Quality Improvement for Ammonia Emission Inventory

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OBJECTIVE

- To develop improved estimates for an ammonia emission inventory by county in Tennessee for the base year of 1999 to serve as input for $PM_{2.5}$ modeling

Why Ammonia?

- Plays an important role in neutralizing compounds such as nitric and sulfuric acids, formed as products of atmospheric oxidation of NOx and SO2 emissions.

- Reactions of NH3 in the atmosphere lead to the formation of PM2.5

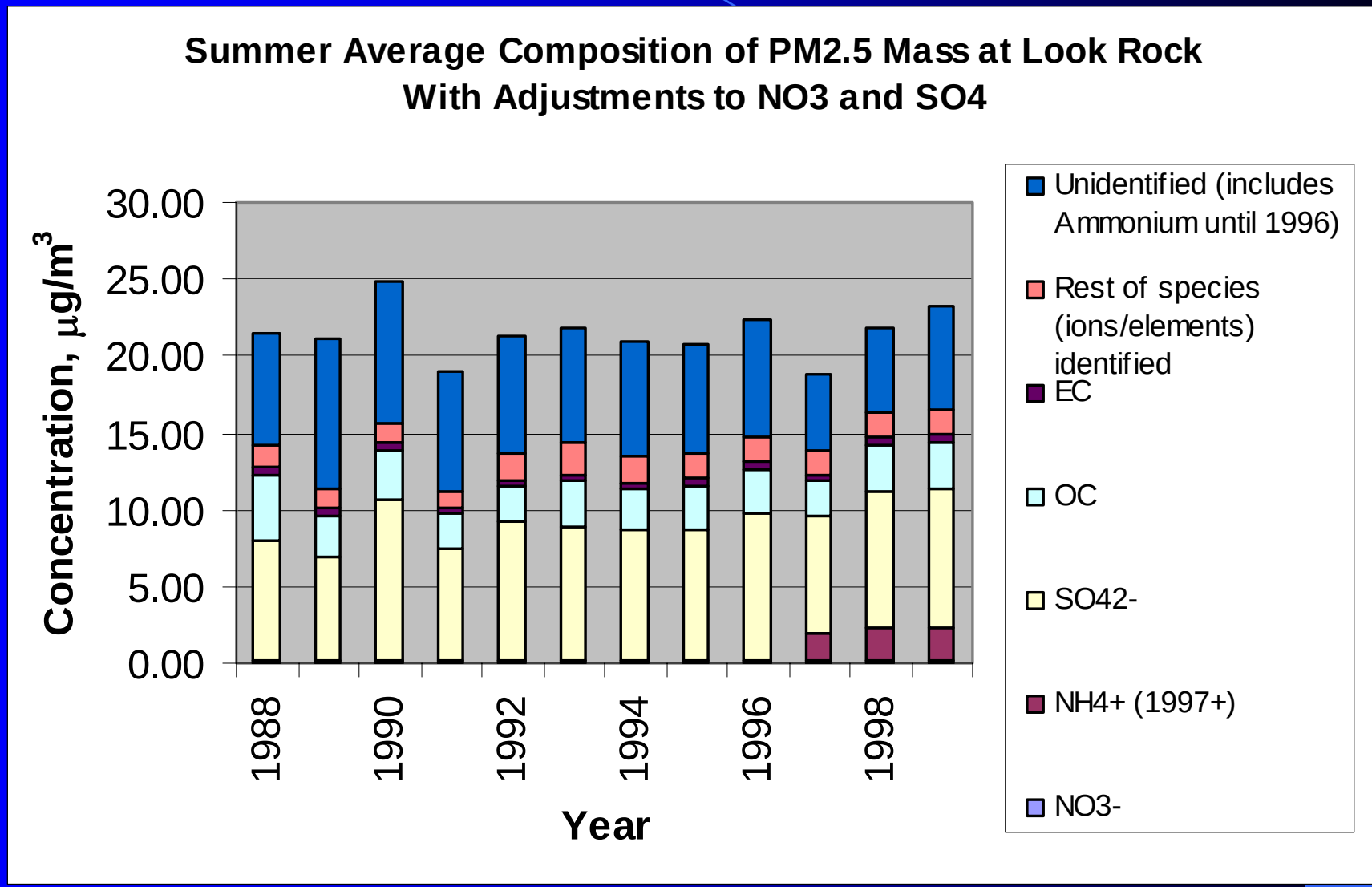
$$NH_{3\,(g)} + HNO_{3\,(g)} \rightarrow NH_4NO_{3\,(s)}$$
$$NH_{3\,(g)} + H_2SO_{4\,(g)} \rightarrow NH_4HSO_{4\,(s)}$$

- These chemicals contribute significantly to PM2.5 mass and negative health effects as well as reduced visibility.

1999 Ambient PM2.5 Composition

Constituent	Eastern US (%)	Western US (%)
Sulfate	56	33
Org. carbon	27	36
Elem.Carbon	5	6
Nitrate	5	8
Crustal	7	17

Data from IMPROVE Network (Interagency Monitoring of Protected Visual Environments)



