REPORT

GHG Emissions assessment of extinguishing systems

PRINCIPAL

Prevent Systems AS

TOPIC

GHG emissions

DATE /AUDIT 7 June 2022 / 25 Aug 2022

DOCUMENT CODE: 10242965-01-RIM-RAP-001

Multiconsult

Multiconsult

REPORT

MISSION	**GHG emissions assessment of extinguishing systems**	DOCUMENT CODE	10242965-01-RIM-RAP-001
TOPIC	Greenhouse Gas Emissions	ACCESSIBILITY	Open
PRINCIPAL	**Prevent Systems AS**	MISSION MANAGER	Anders R. Liaøy
		COMPILED BY	Jo Erik Abildgaard, Trine Lise Folvik, Anders R. Liaøy, Jonas Winsvold
		RESPONSIBLE UNIT	10102021 Lillehammer Section

SUMMARY

Buildings are considered to be a "emissions giant" globally and in Norway, and plumbing accounts for a significant share of greenhouse gas emissions. It has traditionally not been common to take greenhouse gas into account when choosing solutions and materials for firefighting. In order to fulfil national and international objectives, the environment must also be emphasized in the field of firefighting. This report provides a first look at the global warming effect of two possible solutions.

On behalf of Prevent Systems AS, Multiconsult has carried out a comparative greenhouse gas assessment of water mist and conventional sprinklers. To investigate the problem, a hospital building of 20,274 m^2 BTA has been used as a case. Modelling and calculations have been carried out neutrally with regard to the system supplier of extinguishing systems in that typical representative components have been used. The analysis has been carried out for a period of 60 years and includes emissions related to material use when installing the extinguishing system, as well as replacements during the period.

The results from the GHG emissions calculation show that the traditional sprinkler system has emissions of 24 kg CO_2-e./BTA, which for the analyzed building corresponds to 484 tons CO_2-eqvivalent in total. Furthermore, the calculation shows that a water mist system would have emissions of 7 kg CO_2-e./BTA, which corresponds to 140 tons of CO_2-eqvivalents for the analyzed building. This is a 71 % reduction for water mist systems compared to conventional sprinklers.

The environmental documentation used in the project shows that the largest GHG emissions originate from the production stage. This is also typical for other HVAC-equipment, except for machines with high energy consumption. The difference is significant, even though the estimated reduction only covers GHG emissions from material use. It is therefore reasonable to assume that the water mist system has a clearly lower greenhouse gas emissions than conventional sprinkler systems throughout the life cycle.

The difference in emissions for the two solutions is primarily due to the use of 72 % less materials in the water mist system, as presented in Figure 5 and Table 5. Higher pressure and lower water volumes enables significantly smaller dimensions of the water mist system than that of the sprinkler system.

In this report only greenhouse gases for the two possible solutions, for this specific case, has been assessed. When choosing a solution, it is important that an overall assessment is made, including available water supply, need for pump, regulatory requirements and standards, aesthetics, costs, as well as the building's design and suitability for the various solutions. Other environmental indicators such as acidification potential, eutrophication, ozone degradation, etc. should also be considered.

A	29.08.2022	Translation to english	J.W.	T.F.	A.L.
FOX.	DATE	DESCRIPTION	COMPILED BY	VERIFIED BY	APPROVED BY

TABLE OF CONTENTS

1 Introduction

The building and construction sector accounts globally for about 40 % of energy and process-related emissions and the share is increasing due to population growth. In Norway, emissions from the construction industry account for about 15 % of national emissions (Asplan Viak. Bygg- og anleggssektorens klimagassutslipp. 2019) and a reduction in this sector will be crucial to achieving the national target of 50 % reduction in greenhouse gas (GHG) emissions by 2030 and 90–95 % by 2050.

Estimates carried out by Multiconsult indicate that HVAC accounts for 20–40 % of the GHG emissions from new construction and rehabilitation projects, respectively. Research carried out by Multiconsult in the ongoing research project Green HVAC suggests that sprinklers account for a significant proportion of greenhouse gas emissions associated with HVAC installations in buildings.

Today, there are mainly two types of extinguishing systems with water; sprinkler and water mist. Both intend to extinguish and control a fire with water as extinguishing agent. They both have the same structure, but where the sprinkler system dampens/extinguishes the fire with water spread out with a deflectorplate, a water mist valve will nebulize the water into microdroplets that more easily evaporate and thus absorbs the energy from the fire in order to extinguish it.

