

Nonroad Diesel Engine Database and NOx Control Technology Evaluation for the Houston Area

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Project Sponsor

Texas Environmental Research
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Presentation Summary

- Project Summary
- Study Methodology
- Engine Database Development
- Technology Assessment
- GUI Development

Project Summary

- Nonroad diesel engines > 50 hp in Houston
- Target retrofit candidates for potential NOx reductions (locally operated)
 - Construction equipment
 - Commercial Marine Vessels (harbor vessels)

Project Summary cont'd

- Requires in-use engine profile
 - Engine make/model/year level of detail
 - Across range of SICs / operations

- *Not feasible through traditional bottom-up surveys*
 - Sales data combined with scrap rates

Project Summary cont'd

- Estimate baseline NO_x/PM/VOC emissions
 - Populations by type / Tier level
 - Activity by SIC
 - Texas-specific post-processing adjustments (e.g., TxLED, temperature/humidity)
 - Establish per-unit emission factors

Project Summary cont'd

- Identify & quantify promising NO_x retrofit technologies
 - SCR, LNT, LNC, combinations
 - Compile available field data
 - Exhaust gas temperature (EGT) impacts
 - EGT profiles by equipment type/application

Project Summary cont'd

- Apply reduction potentials to in-use engine profiles
 - Potential market penetration
 - NOx reductions
 - GUIs for reporting / scenario evaluation

Project Summary cont'd

■ Potential End Uses

- Assess emission reduction potential for different control options/target equipment
- Estimate SIP credits (e.g., Carl Moyer, TERP)
- Vendor market evaluations
- Fleet-specific evaluations (e.g., state DOTs)

Study Methodology

1. Construct engine & emissions database
2. Identify NOx control options
3. Obtain and evaluate EGT curves
4. Determine NOx redux perf = f [EGT]
5. Match curves with equipment types
6. Develop GUI
7. Calculate NOx reduction potentials by equipment/engine type

Engine & Equipment Database Development

Engine Database Development

- Level of detail
 - Make / model / hp / tier level
 - Operator type (SIC group – e.g., excavation)
 - Hours per year
- In-use population profile
- *Bottom-up survey infeasible*

Engine Database Development cont'd

- Alternative data sources required
 - Equipment data - EDA
 - Sales by county & purchase year
 - Make / Model / Year
 - Buyer SIC

Engine Database Development cont'd

- Engine specs
 - Spec Check
 - Equipment Watch
 - CAT buyer's guide
 - Web searches
- Hrs/year by SIC - previous inventory studies
- Emission & load factors - NONROAD model
- Engine Tier level – EPA Engine Cert. dbase and emission standard phase-in requirements

Engine Database Development cont'd

- Use of alternative data sets assumes
 - No flux in and out of counties
 - Engine make/model/year can be associated uniquely with chassis info
 - No rebuilds to higher tier levels
- Additional study required to establish uncertainty

Engine Database Development cont'd

■ Data Preparation – MS Access format

- Match/merge equipment and engine data

 - Highly problematic for certification database

 - HP “window” of 25% established

- Gap fill engine specs

Engine Database Development cont'd

■ Data Preparation

– Estimate in-use populations

- ID activity by equipment type (48) and operator category (95)
- Apply NONROAD median life, load, and scrap curves to activity and sales data

Harbor Vessel Database Development

- Category I and II vessels only (Cat III vessels typically not local)
 - Line-haul and assist tugs (> 95%)
 - Ferries, fireboats, pilot boats
- In-use engine profile determined directly from survey

Engine Population and Activity Profiles – Summary Data

In-Use Profile by Model Year - Construction Equipment

Model Year	Equipment Population (2006)
1990	223
1991	289
1992	414
1993	526
1994	666
1995	741
1996	927
1997	1,138
1998	1,394
1999	1,715
2000	1,811
2001	1,804
2002	1,783
2003	2,222
2004	2,604
2005	2,976
Total	21,234

Construction Equipment Type Profile – Top 10

Equipment Type	In-Use Population
Loader Backhoes	5,107
Skid Steer Loaders	4,961
Excavators	1,938
Air Compressors	1,773
Personnel Lifts	926
Crawler Dozers	911
LGP Dozers	819
Tracked Skid Steer Loaders	700
Wheeled Loaders	684
Generator Sets	675

Construction Equipment/Engine Profile – Top 10

Engine Manufacturer	Engine Model	SCC Description	Equipment/Engine Count
Caterpillar	3306	Excavators	2,424
Caterpillar	3306	Crawler Tractor/Dozers	1,464
Caterpillar	3116	Crawler Tractor/Dozers	1,019
Caterpillar	3306	Tractors/Loaders/Backhoes	794
Caterpillar	3116	Excavators	577
Caterpillar	3116	Tractors/Loaders/Backhoes	486
Caterpillar	3116	Rubber Tire Loaders	467
Caterpillar	3116	Rollers	421
Caterpillar	3054	Tractors/Loaders/Backhoes	417
Caterpillar	3406	Crawler Tractor/Dozers	316

Construction Operator Profile – Top 10

Operator Category	Equipment Population
Excavation Work	1,872
Highway and Street Construction	1,510
Water/Sewer Pipeline Construction	1,431
Utility Construction	682
Refuse Systems	470
Brick, Stone, and Related Materials	466
Concrete and Asphalt Work	453
Local Government	387
Oil and Gas Field Services	366
Environmental Quality	306

Harbor Vessel Model Year Distribution

Model Year	Engine Population
1956	2
1957	1
1958	2
1959	3
1962	2
1964	1
1967	1
1968	1
1969	2
1971	1
1972	1
1973	4
1974	5
1975	1
1977	5

Model Year	Engine Population
1978	5
1979	1
1980	7
1981	1
1982	1
1999	4
2001	13
2002	6
2003	71
2004	118
2005	111
2006	138
2007	85
(blank)	164
Grand Total	758

Harbor Vessel Makes & Models – Top 70%

Make	Model	Engine Population
Cummins	KTA19M3	111
Cummins	KTA38M0	62
DDEC	Series 60	45
Volvo	122 A	36
Volvo	D 12	36
Caterpillar	3508	31
EMD	8-645-E2	31
Caterpillar	C 18	22
Volvo	D 25	22
EMD	16-645C	18
Caterpillar	3512	18
Cummins	KTA38M2	18
Mitsubishi	S6A3MPTA	18
EMD	12-645-E2	18
EMD	16-567C-E2	18
EMD	8-645-E5	18

Harbor Vessel Horsepower Distribution

HP BIN	Engine Population
200 - 299	4
400 - 499	187
500 - 599	36
600 - 699	142
700 - 799	40
800 - 899	85
900 - 999	76
1000 - 1099	18
1100 - 1199	4
1200 - 1299	4
1400 - 1499	18

HP BIN	Engine Population
1500 - 1599	31
1600 - 1699	15
1800 - 1899	4
1900 - 1999	50
2000 - 2099	4
2100 - 2199	4
2300 - 2399	11
2500 - 2599	8
2800 - 2899	3
3000 - 3099	7
(blank)	5
Grand Total	758

Percent of Harbor Vessel Engines Repowered

Repowered?	Engine Population	% Population
NO	415.7	54.8%
YES	337.4	44.5%
(blank)	5	0.7%
Grand Total	758.1	

Construction Equipment Emissions Estimation

- NONROAD basis
- Texas-specific profiles and adjustments
- SIP-consistent lb/day *for each engine* (NO_x, VOC, PM)

