Chapter 10

Environmental Justice, Children's Environmental Health and Other Distributional Considerations

Evaluating a regulation's distributional effects is an important complement to benefit-cost analysis. Rather than focusing on quantifying and monetizing total benefits and costs, economic impact and distributional analyses examine how a regulation allocates benefits, costs and other outcomes across populations or groups of interest. See Chapter 9 of these *Guidelines* for more information on analyzing economic impacts. This chapter considers the distribution of environmental quality and human health risks across several populations: those that have traditionally been the focus of environmental justice (EJ) (i.e., minority, low-income, or indigenous populations); children; and the elderly. Consideration of costs or other potential impacts may also be addressed in a distributional analysis using approaches discussed in this chapter. The chapter also briefly discusses inter-generational impacts.

This chapter suggests approaches that EPA program offices can use for characterizing distributional effects of policy choices associated with rulemaking activities. Based on academic literature and EPA documents and policies, the chapter provides a variety of methodological approaches that may be suitable across various regulatory scenarios. A clear consensus does not exist, however, regarding the most appropriate methods. Instead, this chapter provides a broad overview of options for analyzing distributional effects in regulatory analysis. Information in the chapter is intended to provide flexibility to programs that face dissimilar data, resources and other constraints while introducing greater consistency in the way EJ is addressed in rulemaking activities.[1]

The purpose of analyzing distributional effects in regulatory analysis is to examine how benefits (e.g., risk reductions or environmental quality) and, when relevant and feasible, costs are distributed across population groups and lifestages of interest.[2] While the chapter is focused on EJ, children, and the elderly, the methods discussed could be applied to any population of concern.

The chapter begins with an overview of Executive Orders (EOs) and policies related to distributional analyses. It then discusses the analysis of distributional impacts in the context of EJ and children's health. The chapter concludes with a brief discussion of other distributional considerations, including the elderly and inter-generational impacts that may arise in select rules.

10.1 Executive Orders, Directives, and Policies

Consideration of distributional effects arises from a variety of executive orders, directives, and other

1 The guidance in this chapter complements, and does not supersede, any subsequent EJ-related guidance released by EPA. In addition, the Office of Environmental Justice website (http://www.epa.gov/environmentaljustice/resources/policy/index.html) provides resources on Plan EJ2014 and other implementation guidelines related to EJ (accessed on January 24, 2012).

2 This chapter recommends examining the distribution of benefits prior to monetization for reasons discussed in Section 10.1.

documents with broad coverage, including:[3]

- EO 12898, "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations" (1994);
- EO 13045, "Protection of Children From Environmental Health Risks and Safety Risks" (1997);
- EO 13166, "Improving Access to Services for Persons With Limited English Proficiency" (2000); and the subsequent EPA Order No.1000.32, "Compliance with Executive Order 13166: Improving Access to Services for Persons with Limited English Proficiency" (2011);
- EO 13175, "Consultation and Coordination with Indian Tribal Governments" (2000);
- EO 12866, "Regulatory Planning and Review" (1993);
- *Circular A-4*, Regulatory Analysis (OMB 2003);
- National Environmental Policy Act (NEPA) Guidance (U.S. EPA 1998a);
- EPA's *Interim Guidance on Considering Environmental Justice During the Development of an Action* (U.S. EPA 2010a); and
- EPA's FY2011-2015 Strategic Plan (U.S. EPA 2010b).

Each of these is described below. Some environmental statutes may also identify population groups that merit additional consideration.[4]

EO 12898, "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations"[5] (1994), calls on each Federal agency to make achieving EJ part of its mission. It directs Federal agencies, "[t]o the greatest extent practicable and permitted by law," to "identify[...] and address[...], as appropriate, disproportionately high and adverse human health or environmental effects" of agency programs, policies, and actions on minority populations and low-income populations. Issued by President Clinton in 1994, it requires that EJ be considered in all Agency activities, including rulemaking activities.

The President issued a memorandum to accompany EO 12898 directing Federal agencies to analyze environmental effects, including human health, economic, and social effects, of Federal actions when such analysis is required under the National Environmental Policy Act (NEPA). The Presidential memorandum also states that existing civil rights statutes provide opportunities to address environmental hazards in minority communities and low-income communities.[6]

EO 13045, "Protection of Children From Environmental Health Risks and Safety Risks" (1997), states that each Federal agency: (1) shall make it a high priority to identify and assess environmental health risks and safety risks that may disproportionately affect children; and (2) shall ensure that its policies, programs, activities, and standards address disproportionate risks to children that result from environmental health risks or safety risks. The EO also states that each "covered regulatory action" submitted to the Office of Management and Budget (OMB), unless prohibited by law, should be accompanied by ". . . an evaluation of the environmental health or safety effects of the planned regulation on children."[7]

3 EPA's Regulatory Management Division's Action Development Process Library (http://intranet.epa.gov/adplibrary) is a resource for accessing relevant statutes, executive orders, and EPA policy and guidance documents in their entirety (accessed on December 1, 2011).

4 See *Plan EJ 2014 Legal Tools* (U.S. EPA 2011a) for a review of legal authorities under the environmental and administrative statutes administered by EPA that may contribute to the effort to advance environmental justice.

5 This chapter addresses analytical components of EO 12898, and does not cover other components such as ensuring proper outreach and meaningful involvement.

6 "In accordance with Title VI of the Civil Rights Act of 1964, each Federal agency shall ensure that all programs or activities receiving Federal financial assistance that affect human health or the environment do not directly, or through contractual or other arrangements, use criteria, methods, or practices that discriminate on the basis of race, color, or national origin." See *Memorandum for the Heads of All Departments and Agencies: Executive Order on Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations* (White House 1994).

7 A "covered regulatory action" is any substantive action in a rulemaking that may be economically significant (i.e., have an annual effect on the economy of $100 million or more or would adversely affect in a material way the economy, a sector of the economy, or the environment) and concern an environmental health risk that an agency has reason to believe may disproportionately affect children.

EO 13166, "Improving Access to Services for Persons With Limited English Proficiency" (2000), requires Federal agencies to examine the services they provide, identify any need for services to those with limited English proficiency (LEP), and develop and implement a system to provide those services so LEP persons can have meaningful access to them. The EO also requires Federal agencies work to ensure that recipients of Federal financial assistance provide meaningful access to their LEP applicants and beneficiaries. EPA's Order 1000.32 "Compliance with Executive Order 13166: Improving Access to Services for Persons with Limited English Proficiency"[8] requires that EPA ensure its programs and activities are meaningfully accessible to LEP persons.

EO 13175, "Consultation and Coordination with Indian Tribal Governments" (2000), calls on Federal agencies to have "an accountable process to ensure meaningful and timely input by tribal officials in the development of regulatory policies that have tribal implications." To the extent practicable and permitted by law, if a regulatory action with tribal implications is proposed and imposes substantial direct compliance costs on Indian tribal governments, and is not required by statute, then the agency must either provide funds necessary to pay direct compliance costs of tribal governments or consult with tribal officials early in the process of regulatory development and provide OMB a tribal summary impact statement.

EO 12866, "Regulatory Planning and Review" (1993), allows agencies to consider "distributive impacts" and "equity" when choosing among alternative regulatory approaches, unless prohibited by statute. EO 13563, issued in January 2011, supplements and reaffirms the provisions of EO 12866.

OMB's *Circular A-4* states that regulatory analyses "should provide a separate description of distributional effects (i.e., how both benefits and costs are distributed among populations of particular concern) so that decision makers can properly consider them along with the effects of economic efficiency." It specifically calls for a description of "the magnitude, likelihood, and severity of impacts on particular groups" if the distributional effects are expected to be important (OMB 2003).

The President's memorandum to heads of departments and agencies that accompanied EO 12898 specifically raised the importance of procedures under NEPA for identifying and addressing environmental justice concerns (White House 1994). The memorandum states that "each Federal agency shall analyze the environmental effects, including human health, economic and social effects, of Federal actions, including effects on minority communities and low-income communities when such analysis is required by [NEPA]." The Council on Environmental Quality (CEQ) issued EJ guidance for NEPA in 1997 (CEQ 1997). EPA issued guidance in 1998 for incorporating EJ goals into EPA's preparation of environmental impact statements and environmental assessments under NEPA (U.S. EPA 1998a).

In July 2010, EPA published its *Interim Guidance on Considering Environmental Justice During the Development of an Action* (U.S. EPA 2010a). This guide is designed to help EPA staff incorporate EJ into the rulemaking process, from inception through promulgation and implementation. The guide also provides information on how to screen for EJ effects and directs rulewriters to respond to three basic questions throughout the rulemaking process:

1. How did your public participation process provide transparency and meaningful participation for minority, low-income, indigenous populations, and tribes?

2. How did you identify and address existing and new disproportionate environmental and public health impacts on minority, low-income, and indigenous populations during the rulemaking process?

3. How did actions taken under #1 and #2 impact the outcome or final decision?

8 EPA Order 1000.32 is available at http://www.epa.gov/civilrights/docs/lep_order_1000_32.pdf (accessed on May 28, 2013).

