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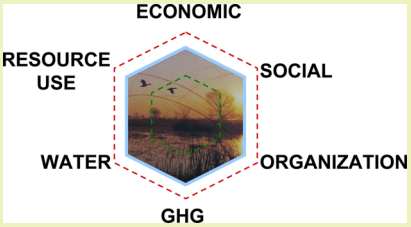
Thinking about More Sustainable Products: Using an Efficient Tool for Sustainability Education, Innovation, and Project Management To Encourage Sustainability Thinking in a Multinational Corporation

David A. M. Russell*,† and Dawn L. Shiang‡

†Sustainability & Life Cycle Assessment Group, EH&S Department, Dow Europe GmbH, 8810 Horgen, Switzerland

‡Sustainable Technologies & Innovation Sourcing Department, The Dow Chemical Company, Midland, Michigan 48674, United States

ABSTRACT: Embedding the concept of sustainability into a company's culture is immensely challenging but is likely to be critical to the long-term viability of science and technology companies that rely on successful innovation to remain competitive. Moving to a more sustainable society can be expected to provide plenty of commercially attractive business opportunities for forward thinking organizations. The combination of life cycle thinking with the enabling science of chemistry will be essential to successfully address world challenges such as the strain on resources caused by population growth and changing demographics. The Dow Chemical Company has been developing strategies and tools around holistic thinking for more than 20 years and has recently introduced a methodology to broaden sustainability knowledge and encourage life cycle thinking among innovators new to this topic while providing insight into the sustainability of new product development. A tool, the Dow Chemical Sustainability Footprint Tool, is described, using examples to illustrate the insights gained by project teams and business management. With more than 250 project assessments carried out so far, it is fair to say that sustainability knowledge among innovators is increasing, that the tool has met its design criteria such as being self-explanatory and easy and quick to use, and that it is providing business management with sustainability overviews of their project portfolios.



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The cover of The Dow Chemical Company (Dow) 1989 Annual Report was mostly plain.[1] It had one small picture of ducks flying over wetlands at sunset at Dow's Eastern Division manufacturing site in Joliet, Illinois, and around this picture in bold writing was set the text, "One issue, more than any other, will affect Dow's prospects in the '90s and beyond. That issue is the environment."

Today, this appreciation of the importance of environmental issues has broadened into the more holistic concept of sustainability and, increasingly, many company CEOs believe that embedding the concept of sustainability into their company's culture—making it part of how the company operates—is a business imperative.[2] This is immensely challenging. Nevertheless, it is in line with the position taken by many stakeholders in Dow's value chains, particularly brand owners and consumer-facing businesses, which are showing an increasing interest in products that contribute toward sustainability. This alone creates a clear and immediate business driver for their suppliers to develop products and services that are progressively more sustainable. Having the executives of a company understand and embrace this imperative is important, and probably essential, to making a company's operations, products, and value chains more sustainable. It is unlikely to be sufficient.

A key group of employees for a science and technology company such as Dow to target with sustainability information and tools is the new product development community, where research and development engineers together with marketing managers conceive and develop new products, applications, and markets. While it is essential to provide these teams with screening tools to evaluate the sustainability of their innovations, it is equally important to provide them with sufficient knowledge to enable them to integrate sustainability thinking from the earliest concept stage of an idea.

On the basis of the belief that people are likely to learn best when they are actively and constructively involved in a new topic that they perceive as both useful and relevant to their job (a concept long recognized by educators[3−5]), a simple tool, The Dow Chemical Sustainability Footprint Tool, was created for company innovators to use to evaluate the sustainability of their current projects, to suggest opportunities for improvement as projects are further developed into potential products or services, and to stimulate new more sustainable project ideas.

