Appendix C – Basics of Visibility and Regional Haze

Glossary of Terms

Aerosols: Suspensions of tiny liquid and/or solid particles in the air.

Ammonium Nitrate (NH_4NO_3): Ammonium nitrate is formed in the atmosphere from reactions involving nitrogen dioxide (NO_2) emissions, which are dominated by anthropogenic sources. Common sources include virtually all combustion activities, especially those involving cars, trucks, power plants, and other industrial processes.

Ammonium Sulfate ($(NH_4)2SO_4$): Ammonium sulfate is formed in the atmosphere from reactions involving sulfur dioxide (SO2) emissions. Anthropogenic sources include coal burning power plants and other industrial sources, such as smelters, industrial boilers, and oil refineries, and to a lesser extent, gasoline and diesel combustion.

Anthropogenic: Produced by human activities.

Area Sources: Sources that are treated as being spread over a spatial extent (usually a county or air district) and that are not movable (as compared to non-road mobile and on-road mobile sources). Because it is not possible to collect the emissions at each point of emission, they are estimated over larger regions. Examples of stationary area sources are residential heating and architectural coatings. Numerous sources, such as dry cleaning facilities, may be treated either as stationary area sources or as point sources.

BART: Best Available Retrofit Technology, a process under the CAA to evaluate the need and, if warranted, install the most effective pollution controls on an already existing air pollution source.

Baseline period: The baseline period, or baseline conditions, is the basis against which improvements in worst day visibility, and lack of degradation for the best day visibility, are judged. For initial RHR implementation plan purposes, the baseline is the average visibility impairment as measured by IMPROVE monitors during the 2000-2004 5-year period.

Biogenic Emissions: Biogenic emissions are based on the activity fluxes modeled from biogenic land use data, which characterizes the types of vegetation that exist in particular areas. Emissions are generally derived using modeled estimates of biogenic gas-phase pollutants from land use information, emissions factors for different plant species, and meteorology data.

Class I area: As defined in the Clean Air Act, areas that were in existence as of August 7, 1977: national parks over 6,000 acres, national wilderness areas and national memorial parks over 5,000 acres, and international parks.

Clean Air Act (CAA): The basic framework for controlling air pollutants in the United States, originally adopted in 1963, and amended in 1970, 1977, and 1990. The CAA was designed to "protect and enhance" air quality. Section 169A of the Clean Air Act (CAA), established in the 1977 Amendments, set forth a national goal for visibility which is the ''prevention of any future, and the remedying of any existing, impairment of visibility in Federal Class I areas (CIAs) which impairment results from manmade air pollution.''

Coarse Mass (CM): Coarse mass refers to the mass of large particles greater than 2.5 and smaller than 10 μm in diameter.

Colorado Plateau: A high, semi-arid tableland in southeast Utah, northern Arizona, northwest New Mexico, and western Colorado.

Current conditions: For purposes of this report, current conditions represent the most recent successive 5-year average after the 2000-2004 baseline conditions, or the 2005-2009 period.

Deciview (dv): The deciview metric is used to track regional haze in the RHR. The Haze Index measured in deciviews) was designed to be linear with respect to human perception of visibility. A one deciview change is approximately equivalent to a 10% change in extinction, whether visibility is good or poor. A one deciview change in visibility is generally considered to be the minimum change the average person can detect.

Dust: Dust emissions may have a variety of sources that could include anthropogenic sources, natural sources, and natural sources that may be influenced by anthropogenic activity. Fugitive dust includes sources such as road dust, agricultural operations, construction and mining operations and windblown dust from vacant lands. Windblown dust includes more of the natural influences such as wind erosion on natural lands.

Elemental Carbon (EC): Elemental carbon is the primary light absorbing compound in the atmosphere. These particles are emitted directly into the air from virtually all combustion activities, but are especially prevalent in diesel exhaust and smoke from wild and prescribed fires.

Environmental Protection Agency (EPA): The EPA is an agency of the U.S. federal government which was created for the purpose of protecting human health and the environment by writing and enforcing regulations based on laws passed by Congress.

