General Comments on the Annex XV Restriction Report for Per- and polyfluoroalkyl substances (PFASs) dated 22.03.2023

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DuPont is a downstream user of fluorinated gases ("F-Gases"), in particular hydrofluoroolefins (HFOs) HFO-1234ze(E) and HCFO-1233zd(E) (hereafter referred to as "HFO ze & zd") that would be subject to the proposed restrictions. We understand the public and environmental concern motivating ECHA's universal PFAS restriction proposal, and we support balanced regulatory measures on PFAS. This submission reflects our intent to provide information on HFO ze & zd, a narrow subset of two HFO compounds that are used as blowing agents in low-pressure spray polyurethane foam (LP SPF) products.

Below we provide a summary of the detailed comments that we provide in this document and its appendices. We address the specific questions 1 – 10 sought by European Chemicals Agency (ECHA) as part of the consultation here as well. While the answers to these specific questions are contained within our general comments for complete context, we have also isolated our input to those questions in the Specific Questions section in Appendix F for ease of access by those reviewing our comments.

Executive summary

In review of the Annex XV report and based on our technical and market expertise regarding low-pressure spray polyurethane foam (LP SPF) products, we submit evidence to support the following conclusions, organized according to categories of interest to ECHA:

Missing Use

- In answer to Specific Question 1, a missing PFAS sub-use should be added to the list of sub-uses named in the Annex in order to recognize the unique applications, performance requirements, and lack of technology options available for the LP SPF sub-use sector, which falls generally under "Applications of fluorinated gases". We ask that this missing sub-use be titled "**Foam blowing agents in low-pressure spray polyurethane foam sprayed on site**"
- Inclusion of this missing use provides clarity for the current use category within the fluorinated gases use sector (vi) Potential derogation marked for reconsideration: "Foam blowing agents in expanded foam sprayed on site for building insulation." As currently labeled, this use category does not recognize the different technologies, technology options, and performance requirements that are implicitly grouped together under this title. For example, the performance requirements and technology options vary significantly between high-pressure spray polyurethane foams and low-pressure spray polyurethane foams.

Lack of Alternatives and Transition Timing

- For foam blowing agents in LP SPF, **alternatives to HFO ze & zd do not exist today**. Over the last decade, driven by the EU F-Gas regulation, the Montreal Protocol and its Kigali Amendment, substantial research has been conducted, exploring an exhaustive set of the options available today with the goal of identifying alternatives to fluorinated gases. That research has revealed that, different from some other foam insulation technologies, no technology alternatives are available today that can meet the requirements of LP SPF product applications.
- **Transition away from HFO ze & zd in LP SPF is not possible over the next 12 years.** Invention and development of new materials that could serve as blowing agent technology options is required and would need to be led by the blowing agent technology developers who have historically developed the blowing agent solutions used within the foam insulation industry.

To our knowledge, there is no research currently underway by blowing agent technology developers to invent new blowing agent options. Additionally, the time required to develop a new solution and implement it within the industry is understood to be on the order of decades, with the most recent blowing agent conversion happening over a span of about 15 years. Therefore, with no line of sight to an alternative solution today, transition within the LP SPF industry is not possible in the next 12 years.

PFAS Emissions and Risk Assessment

- Non-Persistent substances: The HFO ze & zd used in this sector are not persistent substances, as demonstrated by the REACH dossiers[i] [ii] and many other public documents including the 2023 United Nations Environment Programme (UNEP) report [iii].

- Not bioaccumulative or toxic: The HFO ze & zd used in this sector can theoretically break down into trifluoroacetic acid (TFA), which has been classified as a persistent substance, at a theoretical yield of 0% to a maximum of 4%.[iv] [v] [vi] [vii] However, according to a recent United Nations Environmental Effects Assessment Panel (UN EEAP) study conclusion, "TFA does not bioaccumulate nor is it toxic at the low to moderate exposures currently measured in the environment or those predicted in the distant future."[viii]. This conclusion is further supported by the REACH PBT assessment of TFA which notes "…it is neither fulfilling the criteria for toxic and bioaccumulative (PBT-substances), nor the criteria for very bioaccumulative substances (vPvB-substances) according to REACH directive".[ix]

- Low exposure: The emissions of TFA associated with HFO use are not expected to pose an environmental or health concern based on the exposures expected through the year 2100, as reported by the UN EEAP.[x] The estimated emissions of TFA for the foam blowing agents in the LP SPF use/market are small. We estimate product life cycle TFA emissions between 0 and [redacted] for the sector use of HFO ze & zd in LP SPF products in the EU, based on the worst-case theoretical yields reported for TFA.

Socio-Economic Assessment

- Business impact: Implementation of a restriction to ban the use of HFO ze & zd in LP SPF would lead to full loss of business in Europe at the time of entry into force. Because there are no alternatives available today for HFO ze & zd in LP SPF, this regulatory action would put out of business many organizations, including small and medium-sized enterprises (SMEs). This would also eliminate the LP SPF solution from the market and remove this solution as a tool for reducing greenhouse gas (GHG) emissions in buildings through the improved energy efficiency that LP SPF delivers. The impacted value chain that would be forced to exit the market includes product formulators, contract manufacturers, distributors, and professional users. The negative business impact will be articulated in detail in forthcoming SEA and Risk Management Options Analysis reports that are under preparation by the industry organization Cefic and the European FluoroCarbons Technical Committee (EFCTC) respectively; we expect to provide additional comments to ECHA based on these industry-prepared analyses. As an overview of the impact, we provide the following for the use of HFO ze & zd in LP SPF:
    - In answer to question 6g**:** *For cases in which substitution is not technically or economically feasible, information on what the socio-economic impacts would be for companies, consumers, and other affected actors. If available, please provide the annual value of EU sales and profits of the relevant sector, and employment numbers for the sector.*
        - The LP SPF product represents a niche sub-use sector of the EU Spray Polyurethane Foam sector. DuPont estimates that this LP SPF market includes hundreds to thousands of people associated with these products at a total value of tens of millions of Euros. This includes the high number of downstream and upstream employment jobs associated with LP SPF products. Indirect employees would include contract manufacturing sites, distributors, applicators, and end-use sites of the products. Additional information is found under "F-gas downstream

users" sections of the recent report "SOCIO-ECONOMIC ANALYSIS OF THE VALUE OF F-GASES" published in September of 2022.[xi]
        - CBI: [redacted].

  - In answer to question 6c: *The number of companies in the sector estimated to be affected by the restriction*
        - The LP SPF use sector represents a relatively small market in EU, with only two product manufacturers participating in the market. We expect only a few organizations will provide comments on the Annex regarding LP SPF, but these organizations are expected to represent all the product manufacturers in the market, and their collective input should not be viewed as "weak evidence" due to the small number of product manufacturers in the market.

- Impact on EU Climate Targets: LP SPF plays a critical role in achieving EU climate goals by enabling energy efficiency gains through insulation and air sealing functionality delivered through its application. There are no replacement products for these solutions in the market capable of meeting the unique requirements of these applications. These products will continue to play a key role in meeting policy objectives under the EU Green Deal. For example, LP SPF can help enable the required energy efficiency targets required within the updates of the Energy Performance of Buildings Directive (EPBD) and the Energy Efficiency Directive (EED), which determine the requirements to facilitate the goals of the EU Renovation Wave. Since there are no technical alternatives to produce LP SPF without HFO ze & zd, the LP SPF solution would be eliminated from the market at entry into force, thereby compromising the ability of the EU to achieve its climate goals and advance the Renovation Wave.[xii]

Derogation Language

- Accordingly, we conclude that foam blowing agents in low-pressure spray polyurethane foam warrant a time unlimited derogation, and propose the following language for inclusion in the restriction:

    "Foam blowing agents HFO-1234ze(E) and HCFO-1233zd(E) used in low pressure (< 17 Bar (< 1724 kPa)) spray polyurethane foam sprayed on-site are granted a time unlimited derogation"

- "Table 9. RO2 – Summary table of derogations" found in the "Proposal for a Restriction", Annex XV Restriction Report, should include the following sub-use under "Applications of fluorinated gases" to capture the missing use and necessary associated details.

Use sector (with sub-uses)	Proposed derogation	Duration of derogation period, including substantiation	Cost impact of 5 and 12 year derogation periods
Foam blowing agents in low-pressure spray polyurethane foam sprayed on site	Given sufficiently strong evidence that technically and economically feasible alternatives are not available at EiF, derogations are proposed for: • Foam blowing agents in low-pressure spray polyurethane foam sprayed on site	A **time-unlimited** derogation for fluorinated gases in low-pressure spray polyurethane foam, where drop-in alternatives are not available and national safety standards and building codes prohibit the use of alternatives [sufficiently strong evidence base].	The need for public confidence in fire safety systems indicates potential for significant welfare loss in the event that the safety of alternatives is not demonstrated and restrictive building codes remain in force, whilst limiting loss of producer and consumer surplus and welfare losses from use of less effective products.

We provide evidence below to expand upon these points and support this evidence with additional detail in the appendices further below.

Detailed General Comments

In the sections that follow, we provide additional details to expand the comments summarized above in the Executive Summary.

PRODUCT: What is Low-Pressure Spray Polyurethane Foam, and what role do Blowing Agents play?

We begin by providing an overview of the Low-Pressure Spray Polyurethane Foam (LP SPF) products. LP SPF products are sold in portable, self-contained pressurized cylinders, as pictured in Figure 1 below. LP SPF products are created by forming closed-cell, inert polymeric structures with thermal resistance at low pressure. Blowing agents, sometimes referred to as foaming agents, produce and/or use gas to generate cells (gas pockets) in polymeric materials.[xiii] LP SPF products rely on gaseous and/or liquid blowing agents that act to both dispense product and achieve many foam properties in a portable container, delivering high performance product, including insulation properties, at a low pressure.

Figure 1. Portable products provide key energy efficiency functions in niche applications

Blowing agents are the central focus of the LP SPF category with respect to the Annex XV Restriction Report for PFAS substances. Blowing agents must meet a number of technical requirements for successful application in LP SPF products, including the following considerations:

- Blowing agents are incorporated into the foam product within the foam cells, and must largely remain within the foam during the use phase
- Liquid blowing agents help to create uniform cells and control density in the foam
- Gaseous blowing agents act to blow/propel and froth the foam, and serve to insulate the closed-cell foam structure that is formed
- Blowing agents must also act as propellant to help empty the pressurized cylinder, which allows portability and on-site application without requiring the use of applied pressure from an external source
- Today, HFO ze & zd play an integral role as blowing agents in the delivery of LP SPF products and their applications

LP SPF is unique in its portability for required use in critical spaces where other insulation products will not work, e.g., building insulation, food and medical cold storage and cold transportation, and in industrial pipe insulation particularly for cryogenic applications at liquified natural gas terminals.

PRODUCT USE: HFOs used in Low-Pressure Spray Polyurethane Foam is a missing use and should be specified uniquely in the restriction

While building insulation foam is mentioned for a potential derogation in the draft restriction, low-pressure spray polyurethane foam (LP SPF) in building, construction, industrial and transportation for sealant, adhesive & insulation uses are not yet listed.

LP SPF is a vastly different technology category relative to other types of spray polyurethane foams, and its specific requirements warrant consideration as a separate sub-use category. For example, LP SPF has unique requirements compared to high-pressure spray polyurethane foam (HP SPF), which is sold in large drums and sprayed on site for building insulation as referenced in Annex E of the draft restriction (page 297-298). LP SPF has a wider usage than just building insulation and is distinctly technically different from other polyurethane foams that are used to insulate equipment and are applied in an industrial setting.

LP SPF products sold in portable self-contained cylinders are unique in portability for required use in critical spaces, and unique in the low pressure of the application pressure (< 17 Bar (< 1724 kPa)), where other insulation products will not work. LP SPF uses a static nozzle which, at the low pressure, does not aerosolize the components and allows for removal of personal protective equipment in the application area one hour after application. Additional technical aspects of the LP SPF technology include:

- Dispensed at pressures less than 17 Bar (1724 kPa)
- Output at full trigger is 2.3 -3 Kg (5–7 lbs.) per minute
- Product temperature of 21–29°C (70–85°F)
- Quick startup & shutdown
- Minimal maintenance and associated costs
- Lower output, low emissions, quicker re-entry time (One hour re-occupancy)[xiv]

HP SPF products, by comparison, are sold in large industrial sized drums and require ancillary pressure inducing equipment typically housed in a large trailer called a rig. The rig is a significant equipment cost, including heated hoses (up to about 91 meters (300ft) in length), air supply, and other items, which must be parked near the spray site. HP SPF products require approximately 55 to 110 Bar (5512 to 11032 kPa) for application and are used for large area applications; they cannot be used for smaller applications due to cost and additional factors including the application pressure. Additionally, HP SPF is applied using an impingement nozzle which aerosolizes the product requiring the user to wear significant personal protective equipment during application and in the spray zone for 24-48 hours after application.[xv] Additional technical aspects of the HP SPF technology include:

- Typically dispensed at pressures exceeding 69 Bar (6895 kPa)
- Output at full trigger is up to 13.9 Kg (30 lbs) per minute
- Product temperature of 49–65°C (120–150°F)
- One hour startup & shutdown
- 80+ serviceable parts to gun components
- High output, high emissions, greater re-entry time (24–48-hour re-occupancy)
- 55-gallon drums to transport and dispose[xvi]

Accordingly, based on the unique technology requirements, and unique blowing agent solutions available for LP SPF applications, we have recognized that LP SPF is a missing use, and are proposing that a sub-use be added to the restriction under the title “Foam blowing agents in low-pressure spray polyurethane foam sprayed on site”.

For a detailed comparison of LP SPF technology against additional not-in-kind solutions, see Appendix C.

ALTERNATIVES: Alternatives do not exist today for HFO ze & zd used in LP SPF

An exhaustive search for alternative blowing agents in LP SPF products has been conducted by global technology experts over the last 10+ years, in response to the global HFC phasedown driven by the Montreal Protocol and Kigali Amendment. This research explored an exhaustive set of materials available today and considered the key performance requirements for LP SPF applications that include high thermal performance, air sealing performance, closed cell content and low water absorption.

