Sustainability Metrics

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Summary

As more companies embrace the concepts of sustainable development, there is a need to bring the ideas inherent in eco-efficiency and the “triple-bottom line” thinking down to a practical implementation level. Putting this concept into operation requires an understanding of the key indicators of sustainability and how they can be measured to determine if, in fact, progress is being made.

Sustainability metrics are intended as simple yardsticks that are applicable across industry. The primary objective of this approach is to improve internal management decision-making with respect to the sustainability of processes, products and services. This approach can be used to make better decisions at any stage of the stage-gate process: from identification of an innovation to design to manufacturing and ultimately to exiting a business. More specifically, sustainability metrics can assist decision makers in setting goals, benchmarking, and comparing alternatives such as different suppliers, raw materials, and improvement options from the sustainability perspective.

This paper provides a review on the early efforts and recent progress in the development of sustainability metrics. The experience of BRIDGES to Sustainability™, a not-for-profit organization, in testing, adapting, and refining the sustainability metrics are summarized. Basic and complementary metrics under six impact categories: material, energy, water, solid wastes, toxic release, and pollutant effects, are discussed. The development of BRIDGESworks™ Metrics, a metrics management software tool, is also presented. The software was designed to be both easy to use and flexible. It incorporates a base set of metrics and their heuristics for calculation, as well as a robust set of impact assessment data for use in identifying pollutant effects. While providing a metrics management starting point, the user has the option of creating other metrics defined by the user.

The sustainability metrics work at BRIDGES to Sustainability™ was funded partially by the U.S. Department of Energy through a sub-contract with the American Institute of Chemical Engineers and through corporate pilots.

Introduction

As the oft-cited business principle of “what’s measured gets managed” suggests, sustainable development must be understood in terms of measurable results in order to be effectively managed. As companies begin to embrace sustainable development as a core business value, metrics that effectively measure progress towards sustainability becomes increasingly important. These sustainability metrics would support decision makers in setting goals, benchmarking, and comparing alternatives, such as different raw materials and technologies, in terms of sustainability.

Although sustainable development can be defined in many ways, two interrelated ideas are widely accepted in the business community:

(1) eco-efficiency, i.e. increasing value generation while reducing environmental damages and their impacts on the community; and

(2) "triple bottom line," which recognizes that *economic* progress is inextricably linked to the health of the *environment* and the well-being of the *society*.

These concepts originated from the growing concerns regarding the availability of natural resources, increasing regulatory burdens and public pressure to address negative social impacts of corporate operations. Together, they indicate that a company's future competitiveness will depend on how well social and environmental interests, as well as economic interests, are integrated into the business strategy it pursues. A well-constructed set of metrics that capture eco-efficiency and the economic/environmental/ societal triple-bottom-line paradigm can serve as an effective management tool in operationalizing sustainability.

BRIDGES to Sustainability™, an educational not-for-profit organization based in Houston, has been actively involved in the development of sustainability metrics and other decision-support approaches since its inception in 1998. To facilitate the use of sustainability metrics, BRIDGES has recently automated its methodology into the BRIDGESworks™ Metrics software. A tested set of metrics, decision rules, and heuristics are provided as a starting point for companies in using the sustainability metrics, while the flexible nature of the software allow companies to tailor the metrics to their own needs.

This paper provides and overview on the development of sustainability metrics, their construct, and how they are used. Development of the automated metrics software and how the metrics can be linked to other sustainability decision-support approaches are also discussed.

Development of Sustainability Metrics

Companies have long kept track of many elements of the sustainability metrics. These include various resource uses that carry economic costs as well as certain emissions and wastes as mandated by regulation. The challenge in developing sustainability metrics is to organize the information in a format that best support decision-making in terms of sustainability.

Canada's National Round Table on the Environment and the Economy (NRTEE) conducted one of the earliest studies in the development of sustainability metrics (NRTEE, 1999). Their search for a small set of eco-efficiency indicators that is meaningful and applicable across industries became an underlying theme in the later efforts to develop sustainability metrics. The study, which involved eight companies from different industry sectors, recommended a set of "core" metrics that include material intensity, energy intensity, and dispersion of regulated toxics per unit of products or services. The study also suggested the use of complementary metrics, such as greenhouse-gas intensity.

The World Business Council for Sustainable Development (WBCSD) also took on a similar effort (Verfailie and Bidwell, 2000). In addition to the material and energy consumptions, they recognized water consumption as another important eco-efficiency metric. Furthermore, the WBCSD identified the emissions of greenhouse gases and ozone-depleting substances as the only environmental impact metrics that can be calculated based on existing international consensus.

