SUSTAINABILITY SCORECARD

PART 1: WASTE PREVENTION

KPI	SUB-METRIC	PRODUCT/ PROCESS 1	UNEXPECTED SOLUTION:	RATING
Economy of waste	Atom economy (in g/mol, percentage)			
	E-factor			
	Packaging: percentage of readily recyclable material			
Economy of space	Number of units per square foot of product			
	Number of units transported per vehicle			
Process intensification	Productivity/ size ratio Productivity/ weight ratio			

PART 2: MAXIMIZING EFFICIENCY AND PERFORMANCE

KPI	SUB-METRIC	PRODUCT/ PROCESS 1	PRODUCT/ PROCESS 2 (UNEXPECTED SOLUTION)	RATING
Material efficiency	Mass of recycled material/total mass Mass of renewable material/total mass			
Environmental health metrics	Global warming potential (in kg CO_2 equivalent)			
	Acidification potential (in kg CO_2 equivalent)			
	Eutrophication potential (in kg N equivalent)			
	Smog formation potential (in kg O emissions)			

(continued)

PART 2: MAXIMIZING EFFICIENCY AND PERFORMANCE (continued)

KPI	SUB-METRIC	PRODUCT/ PROCESS 1	PRODUCT/ PROCESS 2 (UNEXPECTED SOLUTION)	RATING
Human health metrics	Number of restricted chemicals according to EU and US guidelines			
	Percentage of chemicals linked to high acuity, disease, and procedural complexity (i.e., high-cost patients)			
	Percentage of chemicals linked to high acuity, disease, and procedural complexity (i.e., moderately high-cost patients)			
	Percentage of chemicals with robust data sources on assessment of health impacts			

PART 3: RENEWABLE RESOURCES

KPI	SUB-METRIC	PRODUCT/ PROCESS 1 BEFORE SUSTAINABILITY TRANSFORMATION	PRODUCT/ PROCESS 2 (UNEXPECTED SOLUTION)	RATING
Renewable carbon-free energy inputs	Percentage of renewable carbon (a measure of all carbon sources that avoid fossil fuel sources) Percentage of carbon-negative sources (percentage of sources of product input that remove more carbon than they produce)			
Waste energy utilization				
Renewable feedstocks	Percentage of total inputs that are derived from renewable resources			

PART 4: SAFE DEGRADATION

KPI	SUB-METRIC	PRODUCT/ PROCESS 1 BEFORE SUSTAINABILITY TRANSFORMATION	PRODUCT/ PROCESS 2 (UNEXPECTED SOLUTION)	RATING
Persistence (a measure of transgenerational design)	Percentage of "forever chemicals" in final product			
Bioaccumulation	Bioaccumulation factor			
Exposure	Induction period and duration of product life			
	Latent period and duration of product life			

The Sustainability Scorecard Key Performance Indicators

SCORECARD COMPONENT: WASTE PREVENTION

KPI	SUB-METRIC	PRODUCT/ PROCESS 1 BEFORE SUSTAINABILITY TRANSFORMATION	PRODUCT/ PROCESS 2 UNEXPECTED SOLUTION: SUSTAINABLE EARTH	RATING
Economy of waste	Atom economy (in g/mol, percentage)			
	E-factor			
	Packaging: percentage of readily recyclable material			
Economy of space	Number of units per square foot of product			

SCORECARD COMPONENT: WASTE PREVENTION (continued)

KPI	SUB-METRIC	PRODUCT/ PROCESS 1 BEFORE SUSTAINABILITY TRANSFORMATION	PRODUCT/ PROCESS 2 UNEXPECTED SOLUTION: SUSTAINABLE EARTH	RATING
	Number of units transported per vehicle			
Process intensifi-cation	Productivity/ size ratio Productivity/ weight ratio			

- 0: process recovers *all* (91%–100% by weight) the waste generated.
- 1: process has a *majority* (51%–90% by weight) of its waste recovered through upcycling, landfill-based recovery processes/safe degradation in a graveyard, and/or multiple-use mechanisms ultimately avoiding a graveyard at end of life.
- 2: process has a *majority* of its waste disposed through the landfill, autoclaving, or incineration.
- 3: process leverages graveyards as its sole end of life (91%–100%).

