

**Development of Emission Inventories of
Recreational Boats and Commercial Marine
Vessels for the Central States Regional Air
Planning Association (CENRAP)**

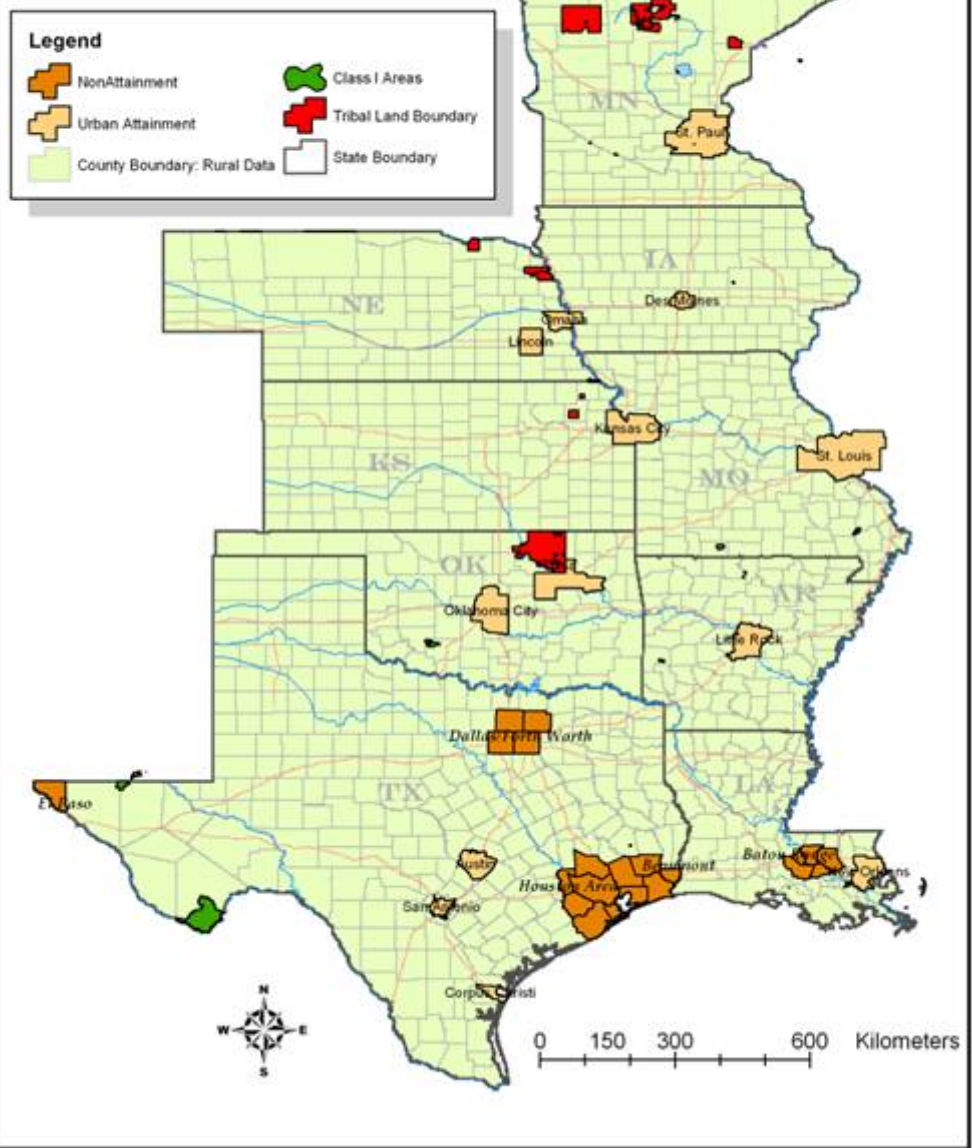
By:

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Presented to:

**U.S. EPA 14th Annual Emission Inventory
Conference
Las Vegas, NV
April 14, 2005**

CENRAP Region





Project Objectives

- Support assessments of the likely visibility impacts of various non-road sources



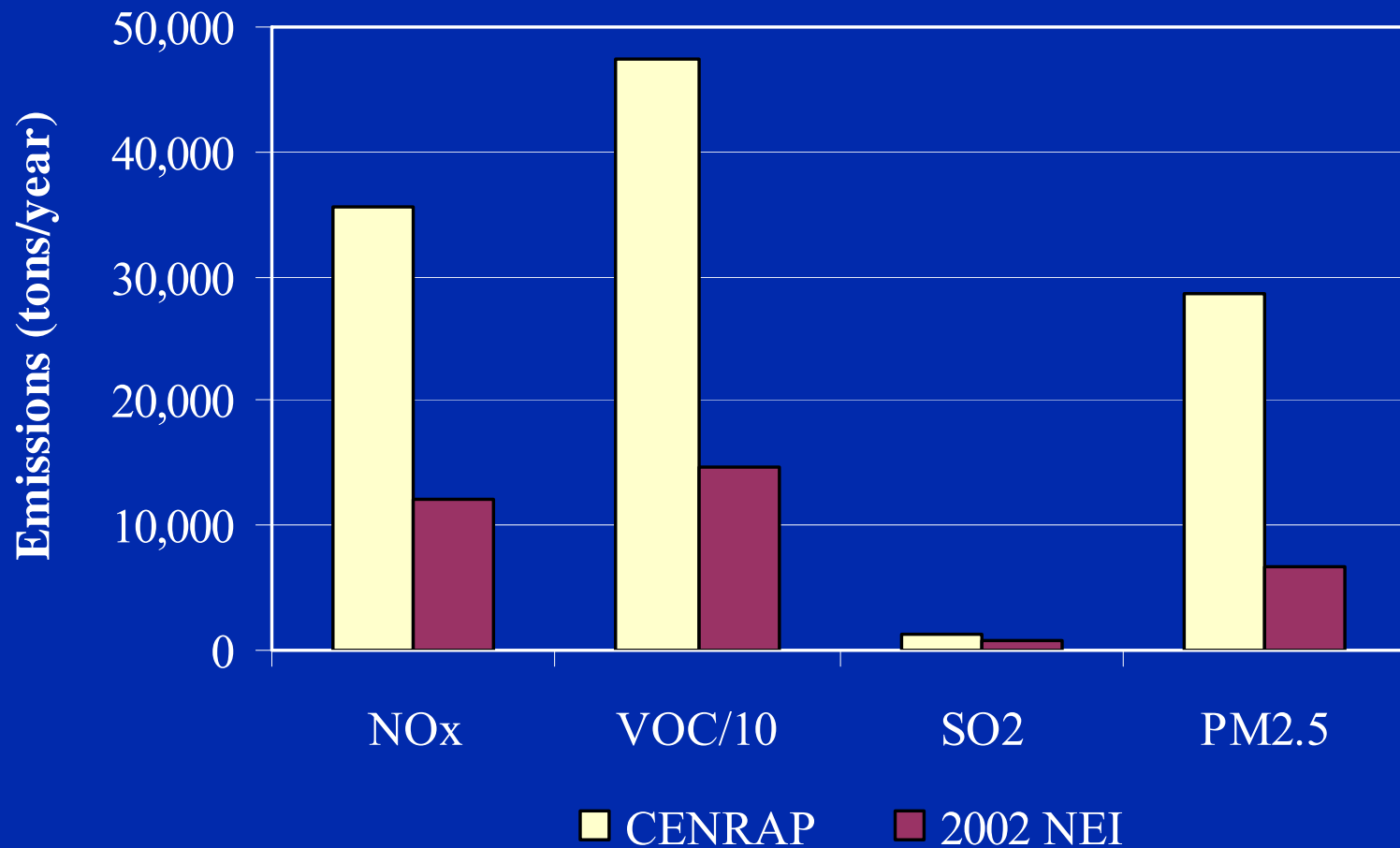
Project Objectives

- Support assessments of the likely visibility impacts of various non-road sources
- Perform bottom-up activity data collection for key non-road sources (including recreational boats and CMV)

