Industry Specific Benchmark Metrics – Integration into Land use Choices

Earl R. Beaver
Practical Sustainability, LLC
14500 White Birch Valley Lane
Chesterfield, MO 63017-2418
Phone: (314) 409-9068
Fax: (636) 536-1256
Email: Erbeav@aol.com

Abstract

There is a lack of accepted methods to assess the current total benefit and cost impact to society of changes a community may make in its infrastructure. If urban planners are to make rational decisions from a sustainability perspective, metrics and a reasonable assessment of societal benefits and costs must be established before new industrial facilities are built or industrial production increases significantly. Indicators of progress need to take into consideration material and energy use, resources depleted, proper use of land and the amount of pollutants dispersed. They need to be assessed in the context of the net total costs they represent to society as well as in the context of an overall value-added that any operation generates.

The design and testing of preliminary metrics by companies under the auspices of the National Roundtable on the Environment and the Economy and of total cost assessment and metrics by the American Institute of Chemical Engineers have been completed. Those efforts yielded a good basis for establishing workable tools for decision making in companies; however, these tools required refinement to ensure that they are simple, easily understood, reproducible, and cost-effective in terms of data collection and suitable for industrial decision making. In addition, work has been needed to adapt them to sectors of the economy other than industry.

Together with other organizations we have refined sustainability tools, including Total Benefit and Cost Assessment in the areas of investigation described above and adapted them to become more robust for use in industrial and government decision-making. In total benefit and cost assessment, particular focus has been placed on understanding societal benefits and costs associated with environmental impacts as an indicator of future costs that government, society at large and companies may bear in the future for decisions made today. Communities can become more humanized tomorrow by taking these concepts into consideration today.

In this manner, we can all become positive agents of change today.

Introduction

Metrics and other indicators must be established before progress in municipal areas with substantial industrial facilities can be measured and goals for improvement can be set. That need for such measures in industry prompted four companies and the United States Department of Energy to fund two projects on metrics and assessment of societal costs. Those projects where conducted by the author and BRIDGES to Sustainability in Houston, Texas.

The objectives of the work reported here are:

- Combine the elements of metrics and total benefit and cost assessment into a single measure which can used to evaluate the costs to society relative to the value to society of options related to industrial growth in municipal areas.

- Develop recommendations for linkage of the findings to activities of non-governmental organizations and governments.

This paper will use the consideration of an option to construct a vinyl chloride monomer plant in an urban area on a freshwater lake as an example of how metrics and total cost and benefit assessment techniques can be combined to evaluate the societal costs relative to the value created for society in producing the product.

There several general requirements for useful decision tools, whether they are related to metrics or total cost and benefit assessment:

- Practical
- Simple to use
- Understandable by audiences
- Easy to reproduce
- Complement existing regulatory programs
- Robust, non-perverse
- Data collection cost-effectiveness
- Usefulness as a management tool
- Protection of proprietary company data

Background

Total Benefit and Cost Assessment (TBCA) is a dynamic and emerging concept that seeks to quantify all impacts and costs associated with a decision. However, a standardized, widely-accepted approach to conducting a TBCA has yet to be developed, published and widely tested. In spite of efforts by some organizations, e.g. ISO, to standardize terminology, many practitioners use common language in describing steps in a life cycle approach to decision making. The architects of CWRT's TCA methodology charted a path to a standardized approach to account for costs that meets the needs of a broad range of industrial sectors.

The management of total costs and impacts for industrial processes requires knowledge of the resources consumed and the waste by-products generated during the lifetime of a product. Life cycle stages encompass: extraction and processing of raw materials; manufacturing, transportation, and distribution; use/reuse/maintenance; recycling and composting; and, final disposition. Life cycle analysis can be used to create scenarios upon which a cost assessment can be performed. TBCA methodology assumes that a life cycle inventory for the product or process has been completed and results are available for incorporation into the TBCA model.

Although TBCA is generally devoted to identifying environmental impacts and costs associated with the manufacture of goods and services, the methodology also includes potential health impacts and costs that may result from exposure to environmental pollutants, because these two areas are difficult to separate.

A model for Total Cost Analysis was developed by Tellus Institute, Boston, MA. The model, which is named P2 Finance, is a simple spreadsheet, thus not sufficiently robust for practical daily use. However, the concepts behind the model can serve as a standardization tool. The P2 Finance tool can be downloaded (at no cost) from the EPA website http://es.inel.epa.gov/partners/acctg.

