It Ain't Easy Being Green: Sustainable Manufacturing with an Eye on Cost Avoidance and Stewardship

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Abstract

The Department of Defense (DOD), one of the largest energy consumers in the world, has committed to sustainability. An important element of sustainable weapon systems acquisition currently not under the purview of the DOD's strategic plan is sustainable manufacturing. This paper will leverage current research and industry best practices to identify the impact of sustainable manufacturing on cost avoidances relating to human health and environmental benefits. Recommendations will be provided for complying with the FAR sustainability requirements.

Keywords: Sustainable Manufacturing, Cost Avoidance, DOD Sustainability Policies and Strategy, FAR, Acquisition

"The Department of Defense (DOD) vision of sustainability is to maintain the ability to operate into the future without decline—either in the mission or in the natural and man-made systems that support it." (DOD Strategic Sustainability Performance Plan, 2012, p. 2).

According to the Fiscal Year 2013 Operational Energy Annual Report, the Department of Defense used an estimated $14.8 billion on operational energy (liquid fuel), equating to approximately 89.8 million barrels of fuel. In a 2007 paper by COL Gregory Lengyel, he cited the statistics that in Fiscal Year (FY) 2006 the Department of Defense used an estimated 30 Million Mega Watt Hours (MWH) of electricity at a cost of approximately $2.2 Billion. In that year, if the DOD had been its own country, it would have ranked 58th in the world for electricity consumption (Lengyel, 2007, p. 14). The FY 2016 budget for the DOD is requested at $534.3 Billion, more than the individual Gross Domestic Product (GDP) of 85% of all nations in the world, according the CIA World Fact Book (2012). Needless to say, the DOD is one of the largest consumers of resources and energy in the world. How does the United States of America protect its borders, keep citizens and allies safe, safeguard freedoms while at the same time optimize and conserve natural resources for future generations? This is a complex problem that in recent years has taken center stage in public policy and strategy. The increase in scholarly research, directives from the President of the United States, Joint Chiefs of Staff, and Secretary of Defense, and policy initiatives by every branch of the Armed services has increased substantially in the past 10 years.

DOD's Vision of Sustainability

As the single largest energy user in the nation (Fiscal Year 2012 Operational Energy Annual Report, 2013), the DOD has a responsibility to develop a cohesive and executable strategic plan to conserve and reduce resource use. The DOD Sustainability Analysis Guidance (DRAFT) v 2.0 dated May of 2014 put it well:

> Sustainability is the capacity to endure. The environmental-related term "sustainability" is often defined as a durable and self-sufficient balance between social, economic, and environmental factors. In the context of the DOD acquisition process, and for the purpose of this guidance, sustainability means wisely using resources and minimizing corresponding mission, human health, and environmental impacts and associated costs during the life cycle (p. 1).

The basis of the DOD's strategic vision for sustainability originates with Executive Order 13514 signed by President Barack Obama on October 5, 2009. In the plan, the President outlines guidance to Federal Agencies to increase energy efficiencies by reducing greenhouse gas emissions via indirect and direct activities, water conservation and protection actions, and waste, especially pollution and hazardous waste. From this Executive Order, the DOD developed several key documents and policies to support the directive including:

- Memorandum of Understanding (MOU) between the DOD and the Department of Energy (DOE), (July 2010)
- DOD Energy Handbook of Alternative and Renewable Energy Options for DOD Facilities and Bases, (March 2011)
- Operational Energy Strategy: Implementation Plan for overall direction, (March, 2012)
- Department of Defense Strategic Sustainability Performance Plan (SSPP) FY 2012, (September, 2012)
- Department of Defense Directive Number 4180.01, DOD Energy Policy, (April, 2014).

Each branch of the Armed Services has also created their own response to the need for a commitment to sustainability. The US Army released their Operational Energy Policy in April, 2013 wherein the Secretary of the Army identified operational energy as a "critical enabler for the range of military operational capabilities from the individual Soldier to strategic levels." The Army defined operational energy as "the energy required for training, moving, and sustaining military forces and weapons platforms for military operations. The term includes energy used by tactical power systems and generators and weapons systems" (p. 1).