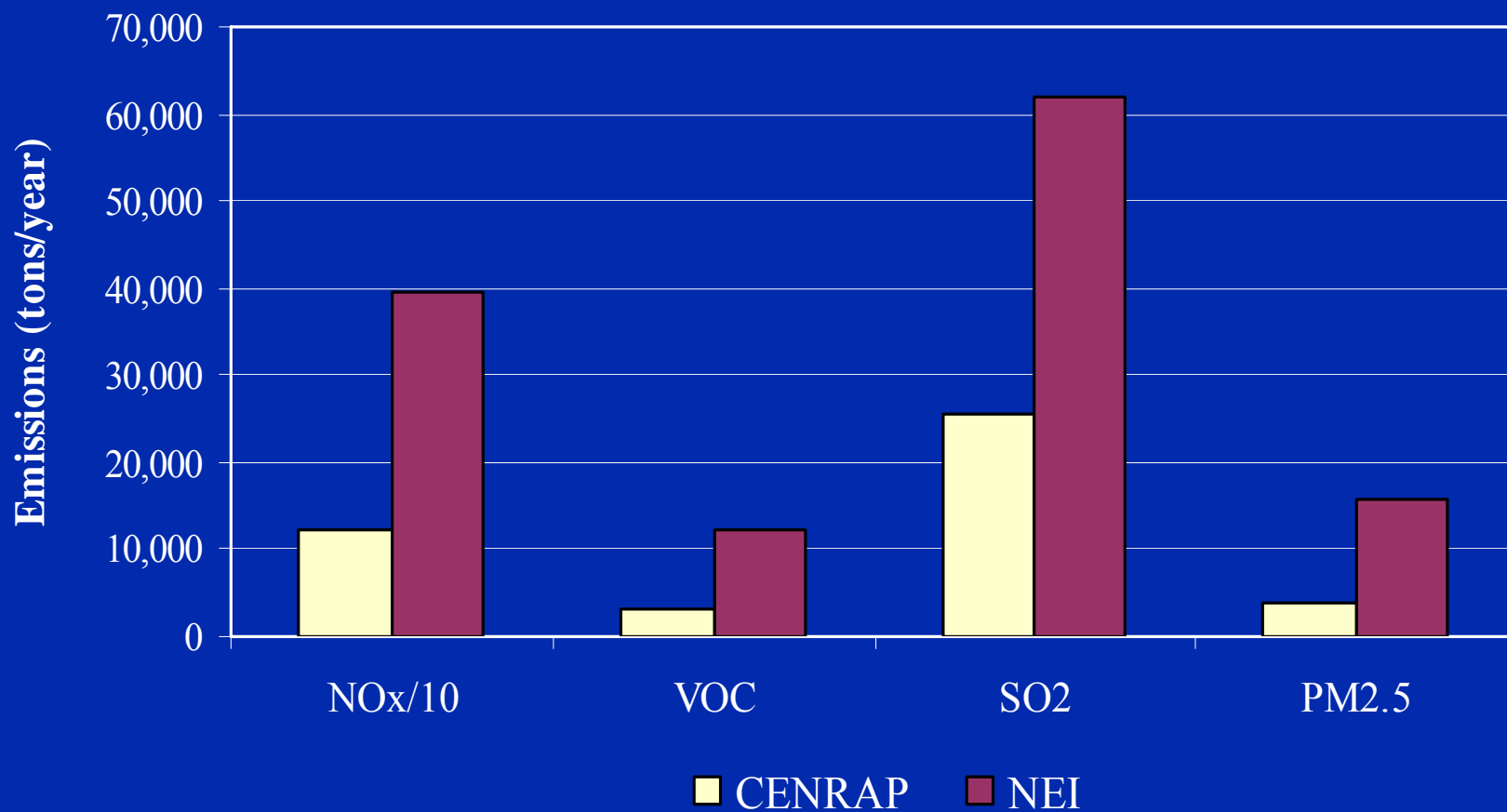
Project Objectives

- Support assessments of the likely visibility impacts of various non-road sources
- Perform bottom-up activity data collection for key non-road sources (including recreational boats and CMV)
- Generate PM_{2.5}, NO_x, VOC, and SO₂ emission estimates for 2002 (NIF3.0 and IDA format)

Recreational Boating Emissions



Commercial Marine Emissions



Recreational Boating Methods

Emissions were estimated using the EPA's NONROAD2004 model.

SCC code	Equipment Description
22-82-yyy-005	Pleasure Craft: Inboard Engine
22-82-yyy-010	Pleasure Craft: Outboard Engine
22-82-yyy-015	Pleasure Craft: Personal Watercraft
22-82-yyy-025	Pleasure Craft: Sailboat Auxiliary Engine

Where yyy = fuel type: 2-stroke gasoline (005), 4-stroke gasoline (010), or diesel (020)

Recreational Boating Methods

NONROAD activity data

- Engine populations
- Engine horsepower ratings
- Average engine load factors
- Annual equipment usage
- Temporal allocation factors (monthly and weekday vs. weekend)

Recreational Boating Methods

New activity data were gathered through a bottom-up survey

- Survey designed to gather activity data used by NONROAD
- 1,400 registered boat owners recruited by telephone

Arkansas Waterways



Arkansas Counties

<u>Number</u>	<u>County Name</u>	<u>Number</u>	<u>County Name</u>	<u>Number</u>	<u>County Name</u>
1	Arkansas	26	Garland	51	Newton
2	Ashley	27	Grant	52	Ouachita
3	Baxter	28	Greene	53	Perry
4	Benton	29	Hempstead	54	Phillips
5	Boone	30	Hot Spring	55	Pike
6	Bradley	31	Howard	56	Poinsett
7	Calhoun	32	Independence	57	Polk
8	Carroll	33	Izard	58	Pope
9	Chicot	34	Jackson	59	Prairie
10	Clark	35	Jefferson	60	Pulaski
11	Clay	36	Johnson	61	Randolph
12	Cleburne	37	Lafayette	62	Saline
13	Cleveland	38	Lawrence	63	Scott
14	Columbia	39	Lee	64	Searcy
15	Conway	40	Lincoln	65	Sebastian
16	Craighead	41	Little River	66	Sevier
17	Crawford	42	Logan	67	Sharp
18	Crittenden	43	Lonoke	68	St. Francis
19	Cross	44	Madison	69	Stone
20	Dallas	45	Marion	70	Union
21	Desha	46	Miller	71	Van Buren
22	Drew	47	Mississippi	72	Washington
23	Faulkner	48	Monroe	73	White
24	Franklin	49	Montgomery	74	Woodruff
25	Fulton	50	Nevada	75	Yell

