Air Quality Management & Mitigation

Karl Schmidt

DIEDRICH® ROASTERS

Overview

- Impact of Environmental Control on Coffee Roasters
- Pollution Occurs at Every Step
- Chemical Elements and Emissions in Roaster Exhaust
- Environmental Regulations and Permits
- Emissions and Abatement
- Thermal and Catalytic Oxidizers
- Roasting Cycle and Exhaust Elements
- Smoke Abatement Technology Innovations

Impact of Environmental Control on Coffee Roasters

Budget:

- Fines for violating regulations
- New equipment for compliance
- Energy usage

Corporate responsibility:

- Environmental awareness and stewardship
- Social responsibility of minimizing smoke and odor

Environmental issues to consider:

- What is your environmental footprint?
- Which state and local regulations apply?
- Which control equipment is best for you?

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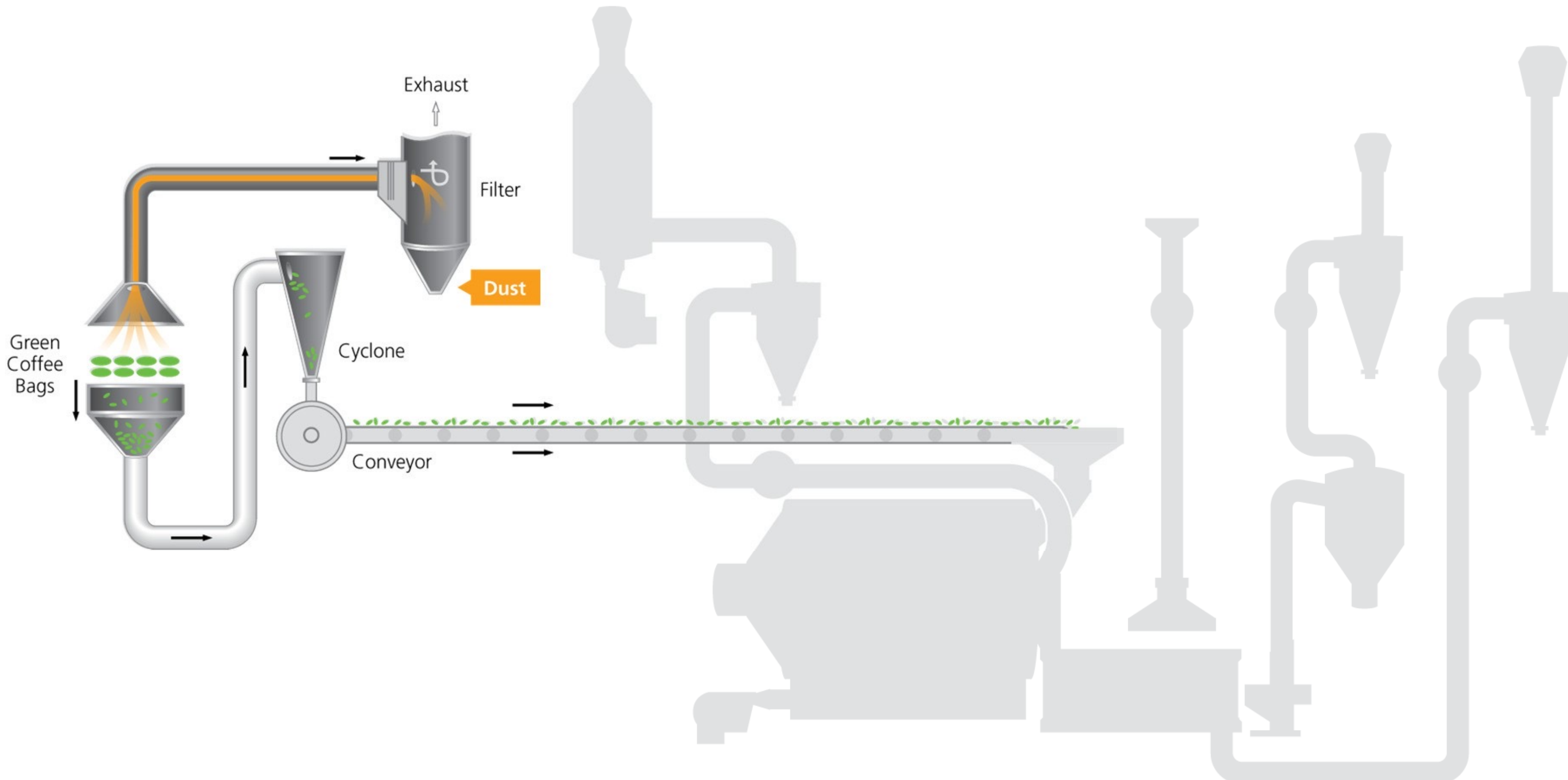
Location, Zoning, Utilities and Permitting

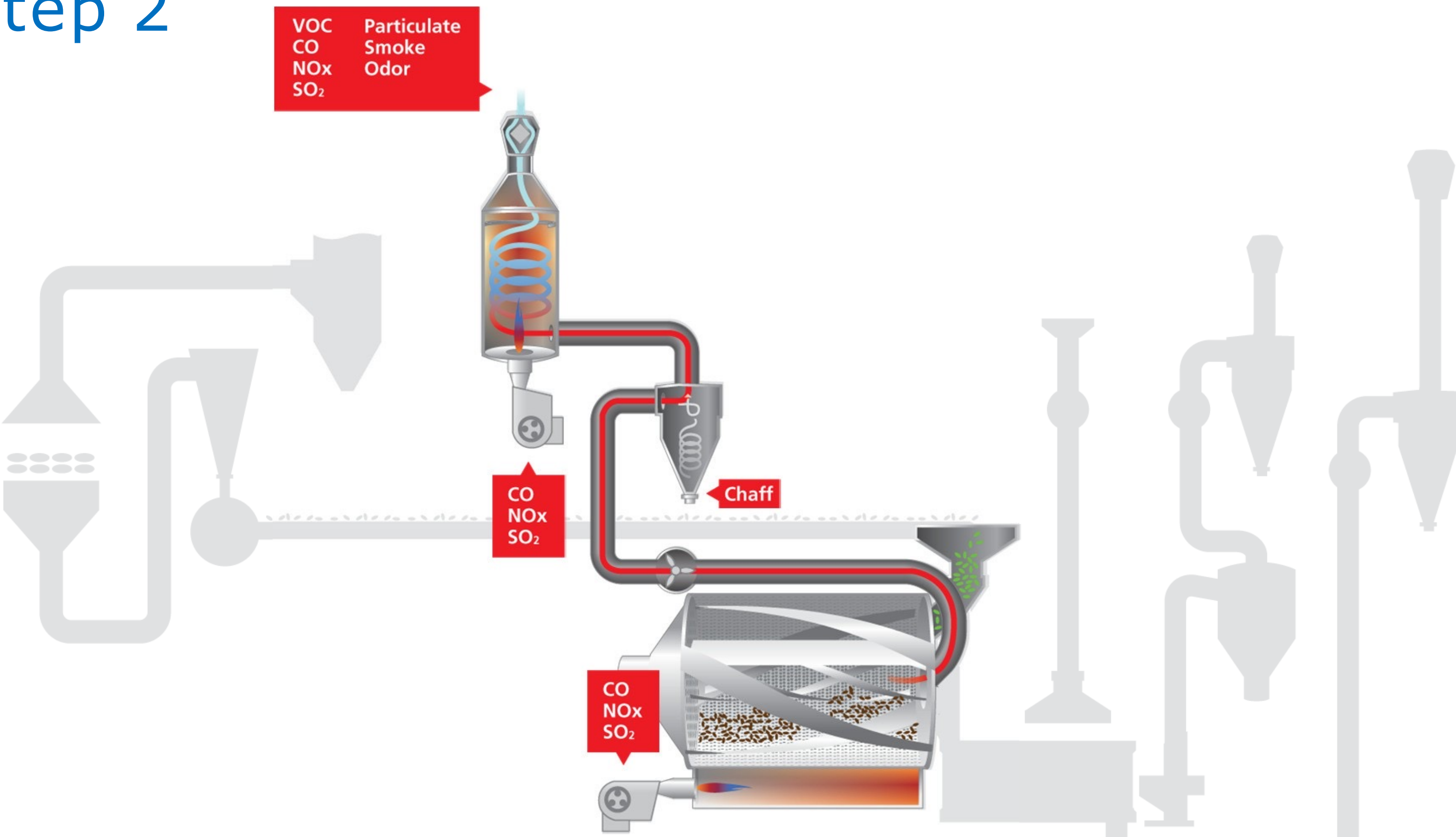
Things to consider:

- Location
- Current zoning
- Truck traffic
- Your neighbors
- Traffic studies
- Utilities
- Closest fire department and street hydrant
- Neighbor impact on your permit application
- Be prepared to educate the AQMD if there are no other roasters in their district or investigate the current BACT list