Another early effort in developing sustainability metrics was undertaken by the Center for Waste Reduction Technologies (CWRT) of the American Institute of Chemical Engineers (AIChE). Representatives from CWRT member companies concluded on a set of basic and complementary sustainability metrics expressed on a choice of denominators that include mass, revenue, and value added.

BRIDGES to Sustainability™ furthered the earlier efforts through a CWRT sub-contract funded by the U.S. Department of Energy. Commencing in 1999, BRIDGES assembled three academic teams from Rice University (under environmental attorney Jim Blackburn), the University of Texas at Austin (Prof. David Allen), and Georgia Institute of Technology (Prof. Tom Graver) to adapt, test, refine and evaluate the use of sustainability metrics. The metrics were piloted in a number of manufacturing facilities including those of Formosa Plastics (petrochemical), Interface Corporation (carpeting), and an asphalt roofing tile manufacturer. Decision rules and heuristics were developed and tested by the BRIDGES team in calculating sustainability metrics for over 50 commodity chemicals from the highly regarded SRI International's Process Economics Program (PEP) data. Results from this study were published in a report to the US DOE (Beaver and Beloff, 2000), the Society of Petroleum Engineers (SPE) proceedings (Schwarz et al, 2000), and the *Chemical Engineering Progress* (Schwarz et al, 2002).

Upon the successful completion of its first metrics project, BRIDGES continues to refine the sustainability metrics and broaden its applicability to more industrial sectors. A methodology to determine practical minimum energy in chemical processes was developed, creating a baseline for the energy metric (Schwarz et al, 2001; Tanzil et al, 2002a). BRIDGES also continues to explore the integration of the metrics approach with other sustainability decision-support methodologies, namely life-cycle assessment (LCA) and total cost assessment (TCA) (Beloff et al, 2000; Schwarz et al, 2002; Tanzil et al, 2002b). Currently, BRIDGES is piloting the sustainability metrics approach in the design of steel components at Caterpillar Inc. (with National Science Foundation funding) and for tool manufacturing facilities at The Stanley Works.

Recent progress has also been made by Britain's Institution of Chemical Engineers (IChemE), with the sustainability metrics expanded to include subsets of economic and societal indicators (IChemE, 2002). While they reflect the triple-bottom-line paradigm, most of the economic and societal metrics are not reported per output basis and therefore do not constitute measurements of eco-efficiency.

IChemE also expanded the sustainability metrics by including measures of the potential impacts of emissions, effluents, and wastes. This reflects a recent trend in sustainability metrics where toxic and pollutant dispersion are measured in terms of their potential impacts to human health and the ecosystem, rather than by a simple total mass dispersed as in most of the early metrics program. IChemE achieves this by using the "environmental burden" approach of ICI. In fact, many impact assessment methodologies are available in the literature, including the recently-developed TRACI methodology (see http://epa.gov/ORD/NRMRL/std/sab/iam_traci.htm) (Bare et al, 2002). The use of these impact assessment methodologies, however, greatly increases the complexity of metrics calculation, and can be done easily only with the help of automated computational tools.

BRIDGES' Sustainability Metrics

BRIDGES' sustainability metrics were designed to meet the following criteria (Beaver and Beloff, 2000):

- Simple to use — not requiring large amounts of time or manpower to develop
- Useful to management decision-making and relevant to businesses
- Understandable to a variety of audiences, from people in operations to finance to strategic planning
- Cost-effective in terms of data collection
- Reproducible — incorporating decision rules that produce consistent and comparable results
- Robust and non-perverse — indicating progress toward sustainability when improvement has in fact been made
- Stackable along the supply chain so they are usable beyond the particular boundaries for which the calculation was performed
- Protective of proprietary information — preventing back-calculation of confidential information

Most of the above criteria are common to all sustainability metrics and were identified through experience and consensus in the early studies. The "stackable" criterion, however, is unique to the design of BRIDGES' metrics (Beaver and Beloff, 2000). Incorporating the supply-chain and life-cycle perspectives greatly increase the robustness of the metrics. By stacking metrics along the supply chain, one can avoid the pitfall of locally optimizing while resulting in the overall decline in the overall eco-efficiency of the life cycle.

Another important characteristic of BRIDGES' sustainability metrics is their scalability. That is, they can be scaled for different boundaries such as around a process, a facility, a business unit, or a product supply chain. Given appropriate boundaries, the metrics can be aggregated using simple algebraic equations, e.g. process-level metrics aggregated to form a facility-level metric. Conversely, a facility-level metric can be disaggregated to produce process-level metrics through the use simple allocation rules (see Formosa Plastics pilot in Schwarz et al, 2000).

