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Updated CO_2 emission factors for stationary combustion of LNG and blast furnace gases in Sweden

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Sammanfattning

Flytande naturgas (LNG) förekommer för första gången i Kvartalsbränslestatistiken (KvBr) i submission 2019 (utsläppsår 2017).

Sedan submission 2019 har CO_2-utsläpp från stationär förbränning (CRF 1A1a, b, c,1A2, 1A4) av LNG skattats med samma emissionsfaktor som naturgas. LNG förekommer i aktivitetsdata från KvBr i CRF/NFR-koder 1A1a, 1A1b, 1A2a, 1A2b, 1A2c, 1A2d, 1A2e, 1A2f och 1A2g. I Sverige används den största delen av LNG inom industrisektorn. Rapporterade mängder av LNG i KvBr var 2019 runt 13,5% av den totala inrapporterade naturgasen. Resterande LNG används mestadels inom transportsektorn. Andelen förbränd LNG 2020 var för 1A1 0,5% och för 1A2 19%.

I detta projekt har vi undersökt möjligheten att använda ett specifikt värmevärde och specifika emissionsfaktor för stationär förbränning av LNG (CRF/NFR 1A1, 1A2 and 1B, utom 1A1c). Även en harmonisering av värmevärden för stationär förbränning och diffusa utsläpp av LNG har gjorts. En ny emissionsfaktor för CO_2 från stationär förbränning av LNG på 56,5 kg/GJ presenteras i rapporten och föreslås användas i den svenska växthusgasinventeringen. Övriga utsläpp från stationär förbränning av LNG föreslås ha samma emissionsfaktorer som naturgas (samma som i submission 2022) i brist på tillgänglig information.

Utsläpp från förbränning av industriella restgaser är baserade på en massbalansmodell utvecklad av SMED, med utgångspunkt från anläggningarnas rapporterade utsläpp i Miljörapporter. Bakåträknade emissionsfaktorer (IEF[1]) tas fram för att publiceras i den nationella växthusinventeringen till UNFCCC och CLRTAP, men även som en emissionsfaktorbilaga på Naturvårdsverket varje år. Under en årlig kvalitetskontroll, genomförd i submission 2022, upptäckte SMED att dessa faktorer inte blivit reviderade i samma takt som själva utsläppen.

I denna rapport presenteras reviderade IEF för CO_2 från förbränning av industriella restgaser. Resultaten visar på smärre skillnader mellan 2014 och 2020 års faktorer jämfört med de presenterade i submission 2022.

[1] eng. Implied Emission Factor

Summary

SMED is short for Swedish Environmental Emissions Data, which is a collaboration between IVL Swedish Environmental Research Institute, SCB Statistics Sweden, SLU Swedish University of Agricultural Sciences, and SMHI Swedish Meteorological and Hydrological Institute.

Liquid natural gas (LNG) appears for the first time in the Swedish Quarterly Fuel Statistics (KvBr) in submission 2019 (emission year 2017). Since submission 2019, CO_2 emissions from combustion of for stationary combustion (CRF 1A1a, b, c,1A2, 1A4) LNG has been estimated with the same emission factors of natural gas. LNG occurs in the activity data from KvBr in the CRF/NFR codes 1A1a, 1A1b, 1A2a, 1A2b, 1A2c, 1A2d, 1A2e, 1A2f and 1A2g. Most of the LNG is consumed the industry sector in Sweden. The reported amounts of consumed LNG in KvBr were for 2019 around 13.5% of the total reported natural gas. The share of consumed LNG in 2020 in 1A1 was 0.5% and for 1A2 19%.

Reported emissions from furnace gases are based on a plant-specific emission mass balance model developed by SMED with the basis from the facilities own Environmental reports. During a quality control SMED discovered that estimated implied emission factors (IEF) had not been revised when the emissions were revised. These implied emission factors are reported in the National Inventory reports to UNFCCC and CLRTAP but also published at the Swedish Environment Protection Agency each year.