Finally, in September 2010 EPA released its FY2011-2015 Strategic Plan outlining how EPA would achieve its mission to protect human health and the environment over the next five years (U.S. EPA 2010b). Included in the plan is a cross-cutting fundamental strategy to focus on "working for environmental justice and children's health." To implement this strategy, EPA released Plan EJ 2014 in September 2011 that provides a roadmap for the Agency to incorporate environmental justice into policies, programs and activities. One of five cross-agency focus areas identified in Plan EJ 2014 is "Incorporating Environmental Justice into Rulemaking."[9]

Together these documents provide a solid foundation for considering distributional effects for population groups of concern in the rulemaking process.

10.2 Environmental Justice

EPA defines environmental justice as "the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies" (EPA 2010a). EO 12898 specifically states that Federal agencies should "...identify and address...disproportionately high and adverse human health or other environmental effects... on minority populations and low-income populations..." (EPA 2010a).

For policies that strengthen an environmental standard, EPA regulatory analyses have often relied on a default assumption that these policies have no EJ concerns because they reduce overall environmental burdens. However, it is incorrect to conclude that tighter standards necessarily improve environmental quality for everyone. The nuances of a rule could result in negative effects, such as higher emissions in some areas, even though net environmental quality improves. It is also possible that older, more polluting facilities close as a result of a rule and new facilities open in different locations, changing the distribution of emissions across communities.[10] Hence, when data are available, a basic analysis can support conclusions regarding potential distributional effects. In addition, while there may be no adverse environmental impacts, other economic impacts, like costs, could affect population groups of concern disproportionately and may warrant examination.[11]

Distributional analysis also improves transparency of rulemaking and provides decision makers and the public with more complete information about a given policy's potential effects. Such documentation helps EPA and the public track and measure progress in addressing EJ concerns. Analysts play a role in ensuring meaningful involvement by explaining distributional analysis in plain language, including key assumptions, methods, and results, and by asking for information from the public (e.g., asking for comment in the proposed rulemaking) on exposure pathways, end points of concern, and data sources that may improve the distributional analysis.[12] Further guidance on ensuring meaningful engagement of environmental justice stakeholders in the rulemaking process can be found in U.S. EPA (2010a).

10.2.1 Background Literature

The study of economic efficiency (the focus of benefit-cost analysis) of regulatory approaches has a long history in the economics literature, including an established theoretical foundation and generally accepted empirical methodology. But an assessment of distributional consequences

9 Plan EJ 2014 is available at http://www.epa.gov/compliance/ej/resources/policy/plan-ej-2014/plan-ej-2011-09.pdf (accessed on May 9, 2012).

10 U.S. EPA (2010a) provides additional information on how an EJ concern may arise in the context of a rule.

11 See U.S. EPA (2008a) for an example where changes in costs are addressed in an analysis of distributional impacts in the context of EJ.

12 Meaningful involvement is defined by EPA to mean that "1) potentially affected community members have an appropriate opportunity to participate in decisions about a proposed activity that will affect their environment and/or health; 2) the public's contribution can influence the regulatory agency's decision; 3) the concerns of all participants involved will be considered in the decision-making process; and 4) the decision makers seek out and facilitate the involvement of those potentially affected" (U. S. EPA 2010a, U.S. EPA 2012a).

has received relatively less attention.[13] Media and government interest in potential environmental inequity arising from landfill siting decisions in the mid-1980s led to an increased focus in the economics literature on distributional issues in the context of race, poverty, and income.[14] This section provides a brief overview of key studies from the economics and health literature. For a more comprehensive discussion see Ringquist (2005), Banzhaf (2012a), and Banzhaf (2012b).

Studies of EJ can vary by specific pollutant, the proxy used for risk or exposure, geographic area, and time period, making it difficult to directly apply general findings to a particular rulemaking. The literature illustrates, however, that EJ is a potential concern with regard to plant emission decisions and is therefore worthy of analysis in a regulatory context (see, for example, Wolverton 2009). It is important to note that the economics literature typically focuses on addressing the question of whether certain population groups are exposed to greater amounts of pollution. There is also the possibility that some populations are more susceptible to pollution for a given level of exposure and that socioeconomic factors may play a role. While literature addressing this issue is not discussed here, Section 10.2.8.5 of this chapter discusses various risk considerations including susceptibility. In addition, both the EJ literature and this chapter tend to focus on the distribution of physical aspects of environmental outcomes.[15]

Evidence exists of potential disproportionate impacts from environmental stressors on various population groups using a wide variety of proxies for exposure. Many studies are proximity-based: distance to a polluting facility is a surrogate for exposure. These studies often find evidence that locally-unwanted land-uses such as landfills or facilities that treat, store, or dispose of hazardous waste are more likely to be concentrated in predominantly minority or low-income neighborhoods (for example, Bullard 1983; GAO 1983; UCC 1987; Boer et al. 1997; and Mohai et al. 2009).[16]

Other studies attempt to better approximate exposure by examining whether existing emission patterns are related to socio-economic characteristics. These studies often focus on a particular type of pollution and geographic area. They also often differ in how they define the relevant neighborhood and comparison group. As such, results with regard to race and income vary across studies. For example, after controlling for other factors, Hamilton (1993, 1995) finds that expansion decisions for waste sites are unrelated to race and finds mixed evidence for income, while Aurora and Cason (1998) find both race and poverty are positively related to toxicity-weighted Toxic Release Inventory (TRI) emissions, although the significance of these relationships varies by region. Gray and Shadbegian (2004) find poor communities are exposed to more air and water pollution from pulp and paper mills, but find the opposite for minority communities.

Finally, other studies attempt to account for health risks. For example, Rosenbaum et al. (2011) combine information on ambient concentrations of diesel particulate matter in marine harbor areas throughout the United States with exposure and carcinogenic risk factors broken out by race, ethnicity, and income. They find that the most important factor in predicting higher particulate

13 For a discussion of the possible distributional effects of environmental policies with regard to income, see Fullerton (2009).

14 The rise in concern over environmental justice is often traced to demonstrations in Warren County, North Carolina in 1982 over the siting of a polychlorinated biphenyl (PCB) landfill in a poor and minority community.

15 Differences in exposures or health effects alone may not be representative of differences in total benefits and costs. As discussed in Serret and Johnstone (2006) and Fullerton (2011), for example, the full distribution of environmental policy could include differences in product prices, wage rates, employment effects, economic rents, etc. It is likely, however, that the methods used to analyze the full distributional effects (e.g., computable general equilibrium models) are beyond the scope of a typical regulatory analysis and the policy tools to address any resultant distributional concerns (e.g., tax policy and redistribution programs) are beyond the scope of environmental policy.

16 Others note the strength of this contemporaneous relationship but find that the direction and magnitude of the relationship between location and race or income at time of siting is less clear (see Been 1994; Been and Gupta 1997; and Wolverton 2009). See Shadbegian and Wolverton (2010) for a summary of the literature on firm location and environmental justice, including a discussion of whether plant location precedes changes in socioeconomic composition that result in higher percentages of non-white and poor households nearby or vice versa. Most of these studies examine partial correlations between pollution and household characteristics, using statistical techniques that control for other factors.

matter intake fractions (i.e., mass of a pollutant inhaled or ingested divided by mass emitted) is population density and that low-income and minority individuals are over-represented in marine harbor areas that exceed risk thresholds. Likewise, Morello-Frosch et al. (2001) combine estimates of hazardous air pollutant concentrations in southern California with information on lifetime cancer risks by socioeconomic status and race and find that even though lifetime cancer risks are high for all individuals in the study, race and ethnicity are positively related to lifetime cancer risk after controlling for economic and land use variables.

Ringquist (2005) conducts a meta-analysis of both facility location and emissions across 49 studies published prior to 2002 and finds evidence that plant location and higher emissions are more likely to occur in communities with a higher percent non-white population. He finds little evidence, however, that this is the case in communities with lower income or higher poverty rates. The finding for race holds across a wide variety of environmental risks (e.g., hazardous waste sites and air pollution concentrations), levels of aggregation (e.g., zip codes, census tracts, and concentric circles around a facility), and controls (e.g., land value, population density, and percent employed in manufacturing). The finding for race appears sensitive, however, to comparison groups (e.g., all communities versus a subset of communities).

A potential unintended consequence of improving environmental quality in some communities more than others is that rents may increase in the improved neighborhoods, making them potentially unaffordable for poorer households. For example, Grainger (2012) shows that about half of the increases in home prices due to the Clean Air Act Amendments are passed through to renters. Thus, the net health effect of improvements in environmental quality for renters depends on whether or not they move. Those who do not move experience higher rents, but also improved neighborhoods. For those who do move the net effect depends on the quality of the neighborhood to which they relocate. If these households receive far less of the health benefit predicted from a static model and also face transaction costs from moving, they could be worse off. The literature refers to this phenomenon as "environmental gentrification" (see also Banzhaf and McCormick 2012).

Sieg et al. (2004) find that even with no moving costs, local households could be worse off because other households move into the clean neighborhood and bid up the rents.[17] Earlier work by Banzhaf and Walsh (2008) shows that neighborhood income increases following cleanup, but more recent analysis (Banzhaf et al. 2012) shows racial characteristics in the neighborhood may not change. The authors postulate that richer minorities may move back into neighborhoods following cleanup.