Harbor Vessel Emissions Estimation

- SEPA emission factors – assume 100% maneuvering, medium-speed engines (not year-specific)
- EPA load factors (line-haul, assist, etc.)
- Hours of operation in area from survey
- Scaling survey results up to entire population
- TxLED adjustments

Baseline NOx Emissions

Sector	NOx TPD
Construction	31.5
Harbor Vessels	7.2

Technology Assessment

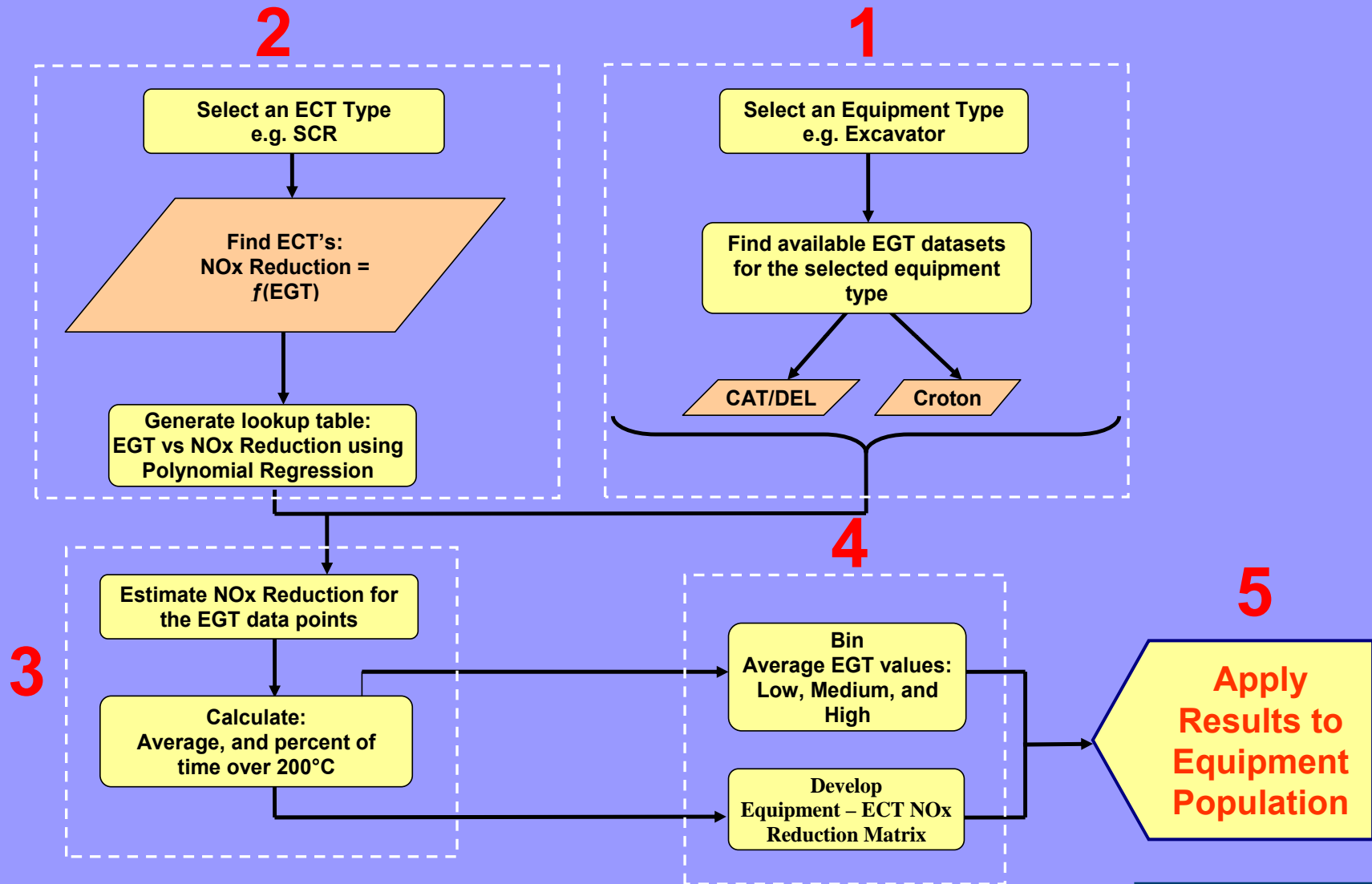
Equipment EGT

&

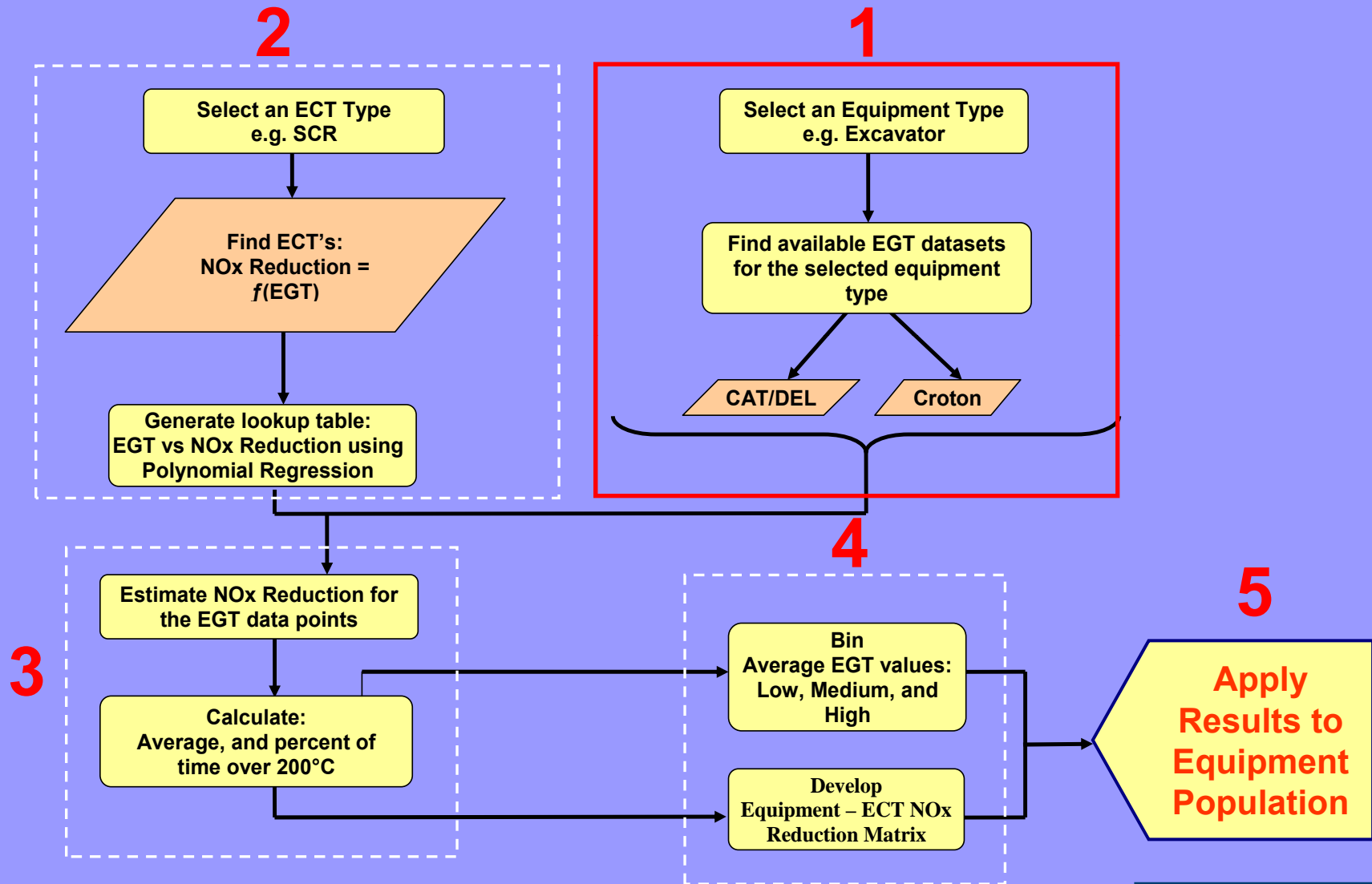
ECT NO_x Reduction

Matrix Development

Five Step Analytical Approach



Analytical Approach – Step 1

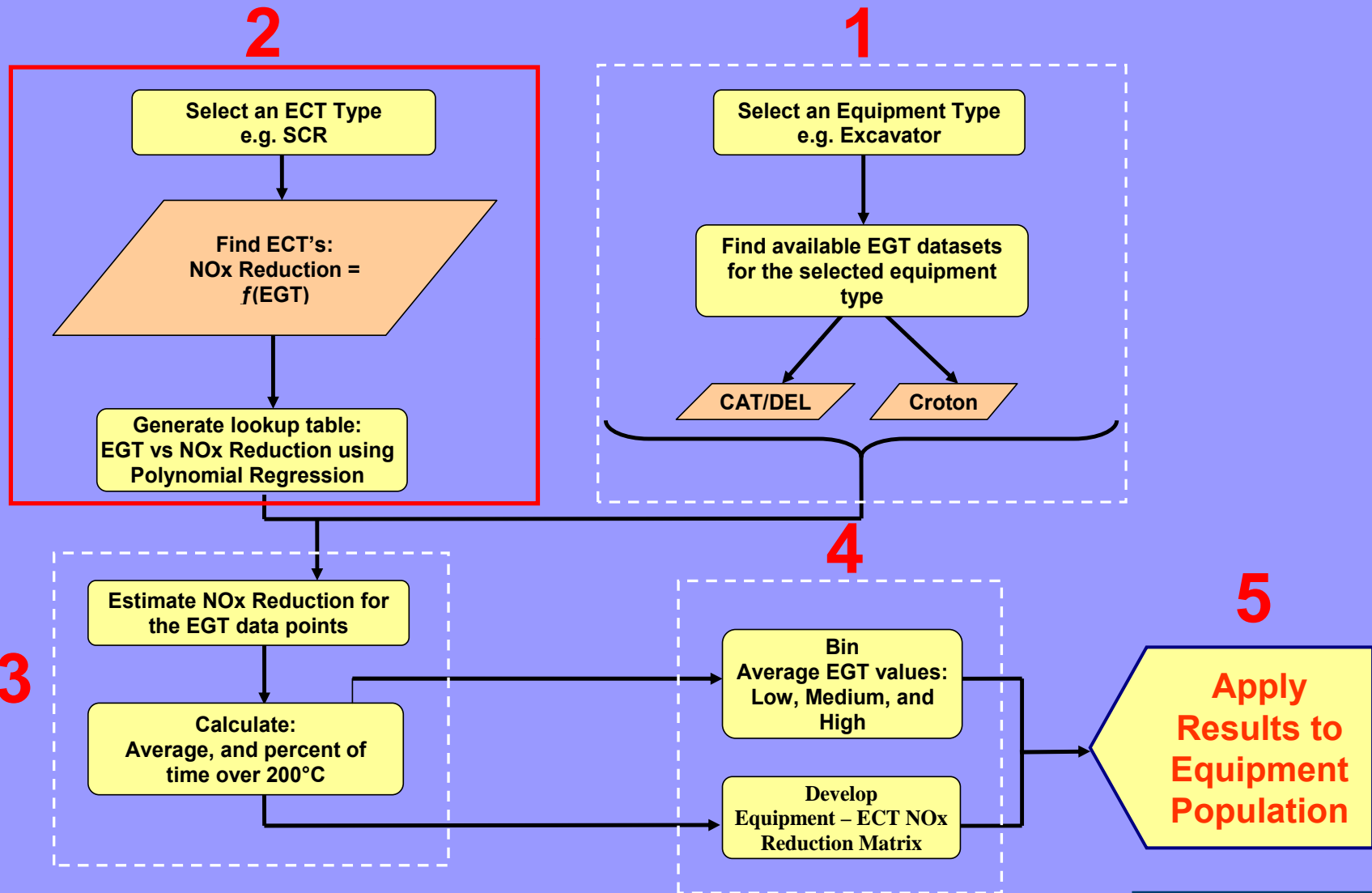


Step 1

Equipment EGT Datasets

Source	Organization	Objective(s) of In-Use Activity	Operations Description	Test Year	Location	Equipment Type	MY ¹	HP ²	EGT ³	MAP ⁴	Q _{eng} ⁵	Q _{act} ⁶	RPM	Torque
CAT/DEL	Emisstar	Evaluate the Local Law 77 compliance status of previously retrofitted equipment or to make “Best Available Technology” determinations for new non-retrofitted equipment	Excavation for UV water treatment plant	2006-2007	Valhalla, NY	Backhoe	1992	111	•	•	•		•	
						Dozer	1989-1999	95-189	•	•	•		•	
						Excavator	1993-2004	131-515	•	•	•		•	
						Motor Grader	1980	99	•	•	•		•	
						Quarry Truck	1988-2006	414	•	•	•		•	
						Wheel Loader	1988-1999	160-362	•	•	•		•	
Croton (Emisstar EGT data)	Emisstar	Evaluate the Local Law 77 compliance status of previously retrofitted equipment or to make “Best Available Technology” determinations for new non-retrofitted equipment	Excavation for under-ground filter-based water treatment plant	2006	Bronx, NY	Excavator	2004-2005	150-684	•					
