THE ENVIRONMENTAL GENOME INITIATIVE

Mapping the building blocks of human creativity

The Supply Chain Dimensions of Alternatives Assessment

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www.environmentalgenome.org

Chemical Systems

- Current and alternatives materials are members of the industrial chemicals-in- commerce family (100,000), even if emerging chemicals.

- The product system
  - A user-facing product that often drives the goal of adopting alternatives chemicals
  - A shadow of the entire cradle-to-chemical system needed to deliver current and alternative chemicals to the use in a product. Shadow because we often do not think of it or occasionally recognize it is there , but it is inescapable part of each chemical. Only escape is we go into the dark

- All chemicals, materials, and products have an impact on the environment and potentially public health, even the benign baby food

- We need to quantify and then make comparative decisions

The Environmental Genome goal is to provide detailed, high transparency, open-access information on each chemical manufacturing process and for each member of all the supply chains for all chemicals-in-commerce (100,000).

- The Environmental Genome mapping technology is proven (www.environmentalgenome.org)

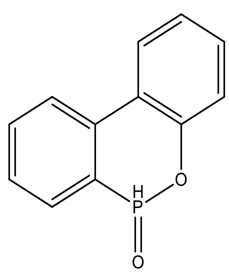
- Capture
  - Routes for manufacturing
  - Detailed process, flows, temperatures, unit process efficiencies, all necessary physical properties, and potential for energy recovery
  - Catalogue of unit process equipment
  - Energy in five modalities to link to impacts of energy generation
  - Chemical losses
  - Non-product chemical use (catalysts, solvents, ancillary chemicals
  - Keys to reducing chemical manufacturing impacts

- High transparency to identify errors, facilitate priorities for process improvement, achieve system-wide analyses

- Leads to very broad and diverse uses on this information (product design, national security, manufacturing technology, and environmental impact)

Alternatives to Brominated Flame Retardants

- Application – printed wiring circuit boards – the product
- Fundamental not incremental alternative
- Brominated FR is used with common epoxy (BPA-epichlorohydrin), but Phosphorus FR needs a Novolac epoxy (phenol-formaldehyde-epichlorohydrin) which is less electrically conductive, so common epoxy is added to get required connectivity
- Environmental Genome was used for each flame retardant, first at cradle-to-gate boundary. These two flame retardants required 70 individual life cycle inventories, many of complex molecules.
- Then extended the analysis to include use in printed wiring circuit boards of products

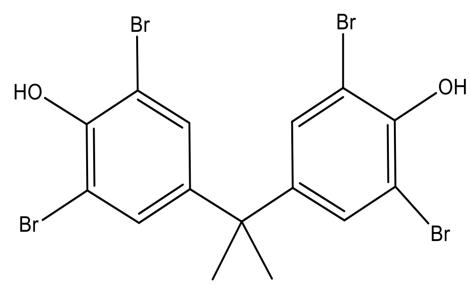


9,10-Dihydro-9-oxa-10-phosphaphenanthrene 10-oxide

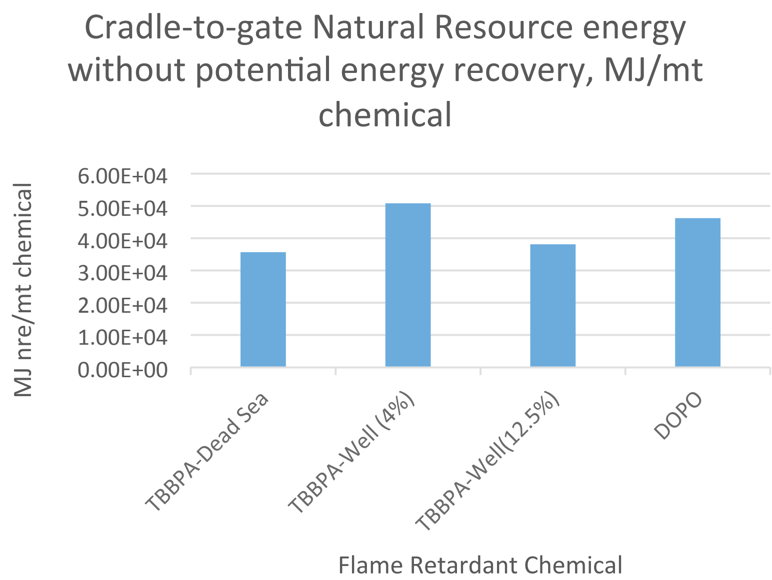
$C_{12}H_9O_2P$

35948-25-5

DOPO



tetrabromobisphenol-A (TBBPA)



