METHODOLOGICAL GUIDE

Programa Clima y Aire limpio en Ciudades de América Latina

METHODOLOGICAL GUIDE FOR DEVELOPING THE NON-ROAD MOBILE MACHINERY INVENTORY

(Machinery population estimate)

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Agencia Suiza para el Desarrollo y la Cooperación COSUDE

swisscontact

CALAC+ is an SDC programme implemented by Swisscontact

Methodological guide for developing the non-road mobile machinery inventory (Machinery population estimate)

Document prepared within the framework of the Climate and Clean Air project in Latin American Cities Plus - CALAC+ (Phase 1) financed by the Swiss Agency for Development and Cooperation - SDC and implemented by the Swiss Foundation for Technical Cooperation - Swisscontact

Prepared by:

Mijahil Alyosha Kingdon Duran
Non-Road Machinery Expert

Reviewed by:

Adrian Montalvo
CALAC+ Program Director

Helberth Santiago Morales Pinilla
CALAC+ Non-Road Coordinator

Guisselle Nancy Castillo Coila
CALAC+ Coordinator for Peru

Cover photo:

TECSUP headquarters in Lima, Peru; AVESCO Langenthal Switzerland (below); Skid-steer loader on public roads in Lima, Peru (above)

Edition: February 2020

The Climate and Clean Air project in Latin American Cities Plus (CALAC+) pursues a vision of healthier cities that seek to reduce their emissions of pollutants and greenhouse gases (GHGs) by encouraging a shift to soot-free, low-carbon city buses and non-road mobile machinery.

This guide is part of a series of 7 technical documents developed by CALAC+ to promote knowledge and environmental management of machinery emissions reduction in Latin America. The topics covered include the generation of inventories, estimation of pollutants, emission control systems, regulatory standards policies and monitoring of measures adopted.

The *Methodological guide for developing the non-road mobile machinery inventory* provides a standardized vision to be used by decision makers to encourage the creation and regular updating of inventories for the adoption of measures that reduce environmental and health impacts.

Content

1. INTRODUCTION

This methodology is aimed at preparing an inventory of Non-road Mobile Machinery (NRMM) in the countries of the Climate and Clean Air project in Latin American Cities Plus (CALAC+)[1]. In that sense, it gathers the experiences and regional particularities involved in preparing those inventories, the Chilean experience being a relevant source of information when estimating its inventory for 2013[2].

A fundamental aspect in developing the inventory is the information available for characterizing the fleet. The Customs database with machinery imports is considered in this case. This is useful in countries that are not manufacturers of this type of equipment, since imports are the main sales register. Other cases should be included in the statistics on domestic manufacture.

The Customs databases include information regarding the date of import, country of origin, information on the importing company, quantity of machinery, in addition to a summary describing the goods, which allows additional information to be obtained, such as equipment type (excavator, front loader, motor grader, etc.), power (in kW, HP or CV), fuel (diesel, gasoline or gas) and sector (agricultural, construction, forestry, industrial or mining). All this information is necessary for the proper classification of the fleet and further calculation of emissions.

Machinery with diesel engines between 19 and 560 [kW][3] has been included in this methodology, as well as in the European legislation from Stage II to Stage IV standard. This considers the fact that WHO has declared diesel emissions to be carcinogenic in the highest risk group (Group 1)[4], as well as the second largest greenhouse gas pollutant[5], after carbon dioxide.

As for gasoline engines, although they generally represent a large number, they have a lower share of emissions considering their activity[6] and the smaller size of the engines[7]. Nevertheless, given these priorities, it is advisable to constantly improve these inventories across all power ranges and fuels.

The methodology presented below allows the estimation of the fleet or machinery inventory as a base methodology applicable in CALAC+ countries, given that they have similar characteristics of available information and market behaviour of NRMM.

---

[1] The cities of Bogota, Mexico City, Lima and Santiago de Chile are currently participating in this initiative.

[2] [GEASUR 2013]

[3] This power range corresponds to that regulated by European legislation from Stage II to Stage IV, for diesel engines. It considers the maximum net power as the reference power (see definition in EU Regulation 2016/1628).

[4] International Agency for Research on Cancer, WHO Press Release N° 213 – 2012.

[5] IPCC AR5 WG1, Chapter 8, 2013

[6] As an example, the results of the Swiss inventory indicate a share in energy consumption, in [PJ], of non-road engines of 88% for diesel and 12% for gasoline. However, non-road gasoline engines are four times the number of diesel engines in this inventory.

[7] European Union legislation considers them to be below 19 [kW] up to Stage IV.

Table1: Examples of Chilean Customs headings for NRMM

CHAPTER 87	
Heading	**Description**
87013000	Caterpillar tractors
87019011	Wheeled tractors. Agricultural
87019012	Wheeled tractors. Forestry
87019019	Wheeled tractors. Others
87019090	Other tractors
87041010	Motor vehicles for transporting goods. Dumpers designed for off-road use - with a load capacity not exceeding 30 tons
87041090	Motor vehicles for transporting goods. Dumpers designed for off-road use - others
87042140	Others, with compression-ignition engine (diesel or semi-diesel) - Of a gross vehicle weight not exceeding 5 tons. Vehicles for off-road transport
87042240	Others, with compression-ignition engine (diesel or semi-diesel) - Of a gross vehicle weight exceeding 5 tons but not exceeding 20 tons. Vehicles for off-road transport
87042321	Others, with compression-ignition engine (diesel or semi-diesel) - Of a gross vehicle weight exceeding 20 tons. Off-road vehicles: Mining trucks
87042329	Others, with compression-ignition engine (diesel or semi-diesel) - Of a gross vehicle weight exceeding 20 tons. Vehicles for off-road transport: other trucks
87043140	Others, with spark-ignition engine - Of a total weight not exceeding 5 tons. Vehicles for off-road transport
87049040	Others: With spark-ignition engine. Vehicles for off-road transport
87091900	Forklift trucks without a lifting device, of the type used in factories, warehouses, dock areas or airports for short distance transport of goods. Others

Source: Prepared by the authors.

