A Zero Waste Management Strategy to Reduce the Cost of Alternative Energy

Gary G. Bergmiller, PhD
Zero Waste Operations Research and Consulting
Boulder, CO 80503
and
Paul R. McCright, PhD
University of South Florida, and
Zero Waste Operations Research and Consulting
Albuquerque, NM 87112

***Abstract*-The single greatest barrier to switching to alternative energy is justifying the cost of the technology (solar, wind, etc). With payback periods generally over ten years, switching takes a personal commitment to this technology few can afford to make. Alternatively, if the cost to produce and install this technology was driven down, this technology would be more affordable and thus more prevalent. As production levels increase, the economies of scale will drive cost down further.**

We have developed a model for integrating Lean and Green Production Systems into a single sustainable cost reduction system we call "Zero Waste Operations" (ZWO). Introduction of ZWO by organizations producing alternative energy technologies can drastically help the supply side of the alternative energy industry through multiple sustainable cost savings opportunities. For example, Toyota made a serious commitment to Lean production years ago. This made them very successful, profitable, and led to their commitment to the environment with hybrid vehicles.

Lower costs bring the potential for exponentially increasing usage of these products, reducing non-renewable energy sources and their nasty greenhouse gas emissions. Applying ZWO, alternative energy technology manufacturers can dramatically improve their companies' sustainability while contributing immensely to the sustainability of the Earth.

INTRODUCTION

The alternative energy industry is at the cusp of its development [1]. With the world-wide economic collapse of 2008-2009, governments are attempting to stimulate their national economies with massive government spending projects [2-4]. In the U.S., the Obama Administration's stimulus package contains significant monies designated for research and development in alternative energy programs [5]. Generally, this stimulus money is meant to be spent very soon and is also meant to boost this particular industry as a way of building America's future as an energy-independent state with minimal production of greenhouse gasses.

There are several hurdles that must be overcome for the alternative energy industry to become dominant in the U.S. The primary greenhouse gas generators in the U.S. are the electric generation industry and the transportation industry. America's move to become energy sustainable rests largely on the country's success at fundamentally changing these two industries.

Historically, over 70% of U.S. electric generation has relied on fossil fuels as the fundamental energy source [6]. Of course, the infrastructure in place to obtain the raw fuel sources, produce, and distribute this electricity represents enormous investment by utilities and government over many decades. Much of this installed infrastructure will have to be abandoned, removed, and remediated when taken out of service. And the electric generating capacity removed will have to be replaced with investments in new alternative energy sources such as hydroelectric, solar, wind, or geothermal power facilities. Obviously, this involves a huge commitment of funds over a very long period of time.

The automobile industry has been notoriously slow in developing and marketing high-mileage vehicles and American geo-social development has long been based on the assumption that Americans can move about with cheap auto transportation. Thus, mass transit systems are not available to a large percentage of the U.S. population and urban sprawl renders existing systems less attractive and less efficient than corresponding systems in many other countries. Pressure is now growing on the U.S. automotive industry to develop higher-mileage fleets and to bring to the market alternative-fuel trucks and automobiles [7]. These developments are also supported by the Obama Administration's stimulus package.

Companies producing the technology and products required for the shift to an alternative energy future face a number of significant challenges. Development of more effective and efficient technologies requires great investment in research and development efforts and time for these efforts to result in usable products. Without more efficient products, the costs of alternative energies will remain high relative to the costs of traditional, high-polluting, existing technologies.

Alternative energy technology producers must improve the cost-benefit ratio of their products. Research may result in improved efficiencies of photovoltaic solar panels that reduce the KWH costs of electricity produced on solar systems. Research may result in improved battery storage systems that help bring down the cost of electric cars. Research may lead to breakthroughs in hydrogen fuel

production that can lead to reasonably priced fuel cell cars. These and other research-based improvements will contribute greatly to the long-term economic and environmental sustainability of the U.S.

A different approach to improving the cost-benefit ratio of alternative energy technology and products involves the application of mundane industrial engineering techniques to removing waste from the systems used to make the wide-range of products needed by the collection of manufacturers working in the alternative energy industry. Over the past two decades, programs designed to reduce the costs of manufacturing have been implemented by many world-class manufacturers, including Toyota, Boeing, and Bausch and Lomb, to name but a few. Collectively, these programs are called Lean Production Systems and are intended to remove wasted materials and labor from the production system and, thereby, foster reduced total cost of production.

Other companies have focused efforts on reducing the negative impacts of their operations on the environment. These companies are implementing what has been called Green Operations Systems in order to reduce or eliminate the wastes produced by their operations [8].

