West Elk Wilderness Area

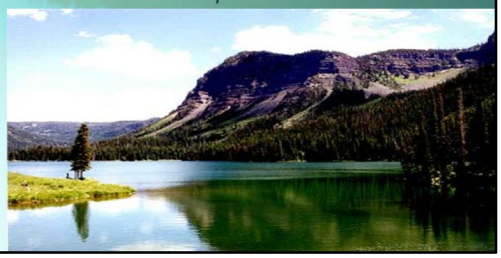
Regional Haze in Colorado: State Implementation Plan Process & Visibility Results

Society of Women Environmental Professionals (SWEP)

November 15, 2012

Lisa Clarke, Air Pollution Control Division

Flat Tops Wilderness Area



A State Implementation Plan (SIP) is a plan that is administered by the U.S. Environmental Protection Agency (EPA) in compliance with the federal Clean Air Act. The Colorado Regional Haze SIP is the culmination of about seven years of work. I want to acknowledge the significant contributions of fellow colleagues Curt Taipale, Kirsten King, Roland Hea, and Chuck Machovec who provided key engineering and modeling assistance on this project. I also want to recognize Tom Moore with the Western Regional Air Partnership (WRAP) who led the development of many data products used in this SIP and others.

Breakdown

- Background & History
  - National Goal
  - Class I Areas
  - Visibility/Monitoring/Metrics
- History
  - Litigation – Consent Decree
  - Colorado Regional Haze Plan Development
- RH Plan Elements
- Emission Control Evaluation
- Balancing Visibility with Controls

Mount Zirkel Wilderness Area

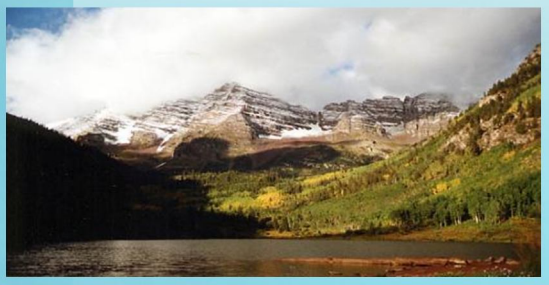
Weminuche Wilderness Area

2

Who here in this room is familiar with Regional Haze? The Colorado experience with Regional Haze is a monstrous topic to cover in 30 minutes, so I am going to focus mostly on the emission control process and ultimate visibility benefits from one pollutant – Nox (nitrogen oxides). I will also cover some background and history to start us off. Please feel free to ask me questions as I go if you don't understand something or if you would like to know more about a particular item.

Visibility Protection - National Goal

Congress… *"declares as a national goal the **prevention of any future** and **remedying of any existing impairment** of visibility in any mandatory Class I Federal areas which impairment results from man-made air pollution"*
(1977 Clean Air Act, §169A)



Maroon Bells-Snowmass Wilderness Area

Great Sand Dunes National Park & Preserve

3

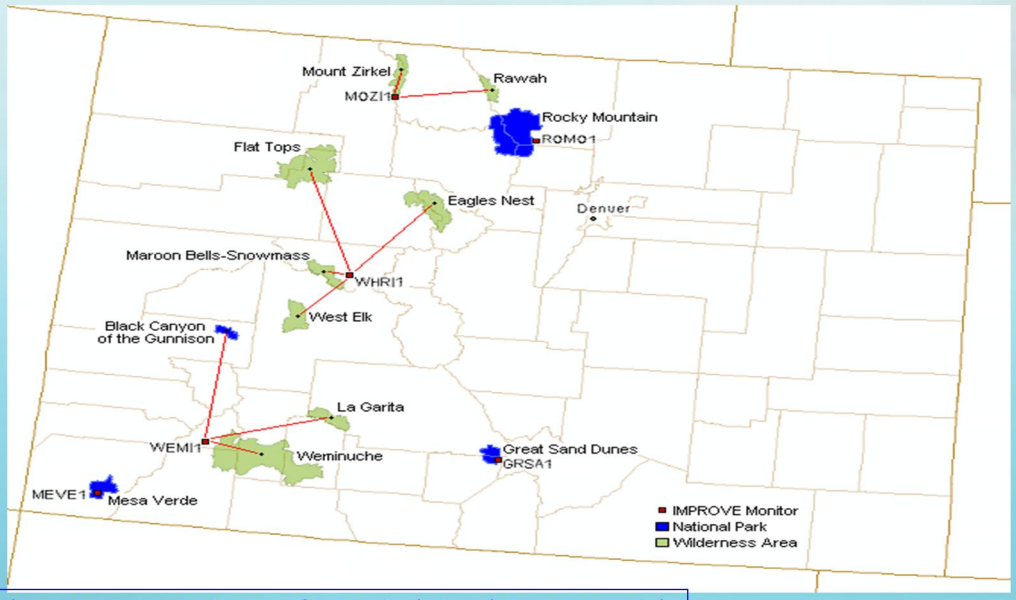
In the 1977 Clean Air Act, Congress set a national goal of preventing future visibility impairment and remedying any existing visibility impairment at Class I federal areas. What is a Class I federal area you might be wondering. The answer is a bit complicated (of course, has anyone read environmental regulations?), but basically these area include national parks, national wilderness areas, and national monuments. These areas are designated by Congress to have special air quality protections under the CAA.

This goal is ambitious and probably won't be realized in our lifetimes for most Class I area in the Western states, because of international pollution transport and events such as dust storms and wildfires that are occurring more and more frequently.

Regional Haze visibility protection is a goal-based aesthetic program unlike the National Ambient Air Quality Standards (NAAQS) which are health-based standards, so the rules of the game are much different for regulations and processes.

Another challenge in determining which impacts are from man-made pollution versus natural pollution. Living in Colorado, we have all walked out in the forests. That wonderful organic "foresty" smell? Volatile organic compounds, or VOCs, which contribute to regional haze. The current visibility monitoring network doesn't provide information on air pollution sources, only levels of various particulates, which I will explore further later.

