Technical, economical and ecological implications of replacing HCFC foaming agents

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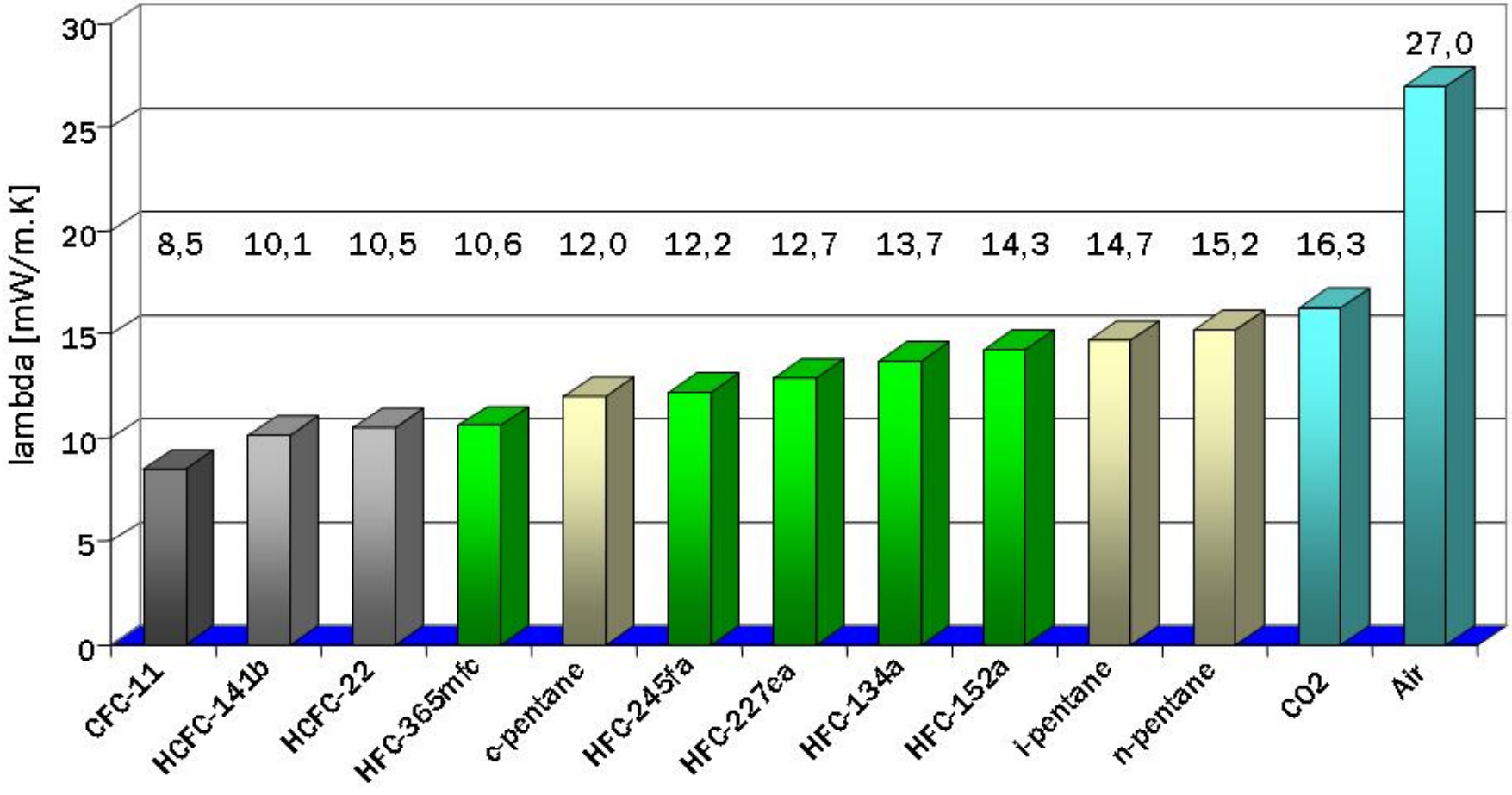
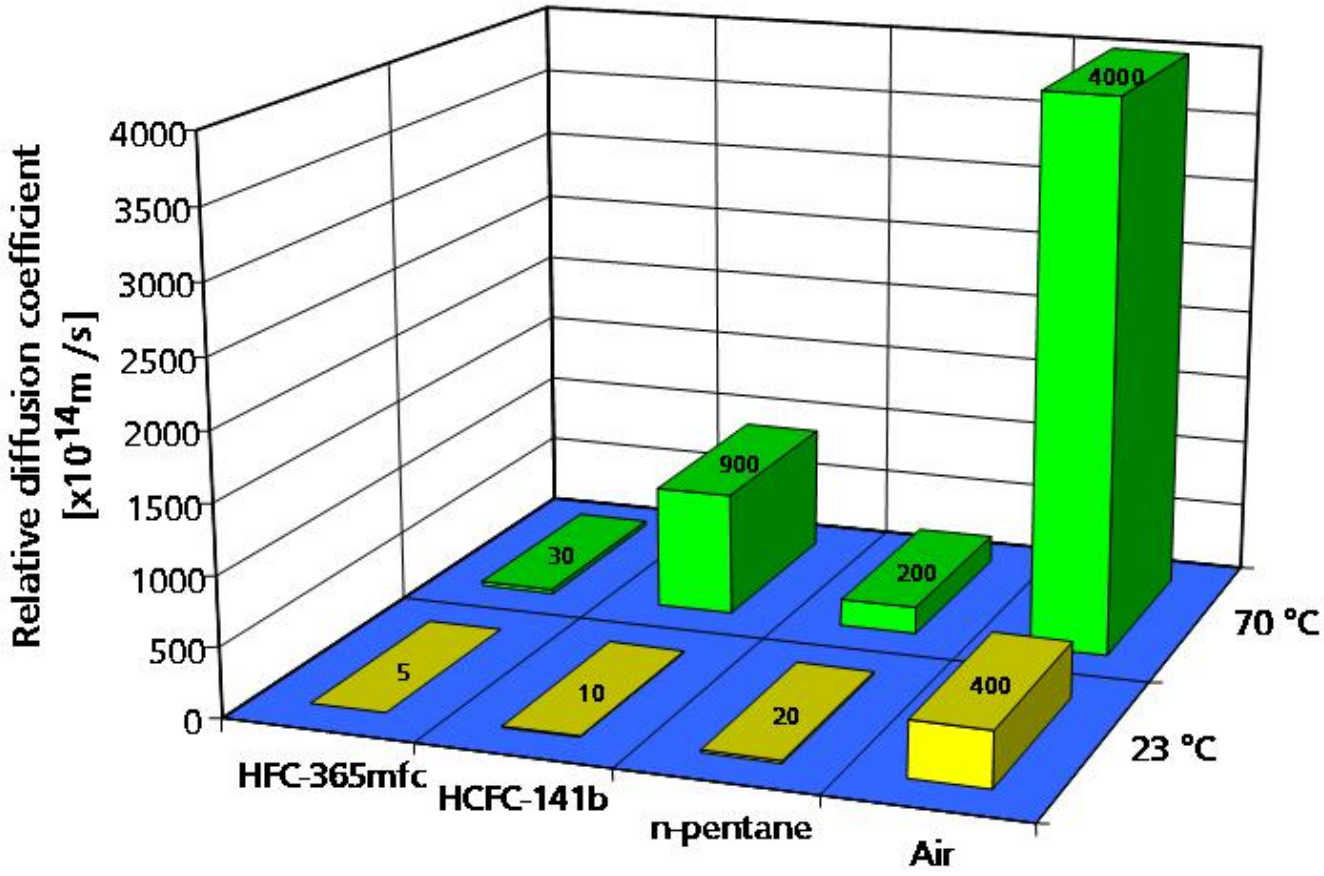
Agenda