The time is right for all makers of alternative energy technology to adopt Lean Production Systems as they work to reduce the cost of their products and build the demand for these products. These companies should also apply the principles of Green Operations Systems to reduce their own negative environmental impacts. Fortunately, these programs are highly synergistic and are most effective when applied together [9]. Nothing less than company survival and long-term sustainability of the U.S. economy rests on these efforts.

LEAN PRODUCTION SYSTEMS

An extensive review of the literature [10] shows that the most advanced model of Lean systems exists in the Shingo Prize model [11]. The Shingo Prize for Excellence in Manufacturing is named for Japanese industrial engineer Shigeo Shingo, who distinguished himself as one of the world's leading experts in improving manufacturing processes. The Shingo Prize, established in 1988, promotes awareness of Lean manufacturing concepts and recognizes companies in the United States, Canada, and Mexico that achieve world-class manufacturing status [12].

The Shingo Prize recognizes organizations that use world-class manufacturing strategies and practices to achieve world-class results. Criteria used by the Prize Committee evaluators are based on leadership, organizational culture, empowerment, manufacturing strategies, system integration, quality, cost, delivery, and customer satisfaction. Applicants with high scores on these criteria receive a site visit from a team of five or more expert examiners. All applicants who receive a site visit will be publicly recognized as Finalists. Recipients of the annual Shingo prize itself are selected from this prestigious group [11, 12].

An Advanced Lean System Model, shown in Figure 1, distills the essence of the leading theories [13 - 16] into one coherent model. Under each category are the many best practices we associate with Lean. For example, under 'operations' are the physical process tools (5S, kanban, TPM, 6-sigma tools, etc) people often perceive as the entire Lean system. This model addresses every aspect of the Lean system within all company functions and including suppliers and customers. So complete is the model that it has been chosen as the basis for knowledge for the first national Lean certification program developed jointly by the three leading Lean organizations (Shingo, SME, and AME) [12].

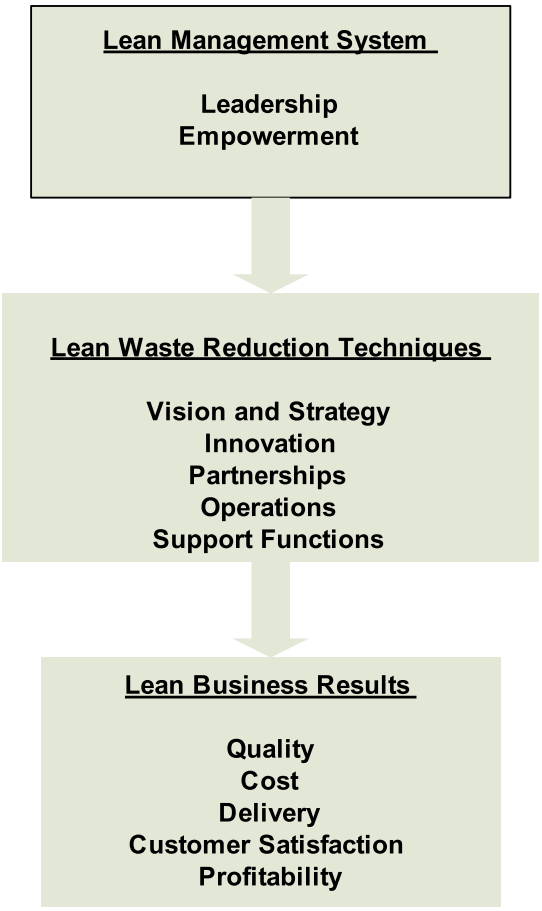

FIGURE 1: ADVANCED LEAN SYSTEM MODEL

This model of an Advanced Lean System shows that the company's management system must provide leadership in terms of setting goals and objectives and communicating them to employees, suppliers, and customers while also empowering its workforce to take actions as required to eliminate waste from the production system. Generic Lean Waste Reduction Techniques (LWRT) are:

- establishing vision of system wastes and developing strategies for eliminating them,
- implementing product and process innovation,
- forming effective partnerships with suppliers and customers,
- enhancing operations through changing equipment, materials, processes, or techniques, and
- streamlining of support functions such as warehousing, purchasing, or accounting.

Business results that can be expected from effective Lean Programs include improved quality, reduced costs, faster delivery, increased customer satisfaction, and higher profitability. These results can be measured to provide "before and after" data and serve as financial justification for the program.

