SGPPA CO_2 baseline reporting

City of Copenhagen, 2nd April 2019

Background

This Scandinavian Green Public Procurement Alliance (SGPPA) project is a collaborative effort of public organizations who are testing green public procurement in a Non-Road Mobile Machinery sector that has become an increasingly important source of CO_2 and air pollution in relative terms, especially of nitrogen oxides (NOx) and particulate matter (PM). Non-Road Mobile Machinery (NRMM) are a wide range of machinery typically used in the construction sector, and in services related to garden and park maintenance in cities. The regulatory scheme for NRMM constitutes a wide product group regulated with a number of EU-directives and national statutory legal orders defining limit values and terms for emissions, noise, etc. In the EU the primary reference directive is Regulation EC 97/68, the so-called "NRMM regulation", with later applied regulation.

The collaboration is between the capital cities of Copenhagen, Oslo and Stockholm aiming at the following:

1. To plan and complete a cross-border green procurement between collaborative cities focusing on the procurement of wheel loaders within the NRMM sector.
2. Greenification of the NRMM market having the capital cities to send a clear signal for suppliers and manufacturers.
3. Progressively reduce CO2 emissions and pollution reductions such as NOx and particulate matter and to phase out polluting equipment through Green Public Procurement while not increasing purchasing prices with more than 5 %.
4. To secure upscaling of the developed green public procurement model to involve more cities

From a climate and environmental perspective, the challenges with the NRMM sector are pollutant emissions from combustion engines (diesel and gasoline) installed in a wide range of machines that significantly contribute to climate change by emitting carbon dioxide (CO2) and air pollution in cities by emitting carbon oxide (CO), hydrocarbons (HC), nitrogen oxides (NOx) and particulate matter (PM), causing health hazards. In the EU the NRMM sector is responsible for around 15% of the total NOx emissions and 5% of total PM emissions. The NOx share is expected to increase to up to nearly 20% in 2020, while the PM share is expected to decrease. NRMM is also accountable for roughly 100 million tons of CO2 equivalent emissions annually, corresponding to 2% of the total greenhouse gas emissions in the EU27. The specific reduction potential on the local city level is still unclear.

This baseline report focuses on the reduction potentials (3) for CO2 and particulate matter (PM) in regards of procurement of a number of wheel loaders. Firstly, a baseline for CO2 and particulate matter is calculated partly based on digital consumptions readers installed in wheel loaders in the City of Copenhagen. Next, the data extrapolated to cover the City of Oslo and Stockholm. Finally, the reduction potential is calculated based on evidence from the green public procurement. The calculated CO2 and PM reduction potential are based on assumptions on how the green procurement is completed as this process is still on-going.

Getting the data

In the ideal world to get the most precise CO_2 data from machines running on diesel, it is necessary to measure the actual consumption from the machine itself. Only few machines have digital fuel consumption readers. Therefore, consumption data can be a bit tricky to get, but there are some solutions or ways to get these data:

1) By registering the number of litres going into an empty machine and to register the amounts of hours the machine can work before getting empty again. Thereby you will get the litre per hour data. This process can be rather time consuming. But there is a second way of doing it.
2) By installing a digital oil-counter in each machine you can get the exact data needed, but it only includes the consumption and not the amounts of operation hours. Or you could use an intelligent tanking system based on RFiD mounted on the tank nuzzle at the external fuel pump.
   On both solutions you need to pair the refuelling data, with GPS data from the machine itself.
3) A third way is to get an overview of the official machine consumption data. These are often given by the machine manufacture in kWh per hour. This figure is then converted to Litres per hour. Often there are two figures given. One based on a heavy-duty cycle and another based on a mild-duty cycle. By duty cycle is meant that the machine manufacture is entitled by European law to give up duty cycle data as part of the European type approval of the machine and the duty cycle is a pre-determined way of running the engine (temperature, load etc that is "realistic" for this specific type of machine). Some machine manufacturers are even testing the machine after an industry norm for the specific machine. An example is sweeping machines sold in EU. These are often being tested based on the EN 15429-2. Here the consumption is based with or without the operation of the mounted brooms. Also, here GPS data from the actual machine is needed to get the operation hours. This model is easier when making calculations for a lot of different vehicles and machines that are constant in operation.
   From the engines type approved EU Stage norm (engines type approval year and engine size), you can also see what the emission limit of particulate matters (as well as NO_X, Hydro Carbons and Carbon Oxide). But these figures are quite uncertain and not reliable enough, compared to the official burn factor of diesel and CO_2 impact from the up-stream part of the total CO_2 value chain of diesel.

