Honeywell

Honeywell Advanced Limited
Riverview House
Harvey's Quay Apartments Limerick V94R3DE
Ireland

24 July 2023

PFAS REACH Annex XV Restriction Report

1ST Public Consultation (22 March – 25 September 2023)

Request for exclusions or derogations from the PFAS REACH restriction Proposal of HCFO-1233zd(E) and HFO-1234ze(E) uses as insulation foam blowing agents.

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1. Executive summary

Honeywell International Inc. (hereinafter - **Honeywell**)[1] is a global manufacturer and importer of various fluorinated gases to the European Union (**EU**), including hydrofluoroolefins (**HFO**) substances **HFO-1234ze(E)**[2] and **HCFO-1233zd(E)**[3] (also often referred as **HFOs**) used *inter alia* as insulation foam blowing agents.

On 13 January 2023, the competent authorities of five EEA members states (**Dossier Submitters**) submitted to the European Chemical Agency (**ECHA**) the *PFAS REACH Annex XV Restriction Report* (**Proposal**)[4]. Although, the above gases formally fall within the definition of PFAS in the Proposal, Honeywell requests that they must be excluded from the scope of potential PFAS REACH restriction in question or made subject to a time-unlimited derogation for uses as foams blowing agents.

Contrary the claims of the Dossier Submitters there are a range of PFAS substances, including HFO-1234ze(E) and HCFO-1233zd(E) gases, that are low hazard, low Global Warming Potential (**GWP**), not persistent and that do not degrade to very persistent substances in any meaningful amounts. In this respect, REACH registration dossiers and Chemical Safety Report (**CSR**) for fluorinated gases HFO-1234ze(E) and HCFO-1233zd(E) contain conclusive scientific evidence, including proper DNEL/PNEC for all relevant compartments, demonstrating that these substances are not persistent and do not exhibit risks similar to PBT/vPvB substances under Article XIII REACH.

According to the most recent scientific data, upon release HFO-1234ze(E) as well as HCFO-1233zd(E) ultimately degrade in the atmosphere to carbon dioxide (**CO_2**), hydrogen fluoride (HF) and in some cases hydrogen chloride (HCl), in approximately 19 - 42 days. This leads to the creation of negligible amounts of the only PFAS arrowhead substance - trifluoroacetic acid (**TFA**).[5] The respective TFA amounts result in *de minimis* increases in overall TFA environmental concentrations by comparison with pre-existing TFA levels.[6] [7]

In this respect, highly qualified independent assessments by UNEP panels have repeatedly concluded that *"The current low concentration of trifluoroacetic acid (TFA) produced by the degradation of several hydrofluorocarbons (HFCs) and hydrofluoroolefins (HFOs), is currently judged not to pose a risk to human health or to the environment."*[8] and that *"available evidence indicates that this breakdown product [TFA] is of minimal risk to human health".*[9]

[1] See the list of acronyms and abbreviations (aligned with the Proposal) in **Annex I** below.

[2] 1-Propene, 1,3,3,3-tetrafluoro-, EC no: 471-480-0, CAS no.: 1645-83-6, Mol. formula: C3H2F4

[3] (1E)-1-chloro-3,3,3-trifluoroprop-1-ene, EC no.: 700-486-0, CAS no.: 102687-65-0, Mol. formula: C3H2ClF3

[4] On 22 March 2023, ECHA published the *PFAS REACH Annex XV Restriction Report* in the Registry of restriction intentions until outcome and started the 1st *Annex XV report consultation* with a final deadline for comments on 25 September 2023.

[5] See SI Table 3 (pages 312-313) and sections SI 4.3.2, SI 4.3.2 (pages 317-318) of the *Environmental Effects of Stratospheric Ozone Depletion, UV Radiation, and Interactions with Climate Change*, EEAP 2022 Assessment Report.

[6] According to the conclusions in Chapter 6, section 3.8 of the *Environmental Effects of Stratospheric Ozone Depletion, UV Radiation, and Interactions with Climate Change*, EEAP 2022 Assessment Report, respective *"releases will add to the existing load of TFA in the environment but predicted amounts are well below the threshold for concern with respect to human and environmental health."*

[7] See also detailed EFCTC position paper on the topic *Published evidence supports very low yield of TFA from most HFOs and HCFOs*.

[8] Page 9, *Environmental effects of stratospheric ozone depletion, UV radiation, and interactions with climate change:* UNEP Environmental Effects Assessment Panel, Update 2020

[9] Pages 8-9, *Summary Update 2021 for Policymakers*, UNEP Environmental Effects Assessment Panel

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The most recent UNEP EEAP 2022 Assessment Report also concludes that *"based on projected future use of these precursors of TFA [incl. HFC/HFO], no harm is anticipated"* and that TFA *"is unlikely to cause adverse effects out to 2100"*.[10]

In this regard, *Q&A 10 of Addendum to the EEAP Assessment Report* also confirmed that "*Now and in the distant future, predicted TFA concentrations in surface waters and terminal basins are thousands of times less than thresholds of concern for human or environmental health.*" [11]

Honeywell provided detailed analysis on degradation of HFOs and relevant hazard, exposure and risks assessments of TFA in submission no: 76bb3d12-2101-4390-82cf-3498b47e8015.

Therefore, the Dossier Submitters erroneously considered (in section 1.1.6 of the Proposal) HFO-1234ze(E) and HCFO-1233zd(E) together with all other PFAS (i.e., as a group) for the purposes of hazard, exposure and risks characterisation assessments within the PFAS REACH restriction process in question. They also wrongly concluded that these substances are among *"non-threshold substances"* with the overall concerns *"very similar to those of the PBT/vPvB substances"* and used any of their emissions *"as a proxy for risk"*.[12]

Moreover, HFO-1234ze(E) and HCFO-1233zd(E) uses in insulation foams are already adequately regulated in EU via effective Risks Management Measures (**RMMs)** under the *EU F-Gas Regulation,*[13]*Industrial Emissions Directive*[14]**,** EU and national laws on waste,[15] ATEX Directive[16], as well as various national building/construction/engineering codes and industry standards.

Several waste disposal techniques for closed and open cell insulation foams have been already approved and implemented in the EU. Main options are *Reuse* (use of insulation in new or renovated buildings) and *Repurpose* (reclamation of raw materials, including blowing agents)**.** Disposal through incineration to generate energy is the most common waste treatment technique for insulation foams. [17] Thermal oxidizer technology used today at many fluorocarbons destruction facilities is able to remove >99.99% of the organic materials, including foam blowing agents.[18] As a result, end of life PFAS emissions attributed to insulation foams blowing agents such as HFOs are much lower than 8% stipulated in table 11 of section 2.4.3.2 of the Proposal.

Further, according to the Proposal, functional and/or chemical (in kind/drop in) alternatives are already available for HFO-1234ze(E) and HCFO-1233zd(E) uses as insulation foams blowing agents in all relevant application. This conclusion is erroneous because the Dossier Submitters failed to assess within their cost/benefit analysis all available information on safety, health, efficiency and environmental properties (e.g., fire safety, air quality (VOC), GHG emissions/savings) of alternatives. However, the "*careful and*

10 See pages 25 and 259 of the EEAP 2022 Assessment Report.

11 Q&A 10*, Questions and Answers about the Effects of Ozone Depletion, UV Radiation, and Climate on Humans and the Environment,* EEAP 2022 Assessment Report.

12 See analysis and conclusions of section 1.1.6 (Risk characterisation) of the Proposal.

13 *Regulation (EU) No 517/2014 of the European Parliament and of the Council of 16 April 2014 on fluorinated greenhouse gases and repealing Regulation (EC) No 842/2006* (as amended and currently under review).

14 *Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control) (as amended).*

15 Directive 2008/98/EC on waste (Waste Framework Directive).

16 *Directive 2014/34/EU of the European Parliament and of the Council of 26 February 2014 on the harmonisation of the laws of the Member States relating to equipment and protective systems intended for use in potentially explosive atmospheres (recast)*

17 See e.g. section 2.14, *IVPU thermal insulation boards with 50 μm aluminum facing,* Environmental Product Declaration as per ISO 14025 and EN 15804+A1, EPD-IVP-20210001-IBE1-EN

18 RECYCLING REACTORS FOR RIGID PU FOAM RESIDUES

impartial" assessment of all information, [19] including all evidence submitted by various stakeholders during two Calls for Evidence (CfE) preceding the Proposal,[20] unequivocally demonstrates lack of feasible, safe and sustainable alternatives for most uses of HFO-1234ze(E) and HCFO-1233zd(E) fluorinated gases as insulation foams blowing agents.

According to publicly available information, HCFO-1233zd(E) and HFO-1234ze(E) are non-flammable fluorinated foam blowing agents used in closed cell insulation foam products, particularly in polyurethane[21], extruded polystyrene and phenolic foam. Closed cell foams are used in the market today because of their superior insulation value and water-proofing behaviour versus other technologies such as open cell foam, mineral wool and glass fibre.

HCFO-1233zd(E) and HFO-1234ze(E) are characterized by three unique properties: - *safety in use,* - *best in class insulation value* and - *unique mechanical properties*. See comparison tables in **Appendix I** below. Additionally, several good end of life solutions for foams containing any of the above two blowing agents are readily available and are in line with circular economy solutions.[22]

- **Safety in use**

Spray polyurethane foam (**SPF**) is a very important in-situ (on site) insulation application in France, Belgium, Netherlands and Spain, to mention some countries. In this application traditional engineering controls over flammables are not possible. The present foam blowing equipment is also not designed to handle flammable foam blowing agents. Therefore, keeping use of non-flammable blowing agents such as HCFO-1233zd(E) and HFO-1234ze(E) in this application is an absolute must (also acknowledged in sections E.2.8.2.3, E.2.8.4.3 of Annex E and page 150 of the Proposal). Additionally, given tight compliance safety requirements under the ATEX Directive[23], in other foam applications the cost to convert to plant equipment capable of handling flammables can be cost prohibitive, especially to small and medium sizes enterprises (SMEs).[24]

19 I.e., under the EU general principle of good administration, *Jean-Louis Burban v European Parliament,* case C-255/90 P; *Detlef Nolle v. Council of the European Union*, case T-167/94*; Przedsiębiorstwo Energetyki Cieplnej sp. z o.o. v ECHA*, case T-625/16, para. 89; BASF and REACH & colours v ECHA, case T-806/17, para. 75; *Technische Universität München v Hauptzollamt München-Mitte*, case C-269/90, para. 14.

20 *Call for evidence supporting an analysis of restriction options for PFAS* – May-July 2020, and 2 Stakeholder Consultation on a Restriction for PFAS - August-October 2021.

21 All references to the *polyurethane* insulation foam in this document is understood to include foams referred to as *polyisocyanurate* foams. These foams have similar chemistries and use similar starting materials. Most foams sold as polyisocyanurate ones are usually mixture of polyurethane and polyisocyanurate polymers. When the term polyisocyanurate foam is used, it is intended to focus only on that subset of polyurethane foam.

22 See e.g., *PU thermal insulation boards with multi-layer aluminium facing*, Environmental Product Declaration as per ISO 14025 and EN 804+A, EPD-IVP-20210003-IBE1-EN

23 *Directive 2014/34/EU of the European Parliament and of the Council of 26 February 2014 on the harmonisation of the laws of the Member States relating to equipment and protective systems intended for use in potentially explosive atmospheres (recast)*

24 See at page 38, Flexible and Rigid Foams Technical Options Committee 2022 Assessment Report*: "Capital costs have been reported to range between $250,000 USD to $1,000,000 USD per operating facility. Hydrocarbons have lower operating costs, but the significant capital investment has made them less attractive for smaller enterprises".*

- **Best in class insulation values**

Best in class insulation becomes relevant in applications where thickness is limited. The *European Green Deal's Renovation Wave* calls for 35 million buildings to be renovated by 2030 in Europe. Many of these buildings listed for renovation in urban areas will face space constraints and require best in class insulation to meet the building envelope insulation standards.[25] A recent study conducted by the University of Sevilla (Spain) (enclosed in **Annex II** below) demonstrates that an average of 3.5% of CO_2 emission savings can be achieved by using closed cell polyisocyanurate or phenolic foam boards blown with HCFO-1233zd(E) versus same boards blown with hydrocarbons.[26] This translates to 167.120 metric tons of GHG (CO_2) emissions saved per year for every one million buildings renovated (see in detail in **Annex II**). [27]

- **Unique mechanical properties; Restrictions present disproportionate risk**

As an example, the use of polyurethane spray foam as under-slab insulation in residential structures is the best option in France.[28] Respective NF DTU 52.10 norms describes the mandatory requirements on compressive creep[29] of insulation materials to assure a good mechanical behaviour over the whole lifetime of the building. The only possibility to comply with these technical specifications for a spray foam is to use HFOs such as HCFO-1233zd(E) as a blowing agent. Due to exceptional mechanical properties and non-flammable characteristics, the latter is the blowing agent of choice for so-called *"Integral Skin"* flexible foams applications.

In these circumstances, the introduction of proposed REACH restrictions (i.e., bans) on HCFO-1233zd(E) and HFO-1234ze(E) uses as insulation foam blowing agents is disproportionate to risks from their degradation product TFA, where emissions from degradation are negligible. The proposed restriction will violate the principles of the REACH Regulation, EU general legal principles and wider EU decarbonization and sustainability policies (including, European Green Deal, Fit for 55, REPowerEU, etc.) resulting in high costs to society.

