TRANSITIONING TO LOW-GWP **ALTERNATIVES IN BUILDING/CONSTRUCTION FOAMS**

Background

This fact sheet provides current information on low-Global Warming Potential (GWP) foam blowing agent alternatives used in building and construction applications, relevant to the *Montreal Protocol on Substances that Deplete the Ozone Layer.*

Several types of foams are used in building/construction applications: extruded polystyrene (XPS) boards and polyurethane (PU) rigid continuous panels, discontinuous panels, spray, boardstock, block, and pipe-in-pipe. The text box (right) describes these types. These foams provide insulation in housing and in commercial and industrial buildings (in walls, roofs, floors, tanks, and pipes). They typically remain intact for the lifetime of the building, which ranges from 25 to 70 years. In many places, the amount of insulation used in homes/buildings has increased over time, as energy efficiency standards have become more stringent.

The U.S. Environmental Protection Agency estimates that global HFC consumption in the building/construction foams sector accounted for approximately 38 million metric tons of carbon dioxide equivalent ($MMTCO_2eq.$) in 2010, with developed countries accounting for 98% of this consumption. Developing countries accounted for very limited HFC consumption because HCFC use was still permitted and, given the high relative cost of HFCs, few users chose to adopt HFCs. However, as the first HCFC phaseout obligations for developing countries approach in 2013, users are considering alternatives. Several low-GWP alternatives have become available over the last few years, offering developing countries an opportunity to transition directly from HCFCs to cost-effective, low-GWP alternatives.

Applications of XPS and PU Foams in the Building/ Construction Sector

XPS Board—used primarily in floor, wall, and roof insulation; a limited amount in pipe insulation. Good compressive strength and resistance to water vapor permeability provide significant advantages for floor insulation.

Continuous Panel—used in wall and roof insulation, cladding of commercial and industrial buildings (e.g., factory units), and applications requiring constant temperatures and hygienic environments (e.g., production of pharmaceuticals, electronics, and foods). In North America and Europe, also used in cold stores.

Discontinuous Panel—used most commonly for internal cold storage (e.g., fish or meat storage) in developed countries and, increasingly, in developing countries. Also used in wall and roof insulation. Commonly manufactured by small- and medium-sized enterprises.

Spray—used primarily to retrofit existing roofs to improve insulation performance. Also used in tank and pipe insulation and to provide insulation on a range of irregular surfaces. Nearly always applied using portable equipment in situ rather than in the factory.

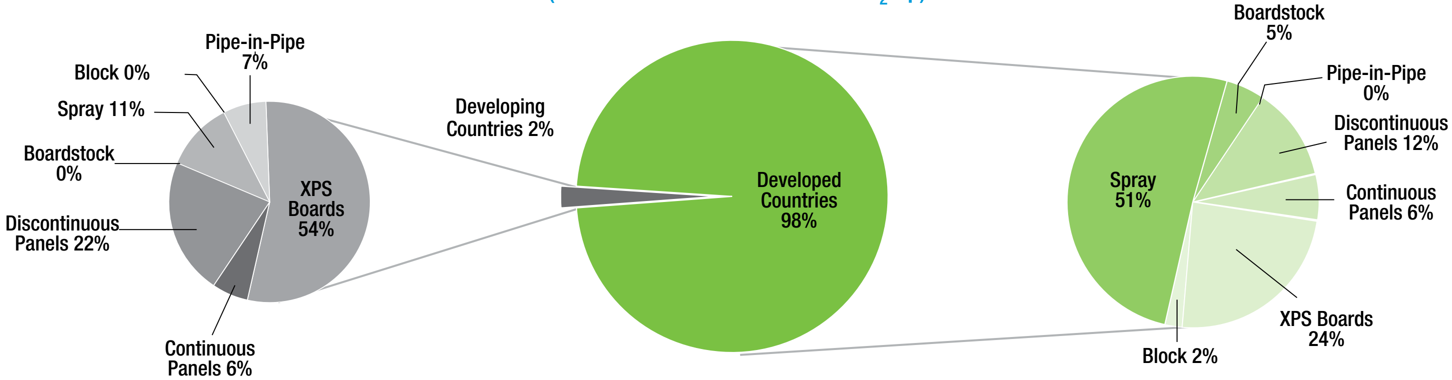
Boardstock—used in wall and roof insulation and, to a lesser extent, in floor insulation. In North America, primarily used as one layer in multi-layer residential walls and roofs; in Europe, primarily used in commercial and industrial buildings, with recent increases in the housing sector.