Metrics construction, organization, and reporting

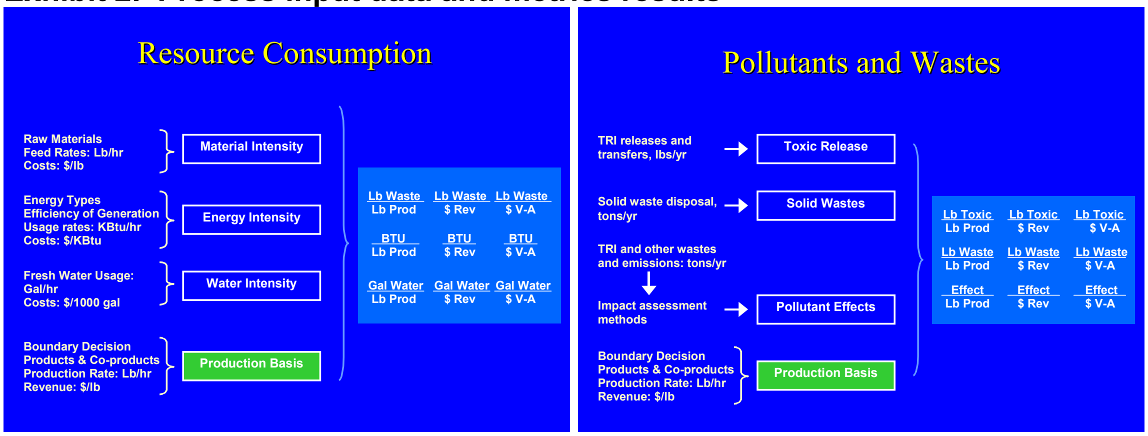
BRIDGES' sustainability metrics are constructed as ratios with environmental impacts in the numerator and a physically- or financially-meaningful representation of output in the denominator. They follow a simple rule of thumb: the lesser the metric the better. The metrics are currently organized into six basic impact categories: material, energy, and water intensities, solid waste to landfills, toxic releases, and pollutant effects. A seventh basic impact category, land use, is currently under development.

Following the CWRT workgroup recommendation, the metrics are usually calculated with mass of product(s), dollar sales revenue, and dollar value-added in the denominator. Other representations of outputs, however, can also be used. This includes other units of production (volume, pieces of products, etc.) and functional units such as service life. To protect proprietary information, the value-added is defined simply as the difference between sales revenue and the costs of raw materials and utilities. Where confidentiality is not concerned (such as for internal use), one may alternatively use profit margin in place of the value-added denominator.

Basic metrics are defined for five of the basic impact categories (all except pollutant effects). These form the simplest set of metrics that can be commonly used across industries and applications. Definitions of the five basic metrics and the pollutant effect metrics are provided in Exhibit 1. Once the boundary for the metrics calculation is

Exhibit 1. Basic sustainability metrics developed by BRIDGES	
Output: *Mass of Product* or *Sales Revenue* or *Value-Added*	**Material Intensity** $\frac{\text{Mass of raw materials} - \text{Mass of products}}{\text{Output}}$ **Water Intensity** $\frac{\text{Volume of fresh water used}}{\text{Output}}$ **Energy Intensity** $\frac{\text{Net energy used as primary fuel equivalent}}{\text{Output}}$ **Solid Waste to Landfill** $\frac{\text{Total mass of solid waste disposed}}{\text{Output}}$ **Toxic Release** Total mass of recognized toxics released Output

Exhibit 2. Process input data and metrics results



defined (e.g. around a process), the metrics can be calculated usually from readily available data (Exhibit 2).

It is important to note that energy consumption is measured in the unit of primary fuels, i.e. fuels that exist in nature such as oil, coal, and gas. This means, losses of primary fuels in the generation and transmission of secondary energy such as electricity (typically 69% losses) and steam (20%) are accounted. Expressing energy consumption in primary fuel equivalents makes the basic energy metric more representatives of the energy cost and the amount of greenhouse-gas emissions associated with the energy use, thus increasing the robustness of the metric.

Another basic metric that warrants further explanation is the toxic release metric. Only toxics recognized by the local regulatory system, such as the Toxic Release Inventory (TRI) in the US or the National Pollutant Inventory (NPI) in Canada, are included. Following the accepted industrial practice, the toxic release is measured in total mass. However, such measurement may be misleading. As toxics have varying degrees of toxicity, dramatic reduction in the mass of a slightly toxic component accompanied with a lesser increase in the mass of an extremely toxic compound will reduce the total mass of toxic released, but may increase the potential damage to human health and the environment. In this case, the toxic release metric can be better understood when complemented with other metrics that measures the potential impacts.

Complementary metrics can be defined and developed as any other need for decision-support emerges. A common temptation in designing metrics is to take into consideration too many factors. Measurements that combine too many components are actually less versatile and less useful for making comparisons across products and industries. Therefore, it is best to maintain a basic set of simple, widely applicable metrics and to construct complementary metrics to meet the needs of specific industry or application. Yet, the use of complementary metrics remains important to better understand the progress towards sustainability.