- **ODP Zero alternatives to replace HCFC-141b: thermo physical properties**
- Main polyurethane applications of HFC Solkane 365/227 and 365/ C5 blends today
- Economic aspects in replacing HCFC-141b
- Environmental Performance of HCFC-141b replacements
- Summary

Gas Phase Lambda Values



Diffusion Characteristic of Foam Blowing Agents



HCFC Alternative Blowing Agent and low GWP Blends for the PUR/PIR Industry

	CFC-11	HCFC-141b	HFC-365mfc	HFC-245fa	S-365mfc/227ea (93/07)	S-365/245fa (60/40)	cyclo-pentane	n-pentane	iso-pentane
Molecular Weight	137,4	116,9	148,0	134,0	149,6	142,4	70,0	72,0	72,0
Normal Boiling Point, oC	23,7	32,1	40,0	15,3	24,0	30,1	49,3	36,0	27,8
Vapor Pressure									
Psia @68°F	12,8	10,0	6,8	17,8	13,5	11,2	4,9	9,4	11,3
Bar, abs. @20°C	0,883	0,689	0,469	1,227	0,929	0,8	0,338	0,648	0,779
Vapor Thermal Conductivity,	8,23	10,04	10,70	12,00	10,90	11,2	11,97	15,00	15,00
Flash Point, oC	None	None	-27	None	None	None	-7	-56.2	-57
ODP	1	0,11	0	0	0	0	0	0	0
GWP, 100 yr time horizion	4600	700	890	950	1230	914,0	11	11	11

	S-365/C5-Pentane Blend 30/70	S-365/ i-Pentane azeotrop [46/54]	S-365/n-Pentane azeotrop [58/42]	S-365/ c-Pentane azeotrop [73/27]
Molecular Weight	funct. of ratio	funct. of ratio	funct. of ratio	funct. of ratio
Normal Boiling Point, oC	22 to 34	22,0	27,0	32,0
Vapor Pressure				
Psia @68°F				
Bar, abs. @20°C	u.i.	u.i.	u.i.	u.i.
Vapor Thermal Conductivity,	u.i.	12,8 calc.	12,9 calc.	11,1 calc.
Flash Point, oC	yes	yes	yes	yes
ODP	0	0	0	0
GWP, 100 yr time horizion	**275 [calc.]**	**409 [calc.]**	**516 [calc.]**	**650 [calc.]**

