
Cache Valley January 17, 2004 1500 hrs
PM2.5 = 107 ug/m3
Credit: Ed Redd
ill Francis

$PM_{2.5}$ – It is not a simple problem, There is not any single simple solution, But we are making progress

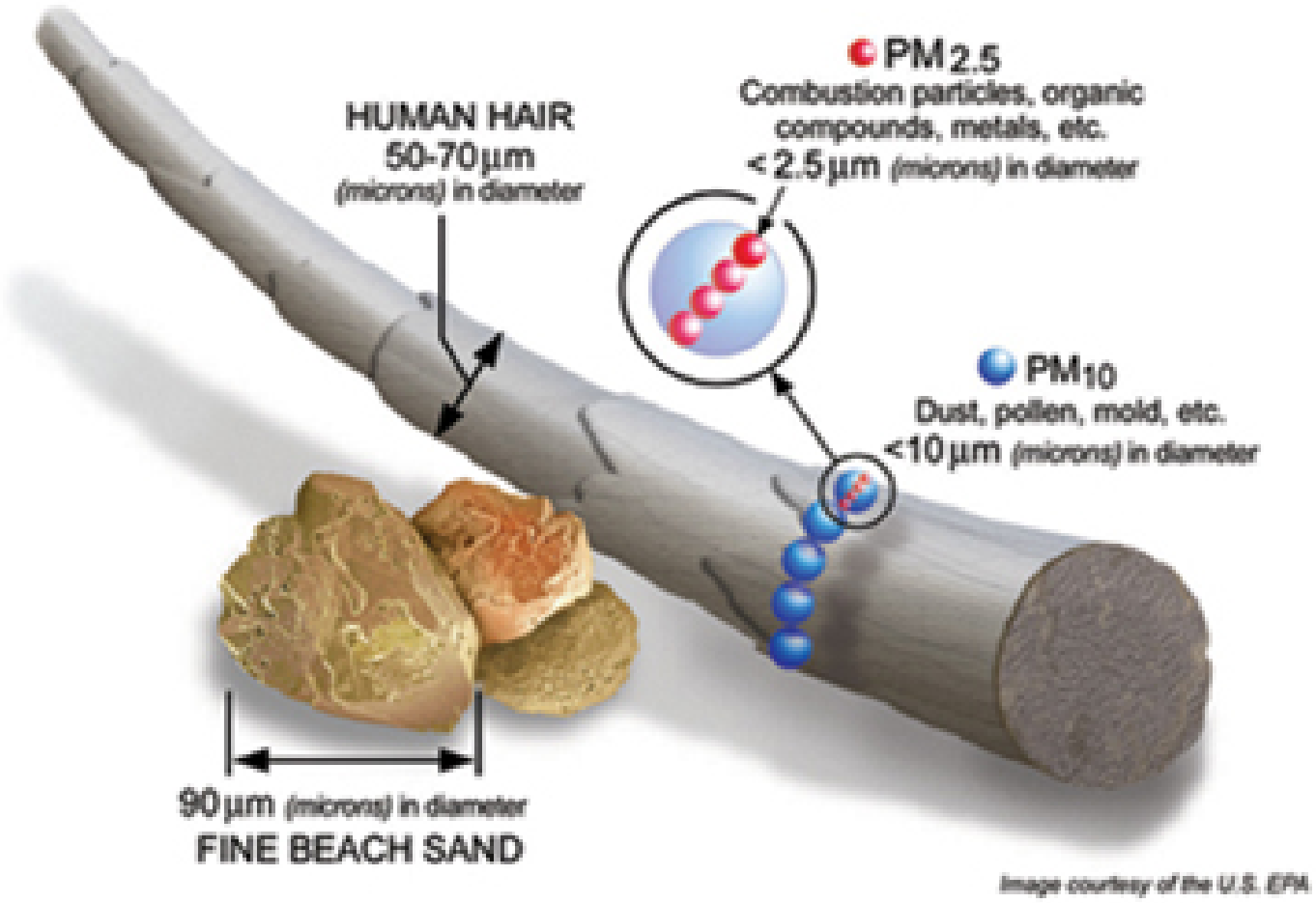
Edward Redd
Utah House of Representatives
House-District 4, Logan UT

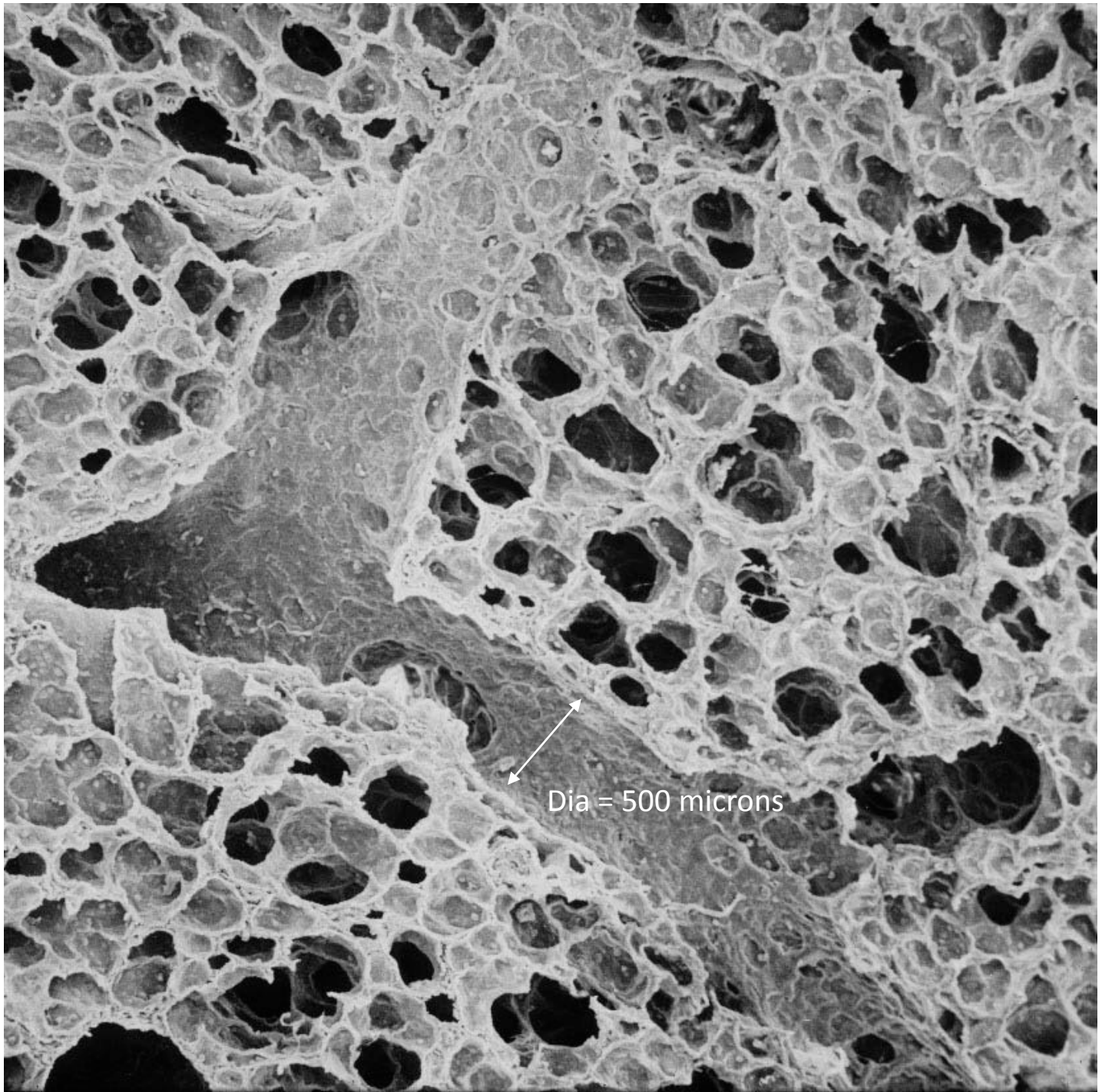
Disclaimer: I have done the best that I can to be accurate, fair, and unbiased in assembling the contents of this presentation – but it is possible that I have either obtained inaccurate data or made assumptions that are not correct in making calculations and drawing conclusions. A lot of the data contained in these slides is based on EPA models that may not apply perfectly to Cache Valley or the Wasatch front.

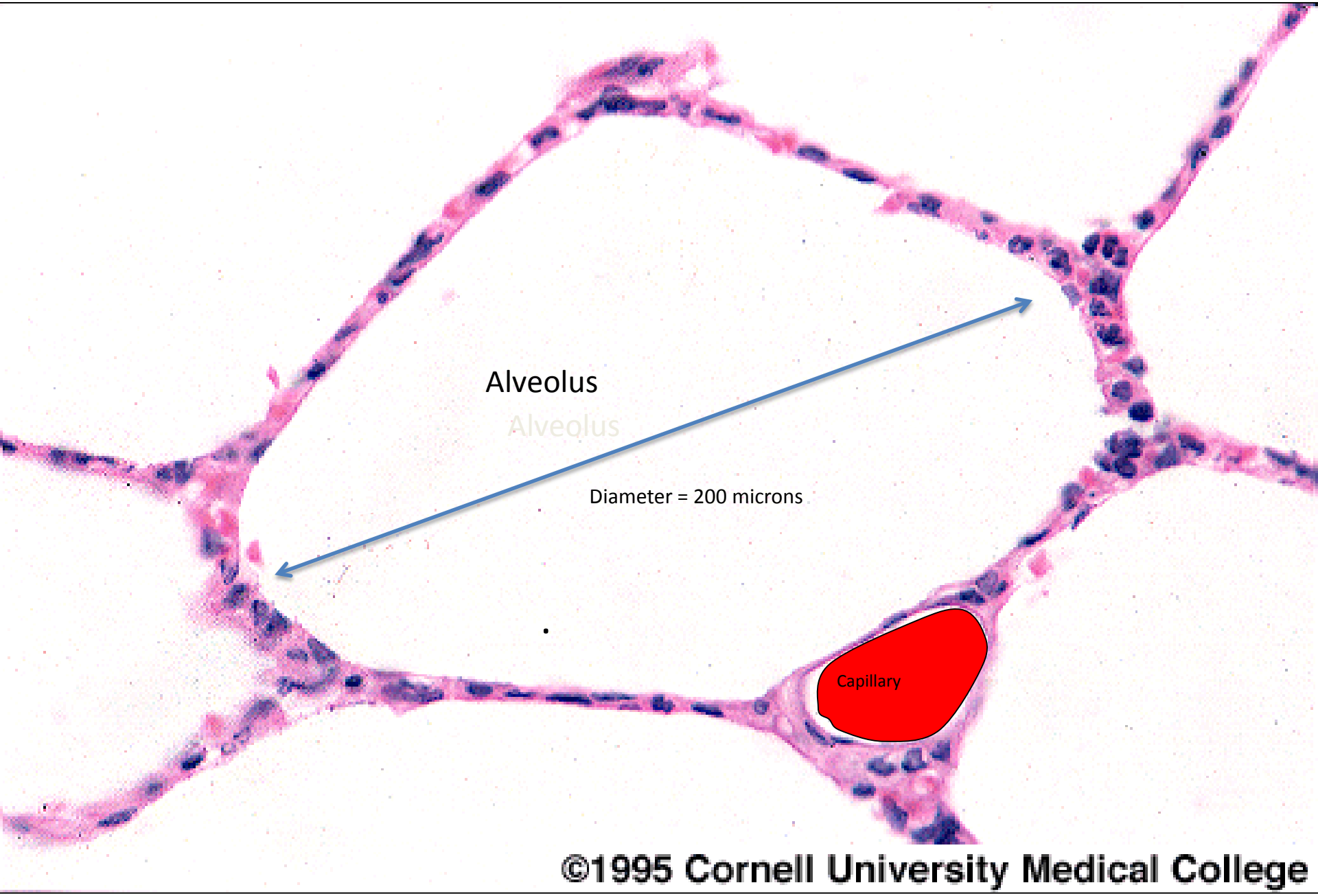
Outline:

- Brief overview of health effects of $PM_{2.5}$
- Temperature inversions and $PM_{2.5}$ chemistry
- Air emissions sources and inventories
- Area emissions and wood smoke
- Tier III low-sulfur fuels
- Cold-start (short-trip) emissions
- The future – why I am optimistic…

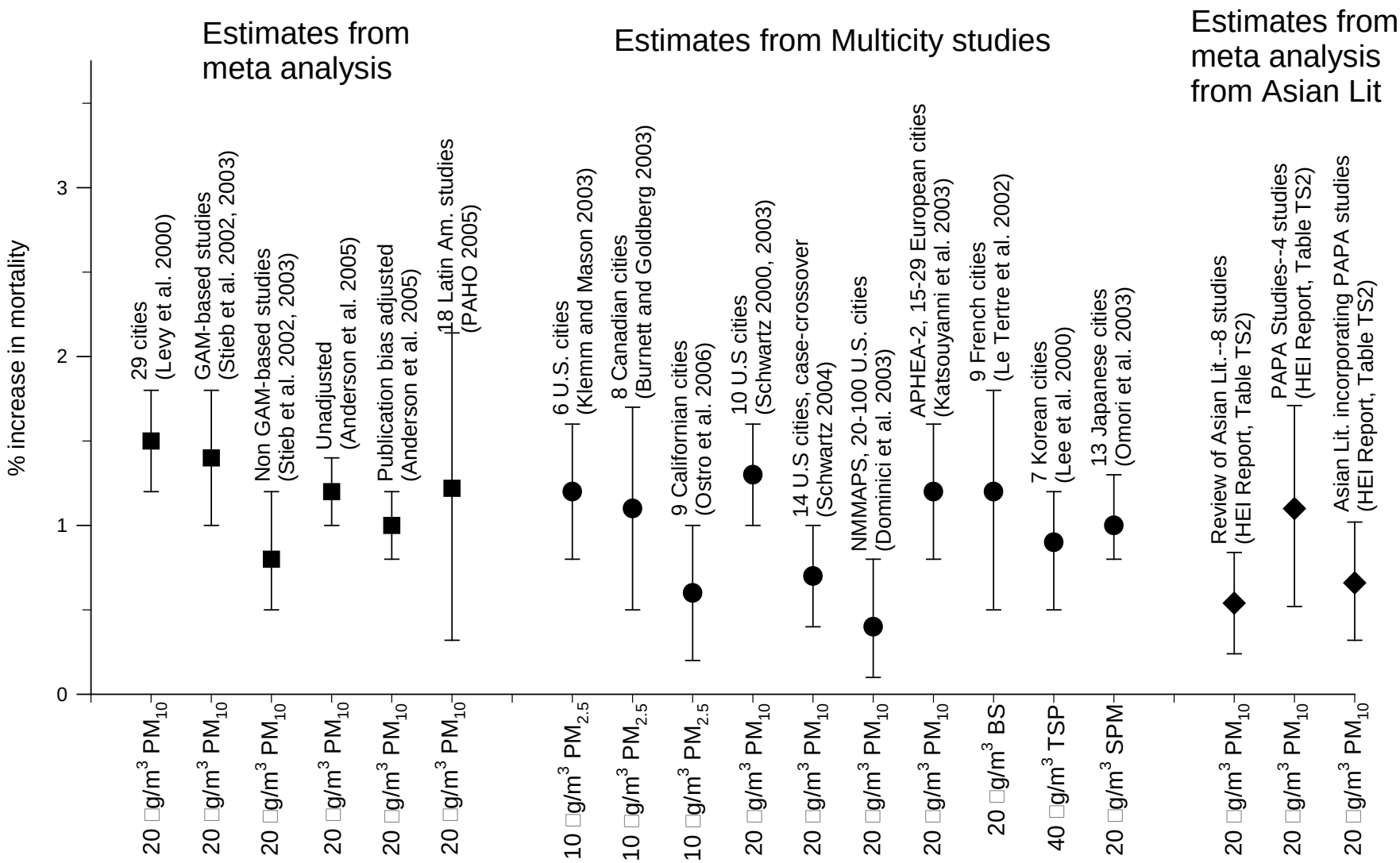
Particulate Matter 2.5




Dia = 500 microns



Daily time-series studies – Effects of **Short-term** exposure to PM - ***of over 200 cities***



10 μg/m³ $PM_{2.5}$ or 20 μg/m³ PM_{10} → 0.4% to 1.5% increase in relative risk of mortality—Small but remarkably consistent across meta-analyses and multi-city studies.

Does Long-Term Exposure to Air Pollution Cause Health Problems?

An Association Between Air Pollution and Mortality in Six U.S. Cities

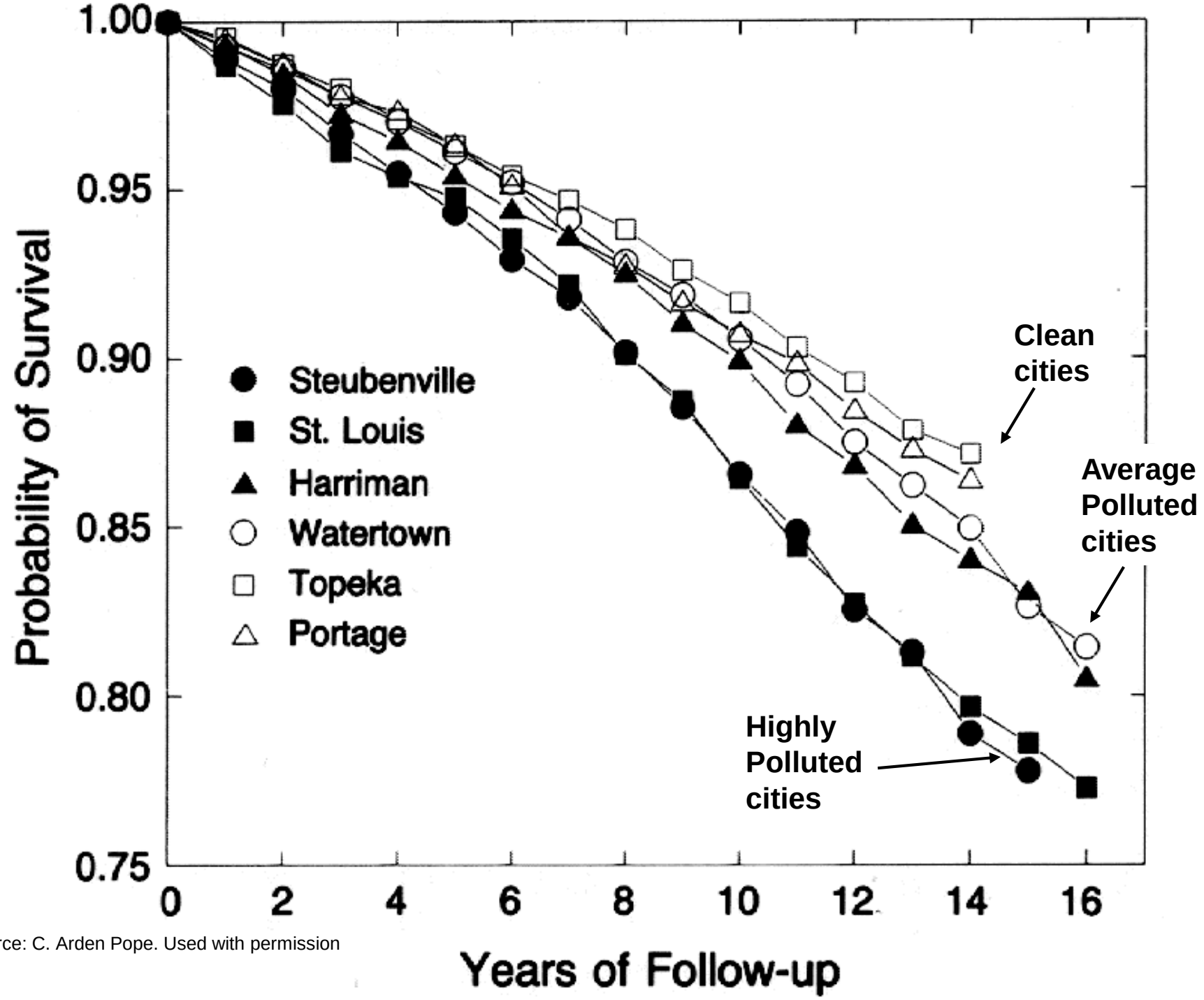
The NEW ENGLAND JOURNAL of MEDICINE 1993

Dockery DW, Pope CA III, Xu X, Spengler JD, Ware JH, Fay ME, Ferris BG Jr, Speizer FE.

Methods:

- 14-16 yr prospective follow-up of 8,111adults living in six U.S. cities.
- Monitoring of TSP PM_{10}, $PM_{2.5}$, SO_4, H^+, SO_2, NO_2, O_3 .
- Data analyzed using survival analysis, including Cox Proportional Hazards Models.
- Controlled for individual differences in: age, sex, smoking, BMI, education, occupational exposure.

Source: C. Arden Pope. Used with permission



Source: C. Arden Pope. Used with permission

Relative risk of death from various causes due to **long-term** exposure to PM2.5

Table 2. Adjusted Mortality Relative Risk (RR) Associated With a 10-μg/m³ Change in Fine Particles Measuring Less Than 2.5 μm in Diameter

	Adjusted RR (95% CI)*		
Cause of Mortality	1979-1983	1999-2000	Average
All-cause	1.04 (1.01-1.08)	1.06 (1.02-1.10)	1.06 (1.02-1.11)
Cardiopulmonary	1.06 (1.02-1.10)	1.08 (1.02-1.14)	1.09 (1.03-1.16)
Lung cancer	1.08 (1.01-1.16)	1.13 (1.04-1.22)	1.14 (1.04-1.23)
All other cause	1.01 (0.97-1.05)	1.01 (0.97-1.06)	1.01 (0.95-1.06)

*Estimated and adjusted based on the baseline random-effects Cox proportional hazards model, controlling for age, sex, race, smoking, education, marital status, body mass, alcohol consumption, occupational exposure, and diet. CI indicates confidence interval.

Source: Pope et al. JAMA March 2002, Vol 287, No. 9. 16-yr follow-up of a half million people in up to 156 metro areas – The largest prospective cohort study on PM2.5 in the world

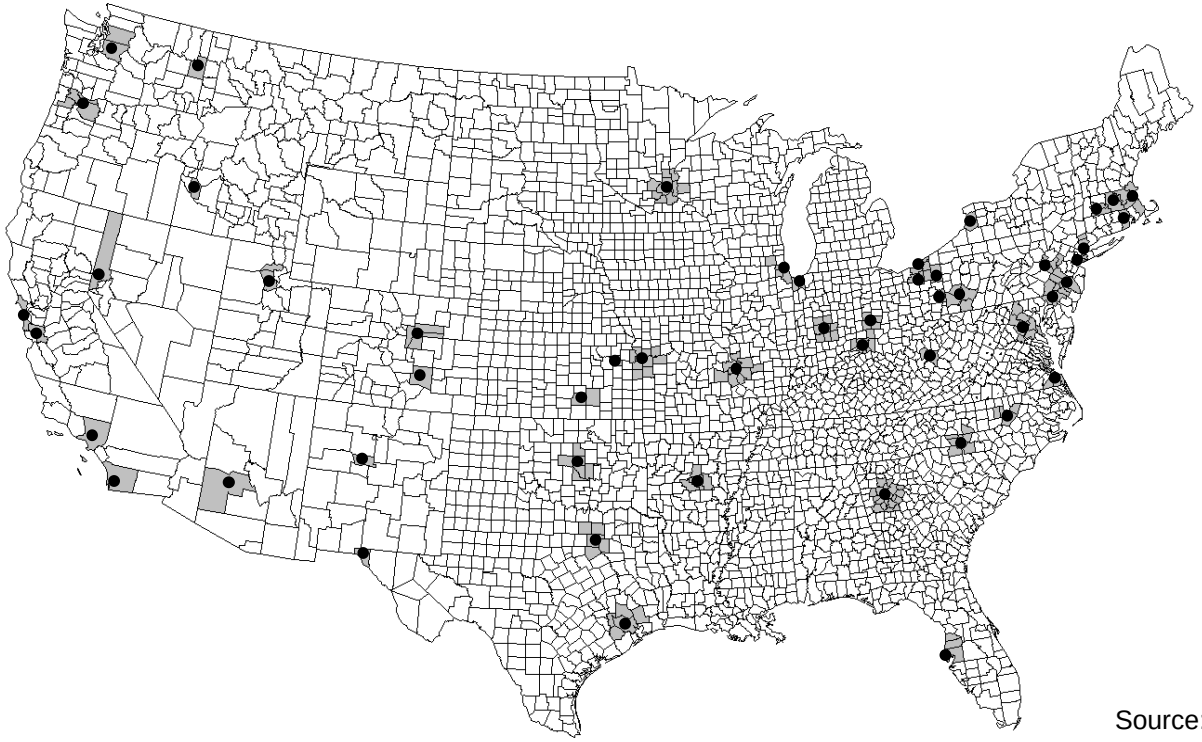
Do cities with bigger improvements in air quality have bigger improvements in health, measured by life expectancy?

The NEW ENGLAND JOURNAL of MEDICINE

January 22, 2009

Fine-Particulate Air Pollution and Life Expectancy in the United States

C. Arden Pope, III, Ph.D., Majid Ezzati, Ph.D., and Douglas W. Dockery, Sc.D.



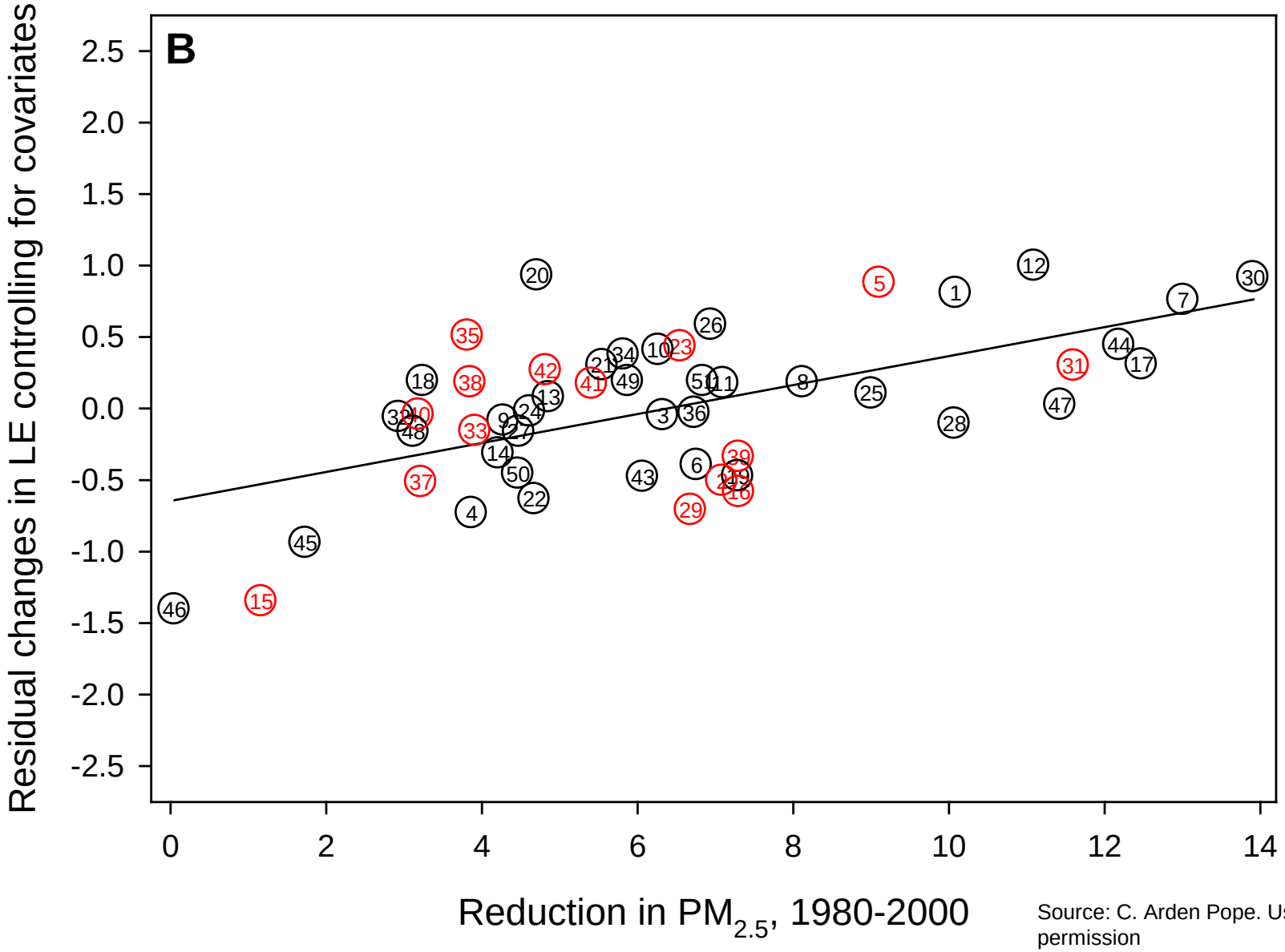
- Matching $PM_{2.5}$ data for 1979-1983 and 1999-2000 in 51 Metro Areas

- Life Expectancy data for 1978-1982 and 1997-2001 in 211 counties in 51 Metro areas

- Evaluate changes in Life Expectancy with changes in $PM_{2.5}$ for the 2-decade period of approximately 1980-2000.

Source: C. Arden Pope. Used with permission

YES. On average, the greater the reduction in air pollution, the greater the increase in life expectancy.



Source: C. Arden Pope. Used with permission

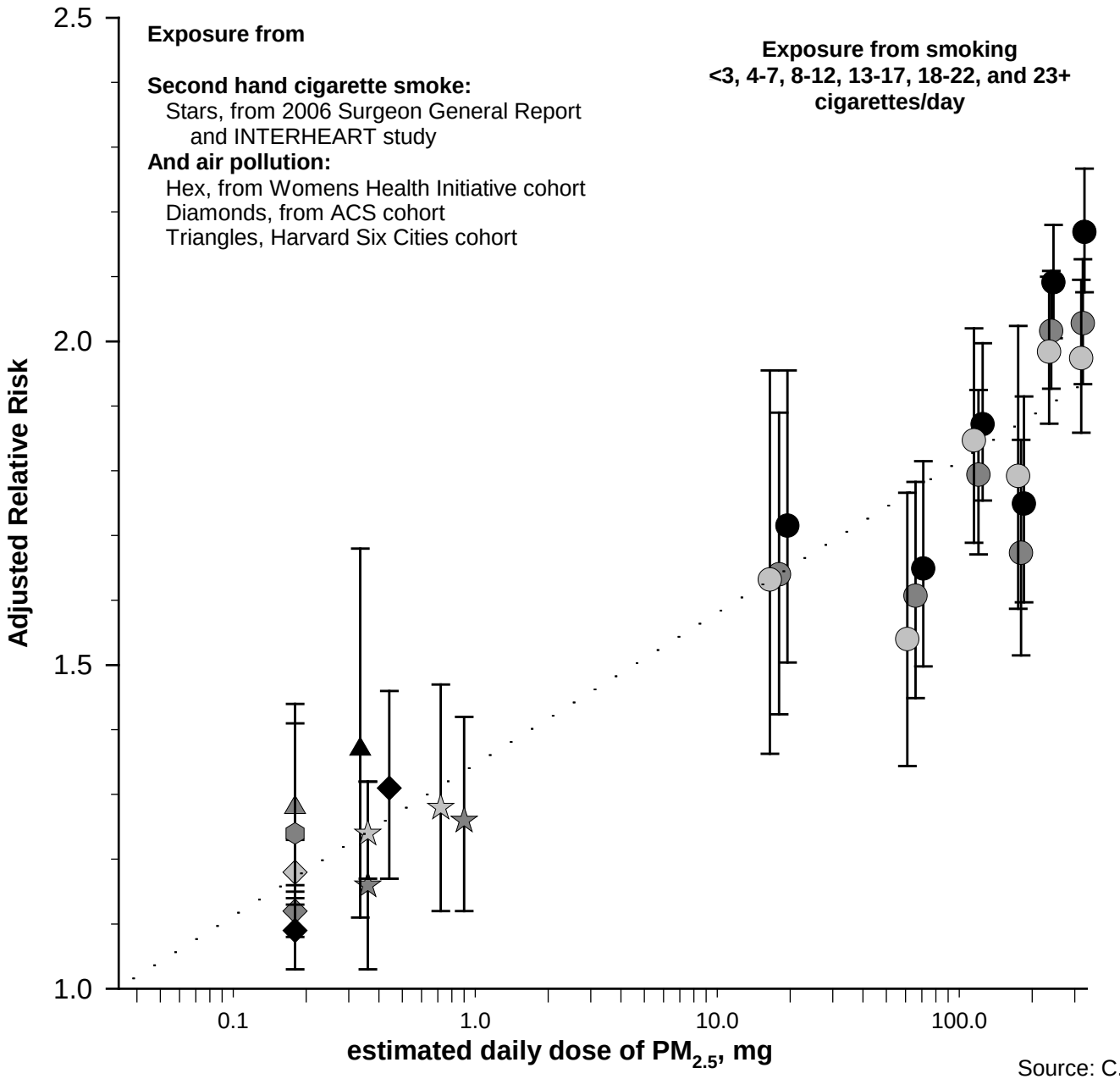
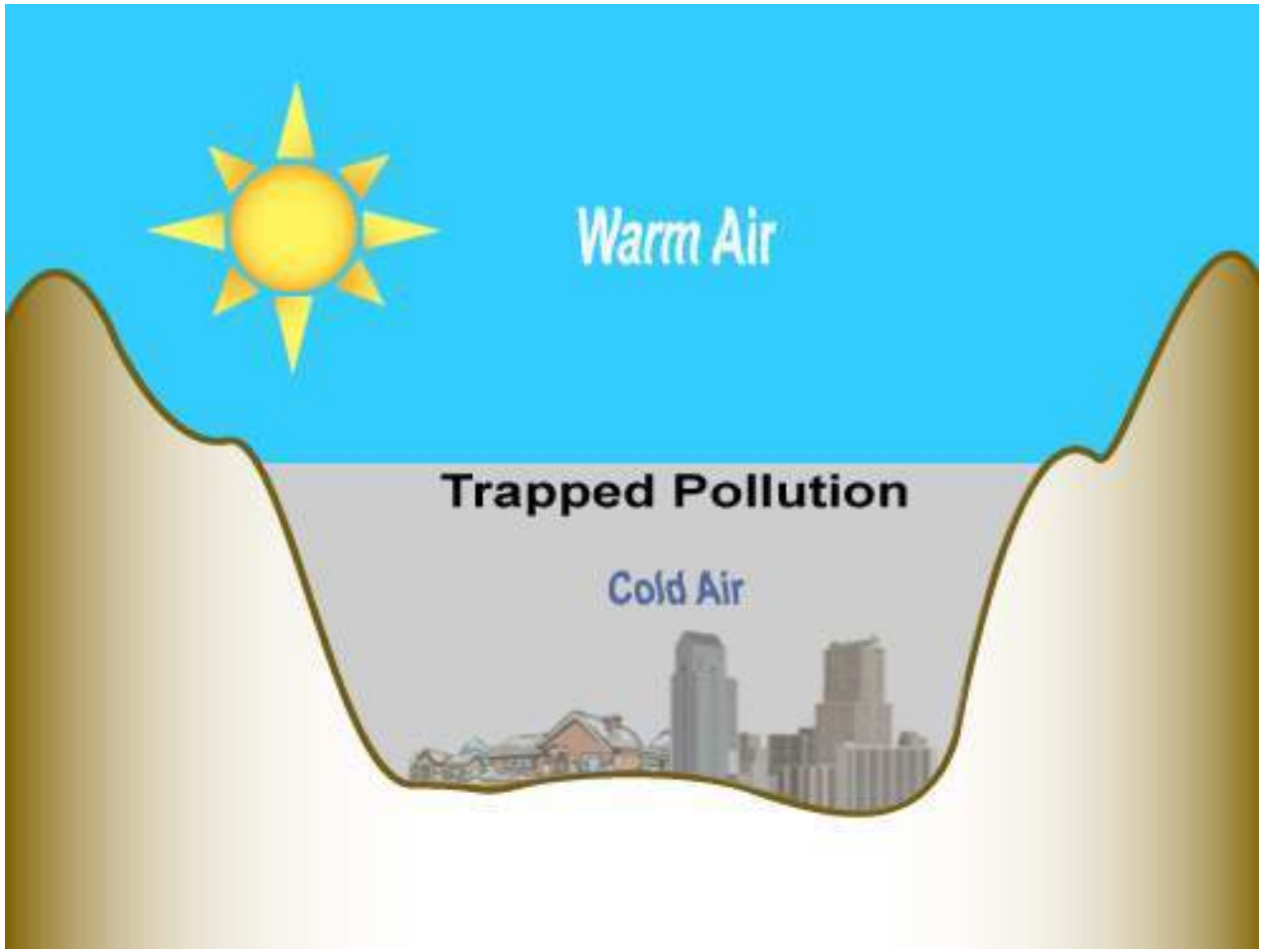


Figure 2. Adjusted relative risks (and 95% CIs) of ischemic heart disease (light gray), cardiovascular (dark gray), and cardiopulmonary (black) mortality plotted over baseline estimated daily dose (using a log scale) of $PM_{2.5}$ from current cigarette smoking (relative to never smokers), SHS, and air pollution.