Exhibit 3. Examples of complementary metrics under each metric category	
Material ❑ Packaging materials ❑ Non-renewable materials ❑ Toxics in product ❑ Toxics in raw materials **Water** ❑ Rainwater sent to treatment ❑ Water from endangered ecosystem sources ❑ Water use relative to water availability **Energy** ❑ Energy consumed in transportation ❑ Non-renewable energy	**Solid waste** ❑ Solid waste disposed relative to landfilling capacity **Toxic release** ❑ Toxic release under each TRI category ❑ Human toxicity (carcinogenic) ❑ Human toxicity (non-carcinogenic) ❑ Ecosystem toxicity **Pollutant effects** ❑ Global warming potential ❑ Tropospheric ozone depletion potential ❑ Photochemical ozone creation potential ❑ Air acidification potential ❑ Eutrophication potential

Exhibit 3 shows examples of complementary metrics under each category. Some complementary metrics contain impacts not included in the basic metrics, such as the use of packaging materials and energy for transportation, and the amount of rainwater contaminated by the industrial operation. Other complementary metrics help decision makers to better understand the sustainability implications of the resource uses and environmental releases. Water usage becomes more critical when it affects an endangered ecosystem, or in a water scarce area. Similarly, solid waste releases can be weighted by the landfill capacity available in the area.

As complementary metrics under toxic release, the potential effects of toxics on human health and the ecosystem can be assessed using available impact assessment methods. Similarly, impact assessment can be applied to calculate the potential pollutant effects on global warming, ozone depletion, photochemical ozone (smog) generation, air acidification, water eutrophication, etc. As mentioned earlier, international consensus has been reached for the calculation of only two of these impacts: global warming and ozone depletion. Other impacts depend on varying degrees on regional and local conditions, although the existing impact assessment methodologies still act a rough guide in weighting the “badness” of different toxics and pollutants.

Exhibit 4. General format of BRIDGES' sustainability metrics report

per unit of output

Measure of impact	/ lb	/ $ Rev.	/ $ V-A
Basic Metric (Material, Energy, Water, Toxics, Waste, Pollutants)	**#.##**	**#.##**	**#.##**
Complementary metric #1	#.##	#.##	#.##
Complementary metric #2	#.##	#.##	#.##
Complementary metric #3	#.##	#.##	#.##

Exhibit 4 shows the general format of BRIDGES' sustainability metrics reporting. Basic metrics are reported under each impact category except pollutant effects. The basic metrics are accompanied by selected sets of complementary metrics deemed relevant to decision making for the particular application. The metrics are tabulated using different output denominators, usually mass of product (or unit production), revenue, and value added.

Using Sustainability Metrics

Sustainability metrics can be used to make better decisions in terms of sustainability at any stage of the stage-gate process: from identification of an innovation to design to manufacturing and ultimately to exiting a business. Exhibit 5 identifies some specific applications, which include benchmarking, tracking progress over time, and comparing business units and alternatives (different suppliers, improvement options, etc.). Exhibit 6 shows a comparison of metrics calculated for 15 chemical products. The best, middle, and worst thirds under each metric category are shown in different colors. For a company that has the 15 products in its portfolio, the color-coded table clearly shows the products that have greater risks in terms of sustainability. Similar comparison

Exhibit 5. Uses for BRIDGES' sustainability metrics

- Support internal decision-making
- Educate the user about environmental impacts and sustainable development
- Spark innovation•Improve managerial cost control & motivation
- Identify / Evaluate improvement options
- Track progress over time
- Benchmark
- Evaluate acquisitions
- Evaluate suppliers
- Respond to government agencies & community