SCORECARD COMPONENT: MAXIMIZING EFFICIENCY AND PERFORMANCE

KPI	SUB-METRIC	PRODUCT/ PROCESS 1 BEFORE SUSTAINABILITY TRANSFORMATION	PRODUCT/ PROCESS 2 UNEXPECTED SOLUTION: SUSTAINABLE EARTH	RATING
Material efficiency	Mass of recycled material/total mass Mass of renewable material/total mass			
Environmental health metrics	Global warming potential (in kg CO_2 emissions)			
	Acidification potential (in kg CO_2 emissions)			
	Eutrophica-tion potential (in kg N emissions)			
	Ozone depletion potential (in kg CDC 11 emissions)			

SCORECARD COMPONENT: MAXIMIZING EFFICIENCY AND PERFORMANCE (continued)

KPI	SUB-METRIC	PRODUCT/ PROCESS 1 BEFORE SUSTAINABILITY TRANSFORMATION	PRODUCT/ PROCESS 2 UNEXPECTED SOLUTION: SUSTAINABLE EARTH	RATING
	Smog formation potential (in kg O emissions)			
Human health metrics	Number of restricted chemicals according to EU and US guidelines			
	Percentage of chemicals linked to high acuity, disease, and procedural complexity (i.e., high-cost patients)			
	Percentage of chemicals linked to high acuity, disease, and procedural complexity (i.e., moderately high-cost patients)			

(continued)

SCORECARD COMPONENT: MAXIMIZING EFFICIENCY AND PERFORMANCE (continued)

KPI	SUB-METRIC	PRODUCT/ PROCESS 1 BEFORE SUSTAINABILITY TRANSFORMATION	PRODUCT/ PROCESS 2 UNEXPECTED SOLUTION: SUSTAINABLE EARTH	RATING
	Percentage of chemicals with robust data sources on assessment of health impacts			

- 0: process is maximally efficient and has no negative environmental or human health externalities.
- 1: process under evaluation is efficient, and the majority (51% or more) of chemicals under evaluation are not linked to high acuity and complexity disorders.
- 2: process under evaluation is efficient, and the majority (51%–90%) of chemicals under evaluation are linked to high acuity and complexity disorders.
- 3: process under evaluation is efficient, and all of the chemicals under evaluation are linked to high acuity and complexity disorders.

SCORECARD COMPONENT: USING RENEWABLE INPUTS

KPI	SUB-METRIC	PRODUCT/ PROCESS 1 BEFORE SUSTAINABILITY TRANSFORMATION	PRODUCT/ PROCESS 2 UNEXPECTED SOLUTION: SUSTAINABLE EARTH	RATING
Renewable carbon-free energy inputs	Percentage of renewable carbon Percentage of carbon-negative carbon			
Waste energy utilization				
Renewable feedstocks	Percentage of total inputs that are derived from renewable resources			
Renewable freestocks	Percentage of renewable carbon Percentage of carbon-negative carbon			

- 0: product under evaluation uses 90%–100% of renewable inputs in the entire known supply chain.
- 1: product under evaluation leverages renewable inputs for the majority (51%–90%) of the entire known supply chain.

- 2: product under evaluation leverages nonrenewable inputs for the majority (51%–90%) of the entire known supply chain.
- 3: product under evaluation leverages nonrenewable inputs for 100% of the entire known supply chain.

SCORECARD COMPONENT: ENSURING SAFE DEGRADATION

KPI	SUB-METRIC	PRODUCT/ PROCESS 1 BEFORE SUSTAINABILITY TRANSFORMATION	PRODUCT/ PROCESS 2 UNEXPECTED SOLUTION: SUSTAINABLE EARTH	RATING
Persistence (a measure of transgenerational design)	Percentage of "forever chemicals" in final product			
Bioaccumulation	Bioaccumulation factor			
Exposure	Induction period and duration of product life			
	Latent period and duration of product life			

- 0: process degrades without any toxic effects on human health and environmental factors *and* extended producer responsibility is in place.
- 1: process degrades without any toxic effects, but extended producer responsibility is not in place.

- 2: majority of the components of the process degrade safely, but extended producer responsibility is not in place.
- 3: process does not degrade safely (i.e., is toxic, persistent, and bioaccumulative).

INHERENT SUSTAINABILITY OF THE OPTIMYZE SOLUTION

	TRADITIONAL SOLUTION	UNEXPECTED SOLUTION (OPTIMYZE)
Source	Petroleum hydrocarbons	Renewable materials (fermentation)
Flammability	Flammable	Water-based, not combustible
Flashpoint	110° (44°C)	No flashpoint
Worker effects	Odors, irritation	Not noticeable
Toxicity	Can be fatal (ingestion, inhalation)	Slight irritation possible when undiluted
VOC content	100%	15%
Hazardous air pollutants	7%–8%	None detected
Aquatic toxicity	10–20 ppm	700 ppm (zebra fish)

Metrics that may serve as KPIs in the inherent safety section are

- Accidents due to intermediate-good trade
- Proportion of intermediate goods that are resilient due to "inherent safety"

ASSESSMENT OF ONE LINE ITEM IN THE SCORECARD: ATOM ECONOMY

KPI	SUB-METRIC	PRODUCT/ PROCESS 1 BEFORE SUSTAINABILITY TRANSFORMATION	PRODUCT/ PROCESS 2 UNEXPECTED SOLUTION:	RATING
Economy of waste	Atom economy (in g/mol, percentage)	75%	90%–100%	0

THE SUSTAINABILITY TRANSFORMATION MATURITY MODEL

	INITIATE	DEVELOP	MATURE
Goal	To strategically differentiate yourself from competition by leveraging unexpected, sustainable solutions to capture market share and realize value.	To continue to maximize profitability and attain a market-leading position related to ESG (environmental, social, and governance) goals.	To transform the industry and influence firms outside our sector, develop long-term relationships with all stakeholders to problem-solve, and create a pathway for continuous improvement and lifetime customer value. To create a legacy for the firm and be known for innovative solutions that will influence sustainable business practices in the next 50–100 years.

