Investment in the Green Chemistry Innovation Fund for SPF Systems

Introduction

We recommend an investment of $8 million in the Green Chemistry Innovation Fund (GCIF) for SPF Systems. This amount should attract multiple quality proposals aimed at different types of potential alternatives (new formulations and exposure reduction technology). This level of investment in the GCIF for SPF Systems can fund several lab-scale projects and has the flexibility to provide some of the funds necessary for scale up or performance testing.

This amount was determined by analyzing the factors laid out in this document. This is a necessary step because each Priority Product (PP) has its own unique set of potential solutions to remove or reduce the Chemical of Concern (CoC), exposure to the CoC, or the adverse impacts. Accordingly, the SCP program deals with each PP on a case-by-case basis. As such, this justification for funding the Advancement of Green Chemistry and Green Engineering Regulatory Response (RR) is unique for spray polyurethane foam systems (SPF Systems) and is not generalizable to other PPs or industries that make PPs.

Factors regarding the cost of research

A) **Responsible Entities' (REs') cost estimates for the development of an alternative.**
The Abridged Alternatives Analysis (AA) Report contained the REs' estimates for development and commercialization of a new product; their report estimates $735,000 - 1.75 million for a single type of SPF (see Table 5.15 from the Abridged AA Report below). However, the sum of the high range cost estimates of all activities listed in table 5.15, is $2.3 million. Replacements are needed for all four types of spray foam (low pressure, 0.5-pound, 2-pound, and 3-pound/cubic foot). Thus, estimated costs need to be multiplied by four to develop an alternative for each of the four products. Using the RE's low and high range estimates, the cost to develop four types of alternatives ranges from $2.94 million to $9.2 million. The AA Report further discusses the cost of manufacturing, outfitting spray rigs, and training employees for a new alternative. These costs are outside the scope of the Green Chemistry Regulatory Response.

Table 1. From the Abridged AA Report, Table 5.15 - Estimated Cost and Time for Research and Development (R&D) of a New Product

Activity	Estimated cost	Estimated time
Research and Development (R&D)	$500,000 to $1,500,000	3 to 5 years
Product Certification Basic Construction (Type V)[1]	$150,000 to $300,000	1 year
Product Certification Basic Construction (Types I-IV)	$50,000 to $300,000	1 year
Annual Listing Fee	$25,000 to $100,000	Not applicable
Other Third-Party Approvals and Certifications[2]	$10,000 to $100,000	Not applicable
Total for R&D	**$735,000 to $1,750,000**	

The REs also point out that not every bench-scale research project will be scalable or capable of being commercialized. Thus, to increase the probability of commercialization, it is necessary to fund multiple bench-scale research projects.

When considering the costs for developing an alternative product, not every research project might need the entire $2.3 million. For example, some alternatives might have overlapping properties that would be suitable for more than one of the four types of spray foam, decreasing the overall cost. In addition, it is important to note that if the product cannot graduate beyond the R&D phase, additional expenses such as certifications and listing fees are not applicable. Therefore, it seems reasonable that the cost needed to successfully develop an alternative would likely be close to, but not exceeding, the high-end estimate proposed by the REs.

Instead, a total investment of $8 million total investment to allocate over a span of 3 years into the Green Chemistry Innovation Fund seems appropriate. This would attract and allow funding of multiple proposals from qualified researchers, enabling a broader exploration of potential alternatives. By supporting a diverse range of projects, the likelihood of developing effective and safe alternatives can be significantly increased. The REs also rely on the supposition that a safer alternative is chemical, rather than one of the alternatives that can lower exposure. This further supports the need for a comprehensive R&D approach.

After consulting with several green chemists and folks with experience in product development, we generated the table below to evaluate various levels of funding and various research projects that could potentially be funded.

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[1] Once a new product is developed, it takes upwards of $150,000-$300,000 to do testing and obtain Evaluation Service listings for its safe use in the field. This provides a basic residential (Type V) listing. For a variety of commercial uses, a further $150,000-$300,000 worth of testing and engineering evaluations is required to get approvals for Types I-IV construction.

[2] Other third-party approvals include GREENGUARD, California Department of Public Health (CDPH) Standard Method v1.2, Bureau of Household Goods and Services, and Factory Mutual Approvals.

Table 2. Level of investment and projects that could potentially be funded.

Approximate Amount	Rationale
$150k	This is roughly equal to the second stage of the two-stage AA. This is the minimum amount implied by the FSOR. We might be able to attract one bench-scale project for one year. This funding level would be unlikely to attract qualified proposals. This is not sufficient to reach the SCP goal of developing a safer product to protect workers.
$1 million	This could likely fund one or 2 bench-scale projects for up to two years. This is not sufficient to reach the SCP goal of developing a safer product to protect workers. Given the difficulty of the chemistry and the state of alternatives, it would be prudent to invest in more projects.
$2 million	This level allows for funding multiple bench-scale projects. Based on our research, this is the minimum needed to meet the goal of identifying a good candidate for a safer product to protect workers. If the 15 REs each paid $150k (the cost of the 2nd stage of the AA), that's $2.25 million.
$5 million	This is probably the funding level needed to scale-up a project and get it to the beginning of the pre-commercialization phase.
$10 million	This level provides flexibility to fund multiple bench-scale projects, including projects on exposure control. Funds for scale up would also be available for worthy projects. Funding could potentially cover some toxicity testing of new chemicals or performance testing of a new potential product. We recognize that considerable performance testing will be needed for a complex and durable product, such as SPF.