Considering all available information Honeywell requests that HFO-1234ze(E) and HCFO-1233zd(E) fluorinated gases should be excluded from the scope of the Proposal or all their uses as foams blowing agents made subject to the time-unlimited derogation.

2. Objective hazard, exposure and risk assessments of HFO-1234ze(E) and HCFO-1233zd(E)

In section 1.1.6 of the Proposal the Dossier Submitters concluded that *"all PFAS" (i.e., as a group)* should *"be treated as non-threshold substances for the purposes of risk assessment in a similar manner to PBT/vPVB substances"* and that any of their releases *"can be used as a proxy for risk"*. This conclusion is overbroad and manifestly incorrect as far as HFO-1234ze(E) and HCFO-1233zd(E) and their atmospheric degradation product trifluoroacetic acid (TFA) are concerned.

- **Unjustified grouping of "all PFAS"**

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25 *Conservation-compatible retrofit solutions in historic buildings: An integrated approach*, A. Buda, A., de Place Hansen, E. J., Rieser, A., Giancola, E., Pracchi, V. N., Mauri, S., ... & Herrera-Avellanosa, D., *Sustainability*, *13*(5), 2927, 2012; *Impact of envelope structure on the solutions of thermal insulation from the inside*, B. Orlik-Kozdon, A. Szymanowska-Gwizdz (2018), *Architecture, Civil Engineering, Environment*, *11*(4), 123-134, 2022.

26 *Eurotherm Seminar #116 "Innovative solutions for thermal energy storage deployment"*

27 Honeywell calculation based on *ibid*. *Eurotherm Seminar #116 "Innovative solutions for thermal energy storage deployment"* https://repositori.udl.cat/items/29285fea-468a-4225-abe3-97d7010136a7

28 https://www.europiso.fr/page/isochape

29 Compressive creep - the gradual loss of thickness a material may experience if placed under a constant load for an extended period of time. Significant compressive creep will result in the packaged product loosening in the cushion and becoming vulnerable to excessive movement inside the package during shipment.

Grouping of HFO-1234ze(E) and HCFO-1233zd(E) with *"all other PFAS"* is not scientifically or legally justified. In this regard, the 2021 OECD's PFAS definition used in the Proposal is not conceived for regulatory purposes, which is also acknowledged by the Dossier Submitters. Moreover, according to the respective OECD report, it does not inform on hazards of substances, even regarding their very persistent (vP) properties, or uses, exposure and risks.[30] In other words, the OECD itself is clear that its definition of PFAS was not intended to be used for regulatory action because it is too broad to enable an effective, science-based risk assessment, which would result in regulation of these (over 10,000) chemical compounds as an entire group. The UK Health and Safety Executive (HSE) [31] service and US Environmental Protection Agency (EPA) [32] share the same opinion.

The most recent EEAP 2022 Assessment Report**[33]**, unequivocally cited a common agreement among the majority of experts that *"all PFAS should not be grouped together, persistence alone is not sufficient for grouping PFAS for the purposes of assessing human health risk, and that the definition of appropriate subgroups can only be defined on a case-by-case manner"* and that "*it is inappropriate to assume equal toxicity/potency across the diverse class of PFAS"*.[34] The Report further concludes that *"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"*[35]

Please refer on the inconsistency of grouping methodologies in the Proposal to relevant sections of Honeywell submission reference no: bb6e00b6-571b-467a-ae79-7b046c6c9ab4.

- **Hazard, exposure and risk assessments of HFO-1234ez(E)/ HCFO-1233zd(E) and TFA**

Contrary to what the Dossier Submitters claim, there is a range of PFAS substances, including HFO-1234ze(E) and HCFO-1233zd(E) and certain other HFC/HFO gases that are low-hazard, have low-Global Warming Potential (**GWP**), are not persistent and do not degrade to very persistent substances in meaningful amounts. For instance, the REACH registration dossiers and CSRs for fluorinated gases HFO-1234ze(E) and HCFO-1233zd(E) contain conclusive scientific evidence, including validated DNEL/PNEC limits for all relevant compartments, demonstrating that these substances are not persistent and do not exhibit risks similar to PBT/vPvB substances under Article XIII REACH. Their REACH registration dossiers also do not demonstrate an existence of hazards assessed in section 1.1.4. of the Proposal.

30 See pages 8 and 25, *Reconciling Terminology of the Universe of Per- and Polyfluoroalkyl Substances: Recommendations and Practical Guidance*, ENV/CBC/MONO(2021)25, OECD, 9 July 2021 (available here): *"The term "PFASs" is a broad, general, non-specific term, which does not inform whether a compound is harmful or not, but only communicates that the compounds under this term share the same trait for having a fully fluorinated methyl or methylene carbon moiety."*

31 See also in section 1.3 of the Analysis of the most appropriate regulatory management options (RMOA), The UK HSE, April 2023, *"A generic PFAS definition may not be particularly useful from a regulatory perspective, and it may be more appropriate to consider regulatory approaches on the basis of particular PFAS groups and/or uses."*

32 The US EPA also uses a narrower working definition of PFAS as "*Chemicals with at least two adjacent carbon atoms, where one carbon is fully fluorinated and the other is at least partially fluorinated"* in their National PFAS testing strategy (see in section 3) as well as their PFAS strategic roadmap. EPA's use of this working definition provides focus on PFAS of concern based on their persistence and potential for presence in the environment and for human exposure. Regarding degradation products, the EPA Office of Chemical Safety and Pollution Prevention have opined that *"trifluoracetic acid is a well-studied non-PFAS."*

33 *Environmental Effects of Stratospheric Ozone Depletion, UV Radiation, and Interactions with Climate Change*, 2022 Assessment Report, Environmental Effects Assessment Panel (EEAP), available at - http://ozone.unep.org/science/eeap

34 *Grouping of PFAS for human health risk assessment: Findings from an independent panel of experts*, J.K. Anderson, et al., 2022

35 See pages 278 and 279 of the 2022 Assessment Report.

Therefore, the conclusions of the Dossier Submitters in section 1.1.6 of the Proposal, that HFO-1234ze(E)/ HCFO-1233zd(E) must be treated as *"non-threshold substances"* with the overall concern *"very similar to those of the PBT/vPvB substances"* and with any emissions *"as a proxy for risks"* are not substantiated in the Proposal. [36]

According to the trifluoroacetic acid (TFA)[37] REACH registration dossier and CSR, this substance does not fulfil the criteria for a PBT or vPvB substance under Annex XIII of REACH. Neither does it raise equivalent levels of concern under Article 57(f) REACH.[38] In this respect, ECHA already reviewed and evaluated the TFA dossier without concluding that further regulatory actions were needed.[39]

For detailed information and objective assessments of TFA, please refer to the Honeywell submission no: 76bb3d12-2101-4390-82cf-3498b47e8015.

According to Honeywell estimates, in 2025, the total use of HCFO-1233zd(E), and HFO-1234ze(E) insulation foams blowing agents in EU will reach app. 6000 and 1000 metric tonnes, respectively. This would constitute only ca. 1.2 % of total EEA F-gases uses tonnages (598,626 tonnes, Table E.84, Annex E of the Proposal). In 2050, assuming 2% annual market growth, this share would be below 2% (i.e., of 982,109 tonnes, Table E.84, Annex E of the Proposal), thus remaining very small. [40]

Further according to the 2022 EEAP Assessment Report, TFA formation yields from HCFO-1233zd(E) and HFO-1234ze(E) are estimated at 2%, with a theoretical upper limit of ~ 30%.[41] Even if one would assume that the yields can reach over 2% (suggested at page 50, Annex B of the Proposal), the contribution of these gases to overall tonnages/emissions, concentrations and level of exposure to TFA would still remain genuinely negligible.[42]

In this respect, Q&A 10 of Addendum to the EEAP 2022 Assessment Report also confirms that "*However, for lakes and oceans, the effects of increased concentrations of naturally occurring mineral salts, such as sodium chloride, and other water-soluble minerals are greater and more biologically significant than those caused by TFA salts. Salts of TFA in soil are taken up by plant roots and concentrate in the leaves, where they appear to have no effects. If animals eat the leaves, TFA is rapidly excreted and does not accumulate in their bodies or in the food chain."* [43]

And further the EEAP concluded that *"Based on current knowledge, [HFC/HFO] breakdown products do not pose environmental concerns. Based on estimates of current and future use of HFCs and other replacements for CFCs, additional inputs of TFA to the ocean will only slightly (less than 0.5% per year) increase the amounts that have been present historically. Now and in the distant future, predicted TFA concentrations in surface waters and terminal basins are thousands of times less than thresholds of concern for human or environmental health."* [44]

[36] See analysis and conclusions of section 1.1.6 (Risk characterisation) of the Proposal.

[37] Trifluoroacetic acid, EC no: 200-929-3, CAS no: 76-05-1, Molecular formula: C2HF3O2

[38] See e.g., *Mammalian toxicity of trifluoroacetate and assessment of human health risks due to environmental exposure*, Dekant *et al*, 17 February 2023.

[39] E.g., in 2017-2021, ECHA concluded comprehensive dossier evaluation of Trifluoroacetic acid, without indications of the need for further actions.

[40] Very low emissions levels of these fluorinated gases are confirmed in Fig. 12 at page 282 (Estimated Global Emissions) of the *Environmental Effects of Stratospheric Ozone Depletion, UV Radiation, and Interactions with Climate Change*, EEAP 2022 Assessment Report.

[41] See pages 317 and 318 of the 2022 Assessment Report.

[42] Please see the Honeywell submission reference no 76bb3d12-2101-4390-82cf-3498b47e8015.

[43] Please also see, Q&A 10*, Questions and Answers about the Effects of Ozone Depletion, UV Radiation, and Climate on Humans and the Environment*, EEAP 2022 Assessment Report.

[44] *Ibid.*

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Moreover, HFO-1234ze(E) and HCFO-1233zd(E) uses in insulation foams are already adequately regulated in EU via effective Risks Management Measures (RMMs) under the *EU F-Gas Regulation,*[45] (F-Gas Regulation)**,** *Industrial Emissions Directive*[46]**,** EU and national laws om waste,[47] ATEX Directive[48], as well as various national building/construction/engineering codes and industry standards such as EN 13166, EN 13164, EN 13165, EN 14509 and EN 14315.

Therefore, HFO-1234ze(E), HCFO-1233zd(E) and TFA should not be treated as "*non-threshold substances"* and *"any of their emissions"* should not be used *"as a proxy for risk"* exposure and risk characterisation purposes of REACH restrictions. The corresponding health and environmental risks from HFO-1234ze(E) and HCFO-1233zd(E) in insulation foams applications could not be legitimately considered as unacceptable within the meaning of Article 68 REACH or to any extent proportional to the ban on this critical use of the above fluorinated gases for the EU decarbonisation goals as envisaged in the Proposal.

3. Assessments of alternatives

3.1. Insulation materials

All insulation materials are not equivalent. Building and insulation science dictates that to be insulated effectively the insulation used must meet the needs of the building and its environment. The table below illustrates that all insulation materials do not provide the same benefits. The table demonstrates that there are multiple properties to consider when choosing insulation. Relevant key comparisons are also provided in **Appendix I** below.

Table 1: Comparison of insulation materials

45 *Regulation (EU) No 517/2014 of the European Parliament and of the Council of 16 April 2014 on fluorinated greenhouse gases and repealing Regulation (EC) No 842/2006* (as amended and currently under review, available here).

46 *Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control) (as amended).*

47 *Directive 2008/98/EC on waste (Waste Framework Directive).*

48 *Directive 2014/34/EU of the European Parliament and of the Council of 26 February 2014 on the harmonisation of the laws of the Member States relating to equipment and protective systems intended for use in potentially explosive atmospheres (recast)*

Insulation Type	Technical Feasiblity	R5 per inch or greater	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	Below grade use	Roofing use include green-roof	Net environmental benefit over 75yr
Low-pressure spray PU foam	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓ [1]
Low-pressure spray PU foam"Alternative"														
Closed-cell Extruded Polystyrene	✗	✓	✗ requires tape	✓	✓	✓	✓	✗ requires fasteners	✗	✗ External only	✗	✓	✓	✓ [2]
Polyisocyanurate board	✗	✓	✗ requires tape	✓	✓	✓	✓	✗ requires fasteners	✓ varies	✗ External only	✓ varies	✗	✓ varies	✓ [3]
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	✗

[1] https://www.sprayfoam.org/files/Demand%20a%20Better%20Insulation.pdf

[2] Life Cycle Greenhouse Gas Emissions Reduction From Rigid Thermal Insulation Use in Buildings, M.H. Mazor, J.D. Mutton, D.A.M. Russell, G.A. Keoleian, J. Ind. Ecology, 15, 2, pp 284-299, April 2011

[3] https://cdn.ymaws.com/www.polyiso.org/resource/resmgr/health&environment/EPD_Wall_2020.pdf

3. 2. Overview of the EU foams market by application

Polymer foams require a blowing agent to expand the polymer to achieve the desired density. Besides the expansion, blowing agents often contribute to some key properties of those foams such as insulation, creep resistance and reaction to fire amongst others.