Extinction (bext): Extinction is a measure of the fraction of light lost per unit length along a sight path due to scattering and absorption by gases and particles, expressed in inverse Megameters (Mm-1).

Fine Soil: Particulate matter composed of pollutants from the Earth's soil that enters the air from dirt roads, fields, and other open spaces as a result of wind, traffic, and other surface mechanical disturbance activities. Fine soil includes soil particles with an aerodynamic diameter less than 2.5 microns.

Fire: Fire sources may have a mix of natural and anthropogenic influences. Natural sources include wildland fires, while anthropogenic sources can include agricultural and prescribed fires.

First progress period: For purposes of this report, the first progress period represents the most recent successive 5-year average after the 2000-2004 baseline conditions, or the 2005- 2009 period.

Grand Canyon Visibility Transport Commission (GCVTC): In 1990, amendments to the Clean Air Act established the Commission to advise the EPA on strategies for protecting visual air quality on the Colorado Plateau.

Haze index (HI): The Haze Index (measured in deciviews) is used to track regional haze in the RHR. It was designed to be linear with respect to human perception of visibility, where a one deciview change is approximately equivalent to a 10% change in extinction, whether visibility is good or poor. A one deciview change in visibility is generally considered to be the minimum change the average person can detect.

Interagency Monitoring of Protected Visual Environment (IMPROVE): A collaborative monitoring program governed by a steering committee composed of representatives from Federal and regional-state organizations to establish present visibility levels and trends, and to identify sources of man-made impairment

Inverse megameters, (Mm-1): A measurement unit used for light extinction, the higher the value, the hazier the air is.

Least impaired days: The least impaired, or best days, refers to the average visibility impairment (measured in deciviews) for the twenty percent of monitored days in a calendar year with the lowest amount of visibility impairment.

Light extinction: A measure of how much light is absorbed or scattered as it passes through a medium, such as the atmosphere. Aerosol light extinction refers to the absorption and scattering by aerosols. Total light extinction refers to the sum of aerosol light extinction, the absorption of gases (such as NO2), and the atmospheric light extinction (Rayleigh scattering). Extinction is often expressed as a measure of the fraction of light lost per unit length in units of inverse Megameters (Mm-1).

Mandatory Federal Class I areas: Certain national parks (over 6,000 acres), wilderness areas (over 5,000 acres), national memorial parks (over 5,000 acres), and international parks that were in existence as of August 1977.

Most impaired days: The most impaired, or worst days, refers to the average visibility impairment (measured in deciviews) for the twenty percent of monitored days in a calendar year with the highest amount of visibility impairment.

Natural background condition: Naturally occurring phenomena that reduce visibility as measured in terms of light extinction, visual range, contrast, or coloration.

Natural conditions: Natural conditions include any naturally occurring phenomena that reduce visibility as measured in terms of light extinction, visual range, contrast, or coloration.

Off-Road Mobile Sources: Off-road mobile sources are vehicles and engines that encompass a wide variety of equipment types that either move under their own power or are capable of being moved from site to site. Examples include agricultural equipment such as tractors or combines, aircraft, locomotives and oil field equipment such as mechanical drilling engines.

Off-shore: Commercial marine emissions comprise a wide variety of vessel types and uses. Emissions can include deep draft vessels within shore and near port using port call data, and offshore emissions generated from ship location data.

Oil and Gas Sources: Oil and gas sources consist of a number of different types of activities from engine sources for drill rigs and compressor engines, to sources such as condensate tanks and fugitive gas emissions. The variety of emissions types for sources specific to oil and gas activity can, in some cases, overlap with mobile, area or point sources, but these can also be extracted and treated separately.

On-Road Mobile Sources: Vehicular sources that travel on roadways. Emissions from these sources can be computed either as being spread over a spatial extent or as being assigned to a line location (called a link). Emissions are estimated as the product of emissions factors and activity data (vehicle miles traveled (VMT). Examples of on-road mobile sources include light-duty gasoline vehicles and heavy-duty diesel vehicles.