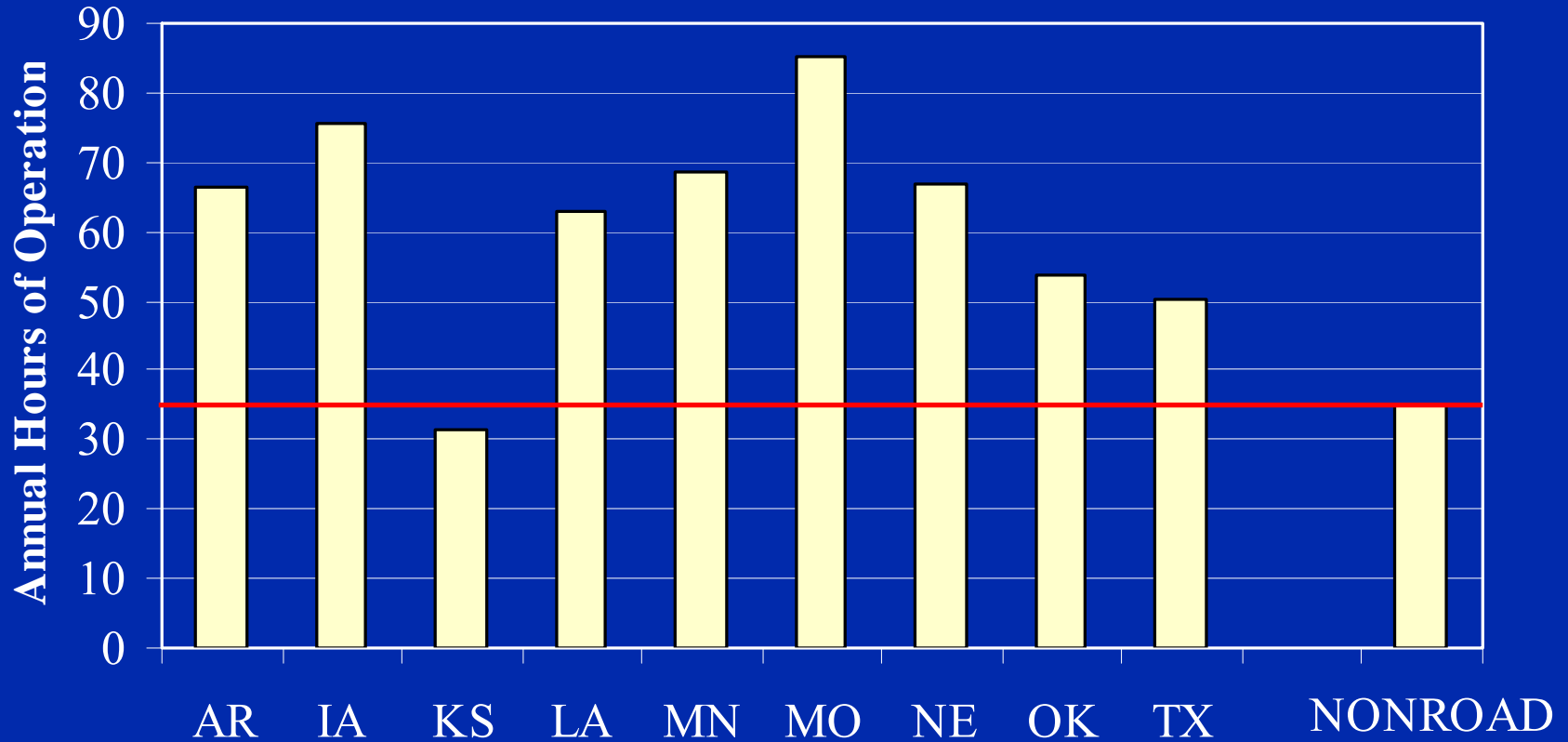
Recreational Boating Methods

New activity data were gathered through a bottom-up survey

- Survey designed to gather activity data used by NONROAD
- 1,400 registered boat owners recruited by telephone
- Questionnaire, waterways map, and incentive sent by mail
- Reminder postcard mailed one week after questionnaire