						Hydraulic Drill	2006	225	•					
						Manlift	2000	64	•					
						Wheel Loader	2005	700	•					
Croton (EC Testing data)	Emisstar	Demonstrate and evaluate the performance of “best available” emission control technologies for reduction of PM and NOx emissions using in-use field testing approaches	Excavation for under-ground filter-based water treatment plant	2006	Bronx, NY	Compressor	2005	170	•		•			•
						Dozer	2004	332	•	•	•		•	
						Excavator	2004	474	•	•	•		•	
						Quarry Truck	2005	700	•		•			
						Wheel Loader	2004	259	•	•	•		•	
						Tiger Drill	2005	173	•		•		•	
DSNY	DSNY	Internal data collection for potential future retrofit	Unknown	Unknown	Queens, NY	Wheel Loader	1998	190						•
SPOT	EPA	Develop simple portable on-board emission testing system	Unknown	2002	Columbus, IN	Dozer	1985-1995	200-285	•			•	•	
						Excavator	1989	165	•			•	•	
						Wheel Loader	1983	285	•			•	•	
						Quarry Truck	2001	375	•			•	•	
WVU Scraper	WVU	Internal university project	Unknown	Unknown	Morgantown, WV	Scraper	NA	NA	•				•	•
Waste Management	Waste Management	Determine “Best Available Technology” determinations for new non-retrofitted equipment	Refuse treatment operations	2007	Bronx, NY	Compactor	2001-2007	340-442	•					
7 World Trade Center	Emisstar	EGT for prospective control technology matching	Construction of 35+ story commercial building	2002-2004	Manhattan, NY,	Crane	1970	500	•					
						Crane	1997	600	•					

