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Eco Efficiency Study
Water vs Solvent vs UV inks on flexible film

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BASF Tools

to measure sustainability

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Simple

- **Sustainability Screening Analysis**
  - Qualitative screening for use in PhaseGate process
- **Pollution Prevention (P2) Framework**
  - Fate, exposure, toxicity, phys/chem, bioaccumulation.
- **Environmental Impact Assessment (EIA)**
  - Evaluate ecological impacts.
- **Total Cost of Ownership (TCO)**
  - Compares costs of two or more products or processes.
- **Eco-Efficiency Analysis (EEA)**
  - Compares ecological and economic impacts over product life-cycle.
- **Socio-eco-efficiency Analysis (SEE® Balance)**
  - BASF developed methodology for ecological, economic and societal impacts.

Complex

▶ *BASF has SD tools and resources beyond our competitors*

Eco-efficiency Analysis

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- BASF strategic tool to help drive towards and measure sustainability
- Developed in Germany in 1996
- Over 400 projects completed globally
- Third-party certified by the German Technical Monitoring Association (TŰV) and pending with NSF International

NSF Protocol ***
Eco-Efficiency Analysis Verified and Available at:
http://www.nsf.org/eco-efficiency
Pending

What is Eco-Efficiency Analysis?

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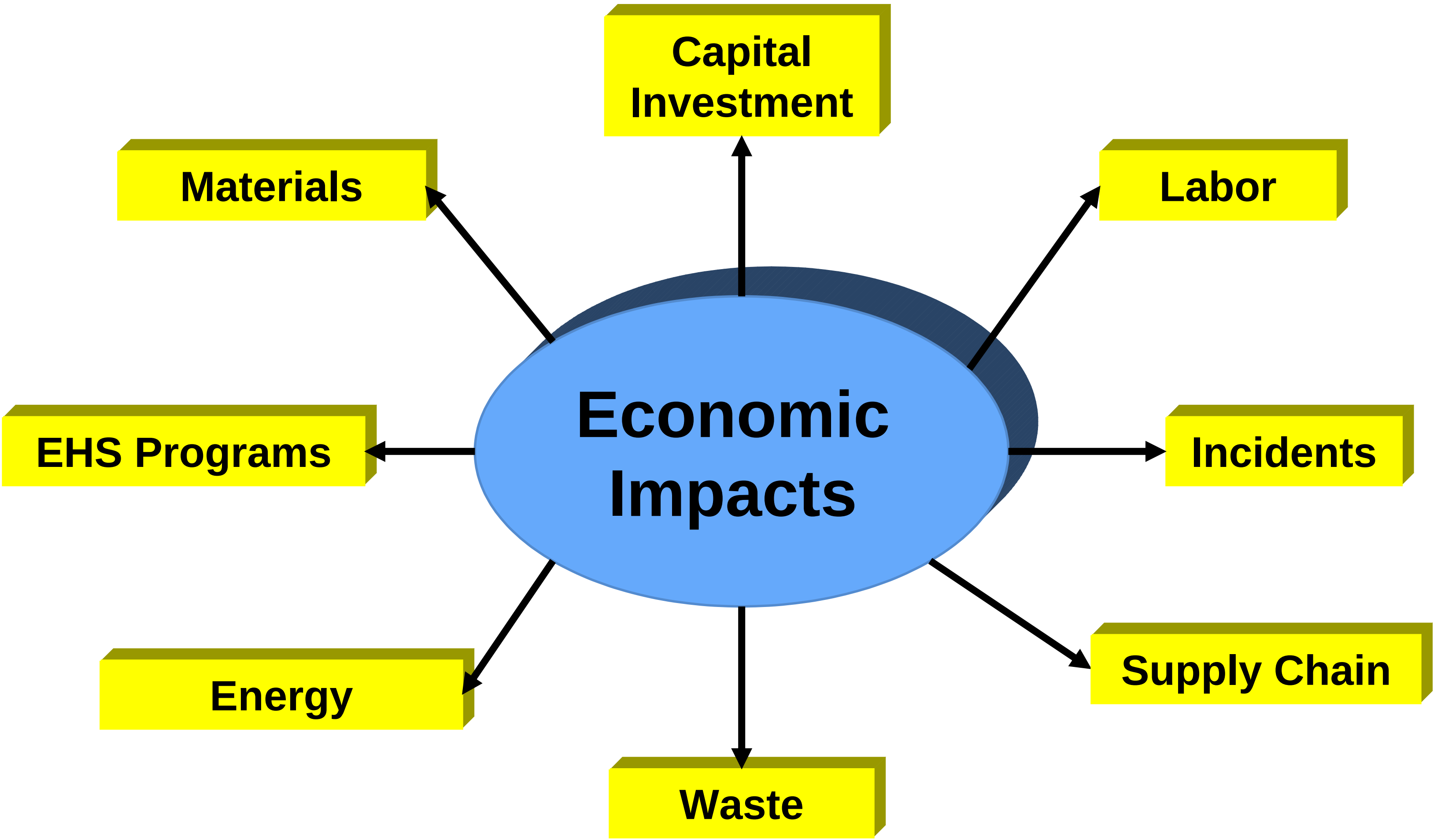
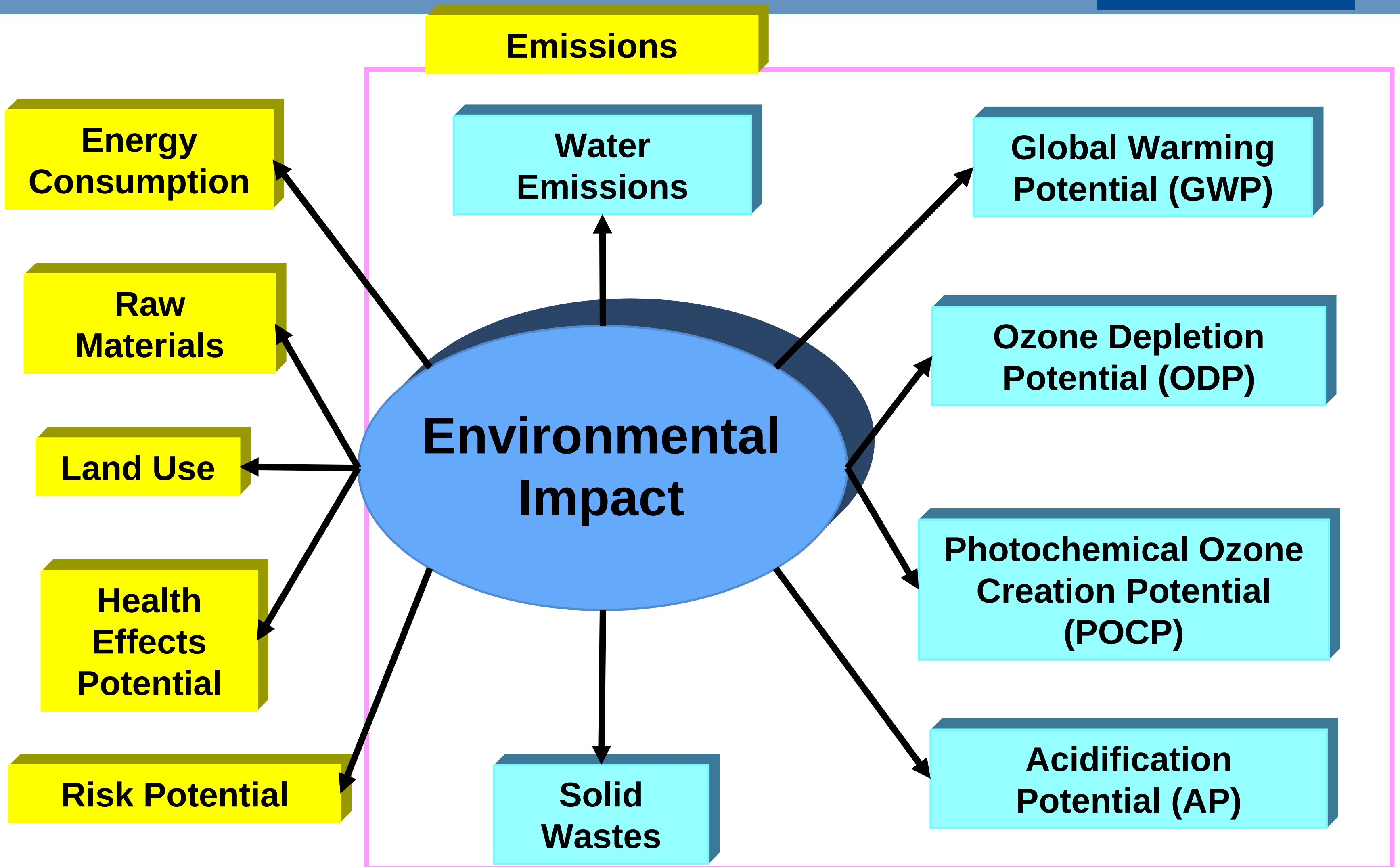
- Methodology for measuring sustainability by comparing the economic and ecological impacts of a product or process over the life-cycle.
- Life-cycle analysis that includes evaluation of production, use and disposal/reuse.
- Ecological and economic aspects are given equal weight in assessments.
- Ability to model results of changing input parameters (e.g. energy costs, new toxicity data).

EEA Impact Categories
Economic



EEA Impact Categories Environmental

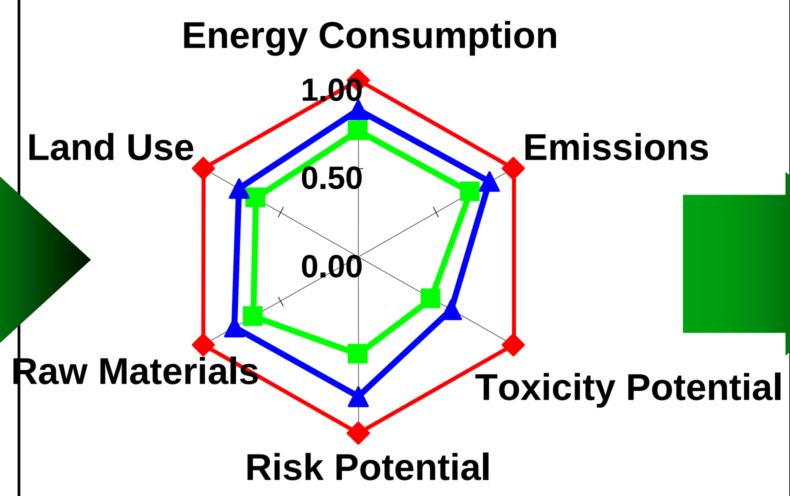


Development of Ecological Value

Parameters considered

- Raw Materials
- Energy consumption
- Land Use
- Emissions
- Toxicity
- Risk potential

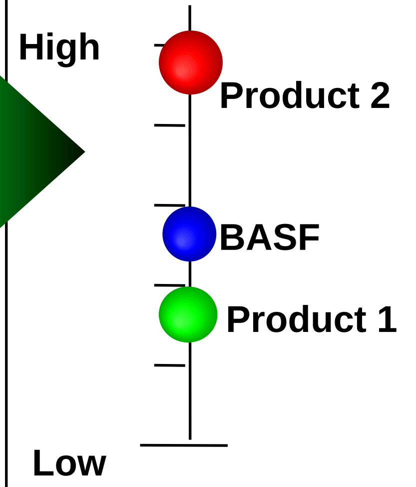
Ecological footprint



1.0 = greatest environmental burden

Ecological advantage

Relative environmental impact



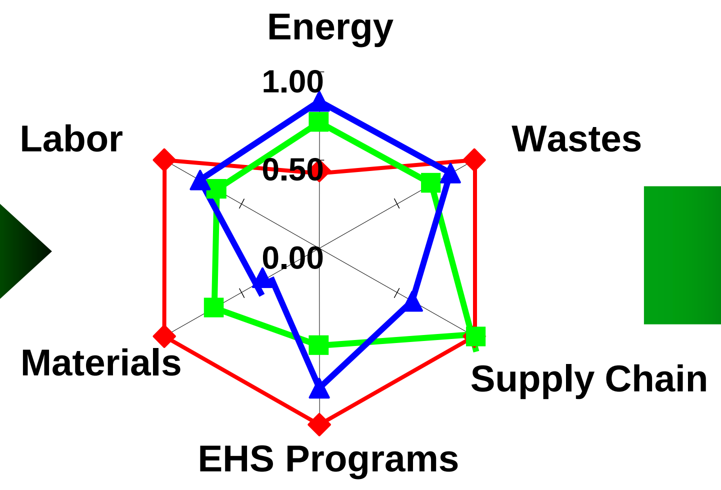
Life-cycle data is gathered in six environmental categories and depicted on an ecological footprint. The data are then weighted and aggregated to obtain an overall environmental impact.