2. CUSTOMS DATABASE CLEANUP

To use the NRMM fleet inventory in the calculation of emissions, the most relevant information is equipment type, engine power, fuel type, sector, age, and emission standard met. This chapter describes the assumptions and criteria to be used for characterizing the fleet based on the information from Customs.

Typology

The characterization of the **type of non-road mobile machinery (NRMM)** is carried out according to the reference definitions contained in the European Union Emission Inventory methodologies called EMEP/EEA Air Pollutant Inventory Guidebook 2013 [CORINAIR 2013], specifically item 2.2 of Chapter 1.A.4. “Non-road mobile sources and machinery”, and in Appendix B of the document “User’s Guide for the Final NONROAD2005 Model” [EPA 2005][8] of the United States Environmental Agency (EPA).

However, the NRMM may have different denominations depending on the country in which it is used and the language of the local construction guilds. Therefore, based on the equipment types defined in these methodologies and by doing a thorough clean-up of the descriptions of imported goods in the customs databases, the terminology should be harmonized with the reference rates.

[8] The reference document "User's Guide for the Final NONROAD2005 Model" has not been modified to date with respect to the equipment types defined in the EPA's Move2014b emissions model.

EXAMPLE 1

As an example, Table2harmonization of terms used in Chile where the column "Customs certification as per classification” contains the names found in the Customs description that were replaced by the agreed typology. An illustrative reference image is also provided to identify the machinery.

Table2: Typologies and definitions of non-road machinery

Typology	Definition	Customs certification as per classification	Reference image
Asphalt paver	Self-propelled machinery used for paving	Paver, asphalt finisher, paving machine.	
Sweeper	Self-propelled sweeping vehicles.	Sweeper	
Bulldozer	A type of grader that pushes and excavates the earth (it is not possible to load materials on hopper trucks). It is mainly used in construction and mining.	Front dozer, crawler dozer	
Off-road truck	Large dumpers for off-road use.	Dumper, tipper, hopper truck and dumper with power over 50 kW	
Log forwarder	Forestry equipment, typically looks like excavators or grapple loaders that usually load entire logs, for transport.	Skidder, forwarder	

Typology	Definition	Customs certification as per classification	Reference image
Front loader	Front loading with a front-mounted bucket for shovelling, although you can use other attachments instead of a scoop.	Loader, front-end loader	
Harvester	Mowing equipment for harvesting and baling	Harvester, reaper, thresher	
Dumper	Small loaders or trucks, for confined spaces and light loads. They are generally used for small construction projects.	Dumper with power less than 50 kW.	
Excavator	Wheeled or crawler excavators, designed primarily for excavating with a bucket or scoop.	Excavator	
Forklift	Forklifts used in warehouses, storage facilities, industries and other general purposes. For lifting materials.	Forklift, forklift truck used in the industrial sector	
Rough terrain forklifts	They can be confused with typical forklifts but have more robust wheels for off-road work. Used in construction, mining, forestry and agriculture.	Forklift trucks, forklifts used in the construction, mining, forestry and agriculture sectors	

Typology	Definition	Customs certification as per classification	Reference image
Telescopic crane	Self-propelled cranes using lifting cables. Not to be confused with truck-mounted or other on-road equipment.	Telescopic crane, cranes.	
Skid-steer loader	It is a small kind of front loader that uses a scoop as its main attachment. You can use other equipment such as a drill.	Skid-steer loader	
Mini-excavator	Generally, chain-mounted, it is a self-propelled machine designed mainly for digging with a bucket.	Mini-excavator	
Motor grader	Used to prepare a site, especially a road for paving.	Grader, motor grader	
Telescopic handler	Self-propelled machinery for handling objects at height.	Telescopic handler, telehandler	

Typology	**Definition**	**Customs certification as per classification**	**Reference image**
Other agricultural equipment	Other types of special farming and agricultural equipment not specified above (grape harvester, sowing machine)	Grape harvester, sowing machine, shaker, grape harvesting machine	
Other construction equipment	It classifies the previously uncategorized equipment used in the construction industry.	Pipelayer	
Other equipment in underground mines	Classifies previously uncategorized equipment used for tunnelling as specially designed to work in confined spaces (tunnelling machine)	Tunnel-boring machine, tunnelling machine	
Drill	Self-propelled drilling equipment used for earth movement.	Drill	
Telescopic boom lifts	Telescopic boom lifts (articulated, scissors, and others) - aerial lifts for personnel also called manlifts.	Aerial lift, scissor lift, telescopic boom	
Snowplough	Self-propelled snow removal machinery. Not to be confused with attachments used on other road vehicles.	Snowplough	

Typology	Definition	Customs certification as per classification	Reference image
Backhoe	Multipurpose machinery that has a loader and a bucket. It fulfils the function of an excavator and a front loader.	Backhoe	
Roller	Self-propelled rollers used to flatten or compact the earth (not to be confused with smaller plate compactors)	Compaction roller, road roller	
Tractor	Large and small tractors, used for hauling, pulling or pushing. Used in construction and mining.	Tractors used in the construction and mining industry.	
Agricultural tractor	Large and small tractors used for hauling, pulling or pushing. For agricultural use.	Tractor used in the agricultural sector.	
Trencher	Large and small trenching machines that normally use a rotating blade at the front to pull the trenching material to one side.	Trenching machine	

Source: [Geasur 2014]

From the same source of information already cited ([CORINAIR 2013] and [EPA2005]), a classification can also be obtained of non-road mobile machinery according to the sector in which it is used.

