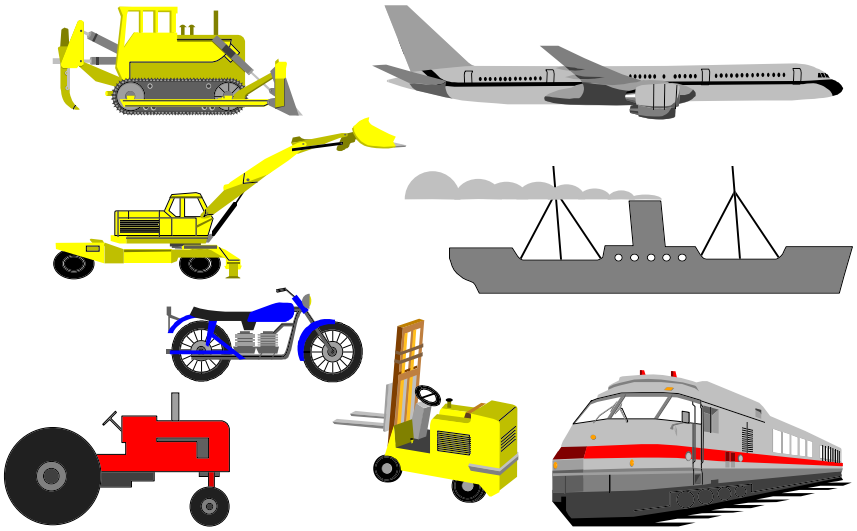
Nonroad Modeling



EPA National Nonroad Emissions Inventory Model (NONROAD)

Workshop
June 25, 1998
Chicago

7/8/98

Today's Topic

- EPA NONROAD Emissions Model
  - » SIP Tool Principal Focus
  - » EPA Regulatory Development
  - » EPA Strategic Planning

Today's Focus

- Ensure User Needs Met
- Explain Draft Nonroad Model
- Feedback
  - » Model features, function, and inputs

Agenda

- Part I
  - » Introduction
  - » Model Overview
  - » Development Schedule
  - » Draft NONROAD Release
  - » Stakeholder/EPA Communications

Agenda (con't)

- Part II
  - » Model Description
  - » Preliminary Results
  - » Specific Default Inputs
  - » Computational Sequence and Methodology
  - » Open Discussion/Audience Presentations
  - » Commercial Marine

Agenda (con't)

- Part III
  - » Workshop Summary
  - » Next Steps
  - » Ajourn Workshop
  - » Hands-On Demonstration

Introductions
NONROAD Team

- EPA's Office of Mobile Sources
  - » Assessment and Modeling Divison
    - – Gary Dolce
    - – Craig Harvey
    - – Greg Janssen
    - – Chris Lindhjem
    - – Mike Sklar
    - – Rich Wilcox

Introductions
NONROAD Contract Support

- ENVIRON International Corporation
  - » Gary Wilson
  - » Alison Pollack
- Dyntel

Model Overview (cont'd)

- Stand Alone *(No User Data Necessary)*
- All Nonroad Sources
  (*except locomotives and aircraft*)
- Differentiated by Equipment Type and Other Characteristics
- HC, CO, NO_x, PM, SO_x, CO_2

Model Overview (cont'd)

- Past, Present and Future Year Inventories
- Temporal Allocation
- Geographic Allocation

Development Schedule

Milestone	Date
» Draft Release	» June 18
» Workshop	» June 25
» Close Comments	» August 18
» Draft Final Release*	» November
» Close Comments	» December
» Final Release	» February '99

* w/ Draft Com. Marine

Draft NONROAD Release

- Availability
  - » Web Site
  - » CD ROM
- Contents
  - » Installation Program
  - » Source Code
  - » User's Guide
  - » Tech Support Documents
  - » Read.me Document
  - » Release Notes

Stakeholder / EPA Communications

- Electronic Information Sources
  - » Listserver
    - – subscriber instructions on nonroad web page
  - » Web Site: http://www.epa.gov/omswww/nonrdmdl.htm
  - » Email: nonroad@epa.gov
- Personal Assistance
  - » EPA Contact Person

Equipment Types

- Airport service
- Agricultural
- Commercial
- Construction
- Industrial
- Lawn & garden
- Logging
- Railroad (not locomotives)
- Recreational equip.
- Recreational marine

(*more than 80 basic and 260 specific categories*)

Pollutants Reported

- HC
  (THC, TOG, NMOG, NMHC, VOC)
- Non-exhaust HC by Mode
  (diurnal, refueling, crankcase)
- HC not reported:
  (hot soak, running loss, resting loss)
- NO_x
- CO
- CO_2
- SO_x
- PM
  (PM_{tot} , PM_{10}, $PM_{2.5}$)
- Fuel Consumption

Geographic Coverage

- US Total
- 50-State
- State
- County
- Option to add sub-county data for nonattainment area analysis.

Temporal Coverage

- Estimates of past, present and future year emissions
- Annual, seasonal, monthly, or daily emissions.
- Daily emissions distinguished by season and weekday/weekend.

Model Structure

- Graphical User Interface (Visual Basic)
  - » Scenario definition
- Core Model (Fortran)
  - » Calculations
- Reporting Utility (Microsoft Access)
  - » Output content selection

Hardware/Software

- Minimum: 486 with 16MB RAM
  (core model will run separately with 8MB)
- DOS, Win 3.1 or Win 95
- MS ACCESS not required

Input Options

- User Selected:
  - » Year
  - » Temporal Period
  - » Geographic Area
  - » Equipment Types
  - » Fuel Characteristics
  - » (altitude unused)

Default Input Data

User Change OK if Better Data

- » Equipment Population *(*.pop)*
- » Growth Rate *(*.grw)*
- » Geographic Allocation *(*.alo)*
- » Temporal Allocation *(season.dat)*
- » Emission Factors *(*.emf)*

User Change Not Recommended

- » Useful Life & Scrappage *(*.pop)*
- » Load Factors & Usage *(activity.dat)*
- » Emission Deterioration Factors *(*.det)*

Output Options

- ASCII File
- Pre-formatted ACCESS Reports
  - » Access not required
- ACCESS database
- Excel Spreadsheet

Report Options

- By County
- By Source Category
- By Equipment type/code
- By Horsepower

Know Limitations

- Error Checking via Interface
- State and County Populations
  - » Certain categories only
- Seasonal or Daily U.S. Totals
- Refueling Method
- Aircraft Ground Equipment Method

Inventory News

- Nat'l Nonroad Inventories Changing
  - » NONROAD vs. NEVES
    - – VOC +25%
    - – NOx +25%
    - – PM Down -5%

Inventory News

- Why?
  - » VOC and NOx -- Updated database has more equipment and new equipment categories added.
  - » PM -- Same as above, but lower EFs.