City of Copenhagen and Oslo are in this report calculating the CO_2 baseline on the third model. When alternative drivelines for articulated wheel loaders is being put into operation, the CO_2 impact will be lower than by conventional diesel-based operation. This also means that the CO_2 impact of a full electric articulated wheel loader will be even lower in Norway than in Denmark. This is due to the different energy systems in Denmark and Norway, which is due to different geographic and topographic circumstances. In Denmark the country is rather flat but usually quite windy. Wind mills are therefore the most common alternative to coal and biomass-based electric power. In 2018 wind power had an average of 40 % of the total Danish energy mix. In western part of Norway it often rains a lot and inside the country snow is often creating huge amounts of melting water. Therefore, hydro power is very common and is playing a major part of the Norwegian electric power. Hydro power in Norway had an average of 98 % of the total Norwegian energy mix. When looking at hybrid-based drivelines (diesel/electric) the consumption is primarily given in diesel generated consumption, like an ordinary machine running on diesel only.

The Cities of Oslo and Copenhagen have different size classes of articulated wheel loaders – ranging from 2 to 37-ton total weight. The City of Copenhagen has an internal fleet of 2.000 vehicles and machines, of which

the city owns 500 light and heavy-duty machines. 15 of these are wheel loaders and are all running on diesel. 3 of these are large wheel loaders with a heavy-duty operation cycle. The last 12 are small and with a light duty operation cycle.

The City of Oslo has approximately 1.400 vehicles and 300 machines. The Agency for Waste Management, "Renovasjonsetaten - REN", is responsible for waste handling and use different types of NRMM on their facilities. The agency needs to replace between 2-4-wheel loaders within the next 4 years. REN already has 2 electric wheel loaders on their sites in a light weight class. These are primarily used for moving garden waste and materials for recycling. Their ambition in the future is to replace the wheel loaders of larger weight classes, to cover the need for moving heavier loads.

The CO_2 baseline for the diesel operation today will be done accordingly for each weight class. The consumption is based on GPS data per weight class for City of Copenhagen and registered hours of operation.

City of Copenhagen

	Small weight class (2,5 tons)	**Medium weight class** (6 tons)	**Large weight class** (14 tons)
Pcs.	5	6	4
Engine Size in kW	25	55	112
EU Stage Norm	Stage 3B	Stage 3B	Stage 3A
Litre per Hour	5	8	15
Yearly Consumption in litre	7.800	12.800	127.500
Yearly CO_2 emissions in tons	24	39	392

Total CO_2 baseline for diesel operation for City of Copenhagen: 455 tons of CO_2.

CO2 reduction potential for Copenhagen

When overgoing from diesel to full electric driveline on the first two weight classes (economic feasible/market initial pricing ranges) in Denmark this will give a CO_2 reduction of 80 %, from 63 tons to 13 tons.

If overgoing to mild hybrid driveline on the third and highest weight class this will give a CO_2 reduction of 15 %, with an average consumption reduction of 15 % (compared to conventional diesel operation) from 392 tons to 333 tons.

City of Oslo – Agency for Waste Management

	Small weight class (<5tons)	**Medium weight class** (>5tons, < 14 tons)	**Large weight class** (>14 tons)	***Comments***

Pcs.	3 diesel 2 electric	4	12	*For Agency for Waste Management only*
Engine Size in kW	25	54	112	*No info available, assumed similar to CPH*
EU Stage Norm	Stage 3B	Stage 3B	Stage 3A	*No info available, assumed similar to CPH*
Litre per Hour	5	10	11	*No info available, assumed similar to CPH*
# of hours operating time per year	750	750	750	*Have assumed 3 hours operation time on average for 250 workdays per year. Varies quite a bit between weight classes and even machines within each weight class, but is not quantified in more detail.*
Yearly Consumption in litres	11 250	30 000	99 000	*Calculated as # of pcs x litres pr hour pr piecer x # of operating hours*
Yearly CO_2 emissions in tons	30	80	264	*Using diesel emission factor of 2,67 kg CO2/l diesel.*

Total estimated CO_2 baseline for diesel operation for wheel loaders at the City of Oslo, Agency for Waste Management: 374 tons of CO_2.

CO2 reduction potential for Oslo

To estimate the potential emission reductions, the following cases have been set up:

Case A: If converting from diesel to full electric driveline on the first two weight classes (economic feasible/market initial pricing ranges) in Norway this will give a CO_2 reduction of 29 %, totalling 110 tons. In reality, this figure is slightly lower than 110 tons given the CO_2-emission factor from Norwegian hydropower. However, since this factor is extremely low (16,4g CO_2/kWh), it is for the purposes of this estimation considered negligible. Hence, we consider electrification as removing the CO_2 emissions in its entirety.

Case B: If converting to mild hybrid driveline on the third and highest weight class this will give a CO_2 reduction of 15 %. This is simply estimated as a consequence of reduced average fuel consumption by 15 % (compared to conventional diesel operation). The corresponding CO_2 emission reduction is 39,6 tons.

In total, by fully electrifying the first two segments and achieving mild hybrid on the last segment, Oslo may reduce its emissions by 149,6 tons CO_2. This is assuming that all the wheel loaders will be replaced, which is not the case in practice. As mentioned earlier, the Agency for Waste Management foresees initial replacement of 2-4 of the smaller sized wheel loaders.