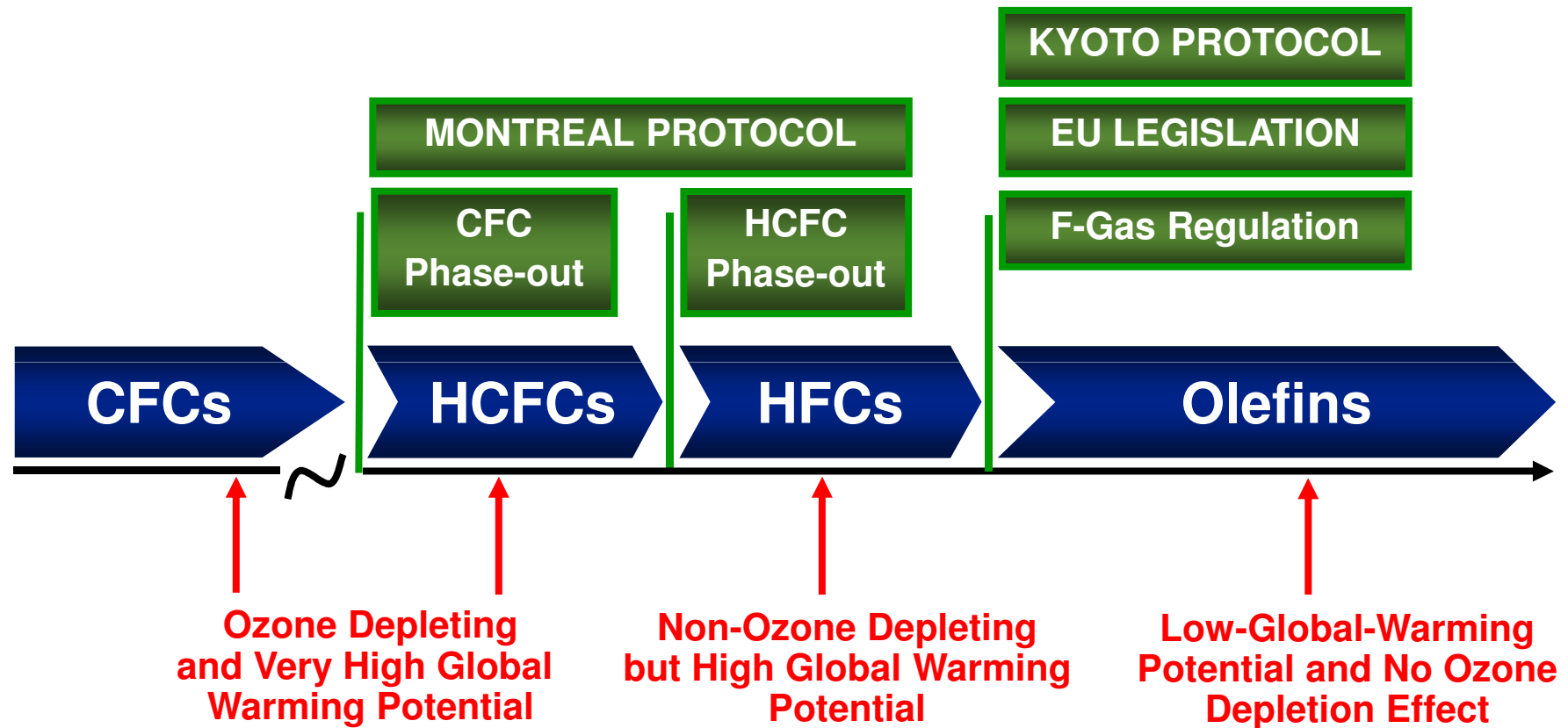




Enovate™ (HFC-245fa) Blowing Agent
Solstice™ Liquid Blowing Agent
Solstice™ Gaseous Blowing Agent
Technical Update

Honeywell

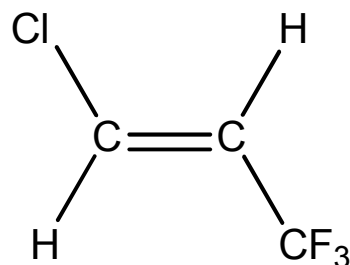
Honeywell – a History of Innovation



Innovating to enable industries' compliance

Solstice Liquid Blowing Agent: 1233zd(E)

- (E) 1-chloro-3,3,3-trifluoropropene
- (E) $\text{CHCl}=\text{CH}-\text{CF}_3$
- Trans or E (*entgegen*) isomer



Short Life = Ultra Low Environmental Impact

Physical Properties

	Solstice LBA	141b	Enovate
Mol. Wt.	130	117	134
Boiling Point, °C	19	32	15
Flame Limits, % by volume in air	None	7.6-17.7	None
Flash Point	None	None	None

Environmental Properties

	Solstice LBA	141b	Enovate
Atmospheric Life	26 days	9.3 yr	7.6 years
ODP	~0*	0.11	~ 0*
GWP ₁₀₀	< 7	725	1030
VOC, USA reg	No (est.)	No	No
Toxicity / OEL	300ppm**	500ppm	300ppm

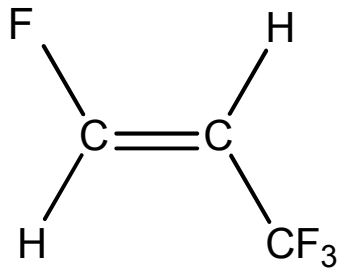
*No impact on depletion of ozone layer and is commonly referred to as zero (0)
(Wuebbles, Private Communication)

** Internal HON OEL

Solstice LBA: Short Lifetime in Atmosphere → Ultra Low Environmental Impact

Solstice Gas Blowing Agent: 1234ze(E)

- (E) 1,3,3,3-trifluoropropene
- (E) CHF=CHCF₃
- Trans or E (*entgegen*) isomer



Short Life = Ultra Low Environmental Impact

Physical Properties

	Solstice GBA	134a
Mol. Wt.	114.0	102.0
Boiling Point	-19°C (-3°F)	-26°C (-15°F)
Flame Limits	None	None
Flash Point	None	None

Environmental Properties

	Solstice GBA	134a
Atmospheric Life	14 days	7.6 years
ODP	~0*	~ 0*
GWP ₁₀₀	< 6	1030
VOC	No (est.)	No
Toxicity / OEL	1000ppm**	300ppm

*No impact on depletion of ozone layer and is commonly referred to as zero (0)
(Wuebbles, Private Communication)

** Internal HON OEL

Solstice GBA: Short Lifetime in Atmosphere → Ultra Low Environmental Impact



Appliance Foam Evaluations

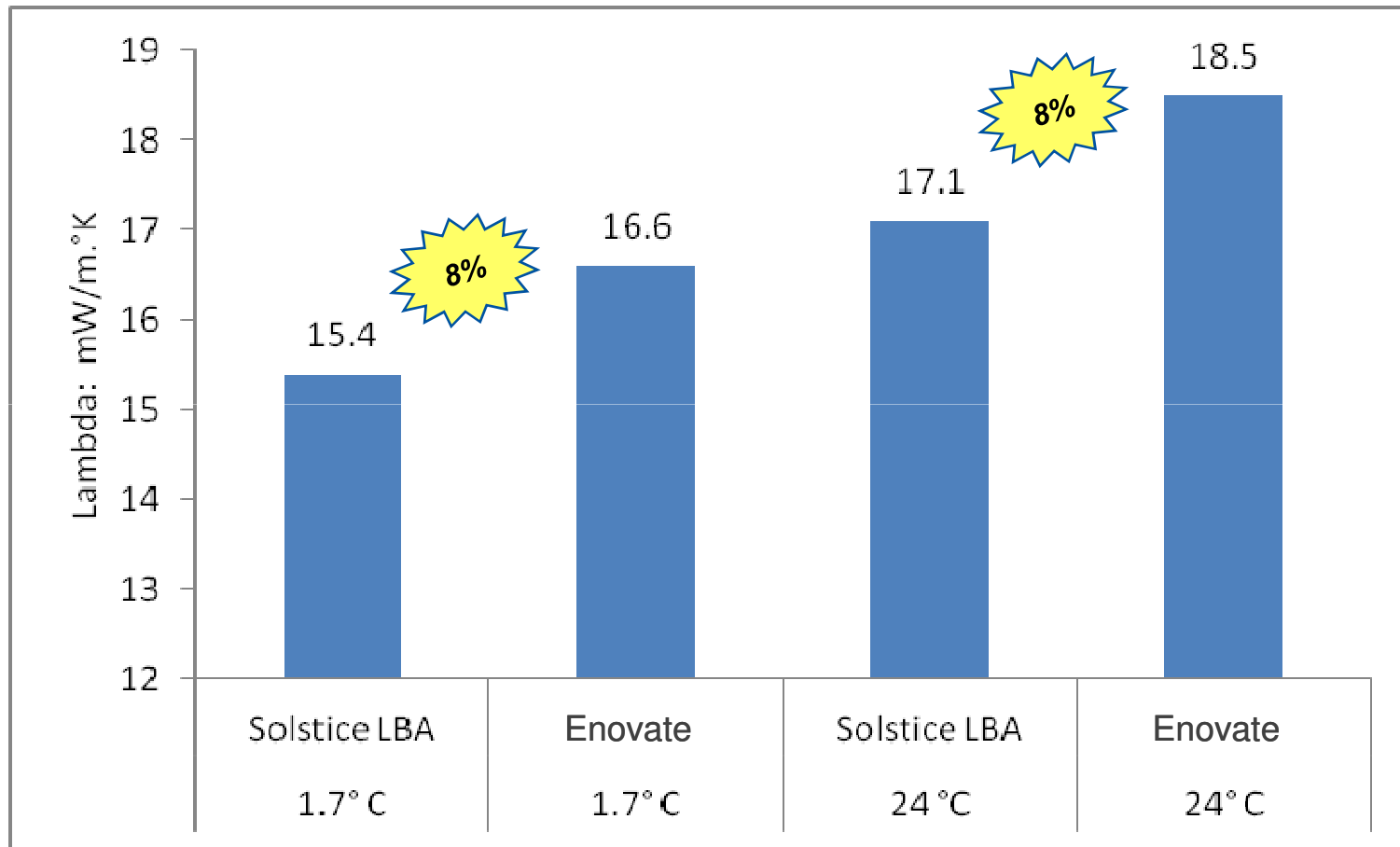
Honeywell

Commercial Appliance Trial Results

- Trial run with major global OEM and major global systems house
 - Commercially manufactured household refrigerator
 - 32 complete units
 - Conventional foam equipment, existing in the factory
 - No modifications to the process or equipment
- Solstice LBA processed very similarly to Enovate (245fa)
 - Comparable in all aspects to world scale processing parameters
 - Foam density: nearly identical
 - Minimum fill weights: nearly identical
 - Demold time: equal / improved
 - HIPS Liner compatibility excellent even after 2 years

