Competing Visions for Building Materials Assessment in US Green Building Certification Programs

Charles Kibert, Professor & Director of the Powell Center for Construction & Environment

Co-Authors: Andriel Fenner, Hashem Izadi Moud, Hamed Hakim & Mohammad Ahmadzade Razkenari

University of Florida

Introduction

- Materials and product toxicity criteria in green buildings: a new frontier in green building assessment.
- Currently there are two competing visions in the US regarding building material toxicity:

Hazard-Based vs. Risk Based

- These competing visions line up with the major US rating systems: LEED, Green Globes, and the Living Building Challenge (LBC)
- Hazard-based assessment has been the strategy of choice but it is not based on toxicological science (LEED and LBC)
- Risk-based assessment is toxicology based and just emerging as an option (Green Globes v3 in 2018)
- The question: what is the best choice for the future as the rating systems evolve?

Hazard-based Assessment (HBA)

- HBA identifies and prohibits chemicals that threaten human and ecosystem health without regard to the exposure scenario.
- Many short and long “Red-Lists” of materials have been developed as a result of this assessment strategy
- Presence of a chemical on a Red List can result in product being banned (LBC) or not eligible for points (LEED)
- *Typical HBA: “The Precautionary List includes substances commonly found in the built environment that have been classified by regulatory entities as being harmful to the health of humans and/or the environment.”* (Perkins+Will)
- Note that neither the dose of the substance nor the scenario in which it is used are mentioned.

Red Lists: Two Examples

LBC and Perkins and Will Precautionary List

+ = LBC only *= Perkins + Will only

Alkyphenols+	Hexavalent Chromium (VI)
Arsenic*	Hydroflurocarbons (HCFCs)
Asbestos+	Lead
Bisphenol (BPA)	Mercury
Bromochlorodifluoromethane*	Organostannic Compounds
Cadmium	Pentachlorophenol*
Chlorinated Polyethylene (CPE)	Perfluorocarbons (PFCs)
Chlorinated Polyvinyl Chloride (CPVC)	Phthalates
Chlorobenzene+	Polystyrene*
Chlorofluorocarbons (CFCs)	Polyurethane foam*
Chloroprene (2-chloro-1, 3-butadiene)	Polyvinyl Chloride (PVC)
Chlorosulfinated Polystyrene (CSPE)	Short Chain Chlorinated Paraffin+
Copper (for exterior material)*	Urea-Formaldehyde
Creosote	Volatile Organic Compounds (VOCs)
Halogenated Flame Retardants	

Risk-Based Assessment (RBA)

- RBA identifies chemical ecologic, health, and safety characteristics of concern, plus process manufacturing factors for assessing sustainability impacts.
- However it also assesses the risk of using materials with some characteristics of concern based on the route, quantity, duration & frequency of exposure.

Risk = f (Hazard x Exposure)

*(*Paracelsus, T. 1538. “Die dritte Defension wegen des Schreibens der neuen Rezepte, Septem Defensiones, Werke Bd. 2.*)*

RBA vs HBA

HBA

- No toxic or hazardous material at specified concentrations should be present in building products.
- Manufacturers are responsible for disclosing all toxic chemicals down to specified concentrations (generally 100 or 1000 ppm).
- The exposure scenario is not considered.
- No standard methodology

RBA

- Banning even very low concentrations of toxic chemicals can be costly and unnecessary
- The exposure scenario for the chemicals is important.
- It is all about the danger posed by the exposure dose and the exposure scenario *(risk).*
- Standard Methodology: ANSI/GCI Standard 355

Risk = f (Hazard x Exposure)