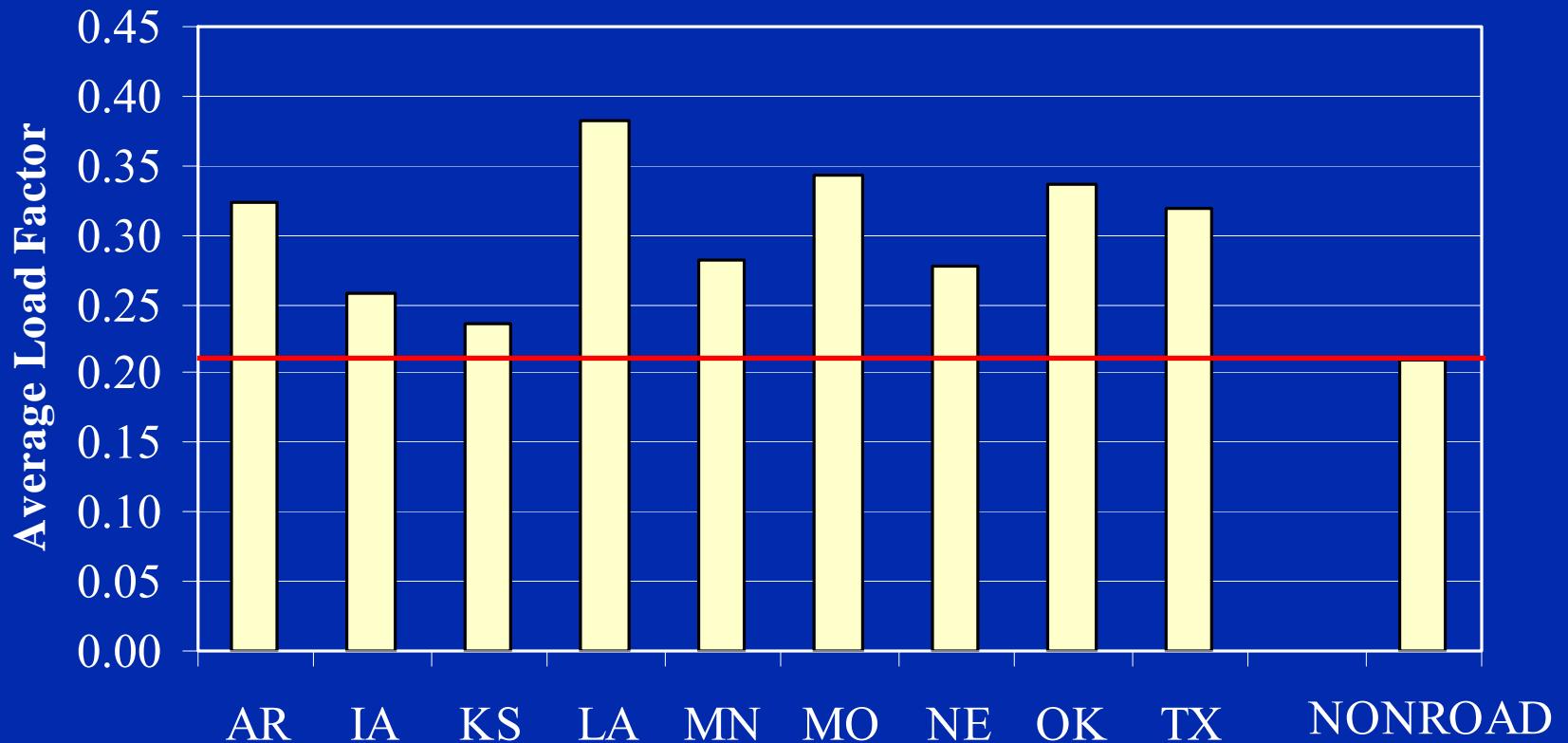
Activity Data Comparison

Annual Hours of Operation 2-stroke Outboard



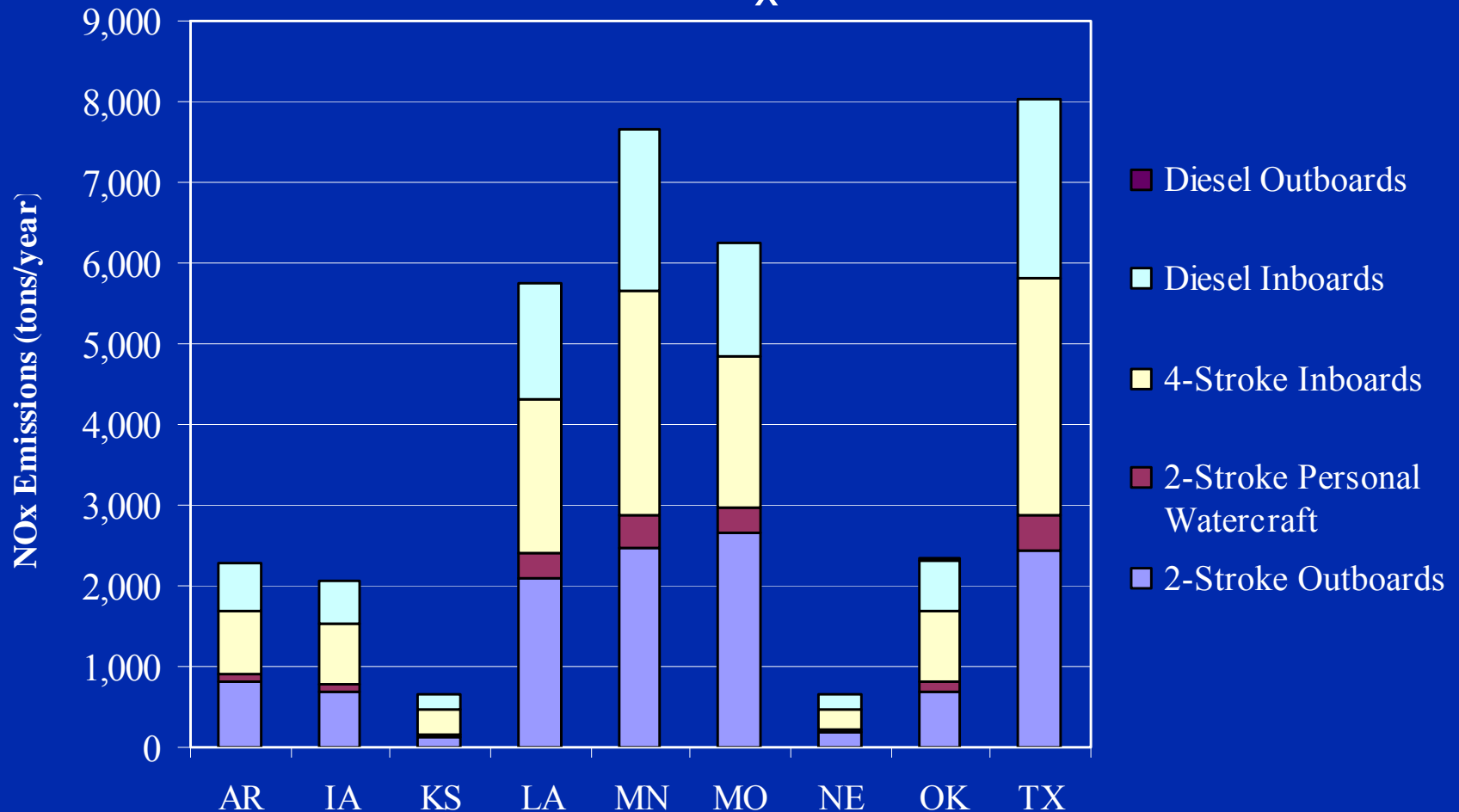
Activity Data Comparison

Average Load Factor 2-Stroke Outboard



