and understanding those impacts could help improve policy implementation in ways that could improve outcomes for these communities.

Understanding the incidence of costs is critical to assessing the net effects of regulations on different population groups. While costs have only rarely and recently been considered in EJ analyses, they could be especially significant for rules affecting drinking water or other public utilities, where costs are often passed through by law directly to consumers. Where legal mandates do not apply, modeling of cost pass-through and incidence can help assess the impacts on different groups of consumers, workers, and investors.

Another important category of potential impacts is climate-related risks. While the EPA commonly uses aggregate metrics such as the social cost of greenhouse gases in its aggregate regulatory analyses, there is currently no widely accepted methodology to translate the aggregate damages from global pollutants to impacts experienced at a local level, including heterogeneity in impacts on certain communities due to lower levels of resilience, poorer infrastructure, and other reduced investments in climate adaptation.

6.2. Procedural Improvements

EJ analyses play an important role in informing the public about the overall consequences of environmental regulation. In our experience, however, finding relevant documents is challenging because of inconsistencies in where the EJ analysis is located in the rule package and how it is labeled. Improving transparency and ease of access to these analyses would improve visibility while allowing more public input, especially from communities of concern. There are straightforward improvements the EPA and other agencies could implement on this front. For example, placing all EJ analyses in a separate repository (whether on regulations.gov or an EPA-specific site), standardizing the document titles, and improving search functionality could improve the public's ability to find the relevant documents.

In addition, continuing to look for ways to consider the potential for EJ concerns early in the analytical process can improve the quality of the final analysis. For example, prioritizing EJ concerns during the beginning stages of the regulatory process can facilitate early identification of data and modeling needs and ensure they are considered during the development of the risk assessment and benefit-cost analysis on which the EJ analysis often relies. A more fulsome EJ analysis will also enhance transparency regarding the potential effects of the rule. Moreover, early planning can help identify additional opportunities to engage with affected communities, including requesting data, obtaining information on key exposure pathways, and gaining other insights to improve the analysis and the options being considered. Better delineation of the way local knowledge may be used to inform the EJ analysis—and the rulemaking more generally—would help communities understand the value of public participation. If people do not understand what the information is being used for, they will not understand why they should engage or how to participate effectively.

Our review has examined all economically significant rules issued since 2012 in an effort to evaluate whether and how well they consider EJ in the regulatory analysis. Of the 68 rules examined, 45 include a quantitative EJ analysis. Despite progress in several areas—including the use of innovative methods to assess differences in vulnerability, evaluate cumulative impacts, and consider cost incidence—we have shown that important limits remain in the EPA's ability to address the underlying heterogeneity in emissions, exposure, and health risks within and across population groups of concern. We have also highlighted the limited assessment of the EJ impacts of regulatory options and the analysis of cost and net benefit impacts across demographic groups. It is our sincere hope that future research and policy analysis will improve the ability to assess the full impacts of new rules, thereby facilitating the consideration of EJ concerns in the regulatory process.

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Appendix 1: EPA Economically Significant Rules in Reverse Chronological Order from 2024 to 2012

Formal rule title	**EPA office**	**Year published**	**Is there an EJ analysis?**	**Is there quantitative EJ analysis?**	**Are any regulatory options included?**
Gas Distribution and Bulk Gas Terminals Review	OAR	2024	Yes	Yes	No
Methylene Chloride; Regulation Under the Toxic Substances Control Act (TSCA)	OCSPP	2024	Yes	Yes	No
New Source Performance Standards for Greenhouse Gas Emissions from New, Modified, and Reconstructed Fossil Fuel-Fired Electric Generating Units; Emission Guidelines for Greenhouse Gas Emissions from Existing Fossil Fuel-Fired Electric Generating Units; and Repeal of the Affordable Clean Energy Rule	OAR	2024	Yes	Yes	Yes
Greenhouse Gas Emissions Standards for Heavy-Duty Vehicles: Phase 3	OAR	2024	Yes	Yes	No
Multi-Pollutant Emissions Standards for Model Years 2027 and Later Light-Duty and Medium-Duty Vehicles	OAR	2024	Yes	Yes	Yes
Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category	OW	2024	Yes	Yes	Yes
New Source Performance Standards for the Synthetic Organic Chemical Manufacturing	OAR	2024	Yes	Yes	Yes