Solstice LBA processes similar to Enovate in refrigerator/freezer applications

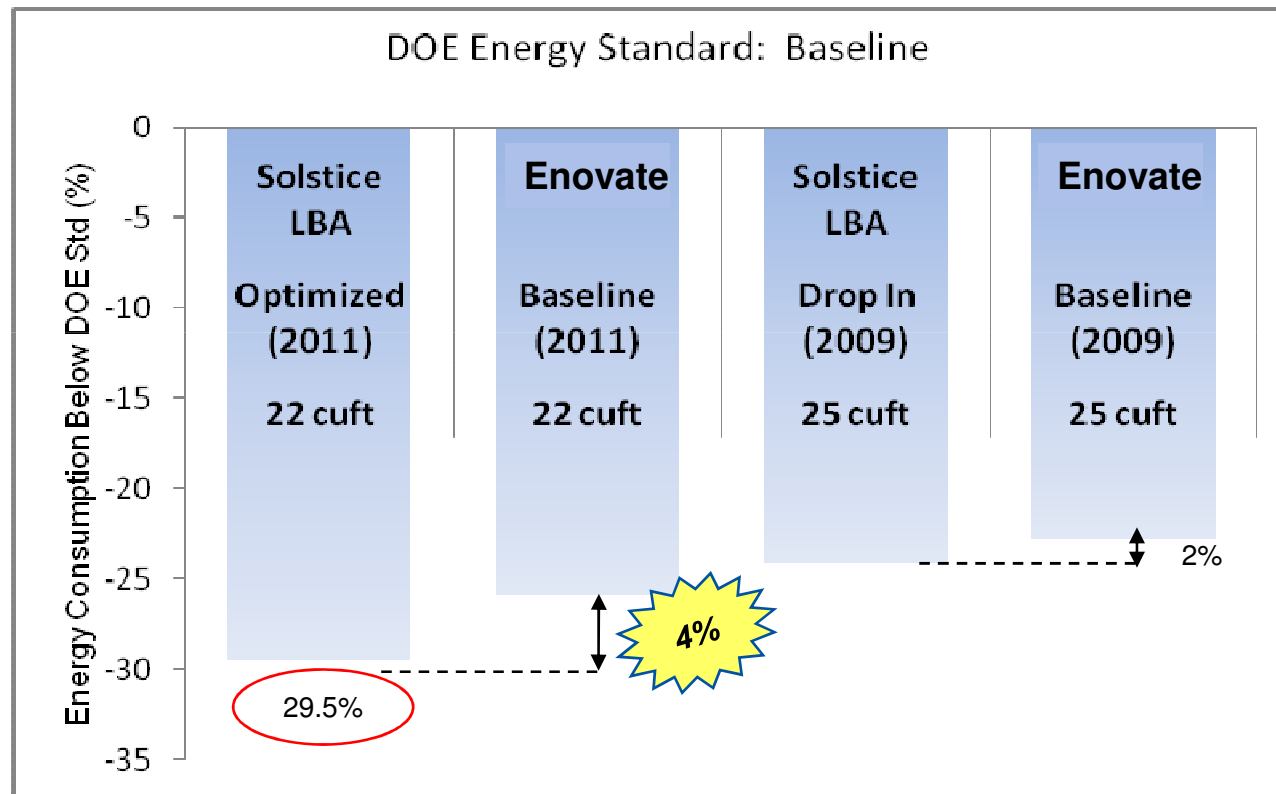
Solstice LBA PUR Cabinet Lambda Data



Solstice LBA optimized: 8% improvement over Enovate baseline

DOE Energy Performance Assessment

- DOE Energy Test Method
- Sets of 5 refrigerators: Solstice LBA and Enovate Blowing Agent baseline

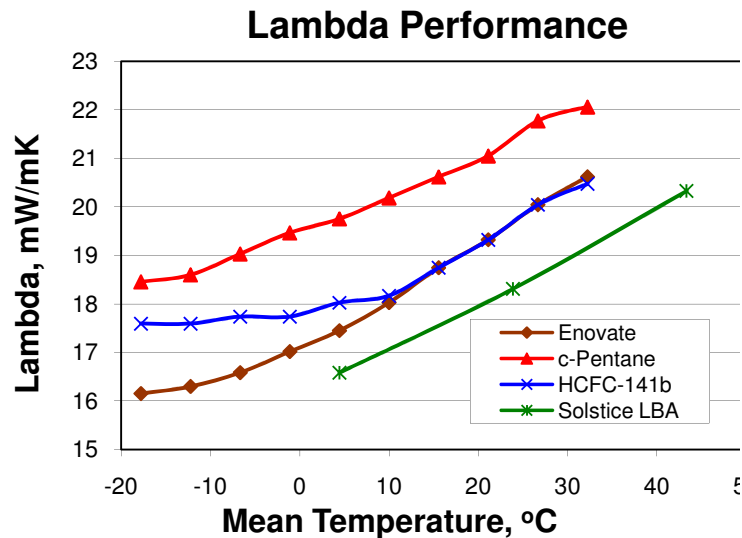


Solstice LBA Refrigerators: DOE Standard minus 29.5% Energy Rating
Solstice LBA Refrigerators: 4% system energy improvement over baseline Enovate

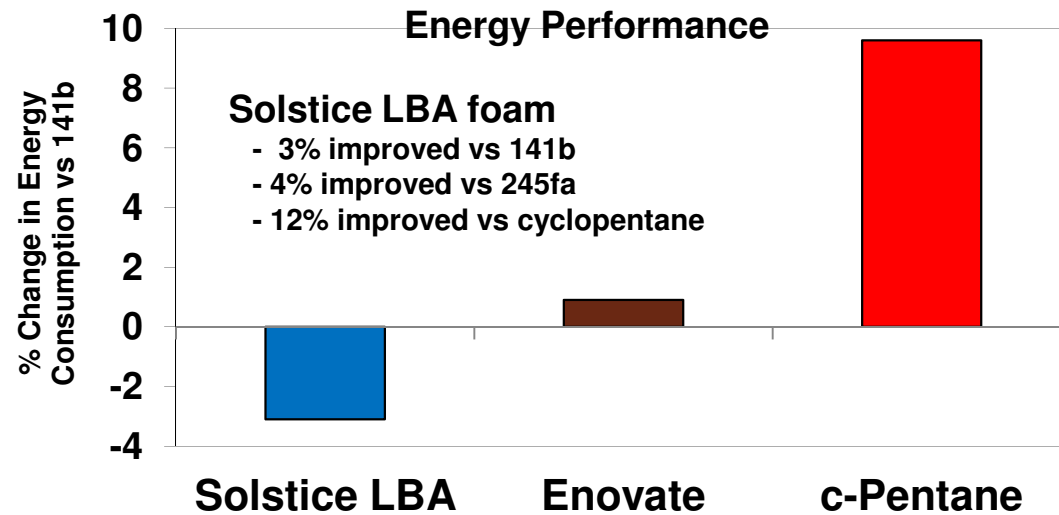
Solstice LBA versus 141b

Foam performance of Solstice LBA

- Polyol miscibility equal to 141b, improved compared to Enovate Blowing Agent
- Similar strength properties to Enovate, improved compared to 141b at equal density
- Improved k-factor than Enovate foams
- Improved k-factor compared to c-pentane foams



Source: AHAM 3rd Gen BA study plus Hon data on Solstice LBA



Lambda and Energy Performance Superior to 141b, CP, and Enovate

Blowing Agents Comparison

	HCFC 141b	Hydro Carbons	Enovate Blowing Agent	Solstice LBA	
Performance	Energy Efficiency	●	●	●	In-Place λ (mW/mK @ 24°C) • 141b 17 • c-pentane 20-21 • Enovate 18-19 • Solstice 17-18
	Adoption Capital/ Ease	●	●	●	
	Lower Cost/Unit	●	●	●	
Cost effective	Global Warming Impact (Direct)	●	●	●	Solstice LBA Best Overall Solution
	Ozone Depletion Impact	●	●	●	
	Volatile Organics	●	●	●	
Environment	Flammability	●	●	●	
	Toxicity	●	●	●	
Safety					

Solstice LBA: application economics, most efficient & environmentally-superior

* Specifics will vary by energy efficiency standards and type of refrigerator



Spray Foam Evaluations

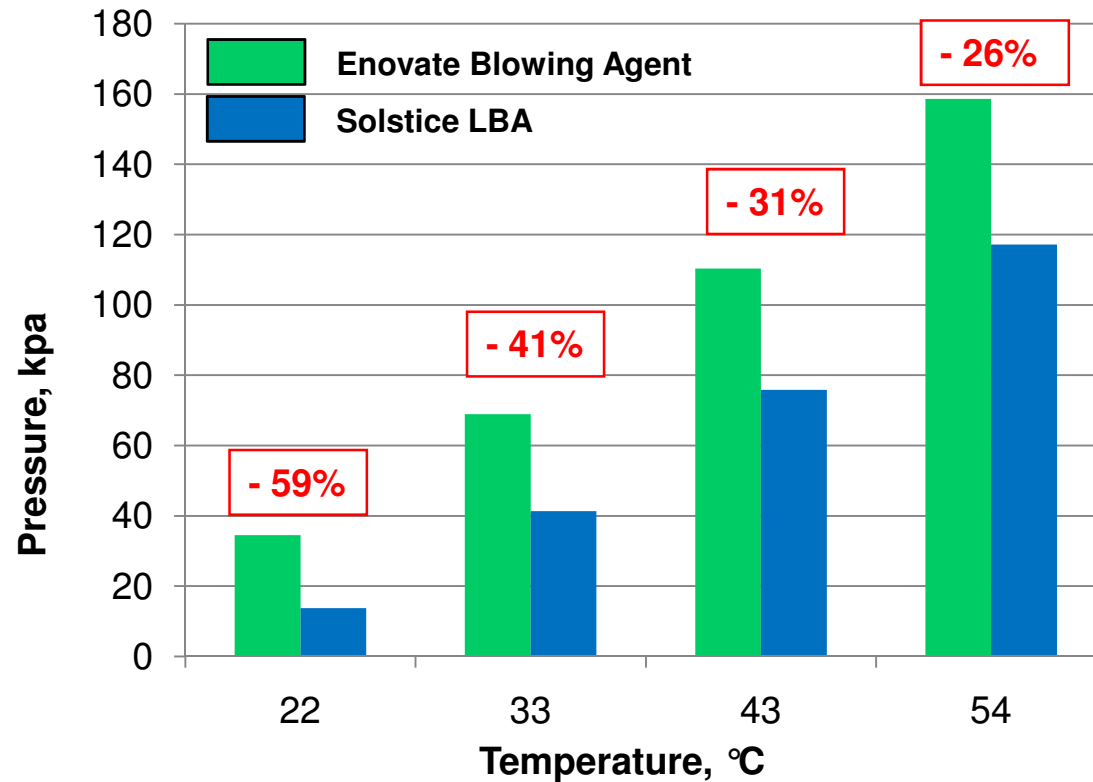
Honeywell

Spray Trial Formulation

Components	Enovate php	Solstice LBA php
Mannich polyether polyol	40.0	40.0
Aromatic polyester polyol	60.0	60.0
Silicone Surfactant	2.0	2.0
Amine catalysts	2.0	2.0
Metal catalysts	4.1	4.1
Flame retardant	20.0	20.0
Water	2.0	2.0
Enovate Blowing Agent	20.0	-
Solstice LBA	-	Equal molar
Index	130	130