THE SUSTAINABILITY TRANSFORMATION MATURITY MODEL (continued)

	INITIATE	DEVELOP	MATURE
Scorecard assessment output	Score a 3 in all four sections of the scorecard, along 90% or more of the line items ■ Firms in the Initiate stage of their sustainability journey will likely fulfill the "complete recoverability" status on zero to a few metrics within a guiding principle of the scorecard. ■ While energy efficiency advantages and a few other sustainability measures are leveraged more readily, the business case for a transformation on the service-line level may not have been made yet.	Score a 2 in all four sections of the scorecard, along 90% or more of the line items ■ Firms in the Develop stage of their sustainability journey will likely fulfill several metrics in their scorecard assessment for one to a few service lines. ■ Recycling and upcycling of various product components are conducted. This necessitates a landfill or grave-to-input supply chain wherein plastics, e-waste components, etc. are recycled back into the supply chain for new product development.	Score a 0 or 1 in all four sections of the scorecard, along 90% or more of the line items ■ Firms in the Mature phase of their sustainability journey are sustainable along 90% of the scorecard criteria and are actively working to achieve complete recoverability along all metrics. ■ Unexpected solutions and breakthrough innovations are integrated into operations, and operational redesign is a continuous and ongoing effort. ■ Deep and embedded relationships with competitors, leading researchers, and associations are leveraged to bring innovative solutions to market and improve enterprise-wide sustainability metrics.

(continued)

THE SUSTAINABILITY TRANSFORMATION MATURITY MODEL (continued)

	INITIATE	DEVELOP	MATURE
	■ Sustainability is co-owned by the corporate social responsibility and regulatory departments.	■ The firm also typically has established partnerships—collaborative relationships with competitors and industry associations—to develop potential solutions for key sustainability focus areas. ■ Sustainability is driven from the finance/audit/risk departments.	■ Sustainability is leveraged as a design feature and embedded within the strategy and operations function of the firm.
Leadership	■ The board and upper management have adopted a risk-driven approach to sustainability that is focused on compliance with regulatory standards.	■ The board and upper management are pursuing sustainability as a corporate social responsibility (CSR) measure. While the overall approach to sustainability may still be risk-driven, as can be seen	■ Board communications and upper management are pursuing sustainability as a strategy and operations function. The approach is proactive, and the focus is on designing the future of the industry. Profit maximization by way of sustainability is regularly achieved and an ongoing effort.

THE SUSTAINABILITY TRANSFORMATION MATURITY MODEL (continued)

	INITIATE	DEVELOP	MATURE
		from the materiality assessments and risk models, the firm is vocal about sustainability goals, and they are a competitive lever against peer organizations. ■ ESG factors may be audited alongside financial metrics, and sustainability reports are typically published annually.	
Operations	■ Operations are compliant with regulations; however, additional measures to compete with peers on sustainable operational goals have not yet been established.	■ Strategic integrated planning solutions for sustainability exist: life-cycle assessments and proactive demand and supply planning to incrementally improve the sustainability measures of service lines.	■ Sustainable integrated planning solutions and operational processes are focused on scorecard principles as design principles for continuous improvement.

(continued)

THE SUSTAINABILITY TRANSFORMATION MATURITY MODEL (continued)

	INITIATE	DEVELOP	MATURE
		■ Incentives and collaborative relationships with competitors/ industry groups and consumer groups have been aligned.	

CHEMICALS THAT MOST FREQUENTLY CREATE ACCIDENT RISKS

SUPPLY CHAIN INPUT	NUMBER OF PROCESSES	PERCENTAGE OF TOTAL
Ammonia (anhydrous)	8,343	32.5
Chlorine	4,682	18.3
Flammable mixtures	2,830	11
Propane (industrial use)	1,707	6.7
Sulfur dioxide	768	3
Ammonia (aqueous, 20% or more conc.)	519	2
Butane	482	1.9
Formaldehyde	358	1.4
Isobutane	344	1.3
Hydrogen fluoride	315	1.2
Pentane	272	1.1

SUPPLY CHAIN INPUT	NUMBER OF PROCESSES	PERCENTAGE OF TOTAL
Propylene	251	1
Methane	220	0.9
Hydrogen	205	0.8
Isopentane	201	0.8
All others	4139	16.1
TOTAL	**25636**	**100%**

Source: Paul Anastas and David Hammond, *Inherent Safety at Chemical Sites: Reducing Vulnerability to Accidents and Terrorism through Green Chemistry* (New York, NY: Elsevier, 2015).

Next consider the operational-process outlook presented above against the industry-level view, where the greatest number of high-risk processes reside.