> We provide a comprehensive overview of that research in our Appendix A -- Evaluation of LP SPF blowing agent options, and we summarize here the overall findings of that effort. **The result of this extensive effort has led to HFO ze & zd being identified as the only viable blowing agent option for LP SPF today.**

Although the Kigali Amendment defined low global warming potential (GWP) and GHG reduction as the main requirement of successful alternative blowing agent technology, a broad set of well-understood technical requirements guided the evaluation and identification of viable blowing agent options for LP SPF foams.

An important consideration in evaluation of alternative blowing agents, which was noted appropriately in Annex F, is that “…deployment of alternatives is limited by legal or technical barriers. An example of a legal barrier concerns the existence of building standards and codes at national or city level that restrict the use of some refrigerants or foam blowing agents in (e.g.) high rise residential buildings.”

This outcome sets LP SPF technologies apart from some other SPF technologies that can use alternative blowing agent options like CO_2 and H_2O. As shown in Appendix A of this report, these blowing agent options are not viable for LP SPF applications.

Hence, recent blowing agent regulation addressing GWP under the Montreal Protocol and Kigali Amendment has driven an exhaustive search for alternative blowing agents within the industry. The alternatives examined within this research considered all available blowing agent options, and no new blowing agent alternatives have been invented that would expand the currently available options listed in Appendix A. **For LP SPF applications it is well known within the industry that there are no viable technology alternatives to HFO ze & zd available today that are capable of meeting all technical performance and regulatory requirements.**

TRANSITION PLANS: Transition plans for HFO use in LP SPF are not possible over the next 12 years

Question 6e. asks "*For cases in which alternatives are not yet available, information on the status of R&D processes for finding suitable alternatives, including the extent of R&D initiatives in terms of time and/or financial investments, the likelihood of successful completion, the time expected to be required for substitution (including any relevant certification or regulatory approvals) and the major challenges encountered with alternatives which were considered but subsequently disregarded.*"

Transition plans are currently not possible, because no alternatives to HFO ze & zd use in LP SPF exist today, as reviewed above. Hence, there are currently no transition plans for HFO ze & zd use in LP SPF.

Transition away from HFO ze & zd is wholly dependent upon development of new materials by blowing agent technology developers and suppliers. To enable transition, new materials must be invented that would expand the technology options beyond the exhaustive set that has already been researched and demonstrated not to meet the LP SPF performance requirements.

To our knowledge, blowing agent technology developers and manufacturers do not have research programs currently underway to develop HFO ze & zd alternatives. We suspect that this activity may be unlikely given that HFO is a technology that has only recently been commercialized after a lengthy research and development program, with products like LP SPF that utilize HFO ze & zd having been introduced to the market as recently as the past year. Without the invention and development of new alternatives by the blowing agent technology developers & manufacturers, the LP SPF industry will be unable to transition away from HFO technology.

Considering the timing of potential transition, we note that the most recent transition out of HFCs used in LP SPF products took the entire industry, considering HFO producers, regulatory approval processes, and downstream users, over 15 years. Applying this experience to a future potential transition away from HFO ze & zd, we estimate that transition would require roughly 25+ years, as summarized in the table below.

Step 1	Invention and development of a new HFO-replacement technology by the blowing agent technology developers	**10+ Years** (Estimated, based on history with our suppliers)
Step 2	Regulatory registrations, scale up and production of the new material by the blowing agent manufacturers	**5+ Years** (Estimated, based on history with our suppliers)
Step 3	Research and development reformulation effort of the LP SPF products by the LP SPF manufacturers	**5+ Years** (DuPont LP SPF history)
Step 4	Implementation of the new technology by LP SPF manufacturing facilities	**5+ Years** (DuPont LP SPF history)

Table 1: Steps required to enable transition away from HFO ze & zd within the LP SPF sub-use sector.

Accordingly, the time to invent and develop new blowing agent technology options that could replace HFO ze & zd will exceed the 12-year timeframe designated in the draft restriction.

Given the current lack of alternatives, and lack of alternative technology development programs, the LP SPF industry will not be available to transition away from HFO ze & zd over the next 12 years.

Hence, to ensure that LP SPF applications can continue to meet market needs in insulation and other applications summarized earlier, we conclude that foam blowing agents in LP SPF warrant a time unlimited derogation, and propose the following language for inclusion in the restriction:

> **"Foam blowing agents HFO-1234ze(E) and HCFO-1233zd(E) used in low pressure (< 17 Bar (< 1724 kPa)) spray polyurethane foam sprayed on-site are granted a time unlimited derogation"**

PERSISTENCE: HFO-1234ze(E) and HCFO-1233zd(E) are not persistent

According to REACH registrations and available toxicological evidence, HFO-1234ze(E) and HCFO-1233zd(E) are not persistent substances. These two substances are not classified as persistent, nor as PBT, nor as vPvB.

The toxicity and environmental impact of HFO ze & zd have been rigorously assessed, both under REACH and in international forums such as the UN Environmental Programme (UNEP) and the Intergovernmental Panel on Climate Change (IPCC). As reported in the ECHA registration dossiers for HFO ze & zd, summarized in the table below, neither substance is classified as a PBT or vPvB by ECHA.

Substance	CAS#	ECHA registration dossier PBT status statement	ECHA registration dossier reference
HFO-1234ze(E)	1645-83-6	"the substance is not PBT / vPvB"	https://echa.europa.eu/de/registration-dossier/-/registered-dossier/31292/2/3
HCFO-1233zd(E)	102687-65-0	"the substance is not PBT / vPvB"	https://echa.europa.eu/de/registration-dossier/-/registered-dossier/10762/2/3

Table 2: Summary of ECHA PBT status statements for HFO ze & zd.

Additionally, we note that persistence criteria has been defined for refrigerant compounds considering the global warming potential (GWP) and ozone depletion potential (ODP) of the substance. These compounds, which include HFO materials, are considered to have low potential for persistence if they exhibit a GWP (100 yr) < 150 kg CO_2-eq/kg and an ODP < 1 kg CFC-11-eq/kg, following globally accepted criteria. [xvii] [xviii] [xix] [xx] [xxi] [xxii] Based on these criteria, neither HFO ze nor HFO zd are considered to be persistent, as summarized in the table below.

Substance	CAS#	Refrigerant compound persistence data	Persistence categorization based on globally accepted criteria in air for refrigerant compounds
HFO-1234ze(E)	1645-83-6	GWP = 1.37 kg CO_2-eq/kg ODP = 0 kg CFC-11-eq/kg [xxiii]	Low potential for persistence
HCFO-1233zd(E)	102687-65-0	GWP = 3.88 kg CO_2-eq/kg ODP < 1 kg CFC-11-eq/kg [xxiv]	Low potential for persistence

Table 3: Summary of ECHA PBT status statements for HFO ze & zd.

TFA EMISSIONS: HFO-1234ze(E) and HCFO-1233zd(E) have potential to form TFA but emissions from the LP SPF use are small

Whereas HFO-1234ze(E) and HCFO-1233zd(E) are not persistent, not bio accumulative, and not toxic, experimental data demonstrate that these two F-gases have theoretical potential to form trifluoroacetic acid (TFA). Modeling work suggests that HFO ze & zd may form up to 2% and 4% TFA, respectively. [xxv] [xxvi] [xxvii] [xxviii]

However, the emissions of TFA that can be expected to be released from HFO use broadly, including from many other uses in addition to use in LP SPF applications, have been recently reviewed by the UN EEAP, and are not expected to pose an environmental or health concern based on the exposures expected through the end of the model year 2100.[xxix] This report supports earlier work that also concluded that TFA emissions from HFO use are not expected to pose a risk to human health or the environment.

In the section below, we provide information sought by ECHA regarding emissions estimates.

In answer to questions 2, 3 & 4 on Emissions in the end-of life phase and 5 & 6a on tonnage used, the following details the estimate of worst-case emissions from the LP SPF sector:

We consider the following life cycle stages and processes that may lead to TFA emissions across the life cycle:

- **HFO ze & zd manufacturing:** We do not have information regarding potential TFA emissions from production of the HFO ze & zd materials by the blowing agent manufacturers. However, we understand the processes to be closed loop manufacturing, and would expect emissions of HFO to be small relative to what we can estimate across the life cycle of the LP SPF application, since the HFO manufacturers are incentivized by economics to have minimal loss of their HFO product during manufacturing.
- **LP SPF manufacturing**: Processing and use of HFO ze & zd is carried out by the LP SPF manufacturer in the LP SPF manufacturing stage, which leads to LP SPF product contained within the pressurized cylinders shown in Figure 1. These charged cylinders are then used in the next stage to spray the product on site. The LP SPF manufacturing process necessarily excludes water at all stages because the formulations are highly water sensitive. Water is a contaminant in LP SPF formulations and is excluded from the process to ensure high quality products, with manufacturing taking place in a closed-loop system. Because of this product quality technical requirement, there are negligible losses of F-gas during the LP SPF manufacturing stage.
- **LP SPF spraying on site:** In the spraying stage of the product life cycle, the LP SPF foam is created as the product is sprayed on-site, as shown in Figure 1. During this spraying process, blowing agents are trapped in the cellular structure of the foam, which is a design feature that helps deliver high thermal resistance as described earlier. The LP SPF products are designed to retain the HFO through the life of the structure in which they are used via the closed-cell structure of the foam. A small amount of blowing agent is lost in processes such as foam expansion and trimming. While the release of the HFO blowing agent will depend upon handling, we estimate that roughly 10% of the HFO contained in the pressurized product cylinders could be released during the spraying stage.
- **LP SPF end of life:** Once the foam is fully cured and stable, data and modelling show that it will take a long time, on the order of years, for blowing agents such as HFO ze & zd to diffuse out.[xxx] Through diffusion of the blowing agents through the foam structure, the installed product loses less than 1% of trapped HFO blowing agent per year, with a diminishing rate of loss over time. Hence for the purpose of this exercise, we have assumed that the remaining amount of blowing agent, the roughly 90% that was not released during spraying, is released at end of life. Here we assume that end of life occurs via landfill, and we note that the lifetime of the sprayed LP SPF product is equal to the lifetime of the building/infrastructure and is commonly assumed to be at least 60 years. Today LP SPF is typically considered a contaminant for other building materials and is typically sent to landfill.[xxxi] New techniques and innovative pathways are being researched to determine the potential for full circularity of the products in the coming years and decades.

These life cycle stages are depicted graphically in Figure 2.

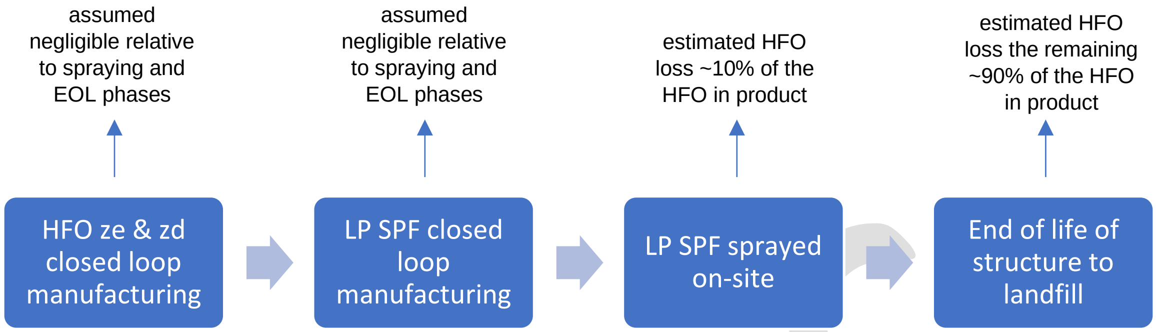


Figure 2. Product Life Cycle for LP SPF considering emissions of blowing agent across the life cycle.

Based on the use of HFO ze & zd within the LP SPF industry, and assuming a worst-case maximum theoretical conversion of 4% TFA formation from these HFO emissions, we estimate that less than [redacted] of TFA could result from LP SPF applications, across the product life cycle, in Europe. This estimate would break down into less than [redacted] of TFA from the on-site spraying stage, and less than [redacted] of TFA at end of life. These values reflect the emissions that we estimate from the total LP SPF industry.

As additional input on HFO ze & zd and TFA estimates, we note that LP SPF products are expected to utilize much less than 3% of total HFO use globally. According to a global report from the US EPA[xxxii], all foams accounted for 2.8% of HFC blowing agent use in 2019. The percentage of foam represented by the EPA includes the largest markets in appliance insulation foam, high pressure (drum) SPF and extruded polystyrene foam, so the niche market of LP SPF is significantly less than 2.8% of foams that use F-gases. Recognition that the LP SPF use of HFOs is less than 3% of the global use of HFOs is consistent with the estimates we provide here that potential TFA formation from the LP SPF industry in Europe is small.

We also note that for LP SPF, HFO ze & zd use is minimized and only used as necessary to deliver product performance and ensure proper creation of the foam. Unlike HFO use in other industries, such as refrigeration or air conditioning, which require high amounts of blowing agents for the use phase of the product, for example to operate the unit, LP SPF products require minimal blowing agents.

__Confidential information regarding estimation of TFA emission from HFO use in LP SPF industry__.

[redacted]

[redacted].

TFA STUDIES: Emissions have been well studied and are unlikely to cause adverse effects

Recent research has demonstrated that TFA is not expected to pose an environmental or health concern based on the exposures anticipated in the decades ahead.

According to the REACH Registration of TFA, the substance fulfills the criteria for persistency, but the available data indicate that it does not meet the criteria for toxic and bioaccumulative substances (PBT-substances), nor the criteria for very bioaccumulative substances (vPvB-substances) according to REACH directive, Annex XIII and as defined in the TGD R.11 of the ECHA.