A variety of foam blowing agents (**FBAs**) and their blends are currently used in the polymer foam industry, including hydrocarbons (pentane and butane isomers), carbon dioxide (CO_2) either directly injected into the foaming mixture or, in the case of polyurethane and polyisocyanurate foams by the reaction of polymeric isocyanate (pMDIs) and water, methyl formate, methylal, 2-chloropropane, and others. A full description of available FBAs can be found in the most recent United Nations Environmental Programme (UNEP) Rigid and Flexible Foams Technical Options Committee **- (FTOC) 2022 Assessment Report**.[49] The selection of FBA is dictated by several factors, including safety in use, performance, mechanical properties, and cost, to name a few. According to the FTOC 2022 Assessment Report, there are multiple blowing agents required as no single drop-in replacement for fluorocarbons exists:

> *"There is no single 'drop-in' FBA replacement for currently used HCFCs or hydrofluorocarbons (HFCs). There are different technical, economic, safety, and environmental performance properties for each low global warming potential (GWP), zero ozone depletion potential (ODP) alternative and different needs for each market subsector.*
>
> *"There is a proliferation of blends across the whole of the foam sector which is an indication of the reality that there is no single best solution."* [50] and further,
>
> *"Often a key factor is the size of the manufacturing plant since the economies of scale have a considerable bearing on the relative importance of capital and operational costs. Overall cost also is a major factor in the consideration of the major emerging technologies."*[51]

49 *Report of the Technology and Economic Assessment Panel Flexible and Rigid Foams Technical Options Committee, January 2023, Volume 1: Assessment Report*

50 Page 14, FTOC 2022 Assessment Report

51 Ibid, page 66.

The major alternative technologies for fluorocarbon blown foams include hydrocarbons, most often C_5 hydrocarbons, methyl formate, methylal, all of which are flammable and carbon dioxide created by the reaction of water and polymeric MDI (CO_2 (water) or by direct injection into the foaming mixture (CO_2(LCD) if injected as a supercritical liquid, or CO_2(GCD) if injected as a gas).

In this respect, non-flammable, high performance FBAs such as HFOs are indispensable due to their: (1) Safety in use; (2) Best in class insulation values, especially in applications where space is limited; and (3) Unique mechanical properties, where specific properties are required that only foams blown using HFOs can provide. This is recognized by UNEP, where it is noted:

> *"Evolving HCFC and HFC phase-out plans will have a large impact on the choices of non-ODP options. Some FC (*fluorocarbon*) use is likely to continue for the foreseeable future: Spray foams and SMEs, for safety reasons, and for insulation where there are stringent thermal performance requirements. There are also uses of FCs where structural or fire safety properties are of concern."* [52]

Table 2: Comparison of foams blowing agents and properties

Blowing Agents	Technical issues	Outcome of technical issues
Hydrocarbons	Flammable	Flammables cannot be used in spray foam – due to safety hazard
Formic acid	Toxic, above 69°C explosive vapor/air mixtures maybe formed	Toxic liquid
Methylal	Flammable	Flammables cannot be used in spray foam
Methyl Formate	Flammable, Toxic vapor mixtures are explosive	Flammables cannot be used in spray foam
Water	Water generates CO_2	High diffusion coefficient, often used in open cell foam
CO_2	Limited solubility, high diffusion coefficient	High pressure, limited solubility, high lambda, co-blowing agent- primary use XPS
HFO	Requires optimization of technology	Low lambda (insulation value), used principally where foam flammability, equipment limitations, and high energy efficiency required in limited space.

Although there are many options not all blowing agents are used in all applications. This is highlighted in the table below and in **Appendix I** to this submission.

[52] Report of the UNEP Technology and Economic Assessment Panel, *Flexible and Rigid Foams Technical Options Committee, 2022 Assessment Report*, January 2023.

Table 3: Comparison of Blowing Agents and Limitations in Applications

Category	Application	Blowing Agent	Flammability - production	Flammability - Final use	Performance (R value)	Unique Mechanical Properties
PU	Spray Foam	HFO	Green	Green	Green	Green
		CO2 (water)	Green	Green	Red	Red
		hydrocarbon -	Not applicable due to flammability			
	Insulation Boards	HFO	Green	Green	Green	Green
		CO2 (water)	Green	Green	Red	Red
		hydrocarbon	Green	Yellow	Yellow	Green
	Metal Sandwich Panels	HFO	Green	Green	Green	Green
		CO2 (water)	Green	Green	Red	Red
		hydrocarbon	Green	Green	Yellow	Green
	Commercial Appliances	HFO	Green	Green	Green	Green
		CO2 (water)	Green	Green	Yellow	Green
		hydrocarbon	Yellow	Green	Yellow	Green
	Discontinuous Panels	HFO	Green	Green	Green	Green
		CO2 (water)	Green	Green	Red	Green
		hydrocarbon	Yellow	Green	Green	Green
	Domestic Appliances	HFO	Green	Green	Green	Green
		CO2 (water)	Green	Green	Red	Red
		hydrocarbon	Green	Green	Yellow	Green
	Pipe in Pipe	HFO	Green	Green	Green	Green
		CO2 (water)	Green	Green	Red	Green
		hydrocarbon	Yellow	Green	Yellow	Green
	Integral Skin	HFO	Green	Green	Not applicable	Green
		CO2 (water)	Green	Green	Not applicable	Red
		hydrocarbon	Red	Green	Not applicable	Green
Phenolic	Boardstock	HFO	Green	Green	Green	Green
		hydrocarbon	Green	Yellow	Yellow	Green
XPS	Boardstock	HFO	Green	Green	Green	Green
		CO_2	Green	Green	Yellow	Yellow
		hydrocarbon	Green	Yellow	Yellow	Green

Green	Best alternative
Yellow	Possible; some barrier to adoption
Red	Significant barriers to adoption

As demonstrated in the table above, based upon the excellent thermal properties, HFOs such as HCFO-1233zd(E) or HFO-1234ze(E) can be used as blowing agents in different polymer foams such as Polyurethane (PU), Extruded Polystyrene (XPS) and Phenolic. Please also consult **Appendix I** below.

- **Polyurethane (PU)**

Polyurethane foam[53] is widely used as an insulating material in construction, including residential, commercial, and industrial. For safety reasons, Spray Polyurethane Foam **(SPF or Spray foam)** requires a non-flammable blowing agent due to its onsite application. This does not allow for traditional engineering controls used in manufacturing facilities to be consistently available. One specific point of concern is the

[53] Note: the term *"polyurethane"* in this document is understood to mean any foam based on isocyanate chemistry. Therefore, foams commercially described as *"polyisocyanurate"* are included in the definition of polyurethane.

application equipment**.** Spray foam can be applied through high pressure or low-pressure devices. The largest volume of product is applied through high pressure devices. There are two types of high-pressure spray foam, *closed cell* and *open cell*. Closed cell foams typically use HFOs as the blowing agent as the combination provides the best insulation value (*lambda*) possible for this application. The *Insulation Boards* segment of this business is characterized by few big OEMs which can handle flammable products, such as pentane, once the capital investment to convert their plants to handle flammable blowing agents is completed. However, HFOs are needed for Insulation Boards in order to obtain a fire classification required under buildings codes (such as Bs2d0 according to the standard EN 135101-1)[54] and also to get the best possible *lambda* required if there are constraints in available thickness. For commercial and industrial applications, the most relevant application is *Metal Sandwich Panels*, where the panel is also used for structural purposes as well as thermal insulation. Similarly to Insulation Boards, HFOs are necessary for Metal Sandwich Panels to obtain the best possible *lambda*.

In the cold chain segment polyurethane foam is used as an insulating material to keep goods fresh. There is polyurethane foam in all *Commercial Appliances* (display units) which can be found in supermarkets, in all the *Discontinuous Panels* typically used to assemble walk in cold rooms and to build refrigerated truck boxes and in all *Domestic Appliances* (refrigerators and freezers). In addition to insulation, polyurethane foam provides structural properties to different articles. Non-flammable blowing agents are mandatory for small/medium OEMs which cannot convert their plants to handle flammable blowing agents due to the huge investment required.[55] HFOs will provide the best possible insulation leading to the best possible energy classes while maximizing internal volume and resulting in lower energy needs for heating, freezing and cooling in line with European Green Deal and REPowerEU objectives.

Pipe in Pipe for district heating is another application where polyurethane foam is used to provide the requested insulation. Flammable blowing agents are possible to handle by most producers but when there is limitation on pipe diameter or better insulation is needed, HFOs are the only option.[56]

Besides rigid foam for insulation, HFOs are also used in flexible foam (**Integral Skin**) to produce different parts for the automotive and furniture industries. HFOs contribute to the mechanical properties (skin formation) and non-flammable blowing agents are mandatory for small/medium OEMs which cannot invest in **ATEX Directive compliant** equipment.

- **Extruded Polystyrene (XPS)**

Extruded Polystyrene is also widely used as insulating material in construction, especially in applications where the insulation may be in direct contact with water or when high compression strength is needed. The main applications for XPS are inverted roofs (including Green Roofs) and building foundations. In terms of blowing agent, CO_2 in combination with other (flammable) co-blowing agents (such as DME, i-butane or EtOH) is quite common in the industry but it provides poor insulation values. HFOs are needed to improve insulation without impacting the production process (extrusion at high pressure and temperature). In renovation projects, it is not uncommon to have thickness constraints and HFO blown XPS is the only way to guarantee that the energy standards are respected.

54 EN 13501-1, Fire classification of construction products and building elements - Part 1: Classification using data from reaction to fire tests.

55 Page 38, *Flexible and Rigid Foams Technical Options Committee, 2022 Assessment Report*, January 2023: "*Capital costs have been reported to range between $250,000 USD to $1,000,000 USD per operating facility. Hydrocarbons have lower operating costs, but the significant capital investment has made them less attractive for smaller enterprises"*.

56 See e.g., at *CALPEX PUR-KING – pre-insulated, flexible PEX pipe system*.

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HFO blown XPS is also used in the floor of refrigerated trucks of various sizes where high compression strength is a must and there are constraints on the available thickness of the floor solution. In this case the best *lambda* possible is a requirement only achievable with the use of HFOs as blowing agents.

- **Phenolic**

Phenolic foam is used as insulating material when excellent reaction to fire performance is required, for example in façade systems. Flammable hydrocarbons are used by some producers as blowing agents which often makes the achievement of the right reaction to fire a challenge.[57] HFOs, being non-flammable, will help achieve the best possible fire classification as well as a reduction (improvement) of the insulation values. Similarly, to what stated for previous polymer foams, when thickness restrictions are in place (especially in building renovation) the use of HFO based Phenolic foam is needed to achieve acceptable thermal resistance of a given construction solution.

Based upon the above analysis of each of the insulation materials the unique properties of HFO blowing agents are essential to meet the below **three primary (key) needs** of insulation materials:

1) Safety in Use
2) Best in class insulation values that allow better insulation, where space is limited, as well as lower energy costs and GHG (CO_2) emissions
3) Unique mechanical properties for applications requiring specific properties that only foams blown using HFOs agents can provide.

Assessment of the main applications of blowing agents *vis-à-vis* the above key criteria for insulations materials is provided below.

3.3. Safety in use requirements

In certain applications, the use of flammable blowing agents can create substantial flammability risks. One such example is the field applied high- and low-pressure Spray Polyurethane Foam (SPF) as noted by several bodies, including UNEP and the US Environmental Protection Agency (**EPA**)[58]. UNEP notes:

> *"Handling and transportation of flammable fluids and blends, including the addition to foam systems, must comply with international shipping requirements, such as those in the Global Harmonized System (GHS). Safety Data Sheets (SDSs) must include flash points and safety information. Local building codes, fire safety requirements, and laws may limit the use of flammable FBAs and even systems containing flammable FBAs. The flash point of blends may not be a sufficient indication of risk while applying spray foam (or other foam manufacturing processes) where there may be localized concentrations greater than the lower explosivity limit (LEL)."*[59]

Also,

> *"In some parties, use of HCFCs* [an earlier generation of fluorocarbons] *is now limited to applications where HCs (hydrocarbons) are nearly universally considered to be unsuitable, such as PU spray foam" and "Historically, non-flammable foam blowing agents have been used because of concerns about flammable mixtures especially in enclosed spaces."*[60]

57 *Kooltherm and Fire Performance*, 2 January 2023.
58 Federal Register / Vol. 64, No. 233 / Monday, December 6, 1999
59 Page 37, *Flexible and Rigid Foams Technical Options Committee, 2022 Assessment Report*, January 2023.
60 Page 27, *Flexible and Rigid Foams Technical Options Committee, 2022 Assessment Report*, January 2023.

