



# General Motors

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## Metrics for Sustainable Manufacturing



### **LABORATORY FOR SUSTAINABLE BUSINESS**

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## Introduction

### Objectives

General Motors defined the project as a review of state-of-the art metrics used in green or sustainable manufacturing. Their request was for a survey of available literature, best practices by other manufacturing firms in automotive manufacturing as well as other industries, and metrics proposed or adopted on a regional basis. Following the survey of existing and proposed metrics, the MIT Sloan team was asked to determine the suitability of the metrics by comparing the effort and effectiveness of each, and suggesting the best of these to implement at GM's various manufacturing operations. The criterion given was to maximize the positive environmental impact relative to the other needs of a large public company.

### Company and Project Background

General Motors Corp. (NYSE: GM), one of the world's largest automakers, was founded in 1908, and today manufactures cars and trucks in 34 countries. With its global headquarters in Detroit, GM employs 234,500 people in every major region of the world, and sells and services vehicles in some 140 countries. In 2008, GM sold 8.35 million cars and trucks globally under various brands (see figure 1).<sup>1</sup>



Figure 1: GM Brands

The company currently has seven sub-groups working on metrics<sup>2</sup>:

1. GM's Global Environmental Metrics Team
2. GM's Global Environmental Issues Team

<sup>1</sup> General Motors. (2009, 5 13). *GM Website*. Retrieved 5 13, 2009, from GM Website: <http://www.gm.com/>

<sup>2</sup> GM CR Report, 2008

3. GM's Energy & Utility Services Group (EUSG)
4. GM Energy Cost Council
5. GM's Global Energy Team (GET)
6. The Energy and Environment Strategy Board (EESB)
7. The GM Worldwide Facilities Group

The goal of this specific project, sponsored by the company's R&D – Manufacturing Systems Research (MSR) Lab in Detroit, MI, was to determine which metrics for sustainable manufacturing should be recommended for later implementation by the Worldwide Facility Group of GM. The metrics are to be focused on manufacturing and operations, the areas where this group is active.

The drivers for sustainability metrics include:

1. Pending regulation in the areas of energy consumption and environment impact (*i.e.* CO<sub>2</sub> cap-and-trade): general world-wide acceptance of climate change and pending environmental regulation and pending standards may impact manufacturing. Europe and Japan have moved aggressively in areas such as emission, waste, and environmental regulations, often in directions different from North America.
2. Energy security: a large operation such as an automobile plant requires some security against extreme energy price fluctuations, which can severely impact margins and render capital planning extremely difficult.
3. Change in public awareness and branding: perceived sustainability of a brand's operations is becoming more and more relevant in purchasing decisions. Changing customer preferences and increased sensitivity to sustainability-related issues.
4. Improved manufacturing methods and technology maturation: improved process efficiencies that have a positive environmental impact are possible now due to technological advancement and lower costs.

A multinational corporation cannot ignore large differences such as those found in sustainability-related normative in the different business environments it operates in.

Energy efficiency, renewable energy sources, reductions of energy and water consumption are of special interest, and the company has set a company-wide target of an 8% reduction in greenhouse gas emissions by 2020 that would return it to 2005 levels.<sup>3</sup>

In 2008, GM approved three sustainability metrics: an energy use index, a water index, and a carbon index to calculate the company's performance and targets.

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<sup>3</sup> General Motors. (2009, 5 13). *GM Website*. Retrieved 5 13, 2009, from GM Website: <http://www.gm.com/>

## Approach to Analysis

The team identified companies and government entities to target for sustainability benchmarking (see figure 2)



Figure 2: List of Benchmarked Firms and Government Agencies

In addition to the firms chosen to benchmark against, the team also used the following resources to gain further insight when thinking about this problem:

- 1) MIT Engineering Faculty
- 2) Course 15.992 Staff
- 3) Class Discussions
- 4) Industry Contacts
- 5) Literature Review

## Sustainable Manufacturing Metrics

Although our focus has been on sustainable metrics for manufacturing, the systemic considerations that follow are general in nature and can be applied to all metrics within a firm.