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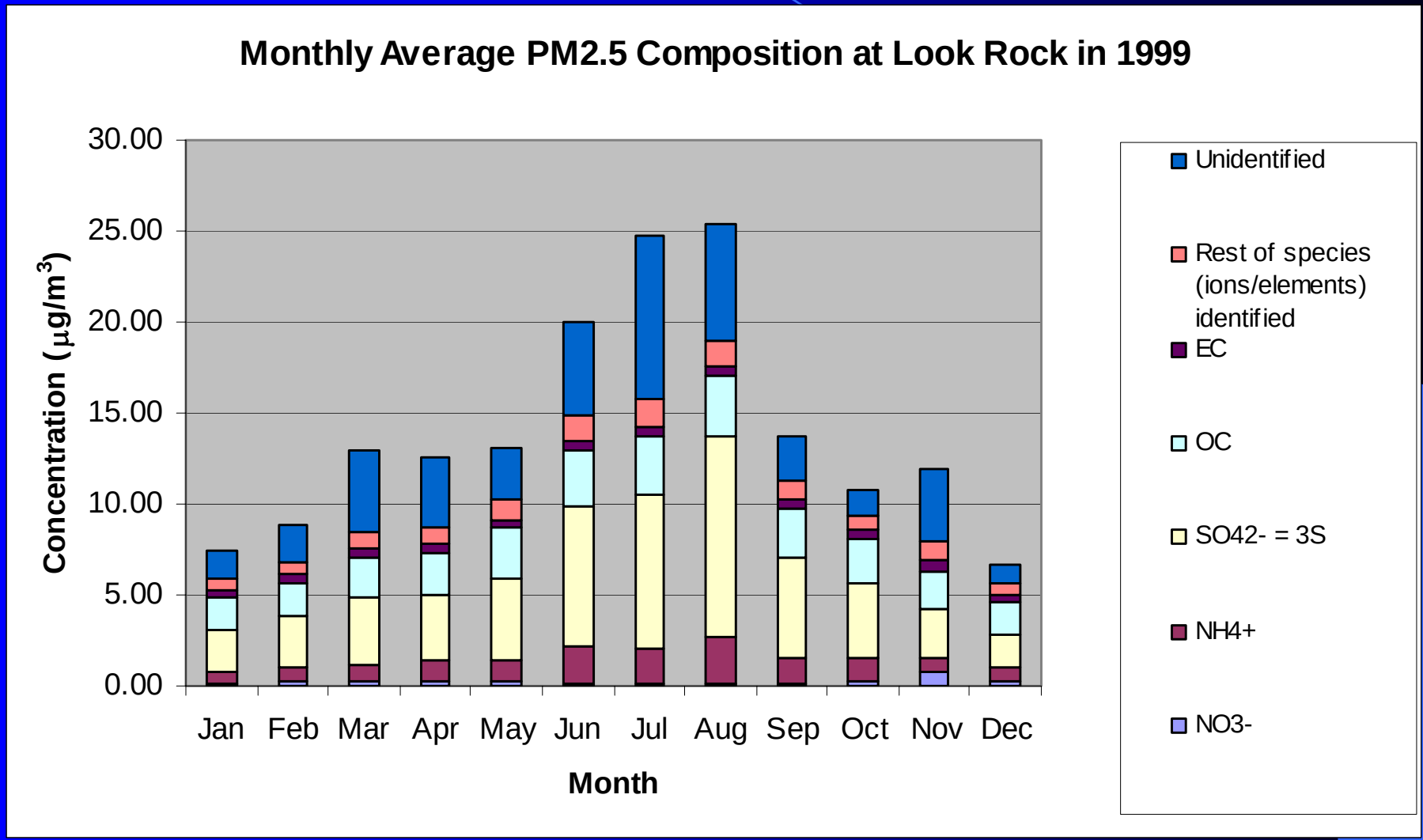


Why Ammonia? (cont.)

- Due to the increasing concentration of PM2.5, the need for a better ammonia emission inventory has become an important air quality issue.
- The air quality research group at the University of Tennessee is involved in modeling PM2.5 formation in Tennessee.

Existing Ammonia Inventories for Tennessee

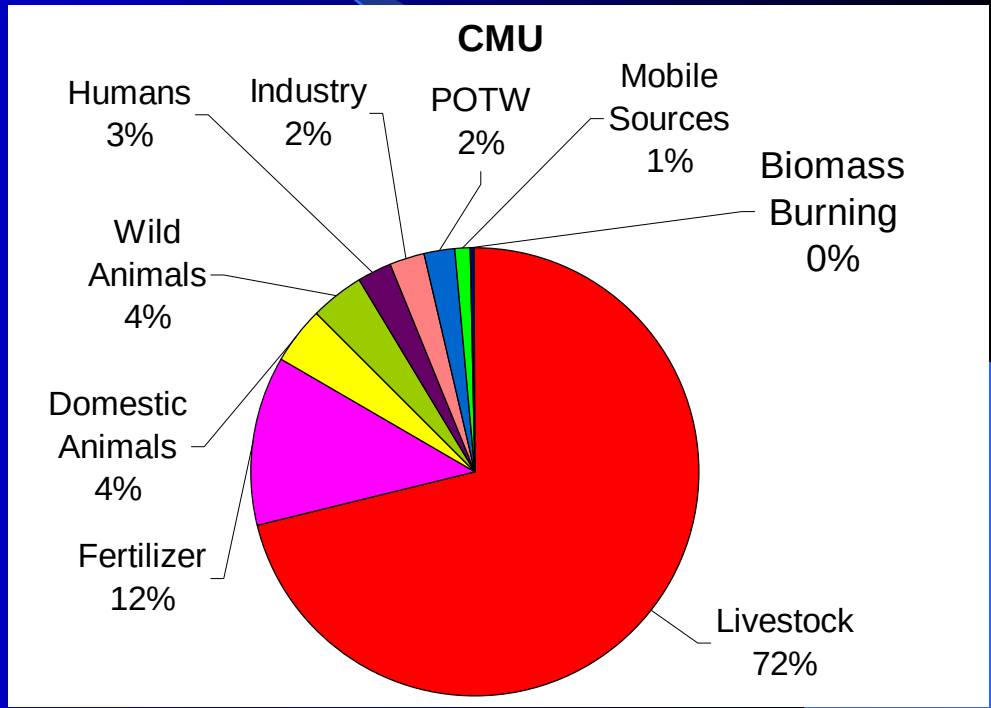
- CMU (Carnegie Mellon University) Emission Inventory

- NET99 Inventory

  (EPA's National Emission Trends for 1999)