HBA Application in LEED v4

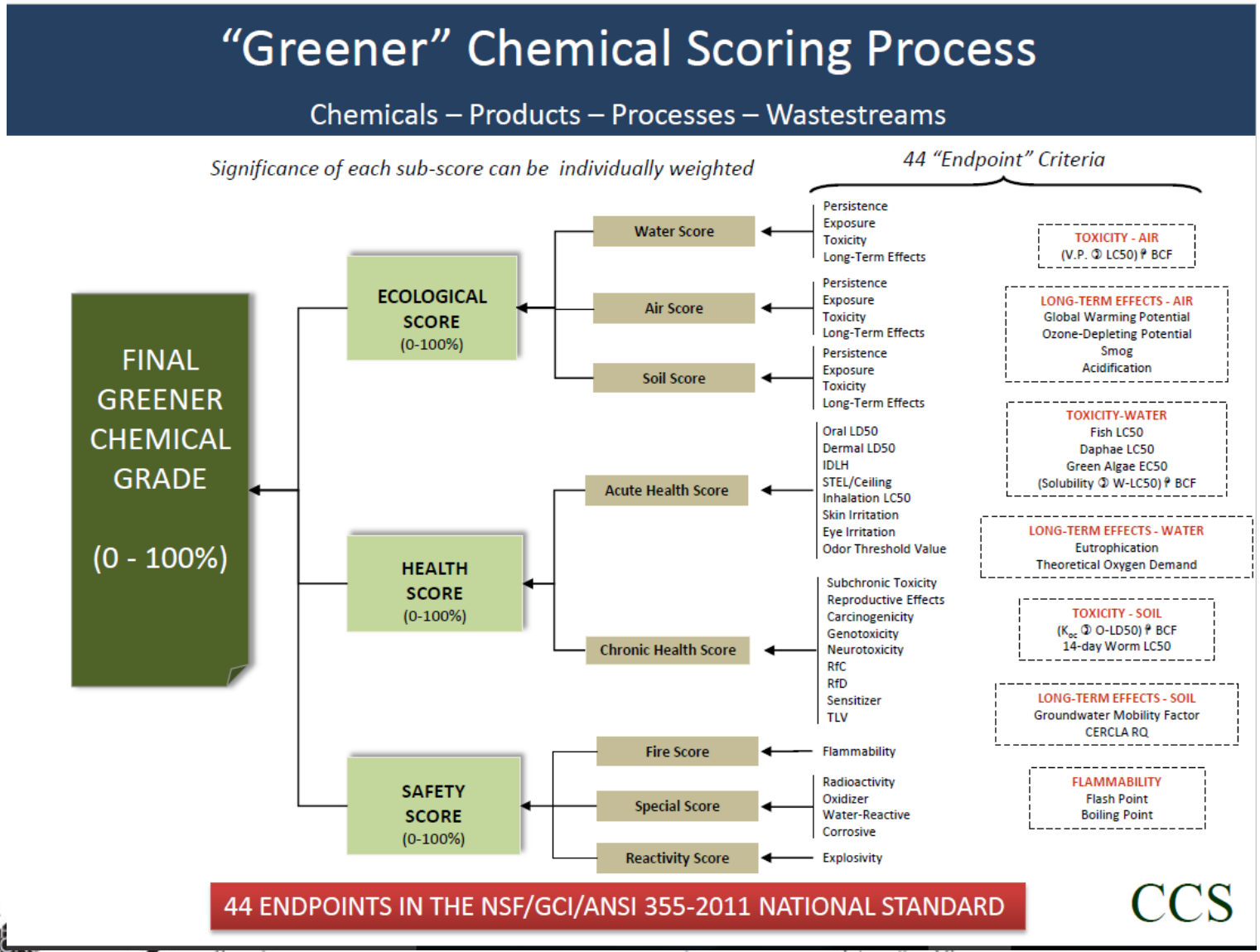
- **Option 1. Material Ingredient reporting**
- **Option 2. Material ingredient optimization**

1. *GreenScreen* benchmark
2. The *Globally Harmonized System of Classification and Labeling of Chemicals rev.6 (2015) (GHS)*
3. *Health Product Declaration*.
4. *Declare Label*
5. *Cradle to Cradle*
6. *BIFMA v3*
7. *Product Lens*
8. *REACH*
9. *Others approved by the USGBC*

RBA Application in Future Green Globes (ANSI/GBI 01-201X)

- F*ormulated products* or *articles* have a completed screening-level risk assessment in accordance with **NSF/GBI/ANSI 355: Greener Chemicals and Processes Information Standard**
- The assessment is based on the *product's intended use*, *concentration of each chemical* constituent within the product, and completion of *an authoritative exposure model*;
- As a minimum, the following *exposure scenario factors* for either interior or exterior product categorized products: *frequency, duration, amount utilized, ventilation rate, wind speed, and room/space size, or unlimited for unconfined spaces*.