On behalf of Prevent Systems AS, Multiconsult has carried out a comparative GHG assessment of water mist and conventional sprinklers for a case project. Modelling and calculations have been carried out neutrally with regard to the system supplier of extinguishing systems and typical representative components have been selected. This means that the report will not be particularly advantageous for one supplier of water mist systems, but a general comparison of two principled solutions for extinguishing systems. The assignment does not include assessing the suitability of the extinguishing solutions for the case project, but only how the solutions affect the environment in the form of GHG emissions.

Historically, the environment and GHG emissions have not been factors that are taken into account when assessing extinguishing solutions in buildings. The results from this report provide a first look at how large GHG emissions from extinguishing systems are, and how the choice of different solutions can affect emissions.

2 Project case

Solutions for automatic firefighting have been assessed for the case project Østfold Kalnes Hospital. The hospital consists of bed buildings, treatment buildings, psychiatric and service buildings. In this report, extinguishing solutions have been assessed for the treatment building, building 8. Modelling and GHG calculations are done for a selected area of 333 m^2 BTA on one floor. The area is chosen so that it contains a representative extinguishing system, a representative amount of equipment/m^2 and gives a good picture of a typical area of a hospital building. In addition, materials of the riser in the shaft and the main distribution pipe are included.

Figure 1: Overview image Østfold Kalnes Hospital (Source: sykehuset-ostfold.no/om-oss/media#pressebilder)

The greenhouse gas calculation is scaled up for the entire treatment building, but floors that do not contain treatment or are primarily used for technical installations have been omitted. Materials of 3 risers and the main distribution pipe from the central have been included. The total area for which the greenhouse gas assessment is made is 20,274 m^2 BTA.

All areas included in this report are classified as Ordinary Hazard Group 1 (OH1). Most areas in hospitals with building height below 45 m and normal use are classified as OH1. This also applies to other types of buildings such as schools, offices and restaurants. In Norway, it has traditionally been common to use sprinkler systems in buildings where automatic extinguishing systems are required. Water mist has been less used due to lack of a standard. A new standard regarding water mist systems, the NS-EN 14972-1, was published 14/01/2021. This standard makes it easier to use water mist in buildings with areas classified as OH-class, without deviation. If the building is built higher than 45 m, the areas will be upgraded to ordinary hazard class OH3. Technical rooms are classified as OH3 and are not included in this report.

3 Projected solutions

To compare water mist and sprinklers, both solutions are designed for a selected area in the case building. We have used existing models for architecture and sprinklers "as built" (with sprinklers) as a starting point. The sprinkler system is designed with some de-escalation of sizes (in difference to laying the whole hallway in the same dimension). It is sprinkled equally above and below the ceiling.

3.1 Method

The design has been carried out using the following procedure:

- Choosing an area for design and comparison of extinguishing systems (see Chapter 2).
- Consider the selected area taking into account which water mist nozzles will be natural to use;
  - Option 1: Nozzles that may result in fewer nozzles in some rooms by comparison with sprinklers.

    The downside is that they use more water, but need lower pressure than two:

    Option 2: Nozzles that require higher pressure, but less water, than option 1, and the possibility of using either *upright* or *pendent* above the ceiling.
  - Option 1 was chosen since it was considered the most likely first choice due to fewer heads and lower pressure.
- Designing the water mist system
  - The software used is Revit 2021.1.6 with MagiCad 2022 UR-2
  - The water mist system is designed according to EN-14972-1:2020, hazard class OH1 and the area of operation is 72 m^2
  - The sprinkler system was designed at an earlier stage, but a new hydraulic calculation according to NS-EN 12845:2015, hazard class OH1 and area of operation 72 m^2 was made to obtain a comparative basis.
- Hydraulically calculate the dimensioning area for both sprinkler and water mist. This is performed above the ceiling for both systems, and the height is corresponding to placement in level 4, with the central located in U1.
- The method applied for designing the water mist system, is strived to be similar to that of sprinklers, so that the basis for comparison is as similar as possible. Hydraulic calculations are used as a basis, so that the resulting dimensions are different for the two solutions.

Technical rooms and areas designed with pre-action sprinkler systems are not included. Technical rooms shall be classified as OH3 with a larger area of operation and will require different design criteria and results. Areas requiring coverage by a pre-action system may in some areas cause the installation of a main pipe in addition to the main pipe of the ordinary sprinkler system.

