GREENHOUSE GAS EMISSIONS, ITS IMPACTS AND MEASURES

INTRODUCTION

Exhaust emissions have both climate related impacts, and local air quality and health impacts. Wärtsilä is committed to reducing the environmental impact of its engines to a minimum.

EMISSION TYPES

Emissions from engines can be divided in two categories. Gas engines can have negligible local emissions and deliver substantial GHG benefits

Category 1: Local emissions: health & environment related

- Contribute to deterioration of human health, loss of wellbeing, early death
- Mainly NOx, SOx and particulates
- Also impact the natural environment (flora & fauna) on short term
- Impact depends very much on location of emission. Focus on densely populated areas and sensitive ecosystems

Category 2: GHG emissions: climate related

- Contribute to global warming / climate change
- Mainly CO2 and CH4 (methane)
- Low to no impact on human health or the natural environment on short term
- Impact is not dependent on location of emission, as climate change is a global problem

FORMATION IN ENGINES AND REACTION IN ATMOSPHERE

Physics govern the formation of emissions

Emissions are formed during fuel combustion. Either from full or partial combustion of fuel, or by reaction of components in air due to high temperature and pressure

- CO2 stems from carbon in the fuel, bonded with atmospheric oxygen
- CH4 is simply non-combusted natural gas, hence the term “methane slip”
- Nitric oxides or NOx forms from atmospheric oxygen and nitrogen in the high temperature combustion zone
- SOx is combusted Sulphur that was present in the fuel, bonded with atmospheric oxygen
- Particulates consist of non- (or partially) combusted fuel, lubricating oil, dust present in intake air or from other sources. It is a blanket term covering all kinds of emissions, from simple elemental carbon to highly complex structures

IMPACTS: DIFFERENT EMISSIONS HAVE DIFFERENT IMPACT

CO2 accelerates the warming of our planet, CH4 also accelerates the warming of our planet, and is 28 times as potent as CO2 in doing so.

Nitrogen oxides or NOx is a known source of smog formation especially in urban highly polluted areas (with related health effects), and causing acidification and eutrophication in nature

SOx emissions contribute to acid rains and promote the formation of small secondary particulates

Particulate emissions impact the local air quality and effects human health as small particles penetrate to respiratory system causing lung diseases and further penetration to blood circulation

Section 1

TRADITIONAL/ LOCAL EMISSIONS

Main health and environment related local emissions from engines

SULPHUR DIOXIDE (SO2)

The largest source of SO2 in the atmosphere is the burning of high sulphur containing fossil fuels by power plants and other industrial facilities. Smaller sources of SO2 emissions include: industrial processes such as extracting metal from ore; natural sources such as volcanoes; and locomotives, ships and other vehicles and heavy equipment that burn fuel with a high sulphur content.

NITROGEN OXIDES (NOx)

Combustion of fossil fuels (e.g. cars, power plants) is by far the dominant source of NOX emissions. The emissions are not dependent solely on the amount of nitrogen in the fuel but also on the air fuel mix ratio. High temperatures and oxidation-rich conditions generally favour NOX formation in combustion.

PARTICULATE MATTER (PM)

PM=Black carbon, sulphate, nitrates, ammonia, sodium chloride, mineral dust, water. Sources of PM include combustion engines, solid fuel combustion for energy production in households and industry and other industrial activities.

Legislation and effective measures have helped to reduce SO2 emissions in the USA and Europe

- In the US and Europe there has been a systematic emission reduction since the 1980s

– This has been achieved by switching to low sulphur fuels such as natural gas, or effluent emission control using scrubbers.

- International shipping emissions have been on a rise – IMO global sulphur limit will be in force 2020

End-of-pipe abatement measures key to reduce global NOx emissions

• Global NOx emissions decreased in the early 90s as for SO2, but shortly followed up by further increases again in the newly industrialized countries.

– Gradual implementation of end-of-pipe abatement measures have helped to reduce emission levels.

Life expectancy has increased across much of Western Europe and North America but decreased elsewhere due to PM2.5

Global population-weighted PM2.5 concentrations have increased by 37.5% over the period 1960 to 2009

– The increase is dominated by China and India due to economic expansion and growth in emissions.

– Air quality regulation and emission controls in the European Union (EU) and United States (US) has reduced concentrations over the same period.

– Nevertheless, fine particulate matter in air has been estimated to reduce life expectancy in the EU by more than eight months.

Section 2

GREENHOUSE GAS (GHG) EMISSIONS IN GENERAL

SOURCES AND SHARES

There are many different sources of anthropogenic greenhouse gases

Many different human activities contribute to global warming Energy production (25%) and transportation (14%) have a significant share of total global emissions (2010 data) Global shipping contributes nearly 3% of global anthropogenic CO2 emissions (2010 data) A major but often forgotten contributor is also AFOLU:

• Agriculture

• Forestry

• Other Land Use

IMPACTS

Emission of greenhouse gases cause a warming and changing of climate

Surface temperature is projected to rise over the 21st century. It is very likely that heat waves will occur more often and last longer, and that extreme precipitation events will become more intense and frequent in many regions. The ocean will continue to warm and acidify, and global mean sea level to rise.