Exhibit 6. Comparing metrics

Product	Material			Energy			Water			Toxics			Pollutants			Greenhouse Gases		
	/lb	/$Rev	/$VA	/lb	/$Rev	/$VA	/lb	/$Rev	/$VA	/lb	/$Rev	/$VA	/lb	/$Rev	/$VA	/lb	/$Rev	/$VA
Polyethylene	0.021	0.061	0.145	1.185	3.386	8.124	0.447	1.277	3.064	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.283	0.809	1.942
Butadiene	0.018	0.146	0.729	1.059	8.763	43.623	0.359	2.971	14.791	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.139	1.151	5.732
Acetic Acid	0.062	0.283	0.395	1.823	8.287	11.592	1.239	5.632	7.878	0.00011	0.00049	0.00069	0.00000	0.00000	0.00000	0.133	0.607	0.849
PVC	0.049	0.084	0.145	3.634	6.266	10.827	0.619	1.067	1.843	0.00203	0.00351	0.00606	0.00000	0.00000	0.00000	0.410	0.708	1.223
Nylon 6	0.026	0.023	0.079	4.749	4.059	14.195	0.670	0.573	2.003	0.00469	0.00401	0.01403	0.00325	0.00278	0.00973	0.237	0.203	0.710
Formaldehyde	0.700	3.744	6.313	-0.427	-2.284	-3.852	1.397	7.475	12.602	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.296	1.585	2.672
Styrene	0.048	0.191	0.459	3.349	13.393	32.253	1.095	4.379	10.546	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.719	2.875	6.924
Aniline	0.432	1.094	6.426	-0.902	-2.286	-13.432	0.696	1.765	10.371	0.00002	0.00004	0.00023	0.00764	0.01937	0.11381	0.097	0.247	1.45
Chlorine	0.011	0.097	0.164	8.062	72.884	122.607	0.632	5.717	9.617	0.00000	0.00000	0.00000	0.00024	0.00215	0.00362	1.090	9.854	16.577
Maleic Anhydride	0.665	1.438	2.024	0.704	1.521	2.142	3.138	6.780	9.545	0.00163	0.00352	0.00495	0.00000	0.00000	0.00000	2.616	5.652	7.958
Hydrofluoric Acid	3.780	5.400	8.394	4.151	5.930	9.218	0.708	1.012	1.572	0.00680	0.00971	0.01510	0.04570	0.06528	0.10148	0.437	0.624	0.97
Ethylene	0.082	0.636	1.481	3.107	23.980	55.825	0.914	7.054	16.421	0.00058	0.00451	0.01050	0.00013	0.00104	0.00241	0.436	3.367	7.838
Ethylene Glycol	0.267	0.875	1.636	2.335	7.643	14.291	2.585	8.461	15.822	0.00756	0.02474	0.04626	0.00000	0.00000	0.00000	0.774	2.534	4.737
Phosphoric Acid	5.440	39.708	318.129	3.332	24.321	194.854	3.560	25.987	208.200	0.07202	0.52567	4.21150	0.00000	0.00000	0.00000	0.191	1.396	11.184
Acrylonitrile	0.493	1.475	4.678	5.211	15.598	49.456	3.372	10.096	32.009	0.01514	0.04533	0.14374	0.00781	0.02337	0.07410	0.966	2.891	9.167

Green – lowest third; **Yellow** – middle third; **Red** – highest third

can be made for different facilities and business units. As another example, Exhibit 7 compares the energy metrics for different facilities belonging the different business units in a company. The figure graphically identifies the best and worst performing business units in terms of energy use per dollar value-added (Beaver and Beloff, 2000).

BRIDGES' sustainability metrics approach is being further developed for two distinct applications, especially through the development of automated metrics management tool. One is for the educational marketplace, where the metrics management

Exhibit 7. Using metrics to measure facility performance
(from Schwarz et al, 2000)