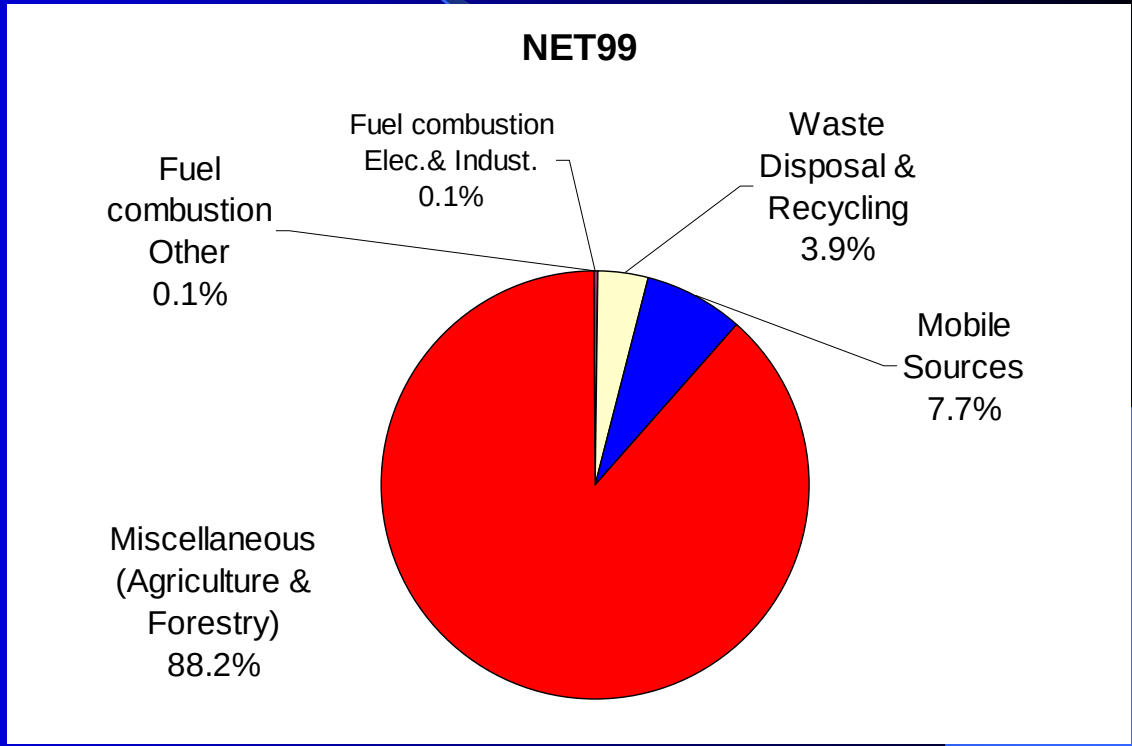
CMU Inventory

- 9 Source categories and 36 Sub-Source categories
- Based on the years of 1995, 1996, and 1997
- Soil source category was not included



NET99 Inventory

- Lacks details about emission sub-source categories such as a breakdown of livestock and human sources.
- Underestimated emissions for point sources.



Emission Sources Included

- 10 Source Categories and 50 Sub-Source Categories (CMU- 9 Source categories and 36 Sub-Source categories)
- Livestock – Cattle & Calves, Milk Cows, Beef Cows, Hogs & Pigs, Poultry (Broilers, Layers, Pullets, Other Chickens), Horses & Ponies, Sheep & Lambs, Goats, Ducks, Geese, and Turkeys
- Soil – Urban, Forest, Wetland, and Barren

Emission Sources Included (cont.)

- Fertilizer – Anhydrous Ammonia, Nitrogen Solutions, Urea, Ammonium Sulfate, Ammonium Nitrate, Ammonium Thiosulfate, Other Straight Nitrogen, Ammonium Phosphates, and N-P-K fertilizer

- Mobile – LDGV, LDGT12, LDGT34, HDGV, MC, LDDV, LDDT, HDDV, and Nonroad Gasoline, Nonroad Diesel, Aircraft, Marine Vessels, Railroad

- Domestic Animals – Dogs and Cats

Emission Sources Included (cont.)

- Wild Animals – Black bear and Deer
- Human – Human Perspiration, Human Respiration, Untreated Human Waste, Cigarette Smoking, Household Ammonia Use, Cloth Diapers, Disposable Diapers, and Homeless People
- Industry
- POTW (Publicly Owned Treatment Works)
- Biomass Burning

Methodology

- Annual emission estimates of ammonia for 10 source categories and 50 sub-source categories were determined for each of the 95 counties in Tennessee for the year 1999.

- Equation used to estimate ammonia emissions:

$$E = EF \times AL$$

where:

E = Ammonia Emission Estimates for sub-source categories

EF = Emission Factor for sub-source categories

AL = Activity Level for sub-source categories

Emission Factors and Activity Levels

- Emission factors affecting ammonia emissions include: animal age, kind, weight, animal housing system, nitrogen content of feed, manure storage practices, the method of applying the manure or fertilizer, time between spreading and plowing, meteorological conditions, and soil properties.

- Activity Levels have large influence on ammonia emissions. It is important to collect accurate and detailed activity data by county for each sub-source category.