Engine Population Estimates

- Recently revised Technical Report available on EPA Web Page (NR-006A)
- Changes in current Report
  - » Request for comment on Mobile vs. Stationary engines
  - » Modification of Residential/Commercial Lawn & Garden split
  - » Modification of small engine classification scheme

Engine Population Estimates
Population Breakdown

- Engine populations rather than equipment populations (based on emissions regs)
- Engine populations are divided into:
  - » Market segments (e.g., Agricultural, Construction, Lawn & Garden, etc.)
  - » Applications (e.g. lawn mowers, leaf blowers, shredders, etc.)
  - » 5 Fuel types: Diesel, Gasoline 2-stroke, Gasoline 4-Stroke, CNG, LPG
  - » 19 Power levels (e.g., 0-1 hp, 1-3 hp, 3-6 hp, etc.)

Engine Population Estimates
Source Classification Codes (SCC)

- Each combination of application and fuel type has a unique SCC
- For most applications:
  - » First 4 digits specify fuel type (2260xxxxxx = 2-stroke gasoline)
  - » Next 3 digits specify market segment (2260004xxx = 2-stroke gasoline lawn & garden)
  - » Last 3 digits specify application (226004010 = residential lawn mowers)
- Marine, rail, and aircraft are exceptions

Engine Population Estimates
PSR Database

- Base year (1996) engine populations come from estimates made by Power Systems Research (PSR)
  - » PSR population estimates are based on manufacturer sales surveys, experimentally determined engine life, and surveys of engine usage
  - » PSR application codes were matched to SCCs

Engine Population Estimates
Changes from NEVES Inventories

- Majority of changes in population between NEVES and NONROAD are the result of:
  - » Updating inventory from 1989 to 1996
  - » Adding several equipment classes no included in NEVES

Engine Population Estimates
Mobile vs. Stationary Nonroad

- An engine that moves from one place in a 12 month period is defined as a mobile source
  - » This distinction is not immediately obvious (e.g., pallet mounted engines appear to be stationary but are moved)
  - » Mobile/stationary allocation taken from Booz, Allen, and Hamilton report to California ARB

Engine Population Estimates
Mobile vs. Stationary Nonroad

- These fractions are applied to PSR populations for generator sets, pumps, compressors and welders.
- Should they also be applied to general industrial engines, hydro power units and irrigation sets?

Power Range (Hp)	Percent Mobile Equipment
0 to 25	90
25 to 40	90
40 to 100	70
100 to 175	20
175 to 300	15
300 to 500	10
500+	0

Engine Population Estimates
Commercial vs. Residential Lawn & Garden

- Many lawn and garden applications are operated by both commercial and residential users
  - » Usage patterns are significantly different
    - – Commercial has higher use in hr./year, shorter average life in years, different hr./weekday vs. weekend compared to residential
  - » PSR populations don't distinguish between the two

Engine Population Estimates
Commercial vs. Residential Lawn & Garden

- Commercial/residential sales fractions by application were derived by California ARB
- Calculation of population fraction from sales fraction:
  - » Commercial Population Fraction = (Commercial Sales Fraction * Commercial Average Life in Years) / (Commercial Sales Fraction * Commercial Average Life + Residential Sales Fraction * Residential Average Life)

Engine Population Estimates
Commercial vs. Residential Lawn & Garden

Application	Residential		Commercial	
	Sales	Population	Sales	Population
Lawn mowers	90.0%	96.3%	10.0%	3.7%
Trimmers/edgers/ cutters	81.9%	89.4%	18.2%	10.6%
Chainsaws	75.0%	93.5%	25.0%	6.5%
Leaf blowers/ vacuums	86.9%	92.5%	13.1%	7.5%
Tillers <6 hp	82.0%	85.7%	18.0%	14.3%
Snowblowers	90.0%	90.0%	10.0%	10.0%
Commercial turf equipment	0.0%	0.0%	100.0%	100.0%
Rear engine rider	95.0%	97.4%	5.0%	2.6%
Lawn and garden tractors	95.0%	97.4%	5.0%	2.6%
Other lawn and garden equipment	25.0%	45.7%	75.0%	54.3%
Front Mowers, Chippers/stump grinders, commercial turf, all other equipment	0.0%	0.0%	100.0%	100.0%

Engine Population Estimates
Small SI Lumping

- Proposed regs for small spark-ignition (SI) engines (<25hp) define engines based on use and displacement while NONROAD classifies by application and power level
- Proposed regs will likely result in shift from 2-stroke to 4-stroke engines
- NONROAD methodology cannot currently accommodate that shift if 2- and 4-stroke engines are in different SCCs

Engine Population Estimates
Small SI Lumping (Cont'd)

- Solution:
  - » All SI engines <25HP (2- and 4-stroke, CNG, and LPG) for a single application were lumped
  - » Distinctions between different types of engines for sales fraction and emission rates are maintained by using technology groups

Engine Population Estimates
Recreational Marine

- In Rec Marine Rulemaking, EPA determined that populations derived from sales data supplied directly by the manufacturers was more accurate than PSR for SI rec marine engines.
  - » NONROAD uses these rulemaking populations
- Same problem as for small SI engines:
  - » Because of inconsistencies between NONROAD and rec marine regs, engines are lumped into a single group with separate tech types

Engine Population Estimates
Summary of Remaining Issues

- Should mobile/stationary fractions also be applied to general industrial engines, hydro power units, and irrigation sets?
- Mistake in Airport Support Equipment populations
  - » Conflicting information as to whether PSR application “Terminal Tractors” falls into the Airport Support Equipment category
  - » Currently they are not included in that category, but at least some of the population should be

Growth Factors

- Technical Report available on EPA Web Page (NR-008)
- Approach described in Technical Report and used in Draft NONROAD is a new one
  - » Comments with suggestions for improvement are encouraged