Development of Economic Value

Parameters considered

- Materials
- Energy
- Wastes
- Supply Chain
- Labor
- EHS Programs

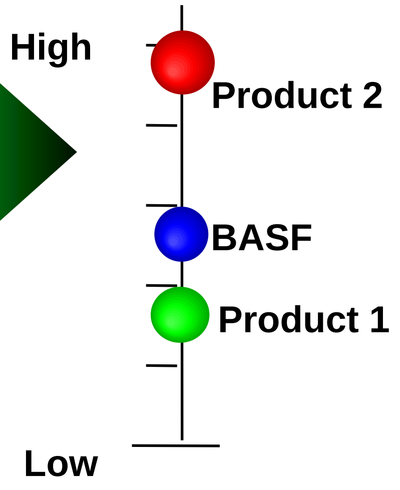
Economic footprint



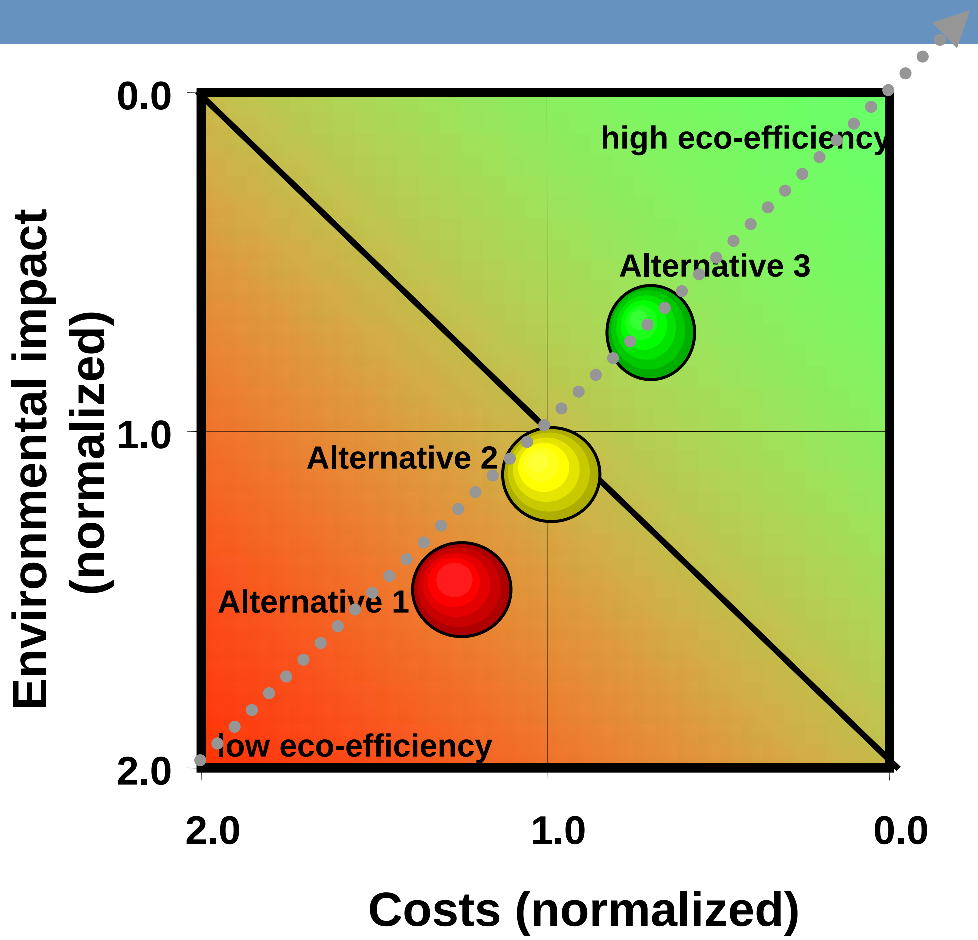
1.0 = greatest environmental burden

Economic advantage

Relative Economic impact



The Eco-efficiency Portfolio:
Environmental & Cost Impacts



Alternative 3 is most eco-efficient.

The most eco-efficient product has the lowest environmental impact and cost. Eco-efficiency is measured from the diagonal line.

Are Bio-Based Products Greener?

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- BASF has conducted 32 eco-efficiency studies that compared bio-based materials to conventional materials.
  - Approximately 71 bio-based materials were involved in these studies (e.g. one study included 5 forms of bio-ethanol).
- Types of Products
  - Plastics (automotive, packaging materials, bags, etc.)
  - Building construction (insulation and roofing materials)
  - Fuels (bio-diesel vs. diesel)
  - Flooring (wood vs. vinyl)
  - Coatings
  - Nutritional and animal feed supplements.

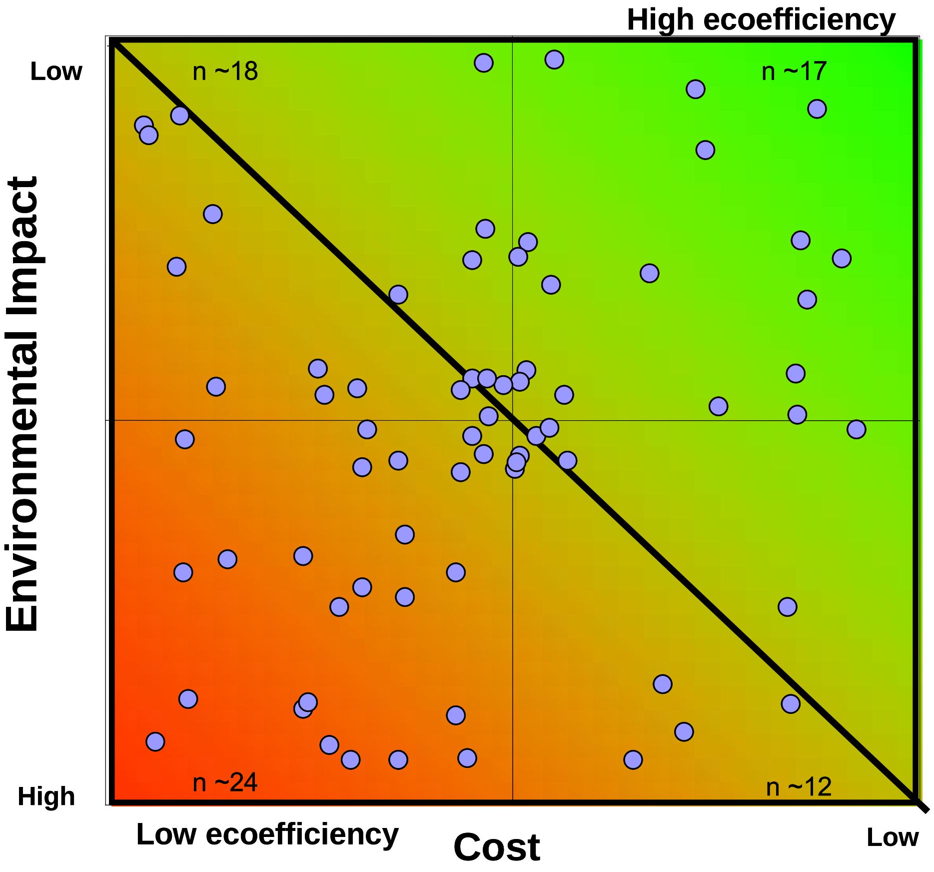
Eco-efficiency of bio-based materials vs conventional materials

BASF The Chemical Company

- BASF has conducted 32 eco-efficiency studies that compared bio-based materials to conventional materials.
  - Approximately 71 bio-based materials were involved in these studies.

Eco-Confusion ?
Bio-based materials may not be better.

Need to do the analysis



Summary of EEA Study on Film Printing Inks

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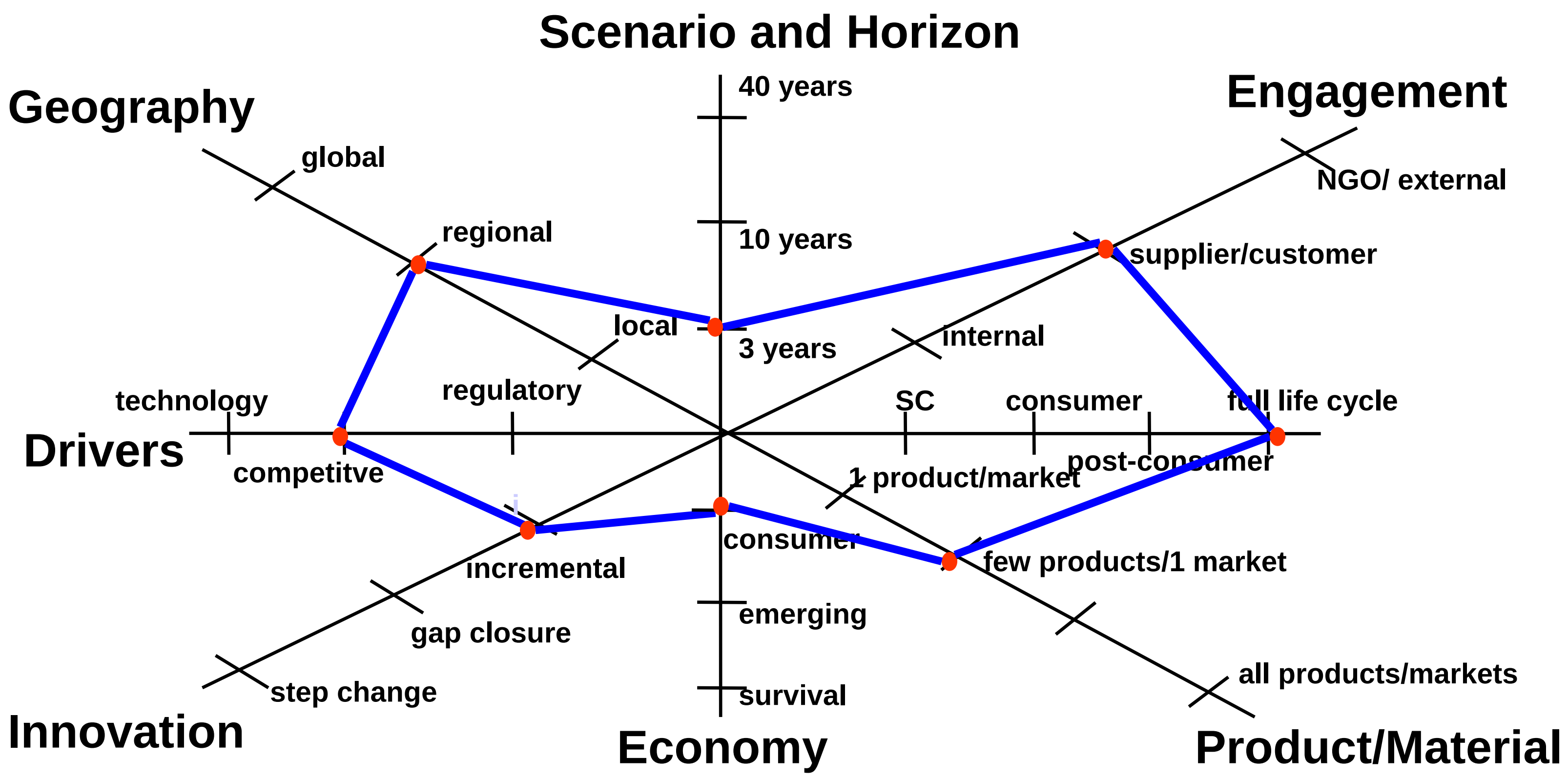
Eco-Efficiency Analysis of Flexo Water, Solvent and UV-Cured Inks in Film Applications