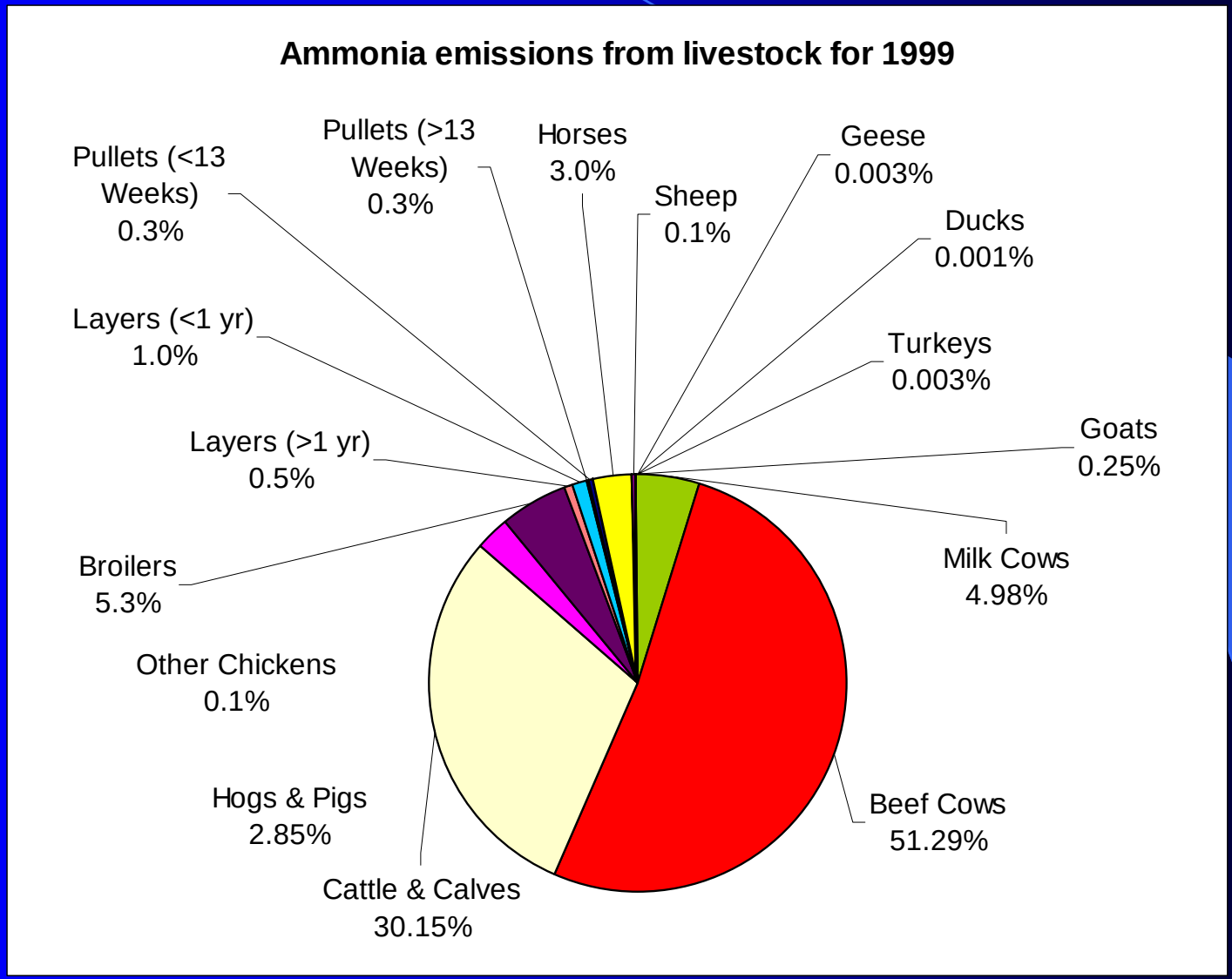
LIVESTOCK

- Composite emission factors obtained from Battye et. al, (1994) were used.
- Activity data for livestock were obtained from 2000 Tennessee Department of Agricultural Statistics and 1997 United States Department of Agriculture Economics and Statistics.
- Activity data for poultry (Broilers, Pullets, Layers, and other chickens) were obtained from Lorie Warren's thesis at UT for the year 1999.

LIVESTOCK (Cont.)

Sub-Source Category	Activity Data (Population)	Emission Factors	Emissions (ton/year)
Milk Cows	100,006	39.72 kgNH3/animal/yr	4,379
Beef Cows	1,030,000	39.72 kgNH3/animal/yr	45,097
Cattle & Calves	1,050,000	22.9 kgNH3/animal/yr	26,505
Hog & Pig	186,134	9.21 kgNH3/animal/yr	2,505
Broilers	25,166,667	0.167 kgNH3/animal/yr	4,633
Layers (>1 yr)	644,738	0.598 kgNH3/animal/yr	425
Layers (<1 yr)	2,527,912	0.305 kgNH3/animal/yr	850
Pullets (>13 Weeks)	985,912	0.269 kgNH3/animal/yr	292
Pullets (<13 Weeks)	1,173,961	0.17 kgNH3/animal/yr	220
Other Chickens	456,690	0.179 kgNH3/animal/yr	90
Horses	85,947	24 kgNH3/animal/yr	2,651
Sheeps	10,850	3.37 kgNH3/animal/yr	48
Goats	48,373	3.6 kgNH3/animal/yr	223
Ducks	8,732	0.117 kgNH3/duck/yr	1
Geese	2,257	0.88 kgNH3/geese/yr	3
Turkeys	2,356	0.858 kgNH3/turkey/yr	2
Total			**87,924**

LIVESTOCK (Cont.)



LIVESTOCK (Cont.)

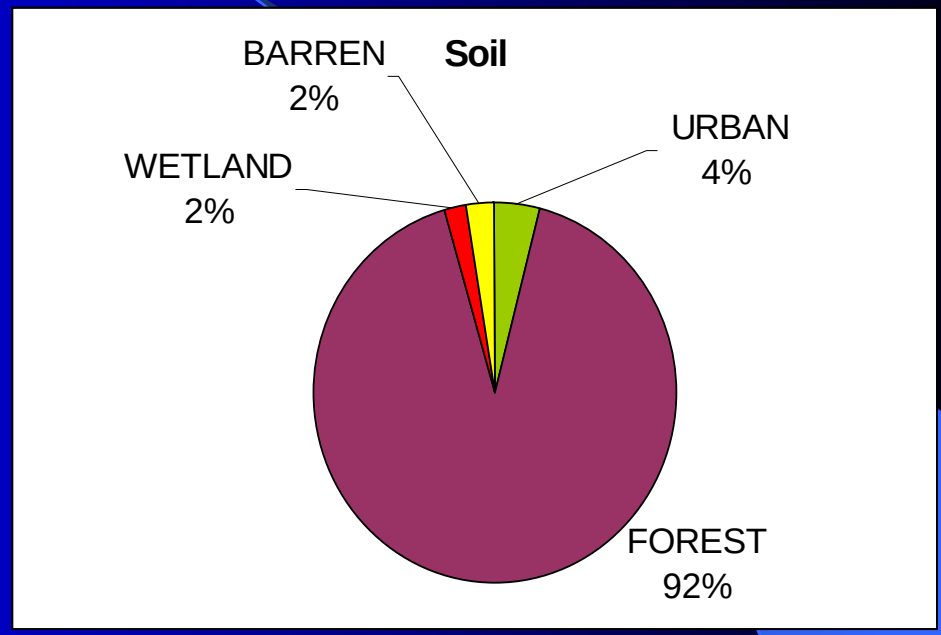
- Livestock was estimated to contribute 60 % of the total ammonia emission inventory for 1999.
- Emissions from Beef Cows were estimated to contribute 51.3% of the total ammonia emissions from livestock.

SOIL

- Emissions from soil depend on the soil type.
- Soils exchange nitrogen with atmosphere.
- Some of this nitrogen is exchanged in the form of ammonia.
- There are many uncertainties in ammonia emissions from soil.
- Soil category did not include ammonia emissions from agricultural lands, croplands, and orchards in this study since this would result in double counting of fertilizer emissions.

SOIL (Cont.)

- Soils were estimated to contribute 18% of the total ammonia emissions.
- Emissions from forests contributed 92% of the total ammonia emissions from soils.