Additionally, a recent publication on the mammalian toxicity of TFA concluded that the Margin of Exposure (MoE) to most humans is 4,000 to 476,000 times, indicating that the levels of TFA in the environment are several magnitudes below what would be considered toxic.[xxxiii]

As mentioned above, the emissions of TFA that can be expected to be released from HFO use broadly, including from many other uses in addition to use in LP SPF applications, have been recently reviewed by the UN EEAP, and are not expected to pose an environmental or health concern based on the exposures expected through the year 2100.[xxxiv] Further, in a series of reports from 2016 to 2022 the United Nations Environment Programme (UNEP) concluded that TFA has been found at levels that are **below** those that would be considered toxic to humans or aquatic environment and will continue to be below these levels for decades. (https://ozone.unep.org/science/assessment/eeap,)**Error! Hyperlink reference not valid.**][xxxv] [xxxvi] [xxxvii] [xxxviii] [xxxix] [xl] [xli]

We propose that a time-unlimited derogation for HFO ze & zd use in LP SPF applications will not pose an environmental or health concern, considering the available scientific evidence and based on emissions of TFA that may be associated with the application.

LP SPF PRODUCTS ARE PLAYING A DEFINED ROLE IN ACHIEVING EU CLIMATE GOALS AND DURABLE INFRASTRUCTURE OBJECTIVES

Key goals of various proposed EU policies being developed to address climate change will depend heavily upon the unique performance attributes of LP SPF that are enabled by HFO ze & zd.

LP SPF products are a high-performing line of products that meet a real and critical need for improving the energy efficiency profile of buildings and infrastructure, a sector that accounts for roughly 40% of global GHG emissions.[xlii] LP SPF technology is critical to achieving climate goals due to the energy efficiency benefits that it helps enable across the life cycle of the building. The benefits of improved insulation directly translate to lower demands on energy sources and the associated reduction in carbon emissions.[xliii]

LP SPF products are applied today in a variety of applications, spanning buildings, industrial pipe insulation, applications with limited space, and cold storage and refrigerated transportation applications. LP SPF can be easily applied in these applications to provide space efficient, high-performance insulation and in combination with air sealing.

These products also enable durable and resilient infrastructure, which also plays a role in achieving EU climate goals, in many applications that include transmission line towers and utility lines, roadway infrastructure, airport infrastructure, railroad infrastructure, and retaining walls.

We note that LP SPF products play a niche role in the industry as there are no other products that can fulfill the same technical and application requirements met by LP SPF today. For example, LP SPF products create closed-cell insulating materials and provide a high-quality foam, portability, and fast reactivity that makes them ideal for in-situ use and repair applications.

As demonstrated in Appendix C, Not-In-Kind (NIK) solutions cannot meet the unique requirements of applications served by LP SPF, as the NIK solutions often encounter functional, cost, and application hurdles. For example, SPF products "can serve as all-in-one thermal and acoustic insulation, an air barrier, a vapor retarder, and, in some cases, a moisture barrier for commercial and residential walls, basements, and roofs".[xliv] Closed-cell SPFs provide more resistance to heat transfer (i.e., lower lambda values), better moisture resistance, and better structural support compared to open-cell SPFs." [xlv] Additionally, many alternative products cannot be applied in situ.

Hence, elimination of the LP SPF product from the market, which would result from adoption of the regulation as currently written, would compromise the ability of the EU to drive progress against its GHG reduction goals and infrastructure objectives.

For example, within the EU Green Deal, the updates of the Energy Performance of Buildings Directive (EPBD)[xlvi] and the Energy Efficiency Directive (EED)[xlvii], which determine the requirements to facilitate the goals of the EU Renovation Wave, represent examples where LP SPF can help enable the required energy efficiency targets for both existing and new residential and public buildings.

Additionally, the advancement of increased energy efficiency in building codes will play a critical role in helping deliver the climate goals of the EU Green Deal. Continued evolution, adoption, and enforcement of building codes, for example through the EN standards, will be required to drive improved energy efficiency of buildings and the associated reduction in GHG emissions related to operating buildings. LP SPF will play a unique role in delivering the needed codes-driven improvement in the energy efficiency of buildings.

We provide additional information on the beneficial role of LP SPF on Key EU Climate Regulations in Appendix D.

CONCLUSION

HFO ze & zd are required for LP SPF products, which play an important role delivering energy efficiency and GHG reduction benefits in their application. The use of HFO ze & zd in LP SPF has resulted from research spanning more than a decade and considering an exhaustive set of blowing agents available today. Because no other blowing agents available today meet the required performance needed for LP SPF applications, transition away from HFO ze & zd in LP SPF is not possible in the near term. Transition out of these HFO blowing agents would require invention and development of new blowing agent materials, and the time to invent, develop, and ultimately implement a new technically viable LP SPF product is expected to be on the order of decades.

Without a time-unlimited derogation, LP SPF product would be eliminated from the market under the current proposal. Since no alternative products to LP SPF that meet the unique performance delivered by these products exist, there would be a market gap created where certain energy efficiency projects would terminate, making it difficult if not impossible for efficiency goals to be achieved. In addition, as a result, value chain players, spanning manufacturers to distributors to professional installers would suffer significant loss of business and jobs including complete loss of business for many participants.

To enable the continued presence of the LP SPF solution in the marketplace and support the GHG reduction goals that this solution can help deliver, we conclude that a time unlimited derogation is warranted for the use of HFO ze & zd in LP SPF products. We recommend the following derogation language:

> **"Foam blowing agents, HFO-1234ze(E) and HCFO-1233zd(E) in low pressure (< 17 Bar (< 1724 kPa)) spray polyurethane foam sprayed on-site receive a time unlimited derogation from restriction."**

"Table 9. RO2 – Summary table of derogations" found in the "Proposal for a Restriction", Annex XV Restriction Report, should include the following sub-use under "Applications of fluorinated gases" to capture the missing use and necessary associated details.

Use sector (with sub-uses)	**Proposed derogation**	**Duration of derogation period, including substantiation**	**Cost impact of 5 and 12 year derogation periods**
Foam blowing agents in low-pressure spray polyurethane foam sprayed on site	Given sufficiently strong evidence that technically and economically feasible alternatives are not available at EiF, derogations are proposed for: • Foam blowing agents in low-pressure spray polyurethane foam sprayed on site	A **time-unlimited** derogation for fluorinated gases in low-pressure spray polyurethane foam, where drop-in alternatives are not available and national safety standards and building codes prohibit the use of alternatives [sufficiently strong evidence base].	The need for public confidence in fire safety systems indicates potential for significant welfare loss in the event that the safety of alternatives is not demonstrated and restrictive building codes remain in force, whilst limiting loss of producer and consumer surplus and welfare losses from use of less effective products.

The Appendices below provide additional details on evaluation of alternative blowing agents, critical product use examples, evaluation of not-in-kind products, LP SPF impacts on the EU Climate Deal, and many additional technical details.

Appendix A – Evaluation of LP SPF blowing agent options: No technically feasible alternative exists, and transition is not possible over the next 12 years.

This section provides further detailed answers to Questions 6b and 6d.

The draft PFAS restriction proposal lists assumed alternatives to foam blowing agents in Appendix E2. The listed options are not viable for LP SPF. Viable options must address the specific unique properties required for LP SPF products that require the formation of a closed-cellular structure to meet end-use requirements.

It is critical that blowing agents are considered viable alternatives only if they meet the requirements for manufacture and safety, as demonstrated below. Blowing agent alternatives must also meet environmental, hazard, economic and functional or performance properties to be considered a solution. Multiple building codes, industry standards and other certifications must also be met after the product is produced prior to commercialization. Therefore, research and development of commercially available blowing agent alternatives requires a complex product assessment that touches on a multitude of factors.

- First and foremost, a blowing agent must have sufficient solubility in the polymer. Only by being sufficiently soluble can a uniform cellular structure be generated yielding desired mechanical properties. Blowing agents should have sufficiently high vapor pressure, in other words they need to be gaseous, so that it can “blow” a low-density foam.
- To achieve a thermal insulating foam, the blowing agent must have low thermal conductivity and low permeability to achieve long-term thermal insulation performance. The many desired requirements for a blowing agent are pictured and outlined below to provide insight into the parameters considered when reformulating a LP SPF for closed-cell foam applications.

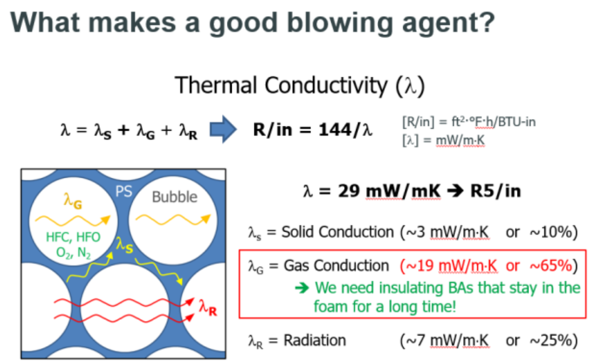


Figure 3. Thermal Conductivity definition

LP SPF blowing agent has many requirements for optimal performance

Blowing agent requirements for LP SPF products:

- Must form a closed-cell structure with resilient mechanical properties and meet performance criteria including moisture resistance, dimensional stability, and compressive strength.
- Insulative gases are a key component of the overall thermal conductivity value of a foamed product; the gas conduction accounts for up to 65% of the total conductivity and without insulating BAs the products cannot meet the thermal resistance specifications as expected in their application.

Figure 4: Requirements of a foam blowing agent in LP SPF

There are no technically feasible alternatives to HFO ze & zd for LP SPF foams today.

For years companies have been trying to replace HFCs that were introduced in the 3rd fluorocarbon blowing agent transition under the Montreal Protocol, and due to the increased cost and limited availabilities of the new blowing agents, product transitions have just begun to occur in the last two to three years. **Where performance metrics and requirements were possible, alternatives like pentanes or water blown foams were transitioned in certain product types. However, after about 20, many critical segments, including LP SPF requiring closed-cell structures, still have not found viable replacements for fluorinated compounds.**

Based on our experience with the conversion to HFOs within the LP SPF industry, and historical transitions outlined below, we anticipate that the transition time would require roughly 25+ years, from starting a new HFO-replacement research program by the blowing agent manufacturers to implementing the new technology at LP SFP manufacturing facilities. An overview of transition history including research, development, building code & regulatory approvals is shown in the chart below.

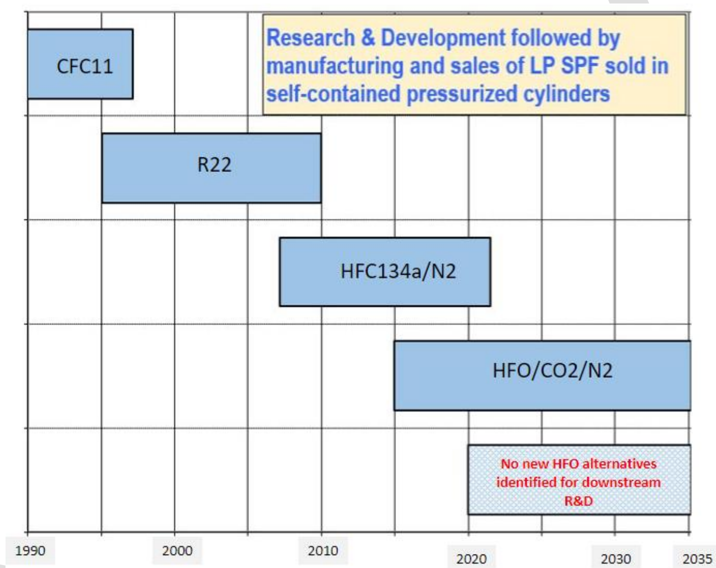


Figure 5: Overview of foam blowing transition history in LP SPF

As United Nations Technical and Economic Assessment Panel (UN TEAP) notes, there are no longer 'drop in solutions' for insulation products as these formulations are complex and substitutes are becoming increasingly more difficult to invent and develop.

> *"Although it is assumed that initial screening of alternatives will determine their suitability for the applications previously served by ODS, it is not always the case. The recent experience with the stability of unsaturated gaseous HFCs/HCFCs in certain LP PU formulations in the United States of America, serves as a timely reminder that* ***alternatives are unlikely to be absolute 'drop-in' replacements and, even with reformulation, are not guaranteed to meet the requirements of the application. In addition to the specific capabilities of an alternative, it is increasingly the case that the range of applications served by a single alternative is reducing.*** *This is partly because of the undeniable versatility of earlier technology options (CFCs), but the trend also reflects the fact that technological developments over the past 20 years have made the users of alternatives more discerning.* ***There are now many more solutions available to choose from, but a need to apply greater scrutiny in decision-making to ensure continuing competitiveness in an increasingly globalised market."*** [xlviii]

Foam blowing agents, based on the unique chemical structures of HFO ze & zd, offer thermal resistivity performance that is up to 20% or greater than hydrocarbon or other not-in-kind blowing agents. This inherent thermal resistivity advantage carries over into the final foam products and is translated into insulation performance that enables energy efficiency realized over the lifetime of a structure. As energy efficiency requirements are increasing for construction and industrial applications, HFO ze & zd are the only available option to deliver the LP SPF products capable of meeting these stringent new targets.

At present, there are no proven, available candidate replacements for HFO ze & zd in LP SPF that meet established performance criteria. Any conclusion alternatives exist today for LP SPF products is unrealistic and unsupported.

The table below outlines years of recent research and development conducted in the effort to replace HFCs in our LP SPF product line.