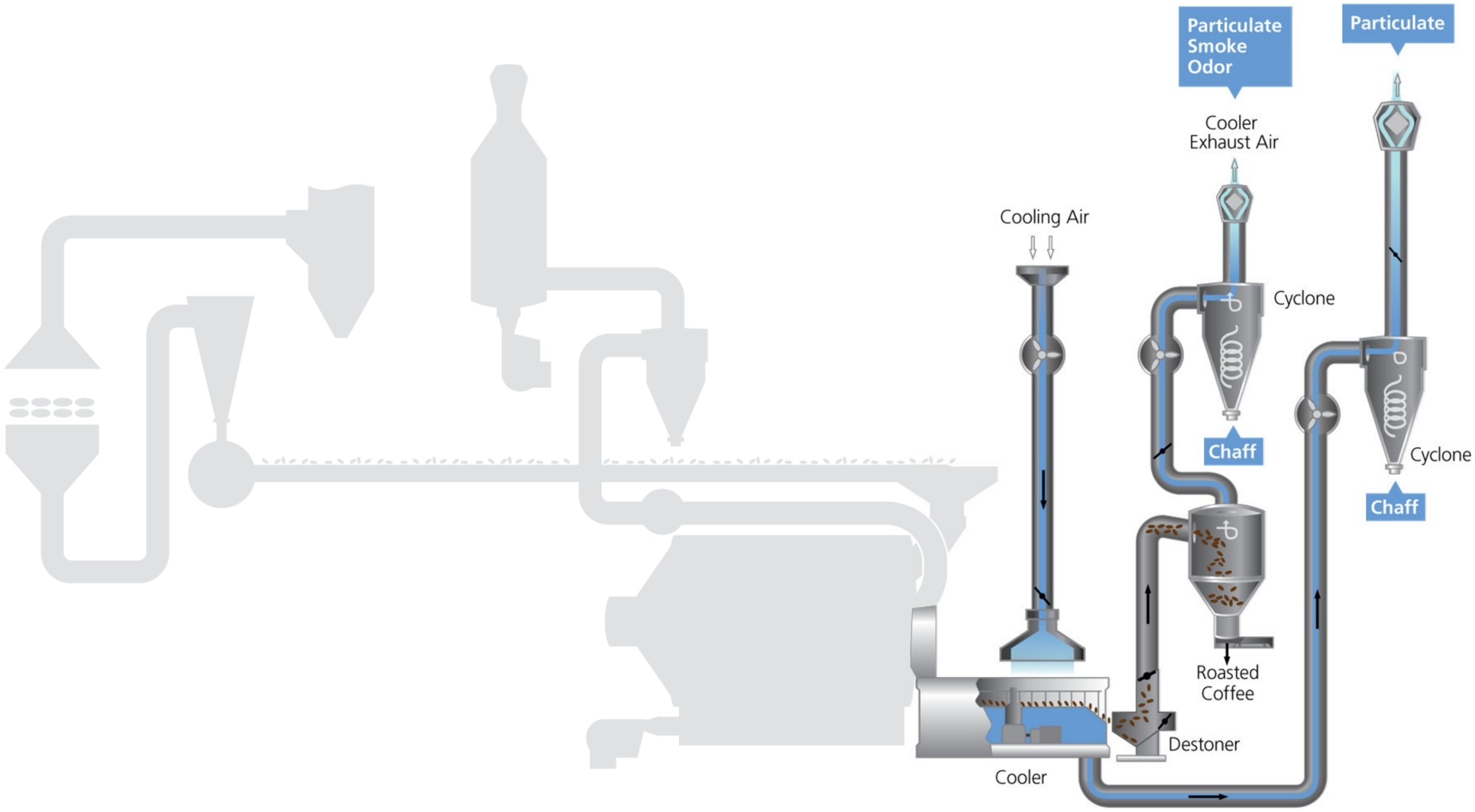
Pollution Occurs at Every Step: Step 1



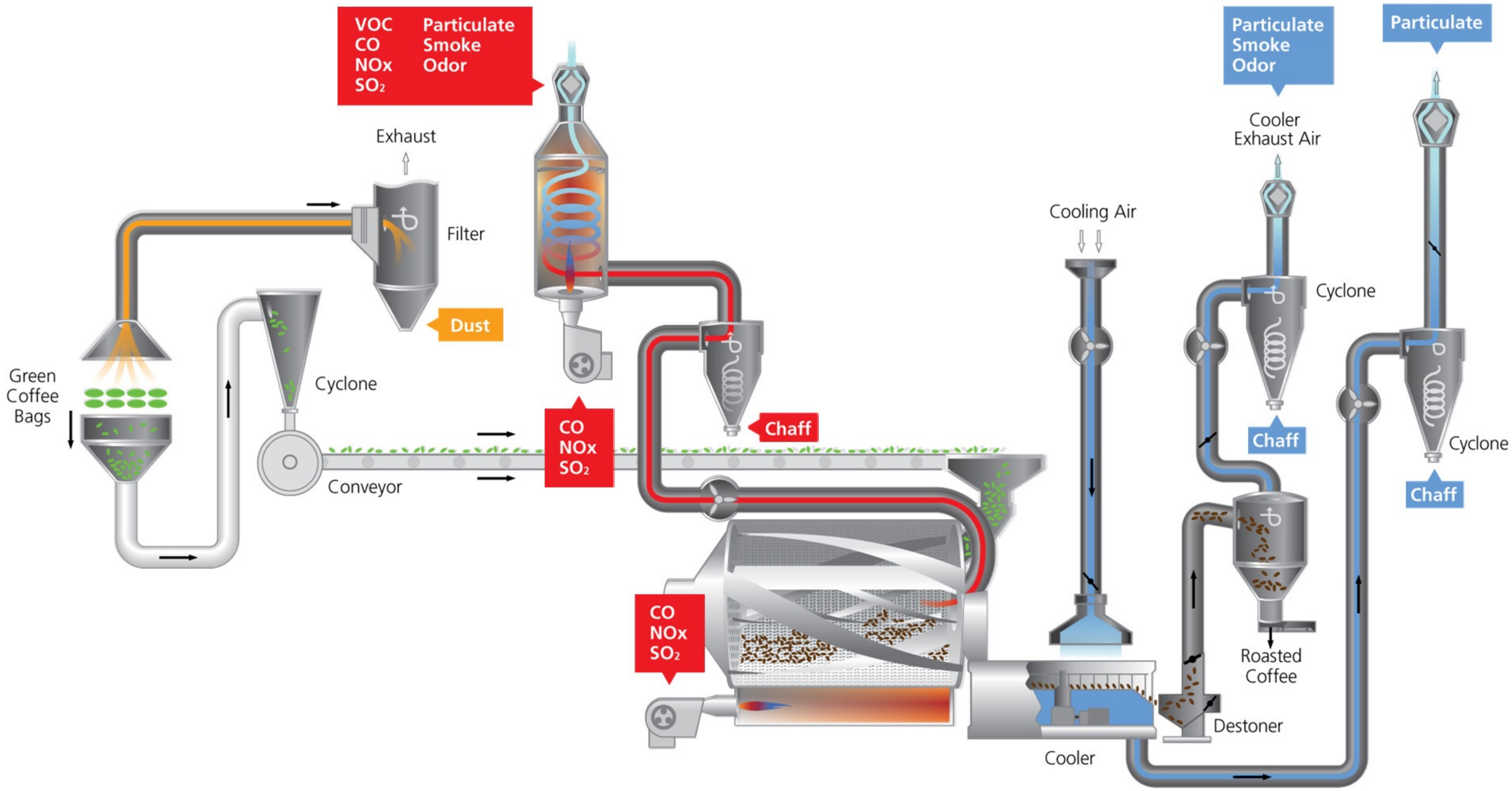
Pollution Occurs at Every Step: Step 2



Pollution Occurs at Every Step: Step 3



Pollution Occurs at Every Step: Final Step



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Quality Is a Key Component

Green Coffee Variables	Process Variables
Coffee Variety Moisture Content Whole / Ground Beans Pretreatments	Coffee Variety Moisture Content Whole / Ground Beans

Roasted Coffee Properties

Degree of Roast
Color Value
Chemical / Physical Properties: Acidity, Extraction Yield, Chlorogenic Acid Content, Aroma Content, Bulk Density, etc.

Quality Aspects

Cup Quality | Appearance | Digestibility | Shelf Life

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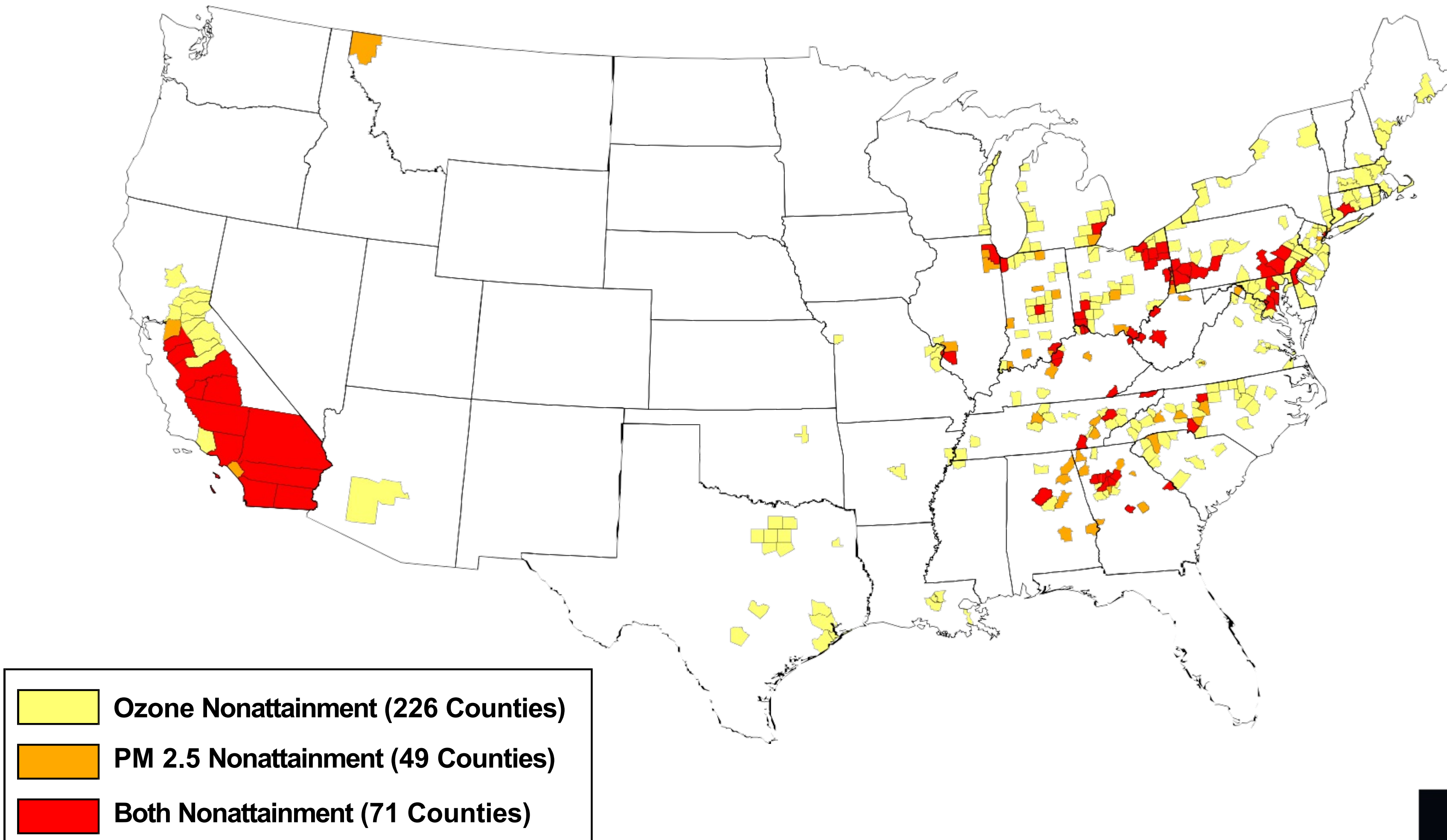
What Is NO_x and CO?