Typical Performance for Panels with Pure/ Blended Foaming Agents

	HCFC 141b	HFC-365mfc	365mfc/ c-pentane	365mfc/ i-pentane	365mfc/ n-pentane
Density [kg/m]^3	30.0	31.7	33.3	33.7	29.6
Therm. Cond. @ 10°C [mW/m.K]	18.6	19.5	19.5	19.8	21.2

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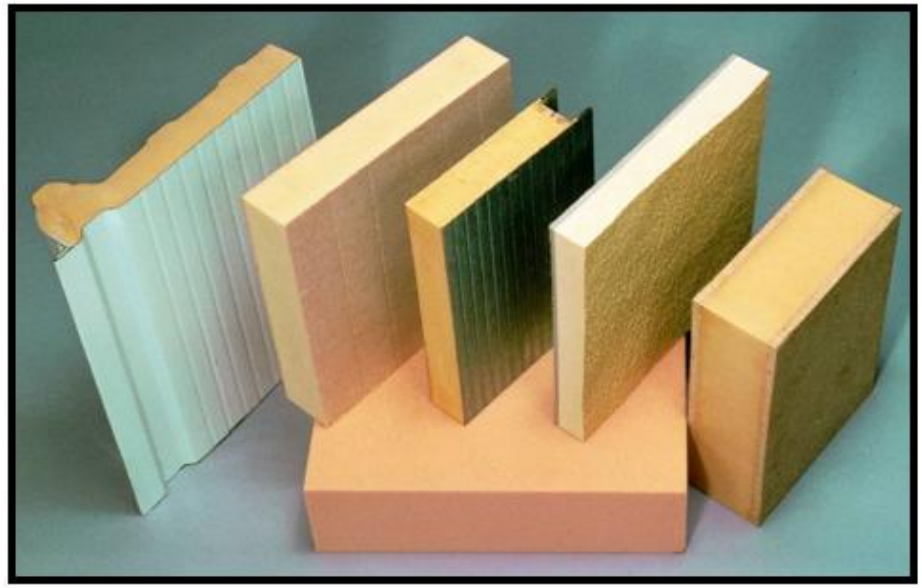


Spray Foam

- Directly sprayed to roofs and walls
- Little prep. of surface necessary / 2-component system
- S-365/227-blown PUR spray foam as cost-effective high-performance solution for renovation
- S-365/277 provides for easy processing under most climates
- Saves more energy at constant budget and reduces CO_2 emissions (see environmental performance)
- HCs no option (safety) – H_2O no option (brittle / λ)

Pre- and On-Site Formulated System for Miscellaneous Applications

- Moulded and pour in place systems for (small) volume productions (niche refrigeration products, water heaters and boilers, pipe insulation,…
- Reefer containers and refrigerated transportation, continuous/ discontinuous insulation panels, sandwich panels, appliances ..)
- S 365/227 offers safe to use non-flammable systems for these markets
- S 365/227 provides for easy handling and best thermal conductivity
- Minimal system modification are required when switching from HCFC141b

Solkane 365mfc and C5 Hydrocarbons in Panel Laminates

Industrial Trial Results

Formulation	C5	C5/S-365
Polyol	100	100
Catalyst	2,4	2,6
n-Pentane	12	10
H_2O	2,2	**1,5**
365/227 93/07	---	8
TCPP	10	10
Surfactant	1,5	1,5
MDI	183	172
Indexes	= constant	=

Results	C5	C5/S-365
Density [kg/m³]	**35**	**31,2**
Core Density [kg/m³]	33,2	29,8
Compr.. [daN/cm²]	1,1-1,2	**1,4**
Lambda [mW/mK]	**22,4**	**20,8**
Thickness [mm]	100	100

S-365/227 lead to improved operation
➔ lower foam density possible

Solkane 365mfc and C5-Hydrocarbons

- HFC 365mfc offers very good dimensional stability and compressive strengths
  - Very low diffusion rate through cell structure
- Lower foam density is possible
- Insulating performance is enhanced at the same time
- Substituting pentane in a system formulation by S-365mfc can lower the cost and improve overall performance of the foam
- GWP of the blend is lowered significantly
- Applications: insulation panels, sandwich panels, appliances

Converting Production Facilities from HCFC-141b to HFC-365mfc/227ea

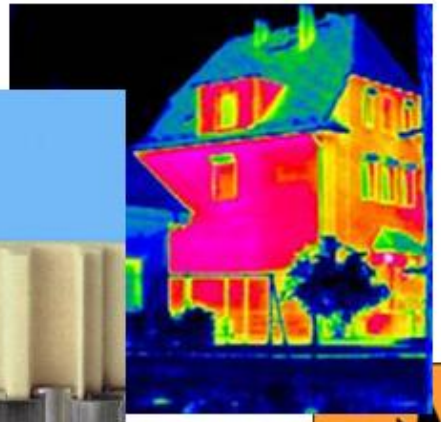
- Existing Storage Facilities can be used
- Detailed handling guidelines are available from Solvay Fluor
- Some precautions are recommended to account for potential flammable mixtures in air (e.g. no smoking policy etc.)