GreenSuite: A tool for RBA



Green Suite Scoring Hierarchy Optional Indicators

Green Score	Alpha Score	Text Descriptor
97 - 100	A+	Highly Probable Non-Risk
93 - 96	A	Very Probable Non-Risk
90 - 92	A-	Probable Non-Risk
87 - 89	B+	Reasonable Non-Risk
83 - 86	B	Possible Non-Risk
80 - 82	B-	Cautious Non-Risk
77 - 79	C+	Minimal Risk
73 - 76	C	Slight Risk
70 – 72	C-	Moderate Risk
65 – 69	D	Serious Risk
> 65	F	Extreme Risk

CCS Relational Chemical and Product Database (R-CPD)
Statistics - 2016

Continuous Data Compilation Since 1985

≥ 80,000,000	Data Elements
280,000	Chemicals
>27,000	Chemicals with 44 EHS Endpoints
> 200	SPF Constituents with 44 EHS Endpoints
> 1,500,000+	Product MSDSs
> 10,000	Manufacturers
1,000	Public Data Sources
> 800	Chemical Regulatory Lists

CCS Relational Chemical and Product Database (R-CPD)

Chemical

Cross Reference Dictionary
- Chemical Names
- Common Names
- Foreign Names
- Numeric Identifiers

Physical/Chemical
- Elemental Composition
- Redox Potential
- Pka/Pkb
- Log Koc, Log Kow
- BP, FP, VP
- Solubilities

Health
- Acute
- Chronic

Safety
- Incompatibilities
- Storage Codes
- Flammables
- Explosives
- Radioactives

Ecological
- Toxicity
- Pesticides
- Long-term Effects
- Persistence
- Exposure

Exposure
- Use Category
- Production Volume
- Persistence/Bioaccumulation
- TRI Emissions

Green
- Ecological
- Health
- Safety

Alternatives
- Acids
- Antioxidants
- Bases
- Binders
- Chelators
- Oxidizers
- Propellants
- Reducers
- Solvents
- Surfactants
- UV Absorbers
- Viscosity Agents
- Other (~30)

Eco-Risk
- Species Factors
- Wildlife Toxicity
- Dietary Considerations
- Ingestion Rates
- Bioconcentration
- Bioaccumulation
- Biotransfer

Human Health Risk
- Biotransfer Animals
  - Biotransfer & Concentration Factors
- Biotransfer Plants
  - Bioconcentration Factors
- Health Benchmarks
  - Cancer Slopes
  - Toxicity Equivalency
- Physical/Chemical Properties
  - Diffusivity
  - Partition Coefficients

Regulatory
- U.S. EPA
- U.S. DOL
- U.S. DOT
- U.S. FDA
- U.S. Other
- States
- Canada
- Europe
- Pacific Rim
- International
- Compounds
- CCS Compiled
- Textiles

Product
- Manufacturers
- Composition
- Description
- Generic Categories
- Inventories
- Alloys
- MSDS Links

Supplier
- Product Dictionary
- Mfr.- Supplier Links
- Supplier-Supplier Links
- CBI

- AAFA
- AFIRM
- H&M
- NIKE
- NSF 336 (Current)
- NSF 140 (Current)
- Oeko-Tex
- PUMA
- SAC

CCS

RBA Case Study: Spray Polyurethane Foam (SPF)

- Spray polyurethane foam (SPF) is an effective insulator and air sealant material, onsite reaction of potentially hazardous formulations.
- SPF is a mixture of isocyanates, polyols, catalysts, fire retardants, and blowing agents. “A” side and “B” side formulations.
- Concerns with the health effects from SPF due to potential exposures to isocyanate exposures to the polyol blend.
- Quantitative risk assessments were performed for three different “X” Polyurethane Systems SPF systems. A Side formulation, with 3 different B Side formulations. Risk assessments were performed utilizing GreenSuite®.