Table 3: Non-road machinery (NRMM) typology by sector

Sectors	NRMM
Agricultural	Harvester
	Leaf stripper
	Weed puller
	Harvesting machine
	Telescopic boom lift
	Shaker
	Seed drill
	Tractor
	Thresher
	Trencher
Forestry	Log skidder
	Log forwarder
	Telescopic crane
	Roller
	Tractor
Mining	Skid-steer loader
	Bulldozer
	Hopper truck
	Front loader
	Dumper
	Excavator
	Fork crane
	Tunnelling machine
	Motor grader
	Drill
	Backhoe
	Roller

Sectors	NRMM
Construction	Asphalt paver
	Bulldozer
	Front loader
	Dumper
	Excavator
	Telescopic crane
	Telescopic handler
	Tunnelling machine
	Skid-steer loader
	Mini-excavator
	Motor grader
	Drill
	Telescopic boom lift
	Backhoe
	Roller
	Pipelayer
	Trencher
Industry	Fork crane
	Front loader
	Telescopic crane
	Telescopic handler
	Telescopic boom lift
	Roller

Source: [CORINAIR 2013] and [EPA2005]

Power

In the case of the engine reference power, the descriptive summary contained in the imports databases can be considered, which may appear in units of [hp], [HP] or [kW]. The power information obtained by engine make/model from the machinery can also be used from catalogues available on the Internet (such as http://www.ritchiespecs.com). Overall, this methodology can be used to characterize most of the fleet (64% for the case of the inventory in Chile).

The missing power can be allocated from the existing information. To do this, the machinery fleet must be grouped with information on power, by sector and equipment type, or at least by equipment type (in the absence of a sector). Then, the power share and the average power value by power range (ranges defined in [EPA 2008]) should be obtained. Finally, the fleet by type and sector should be distributed in the defined power ranges, assigning the corresponding average power value. This extrapolation of power values to the fleet without information is applicable only when there is no other source of information available (industry, guilds, surveys, etc.), to complete the missing information.

EXAMPLE 2

The following is an example of extrapolation of power values to the fleet without information:

Step 1: Estimation of the share by power range in the fleet with information, classified by equipment type and sector. In this case, skid-steer loaders in the construction sector.

Table 4: Share by power ranges
Skid-steer loaders from the construction sector

Power ranges	Fleet share	Average power [Kw]
19 - 37	11.77%	33
37 - 56	64.12%	45
56 - 75	24.11%	60
Grand total	**100.00%**	

Source: [Geasur 2014]

Step 2: Randomly assign the fleet without information to the power ranges, respecting the percentages of share of the fleet with information. One way, among many others, to randomly assign the power ranges, is to generate a random order without repetition, for the fleet without information. The list is then sorted according to this random index and each power range is assigned in an orderly fashion until the assigned share is completed.

Random order with no repetition assigned.

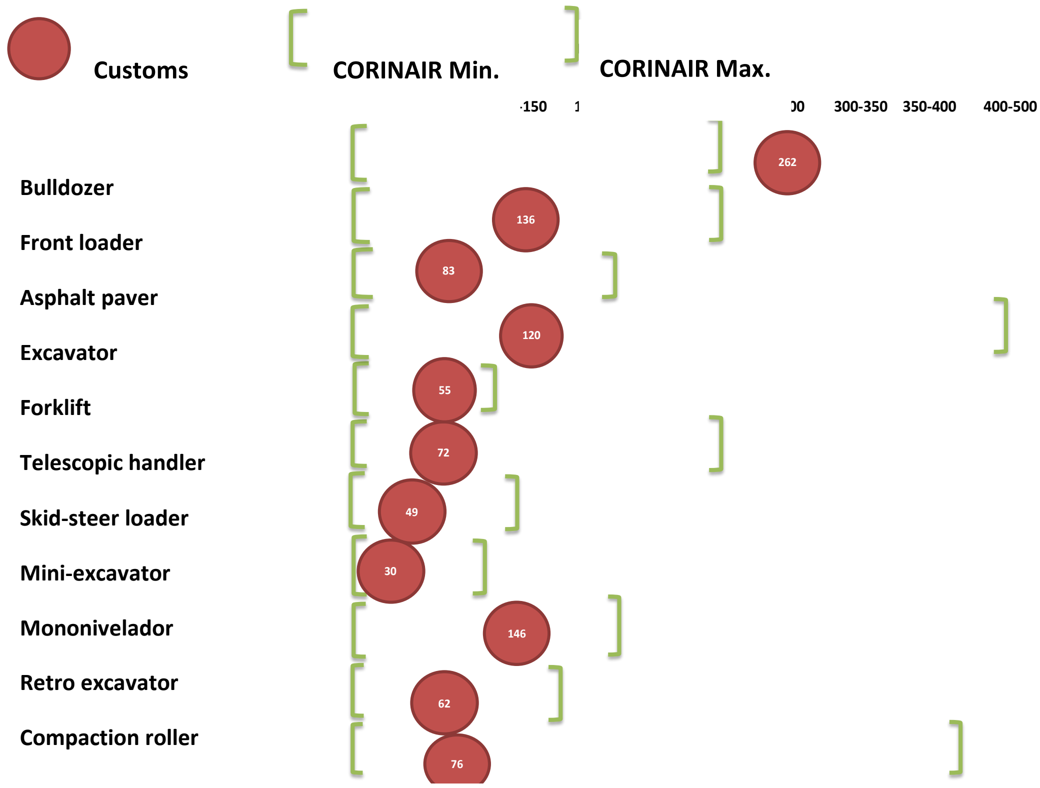
Power range and average power assigned according to share in fleet with information.