An investigation of the possibility to use specific net calorific values and emission factors for LNG combustion in all CRF/NFR codes where LNG occurs (CRF/NFR 1A1, 1A2 and 1B, except 1A1c) with focus on the GHG emissions (CO_2, CH_4 and N_2O), including harmonization of the net calorific values in stationary and diffuse emissions of LNG is made. In addition, an investigation of revision of the implied emission factors of CO_2 for blast furnace gas is made.

A new emission factor for CO_2 and LNG, **56.5 kg/GJ,** is presented and suggested to be used in the Swedish GHG-inventory. Other emissions originating from LNG combustion are suggested to have the same EF as natural gas (same as in submission 2022). In addition, a revised time series of IEF for blast furnace gases is suggested for submission 2023, which causes revisions on the IEF between 2014 and 2020.

Keywords: Emission factor, Implied emission factor, GHG, LNG, Blast furnace gases, National GHG inventory, CO_2-emissions

Background

Liquid natural gas (LNG) appears for the first time in the Swedish Quarterly Fuel Statistics (KvBr) in submission 2019 (emission year 2017). Since submission 2019, CO_2 emissions from stationary combustion (CRF 1A1a, b, c,1A2, 1A4) of LNG has been estimated with the same emission factors of natural gas, which origin from the Danish energy agency[2] and used in the Danish national GHG inventory for reporting to UNFCCC and CLRTAP. For other emissions from other fuels a revision of emission factors for energy production sector was made in 2016[3] and for the industry during 2017[4].

LNG occurs in the activity data from KvBr in the CRF/NFR codes 1A1a, 1A2a, 1A2b, 1A2c, 1A2d, 1A2e, 1A2f and 1A2g. In addition, it also occurs in CRF/NFR codes 1A1b in activity data from EU Emissions Trading System (EU ETS) database.

Most of the LNG for stationary combustion is consumed in the industry sector in Sweden. The reported amounts of consumed LNG in KvBr for energy purposes were for 2019 around 13.5% of the total reported natural gas. The share of consumed LNG for stationary combustion in 2020 in 1A1 was 0.5% and for 1A2 19%.

Recently, SMED revised the emission factors of LNG for navigation[5].The study shows that the net calorific values and the emission factors for LNG varies from the emissions of mobile combustion of natural gas depending on different techniques used. Since the techniques vary in stationary combustion a separate investigation of emission factors and net calorific values of LNG is needed.

Since 2011, LNG is also used as feedstock for hydrogen production in Swedish refineries. By 2020, hydrogen production was initiated in four of the five refineries. The amounts of consumed LNG were around 2500 TJ. The refineries report the consumption of LNG in the EU Emissions Trading System (EU ETS) database and the CO_2 emission factors and net calorific

[2] Energistyrelsen, 2021-02-11 (https://ens.dk/ansvarsomraader/co2-kvoter/stationaere-produktionsenheder/co2-rapportering-og-returnering)

[3] Mawdsley, I., Wisell, T., Stripple, H., Ortiz, C. 2016. Revision of emission factors for electricity generation and district heating (CRF/NFR 1A1a). SMED Report No 194 2016. Agreement No 2250-16-003. Commissioned by the Swedish Environmental Protection Agency

[4] Mawdsley, I., Stripple, H. 2017. Revision of emission factors for stationary combustion within the industrial sector, SMED Report No 7.

[5] Hult, C., Winnes, H. (2020). Emission factors for methane engines on vehicles and ships with a focus on methane emissions. SMED Report No 8 2020

values can be derived from this source. However, most of other emission factors for hydrogen production with LNG as feedstock are not harmonized with net caloric values and emission factors used in the stationary and mobile sectors.

CO_2 emissions from combustion of furnace gases are based on plant-specific emissions reported in the facilities own Environmental reports, and a mass balance model developed by SMED[6]. To estimate implied emission factors (IEF) for reporting in the national emission inventory reports to the UNFCCC and the CLRTAP, the total emissions are divided by the energy consumption (TJ) for each year. These implied emission factors are also published at the Swedish Environment Protection Agency each year. During an annual quality control, SMED discovered that these implied emission factors had not been updated when the emissions were revised.