Some of the sponsors of the Center for Waste Reduction Technologies (AIChE) originally agreed to collaborate on a program to develop a methodology to capture the total costs of chemical and pharmaceutical manufacturing processes. They included: 3M, Dow, Eastman Chemical, Eastman Kodak, General Electric, ICI, Monsanto, Owens Corning, Rhone Poulenc, Rohm & Haas, SmithKline Beecham, Solutia and Union Carbide.

The development of the Total Cost Assessment (TCA) methodology occurred in four phases at AIChE and has proceeded in three additional phases (adding benefits) since then:

1. Identify the best industry practices for total cost assessment
2. Acquire methodologies, automation tools and build databases of available information on direct, indirect and future and contingent costs. Test the tool in three CWRT companies
3. Automate the tools and develop methodology for internal and external intangible costs
4. The development of methodology for evaluation and monetization of societal costs where no cost data are relatively available
5. Develop comparable mechanisms for identifying and monetizing benefits

6. Meld the concepts of TBCA with those of metrics and indicators.
7. Extend concepts beyond manufacturing.

The earlier design and preliminary testing of indicators for energy and materials intensity by twenty companies took place under the auspices of the National Roundtable on the Environment and the Economy (NRTEE, based in Ottawa) and the Center for Waste Reduction Technologies (CWRT, based in New York). That work yielded a good starting point for indicators and metrics of industrial performance. The major themes of those indicators efforts were energy and material use and pollutant dispersion. Metrics for energy efficiency - energy consumed per unit of output – were found to be readily and widely implementable and meaningful for individual large companies. Metrics for material intensity - materials consumed per unit of output – have also been found to be feasible, but are more applicable and relevant in some industry sectors than others.

Metrics Methodology

For the metrics work undertaken by BRIDGES to Sustainability on more than 50 major compounds (including vinyl chloride), a wide spectrum of data was examined from a variety of sources. SRI International has a highly respected client-based program, known as 'PEP' or Process Economics Program. The program includes extensive information on the efficiencies of many processes for producing the selected chemical products. That data served as a large portion of the basis for development of product metrics. Data was also collected by direct examination of company manufacturing data at a large petrochemical complex in Texas, searching university and government databases and using vendor-supplied data. Computation and evaluation of the metrics focused on technical feasibility, such as the required degree of precision and availability of data, the clarity of decision rules, definitions and compilation procedures, and on interpretation issues – the meaning that may be ascribed to the metrics by users. This led to the need to compute metrics with three different denominators: mass of product, sales revenue and value-added. Data from the United States Department of Energy

In order to reliably compute metrics for such a large array of products and supply chains, teams of students and faculty members were employed.

Material Use Metric: materials consumed per unit of output (mass of product, sales revenue and value-added) -- were tested and the relevance to each industry sectors was assessed. The basic metric was material consumed from all sources (numerator, measured in pounds or converted to kilograms) per unit of manufactured output or service delivery (denominator, measured in physical, operational and financial terms).

Water Use Metric: metric for fresh water use, since the basic material metric is calculated on a dry basis. Water usage = (all water used) - (once-through cooling-water not from an aquifer) + (all rain water treated in a waste water treatment plant) - (any seawater used)

Energy Metric: energy consumed from all sources (numerator, measured in or converted to BTUs or joules) per unit of manufactured output or service delivery (denominator, measured in physical, operational or financial terms). Several complementary metric options can be considered for energy, but only the final one was calculated: greenhouse gas emissions. It became a complementary metric for pollutants as well.

Pollutant Dispersion Metric: numerator includes the mass equivalent sum of all emissions.

Toxics Dispersion Metric: widely recognized lists of publicly reported emissions e.g. U.S. Toxics Release Inventory. To the extent possible, data are collected on the following complementary metrics with denominators of sales revenue, mass of product and value-added:

- Greenhouse Gases (GHGs) – expressed as mass of CO_2 equivalents (using 20-year life-time data from table in *Global Warming (IPCC, 1992)* for CO_2 equivalents)

- Acidification (air and water separately) – expressed as mass of SO_2 equivalents (using table in *Acidification (1997) Air Emissions Only* for SO_2 equivalents)

- Eutrophying Substances – expressed as mass of phosphate equivalents

Land Use Metric: All land which is consumed by paved areas, buildings, laydown area or under roof.