Oxides of nitrogen (NO_X): A mixture of nitrogen dioxide and other nitrogen oxide gases. Nitrogen is the most common gas in the atmosphere. In high temperature and/or high pressure burning (as in an engine), the air's nitrogen is broken down and combined with oxygen, forming unstable or reactive NO_X gases. Nitrogen dioxide (NO_2) is yellowish brown, and thus contributes directly to haze. All the NO_X gases react in the air to form haze-causing aerosols and smog.

Particulate Organic Mass (POM): Particulate organic mass can be emitted directly as particles, or formed through reactions involving gaseous emissions. Natural sources of organic carbon include wildfires and biogenic emissions. Man-made sources can include prescribed forest and agricultural burning, vehicle exhaust, vehicle refueling, solvent evaporation (e.g., paints), food cooking, and various commercial and industrial sources.

Point Sources: These are sources that are identified by point locations, typically because they are regulated and their locations are available in regulatory reports. In addition, elevated point sources will have their emissions allocated vertically through the model layers, as opposed to being emitted into only the first model layer. Point sources can be further subdivided into electric generating unit (EGU) sources and non-EGU sources, particularly in criteria inventories in which EGUs are a primary source of NO_X and SO_2. Examples of non-EGU point sources include chemical manufacturers and furniture refinishers.

Prevention of significant deterioration (PSD): A program established by the Clean Air Act Amendments of 1977 that limits the amount of additional air pollution that is allowed in Class I and Class II areas.

Rayleigh: Light scattering of the natural gases in the atmosphere. At an elevation of 1.8 kilometers, the light extinction from Rayleigh scattering is approximately 10 inverse megameters (Mm-1).

Reasonable progress: Reasonable progress refers to progress in reducing human-caused haze in Class I areas under the national visibility goal. The Clean Air Act indicates that "reasonable" should consider the cost of reducing air pollution emissions, the time necessary, and the energy and non-air quality environmental impacts of reducing.

Reconstructed aerosol extinction: The percent of total atmospheric extinction attributed to each aerosol and gaseous component of the atmosphere.

Regional haze: Regional haze refers to visibility impairment that is caused by the emission of air pollutants from numerous sources located over a wide geographic area.

Regional Haze Rule (RHR): Federal rule that requires states to develop programs to assure reasonable progress toward meeting the national goal of preventing any future, and remedying any existing, impairment of visibility in mandatory Class I Federal areas.

Relative humidity: Partial pressure of water vapor at the atmospheric temperature divided by the vapor pressure of water at that temperature, expressed as a percentage.

Scattering efficiency: The amount of light scattered relative to the particle's size.

Scattering: An interaction of light with an object (e.g., a fine particle) that causes the light to be redirected in its path.

Sea Salt: Sea salt is a natural aerosol emitted in coastal areas. In practice, chloride ion measurements are used to represent sea salt in IMPROVE measurements, and measurements may sometimes show anthropogenic or crustal influences at inland monitors.

Sulfur Dioxide (SO_2): SO_2 gas is associated with emissions from processes such as burning fuels, manufacturing paper, or smelting rock. SO2 is converted in the air to other sulfur oxides (SO_X) or haze-causing aerosols (sulfates).

State Implementation Plans (SIPs): A detailed description of the programs a state will use to carry out its responsibilities under the Clean Air Act. State implementation plans are collections of the regulations used by a state to reduce air pollution. Plans devised by states and tribes to carry out their responsibilities under the Clean Air Act. SIPs and TIPs must be approved by the U.S. Environmental Protection Agency and include public review.

Visibility impairment: Any humanly perceptible change in visibility (light extinction, visual range, contrast, coloration) from that which would have existed under natural conditions.

Visibility: Refers to the visual quality of the view, or scene, in daylight with respect to color rendition and contrast definition. The ability to perceive form, color, and texture.

Visual Range (VR): Visual range is the greatest distance a large black object can be seen on the horizon, expressed in kilometers (km) or miles (mi).

Volatile organic compound (VOC): A carbon-containing material that evaporates, such as gasoline, some paints, solvents, dry cleaning fluids, and the like. VOCs contribute to the formation of particulate organic mass.

Western Regional Air Partnership (WRAP): A partnership of state, tribal and federal land management agencies to help coordinate implementation of the GCTVC's recommendation.