FINAL GREEN GRADE: 70 (100%)	Ecological Score: 65 (33.34% AW) (65 Pass/Fail)	Water Score: 42 (33.34% AW) (65 Pass/Fail)	Persistence:	31	(10% AW) (65 Pass/Fail)
			Partition:	37	(10% AW) (65 Pass/Fail)
			Toxicity:	43	(50% AW) (65 Pass/Fail)
			Long-Term Effects:	45	(30% AW) (65 Pass/Fail)
		Air Score: 92 (33.33% AW) (65 Pass/Fail)	Persistence:	41	(10% AW) (65 Pass/Fail)
			Partition:	100	(10% AW) (65 Pass/Fail)
			Toxicity:	100	(50% AW) (65 Pass/Fail)
			Long-Term Effects:	94	(30% AW) (65 Pass/Fail)
		Soil Score: 60 (33.33% AW) (65 Pass/Fail)	Persistence:	31	(10% AW) (65 Pass/Fail)
			Partition:	64	(10% AW) (65 Pass/Fail)
			Toxicity:	41	(50% AW) (65 Pass/Fail)
			Long-Term Effects:	100	(30% AW) (65 Pass/Fail)
	Health Score: 61 (33.33% AW) (65 Pass/Fail)	Acute Score: 48 (50% AW) (65 Pass/Fail)	Oral LD50:	93	(12.5% AW) (65 Pass/Fail)
			Dermal LD50:	95	(15% AW) (65 Pass/Fail)
			IDLH:	0	(25% AW) (65 Pass/Fail)
			STEL/Ceiling:	14	(20% AW) (65 Pass/Fail)
			Inhalation LC50:	74	(18% AW) (65 Pass/Fail)
			Skin Irritation:	80	(3% AW) (65 Pass/Fail)
			Eye Irritation:	54	(4.5% AW) (65 Pass/Fail)
			Odor Threshold Value:	51	(2% AW) (65 Pass/Fail)
		Chronic Score: 75 (50% AW) (65 Pass/Fail)	Reproductive Effects:	95	(20% AW) (65 Pass/Fail)
			Carcinogenicity:	90	(22% AW) (65 Pass/Fail)
			RfC:	0	(4% AW) (65 Pass/Fail)
			RfD:	85	(3% AW) (65 Pass/Fail)
			Sensitizer:	0	(5% AW) (65 Pass/Fail)
			Neurotoxicity:	93	(22% AW) (65 Pass/Fail)
			TLV:	13	(10% AW) (65 Pass/Fail)
			Subchronic Toxicity:	79	(6% AW) (65 Pass/Fail)
			Genotoxicity:	90	(8% AW) (65 Pass/Fail)
	Safety Score: 85 (33.33% AW) (65 Pass/Fail)	Fire Score: 90 (33.33% AW) (65 Pass/Fail)	Flammability:	90	(100% AW) (65 Pass/Fail)
		Special Score: 91 (33.34% AW) (65 Pass/Fail)	Radioactivity:	100	(25% AW) (65 Pass/Fail)
			Oxidizer:	100	(25% AW) (65 Pass/Fail)
			Water-Reactive:	64	(25% AW) (65 Pass/Fail)
			Corrosive:	100	(25% AW) (65 Pass/Fail)
		Reactivity Score: 75 (33.33% AW) (65 Pass/Fail)	Explosivity:	75	(100% AW) (65 Pass/Fail)