B) **Funding level needed to attract qualified researchers with strong proposals**. Presumably, the REs' estimates focused on internal research at the RE's own companies. DTSC explored the appropriate funding levels to attract qualified, external proposals. Our research indicates that grants to academic, not-for-profit, and small business researchers are generally in the range of $350k-600k per year. Amounts less than this would fail to attract top-ranked researchers. The complexity of the chemistry of SPF and its importance in providing effective, energy-efficient building insulation merits the need for innovative research that requires the best minds.

Grants typically last for 2-3 years. Shorter periods do not produce useful results. Longer periods are ill-suited for grants because it is difficult to predict results far enough in advance to write a specific proposal. The high-end estimate is that a single grant would require $1.8 million over 3 years. Every stakeholder SCP sought advice from on implementing the Advancement of Green Chemistry and Green Engineering Regulatory Response emphasized that it was important to have a diverse research portfolio to maximize the likelihood of success. Therefore, the GCIF needs to invest in multiple lines of research, including alternatives with the potential to measurably reduce exposure, to improve the chance that one project will result in a product that can be commercialized. The information here aligns with the estimate of 8 million dollars from the previous factor. Since the two factors are reasonably aligned, we do not see a need to change the proposed amount.

C) The current state of alternatives.

Alternatives without MDI

The Abridged AA Report from October 14, 2020, indicated that there are seven potential alternatives to SPF with MDI that do not use the Chemical of Concern (Firestone/Gaco Canary, NanoSonic Hybridsil, Hybrid Coatings Technologies/Nanotech Industries Green Polyurethane™, Owens Corning, two formulations from DuPont, and Dow). Some of the potential alternatives had characteristics (hydrolytically unstable) or performance that limited their feasibility as alternatives to the four different types of SPF. Little research in this area seems to have been completed since 2018, this may be because industry research shifted towards phasing out HFC blowing agents due to their high global warming potential. Those research efforts were a success and HFCs are now banned in SPF Systems in at least 12 states, including California.

Based on the alternatives without MDI that were included in the Abridged AA Report, the reactive chemistry needed to make sprayable polymer-based insulation frequently incorporates other sensitizers. Information on the potential chemical alternatives evaluated in the Abridged AA Report is in Table 3.

Table 3. Information on sensitizers and irritants in potential alternatives from the Abridged AA Report.

Product	Select ingredients	Hazard categories (per the Abridged AA)
Priority Product	Methylene Diphenyl Diisocyanate (MDI) (CASRN 101-68-8)	- Cat. 1A respiratory sensitizer - Cat. 1B skin sensitizer - Cat 2 for eye & skin irritation/corrosion
Firestone/Gaco Canary	Meta Xylene diamine (CASRN 1477-55-0)	- Cat 1B skin sensitizer - Cat. 1 for eye & skin irritation/ corrosion
Possible formulation: Hybrid Coatings Technology/ Nanotech Industries Green Polyurethane™	DER 331, Bisphenol-A Epoxy Resin (CAS No. 25085-99-8)	- Cat. 1 skin sensitizer (modeled) - Skin irritation or corrosion (modeled) - Endocrine activity due to BPA
Possible formulation: Owens Corning	Epon Multifunctional epoxy resin (CASRN 15625-89-5)	- Cat 1A respiratory sensitizer - Cat 1 skin sensitizer - Cat 2 skin& eye irritation/corrosion
Possible formulation: DuPont patent WO 2013/101682 A1	Difunctional Acrylate A (CASRN 55818-57-0	- Cat 1A Respiratory sensitizer - Cat 1 skin sensitizer
Possible formulation: DuPont patent WO 2018/005142	1,3 & 1,4-cyclohexane dicarboxaldehyde (assuming EC No. 482-020-3)	- Cat 1B skin sensitizer - Cat 1 Eye irritation/corrosion - 30% of the product is uncharacterizable and represents a data gap
Possible formulation: Dow patent WO2015/142564 1A	1,3 & 1,4-cyclohexane dicarboxaldehyde (assuming EC No. 482-020-3)	- Cat 1B skin sensitizer - Cat 1 Eye irritation/corrosion - 45% of the product is uncharacterizable and represents a data gap
Hybridsil	No ingredient information found	

SCP has identified Icynene, as a potential alternative. It is a sprayable insulation that may not contain MDI. An Safety Data Sheet (SDS)for Icynene-LD-C-50 from 2009 indicates that it contains Polymethylene polyphenyl isocyanate (CASRN 9016-87-9) (Icynene 2009), however a more recent brochure from the manufacturer identifies Icynene as containing MDI (Icynene 2016). Regardless, Icynene still uses an isocyanate and therefore sensitization is still a concern. Further, Polymethylene polyphenyl isocyanate may have additional hazards.