ENGAGING BUSY FOCUSED EMPLOYEES

While Dow has considerable expertise in life cycle assessment and sustainability, this expertise is mainly concentrated among a

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relatively small number of individuals, mostly within expert support functions. The intention of the Dow Chemical Sustainability Footprint Tool (DCSFT) was to create a tool that would engage a much wider employee base in sustainability by indicating the extent to which any development project could contribute to a more sustainable world while simultaneously increasing the tool user's understanding of sustainability. Persuading busy focused employees to start to use a new tool that would engage them in a topic that they may know little about and where they may not fully understand the relevance to their specific business was seen as challenging. Also, Dow, like many other companies, spends considerable effort on minimizing bureaucracy, improving efficiency, and increasing employee motivation. Consequently, for successful implementation of the DCSFT, it had to have attributes that would be consistent with these demands, namely, the following:

- be self-explanatory
- be easy and quick to use by research, development, and marketing professionals with limited knowledge of sustainability criteria
- be applicable to all projects (including those with an internal focus, for example, manufacturing plant improvements)
- instantly communicate sustainability advantages and opportunities in a visually engaging way
- provide a record of what was considered when rating a particular sustainability attribute
- be informative of sustainability criteria

Also, the data from project evaluations should be easy to compile into reports that inform management about the sustainability status of a business's portfolio of development projects, highlighting which sustainability areas are well represented and which remain areas of opportunity.

EVALUATING SUSTAINABILITY

Considering sustainability as a market driver leads to the conclusion that the long-term commercial success of new products and services is likely to increase if the following are observed:

- Economics of a value chain service provision to end users is improved.
- Society is enhanced.
- Biosphere is conserved.
- Humans are not harmed.
- Resources remain available.

For convenience, sustainability metrics are often divided among economic, social, and environmental dimensions. These are frequently referred to as the business "triple bottom line", a term first coined by John Elkington in 1994 and later described in detail in his book "Cannibals with Forks" in terms of an organization's relationship with people (fair, ethical, and beneficial business practices), the planet (environmentally sound products from sustainable manufacturing), and profits (which, in this case, includes the economic benefits for the company, its employees, shareholders, and the other organizations in its value chains).[6]

In fact, many sustainability metrics are cross-cutting, contributing to two or sometimes all three dimensions of the triple bottom line. Ecological aspects can impact the social and economic dimensions of sustainability, and the environmental dimension in particular is often given a broad definition that encompasses more than ecologically focused metrics. For example, in 1992, the Canadian government declared a moratorium on fishing for Atlantic Cod (*Gadus morhua*) off their east coast because overfishing had reduced the cod biomass by 99%. Clearly, this signaled an environmental disaster, but it also meant a social disaster for the Newfoundland communities that had relied on this resource for 500 years. This environmental and social disaster had, in turn, significant economic repercussions, requiring Canadian government support for affected communities in excess of 3 billion Canadian dollars over the following decade.[7]

Different to, but consistent with, the triple bottom line concept, the DCSFT assessment is displayed on a six dimension radar (spider) plot (Figure 1) to facilitate

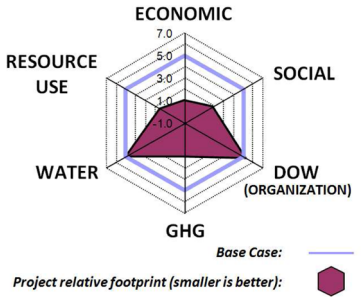

Figure 1. DCSFT evaluation of a longer-life building and construction system.

communication of sustainability criteria without complexity. While each sustainability aspect addressed in the tool is allocated to an appropriate dimension, it is recognized that the cross-cutting nature of such aspects would allow alternative distributions that may also be valid and could provide further insights.

Some important sustainability aspects, for example, biodiversity and ecosystem services, are beyond the current knowledge of many intended users of the DCSFT. Such topics are only considered at a high level and are not currently component metrics of the radar plot. When especially relevant to a project, such aspects are highlighted by a sustainability expert as part of an integrated review process, an essential component of the DCSFT.

THE TOOL

The DCSFT examines sustainability through 23 questions, many of which involve comparisons of a project or new idea with an incumbent product (the base case) that delivers an equivalent service to an end user. Projects are scored on an arbitrary scale from 1 (best possible sustainability score, i.e., a smaller footprint) to 7 (worst possible sustainability score) with the base case scoring 5. When there is no existing product against which a comparison can be made, the new idea is given the base case score to encourage future sustainability improvements. Some questions are absolute rather than relative and are scored on the basis of a property of the new product/idea or the completion of an action by the project owner.