The Department of the Navy released their Strategy for Renewable Energy in October of 2012. The brief outlined the Secretary of the Navy's five energy goals, including that by 2020 50% of the total Navy's energy consumption will come from alternatives sources and 50% of Navy installations will be net-zero (p. 3). The Marine Corps established Marine Corps Order 3900.19 on May 23, 2013 which described its growing reliance of liquid fuel with the overwhelming fact "A Marine infantry company today uses more fuel than an entire infantry battalion did in 2001" (p. 1). The Order sets in place energy performance requirements for reducing liquid fossil fuel by 50% by 2025. It includes an aptly put challenge to all services and those working to increase sustainability in the DOD:

> The challenge with capturing energy in our requirements and acquisition processes is the fact that most energy consumers are often not responsible for the energy they use and those that supply energy have no controls over the consumers (p. 11).

In March 2013, the Air Force published the U.S. Air Force Energy Strategic Plan, a crucial document, especially with the understanding that the US Air Force accounts for 48% of the DOD's total energy consumption, 81% of that being for aviation fuel (p. 6-7). The Air Force Energy vision is to "sustain an assured energy advantage in air, space, cyberspace" and defines energy security as "having assured access to reliable supplies of energy and the ability to protect and deliver sufficient energy to meet operation needs" (p. 1).

When looking at all of the policies, directives and guidance that has been set forth by the President, Department of Defense, and Service Branches it is clear to see there has been much thought and effort put into the vision and plan of action of how to reduce the United States' Armed Forces' reliance on the Earth's valuable resources. Much of the policy and goals revolve around reducing reliance on liquid (fossil) fuels, especially in our key force structure investments, including: aircraft, missiles, water craft and vessels, and Army brigade combat teams. While reliance on fossil fuel is a critical area of emphasis, there is a serious need to incorporate sustainable practices into all facets and processes of the Department, especially the acquisition process. Most of the focus falls in the operation and sustainment portion of program life cycle, and there have been strides in incorporating sustainability into the Development stage (Berry, J. & Asiello, D, 2011). However, there is a gap in incorporating sustainability consideration into the Production and Deployment stage, specifically the manufacturing processes for large weapon systems. This responsibility mainly rests in the hands of the original equipment manufacturers (OEMs), also commonly referred to as “Industry” or “contractors.”

Little guidance is currently available for DOD acquisition professionals on how to incorporate sustainable manufacturing practices into the systems acquisition stage of the Planning, Programming, Budgeting, and Execution (PPBE) process. The SSPP states that sustainable manufacturing is an essential component of sustainable weapon system acquisition. It is “the creation of man-made products with processes that are economically sound, non-polluting, energy efficient, conserving of natural resources, and safe for warfighters, users, employees, and communities” With established acquisition standards, the Department has the potential to directly influence contractors’ manufacturing practices in relation to sustainable manufacturing. In the past twenty-five years the commercial sector of advanced manufacturers have focused their efforts on waste reduction in the manufacturing process, mostly derived from the Toyota Production System, or “lean” manufacturing (*The Machine That Changed the World*, James P. Womack, Daniel T. Jones, and Daniel Roos, Rawson Associates, 1990). While reducing waste in this manner results in lower costs, better quality, and shorter cycle times there is now a push for eliminating wastes in order to benefit the environment and human health, also known as "sustainable manufacturing." This term will be described in more detail in the following section. Its tangible and intangible benefits include lower costs, increased worker safety and less burden on our natural resources.

Reference to sustainable manufacturing is scarce in the documentation previously discussed. Executive Order 13514 (2009) requires that within 240 days of the Order, the Department should include in the Strategic Sustainability Performance Plan (SSPP), the consideration for "pursuing opportunities with vendors and contractors to address and incorporate incentives to reduce greenhouse gas emissions (such as changes to manufacturing,.., or other changes in supply chain activities)" (p. 2). Later in the document, section 2.h specifically calls out for sustainable acquisition, but specifically states that this does not include contracts for acquisitions of weapons systems:

> Advance sustainable acquisition to ensure that 95 percent of new contract actions including task and delivery orders, for products and services with the exception of acquisition of weapon systems, are energy-efficient (Energy Star or Federal Energy Management Program (FEMP) designation), water-efficient, bio based, environmentally preferable (e.g., Electronic Production Environmental Assessment Tool (EPEAT) certified), non-ozone depleting, contain recycled content, or are non-toxic or less-toxic alternatives, where such products and services meet agency performance requirements (p. 5).