And most importantly:

> *"PU-spray foam: This type of foam is always blown at the site being insulated. It is not considered safe to use flammable blowing agents."*[61]

Even in areas where the uses of hydrocarbons are technically allowed in Spray Foams, those uses are significantly limited and require extraordinary levels of training and safety considerations. In this respect, the US EPA notes:

> *"The flammability of hydrocarbon blowing agents… are of particular concern in spray foam applications where a controlled factory environment is not possible... Without adequate ventilation, several situations could lead to explosion or fire. Examples include, but are not limited to, equipment wells on roofs, roofs enclosed by high parapet walls, and interior applications (especially where a basement or other confined space is beneath the spray area). Therefore, it is critical that application in enclosed areas be accompanied by adequate forced ventilation, flammable vapor monitoring and the elimination of all possible ignition sources.*
>
> *The potential for explosion or fire highlights the need for safety training. Exxon will sell Exxsol blowing agents only to systems manufacturers who have contractually guaranteed to provide training on safe storage, handling and application to their customers, contractors, and applicators."*[62]

Because of the US EPA concerns on the use of hydrocarbons in spray foam, only one manufacturer has been listed as an acceptable source of hydrocarbon blowing agents for spray foam (Exxon) as this manufacturer has committed to providing the necessary training. As a result, hydrocarbons and other flammable blowing agents are not considered acceptable in this application.[63] In addition, although, the use of Exxsol material has been approved for spray foams since December 1999,[64] no SPF equipment manufacturers commercially propose such equipment because they are not prepared to assume the risk and no spray foam system supplier has commercialized SPF systems that contain hydrocarbon blowing agents.

Therefore, the use of HFO-1234ze(E) and HCFO-1233zd(E) foam blowing agents in Spray Polyurethane Foam (SPF) applications must be excluded from the scope of PFAS restriction in question or made subject to unlimited derogation under the Proposal due to absence of unacceptable risks (see section 2 above) and safe feasible alternatives.

3.3.1. Spray Foam applications

As outlined above, the Spray Polyurethane Foam (SPF) market can be divided up into two major types - *open cell* (ocSPF) and *closed cell* (ccSPF) polyurethane foam – that are applied *via* three different techniques/technologies – *high-pressure*, *low-pressure* and *aerosol cans*.[65]

SPF high-pressure systems*: Two component, high-pressure systems (typically 800-1600 psi) use 55-gallon drums (ca. 55.2–109 atm., 208 litre drams) and are more often used when insulating larger areas on new construction or for major renovations on walls and roofs. These products are intended for professional use. These products require special training and the use of specialized PPE.*

SPF kits, refill tanks: *For mid-size projects, there are low-pressure (typically less than 250 psi, 17 atm.) two component kits. These two component kits can be used to insulate and seal small to medium sized*

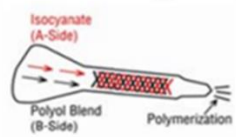
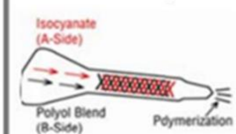
61 Page 5, UNEP Fact Sheet 13, Insulating Foams. April 2015.
62 Page 68041, Federal Register / Vol. 64, No. 233 / Monday, December 6, 1999 / Rules and Regulations
63 See section 3, UNEP Fact Sheet 13, Insulating Foams. April 2015.
64 Federal Register / Vol. 64, No. 233 / Monday, December 6, 1999 / Rules and Regulations
65 Types of Spray Polyurethane Foam (SPF)

areas around the home, such as attics, crawl spaces, and rim joists. These kits are primarily used by SPF contractors and weatherization professionals.

***Aerosol cans** (typically 12-24 oz., ca. 340-680 gr.): In addition to high-and low-pressure SPF insulation products, a smaller sized insulating foam sealant product is available in a can which is called one component foam. With the two component insulation products, the chemicals that make up the foam are kept separated in different drums or containers until mixed. The one component "foam in a can" product has already been partly mixed and partly reacted. That's one of the reasons why this product is widely available to homeowners as a do-it-yourself product in home improvement stores.* [66] Due national safety rules, there are certain one component foam applications where the use of flammables blowing agents is not possible.

Spray foam equipment varies depending on the application as outlined in the chart below. However, none of this equipment is rated for flammables (e.g., Two-Component Kits or Impingement Mixers).

Table 4: Spray Foam Equipment Matrix

	One-Component		Low Pressure Two-Component Kits	Refillable Systems	High Pressure Spray Systems
					
Delivery Systems Pressure	<1.0 bar	<1.7 bar	<1.7 bar	<1.7 bar	<7.0-9.0 bar
Contents	0.2- 1 kg	5-10 kg	1-50 kg *Combined*	113 -771 kg *Combined*	408- 454kg *Combined*
Output	Full Trigger: up to 1-2.5 kg/min		Full Trigger: up to 2.5-3 kg/min Std fan or cone nozzle	Full Trigger: up to 2.5-3 kg/min Std fan or cone nozzle	Full Trigger: up to 14kg/min
Mixing	Prepolymer 	Prepolymer	Static Mixing 	Static Mixing 	Impingement Mixing 
Mixer			Static Mixer	Static Mixer	Chamber Mixing
Housing			Nozzle	Nozzle	Spray Gun
Container *Most Popular Size Sold*	Metal Cans	Single Use Cylinder	Single Use Cylinders	Refillable Tanks	208 kg Drums
Hoses		1.5-3m Hose Assembly	3-5m Hose/Gun Assembly	9 – 18 m Hose Assembly 9 - 46 m Heated Hoses	Transfer pump system Up to 122m Heated Hoses
Product Temperature Recommended Use	70ºF-90ºF (21ºC-32ºC)		70ºF-90ºF (21ºC-32ºC) *optimal temp for std systems*	70ºF-90ºF (21ºC-32ºC) *optimal temp for std systems*	120ºF-150ºF (49ºC-65ºC) *machine heater system*
Foam Properties Curing Tack-Free Time	Moisture Cure 3-20 minutes		Chemical Cure < 1 minute	Chemical Cure < 1 minute	Chemical Cure < 15 seconds
How it is used	Bead Application		Bead Application Spray Coating	Bead Application Spray Coating	Large Area Spray Coating

3.3.2. High-Pressure Spray Foam

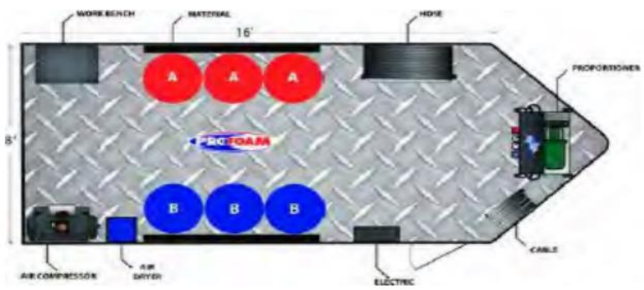
Spray polyurethane foams are applied in the field (on site/in situ). The chemicals used by the spray foam industry to make spray foam are sold in drums. One drum contains the polymeric isocyanate (pMDI) [67]. The other contains the polyol blend containing the foam blowing agent. These drums are transported to the work site in trucks or trailers. These vehicles not only contain the chemicals but also the spray foam

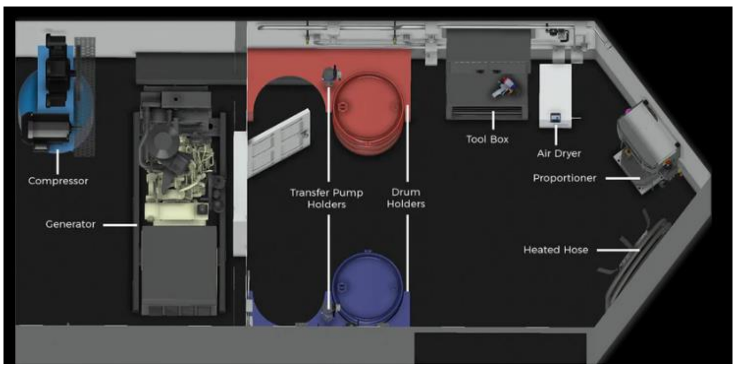
66 Types of Spray Polyurethane Foam (SPF)

67 Isocyanates are highly hazardous substance with high exposure and risks for workers.

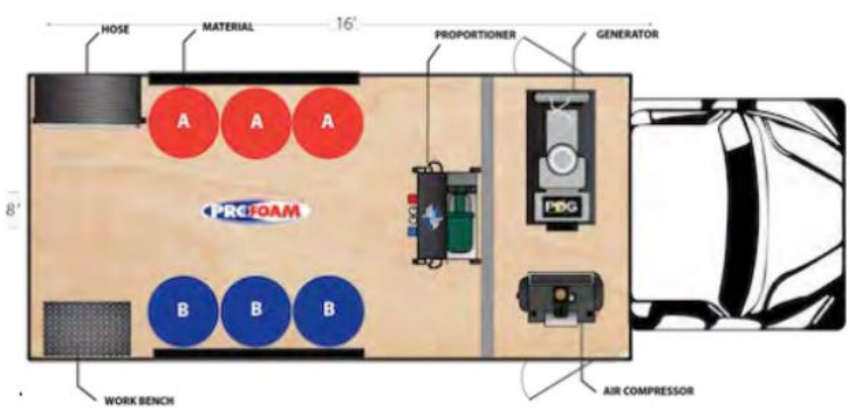
equipment (proportioning, pumps, generator, air drier and heated hoses). Schematics of small trailers and box trucks follow. A diagram of the trailer and box truck follow.

- **TRAILER**[68]





- **Box Truck**[69]



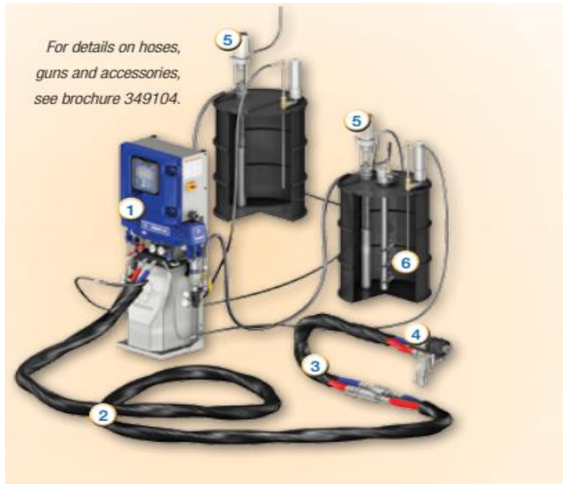
The trailer/ box truck is in fact a workspace with minimal ventilation, climate and fire controls. There are electrical connections required for the proportioner and other equipment present in the trailer. The door is open during the operation of the spray rig allowing for passive ventilation. The chemicals are pumped from drums, heated in the proportioner and then through heated hoses to the jobsite. Trailer equipment genuinely

68 16' Eco Series PMC PH-2 Shore Powered Spray Rig, or SPRAY FOAM RIGS

69 *16' Pro Series PMC PH-2 Integrated 30kw Diesel Powered Box Truck Spray Rig*

characterised by high fire and explosion risks. It is not acceptable to aggravate these risks further by using flammable blowing agents.

- **Other high-pressure Spray Foam Equipment**[70]



A closer look at the equipment demonstrates that not only that the proportioner is not rated for flammables but the hose and the guns are not as well.

- **SPF High-Pressure Gun warning**[71]

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70 *Fast-Set Plural-Component Equipment, For Foam and Coatings Applications*

71 See e.g. Manual, *Air Purge Spray & Pour Gun, AP-2, For use with non-flammable Foam and Polyurea*, For professional use only, Not for use in explosive atmospheres.

- **SPF High Pressure Proportioner Warning**[72]

FIRE AND EXPLOSION HAZARD

Flammable fumes, such as solvent and paint fumes, in **work area** can ignite or explode. Paint or solvent flowing through the equipment can cause static sparking. To help prevent fire and explosion:

- Use equipment only in well-ventilated area.
- Eliminate all ignition sources; such as pilot lights, cigarettes, portable electric lamps, and plastic drop cloths (potential static sparking).
- Ground all equipment in the work area. See **Grounding** instructions.
- Never spray or flush solvent at high pressure.
- Keep work area free of debris, including solvent, rags and gasoline.
- Do not plug or unplug power cords, or turn power or light switches on or off when flammable fumes are present.
- Use only grounded hoses.
- Hold gun firmly to side of grounded pail when triggering into pail. Do not use pail liners unless they are anti-static or conductive.
- **Stop operation immediately** if static sparking occurs or you feel a shock. Do not use equipment until you identify and correct the problem.
- Keep a working fire extinguisher in the work area.

The technology is clearly designed for the use of liquid non-flammable blowing agents only. To change to another technology could take redesign of not only chemicals but potentially all the SPF equipment currently being made.

3.3.3. Low-Pressure Spray Foam

For low pressure spray foam, the chemicals are sold in 2 containers (metal cylinders). The containers are pressurized with a propellant/gas. Since temperature may impact pressure and flow rate, for large jobs equipment may be used to ensure constant application pressure and flow. The chemicals are mixed through a static mixer. This application is primarily used as an adhesive or sealant. Like the high-pressure foam product, the foam is manufactured in the field (on site). In this situation the foam can be installed as a do-it-yourself (DIY) application. As with the high-pressure spray foam this equipment is not rated for use with flammables. [73]

3.3.4. Components and blending/manufacturing

There are other manufacturing/blending facilities that are not set-up for use of flammable materials, including foam blowing agents. These facilities are typically small to medium sized enterprises (SME). The transition for this business will be costly and, in some instances, not possible.