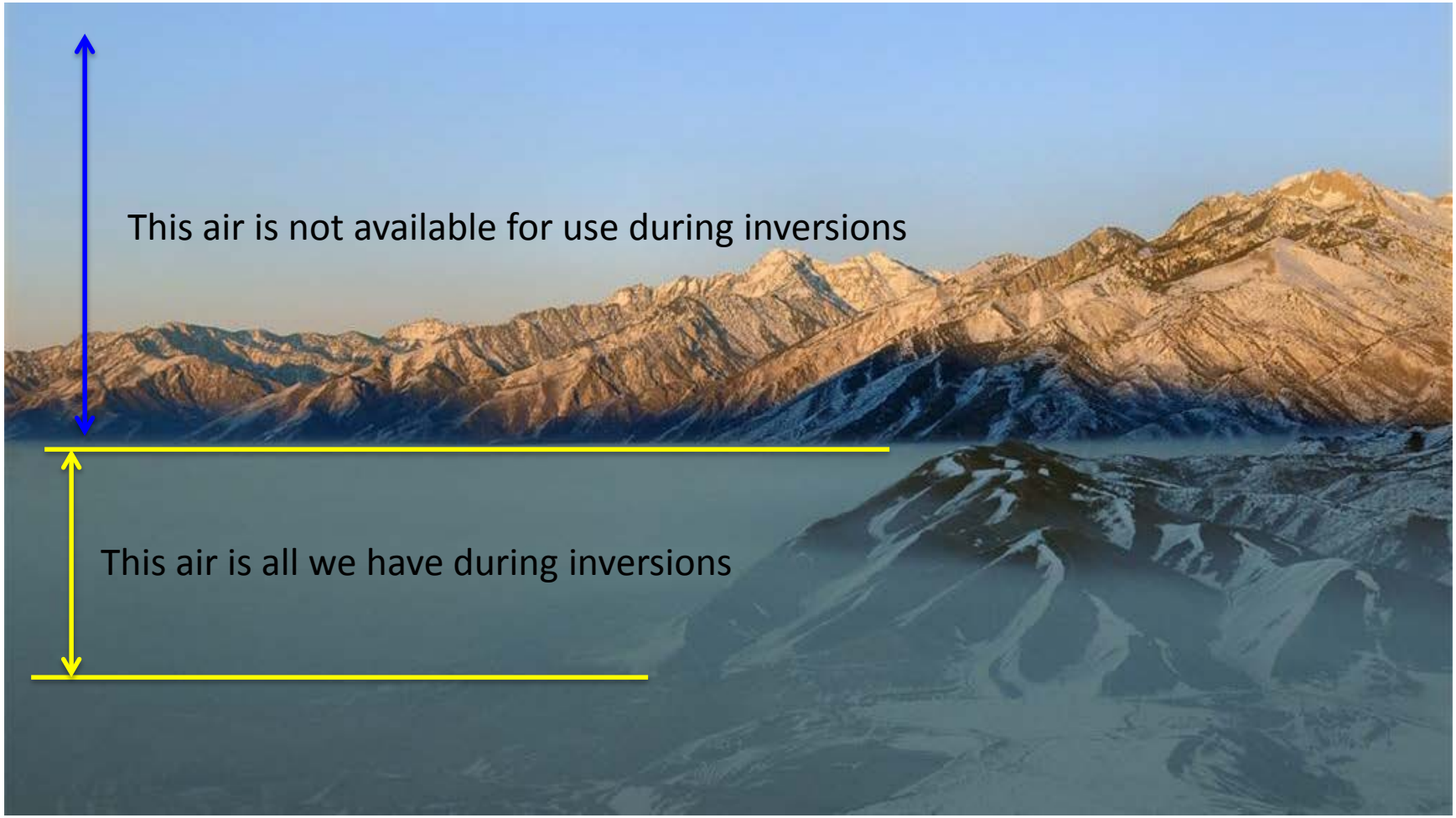
Source: C. Arden Pope. Used with permission

$PM_{2.5}$ chemistry and inversions

Why do inversions happen and why does $PM_{2.5}$ increase during inversions?


Warm Air
Trapped Pollution
Cold Air

Little or no vertical mixing during inversions



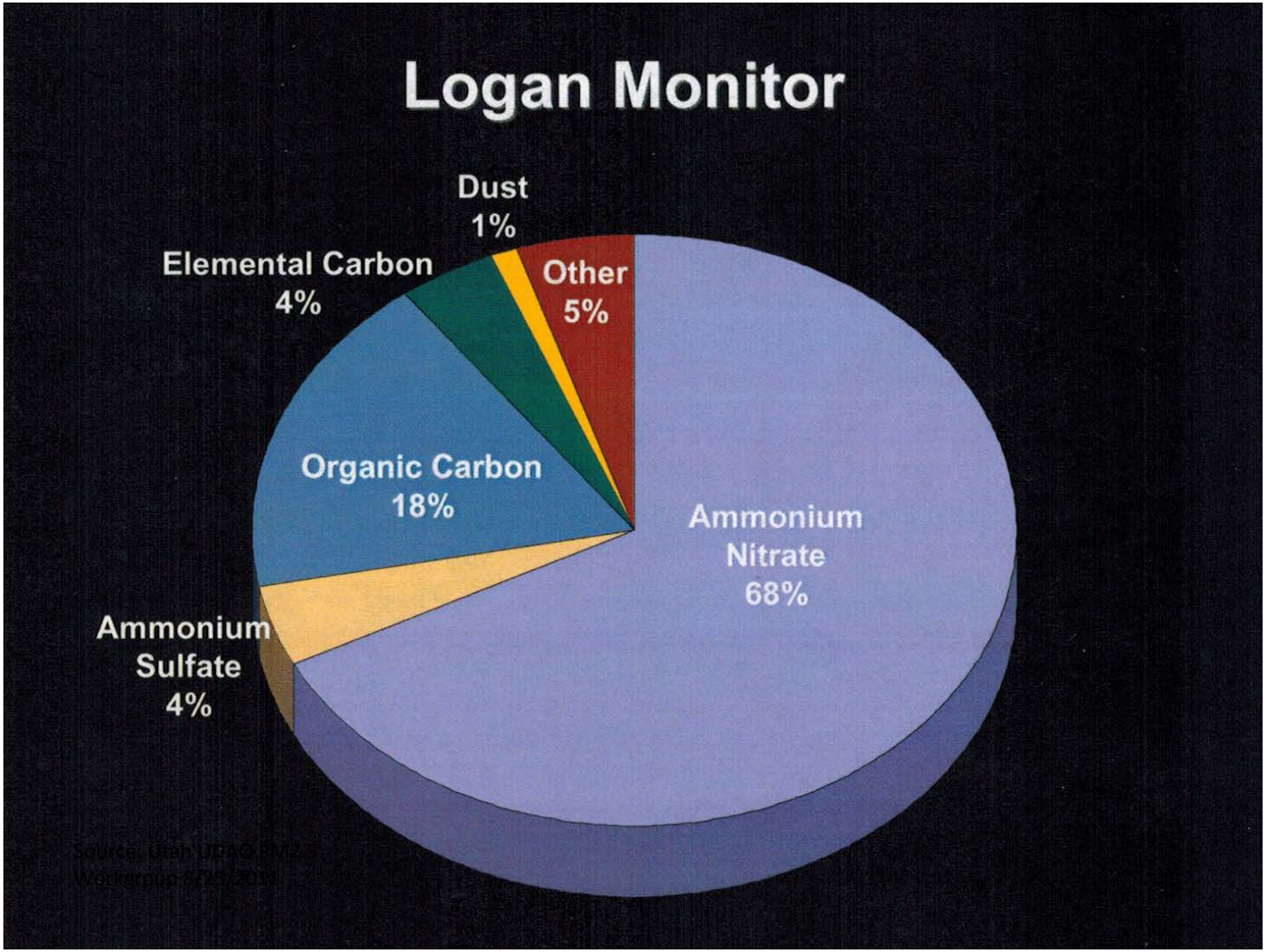
Definitions of Air Emissions and Pollutants

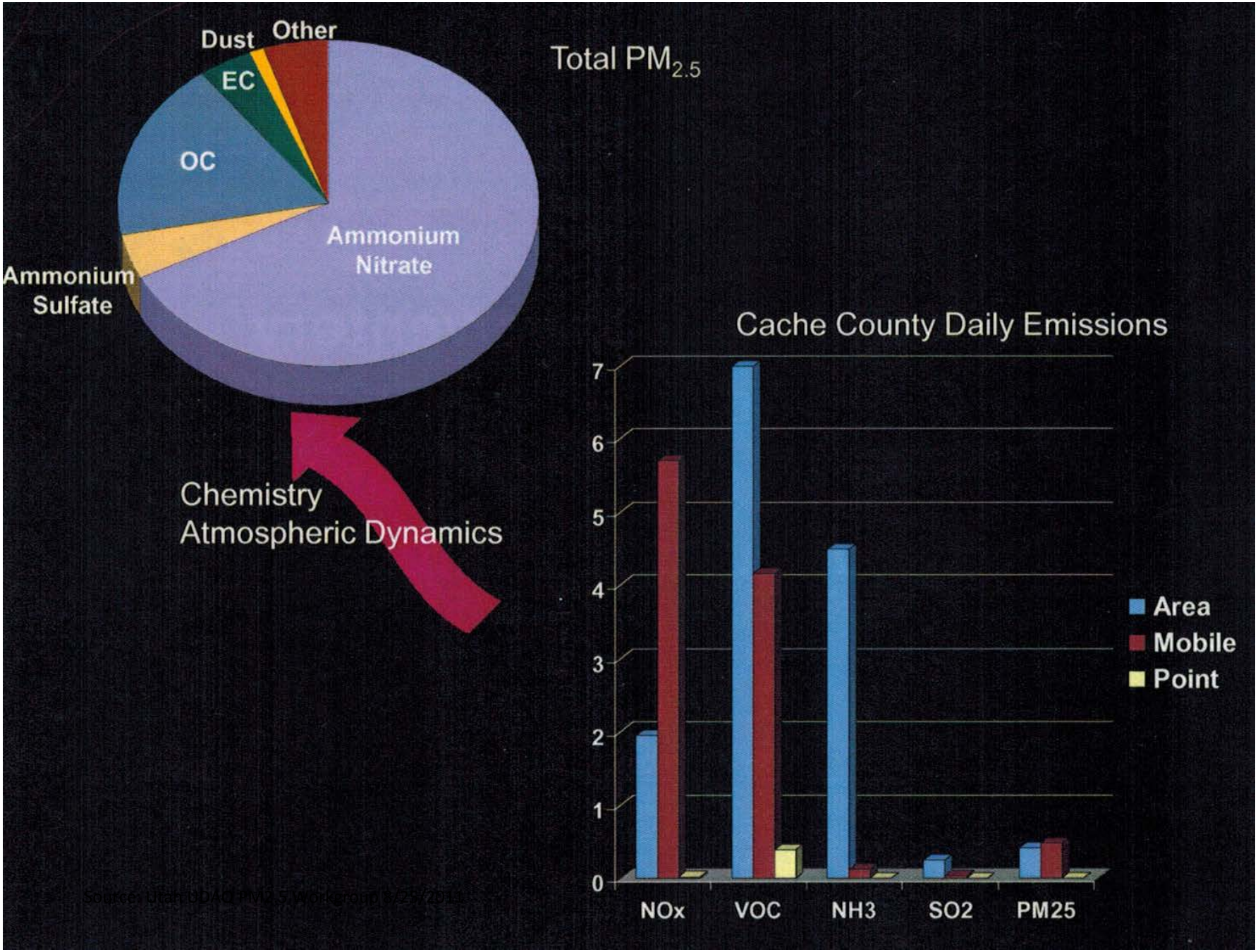
- Emissions that are gases:
- NO_x – Nitrogen oxides $N_2 + O_2 + heat \rightarrow NO_x$
- SO_x – Sulfur oxides Sulfur $+ O_2 + heat \rightarrow SO_x$
- VOC's – volatile organic compounds = hydrocarbons and other organic chemicals that easily evaporate at room temperature – you can usually smell these
- Ammonia – NH_3 – released from breakdown of urea and other bio-matter

- Solid air pollutants:
- Direct or primary $PM_{2.5}$ – particles of smoke or dust that are less then 2.5 microns in diameter – emitted directly into the air from the pollution source
- Secondary $PM_{2.5}$ – Particles of mostly ammonium nitrate that form in the inversion layer during cold temperatures from the above precursor gas emissions (NO_X SO_X VOC NH_4) via complex chemical reactions involving sunlight, ozone (O_3) and other oxygen radicals.

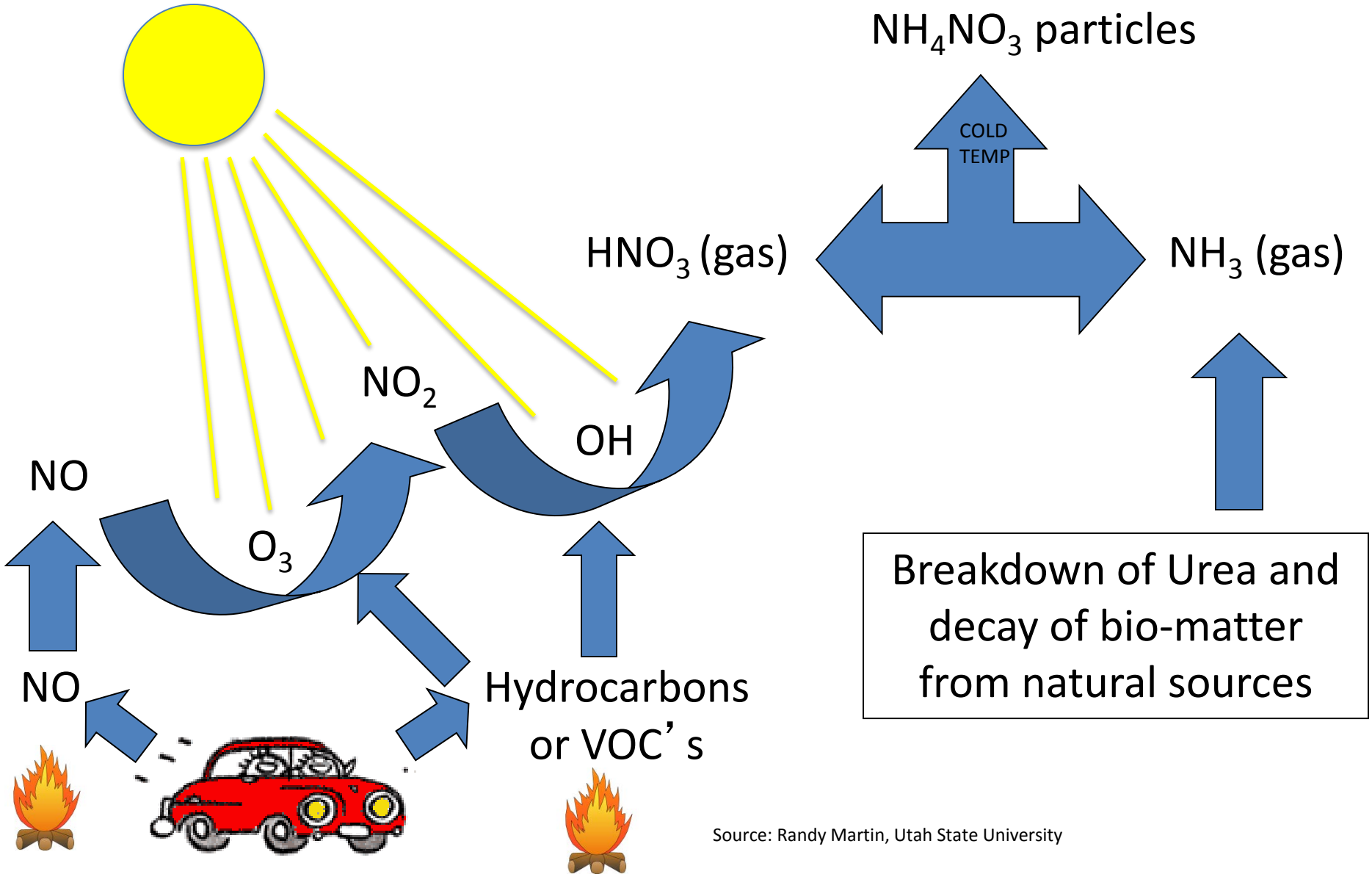
Typical Winter Inversion Day

January 6, 2010

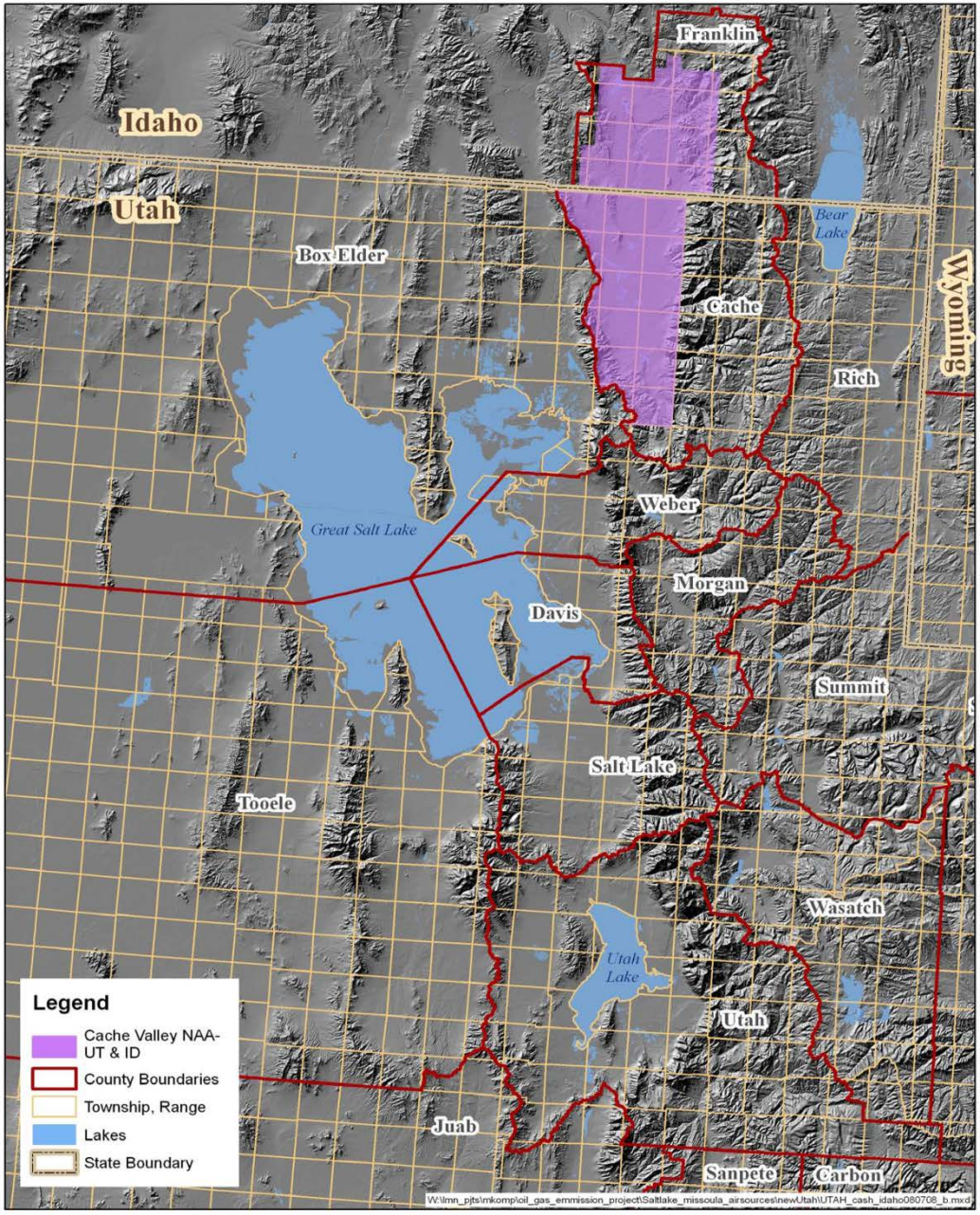



Total $PM_{2.5}$
Dust
Other
EC
OC
Ammonium Nitrate
Ammonium Sulfate
Chemistry
Atmospheric Dynamics
Cache County Daily Emissions
7
6
5
4
3
2
1
0
NOx
VOC
NH3
SO2
PM25
Area
Mobile
Point
Source: Utah UDAQ PM2.5 Workgroup 8/29/2013

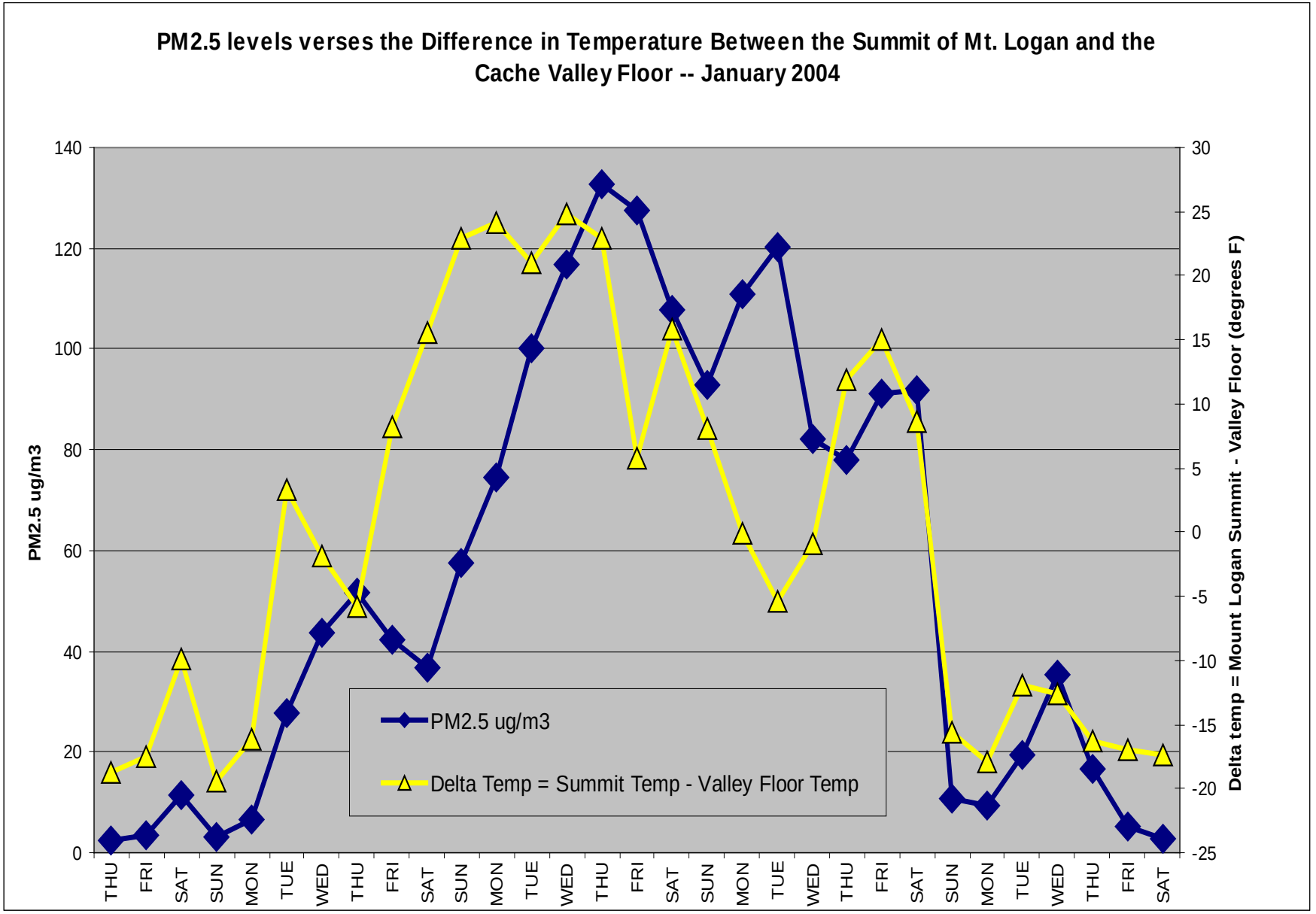
Chemistry of Ammonium Nitrate – NH_4NO_3

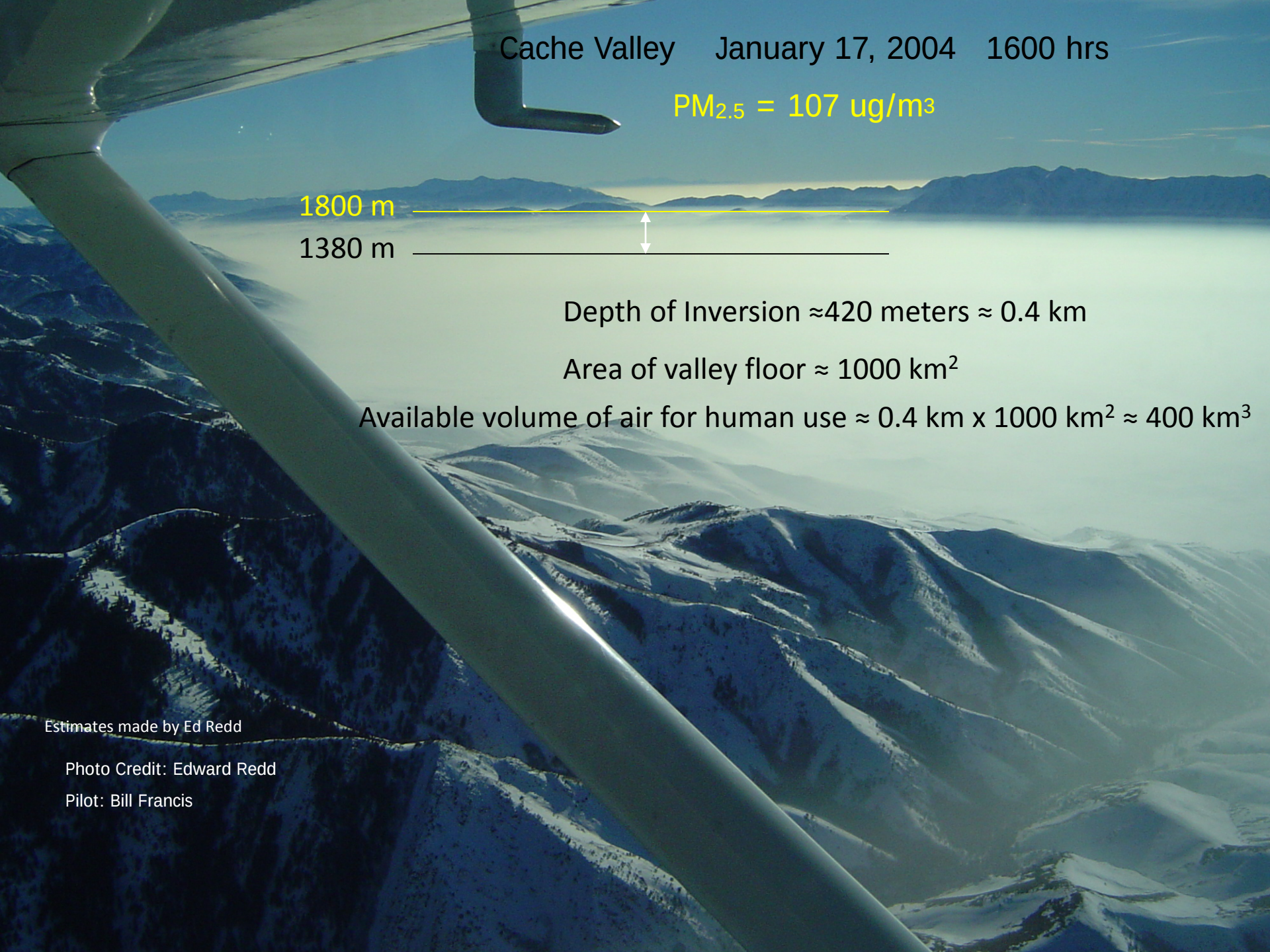


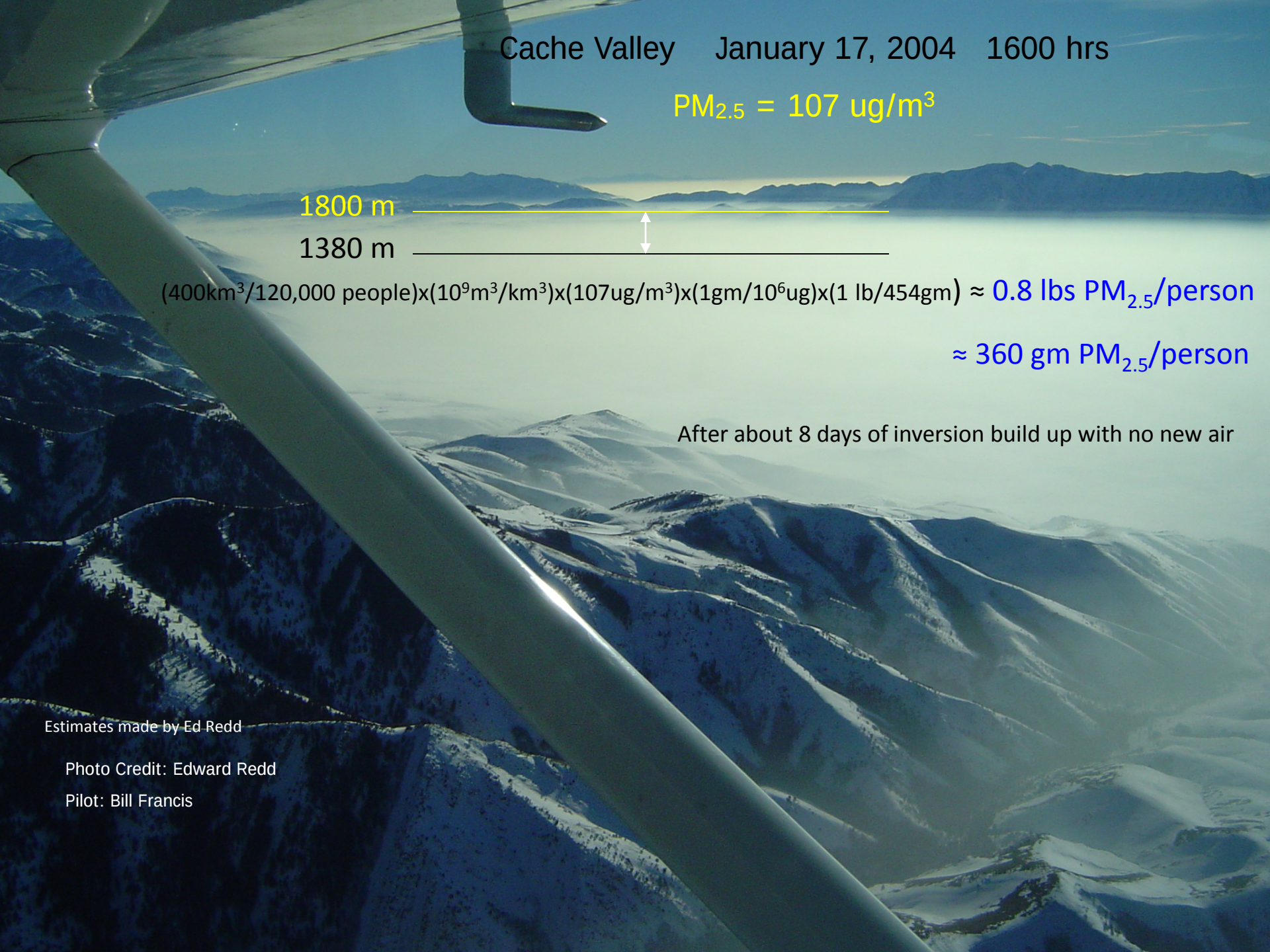
Source: Randy Martin, Utah State University


Idaho
Utah
Franklin
Box Elder
Bear Lake
Cache
Wyoming
Rich
Weber
Great Salt Lake
Morgan
Davis
Summit
Salt Lake
Tooele
Wasatch
Utah Lake
Utah
Juab
Sanpete
Carbon
Legend
Cache Valley NAA-UT & ID
County Boundaries
Township, Range
Lakes
State Boundary
W:\lmn_pjts\mkomp\oil_gas_emmission_project\Saltlake_missoula_airsources\newUtah\UTAH_cash_idaho080708_b.mxd

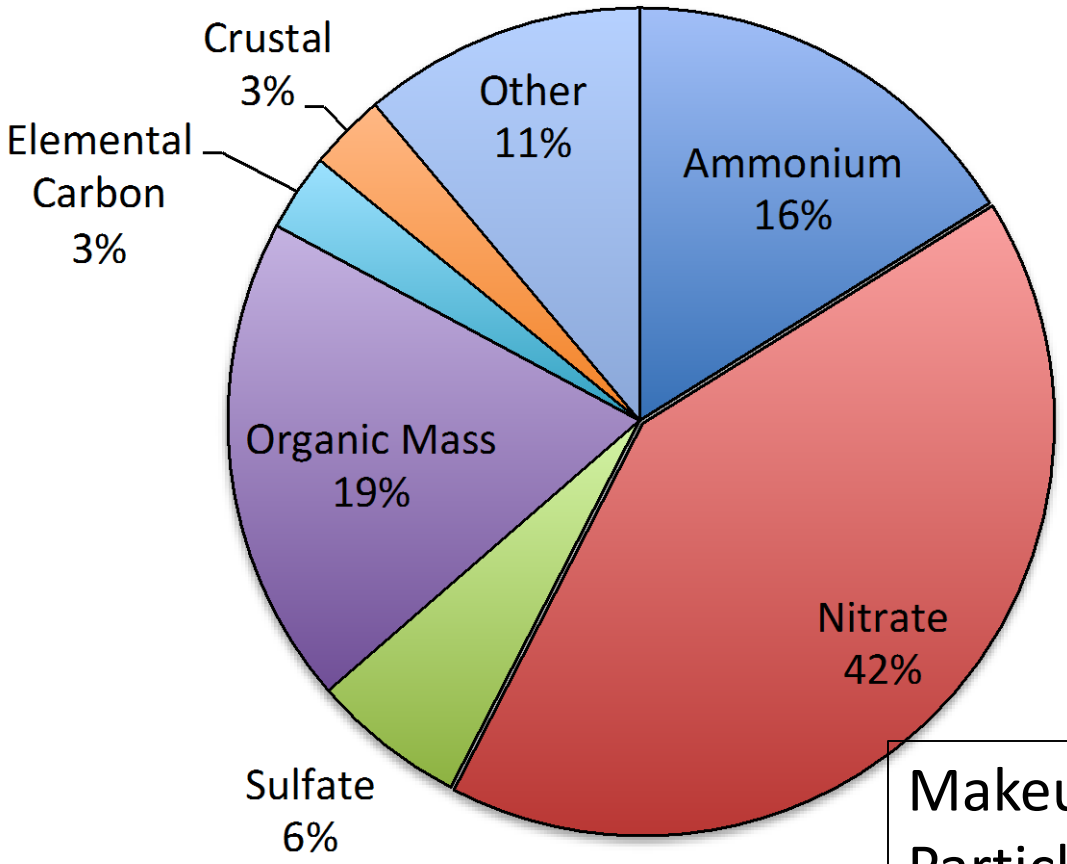
Intensities of inversions in Cache Valley correlate well with levels of $PM_{2.5}$




Cache Valley January 17, 2004 1600 hrs
PM2.5 = 107 ug/m3
1800 m
1380 m
Depth of Inversion ≈420 meters ≈ 0.4 km
Area of valley floor ≈ 1000 km2
Available volume of air for human use ≈ 0.4 km x 1000 km2 ≈ 400 km3
Estimates made by Ed Redd
Photo Credit: Edward Redd
Pilot: Bill Francis


Cache Valley January 17, 2004 1600 hrs
$PM_{2.5}$ = 107 ug/m^3
1800 m
1380 m
(400km^3/120,000 people)x($10^9m^3/km^3$)x(107ug/m^3)x(1gm/10^6ug)x(1 lb/454gm) ≈ 0.8 lbs $PM_{2.5}$/person
≈ 360 gm $PM_{2.5}$/person
After about 8 days of inversion build up with no new air
Estimates made by Ed Redd
Photo Credit: Edward Redd
Pilot: Bill Francis

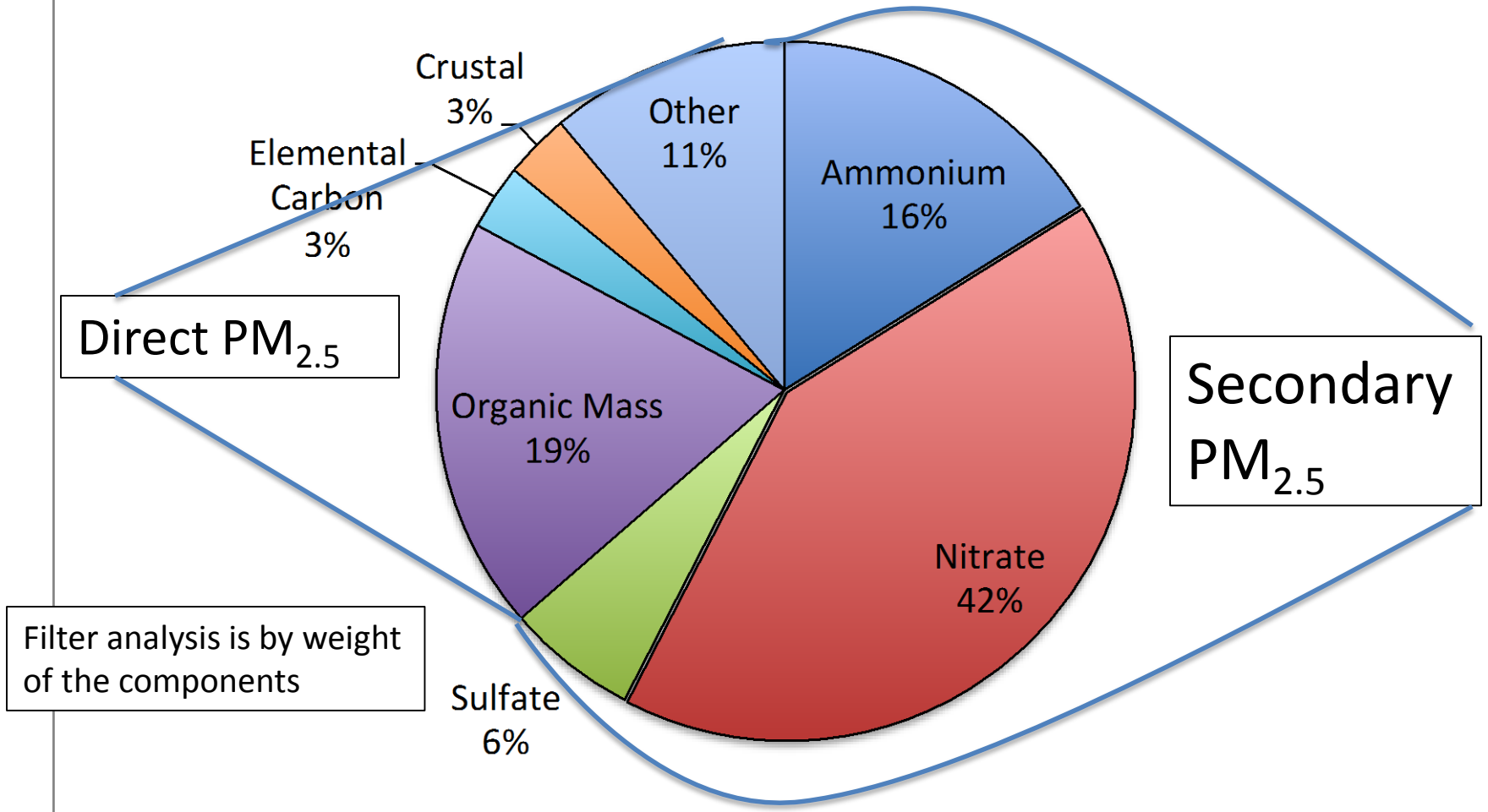
Salt Lake County PM2.5 Speciation - Filter Analysis
Hawthone 2010-2011