Analytical Approach – Step 2

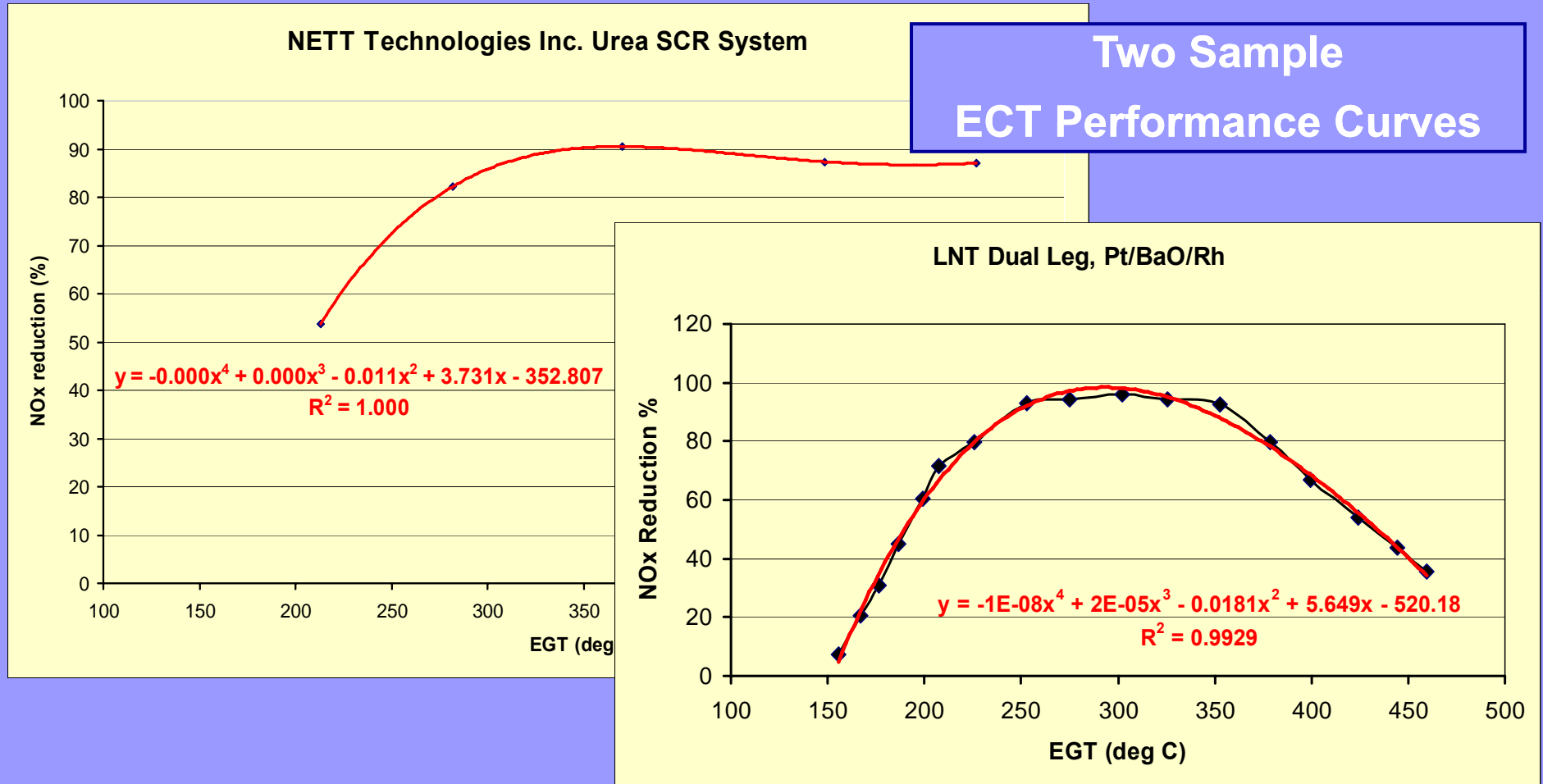


Step 2

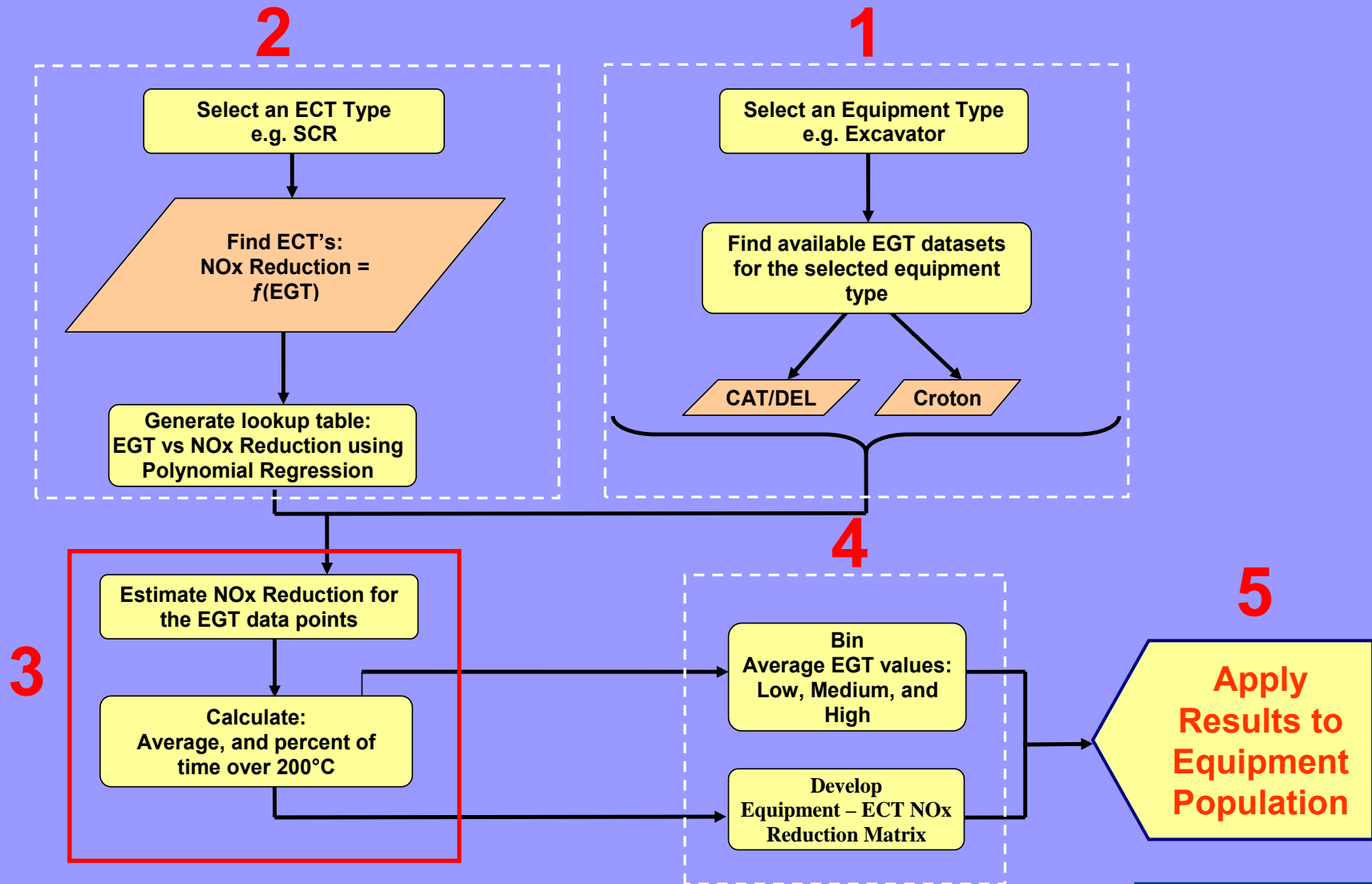
NO_x Reduction Lookup Tables Technologies Considered