The water mist design was chosen to use the same pipeline layout as of the sprinkler pipes in both U1, the shafts and for the main pipes of the corridors in each floor. And de-escalation of the pipe dimensions in the same way, such as sprinklers, but based on hydraulic calculations. From the main pipes to the nozzles, the shortest path has been designed, using as few as possible directional changes. Below ceilings, water mist nozzles are selected that cover a somewhat larger area than the sprinkler heads in rooms/areas which allow this. Therefore, there will be a fewer number of water mist nozzles than sprinkler heads. Therefore, the amount of 18 mm pressfittings will also be lower than the compared amount of the DN25 threaded for the sprinkler system. The areas above the ceiling will normally contain several obstacles, so that it will then be best to choose and place water mist nozzles with the same coverage area as sprinkler heads above the ceiling. Therefore, due to pressure and the quantity requirement, it will be the nozzles above the ceiling that become the dimensioning area for the water mist system.

3.2 Assumptions

To compare on the best possible basis, the following assumptions have been made:

- The design of the areas and functions in selected areas are similar.
- The fire extinguishing systems have the same function and follow the same fire strategy.
- Water pressure and quantity from municipal supply are similar.
- No design has been carried out that entails structural changes. Suspension is not considered a structural change.
- Joining methods follow from the pipe selection and are not decisive for the dimensioning.
- The need for a pump will come as a result after hydraulic calculation and is not the basis for the dimensioning.

3.3 Duct types

The following pipe types and properties are used for sprinklers and water mist.

Sprinkler system:

- Threaded steel pipes for dimensions up to and including DN 25. In practice only DN 25, with a transition to DN 15 for the sprinkler head.
- *Grooved pipes* from sizes over DN 25.
- C-factor (Hazen-Williams): 120.
- No Extended Coverage (EC) heads

Water mist system:

- Stainless Steel pressure fittings in external millimeter sizes. Follows EN 10305.
- Minimum size of 18 mm, with transition to 15 mm for the nozzle.
- C-factor (Hazen-Williams): 150.

Different pipe qualities have different C-factor (also called Hazen-Williams factor) which is a number on the inner resistance of the pipe based on the roughness of the pipe. It is natural that it will be different for different materials. This affects the pressure drop and is taken into account in the hydraulic calculation.

3.4 Results from engineering

The hydraulic calculations for the two systems result in two different pressure and water flow requirements, as shown in the following table:

Table 1:Pressure and water requirements according to hydraulic calculation

After sprinkler/water mist valve in flow direction	Sprinkler	Water mist	
Pressure requirement	3,2	6,6	bar
Water requirements	700,7	493,4	L/min
Sprinkler/water mist valve, non-return valve, and filter	Approx. 2.0	Approx. 1.5	bar

Summed up, the pressure requirement is 5.4 bar for sprinkler and 8.1 bar for water mist at the interior water intake. In addition, pressure loss from the municipal wiring and in, as well as non-return valve (cat. 2) in manholes, but this is not included.

As expected, the results from the calculations provide greater pressure requirement for water mist. This is solved with a pump. While the pressure requirement for sprinklers is within what normally does not trigger a need for a pump, this is due to local conditions and the pressure available in the municipal pipes (in some cases also at lower pressure there may be a need for a pump).

The water requirement is not abnormally high for sprinklers but is advantageously lower for water mist. The water requirement for water mist may be higher than expected. That is because we have chosen to use as many water mist nozzles as sprinkler heads above the ceiling because there are usually many obstacles such as large ventilation ducts and other technical installations above the ceiling that prevent full usage of the spreading pattern.
Pipes used in hydraulic calculations are shown in Figures 2 and 3.