Table 5: Evaluation of Blowing Agents (BAs) in Low-pressure Spray Polyurethane Foam

Blowing agent considerations	Usable?	Technical issues	Outcome of technical issues	References
Hydrocarbons	✗	Flammable, volatile organic compound (VOC)	• VOCs have strict regulations due to smog creation-1991 Geneva Protocol & 1999 Gothenburg Protocol • Flammables cannot be used in spray foam applications - safety hazard UN FTOC	https://www.airgas.com/msds/001045.pdf https://www.eea.europa.eu/data-and-maps/indicators/eea-32-non-methane-volatile-1 https://www.fluorocarbons.org/environment/environmental-impact/vocs-and-pocps/
CFCs	✗	Ozone depleting	Outlawed per Montreal Protocol	Ozone-depleting substances 2020 — European Environment Agency (europa.eu)
HCFCs	✗	Ozone depleting	Outlawed per Montreal Protocol	https://www.epa.gov/ozone-layer-protection/ozone-depleting-substances
HFCs	✗	High global warming potential	Being phased-down per Montreal Protocol's Kigali Amendment	Global Warming Potentials (IPCC Fourth Assessment Report) | UNFCCC
Exxsol Blowing Agents (hydrocarbons)	✗	Flammable, volatile organic compound (VOC)	• VOCs have strict regulations due to smog creation-1991 Geneva Protocol & 1999 Gothenburg Protocol • Flammables cannot be used in spray foam applications - safety hazard	msds (fishersci.com)
Formic Acid	✗	Toxic. Above 69°C explosive vapour/air mixtures may be formed.	Toxic Liquid	msds (fishersci.com)
Electroset Technology	✗	Not applicable to spray applications	Not a blowing agent - semiconductive resin requires application with electric energy	https://ui.adsabs.harvard.edu/abs/1993STIN...9429045R/abstract
Methyl Formate	✗	Extremely flammable. Toxic. Vapour/air mixtures are explosive.	Toxic & Flammables cannot be used in spray foam applications - safety hazard	msds (fishersci.com)
Methylal	✗	Highly flammable, VOC, Vapour/air mixtures are explosive	Flammables cannot be used in spray foam applications - safety hazard	msds (fishersci.com)
Transcend(TM) Technologies	✗	Additive, not a stand alone BA	Not a standalone blowing agent, additive for HFCs and HFOs to improve compatibility	https://www.arkema.com/global/en/products/product-finder/product/fluorochemicals/transcend/
Water	✗	Creates an open-cell, low thermal value foam	Impossible to meet product requirements; loss of compressive strength reduces ability of foam to provide structural support. Cannot meet thermal (R-value) requirements. Co-agent only.	https://www.energy.gov/energysaver/types-insulation
CO2	✗	Limited solubility, Small molecule escapes closed-cell quickly	Impossible to meet product requirements as a stand alone BA; cannot meet thermal (R-value) requirements per building codes. Co-agent only.	https://www.mdpi.com/1996-1944/13/6/1438/pdf U.S. Patent 2020/0308362 A1, LOW-PRESSURE TWO-COMPONENT POLYURETHANE FOAM CONTAINING CO2, Thomas et al., Oct. 1, 2020
Noble gas (argon, etc.)	✗	Diffusivity, poor R-value, Small molecule escapes closed-cell quickly, limited solubility	Impossible to meet product requirements as a stand alone BA; cannot meet thermal (R-value) requirements per building codes. Co-agent only.	https://www.aciscience.org/docs/Physical_properties_of_glycerine_and_its_solutions.pdf
H2O2	✗	produces oxygen, poor R-value, flammable	Flammables cannot be used in spray foam applications - safety hazard	msds (fishersci.com)
Ammonia	✗	Highly reactive with other PU spray components, corrosive to substrates, flammable	Toxic, corrosive, poor performance of spray foam - safety hazard & flammable	001003.pdf (airgas.com)
Super-critical CO2	✗	High pressure system only	Supercritical CO2 is above 100 bar at ~30C, well exceeds low pressure requirements (<250psi) and even high pressures requirements	http://multilateralfund.org/Our%20Work/DemonProject/Document%20Library/7106a1%20super%20C02%20pu%20foam.pdf
HFO-1234ze & HCFO-1233zd	✓	**Numerous technical issues have taken 7-10yrs to find solutions to make this technology workable.**	**Per global regulations, safety restrictions and building code requirements, this class has been deemed the only alternative.**	Journal of Cellular Plastics, Assessment of hydrofluoropropenes as insulating blowing agents for extruded polystyrene foams, 2013, 49(5) 423-438, C. Vo and R. Fox.

'Appendix E2'-Suggested Alternatives to F-gases in Foam-blowing Are Not Viable for LP SPF

The following list, direct from the Draft PFAS Restriction Appendix E2, suggests Alternatives to F-gases in Foam-blowing Applications. None of these options are viable options for LP SPF products. The list notes a **key issue ruling out all but two as options in LP SPF, namely flammability. The remaining two, CO2 and water, are not technically feasible in LP SPF products.**

Table 4: A copy of Appendix E2 of the draft restriction "Alternatives" to F-gases in foam blowing

Cyclopentane	287-92-3	206-016-6	**Flam. Liq. 2; Aquatic Chronic 3**
Iso-pentane	78-78-4	201-142-8	**Flam. Liq. 1; Asp. Tox. 1; STOT SE 3; Aquatic Chronic 2**
n-pentane	109-66-0	203-692-4	**Flam. Liq. 2; Asp. Tox. 1; STOT SE 3; Aquatic Chronic 2**
Isobutane	75-28-5	200-838-9	**Flam. Gas 1; Press. Gas**
n-butane	106-97-8	203-448-7	**Flam. Gas 1; Press. Gas**
2-chloropropane	75-28-5	200-838-9	**Flam. Gas 1; Press. Gas**
Dimethyl ether (DME)	115-10-6	204-065-8	**Flam. Gas 1; Press. Gas**
Methyl formate	107-31-3	203-481-7	**Flam. Liq. 1; Acute Tox. 4; Acute Tox. 4; STOT SE 3; Eye Irrit. 2**
Methylal	109-87-5	203-714-2	Flam. Liq. 2;
CO2	124-38-9	204-696-9	*Press. Gas (Comp.); Press. Gas (Ref. Liq.)*
methyl formate	107-31-3	203-481-7	**Flam. Liq. 1; Acute Tox. 4; Acute Tox. 4; STOT SE 3; Eye Irrit. 2**
CO2 (water)	124-38-9	204-696-9	*Press. Gas (Comp.); Press. Gas (Ref. Liq.)*
CO2 (liquid)	124-38-9	204-696-9	*Press. Gas (Comp.); Press. Gas (Ref. Liq.)*
CO2	124-38-9	204-696-9	*Press. Gas (Comp.); Press. Gas (Ref. Liq.)*
Ethanol	64-17-5	200-578-6	**Flam. Liq. 2**
Water blown foams	7732-18-5	231-791-2	Not classified

Flammable blowing agents, like hydrocarbons (cyclopentane, iso-pentane, n-pentane, isobutane, n-butane, 2-chloropropane, DME, methyl formate) and methylal listed in the table, are not an option for portable LP SPF products which are sprayed at a construction or industrial site, also known as "in situ".

The United Nations Foam Technical Options Committee (UN FTOC) under the UN TEAP of the Montreal Protocol has specifically noted that flammables are not appropriate for spray foam applications:

> *"7.3.4 Polyurethane Spray - Non-Article 5 Parties*
> Polyurethane spray represents one of the more challenging areas from a technical viewpoint, because of **processing risks with using hydrocarbons in field applications**. HCFCs were replaced "en masse" with high-GWP blowing agents such as HFC 245fa (particularly in NA) and HFC-365mfc/227ea (in Europe). HFOs and HCFOs are seen as a future possibility but cost and shelf life stability of these formulations in LP pre-blends have significantly slowed adoption of this technology." [xlix]

“**Applications where hydrocarbons are not suitable, such as spray foam**.” [l]

“For PU Spray foam the major challenge relates to the safe processing of these systems under in-situ conditions within a building. **The potential for the accumulation of blowing agent in ‘pockets’ creates the <u>risk of fire or explosion</u> if flammable materials are used. Therefore, flammable blowing agents including hydrocarbons have broadly been ruled out for polyurethane spray foam.** In addition, some spray foam contractors may not be well trained in safety precautions that would be needed to mitigate these risks. Spray foams have been one of the last foam applications to move away from HCFC-141b as a blowing agent in Article 5 parties largely transitioning to HFC-245fa and HFC-365mfc/HFC227ea with some transition to unsaturated HCFCs and HFCs., Formulators and contractors have started to switch from high-GWP HFCs such as HFC-245fa and HFC-365mfc/227ea to unsaturated HCFCs and HFCs in non-Article 5 parties. Water-blown foam is also used, but there are challenges with dimensional stability (including density which increases costs) and insulating capability.” [li] (emphasis added)

“Commercial availability has been established for HFO-1234ze(E)[20] (gaseous blowing agent), HFO-1233zd(E) (liquid blowing agent), and HFO-1336mzz(Z) (liquid blowing agent)[21]. Markets which require improved thermal efficiency or are **unable to use flammable alternatives (e.g. spray foam** and SMEs) are more likely to adopt these technologies. In addition, the demand to leap-frog high GWP HCFC alternatives in other sectors could further accelerate distribution in Article 5 regions. However, cost remains a key issue and blending with other co-blowing agents may well be required to meet commercial needs.” [lii]

While hydrocarbons have been proposed by some because they can be found in nature, they are not free of concerns.

- Hydrocarbons, notably Propane, Butane and Pentanes are typically produced from crude oil in refineries. They are classified as (extremely) flammable and included in Annex I of the Seveso III Directive (2012/18) on the control of major-accident hazards involving dangerous substances. They are Volatile Organic Compounds (VOCs) which are associated with poor air quality (revision of the EU ambient air quality directive 2022/0347(COD)). Their Photochemical Ozone Precursor Potential (POCP) is orders of magnitude higher than F-Gases.[liii] The atmospheric degradation of Propane results in various carbonyl compounds, with acetone, acetaldehyde, and propionaldehyde among the most prominent. Carbonyl compounds are relevant because of their toxicity and ability to produce free radicals. [liv]

<u>The only non-flammable options listed in the proposal table are CO2 and water. As noted below, neither of these individually or together are technically feasible blowing agent options for LP SPF.</u>

- Water or CO2 alone, or together, do not provide enough blowing power to help dispense the LP SPF product out of the portable, self-contained cylinders.
    - Water does not have the appropriate vapor pressure; low boiling point compounds have high vapor pressure which provides propellant action or blowing power. Water has a high boiling point and a low vapor pressure.
    - It is not possible to get enough moles of CO2 in solution to reach a useful density that provides the required insulation value for LP SPF products; this was recently studied in depth and reported on in our patent.[lv]

- The use of a co-blowing agent is required with CO2 to benefit the environment by creating an insulating value. We use CO2 to limit the amount of HFO used in our LP SPF, but the products still need some HFO ze & zd to function.[lvi]

- The use of water as the primary chemical blowing agent is only useful in open-cell spray foams with an external pressure source to apply the product. The water is converted to CO2 during the exothermic spray reaction which forms only an open-cell foam structure. **For further explanation of closed-cell versus open-cell SPF properties, see Appendix C.**

Another source, the "Report summary F-gas uses" page 25 published by Norway's third-party consultant, Exponent, suggests that methyl formate and CO2 are alternatives, however this is not true for the self-contained LP SPF products which require the alternatives to HFOs to be non-flammable and both a propellant and a foaming agent.

- CO2 and methyl formate do not have the appropriate vapor pressures and foaming abilities to work alone, nor do nitrogen or air, as propellants and foaming agents in our products. Flammable gases like methyl formate are not acceptable alternatives due to safety during use conditions that are required for LP SPF products.

The blowing agent is a critical key to thermal performance of the final foam.

As seen in Annex J.1 of the EU building and construction code for LP SPF[lvii], spray insulation foams with only air/CO2 have higher thermal conductivity and therefore make a less effective and much less desirable insulation. The lower the thermal conductivity, the better the insulation. Because of this, even if it was technically achievable, a LP SPF with only CO2 would not benefit the environment to the extent that one with HFO does.

> "In general, the thermal conductivity ageing characteristics of in-situ polyurethane and polyisocyanurate insulating products are more complicated than for factory made products. Those products give comparable results to in-situ products for only one class of in-situ products, namely the in-situ products in the CCC4 class. This is because both factory made products and CCC4 in-situ products have closed cell contents of 90 % or more and use similar blowing agents which are retained in the cells for more than their economic life and are thus known as "permanent" blowing agents. These blowing agents have very low gaseous thermal conductivities and so the initial thermal conductivities of these types of products are lower than products where the cells contain air. Ageing occurs therefore by ingress of air by diffusion into these closed cells to increase the cell gas thermal conductivity of the resulting cell gas mixture, if this is not prevented by diffusion resistant product surface coverings.
>
> In contrast, the in-situ products which have no closed cells show no thermal conductivity ageing since air at ambient pressure is present in the product in the same way as other solid material based in-situ products. Polyurethane and polyisocyanurate in-situ products in class CCC1 having closed cell contents below 20 % almost reach this situation as only a very small fraction of the cells can perform the ageing process characteristic of the CCC4 products, again only if inward air diffusion is not prevented by suitable surface barriers. However, their initial thermal conductivities will be higher than for CCC4 products since the CCC4 products contain only a minute amount of air initially."

To further understand the implications of thermal degradation over time, see the building code referenced above for details. Additional information showing the quick change of thermal conductivities when small molecules, like hydrocarbons, are used in foams is available in numerous studies.[lviii]

Issues with CO_2 are also noted by the United Nations Foams Technical Options Committee. Note that the references to PU Spray Foam are for High Pressure SPF, and not the Low-Pressure SPF manufactured and sold by DuPont in the EU and under discussion here, but the impact of CO_2 is the same.

- "The higher gaseous thermal conductivity leading to poorer thermal efficiency of the foam"
- "There are also some short-comings in thermal performance against other technological solutions in the sector, especially in relation to the emerging unsaturated fluorocarbons (see next section)."
- "Unsaturated HFCs and HCFCs (often commercially referred to as HFOs/HFCOs) are offering similar or better performance to HCFCs and saturated HFCs, In addition, they have the potential to replace some elements of the hydrocarbon and CO_2-based sectors, based primarily on improved thermal insulating properties."[lix]

Foam blowing agents, based on the unique chemical structures of HFO ze & zd, offer insulation performance that is up to 50% or greater than hydrocarbon or CO_2 or not in-kind insulation methods. This inherent performance advantage carries over into the final foam products, and is translated into insulation performance and energy efficiency, especially over the lifetime of a structure or transportation unit.

LP SPF remains reliant on HFO ze & zd which are physical, non-flammable blowing agents with low boiling points/high vapor pressures.

Use of HFO ze & zd as blowing agents has been scrutinized

There is chemically diverse behavior found among similarly structured substances. Relevant to the exclusion of HFO-1234ze(E) and HCFO-1233zd(E) from other PFAS, these two unique compounds do not persist in the environment, do not bioaccumulate, and are not toxic. Therefore, these substances do not meet the criteria for restriction under REACH.