Some Icynene formulations can be poured (SpecifiedBy 2022) into building cavities and thus would likely represent a lower exposure application method, though not useful for all SPF applications. Icynene advertises that it is water-blown, indicating that it does not contain HFC blowing agents (which have been phased out in California) and presumably no HFO blowing agents, which can degrade into PFASs (another group of Candidate Chemicals under SCP). In addition, Icynene advertises that it does not contain polybrominated diphenyl ethers (PBDE) flame retardants (Icynene 2022); however, the product may contain other problematic flame retardants, such as organohalogens or organophosphates, such as TCPP (Gracilis 2018).

None of the possible alternative formulations are free from sensitizers. Some, like Firestone/Gaco Canary only contain a skin sensitizer; however, a systematic review of the relationship between dermal sensitization and chemical-induced asthma suggests that low molecular weight chemicals that are dermal sensitizers can pose a risk for respiratory responses (Tsui et al. 2020). In addition, some of these chemicals possess other hazards. This is not a complete list of chemicals in the formulation; just the substances with sensitization concerns were highlighted. Please see the Abridged AA Report for a more complete chemical hazard assessment of the formulations.

There are many data gaps regarding the identity and concentration of the chemicals in the alternatives. Even with great modeling and other new approach methodologies, data gaps cannot be filled if the chemical is not known. Therefore, meaningful investment is needed to overcome these challenges.

Alternatives that lower exposure

The Abridged AA Report from October 14, 2020, indicates that, in addition to chemical alternatives, there are four potential technological alternatives that can lower exposure to MDI. Firestone/Gaco Profill System ™ uses plastic membrane barriers that help to contain the MDI. High-Volume Low-Pressure (HVLP) systems presumably lower the pressure resulting in a reduction in aerosolized MDI and pMDI. BASF holds two patents – one for a nozzle that premixes the A and B starting the reaction before the product is sprayed. Currently, this nozzle is too heavy and bulky for mobile spraying applications. BASF's other patent also seems to use pre-mixing of the A and B sides and altering the viscosity of the MDI thereby, lowering the MDI emissions.

Several of these potential lower-exposure alternatives could benefit from further research and development to better evaluate their performance across more conditions or formulations and to make them more suitable for *in situ* application. Further, a consistent method for measuring emissions (distance from source, without ventilation, etc.) is needed to demonstrate that exposure reductions to MDI would be meaningful. The AA Report notes that BASF was, at least at that time, continuing to develop and patent these types of alternatives. Projects such as these demonstrate the value of a diverse research portfolio. Funding multiple lines of research is more likely to achieve the overall goal of developing an alternative that can better protect the users of SPF Systems. $8 million was proposed, in part, so that it could fund multiple research projects so there is no need to adjust the proposed funding level.

D) How much does the industry spend on R&D annually?

The Abridged AA Report included an approximate budget for the REs. It was estimated that the SPF system houses spend 1-3% of annual SPF sales on "codes, quality control, and research." Based on the dollar values provided in Table 4, collectively investing $8 million is not likely a burden on the manufacturers and it is likely to produce some meaningful results.

Table 4. Excerpt from Table 5.14 in the Abridged AA Report

	Smaller specialty SPF firms ($10M - $100M in SPF sales)		Larger multinational SPF firms ($100M - $500M in SPF sales)	
	Low end	High end	Low end	High end
Expenses: Codes, QC, and Research (1-3%)	$100k- $300k	$1M – $3M	$1M – $3M	$5M – $15M

E) Scope and scale of required performance testing

According to the Abridged AA Report, "SPF and any alternative must meet the requirements laid out in various state and local regulations and building standards outlined in AC 377 (ICC-ES, 2018). The performance criteria outlined in AC 377 include thermal resistance (ASTM C177, ASTM C518, or ASTM C1363), core density (ASTM D1622), tensile strength (ASTM D1623), dimensional stability (ASTM D2126), surface burning characteristics (IBC-ASTM E84 or UL 723), and compressive strength (ASTM D1621)." Because SPF is a durable good, applied to buildings for long-term use, we presume that the required performance testing will be more expensive and more extensive than a product with a short lifespan. In addition, because attaining specified performance characteristics may be required for the product to be commercialized, it is more challenging for an alternative to be successful. Some of these costs may have already been incorporated into the estimate of developing and commercializing an alternative (see Table 5.15) and thus does not support altering the proposal for $8 million.

Factors regarding the industry and the market for the PP

F) **The annual revenue for the PP**. *Global Market Insights* (2022) indicates an annual revenue of $687M for North America; $496M represents the U.S. and Mexico. REs estimate that the California market is less than $100M. Even when using the most fiscally conservative revenue estimates (provided by the regulated industry), $8M spread over 3 years accounts for less than 3% the annual revenue for the PP. That is within the typical range of R&D spending for this industry.

G) **Number and size of REs –** There are 15 REs, with extensive variation in annual revenue from SPF sales. The Abridged AA Report indicates that the annual revenues range from $10 million to $500 million. The consortium is welcome to divvy up the contributions to the GCIF in the most equitable manner.

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