- At the first stage, the two flame retardants have a similar energy demand for the ctg

However, when we extended the EG database to capture flame retardant use in products there is a major difference

- 75% of the printed wiring circuit market is large boards and it was discovered that to get signal performance
  it was necessary to use 2-3 times more epoxy was needed for the phosphorus-based flame retardant. This shifts the phosphorous-based flame retardant to a much higher environmental impact

- However, in 15% of the market (small sizes like cell phones, small laptops, etc.) there was no need to increase the epoxy
  and so the same amounts of flame retardant could be used and thus shifting to the phosphorus-based alternative leads to the same environmental impact as the brominated flame retardant and thus is an acceptable shift.

- So using the quantification of the EG lets us target specific products would lead to the ability to remove halogens from these products

The Environmental Genome Database and Analytics

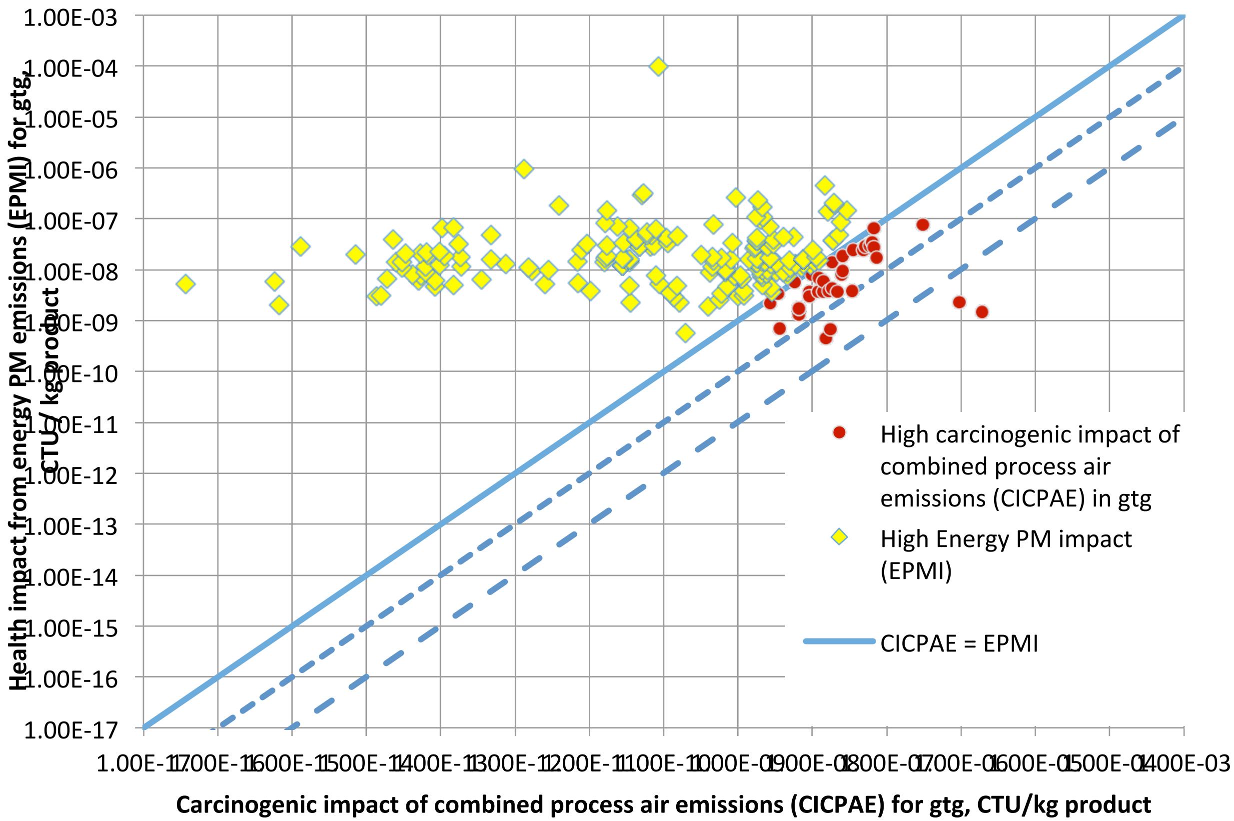
- The large impact of this new database is when used as a part of analytics developed to answer important questions