To be effective, metrics have to, as a guideline, satisfy the following criteria or characteristics<sup>4</sup>:

- Address the needs of all stakeholders (community, government, and business)
- Facilitate innovation and growth; continuous improvement must be the cornerstone
- Harmonize local, state, national, and international levels of business units and operations
- Be fully compatible with existing business systems (add value)
- Measure the right things – what is measured is what gets managed

<sup>4</sup> Eaton, R. J. (2009, 5 1). *Getting the Most out of Environmental Metrics*. Retrieved 5 1, 2009, from NAE: <http://www.nae.edu/nae/bridgecom.nsf/weblinks/NAEW-4NHM88>

A process to build systemic (companywide), as well as local (i.e. manufacturing) set of meaningful sustainability metrics is proposed as follows:

1. Create a list of “reference metrics” for each level, by examining what peer organizations are tracking and listing (at high level). Deduce what must be measurable in order to quote any of these metrics (which experience shows tend to be somewhat aggregated);
2. Consider additional metrics stakeholders are likely to care about and inquire *with* them;
3. Provide proposed metrics for each level; this could be a good time to get a small number of committed individuals from each level in question with effective intra-company network standing to participate in the debate. They can become very effective ambassadors for the program at a later implementation stage. Involving employees (who are often a part of surrounding communities as well) also reinforces point two above by listening to a part of the stakeholders;
4. Examine all the proposed metrics and come up with a list that at least evaluates all major aspects of sustainability;
5. Cross-check the edited list for completeness and coherence; determine which metrics personnel within each level can alter;
6. Work out the detail of what must be measured and how in order to be able to have consistent, meaningful numbers on each metric; ensure comparability across sites and, possibly, to industry standard measurements;
7. Devise ways to normalize the measured quantities, so as to have indexes independent of actual production numbers. This ensures that large fluctuations in production do not substantially alter year-by-year results, helping in benchmarking toward goals;
8. Set achievable but high-bar goals, along each metric, ensuring a milestone path to achieve them. These can be different for specific locations based on the realities on the ground, but must average out to the corporate goals;
9. Enable employees at all levels, especially on the ground, by educating them about sustainability and how they can improve not just the firm’s sustainability metrics, but by doing so they improve efficiency;

Given the above, the team developed a few additional criteria and observations it would like to propose as being potentially useful in building a GM-wide systematic approach to sustainability:

1. Metrics at different levels should be:
  - a. Consistent with the level of abstraction from operational detail relative to the particular level of the firm;

- b. Coherent at the different company levels, so as to push the entire company toward common objectives;
  - c. Interconnected, so as to check each other out and encourage companywide adoption;
2. Systematic measurement should monitor progress and quantify improvement, savings, efficiency gains, etc.
3. Measurement should be complemented by regular and irregular audit, by internal and third party independent auditors
4. Metrics and goals should be set following accepted third party or industry-wide practices, to allow meaningful benchmarking and gain credibility
5. Cross-flow of information is fundamental to spread the progress across the company's operations, across geographies, divisions and sub-divisions, subsidiaries, groups, etc.
6. Independent certification and auditing would give the entire process added credibility to the outside (customers, community, shareholders)

## Regional Standards

We identified a list of existing regionally or internationally accepted manufacturing standards, as shown in Table 1. GM can use regional standards to develop a strategy in which regions target pilot programs within their operations, given that the compliance mandate already exists in some areas. Given the global reach of GM, it may be most sensible to implement international (i.e. ISO) standards everywhere for all fields they cover. This would provide standardization across the company.

## Industrial Standards

The standards listed in Table 1 are widely recognized by industry and customers alike and certified by third-parties. Although some of the standards differ by region, there are international standards. None of these encompass every aspect of sustainable manufacturing (*i.e. one regulates electronic waste, another building codes, etc.*) however. To be sustainable in all aspects of a complex manufacturing, a company like GM must select *several* norms covering different aspects of its operations. A global company should use international norms and standardize practices across regions. Basing GM's metrics on these metrics avoids reinventing and ensures widespread acceptance.