10.2.2 Analyzing Distributional Impacts in the Context of Regulatory Analysis

In the context of regulatory analysis, examining distributional effects of health and environmental outcomes or costs can be accomplished, when data are available, by comparing effects in the baseline to post-regulatory scenarios for minority, low-income, or indigenous populations.[18]

When evaluating health and environmental outcomes, the following fundamental questions can guide the process of considering potential analytical methods for assessing EJ.[19]

- What is the baseline distribution of health and environmental outcomes across population groups of concern for pollutants affected by the rulemaking?[20]

17 The market dynamics associated with the relationship between household location decisions and pollution was first examined in a rigorous context in Been and Gupta (2007), and further explored by Banzhaf and Walsh (2008).

18 OMB (2003) defines the baseline as "the best assessment of the way the world would look absent the proposed action." Section 10.2.6 describes the concept of baseline briefly. For a more detailed discussion on properly defining a baseline to measure the incremental effects of regulation, see Chapter 5 of these *Guidelines*.

19 See Maguire and Sheriff (2011) for more detail.

20 The term "outcome" is used to indicate that these questions should be interpreted more broadly than just applying to health effects. EPA Program Offices have the flexibility to adapt the wording of these questions to reflect the realities of the particular endpoints under consideration for a rulemaking.

- What is the distribution of health and environmental outcomes for the options under consideration for the rulemaking effort?

- Under the options being considered, how do the health and environmental outcomes change for population groups of concern?[21]

Note that these analytic questions recommend the analyst provide information on the distribution of outcomes, but do not ask for a determination of whether differences across population groups constitute disproportionate impacts.[22] The term disproportionate is neither defined in EO 12898, nor does the academic literature provide clear guidance on what constitutes a disproportionate impact. The determination of whether an impact is disproportionate is ultimately a policy judgment.

This chapter presents a suite of methods for analyzing distributional effects across a variety of regulatory contexts. Because the data, time, and resource constraints will differ across programs and rules, these guidelines are intended to provide flexibility to the analyst while introducing greater rigor and transparency in how EJ is considered in a regulatory context.

10.2.2.1 Evaluating Changes in the Distribution of Health and Environmental Outcomes

The analysis of EJ should ideally consider how a policy affects the distribution of relevant health and environmental outcomes (e.g., mortality risk from a regulated pollutant). If the outcome data are unavailable, distribution of ambient environmental quality indicators (e.g., pollutant concentrations) can be a useful proxy. Such indicators are less informative than the outcomes themselves if population groups of concern vary in vulnerability to the pollutant, for example.[23] If projecting ambient environmental quality is not feasible, then the analysis may examine the distribution of pollutants from regulated sources. Distribution of pollutants is less desirable than distributions in ambient environmental quality or health and environmental outcomes due to uncertainty regarding how a reduction in emissions from a given source translates into environmental quality and how that, in turn, translates into the human impacts that are the ultimate objective of the analysis.

It is important to consider changes in distributions of health and environmental outcomes between baseline and various policy options, rather than just the distribution of changes since an unequal distribution of environmental improvements may actually help alleviate existing disparities (Maguire and Sheriff 2011). For example, suppose a policy is expected to reduce a pollutant, causing a greater reduction in particular adverse health outcomes for non-minorities than for minorities. One might conclude that this change in the distribution of outcomes could pose an EJ concern. If, however, the non-minority population suffered greater ill effects from the pollutant at baseline than the minority population, such a change in the distribution of outcomes may reduce, rather than increase, a pre-existing disparity in outcomes.

The difference between these two measures — the distribution of change in health and environmental outcomes and the change in the distribution of health and environmental outcomes — has implications for the suitability of data for analysis. In particular, analyzing the distribution of monetized benefits from a benefit-cost analysis can be problematic. Benefit-cost analyses do not estimate each affected individual's monetized welfare at baseline and policy levels of environmental quality. Instead, they

21 It would be useful to quantify the degree to which disparities change from baseline, so that one could rank in order of preference the relative merits of various options. Any ranking metric, however, would require adoption of an implicit social welfare function. Such approaches are analytically meaningful, but still under development and recommendation of a specific social welfare function is beyond the scope of this chapter. Text Box 10.1 provides additional discussion on this topic.

22 The EJ guidance for NEPA (CEQ 1997) provides some guidance on the use of the term. A population group may be disproportionately affected if health effects are significant or "above generally accepted norms," the risk or rate of exposure is significant or "appreciably exceeds or is likely to appreciably exceed the risk or rate to the general population or other appropriate comparison group," or is subject to "cumulative or multiple adverse exposures from environmental hazards."

23 A large epidemiological literature explores differences in health effects across various demographic groups. See, for example, Schwartz et al. (2011b).

estimate society's willingness to pay for a *change* in environmental quality. Thus, although the distribution of this change in welfare across groups may be of interest in its own right, in isolation it does not inform the question of whether the policy increases or reduces pre-existing disparities.

To address the question of how a policy affects disparities it is necessary to evaluate the distribution of environmental and health outcomes in the baseline and for each policy option. As an alternative to the change in willingness to pay one could examine the distribution of physical indicators. Such an evaluation is fairly straightforward if there is only one outcome to consider. Analysis of multiple outcomes (e.g., asthma risk and fatal heart attack risk) raises the problem of whether and how to aggregate these outcomes into a single measure. Combining several outcomes into a single aggregate measure may be desirable, but entails normative value judgments regarding the weight to be given to each component. For example, how much asthma risk is equivalent to a given risk of a fatal heart attack? One possible weighting scheme would be to use quality-adjusted life years (QALYs) or similar measures, but these are generally not consistent with willingness-to-pay measures and benefit-cost analysis (IoM 2006). Another alternative is to use the willingness-to-pay values from the benefit-cost analysis as weights (see Chapter 7 of these *Guidelines* for a discussion of willingness to pay).

A standard benefit-cost analysis aggregates multiple outcomes by multiplying the number of cases of each outcome by its respective *marginal* willingness-to-pay. In principle one could use this weighting scheme in a distributional analysis. There is a theoretical issue, however. The empirical techniques used to monetize health and environmental benefits estimate an individual's marginal willingness to pay for a change in the outcome. That is, they reflect the amount of money an individual would give up for a very small improvement in the outcome variable, evaluated at a particular level. The problem is that economic theory suggests that even if all individuals had identical preferences, the marginal willingness to pay to avoid a bad outcome should increase with the level of the outcome (e.g., an individual would be willing to pay more to reduce her probability of death from a particular disease from 99 percent to 98 percent, than she would to reduce it from 2 percent to 1 percent). As a practical matter, however, marginal willingness-to-pay measures typically used in benefit-cost analysis are constant values. The approximation implicit in this approach is defensible when the changes considered are not too large. However, it is not necessarily reasonable to multiply, say, the baseline mortality risk by the value of a statistical life in order to get the dollar value of eliminating the entire baseline risk. Yet this type of calculation would be necessary in order to evaluate how policy options would change the distribution of monetized environmental outcomes across population groups of concern. Consequently, if analysts use monetized values to aggregate across outcomes, the exposition should include appropriate caveats and be presented alongside outcome-by-outcome levels for the baseline and each policy option.

10.2.2.2 Evaluating the Distribution of Costs

Activities to address environmental justice often focus on reducing disproportionate environmental and health outcomes in communities. However, certain directives (e.g., EO 13175 and OMB *Circular A-4*) specifically identify distribution of economic costs as an important consideration. The economic literature also typically considers both costs and benefits when evaluating distributional consequences of an environmental policy in order to understand their net effects on welfare. For instance, Fullerton (2011) discusses six possible types of distributional effects that may result from an environmental policy: higher product prices, changes in the relative returns to factors of production, how scarcity rents are distributed, the distribution of environmental benefits, transitional effects of the policy, and the capitalization of environmental improvements into asset prices (e.g., land or housing values). Policy decisions involve trade-offs, and these may differ across affected groups. While health or environmental improvements may accrue to certain population groups of concern, costs may be borne by others. As a result, some groups may experience net costs even if everyone is expected to receive gross environmental benefits.

This chapter frames the discussion in terms of environmental and health outcomes (referred to as benefits, when monetized), but many of the methods can be applied to costs and other impacts as well. Whether or not costs are included in an evaluation of EJ issues associated with a regulation should be evaluated on a case-by-case basis. If regulatory costs are spread fairly evenly across many households (e.g., in the form of higher prices) and expected to be small on a per-household basis, further analysis is likely not warranted or feasible. However, there may be cases where the analysis of the distribution of costs is warranted.[24] Such cases may include situations where costs to consumers may be concentrated among particular types of households (e.g., renters); identifiable plant closures or facility relocations that could adversely affect certain communities; or when households may change their behavior in response to the imposition of costs.

In many cases, detailed analyses of costs may be challenging due to data or modeling constraints. For example, EPA may expect air pollution control costs to be passed on to electricity consumers. The Agency might not have information, however, on how costs are passed through as rate increases, how these increases may be broken down between residential and commercial customers, what assistance is available for low-income consumers, and how consumption patterns differ by race and income. Likewise, if air quality improvements associated with a regulation are unevenly distributed, demand for housing in particular neighborhoods may affect rental prices. While hedonic approaches (discussed in Chapter 7) may be useful for demonstrating how changes in environmental quality factor into housing prices, predicting the effect of such price changes on household migration by race or income may be infeasible.[25] Absent such data, it might not be possible to predict the total impact of the rule on different populations. In these instances, those issues that cannot be quantified can be qualitatively discussed.