What is NO_x?

- Oxides of nitrogen, NO_x, (NO_2 and NO)
- Formed during the combustion of fuels at temperatures above 2,600° F
- NO_x is linked to several environmental and health issues:
  - Reacts to form particles, which cause respiratory problems
  - Contributes to acid rain
  - Deteriorates water quality
  - Contributes to atmospheric particles that cause smog
  - Reacts to form toxic chemicals
  - Contributes to global warming

Counties Exceeding the Ozone and PM2.5 NAAQs in 2002



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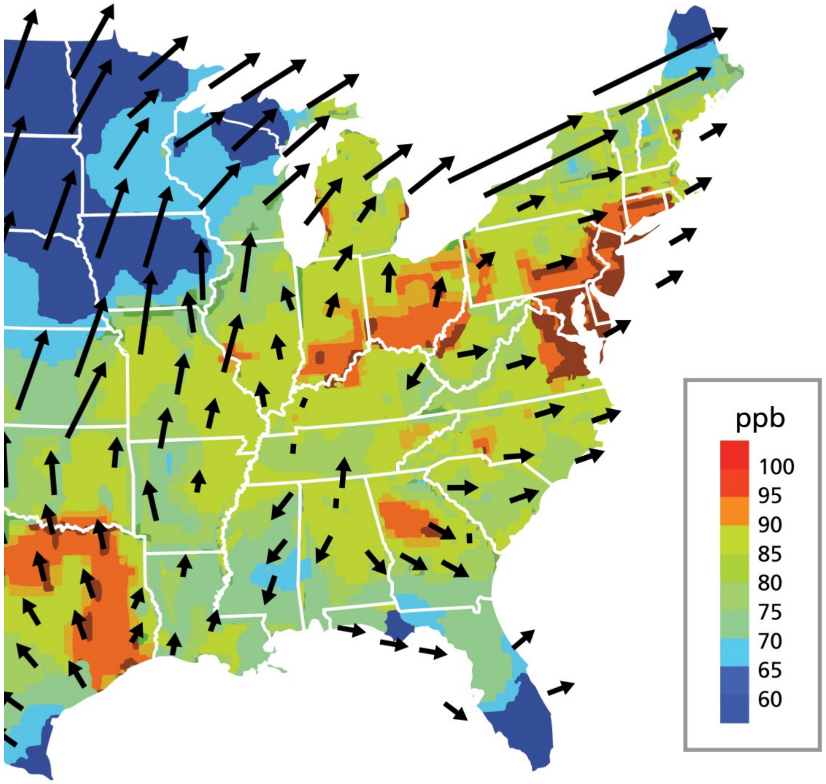
Transport Winds and Ozone Patterns on High Ozone Days



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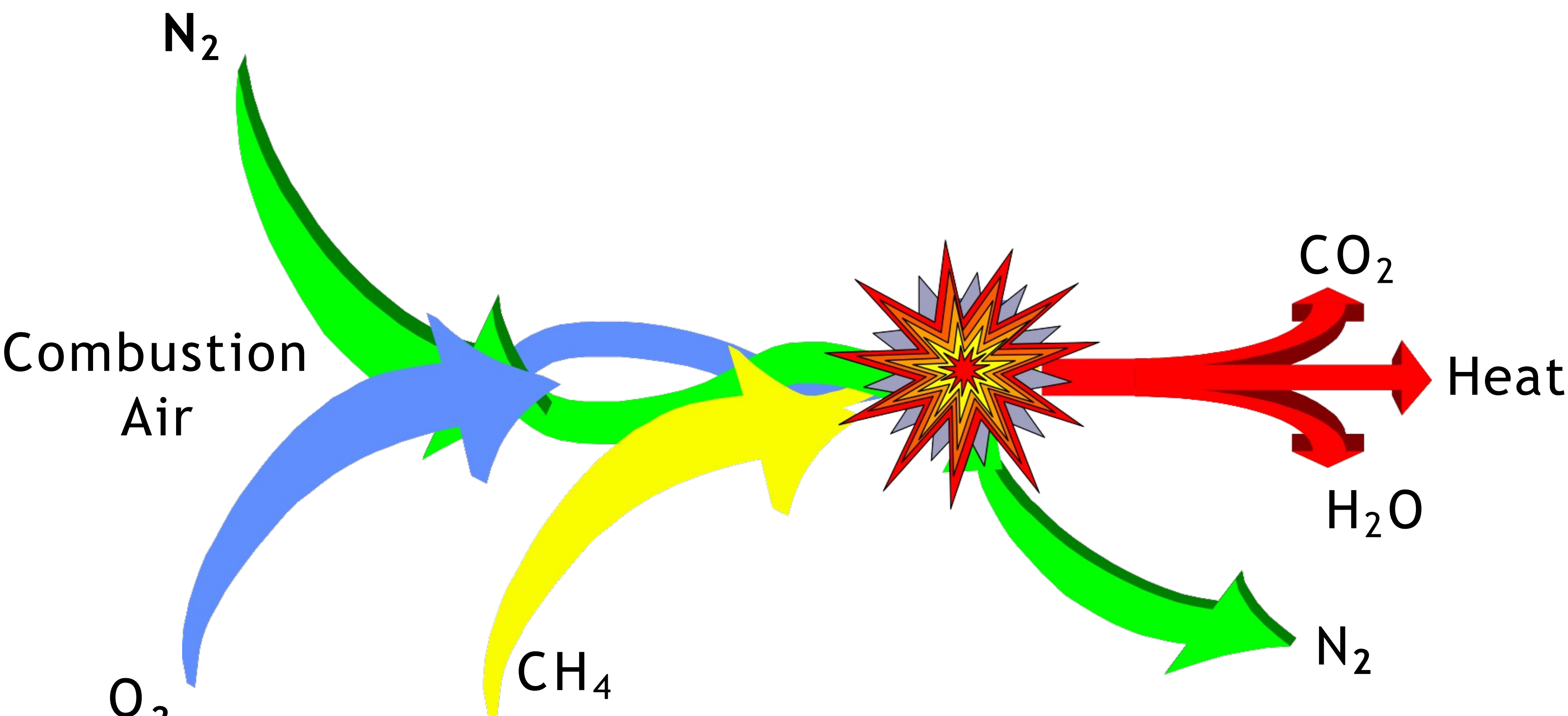
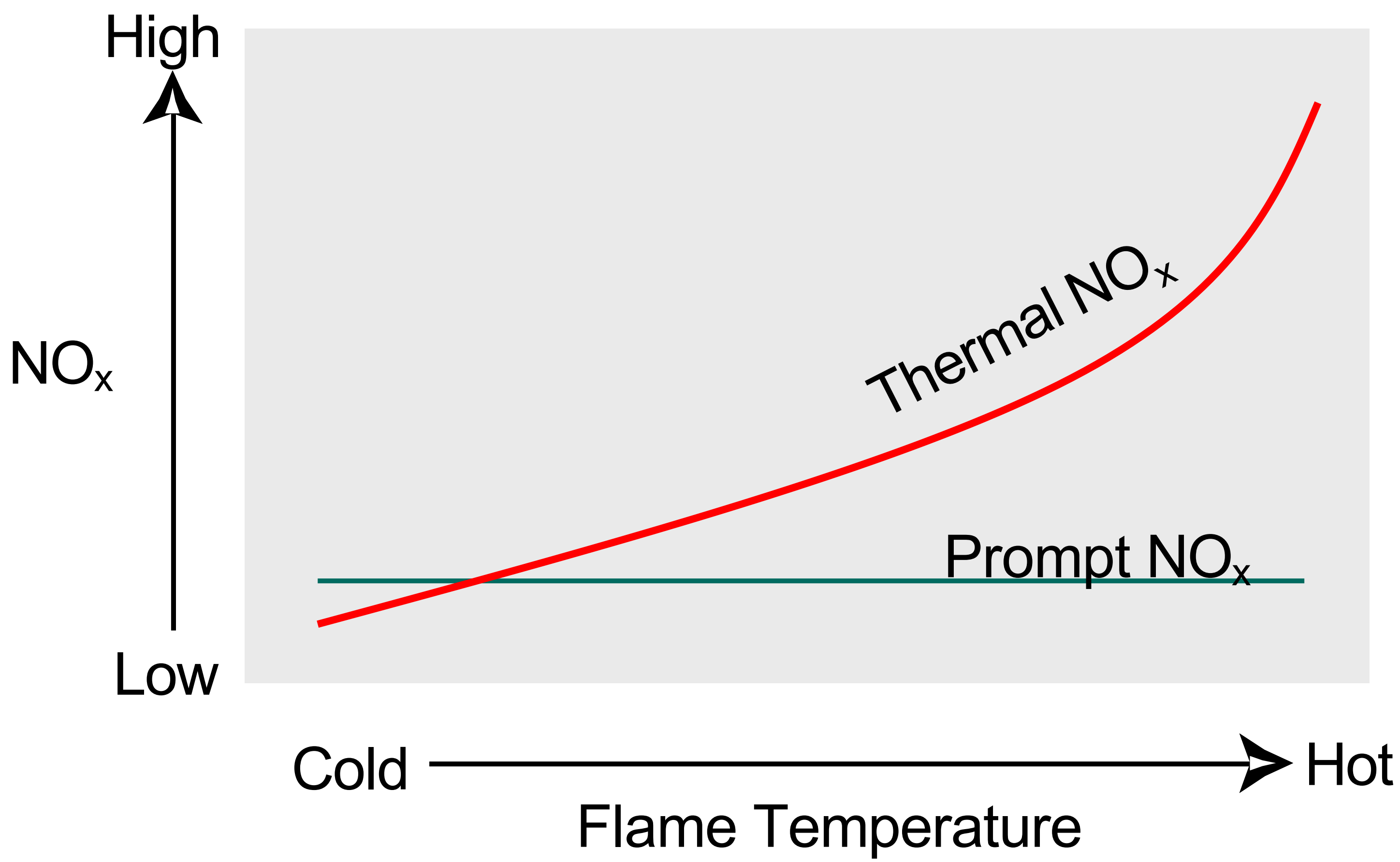
NO_x Formation