**Table 1. International and regional standards affecting sustainability<sup>5</sup>**

Standard	Year	Region	Application
BS 8900	2006	British	managing sustainable development
ELV	2000	Europe	automotive vehicles
Energy Star	1992	USA	products, buildings
EPA's AP-42	1995	USA	emissions factors for stationary sources
IEEE 1680	2006	USA	personal computer products
IMDS	2000	International	automotive industry material data system
IPC 1752	2007	USA	materials declaration in products
ISO 14000 series	1992	International	processes
ISO 19011	2002	International	environmental management systems
JIG-101	2005	International	materials declaration in products
LEED	1998	USA	buildings, homes
NSF-140	2007	USA	carpet industry
REACH	2006	Europe	products with hazardous materials
RoHS	2003	Europe	new electrical and electronic equipments
WEEE	2002	Europe	all waste electrical and electronic equip.

**Table 2: International and regional standards affecting sustainability<sup>6</sup>**

Category	Description	Similar Indicators or Examples
Individual indicators	Measure single aspects individually	Core set of indicators Minimum set of indicators
Key performance indicators (KPIs)	A limited number of indicators for measuring key aspects that are defined according to organizational goals	

<sup>5</sup> The National Institute of Standards and Technology (NIST). (n.d.). Retrieved May 14, 2009, from [www.nist.gov](http://www.nist.gov)

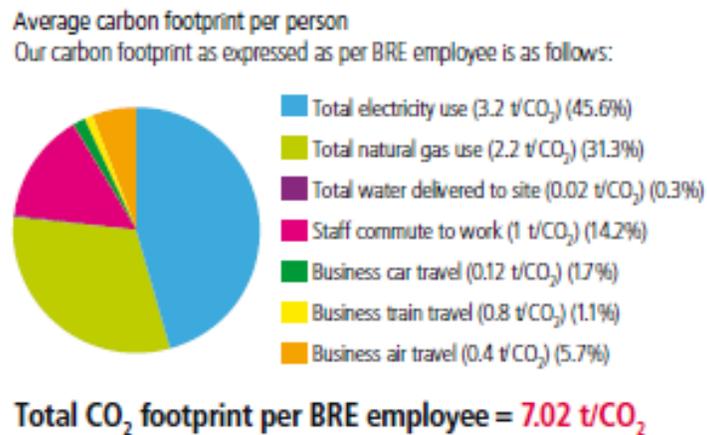
<sup>6</sup> Ibid

Composite indices	Synthesis of groups of individual indicators that is expressed by only a few indices	
Material flow analysis (MFA)	A quantitative measure of the flows of materials and energy through a production process	Material balance Input-output analysis Material flow accounting Exergy; MIPS
Environmental accounting	Calculate environmental-related costs and benefits in a similar way to financial accounting system	Environmental management accounting Cost-benefit analysis Material flow cost accounting
Eco-efficiency indicators	Ratio of environmental impacts to economic value created	Factor
Lifecycle assessment (LCA) indicators	Measure environmental impacts from all stages of production and consumption of a product/service	Ecological footprint Carbon footprint
Sustainability reporting indicators	A range of indicators for corporate non-financial performance to stakeholders	GRI Guidelines Carbon Disclosure Project
Socially responsible investment (SRI) indices	Indices set and used by the financial community to benchmark corporate sustainability performance	Dow Jones Sustainability Indexes FTSE4Good

## Metrics by Scope

Some organizations have decided to organize their sustainability efforts by business units, or to expand it beyond one specific group function. An example implemented by BRE is shown in Figure 3.

Figure 3: Example of Sustainability Reporting: BRE-Breakdown per Employee<sup>7</sup>



<sup>7</sup> BRE. *Sustainability Report 2006/2007*. BRE:  
[http://www.bre.co.uk/filelibrary/corporate/BRE/KN2960\\_Sustainability\\_Report\\_080807.pdf](http://www.bre.co.uk/filelibrary/corporate/BRE/KN2960_Sustainability_Report_080807.pdf).

## Determining the Suitability of Metrics

We determined that the best criteria for choosing which metrics to implement depend on identifying the specific “hotspots”<sup>8</sup> for a company and industry. These are the process stages that have the highest environmental and social impacts. We also determined that the effort required to implement the metrics depended on the existence of at least one of the following:

- Reason for the assessment
- Scope of the tool
- Resources for the assessment
- Time frame
- Data availability<sup>9</sup>

## Effort Required and Effectiveness of Metrics

The effort to accurately collect data and the effectiveness of measuring that data are important considerations when choosing and prioritizing sustainable manufacturing metrics. For example, if expensive new sensors are required to measure trace amounts of a fairly benign chemical by-product that is already estimated to be well within compliance, the installation of the sensors should receive low priority. It is important to objectively weigh these considerations, however, and not use them as an excuse for re-prioritizing projects that may not be popular or have positive results.