INDUSTRY NAICS CODE AND DESCRIPTION	NUMBER OF PROCESSES	PERCENTAGE OF ALL RISK MANAGEMENT PLAN
42291 Farm Supplies Wholesalers	4,409	28.84
22131 Water Supply & Irrigation	2,059	13.47

(continued)

INDUSTRY NAICS CODE AND DESCRIPTION	NUMBER OF PROCESSES	PERCENTAGE OF ALL RISK MANAGEMENT PLAN
22132 Sewage Treatment	1,646	10.77
32411 Petroleum Refineries	1,609	10.52
325199 All Other Basic Organic Chemical Manufacturing	655	4.28
42269 Other Chemical and Allied Products Wholesalers	607	3.97
49312 Refrigerated Warehousing and Storage Facilities	549	3.59
211112 Natural Gas Liquid Extraction	533	3.49
325211 Plastics Material and Resin Manufacturing	418	2.73
325188 All Other Basic Inorganic Chemical Manufacturing	358	2.34
49313 Farm Product Warehousing	345	2.26
32511 Petrochemical Manufacturing	321	2.1
454312 Liquefied Petroleum Gas Dealers	311	2.03
11511 Support Activities for Crop Production	302	1.98

INDUSTRY NAICS CODE AND DESCRIPTION	NUMBER OF PROCESSES	PERCENTAGE OF ALL RISK MANAGEMENT PLAN
311615 Poultry Processing	253	1.65
115112 Soil Preparation, Planting, and Cultivating	207	1.35
32512 Industrial Gas Manufacturing	205	1.34
325998 All Other Miscellaneous Chemical Product Manufacturing	193	1.26
325311 Nitrogenous Fertilizer Manufacturing	159	1.04
49311 General Warehousing and Storage Facilities	151	0.99
TOTAL	**15,290**	**100**

Note that just four chemical processes and just four industries in each table, respectively, account for the majority of the accidents. This data is by no means comprehensive; however, we cite it to demonstrate the business imperative for embedding inherent sustainability as the most effective mechanism for "de-risking" or "de-hazarding," as opposed to traditional solutions that range from personal protective equipment to securitizing operational sites.

Source: Paul Anastas and David Hammond, *Inherent Safety at Chemical Sites: Reducing Vulnerability to Accidents and Terrorism through Green Chemistry* (New York, NY: Elsevier, 2015).

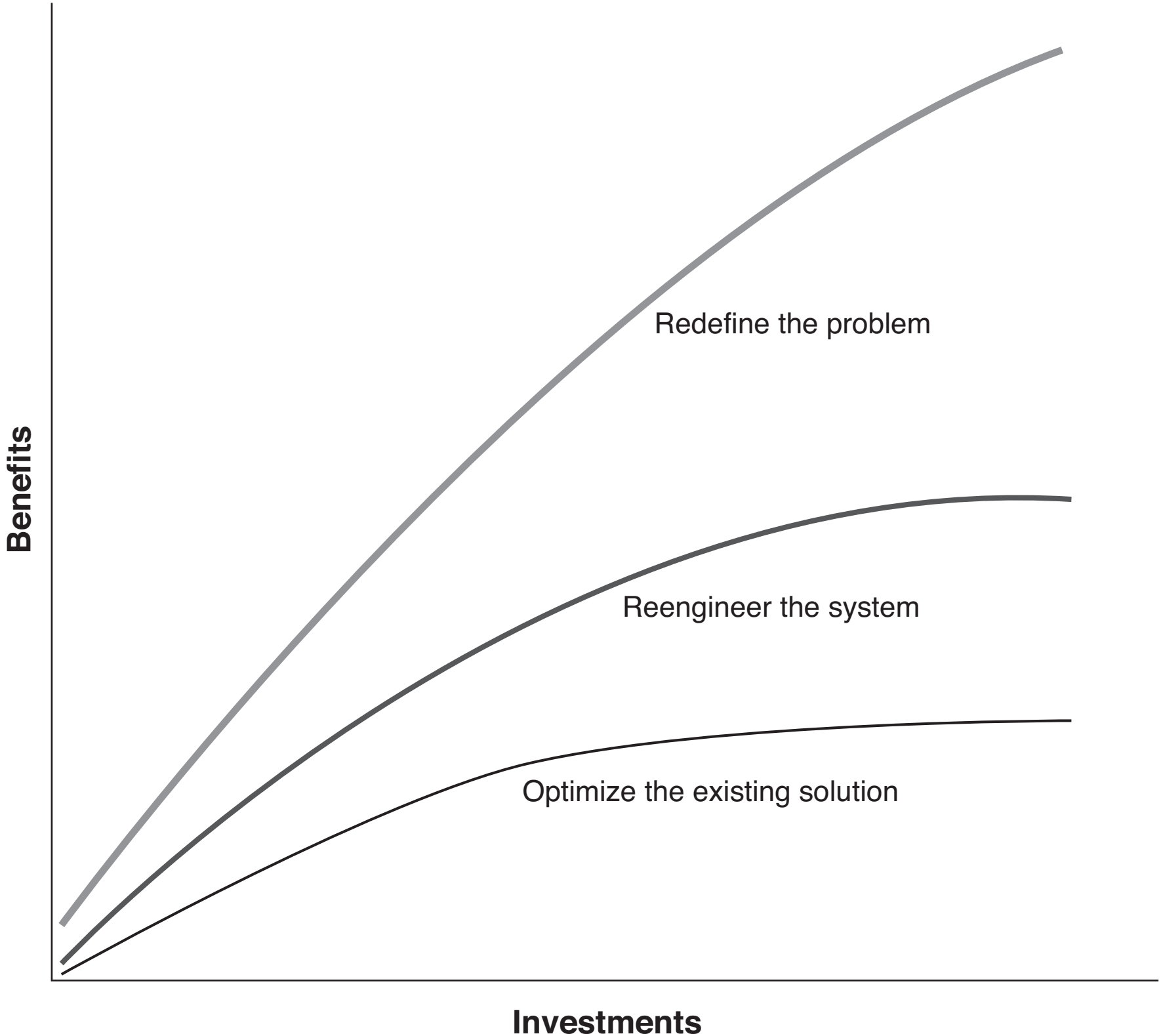
PROPERTIES OF TRADITIONAL AND UNEXPECTED SOLUTIONS LEVERAGING BIO-BASED ELEMENTS