- This study compares water based, solvent based, and UV-cured inks formulated to surface print on polyethylene film.
- The customer benefit is the production, use and disposal of 1,000 m^2 of 3 mil. LDPE film with 25% image coverage on each of 4 stations.
- The ink systems evaluated are:
  - Water – Styrene/ acrylic water-borne thermally cured
  - Solvent - LMW polyamide/ nitrocellulose solvent-borne thermally cured
  - UV-Cured – Polyester/ acrylate UV-cured
- The press conditions were modeled utilizing a 4 color CI press with appropriate curing and VOC abatement equipment.

Context of Study



Ink Formulations

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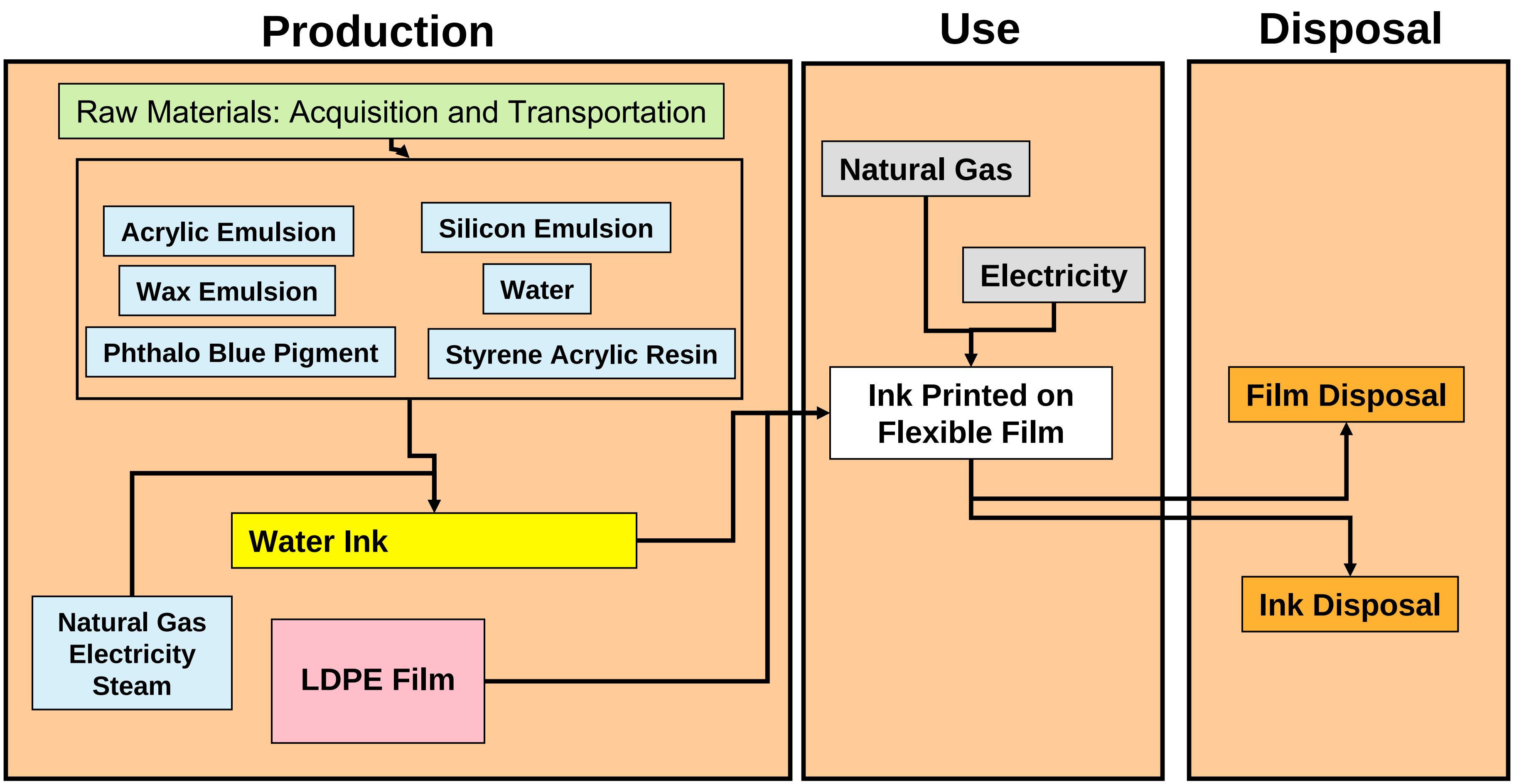
Ink Formulations

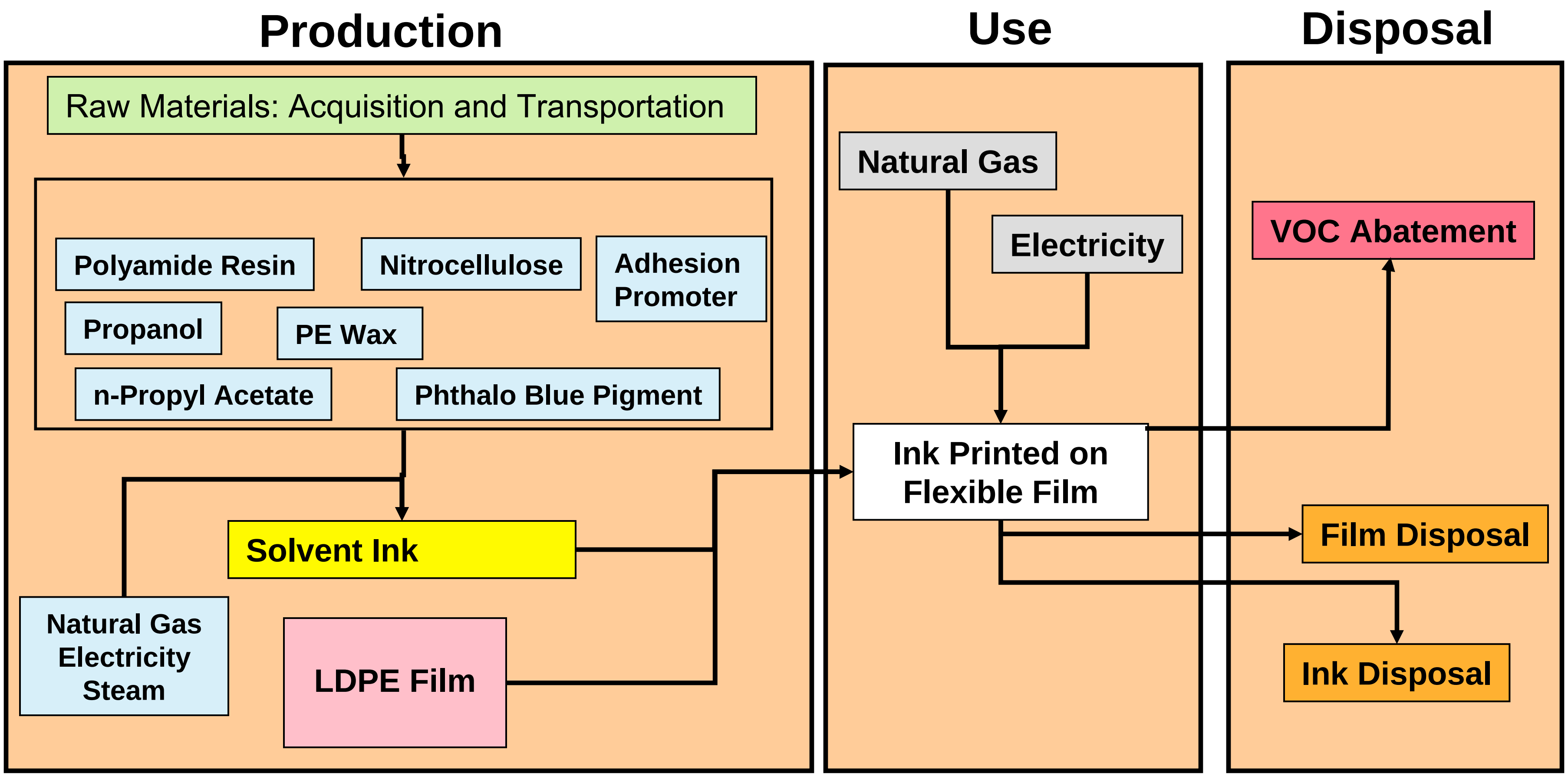
Ink Components	units	
Water ECO		
Heliogen Blue D 7092	%	16
JONCRYL ECO 75	%	15
JONCRYL ECO 2124	%	56.9
Polyethylene wax emulsion (JONCRYL WAX 28)	%	5
Silicone Emulsion (Dow Corning 1101)	%	1
Water	%	6
	Total	100
Solvent		
Heliogen Blue D 7092	%	12
alcohol soluble polyamide resin (Versamid 750)	%	17
nitrocellulose	%	3
polyethylene wax - not an emulsion	%	1
titenate adhesion promoter (Vertec IA10)	%	2
nPropyl acetate	%	11
nPropyl alcohol	%	54
	Total	100

UV-Cured		
Heliogen Blue D 7092	%	22
Laromer 9013	%	20
Laromer PO 94F	%	15
Laromer 8765	%	10
DPGDA	%	10
Laromer 8863	%	7
Disperbyk 168	%	3
Surfynol 104 PA	%	0.95
Irgacure 369	%	3
Irgacure 184	%	4
TPO	%	2
Esacure TZT	%	3
	Total	100.0