An important aspect to ensure the safe handling of flammable blowing agents, including hydrocarbons and to some extent methyl formate and methylal, is very high capital investment required to build or retrofit a foam production or systems blending facilities. According to experts of the UNEP Foams Technical Options Committee:

> *"The necessary safety precautions for handling flammable blowing agents include explosion proofing of facilities and use of non-sparking tools. Capital costs have been reported to range between $250,000 USD to $1,000,000 USD per operating facility. Hydrocarbons have lower operating costs, but the significant capital investment has made them less attractive for smaller enterprises. This is a very significant issue for small to medium enterprises (SMEs)."*[74]

3.3.5. Conclusions on Spray Foams applications

As demonstrated above, on site (*in situ*) use of any flammable blowing agents, such as hydrocarbons, methylal, methyl formate or etc., in Spray Polyurethane Foam insulation materials is strictly limited by (inter) national regulations and standards in EU and beyond. Currently existing respective SPF equipment is not

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72 *Electric, Heated, Plural Component Proportioner, Important Safety Instructions*.

73 See e.g., Nitrosys Geo Low Pressure Mobile Spray Foam Cart w/210′ Heated Hose, Turn Key

74 Page 38, *Flexible and Rigid Foams Technical Options Committee, 2022 Assessment Report*, January 2023.

designed and approved for use of flammable blowing agents either. The same is true regarding mandatory trainings and certification of personnel/workers.

Substantial investments are also required to build or upgrade foams manufacturing and blending facilities. Due to important technical challenges and safety legal requirements respective costs could be prohibitive for many businesses, particularly for SMEs.

The Dossier Submitters acknowledge similar concerns (see e.g., section E.2.8.4.3 of Annex E of the Proposal).

In these circumstances the 6,5 years (after entry into force of the REACH restriction in question) derogation for foam blowing agents in expanded Spray Foams used on site (in situ) for building insulation as envisaged in the Proposal is not sufficient for the overall industry to adapt to the proposed REACH restriction. Consequences of this short-term ban will be disproportionate to any risk from HFO-1234ze(E) and HCFO-1233zd(E) as well as their atmospheric degradation product TFA.

Therefore, Honeywell submits that HFO-1234ze(E) and HCFO-1233zd(E) fluorinated gases should be excluded from the scope of the Proposal or all their uses in all insulation Spray Foams as blowing agents made subject to the time-unlimited derogation.

3.4. Best in class insulation for limited spaces

There are many applications of rigid foam insulation where energy efficiency or building insulation (*R-value*) are mandated and limitations on the thickness of the insulation exist.

This results in the need for high performance insulation that provides the maximum insulation performance (i.e., via minimal thermal conductivity) at the minimum thickness. Best in class insulation is achieved through the use of HFO blowing agents such as HCFO-1233zd(E) and HFO-1234ze(E).

Table 5: Construction Foam Thermal Conductivity

Insulation	**SPF**	**SPF**	**XPS**	**XPS**	**Phenolic**	**Phenolic**	**PIR***	**PIR***
Blowing Agent	**HFO**	**H_2O**	**HFO**	**CO_2**	**HFO**	**HC**	**HFO**	**HC**
Declared aged thermal conductivity 50mm (mW/(m*K))[75]	26	42	27	34	19	20	18	23

*polyisocyanurate (polyiso) rigid foam board (PIR board)[76]

Typical examples of this include household refrigerators, freezers and water heaters, commercial appliances like supermarket display cases and the like, and residential commercial wall insulation, where increasing the thickness of the wall is undesirable due to building practices, cost, and the need to preserve interior space.

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75 Note that thermal conductivity (lambda) values listed here are a measure of the amount of heat that flows through an insulation material. Therefore, in this case, a lower value denotes a better insulation material. In the case of R-value, a measure of resistance to heat flow through an insulation material, reported elsewhere in this report, a higher value denotes a superior insulation material.

76 Why Polyiso? WHAT IS POLYISO INSULATION.

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- **Water Heaters**

For example, a water heater manufacturer in Norway (OSO), in order to produce a domestic water heater that achieves the highest energy efficiency rating in the EU (A rating)[77], needed to improve the efficiency of the foam insulation used in the product. In order to achieve this efficiency improvement, OSO selected to use HCFO-1233zd(E) (i.e., trade name Solstice® LBA), which provided at least 17% improvement in the insulation value of the foam and subsequently an energy efficiency of up to 15%, depending on the model.[78] Hydrocarbons (*pentane*) were considered too, but pentane systems require considerable investment in safety of the equipment because it is extremely flammable (CLP - Flam. Liquid 1, as well as toxic for humans and environment).[79] Hence, any transition to pentane needed to consider the high costs associated with safety equipment needed to mitigate the flammability risk, the operational requirements of constantly monitoring working areas, and the use of specialized detection equipment and powerful ventilation systems.

- **Cold Storage**

Another example is in the production of cold storage panels with polyurethane (PU) or polyisocyanurate (PIR) foam cores. This industry generally sells these panels in a few set thicknesses based on the insulation requirements for the cold room.[80, 81, 82] All subsequent design work on the cold storage panel is based on these standard thicknesses, so any changes in panel thickness would create the need to redesign the entire cold room. Boxcold, a leading cold room manufacturer in EU, needed to cease using HFC blowing agents to meet the *EU F-Gas Regulation* and found that the only option that allowed them a F-Gas compliant drop-in replacement was HCFO-1233zd(E).[83] Other options, such as pentane or carbon dioxide (produced by the reaction of isocyanate and water), would not provide the same insulation value for a given panel thickness, according to Boxcold.[84] Additionally, any transition to pentane needs to consider the high costs associated with safety equipment needed to mitigate the flammability risk, the operational requirements of constantly monitoring working areas, training of skilled personnel and the use of specialized detection equipment and powerful ventilation systems.[85]

- **Commercial Refrigeration**

Another example is from the commercial refrigeration sector. Afinox, located in Italy, is a global specialist in the design and production of blast chillers, refrigerated cabinets, drop in display cases and other equipment for preparing and displaying food in various application fields. They had identified a customer need to improve the energy efficiency of commercial refrigeration cabinets to reduce energy costs and reduce their carbon footprint.[86] By substituting foam made using HCFO-1233zd(E) for their incumbent water-based systems, the insulation used in Afinox equipment offered a 17% insulation value improvement and a 3% energy efficiency gain over their existing high performance HFC-blown foam. Although cyclopentane was considered, Afinox opted for the HFO solution to eliminate the need for costly

77 A Consumer's Guide to Energy-Efficient, Water Heaters

78 See in Annex IV below.

79 See REACH Registration information – Pentane, EC number: 203-692-4, CAS number: 109-66-0.

80 CAT CAMARAS INGLES 0223.pdf (kide.com)

81 Square Panel System Co., Ltd. บริษัท สแควร์ พาแนลซิสเต็ม จำกัด We are Leader of Design, Manufacture and Installation of Insulated Sandwich Panels

82 *Panel Frigorífico. Paneles Para Cámara Frigorífica | Magón (magon.es)*

83 *Boxcold adopts Solstice® LBA for Long-Term Value in Cold Storage | case study*

84 The Boxcold press release (footnote 86 above) provides a comparison of thermal conductivity (*lambda*) of foams made with LBA vs pentane and CO2 (water).

85 *Ibid.*

86 Increased thermal performance with lower environmental impact in commercial appliances. Case study.

flammability mitigation.[87] The suppliers of the foam insulation precursor systems to the commercial refrigeration sector, for example BASF, have developed foam systems based on HFO technology that not only allow the foam manufacturers to meet the need for improved energy efficiency, but also achieves these gains using less material[88], a significant factor for cost savings and EU sustainability objectives through less raw material usage.

- **Domestic appliances (refrigerators and freezers)**

All the refrigerators in our homes are insulated with polyurethane (PU) foam which, besides insulation, provides as well structural strength to the units. Since March 2021 the Commission Delegated Regulation (EU) 2019/2016 of 11 March 2019 is in place to regulate energy labelling of refrigerating appliances in Europe.[89] This regulation provides methods to determine energy consumption as well as the requirements to achieve a certain energy classification (from A to G) aiming to reduce the Energy Consumption of Domestic Appliances. HFO-1234ze(E) and HCFO-1233zd(E) provide the best-in-class insulation to polyurethane foam and will be instrumental to achieve higher energy classes at the right cost, typically by reducing the dependence on Vacuum Insulated Panels (VIP) which provide excellent thermal conductivity but pose substantial challenges in handling as well as recycling end-of-life (i.e. working health and safety concerns).[90] Leading EU appliances manufacturers together with research centres have developed PU foam based solutions to help achieve the highest energy labels when needed.[91] Reportedly, HFO-1234ze(E)/HCFO-1233zd(E) based foams are also the chosen technologies by certain major OEMs in USA and China.[92]

- **Construction**

The European construction and real estate field is responsible for about 40% of energy used and 36% of carbon dioxide (CO_2) emissions.[93] The EU has approximately 210 million buildings of which 75% are residential and 25% are non-residential. The *European Green Deal's Renovation Wave* calls for 35 million buildings to be renovated by 2030 in Europe. Many of these buildings that must be renovated in urban areas will face space constraints and require best in class insulation to meet the building envelope insulation standards.

Insulation for the house plays a vital role in minimizing heat loss or heat gain. The effectiveness of insulation is directly proportional to the thermal conductance of the blowing agent used to formulate the foam. Hence, selection of an optimal blowing agent to formulate an insulating foam for a house could lead to potential energy savings for a heating, ventilation and air-conditioning (HVAC) system resulting in reduction of electricity cost, and the carbon emissions.

XPS foams based on HFO-1234ze(E) can achieve a significantly lower (better) thermal conductivity than the traditional technology based on CO_2.[94] **Table 5** above shows that difference to be up to 20%. The main

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87 See REACH Registration information – Cyclopentane, EC number: 206-016-6, CAS number: 287-92-3

88 *Ibid.*

89 *Commission Delegated Regulation (EU) 2019/2016 of 11 March 2019 supplementing Regulation (EU) 2017/1369 of the European Parliament and of the Council with regard to energy labelling of refrigerating appliances and repealing Commission Delegated Regulation (EU) No 1060/2010*

90 *Study on Recycling of Cooling and Freezing Appliances Containing Vacuum Insulation Panels (VIPs).*

91 See in more detail Elastocool® (PU) - Ingeniously flexible and modular

92 *Whirlpool Corporation Partners with Honeywell, Announces Use of Next Generation Solstice® Liquid Blowing Agent in U.S. Refrigerators*, or *Honeywell's new LBA - Solstice achieves growing global commercial success*, etc.

93 *Assessment of the environmental impacts, energy performance and economic aspects of various construction materials*, Mohsen Bayat Pour, M Labib Elsayed, Lund University, June 2020.

94 *The XPS insulation board with maximum insulation value and maximum installation height*, *RAVATHERM XPS X ULTRA 300 SL*, etc.

applications for XPS are inverted roofs (including Green Roofs) and building foundations. In renovation projects, it is not uncommon to have thickness constraints and HFO blown XPS is the only way to guarantee that the energy standards are respected.[95]

Phenolic foams based on HCFO-1233zd(E) provide the best-in-class thermal conductivity values for this kind of insulating materials (see **Table 5**). In the next section, a study from University of Sevilla assess energy/electricity and CO_2 emissions savings achieved when using such insulation in renovation, specifically in projects facing a limitation of the maximum insulation thickness that can be installed.

3.5. Comparisons of houses with different insulation types

A recent study conducted and presented at Eurotherm Seminar #116 "Innovative solutions for thermal energy storage deployment" (udl.cat) by the University of Sevilla (Spain) demonstrates that an average of 3.5% of CO_2 emission savings can be achieved by using closed cell polyisocyanurate or phenolic foam boards blown with HCFO-1233zd(E) versus same boards blown with hydrocarbons. Full version of the study is available in **Annex II** and the robust study summary is provided below.

- **Goal of the study**

The objective of the study is to determine the best theoretical positioning of rigid foams for thermal insulation that incorporate HFOs blowing agent technology developed by Honeywell against traditional solutions for interior insulation in residential buildings, including:

a) Identification under what conditions rigid foam insulation made with HFO blowing agents would be advantageous against other insulation materials.

b) Quantification of the above advantage (energy and/or economic savings):

b.1.) At equal thickness of insulation, increase in energy performance,

b.2.) At equal thermal resistance of insulation, increase of usable space.

Comparisons between insulation solutions are performed under two scenarios:

- Compliance with construction regulations in Spain (limit values of the Spanish Technical Building Code (CTE))
- Compliance with Passivhaus standard requirements.

- **Methodology to compare internal wall insulation**

Analysis of scenarios where HFO blown insulation has an advantage over alternative incumbent products and their quantification is based on an exhaustive parametric study performed under the following comparison framework:

- The study is based on realms of the Spanish construction market. Spain is a relevant player with over 22 million households.
- 3 single-family homes and 2 multi-family buildings. Figure.11 (below).
- 5 country climate zones linked to the wintertime period (A, B, C, D and E).
- Figure.2 (below).

[95] *FUTURE-PROOFING SCOTLAND'S MOST AMBITIOUS NEW OFFICE SPACE WITH RAVATHERM XPS X ULTRA 300 SL*, also on Green Roofing see here.