	TRADITIONAL SOLUTION 1 (BOVINE LEATHER) (KARIMJEE N.D.)	TRADITIONAL SOLUTION 2 (VEGAN LEATHER FROM HEMP)	UNEXPECTED SOLUTION
Source	Animal husbandry sector	Lamination of a PVC or polyurethane finish to a base material	Renewable materials (mushrooms)
Energy expenditure	High water consumption by the animal. Bovine leather uses 99% more energy than hemp leather, and has 78% more acidification potential for groundwater and 83% higher global warming potential than hemp leather.	High water consumption in the manufacturing phase, although the production phase of hemp is a low-water-usage phase.	Low-density material, as is preferred by in the packaging and fashion industries; demonstrates good thermal and acoustic insulation.
Worker effects	Hide preparation, tanning, and post-tanning processes use over 400 different types of chemicals that result in high production of toxic waste and	NA	Not noticeable

(continued)

PROPERTIES OF TRADITIONAL AND UNEXPECTED SOLUTIONS LEVERAGING BIO-BASED ELEMENTS (continued)

	TRADITIONAL SOLUTION 1 (BOVINE LEATHER) (KARIMJEE N.D.)	TRADITIONAL SOLUTION 2 (VEGAN LEATHER FROM HEMP)	UNEXPECTED SOLUTION
	GHG. In particular, 50% of chromium used in the tanning process is lost in wastewater.		
Toxicity	Can be fatal (ingestion, inhalation)	Low	Slight irritation possible when undiluted
VOC content	High	Medium	Low


Benefits
Redefine the problem
Reengineer the system
Optimize the existing solution
Investments

Example Scorecards

In the next sections, we have provided examples of completed scorecards from the case studies described previously in this book.

Coastwide Labs/Staples

As described within this book, Coastwide Laboratories (later acquired by Staples) created a sustainability transformation within its organization. The scorecard here was leveraged by Coastwide to understand the operational sustainability of their successful Sustainable Earth line of products. This evaluation is an assessment of the chemical formulation of the Sustainable Earth line as well as the business operations of the same service line.

SCORECARD COMPONENT
PART 1: WASTE PREVENTION

KPI	SUB-METRIC	TRADITIONAL PRODUCT: BEFORE SUSTAINABILITY TRANSFORMATION	UNEXPECTED SOLUTION: SUSTAINABLE EARTH®	RATING
Economy of waste	Atom economy (in g/mol, percentage)	50%	90%–100%	0
	E-factor	Over 50	1–4	0
	Packaging: percentage of readily recyclable material	10%–20%	100%	0
Economy of space	Number of units per square foot of product	25% wasted space in packaging	0% wasted space S-shaped bottles allowed for no space to be wasted	0
	Number of units transported per vehicle	25	48	0
Process intensifi-cation	Productivity/ size ratio Productivity/ weight ratio	0	100%	0

Part 1 qualitative analysis: Prior to the sustainability transformation of Sustainable Earth, the service line demonstrated waste in two main areas:

- The chemical formulation itself
- Packaging and transportation

The firm took steps to alter the chemical formulation along the lines of the green chemistry that specifically improved the atom economy, E-factor, and process intensification (waste metrics of chemical formulations) so as to reduce waste and create savings related to operational expenses.