Solstice LBA used in existing generic industry formulation

Formulation Properties - Vapor Pressure



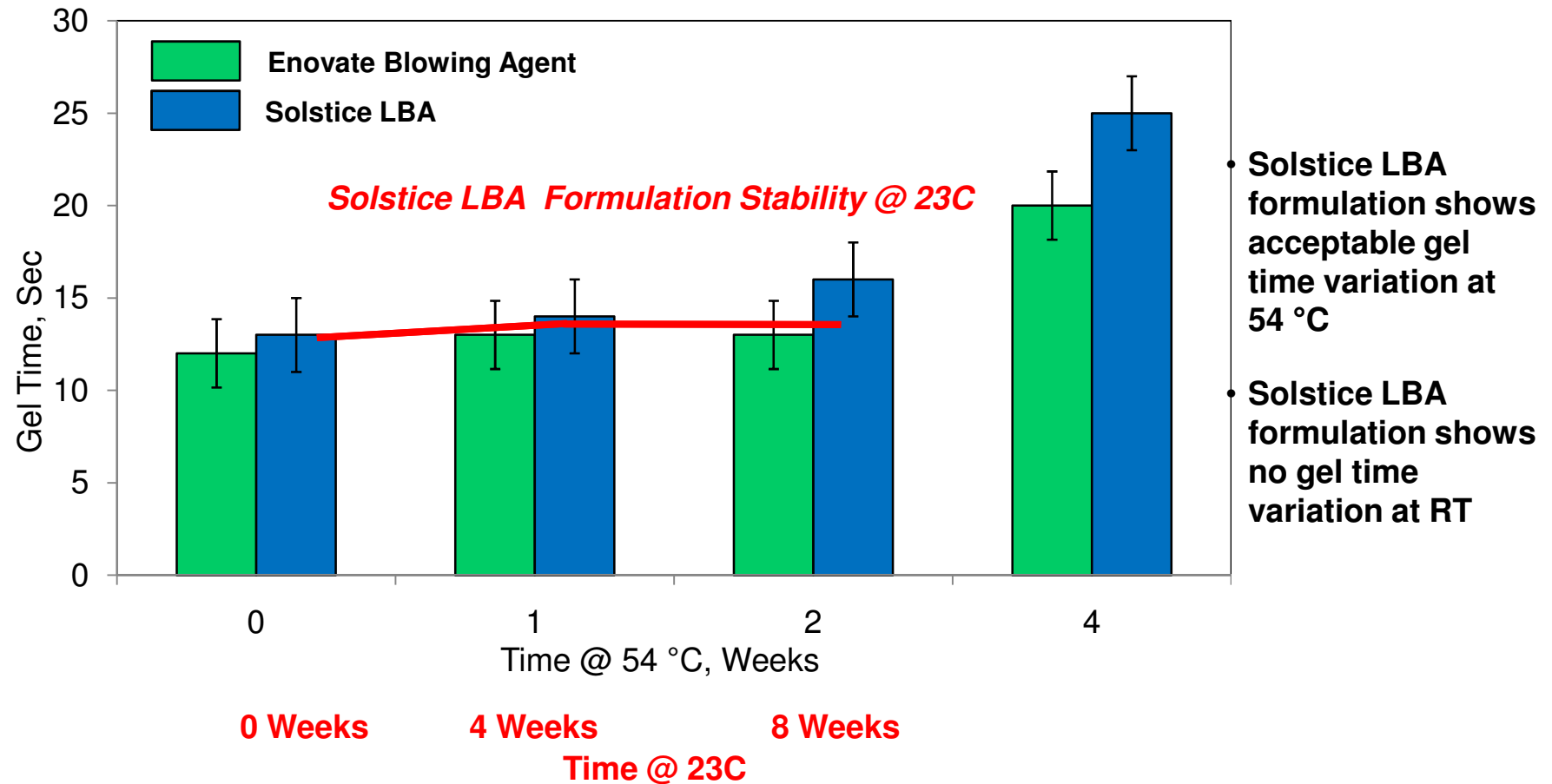
Lower Vapor Pressure Means:

- Less potential for bulging drums
- Potential to use lower gauge drums
- Less potential for blowing agent loss from system

Solstice LBA formulation has significantly lower vapour pressure at all temperatures

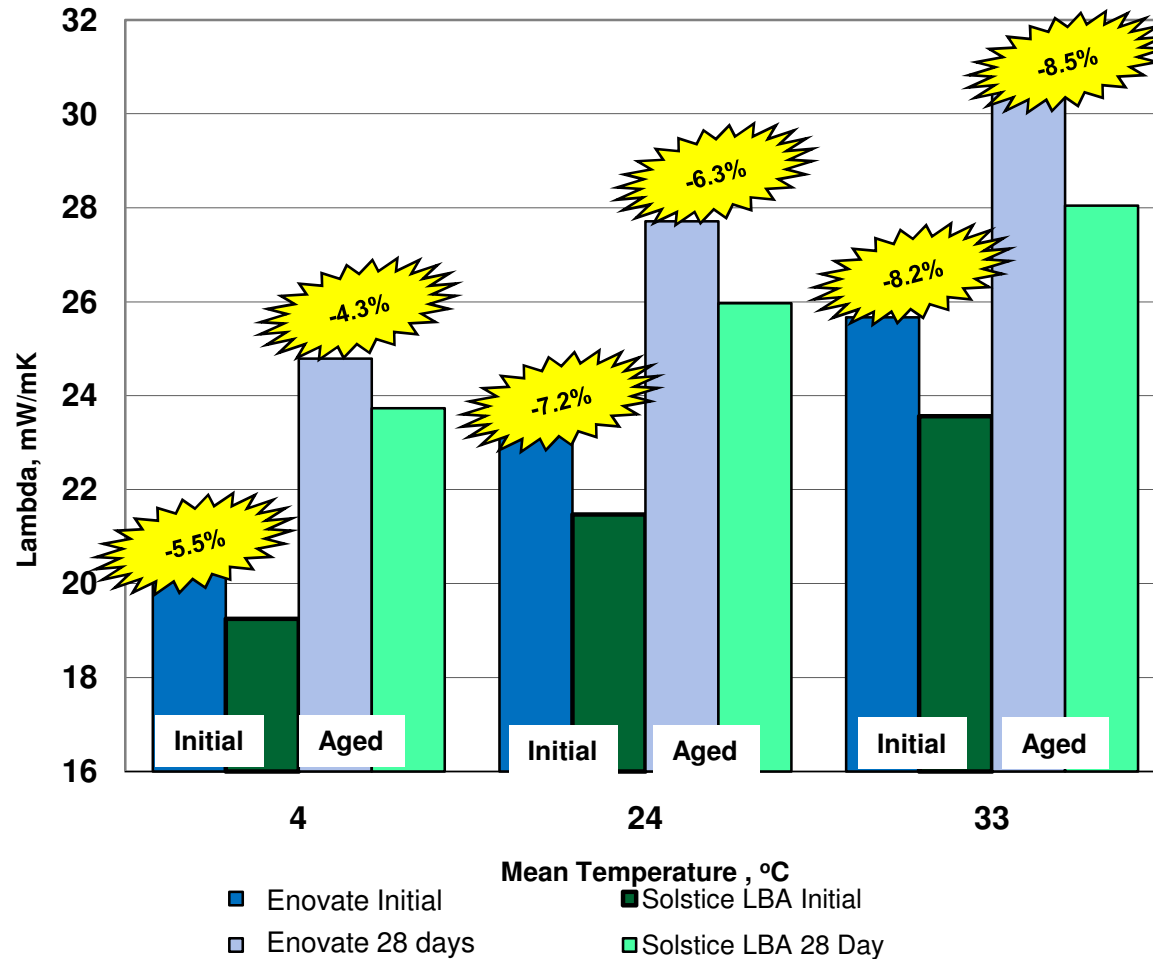
Formulation Properties - Stability

Solstice LBA Formulation Stability @ 54 °C



Solstice LBA formulation has acceptable stability

Lambda of Foam Sprayed @ 25 °C Room Temperature



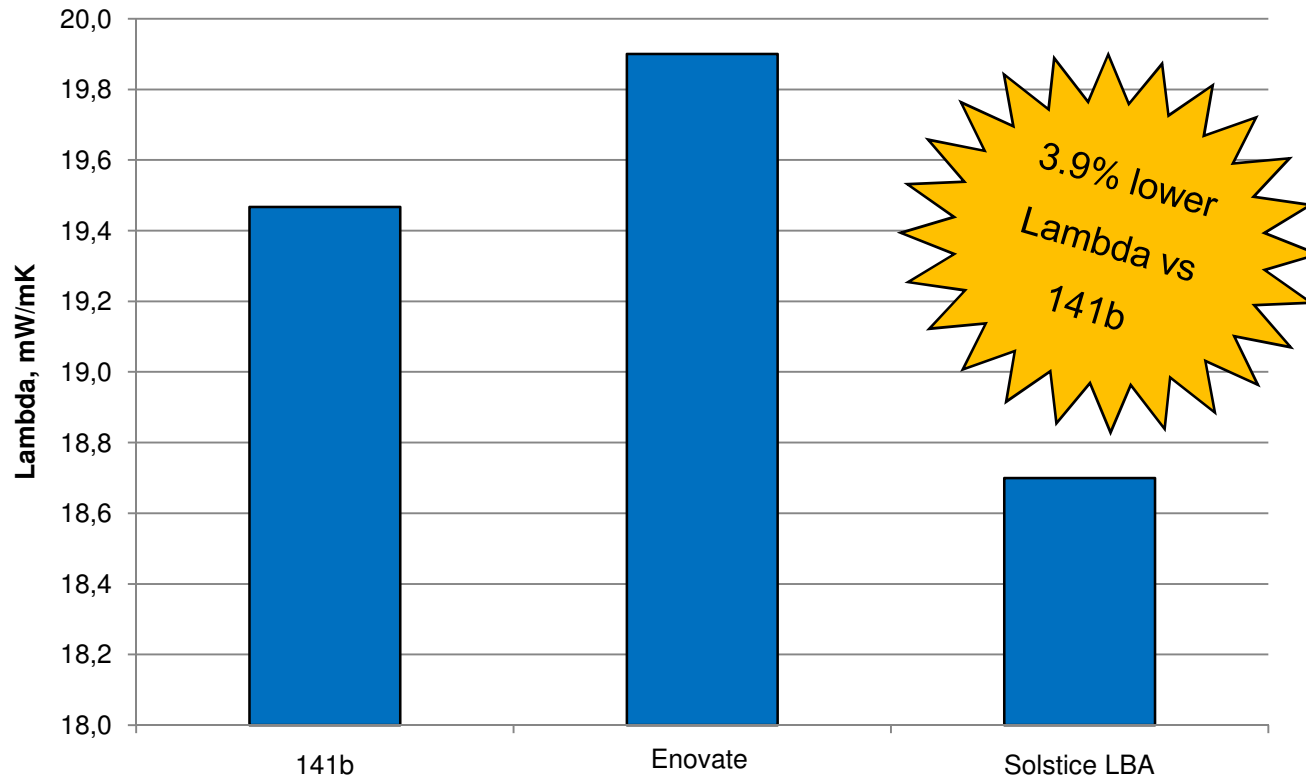
- **Initial lambda**
 - Solstice LBA 5 to 8% lower than Enovate
- **Aged lambda**
 - Solstice LBA 4 to 8% lower than Enovate