Industry and National Emission Standards for Hazardous Air Pollutants for the Synthetic Organic Chemical Manufacturing Industry and Group I & II Polymers and Resins Industry					
Final National Emission Standards for Hazardous Air Pollutants: Coal- and Oil-Fired Electric Utility Steam Generating Units Review of the Residual Risk and Technology Review	OAR	2024	Yes	Yes	Yes
TSCA Section 6a Chrysotile Asbestos Rule	OCSPP	2024	Yes	Yes	No
Designation of Perfluorooctanoic Acid (PFOA) and Perfluorooctanesulfonic Acid (PFOS) as CERCLA Hazardous Substances	OLEM	2024	Yes	Yes	No
Per- and Polyfluoroalkyl Substances National Primary Drinking Water Regulation	OW	2024	Yes	Yes	Yes
Legacy Coal Combustion Residuals Surface Impoundments and CCR Management Units	OLEM	2024	Yes	Yes	No
Proposed National Emission Standards for Hazardous Air Pollutants: Ethylene Oxide Commercial Sterilization and Fumigation Operations	OAR	2024	Yes	Yes	Yes
Review of the NAAQS for PM	OAR	2024	Yes	Yes	Yes
Safer Communities by Chemical Accident Prevention	OLEM	2024	Yes	Yes	No
Standards of Performance for New, Reconstructed, and Modified Sources and Emissions Guidelines for Existing Sources: Oil and Natural Gas Sector Climate Review	OAR	2024	Yes	Yes	Yes
Phasedown of Hydrofluorocarbons: Allowance Allocation Methodology for 2024 and Later Years	OAR	2023	Yes	Yes	No

Federal Implementation Plan for the 2015 Ozone National Ambient Air Quality Standards	OAR	2023	Yes	Yes	Yes
Volume Requirements for 2023 and Beyond Under the Renewable Fuel Standard Program	OAR	2023	Yes	Yes	No
Control of Air Pollution from New Motor Vehicles: Heavy-Duty Engine and Vehicle Standards	OAR	2023	Yes	Yes	Yes
Renewable Fuel Standard (RFS) Program: RFS Annual Rules	OAR	2022	Yes	No	No
Federal Implementation Plan for Oil and Natural Gas Sources; Uintah and Ouray Indian Reservation in Utah	OAR	2022	Yes	Yes	No
National Emission Standards for Hazardous Air Pollutants for Major Sources: Industrial, Commercial, and Institutional Boilers and Process Heaters: Amendments	OAR	2022	Yes	Yes	No
Phasedown of Hydrofluorocarbons: Establishing the Allowance Allocation and Trading Program Under the American Innovation and Manufacturing Act	OAR	2021	Yes	Yes	No
Cross-State Air Pollution Rule (CSAPR) Update Remand for the 2008 Ozone NAAQS	OAR	2021	No	No	No
Revised 2023 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions Standards	OAR	2021	Yes	No	No
National Primary Drinking Water Regulations: Lead and Copper Rule Revisions	OW	2021	Yes	Yes	No
Review of Dust-Lead Post Abatement Clearance Levels	OCSPP	2021	Yes	Yes	Yes
Reclassification of Major Sources as Area Sources Under Section 112 of the Clean Air	OAR	2020	No	No	No

Act					
The Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Years 2021–2026 Passenger Cars and Light Trucks	OAR	2020	Yes	No	No
Oil and Natural Gas Sector: Emission Standards for New, Reconstructed, and Modified Sources Reconsideration	OAR	2020	Yes	No	No
Steam Electric Reconsideration Rule	OW	2020	Yes	Yes	Yes
The Navigable Waters Protection Rule: Definition of "Waters of the United States"	OW	2020	No	No	No
NESHAP: Coal- & Oil-Fired Electric Utility Steam Generating Units: Subcategory of Certain Existing UGUs Firing Eastern Bituminous Coal Refuse for Emissions of Acid Gas Hazardous Air Pollutants	OAR	2020	Yes	Yes	No
Definition of "Waters of the United States": Recodification of Preexisting Rule	OW	2019	No	No	No
Review of Dust-Lead Hazard Standards and the Definition of Lead-Based Paint	OCSPP	2019	Yes	Yes	Yes
Emission Guidelines for Greenhouse Gas Emissions from Existing Electric Utility Generating Units; Revisions to Emission Guideline Implementing Regulations; Revisions to New Source Review Program	OAR	2019	Yes	No	No
Renewable Fuel Standard Program: Standards for 2019 and Biomass-Based Diesel Volume for 2020	OAR	2018	No	No	No
Renewable Fuel Standard Program: Standards for 2018 and Biomass-Based Diesel Volume for 2019	OAR	2017	No	No	No
Accidental Release Prevention Requirements:	OLEM	2017	Yes	Yes	No