- ***Thermal NO_x:** $O + N_2 = NO + N$*
- ***Prompt NO_x:** $CH + N_2 = HCN + N$*

NO_x vs. Flame Temperature



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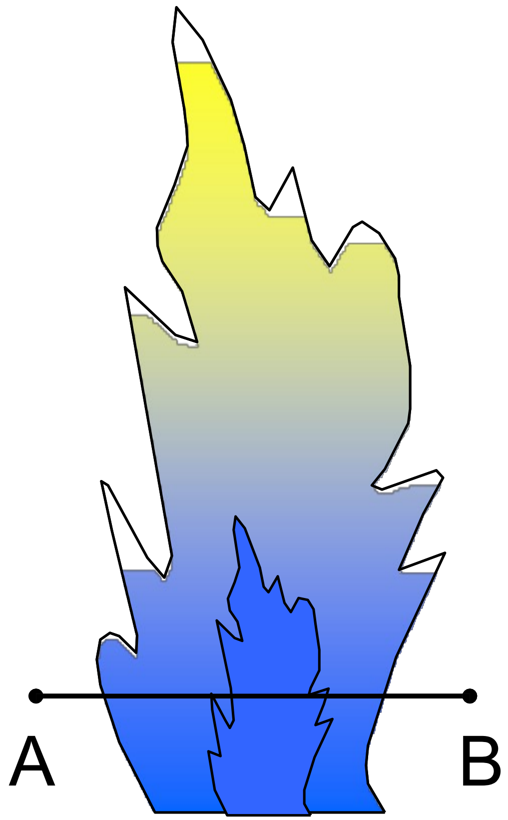
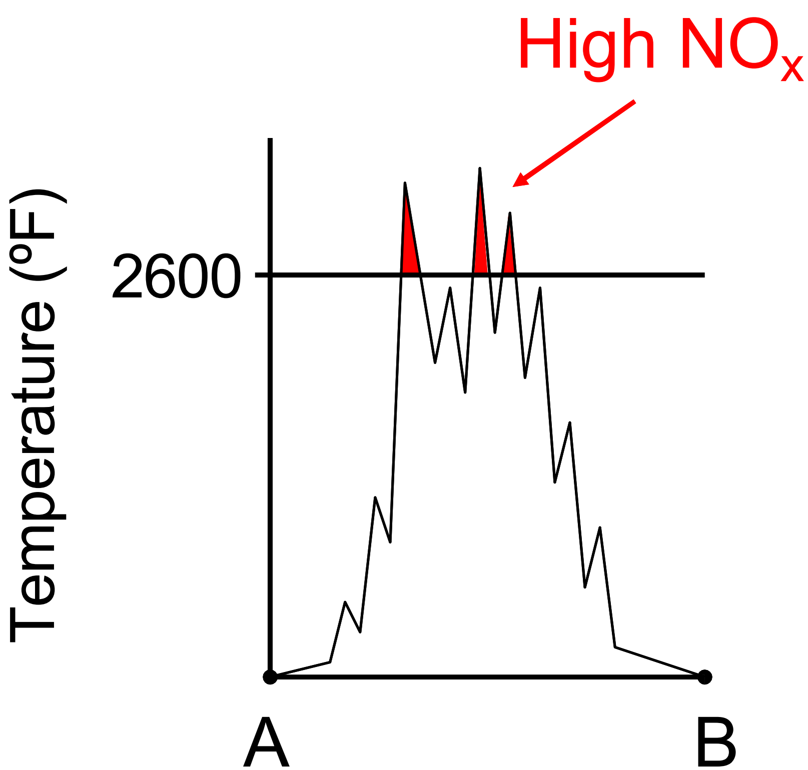
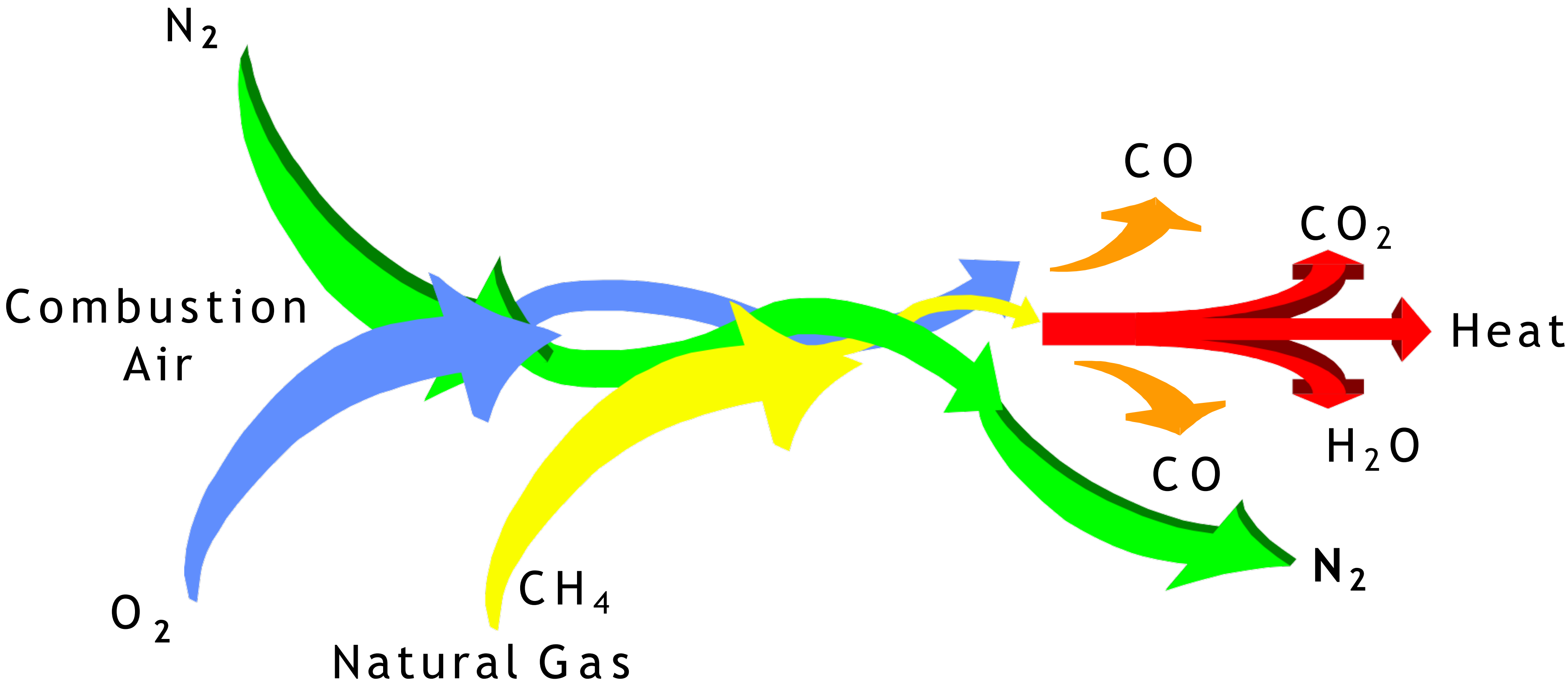
NO_x Formation:
Standard Nozzle Mixing Burner