Makeup of the $PM_{2.5}$
Particles by mass

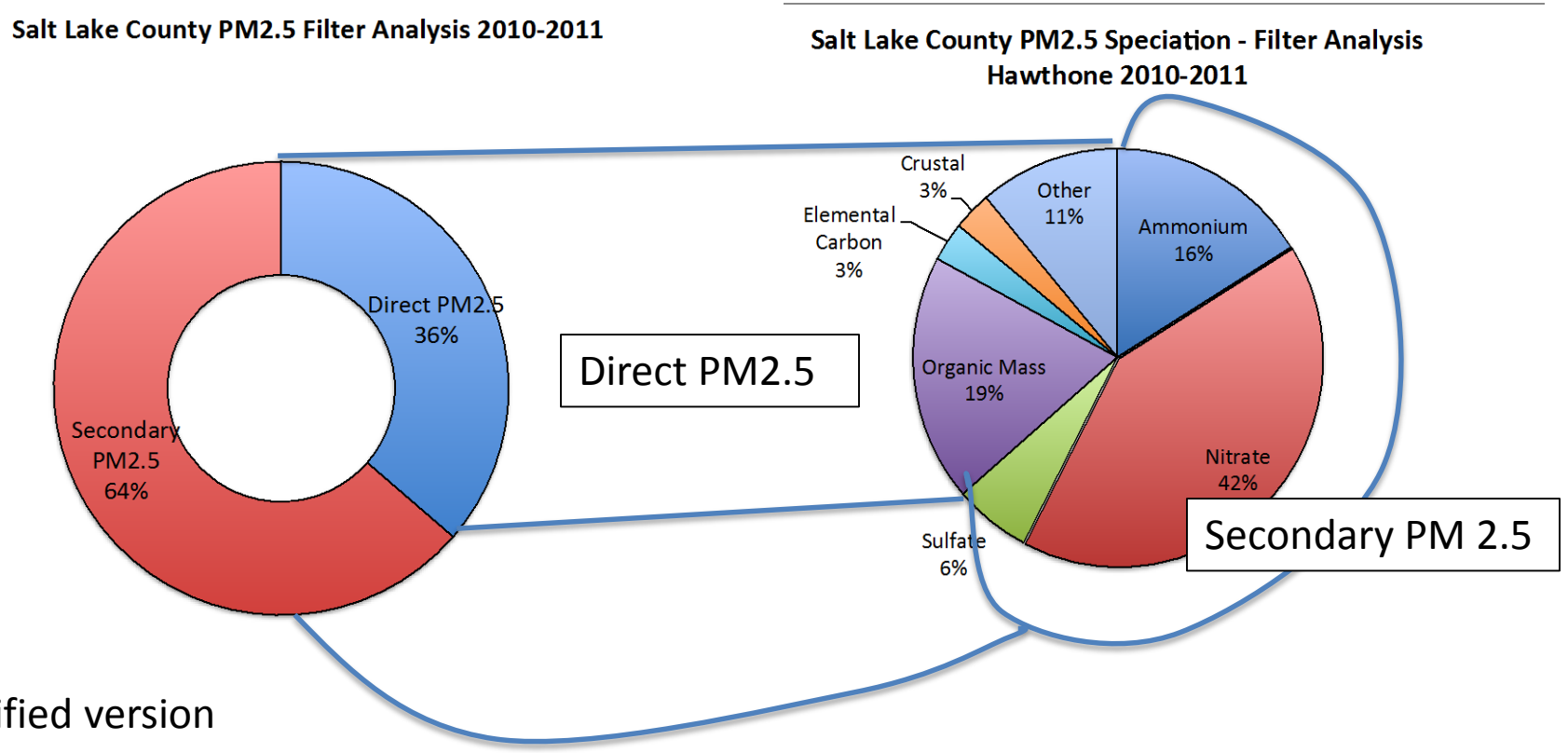
http://www.airquality.utah.gov/Air-Quality-Board/docs/2013/12Dec/ITEM_VII_SIP_IX.A.21_SLC.pdf

Salt Lake County PM2.5 Speciation - Filter Analysis
Hawthone 2010-2011



http://www.airquality.utah.gov/Air-Quality-Board/docs/2013/12Dec/ITEM_VII_SIP_IX.A.21_SLC.pdf

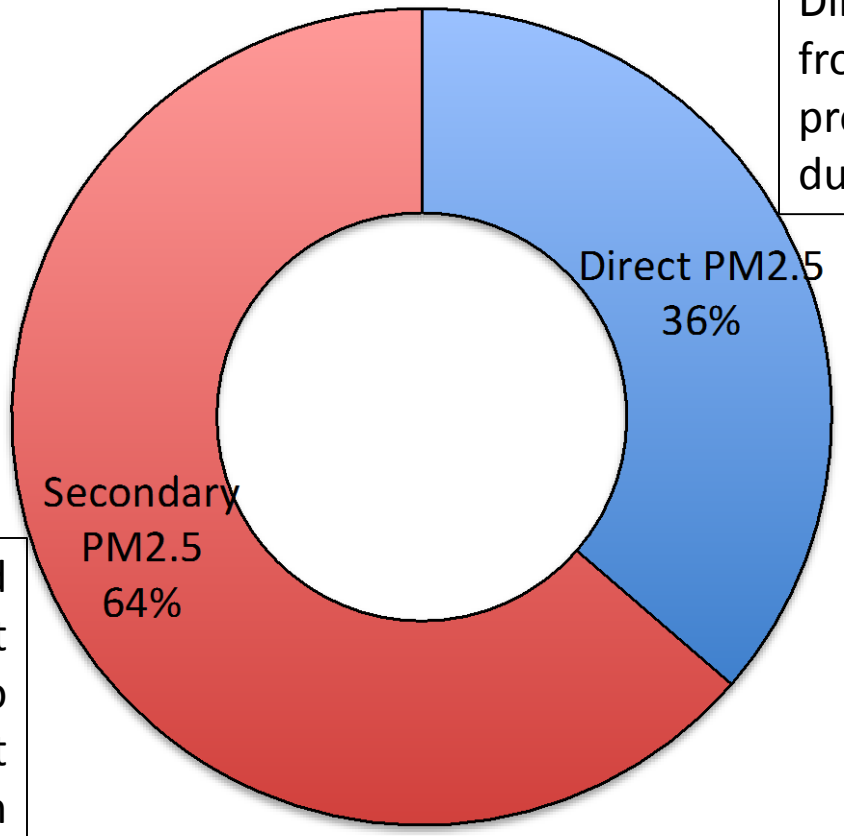
Wintertime Direct and Secondary PM2.5 - simplified speciation



Simplified version

http://www.airquality.utah.gov/Air-Quality-Board/docs/2013/12Dec/ITEM_VII_SIP_IX.A.21_SLC.pdf

Salt Lake County PM2.5 Filter Analysis 2010-2011



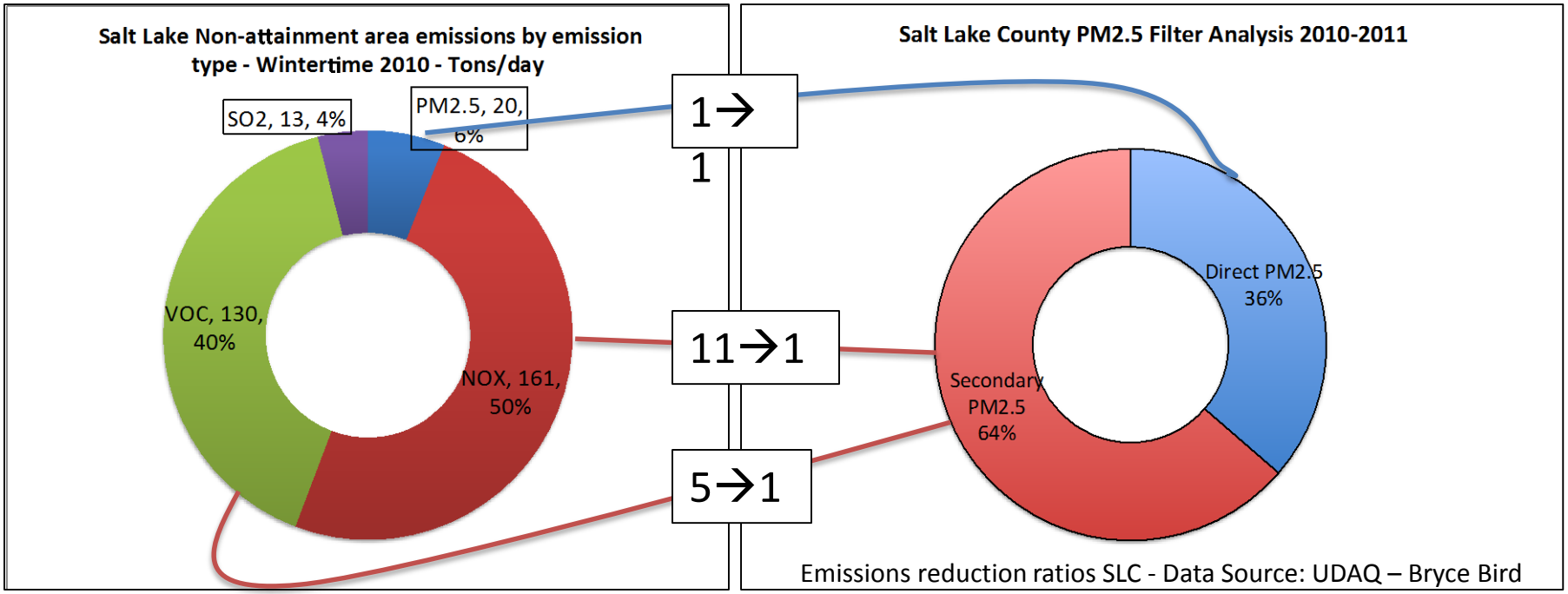
Directly emitted particles from combustion processes and suspended dust particles

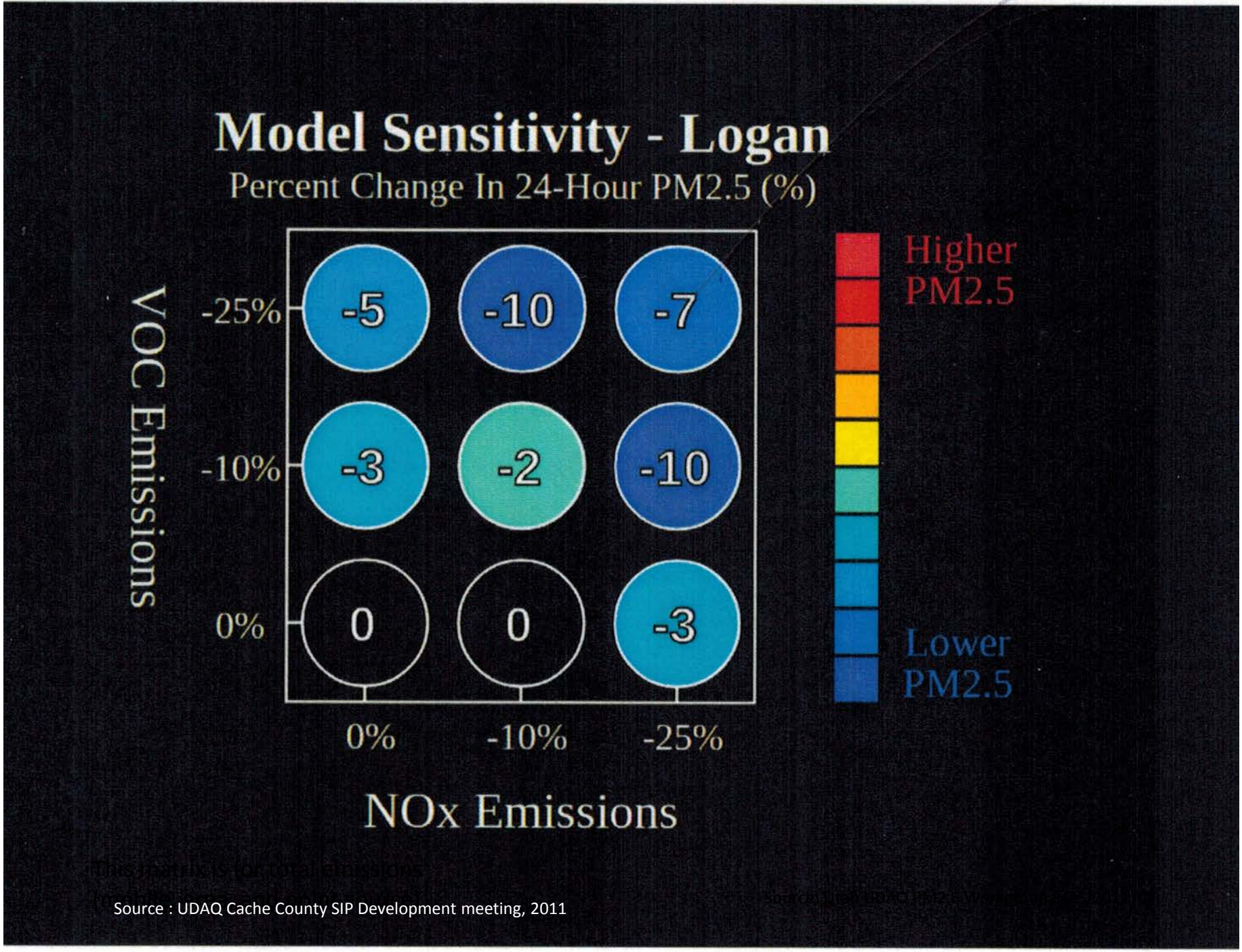
Caused by VOC and NO_X emissions that react with ozone to form Nitric acid that then combines with ammonia to form ammonium nitrate

http://www.airquality.utah.gov/Air-Quality-Board/docs/2013/12Dec/ITEM_VII_SIP_IX.A.21_SLC.pdf

Emissions Reductions vs. $PM_{2.5}$ in the Air

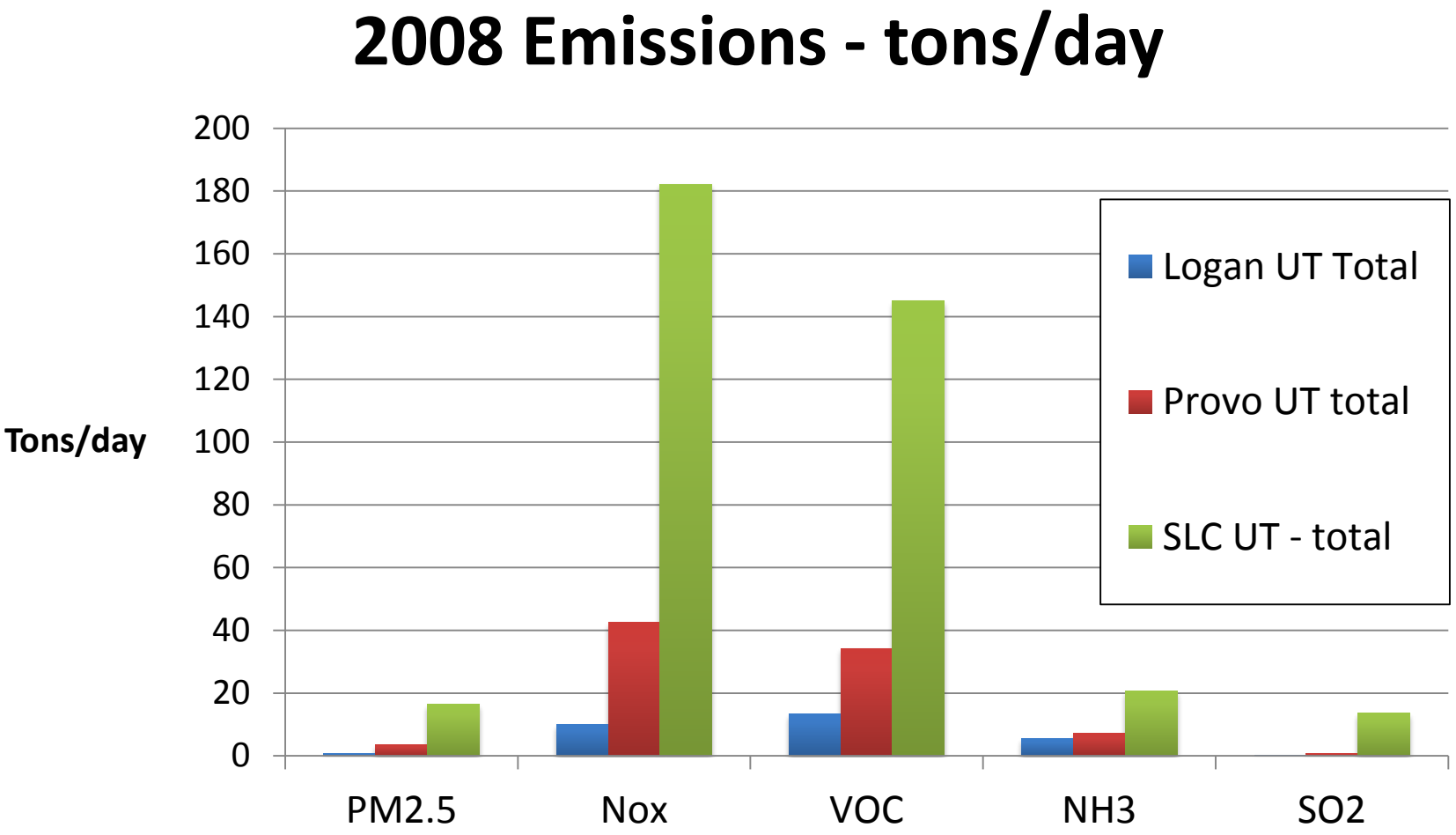
- Not all emissions affect $PM_{2.5}$ levels equally
- 1-ton reduction in Direct $PM_{2.5}$ emissions → 1-ton reduction of $PM_{2.5}$ in the air shed (1:1 reduction)
- 1-ton reduction in VOC, SO_X and NO_X results in significantly less than a 1-ton reduction in Secondary $PM_{2.5}$ in the air shed





Source : UDAQ Cache County SIP Development meeting, 2011

What does this mean for Cache Valley?

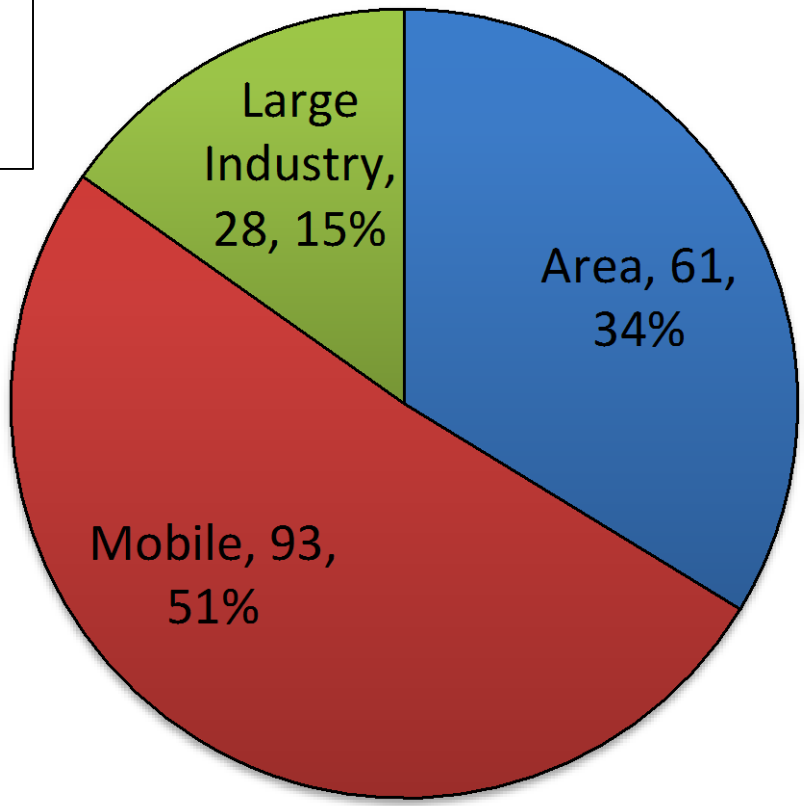


Data Source:http://www.airquality.utah.gov/Planning/SIP/SIPPDF/Dec-2012/SIP_Doc_IX_A_23_FINAL.pdf

Sources of Emissions

Salt Lake Non-Attainment Area - 2010 Typical Winter Weekday Emissions - tons/day

Source of emissions (tons/day)

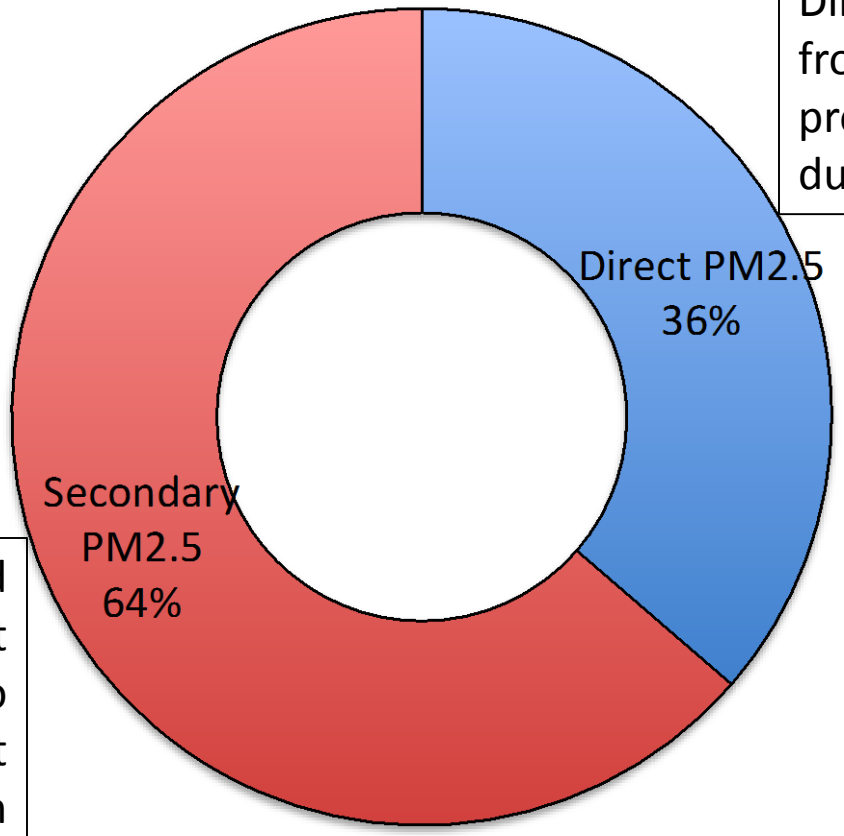


Source: UDAQ

Wood smoke emissions from stoves and $PM_{2.5}$

- Direct $PM_{2.5}$ (the smoke) 100-400 grams/day
- VOC's (part of the smell) 80-500 grams/day
- NOx 70 grams/day

Salt Lake County PM2.5 Filter Analysis 2010-2011



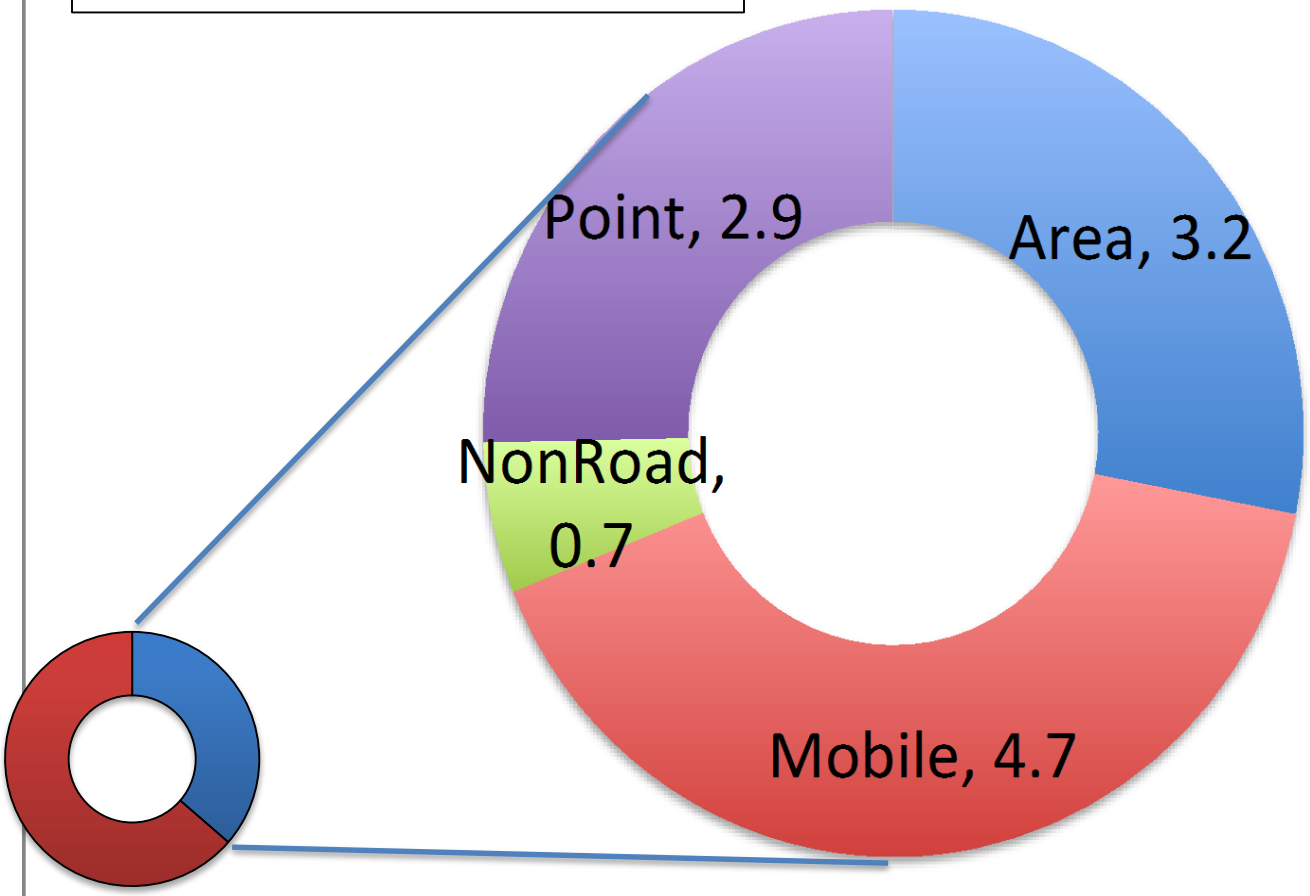
Directly emitted particles from combustion processes and suspended dust particles

Caused by VOC and NO_X emissions that react with ozone to form Nitric acid that then combines with ammonia to form ammonium nitrate

http://www.airquality.utah.gov/Air-Quality-Board/docs/2013/12Dec/ITEM_VII_SIP_IX.A.21_SLC.pdf

Salt Lake County DIrect PM2.5 -- Tons/Day

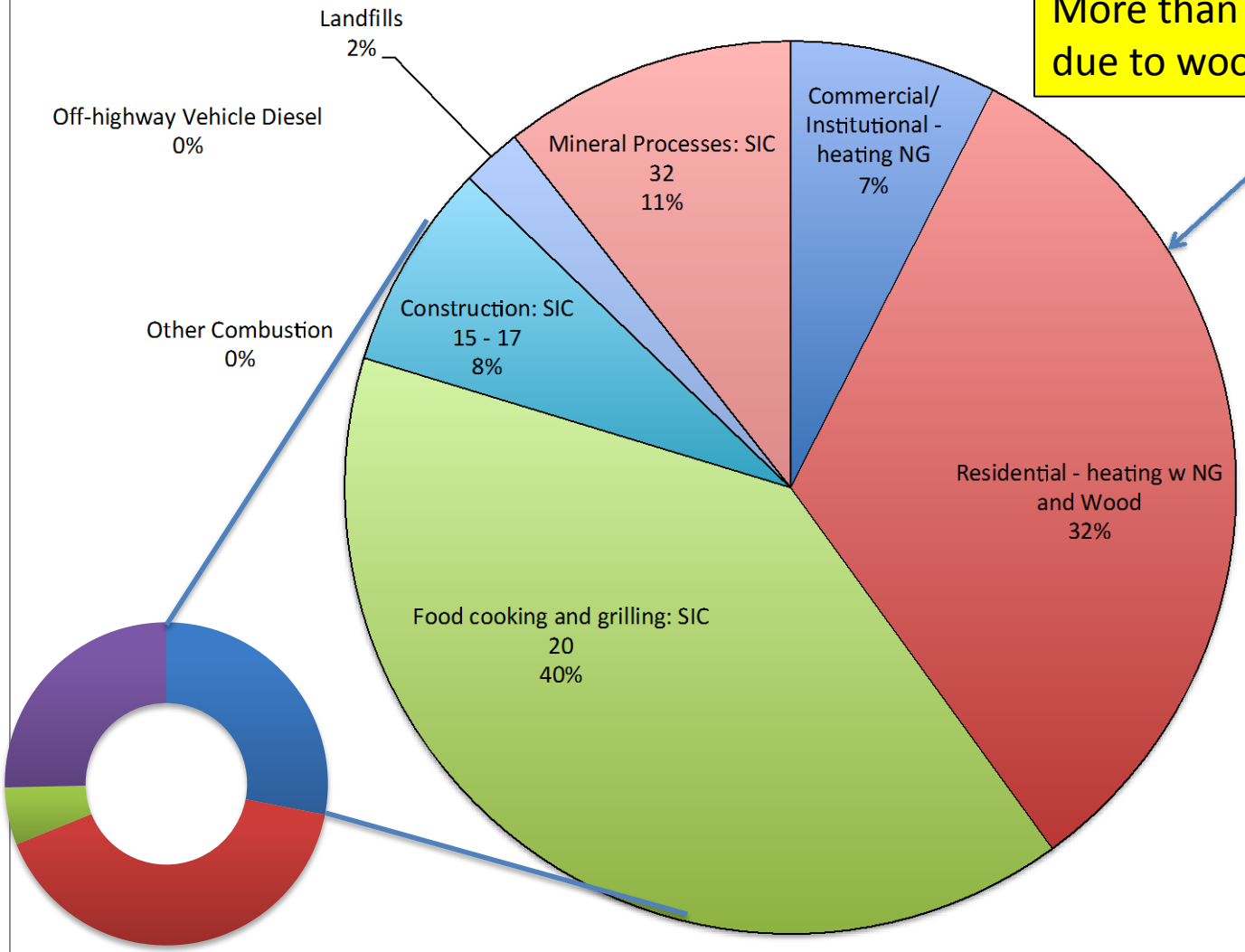
Total direct PM = 11.5 tons /day



http://www.airquality.utah.gov/Pollutants/ParticulateMatter/PM25/CacheValley/index.htm

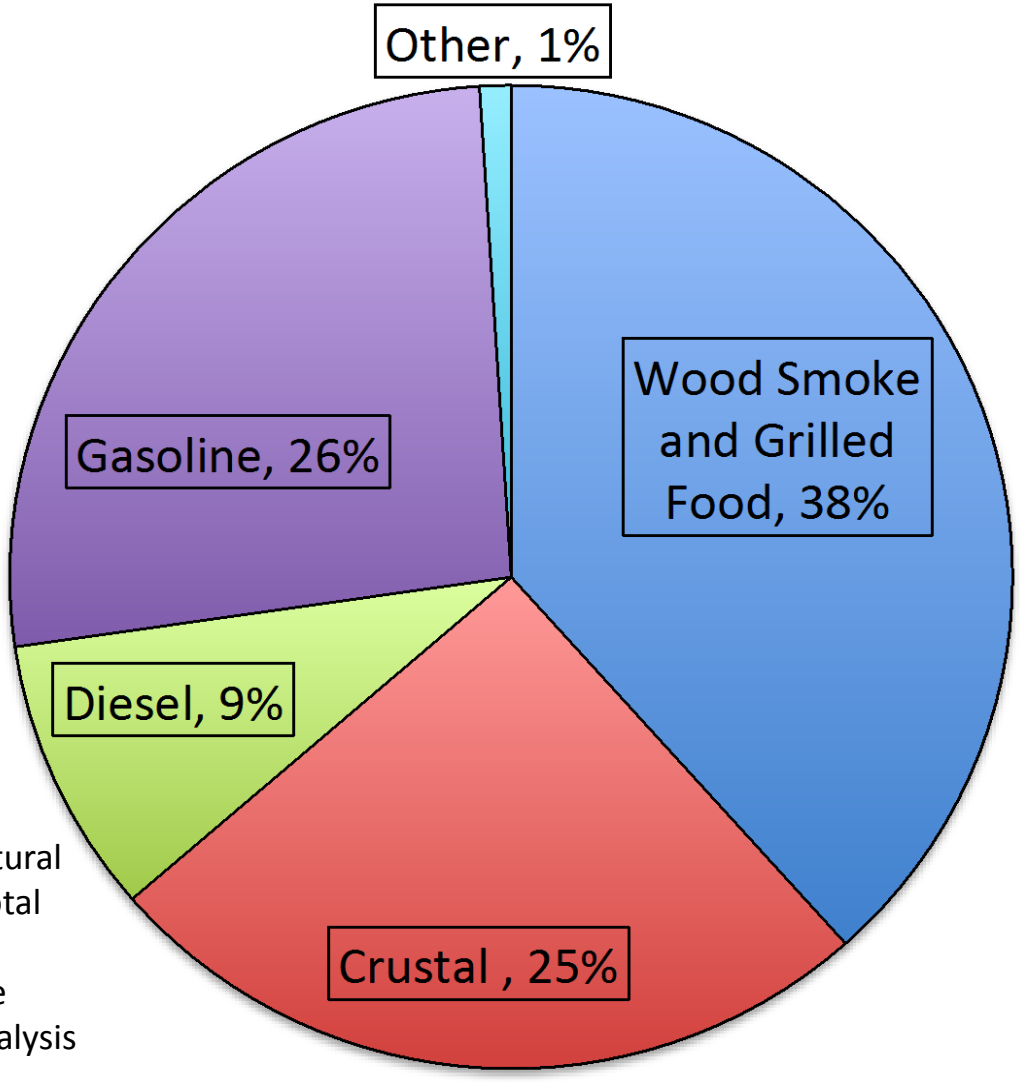
SL County Area Direct $PM_{2.5}$ Emissions - 3.2 tons per day

More than ½ of this direct PM is due to wood smoke (2/3 ton/d)



http://www.airquality.utah.gov/Pollutants/ParticulateMatter/PM25/presentations/Archive/presentation2.html?fips=49035

Directly Emitted $PM_{2.5}$ Hawthon - SL County
University of Utah Source Attribution Study

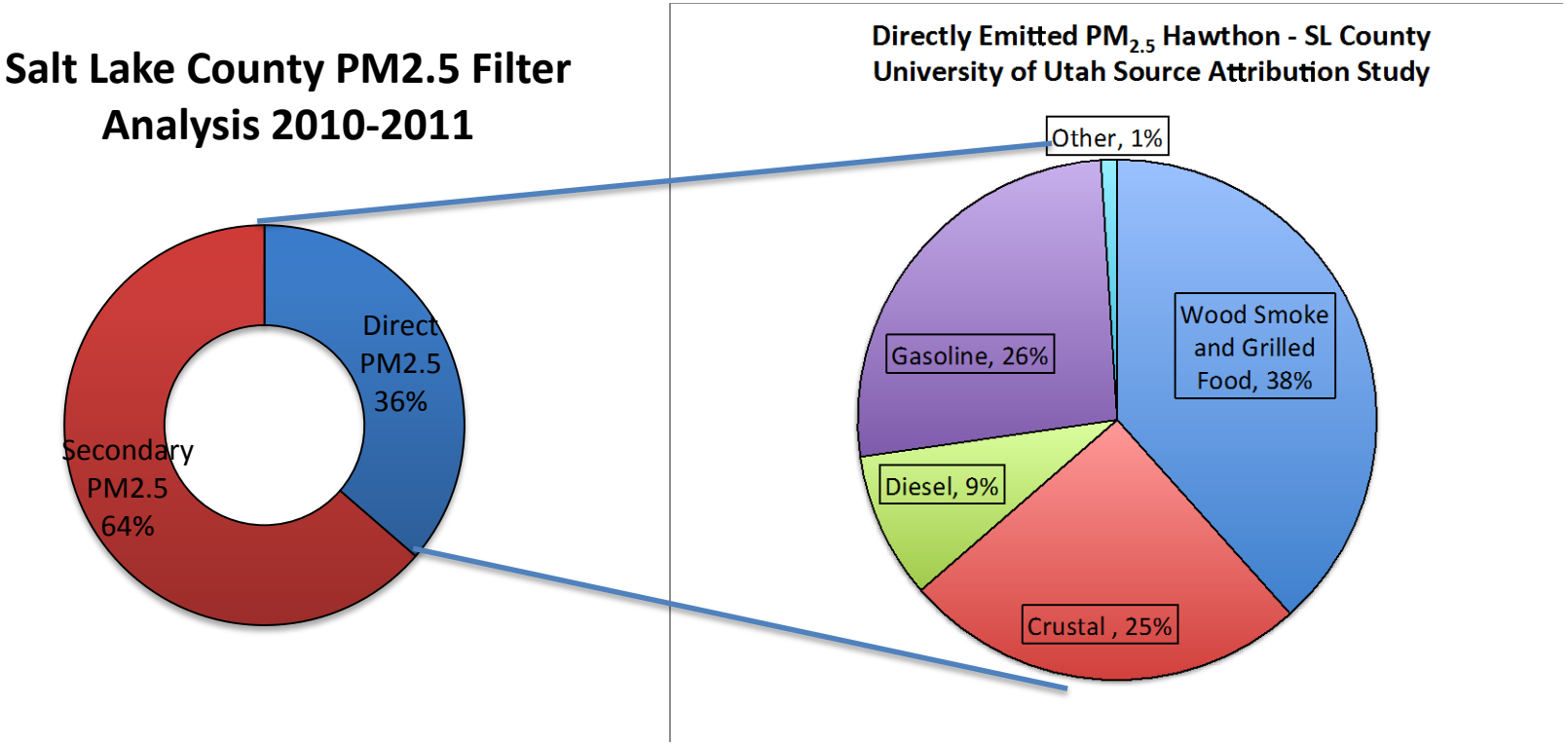


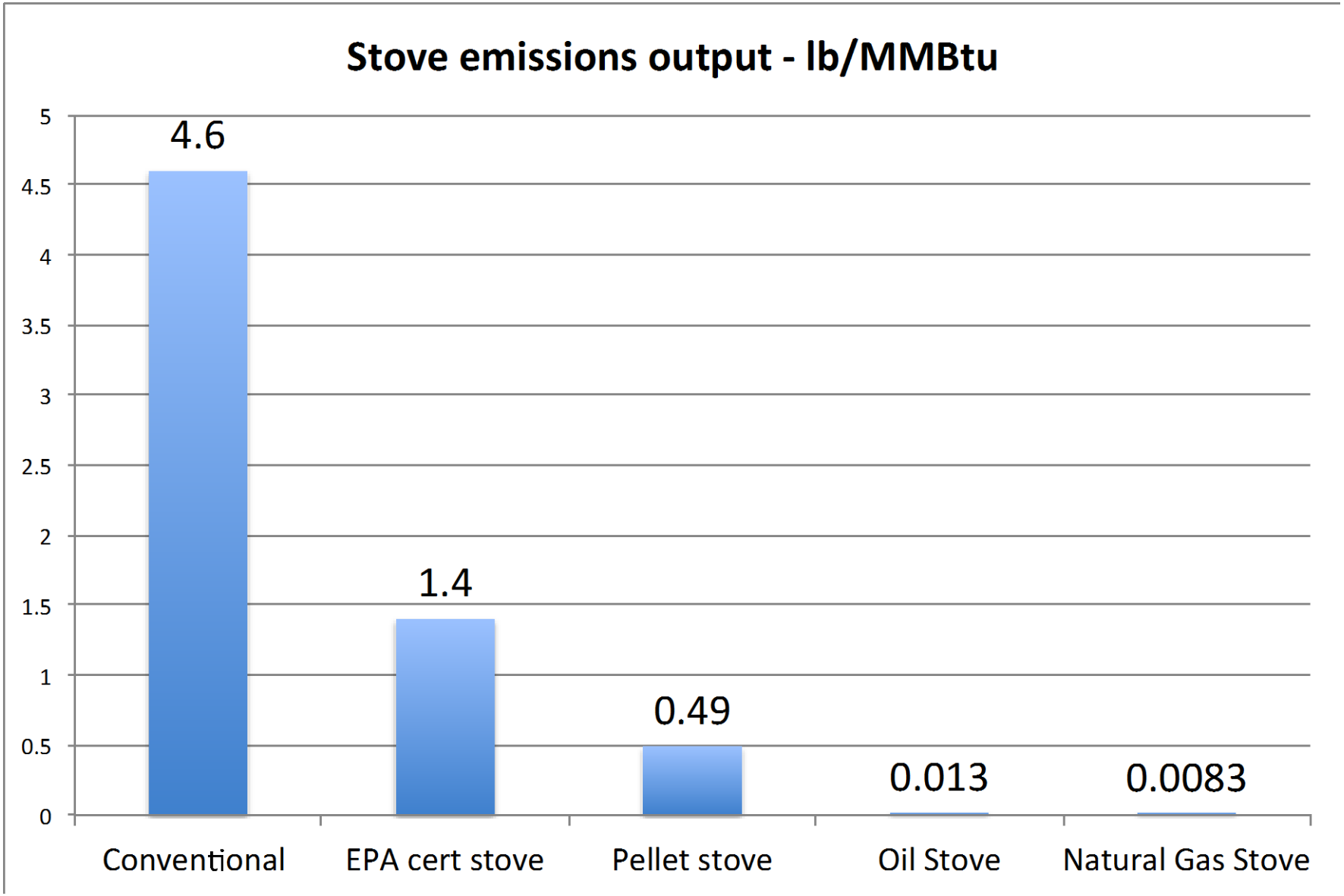
The contribution of direct PM2.5 from burning of natural gas is about 5-7% of the total direct PM inventory and is probably mixed in with the gasoline portion of this analysis