– Using the above-referenced heating and cooling equipment defined in table 4.5-HE0 of the Basic Document HE of the Spanish Technical Building Code.

– Using Life Cycle Cost (LCC) as a decision-making indicator.

– Using data generated from calculations using Lider-Calener Unified Tool (HULC).

– Filtering the combinations that comply with the Spanish Technical Building Code (CTE - Royal Decree 732/2019, of December 20).

– Identifying combinations that meet the Passivhaus standard requirements..

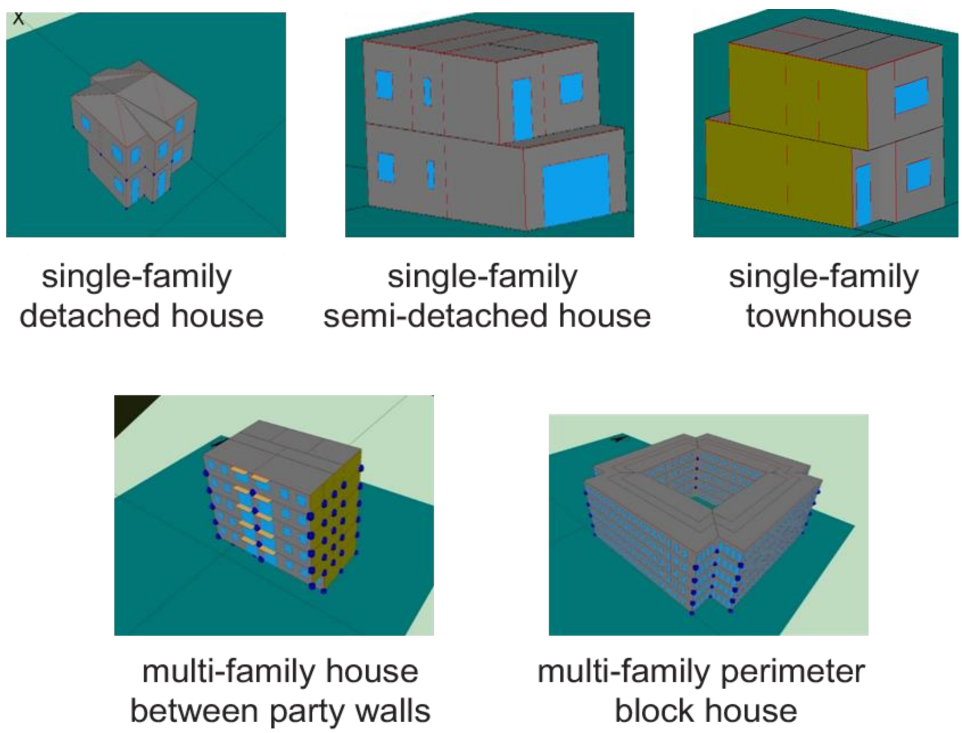


Figure.1. Housing considered in the parametric study.

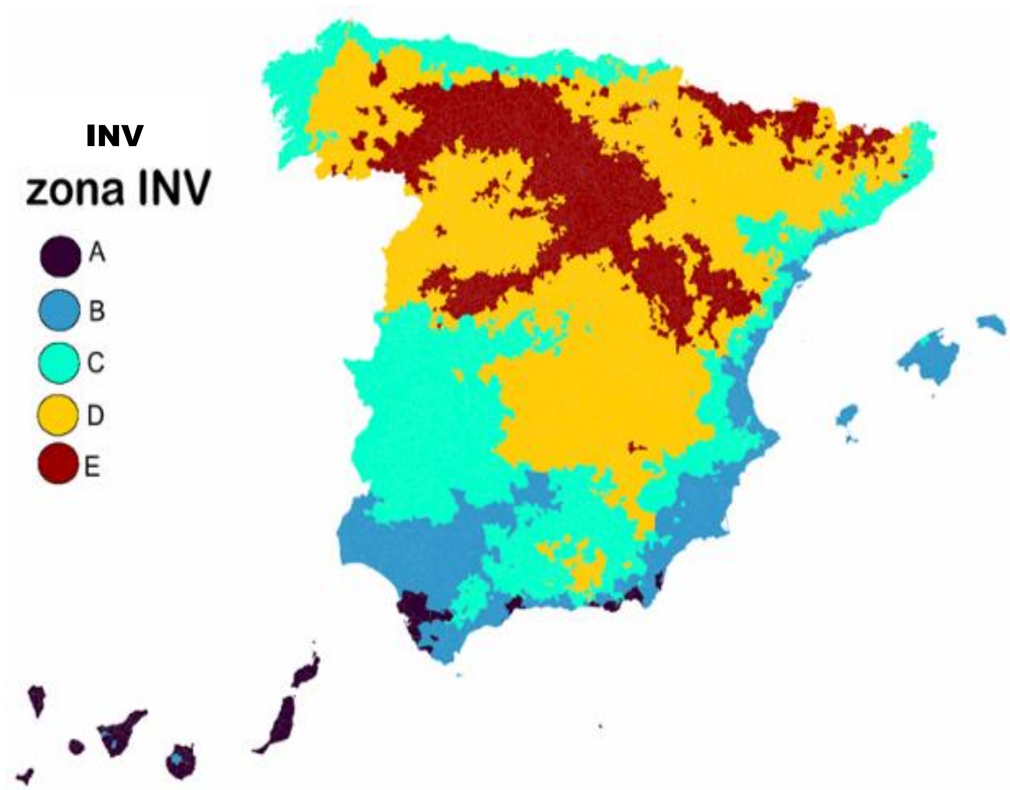


Figure.2. Spain climate zones by heating requirement

The following materials for interior wall insulation are compared to phenolic or PIR (polyisocyanurate) boards blown with HFO:

- Mineral wool
- Graphite EPS (expanded polystyrene)
- PIR (with hydrocarbons (HC) blowing agents)

Table 6 below demonstrates the thermal conductivities and estimated market prices of the insulation materials as of October 2021, having neutralized the cost of the cladding wall for all solutions. It is assumed that the difference in prices among the insulation materials remains constant independently of the market evolution.

Table 6: Conductivity and estimated costs of the insulation materials under study.

Product	Conductivity (W/m·K)	Insulation price €/m^2 per cm of insulation	Insulation price €/m^2 per thermal resistance unit	Labour and ancillary cost per m^2
Mineral wool	0.035	0.80	2.78	2.13
EPS Graphite	0.032	0.69	2.20	5.00
PIR HC	0.022	2.10	4.62	5.00

HFO blown Phenolic/PIR	0.019	3.15	5.67	5.00

- **Overall conclusions of the study**

As expected, for the same insulation thickness, HCFO-1233zd(E) (Solstice in the Table 7 below) blown foams can satisfy the regulatory requirements or those of the Passivhaus standard, while a greater thickness is required for the alternative insulation materials.

The table below demonstrates results for single-family detached house in zone C. The red cells mean that no insulation solution at the specified thickness meets the standard. The green cells mean that the only two insulation solutions meet the standard. Finally, the yellow cells mean that the HCFO-1233zd(E) blown foam meet the standard at the specified thicknesses, while the alternatives don't.

Table 7: Example of application of CTE and Passivhaus standard at equal thickness for single-family detached house home in zone C.

Thickness [cm]	Solstice	Mineral Wool
	CTE (Código Técnico de la Edificación [Technical Building Code]) compliant	**CTE (Código Técnico de la Edificación [Technical Building Code]) compliant**
2	No	No
4	Yes	No
6	Yes	Yes
8	Yes	Yes
10	Yes	Yes

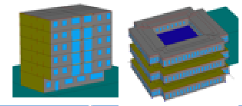
Thickness [cm]	Solstice	Mineral Wool
	Passivhaus compliant	**Passivhaus compliant**
2	No	No
4	No	No
6	No	No
8	Yes	No
10	Yes	No

Additionally, at same thickness (5 cm) the best insulating materials (foam containing HFO, Solstice in the Table 8 below) present a reduction in the heating demand compared to other alternatives (Mineral Wool, EPS or PIR with Hydrocarbon). From the table below, one can conclude that an average of 3.5% of CO_2 emission savings can be achieved by using closed cell polyisocyanurate or phenolic foam boards blown with HFO-1233zd(E) versus same boards blown with hydrocarbons.

Table 8: Summary of the 5 cm equal thickness analysis for multi-family homes.

MULTI-FAMILY BUILDING

MULTIFAMILY



Solstice vs. Mineral wool	Thickness (cm)	A3	B4	C3	D3	E1
Extra-cost (€/m²)	5	4.1-5.2	4.1-5.2	4.1-5.2	4.1-5.2	4.1-5.2
Heating Demand Reduction (%)	5	11.4-16.7	10.0-14.7	10.4-13.1	10.7-12.0	10.0-11.8
Increase to PRC (years)	5	4.2-9.1	2.6-4.9	1.6-2.3	1.1-1.5	0.9-1.2
Solstice vs. Graphite EPS	**Thickness (cm)**	**A3**	**B4**	**C3**	**D3**	**E1**
Extra-cost (€/m²)	5	3.5-4.3	3.5-4.3	3.5-4.3	3.5-4.3	3.5-4.3
Heating Demand Reduction (%)	5	9.7-14.4	8.5-12.6	8.9-11.3	9.2-10.4	8.6-10.2
Increase to PRC (years)	5	3.4-7.4	2.2-4.0	1.3-1.9	0.9-1.3	0.7-1.0
Solstice vs. PIR HC.	**Thickness (cm)**	**A3**	**B4**	**C3**	**D3**	**E1**
Extra-cost (€/m²)	5	1.5-1.8	1.5-1.8	1.5-1.8	1.5-1.8	1.5-1.8
Heating Demand Reduction (%)	5	3.2-4.9	2.8-4.2	3.0-3.8	3.1-3.5	2.8-3.4
Increase to PRC (years)	5	1.6-3.4	1.0-1.8	0.6-0.9	0.4-0.6	0.3-0.4

In summary the study of Sevilla University, demonstrates that for every million of buildings renovated using HCFO-1233zd(E)-blown foam vs. hydrocarbons will save ca. 167.120 metric tons of GHG (CO_2) emissions per year.

- **Conclusions on SPF insulation of single-family houses**

According to recommendations at page 270 of Annex E of the Proposal, CO_2 (produced by the reaction of isocyanate and water), blown foams with a higher *lambda* value can replace HFOs blown foams. However, many structures and applications in EU have limited space to insulate. Table 10 below illustrates the substantial increase in energy use requirements if one was to substitute HFOs by CO_2 (water) blown foam in fixed space spray foam applications.

The study also contains an evaluation of the scenario which assumes that all residential houses in the European Region use SPF insulation formulated either based on HFOs or by using CO_2 (water) as blowing agents. Hence, total GHG emissions (in CO_2 equivalent) and overall cost of electricity to operate HVAC systems of those houses are further compared for HFO *vis-à-vis* non-HFO based solutions.

For these purposes, a thermal model was setup to estimate the cooling and heating load for an insulated single family residential house. The model assumptions are listed in the Table 9 below. The model is formulated based on fundamental thermal equations for the typical cooling/heating load of an average size insulated house ranging from 3 tonnes to 5 tonnes. The load calculation is based on bin temperature data for cold and warm climate which are representative of heating and cooling conditions for Europe and the indoor temperature is fixed at 25°C. The loads considered are only the heat loss/heat gain from the walls and the ceiling. The model compares a structure insulated with open-cell (*lambda* 0.042 W/mK) and closed-cell foam (lambda 0.025W/mK) under both a heating and cooling load considering outdoor temperatures ranging from -25°C to 45°C, and at an average home size in EU 109 m^2.[96] The insulation thickness (0.05m) and room height and heating/cooling source are held constant for the analysis. The life of a building is suggested to be 50 years.

Table 9: Assumptions for House Thermal Model[97]

LOAD		EQUATION
Envelope	Walls & Ceilings	K × S × (delta T) K = 1/(1/α1+1/α2+δ/λ)

The abbreviations used in above table are as follows:

K = Overall Heat Transfer Coefficient (W/m^2K)

α1 = Heat Transfer Coefficient of Outside Air (25 W/m^2K)

α2 = Heat Transfer Coefficient of Inside Air (25 W/m^2K)

δ = Thickness for Insulation (m)

λ = Lambda of Insulation (W/mK)

S = Wall Area + Ceiling Area (m^2)

Results of the modelling are provided in Table 10 and discussed below.

Table 10: Comparison of impact of insulation using CO_2 (water) blowing agents vs structure size on structural heating and cooling load for house in a cold climate (increased electricity costs)

Variable	Unit	Combined Heating & Cooling Load
House size	m^2	109
Insulation thickness	m	0.05
ENERGY COSTS/YEAR per structure	kWhr	6065

96 *How Big is a House? Average House Size by Country – 2023*.

97 ASHARE Fundamentals 2013 (Chapter 17 & 18)

ENERGY COSTS @ LIFETIME (50 yr) per Structure	10^3 kWhr	303
ELECTRICITY ADDITIONAL COST/YEAR per structure	Euro	3,000
ELECTRICITY ADDITIONAL COST @ LIFETIME (50 yr) per structure	Euro	149,000

Weather differences among the EU regions assume that insulation requirements must be designed for a specific region, i.e., cold climates have larger heating loads.