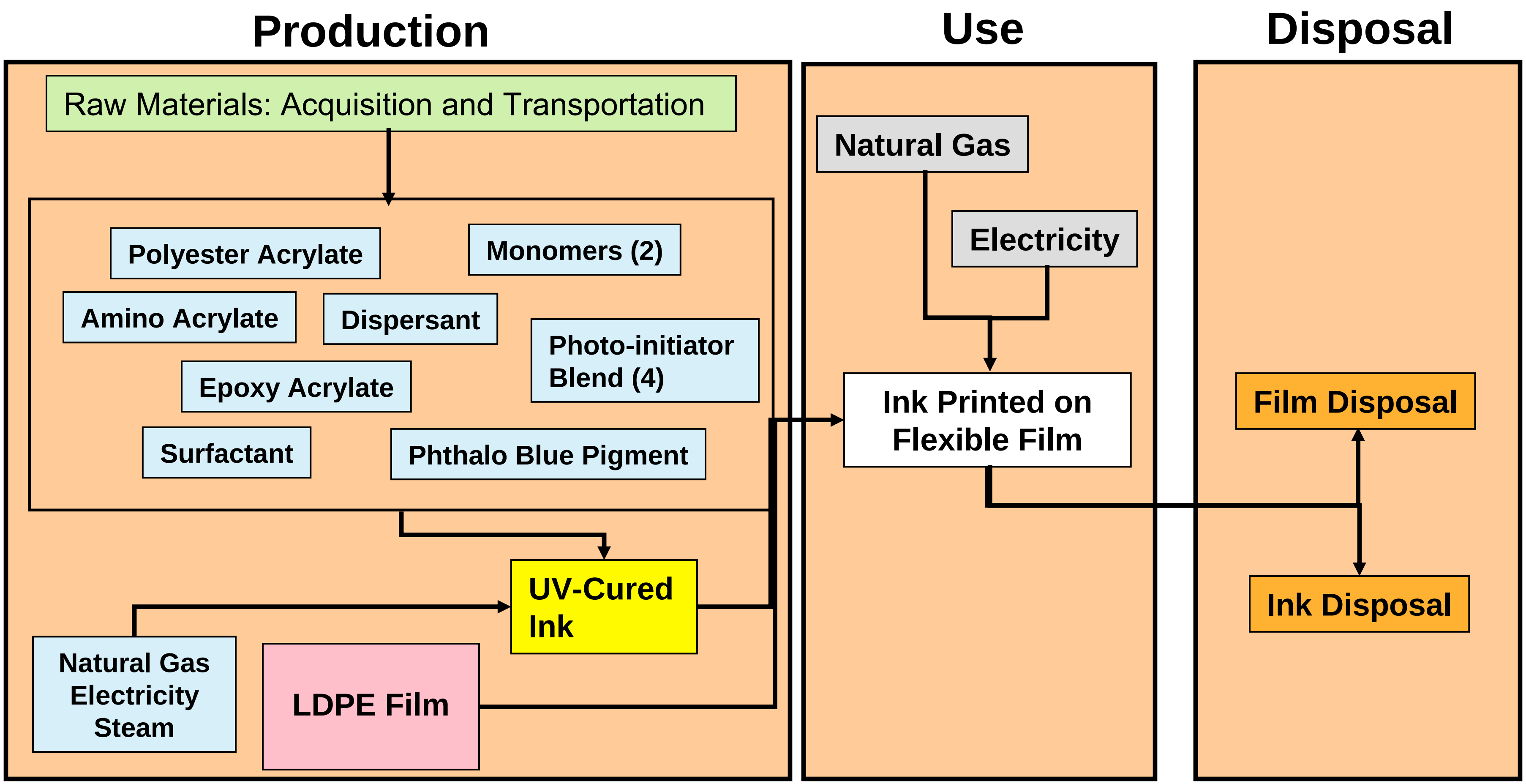
System Boundaries: Water



System Boundaries: Solvent



System Boundaries: UV-Cured



Parameters

Ink Variables	Units	Conventional water	Solvent	UV
Color		cyan	cyan	cyan
Solids	%	42%	33%	100%
Weight per gallon	Lb.	8.4	7.9	9.1
Dry film thickness	microns	2	2.2	3.2
Printed weight wet	g/m2	4.8	6.4	3.5
Printed weight dry	g/m2	2.0	2.1	4
Processing Variables	**Units**	**Conventional water**	**Solvent**	**UV**
Per print station	#	1	1	1
Ink coverage (image)	%	25%	25%	25%
Web width	m	1.5	1.5	1.5
Web speed	m/min	227	378	333
Production rate	m2/min	341	567	500
Production hours	hrs/yr	4,000	4,000	4,000
(CB) Customer Benefit of printed product =		**1000**		
Ink Consumption	**Units**	**Conventional water**	**Solvent**	**UV**
Wet ink usage / CB	Lb	2.6	3.5	1.9
Wet ink usage / hr	Lb	54	120	58

Parameters

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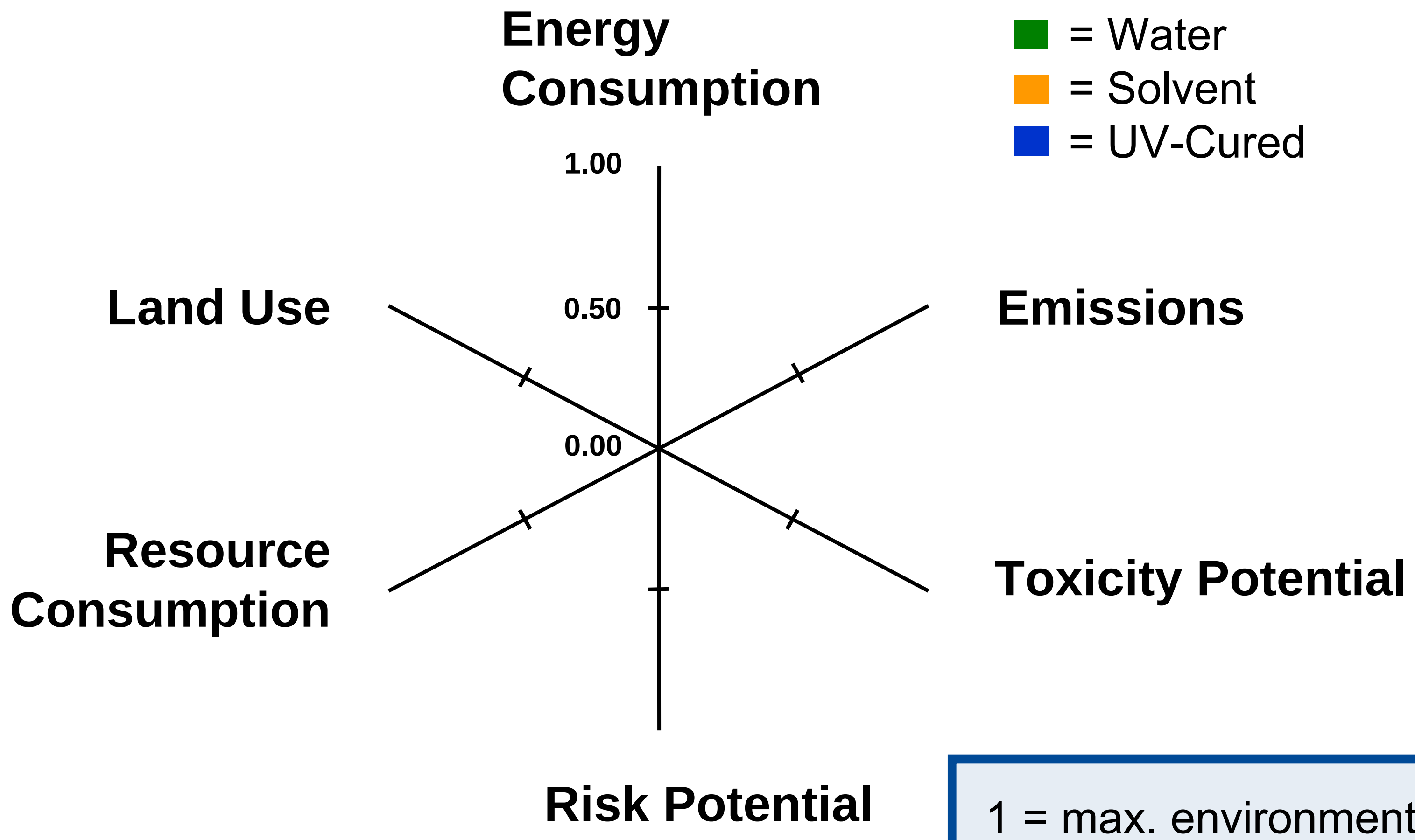
Energy Consumption

Energy	units	Water	Solvent	UV-Cured
Electricity				
Drive power	kWh	108	180	159
Inter-station - Drying	kWh	-	-	130
Inter-station - Blower	kWh	12	12	-
Main (final) - Drying	kWh	-	-	65
Main (final) - Blower	kWh	18	18	-
Inter-station Cooling - UV lamps	kWh	-	-	24
Main Cooling - UV lamps	kWh	-	-	36
Natural Gas				
Inter-station - Drying	MBTU/hr	0.76	0.64	-
Main (final) - Drying	MBTU/hr	1.14	0.96	-
Total	MBTU/hr	1.9	1.6	-
Total	MJ/CB	98	50	-

Ink and Film Prices

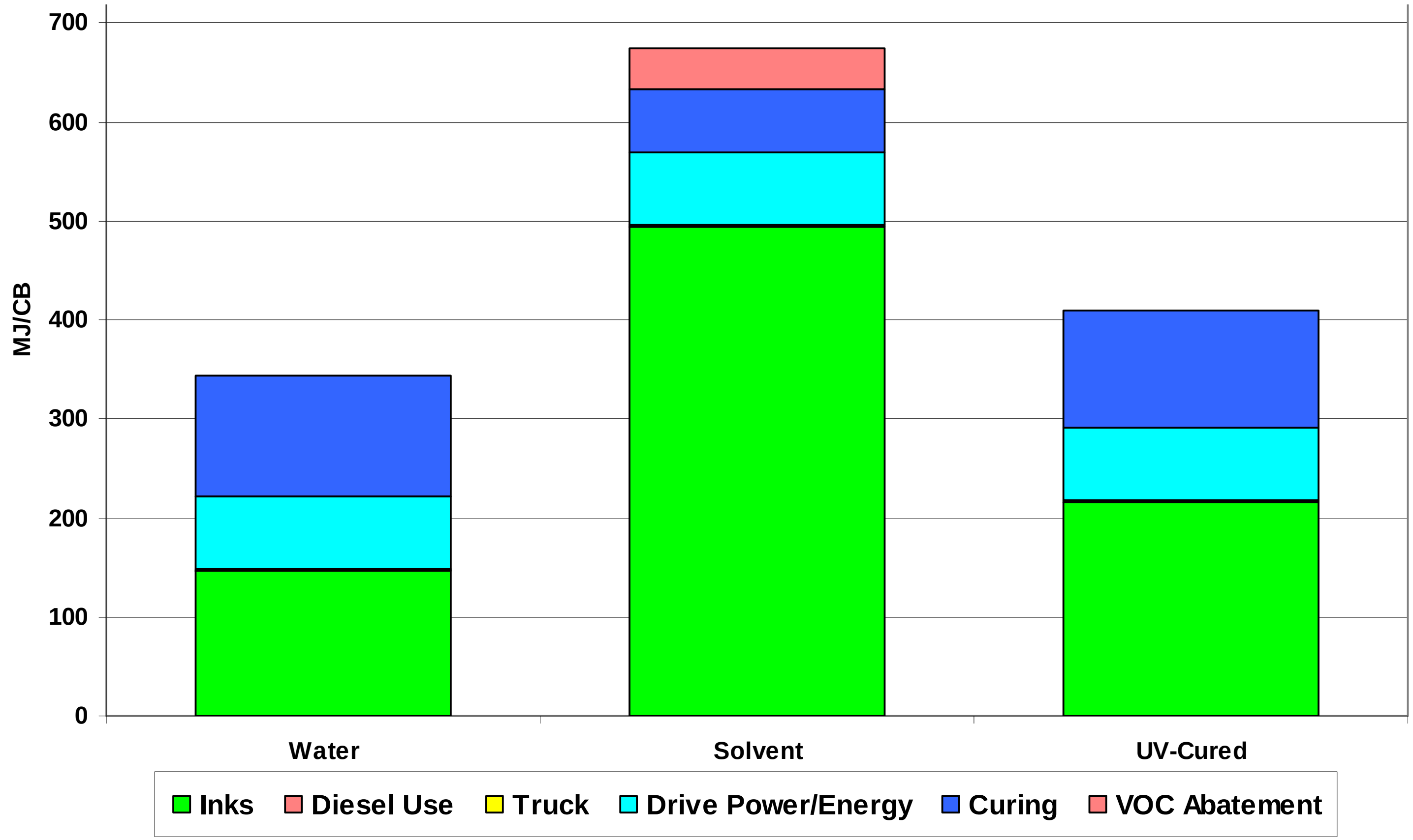
- Ink costs were calculated based on the raw material costs plus an equal percentage mark-up.
- Film cost was based on film type and average pricing.