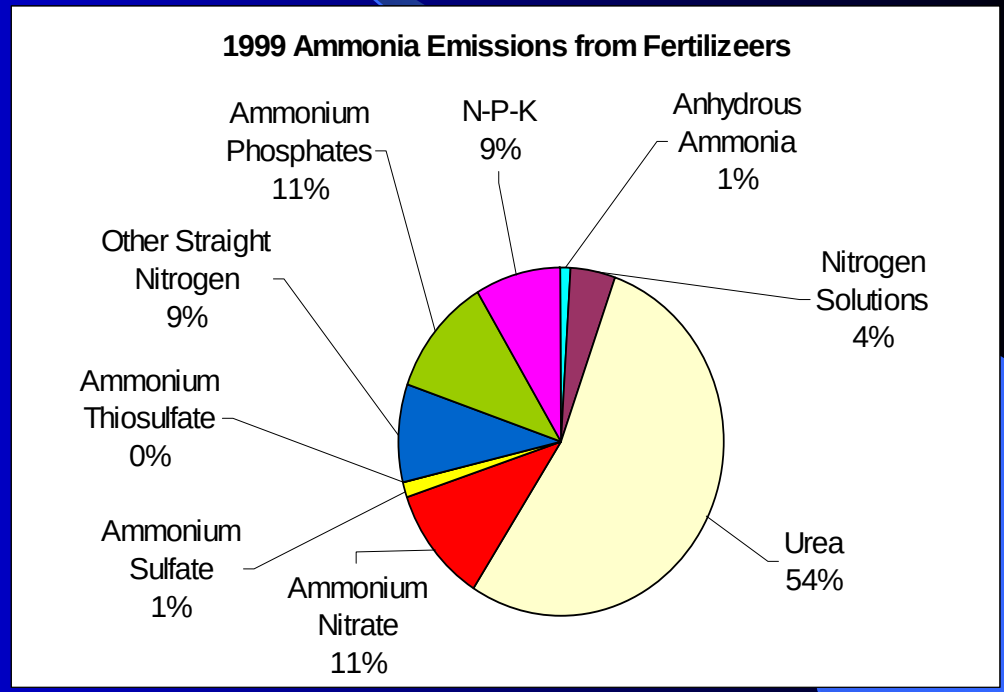


FERTILIZER

- Like soils, fertilizer ammonia emissions can depend on fertilizer components.
- There is also possibility of double counting emissions with soils because fertilizer application is applied directly on soils.
- Activity data were taken from Pechan which prepared it for the U.S.EPA.

FERTILIZER (Cont.)

- Fertilizers were estimated to contribute 8% of the total ammonia emissions.
- Urea was responsible for 54% of the total ammonia emissions from fertilizer.

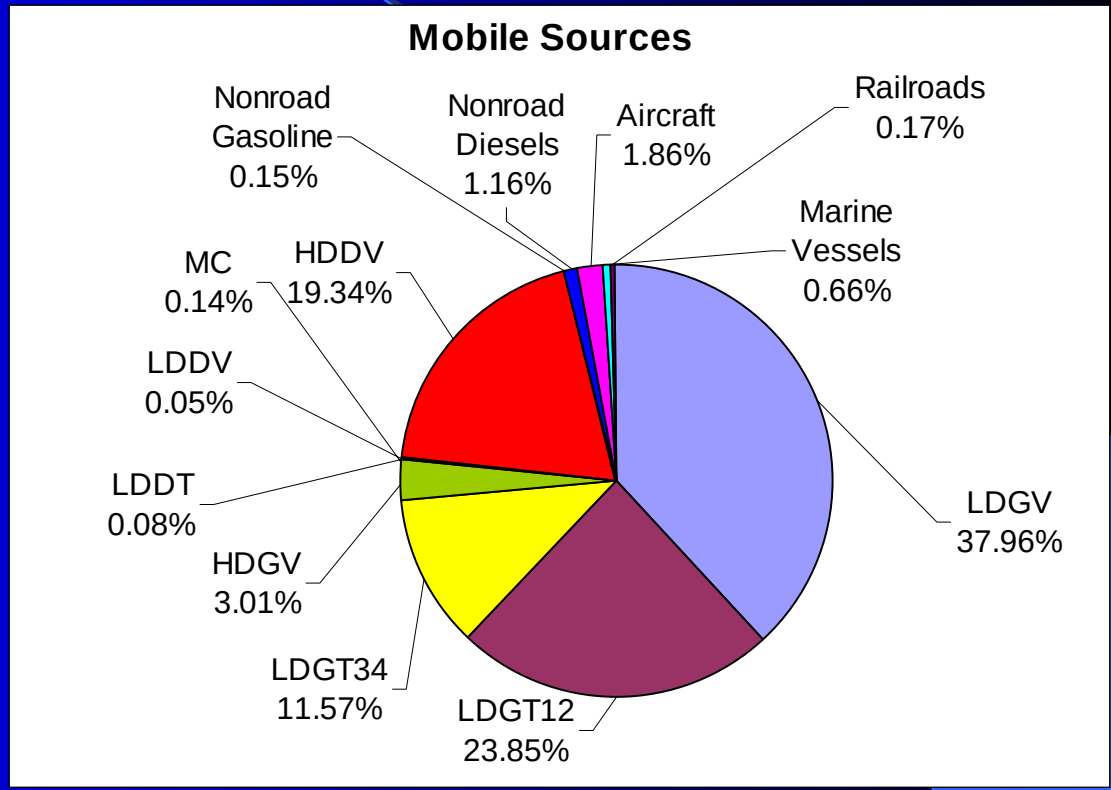


Mobile Sources

- Mobile sources include on-road mobile sources and nonroad vehicles.
- Ammonia emissions from mobile sources are a result of the combustion process.
- Emissions from mobile source may be a significant source of ammonia emissions in some urban counties.

Mobile Sources (Cont.)

- Mobile sources were responsible for 3% of the total ammonia emissions.
- Emissions from LDGV were reported as the largest sub-source category in mobile sources.



Mobile Sources (Cont.)

- Activity data for on-road vehicles were obtained from Tennessee Department of Transportation in the form of Daily Vehicle Miles Traveled for each county in Tennessee.

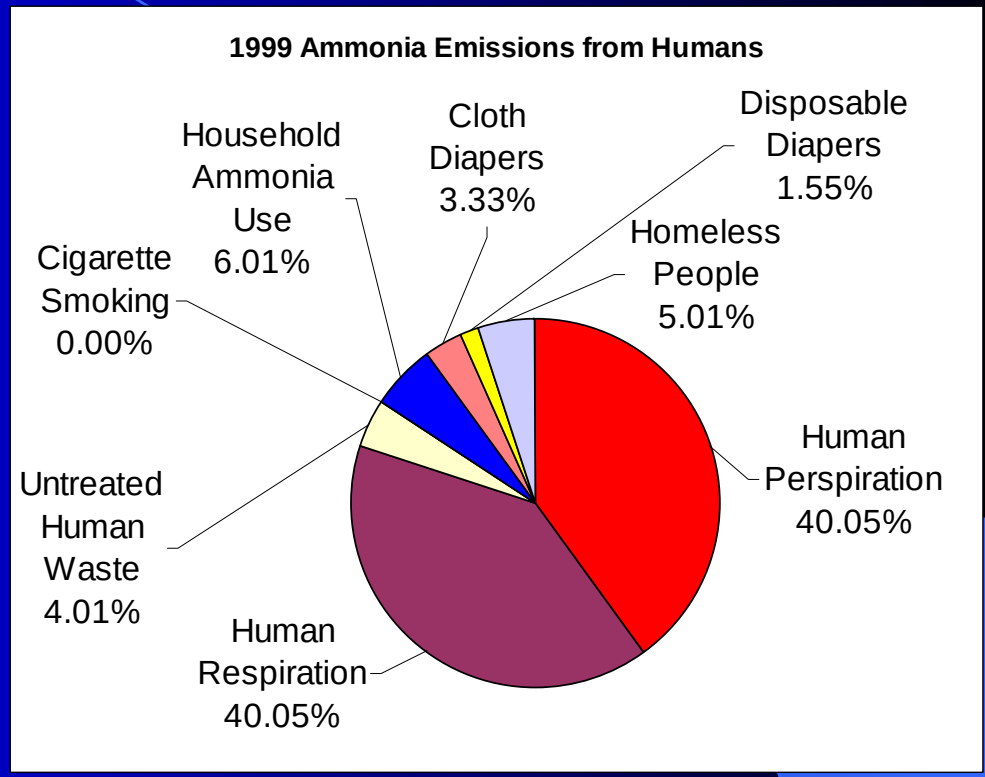
- Activity data for nonroad vehicles were taken from NET99 Tier (EPA's National Emission Trends Tier for 1999) which include emissions from point and area sources.