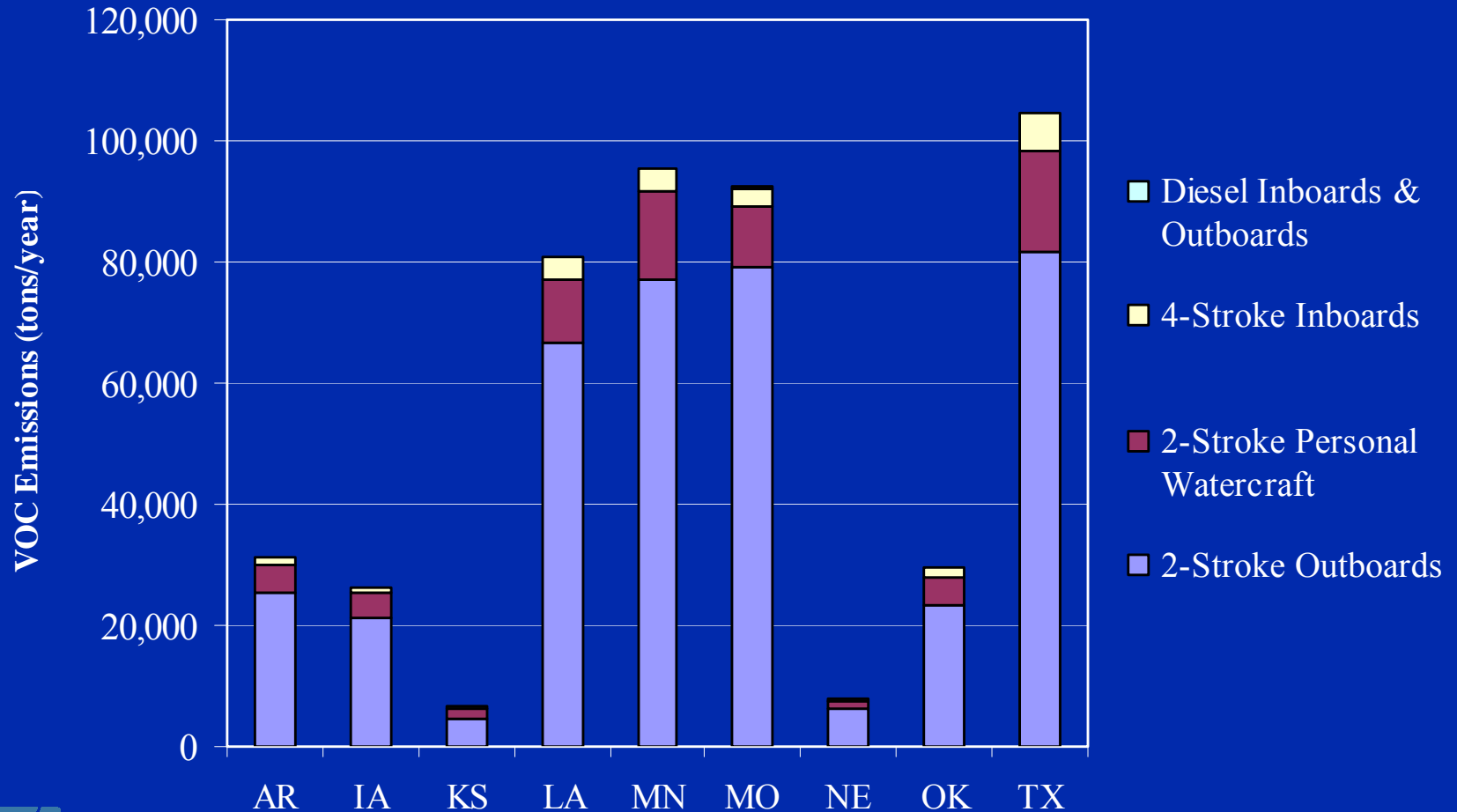
Emissions by State and Boat Type

NO_x



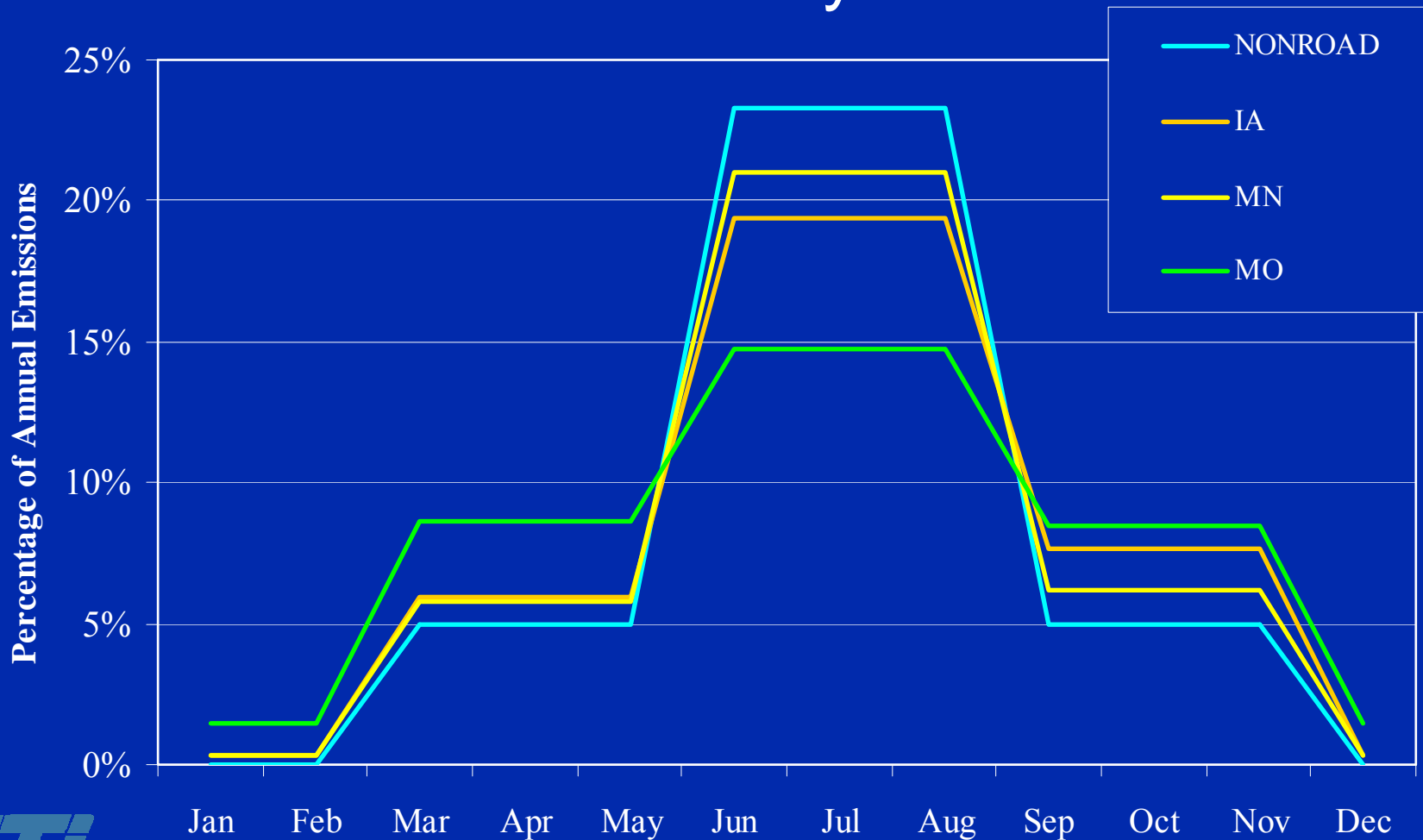
Emissions by State and Boat Type

VOC