The Department of Defense's SSPP FY 2012 briefly describes sustainable manufacturing, but makes no reference to any guidance for ensuring contractors use these techniques in their facilities:

> An essential component of sustainable weapons acquisition is sustainable manufacturing. Sustainable manufacturing is the creation of man-made products with processes that are economically sound, nonpolluting, energy efficient, conserving of natural resources, and safe for warfighters, users, employees, & communities. As a keystone concept that integrates multiple sustainability elements, sustainable manufacturing can make weapons acquisition more affordable through cost avoidance of environmental, health, and safety liabilities. Every dollar spent on liabilities is one less for warfighter capabilities.

> Sustainable manufacturing has a place in both the acquisition of systems and in their logistics sustainment (p. I-15).

The importance of sustainable manufacturing is largely overlooked by current guidance and policy, but the benefits to the manufacturing workers and safety of the facility, the environment, the American taxpayers, the warfighter, and Department of Defense as a whole are innumerable. The authors of this paper will suggest future considerations for policy makers to consider the importance of sustainable manufacturing and how to incorporate these practices into the major weapons acquisition process.

Sustainable Manufacturing

Sustainable manufacturing is "the creation of manufactured products that use processes that minimize negative environmental impacts, conserve energy and natural resources, and are economically sound and safe for employees, communities, and consumers" (International Trade Administration, 2015). There are many factors related to sustainable manufacturing including energy use, water use, waste and recycling, travel and transportation, office equipment and computing, supply chains and purchasing, building design, product and service design, eco-labeling and certification, environmental management systems, and sustainability reporting (Sitarz 2008). Activities related to sustainable manufacturing are numerous and complex, and this paper will focus on sustainable manufacturing in terms of manufacturing facility operations.

Energy, water, and waste are three environmental elements affected by manufacturing facility operations. The three are a main focus within the SSPP and are where sustainable manufacturing practices can have a major impact in terms of resource stewardship and operating costs. The following sections explain sustainable manufacturing practices in terms of energy, water, and waste and provide representative examples of how these practices are being implemented today by industry.

Energy

According to the U.S. Environmental Protection Agency (EPA), more than 30 percent of all energy consumed in the United States is used during manufacturing operations (EPA 2015). Using purchased energy more efficiently and replacing fossil-fuels with renewable energy sources are two tenets of sustainable manufacturing.

Energy efficiency improvements in facility operations can be obtained through changes to lighting and heating, ventilation, and air conditioning (HVAC) systems. Replacing incandescent bulbs with compact fluorescent lamps (CFLs) or light-emitting diode (LED) lights reduce electricity demand, thus lowering utility costs and greenhouse gas emissions (GHGs). Replacing one incandescent bulb with an Energy Star certified CFL or LED bulb can save between $30 and $80 in electricity costs over the lifetime of the bulb (Savings, Energy Star 2015). For HVAC systems, cleaning filters regularly and sealing leaks in duct works helps ensure systems are working efficiently. Weather stripping or caulking the outer shell of a facility prevents heated or cooled air from escaping and installing double-pane windows can reduce heating and cooling costs by over 30 percent (Sitarz 2008). Installing motion sensors allows for only lighting areas that are in use, and shutting off machinery or equipment that are not in use will further reduce energy consumption. Additionally, tax credits and deductions are available for energy efficiency practices in businesses (Sitarz 2008).

Energy efficiency improvements mentioned above are being implemented today by major DOD original equipment manufacturers (OEMs). In their 2013 Sustainability Report, Lockheed Martin cites that energy cost reduction activities at their Mission System and Training facility in