Within packaging, the firm altered the shape of the bottles that were used to transport the cleaning material. The new S-shaped bottles with optimized bottle thickness not only enabled 25 percent more product to fit within a shipping container but also reduced the breakage rate of bottles during transport. This in and of itself optimized the number of total units transported per vehicle, bringing the eventual number of boxes transported up to forty-eight (from an original twenty-five). This increased operational savings further by reducing the number of trips and fuel consumption in transporting the product to suppliers.

SCORECARD COMPONENT

PART 2: MAXIMIZING EFFICIENCY AND PERFORMANCE

KPI	SUB-METRIC	TRADITIONAL PRODUCT: BEFORE SUSTAINABILITY TRANSFORMATION	UNEXPECTED SOLUTION: SUSTAINABLE EARTH ®	RATING
Material efficiency	Mass of recycled material/total mass Mass of renewable material/ total mass	40%	90%–100%	0
Environ-mental health metrics	Global warming potential (in kg CO_2 emissions)	298	Negligible	1
	Acidification potential (in kg CO_2 equivalents)	High	Negligible	1
	Eutrophica-tion potential (in kg N equivalents)	High	Negligible	1
	Ozone depletion potential (in kg CDC 11 equivalents)	High	Negligible	1

PART 2: MAXIMIZING EFFICIENCY AND PERFORMANCE (continued)

KPI	SUB-METRIC	TRADITIONAL PRODUCT: BEFORE SUSTAINABILITY TRANSFORMATION	UNEXPECTED SOLUTION: SUSTAINABLE EARTH ®	RATING
	Smog formation potential (kg O emissions)	High	Negligible	1
Human health metrics	Number of restricted chemicals according to EU and US guidelines	90%	0	0
	Percentage of chemicals linked to high acuity, disease, and procedural complexity (i.e., high-cost patients)	70%	0	0
	Percentage of chemicals linked to high acuity, disease, and procedural complexity (i.e., moderately high-cost patients)	10%	0	0

(continued)

PART 2: MAXIMIZING EFFICIENCY AND PERFORMANCE (continued)

KPI	SUB-METRIC	TRADITIONAL PRODUCT: BEFORE SUSTAINABILITY TRANSFORMATION	UNEXPECTED SOLUTION: SUSTAINABLE EARTH ®	RATING
	Percentage of chemicals with robust data sources on assessment of health impacts	30%	100%	0

Part 2 discussion: Coastwide created a positive environmental and human health impact by eliminating 100 percent of toxic chemicals that were associated with cancer or designed to persist in the human body throughout generations (demonstrating transgenerational design, as we described earlier in this book). Toxic chemical compounds such as FAE blends, APG, AO, 9.5 EO, ethylene glycol monobutyl ether, branched alkyl benzene sulfonates, and endocrine-disrupting chemicals were all eliminated and replaced with environmentally and biologically benign formulations. Further, this new methodology required 50 percent less water for rinsing after use of the cleaning products.[1]

As reported by Darden Business Publishing at University of Virginia, these sustainability transformations that "assumed lower risk through use of benign products would ultimately translate into lower insurance premiums, lower handling costs, fewer sick days, less expense for protective equipment, lower regulatory burdens and expenses, elimination of hazardous material handling training, and lower waste disposal costs. TriMet and a few school districts had already reported a reduction in

the number of sick days ascribed to chemical-related injuries or sickness." Further, Darden reported that "the Sustainable Earth line enabled Coastwide to lower its customers' costs for maintenance by offering system solutions. Higher dilution rates for chemicals, dispensing units that eliminated overuse, improved safety for the end user, and less lost work time because of health problems associated with chemical exposure were reported.

TriMet, the Portland, Oregon, metropolitan area's municipal bus and light rail system, reduced its number of cleaning products from twenty-two to four by switching to Sustainable Earth. Initial cleaning-chemical cost savings to the municipality amounted to 70 percent, not including training cost savings associated with the inventory simplification. In 2006, the Sustainable Earth line performed as well as or better than the market category leaders while realizing a gross margin more than 40 percent higher than on the company's conventional cleaners."[2]

SCORECARD COMPONENT
PART 3: RENEWABLE INPUTS

KPI	SUB-METRIC	TRADITIONAL PRODUCT	UNEXPECTED SOLUTION: SUSTAINABLE EARTH®	RATING
Renewable carbon-free energy inputs	Percentage renewable carbon			
Percentage of carbon-negative carbon	20%	95%–100%	0	

(continued)

PART 3: RENEWABLE INPUTS (continued)

KPI	SUB-METRIC	TRADITIONAL PRODUCT	UNEXPECTED SOLUTION: SUSTAINABLE EARTH®	RATING
Waste energy utilization		20%	80%	0
Renewable feedstocks	Percentage of total inputs that are derived from renewable resources	20%	80%	0

Part 3 discussion: The new chemical formulations were readily biodegradable and had nearly zero volatile compounds. Volatile compounds are substances that evaporate at room temperature and in many cases persist in the environment and even act as biomarkers for certain cancers. The sustainability transformation brought these chemicals down to zero and thereby reduced exposure as well.