1	LNT	LNT Theoretical	Pt/BaO/Rh
2		LNT Dual Leg	Pt/BaO/Rh
3		LNT Single Leg	Pt/BaO/Rh
4	LNC	LNC	Ag/AL ₂ O ₃
5		LNC	Ag/AL ₂ O ₃ w/Ethanol
6		LNC Copper Zeolite	Cu/ZSM-5
7		LNC Platinum/Alumina	Pt/AL ₂ O ₃
8	SCR	SCR Closed Loop Control	No DOC
9		SCR Open Loop Control	No DOC
10		SCR Vanadia	No DOC
11		SCR Vanadia	With DOC
12		SCR "Multi-Function"	non-vanadia Titania (TiO ₂)
13		SCR Closed Loop Control	V ₂ O ₅ /WO ₃ /TiO ₂
14		Nett Technologies SCR	Fe/ZSM; no DOC; closed loop
15	Combinations	LNT+SCR	NH ₃ → for SCR redux
16		H ₂ Assist LNT	Xonon Fuel Processor
17		HC Assist LNC	Reformer Assist

Step 2 Develop Lookup Tables / Match EGT Data With ECT NOx Reductions



Analytical Approach – Step 3



Step 3

Equipment Specific NO_x Reduction Estimation

- Estimate NO_x Reduction for the EGT Datapoints
- Calculate Average, and Percent of Time over 200 °C

Step 3

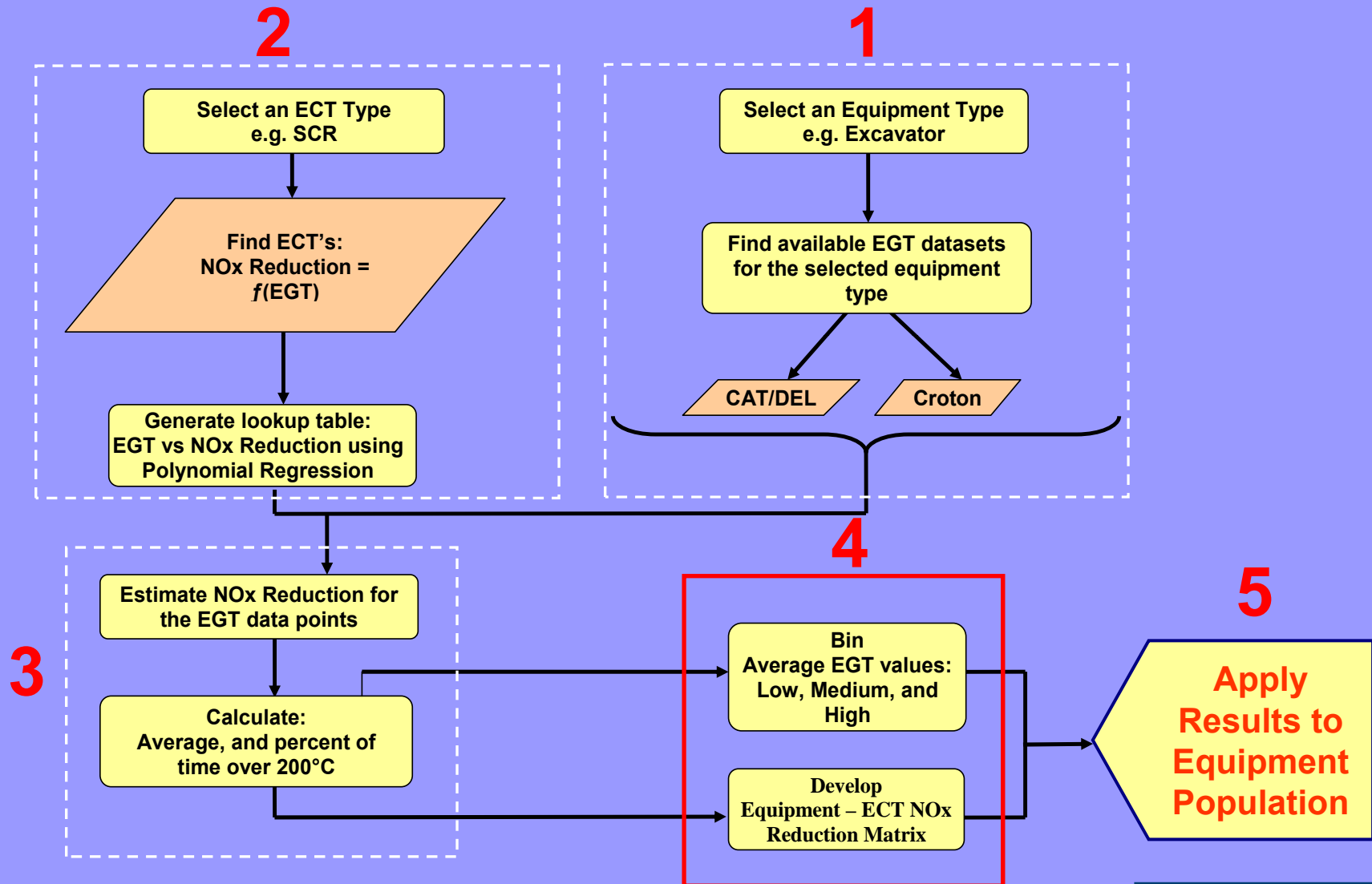
Equipment Specific NO_x Reduction Estimations

Example Outputs

No.	Duty Cycle Bin	Data Source	Equipment EGT Interval (sec)	Chassis				Engine			
				Type	Manufacturer	Model	Model Year	Manufacturer	Model	Model Year	Power (HP)
1	L	CAT/DEL	7	Backhoe	CAT	446 B	1992	CAT	3306	1992	111
43	H	Waste Management	5	Compactor	CAT	826G	2001	CAT	3406	2001	340
44	H	Waste Management	5	Compactor	BOMAG	BC772RB	2007	Deutz	TCD2015V06	2006	442
45	H	Croton WTP	1	Compressor	Ingersoll Rand	IR600	2005	John Deere	61RF8TE	2005	170
46	L	7 World Trade Center	60	Crane	Manitowac	1900	1970	Detroit Diesel	GM12VA59782	1970	500
47	M	7 World Trade Center	60	Crane	Manitowac	1900T	1997	Cummins	QSK19-0	1997	600
48	L	CAT/DEL	7	Dozer	CAT	D6H	1989	CAT	3306	1989	165
49	M	EPA SPOT	1	Dozer	CAT	D8N	1990	CAT	3406	1990	285