RANDOM ORDER	DATE	YEAR	ORIGIN	Q GOODS	EQUIPMENT TYPE	SECTOR	POWER RANGE Kw	AVERAGE POWER Kw
1	05-Jun-08	2008	U.S.A.	1	Skid-steer loader	Construction	19 - 37	33
2	17-Sept-08	2008	JAPAN	1	Skid-steer loader	Construction	37 - 56	45
3	17-Oct-08	2008	U.S.A.	1	Skid-steer loader	Construction	37 - 56	45
4	26-Sept-02	2002	CHINA	1	Skid-steer loader	Construction	37 - 56	45
5	12-Jun-08	2008	CHINA	1	Skid-steer loader	Construction	37 - 56	45
6	18-May-12	2012	CZECH REPUBLIC	1	Skid-steer loader	Construction	37 - 56	45
7	Sept. 8, 2010	2010	U.S.A.	1	Skid-steer loader	Construction	37 - 56	45
8	02-Sept-11	2011	U.S.A.	1	Skid-steer loader	Construction	37 - 56	45
9	12-Oct-07	2007	JAPAN	1	Skid-steer loader	Construction	56 - 75	60
10	04-May-12	2012	U.S.A.	1	Skid-steer loader	Construction	56 - 75	60

Source: [Geasur 2014]

This provides 100% of the power. Figure 1 shows the average power obtained by sector and type for the inventory in Chile. In this case the average powers obtained during the database clean-up were compared with the range established in [CORINAIR 2013] by equipment type, showing that the information is maintained around these values, except for bulldozers where the Customs values are higher than the maximum by 4.8%. All other values are within the international range as shown in the figure below.

Figure 1: Comparison [Corinair 2013] and Customs, Construction



Source: [Geasur 2014]

Sector

To define the sector, several clean-up steps must be taken since this does not depend only on the equipment type, but rather on the use that is given to it.

Four sectors are considered, with reference to those internationally defined in the supporting documentation ([CORINAIR2013] and [EPA2005]): Agricultural-Forestry, Construction, Industrial and Mining.

The following criteria can be used to classify the fleet according to sectors:

- The information of the sector for which the machinery is imported is used and is sometimes explicitly indicated in the Customs database.
- Imported machinery only applies to a specific sector, for example, harvesters apply to the agricultural sector or pavers to the construction industry.

- The company that imported the machinery is associated or oriented to a specific sector, for example, construction companies.

Overall, these criteria allow the characterization of most of the imported fleet (55% in the case of information in Chile).

For machinery that still needs to be classified within a sector, information provided by importers through surveys[9] and interviews can be used. In this respect, the missing information should be complemented with distribution criteria agreed with them.

Fuel

On the other hand, Customs records generally have quite complete information on the type of fuel of the imported fleet, which can be complemented with information collected in catalogues according to the make and model of the equipment.

Any missing fuel type information (which does not appear in the catalogue) can be assigned from the existing information. To do this, as in the case of Power (see Example 2), the machinery fleet must be grouped with information on fuel type, by sector and equipment type, or at least by equipment type (in the absence of a sector). Then, the share by fuel type in the equipment type-sector segment can be obtained. Finally, the fleet without information, also sorted by sector and equipment type, can be distributed according to the share by fuel type of the fleet with information. The above assumes that the distribution by fuel type of the machinery with information is representative of the total of the machinery and is therefore assigned to the missing information according to typology and sector.

[9] [GEASUR 2013]

EXAMPLE 3

As an example, the results obtained from the information on imports from Chile are shown below

Table5 Fuel type indication in Customs database

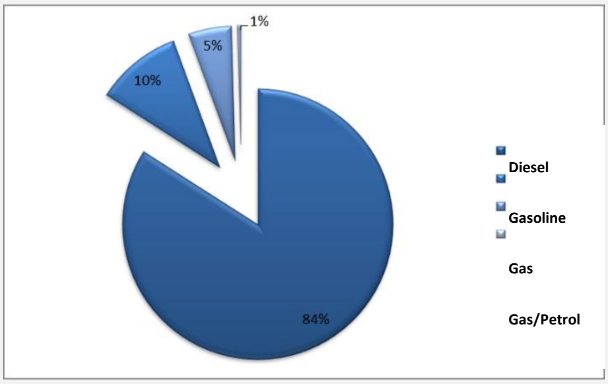
Fuel	Other Indication	Amount of NRMM	% Share
Diesel		85.490	62,92%
Gasoline		10.894	8,02%
Gas		6.462	4,76%
Gas/Petrol		565	0,42%
Not available		23.760	17,49%
Not available	Self-propelled	3.551	2,61%
Not available	Contains engine	3.538	2,60%
Not available	Contains HP	1.421	1,05%
Not available	Contains Displacement	198	0,15%
Grand total		**135.879**	**100,00%**

Source: [Geasur 2014]

As can be seen, 62.9% corresponds to diesel; if gasoline, gas and dual fuel are added, 76.11% is obtained with fuel information. Then 17.49% contains no information of any kind and the other 6.4% contains the indication of engine, power, whether it is self-propelled and/or contains displacement, so the fuel attribute is implicit, but the type of fuel is not stated.

Finally, a graph is presented with the results of the Chilean fleet, considering the 4 types of fuel: diesel, gas, gasoline and dual (gas/petrol).

Figure 2 Share of machinery according to fuel



Source: [Geasur 2014]

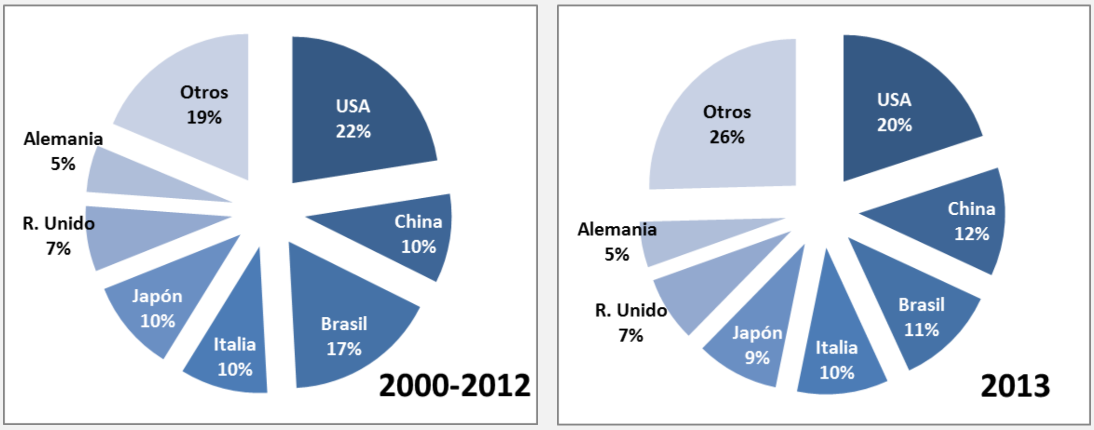
Origin

Regarding machinery origin characterization, this information must be reported in the Customs information.