## Comparisons

Comparison of analyzed companies shows that the best metrics have to be clearly measurable, goals objectively expressed quantitatively and on a time scale, and status clearly communicated. Examples can be seen in Table 3.

**Table 3. Sample Metrics from Several Auto Manufacturers**

COMPANY	METRIC	GOAL	STATUS
TOYOTA	Manufacturing (energy)	Reduce energy usage of manufacturing / facilities / operations in North America to 6.3 MMBTU/vehicle produced	Ongoing
	Manufacturing (water)	Reduce water usage to 0.98 kgal / vehicle	Achieved
	Manufacturing (air quality)	Reduce body painting VOC's to a corporate average of 14 g/m <sup>2</sup>	Achieved
BMW	Manufacturing (Logistics)	Increase (keep) high percentage (>55%) of shipments of new vehicles from plants using low-emissions transportation (i.e. rail)	2007
	Manufacturing (logistics & environment)	Switch to vehicle distribution without surface protection. By start of 2008, 95% of Group's vehicles shipped without extra surface protection	2008

<sup>8</sup> Unger, N., Schneider, F. and Salhofer, S. (2008)

<sup>9</sup> Ibid.

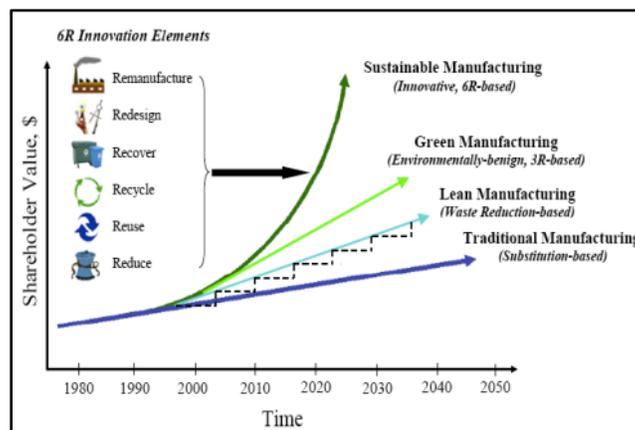
A comparative analysis of the companies was performed, resulting in several strong general conclusions:

1. German and Japanese companies have the longest traditions in the sustainability arena
2. Sustainability has translated into an ingredient of competitive advantage in the marketplace and, in the long run, improved the efficiency of companies that integrate its criteria into their operation
3. Companies that have most success at sustainability are those that adopted a comprehensive, systemic approach to it. This includes all operations of the firm, at all locations, from product design to manufacturing operations, to the way offices and plants are built and operated. In order to achieve this, all successful players have implemented a combination of technological measures and employee awareness, training, and action

## Background

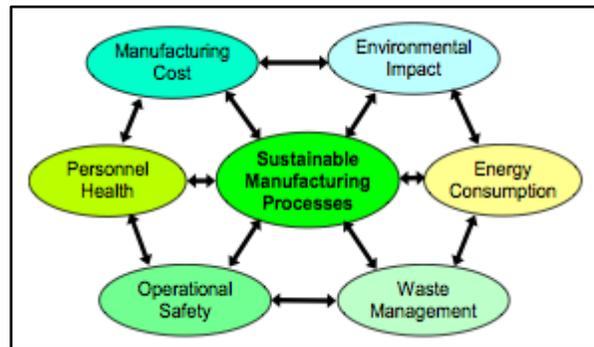
To determine which metrics should be included in a sustainable manufacturing strategy, a literature review was performed. As shown in Figure 4, manufacturing that is performed in a sustainable manner, using the “6R Innovation Elements” has the potential to yield much higher shareholder value than both traditional and lean manufacturing. The next question the team researched was “what defines sustainable manufacturing?” It was immediately obvious from reviewed research that for a company to achieve truly sustainable manufacturing practices, it had to take a holistic approach. The six categories listed in Figure 5 are recognized as important components of sustainable manufacturing. The following sections of the paper will go into each of the six metric categories and provide suggestions on what new metrics GM should consider tracking in their manufacturing processes.