Growth Factors
Option 1: Economic Indicators

- Use Bureau of Economic Analysis growth forecasts for major sectors of the economy
- Match those sectors to the nonroad equipment that would be used in each sector

Growth Factors
Economic Indicators - Limitations

- BEA may tend to under-predict growth
  - » Total growth, 1990-1996
    - – BEA projected: 9.3%
    - – PSR growth in nonroad population: 18.1%
- BEA can't be used to project market shifts
  - » Shift from gasoline to diesel engines
  - » Shift from lower to higher hp
  - » Increased mechanization

Growth Factors

Option 2: Historical Population Growth

- Project future growth by extrapolating from historical growth in nonroad equipment populations
- Population growth estimated from Power Systems Research (PSR) PartsLink database
  - » Includes historical engine population estimates for 1989-1996
  - » Allows for segregation by market sector, application type, fuel type, and horsepower
- Provides a more direct measure of change than economic forecasts

Growth Factors

Historical Population Growth - Limitations

- PSR database may contain errors
  - » Errors have bigger impact as one goes to finer grained breakdown of population
  - » Can limit impact by not going to extremely fine detail
- 1989-1996 may not be representative
  - » Includes periods of low and high economic growth

Growth Factors

Historical Population Growth - Limitations

- 7 years of historical projections is not a long enough period of time on which to base 20-30 year projections
  - » Could modify method to use historical growth for near-term and BEA for long-term or cap long-term growth in some other way

Growth Factors

Projected Annual Growth Rate Comparison

		PSR				
Market Segment	BEA	Total	Diesel	Gasoline	LPG	CNG
Airport Service	5.5%	8.2%	9.4%	1.4%		
Construction	1.0%	2.6%	3.6%	0.3%		
Farm	2.4%	2.8%	3.2%	2.0%		-7.7%
Industrial	1.9%	3.1%	4.4%	-3.5%	4.1%	
Lawn & Garden	1.0%	2.7%	9.6%	2.6%		
Light Commercial	1.9%	4.9%	5.5%	4.7%	14.2%	5.1%
Logging	7.4%	5.2%	-0.8%	5.9%		
Railway	-0.9%	2.7%	5.1%	1.3%		
Recreational	1.0%	0.9%	3.9%	0.9%		

Growth Factors
Market Shifts

- Problem with fuel-specific growth rates
  - » Fuel-specific growth rates must be capped by the overall market segment growth rate
  - » For Draft NONROAD, we have scaled the fuel specific populations to the total market segment population to avoid this problem
  - » In the future, we might want a single market segment growth rate with a separate input to project % market share

Growth Factors
Market Shifts - Scaled Results

	PSR								
Market Segment	Total	Diesel	Scaled Diesel	Gasoline	Scaled Gasoline	LPG	Scaled LPG	CNG	Scaled CNG
Airport Service	8.2%	9.4%	8.3%	1.4%	0.8%				
Construction	2.6%	3.6%	3.3%	0.3%	0.0%				
Farm	2.8%	3.2%	3.1%	2.0%	1.9%			-7.7%	-8.1%
Industrial	3.1%	4.4%	3.6%	-3.5%	-4.3%	4.1%	3.3%		
Lawn & Garden	2.7%	9.6%	9.1%	2.6%	2.5%				
Light Commercial	4.9%	5.5%	5.3%	4.7%	4.6%	14.2%	13.2%	5.1%	5.0%
Logging	5.2%	-0.8%	-1.2%	5.9%	5.4%				
Railway	2.7%	5.1%	4.5%	1.3%	0.8%				
Recreational	0.9%	3.9%	3.8%	0.9%	0.8%				

Growth Factors
State and Local Factors

- Draft NONROAD only contains national growth factors
- We have state by state historical populations from PSR, but haven't analyzed them yet
- We plan to include the state growth factors in the final NONROAD
- States that have their own estimates of state or local growth could substitute them subject to EPA SIP Guidance

Growth Factors
Summary of Remaining Issues

- Should we do something to cap growth rates in the long term? Proposals?
- How fine should we cut the database?
  - » Currently only market segment and fuel
  - » Plan to segment the database by state
  - » Should we include horsepower or applications?

Growth Factors

Summary of Remaining Issues (Cont'd)

- Should we switch to a % market share approach or stick with scaled growth factors?
  - » Change may not be feasible for Final NONROAD
- Growth rate for Airport Service equipment will change
  - » Incorrect populations taken from PSR database
  - » Other sources of information may be better for this category
    - – FAA projections of take-offs and landings?

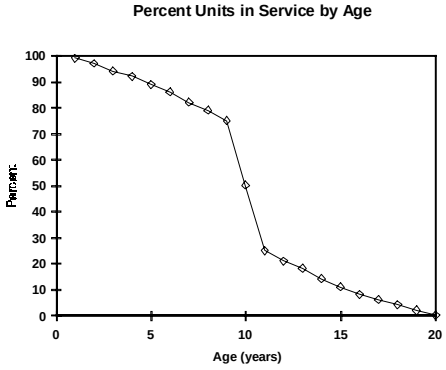
Age Distribution & Scrappage

Chris Lindhjem

NONROAD NR-007

Scrappage Function

Based on a normal distribution

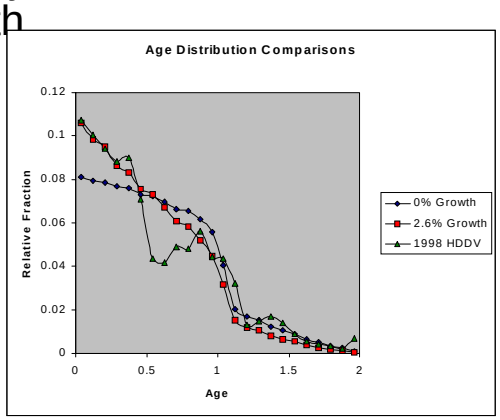


Scrappage in NONROAD

- Included in the Growth File (nation.grw)
- Alternate Scrappage functions can be used
- Will affect fleet turnover and phase-in rates of new engine emission standards
- Currently not using a use-by-age function, so the scrappage distribution estimates both age and use-by-age together