• Climate change will amplify existing risks and create new risks for natural and human systems.

• Risks are unevenly distributed and are generally greater for disadvantaged people and communities in countries at all levels of development.

• Continued high emissions would lead to mostly negative impacts for biodiversity, ecosystem services and economic development and amplify risks for livelihoods and for food and human security.

GHG EMISSIONS FACTOR

Not all greenhouse gases have an equal influence on climate change

Emission factors enable different greenhouse gases to be expressed in a common unit (so-called 'CO2equivalent emissions') These compare the effect of 1kg of CH4, N2O or another component to the effect of 1kg of CO2

• Global Warming Potential or GWP: the relative influence of a certain gas (per kg emitted) on global warming compared to CO2.

• Global Temperature Change Potential (GTP) estimates the change in global mean temperature in the future.

These factors depend on the time horizon that is considered; the 100-year GWP (GWP100) was adopted by the United Nations Framework Convention on Climate Change (UNFCCC) and its Kyoto Protocol and is now used widely as the default metric.

SECTION 3

GHG EMISSIONS IN WÄRTSILÄ ENGINES

Wärtsilä strives for emission reduction

Wärtsilä is committed to reducing the environmental impact of its engines to a minimum. We continuously develop new technologies and upgrade existing ones in order to limit harmful emissions into the atmosphere.

This is achieved through, for example:

– The development of gas and dual-fuel engine technologies

– Industry leading developments in hybrid/electric propulsion for ships

– A broad portfolio of exhaust gas cleaning systems for vessels running on conventional marine fuels.

GHG emissions from Wärtsilä engines have been decreasing for decades Wärtsilä gas engines now outperform Wärtsilä diesel engines by 12-30%

Diesel and gas engines produce greenhouse gases but gas engines compare favorably to diesel engines.

Higher engine efficiency = lower emissions. Wärtsilä is leading

SECTION 4: GHG EMISSIONS IN THE WHOLE VALUE CHAIN

Well-To-Tank, Tank-To-Propeller and Well-To-Wake emissions

"Well-to-wake" (WTW) is a term used to specify the total amount of emissions generated as grams per ton kilometer or mile. I.e. the emissions produced to move one ton of cargo over a certain distance. It is a metric often used to compare different transport modalities (rail versus air versus road versus shipping, for instance).

• It includes the emissions from the vessel, but also those generated during fuel production, transport and storage. These are so-called "upstream" emissions

• Upstream emissions vary widely with the source or “feedstock” of the fuel, and can even be negative for fuels that capture atmospheric CO2 during their production – biofuels from plants that convert CO2 to O2, storing the carbon inside the plant – biogas that avoids emission of methane to the atmosphere from decomposing waste

SECTION 5: EMISSION REDUCTION TECHNOLOGIES

Many options exist to reduce GHG emissions

GHG reduction technology can be grouped in the following way:

- Engine efficiency improvements, leading to lower engine CO_2 emissions
- Fuel de-carbonization, utilizing fuels with a lower carbon content
  Example 1: LNG vs. diesel. Per unit of energy, LNG causes ~20% less CO_2 emission
  Example 2: Biofuels that have a negative CO_2 emission during their production; either by absorbing CO_2 from the air, or by avoiding emissions when feedstock is not used as fuel.
- Lowering non-CO_2 emissions. Prime example is CH_4 emitted from gas engines.
  Example 1: lowering engine-out emissions by improving combustion
  Example 2: lowering stack emissions by using after treatment

Section 6: FUTURE OUTLOOK

Wärtsilä is committed to further reduce gas engine GHG emissions. We will reduce greenhouse gas emissions from gas engines by 15% from 2015 to 2020

During 2017:

• Wärtsilä identified and determined the technology packages for the reduction of greenhouse gas emissions.

• Product specific implementation schedules were also decided.

• Greenhouse gas emissions from gas engines were already 7% below the baseline year.

CONCLUSION

Power generation and transport has lifted billions of people out of poverty, and continues to do so!

• Nearly three billion people rely on wood or other biomass for cooking and heating, resulting in indoor and outdoor air pollution attributable for 4.3 million deaths each year

• Almost one out of every three children goes to a school that lacks electricity

• Without electricity, women give birth in dark hospitals, children's vaccines cannot be refrigerated, students are unable to study after sundown, and doing business is nearly impossible

• Transportation has contributed in many ways to improve human life and wellbeing. From humanitarian assistance to rapid sharing, food and pharmaceutical transportation does benefit mankind in ways that are not always appreciated Power is great, as long as it is produced with great care. Let’s build a sustainable society together!