An earlier study [10] showed that Lean Management System strength correlates to use of Lean Waste Reducing Techniques (LWRT) which also correlates to strength of Lean Results. This strong confirmation of the Advanced Lean System Model illustrates how complete and robust this model is as opposed to the naive view that the only thing you need are the "operations" tools for Lean. In summary, without a strong Management System companies cannot sustain the LWRTs and, therefore, will not have sustainable results.

Green Operations Systems

Several researchers [8, 17 – 21] have proposed models for Green operations systems. All of these models consider support from company management, identification and reduction of environmental wastes, and the business results that can be expected from effective Green systems.

A study conducted by Melnyk, Stoufe and Calantone [20] explored the effect Environmental Management Systems (especially the ISO14001 EMS standard) have on the implementation of "environmental options" (i.e. Green Waste Reducing Techniques) and, interestingly enough, the effect of a formal EMS on "Operations performance" described as Lead Time, Quality, and Cost (i.e. Lean Results).

In this study, Melnyk, et al. used a questionnaire to assess achievement levels of companies responding to the survey. They identified important variables related to management system implementation, use of identified environmental waste reduction techniques, and business results achieved through environmental activities of the company. They conclude that "corporate performance is strongly affected by the presence of a formal EMS" in that stronger EMS correlated to more use of environmental waste reduction techniques and more significant business results [9].

The advanced model of Green Systems, shown in Figure 2, draws heavily on the Melnyk, Stroufe, and Calantone model as it is the most comprehensive and best tested of the Green models. Note that this advanced model, which is only a few years old, does not directly address the issues of global warming and the exhaustion of non-renewable resources. These two critically important issues have not yet been fully integrated into Green System theories.

Figure 2: Advanced Green System Model

An Integrated Model of Lean and Green Systems: Zero Waste Operations

A few scholarly studies have investigated the relationship between Lean and Green manufacturing systems [8, 22, 23]. These studies show a positive relationship between Lean and Green. Rothenberg, Pil, and Maxwell [23] show that Lean companies have better environmental performance and

embrace environmental waste minimization more so than non-lean companies. Florida [22] identified some common best practices between Lean and Green management systems (e.g. management commitment, teams, new process technology, innovative product design, and supply chain management). Each of these studies shows correlation between some elements of a Green manufacturing system and some aspects of a Lean manufacturing system.

The Florida study [22] found that progressive companies applied these advanced management practices toward minimizing environmental waste. Dr. Florida indicated that these techniques are associated with both Lean and Green manufacturing systems. "Advanced manufacturing facilities, such as those organized under the principles of lean production, draw on the same underlying principles – a dedication to productivity improvement, quality, cost reduction, and continuous improvement, and technology innovation – that underlie environmental innovation." [22]

Rothenberg, Pil, and Maxwell [23] studied the automotive industry, known for its leadership in Lean manufacturing implementation. The study shows that Lean manufacturers are more energy efficient than non-lean manufacturers. The study did not show significant reductions in emissions in Lean companies, which may in part be due to the fact that Lean companies tend to focus on source reduction rather than end-of-pipe environmental solutions. This approach is consistent with the Lean philosophy of eliminating non-value added activities and stopping problems at the source.

Since both Lean System models and Green System models emphasize the importance of the management system, applica-tion of various waste reduction techniques, and achievement of desired business results, we have recognized that there is great similarity in the structure of such models. Indeed, many of the elements of the models are very similar if not identical. Therefore, we theorize that Lean and Green Systems can be effectively integrated into one overall System designed to achieve very strong business results through the identification and reduction of all the wastes previously targeted by separate Lean and Green Programs. Several synergistic elements can simultaneously reduce both production and environmental wastes. We, therefore, propose the following model (shown in Figure 3) to integrate Lean and Green Systems into one system we call "Zero Waste Operations" [9].

Model Description

The Zero Waste model proposed here takes the three major components of other models of Lean or Green Systems and adds a fourth: waste identification. This component is certainly implied in all models that suggest the implemen-tation of waste reduction techniques, for it would not be possible to implement the techniques if the wastes had not first been identified. The model is also shown as circular rather than linear because organizational learning and continuous improvement is a basic premise on which the model builds.