Environmental Fingerprint



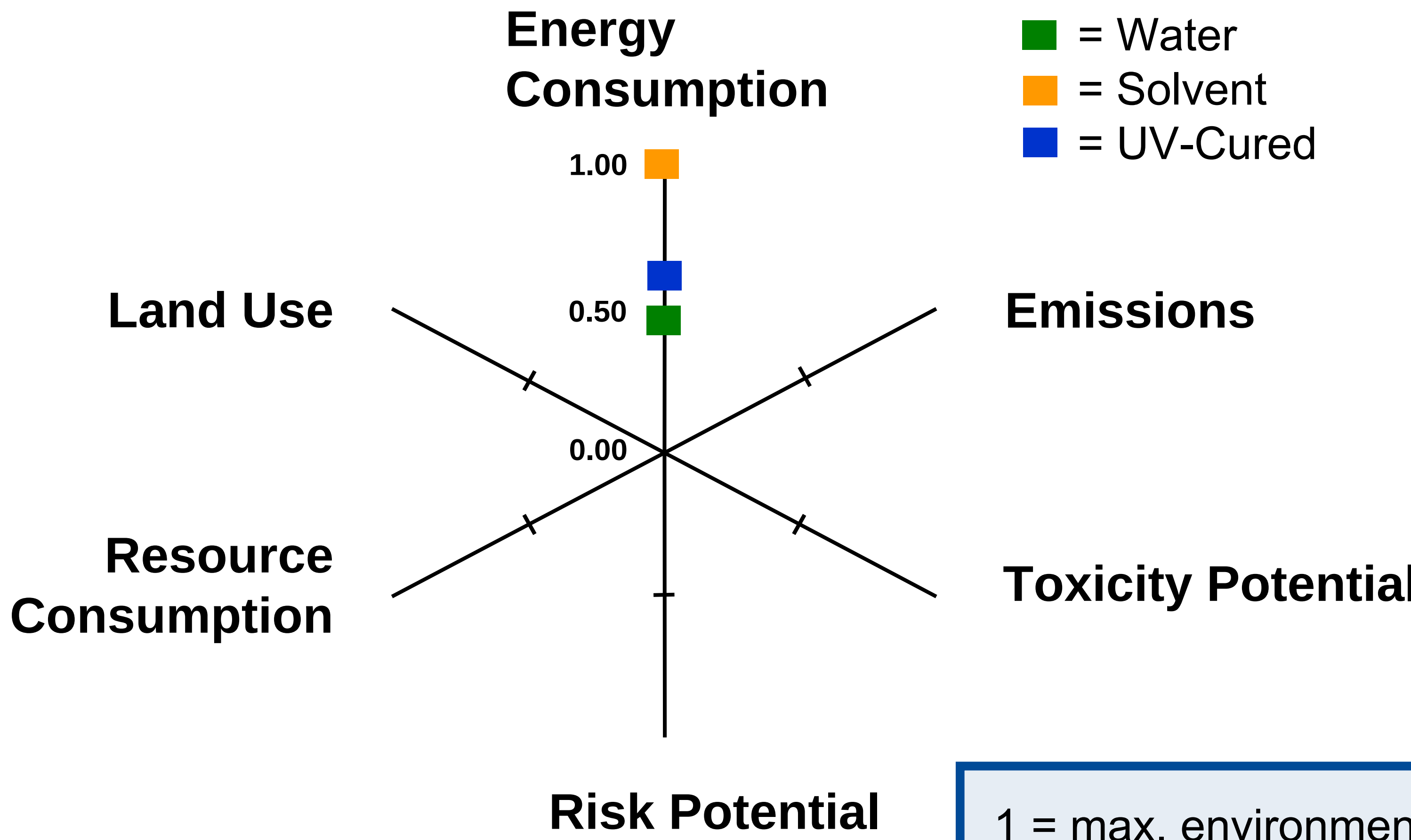
1 = max. environmental impact
0 = min. environmental impact

Energy Consumption



- Solvent has highest overall energy consumption over the entire life cycle, and ink formulation is the key driver.

Environmental Fingerprint



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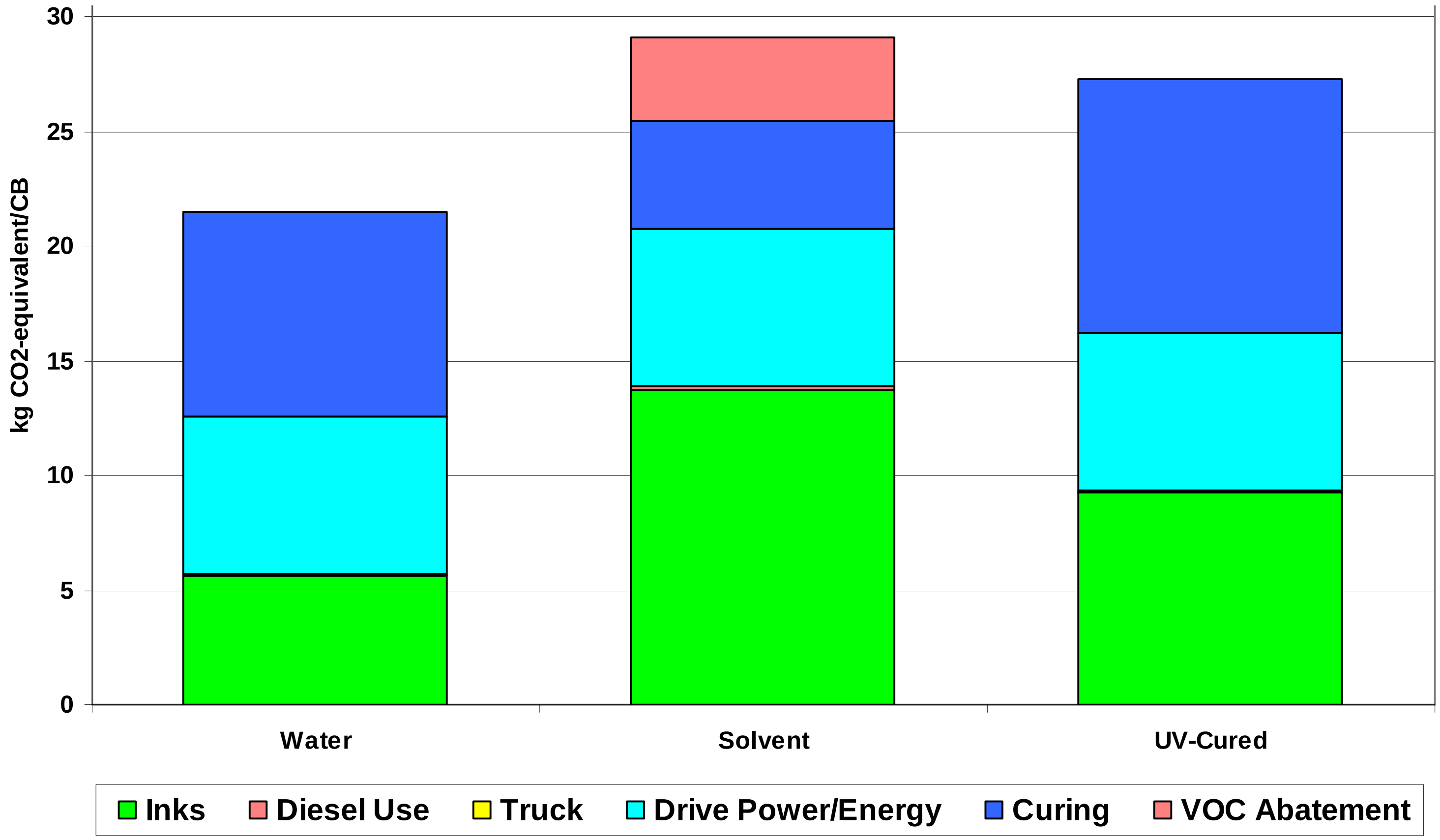
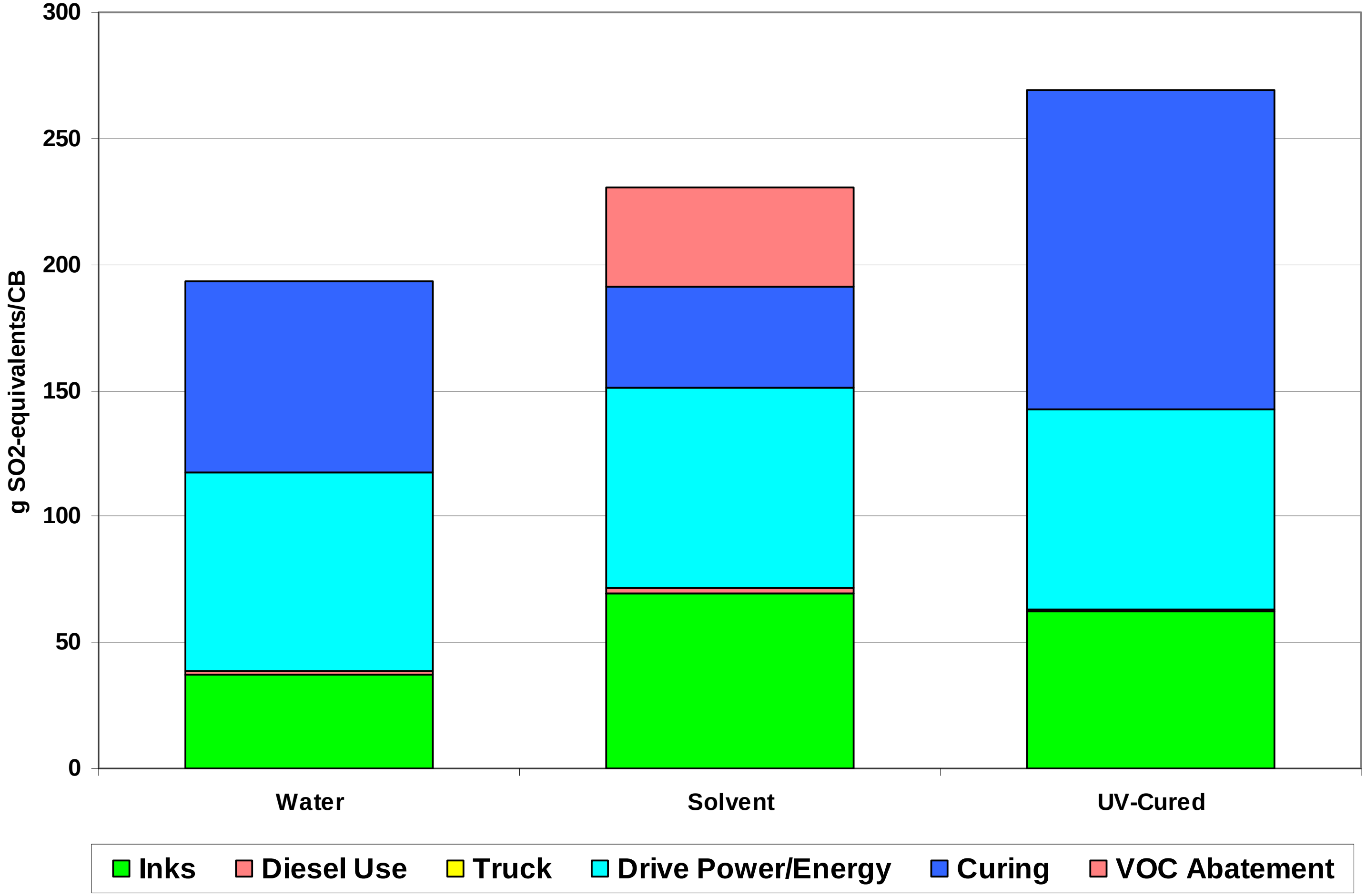
Emissions - Carbon footprint GWP