Kerry Kelly et al. http://dx.doi.org/10.1080/10962247.2013.774819

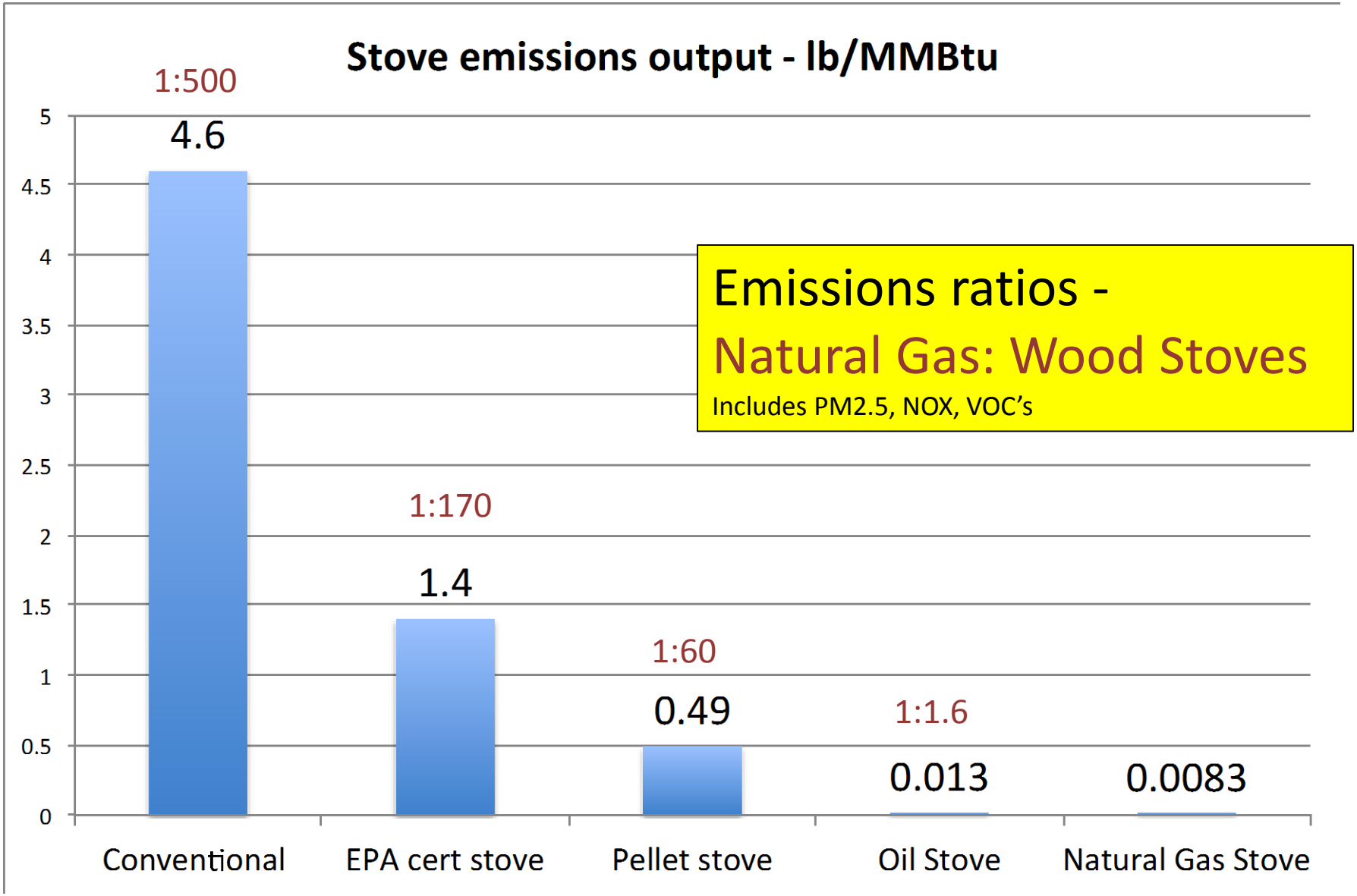
Wood smoke emissions likely cause about 5-7% of total $PM_{2.5}$ elevations during wintertime inversions

(when $PM_{2.5}$ levels are >20ug/m^3)





http://www.epa.gov/burnwise/energyefficiency.html



http://www.epa.gov/burnwise/energyefficiency.html

Sole-Source Wood Burning in Homes – How Much Direct $PM_{2.5}$?

- 203 registered wood-heated sole-source homes – Assume all are in SL County – Assume typical daily use including cold starts
- Direct $PM_{2.5}$ = 117 lbs/year per stove
- Burn days = 150 days per year
- Direct PM emissions/day per stove = 0.8 lbs/day
- Daily PM emissions for 203 stoves = 158 lbs/day
- Total direct $PM_{2.5}$ = 23,000 lbs per day (SL County)
  - SL County Direct PM Inventory of 11.5 tons/day
- Change 203 wood stoves to Nat. Gas → 0.7% reduction in direct PM ≈ 0.25% reduction in total PM
- (this does not include the significant effect of reduction in VOC of about 120 lbs/year/stove due to changing out stoves)

Estimated cost per ton reduction $PM_{2.5}$?

- Natural gas stove – one-time cost = $3,000
- Natural gas furnace – one-time cost = $8,000
- Wood stove emissions/20 years = 1 ton direct $PM_{2.5}$
- total emissions reductions = 2.7 tons PM, VOC & NO_X

- Cost/ton direct $PM_{2.5}$ reduction = $3,000 or $8,000
- Cost/ton total emissions reduction = $1,100 or $3,000

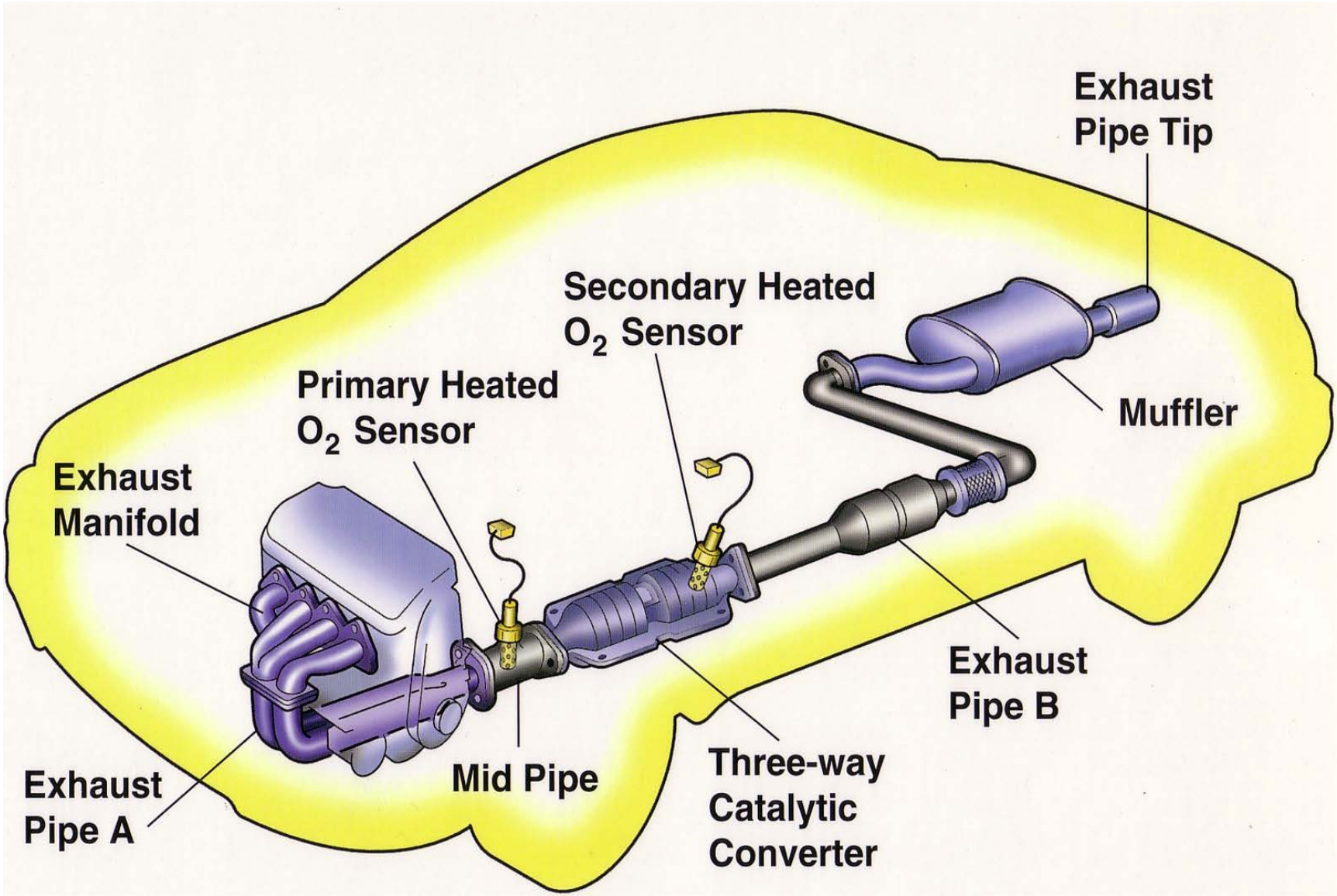
- * Above analysis assumes following wood stove emissions (per stove)

  $PM_{2.5}$ direct = 0.00079 grams/BTU =117 lbs/year
  VOC and Nox= 0.00105 grams/BTU = 154 lbs/year
  67,000,000 BTU/year to heat a home
  Assumes about 50% conventional stoves and 50% EPA certified

What about intermittent use of wood stoves during wintertime inversions?

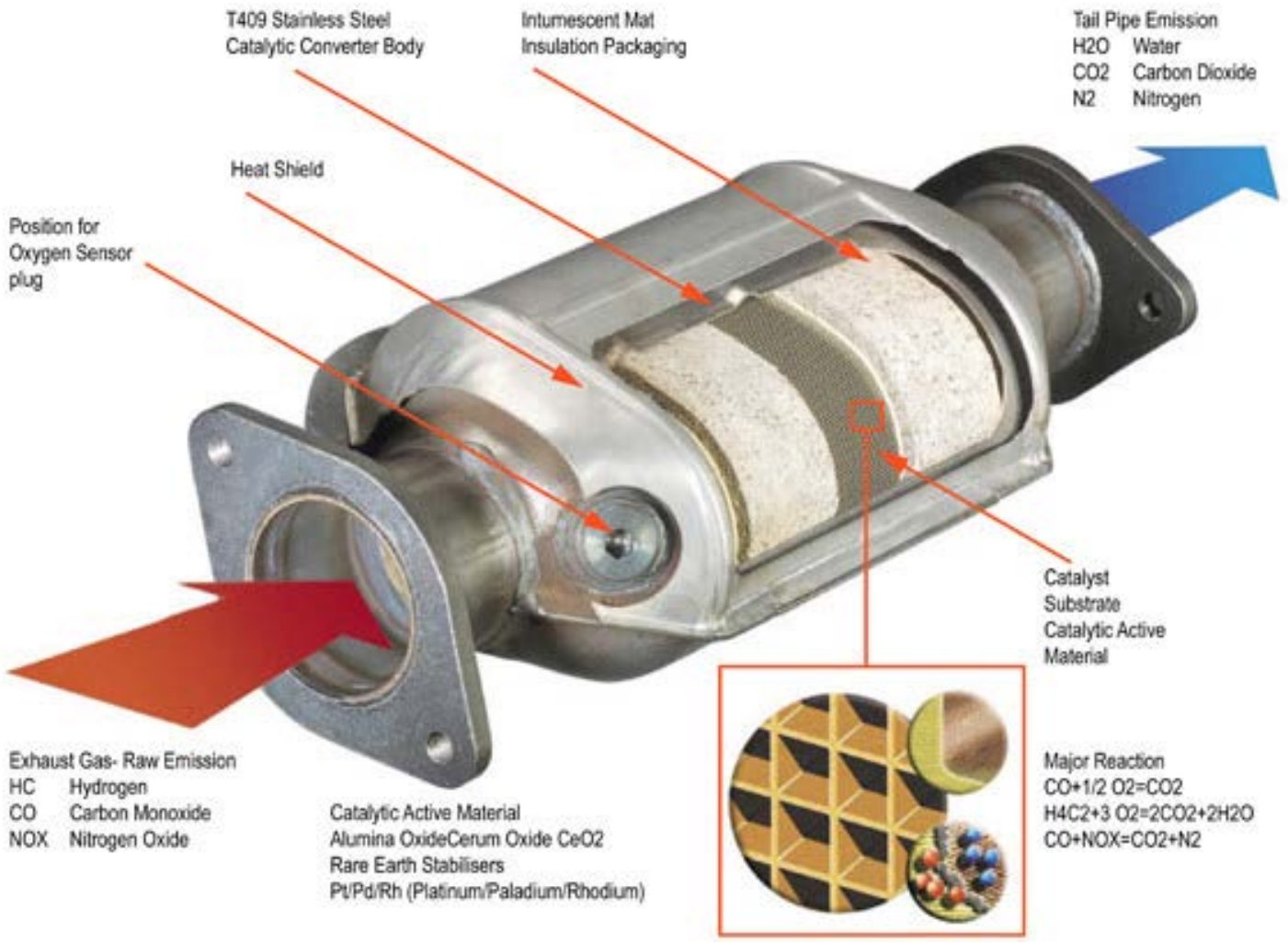
- Wood smoke likely causes about 5-7% of total $PM_{2.5}$ elevations during wintertime inversions
- Change out 203 sole-source stoves → ≈ 0.25% of total $PM_{2.5}$ (sole source heating is about 5% of total wood smoke emissions during inversions)
- There is still significant contributions from wood burning by non-sole source users of wood stoves during inversions.
- Current mandatory no-burn is triggered by absolute levels of $PM_{2.5}$
- Consider additional reduction of wood smoke contribution to $PM_{2.5}$ by earlier no-burn restrictions based on inversion forecasts rather than $PM_{2.5}$ levels?
- Consider additional public education options?

- Tier III fuel – Low-sulfur gasoline
- Tier III vehicle standards
- Effects on Emissions and $PM_{2.5}$



http://1.bp.blogspot.com/-MQw4-6X-fYQ/TpvJl66zV4I/AAAAAAAAAFA/CzAOM2It2VU/s1600/catalytic+converter.jpg

The three-way “Cat”



http://meroock.blogspot.com/2013/02/catalytic-converter.html

Three-way catalytic converter - chemistry

Conversion of NO_x back to nitrogen and oxygen

$2\ NO_2 \rightarrow 2\ O_2 + N_2$

$2\ NO \rightarrow O_2 + N_2$

Reduction

Conversion of carbon monoxide to CO2

$2\ CO + O_2 \rightarrow 2\ CO_2$

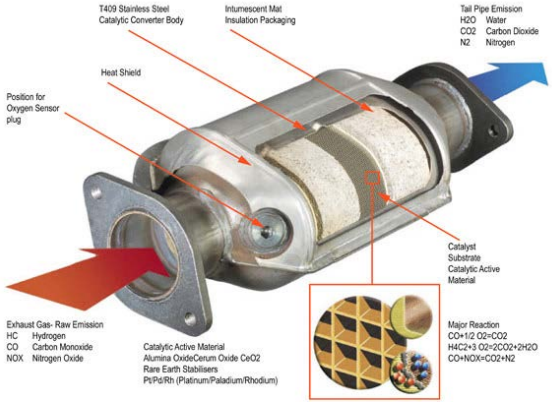
Oxidation

Conversion of hydrocarbons (VOC's) to CO2 and H2O

$C_7H_{16} + 11\ O_2 \rightarrow 7\ CO_2 + 8\ H_2O$

Oxidation

Why lower sulfur fuel?



- Sulfur in fuel gets burned during combustion and forms sulfur oxides (SO_X)
- SO_X competitively binds and loads up the catalyst sites inside the catalytic converter so that NOx cannot be converted into oxygen and nitrogen
- This partially “poisons” the catalytic converter such that it is less effective and NOX, VOC and carbon monoxide tail pipe emissions increase.
- Using lower-sulfur fuels (10 ppm Tier III fuels) in Tier II vehicles cleans up the catalyst sites and improves the function of the catalytic converter resulting in lower emissions.
- Burning Tier II fuel (30 ppm sulfur) in Tier III vehicles → doubles the NOX emissions compared with low-sulfur Tier III fuel (10 ppm)*

* EPA: Draft Regulatory Impact Analysis: Tier 3 Motor Vehicle Emission and Fuel Standards March 2013

Vehicle emissions reductions due to industry's response to EPA regulations (NOx and VOC's)

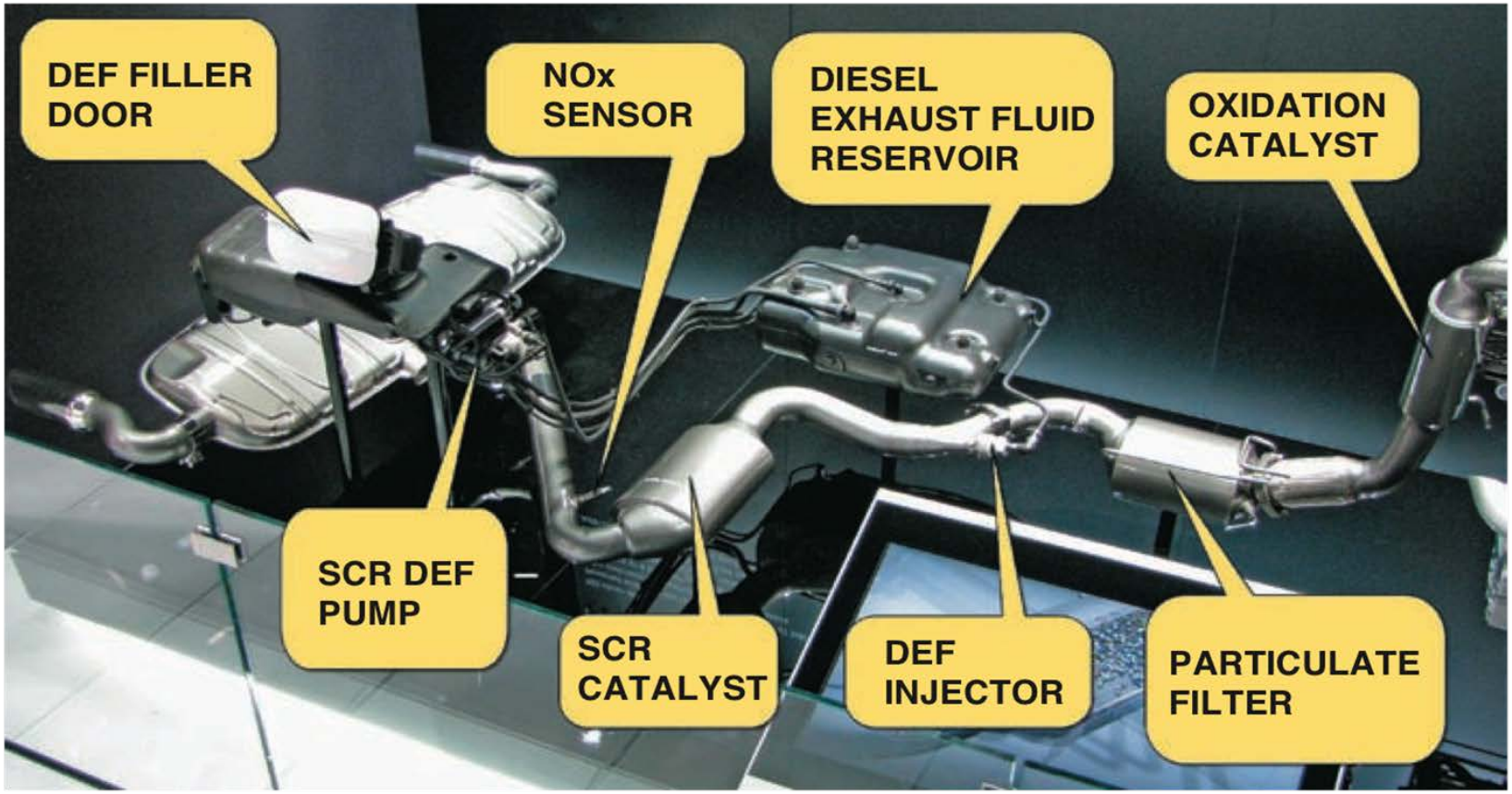
Gasoline cars and light trucks

- Tier 0 → Tier 1 → 32% reduction (1994)
- Tier 1 → Tier 2 → 82% reduction (2004)
- Tier 2 → Tier 3 → 80% reduction (2017)
- Tier 0 → Tier 3 → 98% reduction!!!

Diesel Trucks

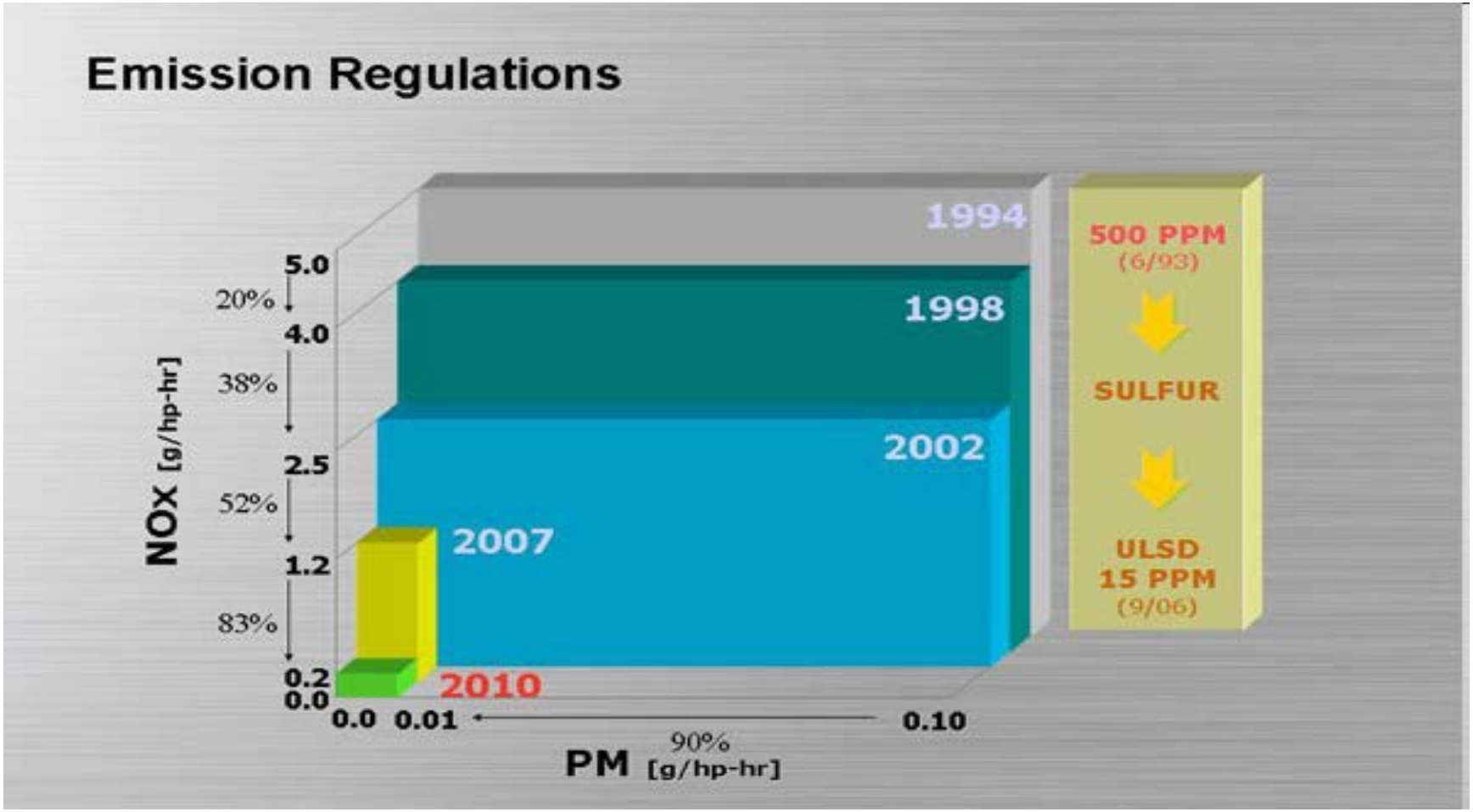
- 1994→2002 → 50% reduction in NOx
- 1994 →2010 → 96% reduction in NOx!!!
- 1994 → 2010 → 90% reduction in PM2.5!!!
- Due due low-sulfur diesel fuels (15 ppm) and emissions control technologies

Improved Diesel Technology



DEF – Diesel Exhaust Fluid

SCR – Selective Catalytic Reduction



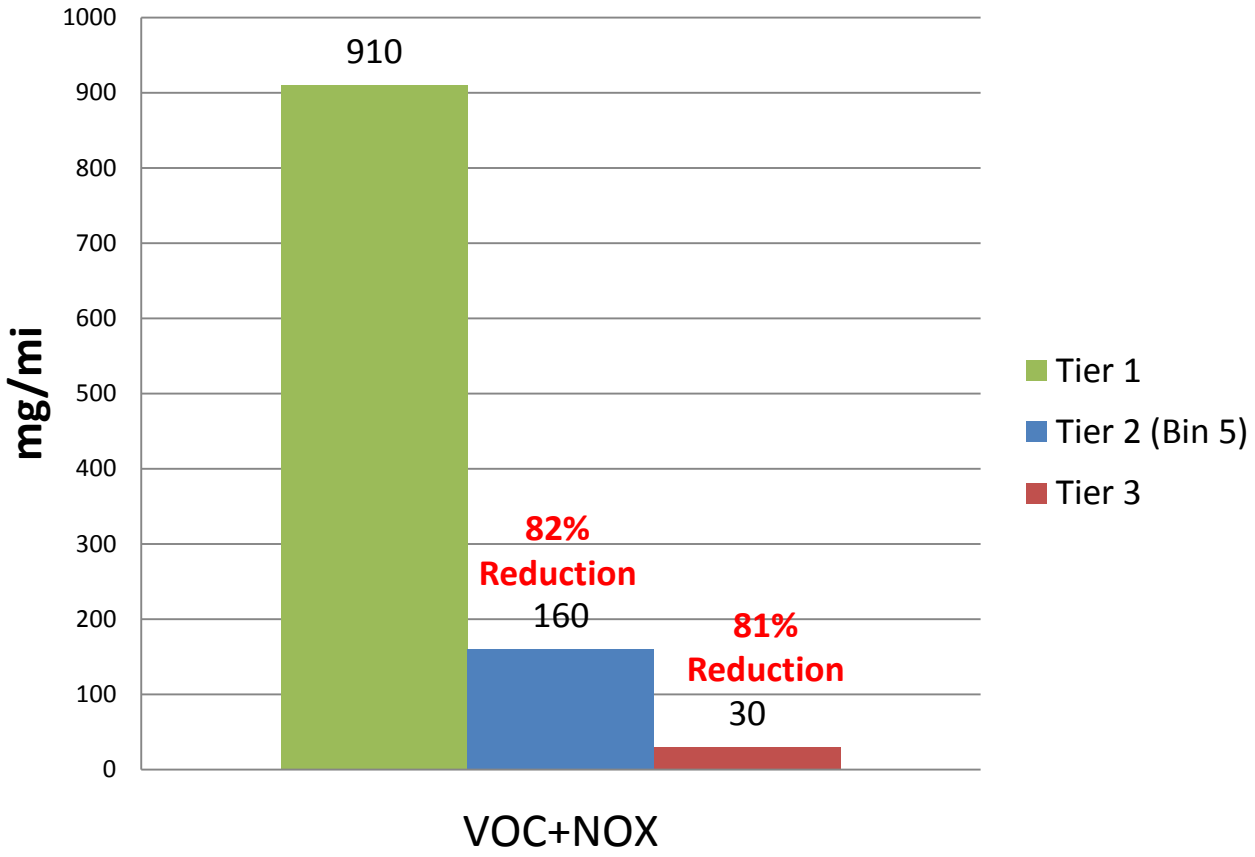
When EPA 2010 standards go into effect, no heavy-duty diesel engine can be emitting levels of nitrogen oxides (NOx) higher than .2 g/bhp-hr (grams per brake horsepower-hour), a standard more stringent than any place in Europe.

Specific to heavy-duty commercial vehicles, the new regulations introduce very stringent emission standards, as follows:

- PM—0.01 g/bhp-hr
- NOx—0.20 g/bhp-hr
- NMHC—0.14 g/bhp-hr

http://www.factsaboutscr.com/environment/epa2010.aspx

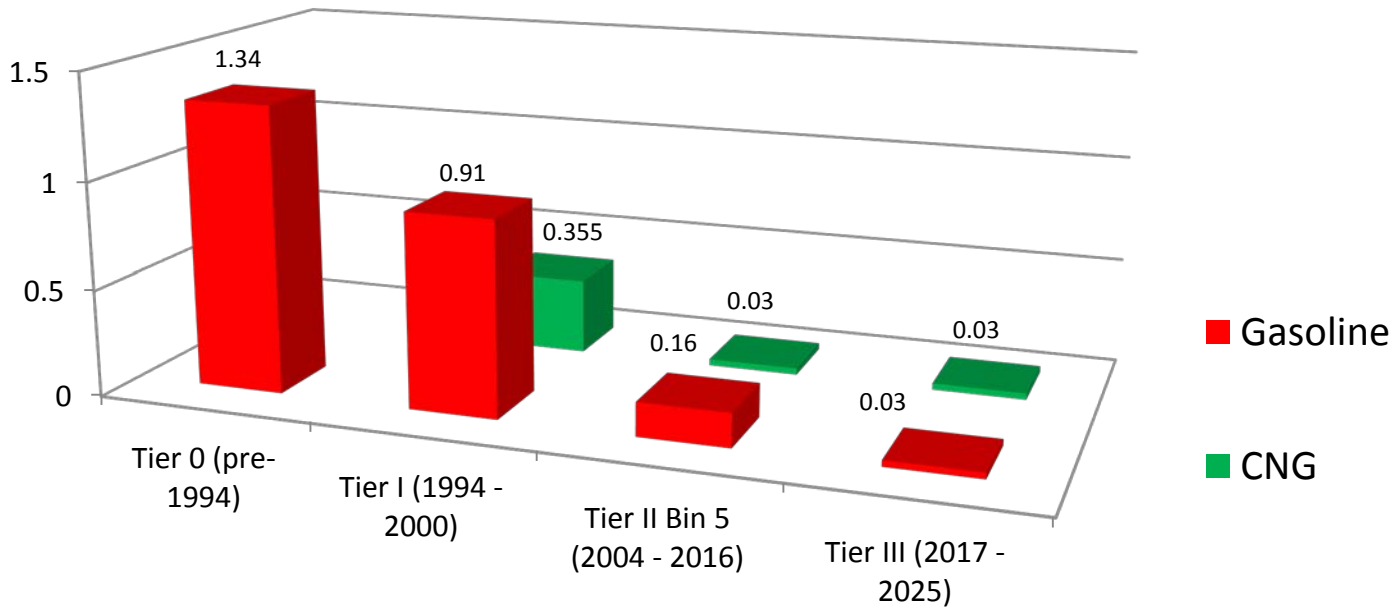
Gasoline Tier 1, Tier 2, and Tier 3*



*30 mg/mi is equivalent to Tier 2 Bin 2 (or approximately the same as a CNG Honda Civic)
30mg/mi = 6 kg (13 lbs)/200,000 miles

Passenger Car Tier Certification Standards

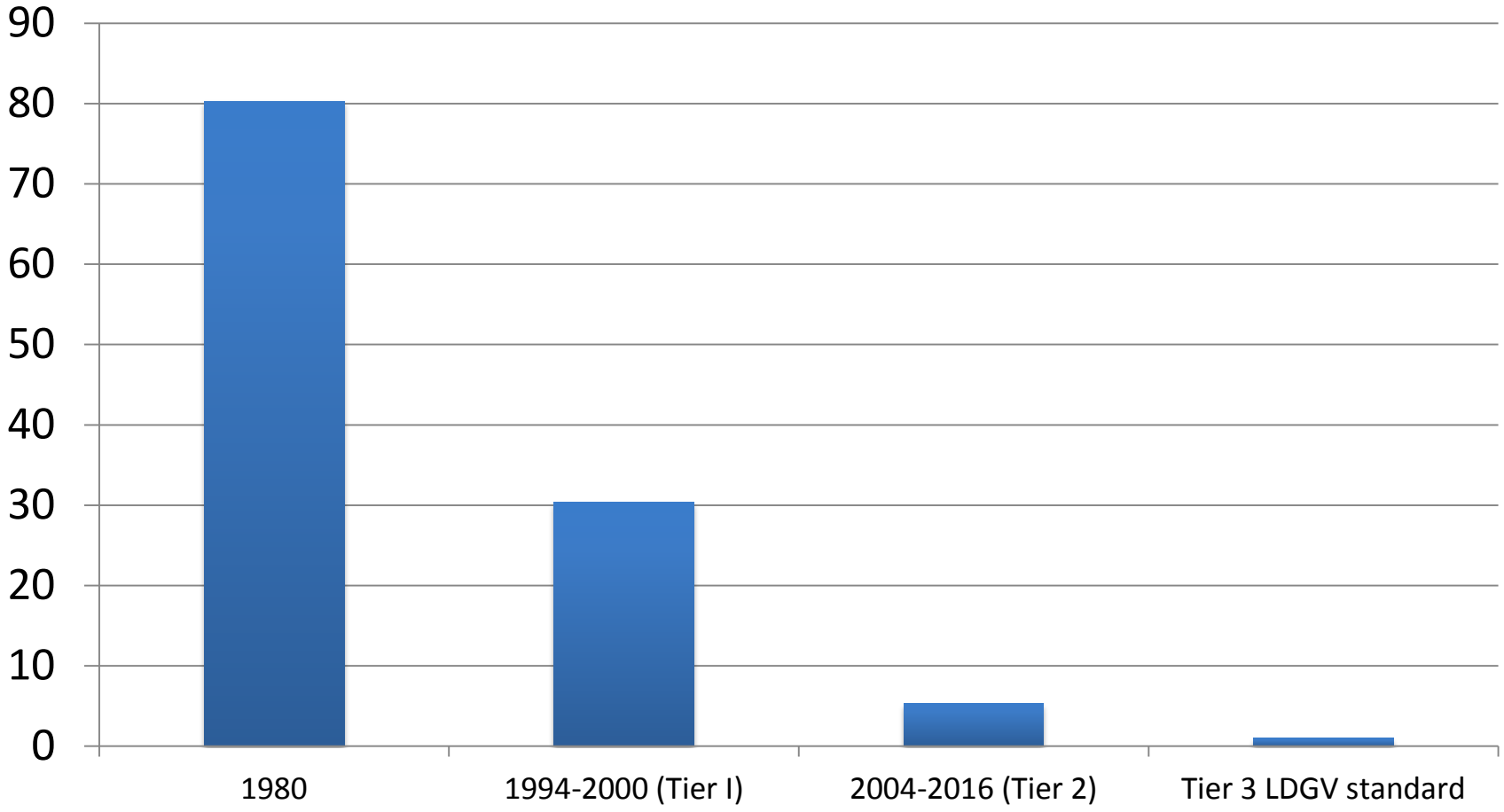
Gasoline vs. CNG and Tier 0 – Tier III



The Honda Civic CNG certification standard under Tier I is for NMOG + NOx. Tier III covers model years 2017 – 2025. The graph shows the 2025 standard.