Class I Areas & IMPROVE Monitors



(Interagency Monitoring of Protected Visual Environments)

4

There are 156 Class I areas in the nation. About 72% of these areas are west of the Mississippi.

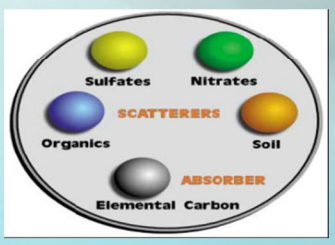
This is a map of Colorado that shows the location of the 12 Class I areas in our state including 4 national parks denoted in blue and 8 wilderness areas (in light green)

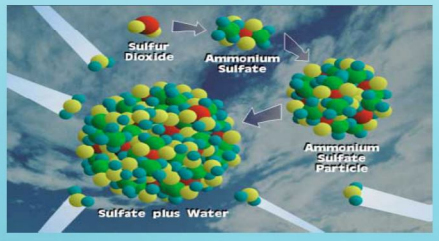
The visibility conditions are monitored by six IMPROVE sites (denoted by the little red boxes). IMPROVE is a cooperative measurement effort governed by a steering committee composed of representatives from Federal and regional-state organizations. It was established in 1985 to aid the creation of Federal and State implementation plans for visibility protection.
Website: http://vista.cira.colostate.edu/improve/Default.htm

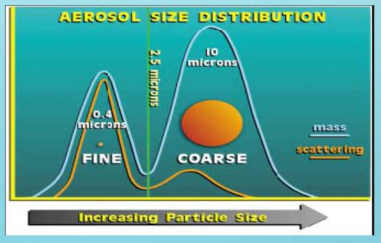
Some monitors represent more than one Class I area. Every IMPROVE site deploys an aerosol sampler to measure speciated fine aerosols and PM10 mass. Certain sites also deploy Transmissometer and nephelometers to measure light extinction and scattering respectively, as well as automatic camera systems to measure the "scene" The equipment has the ability to measure over long distances, which is why one monitor can represent multiple areas.

Visibility Impairment - Particles

- **Six particle components to extinction**
  - Sulfate (ammonium sulfate) *secondary particle*
  - Nitrate (ammonium nitrate) *secondary particle*
  - OC (organic carbon) *primary or secondary particle*
  - EC (elemental carbon) *primary particle*
  - Soil (≤ PM2.5) *primary particle*
  - Coarse Mass (PM10) *primary particle*
- **Sulfate particles can grow with increased humidity**







5

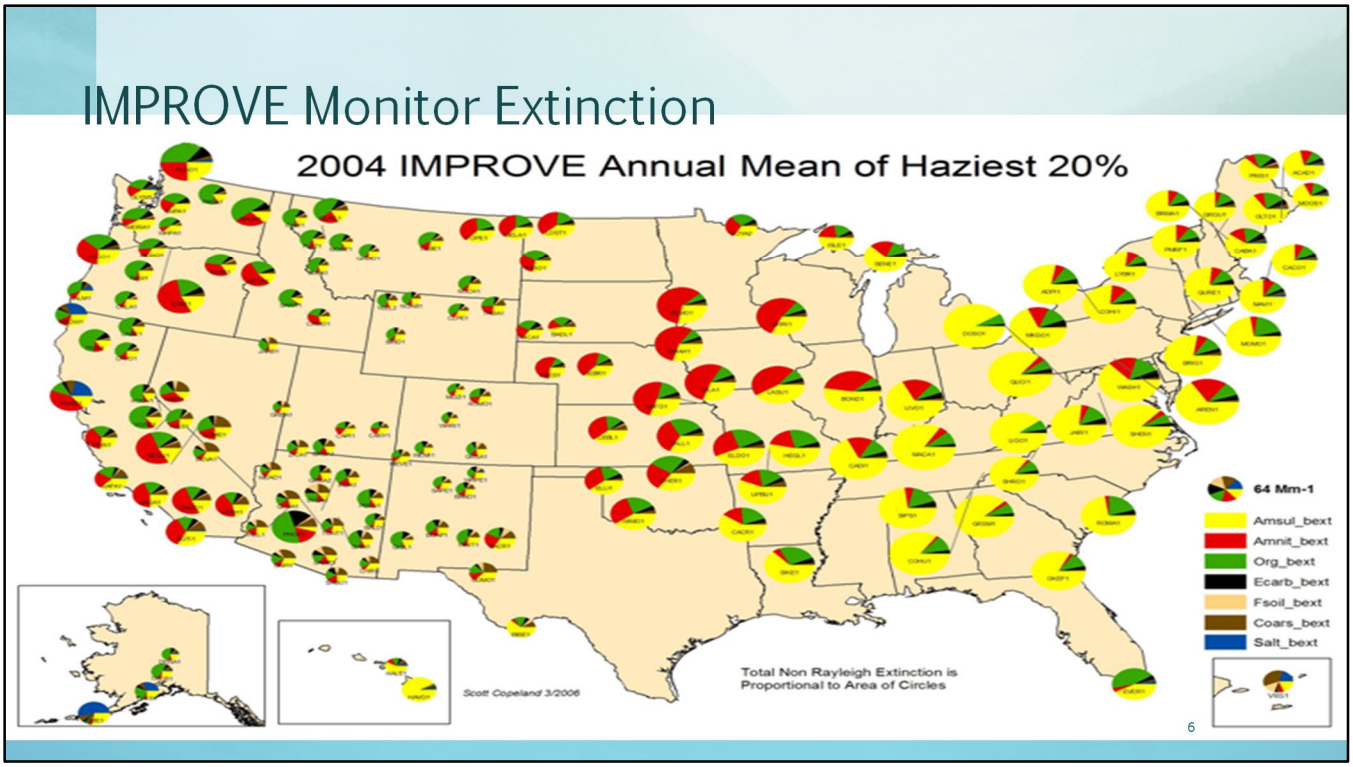
Most visibility impairment is caused by particulate scattering, absorption, and reflection of image forming light. There are six primary particulate components that are measured by the IMPROVE monitors.

Sulfate is a secondary particle formed form gaseous SO2 emission reacting with ammonia to form Ammonium Sulfate.