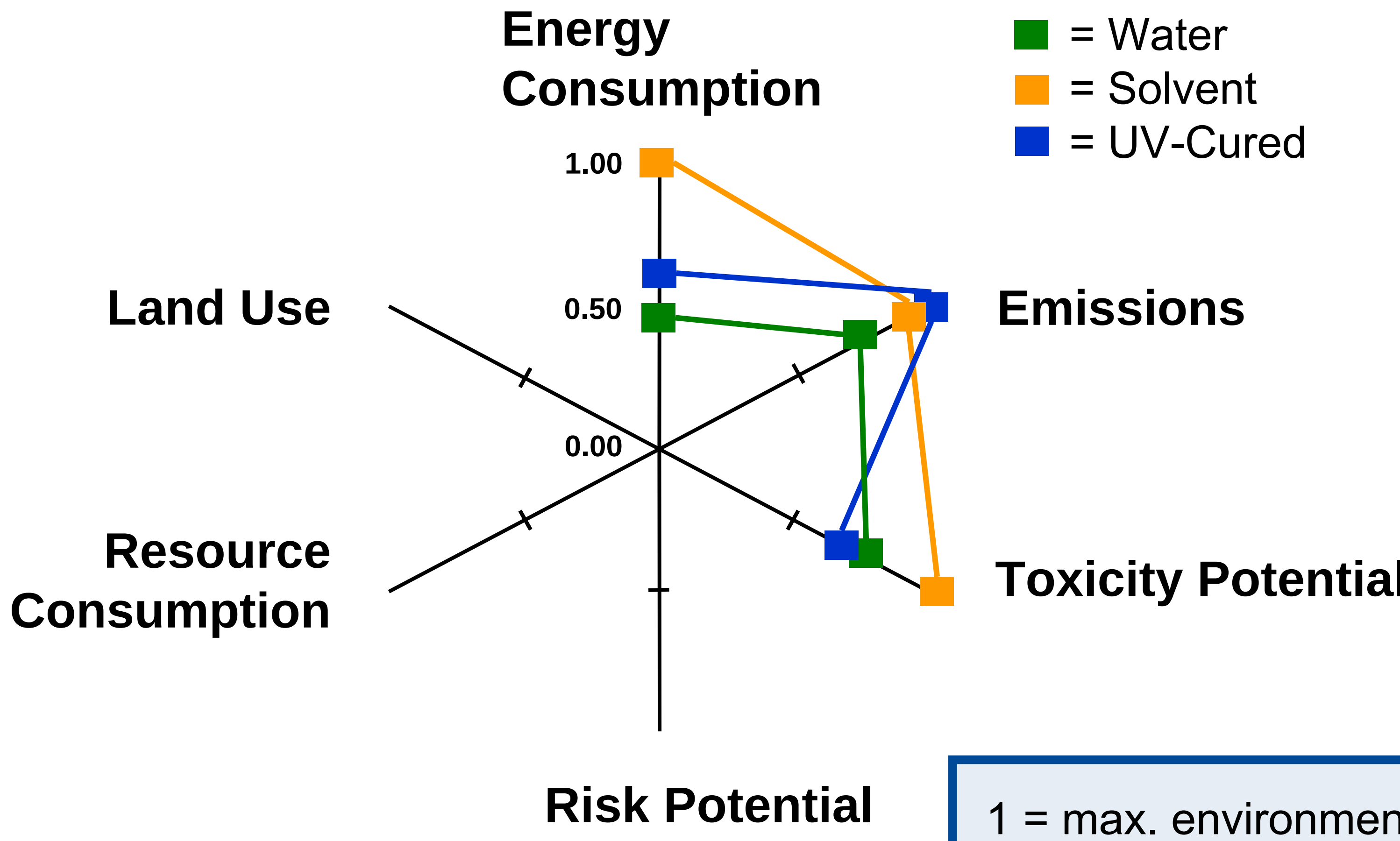
- Electricity usage is more inefficient than natural gas, which contributes to higher GWP during the curing stage for UV-cured inks.

Emissions - Acid Rain Potential (AP)



- Electricity consumption is key driver for Acid Rain Potential.

Environmental Fingerprint



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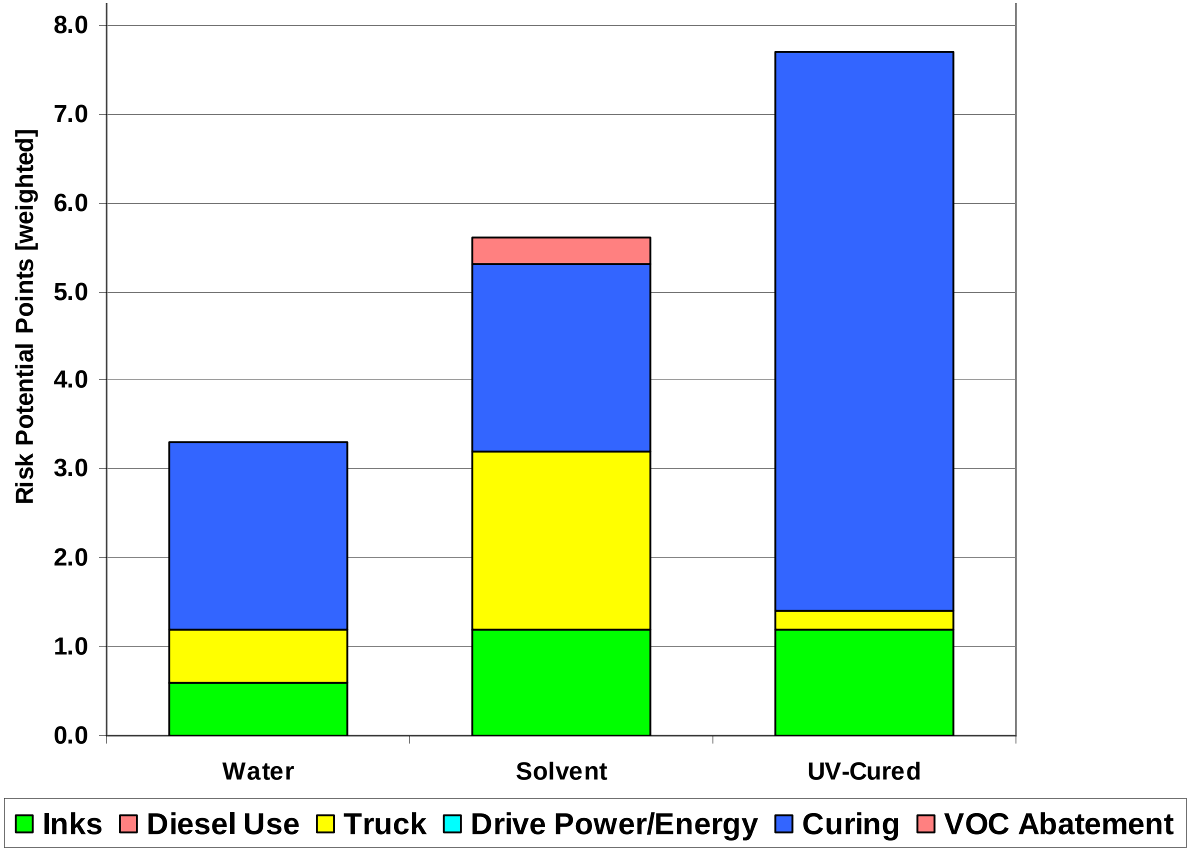
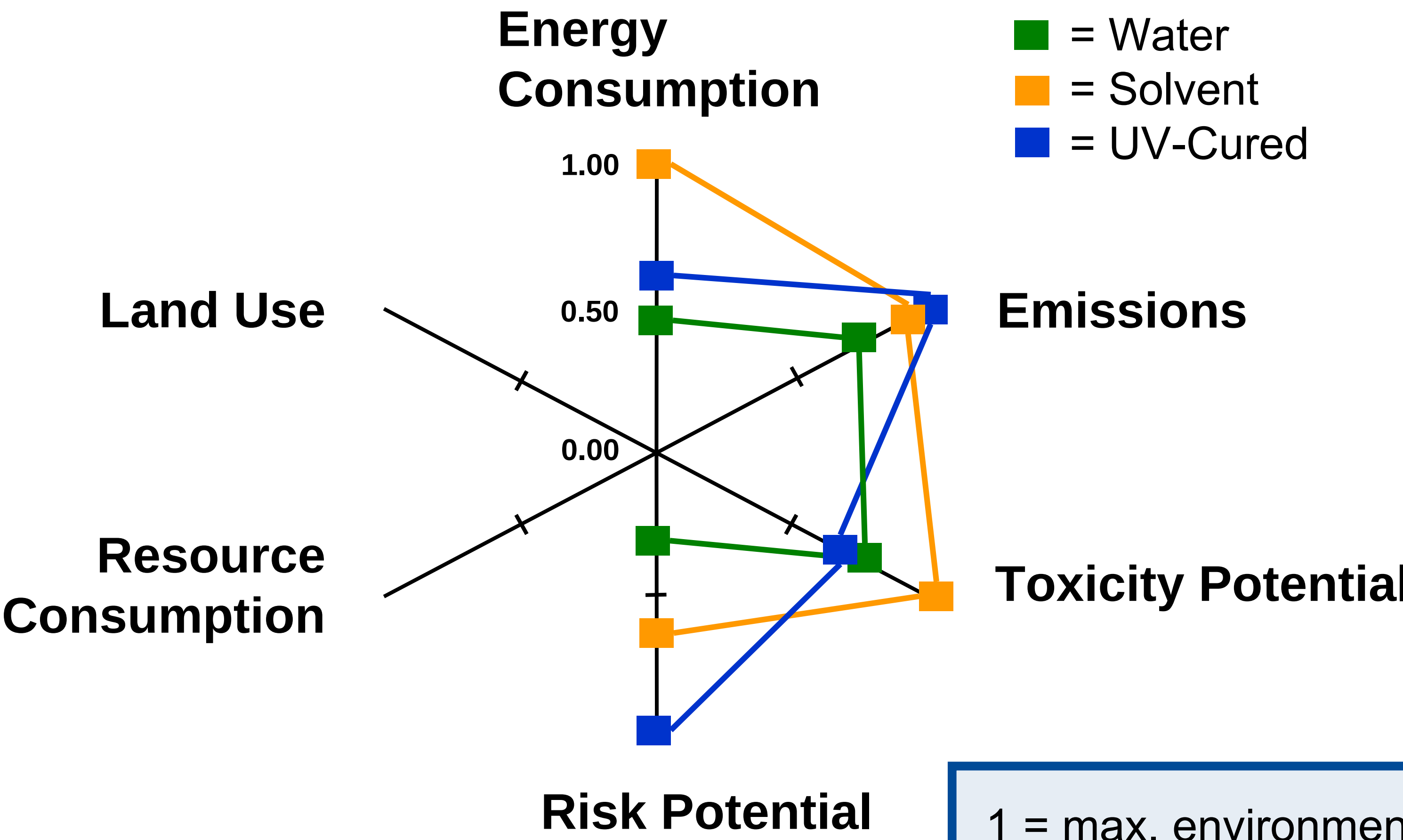
Risk Potential



- Includes worker accidents, fire and explosion hazards and transportation risks.