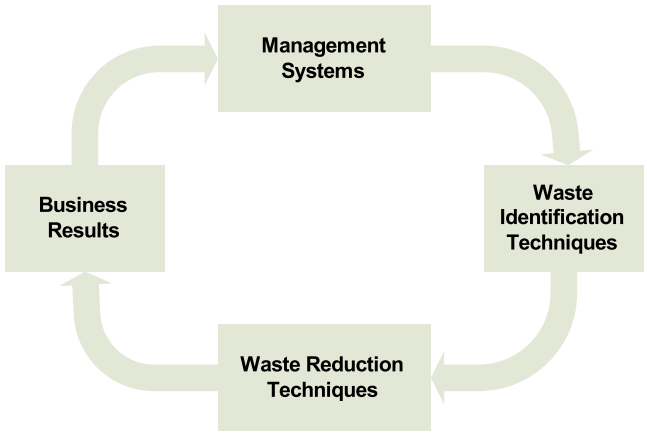

FIGURE 3: ZERO WASTE OPERTIONS MODEL

Management Systems

The model begins with the policies and procedures of the organization as identified and articulated by management. These policies and procedures form the management system and institutionalize the values and norms of the leadership and the organization. All of the researchers and institutions supporting both Lean and Green activities mention the need for management commitment to the process as being of absolute importance to the achievement of any goals and objectives. The Advanced Lean Systems Model calls for leadership from management coupled with empowerment of workers by management. For example, one of the key elements of the Toyota Production System is creation of a culture that encourages any worker to stop the production line immediately to fix a quality problem [13].

The Advanced Green Systems Model notes the critical importance of developing an effective environmental management system as may be accomplished through attainment of ISO14001 certification. Study of the details of the ISO14001 criteria reveals a very high degree of similarity with recognized Lean management system elements [19].

In summary, the management system required for an integrated Lean/Green System includes management commit-ment to achieving both Lean and Green results through leadership, empowerment, and the creation of an effective EMS. Table I shows the elements of an integrated manage-ment system.

TABLE I
ELEMENTS OF AN INTEGRATED LEAN/GREEN MANAGEMENT SYSTEM

An Integrated Lean/Green System Management System
Commitment **Leadership** **Empowerment** **Environmental Management System**

Waste Identification Techniques

Liker [13, 24] emphasizes the importance of identifying various types of waste that may exist in a production system. These wastes are overproduction, waiting, transportation, overprocessing, excess inventory, unnecessary movement, and defects. These are the generally accepted types of waste Lean Systems are meant to reduce or eliminate. Liker suggests a variety of techniques for identifying what types of wastes exist in a production system and where they are found. These waste identification techniques range from observation by walking through the facility to formalized value stream mapping exercises [24].

Environmental wastes may be easier to find than the production system wastes discussed above. These wastes include everything other than completed product that leaves the facility. These categories are green-house gases, waste water, solid wastes, hazardous wastes, and wasted energy. This last waste category often contributes to other waste categories (especially green-house gases), but technically it is using more than necessary to support company operations. These wastes may be identified by looking at EPA reports, waste haulage data, direct measurements of impurities contained in waste water or ventilation air, records of energy purchases, etc. Much of this data is readily available but seldom used for the purpose of identifying wastes [9].

In summary, the waste identification techniques required for an integrated Lean/Green System involve studying the processes and the waste products leaving the facility. Table 4 gives the full list of waste categories to be eliminated by an integrated Lean/Green System. We call this list the "dirty dozen wastes" [9].

TABLE II
WASTE CATEGORIES FOR AN INTEGRATED LEAN/GREEN SYSTEM

An Integrated Lean/Green System Waste Categories
1. Overproduction
2. Waiting
3. Transportation
4. Overprocessing
5. Excess Inventory
6. Unnecessary Movement
7. Defects
8. Green-House Gases
9. Waste Water
10. Solid Wastes
11. Hazardous Wastes
12. Wasted Energy

Waste Reduction Techniques

Depending on which waste categories are identified within a particular facility, waste reduction techniques (WRT) may be selected from a long list of potential WRT's [9]. We have identified 66 WRT's (and the list is still growing) that can be applied to reduce one or more of the dirty dozen wastes. Some WRT's focus on overall programmatic procedures; activity based costing, alliances, encouraging suppliers, educating employees, and total productive maintenance are some examples. Some WRT's focus on process efficiencies; flow production, first in first out, kanban, and just-in-time are some examples. Some WRT's focus on product and process design issues; concurrent engineering, design for manufacturing, disassembly, energy efficient products, pull systems, and six sigma are some examples. Some WRT's focus on facility efficiencies; passive solar designs, insulation, lighting efficiencies, and energy efficient equipment are some examples. When properly applied, these waste reduction techniques can be very effective in reducing and in some cases eliminating many or all of the dirty dozen wastes [8, 11, 13, 19, 24]. Reducing the wastes created while goods and services are being produced can directly impact many important business results.