FINAL GREEN GRADE: 94 (100%)	Ecological Score: 92 (33.34% AW) (65 Pass/Fail)	Water Score: 87 (33.34% AW) (65 Pass/Fail)	Persistence:	82	(10% AW) (65 Pass/Fail)
			Partition:	88	(10% AW) (65 Pass/Fail)
			Toxicity:	96	(50% AW) (65 Pass/Fail)
			Long-Term Effects:	72	(30% AW) (65 Pass/Fail)
		Air Score: 98 (33.33% AW) (65 Pass/Fail)	Persistence:	93	(10% AW) (65 Pass/Fail)
			Partition:	96	(10% AW) (65 Pass/Fail)
			Toxicity:	100	(50% AW) (65 Pass/Fail)
			Long-Term Effects:	99	(30% AW) (65 Pass/Fail)
		Soil Score: 92 (33.33% AW) (65 Pass/Fail)	Persistence:	82	(10% AW) (65 Pass/Fail)
			Partition:	83	(10% AW) (65 Pass/Fail)
			Toxicity:	98	(50% AW) (65 Pass/Fail)
			Long-Term Effects:	89	(30% AW) (65 Pass/Fail)
	Health Score: 92 (33.33% AW) (65 Pass/Fail)	Acute Score: 94 (50% AW) (65 Pass/Fail)	Oral LD50:	97	(12.5% AW) (65 Pass/Fail)
			Dermal LD50:	99	(15% AW) (65 Pass/Fail)
			IDLH:	90	(25% AW) (65 Pass/Fail)
			STEL/Ceiling:	90	(20% AW) (65 Pass/Fail)
			Inhalation LC50:	100	(18% AW) (65 Pass/Fail)
			Skin Irritation:	95	(3% AW) (65 Pass/Fail)
			Eye Irritation:	90	(4.5% AW) (65 Pass/Fail)
			Odor Threshold Value:	90	(2% AW) (65 Pass/Fail)
		Chronic Score: 89 (50% AW) (65 Pass/Fail)	Reproductive Effects:	90	(20% AW) (65 Pass/Fail)
			Carcinogenicity:	90	(22% AW) (65 Pass/Fail)
			RfC:	80	(4% AW) (65 Pass/Fail)
			RfD:	80	(3% AW) (65 Pass/Fail)
			Sensitizer:	90	(5% AW) (65 Pass/Fail)
			Neurotoxicity:	90	(22% AW) (65 Pass/Fail)
			TLV:	90	(10% AW) (65 Pass/Fail)
			Subchronic Toxicity:	90	(6% AW) (65 Pass/Fail)
			Genotoxicity:	90	(8% AW) (65 Pass/Fail)
	Safety Score: 97 (33.33% AW) (65 Pass/Fail)	Fire Score: 90 (33.33% AW) (65 Pass/Fail)	Flammability:	90	(100% AW) (65 Pass/Fail)
		Special Score: 100 (33.34% AW) (65 Pass/Fail)	Radioactivity:	100	(25% AW) (65 Pass/Fail)
			Oxidizer:	100	(25% AW) (65 Pass/Fail)
			Water-Reactive:	100	(25% AW) (65 Pass/Fail)
			Corrosive:	100	(25% AW) (65 Pass/Fail)
		Reactivity Score: 100 (33.33% AW) (65 Pass/Fail)	Explosivity:	100	(100% AW) (65 Pass/Fail)

Product(s) "Greeness" Analysis

Adjustable Weight List: Preferred

Trade Name	T.	ALT	MSDS Chem.%	Re-Cal. Chem.%	Overall Assessment	Green Grade (100%)			Regulatory (LOLs)
						Ecological (33.34%) (65 Pass Score)	Health (33.33%) (65 Pass Score)	Safety (33.33%) (65 Pass Score)	
Adhesive 2 (Material Safety Data Sheet)	G		100%	100%	MOST GREEN	**98.64**			
						98.75	98.66	98.5	
Adhesive 4 (Material Safety Data Sheet)	G		100%	100%	2	**88.29**			
						90.99	83.47	90.42	
Adhesive 3 (Material Safety Data Sheet)	G		100%	100%	3	**85.65**			
						85.86	77.02	94.08	
Adhesive 6 (Material Safety Data Sheet)	G		100%	100%	4	**73.67**			
						71.44	79.57	70	
Adhesive 7	G		100%	100%	5	**73.15**			
						75.81	69.99	73.67	
Adhesive 5 (Material Safety Data Sheet)	G		100%	100%	6	**71.75**			
						75.39	71.53	68.34	
Adhesive 1 (Material Safety Data Sheet)	G		100%	100%	LEAST GREEN	**69.86**			
						71.78	69.15	68.67	