Environmental Fingerprint



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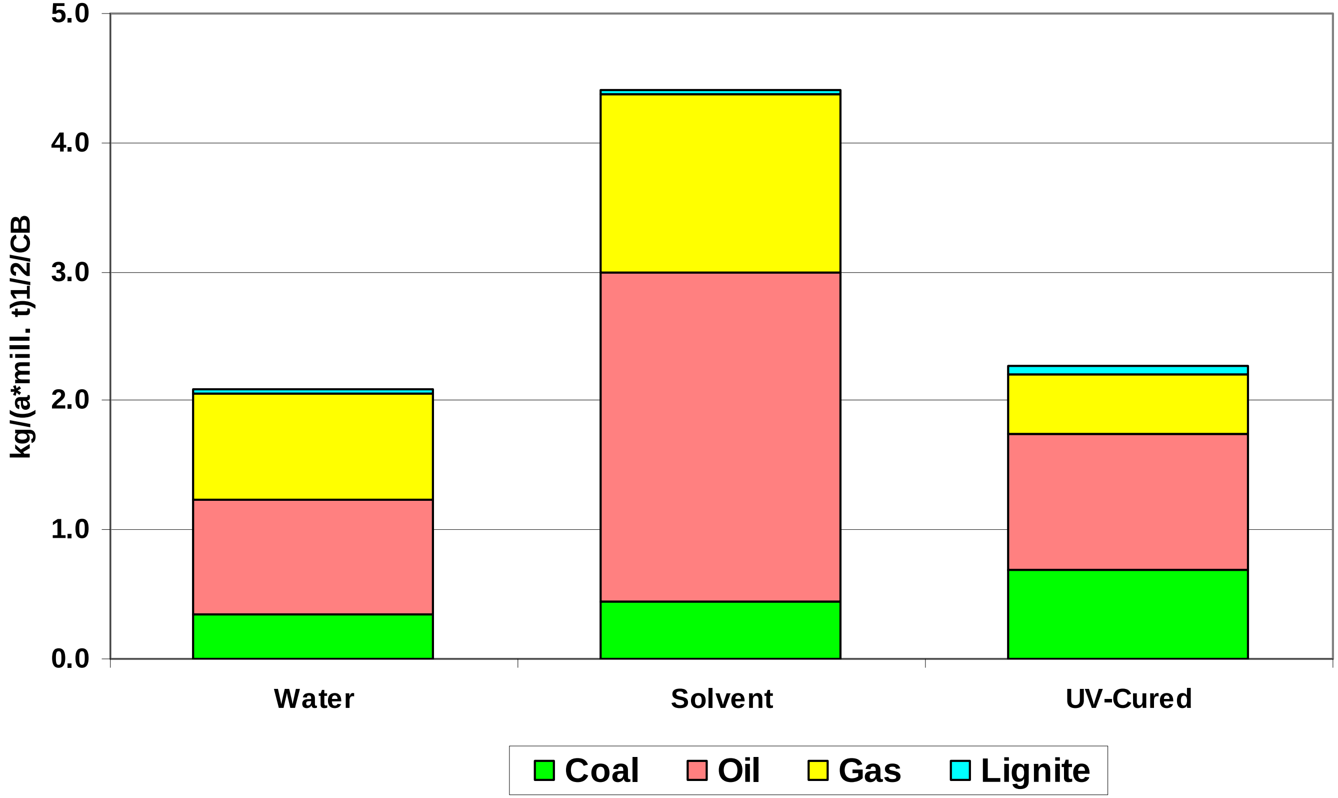
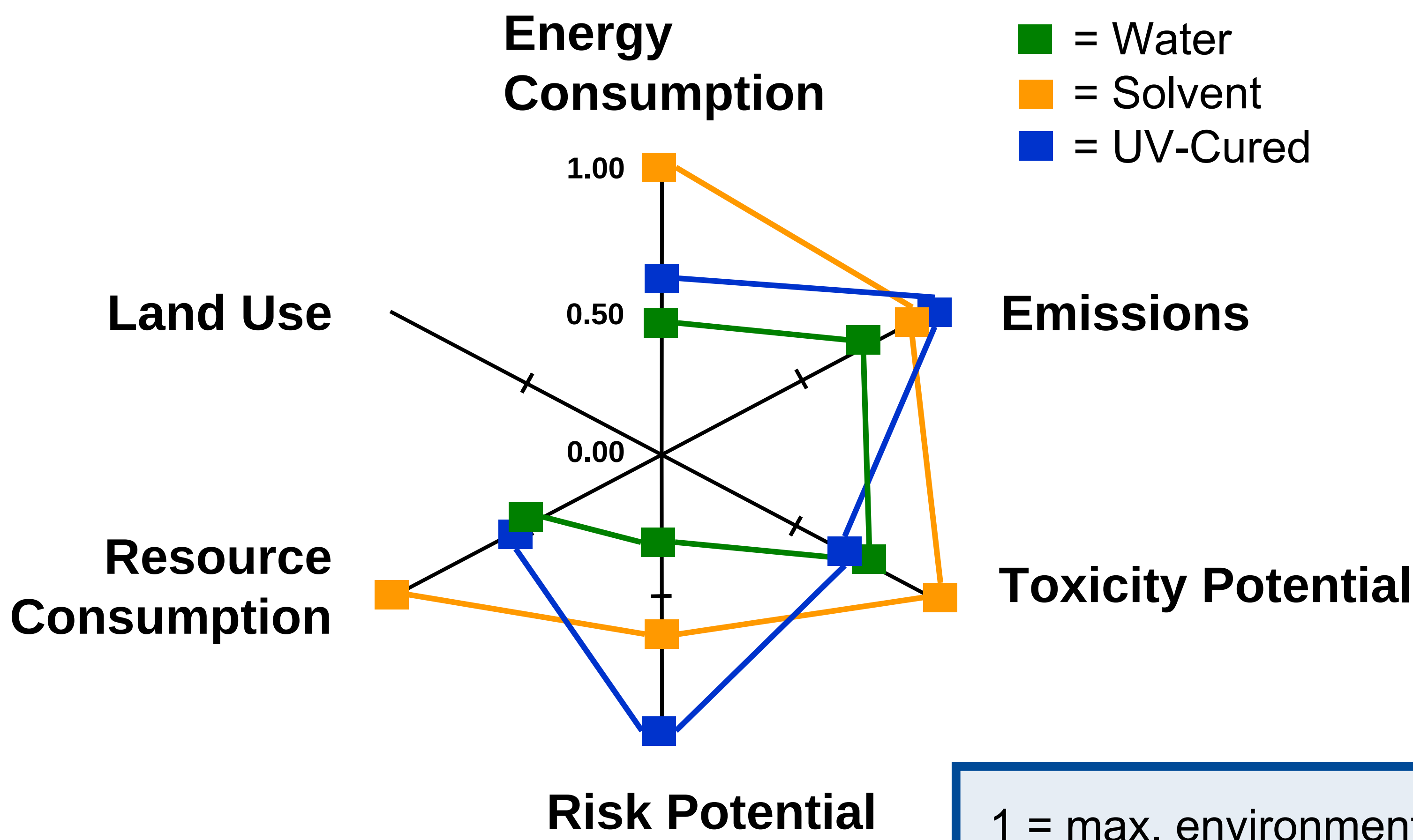
Resource Consumption – Fossil Fuels



- UV-cured and Water inks consume about the same amount of fossil fuels, while Solvent the most.
- VOC abatement contributes to higher consumption for Solvent.