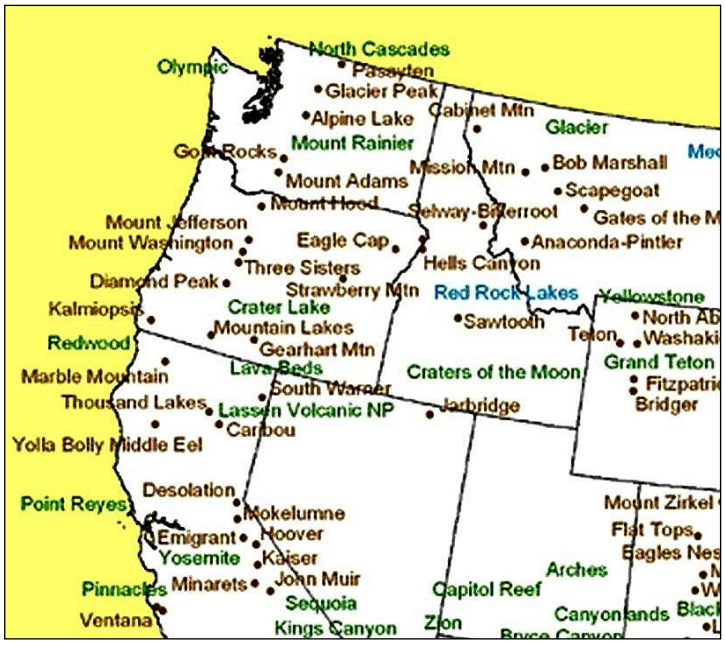
Overview of Visibility and Regional Haze

Good visibility is essential to the enjoyment of national parks and scenic areas. Visibility impairment occurs as a result of the scattering and absorption of light by particles and gases in the atmosphere. This affects the clarity and color of what we see. Without the effects of air pollution, natural visual range is approximately 140 miles in the West and 90 miles in the East. However, over the years, air pollution in many parts of the United States has significantly reduced the range that people can see. In the West, the current range is 35-90 miles, and in the East, only 15-25 miles.

Regional haze is air pollution that is transported long distances and reduces visibility in national parks and wilderness areas. The pollutants that create this haze are sulfates, nitrates, organic carbon, elemental carbon, and soil dust. Human-caused haze sources include industry, motor vehicles, agricultural and forestry burning, and windblown dust from roads and farming practices.

The federal Regional Haze Rule requires states to improve visibility over the next 60 years in 156 national parks and wilderness areas in the country. In 1977, Congress designated all wilderness areas over 5,000 acres and all national parks over 6,000 acres as "mandatory federal Class I areas" (or "Class I areas" for short). These Class I areas receive special visibility protection under the Clean Air Act. The figure below**Error! Reference source not found.** shows the Class I areas located in the Pacific Northwest.