Decision Rules

1. **Denominator Choice:** Three measures of output were calculated: mass of product, sales revenue and "value-added." **Value-Added:** The market price of raw materials costs, utility costs and price of product per unit product was computed. Value-Added is US dollars; costs of capital and labor are not included. It serves as a proxy for the value that manufacturing operation adds to society.

2. **Material Metric:** Mass Intensity = Mass(Raw Material) - Mass(Product) - Mass(Co-products)/output

3. A complementary metric is needed for packaging.

4. **Energy Metric:** For energy consumed, all steam energy used is computed as if 1000 B.t.u./pound is expended, regardless of pressure.

5. **Water:** all water not available for beneficial use. This includes evaporation, direct consumption and deep well disposal. It is considered from an ecological standpoint and is not a chemical engineering water balance calculation, where water is counted both in and out, water in use and water discharged, except non-contact cooling water.

Product Example

Vinyl Chloride monomer provides an excellent example for the metrics with all three denominators. Calculation of the metrics was based on information obtained from the PEP Report data for producing vinyl chloride from ethylene, chorine and oxygen. Price information was obtained from the 1998 PEP Yearbook. The five basic metrics, along with complementary metrics for carbon dioxide equivalents (greenhouse gases) and eutrophication are shown in the table below.

Greenhouse gases result from three sources in this process: the burning of fuel oil for energy, the incineration of a waste stream, and the treatment of organic chemicals in the wastewater stream. All greenhouse gases are expressed as equivalents of carbon dioxide for calculation of the metric.

The eutrophication metric is included to take into account the eutrophication effect that pollutants in the wastewater stream could have on the receiving waters. Along with some toxic chemicals, the wastewater effluent from this process contains ammonium chloride as a result of the use of ammonia for neutralization. The estimated ammonium content of the wastewater effluent is converted to phosphate equivalents and included as the complementary metric for eutrophication.

Metrics for Vinyl Chloride

METRIC	**unit**	/lb	/$Rev	/$VA
Material	lb	0.20263	1.06647	10.73447
Energy	kbtu	4.21900	22.20526	223.50462
Water	gal	2.10183	11.06224	111.34580
Toxics	lb	0.00000	0.00002	0.00025
Pollutants	lb	0.00353	0.01859	0.18713
CO_2 Equiv.	lb	0.37146	1.95503	19.67816
Eutrophication	lb	0.00005	0.00026	.00265
Land	acre	2.44×10^{-7}	1.61×10^{-7}	

Table 1. Calculated Metrics for Vinyl Chloride

Examples of other compounds in the more than fifty products for which metrics have been calculated are:

- Acetic Acid
- Caprolactam
- Chlorine (two processes)
- Maleic Anhydride
- Naphtha
- Nylon 6
- PET Bottles and Resins
- Phosphoric Acid (two processes)
- Phthallic Anhydride
- Polyethylene
- Polyethylene Terephthalate
- Polypropylene
- Propylene
- Polystyrene
- Polyurethane
- Sulfuric Acid (two processes)

Three metrics have been calculated for land use: 1) land required to generate one dollar of annual sales, 2) full-time equivalent jobs generated per acre and pollutants emitted per acre. Over 12,000 cases were examined. Examples of the land use metric for job creation (calculated from the USDOE Industrial Assessment Center data-base) are shown below.

SIC Class	**Products**	**Jobs per Acre**
281	Industrial Inorganic Chem	8.7
286	Vinyl Chloride & Similar	17.0
3089	Plastic Parts	58.9
3354	Aluminum Extrusions	54.6
3398	Heat Treating	42.6
3498	Pipe, tubing	15.1
3519	Turbines	65.4
3524	Lawn Equipment	56.8

Table 2. Jobs per acre for Chemical Industry versus Various Others.

Total Benefit and Cost Assessment Methodology

However, the data set was populated with information primarily focused on direct and indirect costs. There is less information available for future costs such as fines and penalties and very little data or acceptable methodology for obtaining data on societal or external, intangible costs. The project sponsors identified a number of specific types of intangible costs that were of current interest to them, including: societal costs of high reported toxic emissions, use of injection well disposal for wastes, acidification of the environment, eutrophication of waterways, harmless odors and noise. They further identified a need for information on how societal costs vary by nation, by region and by culture. This study utilized two topics, eutrophication and harmless odors as topics to develop methodology, which could then be used for other intangible costs. That effort was successful (Ref. 14). Almost without fail, those costs eventually lead to internal costs for companies, which contribute to the odors or emit materials which cause or increase eutrophication. It is easier to obtain societal costs for eutrophication and harmless odors than it is to estimate the internal costs, which eventually accrue to a company. However, larger societal costs will lead to larger company costs and larger societal costs probably lead to faster internalization of costs.