EXAMPLE 4

In the case of Chile, there are a total of 72 countries of origin for the machinery; however, 80% of the imports come from only 7 countries. The percentages of share are presented in the graph below.

Figure 3 Origin of 80% of imported machinery between 2000 and 2013.



Alemania: Germany / R. Unido: United Kingdom / Japón: Japan / Italia: Italy / Brasil: Brazil

Source: [Geasur 2014]

3. ESTIMATION OF FLEET DISTRIBUTION BY AGE

Machinery imports by type, sector, fuel power and year considered so far, correspond to machinery sold. However, part of this fleet may have reached its average lifetime after one year of inventory. Therefore, the final distribution of the fleet by age is the result of annual sales (yearly imports) minus the "scrapped" units.

The term "scrappage" as used here refers to the final scrapping of equipment such that it no longer contributes to emissions or fuel consumption of the fleet. For estimating the non-road machinery inventory, the EPA scrappage model ([EPA2005-B]) was used in Chile, on the 2010-2013 imports inventory.

The EPA model uses a scrappage curve to determine the proportion of machinery that has been scrapped. It defines "Median Life" as the period of time (in hours) that machinery is used at the engine´s rated load (load factor LF=1 or LF=100%), and for which 50% of the machinery is scrapped. Considering an activity in hours per year (A) for the equipment, and the typical load factor (LF)[10], it is possible to calculate the average lifetime in years, which is the period of time under actual load conditions (LF), for which 50% of the equipment is scrapped. The above can be expressed as follows:

$$Average\ lifetime = \frac{median\ life\ [hrs]}{A\left[\frac{hrs}{year}\right] \cdot load\ factor}$$

For Load Factor (LF) and Activity (A), the values in the Table in Appendix A of [EPA 2008-A] should be used, which provides values by equipment type. However, these values should be validated with locally available information and the input from the local industry.

Table 6 Activity by equipment type.

Equipment type	A [hrs/year]	Load Factor
Asphalt paver	821	0.59
Sweepers	1220	0.43
Bulldozer	899	0.59
Off road trucks	1641	0.59
Log forwarder	1276	0.59
Front loader	761	0.59
Harvester	110	0.59
Dumper	566	0.21
Excavators	1092	0.59
Forklift	1700	0.59
Rough terrain forklift	662	0.59
Telescopic crane	990	0.43
Telescopic handler	878	0.43
Skid-steer loaders	818	0.21
Mini-excavators	818	0.21
Motor graders	962	0.59
Other agricultural equipment	381	0.59
Other construction equipment	606	0.59

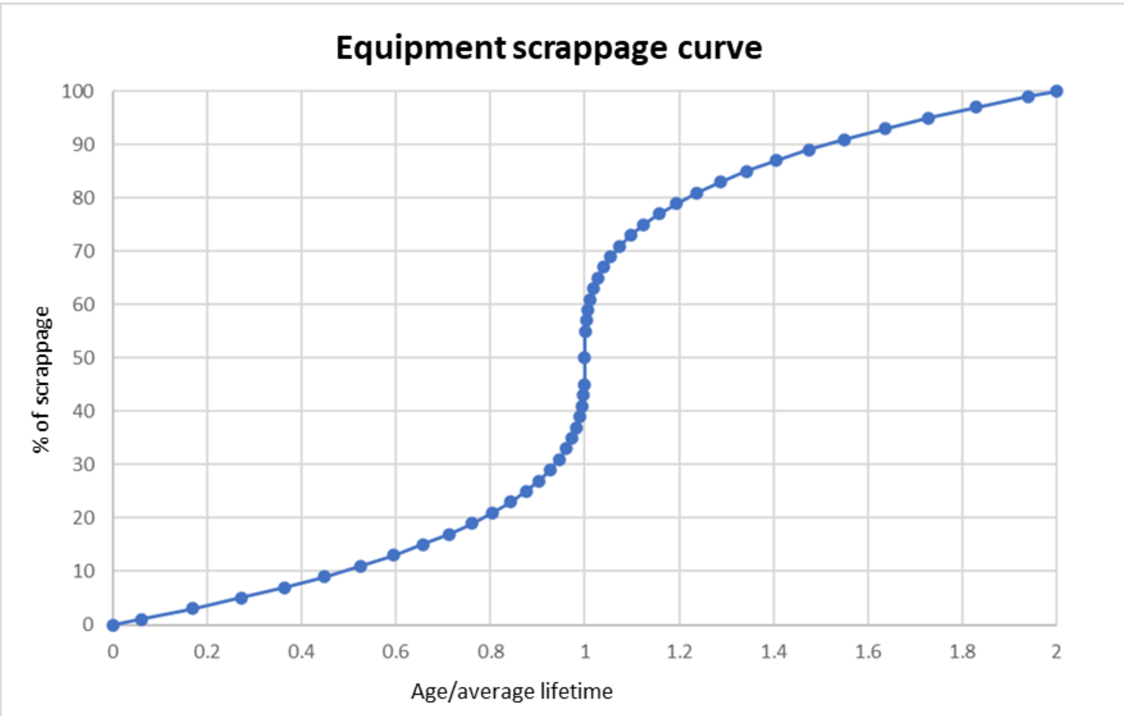
[10] Load Factor (LF) represents the fraction or percentage of the engine's rated power at which the machinery typically operates. For Load and Activity Factor we used the values from the Table in Appendix A of [EPA 2008-A], which provides values by equipment type.