Solstice LBA produces spray with improved lambda vs Enovate

Solstice LBS Versus 141b in Spray Foam

Initial Thermal Conductivity



Solstice LBA shows superior performance to 141b and Enovate Blowing Agent



Panel Foam Evaluations

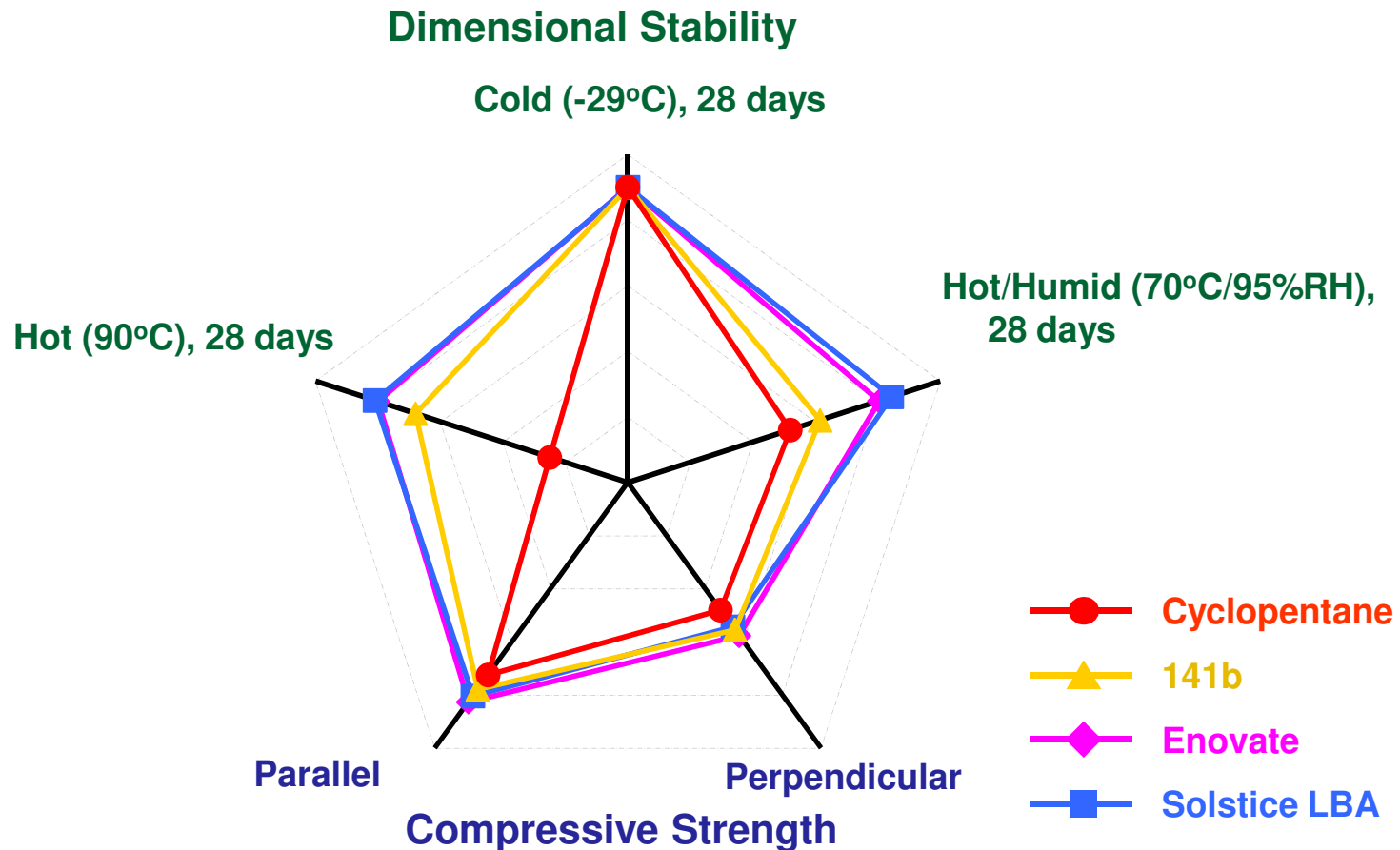
Honeywell

Chinese Generic Discontinuous Panel Formulations

Polyol Blend (B-side)				
Components (php)	Solstice LBA	Enovate	cyclopentane	141b
Polyether Polyol	65.0			
Polyester Polyol	35.0			
Catalyst	2.0			
Surfactant	1.5			
Flame Retardant	22.0			
Water	2.0			
Blowing Agent	23.3	24.0	12.5	21.0
Isocyanate (A-side)				
PMDI	143.6			

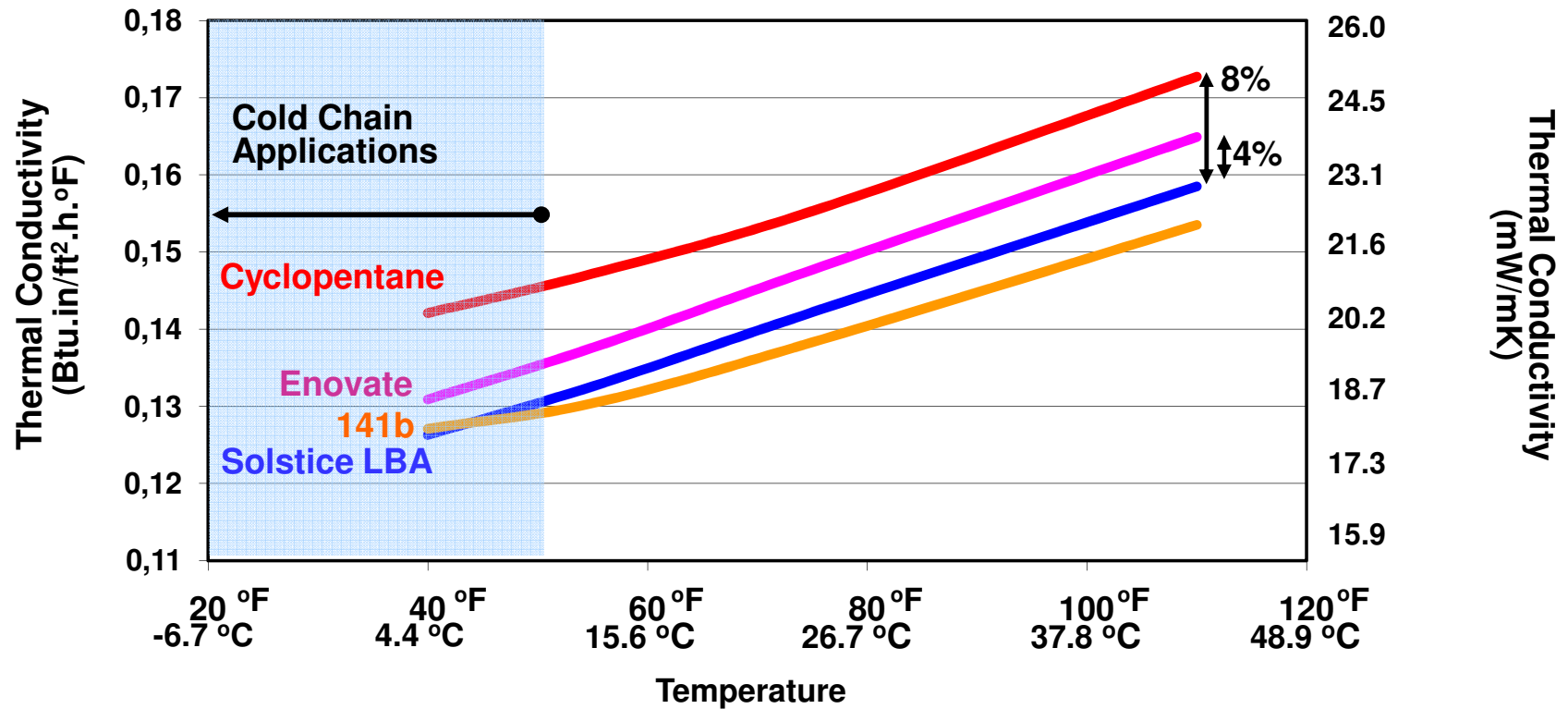
A Blowing Agent “Drop-in” Replacement Study was Conducted

Comparison of Physical Properties



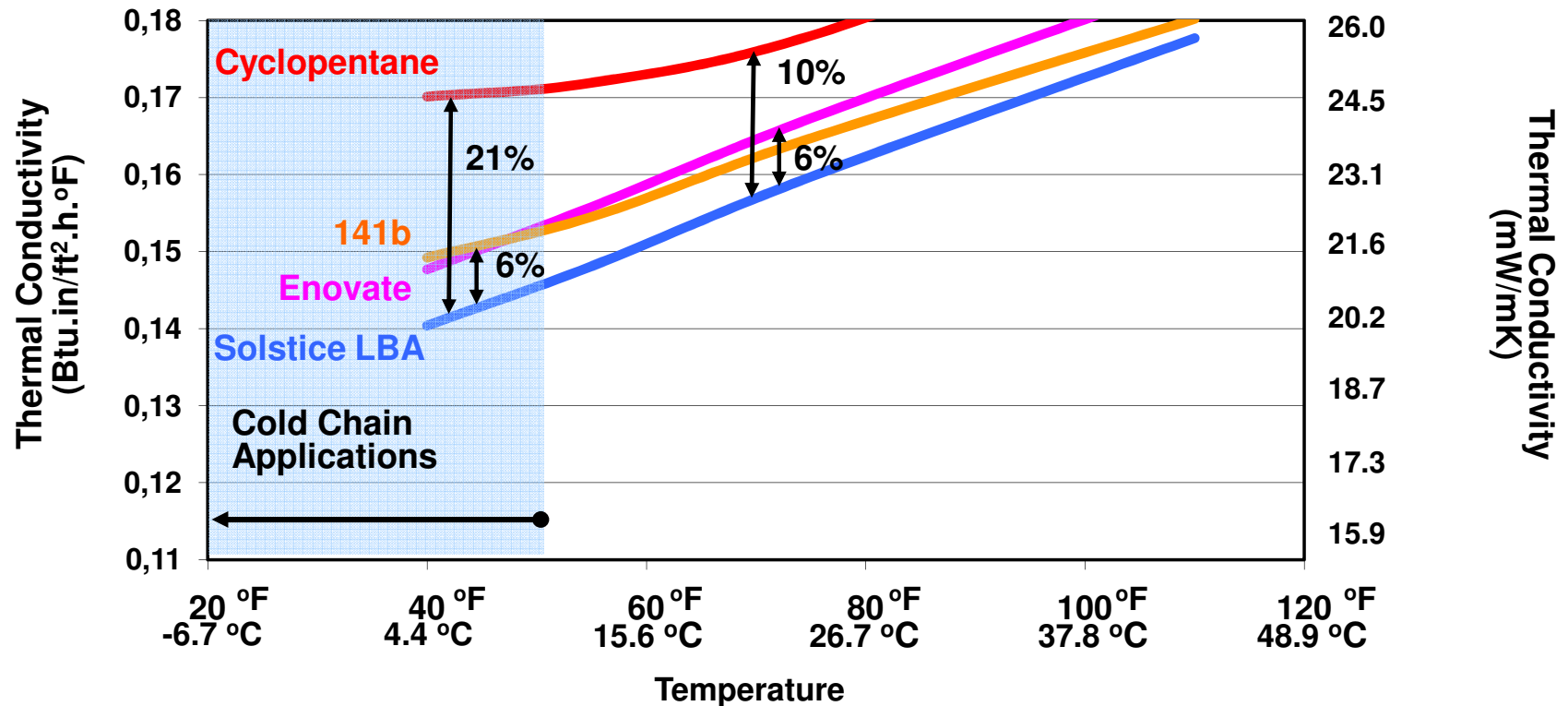
Comparable Properties to Enovate, Better Properties than Cyclopentane