Figure 4: Theoretical Effect of Sustainable Manufacturing on Shareholder Value<sup>10</sup>



<sup>10</sup> Jawahir, I. S. (2007). Sustainable Manufacturing Processes: New Challenges for Developing Predictive Models and Optimization Techniques. *First International Conference on Sustainable Manufacturing* (pp. 1-19). Montreal: Aerospace Manufacturing Technology Centre.

Figure 5: Six Metric Categories Resulting in Sustainable Manufacturing<sup>11</sup>



## Recommendations

### Environmental Impact

Environmental impact metrics can be broken down into two levels. The first level addresses pollutants released directly by GM operations and the second level measures the effects of these pollutants on the local environment. It is important for GM to not only know what it is releasing into the environment but also how its operations affect existing local air and water quality. Suggested goals are based on cutting-edge industry standards and measurements should be normalized to prevent artificial success caused by decreased production.

### Suggested Metrics

- Continue to measure the amount of volatile organic compounds (VOCs) emitted (kg/vehicle)
- Continue testing the level of contaminants in wastewater, such as Biological Oxygen Demand (BOD5), Chemical Oxygen Demand (COD), pH, oil and grease, and heavy metals
- Expand upon five-year target of an 8% reduction in CO<sub>2</sub> emissions from 2005-2010 by increasing the company's goal for 2010-2015 to achieve an additional 20% reduction
- Normalize all greenhouse gas emissions (GHGs) to lbs/vehicle
- Calculate carbon footprint of common business practices (such as travel) and aim for a 20% reduction by 2015
- Measure all employees using public transit/walking/biking
- Measure of pollutant levels in local air and downwind areas
- Gauge the concentration of contaminants in local and downstream surface and ground waters
- Monitor local ground and surface water levels
- Calculate the volume of water used by source with a goal of 100% water re-use at all facilities

<sup>11</sup> Ibid.

- Determine the emissions from vehicles manufactured

## Energy Consumption

Recently, energy consumption and generation has been getting much attention around the world. GM has demonstrated that it is a leader in many aspects of energy generation at its manufacturing facilities. However, there is always room for improvement, and the team determined that the following metrics should be adopted and tracked at GM facilities.

### Suggested Metrics

- Percentage of energy generated from renewable sources at each facility
- Rate of internal recycling/energy recapture
- Amount of energy generated from recapture and reuse
- Dollars saved in energy efficiency investment
- Degree of perfection for each unit produced (ratio of energy that actually went into production of final product to the amount of energy actually used).
- Total energy used annually per unit produced

### Employee Involvement

In order to identify the most energy-intensive processes and devise ways, workarounds, alternatives to improve efficiency, worker engagement is required. The team studied Raytheon, who has recently implemented a program to increase their worker involvement. Highlights of their program are as follows<sup>12</sup>:

- Launched an Energy Citizen campaign to engage employees in energy conservation; qualified almost 12,000 employees in the first quarter of 2009. This is 16.6% of Raytheon's total 72,000 employees
- Further engaged employees through Energy Awareness Month and Earth Day awareness events
- Increased the Energy Champion network to more than 2,000 employees. This is 2.8% of Raytheon's employees.
- Applied Six Sigma focus to energy challenges through the Enterprise Energy Team

We believe that GM could benefit from a similar program.

### Personal Health

Maintenance of a healthy workforce is another key necessity for a sustainable company. While many industrialized countries have strict regulations that protect workers and ensure compliance, companies must also develop their own goals and values in this area. This is particularly important for companies with operations and/or suppliers in developing countries where government regulation may not be as stringent or enforceable.