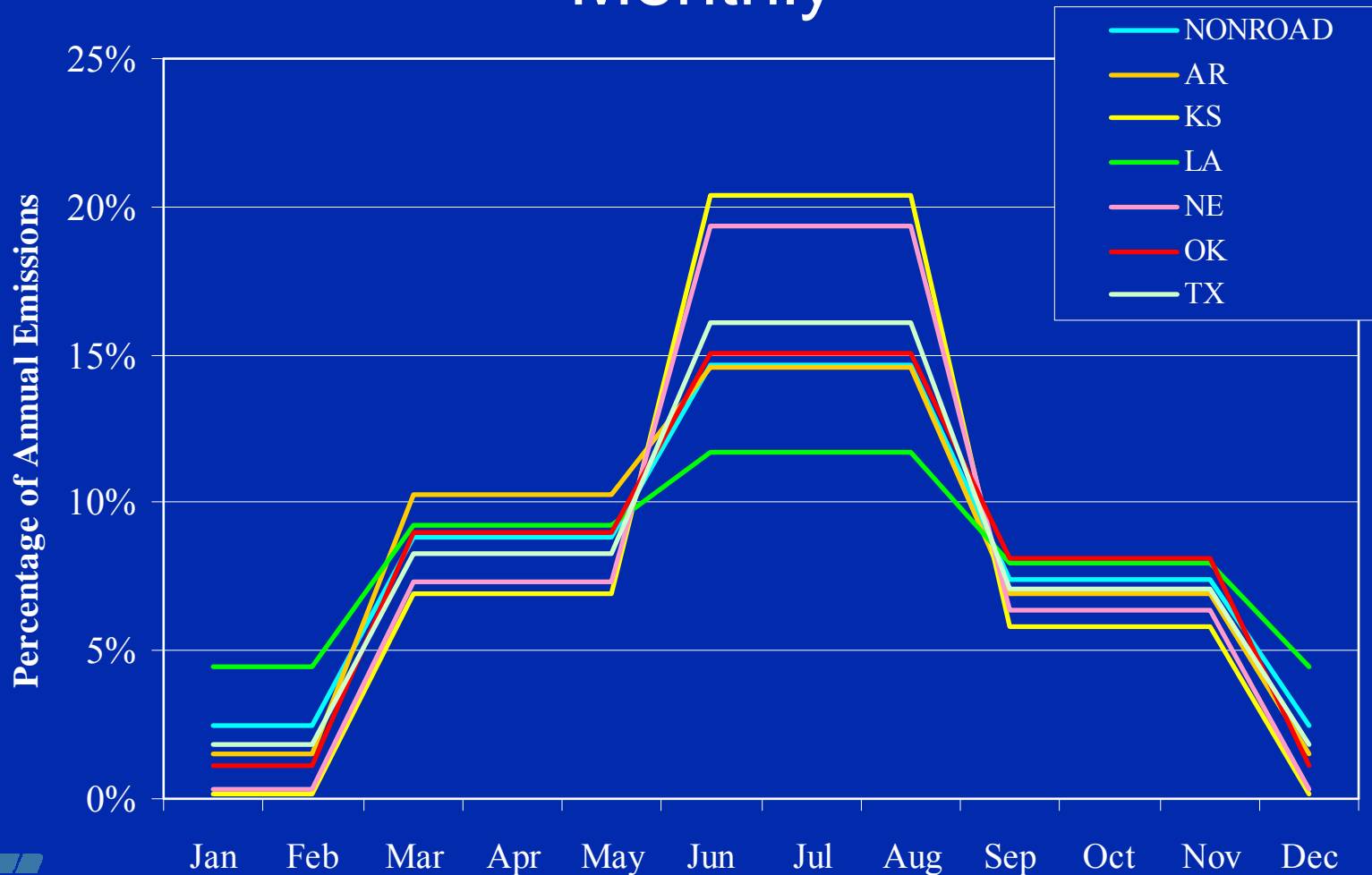
Temporal Variations in Emissions

Monthly



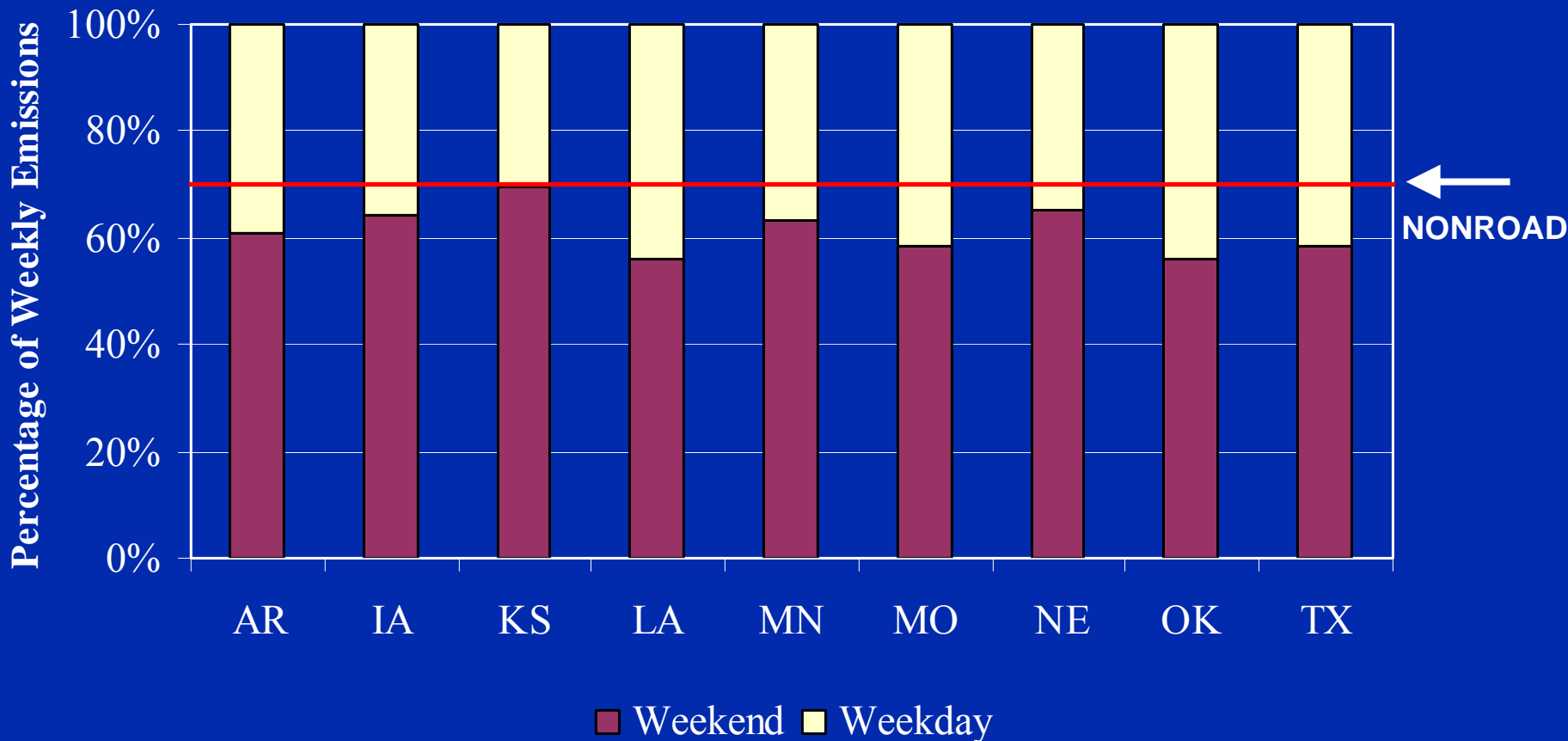
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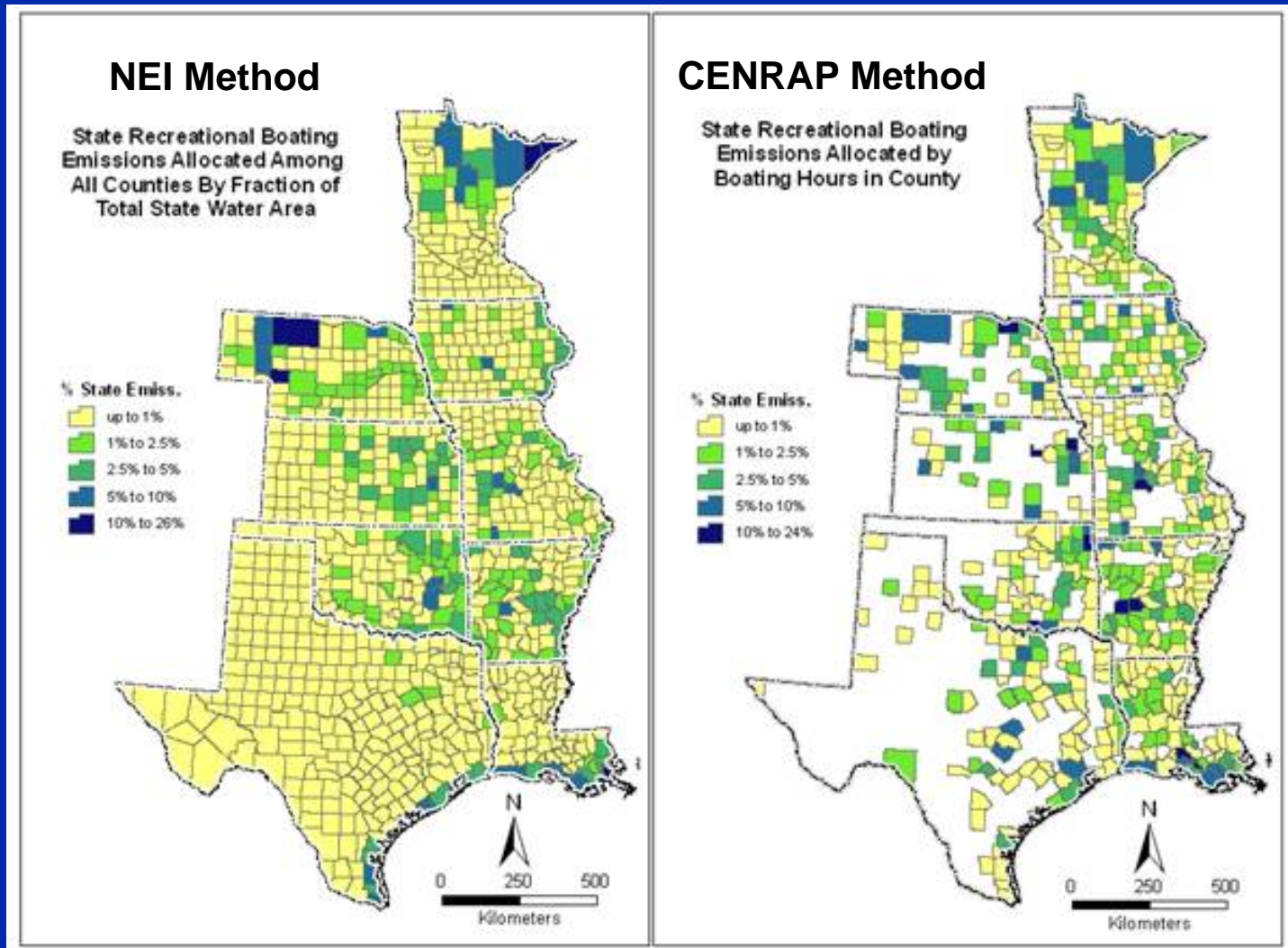