Initial Year (1996) Age Distribution

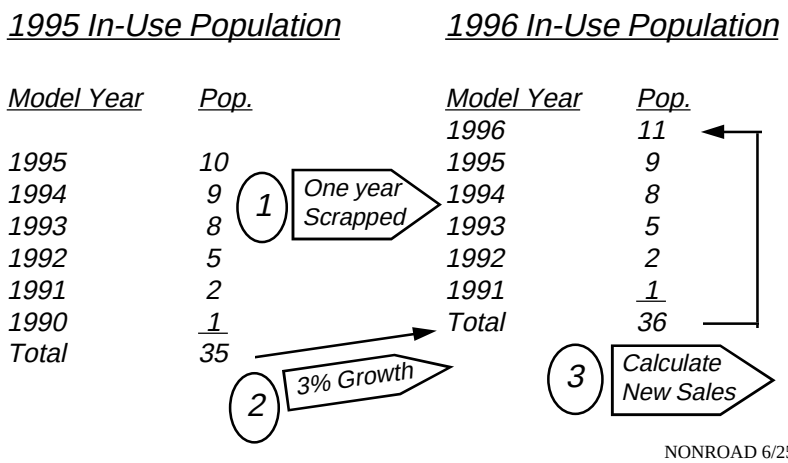
- Initial year assumes 0% historical growth



Age Distribution Calculations

- Future year sales is calculated by adding one year of scrappage and the growth in the overall population (inlcuding some scrappage in the first year)
  - *Previous year's engines are scrapped by one additional year*
  - *Next year's sales is the sum of that year's scrapped engines plus that needed to bring the engine population*

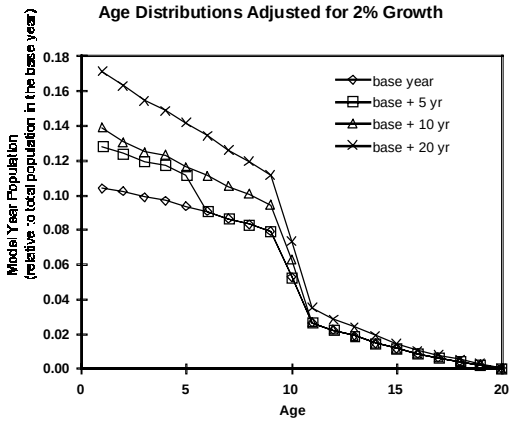
Growth Methodology (sample)



Sales Perturbation

- In the previous example 3% population growth results in 10% sales growth
- Initial year age distribution is responsible for this

Effect on Age Distribution



MOBILE Comparison

- Age distributions predetermined (using a similar methodology)
- Sales growth estimates fixed for the purpose of age distribution
- Travel fractions include both age distribution and use-by-age function

Median Life Estimations

Chris Lindhjem

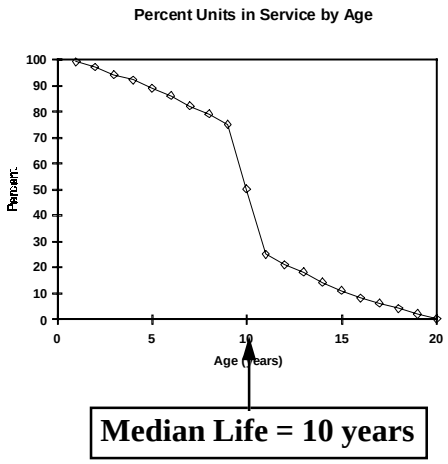
NONROAD Report NR-005A

Definition

- Median Life; 50% of new engines scrapped
- NONROAD input; Hours at Full Load
- Calculation

$$Median\ Lifetime\ (years) = \frac{Median\ Life\ (hrs)}{Activity\ (hrs/yr) * Load\ Factor}$$

Use of Median Life



Information Source

- Energy and Environmental Analysis Inc. analysis of the Power Systems Inc. database for the Air Resources Board of California
- Lawn & Garden - Estimation from EPA\Manufacturers Regulatory Negotiation Committee work - generally lower than EEA estimates
- The median life is found in the *.pop files

Activity and Load Factors

Chris Lindhjem

NONROAD Report NR-005A

General

- Emissions = (Population * Power * Load Factor * Activity * Emission Factor)
- Load Factor - Average Fraction of Available Power
- Activity - Engine Hours Use per Year

Source Information

- Power Systems Research - Conducts User Surveys to Estimate Load and Hours Use *(PSR estimates used for most applications)*
- Other Survey Information for Lawn & Garden and Spark-Ignition Recreation Marine

How to Determine

- Hours is determined by use of meters on engines (often called Hobbs meters); analogous to an odometer
- Load Factor is determined from the Hours and Fuel Consumption

Load Factor Estimations

- Load Factor = EP/(FC/(BSFC * Hours Used))
  - » EP - Engine Power
  - » FC - Fuel Consumption (actual)
  - » BSFC - Brake Specific Fuel Consumption (lb/hp-hr or g/kW-hr); derived from test data
  - » Hours Used - Engine On and Fuel Consumption Information

Collecting New Data

- Important to collect data from professionally designed surveys (apocryphal information abounds)
- Determine engine related parameters (such as power level and age of engine) in addition to hours of use and fuel consumption

Emission Factors

Chris Lindhjem

Reports NR-009A & NR-010A

plus deterioration

Emission Factor

- Emission Factors are zero hour (new engine)
- Deterioration applied for in-use engines
- Emission Factors; gram/hp-hr or g/gallon or g/gallon
- Draft release only uses g/hp-hr factors

CI Emission Factors

Chris Lindhjem

NR-009A

CI Emission Factors

- Pre-1988 model years from NEVES emission rates
- >1988 Precontrolled engine emissions from new (1998) EPA\SwRI study
- New engine standards are included (rulemaking not yet finalized)
- Adjustment from steady-state certification test results to in-use emission rates

Emission Factors in NONROAD

- Pre-Calculation Method
  - » EF = Steady-state EF * Adjustment for In-Use
  - » $EF_{(THC\ for\ Backhoes)}$ = 0.68 (g/hp-hr) * 2.19
- Emission factors calculated outside of the model and included in the data files
- Emission factors are included in *.emf files and new standards are phased-in through technical types in the tech dat

Pre1988; NEVES Factors

- Older Equipment (Early 1980's and older engines)
- NEVES adjusted steady emission rates with the use of highway certification test cycle
- Recast emission factors with new in-use adjustments
- Sparse data delineated by equipment type

>1988 Precontrolled Engines

- New and more test data than NEVES
- Emission factors generally lower (highway diesel engine technology improvements transferred to nonroad engines)
- >100 hp and <100 hp engines treated separately due to emission results (different engine technology; fuel injection systems)

New Standards

- Includes Tier I, II, and III emission standards
- *Tier II and III rulemaking is not finalized so may change from draft version of NONROAD*

Adjustment for In-Use Activity

- Test data on three representative in-use test cycles (backhoe\loader; crawler dozer; and agricultural tractor)
- Transient nature and average load of cycles
- Mapping of the three test cycle adjustments or no adjustment to equipment applications (given in the Report)

Adjustment (cont.)