Of the six sustainability dimensions, three focus on key environmental aspects: life cycle greenhouse gas (GHG) emissions, water requirements, and resource requirements (a combination of raw material requirements and energy consumption over the life cycle). There is one economic dimension, one social dimension, and an organization dimension (labeled Dow in this paper). Organization metrics

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would not typically be singled out as a sustainability dimension, which by definition should take a full life cycle perspective. It is included in the DCSFT to provide a focus on aspects where the innovating company has direct control and to account for purely internal projects, e.g., manufacturing plant improvements.

Before answering the questions, innovators are required to consider and describe the service delivered to (paid for by) the end user (the consumer at the end of the supply chain), who for companies that are upstream in their value chains is not usually their direct customer. For technical specialists, used to working closely with direct customers, precisely defining the functional unit delivered to a final consumer is not always immediately intuitive, resulting in informative discussions with sustainability experts. To further encourage holistic (life cycle) thinking, an inherent aspect of Dow's Sustainable Chemistry 10 year corporate goal,[8] users of the DCSFT must also describe the main material flows between seven predefined life cycle stages noting the main material and energy inputs to each stage (Figure 2).

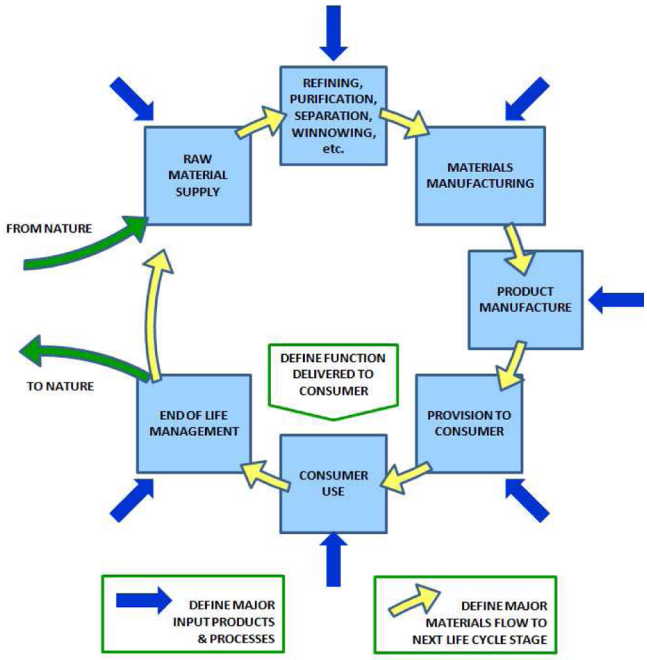

Figure 2. Generic product life cycle diagram indicating where DCSFT user input is required.

On the basis of user input, the tool presents a list of potential sustainability issues that help innovators to appreciate the long-term perspective of human society as articulated by the Brundtland Commission's famous definition of sustainable development, "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs."[9]

A longer life for a new technology or material over an incumbent product is typically introduced by technical service and marketing personnel as a value proposition for customers, e.g., by reducing a customer's replacement costs. However, it has been eye-opening to project teams during DCSFT expert reviews to learn that longer life has additional benefits. By helping innovators understand the sustainability meaning of "functional unit" in life cycle terminology, significant sustainability teaching has been achieved when they connect "longer life" with "efficient life cycle resource use" (material, energy, and sometimes water) and reduced "emissions" (e.g., of greenhouse gases).

One of many such examples occurred during the development of a more durable roofing system that could provide a two to five times longer life than current practice. The DCSFT assessment of the application showed the predictable economic advantage, but discussion of the life cycle environmental advantages resulting from the longer functional lifetime revealed to the team the improved resource use and reduced GHG emissions (Figure 1), something that they had not previously considered and something that was of potential interest to customers.

Another feature of this technology that was highlighted was the strong social dimension advantage, mainly arising from the replacement of an incumbent product that was under pressure for deselection due to mammalian toxicity and ecotoxicity concerns. It became an opportunity to reinforce to innovators how a more sustainable innovation is one that has a higher probability for sustained success because of advantages in multiple dimensions.