No.	Duty Cycle Bin	Data Source	Average EGT (°C)	Percent of Time over 200°C (%)	2004-01-0156	2005-01-1084
					LNT Dual	LNT Single
					Average NO _x Reduction Est. Over EGT Range (%)	Average NO _x Reduction Est. Over EGT Range (%)
1	L	CAT/DEL	145.18	4.9	51.5	39.9
43	H	Waste Management	318.55	70.9	58.1	61.4
44	H	Waste Management	365.45	78.7	53.8	59.4
45	H	Croton WTP	440.08	100.0	46.5	73.5
46	L	7 World Trade Center	156.15	8.0	34.6	18.7
47	M	7 World Trade Center	224.29	84.1	76.8	35.8
48	L	CAT/DEL	222.84	47.7	75.0	65.3
49	M	EPA SPOT	243.26	76.8	85.3	55.0

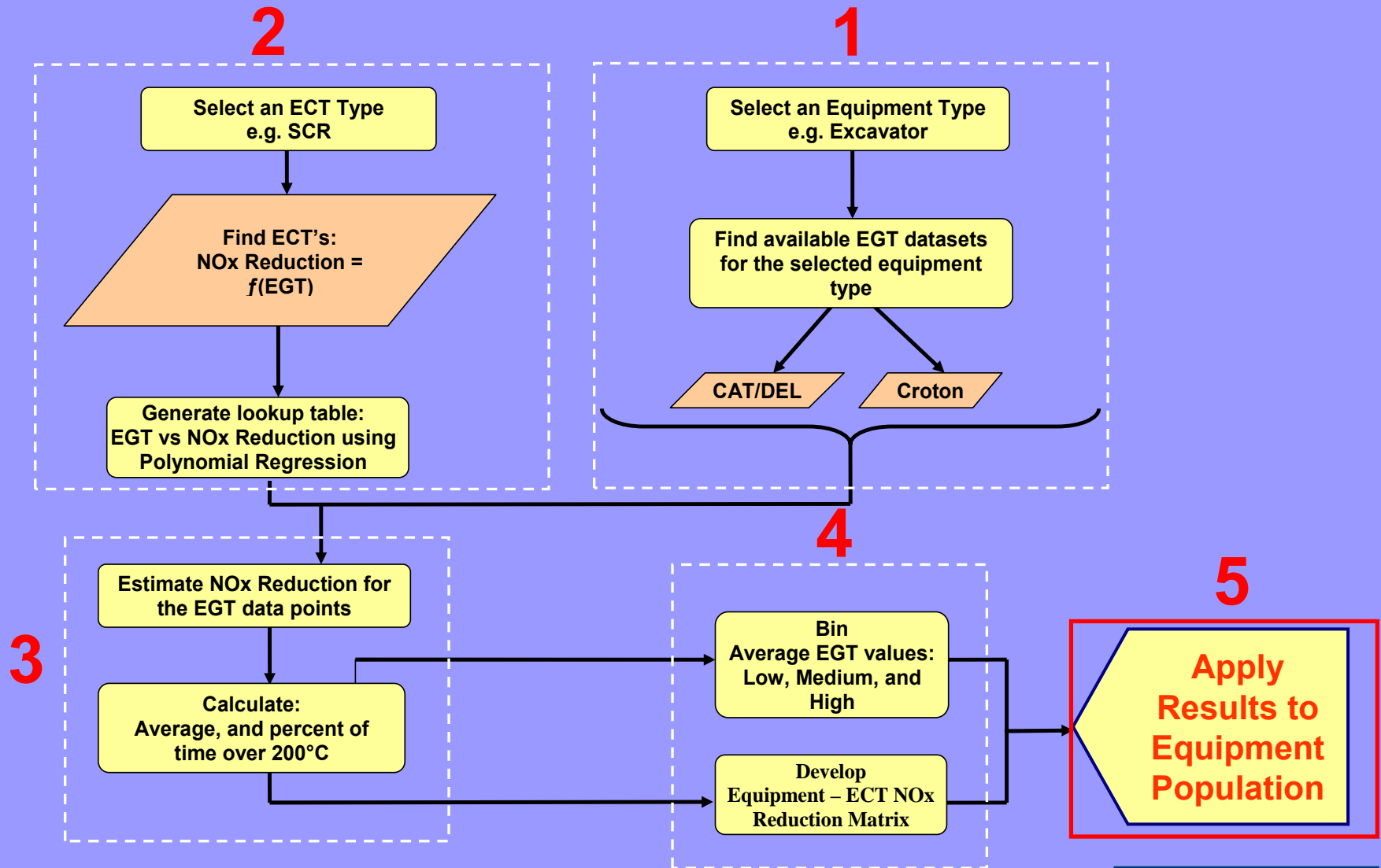
Analytical Approach – Step 4



Step 4 NO_x Reduction Matrix

- **Duty Cycle Development**
 - Binning Average EGT Values
 - Define Low, Medium, and High Duty Cycles
- **Develop Equipment–ECT NO_x Reduction Matrix**
 - Equipment w/o EGT Data (“HGB Equipment”)
 - Equipment Operation → Corresponding EGT
 - Engineering Judgment & Field Operations Suggests Good Correlation

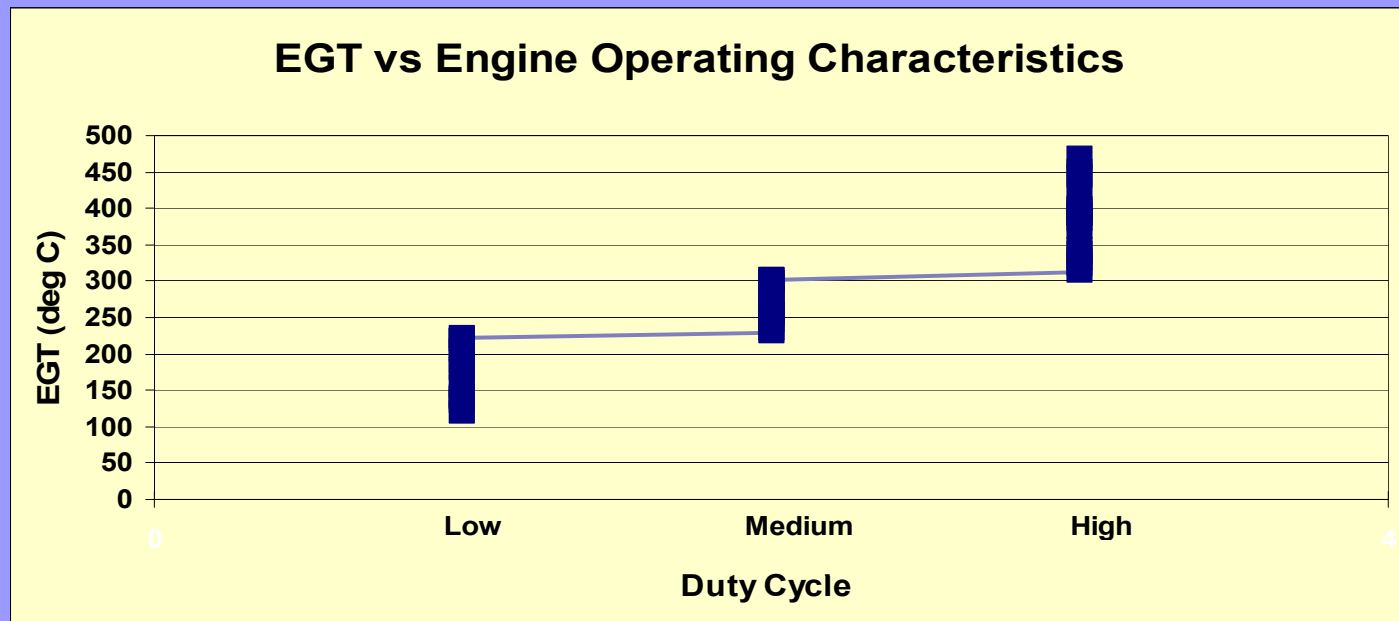
Analytical Approach – Step 5



Step 5

Outputs – HGB Equipment

- Development of EGT/Engine Operating Characteristics
 - Binning exercise – “L”, “M”, “H”
 - Assign representative EGT profile from one of 44 machines that best match equipment w/o EGT