Table C1 NEVES Test Cycle Adjustment from ISO-C1 Emission Factors

	HC	CO	NOx	PM
NEVES Adjustment	1.4	2.0	1	1.6

Table C2 In-use Adjustment Factor (Ratio of Application Test Cycle to Steady-State ISO-C1 Emissions)

Test Cycle	HC	CO	NOx	PM	BSFC
Agricultural Tractor	0.89	0.42	0.99	0.64	0.98
Backhoe\Loader	2.19	2.31	1.03	2.04	1.18
Crawler Dozer	0.93	1.27	0.99	1.21	0.98

New Standards Phase-In

- New emission factors are phased-in through the use of a tech type description
- New technology or new mix of technologies by model year

Tech. Types (example)

Tech types use for standards phase-in for Base (pre-1988), T0 (>1988), T1 (Tier 1 Standards), T2 (Tier 2), T3 (Tier3)

Model Year	SCC	Low & High Hp	Technical Types----------				
	2270005000	175	300	Base	T0	T1	T2	T3
1900				1	0	0	0	0
1988				0	1	0	0	0
1996				0	0	1	0	0
2003				0	0	0.3	0.7	0
2004				0	0	0.15	0.85	0
2006				0	0	0.15	0	0.85
2011				0	0	0	0	1

Fuel Sulfur PM Adjustment

- Diesel PM is a combination of unburnt fuel, engine oil, carbon core, and hydrated sulfate
- Fuel sulfur adjustments affects only the sulfate related PM, not total PM

Fuel Sulfur PM Adjustment

- PM sulfur adjustment for PM

*PM = PMBase - BSFC * A * (0.0033 - Fuel Sulfur)*

where

PMBase = PM emissions with default fuel, in g/hp-hr
PM = PM emissions with test fuel, in g/hp-hr
BSFC = Brake Specific Fuel Consumption in g/hp-hr
A = 0.157 g PM/hp-hr/Weight Fraction sulfur/BSFC
0.0033= the default weight fraction of fuel sulfur for nonroad diesel
Fuel Sulfur = Weight Fraction of sulfur in test fuel

SI Emission Factors

Chris Lindhjem

NR-010A

General Emission Factors

- NEVES baseline for >25 hp SI engines
- Engines unique because of rulemakings
  - » <25 hp general-use engines (except recreational vehicles and underground mining)
  - » Recreational SI marine
- LPG and CNG engines
- Zero-hour (new) engine emission

>25 hp SI Engines

- NEVES
  - » construction
  - » agricultural
  - » all other applications use NEVES industrial

Recreational, LPG, and CNG

- Recreational (motorcycles, all-terrain vehicle, snowmobiles, and other specialty)
  - » Use new data on snowmobile engines
- LPG & CNG
  - » Two types; industrial and all other applications
  - » Emission rates used for <25 hp engines also

<25 SI Emission Factors

- Engines considered under a rulemaking
- 5 engine classifications (Class I-V)
  - » Class I and II; nonhandheld small and large
  - » Class III-V; handheld small to large
  - » Class definition described in Report NR-006A
- Rule definition is by use and engine size - NONROAD defines by use and engine power

Small Engine Rulemaking

- Averaging Standard (some low emitters and some high; averaging lower overall)
- Rulemaking results in lower THC emissions due to lower emission factors for new model years and a shift in technology type from 2-stroke to 4-stroke

Recreational SI Marine

- Averaging standard also
- Outboard (2-stroke) & Personal Watercraft (2-stroke) are the focus of rulemaking
- Inboard (4-stroke) is assumed not to change

Outboards

- Generally two types currently (2 and 4-stroke)
- New engine standards are expected to result in more 4-stroke engines and lower emitting 2-stroke engines
- Emission rates vary by engine power

Personal Watercraft

- Generic name instead of JetSki® brand name
- A move from 2-stroke to 4-stroke is expected here as well

Tech. Type Phase-In (example)

- M2 (standard 2-stroke), M14 (lower emitting 2-stroke) M13 (current 4-stroke)

Table 20 Estimate Phase-in of New Personal Water Craft Engines >50 hp

Year	M2	M13	M14
1900	1.000	0.000	0.000
1999	0.177	0.092	0.731
2000	0.177	0.259	0.564
2001	0.177	0.533	0.291
2002	0.177	0.823	0.000
2004	0.038	0.962	0.000

Deterioration

Chris Lindhjem\Greg Janssen

Report Due Soon

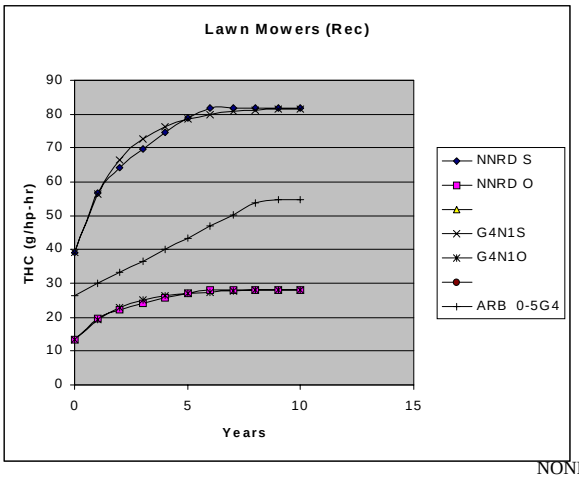
Summary

- Deterioration Report Imminent
- Application
  - » Emission Rate = Emission Factor (zero hour) * Deterioration
    - – Deterioration = 1 + A (age) ^{b}
      - A, b constants
      - Age = Cumulative hours * Load Factor / Median Life
    - – Deterioration caps allowed and used
- Input in NONROAD in *.det files