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<sup>12</sup> Raytheon. (2009, 5 13). *Raytheon Sustainability*. Retrieved 5 14, 2009, from Raytheon: <http://www.raytheon.com/responsibility/stewardship/sustainability/energy/index.html>

## Metrics to Adopt From Others

### *Timberland's Human Rights Code of Conduct*<sup>13</sup>

Timberland has adopted a Code of Conduct that is provided to all factories they have contracts with, translated into the local language. The Code of Conduct includes the right to un-announced visits to verify that the following guidelines are being followed:

- Voluntary Employment
- Freedom of Association
- Fair and equal treatment for workers: environment free of corporal punishment and discrimination based on social origin, social status, heritage, disability, age, marital status, genetic features, sexual orientation, race, color, gender, religious preference, political opinion and nationality
- Child labor prohibitions for individuals younger than 16 years old
- Compensation for regular work hours at a minimum to meet governing standards
- Working Hours not exceeding 48 hours per six day period
- Health and Safety workplace safety based on recognized standards of the ILO and national laws, employee training on safe workplace practices

Other Timberland best practices include quarterly tracking the Lost Work Days due to Injury and Illness rate (LWDII), and a full time Environmental Health and Safety (EHS) specialist. Other Personnel Health initiatives include literacy and General Education Diploma (GED) classes, employee hours served in community engagement, and charitable donations<sup>14</sup>.

HARBEC Plastics<sup>15</sup> measures air safety, and holds regular safety training sessions and employs a safety committee to minimize any work related injuries. They have a party to celebrate every time that they reach 180 days with no loss time due to work related injuries.

## Suggested Metrics

- Employee blood lead levels ( $\mu\text{g}/100\text{ mL}$ )
- Participation in health education and wellness programs, health certification-related courses completed, and monthly on-site fitness equipment use
- Percentage of employees trained in sustainability initiatives (the number trained/the number to be trained)
- Number of employee days away due to injury per shift and per manager
- Number of employee days away due to exposure to toxins
- Ratio of safety gear and safety showers to employees
- Ratio of sick days to work days per facility
- Number of safety measures adopted, safety/fail-safe equipment installations and improvements per year and ROI per improvement

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<sup>13</sup> See Timberland's website, [http://www.timberland.com/corp/english\\_feb02.pdf](http://www.timberland.com/corp/english_feb02.pdf)

<sup>14</sup> See Timberland's Facility Report, [http://www.timberland.com/include/COR34119-DR\\_Mini\\_fff.pdf](http://www.timberland.com/include/COR34119-DR_Mini_fff.pdf)

<sup>15</sup> HARBEC Plastics, <http://www.harbec.com/index.html>

- Health index of onsite food (cafeteria)
- Number of paid days off per facility
- Percentage of employees commuting, participating in subsidized public transportation, or car-pooling to work per facility
- Number of peer nominations for health and safety improvements per month
- Number of complaints from public or employees (#/year)

## Occupational Safety

Just like personal health, occupational safety requires close attention to ensure the quality of a workforce.

### Metrics to Adopt from Others

Many metrics around occupational safety are required to be measured and reported by government agencies, such as OSHA. These include those that GM is already measuring and reporting on their public website:

- Recordable injury rate
- Lost workday case rate

Looking at the OSHA 2007 report, GM has lower rates than the industry average of 6.9 recordable injuries and 1.4 days away cases in their sector of manufacturing transportation equipment.<sup>16</sup> Figure 6 shows the current rate and the impressive trend to reducing injury rate year after year.

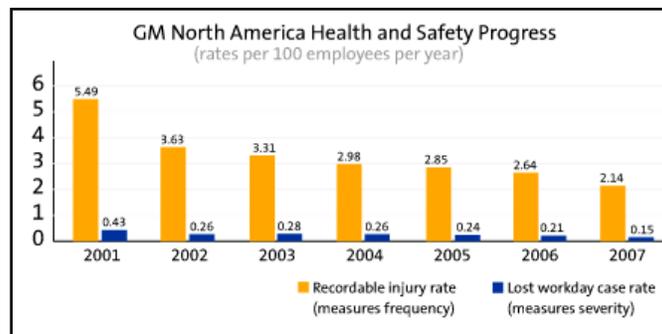


Figure 6: Recordable Injury Rate and Lost Workday Case Rate – GM North American Facilities (2001-2007)<sup>17</sup>

Some other metrics GM might want to consider reporting are:

- Injury rate based on injury type, such as puncture, laceration, or strain
- “safety champion” program
  - 1-3 employees identified in each of the natural work groups

<sup>16</sup> (United States Department of Labor, 2008)

<sup>17</sup> Motors, G. (2009, 5 13). *GM Website*. Retrieved 5 13, 2009, from GM Website: <http://www.gm.com/>

- Potential benefits:
  - Empower the employees with the knowledge to make safer choices for themselves and coach their peers to do the same.
  - Revitalization of employee suggestions for improvement and for one month or one week a month, the focus could be on safety improvements.