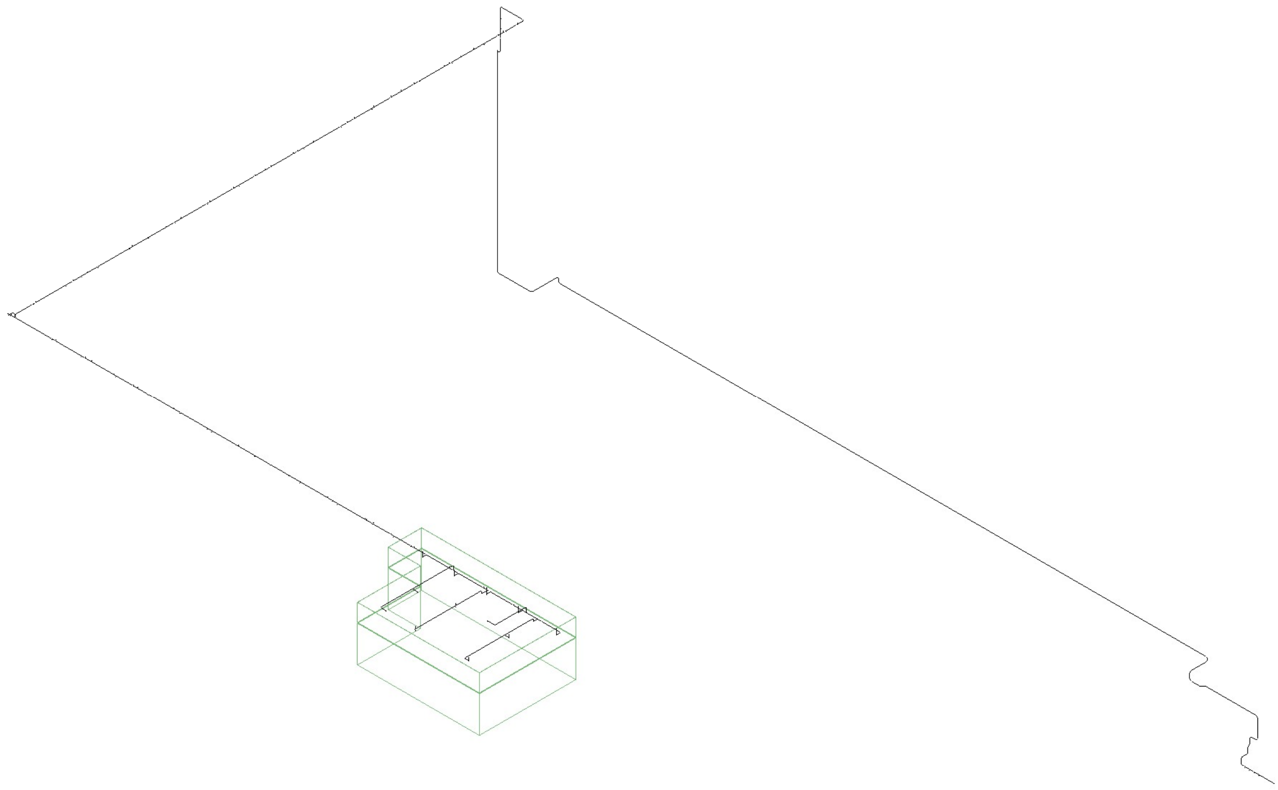

Figure 2: Area for hydraulic calculation, sprinkler

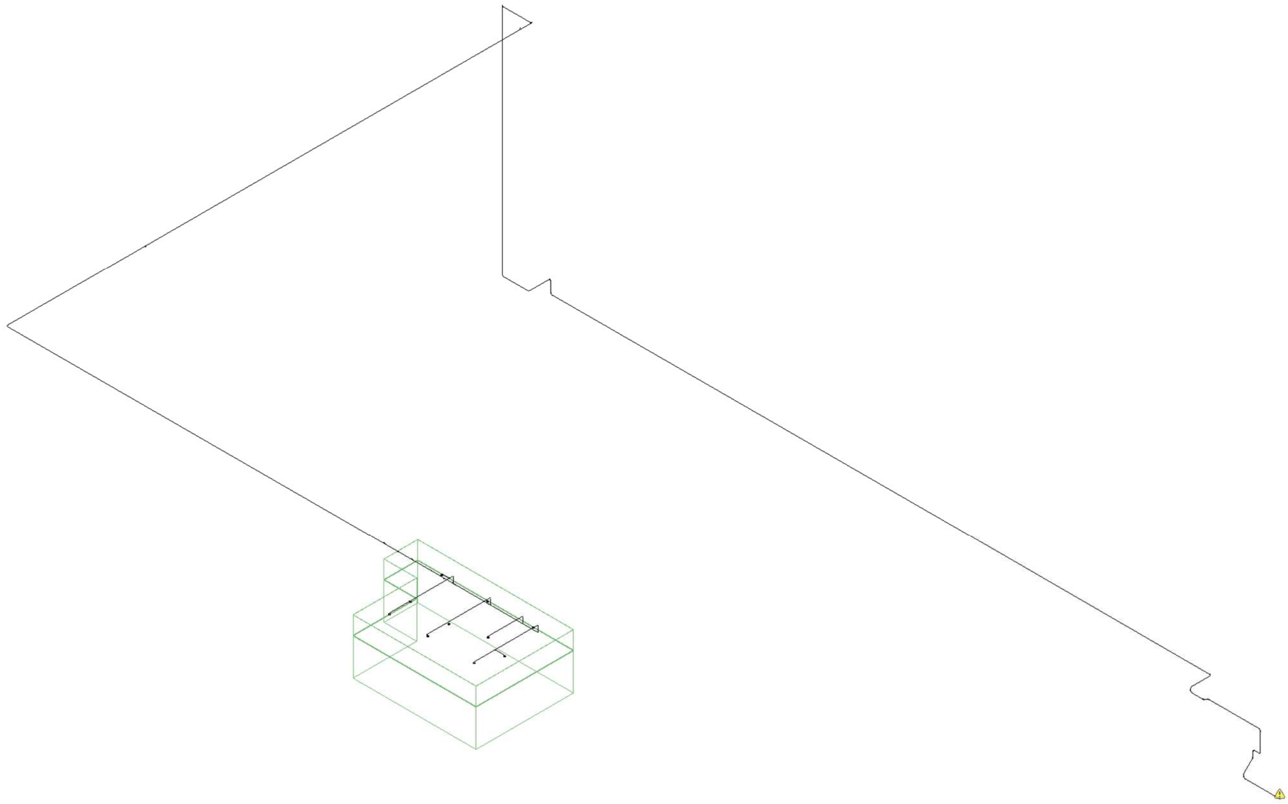

Figure 3: Area for hydraulic calculation, water mist

4 GHG calculations

Life cycle analyses (LCA) are a methodology for systematically assessing all processes that follow a product from the extraction of raw materials to the final disposal of waste. This is also often referred to as cradle-to-grave. Such an analysis can assess different types of environmental impact but is typically used to assess GHG emissions for a product/material related to the entire life cycle of the material.

4.1 Method

NS 3720 Method for greenhouse gas calculations for buildings sets out the guidelines for the preparation of GHG calculations for buildings and building parts. GHG emissions throughout the life cycle are linearly organized in *modules* from A to D (Table Table 2). The system limit of the GHG calculation defines which modules (parts of the life cycle) are included in the individual calculation and is related to the purpose of the calculation. Where the purpose is to form the basis for assessment for different choices of materials, modules A1-A5, B1-B5 and C1-C4 and possibly D should be included, if the information is available.

GHG calculations for materials are based on the third-party certified environmental product declarations (EPDs) of the materials, or if they are not available – using generic data, average data or otherwise representative data.

All calculations are prepared as CO_2-eq. per kg (GWP) of pipe and each piece for other components. Due to limited data for technical installations, greenhouse gas calculation is limited to the production phase and replacement for the pipe qualities included in the report, so-called "cradle-to-port" (A1-A3) and replacement (B4).

Table 2: Phases of the building's life cycle divided into modules. Source: NS 3720

Product stage			The through-guide stage		Usage stage								End of life				Consequences beyond the system limit
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	B8	C1	C2	C3	C4	D
Raw materials	Transport raw materials	Production	Transport to construction site	Construction, construction and assembly work	Custom	Maintenance	Repair	Replacement	Rebuilding	Energy use in operation	Water consumption in operation (not included in NS 3720)	Transport in operation	Demolition	Transport	Waste treatment	Disposal	Material and energy recovery and reuse of materials and exports of self-produced energy