Class I Areas in the Pacific Northwest



Visibility Pollutants in Oregon

Pollutants, Aerosol Species and Major Sources in Oregon

Emitted Pollutant	Related Aerosol	Major Sources	Notes
Sulfur Dioxide (SO_2)	Ammonium Sulfate	Point Sources; On- and Off-Road Mobile Sources	SO_2 emissions are generally associated with anthropogenic sources such as coal-burning power plants, other industrial sources such and refineries and cement plants, and both on- and off-road diesel engines.
Oxides of Nitrogen (NO_X)	Ammonium Nitrate	On- and Off-Road Mobile Sources; Point Sources; Area Sources	NO_X emissions are generally associated with anthropogenic sources. Common sources include virtually all combustion activities, especially those involving cars, trucks, power plants, and other industrial processes.
Ammonia (NH_3)	Ammonium Sulfate and Ammonium Nitrate	Area Sources; On-Road Mobile Sources	Gaseous NH_3 has implications in particle formation because it can form particulate ammonium. Ammonium is not directly measured by the IMPROVE program, but affects formation potential of ammonium sulfate and ammonium nitrate. All measured nitrate and sulfate is assumed to be associated with ammonium for IMPROVE reporting purposes.
Volatile Organic Compounds (VOCs)	Particulate Organic Mass (POM)	Biogenic Emissions; Vehicle Emissions; Area Sources	VOCs are gaseous emissions of carbon compounds, which are often converted to POM through chemical reactions in the atmosphere. Estimates for biogenic emissions of VOCs have undergone significant updates since 2002, so changes reported here are more reflective of methodology changes than actual changes in emissions.
Primary Organic Aerosol (POA)	POM	Wildfires; Area Sources	POA represents organic aerosols that are emitted directly as particles, as opposed to gases. Wildfires in the west generally dominate POA emissions, and large wildfire events are generally sporadic and highly variable from year-to-year.
Elemental Carbon (EC)	EC	Wildfires; On- and Off-Road Mobile Sources	Large EC events are often associated with large POM events during wildfires. Other sources include both on- and off-road diesel engines.
Fine soil	Soil	Windblown Dust; Fugitive Dust; Road Dust; Area Sources	Fine soil is reported here as the crustal or soil components of $PM_{2.5}$.
Coarse Mass (PMC)	Coarse Mass	Windblown Dust; Fugitive Dust	Coarse mass is reported by the IMPROVE Network as the difference between PM_{10} and $PM_{2.5}$ mass measurements. Coarse mass is not separated by species in the same way that $PM_{2.5}$ is speciated, but these measurements are generally associated with crustal components. Similar to crustal $PM_{2.5}$, natural windblown dust is often the largest contributor to PMC.

The following sections describe the basic plan elements and key concepts underlying the Oregon Regional Haze Plan.

Natural Sources of Visibility Impairment

Natural sources, particularly wildfire and windblown dust, can be major contributors to visibility impairment. However, these emissions cannot be realistically controlled or prevented by the states, and therefore the focus of the regional haze strategies in this document are on human-caused (anthropogenic) sources, as described below. While current methods of analysis of monitoring data do not provide a clear distinction between natural and anthropogenic emissions, certain pollutant species, such as sulfur dioxide (SO_2) and nitrogen oxide (NOx) are more representative of anthropogenic sources, while organic carbon (OC) and coarse particulate matter (PM10) are more representative of natural sources such as wildfire and dust, respectively.

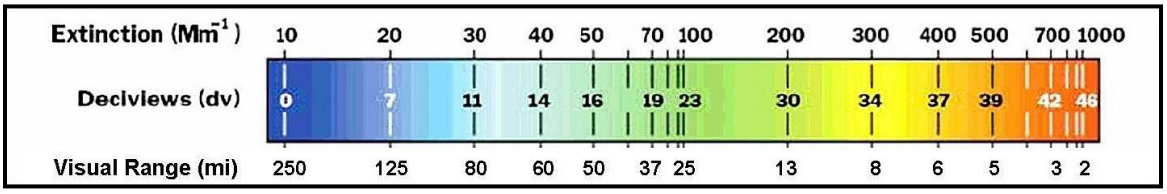
Human-Caused Sources of Visibility Impairment

Anthropogenic or human-caused sources of visibility impairment include anything directly attributable to human-caused activities that produce emissions of visibility-impairing pollutants. Some examples include industry, transportation, agriculture activities, home heating, and managed outdoor burning. Anthropogenic sources can be local, regional, or international. Efforts to regulate anthropogenic emissions are mostly limited to inside the United States. Emissions from Mexico & Canada, and off-shore marine shipping emissions in the Pacific Ocean, are examples of anthropogenic sources that contribute to visibility impairment in Oregon that are beyond the control of the state.

Visibility Measurement

Visibility impairment is measured by a network of monitors that capture pollution and calculate the light scatter effect of each pollutant such as carbon, sulfur and ammonia. The main metric describing visibility impairment is the deciview.