Similarly, Nox emissions react with ammonia to form a secondary Ammonium Nitrate particle.

Organic Carbon can be directly emitted as a particle or formed as a secondary particulate.

Elemental Carbon, Soil, and Coarse Mass are assumed to be directly emitted as particulates.



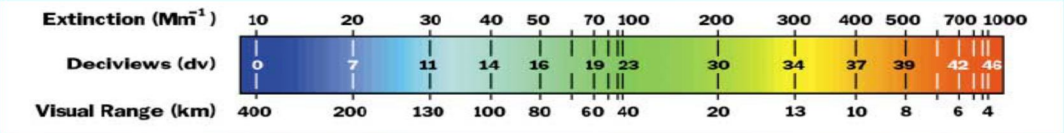
This map shows the 2004 annual data for the 20% worst days at each IMPROVE monitor in the nation.

The different colors denote the six primary particulates: Sulfate in yellow, Nitrate in red, Organic Carbon in green, Elemental Carbon, Soil in light brown, and Coarse Mass in dark brown.

The diameter of the pie indicates the magnitude of the visibility extinction (basically degradation). Generally, the intermountain west has some of the best visibility in the country.

Visibility Metrics

- Each IMPROVE monitor measures various chemical species of particles reported by IMPROVE in concentrations (ug/m3).
- IMPROVE Algorithm/Equation
  - Reconstructed light extinction (b_{ext}) is calculated from concentrations of various particulate species, expressed in inverse megameters (Mm^{-1})
- Conversion to Haze Index
  - The Regional Haze Rule requires tracking of visibility conditions in terms of the Haze Index (HI) expressed in the deciviews (dv)
  - The conversion equation: $HI = 10\ ln(b_{ext}/10)$
  - Main advantage over extinction: A change in 1 dv unit is likely perceptible in ideal conditions, regardless of background conditions



7

I mentioned the equipment that each IMPROVE monitor uses, but how do they actually work? Each monitor has a number of cartridges that sample the air every 3-dyas that are sent to a variety of labs to determine speciation of the particulates.

The resultant data is processed through an equation – called the IMPROVE equation that yields “reconstructed light extinction” in the metric of inverse mega meters.

The conversion equation is used to convert reconstructed light extinction to haze index in deciviews.

The colored bar indicates the conversion to other visibility metrics including visual range in kilometers and the Haze Index in deciviews. The deciview is how we track progress under the Regional Haze Rule.

This photo shows a visual side-by-side comparison of the modeled visibility impairement using the WinHaze Model. Can you see the difference?

The scene is divided along the center of the summit of Longs Peak and shows a 2 dv change between the 14 dv on the right (the hazier perception) and 12 dv on the left (the clearer perception).

The main advantage of the Haze Index is that one deciview of change is generally considered perceptible by most people.

I should note that for the SIP that Colorado just completed, the change for Rocky was 1 dv for the worst days (2002 vs. 2018).

Litigation

La Garita Wilderness Area

- RH SIPs due date - December 17, 2007
- 2009 EPA makes finding of Failure to Submit RH SIPs
  - 14 States submitted a complete SIP
  - 5 States submitted a partial SIP (including Colorado)
  - 34 States/Territories/Districts failed to submit SIP
  - Starts 2-year Federal Implementation Plan (FIP) clock
- 2011 Environmental Groups enter into a Consent Decree (CD) with EPA on four states (CO, MT, ND & WY)
  - Sets specific schedule for EPA proposing approval/disapproval of SIP or promulgating a FIP
- 2012 Environmental Groups enter into a CD with EPA on remaining States/Territories/Districts

9

It is hard to discuss Regional Haze without talking about past litigation. I wanted to show a little history because it provides context about what transpired in Colorado.

Colorado did submit a partial Regional Haze SIP back in 2008, but EPA indicated it wasn't approvable.

In 2009, EPA made a national finding of failure-to-submit a RH SIP on a number of states that started a two-year clock for a Federal Implementation Plan.

In 2011, environmental groups entered into a consent decree with EPA involving Colorado, Montana, North Dakota, and Wyoming (all of these states are part of one EPA Region)

And EPA entered into another consent decree with remaining states, etc. the next year

In late 2009, EPA indicated that they would withhold a significant amount of Colorado Air Grant money to pay for the RH FIP work that would be done by consultants.

Colorado then avoided a FIP by agreeing to work closely with EPA on developing an approvable RH plan.

For a period of approximately 6 months, the state had weekly meetings with EPA to coordinate the SIP development work.

In early 2010, coincident with the RH SIP work, the Colorado Legislature approved the CACJ act that encouraged the use of natural gas and other cleaner energy sources, which ultimately became a large component of the Colorado's RH SIP.

On September 10, 2012, EPA formally approved Colorado's Regional Haze Plan. It has not been published in the Federal Register yet.

The Regional Haze Rule requires that each state establish reasonable progress goals (in deciviews) for each Class I area based on future projections of modeled visibility impairment for the 20% worst days.

The 20% cleanest days (or Best Days) must be maintained, which is addressed in the long-term strategy (LTS).