HFOs have been vetted and approved as safe alternatives to HFCs by regulatory bodies in countries around the world, including the US EPA Significant New Alternatives Policy (SNAP) which requires EPA to evaluate substitutes for the ozone-depleting substances to reduce overall risk to human health and the environment.[lx] On April 28, 2023 the US EPA made the following statement in an explanation of the final rule for SNAP 25 regarding the allowance of HFOs in refrigerant end uses:

> *"Regardless of what definition of PFAS is used, not all PFAS are the same in terms of toxicity or any other risk. Some PFAS have been shown to have extremely low toxicity, for example. If a chemical has been found to present lower overall risk to human health or the environment, it might be found acceptable under SNAP regardless of whether or not it falls under a particular definition of PFAS. Likewise, SNAP might not find a potential alternative acceptable if it presented greater overall risk, regardless of whether or not it falls under a particular definition of PFAS. As described in the risk screens for alternatives found in the docket for this rulemaking, potential risk to human health or the environment has been considered directly for each chemical, and the risks are not assumed to follow from a chemical falling into any particular category of substances."*[lxi]

Many scientific experts agree that HFOs do not belong under the scheme intended to target PFAS, and key scientific leaders agree that PFAS grouping schemes being used by regulatory agencies have issues.[lxii] The Danish Environmental Protection Agency notes that "HFOs are subject to degradation in the lower atmosphere due to the C-H bonds in the molecules that are reactive to hydroxyl radicals… the lifetimes for the main HFOs are down to 0.03-0.04 years." [lxiii]

There are existing significant restrictions on HFC blowing agents globally via international and regional programs, e.g., Montreal Protocol and the Kigali Amendment, and the United Nations Foams Technical Options Committee has noted that HFOs are acceptable substitutes in SPF applications.[lxiv] Allowable substitutes for foam blowing are strictly outlined in some countries. For instance, in the US the EPA's SNAP program lists the allowable chemistries per end use: https://www.epa.gov/snap/substitutes-foam-blowing-agents. The use of F-gases is adequately controlled through existing EU legislation.

The draft restriction proposal fails to provide an accurate estimate of the socio-economic and environmental impact associated with the continued responsible use of F-Gases. A Risk Management Options Analysis (RMOA) is being conducted by the F-gas industry group, European FluoroCarbons Technical Committee (EFCTC), and DuPont has participated in their confidential survey. Per their website, "The RMOA project has been launched in September 2022 and the final outcome is expected by the end of July 2023."[lxv]

Scientific data does not support the conclusion that HFO ze & zd should be regulated as a PFAS due to potential TFA formation.

In May 2023, the United Nations Environment Programme's (UNEP) Environmental Effects Assessment Panel (EEAP) [lxvi] noted:

> "Trifluoroacetic acid has biological properties that differ significantly from the longer chain polyfluoroalkyl substances (PFAS) and inclusion of TFA in this larger group of chemicals for regulation would be inconsistent with the risk assessment of TFA."
>
> "TFA is a perfluorinated acid that has been included in the class of per- and polyfluoroalkyl substances (PFAS). This class of chemicals contains 4730 substances, of which about 256 are in commercial use. Even in the subclass of perfluorinated alkanoic acids, the physical, chemical, and biological properties of these substances differ widely, mostly in relation to length of the alkyl chain. To regulate these substances as a class (as has been suggested) is not scientifically defensible and TFA should be treated as a unique chemical for the purposes of regulation."

In a series of reports from 2016 to 2022, the UNEP concluded that TFA has been found at levels that are **below** those that would be considered toxic to humans or aquatic environment and will continue to be below these levels for decades.[lxvii]

> "An extensive review of the potential effects of TFA in the environment published by the German Environmental Agency [214] did not identify any risks other than the persistence of TFA in the environment, which is a legislative rather than toxicological criterion. "
>
> "TFA does not bioaccumulate nor is it toxic at the low to moderate exposures currently measured in the environment or those predicted in the distant future."

LP SPF products provide exceptional in situ insulation performance, combined with compressive strength necessary for floor, roof and other load bearing construction, transportation and industrial applications. As most applications occur indoors or confined spaces, flammable blowing agents like hydrocarbons are unacceptable for safety reasons. **HFO ze & zd, with their unique atomic compositions, offer foam blowing power without hydrocarbon-like high flammability that enables the production of LP SPF that meets the most stringent end-use requirements and building codes.**

Appendix B - Critical end-use examples of LP SPF

LP SPF is unique and essential as an enabling product in building energy efficiency, industrial pipe insulation, cold-chain storage and transport, and limited space applications. These applications increase the durability of infrastructure and reduce both the embodied and operational energy consumption of the buildings, thereby reducing their GHG emissions. ECHA should not consider not-in-kind insulations when evaluating HFO blowing agent formulated LP SPF products.

Additionally, as noted in Annex E of the draft restriction "The specialist nature of some applications creates difficulty for the introduction of alternatives, recognizing use in niche applications such as truck refrigeration systems, insulation of district heating pipes and insulation of cryogenic gas (LNG) where the use of hydrocarbon blowing agents would be unacceptable due to interference with leak detection devices."

Building and Construction

The EU Renovation Wave[lxviii] is an excellent example of how HFO blown foams can enable the required energy efficiency targets for existing[lxix] and new buildings. **LP SPFs are easily applied to interior walls, floors, roofs and attics to provide space efficient, high-performance insulation and/or air sealing.[lxx] The benefits of improved insulation directly translate to lower demands on energy sources, including those with carbon emission footprints.** This directly supports another key initiative of the Green Deal, decarbonization of the energy sector. In addition, the improved energy efficiency benefits can be extended to household and commercial heating and cooling, therefore enabling the next levels of efficiency requirements and subsequent reduction of energy demand.

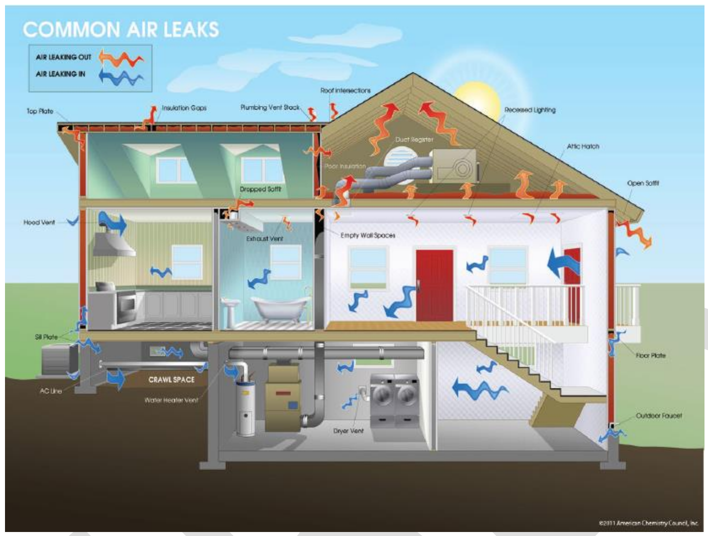


Figure 6: Examples of unique retrofit application potential for closed-cell, LP SPF to improve air sealing[lxxi]

<u>Critical need for building insulation</u>

There are several strategies that can be deployed to reduce GHG emissions, with high performing insulation being an essential component of any effective strategy. Insulation in the building envelope is critical as without it, buildings have a vapor drive potential to accumulate moisture in the walls and roof; rotting the wood and risking mold growth. Without insulation, EU residents would be faced with high heating bills every month of every winter and cooling bills during hot weather. If lower thermal resistivity insulation were the only options available, then thicker walls would be needed to fit thicker insulation to ensure high energy efficiency, adding to the cost of the building and energy efficiency. Based on numerous studies, additional coal, oil, or gas are consumed to heat buildings without insulation.

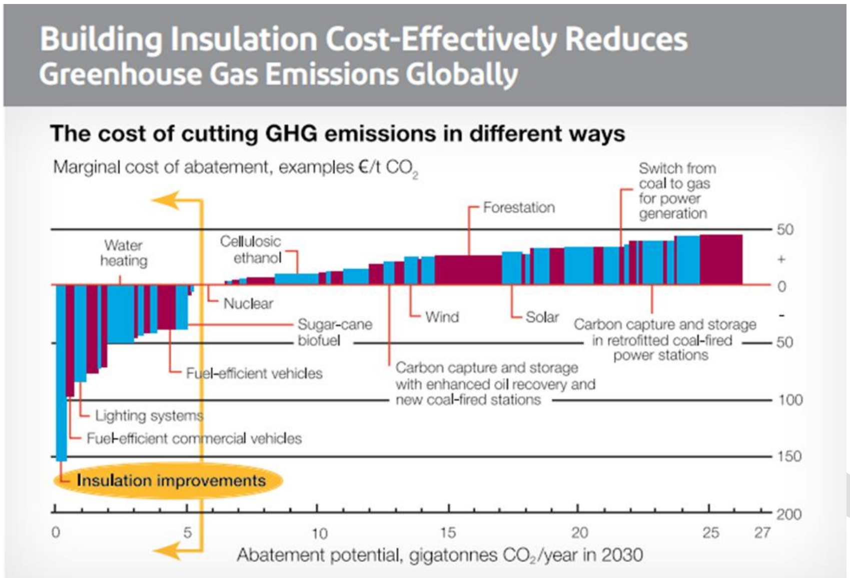
<u>Building energy efficiency and impact of high-performing insulation</u>

According to a McKinsey report on energy efficiency, insulation is a key lever for improving efficiency.[lxxii] Heating accounts for 80% of buildings' sector energy consumption, demonstrating that energy efficiency could provide significant energy savings globally and locally.[lxxiii]

Furthermore, it is reported in the recent C-40 & McKinsey report titled *Focused Acceleration: A strategic approach to climate action in cities to 2030* that "optimizing energy efficiency in buildings could yield 3X the reduction potential from current trends in meeting their Paris Agreement targets."[lxxiv] Several other independent reports point to similar findings that demonstrate how the use of high performing building insulation and air sealing products can help to reliably meet energy demand, which helps support regional and international environmental goals. [lxxv] [lxxvi] [lxxvii]

"Insulation improvements" are among the more economical and effective measures as depicted in the following figure, with insulation-derived improvements highlighted. Insulation provides the fastest payback and should be prioritized for implementation ahead of additional measures. And as the graph shows, “insulation improvements” is key option with respect to a negative marginal cost.

The following figure represents only a few of the GHG abatement options researched.



Source: Study conducted by McKinsey & Company, and Vattenfall

Figure 7: Evaluation of GHG emission reduction with associated cost[lxxviii]

Lifecycle view of building insulation

Since heating accounts for 80% of the buildings’ sector energy consumption, the environmental impact of building insulation must take into consideration an application lifecycle contribution-based approach rather than focusing solely on the manufacturing process and emissions resulting from manufacturing. Using a lifecycle view that incorporates the use-phase of these products in buildings, makes it clear how insulation products are especially helpful for climates that are very cold or hot, as high performing insulation reduces a building’s total energy consumption and total GHG emissions, and hence has a large net positive contribution to GHG emissions reduction.

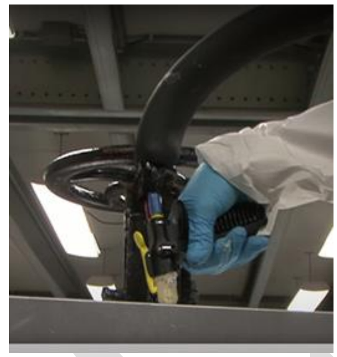
- According to the 2009 McKinsey-ICCA joint report, building insulation and sealants save energy and reduce GHG emissions both in the near and long term. The CO_2 equivalent (CO2eq) emissions avoided over the estimated lifetime of foam insulation can be expected to be orders of magnitude greater than the CO2eq emitted during production and use.[lxxix]
- According to the 2017 joint report published by C40 and McKinsey, new buildings with better insulation and older buildings with improved insulation “reduce building heating and cooling demand by about 40%”. This also enables the installment of fewer and smaller HVAC (Heating Ventilation and Air Conditioning) systems that “could also significantly reduce the emission of HFCs from cooling systems.” [lxxx]

Industrial pipe insulation

Following the desire and need of EU countries to become independent from Russian energy sources, the opportunity arises that additional liquified natural gas (LNG) terminals are right now in design or early construction phase. **Cryogenic application and the insulation of tanks, pipes and valves is crucial for such terminals. “**Energy savings are the result of increased pipe insulation and thermal resistance, which reduces the temperature difference between the system’s working fluid and its ambient conditions, reduces heat transfer”, and thus reduces system energy input requirements.[lxxxi]

The highly effective insulation properties, in particular at low temperature, combined with high compressive strength and the flexibility of a portable kit that doesn't require any external power source makes LP SPF a perfect fit for LNG. Additionally, the use of highly effective (closed-cell), injected LP SPF prevents condensation risk.

Picture 1: LNG Terminal



Picture 2: LP SPF pipe insulation

While tanks can be insulated with board insulation, pipes and valve cabinets are often insulated with injected or in-situ LP SPF. Prefabrication of polyurethane (PU) pipe shells and insulation parts for valve cabinets are not always an option. A grade of portable, high performing and cost-effective LP SPF products are key on LNG sites. The LP SPF product meets the unique criteria of usable in small, often tight, spaces.

Picture 4 and 5: Cured foam after LP SPF injection.

LP SPF systems produced with HFOs combine the properties needed for cryogenic applications: mechanical strength, minimum percentage of open-cell, little/no water absorption and low thermal conductivity at cryogenic temperatures (10°C and beyond). The low pressure used is key to injectability. The injection of LP SPF enables the insulators to achieve a properly insulated and therefore long-lasting cabinet impacting the minimization of energy losses. Mistakes that happen in the insulation phase – in case less suitable products are used - will have a huge impact on the efficiency of a terminal in the first step. In the second step, **huge costs are created when pipes or cabinets must be dismantled and re-insulated.**

Limited space applications

Portable LP SPF systems limit condensation and build a perfect fit when owners retroactively want to insulate their recreation vehicles (e.g., boats) or recreation homes (e.g., cabins). Energy efficiency is a topic not only in the construction industry but also in the recreation segment.