- The database is large enough now to support analytic development

- Example, which chemical manufacturing plants have carcinogenic air emissions

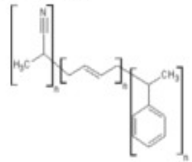
- Environmental Genome database plus TRACI air carcinogen list

Chemical process comparison of cancer risk (Comparative toxicity unit (CTU-HH-cancer)/kg chemical process product) from process emissions versus energy-related emissions



Exterior Casing

Fe Mg Al

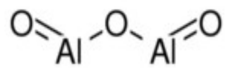


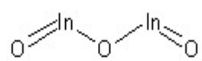
acrylonitrile-butadiene-styrene

58 chemicals in supply chain
49 air emissions (6 carcinogens)
28 water emissions (5 carcinogens)
23 solid emissions (0 carcinogens)

Front Screen

K^+ O=Si=O O=Sn=O

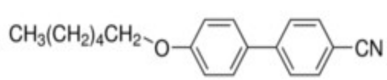




78 chemicals in supply chain
64 air emissions (12 carcinogens)
45 water emissions (6 carcinogens)
33 solid emissions (1 carcinogen)

LCD Display

O=Si=O



4′-(hexyloxy)-4-biphenylcarbonitrile

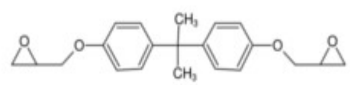
40 chemicals in supply chain
45 air emissions (4 carcinogens)
31 water emissions (2 carcinogens)
9 solid emissions (0 carcinogens)

156 total chemicals in supply chain

	Emissions	Carcinogens
Air	91	17
Water	114	14
Solid	62	2
Total	**267**	**33**

Circuit Board

Ag Cu Au Ta



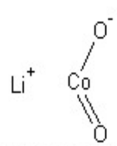
bisphenyl A diglycidyl ether

102 chemicals in supply chain
65 air emissions (8 carcinogens)
58 water emissions (7 carcinogens)
46 solid emissions (1 carcinogen)

Battery

C

graphite (anode)



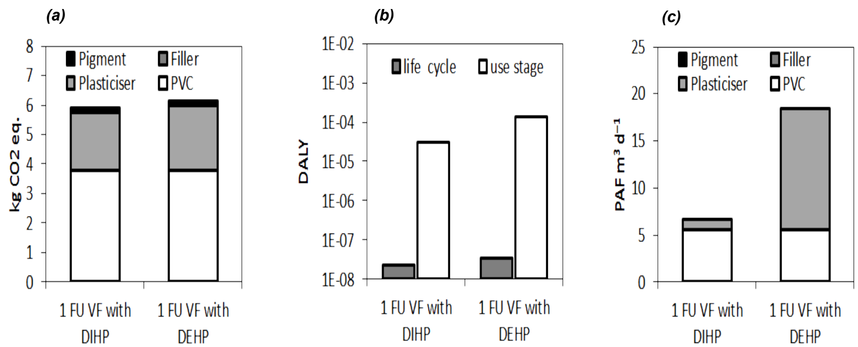
lithium cobalt oxide (cathode)

41 chemicals in supply chain
41 air emissions (5 carcinogens)
28 water emissions (2 carcinogens)
12 solid emissions (0 carcinogens)

All products in society are made from about 100,000 chemicals in commerce

Alternatives for plasticizer in vinyl flooring (Jolliet, Huang, Overcash, Fantke, 2017)

- Comparison of two alternative plasticizers (DEHP-diethylhexyl phthalate vs. DIHP-Diisoheptyl phthalate)
- At the product level these are semi-volatile and the loss to air over 15 years was 2% of the initial amount for DEHP, and 9% for DIHP
- The Environmental Genome was then used to evaluate the environmental effects of manufacturing these two plasticizers



Life cycle climate change (a), human health (b) and ecotoxicity (c) impacts of the two floorings with DIHP and DEHP plasticizers, for a functional unit of 1 m^2 flooring over 15 years

- The Environmental genome data add that the life cycle perspective shows the carbon footprint of these two plasticizers are very similar
- For human health impacts there is a clear difference, with the supply chain and manufacturing of DEHP being 1.5-fold larger than DIHP
- For ecotoxicity, the supply chain and manufacturing of DEHP is about 10–fold higher than that for DIHP and is the dominant contributor.

The combined chemical alternative performance evaluation combined with the manufacturing/supply chain shows that this overall view is an important and expanded perspective. The goal is to make the manufacturing/supply chain data readily available for all the chemicals-in-commerce.

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