At the same time, the investigators determined that using teams of faculty and students is a cost-effective way of developing methodology for obtaining intangible cost information, which is suitable for use with total cost assessment tools. Further benefits are obtained using this approach. Students are given real-world exposure to sustainable development; they are provided with the opportunity to work directly with industry personnel; they are exposed to a process for envisioning the future.

Integrating Metrics with Total Benefit and Cost Assessment

The cost of labor and associated benefits provided by employment is not included because the societal value received by the employees would negate the company cost. A range of societal costs of emitting greenhouse gases is included in the TCAce^{TM} Total Cost Assessment tool. For the calculation of cost of greenhouse gases from the vinyl chloride monomer plant, $13.00 (US) per ton was chosen for illustrative purposes. Some estimates are $86.00 (US) and higher.

Utilizing the Information in Urban Planning

It appears from the sample above and a broader spectrum examined that some manufacturing industries provide a higher combination of employment benefits and tax revenues than others, e.g., ink, rubber goods and plastic parts versus pipe & tubing.

Four years ago it was reported that calculated the value of all the goods and services that the planet provides. These so-called ecosystem services were found to be worth $US33-trillion. That was mind-boggling, considering the total Gross Domestic Product of the Earth was worth $18-trillion.

SALES	**FTE**	**AREA**	**PRODUCTS**	**ft2/$**	**Jobs/ft2**	**PROD'N**
12000000	50	68000	Bleach, Chlorine			12000
6000000	55	140000	Swim pool & hygiene			6000000
3500000	6	10000	liquid CO2, dry ice			70000
3500000	15	13400	Liquid CO2			60000
3800000	3	40000	Industrial gases			95762
16000000	31	27550	special metals/oxides			2400000
10000000	32	50000	Polymer Colorants			3360000
12000000	35	125937	Pigments			40000000
6000000	60	150000	Textile dyes			14000000
35000000	100	210000	Iron Oxide Pigments			38000000
33900000	185	360000	Textile finishing prods			29800000
65000000	138	552000	Hydrated SiO2			120000000
12000000	23	9375	Calcium Carbonate			600000
3000000	9	10000	Powdered Metals			50000
10000000	18	10000	Na, Mg, NH4 bisulfites			9000
22000000	28	16700	Liquid Na Cyanide			60000000
20000000	100	20000	Activated carbon			30000000
75000000	15	30000	Sodium Silicate			36500
13000000	50	40000	Bleach			3650000
120000000	224	50000	Cr-based chemicals			200000000
24000000	76	50740	Lithium Products			13000000
25000000	30	55000	Oilfield chemicals			1680
24122727	**58**	**92668**	**Metrics -- >**	**0.00384**	**0.00063**	**25506588**
Average	**Aver.**	**Average**		**sqft/$**	**Jobs/sqft**	**Average**

Table 3. A sample (SIC Class 281) of 143 sites within US Chemical Industry
Based upon earlier work (Ref. 11) and the Industrial Assessment Center Database, calculations can be made to represent the impact of locating an average chemical plant on a given piece of land.

Overall Chemical Industry Statistics

Total Emissions per dollar revenue	**0.0069 pounds**
Total Emissions per acre per year	**24,900 pounds**
Greenhouse Gas equivalents per dollar revenue	**2.52 lbs. CO_2**
Greenhouse Gas equivalents per acre per year	**4558 tons**
Revenue per acre per year (Inorganic)	**$3.6 M**
Revenue per acre (Organic)	**$6.2 M**
FTE jobs per acre (Inorganic)	**8.7**
FTE jobs per acre (Organic)	**17.0**

Table 4. Metrics for the US Chemical Industry
(based on data for 53 product/process combinations – Ref. 1,4)

Economic values for natural uses of land and relative cost for service delivery when land is developed for industrial and residential purposes are being reported now. Those numbers are being peer reviewed for comparison to industrial application (Ref. 12, 13).

Calculations for other industries are not complete as of this writing.

Summary of Findings

Consensus is building for a common set of simple, basic tools for decision making. This includes total cost assessment, metrics and a set of decision rules to simplify life cycle evaluations.