The aim of this project is to investigate the possibility to use specific net calorific values and emission factors for LNG combustion in all CRF/NFR codes where LNG occurs (CRF/NFR 1A1, 1A2 and 1B, except 1A1c) with focus on the GHG emissions (CO_2, CH_4 and N_2O), including harmonization of the net calorific values in stationary and fugitive emissions of LNG. In addition, the implied emission factors of CO_2 for blast furnace will be revised and updated.

[6] SEPA, 2022. National Inventory Report Sweden 2022 - Greenhouse Gas Emission Inventories 1990-2020. Submitted under the United Nations Framework Convention on Climate Change and the Kyoto Protocol. Section 4.4 Metal industry (CRF 2.C).

Methods

Emission factors for LNG

The investigation was made by a literature study and the reported amounts in KvBr (for stationary combustion) and EU Emissions Trading System (EU ETS) database (for fugitive emissions).

Implied CO_2 emission factor for blast furnace gas

Three different ways of estimating the implied emission factors was made for the time series of 1990 to 2020 (number 3 only for 2015-2020 due to lack of modelled/estimated sold internal gases in the mass balance model earlier years).

1. CO_2 Reported emissions (Environment reports) with reported TJ (Mass balance model)
2. CO_2 Reported emissions form the EU Emissions Trading System (EU ETS) database with reported TJ (Mass balance model)
3. CO_2 (Mass balance model) with TJ (mass balance model) Sold internal gases.

Results

Literature review of LNG in Sweden

Qualities and use of liquid natural gas (LNG) in Sweden

LNG is natural gas that has been cooled below the boiling point (-162 °C) and thus turned into a liquid. In the process, the natural gas is purified of compounds that can freeze during the liquefaction process, and what is left is mostly methane, with small amounts of other hydrocarbons. According to Energigas Sverige, LNG sold in Sweden consists of 98-100 % methane and ethane, with methane varying between 85-100% [7]. As a liquid, LNG takes up more than 600 times less space compared to natural gas, and can be transported by ship, train or by land, avoiding the need of pipelines. This is the reason why LNG may serve as a substitute for natural gas.

Since LNG is not dependent on transport by pipeline, it may originate from different places as opposed to natural gas, which, to Sweden, is exclusively imported from Denmark.

EF based on Environmental reports and energy statistics

To some extent, LNG is used in Swedish industries instead of natural gas and is sometimes not differentiated from natural gas in the companies' environmental reporting. Among the companies reporting use of LNG to the energy statistics, only a few facilities have been identified to distinguish LNG in their environmental reports. Based on this information, implied emission factors for CO_2 and NO_x may be calculated from a single facility and applied to other facilities. However, plant-specific information below is not enough to derive national emission factors:

Arctic Paper Munkedals AB uses LNG for steam generation, and CO_2 emissions from LNG are reported in their environmental report. The implied emission factor for LNG is 55.7 kg/GJ. However, since reported emissions are calculated and not measured, the implied emission factor is simply a result of the emission factor they have chosen.

Hagfors Järnbruk is also using LNG in their process, reporting NO_x emissions from their heating ovens. The implied emission factor is calculated to 0.1 kg/GJ. This implied emission factor is likely not representative for the LNG use at national level since NO_x emissions vary much depending on the temperature of the combustion process.

[7] Energigas, 2022-02-11.(https://www.energigas.se/fakta-om-gas/biogas/faq-om-biogas/vad-ar-energiinnehallet-i-naturgas-biogas-och-fordonsgas/)

Out of five refineries, one is using LNG as feedstock for hydrogen production; however, implied emission factors cannot be obtained from reported emissions, since other feedstocks are also used and only the combined emissions are reported.

In addition to these facilities, SSAB in Borlänge is using LNG to fuel a heating oven, however no information is available that may be used to construct emission factors specific to LNG.