10.2.3 Relevant Populations

EO 12898 identifies a number of relevant population groups of concern: minority populations, low-income populations, Native American populations and tribes, and "populations who principally rely on fish and/or wildlife for subsistence."[26] It may be useful to analyze these categories in combination — for example, low-income minority populations — or to include additional population groups of concern, but such analysis is not a substitute for examining populations explicitly mentioned in the Executive Order. In this section, we discuss existing Federal definitions for population groups of concern in the context of EJ. We also discuss credible options for defining these populations in the absence of a Federal definition.

10.2.3.1 Minority and Native American Populations

OMB (1997) specifies minimum standards for "maintaining, collecting, and presenting data on race and ethnicity for all Federal reporting purposes.... The standards have been developed to provide a common language for uniformity and comparability in the collection and use of data on race and ethnicity by Federal agencies." In particular, it defines the following minimum race and ethnic categories:

- American Indian or Alaska Native
- Asian
- Black or African American

24 EPA's Lead Renovation, Remodeling, and Painting Final Rule (U.S. EPA 2008c) provides the best example to date of consideration of costs in the context of a rulemaking.

25 See Section 8.2.5.1 of the *Handbook on the Benefits, Costs and Impacts of Land Cleanup and Reuse* (U.S. EPA 2011c) for a more detailed discussion of EJ in the context of the potential effects of environmental policy on land values and household location decisions.

26 EO 12898 clarifies in Section 6 that the EO applies to Native Americans and also Indian Tribes, as specified in 6-606, as well as populations who principally rely on fish and/or wildlife for subsistence as specified in 4-401.

- Native Hawaiian or Other Pacific Islander
- White
- Hispanic or Latino

Statistical data collected by the Federal government, such as the U.S. Census Bureau, use this classification system.[27] Beginning with the 2000 Census, individuals were given the option of selecting more than one race, resulting in 63 different categories. OMB (2000) provides guidance on how to aggregate these data in a way that retains the original minimum race categories (i.e., the first five categories listed above) and four double race categories that are most frequently reported by respondents.[28] In addition, the U.S. Census Bureau collects data useful for identifying minority populations not completely captured by either the race or ethnicity categories, such as households that speak a language other than English at home or foreign-born populations.

CEQ's NEPA Guidance for EJ (CEQ 1997) provides useful direction for defining minority and minority population based on these Federal classifications. Minority is defined as "individual(s) who are members of the following population groups: American Indian or Alaskan Native; Asian or Pacific Islander; Black, not of Hispanic origin; or Hispanic." A population is identified as minority if "either (a) the minority population of the affected area exceeds 50 percent or (b) the minority population percentage of the affected area is meaningfully greater than the minority population percentage in the general population or other appropriate unit of geographic analysis." The term meaningfully greater is not defined, although the guidance notes that a minority population exists "if there is more than one minority group present and the minority percentage, as calculated by aggregating all minority persons, meets one of the above-stated thresholds." Finally, the CEQ Guidance states that analysts "may consider as a community either a group of individuals living in geographic proximity to one another, or a geographically dispersed/transient set of individuals (such as migrant workers or Native Americans), where either type of group experiences common conditions of environmental exposure or effect."

27 Analysts should refer to the OMB Federal Register notice for the specific definitions: http://www.whitehouse.gov/omb/fedreg_1997standards/ (accessed on December 20, 2012).

28 See OMB (2000) for specific guidance on how to conduct this aggregation.

10.2.3.2 Low-Income Populations

OMB has designated the U.S. Census Bureau's annual poverty measure, produced since 1964, as the official metric for program planning and analytic work by all Executive branch agencies in *Statistical Policy Directive No. 14* (Federal Register 1978), although it does not preclude the use of other measures. Many Federal programs use variants of this poverty measure for analytic or policy purposes, and the U.S. Census Bureau publishes data tables with several options.

The U.S. Census Bureau measures poverty by using a set of money income thresholds that vary by family size and composition to determine which households live in poverty. If a family's total income is less than the threshold, then that family and every individual in it is considered in poverty. The official poverty thresholds do not vary geographically, but they are updated for inflation using the national Consumer Price Index for All Urban Consumers (CPI-U). The official poverty definition uses money income before taxes and does not include capital gains or noncash benefits (such as public housing, Medicaid, and food stamps).[29] This measure of poverty has remained essentially unchanged — apart from relatively minor alterations in 1969 and 1981— since its inception.[30]

There is considerable debate regarding this poverty measure's ability to capture differences in

29 See "How the Census Bureau Measures Poverty" available at http://www.census.gov/hhes/www/poverty/about/overview/measure.html (accessed on November 30, 2011).

30 The U.S. Census Bureau produces single-year estimates of median household income and poverty by state and county, and poverty by school district as part of its *Small Area Income and Poverty Estimates*. It also provides estimates of health insurance coverage by state and county as part of its *Small Area Health Insurance Estimates*. These data are broken down by race at the state level and by income categories at the county level.

economic well-being. In particular, the National Research Council (NRC) recommended that the official measure be revised because "it no longer provides an accurate picture of the differences in the extent of economic poverty among population groups or geographic areas of the country, nor an accurate picture of trends over time" (Citro and Michael 1995). OMB convened an interagency group in 2009 to define a supplemental poverty measure based on NRC recommendations. The U.S. Census Bureau released the Supplemental Poverty Measure (SPM) in November 2011 (Short 2011). This measure uses different measurement units to account for "co-resident unrelated children (such as foster children) and any co-habitors and their children," a different poverty threshold, and modified resource measures (to account for in-kind benefits and medical expenses, for example). It also adjusts for differences in housing prices by metropolitan statistical area, as well as family size and composition.

The NRC recognized that annual income is not necessarily the most reliable measure of relative poverty as it does not account for differences in accumulated assets across households. Neither the SPM nor the official U.S. poverty thresholds take into account differences in wealth across families. However, the SPM examines whether a household is likely to fall below a particular poverty threshold as a function of inflows of income and outflows of expenses. The U.S. Census Bureau asserts that this measure is therefore more likely to capture short-term poverty since many assets are not as easily convertible to cash in the short run (Short 2012).

The U.S. Census Bureau also includes several additional measures that may prove useful in characterizing low-income families. Unlike poverty, there is no official or standard definition of what constitutes "low-income," though it is expected to vary similarly by region due to differences in cost-of-living as well as with family composition. It is therefore appropriate to examine several different low-income categories, including families that make some fixed amount above the poverty threshold (e.g., two times the poverty threshold) but still below the average household income for the United States or for a region.

Educational attainment or health insurance coverage may also be useful for characterizing low-income families relative to other populations, although we caution analysts that some measures may be hard to interpret and use in a regulatory context. It is also possible to examine the percent of people who are chronically poor versus those that experience poverty on a more episodic basis using the *Survey of Income and Program Participation* which provides information on labor force participation, income, and health insurance for a representative panel of households on a monthly basis over several years (see Iceland 2003). Finally, cross-tabulations often are available between many of these poverty measures and other socioeconomic characteristics of interest such as race, ethnicity, age, sex, education, and work experience.

10.2.3.3 Populations that Principally Subsist on Fish and Wildlife

EO 12898 directs agencies to analyze populations that principally subsist on fish and wildlife. CEQ's NEPA Guidance for EJ (CEQ 1997) defines subsistence on fish and wildlife as "dependence by a minority population, low-income population, Indian tribe or subgroup of such populations on indigenous fish, vegetation and/or wildlife, as the principal portion of their diet." It also states that differential patterns of subsistence consumption are defined as "differences in rates and/or patterns of subsistence consumption by minority populations, low-income populations, and Indian tribes as compared to rates and patterns of consumption of the general population."

Neither the U.S. Census Bureau nor other Federal statistical agencies collect nationally representative information on household consumption of fish and/or wildlife. However, EPA has conducted consumption surveys in specific geographic areas. If fish and wildlife consumption is a substantial concern for a particular rulemaking, EPA's guidance can provide useful information for collecting these data (see U.S. EPA 1998b). There may also be surveys conducted by state or local governments. It is important to verify that any survey used in an analysis of distributional impacts in the context of EJ adheres to the parameters and methodology set out in U.S. EPA (1998b).

10.2.4 Data Sources

Many data sources can be used for conducting analyses of EJ issues. The U.S. Census Bureau's "Quick Facts" website contains frequently requested Census data for all states, counties, and urban areas with more than 25,000 people.[31] Data include population, percent of population by race and ethnicity, and income (median household income, per-capita income, and percent below poverty line).

In 2010 the U.S. Census Bureau began to administer the decennial Census using a short form to collect basic socioeconomic information. More detailed socioeconomic information is now collected annually by the American Community Survey (ACS), which is sent to a smaller percentage of households than the decennial Census.[32] The ACS provides annual estimates of socioeconomic information for geographic areas with more than 65,000 people, three-year estimates for areas with 20,000 or more people, and five-year estimates for all areas.[33] The five-year estimates, which are based on the largest sample, are the most reliable and are available at the census tract and block group levels. Some of the Quick Facts data include estimates from the ACS.