Temporal Variations in Emissions

Weekday vs. Weekend



Spatial Allocation Factors



Commercial Marine Methods

U.S. Inland & Intracoastal Waterways



Inland and Intracoastal Waterways

Commercial Marine Methods

EPA Marine Engine Categories

Category	Displacement per Cylinder	Description
1	disp. < 5 liters power \geq 37 kW	Used in smaller tugboats, ferries, fishing vessels, and dredges.
2	$5 \leq$ disp. < 30 liters	Used in smaller ocean-going vessels, as well as large tugboats, towboats, ferries, and fishing vessels.
3	disp. \geq 30 liters	Used primarily in large, ocean-going vessels.

Commercial Marine Methods

Emission factors

- Work-based (g/kW-hr)
- Fuel-based (lb/gal)

Activity data

- Vessel trips
- Engine power (kilowatts or horsepower)
- Engine load factor
- Time-in-mode
- Fuel consumption

Commercial Marine Methods

Sources of activity data

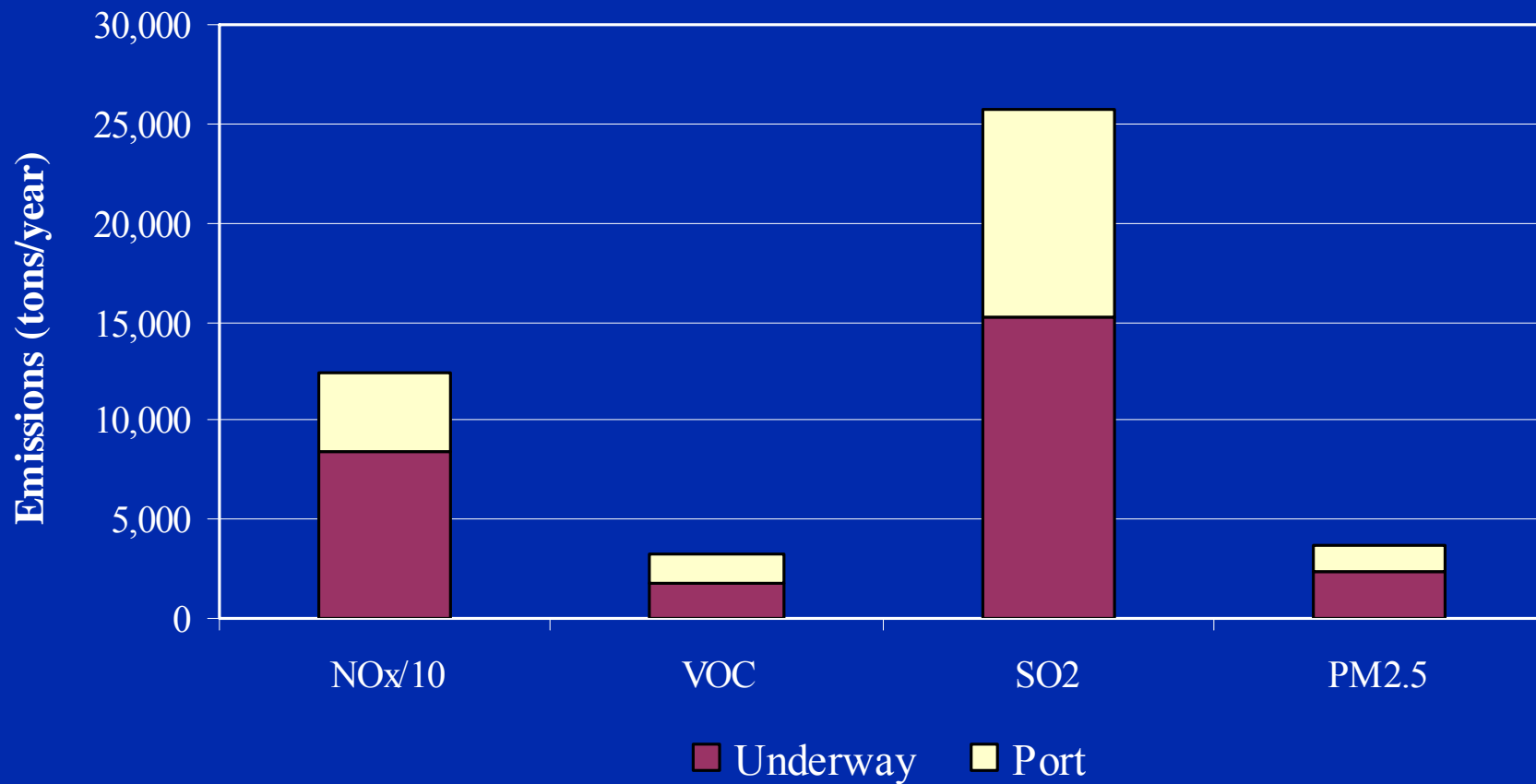
- USACE Waterborne Commerce Statistics Center
- Maritime Administration of the DOT
- Local port authorities
- ARCADIS report

Commercial Marine Methods

For inland river systems

- TVA Barge Costing Model
 - Developed to estimate fuel usage by inland river segment for tax purposes
 - Annual fuel consumption, average vessel horsepower estimated by river segment
 - Model errors have averaged only 1.5% since 1996