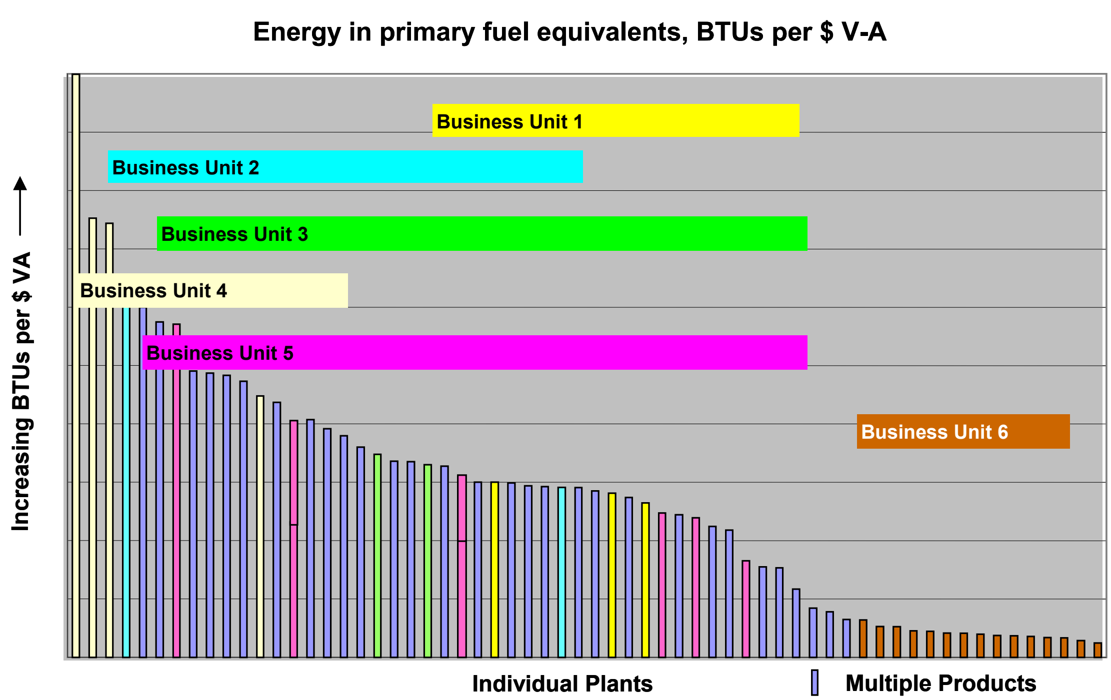
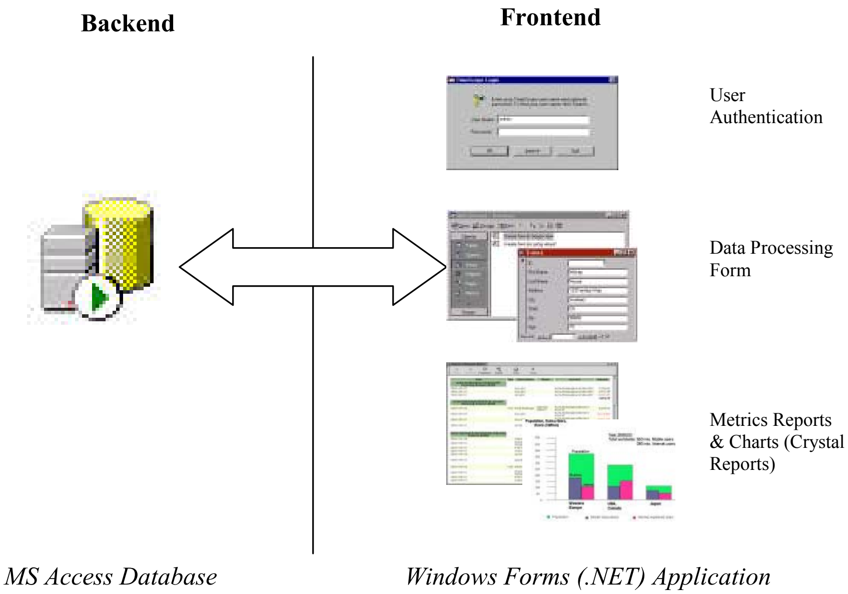


Exhibit 8. BRIDGESworks™ Metrics (desktop version) architecture



tool is populated with case study information and can be used to educate university students as well as corporate trainees about sustainable development. The other is for corporate users with a variety of potential uses. Ultimately the results can contribute to building the business case for sustainable development.

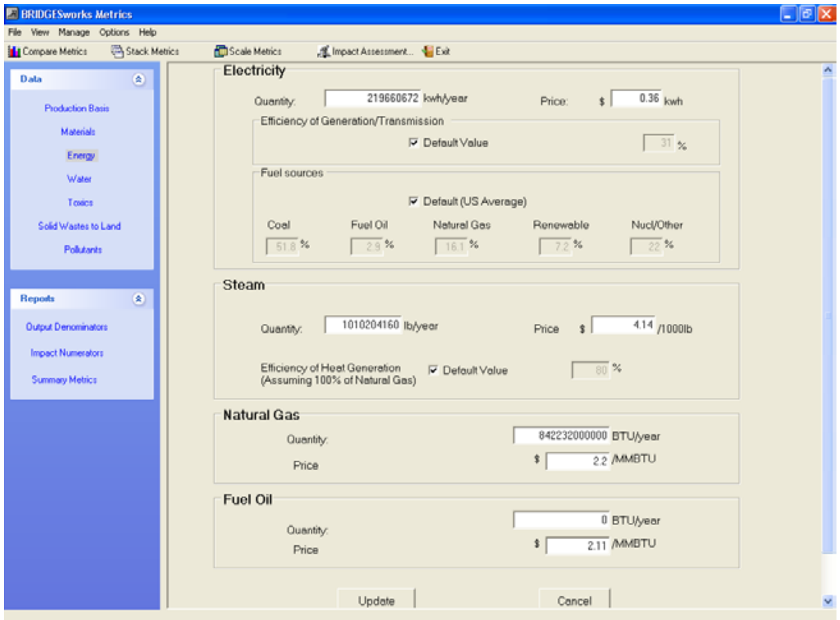
BRIDGESworks™ Metrics Software

BRIDGESworks™ Metrics is a metrics management software tool that identifies key sustainability indicators and offers a variety of metrics for measuring sustainability performance. The tool was designed to offer both convenience and flexibility. It incorporates BRIDGES' set of metrics and their heuristics for calculation, as well as a robust set of impact assessment data for use in identifying pollutant effects. While providing a metrics management starting point, the user has the option of creating other metrics defined by the user. Therefore, the software tool can be easily adapted to simplify calculations for other metric sets, such as IChemE sustainability metrics.