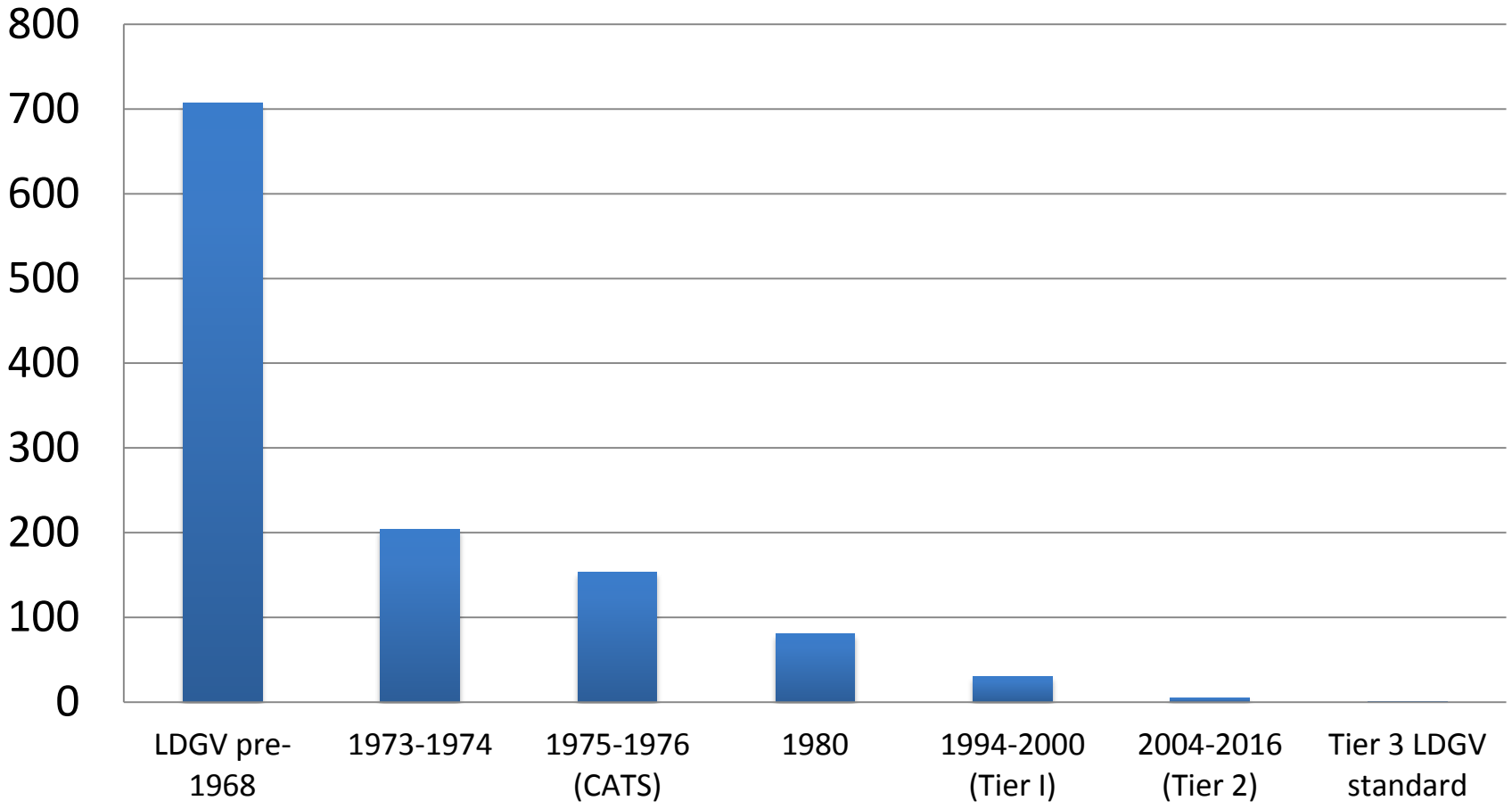
Credit: UDAQ – Joe Thomas

Tier 3 Vehicle Emissions Equivalents



Data Source: UT DAQ and EPA

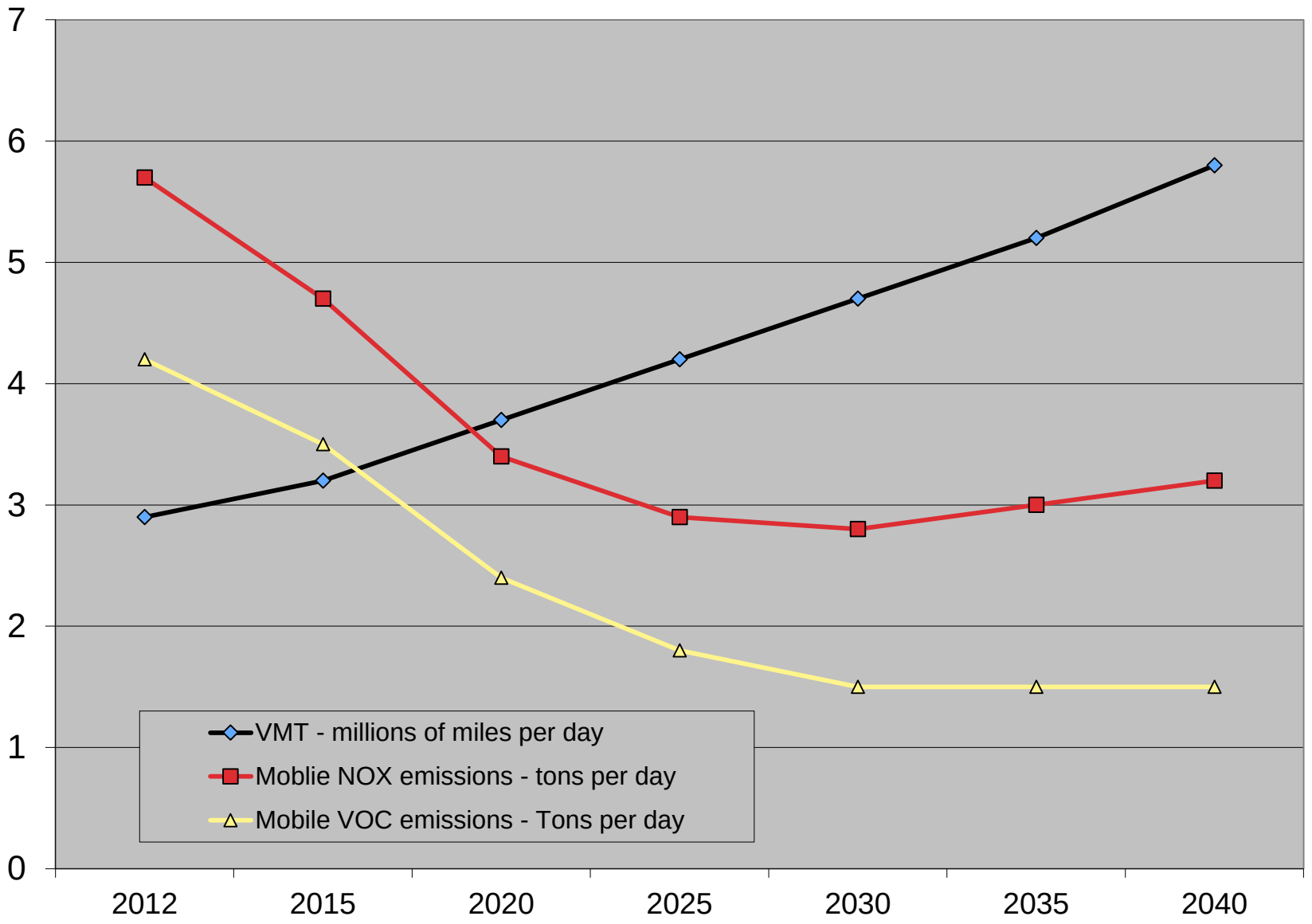
Tier 3 Vehicle Emissions Equivalents



Data Source: Utah DAQ and EPA

Estimates of Future VMT and On-Road Emissions – Cache

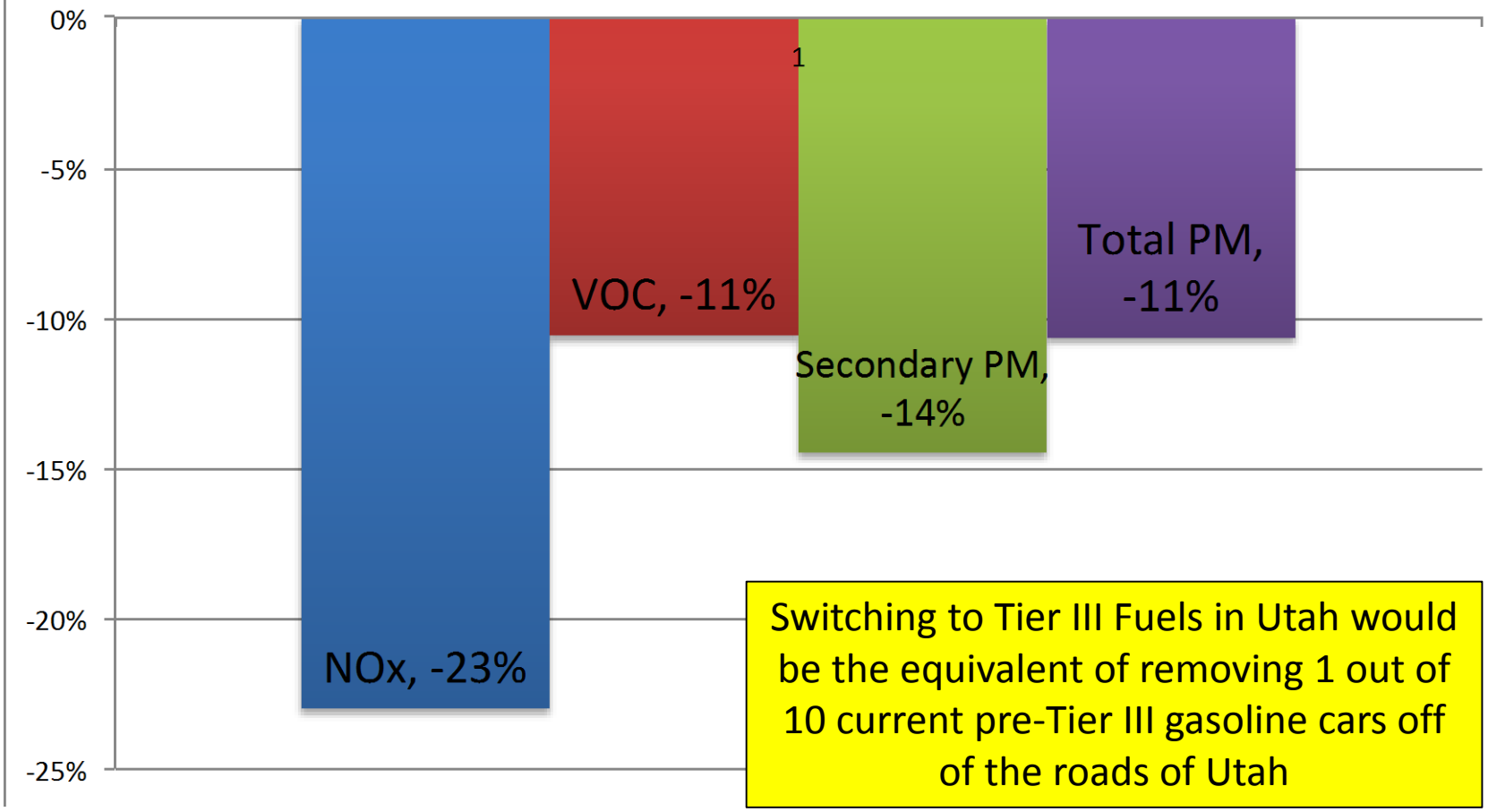
Data source:Utah DAQ Workgroup 21/1/2011



Note: Does not include benefits of Tier 3 emissions standards

Effect of Tier 3 gasoline on Utah's current fleet of Tier 2 and older vehicles

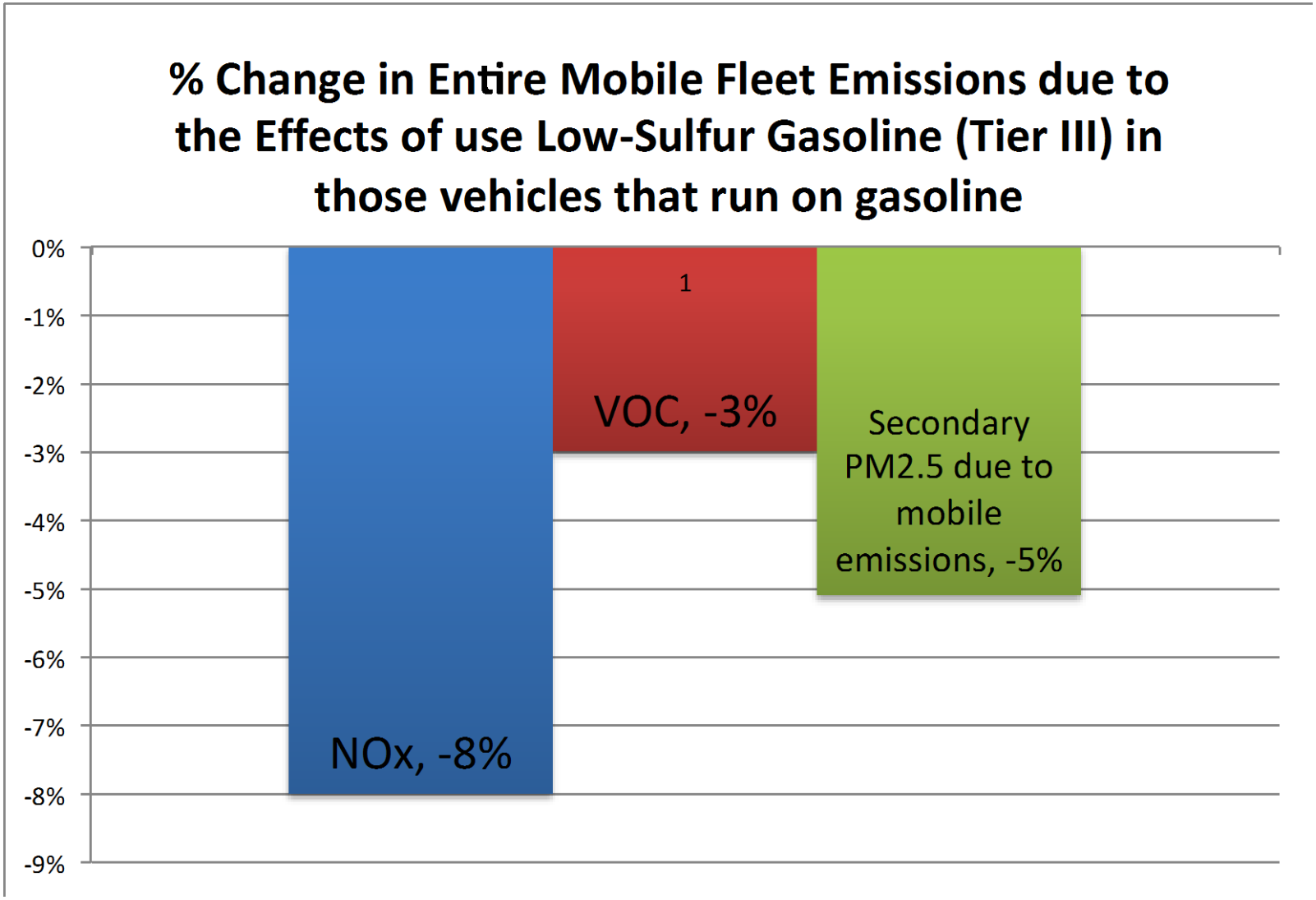
% Change in Emissions in Tier II gasoline vehicles if switch from Tier II gasoline (30 ppm) to low-sulfur Tier III gasoline (<10 ppm)



Switching to Tier III Fuels in Utah would be the equivalent of removing 1 out of 10 current pre-Tier III gasoline cars off of the roads of Utah

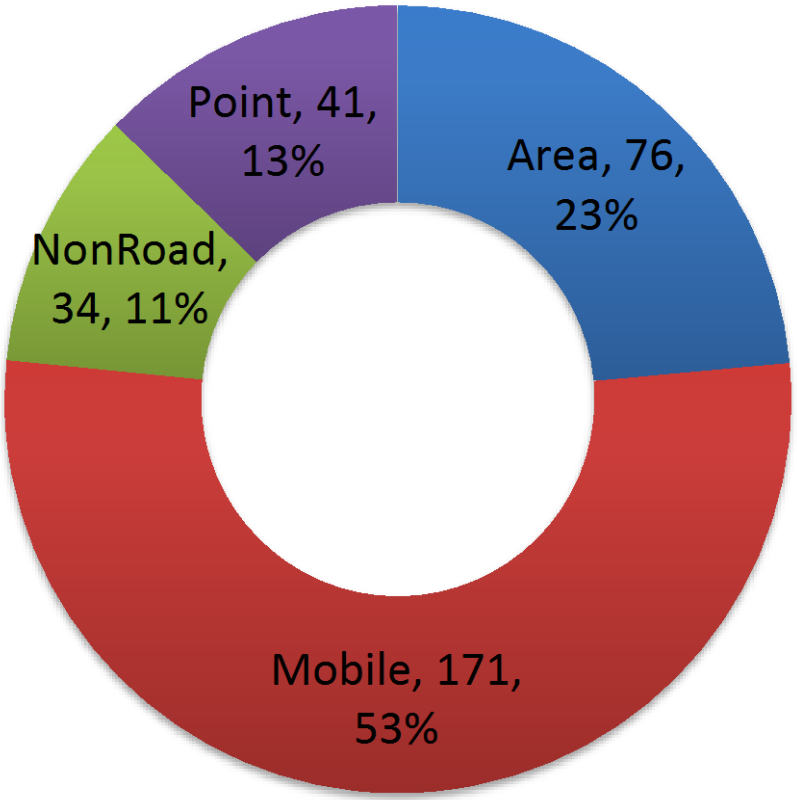
EPA: Draft Regulatory Impact Analysis: Tier 3 Motor Vehicle Emission and Fuel Standards March 2013

Immediate effects of low-sulfur gasoline (Tier III) on emissions from current fleet of all vehicles (gasoline and diesel)



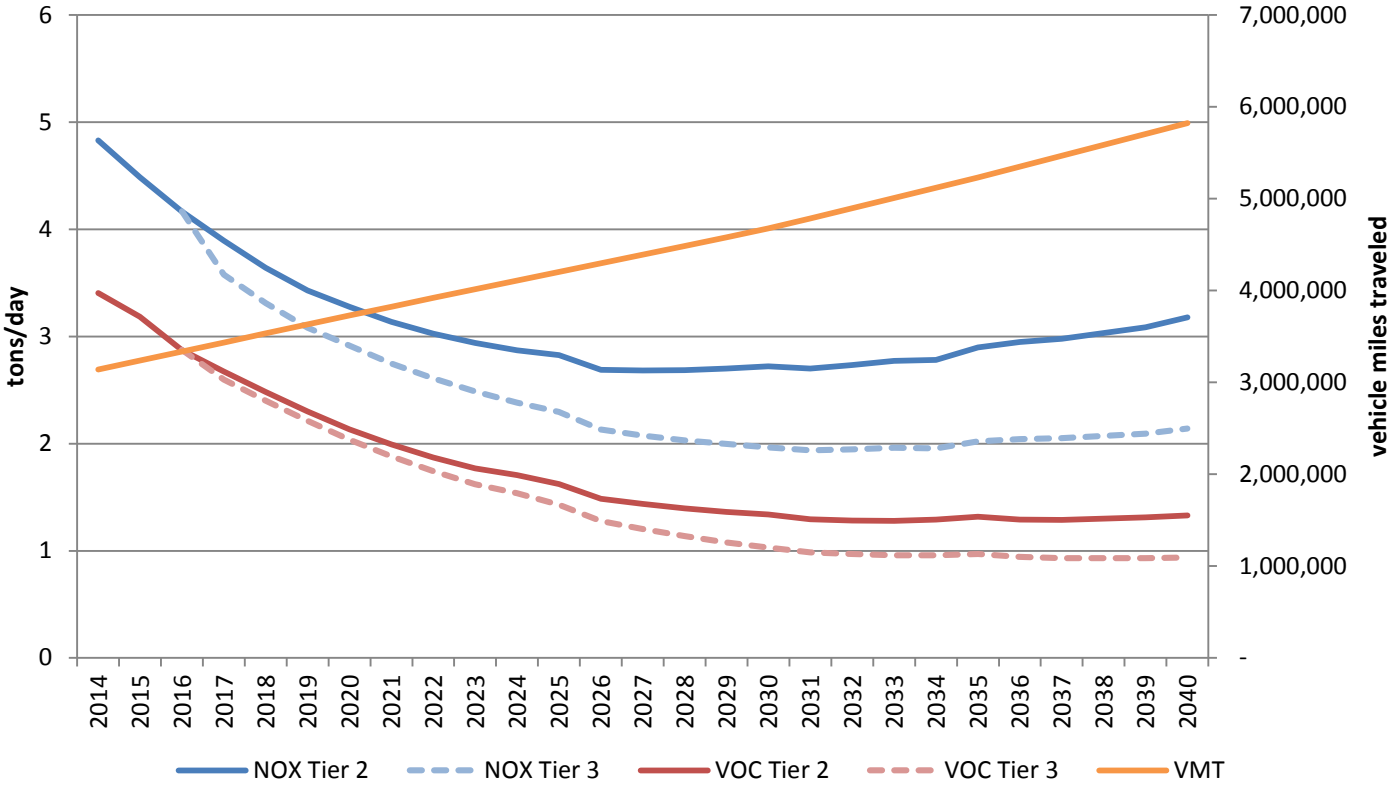
EPA: Draft Regulatory Impact Analysis: Tier 3 Motor Vehicle Emission and Fuel Standards March 2013

Salt Lake Non-attainment area - Winter time total combined emissions - 2010 - total tons/day of combined PM2.5, NOx, SOx, VOC



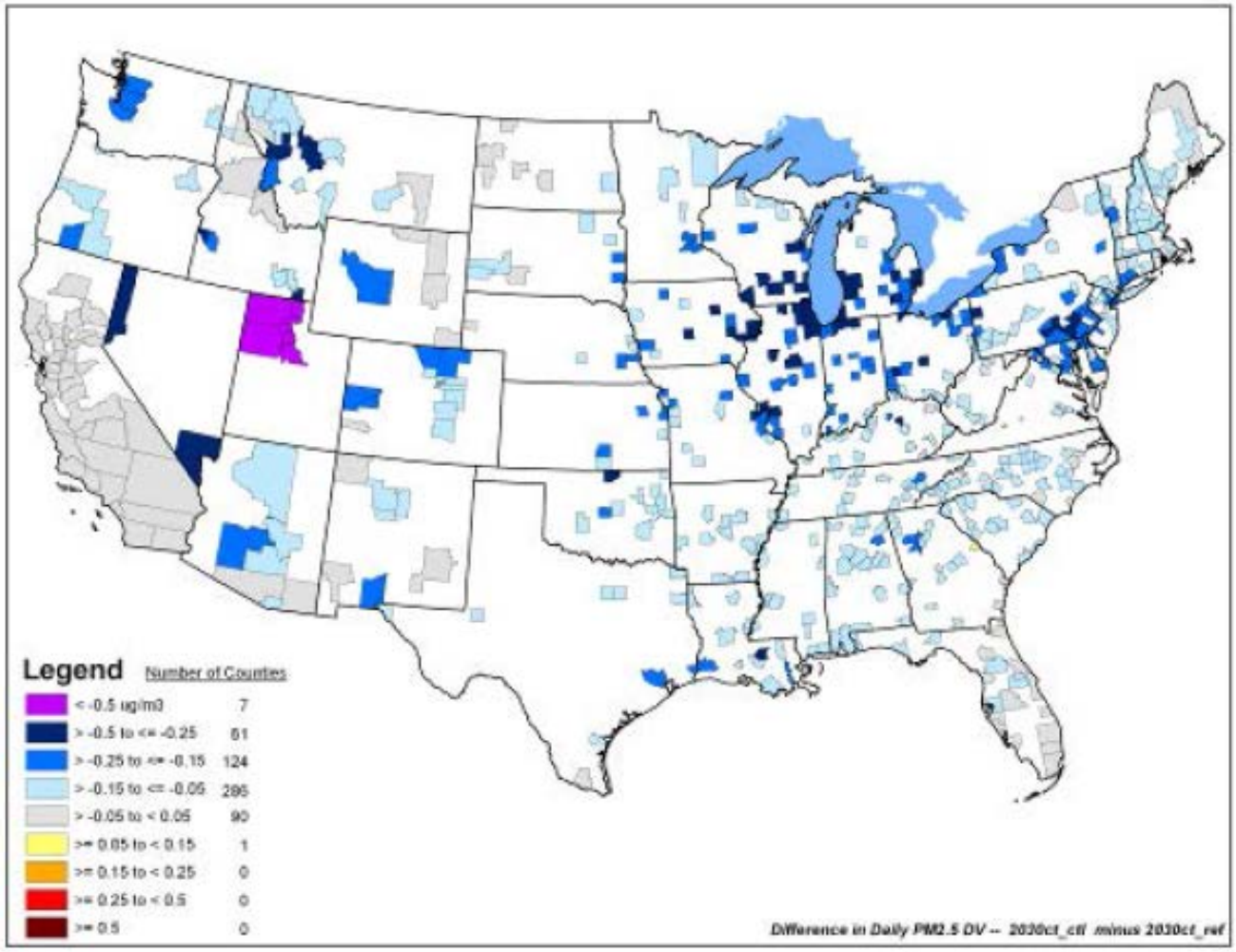
Tier 3 fuels would reduce current Mobile inventory by about 8 tons/day and would result in an immediate decrease of about 2-3% in measured PM2.5 levels in the SL non-attainment area (based on calculations done by Ed Redd)

Cache County
Tier 2 vs. Tier 3: NO_x and VOC



Source: UDAQ Cache County Data

Projected Change in 2030 24-hour $PM_{2.5}$ Design Values from Tier 3



Source: EPA Draft Regulatory Impact Analysis: Tier 3 Motor Vehicle Emission and Fuel Standards, page 400

Tier 3: Costs

- Vehicles: $134 cost per new car

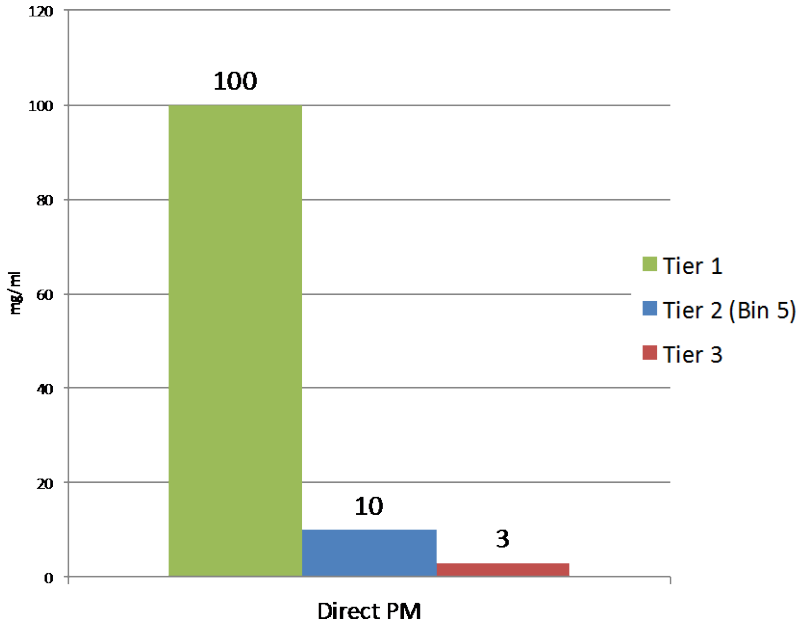
  Less than 1% increase in price of a new car

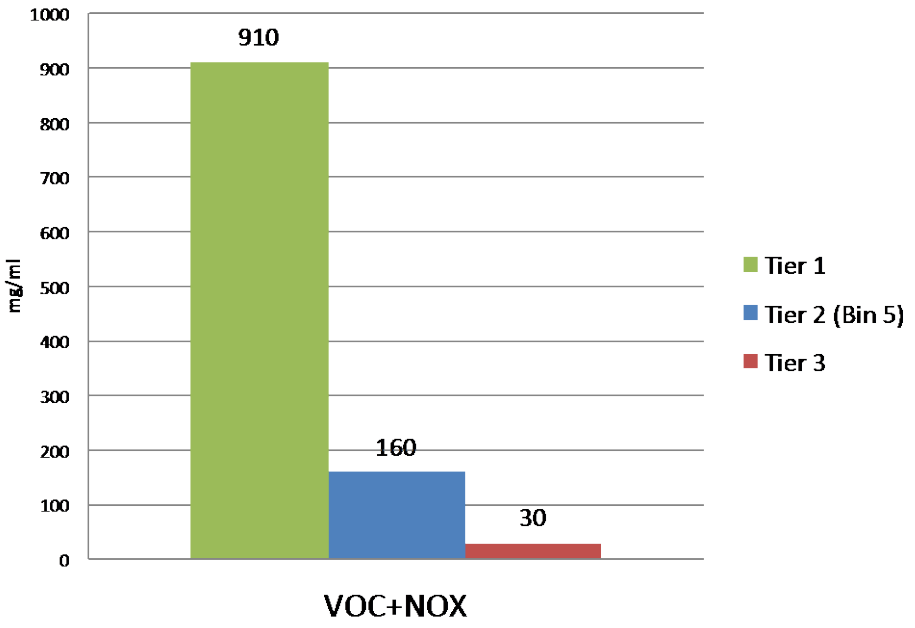
- Additional Fuel costs
- EPA - additional $0.01/gallon
  - (0.3% increase)
- Lee Peacock - “as much as $0.09/gallon”*
  - (3% increase)

* Statement made by Lee Peacock representing Utah Petroleum Association during House Republican Caucus meeting, 02/04/2014

EPA Estimates of Tier III costs -
($ per ton emissions reductions)

- 2017 - $6,072/ton in 2010 dollars
- 2030 - $4,484/ton in 2010 dollars





Source: EPA Draft Regulatory Impact Analysis: Tier 3 Motor Vehicle Emission and Fuel Standards

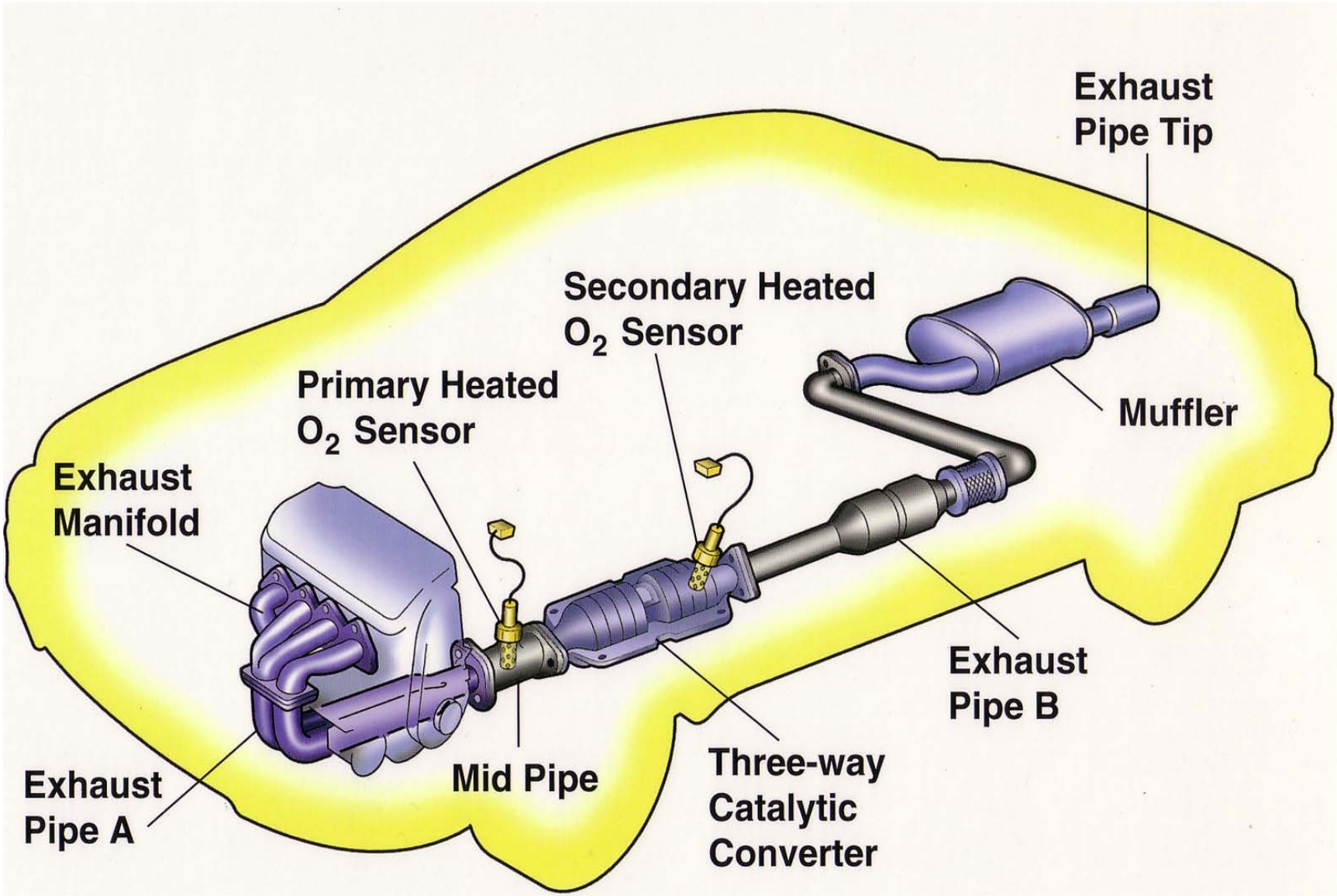
TIER 3: RISKS FOR UTAH

- 3-year compliance extension for Utah refineries -
- National averaging, banking, and trading (ABT) provisions may leave Utah with dirtier fuels for the long term
- Locally-owned single refineries are at a competitive disadvantage

Tier 3 gasoline – What is in it me?