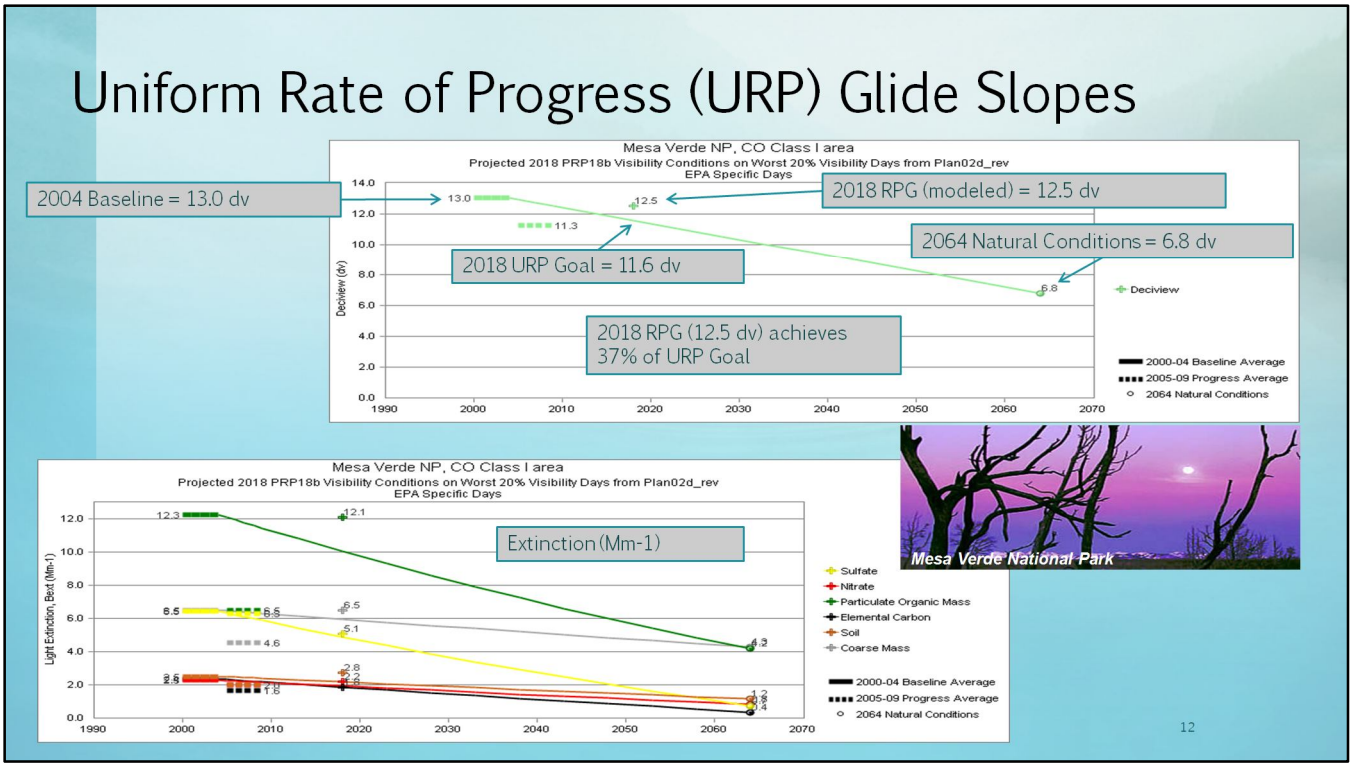
The LTS specifies the ongoing air pollution control programs the state has implemented to protect air quality – including some you may be familiar with, new source review (NSR), prevention of signification deterioration (PSD), smoke management and other initiatives.

The monitoring strategy evaluates the effectiveness of the IMPROVE monitoring network to ensure the data continues to be representative for all class I areas.

The state must also consult with Federal Land Managers (National Park Service, Bureau Land Management, Forest Service) to ensure that they have input in the plan development process that affects the Class I areas they manage.

Regional Haze is a 60-year program, so periodic plan updates are necessary every 10-years and progress reports are required every 5 years.

Uniform Rate of Progress (URP) Glide Slopes



How do we decide how much visibility progress is needed in each planning cycle? The upper graph shows the uniform rate of progress glide slope for the 20% worst days (in deciviews) at Mesa Verde National Park.

The 2004 baseline period is 13.0 dv and the 2064 Natural Conditions is 6.8 dv. The 2018 uniform rate of progress goal is 11.6 dv. The little green plus sign about the URP glide slope denotes the modeled 2018 reasonable progress goal of 12.5 dv.

The lower graph shows the URP glide slope for the 20% worst days for the six components of visibility extinction. This allows for assessing progress for each pollutant. You can see that for organic carbon (in green), the RPG is well above the URP goal, whereas for sulfate (in yellow), the RPG is much closer to the URP goal.

The take way from these glide slops is that we are not on schedule for achieving natural conditions by 2064, not only in Mesa Verde, but in all of Colorado's Class I areas. Based on the current rate of progress for Mesa Verde, we expect to reach natural conditions by 2168, which is 164 years from the 2004 baseline year. The earliest we can hope to meet natural conditions in Colorado is in the Eagles Nest, Flat Tops, Maroon Bells, and West Elk Wilderness Areas in 2083 (79 years from baseline year).

Point Sources Evaluated for Control

- Best Available Retrofit Technology (BART) Sources
  - Subject-to-BART applicability
    - Source has units listed under the 26 "major" source categories
    - Unit built between 1962 – 1977
    - Source visibility impact at CIA is >0.5 deciview
  - Number of Colorado BART Sources = 9 facilities (15 units)
    - 14 units are coal-fired boilers, 1 unit is a cement kiln
- Reasonable Progress (RP) Sources
  - Subject-to-RP applicability
    - Source has actual emissions of SO2, NOx or PM over 100 tpy
    - Source Q/d >20 (sum of SO2, NOx and PM)/(distance to CIA)
  - Number of Colorado RP Sources = 10 facilities (15 units)
    - 14 units are coal-fired boilers, 1 unit is a cement kiln