Deterioration Values

- < 25 hp SI engine emissions deterioration taken from EPA rulemaking
  - » 2-stroke linear deterioration = 1 + A * Age
  - » 4-stroke deterioration = 1 + A * (Age) $^{0.5}$
  - » All deterioration capped at 1 median life
  - » Magnitude taken from Phase I rulemaking RIA
- >25 hp SI deterioration from NEVES

Sample Deterioration Effect



Other Deterioration

- Draft version of NONROAD has no deterioration for diesel for any pollutant
- Initial testing indicates concern
  - » 4 of 9 engines recruited had maintenance problems with manifold leaks
    - – Manifold leaks required repair to measure emissions
    - – Manifold leaks will affect the turbocharger efficiency potentially raising emissions

Non-Exhaust Emissions

Modeled	**Not Currently Modeled**
Diurnal	Hot Soak
Crankcase	Running Losses
Refueling	Resting Losses

Non-Exhaust Emissions: **Diurnal**

Based on NEVES

3.0 g/gallon/day* (>25hp)

Modified for <25hp Engines per ARB Model

1.0 g/gallon/day* (<25hp)

* Grams per Day per Gallon fuel tank capacity

Non-Exhaust Emissions: **Diurnal**

Would consider using method in EPA small engine regulatory model (NSEEM)

Gram per day values for specific applications

Data based on 72-96F tests

Ignores potentially large range of tank sizes within an application (e.g., generator sets)

Non-Exhaust Emissions: **Diurnal**

- **Fuel Tank Size is calculated by model based on engine application and horsepower**
- **See Refueling Loss presentation**

Non-Exhaust Emissions: **Crankcase**

Based on NEVES

Zero for 2-Stroke and Rec Marine

HC Only

Would consider CO & NOx (much smaller)

Non-Exhaust Emissions: **Crankcase**

4-Stroke	Diesel
33.0 % of exhaust HC	2.0% of exhaust HC

Refueling Emissions

- Technical Report not yet available
- All refueling calculations are based on NEVES methodology described in Appendix I of the NEVES Report
- Planned changes from Draft NONROAD to Final
  - » Draft NONROAD uses simplified method
  - » Final NONROAD will revise this

Refueling Emissions

- Two components
  - » Spillage
  - » Vapor Displacement
- These are calculated separately and then combined for output

Refueling Emissions

- Refueling method assumptions
  - » Container filled - all lawn and garden, recreational equipment, outboards and personal watercraft
  - » Pump filled - all others

Refueling Emissions

- Refueling method - Alternative assumptions
  - » NEVES - lawn and garden, recreational, light commercial, and all equipment with tank volumes less than 6 gallons are container filled
  - » ARB - all gas 2-stroke and all equipment less than 15 hp are container filled

Refueling Emissions

- Spillage - Assumptions
  - » All refuelings are fill-ups
  - » 17.0 g per refueling event from containers
  - » 3.6 g per refueling event from gas pump

Refueling Emissions

- Spillage - Calculation
  - » Container:
    - – Spillage (g/gal) = 17.0 / Tank Volume
  - » Pump:
    - – Spillage (g/gal.) = 3.6 / Tank Volume
  - » NONROAD uses fuel consumption to convert g/gal to total emissions in Tons

Refueling Emissions

- Spillage - Tank Volumes
  - » NEVES gave average tank volumes for each application
  - » Within an application, tank volumes vary by engine size
  - » Based on equipment specifications available on the World Wide Web, we developed application-specific tank volumes in gallons/hp

Refueling Emissions

- Spillage - Tank Volumes
  - » Analysis needs more work - could still go back to NEVES approach
  - » Interim values are in ACTIVITY.DAT file
  - » In draft model, ACTIVITY.DAT is only accessed for diurnal emissions calculations
  - » SPILLAGE.EMF contains emission factors for each application based on NEVES tank volumes

Refueling Emissions

- Vapor Displacement - NEVES approach
  - » Disp. = -5.909 - 0.0949 x dT + 0.0884 x Td + 0.485 x RVP
  - » Disp. = Displacement (g/gal)
  - » dT = Temp of Tank (Ambient Temp) - Temp of Dispensed Fuel (^{o}F)
  - » Td = Temp of Dispensed Fuel (^{o}F)
  - » RVP = Reid Vapor Pressure of Fuel

Refueling Emissions

- Vapor Displacement - NEVES approach
  - » NEVES used this formula to create a look-up table for summer and winter temperatures and container and pump refueling
  - » DISPLACE.EMF contains g/gal emission factors based on summer temperatures from the NEVES look-up table and 9.0 RVP
  - » NONROAD uses fuel consumption to convert g/gal to total emissions in Tons

Refueling Emissions

- Vapor Displacement - Final model approach
  - » NONROAD will calculate g/gal emission factors based on the NEVES formula and temperatures and RVP entered under Scenario: Options
  - » Temp. of dispensed fuel will be calculated by the following equation (derived from the NEVES table):
    - – Td = 62 + 0.6 x (Ambient Temp. - 62)

Refueling Emissions

- Summary of remaining issues
  - » Container vs. pump refueling allocation
  - » Tank volumes - use NEVES or collect more data for gal/hp method?
  - » Alternatives to “all refuelings are fill-ups” assumption?

Refueling Emissions

- Summary of remaining issues (cont’d.)
  - » Effect of Stage II controls
    - – Geographical allocation is a problem
    - – Most likely solution is a Stage II switch for county runs
    - – User would have to set the switch
    - – Stage II effectiveness for nonroad refueling?