SCORECARD COMPONENT
PART 4: SAFE DEGRADATION

KPI	SUB-METRIC	TRADITIONAL PRODUCT: BEFORE SUSTAINABILITY TRANSFORMATION	UNEXPECTED SOLUTION: SUSTAINABLE EARTH®	RATING
Persistence (a measure of trans-generational design)	Percentage of "forever chemicals" in final product	70%	0	0
Bioaccumulation	Bioaccumulation factor	High	0	0

Part 4 discussion: The firm scaled the input of renewable resources for the production of chemical formulations as well as the use of waste energy to capture otherwise lost energy The only area where renewable energy was not leveraged was in the trucks that transported the goods to suppliers.

P2Science

This assessment was conducted by P2Science in Nagatuck, Connecticut, to compare its product Citropol® H to a traditional input to cosmetics and hair products: silicones (specifically, dimethicones). Silicones are chemically inert components of cosmetics that function to smooth hair and skin, giving foundation and other makeup a smoother, almost air-brushed distribution. They can even help control the thickness of the product that is applied to skin, which helps hold the moisture in the skin and prevent dryness.

SCORECARD COMPONENT
PART 1: WASTE PREVENTION

KPI	SUB-METRIC	TRADITIONAL PRODUCT: SILICONE (DIMETHICONE)	UNEXPECTED SOLUTION: CITROPOL® H	RATING
Economy of waste	Atom economy (in g/mol, percentage)	Less than 50%	>95%	0
	E-factor	Over 50	<1	0
	Reaction yield	Less than 50%	>95%	0
Economy of space	One-pot synthesis	No	Yes	0
Process intensifi-cation	Productivity/ size ratio	Not continuous, and process is not intensified	100% continous and process intensified	0

Part 1 qualitative analysis: Traditional silicones (brand agnostic) are typically highly wasteful in the design phase, resulting in low yield in comparison to the waste produced in the chemical reaction. P2Science's process resulted in over 95 percent yield (i.e., there was minimal chemical waste), and the company even conducted the reaction in one pot to prevent the use of a large volume of reactors and equipment. This metric can have a significant effect on the PP&E (property, plant, and equipment) line item in financial reports.

SCORECARD COMPONENT
PART 2: MAXIMIZING EFFICIENCY AND PERFORMANCE

KPI	SUB-METRIC	TRADITIONAL PRODUCT: SILICONE (DIMETHICONE)	UNEXPECTED SOLUTION: CITROPOL® H	RATING
Material efficiency	Mass of recycled material/total mass Mass of renewable material/total mass	High	100%	0
Environmental health metrics	Global warming potential (in kg CO_2 emissions)	High	Negligible	0
	Acidification potential (in kg CO_2 emissions)	High	Negligible	0
	Eutrophication potential (in kg N emissions)	High	Negligible	0
	Ozone depletion potential (in kg CDC 11 emissions)	High	Negligible	0

(continued)

PART 2: MAXIMIZING EFFICIENCY AND PERFORMANCE (continued)

KPI	SUB-METRIC	TRADITIONAL PRODUCT: SILICONE (DIMETHICONE)	UNEXPECTED SOLUTION: CITROPOL® H	RATING
	Smog formation potential (kg O emissions)	High	Negligible	0
Human health metrics	Number of restricted chemicals according to EU and US guidelines	80%	0	0
	Percentage of chemicals linked to high acuity, disease, and procedural complexity (i.e. high-cost patients)	60%	0	0
	Percentage of chemicals linked to high acuity, disease, and procedural complexity (i.e. moderately high-cost patients)	40%	0	0

PART 2: MAXIMIZING EFFICIENCY AND PERFORMANCE (continued)

KPI	SUB-METRIC	TRADITIONAL PRODUCT: SILICONE (DIMETHICONE)	UNEXPECTED SOLUTION: CITROPOL® H	RATING
	Percentage of chemicals with robust data sources on assessment of health impacts	40%	100	0

Part 2 qualitative analysis: Most silicones not only degrade as microplastics in the environment but also result in reproductive and other toxicology-related negative externalities. Citropol® H is entirely benign as it relates to toxicology and other high-, moderate-, and even low-risk health effects.

SCORECARD COMPONENT
PART 3: RENEWABLE RESOURCES

KPI	SUB-METRIC	TRADITIONAL PRODUCT: SILICONE (DIMETHICONE)	UNEXPECTED SOLUTION: CITROPOL® H	RATING
Renewable carbon-free energy inputs	Percentage of renewable carbon Percentage of carbon-negative carbon	0–10%	100% renewable electricity	0
Waste energy utilization		0–10%	0%	0
Renewable feedstocks	Percentage of total inputs that are derived from renewable resources	0%	100%	0

Part 3 qualitative analysis: All supply chain inputs and the entire production of Citropol® H leverage over 95 percent of renewable inputs.