Humans

- Ammonia emissions from people include human perspiration, human respiration, and untreated human waste.
- Human waste is divided into two categories based on method of disposal. One part is untreated human waste from homeless people, portable toilets. Treated human waste which is included in POTWs.
- Ammonia emissions from cigarettes are a result of the combustion process.

Humans (Cont.)

- Activity levels for human were obtained from U.S. Census Bureau.
- Human sources were responsible for 2% of the total ammonia emissions, and human perspiration and respiration were reported as the largest portions of human sources.



Domestic and Wild Animals

- The population of domestic animals (dogs and cats) is based on a report by Veterinary Market Statistics.
- For dogs: Number of dogs = 0.534 x total number of households
- For cats: Number of cats = 0.598 x total number of households
- Wild animals were divided into black bears and deer.

Domestic and Wild Animals (Cont.)

- It is possible that ammonia emissions from wild animals might be double counted in the soils category. However, it is assumed that waste from wild animals is not included in the soil category because of low density of black bear and deer population.
- Ammonia emission estimates from domestic and wild animals were each responsible for 2.5%.

Industry, POTW, and Biomass Burning

- Ammonia emissions from industry were obtained from TRI (EPA's Toxic Release Inventory) for 1999. Fugitive ammonia emissions occur from refrigeration, metal heat treating, blueprinting production etc. Industry emissions are treated as point sources.
- POTWs are not included in the TRI inventory. They are treated as point sources.

Industry, POTW, and Biomass Burning (Cont.)

- POTW flow rates were used for activity data. Activity data for POTW were obtained from EPA's office of water (1996) which reported as daily average flow rates.
- 1999 daily average flow rates by county were calculated by multiplying the 1996 daily flow rates and the ratio of the 1999 population to1996 population (1999 population/1996 population).

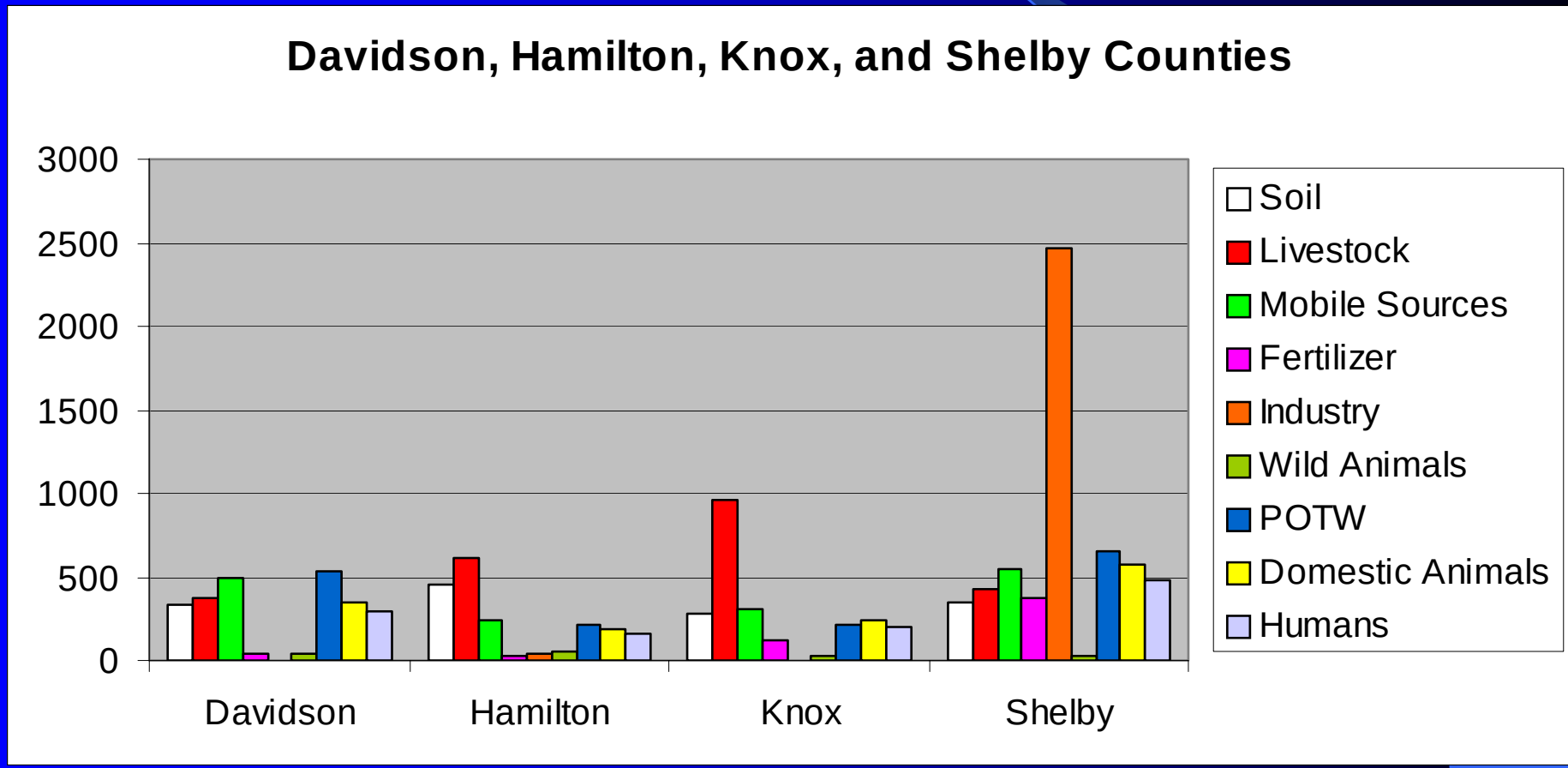
Industry, POTW, and Biomass Burning (Cont.)