Environmental Fingerprint



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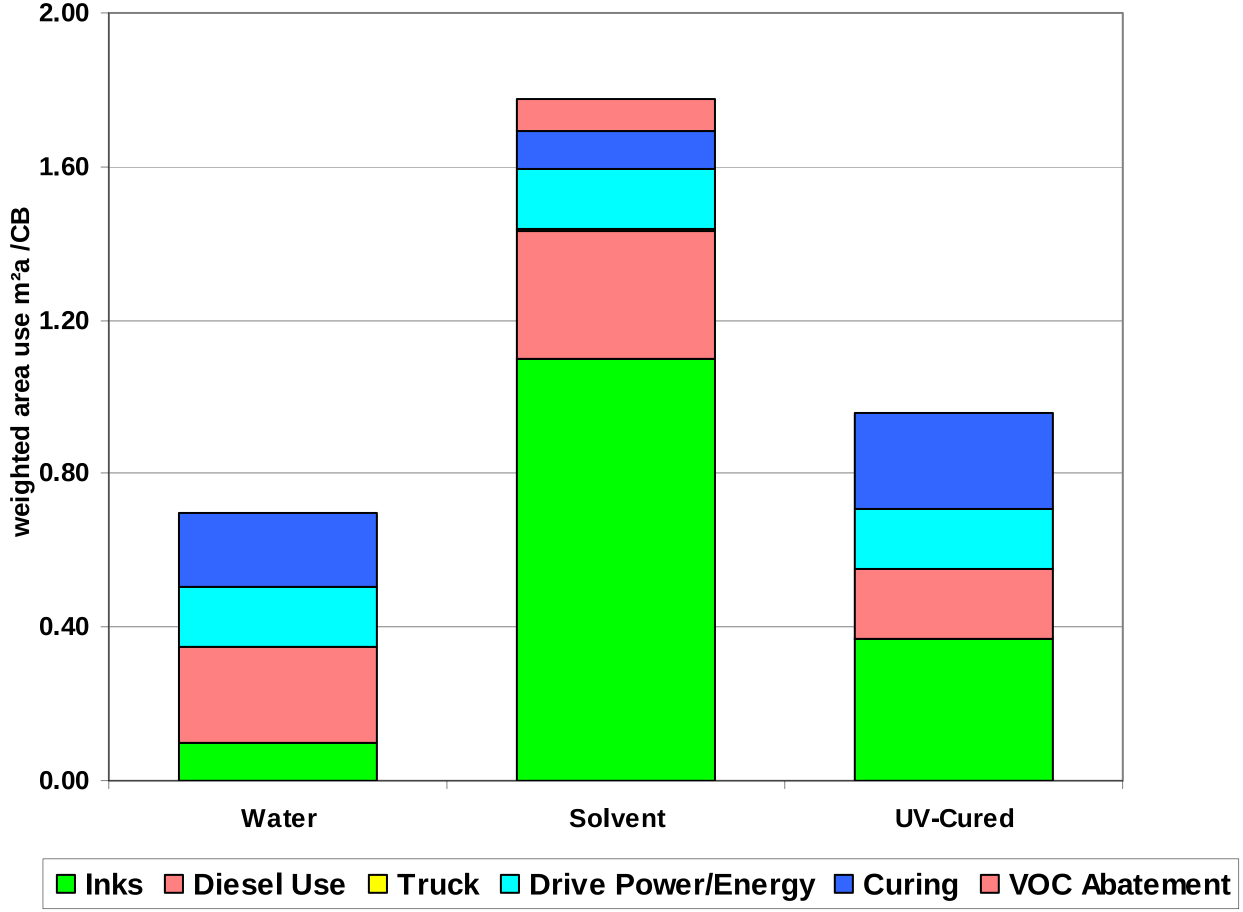
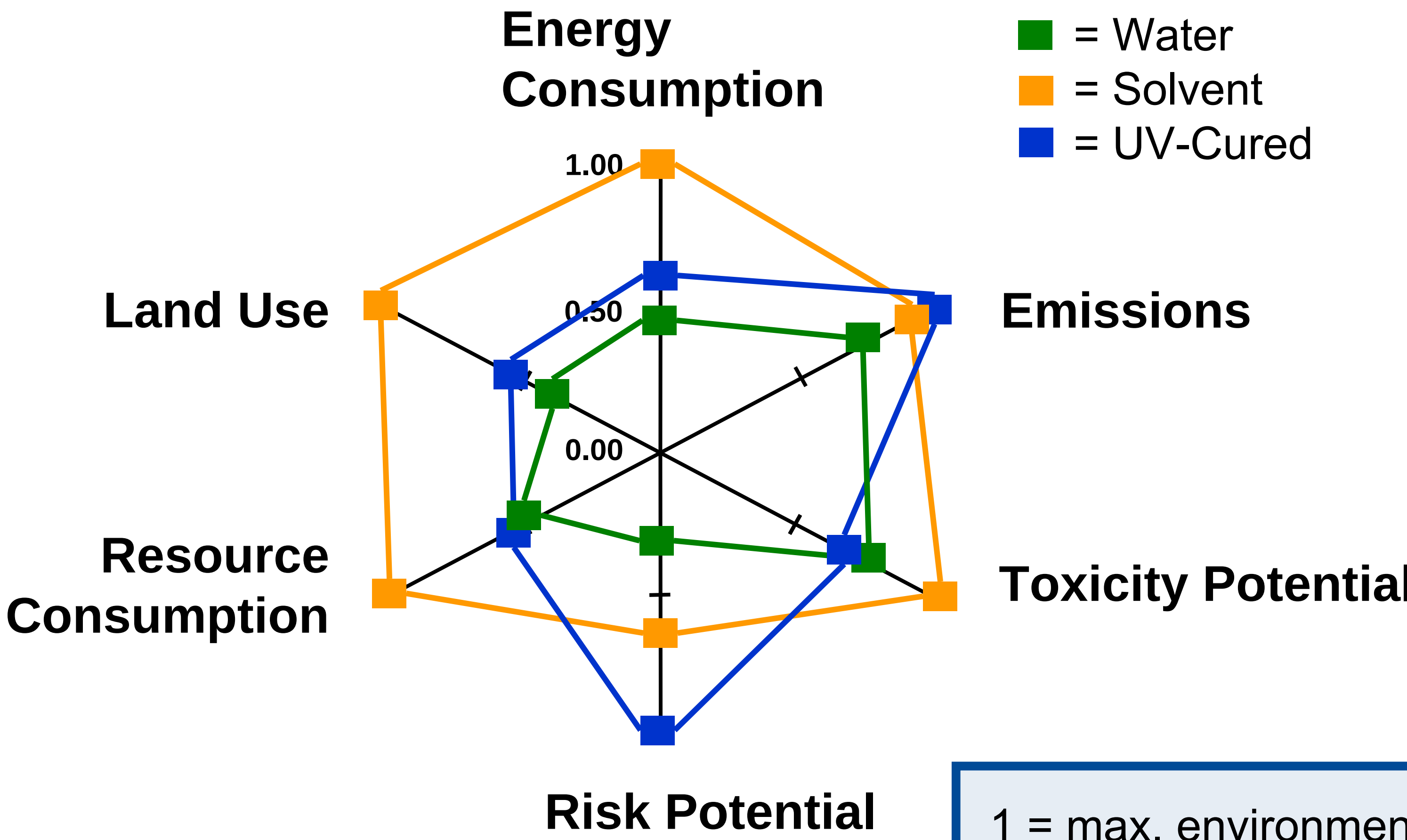
Land use



- Ink formulations and diesel use from drum transport are key drivers to land use impacts.

Environmental Fingerprint



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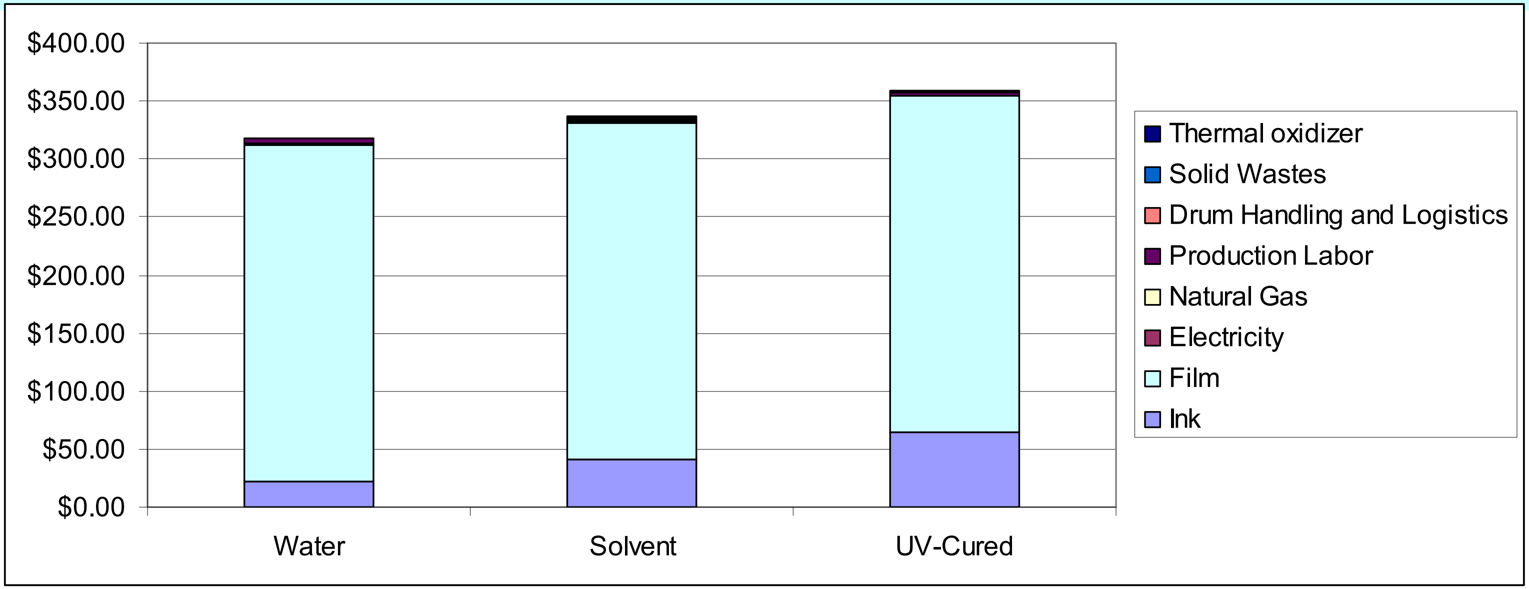
Results - Costs

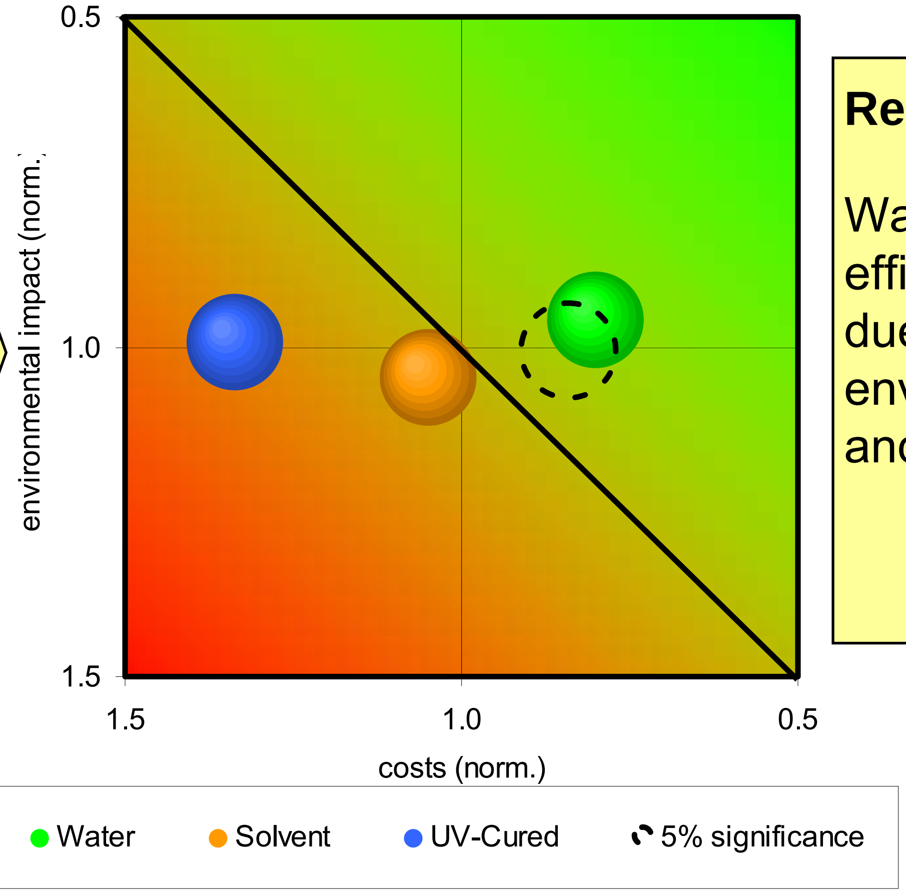
	Water	Solvent	UV-Cured
Ink	$22.70	$41.54	$63.91
Film	$290.00	$290.00	$290.00
Electricity	$0.63	$0.58	$1.29
Natural Gas	$0.10	$0.05	-
Production Labor	$4.26	$2.56	$2.90
Drum Handling and Logistics	$0.50	$0.71	$0.34
Solid Wastes	$0.35	$0.49	$0.25
Thermal oxidizer	-	$1.30	-
	$318.54	**$337.21**	**$358.69**



Results - Portfolio

Customer Benefit

Production, use and disposal of 1000 m^2 of 3 mil. LDPE flexographic film with 25% image coverage.



Results

Water ink most eco-efficient alternative due to slightly lower environmental impact and lower costs.

Water-based Resins
Technical Trends –
Consistent with Eco-Efficiency

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- **JONCRYL FLX 5000- self-crosslinking emulsion to improve the performance of water-based systems (vs. solvent-based systems) in flexible packaging applications**
- **JONCRYL HPD 296- higher pigment dispersion efficiency to allow for higher color concentrations and reduced ink usage; achieve finer graphics; and reduce energy consumption in milling and dispersing operations**
- **JONCRYL LMV- lower maintenance vehicles to improve on-press ease-of-use and minimize rework and waste**
- **JONCRYL 636 and JONCRYL 2156- higher solids emulsions to improve upon dry speed and thereby reduce energy consumption**

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BASF Group: www.basf.com

BASF Corporation: www.basf.com/usa

BASF Resins: www.basf.com/naftaresins

Sustainability:

http://www.basf.com/corporate/Sustainability/index.htm

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Thank You

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