Step 5

Outputs – HGB Equipment

Equipment Information				Emission Control Technology (ECT) Type/Description % NOx Reduction																	Data Source For Machines w/No EGT Data	
No.	Equipment Type	EGT/Load (L, M, H)	No. of Machines	% T >200 deg C	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16		17
					LNT Theoretical	LNT Dual Leg	LNT Single Leg	LNC Ag/AL2O3	LNC Ag/AL2O3 w/Ethanol	LNC CU Zeolite	LNC Pt/AL2O3	SCR Closed Loop Control (no DOC)	SCR Open Loop Control (no DOC)	SCR Vanadia, without DOC	SCR Vanadia, with DOC	SCR TiO2 (no vanadia)	SCR Vanadia (theoretical)	SCR, NETT Tech, Inc. FE/Zeolite	LNT+SCR	H2 Assisted LNT	HC Assisted LNC	
1	Backhoe	L	1	5	OEOR	52	40	OEOR	58	11	20	50	36	14	52	79	63	76	89	85	57	Used average of one each 95 HP Cat dozer and 131 HP Cat excavator, both "M" cycle. These two machines have similar HP and operations as backhoe
		M	0	67	47	75	63	13	74	30	18	74	59	62	78	91	82	84	85	91	76	
2	Compactors	H	2	75	43	56	60	28	82	33	17	80	55	65	74	90	88	86	84	90	84	
3	Cranes	L	1	8	OEOR	35	19	OEOR	43	OEOR	18	25	13	19	30	80	40	80	74	38		
		M	1	84	12	77	36	OEOR	52	OEOR	42	46	32	42	66	95	47	65	80	83	46	
4	Dozers	L	1	48	48	75	65	OEOR	77	35	15	76	60	63	77	91	84	85	86	92	78	
		M	4	71	49	77	63	OEOR	71	27	18	75	60	64	80	92	86	84	86	92	76	
5	Excavators	H	5	90	65	65	72	16	85	44	OEOR	84	69	74	84	92	93	84	86	96	87	
		L	2	42	30	73	57	OEOR	59	17	22	69	54	50	73	90	76	80	84	89	69	
		M	7	73	54	78	67	OEOR	73	31	16	79	64	67	82	92	85	85	86	93	79	
6	Gen Sets	H	2	84	58	55	65	27	84	38	10	83	68	69	69	90	91	87	79	94	87	
		L	1	100	58	47	73	19	86	41	OEOR	88	72	79	85	91	96	89	62	98	91	
7	Grader	L	1	14	OEOR	62	38	OEOR	57	12	25	48	34	39	56	88	66	78	90	86	59	
8	Lifts	L	1	7	10	58	49	OEOR	67	22	19	59	45	36	61	85	76	82	88	89	69	
9	Loaders	L	1	27	18	73	56	OEOR	61	17	21	70	55	61	73	88	76	81	92	90	70	
		M	3	67	47	77	64	18	72	28	17	77	62	66	81	92	83	84	87	92	77	
		H	2	93	70	71	75	12	86	46	8	86	70	77	85	92	93	87	75	97	87	
10	Offroad Trucks	L	2	62	29	75	45	OEOR	54	9	30	57	43	50	69	93	65	72	89	86	59	
		M	4	80	41	82	54	OEOR	58	14	27	67	52	60	78	94	72	79	91	88	66	
11	Pipe Layers	M	0	72	51	78	64	OEOR	70	26	18	77	62	66	81	92	83	84	88	92	77	Used average of four excavators (three Cat, one Komatsu) with "M" Duty-Cycle, 128-321 HP. Seven Pipe Layers in the 100-175 HP range, only one in the 300-500 HP range
12	Reclaimers, Stabilizers, Milling Machines	H	0	75	48	55	65	27	84	38	10	83	68	59	69	90	91	87	79	94	87	Used average of two high HP excavators (Hitachi/Isuzu & Komatsu), "H" cycle. Reclaimers are high HP and have same SIC code as excavators (assumption of similar operations).
13	Rough Terrain Forklift	L	0	5	OEOR	52	40	OEOR	58	11	20	50	36	14	52	79	63	76	89	85	57	Used one Cat backhoe, "L" as it has similar HP (<200) and operations as rough terrain forklift.
		M	0	67	47	75	63	13	74	30	18	74	59	62	78	91	82	84	85	91	76	Used same approach as per backhoe "M" (see above) as it has similar HP (<200) and operations as rough terrain forklift.
14	Scrapers	M	1	57	34	68	58	15	74	25	19	72	57	54	74	90	81	83	87	90	75	
15	Steady-State Machines (Compressors, Pumps)	H	0	100	58	47	73	19	86	41	OEOR	88	72	79	85	91	96	89	62	98	91	Used one IR/Deere compressor w/"H" cycle to represent all "steady-state" machines.
16	Surfacing & Paving Equipment	H	0	100	58	47	73	19	86	41	OEOR	88	72	79	85	91	96	89	62	98	91	Used one IR/Deere compressor w/"H" cycle to represent "surf and paving" machines as they have similar HP (<200) & operations.
17	Trenchers	H	0	100	73	71	76	19	75	36	5	90	74	84	91	93	95	88	78	99	88	Used average of one IR/Deere compressor and one Tamrock/CAT hydraulic drill to represent trenchers as they are all of similar HP (<175) and have similar operation (quasi "steady-state").
18	Boring and Drilling	M	1	97	52	91	59	OEOR	55	12	27	74	59	69	87	96	73	78	92	90	68	
		H	1	100	87	95	78	OEOR	64	31	OEOR	92	75	88	96	96	93	89	94	97	86	
OEOR "Out (of) ECT Operating Range"					Max	87	95	78	28	86	46	42	92	75	88	96	96	96	89	94	99	91
					Min	10	35	19	12	43	9	5	25	13	14	30	79	40	65	62	38	46
					AV	47	67	59	19	70	28	19	72	57	58	74	90	80	83	83	90	75
					LNT Av = 58				LNC Av = 34				SCR Av = 72				Comb Av = 83					

Step 5

Outputs – HGB Equipment (detail)

No.	Equipment Type	EGT/Load (L, M, H)	No. of Machines	% T >200 deg C	1	2	3	4
					LNT Theoretical	LNT Dual Leg	LNT Single Leg	LNC Ag/AL2O3
1	Backhoe	L	1	5	OEOR	52	40	OEOR
		M	0	67	47	75	63	13
2	Compactors	H	2	75	43	56	60	28
3	Cranes	L	1	8	OEOR	35	19	OEOR
		M	1	84	12	77	36	OEOR
4	Dozers	L	1	48	48	75	65	OEOR
		M	4	71	49	77	63	OEOR
		H	5	90	65	68	72	16
5	Excavators	L	2	42	30	73	57	OEOR
		M	7	73	54	78	67	OEOR
		H	2	84	48	55	65	27

