

Estimating the Global Emission Impact of Mobile & Industrial Hydraulic Machinery

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Introduction:
The following aims to estimate the emissions by hydraulic machinery on a global level. At this point limited surveys have been conducted on emissions by hydraulic machinery, and hence the most recent and extensive study on this topic is used as basis. This is related to hydraulic machinery in the US, and global estimates are made based on information from various other sources. It should be noted that the estimates below are related to machinery using hydraulics as a means for power transmission, hence the estimates are related to machine level energy consumption and emissions, and not only to their hydraulic systems. Additionally, the following estimates are based on reasonably conservative considerations. Finally, the estimates presented below are related to mobile and industrial hydraulic machinery, excluding aviation.

Information used:		Year	Reference #	Reference	
US energy consumption by hydraulic systems					
Estimating the Impact (Energy, Emissions and Economics) of the U.S. Fluid Power Industry, Oak Ridge National Laboratory		2012	[1]	Estimating the Impact (Energy, Emissions and Economics) of the U.S. Fluid Power Industry, Oak Ridge National Laboratory, https://info.ornl.gov/sites/publications/files/Pub28014.pdf , 2012.	
Numbers used to extrapolate US numbers to Global numbers					
Global emissions by construction machines:	400,00	MMT CO2/year	2022	[2]	https://www.idtechex.com/en/research-article/electric-construction-machines-vital-for-greener-construction/26187
Global emissions by aviation (domestic):	347,73	MMT CO2/year	2022	[3]	https://www.iea.org/energy-system/transport/aviation
Global emissions by aviation (international):	436,72	MMT CO2/year	2022	[3]	https://www.iea.org/energy-system/transport/aviation
Calculation of global emissions by aviation (sum of domestic & international):	784,45	MMT CO2/year			
Global emissions related to energy:	36800,00	MMT CO2/year	2022	[4]	https://www.iea.org/reports/co2-emissions-in-2022
CO2 by electric energy production in 2022 (EU)	258,00	g CO2/kWh	2024	[5]	Greenhouse gas emission intensity of electricity generation, EU level European Environment Agency's home page
Energy content in diesel fuel	10,70	kWh/l	2022	[6]	https://www.klimafokus.dk/de-fossile-biler-stor-sviner-med-energien/
CO2 emission by diesel fuel combustion	2660,00	g CO2/l	2009	[7]	https://ing.dk/holdning/mindre-co2-udledninger-er-en-kaempe-forretning-os-alle
Calculation of CO2 per energy unit diesel fuel based on references [6] and [7]	248,60	g CO2/kWh			

Assumptions used:
1) The percentage distribution of energy consumption by hydraulic machinery sectors globally is identical to those of the US, specified in [1].
2) The emission per energy unit is identical for mobile and industrial hydraulic machines (conservative as average emissions for electric energy production currently surpasses that of diesel fuel as found from [6] and [7] above)
3) The CO2 emission by sectors specified in [1] is not used here, as especially the the emissions related to electric energy generation are not representative for the emissions for 2022.
4) The CO2 emissions from electric energy generation is diverse when condisering different geographical regions. The associated emissions for Europe are rather low in a global context, and hence used here to be conservative.
Additional information
Numbers in black font or gray font are obtained from the references above, numbers in red font are own extrapolations and numbers in blue font are own calculations.

Estimating the Energy Consumption by Mobile & Industrial Hydraulic Machinery in the US

Using the US numbers reported in [1], the % energy consumption of hydraulic machinery per sector in the table below is obtained.

2012 Energy Consumption by Fluid Powered Machines in the US	Minimum quads/year	Maximum quads/year	Mean quads/year	% of total mean quads/year
Mobile hydraulic machinery				
- Construction machinery	0,233	0,811	0,522	27,4
- Agriculture	0,016	0,056	0,036	1,9
- Other mobile machinery	0,113	0,393	0,253	13,3
Total mobile	0,362	1,260		
Industrial hydraulic machinery	1,096	1,096	1,096	57,5
Total	1,458	2,356	1,907	100,0

Extrapolated data in red font. These numbers are scaled according to the max. and min. quads per year for "Total mobile" specified in [1].
Hence, the % distribution of min. quads/year among "construction", "agriculture" and "other mobile" is assumed identical for max. quads/year.

Estimating the Global Emissions by Mobile & Industrial Hydraulic Machinery

The following estimates are based on the total mean percentage distribution of energy consumption presented above, assuming that the emission level per energy unit for all hydraulic machinery is identical to that of construction machines. In view of the g CO2/kWh for electric and diesel energy generation presented in section "Numbers used to extrapolate US numbers to Global numbers", this is a conservative consideration.

Applying the info on global emissions by construction machines [2] and the percentage US energy consumption by construction machines estimated above, the following MMT CO2 / % energy consumption is obtained:

CO2 per % energy consumption = 14,61 MMT CO2 / % energy consumption

Using this measure, the global emissions by hydraulic machinery is estimated as given in the table below.

Global CO2 Emission Estimates from US Energy % Distribution	% of total mean quads/year	Average MMT CO2/year
Mobile hydraulic machinery		
- Construction machinery	27,4	400,00
- Agriculture	1,9	27,47
- Other mobile machinery	13,3	193,99
Industrial hydraulic machinery	57,5	839,85
Total	100,0	1461,31

Key Estimates Related to Emissions by Hydraulic Machinery

Relative to aviation	
Ratio of Total Emissions by Hydraulic Machinery Estimate-to-Global Aviation Emissions (International and domestic)	1,86
Ratio of Total Emissions by Construction Machinery Estimate-to-International Aviation Emissions	0,92
Relative to global	
Total Hydraulic Machinery Emission Estimate in % of Global Emissions	3,97

Energy Efficiency of Hydraulic Machinery

Using the average efficiencies for mobile and industrial hydraulic machines [1], and the respective % energy consumption, a total weighted efficiency for mobile and industrial hydraulic machinery is obtained as given in the table below.

Weighted Energy Efficiency Estimates from US Energy % Distribution	% of total mean quads/year	Average efficiency in % [1]	Weighted efficiency
Mobile hydraulic machinery	42,5	21	8,9
Industrial hydraulic machinery	57,5	50	28,7
Total	100,0		37,7

Tables from reference # [1]

Table 4. Efficiency Overview

Sector	Energy	Efficiency	Weighted Efficiency
Mobile	0.25	21%	5%
Industrial Hydraulics	0.18	50%	9%
Pneumatics	0.50	15%	8%
		Total	22%

Table 5. Energy Summary

Sector	Energy (Quads)		Market %	Fuel (billion gallons)		CO2 (MMT)	
Mobile Hydraulics	Low	High		Low	High	Low	High
Agriculture	0.016		33.65%	0.11		1.15	
Construction	0.233		35.24%	1.68		16.98	
Sub Total	0.249		68.89%	1.80		18.13	
Total Mobile Hyd.	0.362	1.260		2.61	9.08	26.32	91.728
Industrial Hydraulics							
Injection Molding	0.181		4.86%			32.37	
Metal Forming	0.009		12.43%			1.55	
Sub Total	0.190		17.30%			33.92	
Total Industrial Hyd.	1.096	1.096				196.12	196.12
Aerospace	0.024	0.024		0.170	0.170	1.71	1.71
Total Hydraulic	1.48	2.38					
Pneumatics	0.50	0.50				84.12	91.11
Total	1.98	2.88		2.78	9.25	308.27	380.67