Initial Thermal Conductivity



Best Thermal Insulation Performance for Cold Chain Applications

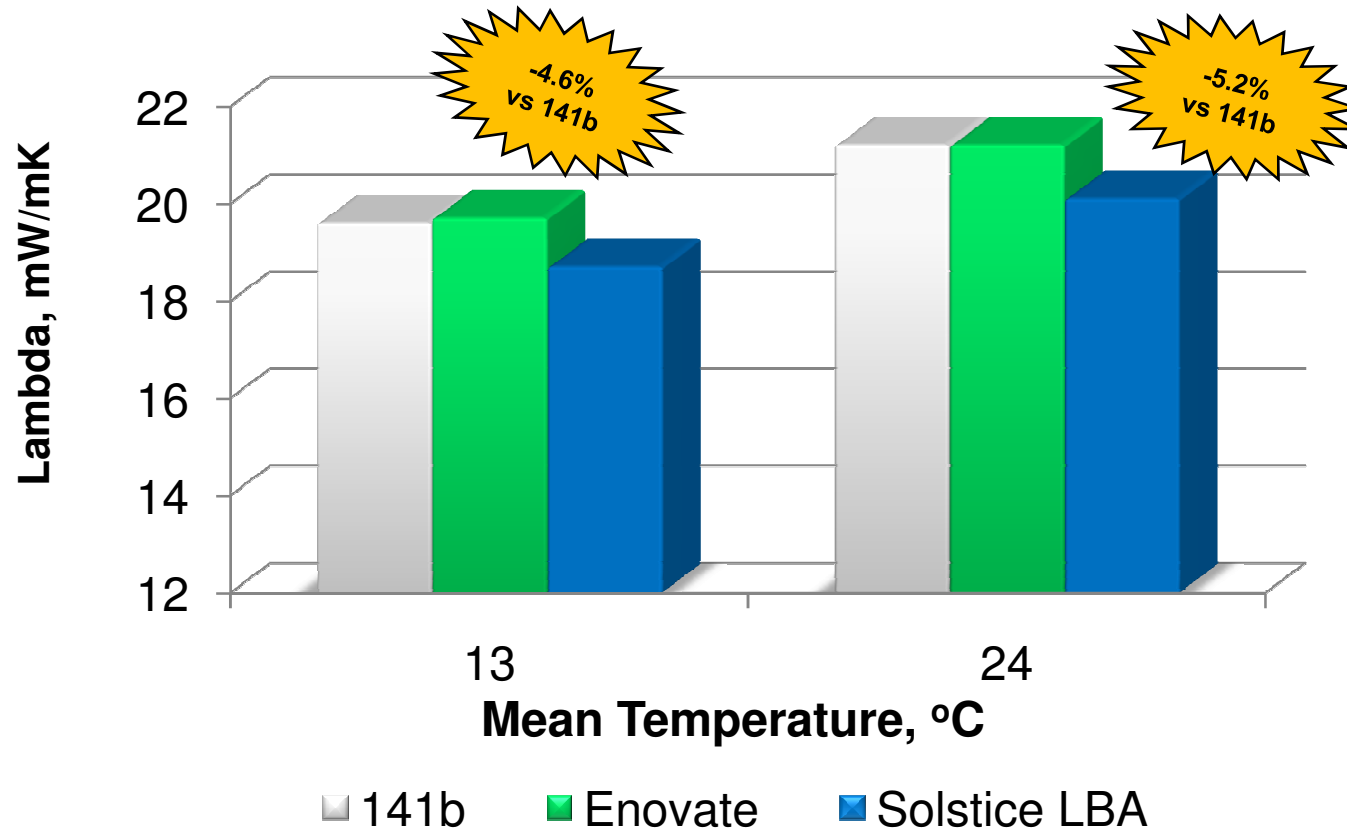
28 Day Aged Thermal Conductivity



Best Thermal Insulation Retention at All Evaluated Temperatures

Solstice LBA in Panel Foam

Initial Thermal Conductivity Vs Temperature



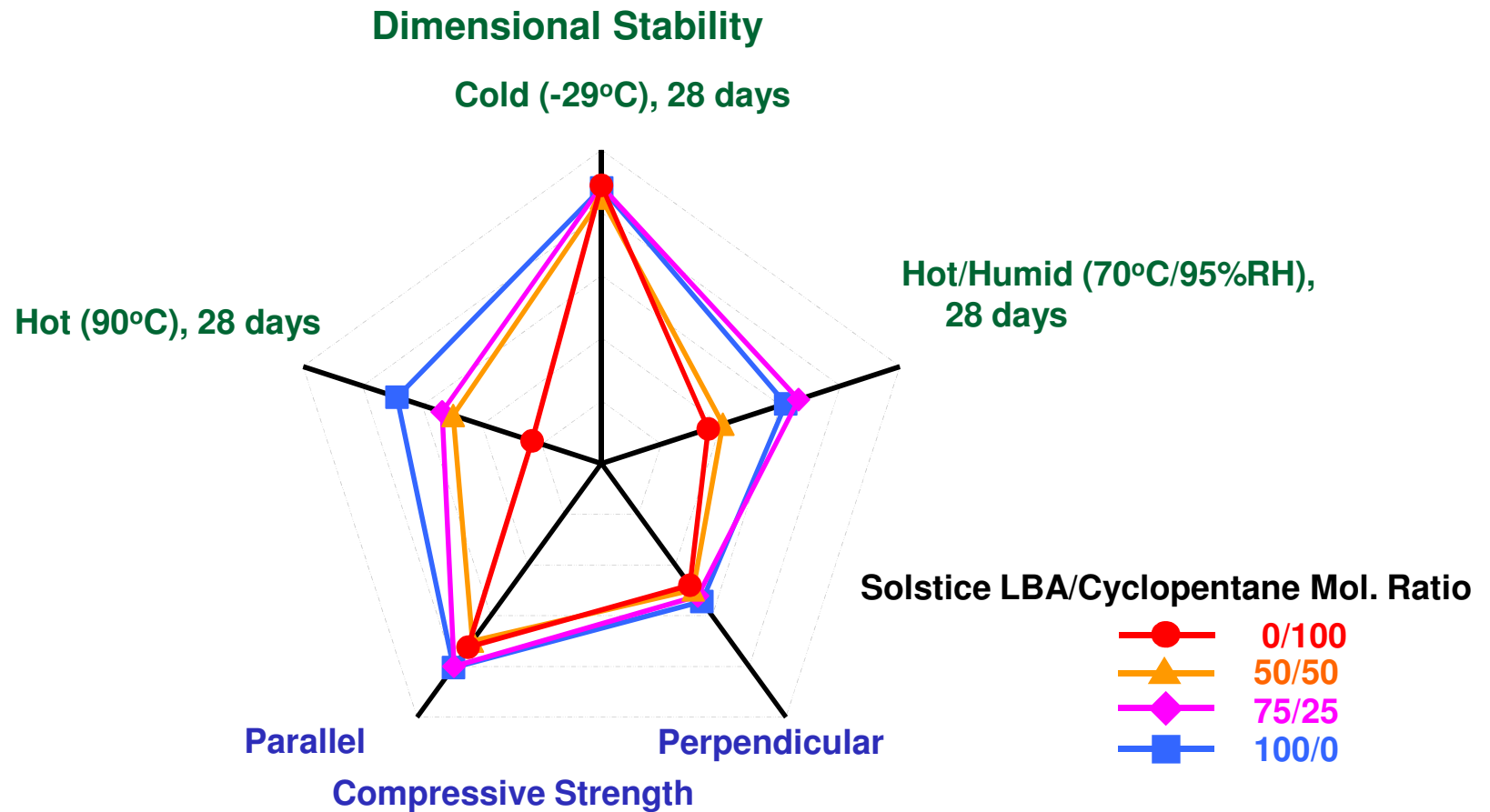
HBA-2 shows superior performance to 141b and Enovate