Block—used primarily in pipe insulation and cold stores, and to a limited extent, in roof insulation. Often cut into slabs for composite panels (with metal or plasterboard surfaces) or cut into pipe sections for use in smaller insulated buildings. Typically the first building/construction foam type to be manufactured in emerging markets, due to low investment cost and range of end-use applications.

Pipe-in-Pipe—used primarily in pipe insulation, particularly for district central heating systems in cities.

2010 HFC Consumption

(Estimates Presented in $MMTCO_2eq.$)



Global HFC Consumption Building/Construction Foams Total: 38 $MMTCO_2eq.$

HFC Alternatives and Market Trends

A variety of climate-friendly blowing agents have been or are being developed for use in building/construction foam applications to replace CFCs, HCFCs, and HFCs. For example, for production of XPS boards, low-GWP hydrocarbon (HC) alternatives already comprise more than half of the global market, while CO_2 is also being used. Similarly, for PU rigid foams, HCs are being used to produce panels, boardstock, block, and pipe-in-pipe foam. For spray foam, low-GWP alternatives, such as CO_2, are being explored. Other low-GWP options, such as methyl formate and HFOs,[1] have also been proposed across various building/construction foam applications. These alternatives are described further below.

HCs (cyclopentane, cyclopentane blends, isobutane, and n-pentane)

- New equipment needed to handle flammable agents
- Good blowing efficiency (requires less blowing agent in the system than HCFCs)
- Blended easily to provide a combination of properties

CO_2

- Lower insulation value compared to HCFCs requires 30–50% increase in foam thickness
- Non-flammable
- Can be generated in situ
- Commonly used as a co-blowing agent in PU rigid foams

Di-methyl Ether

- New equipment needed to handle flammable agents
- Established market (primarily due to use in XPS and one-component foams in Europe and China) with growing capacity

Methyl Formate

- Good blowing efficiency (requires less blowing agent in the system than HCFCs)

Methylal

- Under evaluation as co-blowing agent with HCs and HFCs in a range of building/construction foam applications

HFOs (HFO-1234ze, others)

- Few facility modifications required to transition from HCFCs
- Low to mild flammability
- Good solubility properties
- Being evaluated for building/construction foam applications; could be available as early as 2013

The actual and potential transition to these alternatives in each of the building/construction foam applications is described on the following page.[2]

Europe's Experience

The European Union phased out HCFCs in 2003 and much of the building/construction sector transitioned directly to HCs, having used these blowing agents since 1992. Some smaller companies, as well as those making foams with stringent end-use flammability standards, used HFCs. Through product development, most of these standards now can be met with HC-based foams, and HFC use has diminished. The only exception is the spray foam application, which still relies on HFCs.

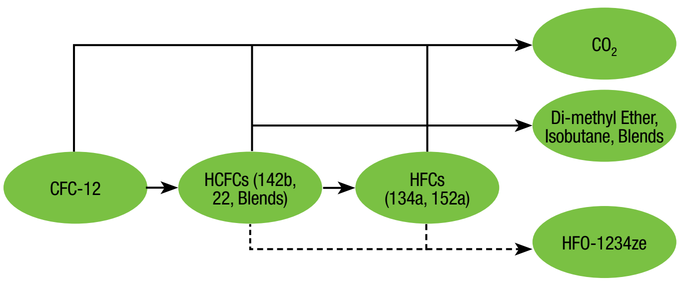
Chemical	GWP	ODP[a]
CFC-12	10,900	1
CFC-11	4,750	1
HFC-227ea	3,220	0
HCFC-142b	2,310	0.065
HCFC-22	1,810	0.055
HFC-134a	1,430	0
HFC-245fa	1,030	0
HFC-365mfc	794	0
HCFC-141b	725	0.11
HFC-152a	124	0
Cyclopentane	<25	0
n-Pentane	<25	0
Methyl Formate	<25	0
Methylal	<25	0
Other HFOs	<25	0
HFO-1234ze	6	0
Isobutane	3	0
Di-methyl Ether	1	0
CO_2	1	0

[a]ODP = ozone depletion potential

XPS Board

XPS boards historically used CFC-12 as the blowing agent, and then predominantly transitioned to HCFC-142b/22 blends. In developed countries, HFC-134a and HFC-152a have replaced some ozone-depleting substances (ODS) use, but other low-GWP options—isobutane, di-methyl ether, blends of those two agents, and CO_2—are also used. HFO-1234ze is also being evaluated for this application.