Picture 6: Boat wall insulated with LP SPF.

Picture 7: Container walls and ceiling insulated with LP SPF.

Besides the high thermal resistance at already thin thickness, another key argument for LP SPF is the limiting of condensation risks. The gap to be insulated can be fully filled with LP SPF insulation to prevent condensation from occurring. Moisture issues are the main threats as it destroys the efficiency of any insulation immediately. Alternative products, such as mineral wool, would not work due to the higher thickness required to get the same thermal performance compared to LP SPF. In these particular applications, a mineral fiber product is not closed cell, thereby allowing for the dewpoint to occur in the insulation which would result in a condensation risk. Additionally, high pressure SPF is not an alternative for these small space applications as they spray a high volume of material at a very high pressure. Therefore, LP SPF is most suitable for these uses.

Portable, LP SPF systems enable owners of such vehicles and homes to save energy and to reduce CO2 emissions. This is in line with the key initiative of the Green Deal, decarbonization of the energy sector.

Cold storage and refrigerated transport

LP SPF insulation plays an essential role in refrigerated transportation, as designing for thermal and moisture control is crucial to long-term performance, reduction of waste, and energy savings.

The Food and Agriculture Organization of the United Nations (FAO) estimates that each year, one-third of all food produced for human consumption in the world (around 1.3 billion tons) is lost or wasted.

Decaying food generates methane, which is a potent greenhouse gas that traps heat in the atmosphere at a rate 28 to 36 times faster than CO_2 over a 100-year period, as per the Intergovernmental Panel on Climate Change (IPCC) per the assessment report (AR5).

Methane emissions from waste have 86 times the near-term global warming potential of carbon dioxide, making it an urgent priority for preventing the most adverse effects of climate change. Food waste is a global challenge that is possible to prevent with the right resources.

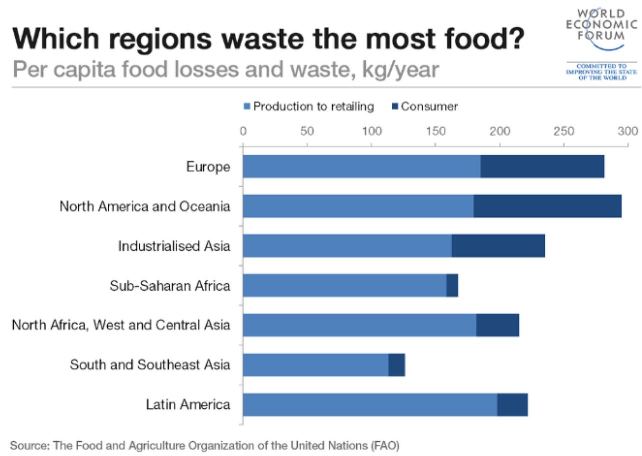


Figure 8: Food waste per region.
https://www.weforum.org/agenda/2015/08/which-countries-waste-the-most-food/

To ensure public health, safety, and reduce waste, our portable LP SPF System is utilized by multiple sensitive market segments including the food cold-chain where reliable cold transportation and storage is key to ensuring food hygiene, safety and nutritional quality, and the pharmaceuticals industry that requires cold shipment and storage of live vaccines and other sensitive medications like insulin.

LP SPF is a crucial product for repair works of insulated containers and refrigerated trucks to avoid any thermal bridges that would lead to condensation and energy losses. In case of damage, the side walls, roof, and floor need to be repaired properly to avoid future leakage. In such cases products like our portable, LP SPF products are used to fill the space completely with a strong product with high thermal resistance.

Refrigerated containers and cabins can effectively be insulated with light-weight, durable LP SPF. Due to the short curing time, horizontal and vertical components can easily be insulated. The energy efficiency of such foam systems allows the most effective use of interior spaces.

Picture 8 and 9: LP SPF application in limited space refrigerated transport containers.

To insulate huge cold stored structures, usually rigid insulation boards are used. Joints and hard to reach areas cannot simply be closed with one-component polyurethane foams or tapes. Even for such finishing work a high-performing closed-cell foam applied at low pressure is required to avoid any damage and provide a hermetically sealed enclosure. Low water pick-up, durability even at low temperature, and high thermal resistance are key properties for products used in this application.

Picture 10: LP SPF cold storage application

In cold shipment, it is especially important to note that limiting thickness of cold storage walls and floors is critical. One might say that the simple solution when reducing the performance of the insulating product would be to increase the thickness of the storage walls and floors. However, thin high-performance insulation is key to eliminating the moisture transfer of hot air moving thorough materials to colder air which causes ice buildup in refrigeration. **Lower performing insulation would allow for ice buildup.**

Appendix C – Not-in-kind insulation evaluation

Performance specifications are typically set by our customers or by industry code compliance requirements such as building and construction codes.

“A set of specific criteria that help verify that SPF products conform to the complicated building code requirements for their intended use have been developed. All SPF products and potential alternatives must conform to the requirements laid out in the building standards.” [lxxxii]

Polyurethane spray foams “serve as insulation and an air, sound, and vapor barrier for residential and commercial buildings. LP SPF has several advantages over other insulations: it applies quickly; it reaches into voids that are difficult to access with traditional materials; and, it resists many environmental nuisances that affect other material, including moisture and mold growth”. [lxxxiii] Some products also function as moisture barriers.

<u>The key performance requirements for a LP SPF are as follows:</u>

- “The product must be an effective barrier to heat (*i.e.*, the product must have thermal resistance and be an effective insulator). One reason that consumers may choose to use LP SPF products in a building is because of the high thermal resistance (R-value per inch) compared to other insulation products. The unique application process allows builders to create architectural designs that could not otherwise meet required energy performance standards using other insulation products.

- The product must be able to seal a wall assembly (where it is applied), serving as an effective barrier to air, vapor, moisture (closed-cell SPF), and sound.
- The product must resist the spreading of flames and emission of smoke in the case of a fire. Mandatory criteria for surface burning characteristics have been established by building codes to help ensure fire protection. For this reason, LP SPF products contain flame retardants.
- The product should have an appropriate reaction rate consistent with successful application of the product (in terms of seal, longevity, appearance, insulation capacity, *etc.*). For example, polyurethane-based spray foam polymerizes quickly, which:
- Prevents slumping, thus providing a good seal for insulated cavities. Any alternatives would need to have equivalent performance properties in order to maintain the tight air barrier properties of LP SPF.
- Reduces potential exposure to airborne pMDI. After application, the potential exposure is reduced to a level that allows other trades to enter the construction site in a timely manner.
- Ensures that the product is fully reacted once it attains its final characteristics, which eliminates building occupants' exposure to pMDI.
- The product must have good dimensional stability (<15% change by volume). LP SPF products should resist structural deterioration/decomposition and resist settling, which maintains insulation performance over time.
- The product should also adhere directly to building materials (*e.g*., wood, metal, plastic construction materials) and therefore improve structural integrity and stability.
- The product must be easy to spray, so that surfaces can be covered evenly, and the product can get into gaps to properly form an air, sound, and/or moisture barrier.
- The product must maintain minimum standards for shelf life in order to provide consistent quality of the product and hence meet the required performance standards."[lxxxiv]

<u>Key Definitions: on the criteria for various physical characteristics of LP SPF products for different types and applications</u>:

- "Thermal Resistance (R-Value): A measure of a material's resistance to conductive heat flow. The higher the thermal resistance (R-value), the greater the insulating power and the more the insulating material on a fixed-volume basis (US DOE, 2020a).
- Surface Burning Characteristics:
    - Flame-Spread Index: "A comparative measure, expressed as dimensionless number, derived from visual measurements of the spread of flame versus time for a material tested in accordance with ASTM E84 or UL 713" (ICC, 2015).
    - Smoke-Developed Index: "A comparative measure, expressed as dimensionless number, derived from smoke obscuration versus time for a material tested in accordance with ASTM E84" (ICC, 2015).
    - Core Density: "Density is expressed most often in pounds per cubic foot… Core density… is the weight from the center of the sample" (Cutcher, 2016).
    - Tensile Strength: "[T]ensile (pulling or stretching) force necessary to rupture a material sample divided by the sample's original cross sectional area. Units are usually kPa or psi or lb/in2" (SPFA, 2020a).
    - Dimensional Stability: "[T]he ability of a material to retain its original size and shape. For polyurethane foam, dimensional stability is determined over time under conditions of controlled temperature and humidity. Measured as a percent of original dimension" (SPFA, 2020a).
    - Compressive Strength: "[T]he stress or force applied parallel to the direction of the polyurethane foam rise at 10% deformation or at yield point" (SPFA, 2020a)."[lxxxv]

Property explanations from the above information fit the below Europe standard tests. There is a harmonized European standard laying out the requirements for applying the CE mark to our LP SPF or any other in-situ sprayed PUR or PIR foam for building and construction applications.

Exact reference: EN14315-1 Thermal insulating products for buildings – In-situ formed sprayed rigid polyurethane (PUR) and polyisocyanurate (PIR) foam products – Part 1: Specification for the rigid foam spray system before installation[lxxxvi]

Key criteria we declare and monitor according to the above standard are:

- Thermal conductivity & resistance declared at 10°C and in the range of -40 to 100°C acc. to EN12667
- Reaction to fire, rated acc. EN13501-1, ignitability tested acc. to EN11925-2 Annex H
- Dimensional stability at specific temperatures and humidity conditions per EN1604
- Short-term water absorption by partial immersion, EN1609

Some additional building code requirements in the EU are found at: https://eurocodes.jrc.ec.europa.eu/ and https://www.eota.eu/en-GB/content/eads/56/ and https://www.cen.eu/work/Sectors/Construction/Pages/JIS5.aspx

Not-in-kind

"Other types of insulation, such as fiberglass, mineral wool, cellulose, natural fibers, polystyrene, and cementitious foam, would provide only some of the same functions as PU SPF. None of these products replicate the multiple functional benefits of SPF (air barrier, moisture barrier, vapor retarder, thermal and acoustic barrier, and added structural strength) without secondary products. For example, additional insulation thickness is required for these other types of insulation materials to achieve the equivalent R-values that SPF can provide." [lxxxvii]

Water blown SPF

Polyurethane foam made with water creates an open-cell foam which is completely different in functionality from closed-cell formed by LP SPF. Open-cell foams are not as good of insulators or vapor barriers but are useful in hot climates where loads are primarily cooling. Closed-cell foams are more expensive but superior insulators and water/vapor barriers.

> **LP SPF is sold in portable, self-contained pressurized cylinders and studies have proven that water is not a sufficient pressure inducer to allow for the creation of a spray product** (see Appendix A). Transportation, construction and industrial uses of these products require a foam which applies at a low-pressure and that ultimately provides structural support, dimensional stability, vapor barrier and high thermal efficiency as noted in the use cases of Appendix B.

Concerning in situ products like spray polyurethane foam, water blown products are less expensive on a weight basis by as much as 50%, however the resulting foams have a much lower insulation performance (50%) which excludes their use in most northern European applications limited by wall cavity space. In addition, these products are completely unsuitable for structural support applications including heated flooring constructions. Water blown foams create carbon dioxide during application which functions as the blowing agent and are which cannot provide sufficient dimensional stability (compressive strength) and aged insulation performance to meet strict building codes.

> **Water blown polyurethane foam is found in the high-pressure SPF market**; these products are sold in large industrial sized drums and require ancillary pressure inducing equipment typically housed in a large trailer called a rig as discussed in our opening. These water-blown products are used in high-volume SPF applications that typically have no requirements for structural support, dimensional stability and low thermal requirements. (Note - some high-pressure SPF products use F-gases for closed-cell foams which is not the focus of this section.)

High Pressure SPF rig and use examples

Picture 11 and 12: High-pressure rig and high-pressure SPF application.

- "Open-cell foam is characterized as being composed of many air bubbles held within a polyurethane matrix. As with many insulations such as fiberglass, it is this trapped air that lessens the heat transfer through the foam.
    - Open-cell foam does not block vapor but instead allows it to pass through the foam matrix. It is particularly effective in hot climates where loads are primarily cooling. "

- "Closed-cell foam uses the same suspended bubbles in a polyurethane matrix as the open form but the bubbles are filled with a blowing agent. The blowing agent provides a more effective thermal barrier than air, leading to higher R-values compared to other insulations. Closed-cell foam insulation is denser than open-cell foam, which breathes; closed-cell foam is essentially incompressible once cured. [structural support]". Additionally, closed-cell foams
    - "…resist water penetration and moisture build-up. Moisture can eventually attract bacterial growth, promoting mold, which can eat away at wood and compromise structural integrity. Closed-cell foams can be exposed to water without absorbing it, making it particularly useful against a subgrade foundation, for example. It does not expand in volume as much as open-cell foams do."
    - "Once cured, closed-cell foam assumes a very rigid structure and can add some strength to walls, roofs, and ceilings."
    - "Closed-cell spray foam insulation is also dense enough to insulate against air movement, preventing drafts and keeping in regulated temperatures. This density also prevents mold growth because temperature control can cut down on humidity, which spawns mold. In order to maintain their resistance, closed-cell foams are usually dense and strong and resemble solids when they fully form and cure."[lxxxviii]

Not in-kind insulation replacements such as mineral wool, which are also less expensive, are also not suitable alternatives to LP SPF for the same fundamental reasons. The quotes in the section below, and additional information, are found in the industry documentation prepared for the State of California, U.S.A, "Abridged Alternatives Analysis Report for Two-component Low- and High-pressure Spray Polyurethane Foam Systems Containing Unreacted Methylene Diphenyl Diisocyanate", Gradient Corp., October 2020.

Fiberglass

"Fiberglass is an insulation material consisting of fine glass fibers. Fiberglass insulation products are not an alternative to SPF. Fiberglass products are typically used only in interior applications, while SPF can be used in both interior and exterior applications. Fiberglass insulation products are air permeable and cannot function as an air barrier or sealant (Holladay, 2009) without the use of additional products. Fiberglass insulation products by themselves cannot function as a water-resistive barrier. Fiberglass insulation cannot strengthen the structure of a building."