Solstice LBA / Cyclopentane Blends

Honeywell

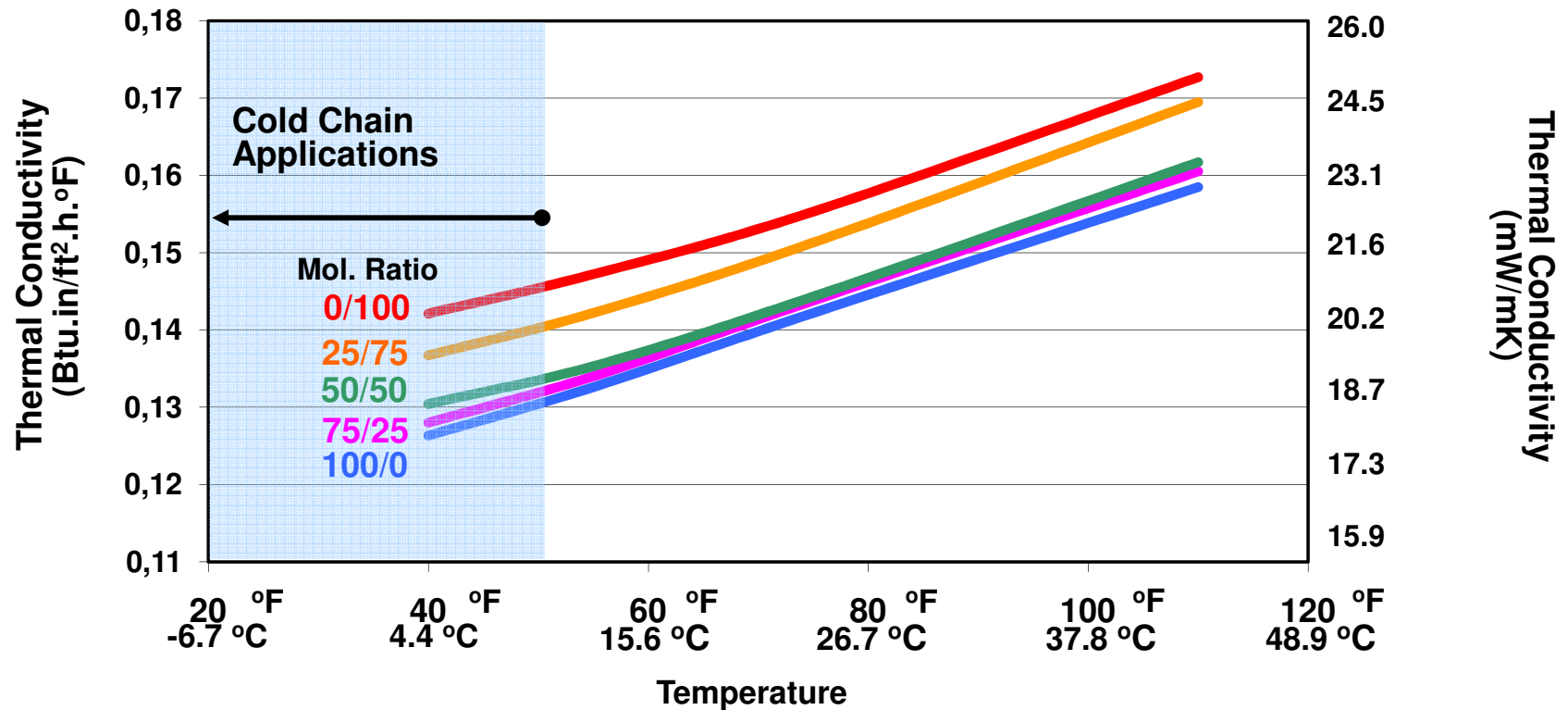
Comparison of Physical Properties



Solstice GBA/C-C5 Blend: Balanced Solution for Cost and Physical Properties

Initial Thermal Conductivity

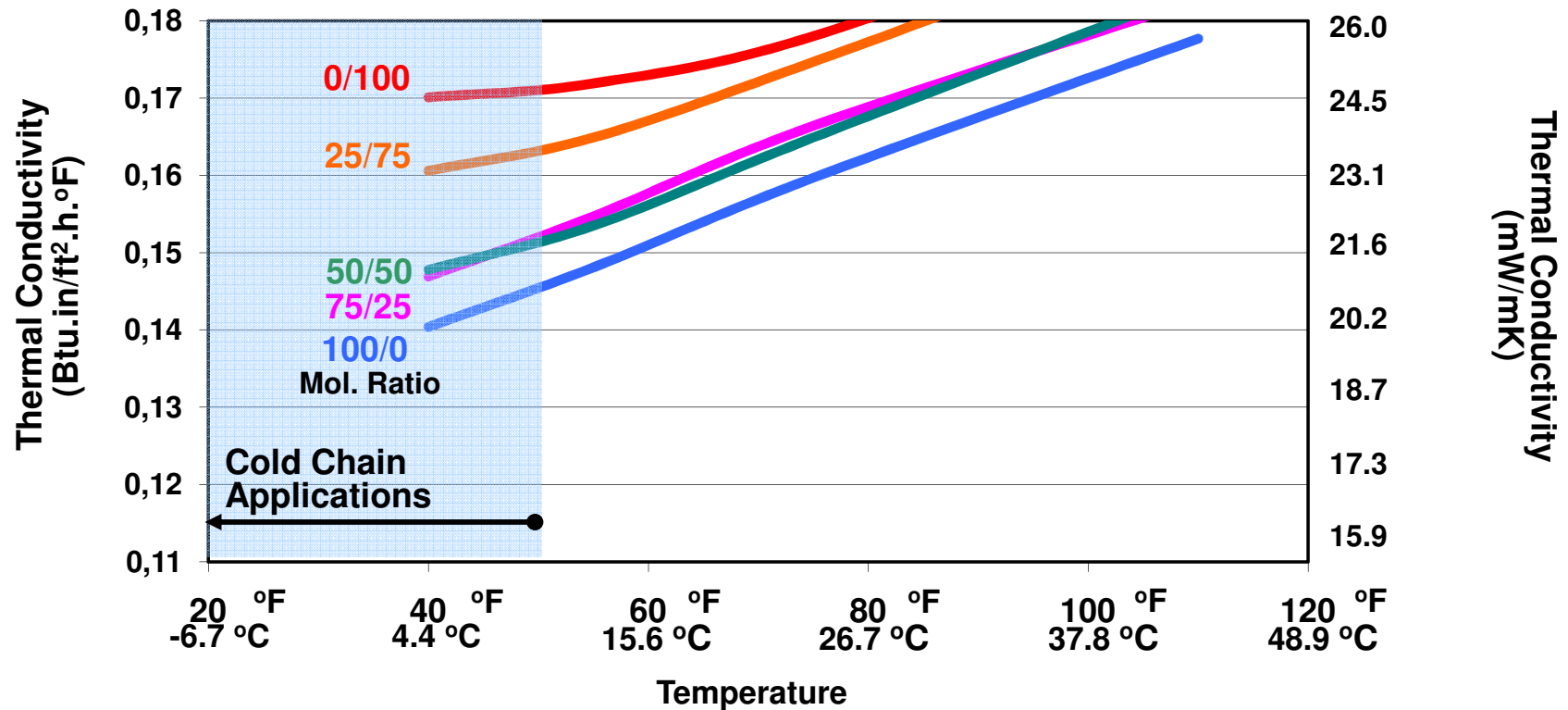
Solstice LBA/Cyclopentane Blends



Solstice LBA/Cyclopentane Blend: Balanced Solution of Cost and k-factors

28 Day Aged Thermal Conductivity

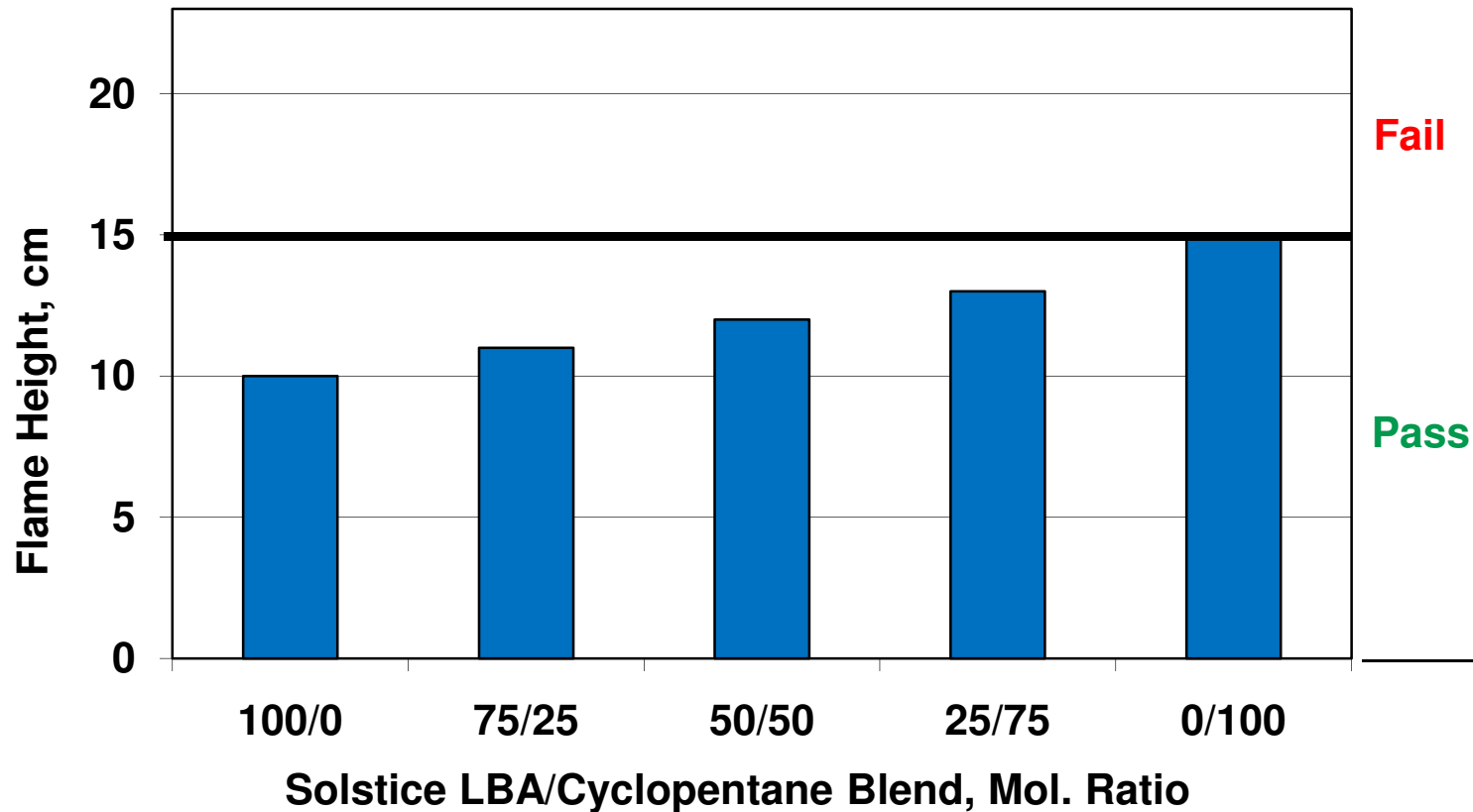
Solstice LBA/Cyclopentane Blends



Addition of Solstice LBA Enhanced Thermal Insulation Retention

Foam Flammability Evaluations

DIN 4102-1:Class B2



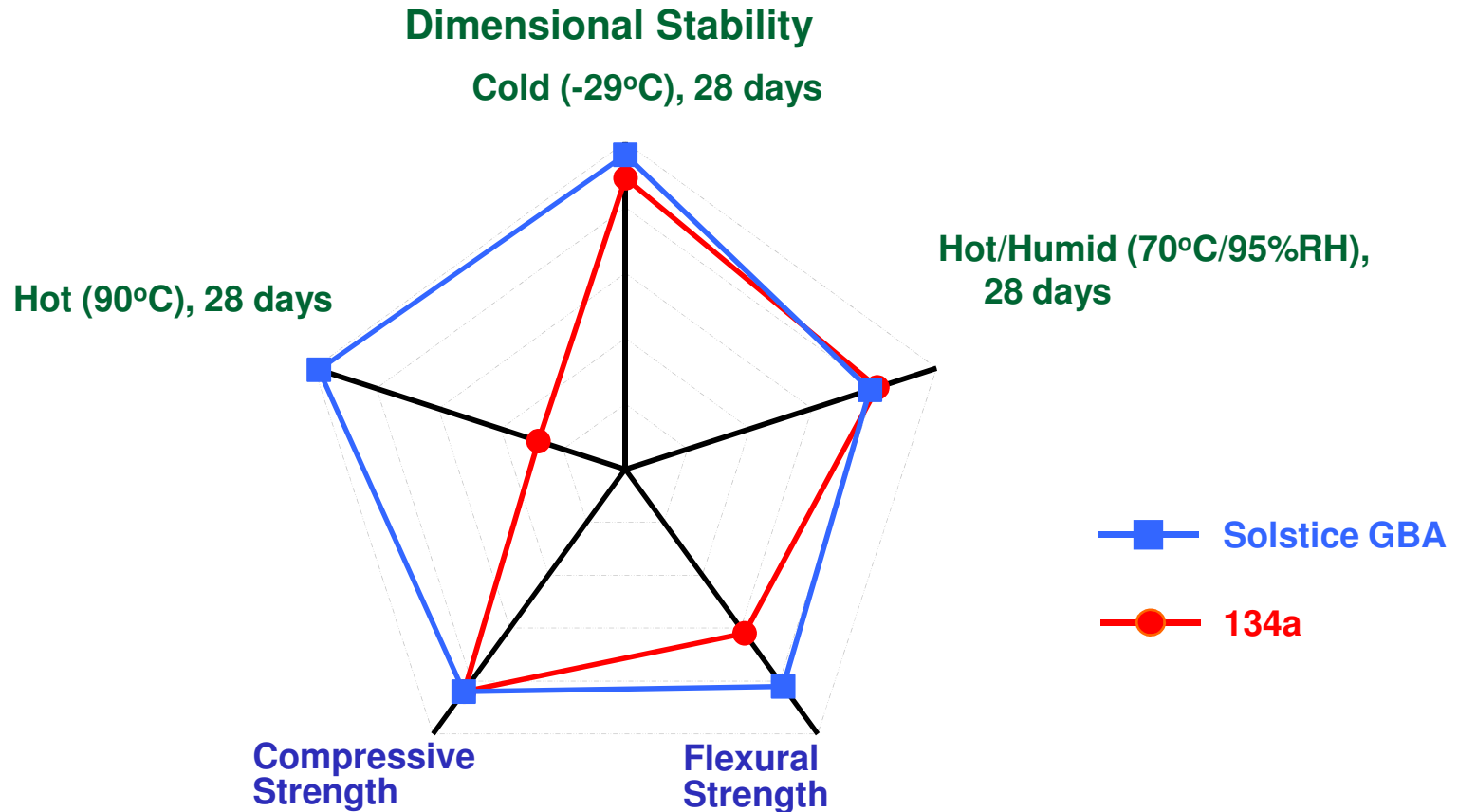
Solstice LBA: Enhanced Foam Fire Retardancy