PRODUCT: Adhesive 6
Ecological Score: 71.44 (65 Pass/Fail)

(LOLs) Ecological List of General/Air/Water

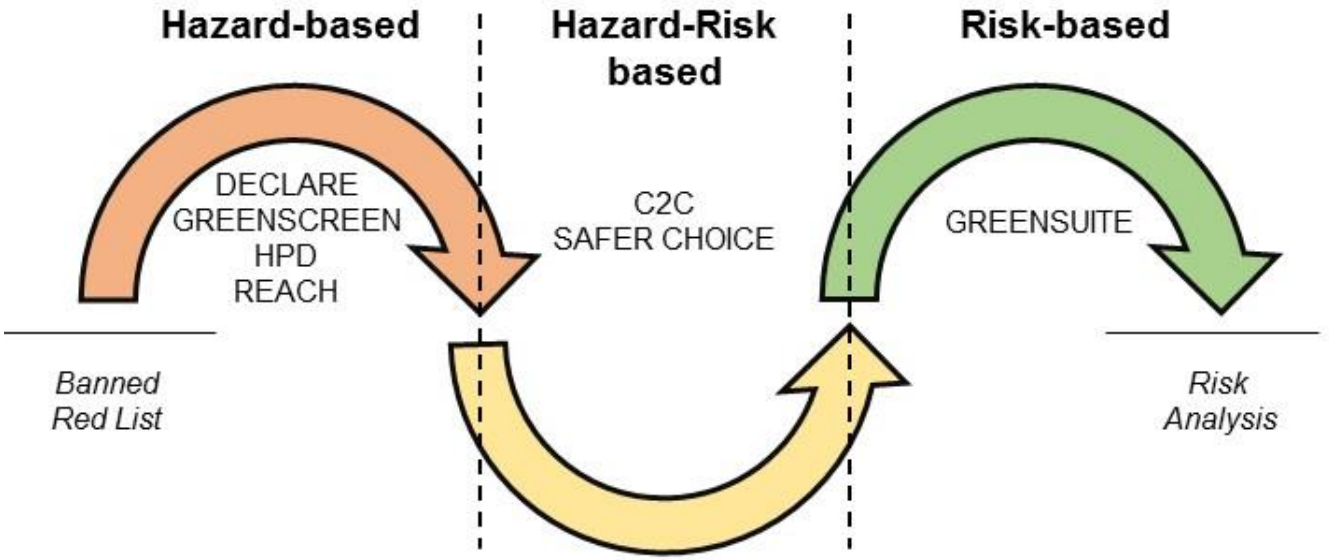
Water Score: 59.64 (33.34%) (65 Pass/Fail)		Air Score: 78.3 (33.33%) (65 Pass/Fail)		Soil Score: 76.39 (33.33%) (65 Pass/Fail)	
Persistence: (10%) (65 Pass)	52.49	Persistence: (10%) (65 Pass)	30.66	Persistence: (10%) (65 Pass)	52.49
Exposure: (10%) (65 Pass)	57.07	Exposure: (10%) (65 Pass)	44.78	Exposure: (10%) (65 Pass)	74.33
Toxicity: (50%) (65 Pass)	58.57	Toxicity: (50%) (65 Pass)	84.24	Toxicity: (50%) (65 Pass)	80.93
Long-Term Effect: (30%) (65 Pass)	64.68	Long-Term Effect: (30%) (65 Pass)	95.45	Long-Term Effect: (30%) (65 Pass)	77.46