CO Formation



$$2CH_4 + 3O_2 \longrightarrow 2\,CO + 4\,H_2O$$

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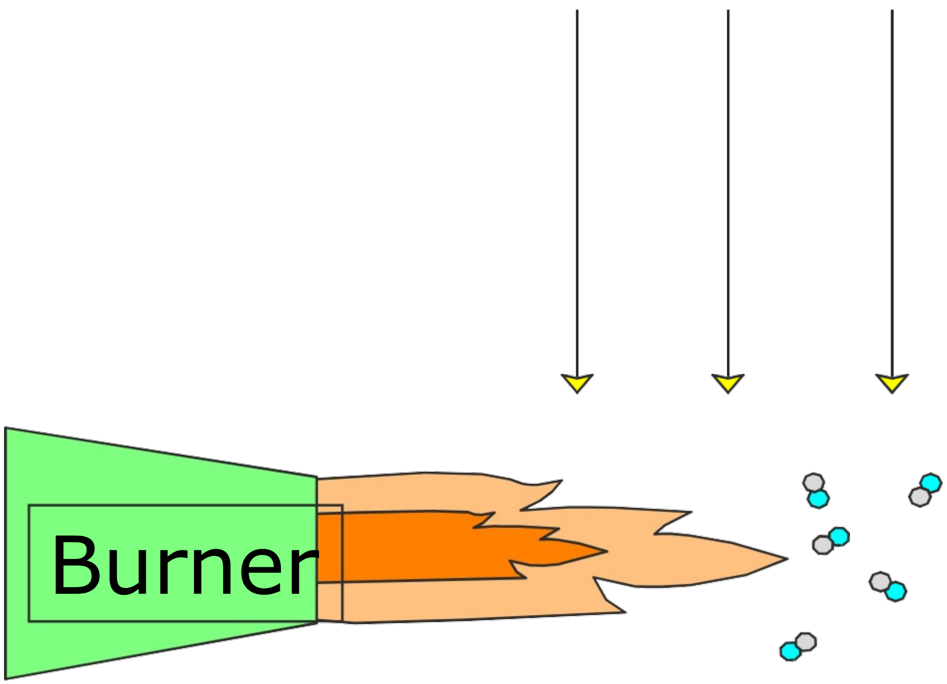
Process air stream



CO forms where cool gases quench the flame.

Chamber conditions affect CO more than NO_x.

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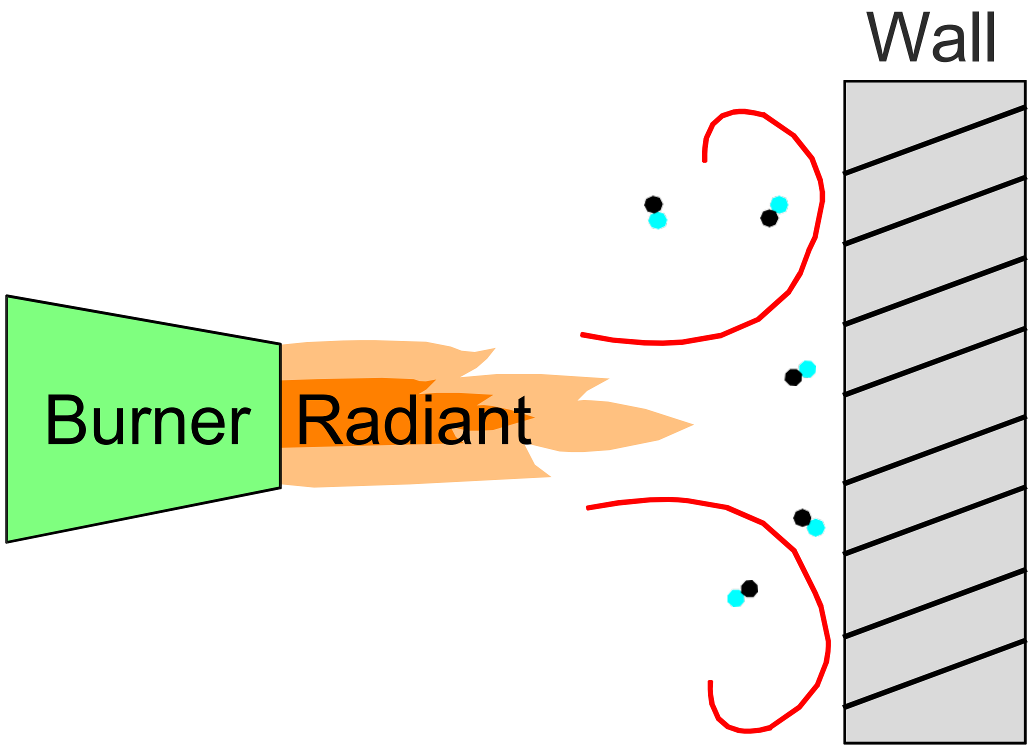
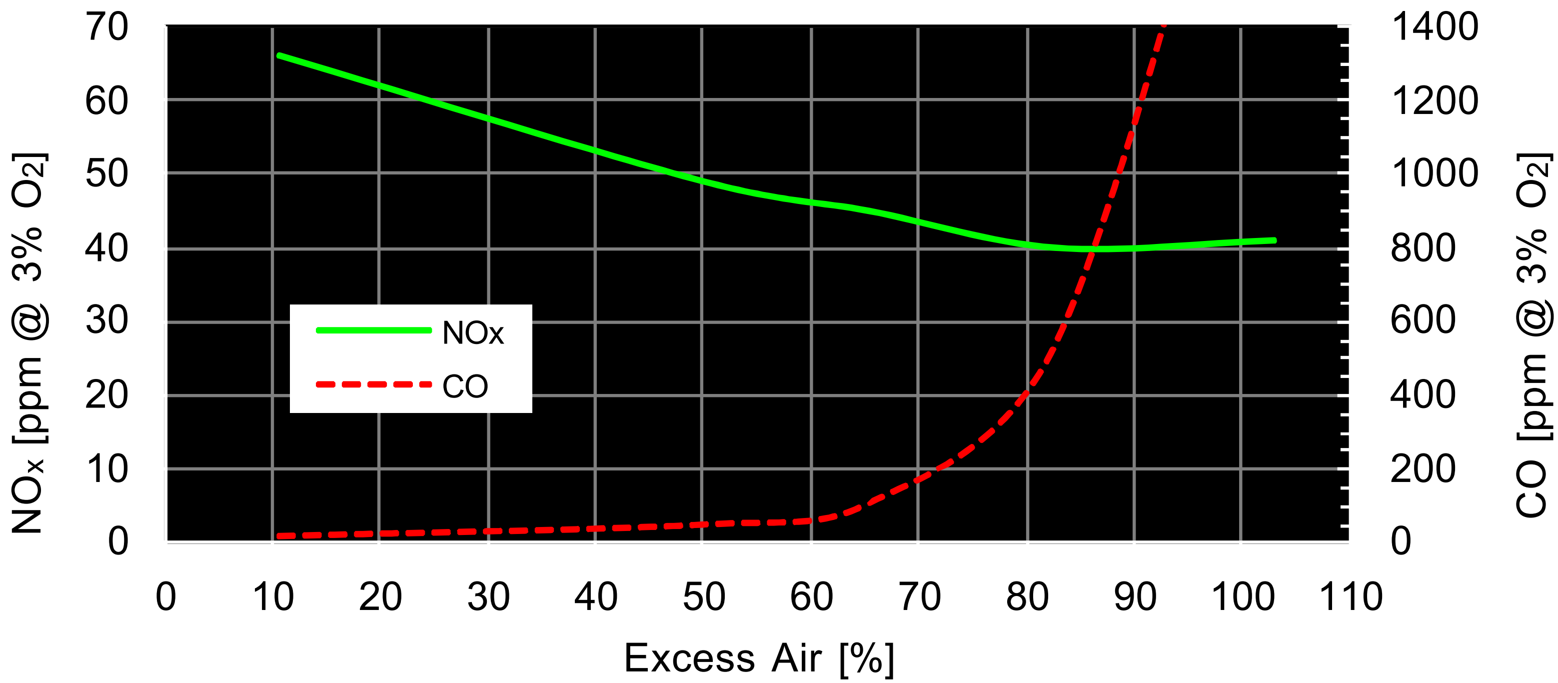


CO forms where flame (>1,650° F) contacts a surface (< 1,650° F) and the flame is quenched.

Effect of Excess Air on Emissions
(Typical Nozzle Mix Burner Firing Natural Gas)



Chamber and burner firing arrangement will have a strong effect on CO emissions.

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SCAQMD Rule 1147 — NO_x Limits

What is a low NO_x burner?

- Mixes air and gas before combustion and surrounds flame with excess air:
  - Produces flame temperature lower than 2,500° F
  - Reduces NO_x formation to 20–30 ppm
- A traditional burner operates up to 3,500° F with NO_x at 80–100 ppm

What is the solution?