THE QUESTIONS

The DCSFT questions address a time in the future when a project has been commercialized. For most questions, innovators are asked to consider the whole life cycle invoked by the provision of the previously defined unit of service to an end consumer. For each question, a range of possible answers, each of which has been allocated a sustainability footprint score, is presented. The innovator must give a short explanation of the reasoning that led to their choice of answer. This provides both a historical record of the evaluation and an indication to the expert reviewer of the innovator's level of understanding at the time of the assessment. Increasing sustainability earns a negative score that reduces the default footprint score of 5. Scores for each question within a dimension are averaged according to a weighted key and then added to the default dimension score of 5 to determine the actual dimension score.

The Economic Dimension. Innovators are asked to consider and score three market aspects of their idea and to fulfill one requirement:

1. Value Chain Economic Benefit. Important contributors to a project's commercial success are the economic benefits that accrue to the companies in the value chain. This is separate to the cost to the end user as savings or costs are not always passed on to the consumer.

2. End-User Economic Benefit. Separately, but of similar importance, is the cost to the end user; a cheaper product that provides the same service or a similarly priced product that provides extra benefits is more likely to be successful in the marketplace.

3. Market Acceptance 1. Even if the above cost pictures look promising, a project may not be successful if there are aspects of its product or its supply chain that are thought by the market to be undesirable or are expected to have their use constrained by proposed regulations. The innovator is asked to consider substances that are being targeted for deselection by regulators, companies, or nongovernment organizations (NGOs), including the raw materials required for manufacture and the products themselves.

4. Market Acceptance 2. As innovators are not expected to be experts in regulatory compliance or toxicology (this relates

to answering questions 8 and 9 below), it is important that they obtain sound advice at an early stage of a project to prevent wasting resources on an idea that may not be accepted by the market. This question requires the innovator to have reviewed their project with someone who has the relevant expertise (e.g., a Product Steward). There is a default penalizing score if this task is not completed.

The Social Dimension. *5. Life Cycle Knowledge.* This requires the innovator to have defined the functional unit, listed the main product flows between life cycle stages, selected the key process and material inputs to each stage, and reviewed the list of potential sustainability issues. The inherent idea is to encourage innovators to look for sustainability opportunities over the whole life cycle of their idea.

6. Potential To Address World Challenges. Innovators can choose up to four aspects inspired by the United Nations Millennium Development Goals[10] explaining how their idea provides a significant social benefit in each case. These aspects are as follows:

- healthier drinking water
- affordable housing
- improved food production (e.g., agricultural productivity)
- improved personal/public health
- improved (end user) safety
- improved biodiversity
- improved communications infrastructure
- improved access to (renewable energy-based) electricity
- improved access to markets (including improved transportation infrastructure)

7. Development. Projects are automatically penalized unless two conditions are met: the end-user service enabled by the commercialization of the idea must be relevant to the development needs of citizens in emerging economies and the cost of the product or service should be affordable (i.e., not prohibitively expensive) to the emerging middle class.

8. Mammalian Toxicity. This is assessed relative to the incumbent system.

9. Ecotoxicity. This is assessed relative to the incumbent system.

10. Value Chain Process Safety. This is assessed relative to the incumbent system.

The Organization Dimension. The next nine questions concern those aspects of the life cycle where the organization carrying out the DCSFT assessment has direct control ("inside the fence line").

11. Water Requirement. This is assessed relative to the incumbent system.

12. GHG Emissions. This is assessed relative to the incumbent system.

13. Energy Consumption. This is assessed relative to the incumbent system.

14. Resource Quality 1. How abundant are major raw material(s) used to produce the new product?

15. Resource Quality 2. Are the resources well, averagely, or poorly managed?

16. Use of Renewable and Recycled Raw Material. Projects are automatically penalized in this question unless the raw materials used include renewable or recycled materials (post-consumer or post-industrial, but not within the same process).

17. Conversion Efficiency. This is the weight percentage of raw materials input that becomes useful product.

18. Process Safety. This is assessed relative to the incumbent system.

19. Chemicals Management. This is assessed relative to the incumbent system.

The above organizational focus of the DCSFT has revealed trade-offs and provided informed opportunities to mitigate potential impacts. For example, a DCSFT assessment of a new anti-microbial technology showed strong advantages in both economic (value chain and end-user costs savings) and social dimensions (improved public health and decreased mammalian toxicity and ecotoxicity) but disadvantages across most of the Dow manufacturing footprint (Figure 3). It was important for