The five basic metrics were calculated for a fictitious proposed vinyl chloride monomer plant in an urban area (material intensity, energy intensity, water consumption, toxics dispersion and pollutant dispersion).

Using “value-added” as a denominator allows for easy integration of metrics along the supply chain. It also allows for relative comparison to societal costs.

Societal costs, when considered can substantially reduce the perceived value of increased industrial growth in an urban area.

The approach reported is a cost-effective means of gathering data of industrial performance metrics.

Conclusions

- A simple set of metrics can be used to make decisions regarding impacts of various types of businesses which might be located on specific pieces of land.

- Useful metrics can be computed from publicly available data such as the Industrial Assessment Center Database.

- There is a wide variation in number of jobs created, revenue generated, emissions and tax base for industries and simple calculations can represent those factors.

Future Work

Future work will focus on 1) refining the emissions choices and computing those values for the SIC Codes, 2) calculating service costs, and 3) estimating value-added by various business types.

References

1. Beloff, Beth and Earl Beaver, *"Sustainability Indicators and Metrics of Industrial Performance,"* SPE International Conference on Health, Safety, and the Environment in Oil and Gas Exploration and Production held in Stavanger, Norway, 26–28 June 2000.

2. Beaver, Earl *"Total Cost Assessment and LCA"* , **Environmental Progress**, Summer 2000 (Vol. 19, No.2).

3. "*An Introduction to Environmental Accounting as a Business Management Tool: Key Concepts and Terms*", USEPA 742-R-95-001, June 1995.

4. Schwarz, J., Beth Beloff and Earl Beaver**,** *"Use Sustainability Metrics to Guide Decision-Making,"* **Chemical Engineering Progress July 2002.**

5. Schwarz, J., Beth Beloff, Earl Beaver and Dicksen Tanzil, *"Practical Minimum Energy Requirements for Chemical Product Manufacturing,"* **Environmental Quality Management Journal**, **Winter 2001.**

6. *"Industrial Environmental Performance Metrics: Challenges and Opportunities,"* National Academy of Engineering, 1999. ISBN 0-309-06242-X.

7. *"Measuring Eco-Efficiency in Business: Feasibility of a Core Set of Indicators,"* National Roundtable on the Environment and the Economy, 1999, ISBN 1-895643-98-8.

8. Fava, James A., Steven B. Young and Agis Veroutis. *"Making Sustainability Accessible: Use of Sustainability Measures,"* by Strategic Environmental Management, 1999. ISSN 1097-1823/99.

9. Adler, Steven F. ed. *"Sustainability Metrics Interim Report #1"* Center for Waste Reduction Technologies, 1998.

10. Adler, Steven F. ed. *"Sustainability Metrics Interim Report #2"* Center for Waste Reduction Technologies, 1999.

11. Beaver, Earl R., "Site Issues in Locating New Plants in or Near Municipalities" **Conference Proceedings, Sustainable Engineering: Sustainability and Life Cycle, AIChE 2003.**

12. Haggerty, Mark, *"Economic Values of Wildlife and Open Space Amenities",* http://ndis.nrel.colostate.edu/ndis/economics.htm, 2002.

13. Mesterson-Gibbons, Michael and Eldridge S. Adams, *“The Economics of Animal Cooperation”,* **Science, Vol. 298,** 13 December 2002, pp. 2146-7.

14. Beloff, Beth R. and Earl R Beaver, *“Evaluation of Societal Costs: Odors and Eutrophication”,* BRIDGES to Sustainability (Houston), 2000.

15. R. Costanza et al., *"The Value of the World's Ecosystem Services and Natural Capital,"* **Nature Vol. 387 (1997);** Daily, Gretchen “Putting the Right Price on Nature” Broadcast August 9, 2001. http://www.stanford.edu/group/CCB/Staff/gretchen.htm#top

Acknowledgements

I gratefully acknowledge the assistance of James Eggebrecht of Texas A&M University and earlier contributions of Beth R. Beloff and Dicksen Tanzil of BRIDGES to Sustainability, and Kimberly Murphy (currently at Five Winds, International). I acknowledge the previous financial support of the United States Department of Energy Office of Industrial Technologies for the underlying work from two earlier projects and the support of Dow Chemical, Monsanto Company, Owens Corning and GlaxoSmithKline.

These projects would not have been possible without the earlier work by the teams of industrial participants in metrics efforts at the National Roundtable on the Environment and the Economy and those of the Center for Waste Reduction Technologies (Ref. 7, 9, 10).