### **Suggested Metrics**

In addition to the metrics previously mentioned, another metrics to consider is the number of times the line stops for a safety concern. There are numerous reasons the line might be stopped by an employee, however tracking how many times it stops for a safety concern or more immediate accident prevention. This metric would give some visibility to how many “near misses” are occurring which is a much more difficult metric to mention.

### **Waste Management**

This category accounts for the recycling and the disposal of all types of manufacturing wastes, during and after the manufacturing process is complete.<sup>18</sup>

#### **Suggested Metrics**

- Introduce company-wide waste management system, separating and recycling so as to achieve zero waste in all plants and offices; extend to dealerships to provide coherent company image.
- Reuse all production wastewater through filtering. Saves water and reduces chemical compounds (waste) discharged.
- Spread dry or near-dry machining to all processes where feasible to reduce waste generated by machining fluids and metal scrap.
- Reduce compensated waste (nonhazardous waste plus what company pays to be recycled) to 30 kg/vehicle.
- Reduce waste by avoiding it. Rethink and redesign processes to reduce waste.
- Reuse organic and other suitable waste by generating landfill gas.
- Actively encourage suppliers to put in place active waste management, exploiting if necessary synergies of scale with GM.
- Engage specialists inside the plants to systematically explore ways to reduce waste by optimizing and rethinking manufacturing processes, analyzing sources of waste, and exploring alternative ways of doing things.
- Find applications for waste or byproducts, suitability to sell them into scrap markets.

### **Manufacturing Costs**

Reduced manufacturing costs can be provided by optimal use of machines and tooling including jigs and fixtures.<sup>19</sup> Additionally, measurements of key resources and consumables are required to track efficiency and meet goals.

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<sup>18</sup> Jawahir, I. S. (2007).

## Suggested Metrics

- Monitor machine power consumption and optimize machine usage patterns; define metrics to describe and drive machine power usage relative to parts production;
- Track amount of scrap metal machined away by design, driving engineers to optimize design and fabrication processes;
- Track consumption of compressed air, operating fluids (actuator oils, etc.), identifying and repairing leaks
- Reuse or recycle parts packaging; track reduction
- Reduce or eliminate protective coatings for transport (wax, etc); track reduction
- Collect and recycle process material (i.e. sandblasting, cooling fluids, etc.); track reuse

## Summary and Conclusion

The team proceeded in thinking how the recommended metrics could be implemented in an organization as large as GM, with the knowledge that companies that have most success at sustainability are those that adopted a comprehensive, systemic approach to it.

First, an example of GM's organizational structure was developed, as shown in Figure 7. Clearly, different types of sustainability-related decisions and mandates are most appropriate for each of the levels indicated on the left hand side. For example, while a plant might decide to increase the amount of purchased energy that is from renewable sources in its vicinity, clearly the decision of large capital outlays to build an efficient co-generation power station or a large solar panel or wind installation is a corporate decision. Besides ensuring that among all branches and regions of GM are measuring the same thing and striving towards the same goal, it is also important to make those goals aggressive and widely communicated. Again, without engaging the workforce at all levels, this effort will not endure and runs the risk of becoming the "newest program" and not something the company is committed to at the core of its business.

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<sup>19</sup> Ibid.