Hayden Power Plant

13

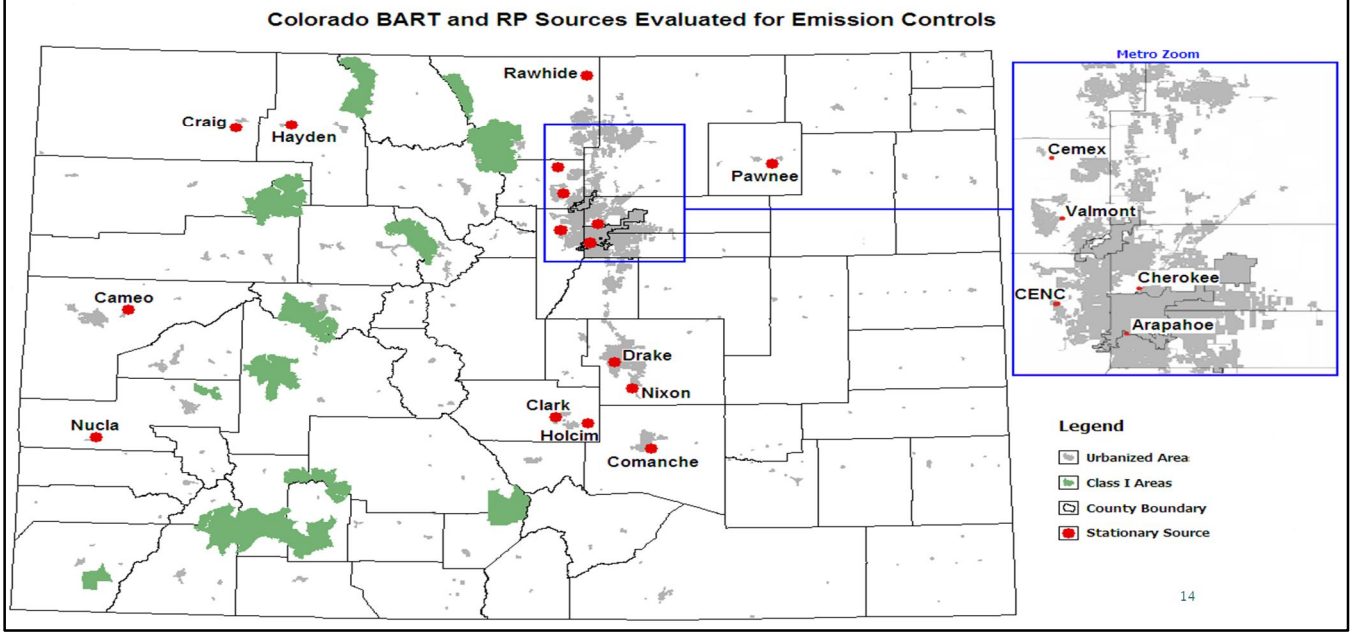
OK, well that was a super quick tutorial of visibility and Regional Haze.

Now onto a discussion of source controls.

The first group of point sources evaluated for emission controls under the visibility are what we called BART (Best Available Retrofit Technology) sources. These stationary sources have potential to emit over 100 tons per year and belong to a defined "list of 26" major emitting facilities. The source must have units built between 1962 and 1977 and the sources modeled impact must be greater than 0.5 deciviews at a Class I area. There are 15 units that meet this criteria in Colorado.

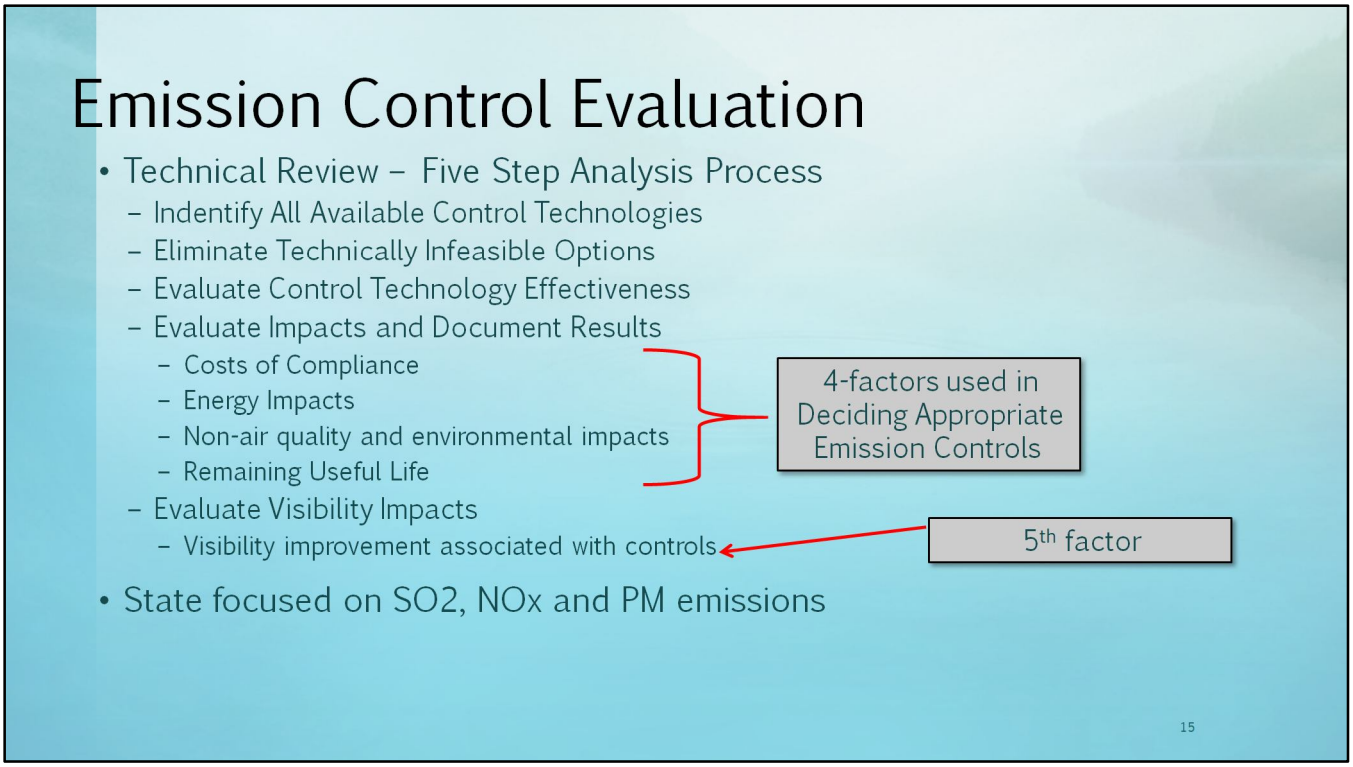
The next group of sources the state evaluated are called Reasonable Progress sources that have actual emission over 100 tpy and have a "Q over d" ratio over 20. Where "Q" is the sum of SO2, Nox, and PM10 actual emissions in tpy and "d" is the distance from the centroid of the source to the boundary of a C1A in kilometers. If a source exceeds 20, the source is subject-to-RP. Any units at sources that have already been evaluated under the BART review process are excluded from the RP review. The number of RP units is 15.