- Roasters and afterburners can be retrofit with low NO_x burners
- Please allow 4–6 months for this process
- Please contact your roaster and afterburner manufacturer for more information

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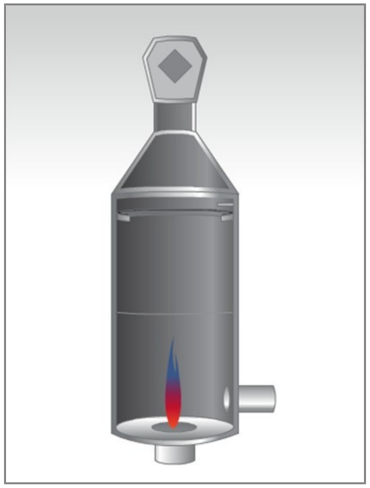
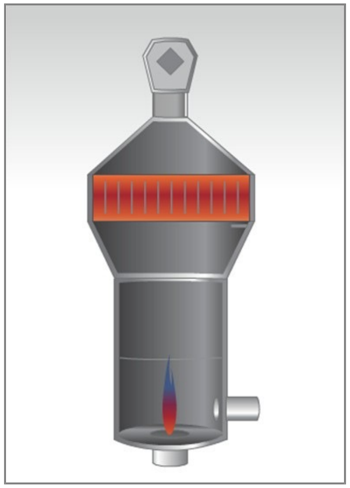
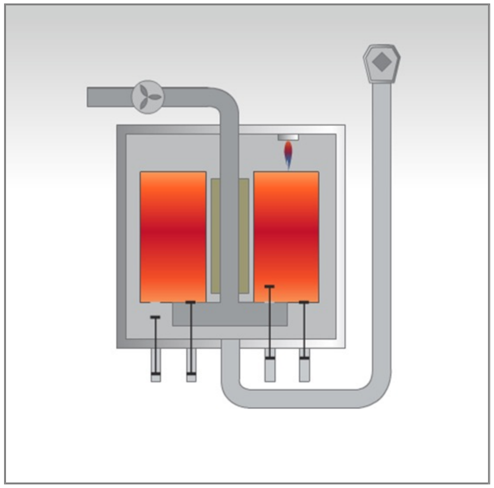
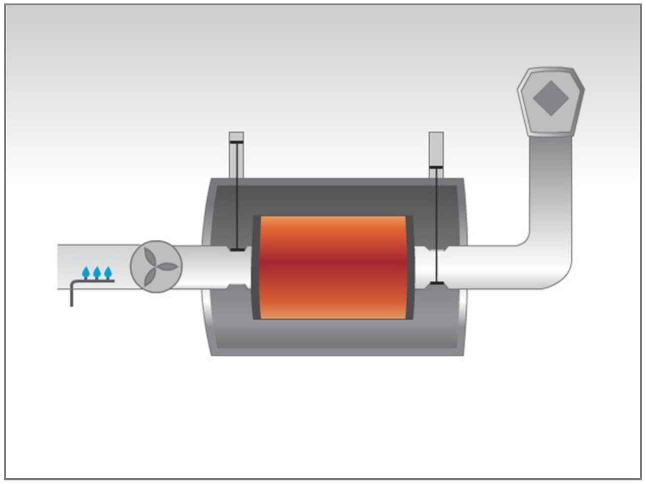
Environmental Control Options: Destroy up to 95% of Emissions

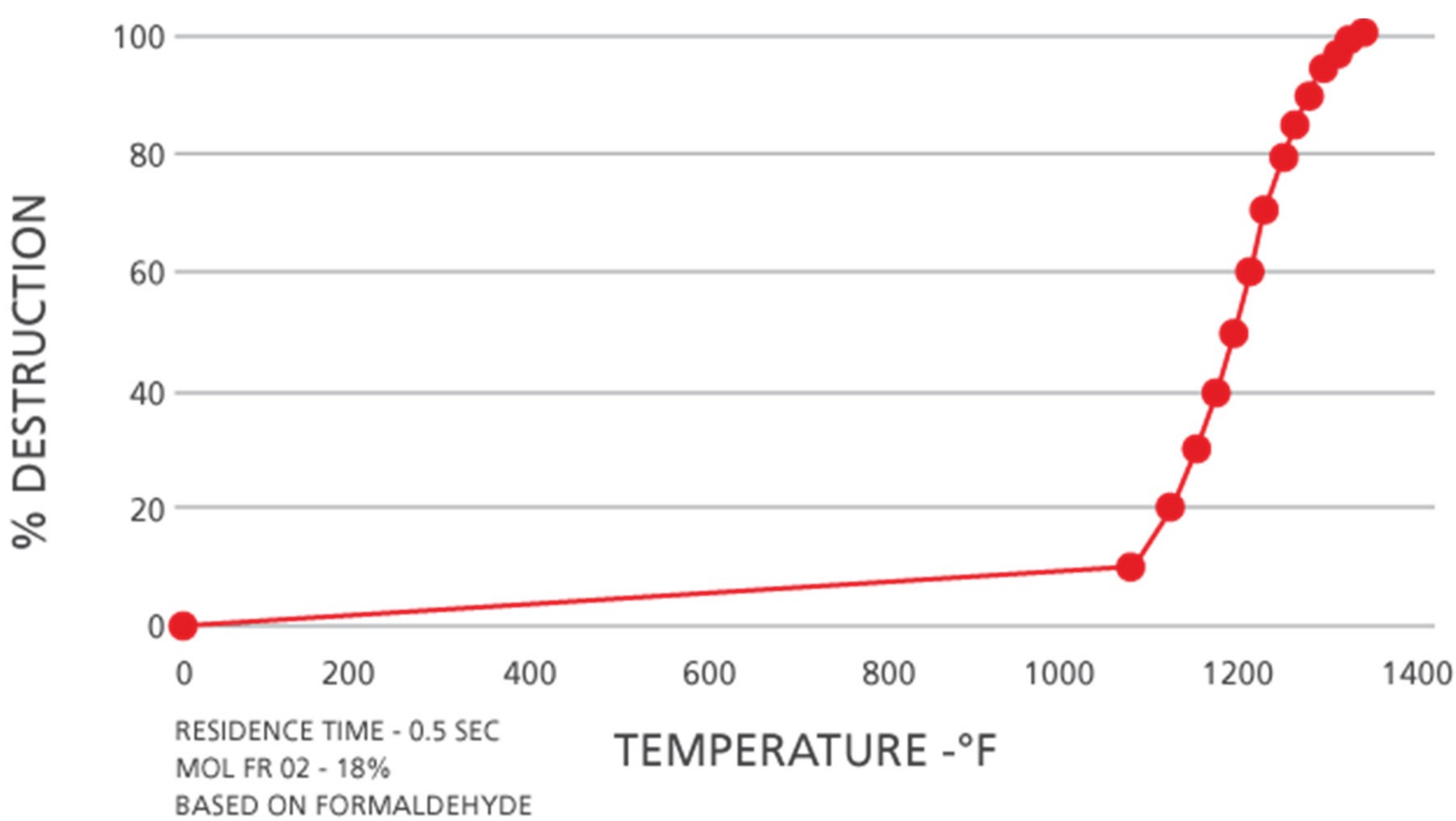




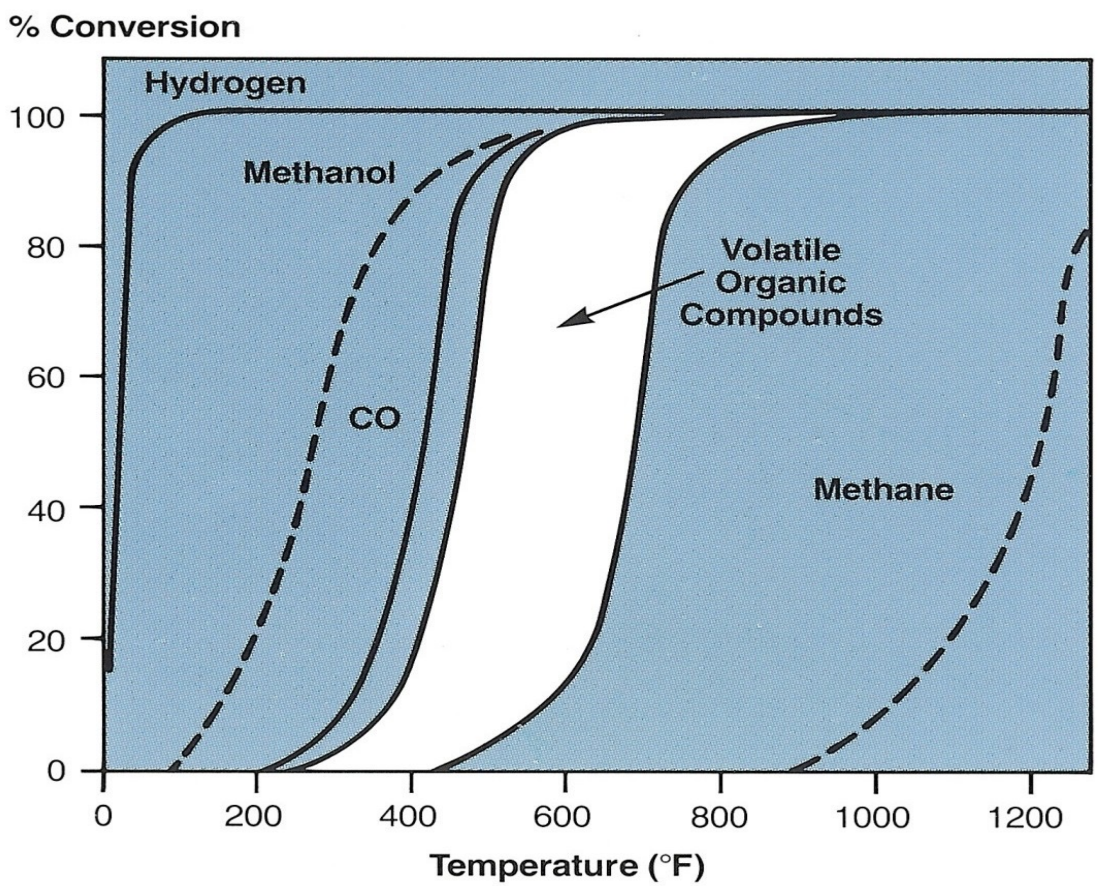




Thermal Afterburner Light-Off Curves for VOCs



Light-Off Curves for VOC Catalytic Incineration



NO_x and Operating Cost

	SCFm			lbs / hr	NO_x lbs / hr			MM BTU / hr		
	Max Roaster Flow	Min Flow	Average Flow*	VOC Present	RTO Burner	Catalytic Burner	After burner	Gas Usage in 95% TER RTO	Catalytic Gas Usage	After Burner Gas Usage
1 bag	600	504	405	1.2	0.0054	0.0288	0.105	35,703	240,324	701,690
2 bag	900	540	608	1.7	0.0080	0.0433	0.158	53,555	360,485	1,052,535
2 bag recirculating	1,200	480	810	2.3	0.0107	0.0577	0.211	71,407	480,647	1,403,380
7,000 lbs / hr green high yield	2,000	800	1350	3.9	0.0179	0.0961	0.351	119,011	801,079	2,338,966
2,200 lbs / hr green	1,700	680	1148	3.3	0.0152	0.0817	0.298	101,160	680,917	1,988,121
3,300 lbs / hr green	3,700	1,480	2498	7.2	0.0330	0.1778	0.649	220,171	1,481,996	4,327,088
4,400 lbs / hr green	4,450	1,780	3004	8.6	0.0397	0.2139	0.781	264,800	1,782,400	5,204,200
6,600 lbs / hr green	4,600	1,840	3105	8.9	0.0411	0.2211	0.807	273,726	1,842,481	5,379,622
8,800 lbs / hr green high yield	4,500	1,800	3038	8.7	0.0402	0.2163	0.789	267,775	1,802,427	5,262,674

Combustion Chamber Temperature

1,600° F (RTO), 1,400° F (TO), 750° F (Catalytic)

Combustion Chamber Temperature = 1,600° F

(RTO), 1,250° F (TO), 750° F (Catalytic)

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Regulating Emissions

The EPA sets standards for emissions, but specific requirements vary at the state and local levels.