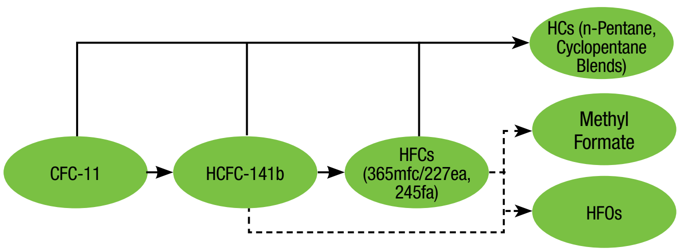
Blowing Agent Transition: XPS Board



Continuous and Discontinuous Panels

Most of the rigid panel foam industry transitioned from CFC-11 to HCFC-141b, except for a number of European manufacturers that transitioned directly to HCs. Subsequent transitions have been to HFCs—typically HFC-365mfc/227ea blends and HFC-245fa—although with technological advances in recent years, there has been an increasing shift toward HCs (n-pentane and cyclopentane blends). Methyl formate and HFOs are being evaluated for these applications and may become viable alternatives.

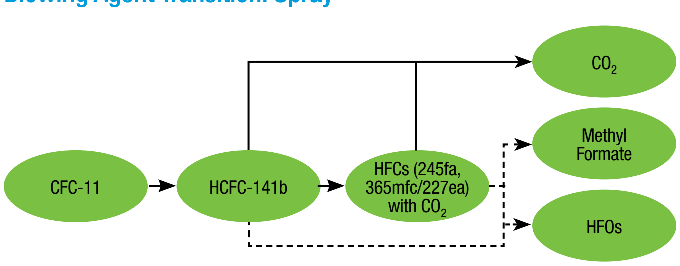
Blowing Agent Transition: Continuous and Discontinuous Panels



Spray

In North America, HCFC-141b was replaced by HFCs, primarily HFC-245fa, in spray foam applications. In Europe, both HFC-245fa and HFC-365mfc/227ea blends have been adopted, mostly co-blown (diluted) with CO_2. In Japan, CO_2, including super-critical CO_2, is being used to a limited extent, in addition to HFC-245fa. Technologies being evaluated for spray foam include methyl formate and HFOs. Hydrocarbons have not been used extensively in this application due to safety concerns. Additional research and development are needed to fully transition this end-use to low-GWP alternatives.

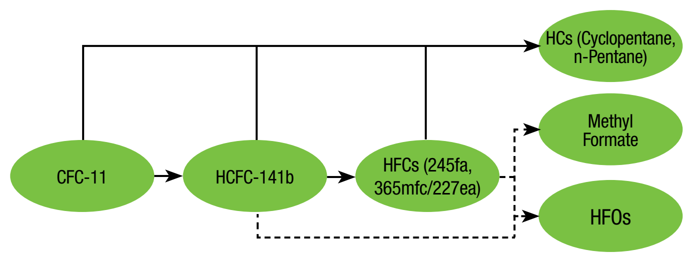
Blowing Agent Transition: Spray



Boardstock

Most of the boardstock foam industry transitioned from CFCs to HCFC-141b, although a number of European manufacturers transitioned directly to HCs, such as n-pentane and cyclopentane. The use of cyclopentane in Europe began later than n-pentane, when availability of cyclopentane increased and prices decreased. Since the phaseout of HCFC-141b in 2003, North America has also shifted primarily to HCs (cyclopentane). A few manufacturers in other developed countries transitioned to HFCs (HFC-245fa, HFC-365mfc/227ea blends) to meet product fire requirements and/or where the cost burden could be absorbed—although most of these applications can now use HCs. Currently, most developing countries producing boardstock foam rely on HCFC-141b. Methyl formate and HFOs may become viable alternatives.