SCORECARD COMPONENT
PART 4: SAFE DEGRADATION

KPI	SUB-METRIC	TRADITIONAL PRODUCT: SILICONE (DIMETHICONE)	UNEXPECTED SOLUTION: CITROPOL® H	RATING
Persistence (a measure of transgenera-tional design)	Percentage of "forever chemicals" in final product	100%	0	0
Bioaccumula-tion	Bioaccumula-tion factor	High	0	0
Exposure	Induction period and duration of product life	High	0	0
	Latent period and duration of product life	High	0	0

Koninklijke Philips N.V.

This assessment was provided by Philips N.V. to demonstrate the environmental and health-related effectiveness of their upcycling and refurbished medical devices service line.

SCORECARD COMPONENT
PART 1: WASTE PREVENTION

KPI	SUB-METRIC	TRADITIONAL PRODUCT	UNEXPECTED SOLUTION: REFURBISHED MEDICAL DEVICES AND EQUIPMENT	RATING
Economy of waste	Percentage of mass of upcycled material/total mass of product	50%	90%–100%	0
	Packaging: percentage of readily recyclable material	10%–20%	100% in OR	0
	Extended product life (in years)	0	+ 20 years (approximately) in the case of MRI machines and other durable medical equipment	0

Part 1 qualitative analysis: Prior to the sustainability transformation, Philips had no visibility into its supply chain after the medical devices were collected by end users. By way of introducing a collection-and-refurbishment methodology, the firm created operational expense savings, extended the product life, and were able to leverage revenue through an increased number of sales per product.

SCORECARD COMPONENT
PART 2: MAXIMIZING EFFICIENCY AND PERFORMANCE

KPI	SUB-METRIC	TRADITIONAL PRODUCT	UNEXPECTED SOLUTION: REFURBISHED MEDICAL DEVICES AND EQUIPMENT	RATING
Material efficiency	Mass of recycled material/total mass Mass of renewable material/total mass	0%	90%–100%	0
Environ-mental health metrics	Global warming potential (in kg CO_2 emissions)	Net increase in GWP due to increased material and energy use in production	Neutralized	1
	Acidification potential (in kg CO_2 emissions)	Net increase in AP due to increased material and energy use in production	Neutralized	1
	Eutrophica-tion potential (in kg N emissions)	Net increase in EP	Neutralized	1
	Ozone depletion potential (in kg CDC 11 emissions)	Net increase in ODP	Neutralized	1

(continued)

PART 2: MAXIMIZING EFFICIENCY AND PERFORMANCE (continued)

KPI	SUB-METRIC	TRADITIONAL PRODUCT	UNEXPECTED SOLUTION: REFURBISHED MEDICAL DEVICES AND EQUIPMENT	RATING
	Smog formation potential (kg O emissions)	Increase in SFP	Neutralized	1
Human health metrics	Number of restricted chemicals according to EU and US guidelines	0%	0	2
	Percentage of chemicals linked to high acuity, disease, and procedural complexity (i.e., high-cost patients)	50%	Low, 0–10%	2
	Percentage of chemicals linked to high acuity, disease and procedural complexity (i.e., moder-ately high-cost patients)	50%	0–10%	2

PART 2: MAXIMIZING EFFICIENCY AND PERFORMANCE (continued)

KPI	SUB-METRIC	TRADITIONAL PRODUCT	UNEXPECTED SOLUTION: REFURBISHED MEDICAL DEVICES AND EQUIPMENT	RATING
	Percentage of chemicals with robust data sources on assessment of health impacts	10%	0–10%	2

Part 2 qualitative analysis: Reclaiming chemicals and components that would otherwise pose negative health effects in landfills or other modes of end of life, the firm was able to upcycle these components in an environmentally benign manner. This eliminates the health effects to humans by way of groundwater contamination and the like, and keeps unsustainable products in circulation in the economy, ultimately avoiding a graveyard end of life.

SCORECARD COMPONENT
PART 3: RENEWABLE RESOURCES

KPI	SUB-METRIC	TRADITIONAL PRODUCT	UNEXPECTED SOLUTION: REFURBISHED MEDICAL DEVICES AND EQUIPMENT	RATING
Renewable carbon-free energy inputs	Percentage of renewable carbon Percentage of carbon-negative carbon	0%	75% carbon neutral	0
Waste energy utilization		0%	75%	0
Renewable feedstocks	Percentage of total inputs that are derived from renewable resources	0%	75%	0

Part 3 qualitative analysis: Philips currently leverages 75 percent renewable energy and is on track to attain 100 percent renewable energy for all business practices.

SCORECARD COMPONENT
PART 4: SAFE DEGRADATION

KPI	SUB-METRIC	TRADITIONAL PRODUCT	UNEXPECTED SOLUTION: REFURBISHED MEDICAL DEVICES AND EQUIPMENT	RATING
Persistence (a measure of transgenerational design)	Percentage of "forever chemicals" in final product	60%	0	1
Bioaccumulation	Bioaccumulation factor	High	0	1
Exposure	Induction period and duration of product life	High	0	1
	Latent period and duration of product life	High	0	1