Published standards are not readily available and may not be accurate for your facility.

Emissions

The EPA calculates the following coffee roasting facility emissions:

- Particulate (PM10)
- VOC
- CO
- NO_x
- SO_2
- Air toxics

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Confusion Around Calculating Emissions Levels

- The local Air Quality District normally uses AP-42 factors to calculate emissions.
- BAAQMD has developed some calculation factors from its experience.
- South Coast/Los Angeles has developed some of its own factors for calculating NO_x and SO_2 gas burner emissions.
- Manufacturers' data may be used to calculate emissions, but source testing may be required for verification.
- The local Air District calculates the following air toxics:
  - Acetaldehyde
  - Acrolein
  - Formaldehyde
- South Coast/Los Angeles uses Ventura County AB2588 factors for natural gas fired combustion equipment <10 MMBtu for all toxics listed (dated 8/95).
- BAAQMD uses recent data from a local source test.

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Examples of Published Standards

SUMMARY OF SOME BASIC ROASTER EMISSIONS FACTORS (Check your local laws for applicability)

POLLUTANT	TYPE	WHO(1)	EMISSIONS FACTOR LBS/TON COFFEE	EMISSIONS FACTOR LBS / MMBTU(2)	CONCERN LEVEL(3) TONS COFFEE / NOTED PERIOD
VOC	Batch Roaster No Abatement	EPA	0.86		
	Batch Roaster Thermal Afterburner	EPA	0.047		213 / Day
	Batch Roaster Thermal Afterburner	Private Source Test	0.01		
CO	Batch Roaster No Abatement	EPA	ND		
	Batch Roaster Thermal Afterburner	EPA	0.55		36,364 / Year
	Batch Roaster Thermal Afterburner	Private Source Test		0.4	
PARTICULATE	Batch Roaster No Abatement	EPA	4.2		
	Batch Roaster Thermal Afterburner	EPA	0.12		86 / Day
NO_x	Batch Roaster Thermal Afterburner	Private Source Test		0.18	10,526 / Year
PARTICULATE	Cooler / Destoner No Abatement	BAAQMD	1.4		
	Assumed 90% Removal Efficiency	-------	0.14		

(1) EPA data taken from AP-42, (2) Based upon MM BTUs used by the roaster burner, (3) The roasting capacity where the Air Control District will exercise more concern. For VOCs and Particulate the basic limit is 10 lbs / day. For NO_x and CO the total capacity limit is 10 tons / year. Above this offsets are needed. In BAAQMD offsets are provided free until 35 tons / year is reached. Above that the roaster will need to pay for all offsets above 10 tons.

Examples of Published Standards

BURNER EMISSION FACTORS

COMBUSTER TYPE MM BTU / HR	EMISSION FACTOR NO_x LBS / 10^6 SCF	EMISSION FACTOR CO LBS / 10^6 SCF	EMISSION FACTOR SO_2 LBS / 10^6 SCF	EMISSION FACTOR VOC LBS / 10^6 SCF	EMISSION FACTOR PM LBS / 10^6 SCF
<100 MM BTU / HR Uncontrolled	100	84	0.6	5.5	7.6
<100 MM BTU / HR Low NO_x Burner	50	84	0.6	5.5	7.6

AIR TOXICS EMISSION FACTORS (Puget Sound Clean Air District)

AIR TOXIC	BEFORE AB EMISSION FACTOR LBS / TON COFFEE	AFTER AB EMISSION FACTOR LBS. / TON COFFEE(1)	TRIGGER LEVEL LBS / YR	CONCERN LEVEL(3) TONS COFFEE / YR
Acetaldehyde	0.0829	0.036	64	1,778
Acrolein	0.0153	0.018	2.3 (2)	
Formaldehyde	0.2	0.062	30	484

(1) These factors are believed to be on the high side.
(2) The Acrolein test method is not believed to be reliable.
(3) Numbers are for combustion only.

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Afterburner Temperatures — More Complications

- AQMD mandates that afterburners adhere to the operating temperature determined by BACT at time of application filing.
- BAAQMD specifies operating temperatures and will allow lower temperatures with source test confirmation.
- Mendocino District, for example, requires afterburners but does not specify a temperature.
- AQMD reserves the right to ask for stack testing, though this is not common.
- BAAQMD requires initial stack tests after installation. Frequency of testing is based on capacity.
- South Coast/Los Angeles requires offsets for NO_x/VOC levels above 0.5 lbs. per day.

Effect of Emissions on Permits

The local air district will not issue a permit unless BACT and offset requirements are met.

Concern over PM10 emissions has no impact (yet) on coffee roaster permits.

Concern over CO_2 emissions has no impact (yet) on permits, but BAAQMD charges extra fee for permit renewal to help fund study on the subject.

According to the local air district, none of the regulations currently pending will affect issue of permits for coffee roasters.

South Coast/Los Angeles

- Takes up to three to six months, including time for health assessment.
- Permit moratorium ended last year.

BAAQMD

- Takes one month unless a health assessment or public notice is required.

For more information, refer to the Environmental Control Forms listed in the handout located on the SCAA website.

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SCAQMD Rule 1147 — Implications for Roasters

South Coast/Los Angeles Air Quality Management District — Rule 1147

- Limits NO_x from burners
- Requires low-NO_x technology be installed on all permitted burners; regardless of size, use or age
- No grandfather clause — timeline provided for implementation
- Rule 1147 enacted on January 1, 2010

Solution

- Roasters and afterburners can be retrofitted to be Rule 1147-compliant
- Some roasters have already been converted at several locations

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SCAQMD Rule 1147 — NO_x Limits

NO_x limits as stated in Rule 1147, as applicable to coffee roasters:

Unit	Operating Temperature	NO_x Emission Limit
Roaster main burner	<1,200° F	30 ppm or 0.036 lbs of NO_x / MM BTU
Thermal or catalytic afterburner	< 800° F	60 ppm or 0.073 lbs of NO_x / MM BTU

NO_x emissions from typical burners:

Unit	AP 42 Emission factor	Stated Maxon Emissions
NO_x uncontrolled burner	0.22 lbs of NO_x / MMBTU	80–100 ppm of NO_x (Maxon Ovenpak or similar)
NO_x controlled — low NO_x burner	0.064 lbs of NO_x / MMBTU	20–30 ppm of NO_x (Maxon Mpact or similar)

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SCAQMD Rule 1147 — NO_x Limits

Compliance timeline:

Unit	Compliance Date
Roaster burner built before 1986	July 1, 2010
Roaster burner built between 1986–1991	July 1, 2011
Roaster burner built between 1992–1997	July 1, 2012
Roaster burner built after 1997	July 1 on the 15th anniversary of the equipment manufacture year
Any afterburner built before 1998	July 1, 2013
Any afterburner built after 1997	July 1 on the 15th anniversary of the equipment manufacture year

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SCAQMD Rule 1147 — Further Rule Details

- If you operate more than 5 roasters, Rule 1147 provides for phased implementation.
- Regenerative thermal oxidizers are exempt from this rule.
- Beginning January 1, 2011, all burners must have a totalizing natural gas meter.
- Owners must maintain the low NO_x burners per manufacturers recommendations.
- Source testing required after low NO_x burner installation.
- Owners must keep the source testing and maintenance information on-site.

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Conclusions

- Today's technologies can help you minimize your environmental footprint and save energy in your plant.