Location of Sources Relative to ClAs



This map shows the location of the sources relative to the 12 Class I areas.

The 30 BART & RP units are located at the 16 sources identified on the map. The C1As are denoted in green and populated areas are gray.



Back in 2005, the EPA promulgated a Best Available Retrofit Technology (BART) rule that requires a 5-step process for systematically evaluating emission controls.

The steps include identifying all emission controls for a particular pollutant, eliminating the technically infeasible options, evaluating the cost and effectiveness of controls, looking at the impacts and assessing the modeled visibility improvement from the various control options. The RP review process is similar except that time necessary for compliance is also a factor.

It is important to note that in this first planning period, the state decided to focus on 3 of the 6 components of visibility extinction: sulfate, nitrate, and particulate matter.

The other 3 components – OC, EC, and soil are less understood and the emission sources are not well characterized. This is an important decision because it narrowed the emission review process down to SO2, Nox, and PM10.

EGU – Evaluation Criteria for NOx

- For coal-fired electric generating units (EGUs), Colorado determined that two of the 5-factors should be given more weight in deciding potential post combustion NOx controls
- For the top tier post combustion NOx control technology – Selective Catalytic Reduction (SCR):
  - Cost of Control – must be <$5,000/ton of NOx removed
  - Degree of Visibility Improvement – must be ≥ 0.5 Δ deciview
- For the 2nd tier post combustion control technology – Selective Non-Catalytic Reduction (SNCR):
  - Cost of Control – must be <$5,000/ton of NOx removed
  - Degree of Visibility Improvement – must be ≥ 0.2 Δ deciview
- If an EGU didn't meet the above criteria, other NOx control technologies were evaluated (e.g., newer Low NOx Burners, Ultra-LNB, Over Fire Air and Separated-OFA, Enhanced Combustion Controls)

16

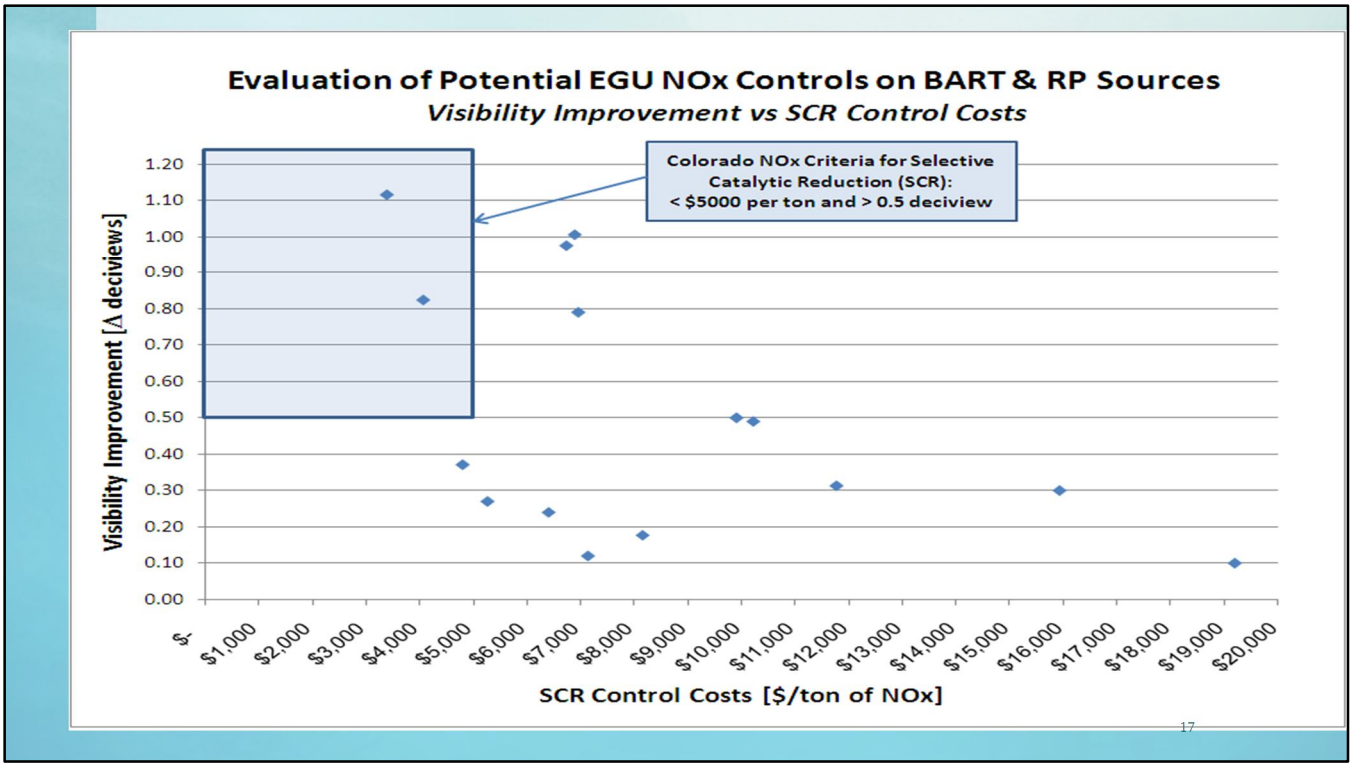
In the interest of time, I will focus on our largest group of sources, the coal-fired boilers that are used for generating electricity and limit the discussion to Nox controls because this pollutant has received the most scrutiny (and has the most potential for reduction after other CAA rules controlled other pollutants) in the Regional Haze process.

EGUs comprise over 90% of the sources involved in the BART and RP emission control evaluation and range in size from 20 MW to over 500 MW.

The 5-factor evaluation involves a case-by-case analysis of all technically feasible Nox controls. The state decided two of the 5-factors should be given more weight in the Nox evaluation process – control cost and degree of visibility improvement.