- Improved air quality
- Longer life span of catalytic converter

- Cold Start Emissions
- Trip Chaining
- Idling Emissions

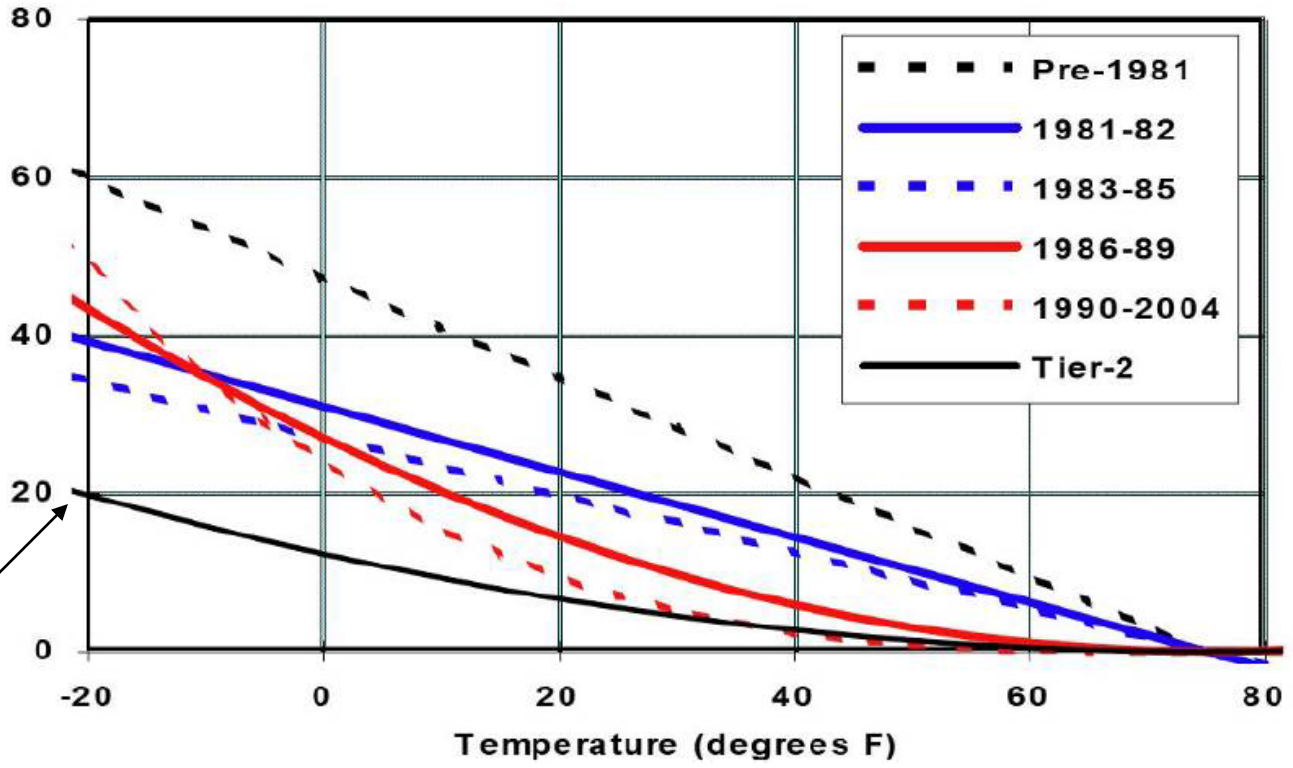


http://1.bp.blogspot.com/-MQw4-6X-fYQ/TpvJl66zV4I/AAAAAAAAAFA/CzAOM2It2VU/s1600/catalytic+converter.jpg

Requirements for the Cat to fire up

- Internal Cat temperature > 700° F
- Adequate amounts of oxidizer (oxygen)

Comparing Temperature Effects on Cold-Start HC Emissions

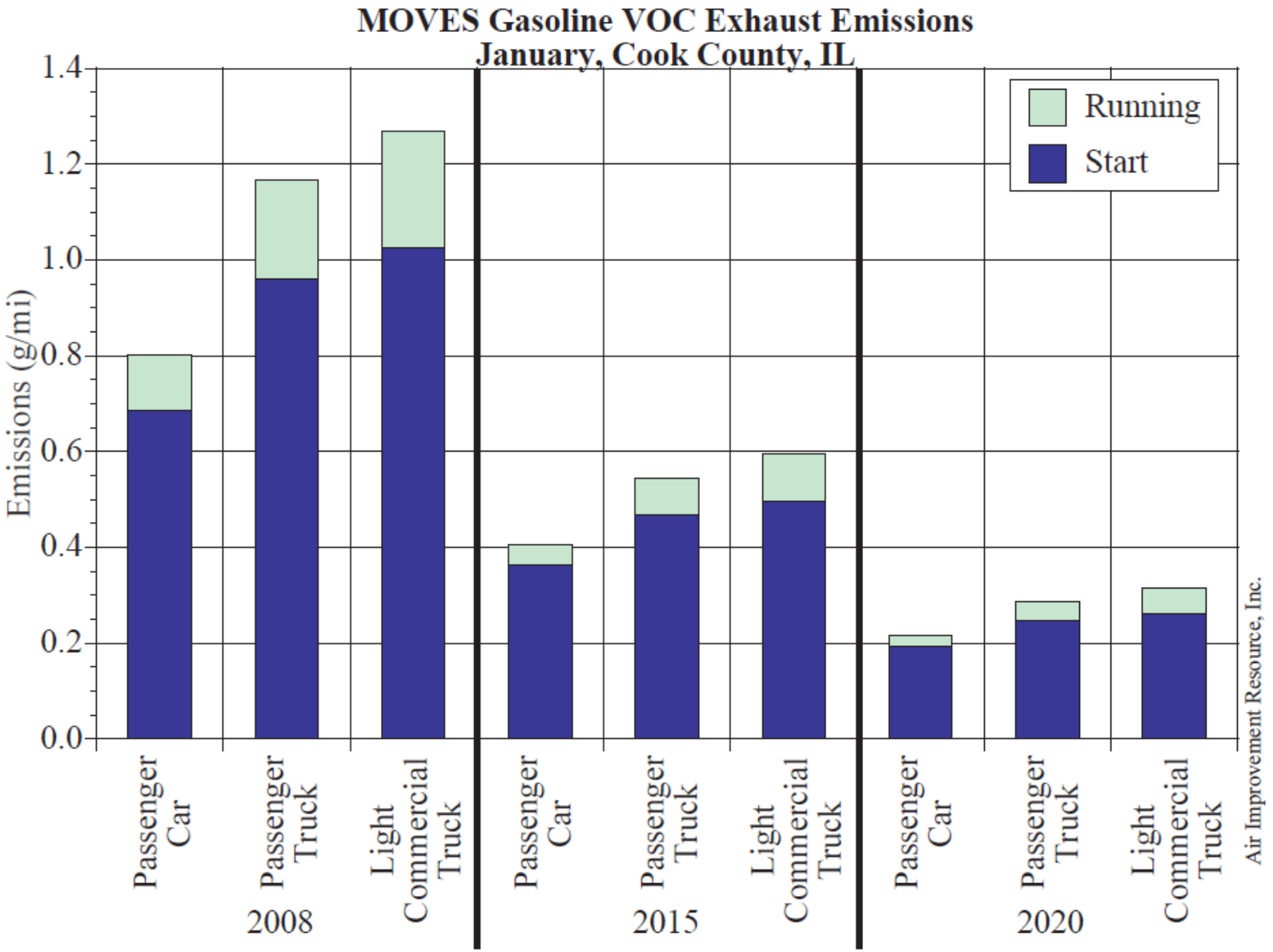


Note: Tier 2 HC (VOC) standard is 0.09 g/mile

A cold start at – 20 F is equal to 200 + miles of hot cat VOC emissions

http://www.crcao.com/reports/recentstudies2011/E-68a/Final%20CRC%20E-68a%20Report_V6.pdf

Figure 10-13. Exhaust VOC in Winter



http://www.crcao.com/reports/recentstudies2011/E-68a/Final%20CRC%20E-68a%20Report_V6.pdf

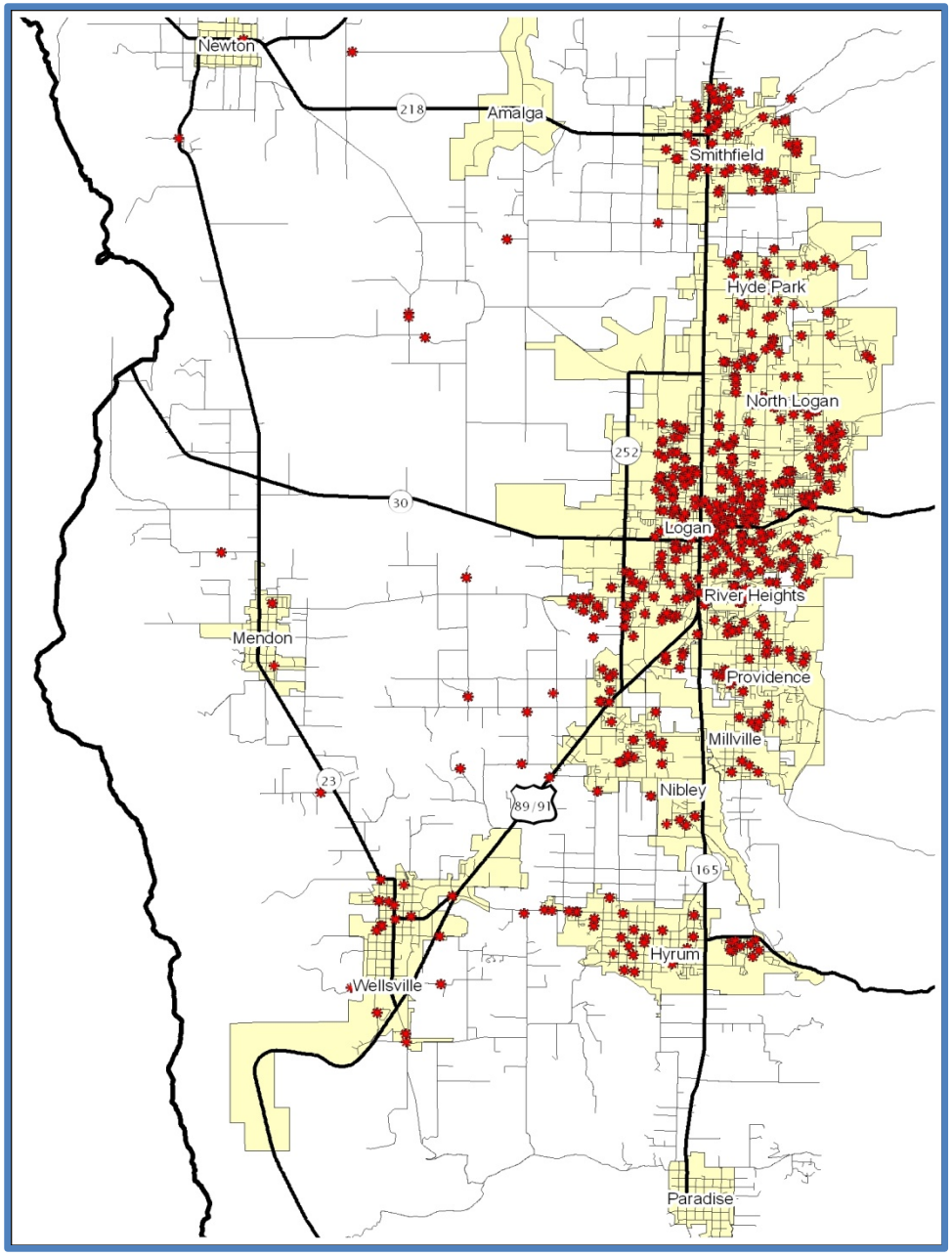
Cold Start Emissions

- Cold Start – engine shut off for 12 hrs
- Start-up period and first 9 minutes of operation (3-5 miles)
- Catalytic converter takes time to heat up to operating temperature (≈700 degrees F)
- When it is cold, a CAT does not catalyze reactions and NOX and VOC's are released from the tail pipe.
- The best way to minimize cold start emissions is to get in your car and step on the gas and then combine trips (trip chain) so that your cat is not starting cold

Home Travel Survey

Region	Households
Cache	808
Washington Co	1,015
Rural Utah	1,540
Wasatch	5,792
Total	9,155

Source: Jeff Gilbert CMPO

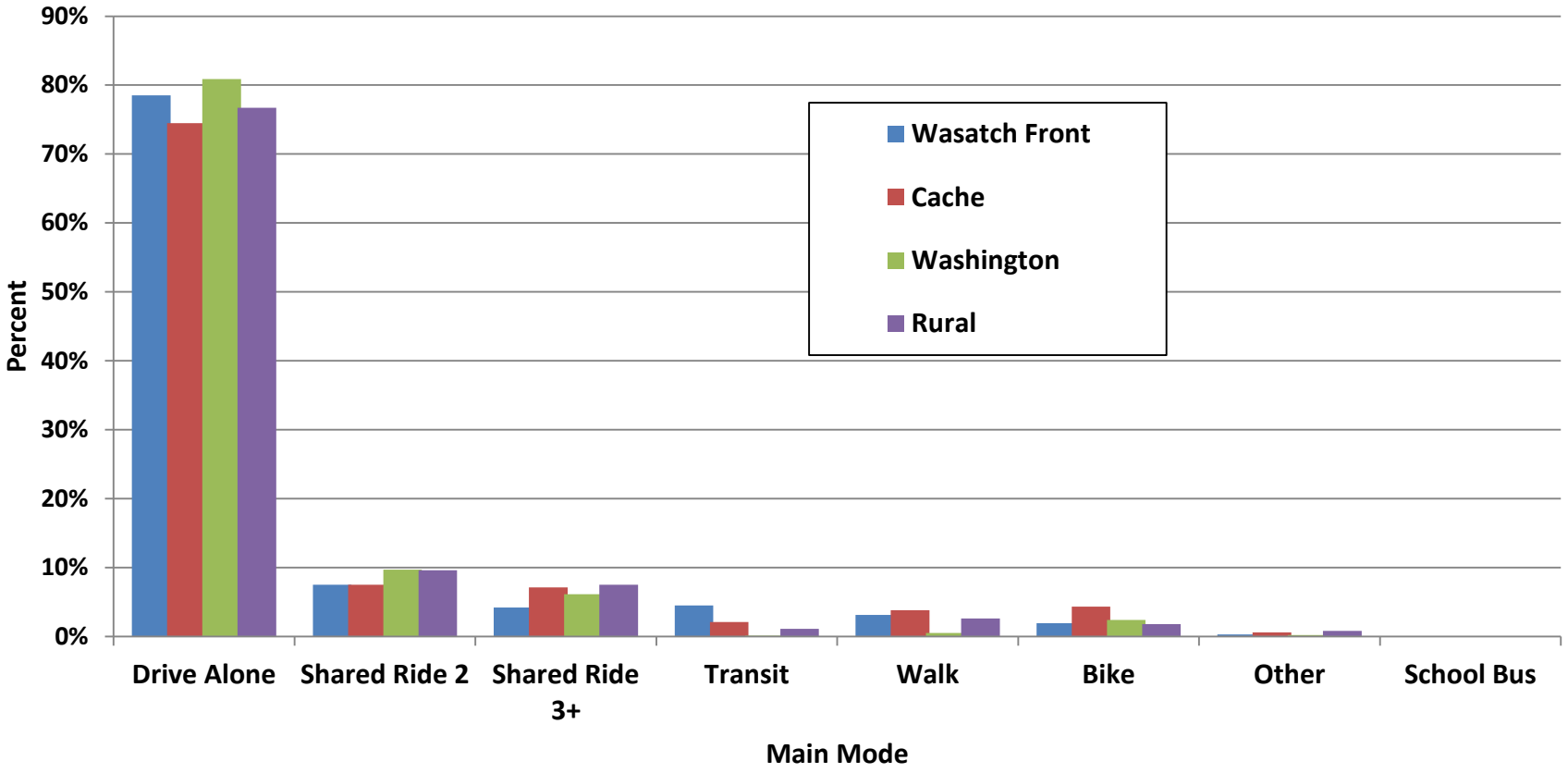


Cache Household Trips per Day

	Average Trips Per Household			
	Home/ Work	Home Other	Non-Home Based	Total
Wasatch Front	1.7	6.5	3.0	11.2
Cache Co	1.8	6.6	3.5	11.9
Washington Co	1.3	6.3	3.3	10.9
Rural Utah	1.6	6.2	3.5	11.3
1993 Survey	1.8	7.5	3.8	13.0
National Avg				9.5

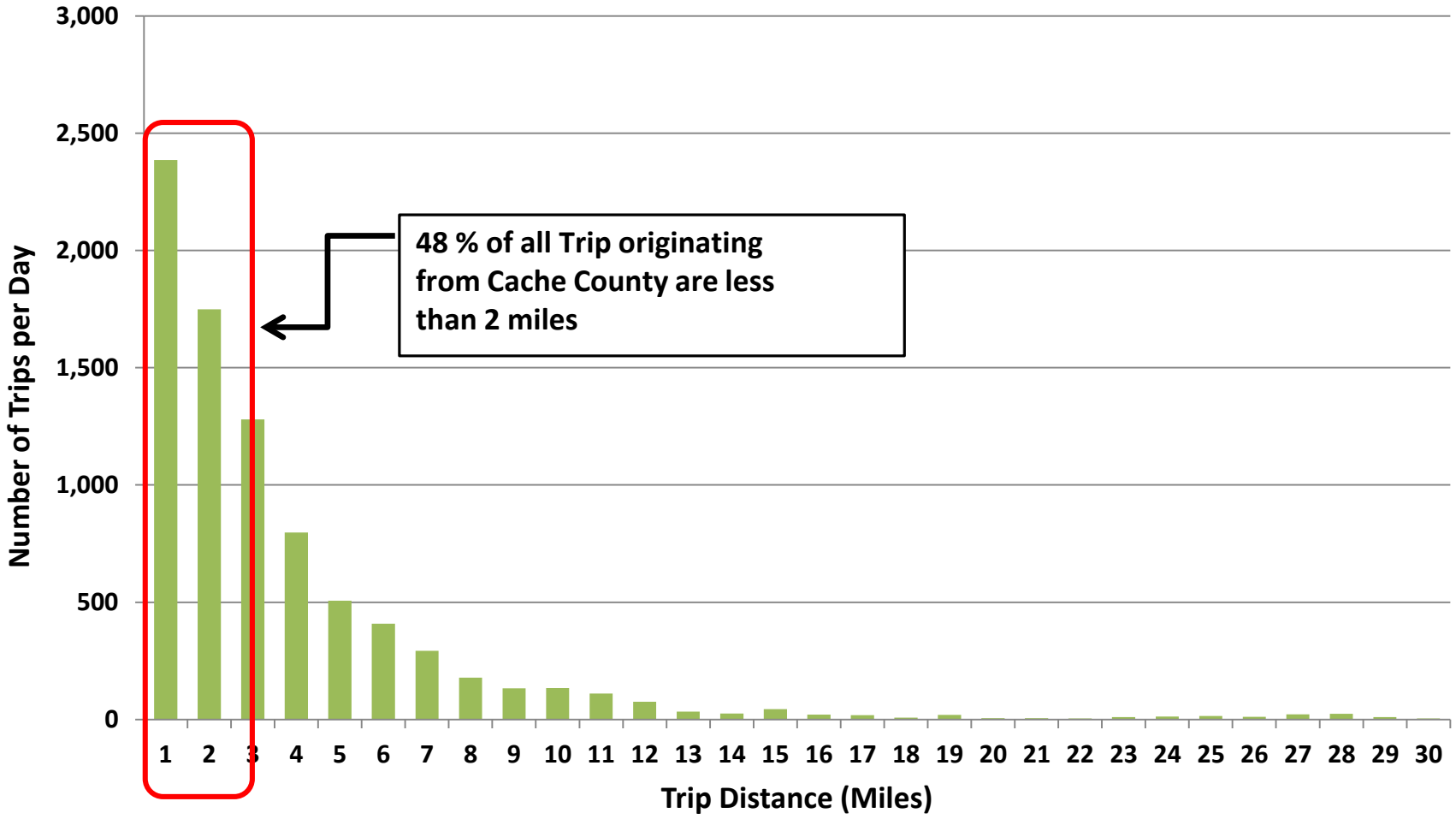
Source: Jeff Gilbert CMPO

Cache Work Trips (Main Mode)



Source: Jeff Gilbert CMPO

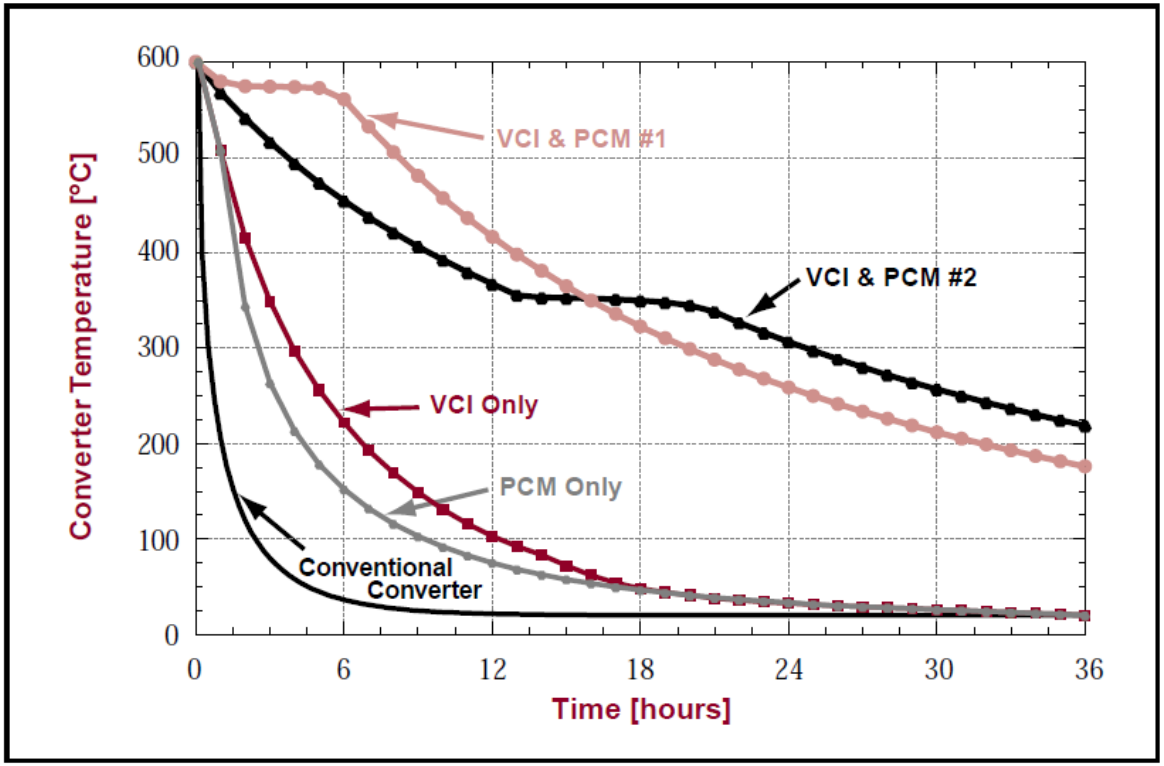
All Daily Trips-Distance – Cache County



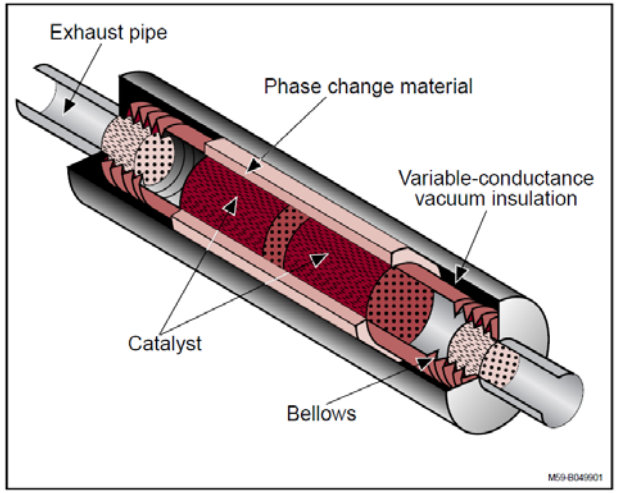
Source: Jeff Gilbert CMPO

Many of these 2-3 mile trips are “Tier Zero” trips – CAT never fires up

Cold-start hope for the future?



The combination of variable-conductance insulation (VCI) and phase-change material (PCM) allows the VCI converter to remain at operating temperature for a full 24 hours after the engine is turned off. This makes the catalyst effective immediately for the next trip, solving the problem of cold-start emissions. Note how different PCMs "plateau" at different temperature allowing for optimal designs for different converters.



This cut-away drawing of the VCI catalytic converter shows the vacuum insulation, phase-change material, and bellows that make possible its extraordinary heat retention. The variable insulation automatically "turns off" above a certain temperature, allowing the converter to shed heat and keep from getting too hot.

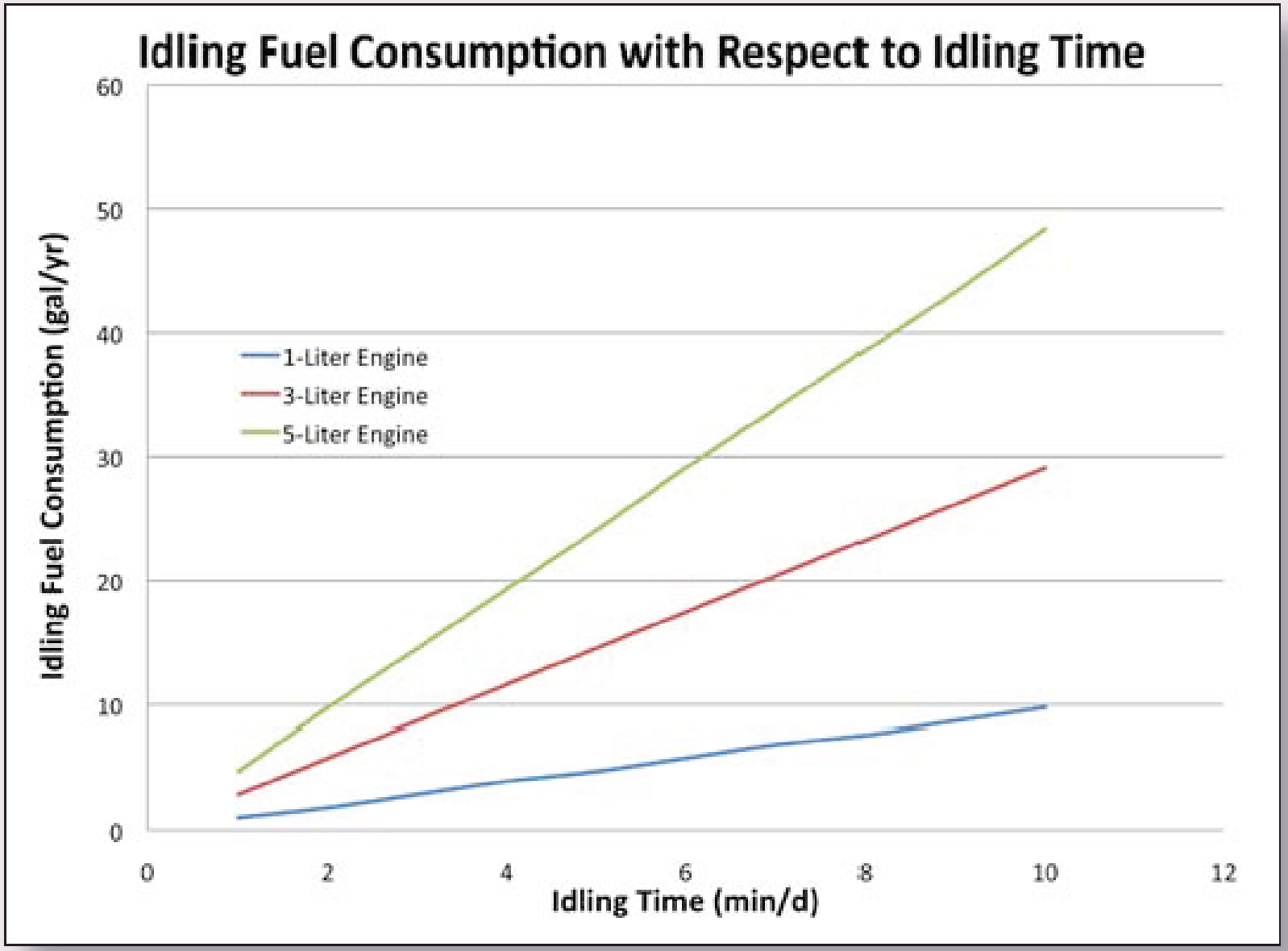
http://www.nrel.gov/vehiclesandfuels/energystorage/pdfs/techbr.pdf

Idling – wasted fuel and more emissions

and you are going nowhere

- One hour of idling = 10-20 miles of wasted gasoline
- One hour of idling = 150 miles of unnecessary VOC emissions
- Restart break-even point = 10 sec of idling

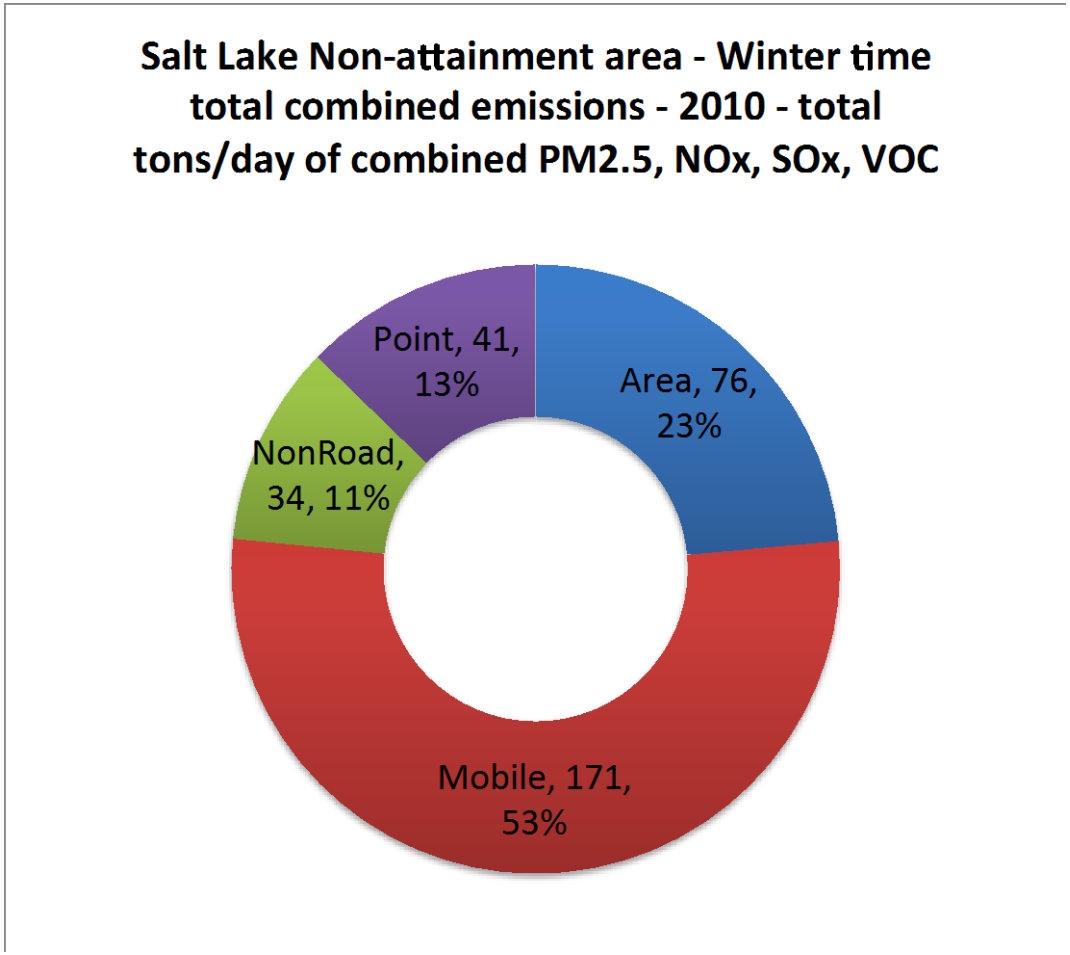
- Recommendation:
  - don't idle longer than 10-20 seconds unless you are in traffic
  - Your Cat will still be hot and ready to fire after a 15 min stop
  - When you do idle, the Cat cools down rapidly – significantly faster than if you had shut off the engine.
  - Cold Cats get more easily poisoned with sulfur oxides and do not work as well even after you warm them up under load after you are done idling.



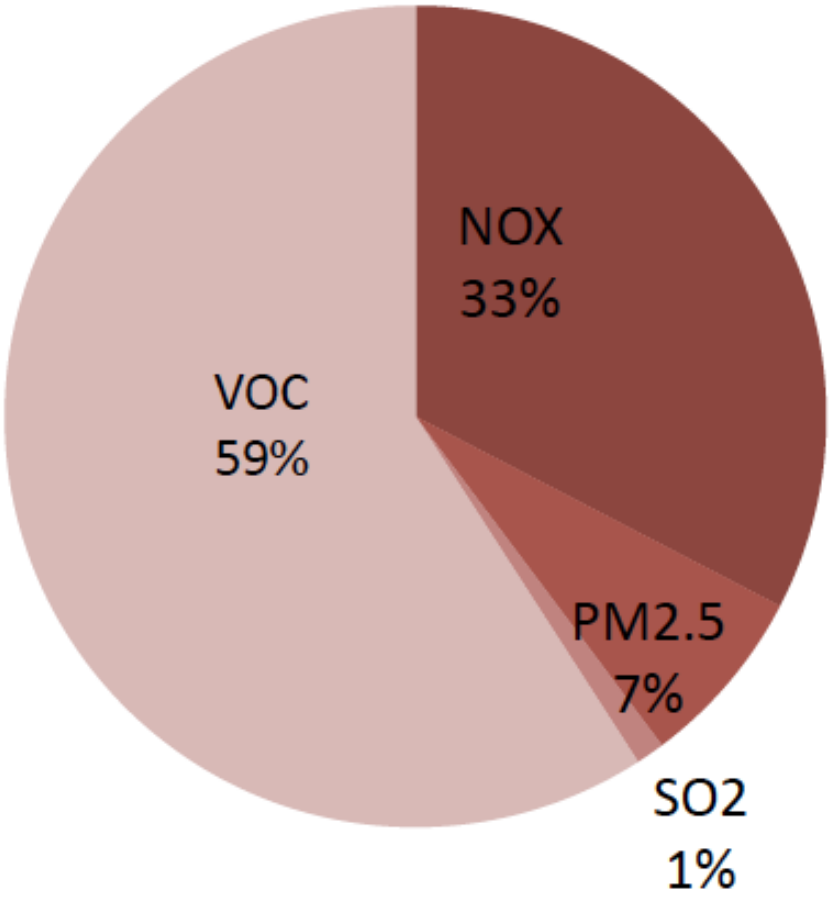
To Idle or Not To Idle: That Is the Question

Linda Gaines, Terry Levinson, and Steve McConnell, Argonne National Laboratory, Argonne, IL 60439

What about non-mobile sources?

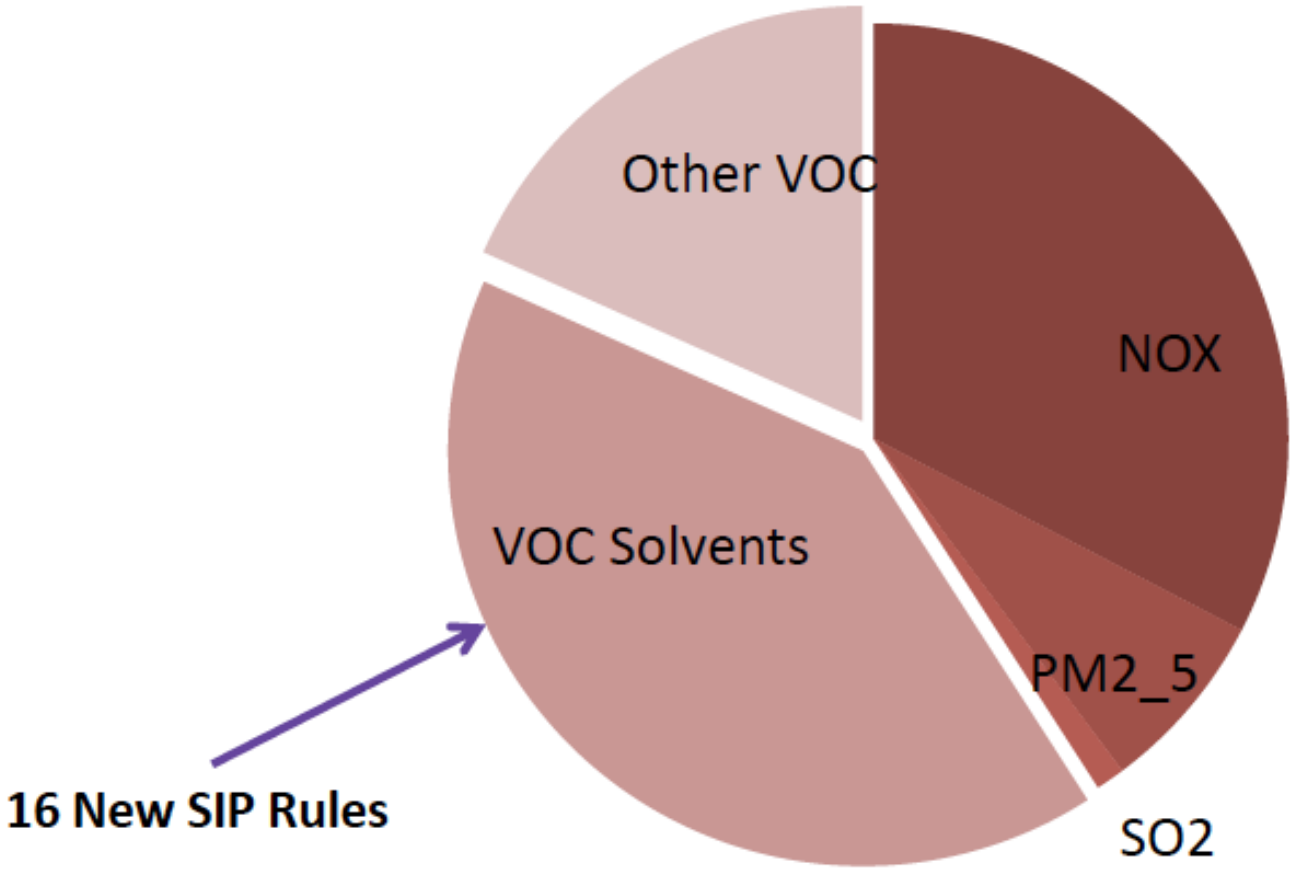


Area Source Emissions



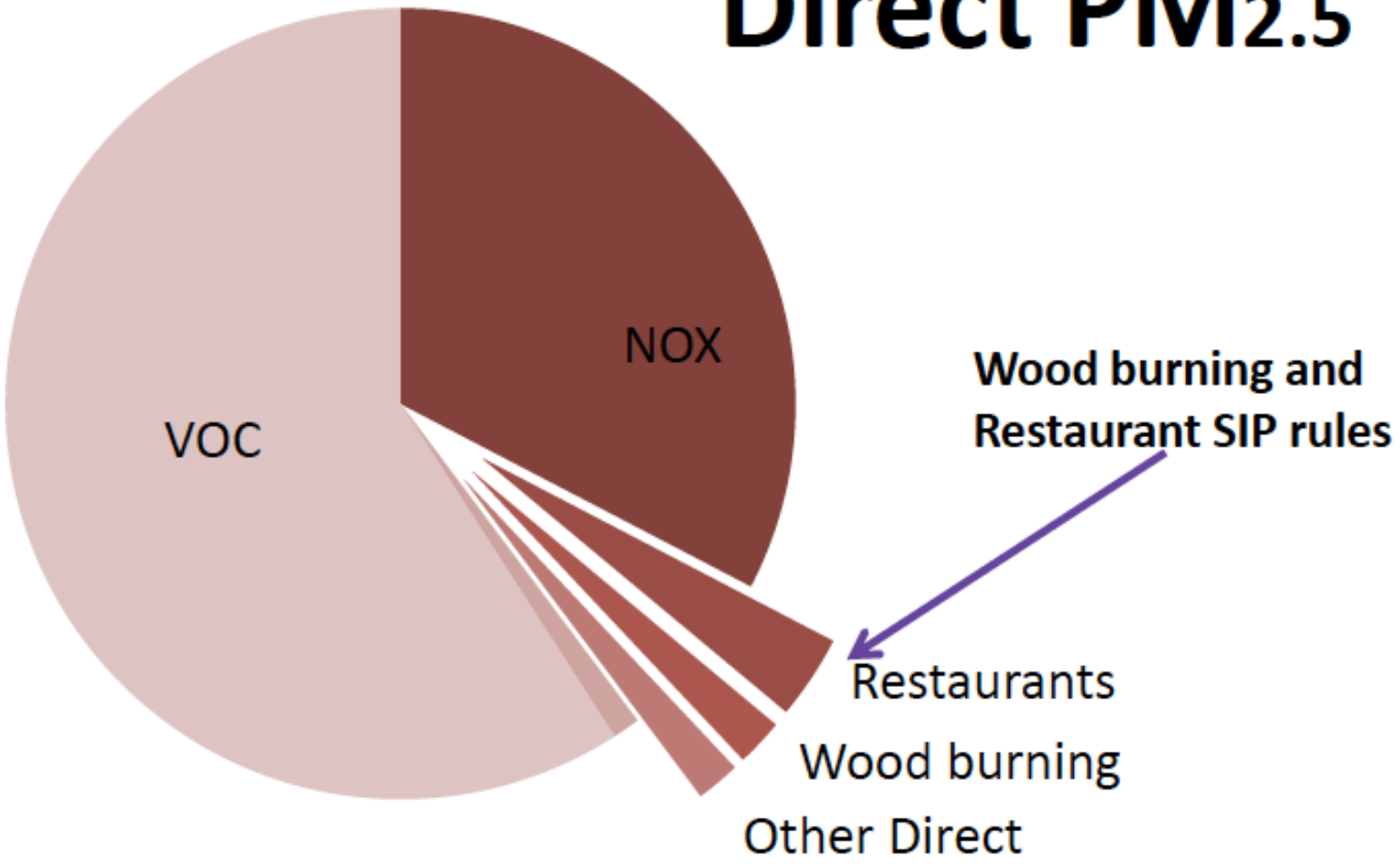
Source: Patrick Barickman – UDAQ – Area Source Emissions Inventory – Presentation to CAAT July 22, 2014

VOC



Source: Patrick Barickman – UDAQ – Area Source Emissions Inventory – Presentation to CAAT July 22, 2014

Direct $PM_{2.5}$



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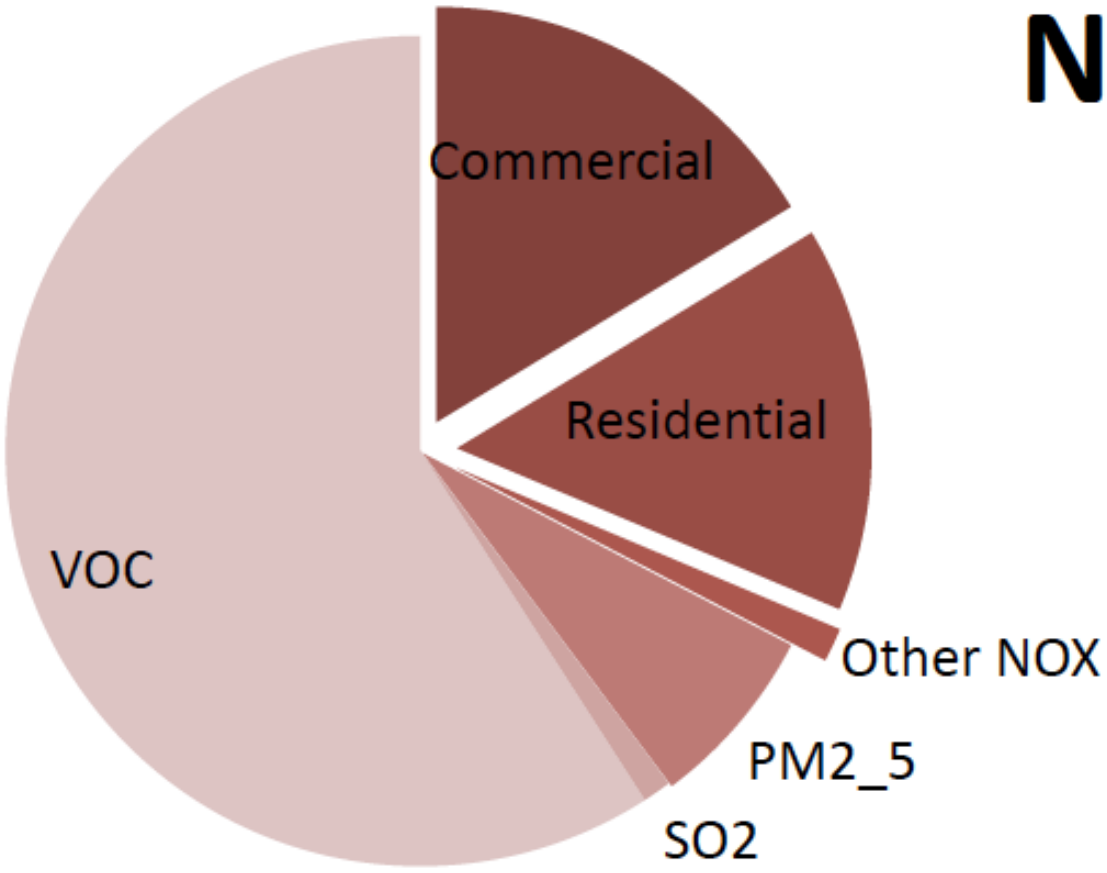
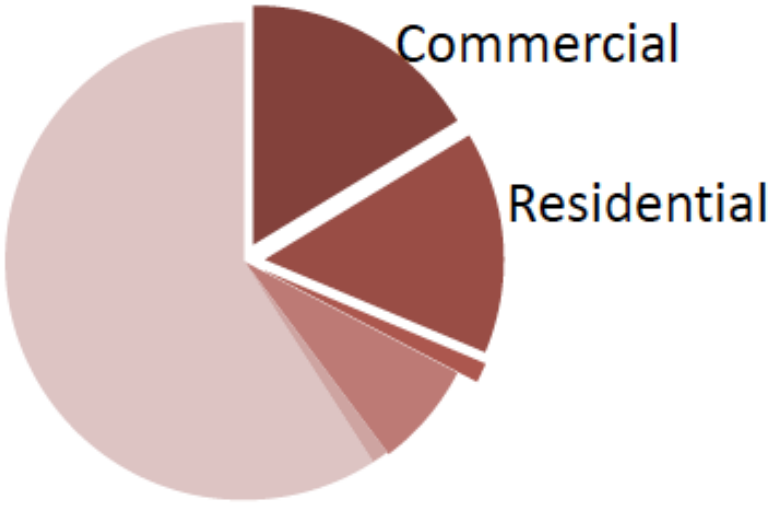


Source: Patrick Barickman – UDAQ – Area Source Emissions Inventory – Presentation to CAAT July 22, 2014

Area Sources (Buildings)

- Update Residential and Commercial building codes to promote energy efficiency?
- Incentivize retrofitting existing buildings for energy efficiency?
  - Windows/Doors
  - Insulation
  - Appliances
  - Geothermal heating & cooling
- Is there a Return on Investment?
- Solar energy potential?
- Low NOx Water heaters and furnaces?