- Select your emissions mitigation equipment based on:
  - Standards and formulas
  - Your local regulations
  - Your roasting process

Regulating Government Agencies

- There are a number of agencies that impose air toxic emission levels around the country. Most (such as BAAQMD), impose an exposure limit based on the health effect of the given toxic (expressed in units such as ppm and mg/m^3). In order determine whether a new coffee roasting system does not exceed these exposure limits, dispersion modeling is required based on the actual toxic emitted (in the surrounding area—including neighboring companies), the prevailing winds, and the proximity of people.
- Some local agencies, such as *Washington Administrative Code* (WAC) which PSCAA complies with, manage the exposure limits by imposing "trigger" emission levels so a coffee roaster can determine whether their toxic emissions are trivial or sufficiently minor to avoid any dispersion modeling. Most coffee roasters currently fall within the minor toxic levels, but larger facilities can exceed the trigger levels to warrant dispersion modeling.
- The Federal agencies that provide exposure limits include:
  - EPA's Integrated Risk Information System (IRIS)
  - Agency for Toxic Substances and Disease Registry (ATSDR)
  - American Conference of Governmental Industrial Hygienists (ACGIH)
  - CDC's National Institute for Occupational Safety and Health (NIOSH)
  - Occupational Safety and Health Administration (OSHA)
- Some of the state agencies that provide exposure limits include:
  - California Office of Environmental Health Hazard Assessment (OEHHA)
  - California Department of Fish and Wildlife (DFG)
  - Oregon Department of Environmental Quality (Oregon DEQ)
  - Idaho Department of Environmental Quality (Idaho DEQ)

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Air Toxic Limits

BAAQMD Air Toxic's List

Chemical	CAS #	Acute Inhalation REL (ig/m^3)	Chronic Inhalation REL (ig/m^3)	Chronic Oral REL (mg/kg-day)	Inhalation Cancer Potency Factor (mg/kg-day)	Oral Cancer Potency Factor (mg/kg-day)	Acute 1 hr max Trigger Level (lbs/hr)	Chronic Trigger Level (lbs/yr)
Acetaldehyde	75-07-0		9		0.01			64
Acrolein	107-02-8	0.19	0.06				.00042	2.3
Formaldehyde	50-00-0	94	3		0.021		0.21	30

Puget Sound

Common Name	CAS #	Averaging Period	ASIL (µg/m^3)	SQER (lbs/averaging period)	De Minimis (lbs/averaging)
Acetaldehyde	75-07-0	year	0.37	71	3.55
Acrolein	107-02-8	24-hrs	0.06	0.00789	0.000394
Formaldehyde	50-00-0	year	0.167	32	1.6

The following table lists the common name of toxic air pollutants, the small quantity emission rate (SQER); and de minimis emission values the chemical abstract service (CAS) number; the averaging period; the acceptable source impact level (ASIL); the small quantity emission rate (SQER); and de minimis emission values

Emission Factors lbs/ton

	Puget Sound	BAAQMD
Acetaldehyde	0.00284	0.005
Acrolein	0.00235	N/A
Formaldehyde	0.00536	0.008

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Air Toxic Limits

Emission Factors lbs/ton

	Puget Sound	BAAQMD
Acetaldehyde	0.00284	0.005
Acrolein	0.00235	N/A
Formaldehyde	0.00536	0.008

Comparison of Air Toxic Limits

Agency	Criteria	Acrolein	Acetaldehyde	Formaldehyde	Comments
	Chemical Formula:	C_3H_4O	CH_3CHO	CH_2O	
	Molecular Weight:	56.063 g/mol	44.053 g/mol	30.026 g/mol	
	Boiling Point:	127.4 F	69 F	208.4 F	
	Specific Gravity:	0.841	0.79	0.815	
	Vapor Pressure:	220 mmHg@77 F	902 mmHg@77 F	3890 mmHg@77 F	
	Henry's Law Constant:	0.0000044 atm-m^3/mol@77 F	0.0000661 atm-m^3/mol@77 F	0.000000167 atm-m^3/mol@77 F	
	Convert ppm to mg/m^3	2.33	1.831	1.248	
ACGIH	2008 STEL:	0.1 ppm	25 ppm	0.37 mg/m^3	*Short Term Exposure Limit*
	2008 Carcinogen Class:	A4	A3	A2	
ATSDR	GMMC Air:	0.00971 mg/m^3		0.01937971 mg/m^3	*Geometric Mean Maximum Concentration for Air*
	Chronic MRL:			0.008 ppm	*Minimal Risk Level over a long time (> 365 days)*
	Acute MRL:	0.003 ppm		0.04 ppm	*Minimal Risk Level over a short time (1 to 14 days)*
	Interim MRL:	0.00004 ppm		0.03 ppm	*Minimal Risk Level over an intermediate time (14 to 365 days)*
	Carcinogenicity Class:	3		3	
IRIS	INH Ref Conc (non cancer):	0.00002 mg/m^3	0.009 mg/m^3		*Reference Concentration for Chronic Inhalation Exposure*
	URF (cancer):		0.0000022 per µg/m^3	0.000013 per µg/m^3	*Quantitative Estimate of Carcinogenic Risk from Inhalation Exposure (Unit Risk Factor)*
			0.4545455 µg/m^3	0.076923077 µg/m^3	*Inhalation Concentrations at Risk Level E6 (1 in 1,000,000)*
NIOSH	RTECS No.:	AS1050000	AB1925000	LP8925000	
	ICSC No.:	0090	0009	0275	
	REL TWA:	0.25 mg/m^3	mg/m^3	0.016 mg/m^3	*Recommended Exposure Limit (Time Weighted Average)*
	STEL:	0.8 mg/m^3	mg/m^3	0.1 mg/m^3	*Short Term Exposure Limit*
	IDLH:	2 ppm	2000 ppm	20 ppm	*Immediately Dangerous to Life and Health*
OSHA	PEL TWA:				*Permissable Exposure Limits (Time Weighted Average)*
	STEL:		200 ppm	2 ppm	*Short Term Exposure Limit*
OEHHA	Acute REL:	2.5 µg/m^3	470 µg/m^3	55 µg/m^3	*Reference Exposure Level over short time*
	Chronic REL:	0.35 µg/m^3	140 µg/m^3	9 µg/m^3	*Reference Exposure Level over long time*
	URF (cancer):		0.0000027 per µg/m^3	0.000006 per µg/m^3	*Unit Risk Factor from Inhalation Exposure*
			0.3703704 µg/m3	0.166666667 µg/m^3	
BAAQMD	Acute Inhalation REL:	2.5 µg/m^3	470 µg/m^3	55 µg/m^3	*Reference Exposure Level over short time*
	Chronic Inhalation REL:	0.35 µg/m^3	140 µg/m^3	9 µg/m^3	*Reference Exposure Level over long time*
	CREL Weighting Factor:	0.35	140	9	
	Inhalation Cancer Potency Factor:		0.001 mg/kg-day	0.021 mg/kg-day	
	CP Weighting Factor:		0.001	0.021	
	Acute (1hr max) Trigger Level:	0.0055 lbs/hr	1 lbs/hr	0.12 lbs/hr	*Level where BAAQMD's New Source Review applies*
	Chronic Trigger Level:	14 lbs/yr	38 lbs/yr	18 lbs/yr	*Level where BAAQMD's New Source Review applies*
WAC	De minimus:	0.000394 lbs/24hrs	3.55 lbs/yr	1.6 lbs/yr	*Trivial levels of emissions that do not pose a threat to human health or the environment*
	SQER:	0.00789 lbs/24hrs	71 lbs/yr	32 lbs/yr	*Small Quantity Emission Rate - Level of emissions below which dispersion modeling is not required.*
	ASIL:	0.06 µg/m^3	0.37 µg/m^3	0.167 µg/m^3	*Acceptable Source Impact Level - a screening concentration in ambient air*
Oregon DEQ	Ambient Benchmark Concentration:	0.02 µg/m^3	0.45 µg/m^3	3 µg/m^3	*Concentrations that result in cancer risk on one-in-a-million based on lifetime exposure*
Idaho DEQ	Type:	Non-Carcinogenic	Carcinogenic	Carcinogenic	
	OEL (non cancer):	0.25 mg/m^3			*Reference Occupational Exposure Limit*
	AAC (non cancer):	0.0125 mg/m^3			*Acceptable Ambient Concentrations*
	Emission Level:	0.017 lbs/hr	0.003 lbs/hr	0.00051 lbs/hr	
	URF (cancer):		0.000002 per µg/m^3	0.000013 per µg/m^3	*Unit Risk Factor from Inhalation Exposure (from EPA)*
	AACC (cancer):		0.45 µg/m^3	0.077 µg/m^3	*Acceptable Ambiant Concentrations (for Cancer)*

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Air Toxic Limits

	Date	Roaster Information	Test Method	Thermal Afterburner: Exhaust Temperature (°F)	Thermal Afterburner: Probat's Understanding of Residence Time (sec)	Acetaldehyde Emissions (lbs/T_{GB})	Acrolein Emissions (lbs/T_{GB})	Formaldehyde Emissions (lbs/T_{GB})	Comments
Java Trading	2003	JPR150	CARB 430	1300	0.5	0.02686	0.01163	0.06429	Historically removed from analyses as "old technology"
Java Trading	2003	JPR150	CARB 430	1100	0.5	0.04592	0.02396	0.05992	
Starbucks - Kent	2006	T1	CARB 430	1576	> 1	0.009	0.009	0.009	Most test results below method detection level
Peet's Coffee - Alameda, CA	2007	R4 - R1500	CARB 430	Not measured	> 1	0.0005		0.0012	Two runs had values less than method detection level
Peet's Coffee - Alameda, CA	2007	R3 - R1000	CARB 430	Not measured	> 1	0.0032		0.0072	Production rate low
Peet's Coffee - Alameda, CA	2007	R2 - R1000	CARB 430	Not measured	> 1	0.0005		0.0008	One run had values less than method detection level
Average (excluding CARB 430 Acrolein)						0.0143	N/A*	0.0237	
BAAQMD Handbook						0.0005	None	0.0008	BAAQMD Selected these factors based on 2007 Peet's Coffee tests
Average Peet's Coffee Data						0.0014		0.0031	
Stated Emission Estimates Cascade Coffee - Everett, WA		R6 - R2000R		1450	0.5	0.0014	N/A	0.0031	

* Acrolyn has previously been removed from submission as ARB issued an advisary notice in 2000 (http://www.arb.ca.gov/ei/acrolein.htm) stating Acrolein data from CARB 430 tests should be considered suspect.

Information sourced from Bridgewater Group's submission to PSCAA on behalf of Cascade Coffee

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