- To obtain ammonia emissions from biomass burning, the number of acres burned in Tennessee was multiplied by typical fuel loading for the region of the country, and then by an emission factor.
- Data for the number of acres burned per state were obtained from the National Interagency Fire Center for 1994. Typical fuel loading amounts were obtained from EPA.

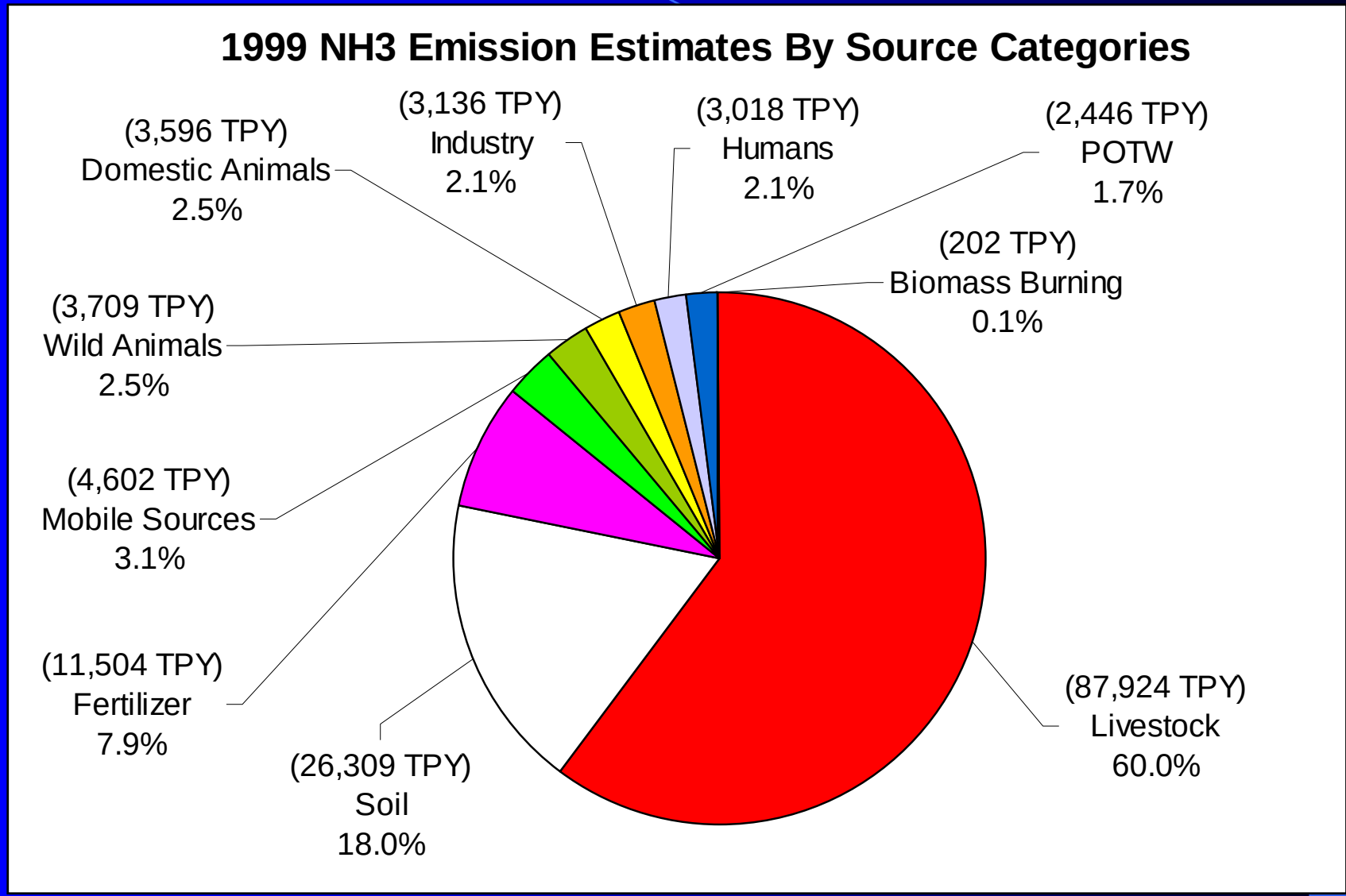
RESULTS

- The results from this study show that ammonia emissions from livestock and soil were contributed 78% of the total ammonia emission inventory.
- Shelby County ammonia emissions were the largest county in Tennessee.
- Most of urban counties have point source and mobile source emissions equivalent to or greater than livestock emissions.

Davidson, Hamilton, Knox, Shelby Counties



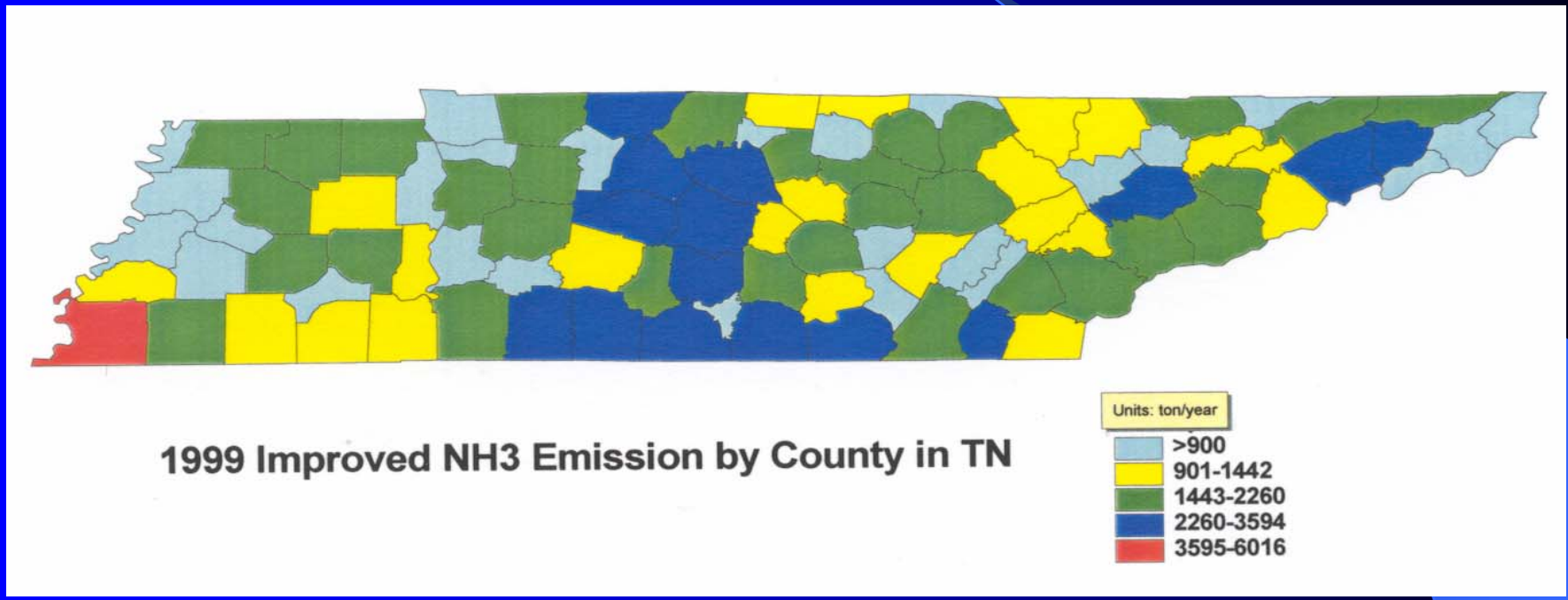
RESULTS (Cont.)