The U.S. Census Bureau's American Housing Survey (AHS), is a housing unit survey that provides data on a wide range of housing and demographic characteristics, including information on renters.[34] Unlike the ACS, which selects a random sample every year, the AHS returns to the same 50,000 to 60,000 housing units every two years.

10.2.5 Scope and Geographic Considerations

Most EPA rules are national in scope. Therefore, the entire country is typically considered within the scope of analysis. However, there may be reasons to consider a rule's distributional effects at a sub-national level. For example, for a regulation of hazardous waste sites it may be appropriate to conduct separate state-level analyses due to differences in implementation of state-level regulations. A rule may also affect a limited part of the country. The 2011 Cross-State Air Pollution Rule (U.S. EPA 2011b), for example affects mainly eastern states.[35] In such cases the analyst may wish to evaluate the effects of the regulation at a regional level. Finally, for some regulations, such as those governing the use of a household chemical or as a product ingredient, geography may not be as relevant for determining how health and environmental outcomes vary across population groups of concern. Two main issues to consider when comparing impacts of a rulemaking on minority, low-income, or indigenous populations across geographic areas are:

- Unit of analysis (e.g., facilities or aggregate emissions to which a population group is exposed within a designated geographic area); and
- Geographic area of analysis used to characterize impacts (e.g., county or census tract).[36]

The unit of analysis refers to how the environmental harm is characterized. For instance, in a proximity-based analysis the unit of analysis could be an individual facility or the

31 Quick Facts is available at: http://quickfacts.census.gov/qfd/index.html. The year associated with data from Quick Facts is important to note. Data are updated as new information becomes available. Therefore, not all data elements represent the same year.

32 The ACS is available at: http://www.census.gov/acs/www/index.html. (accessed December 1, 2011.)

33 Because ACS variables change over time, caution should be used when comparing ACS estimates across samples and years. Guidance for comparing ACS data can be found at: http://www.census.gov/acs/www/guidance_for_data_users/comparing_data/ (accessed on April 27, 2011).

34 Information on owner-occupied homes versus renters may be useful when exploring issues of gentrification, where renters could be worse off due to rising housing costs.

35 See http://www.epa.gov/airtransport/ for details. (accessed December 1, 2011.)

36 This is often referred to in the literature as geographic scale.

total number of facilities within a particular geographic area (e.g., a county or census tract). In an exposure-based analysis the unit of analysis could be emissions aggregated within a particular geographic area to which the population is exposed. The unit of analysis is often identical to the geographic scale used to aggregate and compare effects on minority, low-income, or indigenous populations in one area to another (see Section 10.2.7 regarding how to select an appropriate comparison group).[37] The choice will vary depending on the nature of the pollutant (e.g., point sources may use a facility as the unit of analysis, while area sources may use a geographic unit). In considering various units, an important consideration is whether the data are sufficiently disaggregated to pick up potential variation in impacts across socioeconomic characteristics. More aggregated units of analysis (e.g., metropolitan statistical area (MSA) or county) may mask variation in impacts across socioeconomic groups compared to more disaggregated levels (e.g., facility or census tract).

The geographic area of analysis is the area used to characterize impacts (e.g., distance around a facility). Outcomes are aggregated by population groups within geographic areas to compare across groups. As with unit of analysis, choice of options for defining the geographic area will vary depending on pollutant and rule. Some air pollutants, for example, may travel hundreds of miles away from the source, making it appropriate to choose a large area for measuring impacts. In contrast, water pollutants or waste facilities may affect smaller areas, making it appropriate to consider a smaller area for analysis. Likewise, an assessment of outcomes from specific industrial point sources may require more spatially resolved air quality, demographic and health data than one that affects regional air quality, where coarser air quality, demographic and health data may suffice. Using more than one geographic area of analysis to compare effects across population groups may also be useful since outcomes are unlikely to be neatly contained within geographic boundaries. The literature has demonstrated that results are sensitive to the choice of the geographic area of analysis (Mohai and Bryant 1992; Baden et al. 2007).

Commonly used geographic areas of analysis include:

Counties: The United States has more than 3,000 counties according to the 2007 Census of Governments. Although counties are well-defined units of local government and provide complete coverage of the United States, they vary in size from a few to thousands of square miles and population density ranges from less than one person per square mile in some Alaskan counties to over 66,000 in New York County. In addition, spatial considerations associated with using counties present concerns for an analysis of distributional impacts in the context of EJ. A facility located in one corner of a county may have greater effects on neighboring counties than on residents of the county where the plant is located.[38, 39]

Metropolitan and Micropolitan Statistical Areas: The U.S. Census Bureau publishes data on metropolitan and micropolitan statistical areas, as defined by OMB (OMB 2009). Metropolitan statistical areas include an urban core and adjacent counties that are highly integrated with the urban core. A micropolitan statistical area corresponds to the concept of a metropolitan statistical area but on a smaller scale. Metropolitan statistical areas have an urban core of at least 50,000 persons; micropolitan statistical areas have an urban core population between 10,000 and 50,000 persons. Rural areas of the United States are not covered by these statistical designations, though according to the U.S. Census Bureau, almost 94 percent of the U.S. population lived in a metro- or micropolitan statistical area in 2010.

Zip codes: Zip codes are defined by the U.S. Post Office for purposes of mail delivery and may change over time. They also may cross state, county, and other more disaggregated Census

37 In Fowlie et al. (2012), for example, the scale of the analysis varies between 0.5, 1 and 2 miles of the facility (which is the unit of analysis).

38 These same advantages and disadvantages can apply to other units of government.

39 For criteria pollutants, baseline health data may be available at the county level (e.g., baseline death rates, hospital admissions, and emergency department visits).

statistical area definitions, making them difficult to use for analysis. Zip code tabulation areas are statistical designations first developed by the U.S. Census Bureau in 2000 to approximate the zip code using available census block level data on population and housing characteristics. Data are readily available for the approximately 33,000 U.S. zip code tabulation areas. While smaller than counties, they also vary greatly in size and population. As a result, they may often be less preferable than other geographic areas for analyzing distributional effects across population groups of concern.

Census tracts/block groups/blocks: Census tracts are small statistical subdivisions of a county, typically containing from 1,500 to 8,000 persons. The area encompassed within a census tract may vary widely, depending on population density. Census tracts in denser areas cover smaller geographic areas, while those in less dense areas cover larger geographic areas. Census tract boundaries were intended to remain relatively fixed. However, they are divided or aggregated to reflect changes in population growth within an area over time. Although they were initially designed to be homogeneous with respect to population characteristics, economic status, and living conditions, they may have become less so over time as demographics have changed.

Analysts may also choose to use census blocks or block groups. A census block is a subdivision of a census tract and the smallest geographic unit for which the U.S. Census Bureau tabulates data, containing from 0 to 600 persons. Many blocks correspond to individual city blocks bounded by streets, but may include many square miles, especially in rural areas. And census blocks may have boundaries that are not streets, such as railroads, mountains or water bodies. The U.S. Census Bureau established blocks covering the entire nation for the first time in 1990. Census block groups are a combination of blocks that are within — and a subdivision of — a given census tract. Block groups typically contain 600 to 3,000 persons.[40]

40 Other Census statistical area definitions (e.g., public use microdata areas or PUMAs) are also available.

GIS methods: Because Census-based definitions often reflect topographical features such as rivers, highways, and railroads, they may exclude affected populations that, although separated by some physical feature, receive a large portion of the adverse impacts being evaluated. Since Census-based definitions vary in geographic size due to differences in population density, Geographic Information System (GIS) software and methods may enable the use of spatial buffers around an emissions source that are more uniform in size and easier to customize to reflect the appropriate scale and characteristics of emissions being analyzed for a given rulemaking.

Analysts should be aware that there are a number of challenges typical of working with geospatial data. In some cases, statistical techniques rely on assumptions that often are violated by these types of data (Chakraborty and Maantay 2011). For instance, spatial autocorrelation — when locations in closer proximity are more highly correlated than those further away from each other — violates the assumption that error terms are independently distributed (an assumption that underlies ordinary least squares).

10.2.6 Defining the Baseline

Proper definition of the baseline is crucial for evaluating a rule's distributional effects. OMB (2003) defines the baseline as "the best assessment of the way the world would look absent the proposed action." The baseline allows one to determine how a rule's effects are distributed across population groups of concern and to assess whether some groups may be disproportionately affected. Baseline assumptions used in a distributional analysis should be consistent with those used in the benefit-cost analysis. See Chapter 5 for a more detailed discussion of baseline issues.

10.2.7 Comparison groups

The choice of a relevant comparison group is important for evaluating changes in health, risk, or exposure effects across population groups of concern relative to a baseline. Within-group comparisons involve comparing effects on the same demographic group across different areas in the state, region or nation, while across-group comparisons examine effects for different socioeconomic groups within an affected area. From the perspective of EO 12898, across-group comparisons may be most relevant. The literature suggests using more than one comparison group to analyze whether a finding of disproportionate impacts is sensitive to how it is defined. Bowen (2001) also argues that restricting the comparison group to alternative locations within the same metropolitan area may be more defensible than a national level comparison in some instances, given heterogeneity across geographic regions in industrial development and economic growth over time and inherent differences in socioeconomic composition (e.g., relatively more Hispanics reside in the Southwest). Ringquist (2005), however, notes that placing restrictions on comparison groups in this way may "reduce the power of statistical tests by reducing sample sizes" or bias results against a finding of disproportionate impacts because such restrictions reduce variation in socioeconomic variables of interest.