Water heaters – 7 year life cycle

- Potential 70% reduction

Furnaces – 20 year life cycle

- Potential 65% reduction

Low NOx Burners

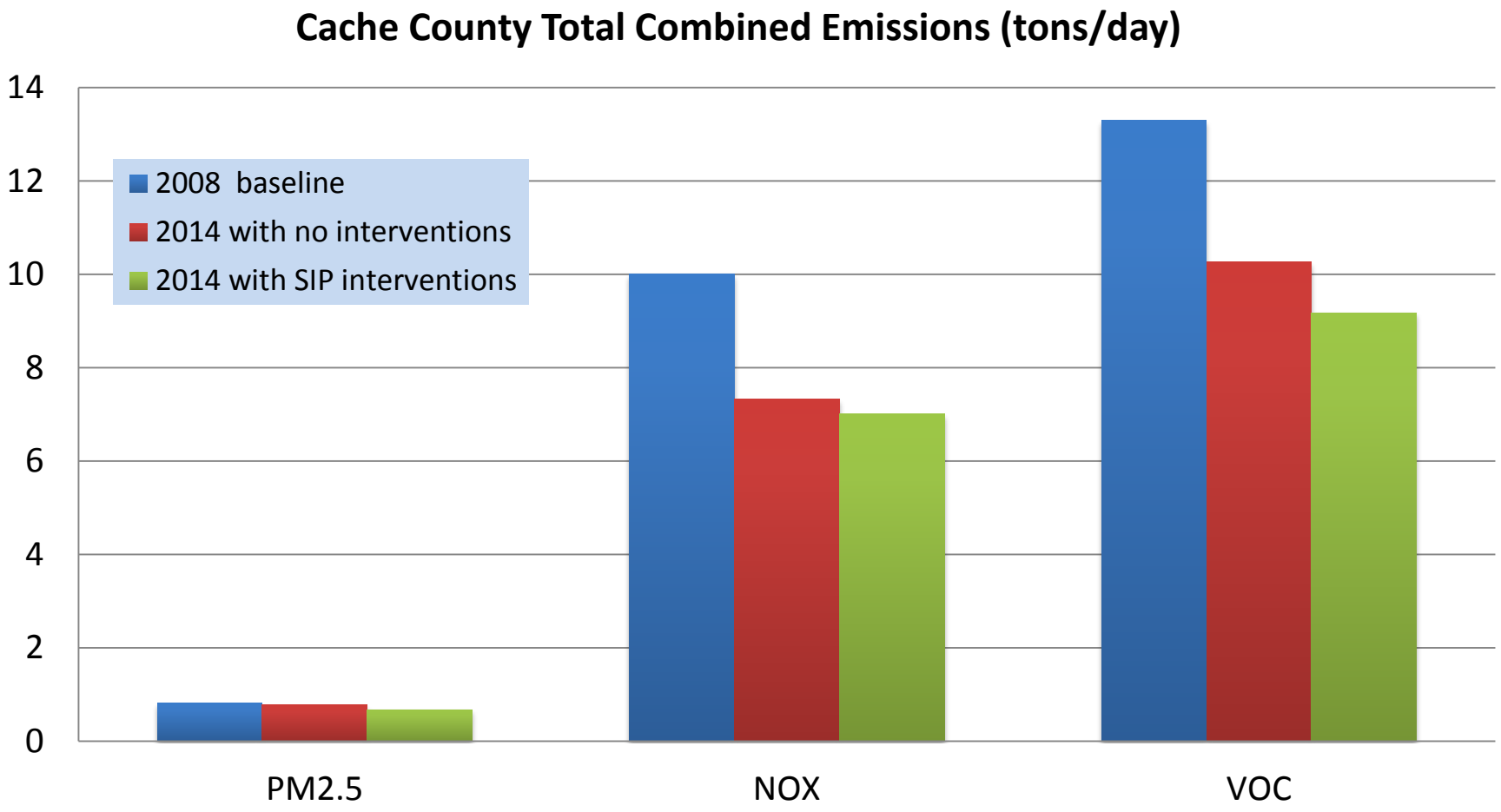
Source: Patrick Barickman – UDAQ – Area Source Emissions Inventory – Presentation to CAAT July 22, 2014

Hope for the future……

Cache County SIP

- Emissions inspection and maintenance program (I/M) on cars and trucks
- Area emissions reductions
  - Wood burning stoves
  - Commercial cooking
  - Printing and publishing
  - Painting
  - Degreasing

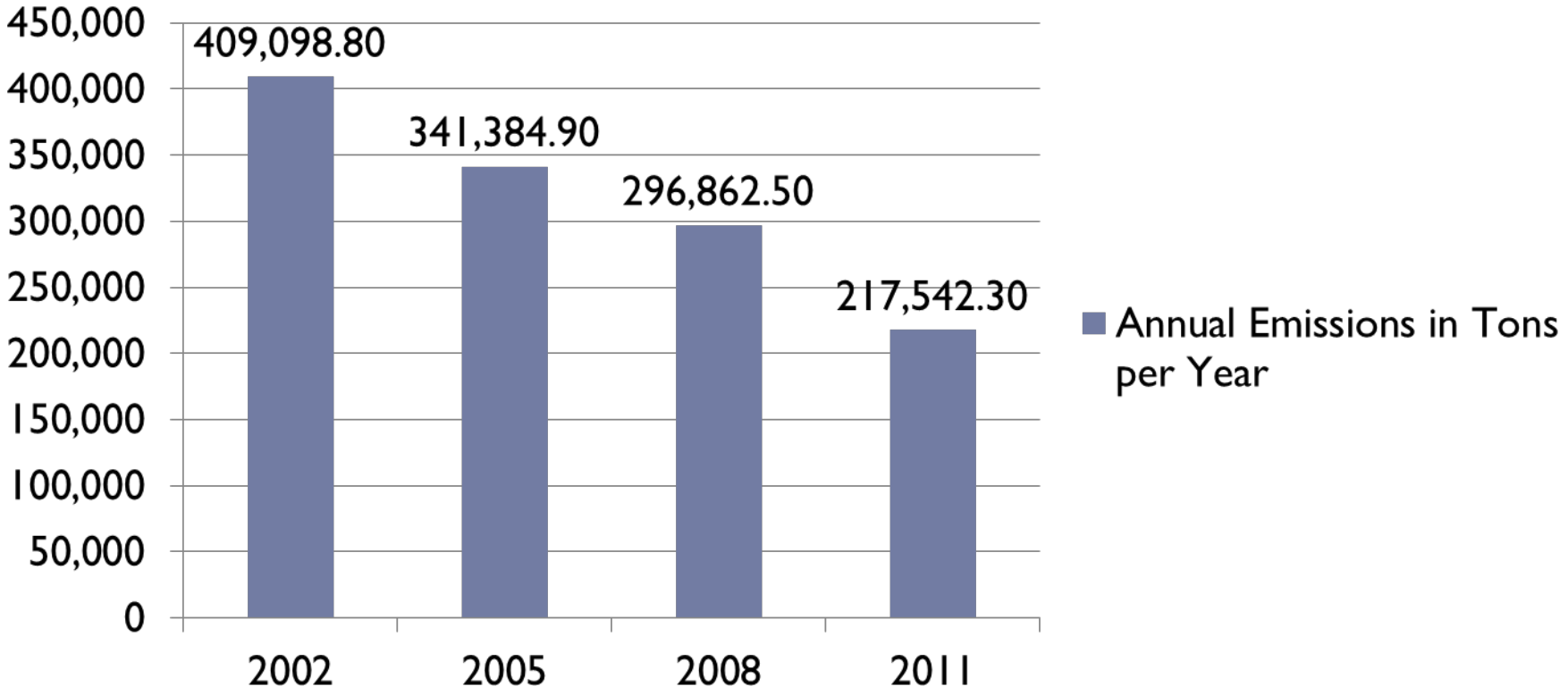
Modeled Effects of the Cache County SIP



Based on data from SIP for Logan UT, Section IX, Part A23 - UDAQ and MOVES estimates that I/M program will result is a 6% reduction in on-road VOC and NOx mobile emissions

Emission Trends

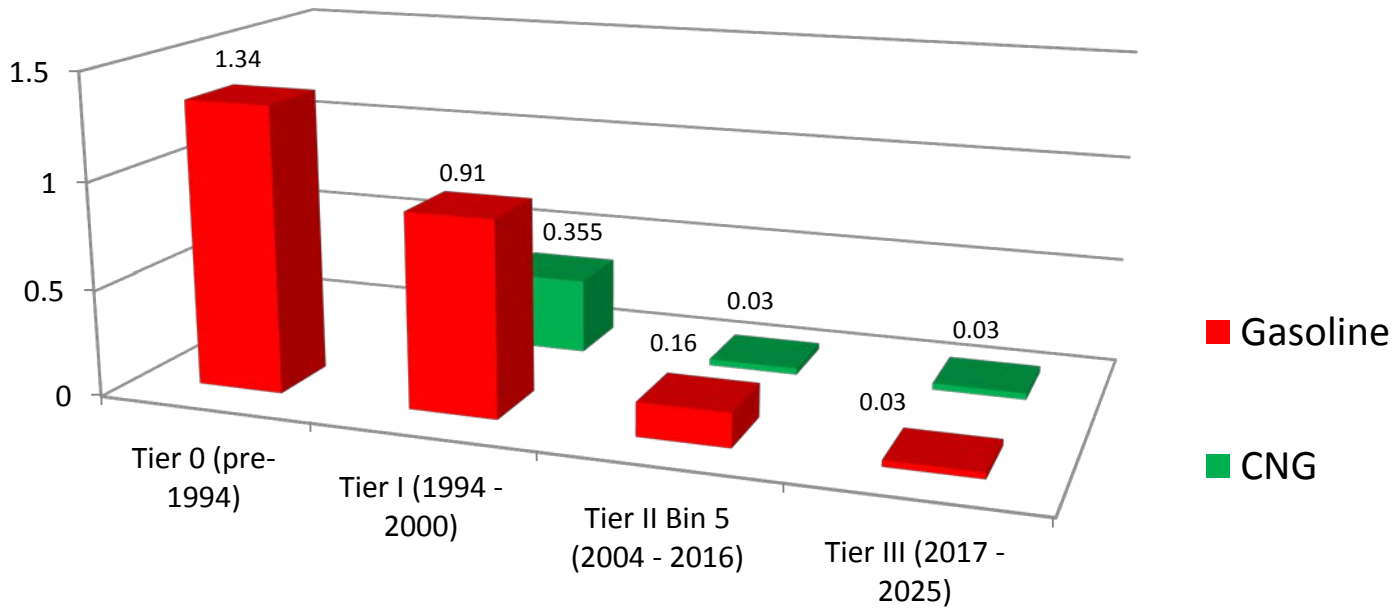
Salt Lake County annual emissions for all inventoried pollutants



http://www.airquality.utah.gov/Planning/Emission-Inventory/Available_inventory.htm Utah Division of Air Quality, 2013

Passenger Car Tier Certification Standards

Gasoline vs. CNG and Tier 0 – Tier III



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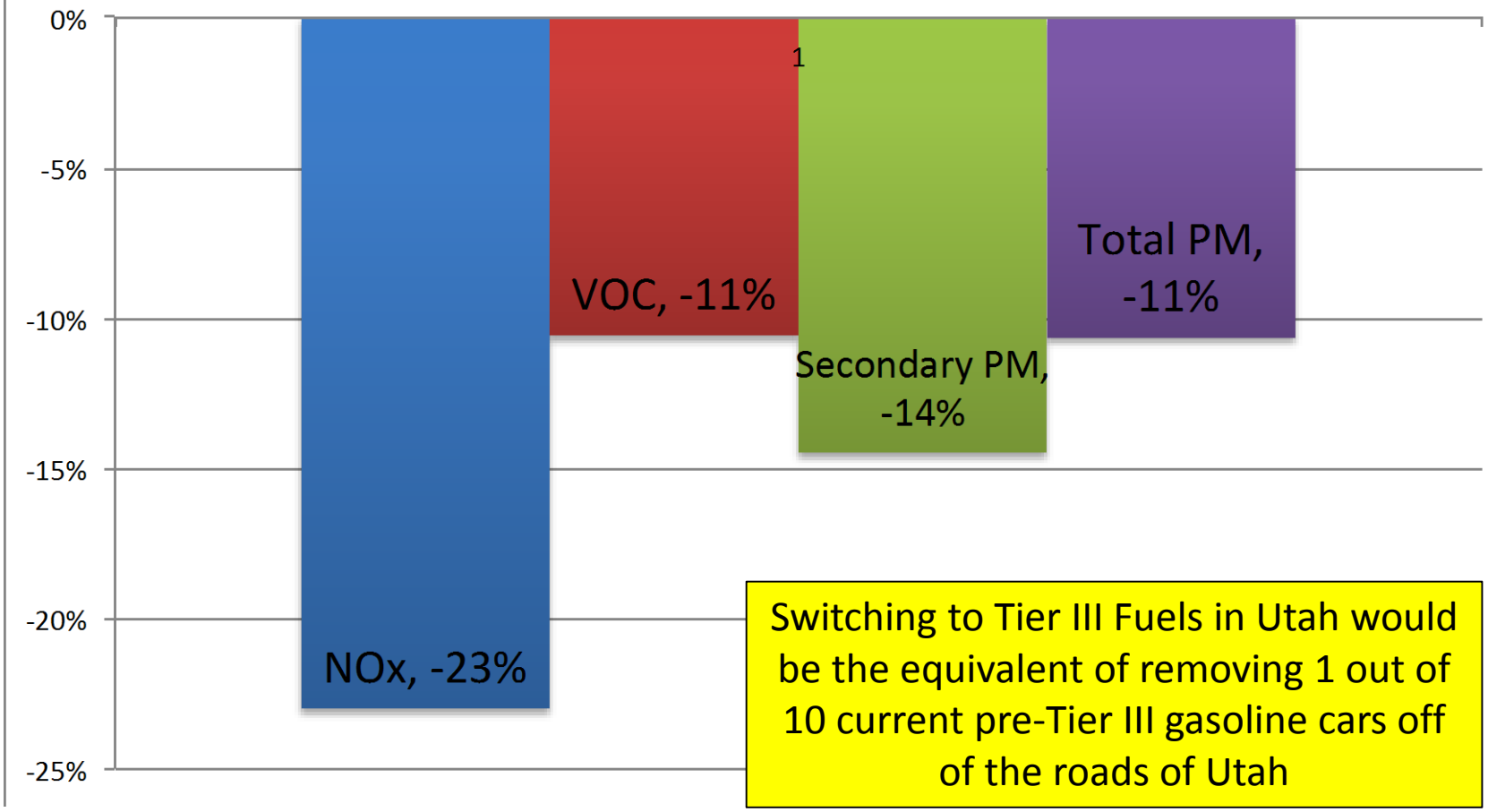
% Change in Emissions in Tier II gasoline vehicles if switch from Tier II gasoline (30 ppm) to low-sulfur Tier III gasoline (<10 ppm)

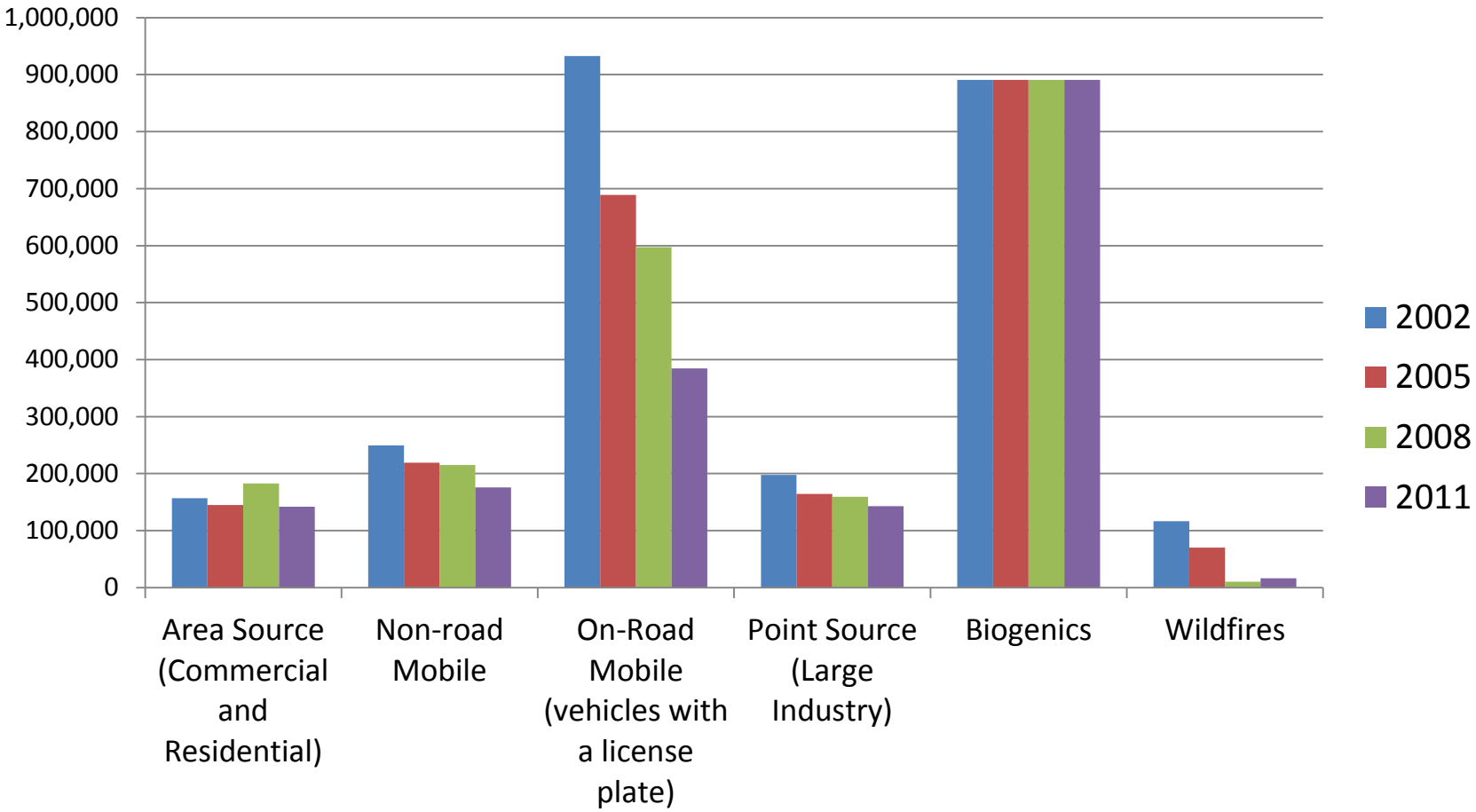


Switching to Tier III Fuels in Utah would be the equivalent of removing 1 out of 10 current pre-Tier III gasoline cars off of the roads of Utah

EPA: Draft Regulatory Impact Analysis: Tier 3 Motor Vehicle Emission and Fuel Standards March 2013

Utah Summary of State Air Emissions

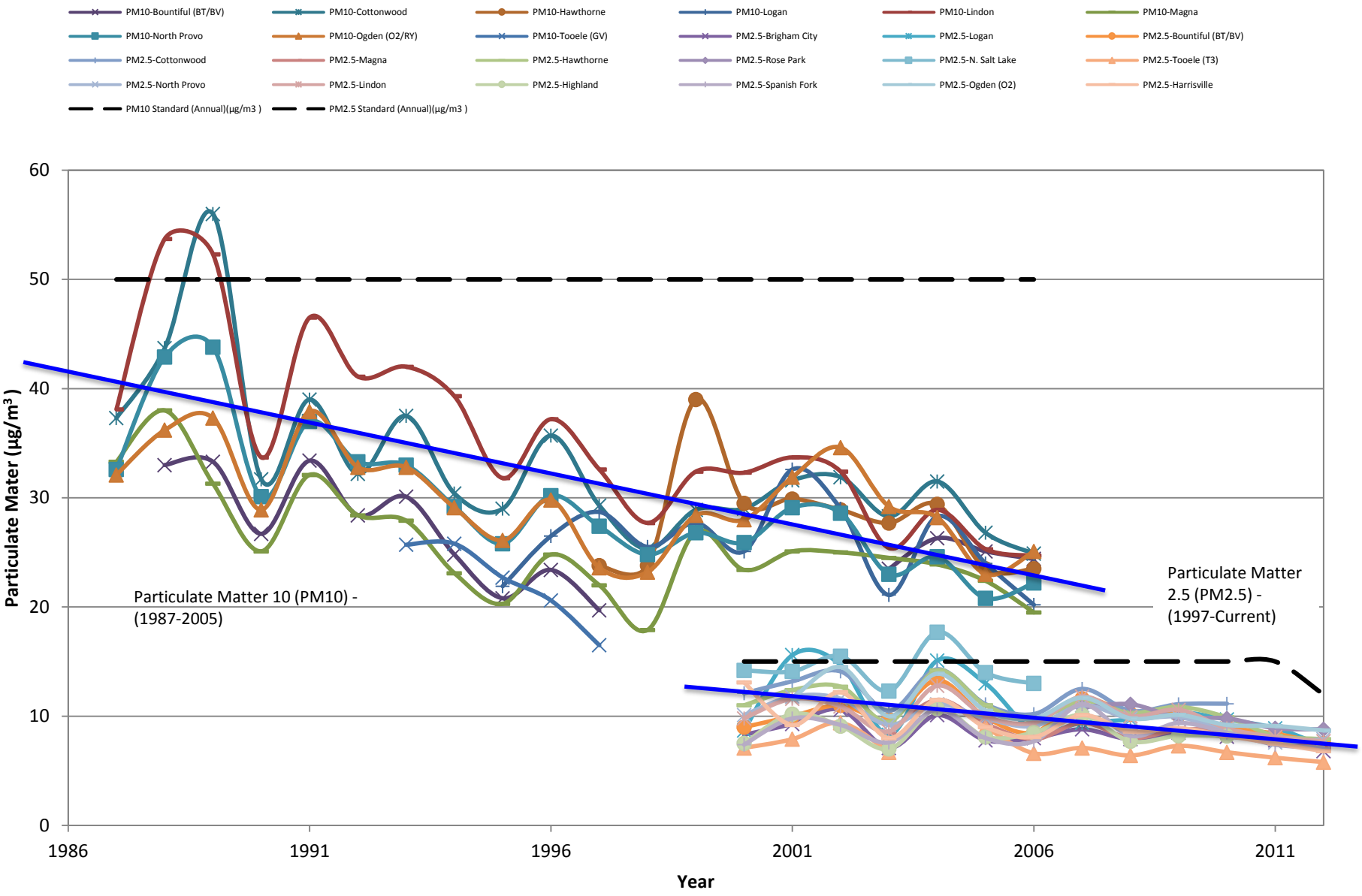
Total Tons Emitted by Sector
(PM, NOX, SOX, VOC, CO)



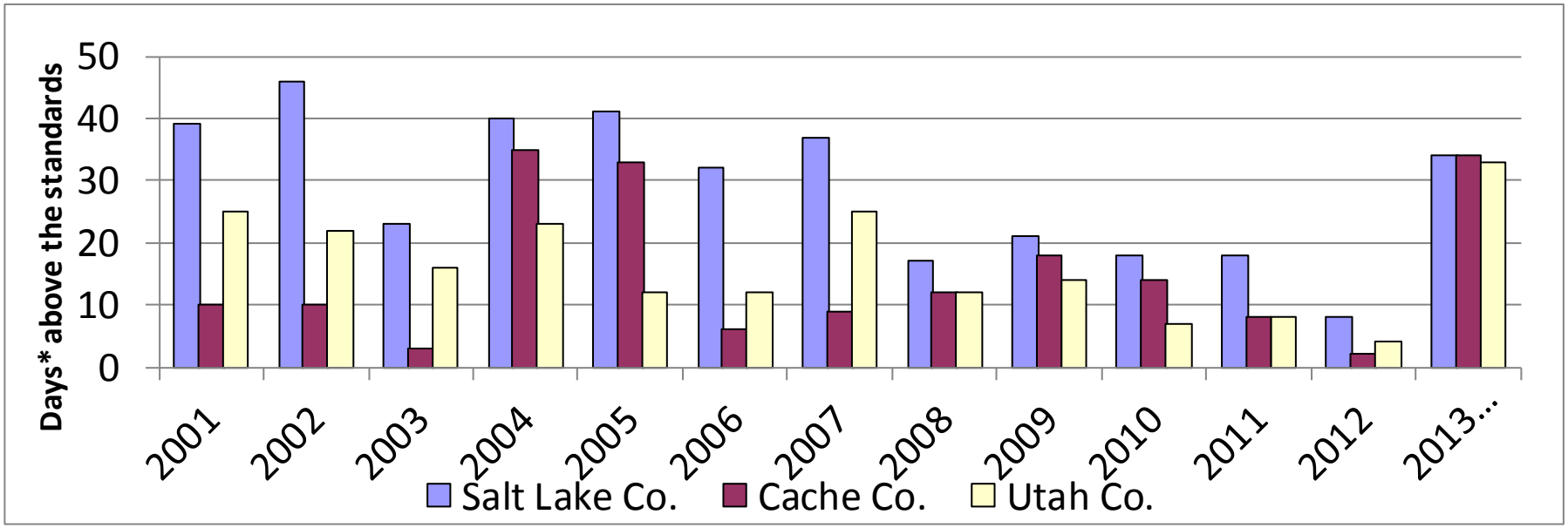
Biogenics are mostly VOC evaporative emissions from living and dead plants (e.g. tree sap) and animals and occurs mostly during warmer weather.

Reduction in On-Road Mobile Emissions is due mostly to lower sulfur content in Tier II fuels 2004-2008 phase in (100 ppm → 30 ppm in gasoline and <15ppm in diesel) and vehicle fleet turnover – This occurred despite increased VMT over the same period of time

Particulate Matter (PM) Standards - Annual

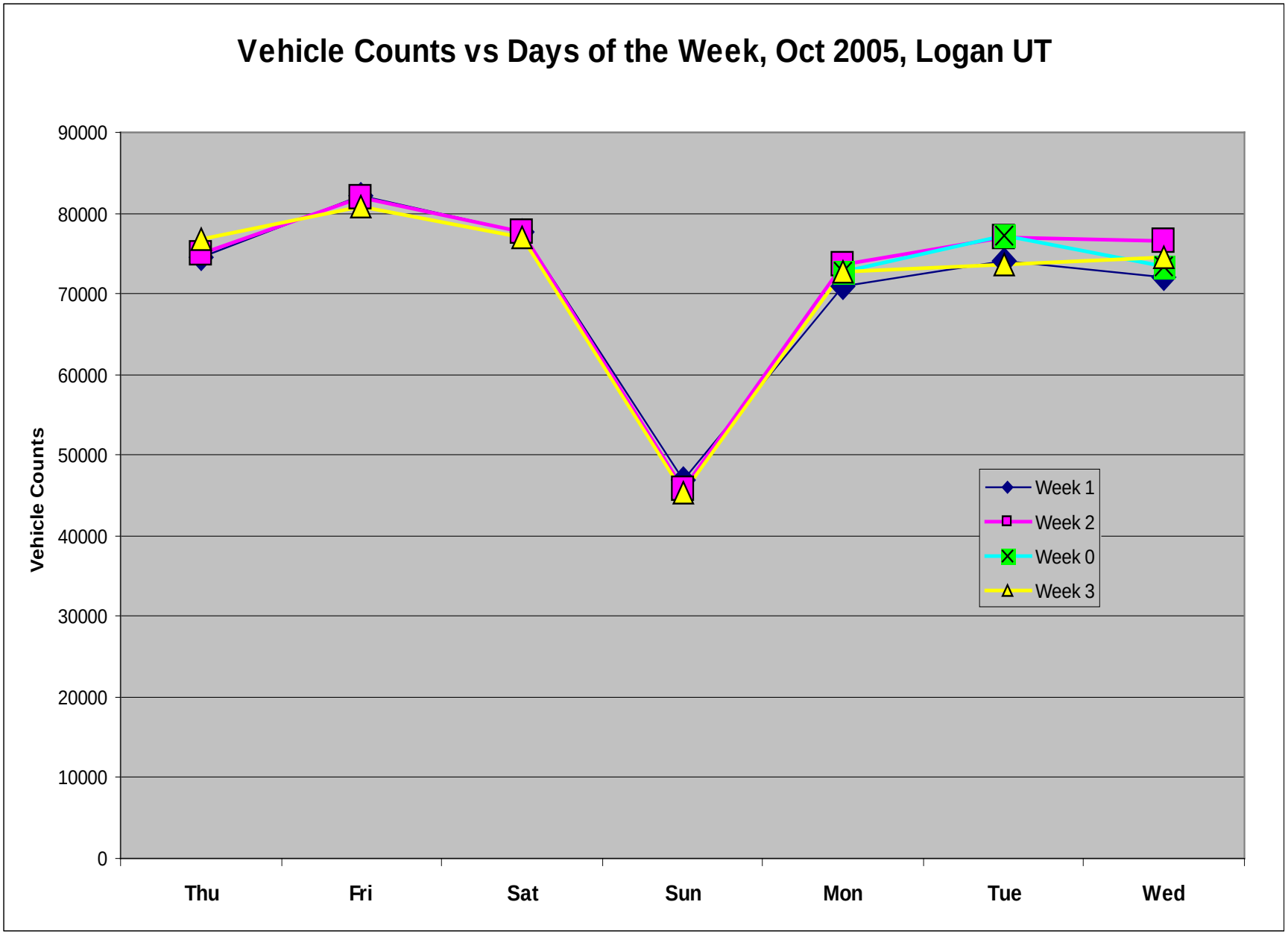


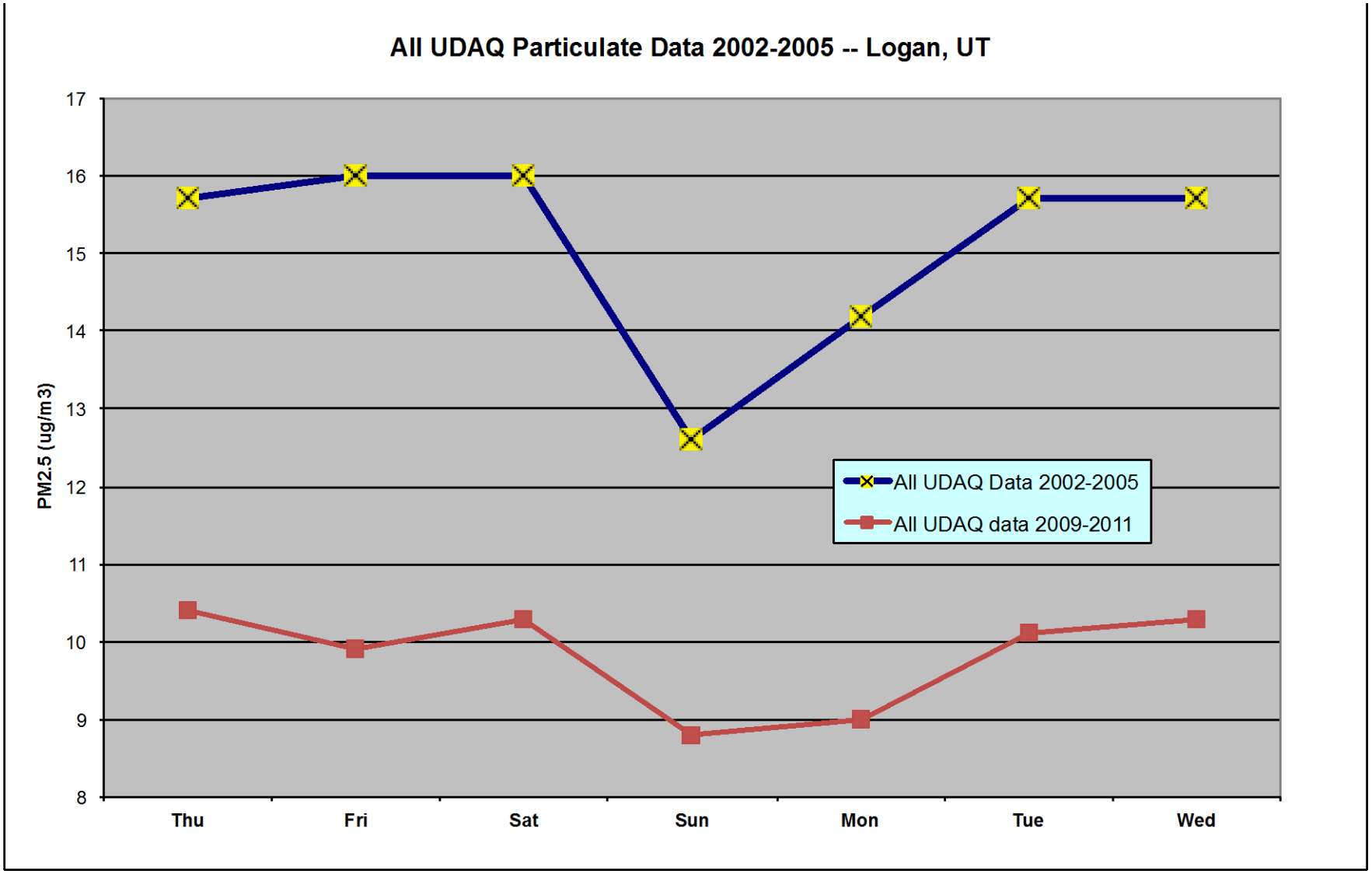
Number of Days That Are and Those That Would Have Been Above the Current Federal Standards
Salt Lake, Cache, and Utah County Areas



* Days with monitored values above the level of the ***current*** National Ambient Air Quality Standards combined for PM2.5 and ozone (PM2.5 standard revised in 2006, ozone standard revised in 2008)

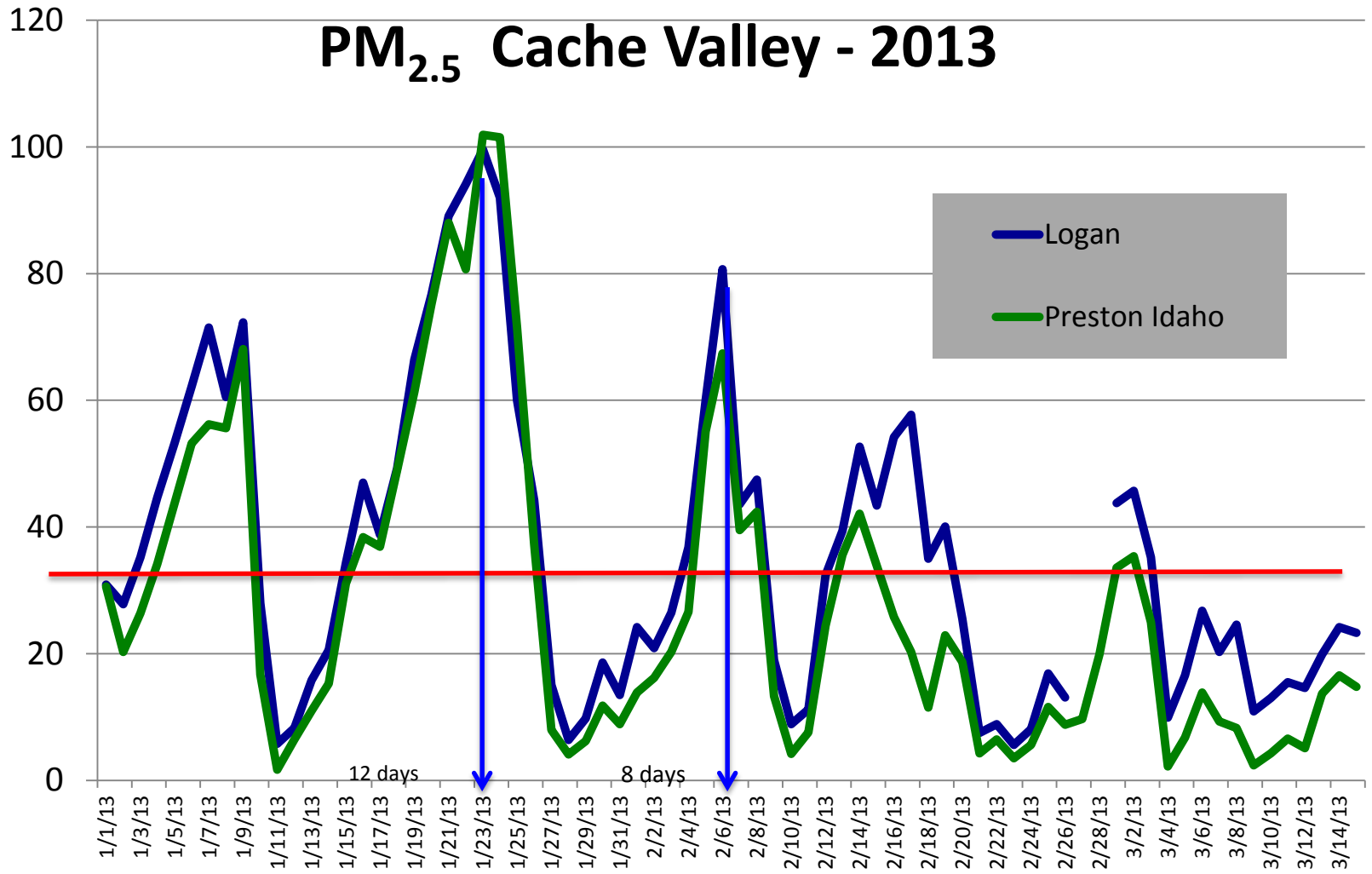
** 2013 includes values that have not completed Quality Assurance