X	X	X						X									

Piping systems include more than the pipes themselves, such as bends, T-pieces, transitions, clinging, sealants and glue. Therefore, an EPD should include additions that will be necessary for a complete piping system. These parts are to a varying degree included in EPD's included in this data basis, see Chapter 4.3**Error! Reference source not found.**

Since the environmental declarations only specify pipes, are the bends and pipe parts converted to pip length. This conversion causes some uncertainty, but this will apply to all pipe qualities compared in this report.

4.2 GHG calculation tools for plumbing

The greenhouse gas calculations are carried out using *Multiconsult's* internally developed GHG calculation tool associated with plumbing technical installations. The tool is an add-on for Revit and relies on the technical system being modeled in Revit. Based on EPD's and other available emission data, are GHG emissions calculated for the various components of the system. In the tool, GWP values per kg of pipe are used together with calculated kg of material for all pipe dimensions, pipe- and technical parts described in Chapter 4.3.
Error! Reference source not found.

4.3 GHG data

There are varying degrees of EPDs for the pipe qualities included in this report. The following sections explain which data is used in the calculations for the different pipe qualities.

Pipes and pipe parts

There are generally a marginal amount of EPD's available for metal pipes. Therefore, for the sake of data quality, it has been chosen to be based on a generic EPD from Okobaudat for all types of steel pipes and parts such as threaded steel pipes, groove pipes and acid-resistant press fittings.

The EPD's specify only pipe lengths. It is assumed that energy consumption and GHG emissions associated with the making of bends and parts are greater than what the mass-equivalent pipe length corresponds to. This conversion causes some uncertainty, but this will apply to all pipe qualities compared in this report.

Heads and nozzles

Sprinkler heads are standard mainly in brass: for standard brass sprinkler heads, a generic EPD from French INIES is used.
Water mist nozzles are standard mainly in steel: for stainless steel sprinkler heads, generic stainless steel EPDs from Okobaudat are used.

Pump

For pumps, a production specific EPD from Grundfos is used.