Equipment type	A [hrs/year]	Load Factor
Other Underground Mining Equipment	1533	0.21
Drill	466	0.43
Telescopic boom lift	384	0.21
Snowplough	40	0.34
Backhoe	1135	0.21
Rollers	760	0.59
Non-agricultural tractors	1135	0.21
Agricultural and forestry tractors	475	0.59
Trenchers	593	0.59

Source: Prepared by the authors based on [EPA2008].

The model uses a normal distribution to characterize the equipment scrappage curve, considering that 50% of the fleet is scrapped by the time it reaches the average expected lifetime and 100% is scrapped by twice the average lifetime. To express this curve in a standardized way, for all cases of average lifetime, the "age factor" is calculated, which is the quotient between equipment age and its average lifetime (age/average life). This factor is used to find the percentage of units to be scrapped. Below is a graphical depiction of the scrappage curve:

Figure 4 Scrappage curve



Source: EPA 2005-B

Table 7 Scrappage Table

Age Factor	Cumulative Percent Scrapped
0.0000	0
0.0588	1
0.1694	3
0.2710	5
0.3639	7
0.4486	9
0.5254	11
0.5948	13
0.6570	15
0.7125	17
0.7617	19
0.8049	21
0.8425	23
0.8750	25
0.9027	27
0.9259	29
0.9451	31
0.9607	33
0.9730	35
0.9824	37
0.9894	39
0.9942	41
0.9973	43
0.9990	45
1.0000	50

Age Factor	Cumulative Percent Scrapped
continued...	
1.0010	55
1.0027	57
1.0058	59
1.0106	61
1.0176	63
1.0270	65
1.0393	67
1.0549	69
1.0741	71
1.0973	73
1.1250	75
1.1575	77
1.1951	79
1.2383	81
1.2875	83
1.3430	85
1.4052	87
1.4746	89
1.5514	91
1.6361	93
1.7290	95
1.8306	97
1.9412	99
2.0000	100

Source: EPA 2005-B

EXAMPLE 5

Below is an example of the scrappage calculation for the excavators listed below:

VARIABLE/PARAMETER	VALUE	UNITS
Country of origin	USA	
Sector	Construction	
Type ($Etyp$)	Excavator	
EPA power ranges ($Rpow$)	$56 \leq kW < 75$	
Year of importation	2013	
Year of manufacture	2013	
Quantity	252	
Average power (Pow)	66	[kW]
Emissions standard ($Esta$)	Tier 3	
Age in years (Age)	1	[years]

The activity in annual fleet hours (A), and the load factor (LF) depend directly on the equipment type ($Etyp$). According to Table 6 of the Guide, excavators have an estimated value of 1092 [hrs/year]. As for the LF, the Table provides a value of 0.59 for this equipment type.

The median life for engines in the power range of the subsegment is 4667 hours at full load. To calculate the Age Factor, which is the fraction of the median life of the unit, under actual operating conditions (at a fraction of full load), the years of service ($A*AGE$=1092*1=1092) and the fraction of the rated power at which the fleet operates on average (LF=0.59) must be considered.

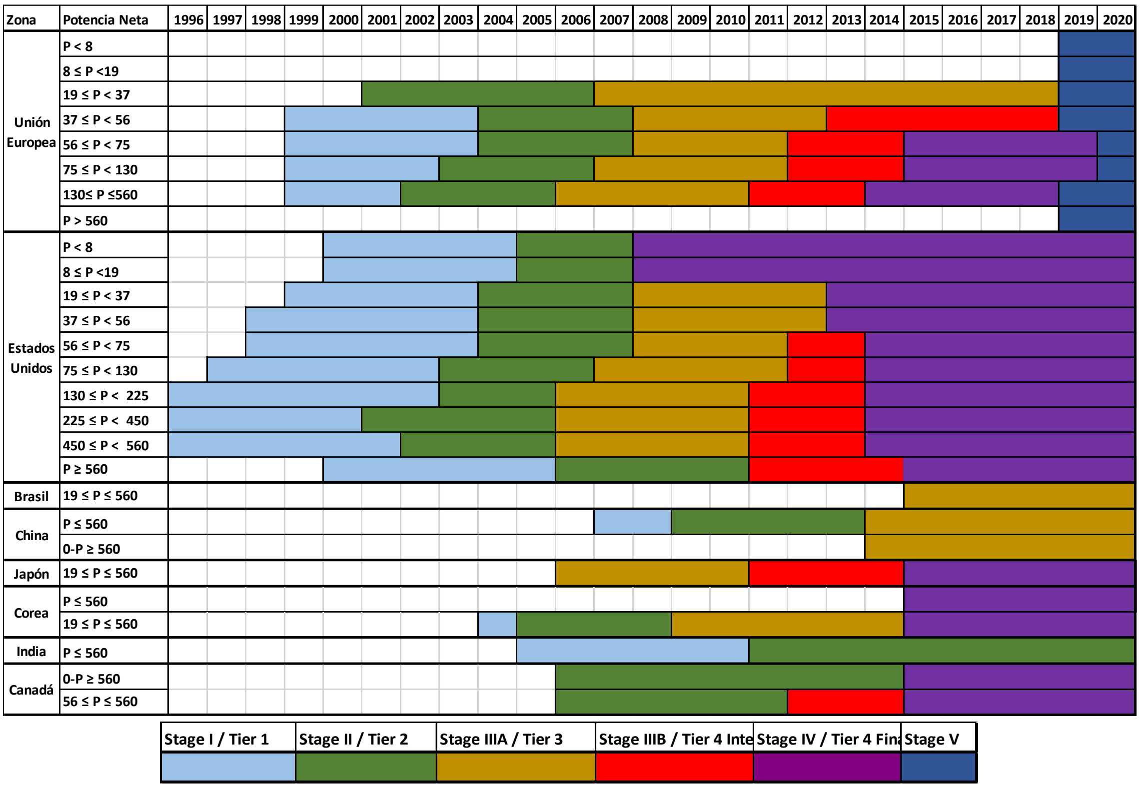
$= 0.14$

For this value of the Age Factor, the scrappage rate is approximately 3%, which corresponds to 7 fewer machines from the fleet of 252 units, at the date of the inventory.