Refueling Emissions

- Summary of remaining issues (cont'd.)
  - » Diesel emissions
    - – None in Draft NONROAD
    - – NEVES used 0.041 g/gal at 80 ^{o}F for displacement
    - – Spillage is unknown
  - » Accounting for spillage and displacement when filling portable containers
    - – Unlikely to be addressed in Final NONROAD

Temperature & RVP Effects

Only affects calculated Diurnal loss

Based on MOBILE5
(Uncontrolled Diurnal Index, Wade equation)

- Start with base rate for 60-84F
- Adjust Vapor Pressure to desired Temperature & RVP

Fuel Sulfur & Oxygen Effects Spark-Ignition

- **Oxygen Effects**

  Exhaust CO, NOx, and VOC

- **Sulfur Effects**

  Exhaust SOx and PM

Fuel Sulfur & Oxygen Effects Spark-Ignition

- Assume no Feedback (closed-loop) controls
- Assume no Catalysts
  - » No reduction of catalyst efficiency
  - » Will need to revisit in future
- Effects of Aromatics, Olefins or Distillation curve are ignored
- Default gasoline sulfur content = 339 ppm

Fuel Sulfur & Oxygen Effects
Spark-Ignition

- **97% of fuel Sulfur converted to SO_2**
- **3% of fuel Sulfur emitted as PM**

Fuel Sulfur & Oxygen Effects
Oxygen

- **Oxygen Effects based on older highway vehicle and some small engine testing**
- **CO & VOC decrease proportional to fuel oxygen**
- **NOx increases proportional to fuel oxygen**

Fuel Sulfur & Oxygen Effects*

Oxygen

4-Stroke		2-Stroke	
VOC	-4.5%	VOC	-0.6%
CO	-6.5%	CO	-6.5%
NOx	+11.5%	NOx	+18.6%

* Per Percent Fuel Oxygen

Hydrocarbon Report Types

Chris Lindhjem

NONROAD Report NR-002

Definition of THC

- THC is total hydrocarbons
- Measured with a flame ionization detector (FID) calibrated with propane; the FID measures carbon content of sample.
- Hydrogen is added to the carbon emission rate to represent hydrocarbon emissions

THC (grams) = (FID Response) * (12 (Carbon) + ~1.8 (Hydrogen))

12 - Molecular weight Carbon

1.8 - Number of Hydrogen atoms associated with Carbon

Definition of TOG

- TOG - total organic gas
- FID doesn't measure carbon atoms associated with oxygen such as aldehydes and alcohols
- Aldehydes and alcohols are measured separately and added to the THC by weight as formaldehyde and methanol

TOG = THC + (total aldehydes) + (total alcohols)

Definition of NMHC, NMOG, and VOC

- NMHC - nonmethane hydrocarbons
- ***NMHC = (THC - methane)***
- NMOG - nomethane organic gas
- ***NMOG = (TOG - methane)***
- VOC - volatile organic compounds
- ***VOC = (NMOG - ethane)***

Results

Engine Type	TOG/THC	NMOG/THC	NMHC/THC	VOC/THC
2-Stroke Gasoline [2]	1.044	1.035	0.991	1.034
4-Stroke Gasoline [2, 3]	1.043	0.943	0.900	0.933
Diesel [4]	1.070	1.054	0.984	1.053
LPG [5]	1.036	0.740	0.704	0.647
CNG [5]	1.002	0.049	0.048	0.004

Use in NONROAD

- Applied in the Reporting Utility not in the Core Model
- Lumped equipment (<25 hp SI) treated as either 2-stroke or 4-stroke gasoline whichever predominates

Geographic Allocation Basic Approach

- Technical report available by mid-July
- Geographic allocation of engine populations accounts for how many and what types of equipment are being used in a certain location
  - » Default data allocates to the county level
  - » NONROAD can allocate equipment populations to the subcounty level, but user must provide fractions to allocate from the county to subcounty level

Geographic Allocation
Basic Approach

- National engine/equipment populations from Power Systems Research (PSR)
  - » PSR has state and county level numbers but methodology used to derive them is proprietary
  - » Publicly available data used as much as possible to allocate populations
- PSR national populations allocated outside NONROAD to county level using county-specific surrogate indicators
- County populations are then aggregated to produce default state population input files

Geographic Allocation
Basic Approach

- NONROAD allocates state level default population input data down to the county level for each equipment type using the county-specific surrogate indicators
  - » $\text{Equip. Pop}_{county} = \text{Equip. Pop}_{state} \times \frac{\text{Surrogate}_{county}}{\text{Surrogate}_{state}}$
- Allocating equipment populations is surrogate for allocating activity
  - » NONROAD only has one activity level (hours/year) for each equipment type for all of U.S.
- Option for user to specify own state/county surrogate indicators
  - » Equipment category or by individual equipment types

Geographic Allocation
Application-Specific Surrogate Indicators

- Residential Lawn and Garden (except snowblowers) : 1 & 2 unit single family homes from 1990 Census (draft version)
  - » Final version adjusted by 1997 human population estimates
- Commercial Lawn and Garden (except snowblowers): number of employees in landscape and horticultural services (SIC 78)
  - » U.S. Census County Business Patterns 1995 (CBP)

Geographic Allocation
Application-Specific Surrogate Indicators

- Snowblowers
  - » Same as above, but plan to adjust by annual average snowfall data from NOAA for final version
  - » Set to zero for counties and states in draft version
- Construction: F.W. Dodge Database of total construction dollar value by county
  - » Census Bureau tracks value but only at MSA level
  - » CBP number employees does not address inter-county movement of equipment
- Agricultural: acreage of harvested cropland
  - » Source: Census Bureau: USA Counties Database 1996

Geographic Allocation
Application-Specific Surrogate Indicators

- Light Commercial Equipment
  - » Census CBP, number of wholesale establishments (SIC 50)
- Industrial
  - » Census CBP, number of employees in manufacturing (SIC 20)
- Oil Field Equipment
  - » Census CBP, number of employees in oil and gas extraction (SIC 1300)

Geographic Allocation
Application-Specific Surrogate Indicators

- Logging
  - » Draft version: number of employees in logging (SIC 2410) plus number of employees in saw and planning mills (SIC 2420)
    - – number of employees in saw and planing mills allocates to urban areas in some cases
  - » Final version will only use number of employees in logging

Geographic Allocation
Application-Specific Surrogate Indicators

- Recreational Marine
  - » Boats not necessarily used in county where purchased, registered, or stored
  - » Draft version uses water surface area
    - – Doesn't account for navigational limitations or max. number of boats that can fit on waterbodies
  - » Effort will be made to refine water surface area method or find a better method
  - » EPA open to ideas & suggestions for default surrogate allocation indicators
  - » Local data is probably best alternative