  - no ex-proof fac. required
- Converting foaming machines from HCFC-141b to HFC Solkane 365/227 or HFC 365mfc/245fa is easy and cost effective
- 365/227 as well as 365/245 gives:

  superior insulation performance, excellent fire resistance, easy processing

A need for HFCs

where insulation performance counts



where high fire resistance is a must

where other products don't do the job

where production safety guidelines are prohibitive

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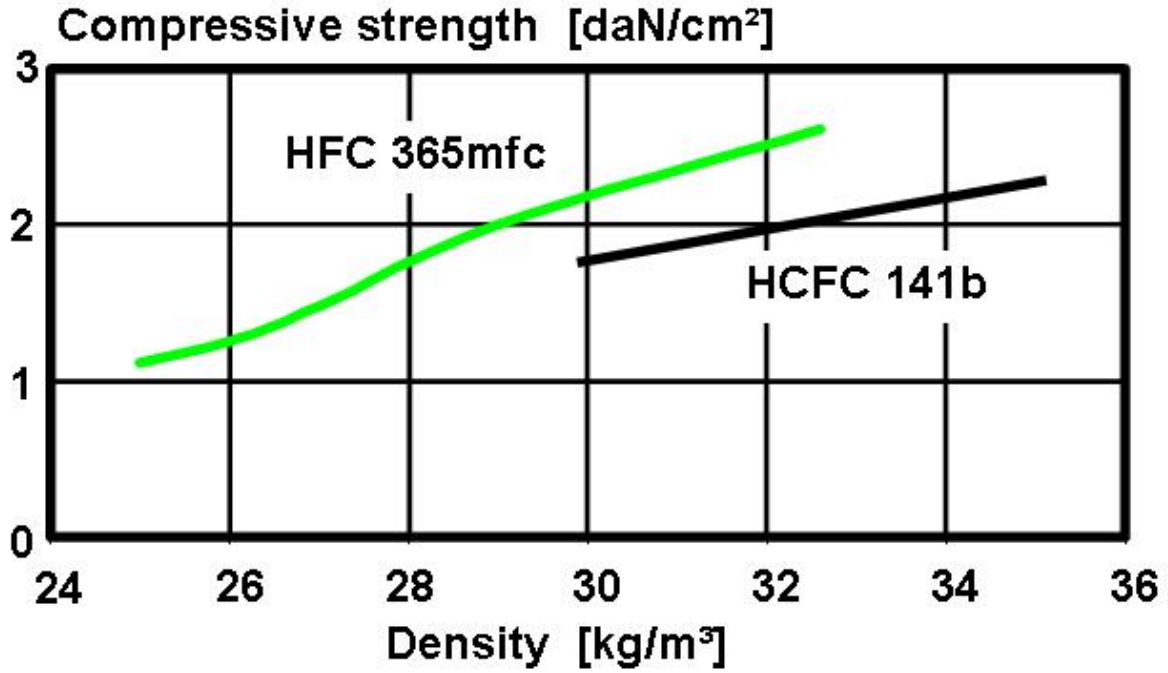
Economical Aspects

- Cost for HFC blowing agents >> HCFC-141b (Factor 3-5) but:
- Governing is cost per m^3 of foam not cost per kg of foaming agent
- HFC-365mfc provides for better compressive strength, reduced flammability and improved λ in comparison to pure C5 blown systems

Economical Aspects: Improved Compressive Strength

- HFC -365mfc foamed PU has excellent compressive strength
- Low densities possible / good properties as construction element



Cost evaluation PIR-system for with n-Pentane vs HFC-365mfc Co-blowing*

	Formulation*		Costs	
	n-Pentane	365 Co-Blowing	n-Pentane	365 Co-Blowing
	[pbw]	[pbw]	[EURO]	[EURO]
Polyol +FR + Cat	82.5	69.3	29.92	28.08
Catalyst 1	3.0	2.5	1.63	1.52
Catalyst 2	0.9	0.6	0.82	0.61
n-Pentane	6.5		1.30	
S 365mfc/n-Pentan (30:70)		6.2		2.85
MDI	124	104	44.90	42.15
Sum	216.7	182.6	78.57	75.21
Density [kg/m³]	39.3	37.0	39.3	37.0
Comp. Strength [kPa]:	120	129		
Lambda [mW/m.K]:	21.8	20.9		
Difference in savings for 365mfc co-blowing via density reduction:			- 3.36 €/m³ foam	