Software architecture

There are two primary components in current desktop version of BRIDGESworks™ Metrics: the backend database using MS Access and the frontend application using the Windows Forms classes integrated with Crystal Reports (see Exhibit 8). The data link between the backend database and the frontend application is OleDB. BRIGESworks™ Metrics uses DataSet objects of the ADO.NET library in the .NET Framework to manage data. (A DataSet is an object containing a cache of the data retrieved from the database.) Crystal Reports generated by the software tool can be exported to other convenient formats, such as MS Excel, MS Word and PDF.

Exhibit 9. BRIDGESworks™ Metrics sample data entry screen



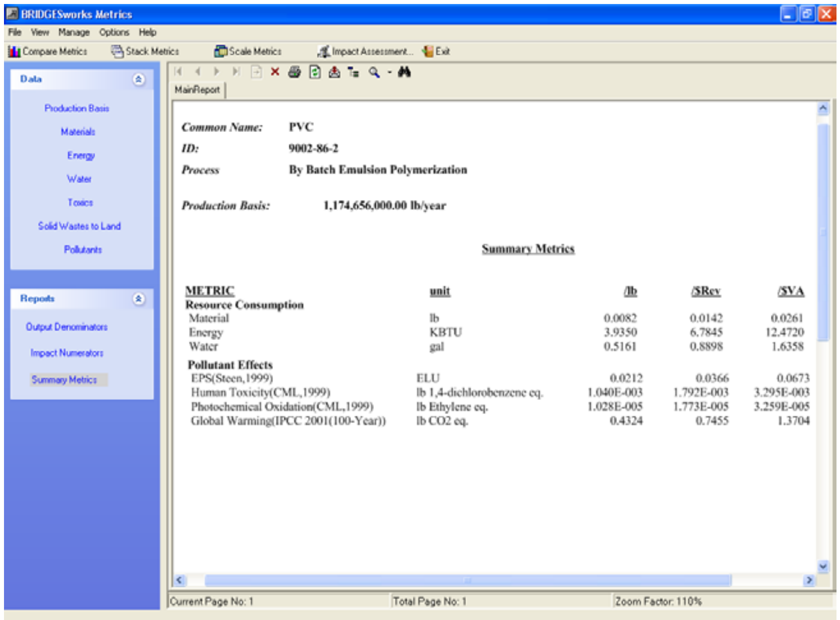
All of the shared data is stored in an MS Access database. It includes two parts: Lookup Data and Inventory Data. Lookup Data are data that will not be frequently updated once entered into database. These include the impact assessment data and chemical identifications and properties. Inventory Data, on the other hand, require user to manually input or import for other data source as batch work. Resource use, pollutant release, and cost data are parts of the Inventory Data. The relationship between lookup and inventory data is defined through unique identifiers.

A client/server or Web version of BRIDGESworks™ Metrics will be developed soon to meet users' additional requirements such as remote access and easy deployment and update. In the Web version, the database can be migrated to MS SQL Sever or Oracle. There will be a new component – XML Web service added as a middle layer to handle the authentication and data requests from client application that accesses database server.

Using the software tool

Data can be manually entered by the user or imported from other sources such as MS Excel. The user can then review the heuristics and assumptions built-in in the software. For example, Exhibit 9 shows the manual data entry screen for energy consumption. Several sets of default assumptions are shown on the screen, including the US average mix of fuels for electricity generation (used in calculating greenhouse-gas emissions) and the typical efficiencies in the generation and transmission of electricity and steam (used in calculating primary fuel consumption). When necessary, the user can modify the above assumptions to match local settings.

Exhibit 10. BRIDGESworks™ Metrics sample summary report screen



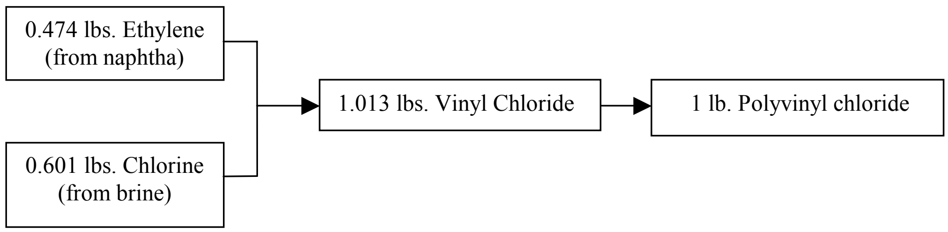
While commonly used complementary metrics and impact assessment systems are selected in the software by default, the user can review the selection and make changes as desired. Over thirty complementary metrics and impact assessment methodologies are currently included in the software, with more being developed and incorporated. Exhibit 10 shows a sample summary report, including the selected complementary metrics. The resulting set of metrics can then be compared with other metric sets or become a data point in tracking progress towards sustainability. The software also allows the aggregation or stacking of different metric sets once the relationships among them are defined.