Geographic Allocation
Application-Specific Surrogate Indicators

- Recreational Equipment (except snowmobiles and golf carts)
  - » Problem similar to recreational marine
  - » Have not been able to find reasonable surrogate indicator at county level
  - » Draft using number of RV park/camp establishments (SIC 7030) from Census CBP
    - – Only placeholder because these data appear to be incomplete
  - » EPA open to ideas and suggestions for defaults
  - » Local data is probably best alternative

Geographic Allocation
Application-Specific Surrogate Indicators

- Snowmobiles
  - » Allocation method not complete in draft version
  - » Could be allocated using same indicator as other recreational equipment or separately
  - » Draft version will report national population and emissions, but zero out state and county level information
  - » Final version will limit geographic allocation using annual average snowfall data from NOAA
  - » Local data may be best alternative

Geographic Allocation
Application-Specific Surrogate Indicators

- Golf carts
  - » Draft version uses number of employees at public golf courses (SIC 7992) from Census CBP
  - » These data have significant gaps
    - – No data available for many states
  - » Will be corrected for final version

Geographic Allocation
Application-Specific Surrogate Indicators

- Aircraft Ground Support Equipment
  - » Draft version uses number of employees in air transportation (SIC 4500) from Census CBP
  - » For final version, investigating the use of DOT landing/takeoff data at airports with commercial operations
- Railroad Maintenance Equipment
  - » Draft version uses 1990 human population
  - » Investigating better alternatives
    - – Track mileage by county?

Geographic Allocation
Application-Specific Surrogate Indicators

- Underground mining equipment
  - » Draft version uses number of employees in metal mining (SIC 1000) from Census CBP
  - » Final version will use indicator more appropriate to underground mining
    - – number of employees in coal mining (CBP 1200)?
- AC/refrigeration equipment
  - » Used on Truck Trailers
  - » Draft version uses 1990 human population
    - – Human population consistent with where this equipment operates

Seasonal Allocation Background

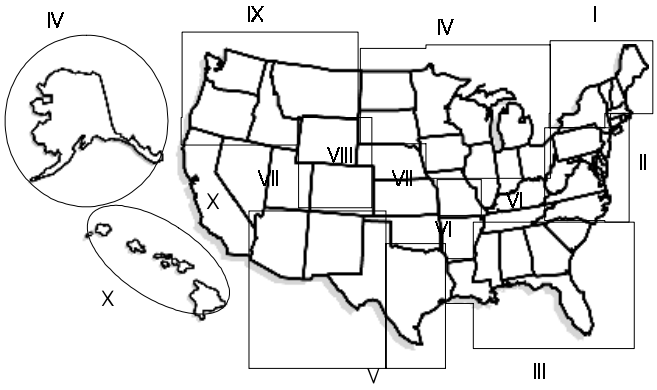
- Technical report available on OMS web page
- Seasonal allocation fractions account for the effect of climatic variations on nonroad equipment usage patterns
- 1995 CA ARB TSD for OFFROAD model used for CA seasonal allocation

Seasonal Allocation Background

- NEVES used for rest of country
  - Recreational equipment seasonal allocation data based on 1990 MIC survey
  - Recreational marine data based on 1991 NMMA survey of boaters
  - Other categories based on 1973 SwRI report by Hare and Springer, 1987 SIPs, 1991 CA ARB lawn & garden emission standards and testing procedures TSD

Seasonal Allocation Regions

- Ten regions
  - » Composite of regions from the 3 sources in NEVES



Seasonal Allocation

- Seasons divided into 3 month periods
  - » 1 month = season/3
- NEVES only contained fractions for Summer and Winter
- Spring and Fall extrapolated by:
  1-(Summer + Winter)/2

Seasonal Allocation

- States assigned to regions by geography and climate
  - » No data for HI and AK
    - – AK assigned to Great Lakes/Midwest region
    - – HI assigned to West Coast region along with CA (1995 CA ARB TSD)
  - » Best judgment used for large states spanning more than one region and having several climatic tendencies that could be categorized in more than one region.
    - – NY: Northeast/New England, Great Lakes/Midwest Middle Atlantic
    - – WY: Rocky Mountain, Central West, Northwest

Weekday/Weekend Allocation

- From CA ARB original draft MVOFF model
  - » Fractions allocate emissions for average week or weekend day
  - » Can be specific to the equipment type
    - – Currently specific to equipment category only
  - » EPA planning to study further and would like to hear ideas and suggestions

Commercial Marine Module
Default Input Data

- Covers top 150 U.S. ports
  - » number of trips and tonnage by vessel category
- 12 well-characterized ports
  - » Based on:
    - – representativeness of operations & geographic location
    - – data availability
  - » Ports matched up with 150 top ports

Commercial Marine Module
Detailed Port Data

- 5 large ocean ports
  - » NY/NJ, Philadelphia, Seattle, Corpus Christi, New Orleans
- 2 typical international ocean ports
  - » Baltimore, Coos Bay
- 1 typical domestic ocean port
  - » Tampa
- 2 river ports
  - » St. Louis, Cincinnati
- 2 Great Lake ports
  - » Burns Harbor, Cleveland

Commercial Marine Module Detailed Port Data

- Detailed Port Activity by Vessel Category
  - » Average Horsepower
  - » Engine/Fuel Type
  - » Range of dead weight tons
  - » Number of Trips
  - » Average Hours in Mode
    - – Mode = Cruising, Maneuvering, and Hoteling

Commercial Marine Module Methodology

- User specifies one of the top 150 ports
- Model matches a given port with a well-characterized port of a similar vessel mix and scales the emissions by activity per vessel category

Commercial Marine Module Methodology

- Module calculates emissions for one of the 12 detailed ports matched with the port chosen by user from the top 150
- For each vessel category and load by mode module will calculate emissions by mode
  - » Emissions by Vessel Category and Mode = Emission Rate$_{\text{(ship \& engine type, mode)}}$ * Hours$_{\text{(mode)}}$ * Load$_{\text{(mode)}}$ * # Ship$_{\text{(Type)}}$ * # Trips

Commercial Marine Future Plans

- Work still underway on module and data
- Draft release expected Fall 1998
- Additional work
  - » Acquiring data on interport emissions on the Great Lakes and rivers
  - » To be included in future version of commercial marine module.