Commercial Marine Emissions



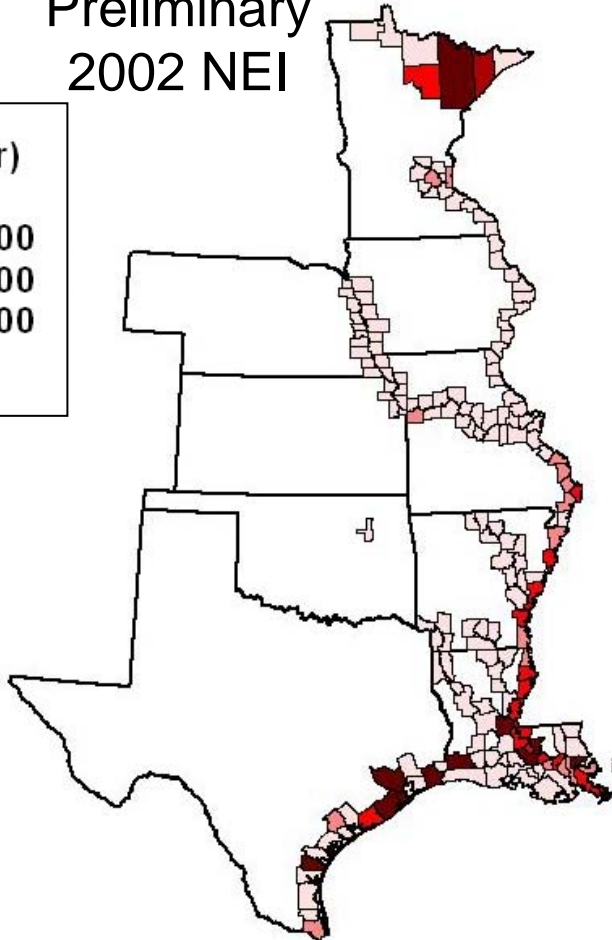
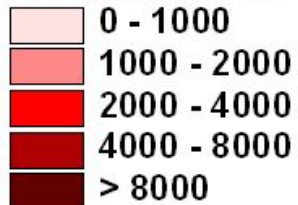
Port-Specific Comparisons

Port	Inventory	PM _{2.5}	NO _x	CO	VOC	SO ₂
Baton Rouge	1991 Booz-Allen Hamilton	129	2,187	449	203	928
	2002 CENRAP	196	5,355	737	170	1,562
	2002 NEI	1,407	36,088	4,756	1,128	5,291
Houston-Galveston	1991 Booz-Allen Hamilton	887	14,977	2,131	1,391	6,554
	2000 Starcrest	-----	7,336	1,022	219	-----
	2002 CENRAP	318	7,232	943	245	2,610
	2002 NEI	2,955	75,787	9,989	2,370	11,111

Comparison of CMV NO_x Emissions

Preliminary
2002 NEI

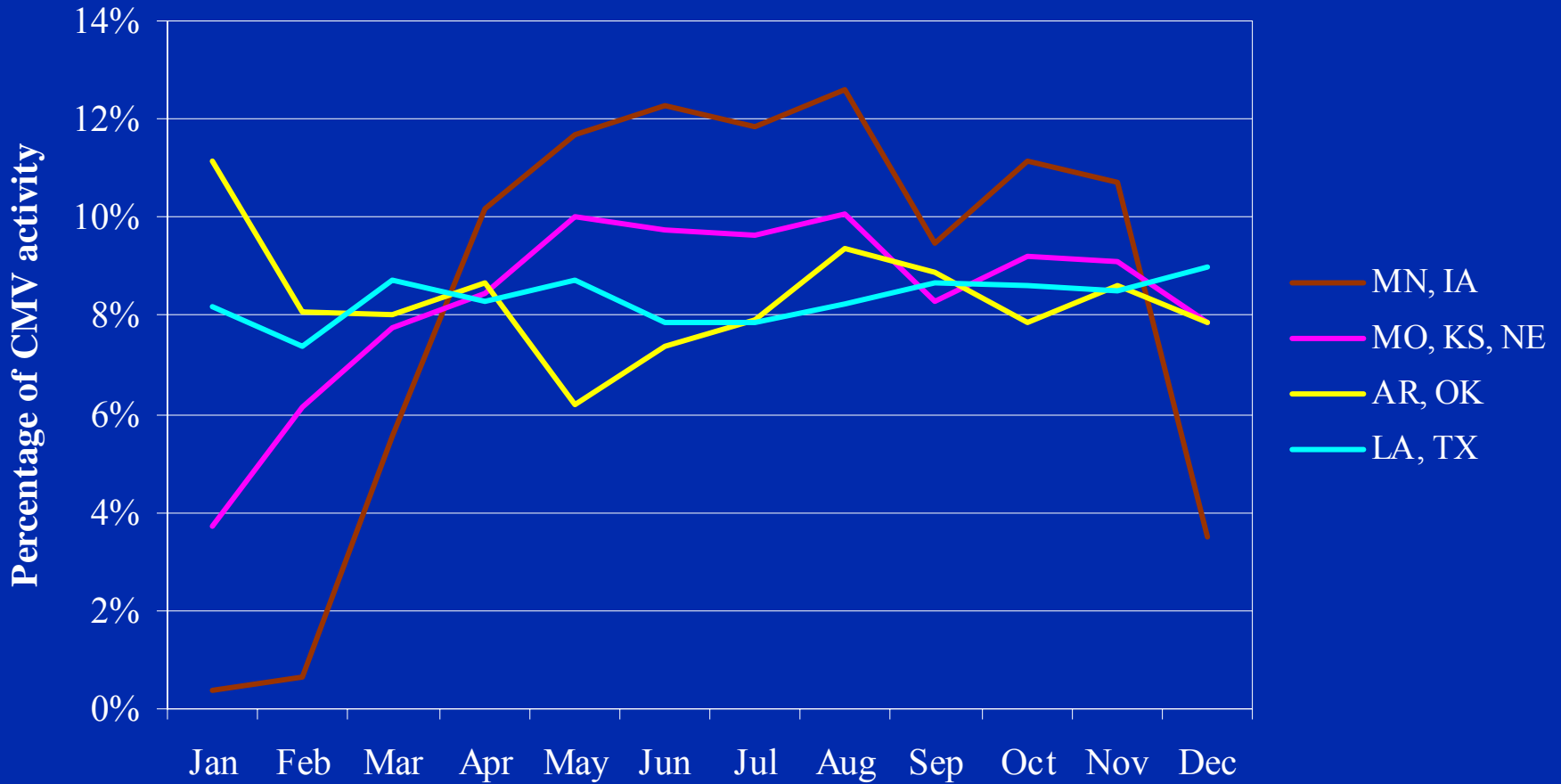
NO_x (tons/year)



CENRAP



CMV Monthly Variations



Conclusions

- Improvement over existing inventories due to use of local activity data
- Emissions from recreational boat usage estimated to be 2-4 times higher than preliminary 2002 NEI
- Emissions from CMV estimated to be 1/3 as high as those in the preliminary 2002 NEI
- Spatial and temporal allocation of emissions enhanced through surveys and other data collection efforts

Glossary

CENRAP = Central States Regional Air Planning Association

CMV = Commercial Marine Vessels

DOT = Department of Transportation

IDA = Inventory Data Analyzer

NEI = National Emissions Inventory

NIF = NEI Input Format

NMIM = National Mobile Inventory Model

SMOKE = Sparse Matrix Operator Kernel Emissions Modeling System

TVA = Tennessee Valley Authority

USACE = United States Army Corps of Engineers