Each IMPROVE monitor collects particulate concentration data which are converted into reconstructed light extinction through a complex calculation using the IMPROVE equation. Reconstructed light extinction (denoted as bext) is expressed in units of inverse megameters (1/Mm or Mm-1). The Regional Haze Rule requires the tracking of visibility conditions in terms of the Haze Index metric expressed in the deciview (dv) unit (40 CFR 51.308(d)(2)). Generally, a one deciview change in the haze index is considered a humanly perceptible change under ideal conditions, regardless of background visibility conditions. The relationship between extinction (Mm-1), haze index (dv) and visual range (mi) are indicated by the following scale:



Baseline and Current Conditions

The Regional Haze Rule requires the calculation of baseline conditions for each Class I area. Baseline conditions are defined as the five year average (annual values for 2000 - 2004) of IMPROVE monitoring data (expressed in deciviews) for the most-impaired (20% worst) days and the least-impaired (20% best) days. For the first regional haze plan submittal, the baseline conditions are the reference point against which further visibility improvement is tracked. For future plan progress reports and updates, baseline conditions are used to calculate progress from the beginning of the regional haze program. Current conditions for the best and worst days are calculated from a multiyear average, based on the most recent 5-years of monitored data available. This value will be revised at the time of each periodic plan revision, and will be used to illustrate: (1) The amount of progress made since the last plan revision, and (2) the amount of progress made from the baseline period of the program.

Natural Conditions

The visibility that would exist under natural conditions (absent any man-made impairment) would vary based on the contribution of natural sources and meteorological conditions on a given day. For that reason, natural conditions, as defined in this document, consists of a level of visibility (in deciviews) for both the most-impaired (20% worst) days and the least-impaired (20 % best) days. Since no visibility monitoring data exists from the pre-manmade impairment period, these estimates of natural conditions are based on EPA guidance on how to estimate natural conditions.

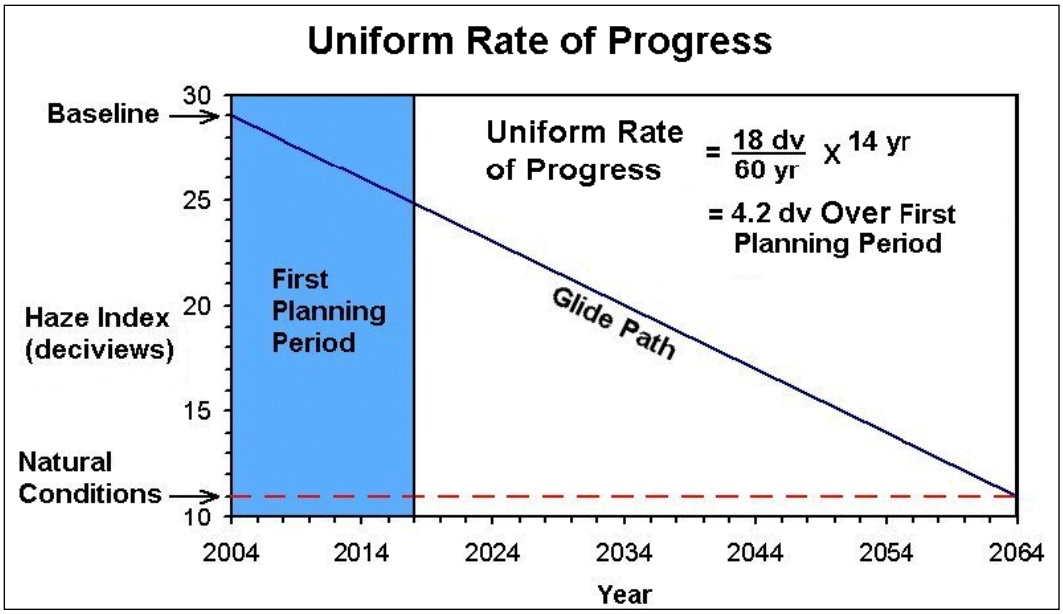
Reasonable Progress Goals

For each Class I area the State must establish goals (measured in deciviews) that provide for reasonable progress towards achieving natural visibility conditions. The reasonable progress goals (RPG) are interim goals that represent incremental visibility improvement over time for the most-impaired (20% worst) days and no degradation in visibility for the least-impaired (20% best) days. The first regional haze plan that States must submit to EPA needs to include RPGs for the year 2018, also known as the "2018 milestone year". The State has flexibility in establishing different RPGs for each Class I area. In establishing the RPG, DEQ considered four factors: the costs of compliance; the time necessary for compliance; the energy and non-air quality environmental impacts of compliance; and the remaining useful life of any potentially affected sources. DEQ demonstrated how these factors were taken into account when establishing the RPGs in the 2010 plan.