Integrating Sustainability Metrics with Other Approaches

Sustainability metrics can serve as the basic building block for other sustainability decision-support approaches. As mentioned earlier, BRIDGES' metrics are designed to be stackable along the supply chain. Using data from public and private life-cycle sources and databases, the stackable metrics approach can be used to facilitate a simplified life-cycle assessment (Beloff et al, 2002). Exhibit 11 demonstrates how the metrics can be stacked along a part of the life cycle (Schwarz et al, 2002).

The sustainability metrics approach can also be integrated with the total cost assessment (TCA) methodology. TCA attempts to calculate all costs and savings associated with a decision (e.g. selection of a technology). This includes costs internal to the company (direct, indirect, liability, and intangible costs) as well as those that are not yet internalized (societal or externality costs) (CWRT, 1999). These costs are associated with the impacts calculated in the metrics. Once the costs per unit of impact are

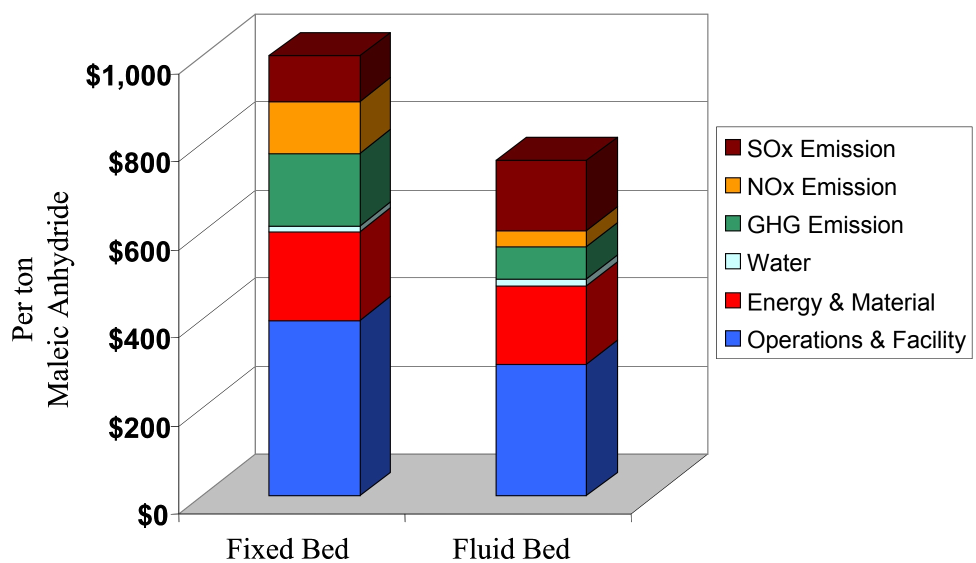
Exhibit 11. Stacking metrics along supply chain
(from Schwarz et al, 2002)



Metric	Material (lb/lb PVC)	Energy (kBTU/lb PVC)	Water (gal/lb PVC)	Toxics (lb/lb PVC)	Pollutants (lb/lb PVC)	CO_2 (lb/lb PVC)
Ethylene X 0.474	0.039	1.473	0.433	0.00027	0.00006	0.207
Chlorine X 0.601	0.007	5.050	0.380	0.00000	0.00014	0.748
Vinyl Chloride X 1.013	0.206	4.966	2.129	0.00000	0.00356	0.756
Polyvinyl chloride	0.049	3.935	0.619	0.00203	0.00000	0.546
PVC Supply Chain	**0.300**	**15.424**	**3.561**	**0.00230**	**0.00376**	**2.257**

identified, the sustainability metrics can be translated into total cost figures. Exhibit 12 shows an example of total costs calculated from metrics data (Tanzil et al, 2002b). Further, the metrics can be integrated with not only total cost assessments but also total benefit assessments. This would pull both corporate and societal benefits into the equation.

Exhibit 12. Translating metrics into total costs
(from Tanzil et al, 2002b)



SOx & NOx valuations based on So. California; GHG from IPCC

Conclusions

Sustainability metrics provide decision makers with simple yardsticks to calibrate how well their company is doing and to compare alternatives from sustainability perspectives. The use of automated metrics management tools, such as the BRIDGESworks™ Metrics software, further simplifies the development and calculation of the metrics. The value of the sustainability metrics can be additionally enhanced when used in conjunction with other sustainability decision-support tools, such as life-cycle assessment and total cost and benefit assessment.

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