4.4 Assumptions

4.4.1 Time horizon

The time horizon for the calculation is set to the default building lifetime of 60 years.

4.4.2 Functional equivalent

The GHG calculation has been prepared for fire protection of 1 m^2 of a building of the type of hospital, over the life of the building of 60 years.

4.4.3 Lifetimes

The predicted lifetimes of the modelled components are based on standard EN 15459-1 Annex D together with the analysis "NOU 2012: 4 Safe at home– Fire safety for vulnerable groups" and presented in Table 3 below.

Table 3: Overview of predicted lifetimes of the various components.

Component	Lifespan (years)
Pipes & Pipe Parts	30
Sprinkler heads/nozzles	30
Pump	15

5 Findings

This chapter presents estimated GHG emissions for the two alternative extinguishing systems, sprinklers and water mist. A comparison of specific and total GHG emissions is also presented for the two solutions.

5.1 Sprinkler

The results from the GHG calculation for the entire building's sprinkler system are presented in Table 4 and graphically presented in Figure 4. The results are scaled from a model for a selected zone of the building, as described in Chapter 2.

Table 4: GWP [kg CO_2 equivalents] from modelled quantities [kg] in the sprinkler system.

System Section	GWP (A1-3, B4)	Kg
Pipe	387 505	36 765
Pipe parts	95 678	1 741
Sprinkler heads/ nozzles	1 209	134
Pump	-	-
Total	484 392	38 641

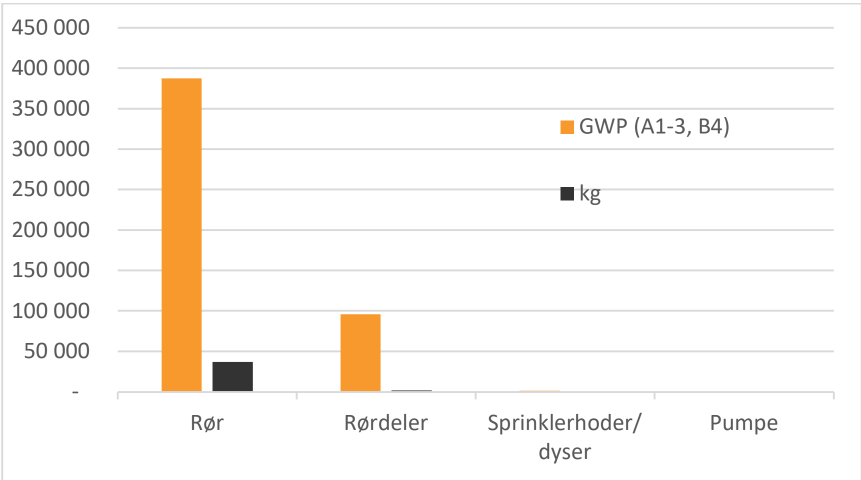

Figure 4: GWP [kg CO_2 equivalents] from modelled quantities [kg] in the sprinkler system.

5.2 Water mist

The results from the GHG calculation for the entire building with water mist systems are presented in Table 5 and graphically presented in Figure 5. The results are scaled from a model for a selected zone of the building, as described in Chapter 2.

Table 5: GWP [kg CO_2 equivalents] from modelled quantities [kg] in the water mist system.

System Section	GWP (A1-3, B4)	Kg
Pipe	104 136	9 841
Pipe parts	24 407	443
Sprinkler heads/ nozzles	3 465	329
Pump	7 328	-
Total	139 336	10 612

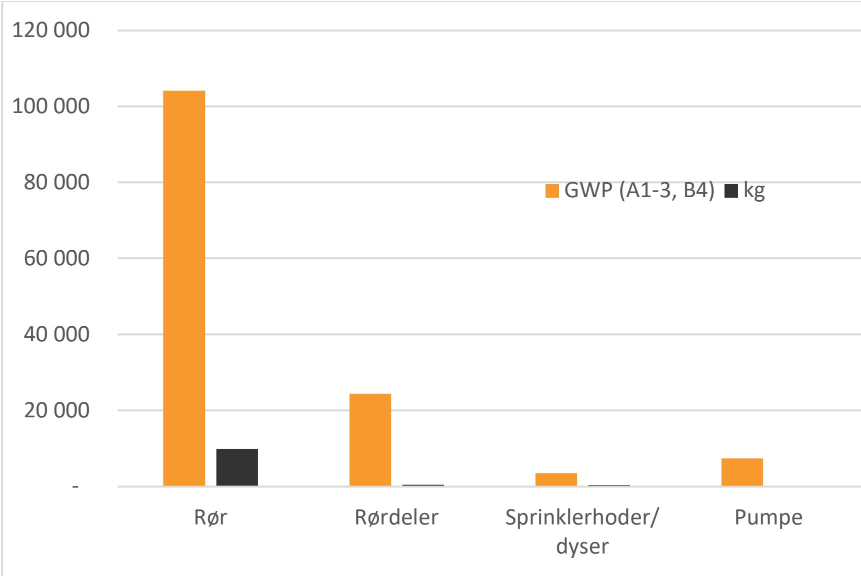

Figure 5: GWP [kg CO_2 equivalents] from modelled quantities [kg] in the water mist system.