All BART/RP EGUs in the state have some variety of low Box burners, but none have any post combustion controls such as Selective Catalytic Reduction (SCR), which the top tier Nox control, or Selective Non-Catalytic Reduction.

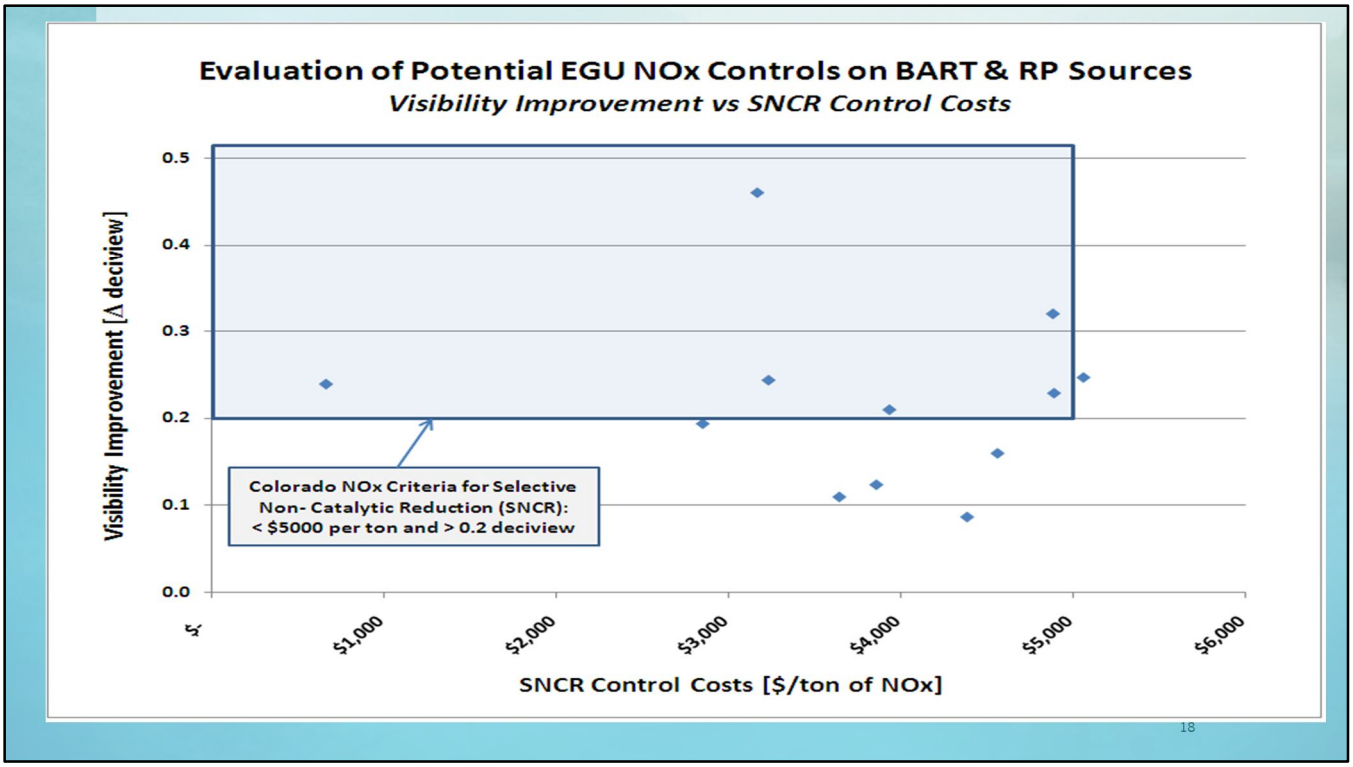
MAYBE SAY: Basically, an SCR reduces Nox through a reaction with ammonia on the surface of a catalyst to produce elemental nitrogen and water. The ammonia is injected upstream of the catalyst where the exhaust temperature is around 700ºF/ An SNCR lacks the catalyst so the exhaust temperature needs to be much higher, around 2000ºF, to get the desired reaction.



This graph plots the top-tier SCR control costs for 15 units, in dollars per ton on the x-axis and the degree of visibility improvement, in deciviews, on the y-axis.

There are 13 EGUs missing from this chart because 9 units are shutting down, SCR was determined to be technically infeasible on one unit and three units were part of a better-than-BART alternative plan where the costs were not shared (one of these units did install SCR and two converted to natural gas).

The little blue box reflects the state's review criteria for SCR controls (under $5,000 per ton and over 0.5 dv of visibility improvement). You can see that 2 of the units satisfy the SCR control criteria. These are units 1 and 2 at the Hayden Power Plant in the northwest corner of our state, about 30 miles west of Steamboat Springs.



This graph plots the second tier SNCR control costs for 13 units (minus the two Hayden units) in dollars per ton and degree of visibility improvement in deciviews.

The blue box represents the states review criteria for SNCR controls (under $5,000 per ton and over 0.2 dv of visbiility improvement). You can see that 6 units fall into the SNCR control criteria. These are units 1, 2, and 3 at the Craig Power Plant in the northwest portion of Colorado (40 miles west of Steamboat Springs), unit 5 at Colorado Energy Nations Company (which powers Coors Brewing in Golden), unit 1 at Rawhide (the main power plant for Fort Collins), and unit 7 at Drake (in central Colorado Springs).

3 of the 6 units ended up using different controls that resulted in equivalent or better visibility improvements at a lower cost except for the Craig Power Plant. TriState, owners of Craig, reached an agreement with the Environmental Coalition group during negotiations that resulted in use of SCR controls on Craig unit 2.