*(steel) sandwich system formulation

*Co-blowing: Solvay's internal wording for 365mfc/C5 hydrocarbon foaming blends

Cost Optimisation of HFC blown PUR systems

- Straight substitution of HCFC-141b with Solkane 365/227 (equal H_2O contents..0.5 parts): 365- foam is 15-20% more costly (per m^3)
- Increasing water content to 1.5 parts with S-365/227 results in cost differences of less than 5% m^3/ foam
- Decreasing densities (using less MDI and Polyol) can further reduce the overall cost based on the needed raw materials
- Less energy utilization (long-term) will additionally promote savings
- Using the co- blowing approach (HFCs blended with pentanes) can improve cost effectiveness compared to pure pentane and HCFC-141b blown foams (density reduction & lambda improvement)

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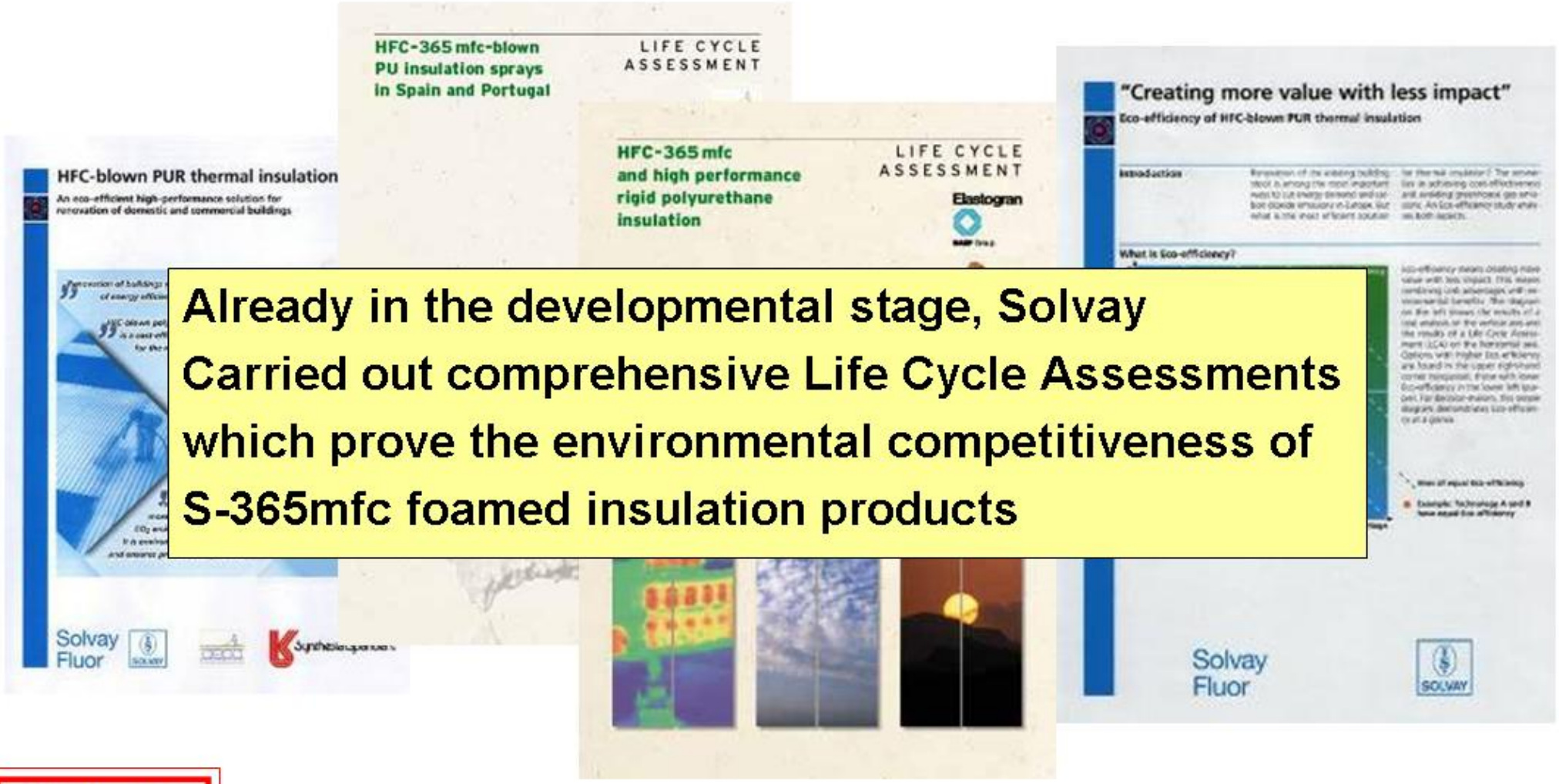
Sustainability and Life Cycle Assessments



Already in the developmental stage, Solvay Carried out comprehensive Life Cycle Assessments which prove the environmental competitiveness of S-365mfc foamed insulation products