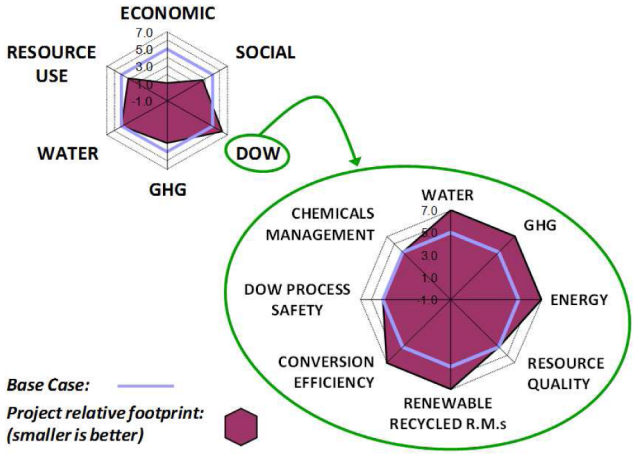

Figure 3. DCSFT assessment of a new anti-microbial technology showing the trade-off between increased resource use in manufacturing and overall life cycle benefits.

the innovators to understand the apparently disadvantaged manufacturing step in the context of the entire life cycle, where there were clear overall benefits relative to the incumbent system. Future areas for targeted research are likely to include manufacturing process optimization to improve yield, energy, and water use.

Environmental Dimensions. *20. Life Cycle Greenhouse Gas Emissions.* That which is relative to the incumbent system.

21. Life Cycle Water Requirements. That which is relative to the incumbent system.

The DCSFT has been useful in discussing complicated issues associated with impacts and trade-offs such as those routinely observed between a biobased material's potential GHG advantage and its commensurate potential water disadvantage. Figure 4 shows an assessment of a biobased developmental composite, contrasting social, GHG, renewable raw material, and resource quality advantages with higher life cycle water requirements. Highlighting such trade-offs informs innovators and supports balanced marketing communications.

Life Cycle Resource Requirement. *22. Life Cycle Energy Consumption.* Many organizations have set corporate sustainability goals in the arena of energy and GHG emission reduction. DCSFT assessments have proved useful in conversations with customers around this topic regarding early stage technology development.

The DCSFT is helping innovators to appreciate the linkage among different sustainability aspects. An unexpected example of this was a formulation development project where a solid-based product was being explored to replace a liquid-based formulation. The aim of the research was to improve value

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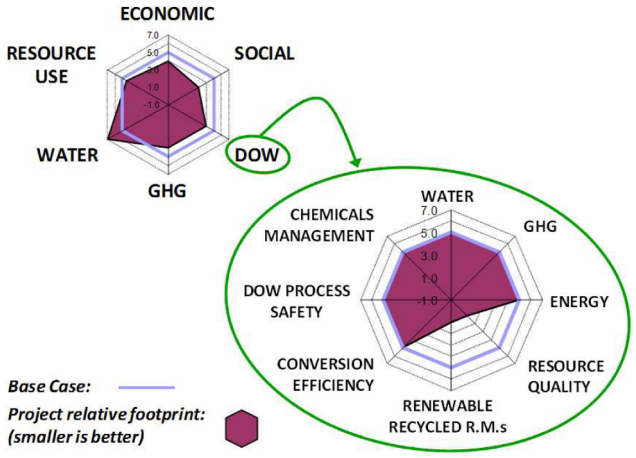

Figure 4. DCSFT assessment illustrating sustainability trade-offs for a biobased developmental composite.

chain safety, as the liquid-based material had potential safety hazards associated with handling (spills and splashes of a corrosive material). The DCSFT assessment highlighted the collateral benefit of the solid formulation having transportation cost savings with positive impacts on life cycle energy and GHG emissions for customers (Figure 5).

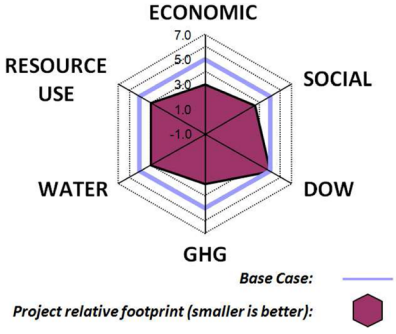

Figure 5. Multiple benefits for a solid formulation compared to a liquid one.