Balancing Visibility Improvement with Emission Controls

Facility	Unit	Review Type	NOx Final Determinations				SO2 Final Determinations			
			Emission Reduction [tons/year]	Assumed Control Technology (*Italics-Existing* /Bold-new)	Control Costs [$/ton]	CALPUFF Visibility Improvement [Δ dv]	Emission Reduction [tons/year]	Assumed Control Technology (*Italics-Existing* /Bold-new)	Control Costs [$/ton]	CALPUFF Visibility Improvement [Δ dv]
PSCo Cameo	1 & 2	RP	1,140	**Shutdown**	-	not modeled	2,618	**Shutdown**	-	not modeled
Cemex	Kiln	BART	846	**SNCR**	$ 1,934	0.41	-	-	-	-
CENC (TriGen)	3	RP	-	-	-	not modeled	-	-	-	not modeled
	4	BART	214	**LNB-SOFA**	$ 3,234	0.08	-	-	-	-
	5	BART	354	**LNB-SOFA-SNCR**	$ 4,918	0.26	-	-	-	-
PSCo Comanche	1	BART	-	*LNB*	-	-	-	*Semi-Dry FGD*	-	-
	2	BART	-	*LNB*	-	-	-	*Semi-Dry FGD*	-	-
TriState Craig	1	BART	727	*ULNB* **-SNCR**	$ 4,877	0.31	-	*Wet FGD*	-	0.03
	2	BART	3,975	*ULNB* **-SCR**	$ 6,299	0.98	-	*Wet FGD*	-	0.03
	3	RP	853	*ULNB* **-SNCR**	$ 4,887	0.32	-	*Semi-Dry FGD*	-	-
Holcim-Florence	Kiln	RP	1,028	*SNCR*	$ 2,293	0.29	-	*Wet Lime Scrubber*	-	-
CSU Drake	5	BART	215	**ULNB-OFA**	$ 1,342	0.08	762	**DSI**	$ 1,760	0.12
	6	BART	509	**ULNB-OFA**	$ 664	0.20	2,368	**FGD**	$ 2,808	0.24
	7	BART	749	**ULNB-OFA**	$ 616	0.26	3,764	**FGD**	$ 2,345	0.39
PSCo Hayden	1	BART	3,032	*LNB* **-SCR**	$ 3,385	1.12	61	*Semi-Dry FGD*	$ 2,317	0.10
	2	BART	3,120	*LNB* **-SCR**	$ 4,064	0.85	39	*Semi-Dry FGD*	$ 3,626	0.21
CSU Nixon	1	RP	707	**ULNB-OFA**	$ 1,372	0.16	3,215	**Semi-Dry FGD**	$ 3,744	0.46
TriState Nucla	1	RP	-	*SNCR* **-Study**	-	-	-	*LI* **- Study**	-	-
PRP Rawhide	1	RP	448	*LNCFS-SOFA* **-ECC**	$ 644	0.45	-	*Semi-Dry FGD*	-	-
PSCo Arapahoe	3	BART Alt	1,770	**Shutdown**	-	not modeled	925	**Shutdown**	-	not modeled
	4	BART Alt	248	**Convert to NG**	-	not modeled	1,764	**Convert to NG**	-	not modeled
PSCo Cherokee	1	BART Alt	1,556	**Shutdown**	-	not modeled	2,221	**Shutdown**	-	not modeled
	2	BART Alt	2,895	**Shutdown**	-	not modeled	1,888	**Shutdown**	-	not modeled
	3	BART Alt	1,866	**Shutdown**	-	not modeled	743	**Shutdown**	-	not modeled
	4	BART Alt	2,211	**Convert to NG**	-	not modeled	2,127	**Convert to NG**	-	not modeled
PSCo Pawnee	1	BART Alt	3,135	**LNB-SCR**	<$5,000	0.32	11,066	**Semi-Dry FGD**	<$ 3,000	0.68
PSCo Valmont	5	BART Alt	2,314	**Shutdown**	-	not modeled	758	**Shutdown**	-	not modeled
Black Hills Clark	1 & 2	RP	861	**Shutdown**	-	not modeled	1,457	**Shutdown**	-	not modeled

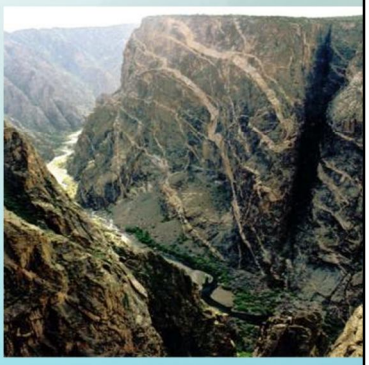
19

I realize that this table might be a little to read (and understand!) but it is a complete summary of the final Nox and SO2 determinations for the 30 BART / RP units evaluated for controls along with the control costs and modeled visibility improvement.

The existing controls are denoted in italics and new controls are in bolded text.

Balancing Visibility with Costs

- Differences in Visibility Models
  - BART and RP sources modeled using CALPUFF
    - Specific to each source
    - Each source modeled in isolation
  - CIA RPGs established using Regional Model – CMAQ
    - IMPROVE data used to calibrate model visibility estimates
    - Visibility benefit final controls not known
      - Final emission reductions beyond 2018(b) baseline were not modeled
        - NOx = 30,678 tons/yr (11% of projected 2018 NOx statewide)
        - SO2 = 13,807 tons/yr (24% of projected 2018 SO2 statewide)
- Total Emission Control Costs of Colorado RH SIP:
  - $1.75 Billion on 16 Facilities with 30 BART/RP Units



Black Canyon of the Gunnison National Park

20

In closing, I should mention that comparing visibility benefits realized through the BART and RP emission controls are not directly comparable to the modeled Reasonable Progress goals for each Class I area because the models are different.

So, we really don't know the total visibility improvement at all! It is difficult to discern because each Class I area has unique geographical constraints and pollutant contributions.

Although, I think it is reasonable to conclude that over 44,000 tons of additional Nox and SO2 reductions should lower the RPGs for most of Colorado's ClAs.

The total capital cost for installing all of the SO2 and Nox emission controls, including shutdowns and replacements on 30 units, is around 1.75 billion dollars. Wow.

Eagles Nest Wilderness

Thank you!

Lisa Clarke –
303-692-3117

Lisa.Clarke@state.co.us

More details on the Colorado RH SIP:
http://www.cdphe.state.co.us/ap/regionalhaze.html