4. TECHNOLOGICAL OR REGULATORY LEVEL OF THE FLEET

The technological level is essential for the characterization of the fleet to allow the calculation of its emissions and an estimation of the inventory, since it ultimately determines its level of emissions during operation. Along with the international development of emission standards for non-road diesel engines, technology has been developed to control these emissions, mainly with regard to injection systems, improvements in the intake systems, in the combustion chamber and finally in the emissions after-treatment systems.

Figure 5 General comparison of international standards



Translation of text in table:

Zona: Zone / Potencia Neta: Net Power/ Unión Europea: European Union/ Estados Unidos: United States/ Brasil: Brazil / Japón: Japan/ Corea: Korea/ Canadá: Canada

Source: Developed from Worldwide emissions standards On and off-highway commercial vehicles (Delphi Tecnologies 2018/2019)

For CALAC+ countries, where there are no entry regulations for this type of sources, it is possible to assume as an unfavourable case that the machinery has entered without any emissions control. However, this is a very unfavourable assumption since the incorporation of better technologies in injection systems or in the engine overall are the state of the art in the industry worldwide. For example, in the case of Chile, where there was no regulatory timetable for the NRMM at the time of its inventory, an approximation criterion had to be discussed for classifying the industry's imports or sales at some technological level. The standard agreed with the industry was that machinery arrived in Chile fulfilling mostly the entry standard of the country of origin with a delay of 5 years. However, such a standard is not general and must be agreed locally with industry experts.

5. GEOGRAPHIC ALLOCATION

To allocate non-road machinery from the national level to the regional level, the EPA[11] methodology was used, with the statistical and economic indicators available in Chile.

Construction machinery indicators

The construction equipment activity indicator, proposed by EPA, is the ***dollar value of construction***[12], which is a good reflection of the activity, since there is a proportional relationship between the dollars spent in construction and the construction sector activity in a certain area, indicating where the equipment is actually being used.

EXAMPLE 6

By way of example, we will examine the case of Chile, which has a dollar value of construction indicator[13] published by the Chilean Chamber of Construction (CChC) that considers projects over US$5 million for productive infrastructure.

In order to consider lower-value building projects in the indicator, the authorized building permits of the official statistics of Chile's National Institute of Statistics (INE) are considered. The INE presents the authorized statistics of the private and public sectors, in square meters, for new works and expansions according to destination.

According to the CChC experts, the distribution of investment in Chile between building and infrastructure is 30% and 70% respectively; thus, the following indicator weighted between the two is proposed:

$$Activity\ Indicator = 0.3 * (Building\ permits) + 0.7 * (Dolar\ value\ of\ construction)$$

Both indicators and their weighting are presented below for all regions of Chile:

[11] [EPA 2005-C], "Geographic Allocation of Nonroad Engine Population Data to the State and County Level", EPA420-R-05-021 December 2005 NR-014d.

[12] The value of construction includes the cost of labor and materials, architectural and engineering costs, management costs, interest and taxes paid during construction, and profits (https://www.investopedia.com/terms/c/constructionspending.asp)

[13] The dollar value of construction indicator for works includes engineering, machinery and equipment, construction and others (labor, permits, among others). Additionally, more specific indicators could be considered such as dollar value of equipment, if available.

Table 8 Dollar Value of Construction in Millions of Dollars. 2013

	Dollar Value of Construction 2013		Building Permits 2013		Weighted Indicator
Region	**(Mill. USD)**	**Share (%)**	**(m^2)**	**Share (%)**	**Share (%)**
Arica	74	0.94%	89,920	0.73%	0.88%
Tarapacá	336	4.29%	254,126	2.06%	3.62%
Antofagasta	2,933	37.43%	659,948	5.34%	27.80%
Atacama	1,315	16.78%	241,456	1.95%	12.33%
Coquimbo	225	2.87%	582,626	4.72%	3.42%
Valparaíso	339	4.33%	1,185,883	9.60%	5.91%
Metropolitan	1,604	20.47%	5,778,767	46.77%	28.36%
O'Higgins	310	3.96%	469,799	3.80%	3.91%
Maule	45	0.57%	674,856	5.46%	2.04%
Biobío	305	3.89%	1,231,012	9.96%	5.71%
Araucania	65	0.83%	453,350	3.67%	1.68%
The Rivers	5	0.06%	191,014	1.55%	0.51%
The Lakes	125	1.59%	401,390	3.25%	2.09%
Aysén	7	0.09%	68,180	0.55%	0.23%
Magellan	149	1.90%	72,624	0.59%	1.51%
Total	7,837	100.00%	12,354,951	100.00%	100.00%

Source: Chilean Chamber of Construction (CChC), National Institute of Statistics (INE) of Chile

Agricultural machinery indicators

For this category, the EPA ([EPA2005-C]) uses the ***harvested cropland*** indicator to allocate the farming equipment population. EPA states that the amount of harvested cropland is a good predictor of farm equipment activity, since there is usually a proportional relationship between the amount of harvested cropland and the amount of activity to prepare the land, plant, maintain, and harvest the crops. Then, as the purpose of the model is to estimate emissions and given that emissions are more directly associated with activity than with equipment populations, the EPA considers the amount of harvested cropland as an appropriate allocation factor.