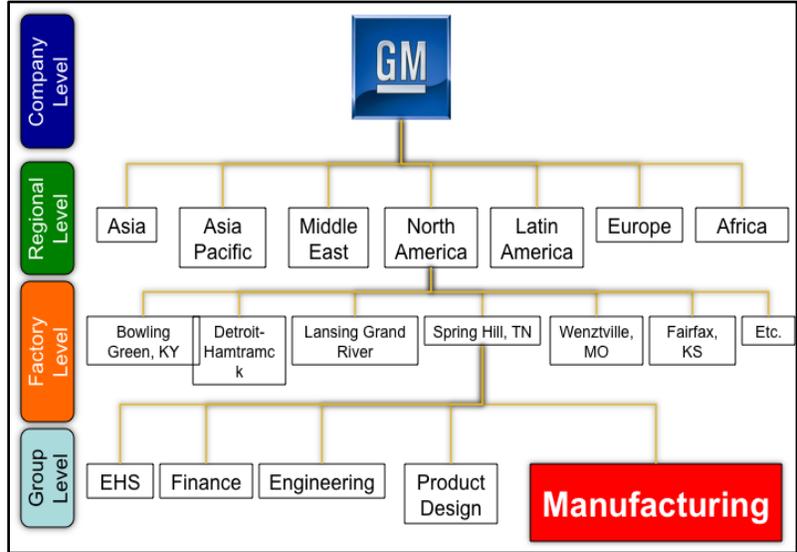


Figure 7: Example of GM's Organizational Structure

The focus of this project was the development of metrics to ensure sustainable manufacturing. As such, the team used the analysis performed to determine which metrics should be used by GM, and built the image shown in Figure 8.



Figure 8: Proposed metrics for each major category in sustainable manufacturing

Finally, the team brainstormed the following list of recommendations for GM as they go forward with choosing and implementing the metrics:

1. *Choose a minimum number of relevant standards to cover every aspect of car production activity.* We have provided an extensive list of potential metrics to use; however, too many metrics can dilute the value of the important metrics, and decrease the broad understanding of the strategy amount the workforce.
2. *Educate the workforce to the chosen standards, and establish active implementation groups.* A realistic goal is for every UAW partner to be able to describe which metrics are tracked, and why the metric is tracked both in manufacturing and by the GM Corporate Office.
3. *Systematic measurement to monitor progress and quantify improvement.* By monitoring progress, a continuous improvement mentality for sustainability can be established throughout the manufacturing organization.
4. *Complement measurement by regular and short-notice internal and external audit.* To both build credibility and encourage UAW participation and education, audits should be performed.
5. *Set metrics and goals following accepted third party or industry-wide practices.* One of the biggest challenges for metric tracking is the setting of goals in both the short and long term. The team reviewed recommended metrics that are tracked by many of GM's competitors to establish any specific goals that were mentioned in this paper. Additional research should be performed by GM, and the use of third party non-governmental organizations (NGOs) could be consulted to determine the exact goal for each metric.

*Spread progress across the company's operations, across geographies, divisions and sub-divisions, subsidiaries, groups, etc.* By disseminating information on goals, progress, and best practices to multiple manufacturing facilities, GM can ensure that they become a best in class manufacturing in term of sustainability.

## References

BRE. *Sustainability Report 2006/2007*. BRE:

[http://www.bre.co.uk/filelibrary/corporate/BRE/KN2960\\_Sustainability\\_Report\\_080807.pdf](http://www.bre.co.uk/filelibrary/corporate/BRE/KN2960_Sustainability_Report_080807.pdf)

Eaton, R. J. (2009, 5 1). *Getting the Most out of Environmental Metrics*. Retrieved 5 1, 2009, from NAE: <http://www.nae.edu/nae/bridgecom.nsf/weblinks/NAEW-4NHM88>

General Motors. (March 10, 2009). *Corporate Responsibility Report*. Detroit, MI: GM Communications.

General Motors. (April 20, 2009). *General Motors Redefining Environmental Sustainability of its Plants*. Detroit, MI: GM Communicatioins.

General Motors. (2009, 5 13). *GM Website*. Retrieved 5 13, 2009, from GM Website: <http://www.gm.com/>

Jawahir, I. S. (2007). Sustainable Manufacturing Processes: New Challenges for Developing Predictive Models and Optimization Techniques. *First International Conference on Sustainable Manufacturing* (pp. 1-19). Montreal: Aerospace Manufacturing Technology Centre.

Raytheon. (2009, 5 13). *Raytheon Sustainability*. Retrieved 5 14, 2009, from Raytheon: <http://www.raytheon.com/responsibility/stewardship/sustainability/energy/index.html>

The National Institute of Standards and Technology (NIST). (n.d.). Retrieved May 14, 2009, from [www.nist.gov](http://www.nist.gov)