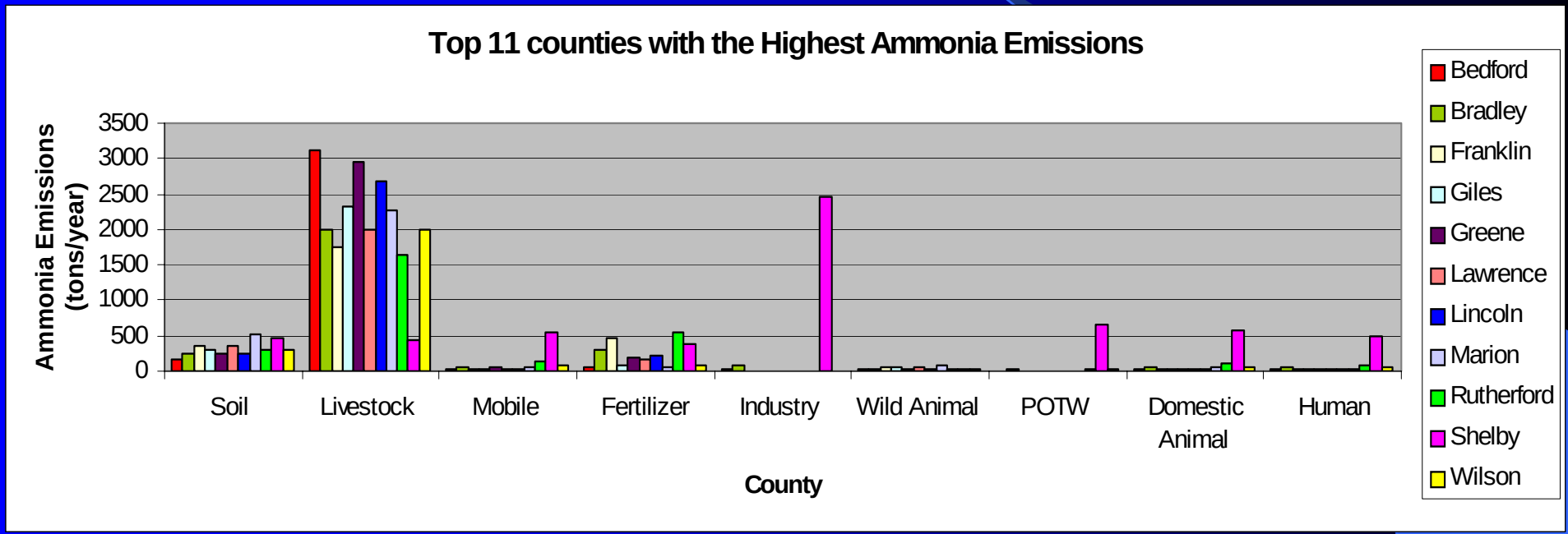
RESULTS (Cont.)

- 11 COUNTIES -- **Shelby, Greene, Bedford, Lincoln, Marion, Rutherford, Bradley, Giles, Franklin, Lawrence, and Wilson** – each had over 2,600 tons per year of ammonia emissions.
- These 11 counties represented 25% of the ammonia emissions for Tennessee.
- Tennessee's 95 counties had estimated ammonia emissions ranging from 262 to 6,015 tons in 1999.

RESULTS (Cont.)



RESULTS (Cont.)



RESULTS (Cont.)

	CMU		Improved 1999 NH3 inventory	
Source	**Emissions (ton/yr)**	**% of total**	**Emissions (ton/yr)**	**% of total**
Livestock	71255	71.1	87,924	60
Soil			27,705	18
Fertilizer	12,125	12.1	11,553	7.9
Mobile	1,131	1.1	4,602	3.1
Wild animal	3,708	3.7	3,708	2.5
Domestic Animal	4,399	4.4	3,596	2.5
Industry	2,468	2.5	3,136	2.1
Human	2,606	2.6	3,018	2
POTW	2,322	2.3	2,446	1.8
Biomass Burning	202	0.2	202	0.1
Total	100,014	100	147,890	100

	NET99	
Source	**Emissions (ton/yr)**	**% of total**
Mobile	6,360	7.7
Area	75811	92.2
Point	89	0.1
Total	82,260	100

RESULTS (Cont.)

Rank	Sub-Source Category	Ammonia Emissions (tons/year)
1	Beef Cows	45,097
2	Cattle and Calves	26,505
3	Forests	24,036
4	Urea	6,164
5	Broilers	4,633
6	Milk Cows	4,379
7	Deer	3,703
8	Dogs	2,655
9	Horses	2,651
10	Hogs & Pigs	2,505

CONCLUSIONS

- Livestock is a major source of ammonia emissions in Tennessee, responsible for emitting 87,924 tons per year. Beef Cows are the largest sub-source category within the livestock category, emitting 45,097 tons per year.
- Soils are the second largest contributor of ammonia emissions at 27,705 tons per year. Some double counting may occur in the fertilizer source category.

CONCLUSIONS (Cont.)

- Fertilizer ammonia emissions were the third largest contributor with 11,533 tons per year. 6,164 tons per year were from urea.
- In some urban counties (Davidson,Hamilton, Knox, Shelby), soil, mobile sources, and POTW's had large emissions ranging from 17-20% each of the total. However, livestock was again the single largest source with the exception of Shelby and Davidson Counties.

Thank you