LNG will replace coke oven gas in SSAB Oxelösund as part of their efforts to produce fossil free steel, before moving to liquid biogas.

Emission factors for LNG from other sources

2006 IPCC Guidelines and EMEP/EEA Guidebook 2019

There are no emission factors in neither 2006 IPCC Guidelines nor EMEP/EEA Guidebook 2019 that are specific to LNG.

Transport sector

LNG is used in the transport sector as a cleaner alternative to other fossil fuels. In a recent SMED report (Hult&Winnes, 2020), emission factors for LNG were established. Emissions depending on combustion conditions, such as CH_4 and NO_x, are not expected to be similar to LNG use within stationary combustion, since the combustion conditions are different in the mobile sector compared to stationary combustion. CO_2 emissions are however expected to be similar, and the CO_2 EF for the transport sector is the same as for natural gas. Emissions of sulphur, particles, metals and POPs are very small.

Other countries

Neither Norway nor Finland reports specific emission factors for LNG.

Data base for EU ETS reporting of CO2 emissions

A few facilities report LNG in the Swedish database for EU ETS. Emissions and heating values reported here are most often the same as for natural gas used in the Swedish emission inventory.

Calorific values for LNG

The calorific value that will be used for LNG is reported by the companies to the Swedish energy statistics. It is similar to, but not the same as, that of natural gas. Currently, CO_2 emissions for natural gas in the stationary combustion are estimated with emission factors and calorific value based on the Danish Energy Agency estimates.

Summary and conclusions regarding emission factors for LNG

Due to the lack of information and data on LNG as separate a fuel from natural gas, emission factors for natural gas for stationary combustion (in kg/t) are recommended to be used also for LNG. However, the slightly different calorific value for LNG as reported to the Swedish energy statistics, result in slightly different emission factors expressed in kg/GJ. For all pollutants except CO_2, this difference is much smaller than the uncertainty attached to the emission factor. No changes compared to previous submission are thus recommended, see Table 1.

However, for CO_2, a specific emission factor for LNG may be calculated. Based on the assumption that LNG consist of between 85-100% methane and 0-15% ethane[8], the emission factor for CO_2 ranges from 56.25-56.81 kg/GJ, with an average emission factor of 56.5 kg/GJ. Since the composition is not expected to vary over time, an emission factor of **56.5 kg/GJ** is proposed for the entire time series from 1990 onwards, including projections. The uncertainty for CO_2 EF is calculated based on the varying composition and is ±0.5%.

Proposed emission factors for LNG are listed in Table 1.

Table 1. Proposed emission factors for LNG. All emission factors except for CO_2 are the same as for natural gas.

Pollutant	Sector	EF	Unit	Reference
CO_2	1A1, 1A2	56.5	kg/GJ	Based on carbon content[7]
CH_4	1A1, 1A2	0.001	kg/GJ	2006 IPCC GL
N_2O	1A1, 1A2	0.0001	kg/GJ	2006 IPCC GL
Nox	1A1, 1A2	0.01425-0.05	kg/GJ	Mawdsley et al. 2016

[8] Energigas, 2022-02-11.(https://www.energigas.se/fakta-om-gas/biogas/faq-om-biogas/vad-ar-energiinnehallet-i-naturgas-biogas-och-fordonsgas/)