Risk Management Programs under the Clean Air Act					
Oil and Natural Gas Sector: Emission Standards for New, Reconstructed, and Modified Sources	OAR	2016	No	No	No
Greenhouse Gas Emissions and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles-Phase 2	OAR	2016	No	No	No
Emission Guidelines and Compliance Times for Municipal Solid Waste Landfills	OAR	2016	Yes	Yes	No
Standards of Performance for Municipal Solid Waste Landfills	OAR	2016	Yes	Yes	No
Interstate Transport Rule for the 2008 Ozone NAAQS	OAR	2016	No	No	No
Renewable Fuel Standard Program: Standards for 2017 and Biomass-Based Diesel Volume for 2018	OAR	2016	No	No	No
Formaldehyde Emission Standards for Composite Wood Products	OCSPP	2016	Yes	Yes	Yes
Renewable Fuel Standard Program: Standards for 2014, 2015, and 2016 and Biomass-Based Diesel Volume for 2017	OAR	2015	No	No	No
Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units	OAR	2015	Yes	Yes	No
Review of the National Ambient Air Quality Standards for Ozone	OAR	2015	Yes	Yes	No
Standards of Performance for New Residential Wood Heaters and New Residential Hydronic Heaters and Forced-Air Furnaces	OAR	2015	Yes	Yes	No
Clean Water Rule: Definition of “Waters of the United States”	OW	2015	Yes	No	No

Petroleum Refinery Sector Risk and Technology Review and New Source Performance Standards	OAR	2015	Yes	Yes	Yes
NESHAP for Brick and Structural Clay Products Manufacturing and NESHAP for Clay Ceramics Manufacturing	OAR	2015	Yes	Yes	No
Revising Underground Storage Tank (UST) Regulations: Revisions to Existing Requirements and New Requirements for Secondary Containment and Operator Training	OLEM	2015	Yes	No	No
Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category	OW	2015	Yes	Yes	Yes
RCRA Final Rule Regulating Coal Combustion Residual (CCR) Landfills and Surface Impoundments at Coal-Fired Electric Utility Power Plants	OLEM	2015	Yes	Yes	No
Control of Air Pollution from Motor Vehicles: Tier 3 Motor Vehicle Emission and Fuel Standards	OAR	2014	Yes	Yes	No
Criteria and Standards for Cooling Water Intake Structures	OW	2014	Yes	Yes	No
Revisions to the Definition of Solid Waste	OLEM	2014	Yes	Yes	No
National Emission Standards for Hazardous Air Pollutants for Major Sources: Industrial, Commercial, and Institutional Boilers and Process Heaters; Proposed Reconsideration	OAR	2013	No	No	No
Reconsideration of Final National Emission Standards for Hazardous Air Pollutants for Reciprocating Internal Combustion Engines (RICE)	OAR	2013	No	No	No

Review of the National Ambient Air Quality Standards for Particulate Matter	OAR	2013	Yes	Yes	Yes
National Emission Standards for Hazardous Air Pollutants from Coal- and Oil-Fired Electric Utility Steam Generating Units and Standards of Performance for Electric Utility Steam Generating Units	OAR	2012	Yes	Yes	Yes
Oil and Natural Gas Sector: New Source Performance Standards and National Emission Standards for Hazardous Air Pollutants	OAR	2012	Yes	Yes	No
2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards	OAR	2012	Yes	No	No
Petroleum Refineries: New Source Performance Standards (NSPS)—Subparts J and Ja	OAR	2012	No	No	No
Regulation of Fuels and Fuel Additives: 2013 Biomass-Based Diesel Renewable Fuel Volume	OAR	2012	No	No	No

Appendix 2: Environmental Justice Analysis Full Citations

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