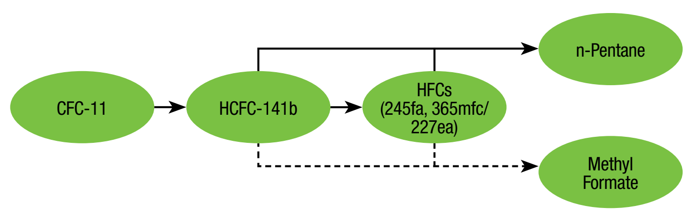
Blowing Agent Transition: Boardstock



Block

After transitioning from CFC-11 to HCFC-141b for the production of block foam, the majority of developed countries transitioned to HFCs—with Europe relying primarily on HFC-365mfc/227ea blends and North America on HFC-245fa. However, some producers transitioned directly from HCFC-141b to n-pentane. Today, most production in Europe is with n-pentane. Methyl formate is being explored as a potential alternative, but concerns related to flammability exist.

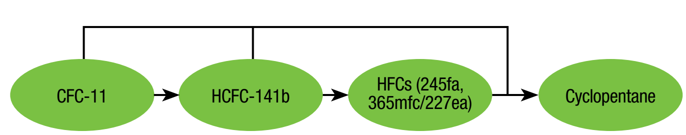
Blowing Agent Transition: Block



Pipe-in-Pipe

A number of European manufacturers have adopted optimized HC systems based on cyclopentane in pipe-in-pipe foam, while other developed countries have adopted HFC-245fa or HFC-365mfc/227ea blends. The technology options being explored for pipe-in-pipe PU foams in developing countries are focused on HC technologies, as there is little penalty in insulation thicknesses and the manufacturing process is sophisticated, with proven engineering solutions. Moreover, since pipe-in-pipe products are largely used underground, they represent little intrinsic hazard.

Blowing Agent Transition: Pipe-in-Pipe



Challenges to Market Entry and Potential Solutions

The following table summarizes the challenges associated with the adoption of various alternatives as well as potential solutions to overcoming the challenges.

Alternative	Foam Type	Challenges to Market Entry	Potential Solutions
HCs	• XPS Boards • Continuous Panels • Discontinuous Panels • Boardstock • Block • Pipe-in-Pipe	• High Flammability	• Engineering Design and Pre-Blending • Research and Development to Improve Thermal Performance • New Equipment Required to Handle Flammable Agents
CO_2	• XPS Boards • Spray • Other (As a Blend to Primary Blowing Agent)	• Increased Quantities of Foam Required to Accommodate Lower Insulation Value • Poor Stability When Used as Sole Blowing Agent • Poor Gas and Foam Thermal Conductivity • High Permeability Through Cell Walls	• Higher Densities to Compensate for Poor Stability
Di-methyl Ether	• XPS Boards	• Moderate Flammability	• Engineering Design and Pre-Blending • New Equipment Required to Handle Flammable Agents
Methyl Formate	• Potential Use in Several Applications (e.g., Discontinuous Panels, Spray, Block)	• Unknown Flammability • Lack of Application Data • High Permeability Through Cell Walls	• Research and Development
Methylal	• Potential Blend Component in Several Applications	• Slight Flammability • Limited Experience as the Sole Blowing Agent	• Research and Development
HFOs	• Potential Use in Several Applications (e.g., XPS Boards, Discontinuous Panels, Spray, Boardstock)	• Not Commercially Available	• Research and Development

Future Outlook

Most building/construction foam applications have readily available, low-GWP alternatives that will naturally be adopted as HCFCs are phased out. However, in the case of spray foams, continued research and development are needed to identify technically feasible, low-GWP alternatives. In other types of foams, continued research and development may expand the list of available low-GWP options. Together, the suite of currently known alternative chemicals and new technologies can significantly reduce future HFC consumption in both the near and long terms, while simultaneously completing the HCFC phaseout. Although much work remains to fully adopt these chemicals and technologies, and some unknowns still remain, the industries currently using HCFCs and HFCs have proven through the ODS phaseout that they can move quickly to protect the environment. Already, a number of projects are underway to transition building/construction foam production away from HCFCs to low-GWP alternatives in developing countries—including the production of spray foam using super-critical CO_2 in Colombia; the production of discontinuous panels and block foam using pre-blended HCs in China; and the production of panels, spray, block, and pipe-in-pipe foam in Brazil using methylal.

[1] HFOs (hydrofluoro-olefins) are unsaturated HFCs.

[2] For all transition diagrams, solid arrows represent alternatives already available in the market for these systems; dashed arrows represent those likely to be available in the future.

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