Gas Blowing Agent Evaluations Solstice GBA in Panel Applications

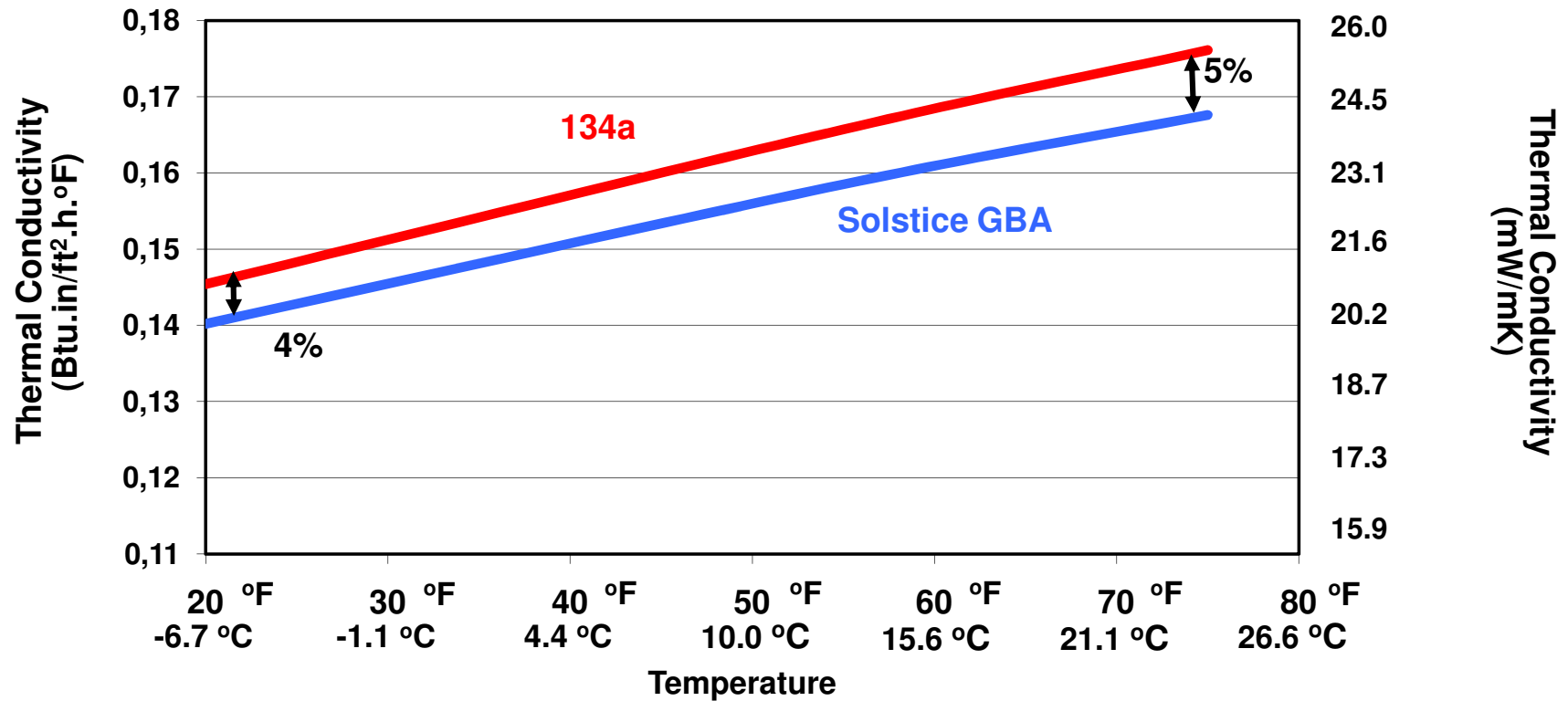
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Comparison of Physical Properties



Solstice GBA: Similar Physical Properties to 134a in Commercial Formulation

Initial Thermal Conductivity



Solstice GBA: 4% - 5% Better Thermal Insulation Value

Toxicity / Registration / Commercialization Status

Solstice LBA

- Toxicity – nearly complete
- Global Registrations
 - U.S.: SNAP / PMN applications filed with U.S. EPA → under review
 - EU: REACH registration in-process
 - Current REACH registration to 10 tonnes
 - Japan: Registration complete → commercial sales can commence
 - Japan Chemical Substances Control Law
 - ROW Registrations to meet regional commercialization needs
 - Solstice LBA registration complete: Mexico and India
- Commercialization
 - Semi-commercial – late 2012
 - Commercial - 2013

Solstice GBA

- Toxicity – Complete
- Global Registrations
 - U.S.: SNAP / PMN approvals complete – commercial sales can commence
 - EU: REACH registration process underway
 - Current REACH registration to 10 tonnes
 - Japan: Registration complete → commercial sales can commence
 - Japan Chemical Substances Control Law
 - ROW Registrations to meet regional commercialization needs
 - Solstice LBA registration complete: Mexico and India
- Commercialization
 - Semi-commercial - NOW
 - Commercial - 2013

Low environmental impact solutions will meet regulatory needs timing

Conclusions

- **A environmentally sustainable and safe product**
 - Low GWP: Solstice GBA is < 6; Solstice LBA is < 7
 - Both are not flammable
- **In foams, both molecules perform better than third generation benchmarks**
 - Solstice GBA
 - 5% better thermal conductivity than 134a
 - Comparable physical properties
 - Solstice LBA
 - Lowest thermal conductivity and best thermal insulation retention
 - Comparable dimensional stability to Enovate and better than cyclopentane
- **Solstice LBA/Cyclopentane Blend**
 - A solution for formulation flexibility, but the blowing agent blend is most likely flammable
- **Commercialization Status**
 - Solstice GBA is commercialized, Solstice LBA will be commercialized in late 2012

Solstice LBA or GBA: The Best Choices for Panel Foams



Enovate™ blowing agent HFC-245fa blending solutions

Shanghai Lab

Honeywell

Technical development background

- **China updated energy efficiency standards,**
 - China appliance OEMs to face technical limits with CP system
- **245fa/CP technology is becoming a major solution for China appliance industry**
- **245fa/CP technology provides an optimal combination of performance and cost**
- **Honeywell is the leader in 245fa/CP blend development and has IP for 245fa/CP application**
- **Honeywell has comprehensive technology solution for 245fa/CP application**
 - Strong development capability
 - Good relationship with system house and equipment supplier
 - Offers refrigerator OEMs with tailor made solution for 245fa/CP blend technology
 - Offers excellent service

Honeywell is the leadership for 245fa application

Boiling point of 245fa/CP blend

- 245fa/CP is an Azeotrope-like Blend

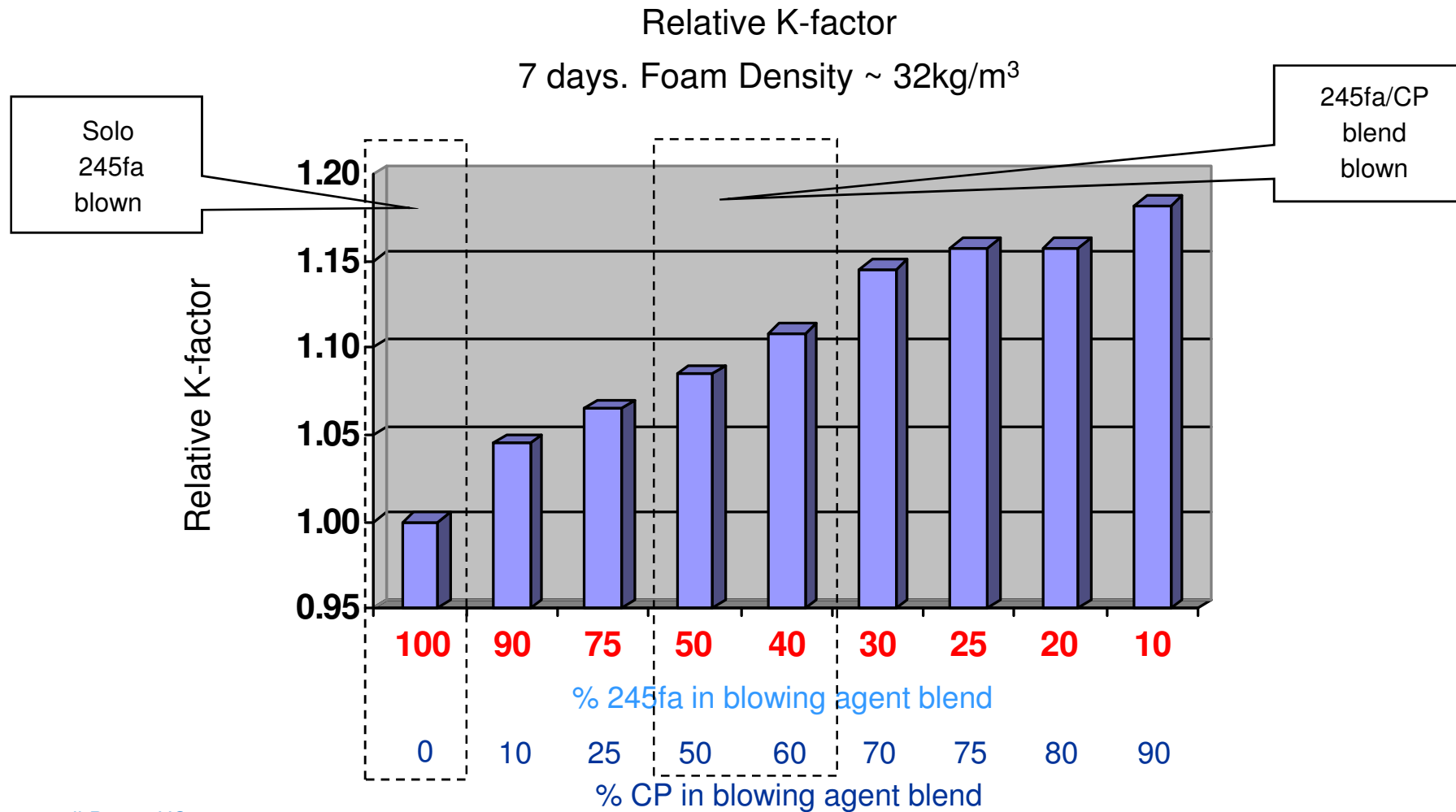
Blowing agent (wt%)		Boiling point at 745mmHg (°C)
245fa	CP	
100	0	14.6
95~40	5~60	11.7±1
0	100	49

- The Boiling Point of Blend is Lower than 245fa and CP

* Honeywell Patent US 5,677,358

Lower boiling point, better flowability

Thermal conductivity of 245fa/CP blown foam

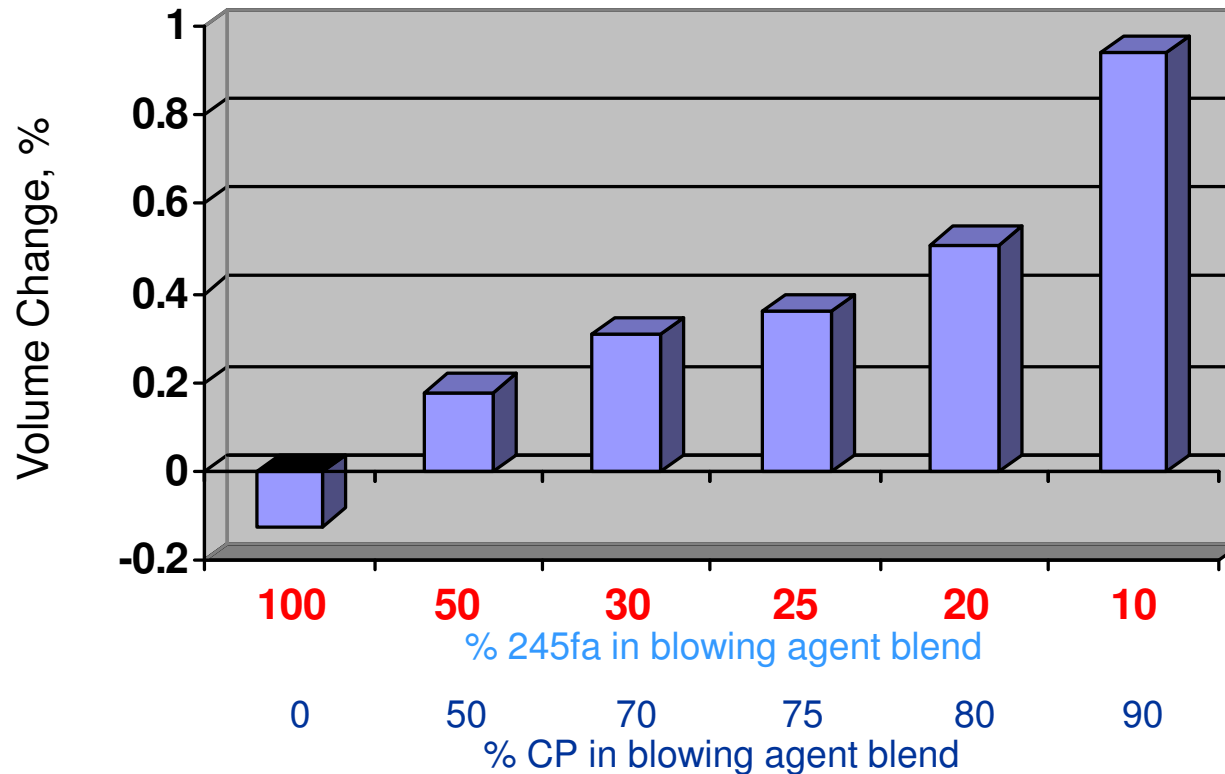


* Honeywell Patent US 5,677,358

Better K-factor as 245fa Levels Increase

Dimensional stability of 245fa/CP co-blown foam

Dimensional stability, -20°C after 22 days. Foam Density ~ 2.0lb/ft³ (32kg/m³)