Detail Chemical List
Sort by: Ecological Score

CAS#: 75-28-5 (Value) (Synonym) Chemical: ISOBUTANE Percentage: 20% Master: Adhesive 6 (1)	**Ecological Score: 67.69** (65 Pass/Fail)				
	Water Score: 54.49 (33.34%) (65 Pass/Fail)	Persistence: (10%)	Exposure: (10%)	Toxicity: (50%)	Long-Term Effect: (30%)
		50	45.29	56.83	55.17
	Air Score: 80.42 (33.33%) (65 Pass/Fail)	Persistence: (10%)	Exposure: (10%)	Toxicity: (50%)	Long-Term Effect: (30%)
		24.41	22.08	94.87	94.44
	Soil Score: 68.16 (33.33%) (65 Pass/Fail)	Persistence: (10%)	Exposure: (10%)	Toxicity: (50%)	Long-Term Effect: (30%)
		50	99.05	76.51	50
CAS#: 110-54-3 (Value) (Synonym) Chemical: n-HEXANE Percentage: 20% Master: Adhesive 6 (1)	**Ecological Score: 68.65** (65 Pass/Fail)				
	Water Score: 44.11 (33.34%) (65 Pass/Fail)	Persistence: (10%)	Exposure: (10%)	Toxicity: (50%)	Long-Term Effect: (30%)
		74.97	40.95	31.55	55.81
	Air Score: 77.11 (33.33%) (65 Pass/Fail)	Persistence: (10%)	Exposure: (10%)	Toxicity: (50%)	Long-Term Effect: (30%)
		50.57	36.32	82.07	91.27
	Soil Score: 84.75 (33.33%) (65 Pass/Fail)	Persistence: (10%)	Exposure: (10%)	Toxicity: (50%)	Long-Term Effect: (30%)
		74.97	95.22	75.52	99.9
CAS#: 74-98-6 (Value) (Synonym) Chemical: PROPANE Percentage: 20% Master: Adhesive 6 (1)	**Ecological Score: 69.39** (65 Pass/Fail)				
	Water Score: 62.78 (33.34%) (65 Pass/Fail)	Persistence: (10%)	Exposure: (10%)	Toxicity: (50%)	Long-Term Effect: (30%)
		50	99.23	62.53	55.29
	Air Score: 82.07 (33.33%) (65 Pass/Fail)	Persistence: (10%)	Exposure: (10%)	Toxicity: (50%)	Long-Term Effect: (30%)
		18.08	12.23	100	96.81
	Soil Score: 63.33 (33.33%) (65 Pass/Fail)	Persistence: (10%)	Exposure: (10%)	Toxicity: (50%)	Long-Term Effect: (30%)
		50	50.68	76.53	50
CAS#: 110-82-7 (Value) (Synonym) Chemical: CYCLOHEXANE Percentage: 20% Master: Adhesive 6 (1)	**Ecological Score: 69.58** (65 Pass/Fail)				
	Water Score: 47.02 (33.34%) (65 Pass/Fail)	Persistence: (10%)	Exposure: (10%)	Toxicity: (50%)	Long-Term Effect: (30%)
		50	39.19	41.92	57.14
	Air Score: 83.83 (33.33%) (65 Pass/Fail)	Persistence: (10%)	Exposure: (10%)	Toxicity: (50%)	Long-Term Effect: (30%)
		60.26	55.32	87.7	94.75
	Soil Score: 77.89 (33.33%) (65 Pass/Fail)	Persistence: (10%)	Exposure: (10%)	Toxicity: (50%)	Long-Term Effect: (30%)
		50	86.1	76.11	87.4
CAS#: 100-19-6 (Value) (Synonym) Chemical: P-NITROACETOPHENONE Percentage: 20% Master: Adhesive 6 (1)	**Ecological Score: 81.9** (65 Pass/Fail)				
	Water Score: 89.82 (33.34%) (65 Pass/Fail)	Persistence: (10%)	Exposure: (10%)	Toxicity: (50%)	Long-Term Effect: (30%)
		37.5	60.7	100	100
	Air Score: 68.07 (33.33%) (65 Pass/Fail)	Persistence: (10%)	Exposure: (10%)	Toxicity: (50%)	Long-Term Effect: (30%)
		0	97.98	56.54	100
	Soil Score: 87.81 (33.33%) (65 Pass/Fail)	Persistence: (10%)	Exposure: (10%)	Toxicity: (50%)	Long-Term Effect: (30%)
		37.5	40.6	100	100

Conclusion

1.Evolution of Product/Toxicity Assessment



2. Future: Fusion of Leading Edge Concepts

Risk-Base LCA = LCA + RBA

谢谢