Vehicle Counts vs Days of the Week, Oct 2005, Logan UT
Vehicle Counts
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
Thu
Fri
Sat
Sun
Mon
Tue
Wed
Week 1
Week 2
Week 0
Week 3



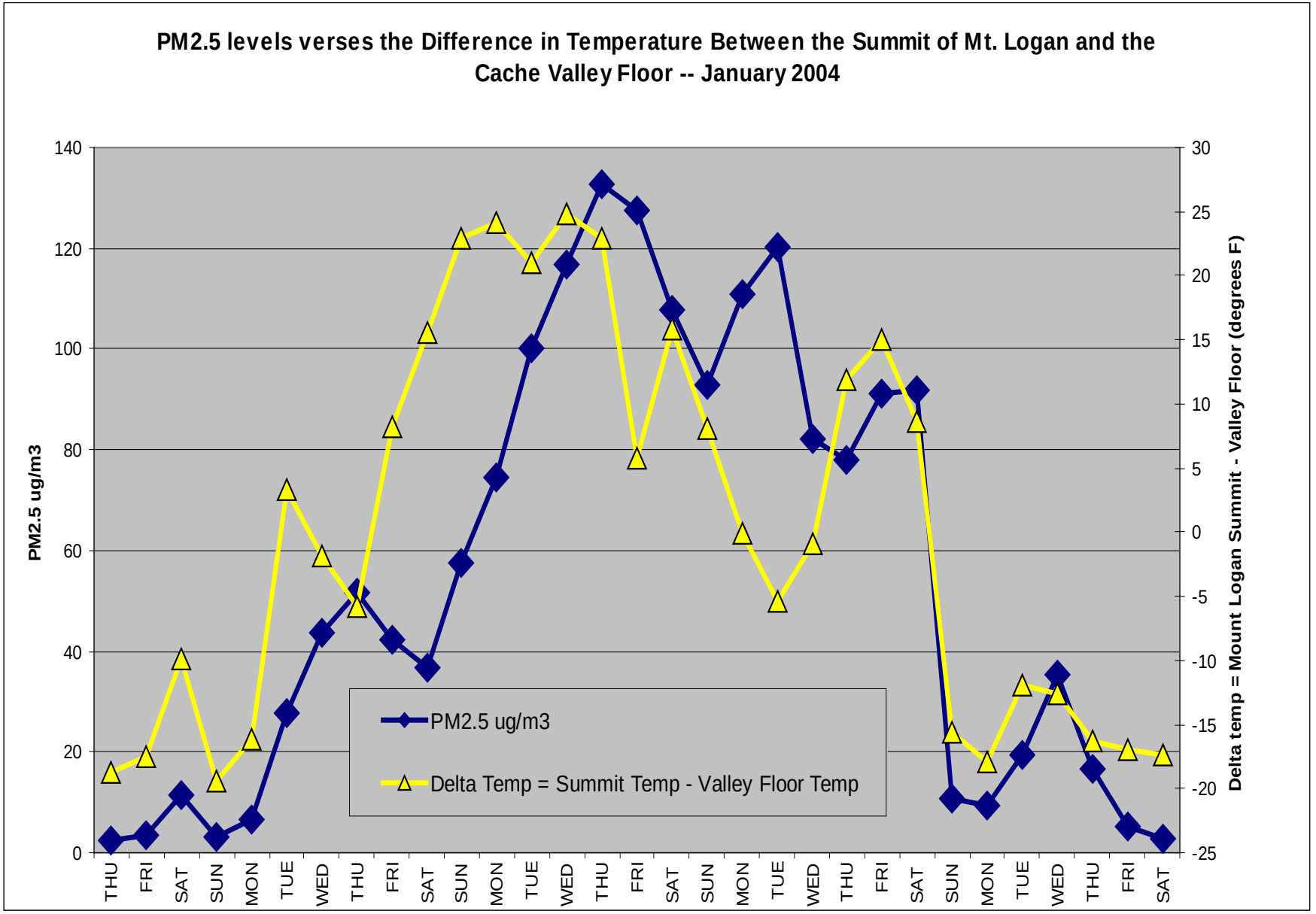
These are the average PM2.5 levels on each day of each week from 2002-2005 and 2009-2011

2013 Inversions – Delta PM/day = 10ug/m^3/day



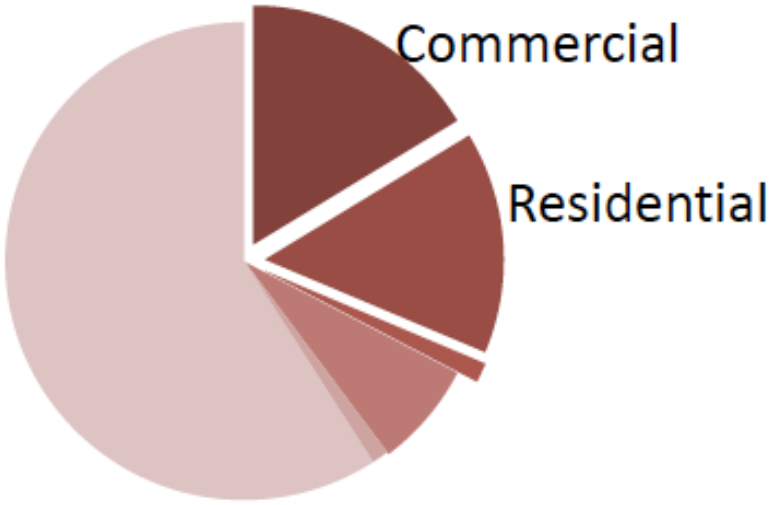
Data Source: UDAQ – Oct 2013

Intensities of inversions in Cache Valley correlate well with levels of $PM_{2.5}$



Area Sources (Buildings)

- Should we update Residential and Commercial building codes to promote energy efficiency?
- Should we incentivize retrofitting existing buildings for energy efficiency?
  - Windows/Doors
  - Insulation
  - Appliances
  - Geothermal heating & cooling
- Is there a Return on Investment?
- Low NOx furnaces and water heaters?
- Solar energy?



Water heaters – 7 year life cycle

- Potential 70% reduction

Furnaces – 20 year life cycle

- Potential 65% reduction

Low NOx Burners

Source: Patrick Barickman – UDAQ – Area Source Emissions Inventory – Presentation to CAAT July 22, 2014

Alternative Transportation Fuels

- Electric Vehicles (EV)
- Compressed and liquefied natural gas (CNG LNG)
- ATP – (adenosine triphosphate)
- Future Technologies (right here at USU)
  - Photocatalysis of water → Hydrogen gas generation
  - In-road induction transmission of electricity for EV's


TREK

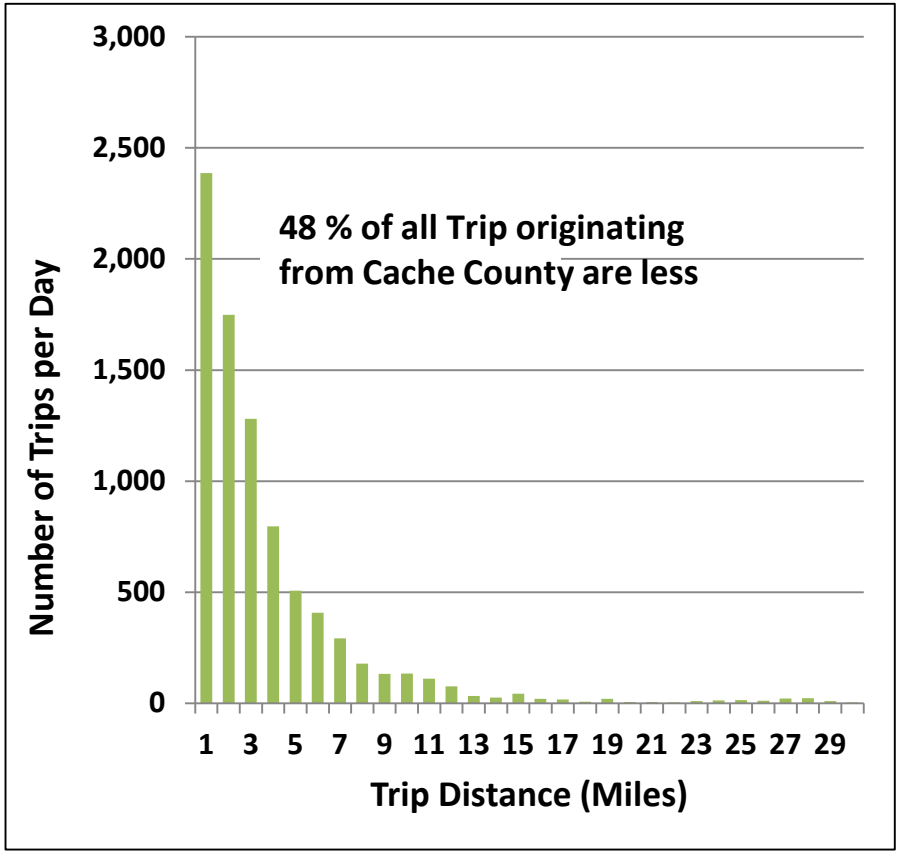
Active TransPortation – ATP

Can some people use ATP during the wintertime?

The Bicycle is the most efficient machine ever invented

Is bicycling 2 miles during an inversion harmful to your health?

Is walking 3 blocks to your church or the bus stop during an inversion dangerous?



John Loveless – graduate of USU

"In my Electric Truck, it takes 12.8 KWH to drive 40 miles or about $1.28 a day (@10 cents per KWH). That's 3.2 cents per mile. Comparing that to a 20mpg vehicle, that's like only paying 40 cents a gallon for gas. Since I have solar panels, it cost me essentially nothing to drive work and back."

Advantages of EV

- Zero local emissions – no “Cold Start”
- Efficient transfer of energy ≈ 100 mpg equivalent
- Fuel costs $0.40 -$0.60 per gasoline gallon equivalent
- 100,000 mile fuel cost savings of $15,000 +
- Potential for solar power charging applications
- Economic feasibility is improving with time
- Excellent local commuter applications

Approximate Cost of Solar Panel Systems

- 2010 - $6.50/watt installed [1]
- 2010 - $4.50/watt installed after tax credits
- 2013 - $3.00/watt installed [2]
- 2013 – 8000 kwatt system = $24,000
- What monthly bills will you avoid for this investment?
- Electric bills, natural gas bills, and gasoline expenses
- 40 miles/day EV = $168 per month if had been using gasoline
- Electric bill = $100 per month
- Gas bill = $50 per month
- Depreciation over 25 years = $80 per month
- Return on $24,000 = $238/month or $2856/year = 12%

1. Source: Edwin Stafford – resident of Logan, Utah
2. Source: Mark Richards – Intermountain Wind and Solar, Woods Cross, UT

Future Public Policy Questions for Cache County

- Is relatively clean air most of the days a community priority?
- Can we grow without growing VMT and mobile emissions?
- Can we control the growth of area emissions?
- Building codes?
- Low-emissions industries?
- Land use policies – planning and zoning?
- ATP and Public transportation options in Cache County
- Solar power and electric vehicles?
- Photo-catalysis?

Recommendations for Wintertime :

- Drive the newest most fuel-efficient vehicle
  - that you have available to you
- Park your car in a garage
  - whenever possible
- On a cold start, start the engine and drive the car.
  - (Get the "Cat" fired up)
- Avoid idle warm-ups
  - They do not save gas, and do not reduce emissions
  - BUT if your windshield is frosted over an idle warm-up might save you from killing a pedestrian or bicyclist

Recommendations for Wintertime:
(Continued)

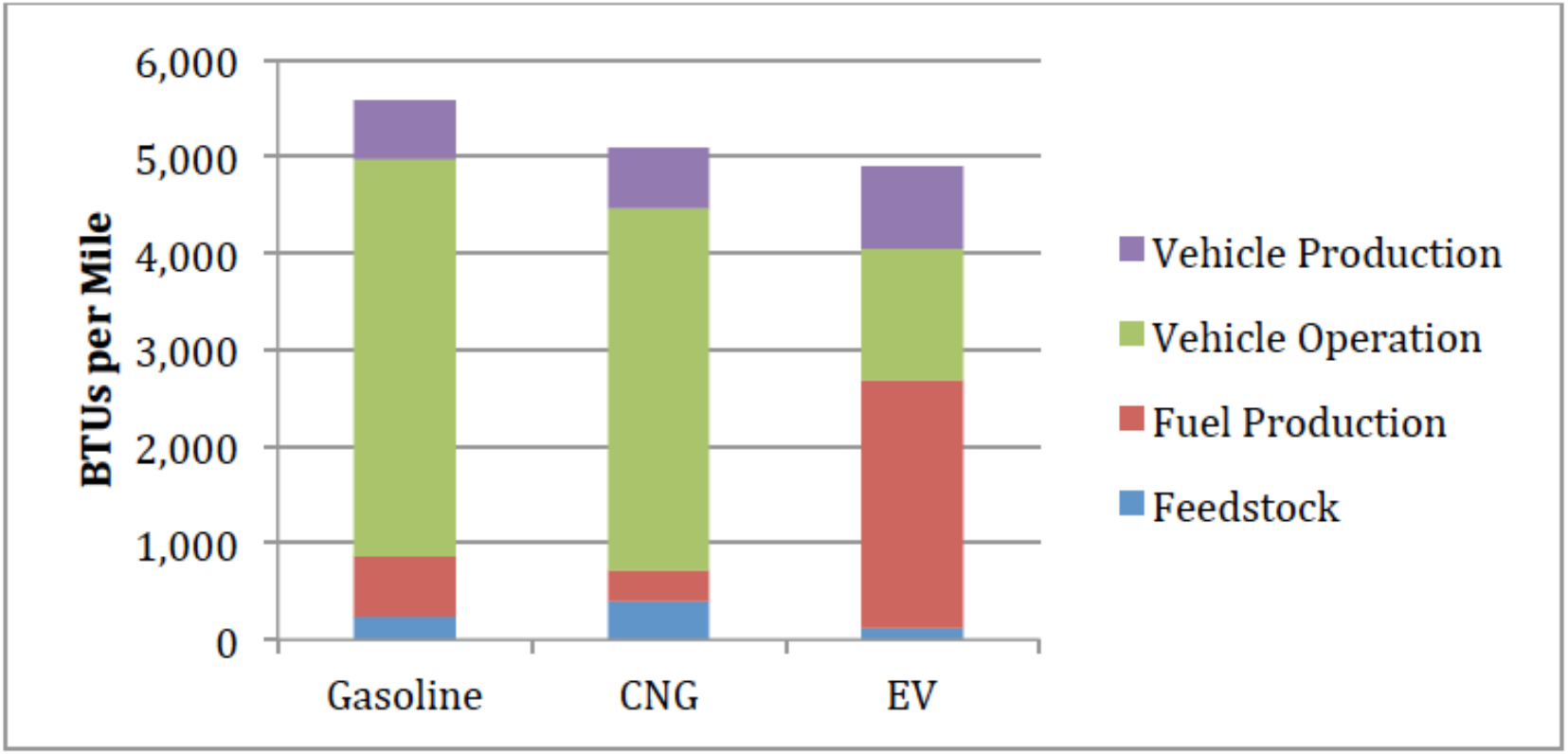
- Avoid idling > 10 seconds unless you are in traffic.
  - The Cat cools down when idling → increased NOx and VOC emissions
- Trip-chain whenever possible
  - hot "Cats" really help reduce vehicle emissions – 90+%
  - "Cats" can remain hot and active for 15-30+ minutes after shutting the engine off
- "Check Engine" means that there is a problem.
  - Get your emissions control system tested ASAP.

What can we do as individuals and as a community outside of the SIP?

- Transportation choices
- Cold starts and idling
- Alternative-fueled vehicle
- Active transportation

- Non-mobile Area Emissions reduction efforts

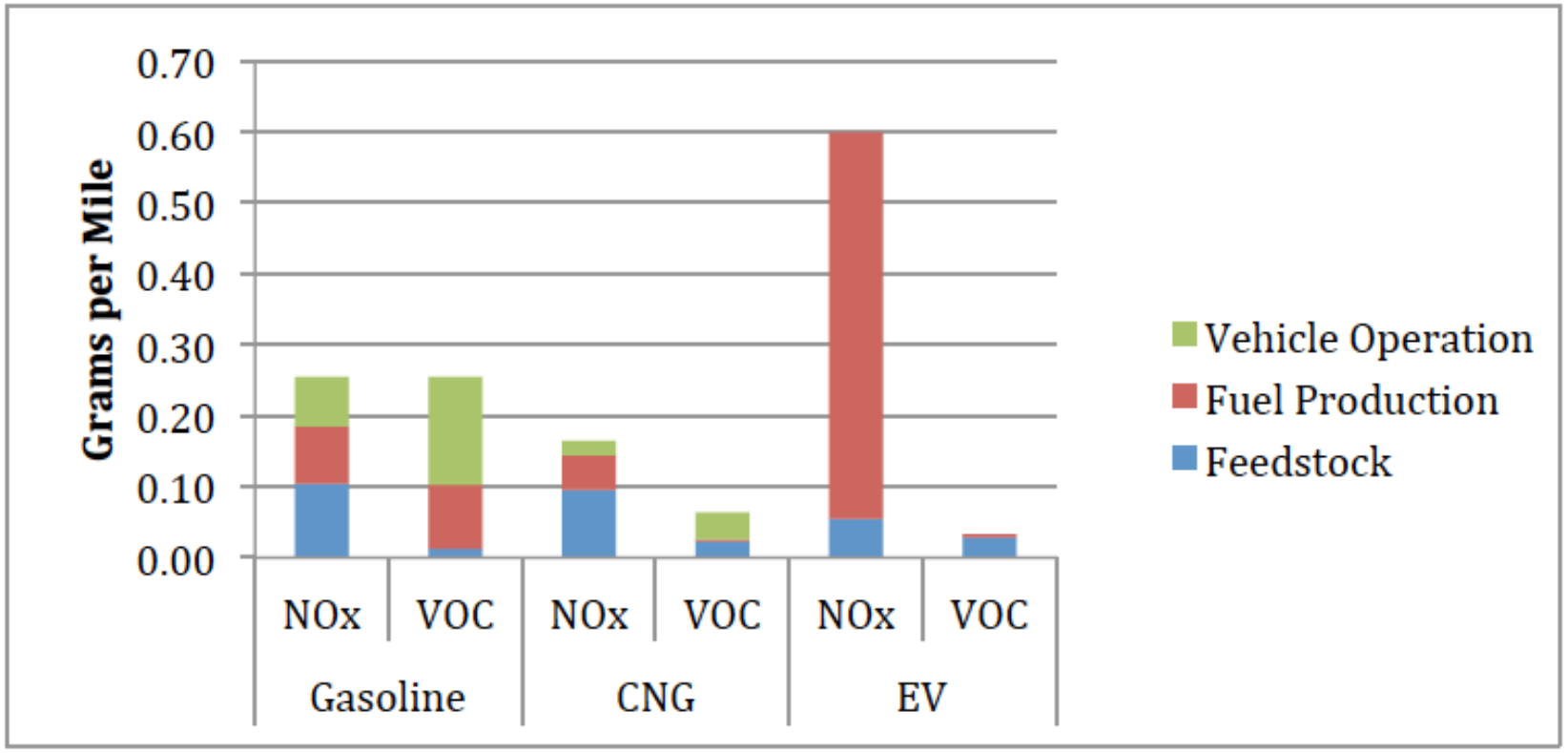
Figure 49. Energy Consumption, New Vehicles in 2013 – Utah



Vehicle Production = Energy and emissions due to manufacturing and disposal of vehicle
Vehicle Operation = Energy used and emissions from vehicle while it is being driven
Fuel Production = Energy/emissions for production transportation and storage of fuel
Feedstock = Energy/emissions due to extraction, transportation, storage of the fuel base

http://www.swenergy.org/publications/documents/Regional%20Fuel%20EmissionsFNL.pdf

Figure 50. Ozone Precursor Emissions, New Vehicles in 2013 – Utah



http://www.swenergy.org/publications/documents/Regional%20Fuel%20EmissionsFNL.pdf

Advantages of EV

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- Efficient transfer of energy ≈ 100 mpg equivalent
- Fuel costs $0.40 -$0.60 per gasoline gallon equivalent
- 100,000 mile fuel cost savings of $15,000 +
- Potential for solar power charging applications
- Economic feasibility is improving with time
- Excellent local commuter applications

Disadvantages of EV

- Trip range less than 100 miles
- Recharge takes longer than 5 minutes
- Rapid recharge (30 min) may require 3-phase 480 volt power and an expensive charging device.
- Intermediate charge (3-4 hours) 220 volts, 6000 watts
- Replacement costs of battery pack sometime after 100,000 miles

Advantages of CNG

- Cost – $1.50 per gasoline-gallon equivalent
- One-time UT income tax credit of up to $2,500
- 100,000 mile fuel cost savings of $10,000 +
- Relatively low refinery emissions
- No trucking emissions – piped in the ground
- Domestic locally-produced fuel
- Cold-start CNG VOC emissions are less reactive

Disadvantages of CNG

- Bulky tank
- Travel range 80-200 miles
- Lack of wide-spread fueling stations
- Cost of CNG conversion can be $4,000 - $8,000
- Exception is factory-built dedicated CNG vehicles

Advantages of Bikes - ATP

- Zero NOx emissions – very low VOC emissions
- Readily available fuel
- Don’t have to scrape ice off of your windshield
- Lowest cost of all transportation
- Faster and more convenient than a bus
- No need for a gym memberships
- Psychologically therapeutic
- Physically therapeutic – low impact
- Practical for most trips under 10 miles

Disadvantages of Bikes – ATP

- Increased deodorant costs
- Some risk due to inattentive drivers of other vehicles
- Small risk of wipeouts on ice patches
- Not much fun during an actual snow storm
- Prolonged exertion when PM2.5 is elevated may cause health problems.
- Not advisable or practical for some individuals

Reduction in VOC and NOX Mobile Emissions

- Tier II and Tier III vehicle emissions standards
- Emissions inspection – keep clean technology functioning properly
- Alternative fuel vehicles
  - CNG – big picture benefits – theoretical cold-start advantage and lower point source refinery and transportation emissions
  - EV (electric vehicles)
  - Hybrid vehicles
- Carpooling to work and school – start one car instead of 4 cars
- Public transportation – do not start your car
- Active transportation (walk and bike) for short trips (< 2 miles) especially to bus station or train station
- Do not idle > 10 seconds unless you are in traffic
- Trip chaining (plan ahead) – get it all done in one trip
  - Avoids significant cold start emissions – hot Cat → decreased emissions

Area NOx Emissions Reductions

- Decrease burning of fossil fuels for heating and cooling of homes and businesses
  - Use of geothermal heat pumps in place of natural gas furnaces and water heaters
  - Solar panels for generation of part of electrical energy needs. Coal-fired power plants release significant amounts of NOX
  - Improve insulation and weatherization – change in building codes

What can one person do to reduce Area NOX?

- Make your home energy efficient
- Consider geothermal heat pump when replacing a natural gas furnace
- Use only an EPA-certified wood-burning stove if burning bio fuels to heat home
- Do not use any wood-burning stove during non-storm conditions (yellow and red-air days)
- Low-NOx furnace and water heater replacement

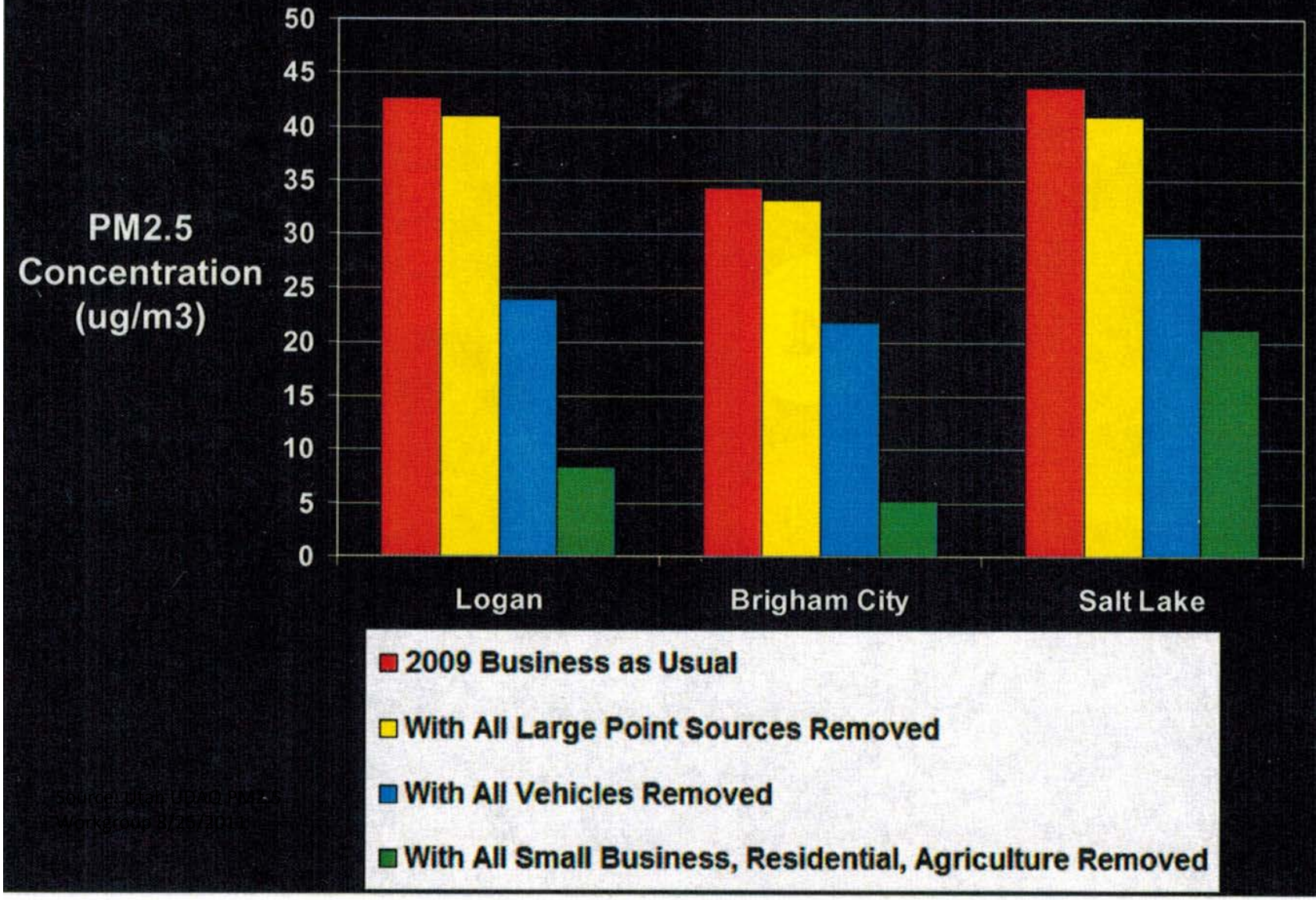
What can one person do to reduce Area VOC's

- Be aware of solvents, gasoline cans, certain hair sprays, oil-based paints, and other VOC's around home. Avoid using them whenever possible, especially during wintertime.
- Do not operate wood-burning stove during wintertime temperature inversions (yellow and red air days).
- Do not grill or burn food during wintertime temperature inversions

What can one person do to reduce mobile emissions of NOX and VOC's and PM2.5?

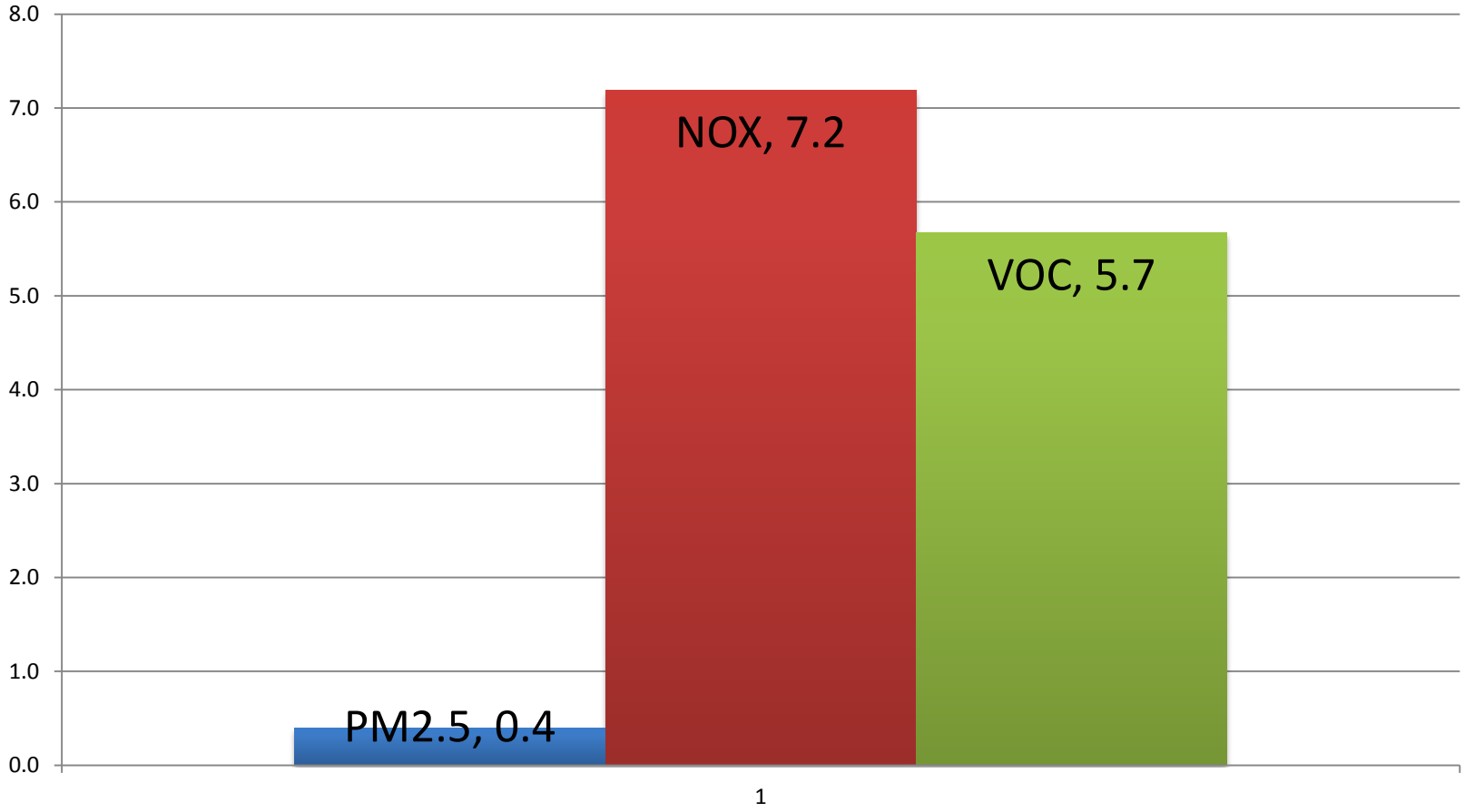
- Park car in garage (Cat doesn't get so cold)
- Plan vehicle use to minimize cold starts
- Carpool – one car with a cold cat gets started instead of 5 cars
- Public transportation – no cold starting of personal car
- Active transportation – no cold starting of personal car
- Maintenance – Check Engine light
- Consider alternate cleaner transportation fuels (CNG, EV)

Modeled PM2.5 Concentrations



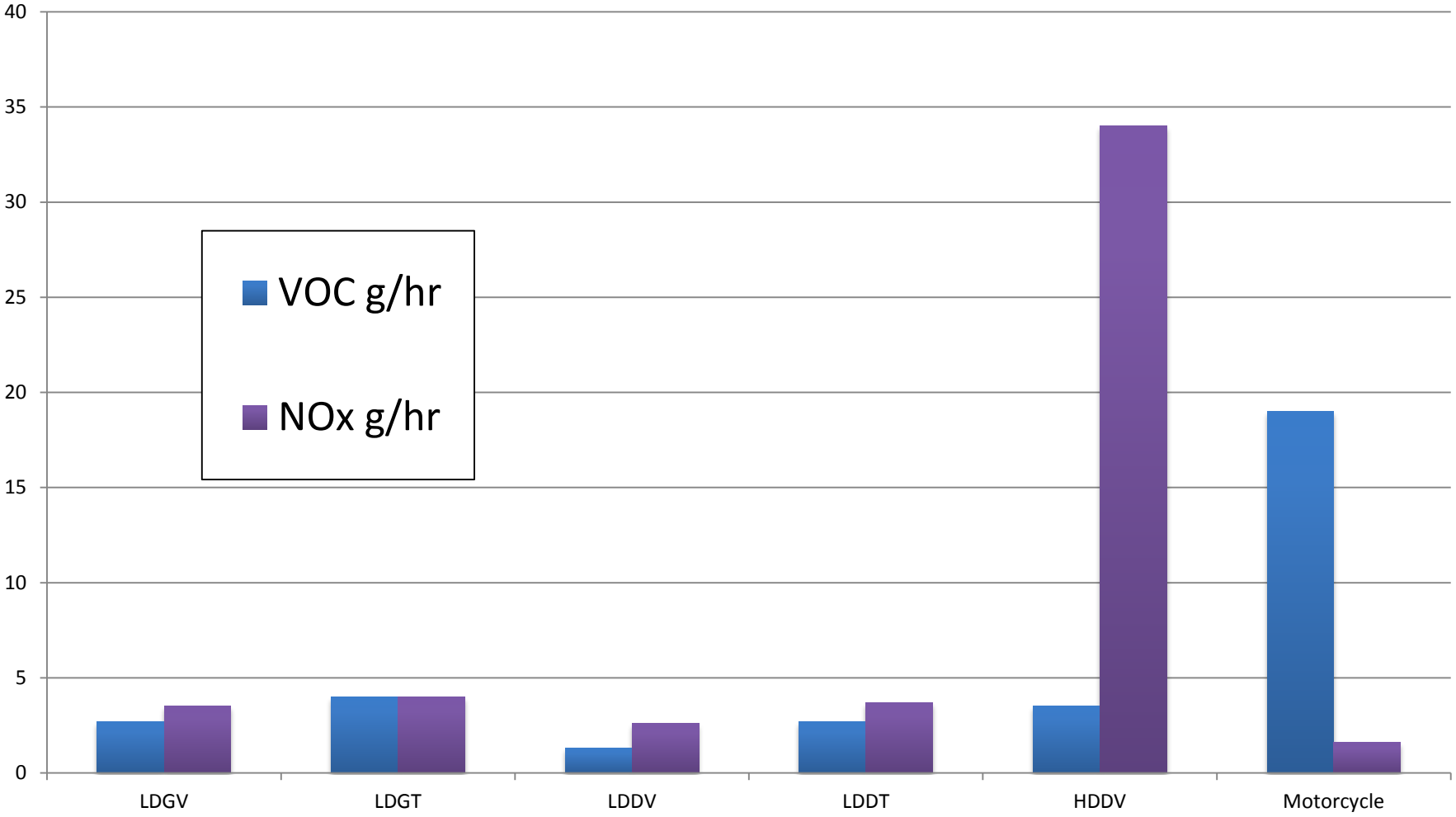
Source: Utah UDAQ PM2.5 Workgroup 8/25/2011

Cache County Mobile Emissions 2008 (tons/day)



Source UTAH DAQ

Idling Emissions - USA average fleet - EPA 2008



Cold Start Idling – Cache County

- Assume 1 out of 20 registered cars does a 10 min cold-start idle warm-up each day
- 3,000 vehicles - cold start idles for 10 min
- Assume that their cats are not fired up
- Assume 5 gm/hr NOX and 40 gm/hr VOC idling
- VOC due to cold start idle = 0.17 hrs x 40 gm/hr x 3,000 x 1 lb/454gm x 1 ton/2000 lbs = 0.02 tons/day or 40 lbs/day = 1/3rd of 1 % of all mobile VOC emissions/day
- NOX due to cold start idle = 0.17 hrs x 5 gm/hr x 3000 x 1 lb/454gm x 1 ton/2000 lbs = 0.003 tons/day or 5 lbs/day which is < 1/20th of 1% of mobile NOX emissions/day

Idling at schools and drive-throughs

- Assume 5,000 warmed up vehicles idle for 15 minutes/day while waiting for kids or bank tellers or hamburgers
- Assume 2008 average summertime idling emissions x 2 for VOC's = 5 gm VOC/hr idling (higher VOC's due to cold temperatures)
- VOC due to warm idle = 5,000 cars x 0.25 hrs x 5gm/hr x 1 lb/454gm x 1 ton/2000 lbs = 0.006 tons = 1/20th of 1 % of mobile VOC emissions
- NOX due to warm idle = 5,000 cars x 0.25 hrs x 4 gm/hr x 1 lb/454gm x 1 ton/2000 lbs = 0.006 tons = 1/10ths of 1% of mobile NOX emissions

Questions to ask?

- Will there be a measureable improvement in air quality if you do a mandatory citation-enforced idle reduction campaign?
- Will we save any lives or prevent any illness due to reduced $PM_{2.5}$ with such a program?
- Is it possible that such an ordinance could result in unintended bodily injury or death?
- What are other potential risks of doing a mandatory no-idling ordinance?
- Could a less-intrusive educational effort that teaches people about the personal benefits of idle reduction be as effective as a mandatory program with citations?