Consequently, the table above demonstrates that in case 2.1 million houses would be equipped with a spray foam insulation using open-cell CO_2 (water) blown foam instead of HFO based blown foams, as suggested in the Proposal, for the structures in cold climates there would be an <u>increased electrical load of 12.7 TWhr/year</u>. With an average emission factor of 0.43 kg CO_2eq/kWhr this would mean that additional <u>6.7 million tonnes of CO_2 eq would be emitted</u> into the environment due to the proposed substitution. This would also represent <u>a 3 000 € additional electricity costs</u> per home per year. Considering a 50-year life span of 2.1 million houses, overall additional economic costs on the society will be huge and clearly disproportionate to risks of TFA emissions due to uses of HFO-1234ze(E) and HCFO-1233zd(E) insulation foam blowing agents. Therefore, consequences of the proposed REACH restriction (ban) on respective uses of HFO-1234ze(E) and HCFO-1233zd(E) will be in breach of wider EU sustainability policies, including European Green Deal, Fit for 55 and REPowerEU.

The study was only looking at spray foam (SPF) installation and does not include other foam products such as HFO based board stock and panel foam that also offer superior insulation efficiency versus CO_2, hydrocarbon or water blown alternatives.

3.6. Unique mechanical properties

According to Table 1 above, there are several applications of insulation foams that require specific and unique physical properties. Please also consult **Appendix I** below.

In this respect, it is suggested at page 270 of Annex E of the Proposal that for high-pressure Spray Foams (SPF, see above) - "*For spray of dispensed foam, the alternative is to go to open cell products with CO_2 or water blown systems)*." Hence, it is suggested to use water and CO_2 as blowing agents as alternatives to HFOs based foams technology.

However, CO_2 is a high-pressure liquified gas. There is no commercial foam blowing equipment available in the EU or North America that is designed to use this gas. The use of this technology would require that the blowing agent be added third stream to a non-flammable blowing agent and only at low concentrations. It would involve the transportation and use of a high-pressure gas cylinder in the spray foam trailer. This creates not only another safety concern but requires the design, production and purchase of new equipment.

Water could be used as a chemical blowing agent, which reacts with the polymeric isocyanate (pMDI) to generate CO_2. However, it is necessary to assess specific applications of spray foams to determine where this technology could be used. Table 11 below provides characteristics of spray foam (SPF) applications.

Honeywell

Table 11: Spray Foam (SPF) characteristics[98]

Insulation	Closed cell - SPF[99]	Open cell - SPF[100]
Blowing Agent	**HFOs (e.g., HCFO-1233zd, HFO-1234ze)**	**CO_2, water**
Closed cell content (According to ISO 4590)	CCC4 according to EN 14315 ≥90%	CCC4 according to EN 14315 <20%
Thermal Conductivity (Adged value according to EN 12667 and for thick products EN 12939)	0.026-0.028 W/m-K	0.035-0.042 W/m-K
Water Resistance (according to EN 12087)	Long term water absorption < 2%	Not recommended for applications involving a possible direct contact with water (such as roofing, etc.)
Water vapour resistance factor (μ) (according to EN 12086)	Medium permeability 50<μ< 150	High permeability μ< 15
Air flow resistance	Closed-cell foam helps to improve the air tightness of buildings	Open-cell foam can help to improve air tightness of buildings at higher installed thickness
Compressive strength (According to EN 826)	170-500 kPa	5-30 kPa
Strength and Rigidity	Higher strength and rigidity. Depending on density, may add structural strength to certain load-bearing building elements (in particular, timber constructions)	Low strength and rigidity (will not add structural strength to load-bearing elements)
Density (According to EN 1602)	30-60 kg/m^3	8-15 kg/m^3 (up to 60 kg/m^3)
Acoustic absorption coefficient (According to EN ISO 11654)	Medium Sound absorption 0.3	High Sound absorption 0.5
Reaction to Fire Classification (*)	Generally E (Range from C, s3-d0-F)	F

98 PU Europe Fact Sheet No 22, Closed- and Open-Cell Spray Polyurethane (PU) Foam.
99 Solutions for construction - https://www.synthesia.com/en/applications/construction/
100 *Ibid.*

(According to EN 13501-1)		

(*)- Classification for naked foam only. Classifications for end-use application may reach up to B, s1-d0.

According to the above table, closed cell SPF with HFOs have higher closed cell content which reduces its water absorption and improves its vapor permeability. The difference in these properties is not resolved with increasing the thickness of open cell foam. As a result:

- While both open and closed cell spray foam will entirely fill the cavities where they are installed (when installed properly), only closed cell spray foam can offer the added benefit of a vapor barrier. If the application calls for an integrated vapor barrier and insulation all in one, closed cell spray foam insulation will provide this necessary performance. For this reason, all continuous exterior insulation applications using spray foam should be closed cell.[101]
- Spray foam is also an air barrier, meaning it resists airflow between conditioned and unconditioned spaces. Air barriers are important considerations in building science because they can improve insulation performance and indoor air quality.
- Air barriers also help keep pollen, dust, insects and other allergens from entering the home or building through cracks or crevices in the wall assemblies. Spray foam adheres to the walls, boards and studs of your home, creating tight seal that limits potential intrusions.[102]
- Closed cell spray foam often qualifies as a Class II vapor retarder, as defined by the International Residential Code. A vapor retarder works to prevent moisture (water vapor) from easily passing through building material. Good building design and practices include controlling the movement of moisture inside and outside a home or building. Excessive moisture inside a building can facilitate mold growth and degrade building or home performance and building material service life.[103]

The above Table 11 also highlights the difference in density, strength, and rigidity between the products. In the meantime, the EU is experiencing increases in severe weather.

> *"Severe windstorms can cause widespread damage to forests, buildings, and transport and energy infrastructure. High winds at sea contribute to storm surges, which can be destructive for coastal regions. Storms were the costliest natural hazard in terms of insured losses in Europe, with the highest impacts in north-western Europe, especially in coastal areas.*[104]

For this reason, closed cell spray foam could be used in external and internal applications presenting a significant benefit for severe weather areas. This type of Spray Foam (i.e., ccCPF) improves weather and storm resistance as explained below:

- A ccSPF (i.e., closed cell spray polyurethane foam) fillet can increase the wind uplift capacity by more than 2x the uplift capacity of the panel fastened using only nails.

  A continuous 3 in. (7.62 cm) thick ccSPF layer can increase the wind uplift capacity by as much as 3x that of the control roof panel [105]

101 *Spray Foam: Open-Cell vs. Closed-Cell.*
102 *WHY SPRAY FOAM INSULATION.*
103 Ibid.
104 *Wind — severe windstorms.*
105 *CLOSED-CELL SPRAY FOAM, Resisting Wind Uplift in Residential Buildings*

- There is various evidence outlining advantages of closed cell spray foam over other insulation materials. Since SPF is applied on the site, it has significant severe weather advantages over other insulation materials that need to be mechanically fastened to the surface.[106]
- SPF also can add structural strength to buildings. NAHB Research demonstrated SPF filled walls could add from 75% to 200% racking strength to walls of OSB, plywood, light gauge metal, vinyl siding or gypsum board.[107]
- ccCPF stops the 30% heat loss through the roof that happens with conventional insulation like Fiberglas and cellulose.[108]

For instance, HFO blowing agents are critical for the on-site *(in situ)* polyurethane spray foam use as under-slab insulation in residential structures. Because this application involves pouring concrete over the foam, minimizing lateral movement over time (compressive creep) is an important requirement. In France, specification NF DTU 52.10 specifies the maximum amount of compressive creep that is allowed.[109] A list of products that have been tested by the certifying body, CTSB, and approved is available online[110]. Analysis of the listings for each of these products confirms that only foams that utilize HFC or HFO blowing agents are approved. There are no foams blown with CO_2 (generated from the reaction of isocyanate[111] and water) that have passed this compressive creep test. This illustrates one of the applications where the use of HFOs is critical with no alternatives available.

Table 11: Comparison of Closed and Open Cell Applications

Closed Cell		**Open Cell**	
Application	**Sample Customer product[112]**	**Application**	**Sample Customer product[113]**
Roofing – external High density Compressive > 300 kPa	Poliuretan Spray 7129 Roof HFO Poliuretan Spray S-503 HFO	Partition walls	Poliuretan Spray S-OC-008 Poliuretan Spray S-OC-008E
Facades- external Low water absorption/ high R-value	Poliuretan Spray S-303 HFO Poliuretan Spray S-303 HFO Poliuretan Spray S-35RGB/ECO	Pitched roofs-internal	Poliuretan Spray S-OC-008 Poliuretan Spray S-OC-008E

106 See e.g., *Severe Weather and Walls/Roofs, The case for using spray polyurethane foam (SPF) in hurricane zones.*
107 See *Closed Cell vs. Open Cell Foam, What is the Difference between Open cell and Closed Cell Polyurethane Foams?*
108 Ibid.
109 NF DTU 52.10, see *also NF DTU 52.10 Application of Insulation Pads Under Screed or Floating Boards and Under Sealed Tile*
110 CSTB, *ATec or DTA : in-situ polyurethane*
111 Isocyanates are highly hazardous substance with high exposure and risks for workers.
112 Solutions for construction - https://www.synthesia.com/en/applications/construction/
113 *Ibid.*

Suspended floors Compressive strength High R-value Limited space High load	Poliuretan Spray S-383 HFO	Suspended floors- high density	Poliuretan Spray S-OC-008 Poliuretan Spray S-OC-008E
Suspended ceiling Resistance to fire High R-value	Poliuretan Spray S-303 HFO Poliuretan Spray S-303 HFO Poliuretan Spray S-35RGB/ECO		

Due to the unique properties of HFO, including HCFO-1233zd(Z) and HFO-1234ze(E), closed cells insulation foams provide unique structural strength characteristics to SPF that are critical for many applications (e.g., roof and outside) and that are impossible to reach by other types of SPF and blowing agents. Respective technical specifications of insulation materials are mandatory under the buildings codes of many EU member states.

As discussed in section 3.2 above, the Integral skin foam is another form of polyurethane foam that is used mainly for to make many automotive parts, exercise equipment, and furniture. The key feature of these foams is a very tough, abrasive resistant skin surrounding a more flexible core. This skin is created during the foaming process by a combination of mold pressure/temperature and blowing agent. The key attribute of the blowing agent in this application is not only to create the cellular interior structure, but not to interfere with the formation of the skin. HCFO-1233zd(E) has been found to be particularly effective in providing these key attributes1 while at the same time avoiding the need to spend significant capital to convert to flammable blowing agents. CO_2 (water) has been evaluated as another blowing agent option, but this blowing agent tends to interfere with the formation of the tough outer skin and cannot be used in many integral skin foam applications.[114]

4. Existing technologies for safe end-of-life

An important component for the safe use assessment of any insulation substance or construction material is its end-of-life stage. HFC/HFO foam blowing agents have been extensively used worldwide for decades.

Previously, many products containing insulation foams and construction waste materials historically are sent to landfills. However, the situation is rapidly changing. Currently, there are three practical options for the end-of-life stage of insulation products.

1) *Destruction* – incineration/ biodegradation.
2) *Reuse* - use of insulation in next buildings.
3) *Repurpose* - reclamation of blowing agent for reuse.

114 A review of modern polyurethane integral skin foams.

According to the EU Waste Framework Directive (WFD)[115] and the regulations on the European Waste List (EWL)[116], polyurethane insulating material shall not be disposed of without prior treatment. The waste disposal code for construction waste is 170604.[117]

According to the *EU F-Gas Regulation* and respective Guidance, operators of products and equipment that contains F-Gases should arrange for the recovery of gases *"to the extent that it is technically feasible and does not entail disproportionate cost".*[118]

In this respect, there are established technologies for the collection and further treatment of waste depending on types of industries and products at stake as summarised below.

– **Appliances (home/commercial refrigerators, boilers, air conditions and etc.)**

The European Commission final report *Waste Management Options and Climate Change*,[119] discusses greenhouse gas emissions from WEEE (Waste from Electrical and Electronic Equipment recycling) disposal and recycling from appliances. This report estimates that 60% of the CFC/HFC in appliances insulation foams escapes during recycling and landfill. In landfilling, all the emissions are assumed to take place after burial and would be collected with landfill gas and destroyed by flaring or combustion in energy recovery. The destruction of fluorocarbons in flaring and fluxes of this kind of waste is confirmed in the study published by California Polytechnic State University *Field Emissions of (Hydro)Chlorofluorocarbon and methane form a California landfill.*[120]

Table 4.3. Current situation on foam recycling/recovery techniques used in five European countries today

Country	Foam recycling/recovery techniques	Recycling facilities
Denmark	Crushing of R/F in a sealed facility→treatment of exhaust air stream by catalysis →HCl/HF + shredded foam (incineration)	Dansk Genindvinding
Sweden	Shredding in closed units→ collection of air→ treatment of exhaust air stream by condensation→CFCs + shredded foam (incineration)	Bjästa Återvinning Stena Bilfragmentering Svensk Freonåtervinning
Germany	Crushing of R/F in a sealed facility→separation of PU foam→pore and matrix degasification→condensation of exhaust air→ CFC (purity 99,9%) + shredded foam (incineration +landfill)	25 special facilities for handling used freezer/refrigerators
Netherlands	Shredding of R/F→ degasification→(H)CFCs incineration. 100% reuse of degassed foam (powder) as adsorption material – after reuse it goes to a cement kiln for incineration	Coolrec (facilities in Einhoven and Dordrecht)
Ireland	No recovery of CFCs in insulation foam in R/F. Residue (including foam) from iron and steel recovery plants are landfilled	

Denmark, Sweden, Germany, and Netherlands all had regulations that covered handling of insulation foam in F/R before December 31, 2001.