* Honeywell Patent US 5,677,358

Better Dimension Stability as 245fa Portion Increases

245fa in Spray Applications

- Major challenges in 141b phase-out
 - Cost sensitive segment (Construction)
 - HC and HFC 365mfc will not be an option due to safety concerns
 - Water: poor thermal insulation and adhesion

- Blowing agent comparison:

	245fa	HCFC-141b	365mfc	Water
insulation	++	++	+	-
Foam cell	++	++	-	-
Flammable	++	++	-	++
handling	+	++	-	++
adhesion	++	+	+	-
price	-	++	-	++
ODP	++	-	++	++

Spray system development

Test Item	Unit	Standard	Wall system		Roof system	
			Requirement	245fa foam	Requirement	245fa foam
Density	kg/m ³	GB/T 6343	≥35.0	37.0	≥55.0	55.5
Thermal conductivity	W/m·k	GB 3399	≤0.024	0.0208	≤0.024	0.022
Compressive strength	kPa	GB/T 8813	≥150	240	≥300	340
Dimensional stability •-30□•48h•	%	GB/T 8811	≤1	0.8	≤1	≤1
Flammability	cm	GB/T 8624	≤15	12	≤15	13
Dimensional stability •70□•48h•	%	GB/T 8811	≤5	3.7	≤5	3.7
Closed cell content	%	GB/T 10799	≥90	93	≥90	95

HFC 245fa advantages in spray application

- Quicker rise
- Larger application window
- Lower operating temperature
- Less shrinkage - reversion
- Easily applies on cold surfaces
- Equivalent or better yield
- Drums used for 141b systems can be used for systems with ~10% of 245fa
- Minimal 245fa loss during blending
 - Confirmed by calculation and experimentation



245fa in Panel Applications

- Some continuous panel manufacturers switching to HC and water from 141b
- Almost all discontinuous panel manufacturers are using 141b
- Major challenges in 141b phase-out
 - Water: poor thermal insulation and adhesion
 - HC: high capital investment; safety

•Blowing agent comparison:

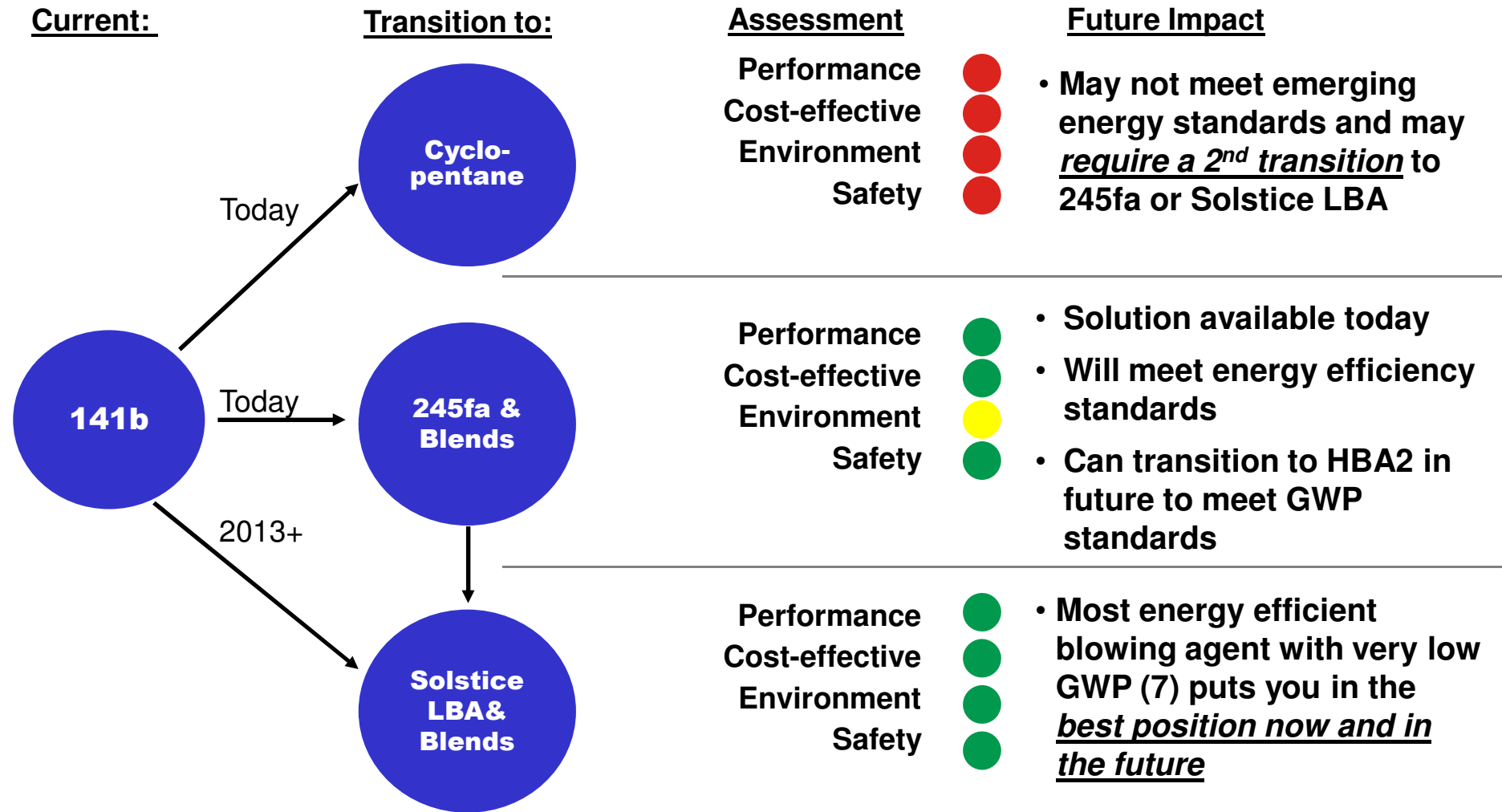
	245fa	HCFC-141b	365mfc	Cyclopentane
insulation	++	++	+	+
flowability	++	++	+	+
Demouldability	++	+	+	+
Polyol compatibility	++	++	+	-
Foam cell	++	++	-	-
Flammability	++	++	-	-
Handling	+	++	-	-
Adhesion	++	+	+	-
Price	-	++	-	++

++ best + average - worst

Panel application

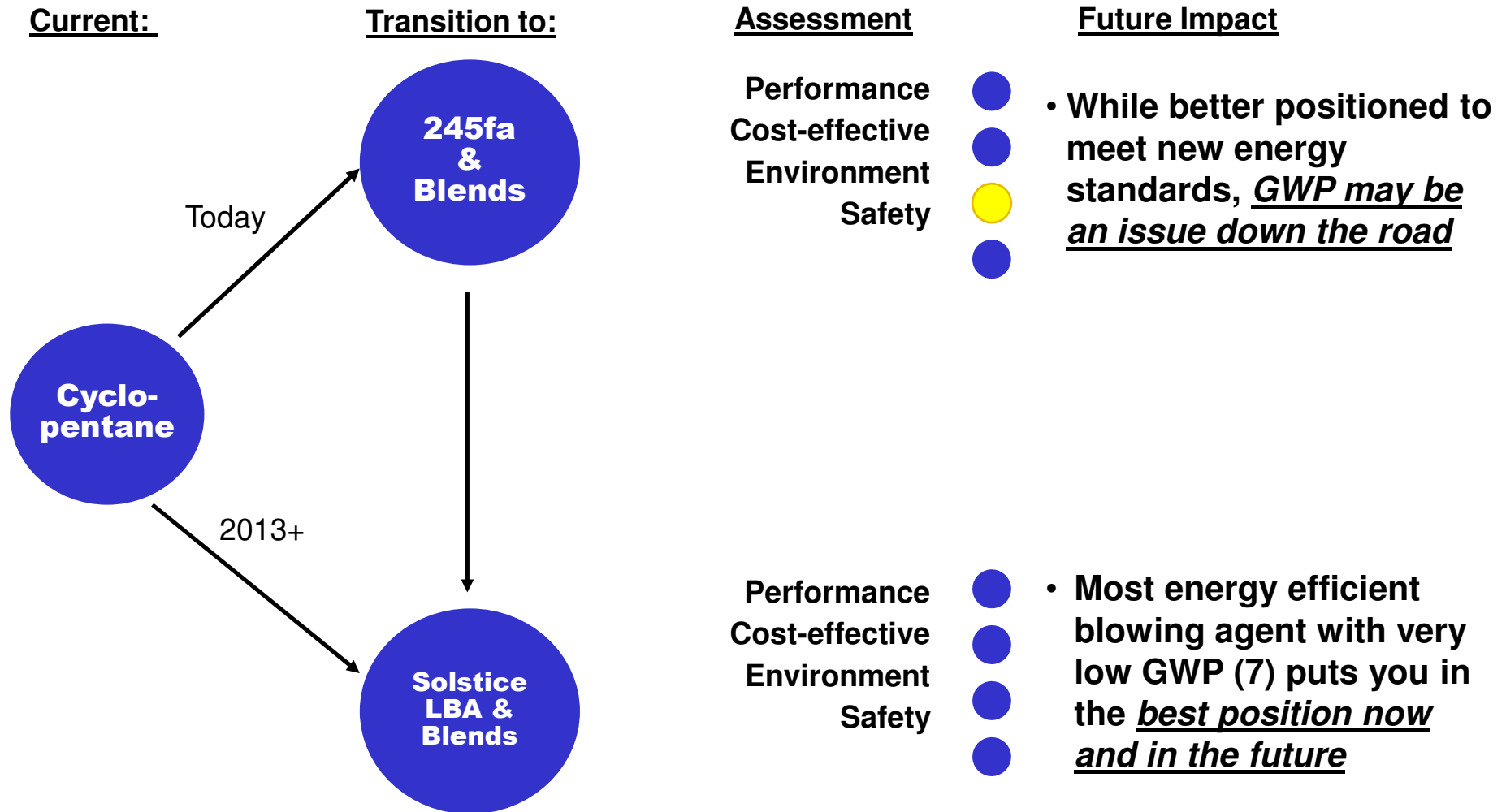
		HCFC-141b	245fa/HCFC-141b		245fa	
A		100	100		100	
B		92	92		92	
CT		22	17		27	
GT		67	66		73	
TFT		105	105		115	
FRD		26.7	25.3		27.5	
filling W		500	452	437	420	454
CD		42.2	42.6	40.8	42.8	44.8
K factor		21.69	21.52		21.45	
Compressive strength		122	143	124	202	194
		161	186	164	244	290
Demouldability	30 min	10.5	9.9	NA	3.13	NA
	33min	12.1	11.76		4.51	
	36min	12.43	11.57		4.46	
	39min	12.16	11.25		4.32	
	42min	11.95	10.96		4.18	
Dimensional stability	-30 •	-0.90%	-1.11%	-1.47%	-1.17%	
	70 •	1.39%	1.30%	1.63%	0.17%	

Transitioning from Blowing Agent 141b



245fa and LBA & Blends: Low Capital and Cost Transitions

Transitioning from Cyclopentane



245fa and LBA & Blends Offer Better Solutions Than Cyclopentane

Honeywell

www.honeywell.com

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