10.2.8 Measuring and estimating impacts

This section presents a range of potentially useful approaches for describing distributions in regulatory analysis. To the extent feasible, basic summary statistics of a regulation's impacts on relevant endpoints by race and income are recommended for distributional analyses. Summary statistics may be straightforward to calculate when data are available, and providing such information promotes consistency across EPA analytical efforts. A related document, the Interim Guidance on *Considering Environmental Justice During the Development of an Action* (U.S. EPA 2010a), suggests conducting a screening process for determining when an action may require evaluation. For economically significant actions, it is recommended that the results of the screening be demonstrated through the use of summary statistics. Summary statistics can be supplemented with other approaches described below when a screening analysis indicates that a more careful evaluation is needed.

The health effects of exposure to pollution may vary across populations (likewise, with costs). One way to capture these effects is to use information regarding variation in risk and incidence by groups, when available, to characterize the baseline and projected response to a change in exposure (for example, see Fann et al. 2011). However, available scientific literature and data (which also often requires some level of spatial resolution) may not allow for a full characterization. In these cases, it is recommended that the analyst qualitatively discuss conditions that are not adequately accounted for in the risk and exposure characterization used to assess health effects for minority populations or low-income populations and the key sources of uncertainty highlighted in the literature (U.S. EPA 2010a). When data are available to approximate risk or exposure, for instance location of emitting facilities, some level of quantitative analysis may be possible.

Text Box 10.1 discusses the potential usefulness of social welfare functions and inequality indices for ranking distributions. While these methods are useful for combining efficiency and equity considerations into one measure, these tools are not sufficiently developed for application to regulatory analysis. For a more detailed discussion of the advantages and disadvantages of methods commonly used to rank environmental outcomes see Maguire and Sheriff (2011).

10.2.8.1 Simple Summary Statistics

Simple summary measures can characterize potential differences in baseline and regulatory options within and across populations of concern relative to appropriate comparison groups. Such statistics can be calculated, if data are available, to address the three questions outlined in Section 10.2.2. It is important to note, however, that summary statistics alone do not necessarily provide a complete description of differences across groups. Omitted variables are one important limitation of examining single statistics. In addition, summary statistics (e.g., means) can mask important details about the tails of the distribution which can be important for identifying potential EJ concerns

Text Box 10.1 - Social Welfare Functions and Inequality Indices

The costs, benefits, and distributional effects of a regulation can be evaluated by a single social welfare function (SWF). A SWF provides a way to aggregate welfare or utility across individuals into a single value, thus allowing simple, direct comparisons in ranking alternative allocations. Such comparisons are potentially useful in evaluating whether a change from the baseline to a regulatory option makes society better off. Likewise, they can also facilitate comparisons between possible regulatory options (see Adler 2008, 2012 for a discussion). Sen (1970), Arrow (1977), and Just et al. (2004) provide theoretical discussions of SWFs, and Norland and Ninassi (1998) provide an example of an application to energy markets. Adler (2012) addresses practical issues of incorporating both health and income effects in a SWF.

Any ranking of alternative outcomes uses an implicit set of normative criteria; a SWF makes the criteria explicit regarding how society prefers to distribute resources across individuals. Since there is no consensus regarding those preferences, a universally-accepted SWF does not exist. For example, suppose an increase in exposure to a particular pollutant results in an average loss of 0.1 IQ points across a population of 1,000 children (100 IQ points total). It is not obvious how society should rank alternative distributions of this loss. Is it worse to have 250 individuals suffer a loss of 0.1 each, 250 suffer a 0.3 loss, and 500 suffer no loss? Or 500 individuals suffer a loss of 0.01 and 500 suffer a loss of 0.19? Many sensible SWFs could be specified; some may prefer the first outcome, some may prefer the second, and some may be indifferent between the two.

An inequality index is a related concept used to assign a numerical value to distributions of a single "good" or "bad" (e.g., income or pollution), independent of the total amount produced. A distribution with a higher index value is less "equal" than one with a lower number. Commonly used indices are based on simple SWFs and are subject to the same limitations (Blackorby and Donaldson 1978, 1980). However, unlike a SWF, an index number value has cardinal significance, i.e., the magnitudes, not just the rankings, contain information about how much society would be willing to give up in exchange for the rest to be equally distributed.

Inequality indices were originally developed for ranking "goods," like income. In general, it is inappropriate simply to use positive values of a bad outcome (e.g., pollution exposure) in the formula for an index, since doing so would imply that the underlying SWF is increasing in pollution, i.e., it would rank scenarios with higher overall pollution as more desirable. Since indices cannot accommodate negative values, some commonly used income inequality measures, such as the Gini coefficient, and Atkinson index, are inappropriate for evaluating distributions of adverse outcomes. The Kolm index (Kolm 1976a, 1976b), in contrast, does not suffer from this problem (see Maguire and Sheriff 2011). Given that the peer-reviewed literature does not yet contain environmental applications of the Kolm Index, and the Atkinson Index is undefined for "bads," we do not recommend inequality indices be used in regulatory analysis of distributional impacts in the context of EJ at this time.

(see Gochfeld and Burger 2011). Nonetheless, such information can provide useful information on potential differences.

After reviewing the available data and feasible methods for developing information on potential differences, the analyst should present information in a transparent and accessible manner such that the decision maker can consider:

- Population groups of concern for the regulatory action,
- Geographic scale and unit of analysis, when relevant,
- Primary conclusions (e.g., statistical differences),
- Sources of uncertainty across alternative results (e.g., comparison groups and geographic scale), and
- Data quality and limitations of the results.

A variety of measures can be used to characterize an action's distributional effects for population groups of concern.

Means and quantiles

Reporting mean outcomes by group at the baseline and for each regulatory option is a straightforward way to display information. Tests for statistical significance across means provide additional information about differences (see Been and Gupta 1997 and Wolverton 2009). However, mean estimates can mask what might be important information in the tails of the distribution. For example, the baseline outcomes could be uniformly distributed across the population but concentrated around the mean for the regulatory scenario. Examining differences around the central tendency only would not reveal this information. Presenting data using different quantiles can provide additional information illuminating these effects.

Ratios

A simple ratio can be calculated to determine whether certain groups are relatively more exposed to an environmental hazard. For instance, the probability that an individual is minority conditional on being exposed can be divided by the probability that an individual is not minority conditional on being exposed. Alternatively, one can also create a ratio of the probability that an individual is exposed to an environmental risk conditional on being minority divided by the probability that an individual is not exposed conditional on being in the same demographic group. Because ratios may mask absolute differences, ratios should be used in conjunction with other statistics. For example, a ratio may show a 100-fold difference between two groups' exposure to an environmental hazard but the absolute difference could be small. Ratios may exaggerate the importance of differences.

Tests for Differences

Statistical tests can determine whether a significant disparity exists across demographic groups. One of the simplest is a *t*-test of the difference in means. However, a *t*-test assumes a normal distribution so it would be inappropriate for non-normal distributions. For non-normal distributions, nonparametric methods may be used. In cases where comparisons are made based on the difference in probabilities between two groups, tests such as the Kendall test and the Fisher Exact test (for small samples) may be used. These tests compare standard errors of two separate and independent statistics to determine how likely it is that the calculated distribution is the actual one. More sophisticated tests are needed when making comparisons across more than two groups or a more formal examination of the full distribution is desired.

Correlation coefficients

Simple pair-wise correlations between impacts and relevant demographic groups may be useful information for characterizing distributional effects (e.g., Brajer and Hall 2005). It is important to note, however, that the value of a Pearson correlation coefficient, for example, is a measure of how closely the distribution of the relationship between two variables (e.g., percent minority population and ambient pollution concentrations) can be represented by a straight line. It does not provide information regarding the slope of the line, apart from being positive or negative. Similarly, a Spearman rank correlation coefficient measures how closely the relationship can be captured by a generic monotonically increasing or decreasing function. Determination of what constitutes a "strong" or "weak" correlation is somewhat arbitrary, and caution should be used when comparing coefficients across socio-economic variables of interest.

Counts

A count of geographic areas (e.g., counties) where the incidence of an environmental outcome affected by a rule, disaggregated by race/ethnicity and income, exceeds the overall average is a useful measure. For comparison, this count should be accompanied by a count of geographic areas where the incidence does not exceed the overall average.

These counts do not account for magnitude of differences, but can help identify the need for more detailed analysis.

10.2.8.2 Visual Displays

Maps, charts, graphs, and other visual displays are commonly used in EJ analyses (see Shadbegian et al. 2007, for example). With increased access to GIS software and built-in graphical functions in spreadsheet or statistical software, it is relatively easy to produce a variety of visual displays of EJ-related information. Visual displays can be helpful in displaying baseline levels of pollutants or locations of certain facilities, and the distribution, demographic profile and baseline health status of population groups of concern.