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115 *Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives*

116 See also German Ordinance on List of Wastes (Abfallverzeichnisverordnung – AVV)

117 See e.g., Environmental Product Declaration as per ISO 14025 and EN 15804+A1, PU thermal insulation boards with multi-layer aluminum facing (IVPU), EPD-IVP-20210003-IBE1-EN.

118 *EU F-Gas Regulation Guidance, Information Sheet 7: Foam Insulation Products.*

119 Pages 191-192, *Waste Management Options and Climate Change*, Final report to the European Commission, DG Environment.

120 *Field Emissions of (Hydro)Chlorofluorocarbon and methane form a California landfill*, California Polytechnic State University, 2016.

Table Reference[121]

Although not all recyclers in the EU are required to collect or destroy bowing agent releases, this technology exists, already implemented and even is obligatory in many countries (see table above and source publication).[122] It is important to understand that greenhouse gas fluxes associated with transport and landfill operations are minimal. Many recyclers have reported that hydrocarbon and vacuum insulation panel (VIP) products make the recycling of appliances more difficult due to the associated human and environmental hazards.[123] For reference, VIPs are a construction that consists of a multi-layered gas-impermeable wall material and a core that can be powder, fibres, or open-celled foam. A vacuum is created in the interior of the panel, which can improve the insulation efficiency of the panels by as much as 5 times.[124] VIPS are usually used in conjunction with PU foam to create the insulation layer in a refrigerator cabinet. The core material in most VIPs used today is fumed silica powder.[125]

- **Empty PU cans - OCF (One Component Foam):**

It is estimated that about 25 million cans of PU foam are consumed annually in Germany.[126] National legislation classified the empty PU cans as hazardous. Over 95% of these cans are collected and returned to producers. The PU-foam can industry has developed and implemented a recycling program for these materials. The program not only recycles the metal from the cans but collects the propellants.[127] The cost of the recycling has been built into the price of the product. During this process, there is a potential to collect and reuse the foam blowing agent, i.e., relevant technologies exist and are ready for wider implementation.

- **Phenolic Boards**

The material is dismantled and transported to a facility where it is crushed and compacted into briquettes for incineration.[128] During this process, there is a potential to collect and reuse the blowing agent. At this time, while the technology exists, it is not practiced but could be and was previously explored in multiple countries.[129]

- **PIR Board**

Dismantling polyurethane insulating materials as well as sorting and waste identifying can be done without difficulties, since they are usually mounted mechanically or laid loosely. Clean and undamaged polyurethane insulation boards can be reused as well as recycled mechanically or raw materially (glycolysis). Glycolysis means that at approx. 200°C, polyurethane rigid foam waste is transformed into a fluid substance called glycolysis polyol, which can be used again as raw material in the production of polyurethane.[130]

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121 Page 7, *Determination of the fraction of blowing agent released from refrigerator/freezer foam after decommissioning the product*, Scheutz, Charlotte; Kjeldsen, Peter, Kgs. Lyngby, Denmark: Environment & Resources DTU, Technical University of Denmark, 2002.
122 *Ibid.*
123 *Study on Recycling of Cooling and Freezing Appliances Containing Vacuum Insulation Panels (VIPs).*
124 A VIP refrigerator - Evonik Industries
125 Vacuum Insulation Panels for Refrigerators, Verma et al, International Journal of Refrigeration 112, 2020, pp. 215–228
126 *Recycling of PU foam cans.*
127 *Ibid.*
128 *Study on Recycling of Cooling and Freezing Appliances Containing Vacuum Insulation Panels (VIPs).*
129 https://www.urt-recycling.com/seite/en/disposal/039:50/tn_50/Fridge_Recycling.html
130 *IVPU thermal insulation boards with 50 µm aluminum facing,* Environmental Product Declaration as per ISO 14025 and EN 15804+A1, EPD-IVP-20210001-IBE1-EN

It is noteworthy that within the context of the EU initiative on broad *"depolymerization"*, the following companies were already developing relevant recycling facilities across the EU. For instance, Orrion Chemicals (France) in cooperation with DOW operates respective recycling plant since autumn 2021.[131] Repsol built a chemolysis process facility in Spain and the production has now started.[132] Retour mattress is majority held by the holding company IKEA, has also built a chemolysis plant in the Netherlands which has started to work in 2023.[133] Company Evonik had also started a hydrolysis recycling production.[134] Triple Helix in Belgium has obtained planning permission for a chemolysis plant in the Port of Antwerp.[135] In 2021, Covestro started a pilot plan for PU chemical recycling in cooperation with eco-mobilier (as announced in 2021).[136] In addition, firms like H & S Anlagentechnik have equipment that can recover blowing agent and recycle rigid polyurethane foam. [137]

There is a potential to collect or reuse the HFC/HFO blowing agents during this recycling process. The necessary technologies exist and were previously explored in many countries.

- **Safe incineration is an existing option**

During thermal treatment (incineration) the energy content of the insulation material (including SPF) can be recovered. The separated waste streams can be incinerated with the gas stream being cleaned with a thermal oxidizer. The Honeywell's Callidus® technology provides the required effective and safe technical solutions: *"Our broad base of incinerator designs and wealth of experience allow us to evaluate your environmental problems and provide custom designed solutions for your specific situation. Our incineration systems are in service in a variety of gas and liquid waste applications including halogenated, chlorinated, fume, tail gas and nitrogen bearing wastes. Each system is designed and built to meet the highest quality standards and to meet or exceed the latest environmental regulations including NOx standards."*[138]

This thermal oxidizer technology is used today at many fluorocarbon facilities removing > 99.99% of the organic materials with starting concentration levels significantly higher than would be seen in construction waste.[139] In addition, the emissions from these incineration units go through three scrubbers which remove any acid generated from the gas stream. Ensuring that the use of HFO insulation provides significant energy saving with minimal environmental footprint.

Although work is continuing to be done to optimize incineration of PFAS materials, from the calculated removal factors it can be concluded that the majority of PFASs are removed effectively from flue gas.[140]

As one manufacturer states in their Environmental Product Declaration (EPD), "*upon removal from the building, products are assumed to be transported 100 km (module C2) to a recycling facility. The foam waste in the EoL phase is sent to a waste incineration plant. The waste is shredded and incinerated. These*

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[131] *PU in the sustainability and circular world*, Bart J. ten Brink, For International PU Forum Nagoya Japan June 2023, see in **Annex III** below.

[132] *Repsol to build Spain's first polyurethane foam recycling plant in Puertollano.*

[133] *THE END-OF-LIFE OF FLEXIBLE POLYURETHANE FOAM FROM MATTRESSES AND FURNITURE.*

[134] *Evonik partners with The Vita Group for pioneering efficient polyurethane mattress recycling process.*

[135] *Triple Helix to build polyurethane recycling plant at Port of Antwerp.*

[136] *PU in the sustainability and circular world*, Bart J. ten Brink, For International PU Forum Nagoya Japan June 2023, see in **Annex III** below.

[137] https://www.hs-anlagentechnik.de/en/recycling-reactors-for-rigid-pu-foam-residues.html

[138] *Innovative Solutions for Combustion and Emissions Challenges,* Process Heater Burners, Flare Systems, Thermal Oxidizers and Catalyst Systems, Callidus Combustion Technology.

[139] RECYCLING REACTORS FOR RIGID PU FOAM RESIDUES

[140] *Per- and polyfluorinated substances in waste incinerator flue gases,* J. Bakker, B. Bokkers, M. Broekman, National Institute for Public Health and the Environment Ministry of Health, Welfare and Sport, RIVM report 2021-0143.

processes are grouped to module C3. Resulting potential benefits for electricity and thermal energy due to the incineration are grouped to module D. Aluminum facings are recycled. "[141]

In other words, there are technologies that allow safe and effective incineration (destruction) of insulation materials containing fluorocarbon foam blowing agents. Although their uses are not mandatory in the EU, there are numerous examples of their practical implementation in EU and worldwide.

The same is true for other waste treatment techniques (i.e., reclamation/repurpose and reuse) as demonstrated above.

5. Conclusions

HFO-1234ze(E) and HCFO-1233zd(E) fluorinated gases should be excluded from the scope of the PFAS restriction Proposal because they are low hazard, not persistent substances according to Annex XIII REACH and concentrations of TFA produced from their atmospheric degradation are negligible. Extremely low current and predicted levels of TFA concentrations unequivocally confirm the absence of unacceptable risks within the meaning of Title VIII REACH. Respective risks are already adequately controlled by the EU-wide RRMs (including at the end-of-life stage) that could be adjusted at any time. In this respect, short atmospheric lifetimes of these gases allow effective and rapid regulatory interventions, if warranted.

Both above gases are used as innovative *"fourth generation"* foam blowing agents for various insulation products, including on site (*in situ)* formed high and low-pressure Spray Foams[142] as well as other polyurethane (PU) foams required for insulation of home appliances, transportation and industrial sectors. Where thinner insulations layers are required due to space constraints (transportation, boats, trucks, pipes, etc.) and/or superb mechanical properties (compressive creep, vapour barrier, etc.) or for higher energy efficiency performance (10-15% increase in energy performance (superior *lambda*) for certain applications and 20% higher R-value for less thickness) *"fourth generation"* foam blowing agents provide solutions. This allows for important savings in terms of energy and GHG emissions. They are also non-toxic, non-ODS, low-GWP and non-flammable gases that are not considered volatile organic compounds (VOC). There are techniques in the EU and worldwide allowing for safe end-of-life treatment of insulation materials containing HFOs foams blowing agents.

The introduction of the REACH restriction as proposed in these circumstances will violate REACH Regulation, EU general legal principles and wider policies, resulting in very high costs on society, and will be subject to countless EU and international legal actions.

As for *in situ* foam applications, whether sprayed or dispensed, the blowing agent must not be flammable under normal application conditions. Use of flammable agents such as pentane (hydrocarbon) is not possible for board/blocks insulation foams required for better fire rated products. This will also require significant investments in respective production lines complying with the ATEX Directive[143] rules, that will mainly impact SME.

Developing and registering new molecules, followed by testing and certifying a new Spray PU Foam product and use/manufacturing equipment for the industrial and construction market, requires at least 12 years.

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141 Page 6, ENVIRONMENTAL PRODUCT DECLARATION as per ISO 14025 and EN 15804+A1, PU thermal insulation boards with multi-layer aluminium facing, 2021.

142 See on technical specifications *Closed- and Open-Cell Spray Polyurethane (PU) Foam* (PU-Europe)

143 *Directive 2014/34/EU of the European Parliament and of the Council of 26 February 2014 on the harmonisation of the laws of the Member States relating to equipment and protective systems intended for use in potentially explosive atmospheres (recast)*

Therefore, Honeywell requests that fluorinated gases HFO-1234ze(E) and HCFO-1233zd(E) should be excluded from the scope of PFAS REACH restriction or given the time-unlimited derogation for uses as blown agents in all types (industrial, appliances, transportation, construction, etc.) of insulation and integral skin foams.

Appendix I - Comparison table of foam blowing agents for SFP, including references and information sources.

Blowing agent considerations	Usable?	Technical issues	Outcome of technical issues
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
CFCs	✗	Ozone depleting	Outlawed per Montreal Protocol
HCFCs	✗	Ozone depleting	Outlawed per Montreal Protocol
HFCs	✗	High global warming potential	Being phased-down per Montreal Protocol's Kigali Amendment
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
Formic Acid	✗	Toxic. Above 69°C explosive vapour/air mixtures may be formed.	Toxic Liquid
Electroset Technology	✗	Not applicable to spray applications	Additive only - not a blowing agent
Methyl Formate	✗	Extremely flammable. Toxic. Vapour/air mixtures are explosive.	Toxic & Flammables cannot be used in spray foam applications - safety hazard
Methylal	✗	Highly flammable, VOC, Vapour/air mixtures are explosive	• VOCs have strict regulations due to smog creation-1991 Geneva Protocol & 1999 Gothenburg Protocol • Flammables cannot be used in spray foam applications - safety hazard
Transcend(TM) Technologies	✗	Additive, not a stand alone BA	Not a standalone blowing agent, additive for HFCs and HFOs to improve compatibility
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.
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.
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.
H2O2	✗	produces oxygen, poor R-value, flammable	Flammables cannot be used in spray foam applications - safety hazard
HFO-1234ze & HCFO-1233zd	✓	**Numerous function 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.**

Annexes I-IV - attached in separate files:

Annex I – Table of acronyms and abbreviations

Annex II – Study of the University of Sevilla (Spain)

Annex III - PU in the sustainability and circular world, Bart J. ten Brink, For International PU Forum Nagoya Japan June 2023

Annex IV - OSO Hotwater case study