The figure below shows environmental impact on the vertical axis and time on the horizontal axis for SPF versus fiberglass. “SPF is air impermeable, fully adhered to the sheathing and framing members within the cavity, will not sag over time or suffer convective loss as the material gets thicker like fiberglass insulation. These additional energy saving benefits account for the steeper slope of the orange line. You get more benefit in a shorter period. At some point during the 75-year insulation service life[iv], the environmental impact line from SPF will cross the environmental impact line of fiberglass. The time (in years) at which this intersection occurs is referred to as the “environmental recovery period”. Beyond this environmental recovery period, the use of SPF insulation will have a greater positive environmental impact for the building when compared to fiberglass insulation.”

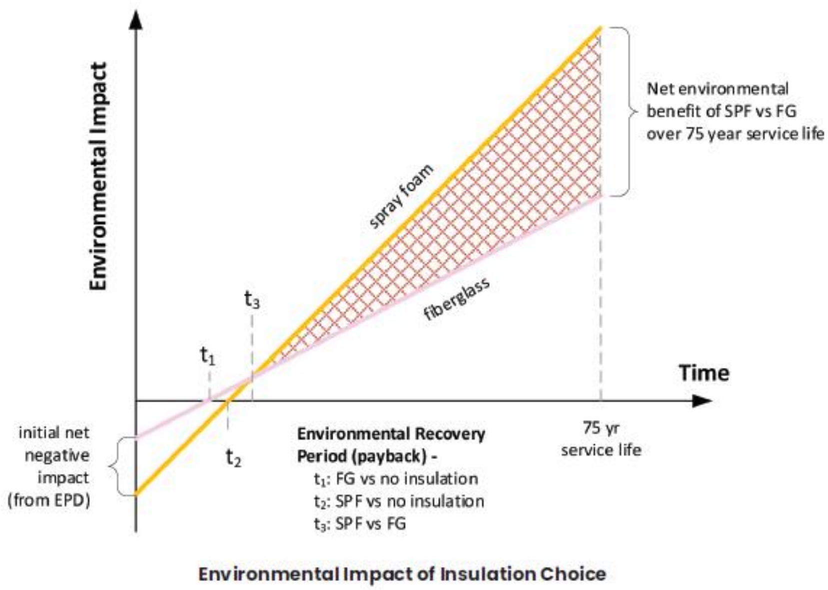


Figure 9: Long term positive environmental impact of LP SPF. [lxxxix]

Mineral Wool

“Rock wool, rock and slag wool, and slag wool are insulation fibers made up of different proportions of blast furnace slag, aluminosilicate rock (*e.g.*, basalt), and other rocks” (US DOE, 2020b). Mineral wool insulation products are not an alternative to LP SPF. Mineral wool insulation products are air permeable and cannot function as an air barrier or sealant without the use of additional products. Mineral wool insulation products by themselves cannot function as a water-resistive barrier. Mineral wool insulation cannot strengthen the structure of a building.

Cellulose

“Cellulose insulation typically consists of recycled paper, borate, and ammonium sulfate” (US DOE, 2020b). Cellulose insulation products are not an alternative to LP SPF. Cellulose insulation products are only used in interior applications, while LP SPF can be used in both interior and exterior applications. Cellulose insulation products are air permeable and cannot function as an air barrier or sealant without the use of additional products. Cellulose insulation products by themselves cannot function as a water-resistive barrier. In fact, cellulose insulation products are susceptible to water damage. Cellulose insulation cannot strengthen the structure of a building.

Natural Fiber

Natural fiber insulations include cotton, sheep's wool, *etc.* (US DOE, 2020b). Natural fiber insulation products are not an alternative to LP SPF. Natural fiber insulation products are only used in interior applications, while LP SPF can be used in both interior and exterior applications. Natural fiber insulation products are air permeable and cannot function as an air barrier or sealant without the use of additional products. Natural fiber insulation products by themselves cannot function as a water-resistive barrier. Like cellulose insulation products, natural fiber insulation products are susceptible to water damage. Natural fiber insulation cannot strengthen the structure of a building.

Polystyrene

Polystyrene is a thermoplastic insulation that comes in various forms, such as extruded or expanded foam boards, concrete blocks, and compressed bead boards (US DOE, 2020b). Polystyrene insulation products are not an alternative to LP SPF. While polystyrene materials are air impermeable, additional products are required for polystyrene wall assemblies to meet air barrier performance requirements. Polystyrene insulation products cannot seal cracks and gaps. Polystyrene insulation cannot strengthen the structure of a building.

Cementitious Foam

As the name suggests, cementitious foam is a cement-based foam either installed as spray-applied or foam in-place insulation (US DOE, 2020b). Cementitious foam insulation products are not an alternative to LP SPF. Cementitious foam insulation products are fragile and crumble (Roberts, 2014); therefore, they are air permeable and cannot function as an air barrier or sealant without the use of additional products. Cementitious foam insulation products by themselves cannot function as a water-resistive barrier. Cementitious foam insulation cannot strengthen the structure of building. “

Polyisocyanurate

Polyisocyanurate or polyiso is a thermoset plastic, closed-cell foam similar to polyurethane insulation (USDOE, 2020b). Polyisocyanurate rigid board insulation products are not an alternative to LP SPF. Like polyurethane, polyisocyanurate is created *via* a thermochemical reaction between MDI and polyols and catalysts, surfactants, and flame retardants (PIMA, 2015). However, this process occurs at a manufacturing site using a vastly different process, typically including the use of metal or plastic facers, which require specialized lamination equipment. Polyisocyanurate insulation products are not spray applied. While polyisocyanurate materials are air impermeable, additional products are required for polyisocyanurate wall assemblies to meet air barrier performance requirements. Polyisocyanurate insulation products cannot seal cracks and gaps.

An overview evaluation of LP SPF versus other not-in-kind products is shown in Table 6 on the following page.

The product requirements in Table 6, next page, follow the industry standards defined as follows:

[1] Air Sealing: Air permeance (ASTM E283 or E2178) < 0.004 cfm/ft2 as applied in field, (EN1211/DIN18542) <0.1m*7m.h @600Pa
[2]Structural support as defined by compressive strength (ASTM D1621) > 15psi, (EN826) min 100kPa
[3]Dimensional Stability (ASTM D2126) <15 % at 24 and 168hrs in 158 °F and 97% relative humidity
[4]Water resistive as defined by Water Absorption (ASTM 2842) by Volume <4%, (EN1609) <0.3kg/m2
[5]Vapor Retardant as defined by Water Vapor Permeance
[6]Adheres to structure indicates it must adhere to wood, steel, metal board, gypsum on application
[7]Acoustic barrier (EN ISO 717-1) 58dB
[8]Indoor air quality AGB/AgBB-pass & French VOC A+ rating

Table 6: An overview evaluation of LP SPF versus other not-in-kind products. xc xci xcii

Insulation Type	Technical Feasiblity	R5 per inch or greater	Portability	Air Sealing[1]	Structural Support[2]	Dimensional Stability[3]	Water resistive[4]	Vapor retardant[5]	Adheres to structure[6]	Acoustic barrier[7]	Retrofit: Can be applied in-situ w/o deconstruction	Exterior & Interior use[8]	Roofing use include green-roof
Low-Pressure Closed-cell SPF	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Low-pressure SPF "Alternative"													
High-pressure closed-cell SPF	✗	✓	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Closed-cell Extruded Polystyrene	✗	✓	✓	✗ requires tape	✓	✓	✓	✓	✗ requires fasteners	✗	✗ External only	✗	✓
Polyisocyanurate board	✗	✓	✗	✗ requires tape	✓	✓	✓	✓	✗ requires fasteners	✓ varies	✗ External only	✓ varies	✓ varies
High-pressure Water blown (Open-cell) SPF	✗	✗	✗	✓	✗	✗	✗	✗	✓	✓	✓	✗	✗
Fiberglass	✗	✗	✓	✗	✗	✗	✗	✗	✗	✓	✗	✗	✗
Mineral Wool (Rock/slag wool)	✗	✗	✓	✗	✗	✗	✗	✗	✗	✓	✗	✓	✗
Cellulose	✗	✗	✓	✗	✗	✗	✗	✗	✗	✓	✓	✗	✗
Natural Fiber	✗	✗	✓	✗	✗	✗	✗	✗	✗	✓	✗	✗	✗
Cementitious Foam	✗	✗	✗	✗	✓	✓	✓	✗	✓	✓	✗	✓	✓
Expanded Polystyrene	✗	✗	✗	✗ requires tape	✓	✓	✗	✗	✗ requires fasteners	✗	✗ External only	✗	✗ requires membrane

Appendix D - Positive impact of LP SPF on Key EU Climate Regulations

LP SPF products are used in a variety of applications, spanning residential, commercial, and infrastructure, including walls, roofs, pipes and foundations. At DuPont Performance Building Solutions and Corian Design our insulation material has a lifetime of at least 25 years. In practice the lifetime is expected to be greater than 60 years, with the blowing agents remaining in the insulation material (in a gaseous form) over the long-term.

LP SPF creates a closed-cell rigid foam which is used to protect and enhance the durability of buildings and critical infrastructure elements. It is used in many applications including residential homes, commercial buildings, bridges, pipelines, storage tanks, refrigerated storage and transport, racks that support solar panels, and airports. LP SPF is used for numerous reasons including its ability to provide all of the following attributes from a single product:

- High insulating value (R-value) for long-term improved energy efficiency (ASTM C518, R6 minimum)/ (EN12667, 0.022W/m.K & ASTM C591 max 026W/m.K)
    - protects against cold and frost damage in infrastructure, including hockey rinks, airport runways, taxiways & embankments, motorways, tunnels and highway embankments, transmission line towers, utility lines, culverts, railroads: under track, grade crossing, switching rail yards and other facilities, retaining walls, and more.
- Reduction of thermal bridging
- Inertness and non-reactivity
- Resistance to harsh chemicals
- Resistance to high temperatures and low temperatures (EN12667, -150°C to +100°C)
- Durability - Resiliency in the face of climate change. Increased life of pipelines, buildings and roofs.
- Compressive strength (ASTM D1621, minimum 15psi)/ (EN826, min.100kPa)
- Moisture resistance & vapor barrier: Hydrophobicity; neither water nor water-containing substances wet the foam (Water resistive per ASTM 2842)/ (water absorption EN1609, max 0.3kg/m2)
- Air barrier properties (ASTM E283 or E2178)/ (EN12114/DIN18542 <0.1m3/m.h @600Pa)
- Low bacterial / algae growth
- Adhesion to many surfaces for improved air sealing and durability
- Vibration dampening
- Easy transport of cylinders and application in-situ

High performing insulation must be a significant part of any effective strategy to reduce GHG emissions, and to increase the energy performance class of buildings. Insulation is critical, as without it, buildings quickly accumulate moisture in the walls and roof, rotting the wood and risking the development of mold. Without insulation, global residents face high heating bills during every month of every winter. In addition, thicker walls are needed to fit thicker insulation to ensure high energy efficiency when using lower performing building insulation. That adds to the cost of the building to provide the same energy efficiency, and additionally reduces the available living space. Based on a published study, additional coal, oil, or gas consumed to heat a building without insulation would emit over its lifetime at least an order of magnitude more GHGs than a properly insulated building. [xciii]

The benefits of improved insulation directly translate to lower demands on energy sources, including those with carbon emission footprints. This directly supports a key initiative of the EU Green Deal, decarbonization of the energy sector. In March 2020, the Commission tabled a proposal for a European Climate Law to decarbonise Europe by 2050. In its Climate Target Plan (CTP)[xciv], the Commission proposed to raise the Union's ambition on reducing greenhouse gas emissions to at least 55% below 1990 levels by 2030, which is a substantial increase compared to the existing 40% target. The Climate Target Plan is also in line with the Paris Agreement' objective to keep the global temperature increase to well below 2°C and pursue efforts to keep it to 1,5°C. The European Commission 2021 Work Programme[xcv] announced a 'Fit for 55' package to reduce GHG emissions by at least 55% by 2030 and achieve a climate-neutral Europe by 2050. Energy efficiency is a key area of action, without which the full decarbonisation of the Union economy cannot be achieved[xcvi]. Heating and cooling, therefore, plays a crucial role in the Union's ambition to transition into a clean and carbon-neutral economy by 2050. Much of the effort is needed in the field of better insulating buildings. A study based on U.S. buildings shows the use of insulation and sealant has the potential to "drive annual CO_2 equivalent emission reductions of nearly 282 million tons" in the United States alone. In the U.S., "The longevity of insulation measures translates to lifetime CO_2 equivalent emission reductions of more than 11.5 billion tons. These reductions are the equivalent of annual emissions from over 3,000 coal-fired power plants, or the electricity used in a year by almost 2.5 billion gasoline-powered passenger vehicles driven for one year. Most importantly, insulation improvements can be implemented immediately with off-the-shelf technology while allowing longer-term investments and electrification technologies to be planned and deployed." [xcvii]

Key goals of the proposed EU Green Deal being developed will depend heavily upon the unique performance attributes of non-persistent/non-bioaccumulative/non-toxic, HFO materials which are a non-replaceable key component of LP SPF.

We disagree with any assumption that building codes would ever be relaxed, especially in light of the recently announced climate initiatives around the globe, including the European Green Deal which calls for increased energy efficiency of buildings.

The LP SPF products as mentioned above can contribute to achieving the energy efficiency targets of the EU Renovation Wave[xcviii] which focuses on the energy renovation of buildings in the EU with a target of a 3% annual energy renovation rate. The EU Renovation Wave, while focused on energy efficiency, also considers material efficiency and circularity as ways of reducing the whole life cycle carbon emissions of buildings.

The targets of the EU Climate Law (which provides the legal basis for Europe becoming net-zero on greenhouse gas emissions by 2050[xcix] with an interim reduction target of 55% by 2030, compared to the levels in 1990)[c] could also be achieved by using LP SPF products. These targets can only be met if a reduction of buildings' emissions (which in the EU are responsible for 36% of all greenhouse gas emissions[ci]) with such products. In line with the aims of the EU Climate Law, the vision of the Energy Performance of Buildings Directive (EPBD)[cii] is also a zero-emission building stock by 2050. The achievement of this goal is clearly tied to renovation as almost 75% of the current building stock in the EU is considered to be inefficient according to current building standards, and 85-95% of these buildings are expected to still be standing in 2050.