There are several challenges with GIS analysis of distributional information. These include spatial and data deficiencies as well as geographic considerations that can lead to misleading or inaccurate results.[41] It may be difficult to discern differences that arise between baseline and regulatory options, unless such differences are stark. While the use of visual displays in an analysis of distributional impacts in the context of EJ may be useful for helping to communicate the geographic distribution of impacts, this information may be more effective if it is accompanied by other analytical information.

10.2.8.3 Proximity-Based Analysis

Proximity- or distance-based analysis is an approach commonly used in the EJ literature as a surrogate for more direct measures of risk or exposure when such information is not easily available. This approach examines demographic and socioeconomic characteristics in proximity to a particular location, typically a waste site, permitted facility, or some other polluting source (for instance, see Baden and Coursey 2002, Cameron et al. 2012, and Wolverton 2009). While a simplistic approach is to examine the population within a Census-defined geographic boundary of a location, it is also possible to use GIS methods to draw a concentric buffer around an emission source, such as a one mile radius around a site to approximate the distance that a particular pollutant may travel. In some cases, it may also be possible to use dispersion models to select a buffer that approximates the effect of atmospheric conditions (for instance, wind direction and weather patterns) on exposure, though these types of models are data-intensive (Chakraborty and Maantay 2011).

Several analytical considerations are important for conducting a proximity-based analysis.[42] First, accurate information is needed for the location of polluting sources. Addresses or latitude/longitude coordinates must reflect physical locations of polluting facilities, and not the location of a headquarters building, for example. Second, a decision must be made regarding the appropriate distance from the facility to examine community characteristics. A solid waste facility with strict monitoring and safety controls is likely to have a limited geographic impact, whereas a permitted air pollution source may have the potential for a more widespread geographic impact. In general, Census-defined geographic boundaries (e.g., county, MSA) are unlikely to provide an accurate portrayal of the relevant affected population because emission sources are often not found in the center of the area (i.e., they are sometimes along a boundary and thus mostly affect a neighboring jurisdiction) and pollutant exposures do not conform to these boundaries.[43] In addition, Census-defined areas often vary widely in size, implying that they may differ in how well they proxy for actual exposure. Defining proximity or distance using buffer-based approaches (e.g., through GIS or fate and transport modeling) around an emissions source has the potential to more closely approximate actual risk and exposure, but the appropriate distance measure can vary by situation. The literature has demonstrated that results in proximity-based analyses can vary substantially with the choice

41 See Chakraborty and Maantay (2011) for further discussion of the limitations of using GIS for EJ analyses.

42 For an overview of proximity analysis, including a discussion of various spatial analysis techniques used in the literature see Chakraborty and Maantay (2011) and Mohai and Saha (2007).

43 Mohai and Saha (2007) refer to this as the "unit-hazard coincidence" approach because the analyst uses the available geographic units and determines whether they are coincident with an environmental hazard instead of first identifying the exact location of the hazard and then examining effects within a particular distance.

of the geographic area of analysis (see Rinquist 2005; Mohai and Saha 2007). For this reason, it is recommended that the analyst explore the potential value of defining and applying more than one specification for distance or proximity.[44]

When this approach is used, it is important to be aware of biases and limitations introduced when proximity or distance is used as a substitute for risk and exposure modeling and that these limitations be clearly discussed (see Chakraborty and Maantay 2011). In particular, it may only be possible to make limited observations with regard to the possibility of disproportionate impacts based on proximity-based analysis alone.

10.2.8.4 Exposure Assessment

Spatial patterns associated with environmental burdens across individuals or communities are difficult to analyze when pollution is diffuse. Air and water pollution, for example, are typically dispersed widely and subject to atmospheric or geologic features. As such, identifying the "proximity" to the hazards via some type of GIS analysis, as described above, is less useful. However, monitoring and/or modeling data may generate distributional effects at a disaggregated level.

Criteria air pollutants (i.e., carbon monoxide, lead, nitrogen dioxide, ozone, particulate matter and sulfur dioxide) are monitored nationally. EPA's National Air Toxics Assessment (NATA) data provide an assessment of hazardous air pollutants across the U.S. at the census tract level.[45] Data from these monitoring networks may potentially be combined with demographic data and dispersion models to generate baseline and regulatory distributions of pollutants by population groups of concern.[46]

While this approach is promising due to spatial detail associated with monitoring data, it is currently only available for certain air pollutants. In addition, it is important to note that monitoring data measure emissions, not individual exposures or health effects associated with the pollutant under consideration. As such, these data are a proxy for actual effects associated with a particular regulation. Further, all individuals within a grid cell are assigned the same emissions (or concentrations based on air quality modeling). Actual exposures or health effects may differ across individuals for a variety of reasons discussed throughout this chapter.

10.2.8.5 Risk Considerations

Certain factors make some populations more susceptible (i.e., experience a greater biological response to a specific exposure) to a particular environmental stressor (see Adler and Rehkopf 2008, Sacks et al. 2011 and Schwartz et al. 2011a).[47, 48] These factors can be genetic or physiological (such as sex and age). They may also be acquired due to variation in factors such as health-care access, nutrition, fitness, stress, housing quality, other pollutant exposures, or drug and alcohol use.[49] For instance, many populations face exposures from multiple pollutants or exposures that have accumulated in ways that may affect their susceptibility to a particular pollutant and introduce complex considerations when attempting to address EJ concerns.[50]

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44 The analysis of distributional impacts in the context of EJ completed for EPA's proposed Definition of Solid Waste is an example of this type of analysis in a rule-making context. See EPA's Draft Environmental Justice Methodology for the Definition of Solid Waste Final Rule, January 13, 2009, available at: http://www.epa.gov/epawaste/hazard/dsw/ej-meth.pdf (accessed on December 1, 2011).

45 See Apelberg et al. (2005) for an application to Maryland and Morello-Frosch et al. (2002) for an application to southern California.

46 See, for example, U.S. EPA (2011b), Fann et al. (2011), and Post et al. (2011).

47 A special issue of the *American Journal of Public Health* (Volume 101, Issue S1, December 2011) provides a set of papers exploring these and other issues.

48 EPA's Integrated Risk Information System (IRIS) defines susceptibility as "increased likelihood of an adverse effect, often discussed in terms of relationship to a factor that can be used to describe a human subpopulation (e.g., life stage, demographic feature, or genetic characteristic)." See http://www.epa.gov/iris/help_gloss.htm#s (accessed on December 1, 2011).

49 Sexton (1997) suggests that low-income families may be more susceptible to environmental stressors due to differences in quality of life and lifestyle. Centers for Disease Control data show higher incidences of asthma-related emergency room visits and asthma-related deaths among African-American populations. See http://minorityhealth.hhs.gov/templates/content.aspx?ID=6170 (accessed December 1, 2011).

50 EPA's *Framework for Cumulative Risk Assessment* may serve as a useful reference when assessing how prior exposures may affect the impacts of emission changes from the rule being analyzed, available at http://oaspub.epa.gov/eims/eimscomm.getfile?p_download_id=36941 (accessed November 2, 2010).

In addition, activities linked to a specific cultural background or socioeconomic status could expose populations to higher levels of pollution. For example, some indigenous peoples and immigrant populations rely on subsistence fishing which could result in higher mercury levels from consumption of fish or expose these populations to other forms of pollution if fishing occurs in contaminated waters (see Donatuto and Harper 2008).[51]

10.3 Children's Environmental Health

Distributional analysis may shed light on differential effects of regulation on children, a lifestage-defined group characterized by a multitude of unique behavioral, physiological, and anatomical attributes. There are two sets of important differences between children and adults regarding health benefits. First, there are differences in exposure to pollutants and in the nature and magnitude of health effects resulting from the exposure. Children may be more vulnerable to environmental exposures than adults because their bodily systems are still developing; they eat, drink, and breathe more in proportion to their body size; their metabolism may be significantly different — especially shortly after birth; and their behavior can expose them more to chemicals and organisms (e.g., crawling leads to greater contact with contaminated surfaces while hand-to-mouth and object-to-mouth contact is much greater for toddler age children). Second, individuals may systematically place a different economic value on reducing health risks to children than on reducing such risks to adults (U.S. EPA 2003).

EO 13045 requires that each federal agency address disproportionate health risks to children. In addition, EPA's Children's Health Policy requires the Agency "consider the risks to infants and children consistently and explicitly as a part of risk assessments generated during its decision making process, including the setting of standards to protect public health and the environment."[52]

Generally, many approaches described earlier in this chapter to characterize the distribution of impacts may be adapted to evaluate children's environmental health risks.[53] For example, when proximity-based analysis is appropriate for evaluating environmental justice impacts, it might also be used to examine whether children are disproportionately located near facilities of concern. In such a case, the considerations described earlier about geography, defining the baseline and comparison groups, and use of summary statistics would all apply.

10.3.1 Childhood as a Lifestage

Evaluating distributional impacts of regulatory actions on children differs in an important way from evaluating the same impacts on population groups of concern for EJ. When EPA evaluates disproportionate health risk impacts from environmental contaminants, it views childhood as a sequence of lifestages from conception through fetal development, infancy, and adolescence, rather than a distinct "subpopulation."