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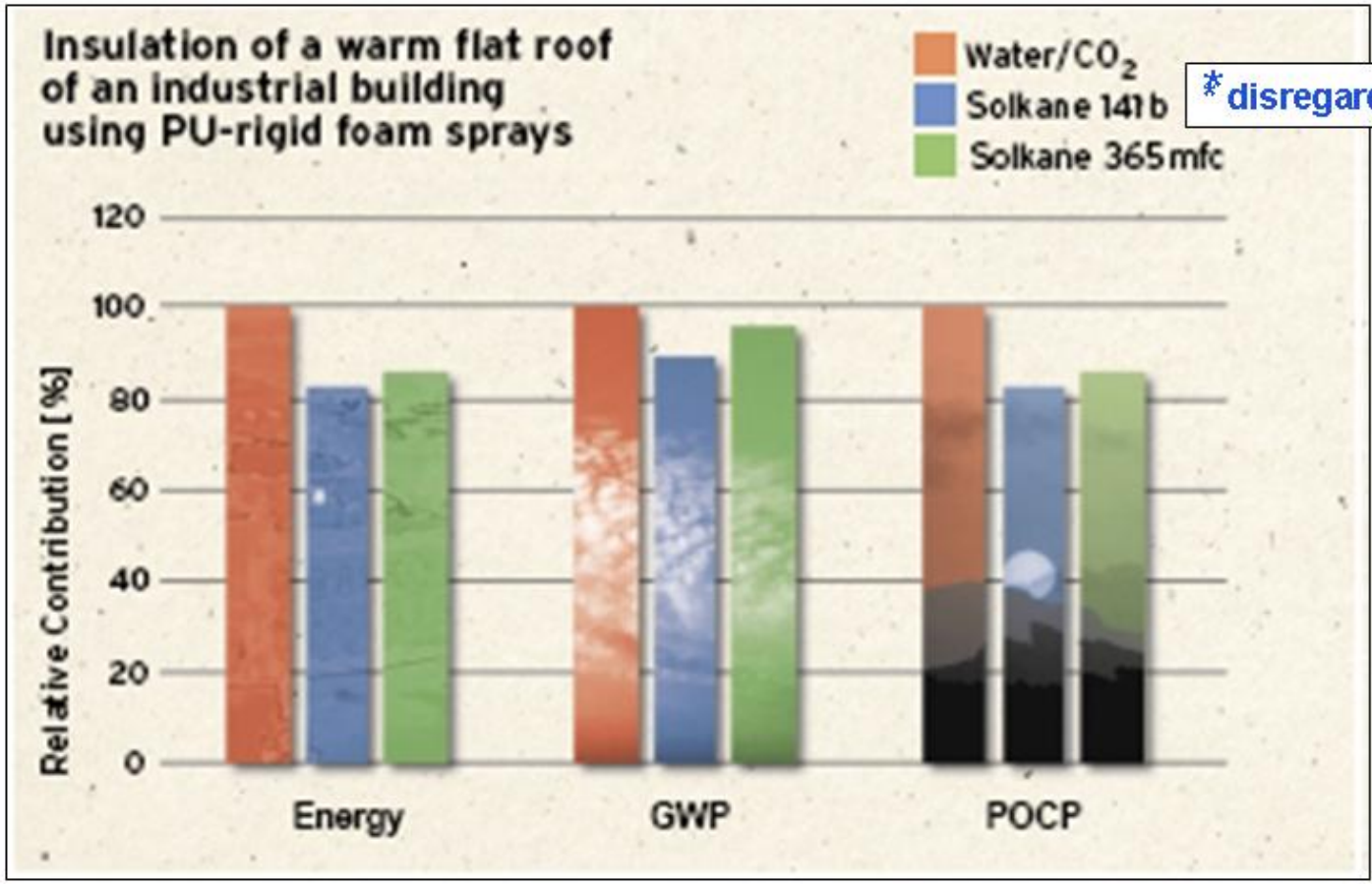
Life Cycle Environmental Profile* of Water/ CO_2 vs HCFC-141b vs HFC-365mfc