Pollutant	Sector	EF	Unit	Reference
NMVOC	1A1 el*	0.002	kg/GJ	Kindbom et al. 2003
NMVOC	1A1 dh*, 1A2	0.001	kg/GJ	Kindbom et al. 2003
CO	1A1, 1A2	0.015	kg/GJ	Boström et al. 2004a
NH_3	1A1, 1A2	0.001	kg/GJ	Boström et al., 2004a
TSP	1A1, 1A2	0.0001	kg/GJ	Boström et al. 2004b
PM_{10}	1A1, 1A2	0.0001	kg/GJ	Boström et al. 2004b
$PM_{2.5}$	1A1, 1A2	0.0001	kg/GJ	Boström et al. 2004b
BC	1A1	0.0000025	kg/GJ	EMEP/EEA 2019
BC	1A2	0.000004	kg/GJ	EMEP/EEA 2019
BaP	1A1, 1A2	0.00056	t/GJ	EMEP/EEA 2019
BbF	1A1, 1A2	0.00084	t/GJ	EMEP/EEA 2019
BkF	1A1, 1A2	0.00084	t/GJ	EMEP/EEA 2019
Inp	1A1, 1A2	0.00084	t/GJ	EMEP/EEA 2019
PAH_{1-4}	1A1, 1A2	0.00308	t/GJ	EMEP/EEA 2019
Dioxin	1A1, 1A2	0.0005	g/GJ	EMEP/EEA 2019

***el – electricity production. dh – district heating.**

Implied CO_2 emission factor for blast furnace gas

The emissions of CO_2 from blast furnace gases are mainly originated from two integrated iron and steel production facilities. The activity data and emissions from these facilities are based on IPCC Tier 3 method and are estimated on a mass balance model based on the facilities' annual Environmental Reports. Part of the emissions originating from combustion of blast furnace gases are reported in 1A1a since the gases are transported and sold to a two heat and warming producing facilities nearby. These emissions are indirectly based on the mass-balance model. The activity data for this heating production is from the facilities reporting to the Quarterly Fuel Statistics. The emissions are then estimated based on the reported consumed amounts from KvBr multiplied with the implied emission factors from the mass balance model (Environmental reports) from reported amounts of CO_2-emissions.

The IEF in the current submission (2022) (Table 2) have been investigated and revised as the mass balance model was revised. However, the nationally published IEF (EF-supplement) has not been revised. The IEF originated from reported emissions to EU-ETS is comparable but differs a bit each year (nor reported here due to confidentiality reasons).

The new proposed IEF are slightly changed for the years between 2010, 2013 to 2020. Since IEFs need to be adjusted/calculated in a way so that the total reported CO_2 emissions are the same as reported in the facilities' Environmental reports, the IEF might vary between the years, depending on the reporting of fuel used in the Quarterly Fuel Statistics Fuel Statistics compared to the fuel use reported in their Environmental reports.

Table 2. Comparison of implied emission factors for CO_2 combusting blast furnace gases in the Swedish GHG inventory

Year	IEF Submission 2022	EF-supplement (submission 2022)	Proposed new IEF
1990	294	311	**294**
1991	269	265	**269**
1992	270	267	**270**
1993	296	314	**296**
1994	288	302	**288**
1995	298	320	**298**
1996	338	394	**338**
1997	280	284	**280**
1998	279	282	**279**
1999	275	276	**275**
2000	285	294	**285**
2001	292	304	**292**
2002	296	311	**296**
2003	308	296	**308**
2004	284	269	**284**
2005	250	266	**250**
2006	272	305	**272**
2007	294	294	**294**
2008	280	280	**280**
2009	282	282	**282**
2010	289	289	**289**
2011	275	275	**277**
2012	278	278	**278**
2013	303	303	**303**

2014	275	275	***300***
2015	296	296	***274***
2016	272	272	***276***
2017	298	298	***277***
2018	273	273	***279***
2019	273	273	***274***
2020	264	264	***263***

Conclusions

A new CO_2 emission factor for stationary combustion of LNG, **56.5 kg/GJ,** is presented and suggested to be used in the Swedish GHG inventory. Other emissions originating from LNG combustion are suggested to have the same EF as natural gas (same as in submission 2022).

In addition, revised IEF time series of CO_2 emissions for blast furnace gases 2011, 2014-2020 are suggested for submission 2023.

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SEPA, 2022. National Inventory Report Sweden 2022 - Greenhouse Gas Emission Inventories 1990-2020. Submitted under the United Nations Framework.Convention on Climate Change and the Kyoto Protocol. Section 4.4 Metal industry (CRF 2.C).