Use of the term "subpopulation" is ingrained in both EPA's past practices as well as various laws that EPA administers such as the Safe Drinking Water Act Amendments. Prior to publication of revised risk assessment guidelines in 2005,[54] EPA described all groups of individuals as "subpopulations." In the 2005 guidelines, the Agency recognizes the importance of distinguishing between groups that form a relatively fixed portion of the population, such as those described Section 3 of this document, and

51 It is also worth considering conditions that reduce a community's ability to participate fully in the decision-making process such as time and resource constraints, lack of trust, lack of information, language barriers, and difficulty in accessing and understanding complex scientific, technical, and legal resources (see Dietz and Stern 2008).

52 See http://yosemite.epa.gov/ochp/ochpweb.nsf/content/policy-eval_risks_children.htm (accessed on December 1, 2011).

53 In principle there is a potential distinction in distributional analysis to be made between factors that are fixed, such as race and sex, and those defined by lifestages. The latter raises the possibility, at least, of examining distribution concerns through the lens of differences in lifetime utility or well-being rather than focusing on a single lifestage. See Adler (2008) for one proposal consistent with this approach.

54 See http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=55907 (accessed on December 1, 2011).

lifestages or age groups that are dynamic groups drawing from the entire population.

The term "lifestage" refers to a distinguishable time frame in an individual's life characterized by unique and relatively stable behavioral and/or physiological characteristics associated with development and growth. Thus, since 2005 EPA characterizes childhood as a sequence of lifestages.[55]

10.3.2 Analytical Considerations

Assessing distributional consequences of policies that affect children's health requires considerations that span risk assessment, action development, and economic analysis. In each case there are existing Agency documents that can assist in the evaluation.

10.3.2.1 Risk Assessment

Effects of pollution can differ depending upon age of childhood exposure. Analysis of disproportionate impacts to children or from childhood lifestages begins with health risk assessment, but also includes exposure assessment. Many risk guidance and related documents address how to consider children and childhood lifestages in risk assessment.

A general approach to considering children and childhood lifestages in risk assessment is found in *A Framework for Assessing Health Risks of Environmental Exposures to Children* (U.S. EPA 2006a). The framework identifies existing guidance, guidelines and policy papers that relate to children's health risk assessment. It emphasizes the importance of an iterative approach between hazard, dose response, and exposure analyses. In addition, it includes a discussion of principles for weight of evidence consideration across life stages.

EPA's 2005 *Cancer Guidelines* (U.S. EPA 2005a) explicitly call for consideration of possible sensitive subpopulations and/or lifestages such as childhood. The *Cancer Guidelines* were augmented by *Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens*.[56] Recommendations from this supplement include calculating risks utilizing lifestage-specific potency adjustments in addition to lifestage-specific exposure values which should be considered for all risk assessments.

EPA's *Child-Specific Exposures Handbook* (U.S. EPA 2008b)[57] and *Highlights of the Child-Specific Exposure Factors Handbook* (U.S. EPA 2009a)[58] help risk assessors understand children's exposure to pollution. The handbook provides important information for answering questions about lifestage specific exposure through drinking, breathing, and eating. EPA's guidance to scientists on selecting age groups to consider when assessing childhood exposure and potential dose to environmental contaminants is identified in *Guidance on Selecting Age Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants* (U.S. EPA 2005c).

10.3.2.2 Action Development

Disproportionate impacts during fetal development and childhood are considered in EPA guidance on action development, particularly the *Guide to Considering Children's Health When Developing EPA Actions: Implementing Executive Order 13045 and EPA's Policy on Evaluating Health Risks to Children* (U.S. EPA 2006b). The guide helps determine whether EO 13045 and/or EPA's Children's Health Policy applies to an EPA action and, if so, how to implement the Executive Order and/or EPA's Policy. The guide clearly integrates EPA's Policy on Children's Health with the Action Development Process and provides an updated listing of additional guidance documents.

55 The 2005 Risk Assessment Guidelines "view childhood as a sequence of lifestages rather than viewing children as a subpopulation, the distinction being that a subpopulation refers to a portion of the population, whereas a lifestage is inclusive of the entire population." (U.S. EPA 2005, p 1-15).

56 Available at http://www.epa.gov/cancerguidelines/guidelines-carcinogen-supplement.htm (accessed on December 1, 2011).

57 Available at http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=199243 (accessed on December 1, 2011).

58 Available at http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=200445 (accessed on December 1, 2011).

10.3.2.3 Economic Analysis

While these *Economic Guidelines* provide general information on benefit-cost analyses of policies and programs, many issues concerning valuation of health benefits accruing to children are not covered. Information provided in the *Children's Health Valuation Handbook* (U.S. EPA 2003), when used in conjunction with the *Guidelines*, allows analysts to characterize benefits and impacts of Agency policies and programs that affect children.

The *Handbook* is a reference tool for analysts conducting economic analyses of EPA policies when those policies are expected to affect risks to children's health. A major emphasis of the *Handbook* is ensuring that a regulation or policy's economic impacts on children are fully considered in supporting analyses. This analysis includes incorporating children's health considerations in an assessment of efficiency, as well as in any distributional analysis focused on children. Decision makers may also find it useful to have information on a policy's specific impact on children's health, regardless of whether the impact heavily influences overall benefit-cost analysis.

Economic factors may also play a role in other analyses that evaluate children's environmental health impacts. For example, if a higher proportion of children live in poverty, the ability of households with children to undertake averting behaviors might be compromised. This type of information could inform the exposure assessment.

10.3.3 Intersection Between Environmental Justice and Children's Health

The burden of health problems and environmental exposures is often borne disproportionately by children from low-income communities and minority communities (e.g., Israel et al. 2005; Lanphear et al. 1996; Mielke et al. 1999; Pastor et al. 2006).

The challenge for EPA is to integrate both environmental justice and lifestage susceptibility considerations for children where appropriate when conducting distributional analysis. This is especially true when short-term exposure to environmental contaminants such as lead or mercury early in life can lead to life-long health consequences.

10.4 Other Distributional Considerations

10.4.1 Elderly

Another important lifestage to consider is that of the elderly.[59] While there are no standard procedures for including the elderly in a distributional analysis, EPA stresses the importance of addressing environmental issues that may adversely impact them. Most of the Agency's work in this area has been related to risk and exposure assessment.

Older adults may be more susceptible to adverse effects of environmental contaminants due to differential exposures arising from physiological and behavioral changes with age, disease status, drug interactions, as well as the body's decreased capacity to defend against toxic stressors. These considerations are highlighted in EPA's *Exposure Factors Handbook* (U.S. EPA 2011d) and have led EPA's Office of Research and Development to consider an exposure factors handbook specifically for the aging (see U.S. EPA 2007). Additionally, the toxicokinetic and toxicodynamic impacts of environmental agents in older adults have been considered in EPA's document entitled *Aging and Toxic Response: Issues Relevant to Risk Assessment* (U.S. EPA 2005b).[60]

10.4.2 Intergenerational Impacts

Concern for intergenerational impacts arises when those affected by a policy are not yet alive when the policy is developed. If a policy's benefits, costs, and impacts primarily fall upon the current

59 There is a lack of broad agreement about the beginning of the "elderly" lifestage. The U.S. and other countries typically define this lifestage to begin at the traditional retirement age of 65, but, for example, the U.N. defines "elderly" to begin at age 60 (U.S. EPA 2005b).

60 Available at http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=156648 (accessed on December 1, 2011).

generation, or if policy decisions are reversible within this time frame, there is little need for explicit consideration of intergenerational impacts. However, in other cases, benefits and/or costs of the policy will be borne by future generations, and it is important to consider impacts on these generations. One such case would be policies to reduce greenhouse gases, which are expected to result in benefits related to reduced changes in climate for future generations. Other examples may relate to toxic chemical exposures. Exposures to parents prior to their child's conception can result in adverse health effects in the child, including effects that may not become apparent until the child reaches adulthood.[61]

Assessing intergenerational impacts can be related to the social welfare function approach, described in Text Box 10.1 of this chapter, and to social discounting. In both cases, normative judgments need to be made about which there is no consensus. Under the Ramsey approach to intergenerational discounting, this judgment is reflected in a "pure rate of time preference" parameter that weighs the welfare of current and future generations. See Section 6.3.1 for more information on intergenerational discounting and debate about the value of this parameter. One way to clarify distributional consequences if intergenerational impacts are important is to display time paths of benefits and costs without discounting, as recommended in Chapter 6 of these *Guidelines*.

10.5 Conclusion

This chapter provides a variety of tools, analytical considerations and guidance for conducting distributional analyses for environmental justice, children's environmental health and other factors. Tools and methods are intended to be flexible enough to accommodate various data and other constraints associated with particular scenarios, while introducing consistency and rigor in the way regulatory analyses consider distributional effects.

Methods for analyzing distributional impacts in the context of EJ, in particular, are continually being discussed, debated, and improved. For instance, EPA is in the process of developing more specific guidance on considering environmental justice concerns when planning human health risk assessments (U.S. EPA 2012b). Updates to this chapter about strengths and limitations of various analytical options, as well as new approaches, will be added when appropriate.

61 See U.S. EPA (2006a) and WHO (2007). The latter is available at http://www.who.int/ipcs/features/ehc/en/index.html (accessed on January 11, 2013).