5.3 Comparison

Specific and total GHG emissions from the GHG calculations for the two systems are presented in Table 6 and Figure 6 below.

Table 6: GWP [kg CO_2 equivalents] from the modelled facilities together with specific emission values [GWP/BTA] and total for the entire building.

	Sprinkler	Water mist
Pipe	19,11	5,14
Pipe parts	4,72	1,20
Sprinkler heads/nozzles	0,06	0,17
Pump	-	0,36
GWP/BTA	**23,89**	**6,87**
The whole building	**484 392**	**139 336**

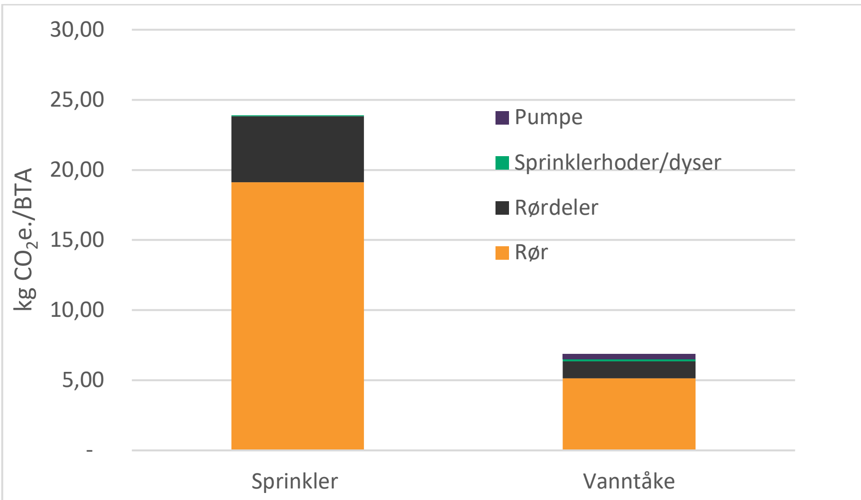

Figure 6: GWP [kg CO_2 equivalents] from the modelled plants.

The modelled water mist system achieves an emission reduction of 71% compared to the traditional sprinkler systemt. The reason for this is that 72% less material is used in the water mist system.

6 Discussion

The results in this report only present GHG emissions for the production of products and replacement of the systems, see Table 2 (modules A1-A3 and B4). In other words, it does not take into account other factors such as energy use in operation and disposal. Previous GHG assessments carried out by Multiconsult indicate that the largest part of the emissions from HVAC equipment are linked to the production phase, with the exception of machines with high energy consumption. Sprinkler systems do not have a large energy consumption in operation. Although the estimated reduction only covers GHG emissions from material use, the difference is significant. For example, reduced material volume in water mist systems will contribute to a further reduction related to transport in module A5. It is therefore reasonable to assume that the water mist system has a clearly lower GHG emissions than sprinkler systems throughout the life cycle.

There will always be great uncertainty associated with the lifetimes of the modeled componente, therefore conservative lifespans are provided. Due to lack of documentation, a common service life has generally been set for pipes that will lead to uncertainty as different pipe qualities may have different service lifes. Technical facilities are often replaced frequently due to short-term leases and frequent refurbishments. Theoretical lifespan may be considerably longer than those assumed here and several sources such as the Norwegian Price Book and the NOU 2012: 4 Safe at Home– Fire Safety for Vulnerable Groups" point out that the lifespan can be up to 60 years. An important environmental measure in projects is therefore to ensure that the entire life of the system is utilised and that components with a remaining service life are reused. For example, a dry system will have a much longer service life than a wet system.

There are also uncertainties associated with the calculation in the tool. Due to the lack of data and functionality of the software, quantities of pipe parts are not differentiated between pipe qualities but used a conservative generic quality.