* disregarding ODP

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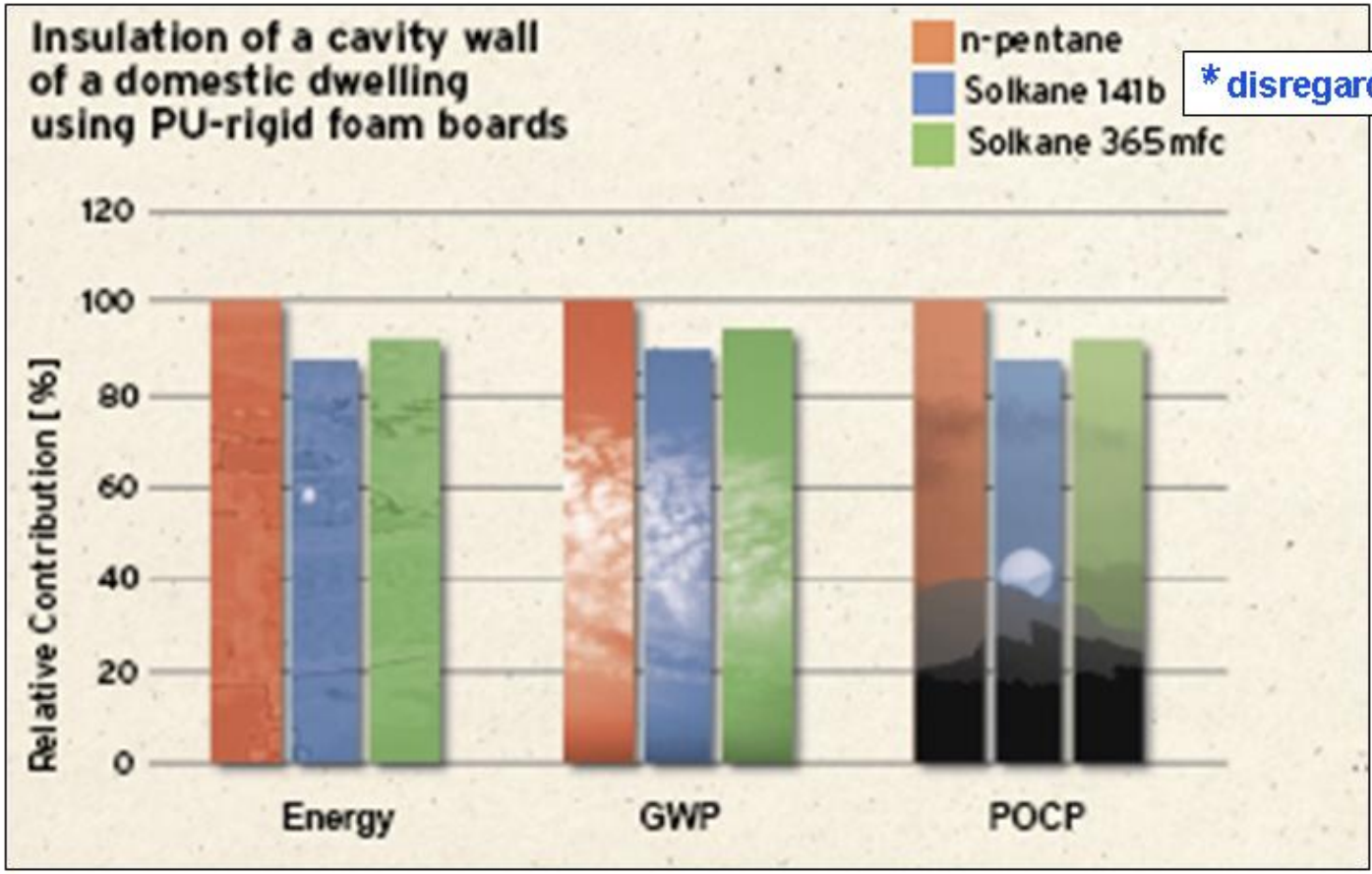
Life Cycle Environmental Profile* of HCFC-141b vs HFC-365mfc vs n-Pentane



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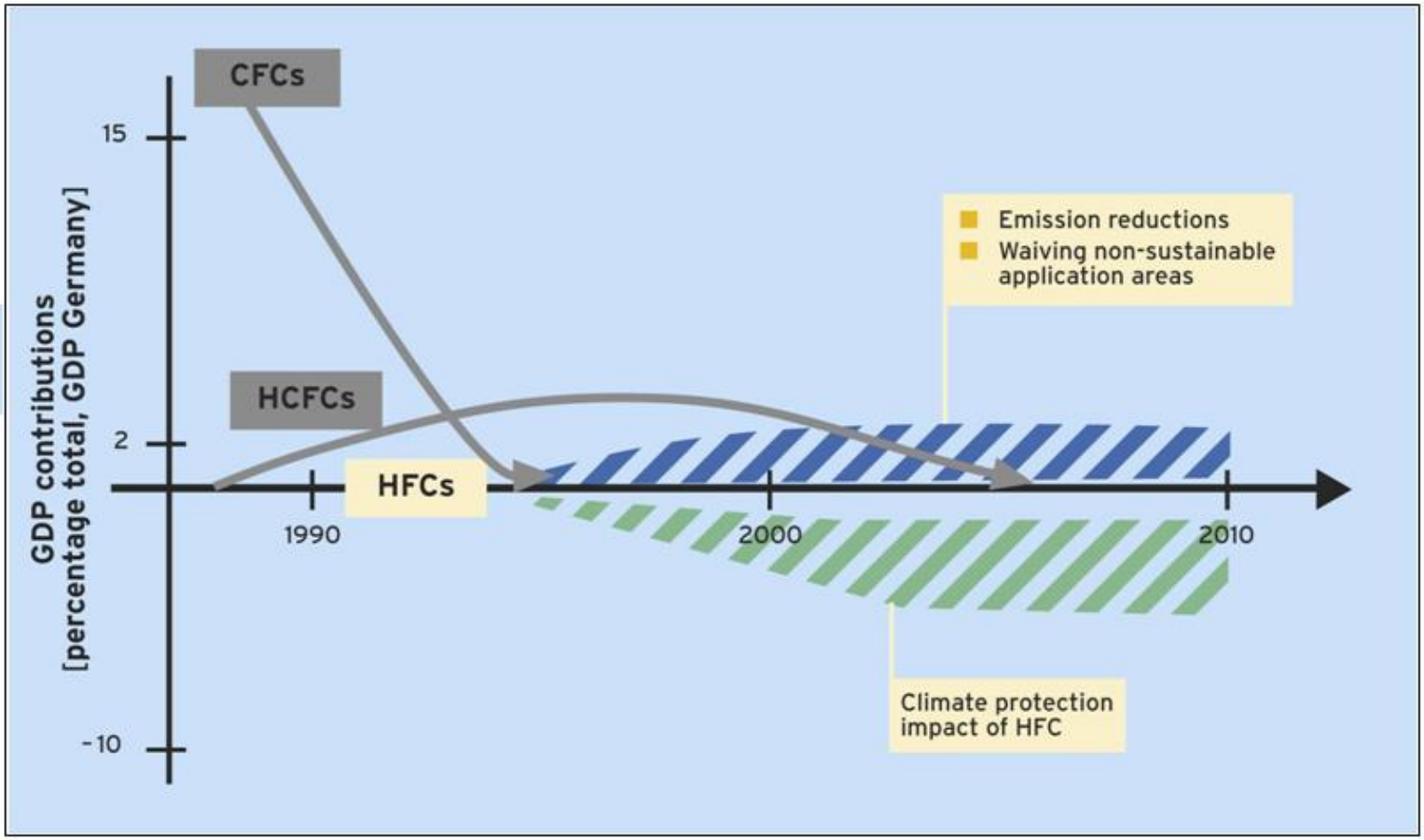
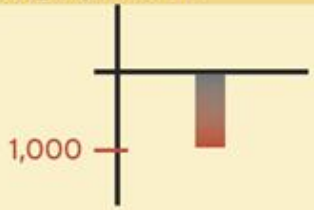
HFCs to Generate Climate Protection Effects