23. Life Cycle Raw Material Consumption. Water and renewable or recycled materials use are excluded from the estimate of raw materials consumption.

The life cycle view of these last three dimensions can include aspects considered in other dimensions such as economic or organization. Consequently, there can be double counting. This is not considered a disadvantage as it serves to highlight the importance of sustainability aspects in multiple dimensions.

When developing products to support customers in meeting their sustainability goals, Dow businesses are finding the DCSFT is an excellent way to discuss progress. The sustainability advantages of a metal-free emulsion for the formulation of floor polishes with a significant reduction in coingredients, DURAGREEN 4373 Polymer, are easily communicated by referring to its DCSFT spider chart (Figure 6). The economic dimension highlights value chain and end-user cost benefits from the elimination of zinc and the social dimension benefits from improved mammalian and eco-toxicology with potential benefits for personal/public health and drinking water, while the delivered functionality with less material shows up in each life cycle environment category (resource use, water, GHG).

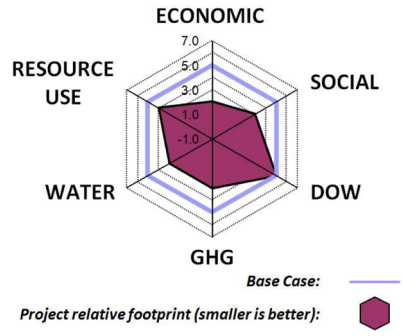

Figure 6. The DCSFT assessment for DURAGREEN 4373 Polymer.

DISCUSSION

Sustainability knowledge among innovators was found to show considerable variation. Where understanding is low, the value of using sustainable principles during technology development may not be appreciated. A few project teams and R&D managers were suspicious that promising projects could be undermined by poor scores from what they consider an unproven tool. In order to get commitment from development teams, a clear statement of the business case for sustainability enhanced innovation had to be made. This included aspects such as the following:

- Reduced Costs: return on R&D investment, lower energy footprint, improved atom utilization
- Competitive Differentiation/Revenue Generation: deliver higher value products, alternative perspective to problem-solving
- Improved Brand Reputation: innovations addressing world challenges, use with customers
- Reduced Risk: improved value chain environment, health and safety, incorporate longer term trends

Additionally, the speed and ease of use of the DCSFT had to be emphasized.

The DCSFT is a user-driven process and as such could lead to variable assessments with missed opportunities and questionable knowledge gain. A key component is the sustainability expert review. This ensures that questions have been thought through thoroughly (the educational part for the teams) and that there is reasonable consistency across all assessed projects. Nearly every project has shown some sustainability strengths, while opportunities for further improvement have been highlighted.

When compiling management reports on assessed projects, it is important to resist averaging a portfolio (e.g., all projects from one business unit or division). This makes no sense when projects target different applications/markets where life cycles differ and sustainability aspects may not be equally important. For example, a focus for the Dow Water Solutions business is technology development for reduced life cycle energy, but another business may concentrate on toxicity reduction. Assessments are best viewed in the context of business strategy and drivers. If energy use is critical for the market segment, the assessed portfolio should reflect this. While the DCSFT is not suitable for use as a screening tool among dissimilar applications, it is helping Dow innovators to appreciate when the successful commercialization of a project is expected to lead to a more sustainable service delivered to an end user.

The tool evaluates projects at a very high level compared to database enabled, expert-oriented tools such as life cycle

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assessment or site specific risk assessment and is not intended to substitute these. As DCSFT users and businesses become more knowledgeable of sustainability, more detailed underlying aspects of the current metrics will be added.

Experience from over 250 projects has shown the tool to be self-explanatory and easy and quick to use, with Dow innovators typically taking 30 min to an hour to complete an assessment (excluding first time use, which takes longer). Also, there has been a clear increase in the sustainability knowledge of DCSFT users, while "functional unit"-based thinking is helping them become "material/technology/product agnostic"—truly liberating them in creativity.

Empowering employees to develop more sustainable solutions to market needs is a business imperative, and as recent evidence[11] shows, having employees understand how they are contributing to a more sustainable society is a key motivator.

AUTHOR INFORMATION

Corresponding Author

*E-mail: darussell@dow.com.

Notes

The authors declare no competing financial interest.

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