One of the greatest environmental benefits that can be achieved with good fire safety in buildings will only occur if a real fire occurs. A fire is in itself a destructive and environmentally harmful event, and an automatic extinguishing system is one of several possible solutions that limit the spread of fire and associated emissions. This may therefore be the argument for installing extinguishing plants in buildings, despite GHG emissions associated with the production of equipment. There are various methods for LCA analysis of fire, but there is no extensive use of these, and such assessments are not included in standard LCC and LCA methodology for buildings. It is not given how an extended LCA analysis including the total course of fire will have an impact on automatic extinguishing systems, and thus whether the environment is an argument for or against such a technical installation in buildings (compared to notification only).

The interaction between the projecting and contracting parts is important. The design of the facilities may differ from projected to contracted. From drawing to finished project, there may be changes for different reasons. One challenge may be that a more optimal dimensioning can lead to several different pipe dimensions, while it can be lighter, faster, and perhaps cheaper to lay longer pipe stretches in the same large dimension. Furthermore, time spent on engineering can provide more or less optimally dimensioned solutions. For example, careful dimensioning may result in no need for a pump, while the choice of pump may provide opportunities for using smaller pipe dimensions.

Further optimization of the pipe dimensions may result in even lower GHG emissions from the materials for the water mist plant. Since the results from hydraulic calculations already require a pump, any larger pump (and necessary power consumption) would have an impact on the GHG accounts. Compared to sprinkler systems without a pump, a water mist system is somewhat more energy-intensive over time.

In some cases, a back-up pump will also be required. If this is the case, this will result in somewhat higher energy consumption over time. This additional pump can be an electric pump connected to another power source, but potentially this must be a diesel pump that must be tested weekly for 20 minutes. In that case, it will be even more advantageous with a careful dimensioning of the water mist system to achieve the minimum diameter of the pipes, while keeping the pump size as low as possible.

Smaller pipe dimensions will be advantageous when transporting. The same goes for lighter pipes. In total, it will be possible to transport larger lengths of pipes, which in turn can result in lower transport costs and lower GHG emissions.

Lighter pipes are also beneficial for the installer, both in terms of HSE and occupational damage, and perhaps in terms of the number of installers required. Since there are different joining methods using different pipe types, this can also affect assembly time.

In order to facilitate future reuse and utilization of materials, it is advantageous that components and materials can be separated from each other, without requiring major work or processes. For piping systems, dismountability is important and in a circular economic perspective, thread and groove joints are therefore preferable. Pipe parts for press fitting systems are not sufficiently adapted for disassembly and reuse.

7 Conclusion

The results from the GHG calculation show a significant reduction in greenhouse gas emissions from the water mist plant compared to the traditional sprinkler system. This reduction only includes GHG emissions from material use and does not take into account other factors discussed in this report. In this report only greenhouse gases for the two possible solutions, for this specific case, has been assessed. In all projects, an overall assessment must be made when choosing a solution. When choosing a solution, it is important that an overall assessment is made, including available water supply, need for pump, regulatory requirements and standards, aesthetics, costs, as well as the building's design and suitability for the various solutions.

The reason for the reduction in GHG emissions for water mist systems is fewer water mist nozzles, smaller and lighter dimensions. This results in smaller amounts of material in the water mist system compared to the sprinkler system.

The EPD’s used in the project and generally shows that the largest part of the GHG emissions originate from the production stage. Although the estimated reduction only covers GHG emissions from material use, the difference of 71% is significant. It is reasonable to assume that the water mist system has a clearly lower GHG emissions than sprinkler systems throughout the life cycle.

8 Suggestions for further work

- Examination of alternative material qualities, such as plastic pipes (pex, PP-R, or others). These could potentially be measures to achieve even greater savings in GHG emissions. A comparison of a larger scale between several types of pipes will also have to include GHG calculations around the different building conditions that follow. When casting, casing, or other "extra" building material use the choice of pipe type entails.
- Lighter pipe types and/or smaller dimensions may result in other suspension methods and/or fewer suspensions, but Multiconsult has calculated in previous estimates that suspension systems account for a small proportion of total GHG emissions for piping systems. But this can affect the economy and GHG accounts.
- When comparing different pipe types with different jointing methods, it may make sense to discuss other qualities, such as different jointing methods, experiences, time spent, sheath/surplus, HSE, chips/dust/microplastics, economic differences and environmental impacts.
- Examination of conventional sprinkler system with pressure booster pump, to reduce pipe dimensions.
- Examination of how common it is that an extinguishing system with a pressure booster pump must have both a pump and a back-up pump, as well as how often the back-up pump must then be powered by diesel. The study should include GHG calculations for diesel pump maintenance (typically to be tested every week for 20 minutes).
- Extended LCA analysis for buildings, where emissions related to actual fire are included and weighted with the probability of this occurring.
- Develop data basis for mass calculation of pipe parts.