Uniform Rate of Progress

The uniform rate of progress is the calculation of the slope of the line between baseline visibility conditions and natural visibility conditions over the 60-year period. For the first regional haze plan, the first benchmark is the deciview level that should be achieved in 2018, as indicated in blue below as the first planning period. This is 2018 Milestone, and applies to both the 20% worst days and the 20% best days.

Example of Uniform Rate of Progress Determination



- Compare baseline conditions to natural conditions. The difference between these two represents the amount of progress needed to reach natural visibility conditions. In this example, the State has determined that the baseline for the 20 percent worst days for the Class I area is 29 dv and estimated that natural background is 11 dv, a difference of 18 dv.

- Calculate the annual average visibility improvement needed to reach natural conditions by 2064 by dividing the total amount of improvement needed by 60 years (the period between 2004 and 2064). In this example, this value is 0.3 dv/yr.

- Multiply the annual average visibility improvement needed by the number of years in the first planning period (the period from 2004 until 2018). In this example, this value is 4.2 dv. This is the uniform rate of progress that would be needed during the first planning period to attain natural visibility conditions by 2064.

The URP is not a presumptive target. When establishing RPGs, the State may determine RPGs at greater, lesser or equivalent visibility improvement than the URP. In cases where the RPG results in less improvement in 2018 than the URP, the State must demonstrate why the URP is not achievable, and why the RPGs are "reasonable".

For the 20% worst days, the URP is expressed in deciviews per year (i.e. slope of the glide path) is determined by the following equation:

URP = [Baseline Condition - Natural Condition] / 60 years

The 2018 Progress Goal (i.e. the amount of reduction necessary for the 1st planning period) is determined by multiplying the URP by the number of years in the 1st planning period.

2018 Progress Goal = [Uniform ROP] x [14 years]

The 14 years comprising the 1st planning period includes the 4 years between the baseline and the SIP submittal date plus the standard 10-year planning period.

Long-Term Strategy

The Regional Haze Rule also requires States to submit a long-term strategy that includes enforceable measures to achieve reasonable progress goals. The long-term strategy must identify all anthropogenic sources inside the State that are affecting Class I areas both inside and outside the State. The first long-term strategy will cover 10 to 15 years, with reassessment and revision of those goals and strategies in 2018 and every 10 years thereafter. At a minimum, the following factors must be considered in developing the long-term strategy:

- Measures to mitigate the impact of construction activities;
- Emission limitations and schedules for compliance to achieve the RPG;
- Source retirement and replacement schedules;
- Smoke management techniques for agricultural and forestry burning, including plans to reduce smoke impacts;
- Enforceability of emission limitations and control measures; and
- The anticipated net affect on visibility due to projected changes in point, area, and mobile source emissions over the period addressed of the long term strategy.

Best Available Retrofit Technology

The RPGs, the long-term strategy, and BART are the three main elements of a Regional Haze Plan. Best Available Retrofit Technology requirements apply to certain older industrial facilities that began operating before national rules were adopted in 1977 to prevent new facilities from causing visibility impairment. BART applies to facilities built between 1962 and 1977, have potential emissions greater than 250 tons per year, and which fall into one of 26 specific source categories. These facilities must be evaluated to see how much they contribute to regional haze and if retrofitting with controls is feasible and cost effective.

The BART process consists of three-steps: (1) determining BART-eligibility; (2) determining is a source is “subject to BART” by conducting modeling of Class I visibility impacts; and (3) conducting an analysis of BART controls (retrofitting) for those sources subject to BART that contribute to regional haze.

In determining BART controls, the State must take into account several factors, including the existing control technology in place at the source, the costs of compliance, energy and non-air environmental impacts of compliance, remaining useful life of the source, and the degree of visibility improvement that is reasonably anticipated from the use of such technology.