**OEOR: Out of ECT Operating Range

Constraints and Caveats

- *Exhaust Gas Temperature (EGT)*
- Space Velocity
- Transient Operation
- NO/NO₂ Ratio
- Reductant Injection and Mixing
- Control Technology/Engine Turbocharger
Outlet Orientation

GUI Development

- Front-end for dbase management
- Facilitates grouping/analysis by
 - Equipment type
 - Engine make/model/year
 - HP range
 - “Load category”
 - Operator SIC and county
- Separate interfaces for different applications

GUI – Emissions Calculator

frmRegulators : Form

Emissions Calculator

* - denotes a required filter

Field Name **Filter Criteria**

Sector: Construction

County: (No Filter)

Equipment Type: EXCAVATOR

Standard Industrial Classification: (No Filter)

* Engine Control Technology: SCR Open Loop Control (no DOC)

* Load: M

Year: to

HP Range: to

Pollutants

NOx (ppd)

PM2.5 (ppd)

VOC (ppd)

Group Results By: SIC

Calculate Export Results

Reset Defaults Exit Regulatory Calculator

SIC	NOx Emissions	Adjusted NOx	PM	Population	AvgHP	AvgNOxRedu
REPAIR SERVICES NEC	1,412.6	508.5	115	233,042	222.3	64.0
RESIDENTIAL CONSTRUCTION NEC	16.4	5.9	0.7	4,717	247.0	64.0
RETAIL NURSERIES & GARDEN STORES	5.8	2.1	0.9	2,422	94.0	63.8
RICE	7.9	2.8	0.7	2,763	168.0	64.6
SANITARY SERVICES NEC	19.6	7.0	1.6	1,844	176.0	64.3
SCRAP AND WASTE MATERIALS	867.1	312.2	69.9	121,972	231.7	64.0
SPECIAL TRADE CONTRACTORS NEC	83.6	30.1	7.6	20,011	128.0	64.0
SUBDIVIDERS & DEVELOPERS NEC	347.1	125.0	28.5	57,260	222.0	64.0
TOWING SERVICES	347.1	125.0	28.5	57,260	222.0	64.0
TRUCK SERVICE	437.2	157.4	30.3	77,617	242.7	64.0
TRUCKING (LOCAL AND LONG DISTANCE)	24.2	8.7	2.0	3,994	228.0	64.0
UNDERGROUND STORAGE TANK REM INST	88.5	31.9	6.0	20,543	227.2	64.0

Record: 14 of 37

frmRegulators : Form

Emissions Calculator

* - denotes a required filter

Field Name **Filter Criteria**

Sector: Construction

County: (No Filter)

Equipment Type: EXCAVATOR

Standard Industrial Classification: (No Filter)

* Engine Control Technology: SCR Closed Loop Control (no DOC)

* Load: M

Year: to

HP Range: to

Pollutants

NOx (ppd)

PM2.5 (ppd)

VOC (ppd)

Group Results By: SIC

Calculate Export Results

Reset Defaults Exit Regulatory Calculator

SIC	NOx Emissions	Adjusted NOx	PM	Population	AvgHP	AvgNOxRedu
REPAIR SERVICES NEC	1,412.6	296.6	115	233,042	222.3	79.0
RESIDENTIAL CONSTRUCTION NEC	16.4	3.4	0.7	4,717	247.0	79.3
RETAIL NURSERIES & GARDEN STORES	5.8	1.2	0.9	2,422	94.0	79.3
RICE	7.9	1.7	0.7	2,763	168.0	78.5
SANITARY SERVICES NEC	19.6	4.1	1.6	1,844	176.0	79.1
SCRAP AND WASTE MATERIALS	867.1	182.1	69.9	121,972	231.7	79.0
SPECIAL TRADE CONTRACTORS NEC	83.6	17.6	7.6	20,011	128.0	76.9
SUBDIVIDERS & DEVELOPERS NEC	347.1	72.9	28.5	57,260	222.0	79.0
TOWING SERVICES	347.1	72.9	28.5	57,260	222.0	79.0
TRUCK SERVICE	437.2	91.8	30.3	77,617	242.7	79.0
TRUCKING (LOCAL AND LONG DISTANCE)	24.2	5.1	2.0	3,994	228.0	78.9
UNDERGROUND STORAGE TANK REM INST	88.5	18.6	6.0	20,543	227.2	79.0

Record: 1 of 37

GUI – Equipment Data Lookup

frmVendors : Form

Equipment Data Lookup

* - denotes a required filter

Field Name	Filter Criteria
* Engine Control Technology	SCR Open Loop Control (no DOC)
Sector	Construction
Equipment Type	EXCAVATOR
Equipment Make	(No Filter)
Equipment Model	(No Filter)
Engine Make	(No Filter)
Engine Model	(No Filter)
Standard Industrial Classification	(No Filter)
* Load	M
Year	to
HP Range	to

Calculate

Export Results

Reset Defaults

Exit Vendor Data Lookup

Pollutants

NOx (ppd)

PM2.5 (ppd)

VOC (ppd)

ECT Desc	Sector	EDA_BASE_EC	EQTMAN	EQTMODEL	EDA_BASE_Er	EDA_BASE_Er	Year
▶ SCR Open Loop	Construction	EXCAVATOR	CAT	330-B	Caterpillar	3306 TA	
SCR Open Loop	Construction	EXCAVATOR	CAT	330-B	Caterpillar	3306 TA	
SCR Open Loop	Construction	EXCAVATOR	CAT	330-B	Caterpillar	3306 TA	
SCR Open Loop	Construction	EXCAVATOR	CAT	330-B	Caterpillar	3306 TA	
SCR Open Loop	Construction	EXCAVATOR	CAT	330-B	Caterpillar	3306 TA	
SCR Open Loop	Construction	EXCAVATOR	CAT	330-B	Caterpillar	3306 TA	

Record: 1 of 4064

Totals:

Population	NOX Emissions	Adjusted NOx	PM Emissions
▶ 10,106.255	39,226.2	14,905.9	2,826.2

Record: 1 of 1

GUI – Equipment Details

- Buyer category
- Equipment type
- Equipment make/model
- Equipment population
- Engine make/model/year
- HP
- Displacement
- Cylinders
- Rated RPM
- Aspiration
- Fuel system
- Tier Level
- Engine family code
- Emission control system
- NOx certification limit
- NOx FEL
- % time > 200 °C
- Emission control type
- NOx/PM/VOC lb/day
- NOx % Reduction

NOx Emission Reduction Potentials (TPD for selected Equipment Types/ECTs)

<u>Equipment Type</u>	Control Technology		
	<u>HAM</u>	<u>SCR Open Loop</u>	<u>SCR Closed Loop</u>
Harbor Vessels	5.1	-	-
Excavators	-	6.5	8.0

Opportunities for Improvement

- Integration of National PEMS study data
- Refined scrap functions/projections
- Regional fleet variability
- More equipment EGT datasets – gap fill
- EGT – Engine Operating Relationship
- Further ECT assessment & research –
detail and expansion

Future Applications

- Fleet-specific evaluations (e.g., large public fleets such as state DOTs)
- Other regional & local areas
- Nationwide coverage?
- Cost-effectiveness module
- New nonroad applications
 - Commercial/industrial equipment
 - Locomotives?

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