EXAMPLE 7

As an example, the information available for developing national indicators in Chile is based on the areas farmed at the regional level, which are included in the statistics reported by INE and supported by ODEPA (Office of Agrarian Studies and Policies). The data are available for the agricultural years 1979/1980 to 2013/2014. For the regional distribution of agricultural activity in this study, the agricultural year 2013/2014 is considered.

On the other hand, for forestry equipment, despite the fact that the EPA does not refer to the allocation of the forestry sector, a decision was made to make the regional distribution along the same lines as the agricultural allocation, through ***"Forested and Reforested Area, 2013***

per Hectare". The statistical information was obtained for 2013 from the National Forestry Corporation (Conaf) website.

In Table , the agricultural and forestry indicators are integrated according to the weight that each one has in terms of machinery in the fleet (98% Agricultural and 2% Forestry).

Table 9 and Reforested Area at Regional Level 2013, in hectares.

Region	Agricultural(1)	Forestry(2)	Agricultural-Forestry
XV	0,08%	0,03%	0,08%
I	0,08%	0,00%	0,08%
II	0,08%	0,02%	0,08%
III	0,08%	0,06%	0,08%
IV	0,50%	0,06%	0,49%
V	0,60%	2,28%	0,64%
RM	3,00%	0,24%	2,93%
VI	9,70%	2,07%	9,51%
VII	16,30%	19,04%	16,37%
VIII	24,80%	48,01%	25,37%
IX	36,20%	18,50%	35,76%
XIV	3,80%	7,65%	3,90%
X	4,60%	1,95%	4,53%
XI	0,08%	0,03%	0,08%
XII	0,08%	0,05%	0,08%

Source: (1) INE. Estimated area farmed at regional level - agricultural year 2013/2014. (2) CONAF statistical databases. 2013

Industrial machinery indicators

In relation to industrial machinery, the EPA uses the ***number of employees in the manufacturing sector***. These are a good predictor according to the EPA since manufacturing companies do not move from one geographical location to another as they do in the construction sector.

EXAMPLE 8

As an example, information on employees by branch of economic activity and by region is available for Chile for 2013. These statistics are obtained from the INE (National Institute of Statistics).

The table below presents the employees in the industrial sector, in thousands of people, and the percentage of share in each region.

Table 10 Employees in the Industrial Sector, by Region. In thousands of people. 2013

Region	Employees in Industry 2013	Share 2013/2014
XV	5	0,60%
I	10	1,10%
II	25	2,80%
III	10	1,10%

IV	19	2,10%
V	66	7,30%
RM	449	49,40%
VI	33	3,60%
VII	41	4,50%
VIII	107	11,70%
IX	47	5,10%
XIV	24	2,70%
X	61	6,70%
XI	6	0,60%
XII	6	0,60%
Total Country	**909**	**100,00%**

Source: INE. Employees by branch of economic activity. 2013

Mining machinery indicators

To allocate the population of mining equipment and activity in the sector, the EPA uses ***coal production tons*** as an indicator***.*** However, consideration should be given to the dominant mining resource being exploited in each country.

EXAMPLE 9

For example, in the case of Chile the best indicator is the metallic production of copper ores, which is measured in Fine Metric Tons (fmt). This is the only information available at the regional level. For this study, copper fmt will be used. Information by region as of 2013 is available in the mining production statistics of the Ministry of Mining (http://www.sernageomin.cl/sminera-estadisticasprod.php).

Table 11 Copper production by region, 2013 (fmt)

Region	Copper Production	Share 2013
XV	647	0,01%
I	587881	10,05%
II	3048303	52,10%
III	420992	7,20%
IV	577495	9,87%
V	329422	5,63%
R.M.	415784	7,11%
VI	470596	8,04%
TOTALS	**5.851.120**	**100,00%**

Source: Sernageomin. 2013

6. REFERENCES

[EPA 2014] "Exhaust and Crankcase Emission Factors for Nonroad Compression-Ignition Engines in MOVES2014b", EPA-420-R-18-009, July 2018.

https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100UXEN.pdf

[EPA 2008] "Median Life, Annual Activity, and Load Factor Values for Nonroad Engine Emissions Modeling", EPA-420-R-10-016 NR-005d July 2010.

https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P10081RV.pdf

[EPA 2005-A] "User's Guide for the Final NONROAD2005 Model", EPA420-R-05-013 December 2005.

https://nepis.epa.gov/Exe/ZyPDF.cgi/P1004L24.PDF?Dockey=P1004L24.PDF

[EPA 2005-B] "Calculation of Age Distributions in the Nonroad Model: Growth and Scrappage", EPA420-R-05-018 December 2005 NR-007c.

https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1004L8U.pdf

[EPA 2005-C] "Geographic Allocation of Nonroad Engine Population Data to the State and County Level", EPA420-R-05-021 December 2005 NR-014d

https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1004LDX.pdf

[CORINAIR 2013] "Non-road mobile sources and machinery", Guidebook 2013.

https://www.eea.europa.eu/publications/emep-eea-guidebook-2013/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-4-non-road-mobile-sources/view

[GEASUR 2014] "Análisis técnico-económico de la aplicación de una nueva norma de emisión para motores de maquinaria fuera de ruta a nivel país", study conducted by Geasur in 2014

[GEASUR 2013] "Elaboración de Diagnóstico e Inventario de Emisión para Maquinaria Fuera de Ruta", study conducted by Geasur in 2013.

A program of: Implemented by:

calac@swisscontact.org.pe
www.programacalac.com
Facebook: @CALACplus
Twitter: @Calacplus

Prolongación Arenales Nº722, Miraflores
Lima 15074 - Peru
Phone numbers: +511 2641707, 2642547
Fax: +511 2643212
www.swisscontact.org