In the EU, heating, cooling and domestic hot water account for around 80% of energy consumed in residential buildings. Due to the current use of predominantly fossil energy sources, particularly for heating, this energy corresponds to a substantial part of the greenhouse gas emissions of a building. Consequently, thermal insulation provided by LP SPF products and efficient heat sources are key levers for the energy efficiency of buildings.

Beyond sustainability contributions, improved insulation of buildings provides social co-benefits. The thermal insulation the LP SPF products can provide keeps inside temperatures within a narrower range, thereby protecting, in particular, vulnerable populations from cold and heat. Many thermal insulation measures carry a co-benefit of noise insulation, providing quieter, more livable indoor spaces. Finally, insulation leads to heating cost savings for citizens, reducing their risk of being affected by energy poverty. Substantial savings of heating energy and greenhouse gas emissions (due to today's predominantly fossil heat sources) are possible through thermal insulation. The savings potential is estimated to be about ~80% [21] over a non-insulated building. As a co-benefit, additional savings for cooling energy can be obtained in case the building is also actively cooled in warm months.

As part of the installation of external thermal insulation systems, LP SPF products can increase the durability and performance of insulation panels[ciii]. Because adhesives allow for area bonding, high shear and peel resistance are realized, keeping panels reliably in place. By accommodating thermal deformation stresses, adhesive-based installation of foam insulation panels reduces the risk of damage (cracking) compared to mechanical anchor-based installation. In combination, a more consistent and reliable insulation is achieved. These products also provide insulating gap filling properties that augment the overall performance of external thermal insulation systems and buildings. PU foams allow, for example, for the compliant integration of windows and doors into the building envelope without thermal bridges and they can also fill gaps in external thermal insulation systems. Airtightness is crucially important to the overall thermal insulation performance of a building, as air leakage can represent up to 50% of the energy losses in a building. Additional benefits of airtightness can result from keeping insulation materials free of humidity and thereby allowing them to perform better. The LP SPF products are unique in providing airtightness to the building envelope using a low-pressure, portable unit.

Material efficiency is about maximizing productive use of employed materials and minimizing waste, which represents loss of material. Material efficiency is not only an economically attractive practice but also provides substantial ecological benefits. Efficient use of materials supports the preservation of depletable resources, which is particularly relevant for inorganic and fossil-based materials for which natural reservoirs are not replenished (in distinction to, for example, biomass). The reduction of waste avoids the associated footprint as well as possible further negative side effects of waste disposal. Importantly, with rising energy efficiency, the embodied carbon footprint of buildings becomes more important. In fact, in modern, highly energy-efficient buildings, embodied carbon can be higher than the 50-year use-phase emissions[civ]. Embodied carbon cannot be reduced by use phase energy efficiency measures; it must be addressed through material efficiency. Material-efficient construction with low footprint / low embedded carbon materials therefore becomes key for further overall reductions of a building's footprint. A key tool in discussing material efficiency is the waste hierarchy (adapted to the construction sector):

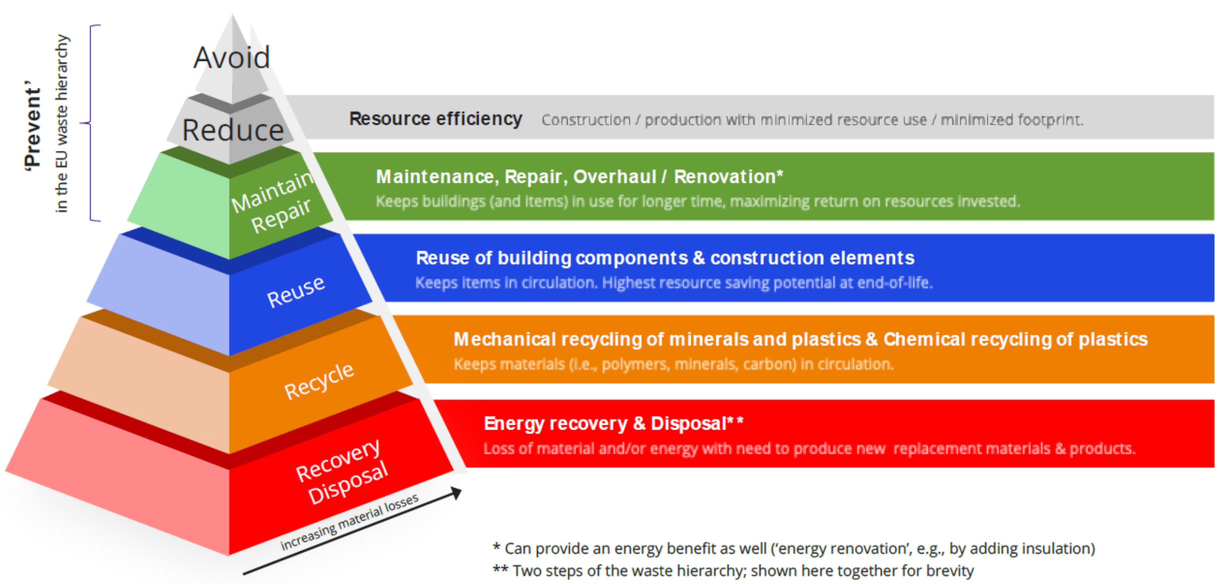


Figure 10: Overview of material efficiency

The waste hierarchy defines the most and the least preferable approaches to the use of materials from the angle of the waste that is created. As described above, waste can be understood as the inverse of material efficiency. Renovation is key for EU climate targets because most buildings will still be in use in 2050, when climate targets are to be reached[cv]. Renovation also provides substantial energy and footprint savings over rebuilding: the added embodied carbon from renovation is typically less than 50% of the amount for a new building. During building maintenance and repair, SPF product can keep more material in use for longer periods of time and can prevent the replacement of entire building elements by allowing for repair.

The SPF products, therefore, present numerous specific benefits to the construction sector. When used in the manufacture of construction products and/or in the construction of a building itself, they help improve energy efficiency through insulation and enable material efficiency through material reduction and/or the use of more sustainable materials. During the lifetime of the building, they support maintenance, repair and renovation and can thereby increase a building's durability.

Appendix E - Socio-economic impacts

<u>In answer to Question 6g</u>, *For cases in which substitution is not technically or economically feasible, information on what the socio-economic impacts would be for companies, consumers, and other affected actors.*

The loss of LP SPF in the EU will have a significant negative impact in Europe. This detrimental impact will be shared in greater detail in a forthcoming SEA paper from industry to which DuPont's input was given, and which we will submit as a future comment. At this time, we provide the information shared during the consultation phase of the restriction process:

Figure 11: SEA overview shared during the consultation phase

	Ranking of likely responses to a restriction: **1** = most likely, **2** = likely, **3** = potentially, **4** = unlikely, **5** = non-viable			
Function	Chemical substitution	Alternative technique	Discontinue PFAS-dependent operations	Operations would not be affected, i.e. business as usual
Foam blowing	**5**	**5**	**5– operations would leave the EU**	**5 – operations would be forced to leave the EU if restrictions occur**

11. Can you provide estimates of the costs that might be incurred by your company or members from a potential REACH restriction of PFAS for your business?

Function	**One-off costs (e.g. R&D and investments)**	**Annual recurring costs (e.g. production costs and testing costs)**	**Other (please specify)**
Foam blowing	**Multiple millions of dollars**	**Multiple millions of dollars**	**Lost Business due to lack of HFO alternatives: Multiple millions of dollars**

Appendix F – Overview of 10 questions from ECHA

Section III. Non-confidential comments – General Comments		
We are submitting comments in support of a missing use that we have identified, which we propose be included in Use Sector "g) Evaluation of environmental impacts of RO2 relating to applications of fluorinated gases" and be titled "**Foam blowing agents in low-pressure spray polyurethane foam (LP SPF) sprayed on site**". In addition to this general comment, we provide overview points to the specific information requests 1 through 10, attach a detailed public document, and attach a confidential document with extensive details.		
Section III. Specific Information Requests		
Question	**Information?**	**Overview and document references**
Non-Confidential Comments	Yes	Our online responses to the specific questions contain non-confidential information only.
1. Sectors and (sub-)uses	Yes	We are submitting comments in support of a missing use that we have identified, which we propose be included in Use Sector "g) Evaluation of environmental impacts of RO2 relating to applications of fluorinated gases", and be titled "**Foam blowing agents in low-pressure spray polyurethane foam (LP SPF) sprayed on site**". For a complete understanding, please take the time to read the full attached public report and confidential information attachment. This question is addressed on page 1, 3, 4-6 and pages 23-35 with additional context throughout the documents.
2. Emissions in the end-of-life phase (across manufacture phase, use phase, EOL phase)	Yes	We are submitting comments that indicate estimated annual emissions at the sub-sector level for "Foam blowing agents in low-pressure spray polyurethane foam sprayed on site" (LP SPF), including manufacturing, use and end of life. For a complete understanding, please take the time to read the full attached public report and confidential information attachment. This question is addressed on page 2 and 9-10 with additional context throughout the documents.
3. Emissions in the end-of-life phase (waste management / effectiveness of incineration)	Yes	Due to the type of waste stream, building and infrastructure, LP SPF is not incinerated. For a complete understanding, please take the time to read the full attached public report and confidential information attachment. This question is addressed on page 2 and 9-10 with additional context throughout the documents.
4. Impacts on the recycling industry	Yes	We have provided industry information on typical end of life expectation for LP SPF.

		For a complete understanding, please take the time to read the full attached public report and confidential information attachment. This question is addressed on page 2 and 9-10 with additional context throughout the documents.
5. Proposed derogations – Tonnage and emissions	Yes	We submit a Confidential Information document which provides details on the estimate of emissions from the LP SPF sub-sector. For a complete understanding, please take the time to read the full attached public report and confidential information attachment. This question is addressed on page 2 and 9-10 with additional context throughout the documents.
6. Missing uses – Analysis of alternatives and socio-economic analysis	Yes	We have identified a missing use. In addition to the socio-economic analysis (SEA) information provided in our current documents, further industry reports will be released and shared before the submission deadline.
6a. Annual Tonnage & emissions and type of PFAS	Yes	6a. We have provided an estimate of annual emissions for the sub-sector as well as confidential information on our use. For a complete understanding, please take the time to read the full attached public report and confidential information attachment. This question is addressed on pages 1-2, 8-10 and 22-23 with additional context throughout.
6b. Key functionalities provided by PFAS	Yes	6b. For a complete understanding, please take the time to read the full attached public report and confidential information attachments. This question is addressed on pages 4-6, 11-12, 14-15, and 21-39 with additional context throughout.
6c. Number of companies in the sector affected	Yes	6c. There are only two (2) manufacturers of low-pressure spray polyurethane foam (LP SPF) in the EU. Fewer than five (5) comments are expected for this sub-sector use due to the limited number of manufacturers. This should not be considered “weak evidence” since it will constitute the entire industry. The number of companies/users, beyond manufacturers, affected by this restriction will expand into the thousands. For a complete understanding, please take the time to read the full attached public report and confidential information attachments. This question is addressed on page 2-3 with additional context throughout.
6d. Availability, feasibility, hazards and risks of alternatives	Yes	6d. There are no alternatives to the current blowing agents used in LP SPF. For a complete understanding, please take the time to read the full attached public report and confidential information attachments. This question is addressed on pages 1-2, 4-11 and 14-23 with additional context throughout.
6e. Information on the status of finding alternatives	Yes	6e. All possible alternatives have been considered and have proven not to be feasible. A new alternative will require invention by blowing agent technology developers. For a complete understanding, please take the time to read the full attached public report and confidential information attachments. This question is addressed on pages 1-2, 4-11 and 14-23 with additional context throughout.

6f. For cases in which substitution is technically feasible	Yes	6f. There are no technically feasible alternatives to the two HFOs used in low-pressure spray polyurethane foams. For a complete understanding, please take the time to read the full attached public report and confidential information attachment. This question is addressed on page 1-2, 4-11 and 14-23 with additional context throughout.
6g. For cases in which substitution is not technically feasible, information on impacts & value of EU sales/profits and employment numbers	Yes	6g. We have provided information on the negative impact to EU policy goals, the detrimental impact on EU business and confidential data on sales/profits and employment impact. For a complete understanding, please take the time to read the full attached public report and confidential information attachments. This question is addressed on page 2-3, 11-12, 23-29 and 36-39 with additional context throughout.
7. Potential derogations marked for reconsideration – Analysis of alternatives and socio-economic analysis	Yes	We have identified a missing use. This question is addressed more thoroughly in Question 1 and Question 6. For a complete understanding, please take the time to read the full attached public report and confidential information attachments.
8. Other identified uses – Analysis of alternatives and socio-economic analysis	Yes	We have identified a missing use. This question is addressed more thoroughly in Question 1 and Question 6. For a complete understanding, please take the time to read the full attached public report and confidential information attachments.
9. Degradation potential of specific PFAS sub-groups	Yes	Regarding trifluoromethoxy, trifluoromethylamino- and difluoromethanedioxy derivatives, these compounds aren't derivatives/degradants of HFOs. There is a wealth of information regarding the degradation of HFO and relevant compartments in the public sector. Potential degradation pathways, kinetics or produced metabolites in relevant environmental conditions are discussed in detail in our attached reports. For a complete understanding, please take the time to read the full attached public report and confidential information attachments. This question is addressed on page 2, 8-11 and 19-23 with additional context throughout.
10. Analytical methods	No	I don't have information on this topic.
Section IV. Non-Confidential Attachment		
We are submitting a Non-Confidential Document articulating the justification for derogation with evidence + providing non-confidential data		
Section V. Confidential Attachment		
We are submitting a Confidential Document that expands with detail where needed beyond the Non-Confidential Document. The attached is considered Confidential Business Information for protection of our commercial interests, including intellectual property, which would be undermined if this information were released.		

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