HFC-365mfc to Save on CO_2 Equivalents

Product	**1 kg HFC (SOLKANE® 365mfc)** in insulation products	
Assessment criteria	**Only environmental burdens (here: HFC emissions) considered**	**Climate protection effect ("net") arising from** ■ **Environmental burdens (here: HFC emissions)** ■ **Reductions of environmental effects (here: CO_2 reductions; "gross")**
Environmental effects	Environmental burdens approx. 150 – 750 kg CO_2 equivalent 	 1 kg HFC in polyurethane building thermal insulation saves up to 1,000 kg CO_2 equivalents compared with next best alternative
Political measures	■ **Reduce emissions** ■ **Restrict applications** ■ **HFCs bans**	**Promote specific applications** ■ System prospects/innovations ■ Agreements on emission control ■ Monitoring, waste management

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Summary

- PU insulation of buildings is THE most cost effective way to reduce CO_2 emissions (any insulation technology is better than no insulation)!
- Several application areas will require HFC blowing agents for different reasons (performance, safety, ..)
- Blowing agents are becoming more customized
  - more options to chose from
  - trend towards blends of different blowing agents like S-365mfc/pentane blends ("co-blowing") to optimize cost and performance while minimizing the GWP
- Environmental competitiveness of HFC blowing agents was proven in various LCA and eco-efficiency studies
- Phasing out HCFCs and switching to HFCs or HFC/C5-blends is an appropriate and sustainable ecological as well as economical commitment

WARNING

All statements, information, and data given herein are believed to be accurate and reliable but are presented without guarantee, warranty or responsibility of any kind, express or implied. The user should not assume that all safety measures are indicated, or that other measures may not be required. In any case, the user is not exempt from observing all legal, administrative and regulatory procedures relating to the product, personal hygiene, and protection of human welfare and the environment.

All statements or suggestions concerning the possible uses of HFCs and blends thereof are made without any representations and/or warranties whatsoever that any such use is free of legal constraints.

In particular, the use of Solkane® 365mfc and of blends containing Solkane® 365mfc might fall within the scope of European Patent 381 986 and its counterparts. Solvay has acquired certain rights from Bayer under these patents, according to which Bayer has agreed not to assert any of such patent rights against any purchaser of Solkane® 365mfc and blends containing Solkane® 365mfc from Solvay for use as foam blowing agent outside the USA and Canada.

The following must be noted regarding the USA and Canada: (1) Solkane® 365mfc cannot be used in the USA or Canada, by itself or in a blend, as a blowing agent to foam a plastic based on an isocyanate to form plastic foam compositions; (2) Solkane® 365mfc and blends containing Solkane® 365mfc must not be made, used, offered for sale, or sold in the USA or Canada, or imported into the USA or Canada, for such blowing uses; and (3) closed cell plastic foam compositions prepared by foaming a plastic material based on isocyanate in the presence of a propellant comprising Solkane® 365mfc and/or a blend containing Solkane® 365mfc, cannot be made, used, offered for sale, or sold, within the USA or Canada, or imported into the USA or Canada. To do so can result in a claim of patent infringement under U.S. patent no. 5,496,866 and Canadian patent no. 2,009,169. Solvay will not sell Solkane® 365mfc or blends containing Solkane® 365mfc to any purchaser intending to use the product accordingly.