Business Results

The business results relevant to the Integrated Lean and Green Systems model (see Table III) are those that can be measured and can be affected by the activities of such systems. Some of the results are associated with measuring actual waste produced and some are associated with company profitability that may be influenced by changes in the production systems necessitated by waste reduction goals. The primary business results of concern are overall business success parameters (total costs, market position, reputation, general benefits to the company that outweigh the costs, and international sales levels) and production process parameters (product design improvements, lead times, product quality, process waste reductions, and equipment selection improvements). Together these parameters can give a picture of business success levels at a particular point in time, a view of both short-term and long-term improvements, or a point of comparison with other organizations [9, 11, 13].

TABLE III
BUSINESS RESULTS OF AN INTEGRATED LEAN/GREEN SYSTEM

An Integrated Lean/Green System Business Results
Lower Total Costs
Improved Market Position
Enhanced Company Reputation
Benefits that Outweigh Costs
Greater International Sales
Product Design Improvements
Lead Time Reductions
Higher Product Quality
Process Waste Reductions
Equipment Selection Improvements

Periodic evaluations of the business results support organizational learning and can assist managers in determining how to alter their programs to achieve even

better future results, which brings the model back to management systems. Although not obvious from this discussion, the ten business results listed here are not necessarily independent. For example, higher product quality means fewer defects are produced, generally leading to reduced process waste, lower total costs, and likely improved company reputation and market position [9].

Summary

Drawing from the major models of Lean Production Systems and the major models of Green Operations Systems, we have constructed a four-part model for an Integrated Lean/Green System that can move organizations towards a Zero Waste Operations position with results that can contribute significantly to the long-term financial and environmental sustainability of the firm.

Significance of the Model

In collaboration with Ross & Associates, the EPA conducted a study of Boeing Corporation to determine if Boeing's Lean manufacturing program generated environmental improvements. The study showed that Boeing's Lean manufacturing program reduced environmental waste as a byproduct of process efficiency and quality improvements associated with "Leaning" the manufacturing process. Secondly, the study showed that the "waste reducing culture" associated with Boeing's Lean manufacturing program is exactly the type of culture the EPA has deemed essential for sustained environmental improvement. Lean manufacturing programs/systems at Boeing and in general do not specifically address environmental waste reduction as a core objective of the program and considerable research opportunities exist to "build a bridge" between Lean and Green manufacturing systems [8]. The model developed and presented here is a significant step in building this bridge to take advantage of the natural synergies existing between Lean management systems and Green management systems, Lean methods and Green methods, and Lean results and Green results.

With a study focused on companies identified by the Shingo Prize as being significantly lean [10], we were able to confirm that strength of Lean management system is statistically correlated to the degree of implementation of Lean waste reducing techniques (WRT) and that the strength of implementation of the WRTs is statistically correlated to Lean business results. We were also able to show that strength of Green management system is statistically correlated to the degree of implementation of Green WRTs and that the strength of implementation of the WRTs is statistically correlated to Green business results. This finding confirmed the major finding by Melnyk, et al. [20].

Shingo plants implementing Green Management Systems (GMS) and Green Waste Reduction Techniques (GWRT) show higher Lean results than those less environmentally inclined [9]. This indicates *synergy* because Green practices improve both Green and Lean results when implemented in a Lean environment. Green variables pertaining to GMS and GWRT significantly influenced all categories of Lean results. Most striking is how strongly the Green variables correlated to Cost, perhaps the most important measure of Lean. This last finding shows that good environmental programs contribute significantly to lowering total production costs and, therefore, contribute significantly to long-term economic sustainability of the companies.

Conclusion

Noting that our results indicate Lean and Green Programs when seriously applied lead to improved business results, we have empirically shown the value of such programs to the companies that choose to implement them. The Integrated Lean/Green Systems Model provides an overall guideline to the expansion of successful Lean Programs to gain the advantages inherent in environmental improvements. Likewise, this model provides a guideline to the expansion of successful Green Programs to harvest the environmental improvements available through Lean Programs. For those firms just starting the journey, the model can serve as a guide to attaining the benefits of both Lean and Green Programs by building an integrated system within the organization, thus securing the synergistic results of both Programs and long- term sustainability for the firm.

Application of a Zero Waste Operations approach to the existing and developing systems for producing alternative energy technologies will assure that these important industries are highly efficient, thus contributing significantly to making these technologies economically competitive with existing non-renewable energy technologies. ZWO will also assure that these industries established to contribute to long-term societal sustainability will indeed be as environmentally beneficial as possible.

Every organization involved in developing and producing Green technologies should strongly consider the implementation of an integrated Lean/Green systems approach to the improvement of its production system. This will allow these companies to reduce significantly the costs associated with society's adoption of Green technologies and will also assure these companies the greatest opportunity to achieve long-term sustainability.

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