Orlando, Florida, including turning off task lighting and unplugging equipment, equates to about $330,000 cost reductions annually. Lockheed's facility in Grand Prairie, Texas, reduced energy consumption by 5,256,000 kWH/year in 2012 after the first phase of a multi-year HVAC upgrade was completed. This upgrade involved installing variable frequency drives on fans, the first step in converting their system into a Variable Volume on Demand HVAC system. This first phase of the upgrade saved $368,000 per year in energy costs (CDP 2013). General Dynamics Ordnance and Tactical Systems (GD-OTS) worked with the U.S. DOE Advanced Manufacturing Office to complete a Superior Energy Performance (SEP) certification. The SEP is a market-based plant certification program that requires the implementation of an ISO 50001 compliant energy management system (EnMS) and continual, verified energy performance improvements. Using their EnMS, GD-OTS identified significant energy users (SEUs) in their facility: SEUs that consumed natural gas included forging furnaces, heat-treating furnaces, and boiler systems; SEUs consuming electricity included cooling towers, lighting, forging presses, and air compressors. After implementing energy efficiency measures to these SEUs, GD-OTS reports savings of 107 billion Btu and $956,000 in costs annually (GSEP).

Using renewable sources of energy is another tenet of sustainable manufacturing that can lower negative environmental impacts of facility operations. Resources for renewable energy rely on fuel sources that restore themselves over short periods of time and do not diminish; examples of these fuel sources include the sun, wind, moving water, organic plant and waste material, and geothermal (EPA *Green Power Market*). Businesses can generate their own renewable energy, purchase it from other producers, or purchase renewable energy certificates (RECs). A REC "represents the property rights to the environmental, social, and other non-power qualities of renewable electricity generation" (EPA *Renewable Energy Certificates*).

Environmental, economic, and health benefits of renewable energy include little to no greenhouse gas emissions (IPCC 2011), reduced premature mortality, lost workdays, and overall healthcare costs (Machol and Rizk 2013), reduction in air pollution, and diversification of energy supply (UCS 2015).

OEMs today are utilizing renewable energy at their facilities. According to The Boeing Company's 2014 Environment Report, Boeing uses hydroelectric and renewable energy sources for nearly half of their total electricity consumption. Their North Charleston, South Carolina site is powered by 10 acres of solar panels on the roof of their final assembly building, and to achieve 100% renewable energy at that facility, Boeing purchases RECs from the local utility. Wind energy powers 20% of the power that runs Boeing facilities in Southern California (Boeing 2014). According to a 2008 Raytheon news release, the company purchased more than 2.5 million kilowatt-hours of electricity generated by wind to meet 10% of its Aurora, Colorado facility's electricity needs. Lockheed Martin has implemented a 500 kW solar array that will fuel the electric grid at its Denver, Colorado site (LM 2013).

Water

Water use is the second major element of sustainable manufacturing. The most common uses of water in manufacturing are cooling, process uses, cleaning, steam generation, employee sanitation, and irrigation (Alliance for Water Efficiency 2015). Water is often used to transfer heat away from machinery, through a recirculating cooling pond or cooling tower where water is pumped to undergo evaporative techniques to rid the waste heat and cool the water. Many different manufacturing operations use water for the following: cleaning and rinsing products, parts, and vessels; transporting parts or ingredients; as a lubricant; as a solvent or reactant in a chemical reaction; forming a water seal to block contact with air; pollution control; or including it in the product (ibid). Water use is tied to costs of manufacturing processes, both in water bills and electricity bills. Reducing water use will lower water bills and preventing unnecessary heating or treating of water can decrease energy bills. Reducing the overall use of water can reduce the quantity of disposed water and the risk of litigation from water that might be tainted with toxic or hazardous chemicals (Sitarz 2008). Concerns over the disposal of liquid effluent has resulted in an increased emphasis to reduce the use of fluids in manufacturing. Examples of processes under development to reduce fluid use during the manufacturing process include dry machining, minimum quantity lubrication, powder coating, and other finishing operations (Haapala et al. 2013). Other methods to reduce water consumption in facilities include installing water meters for monitoring, installing pressure-reducing valves, checking a facility for water leaks and repairing leaking pipes, installing low-flow showers, faucets, and toilets, installing water meters for landscape irrigation, using recycled water or rainwater for landscaping, and planting native vegetation (Sitarz 2008).

Many water conservation practices are being used today by businesses. Both Boeing and Lockheed have utilized reverse-osmosis filtration techniques to filter existing wastewater and make it reusable as make-up water for cooling towers or to be recycled back into the tank line system (LM 2013; Boeing 2014). Water conservation actions taken by Lockheed Martin have included upgrading cooling towers with more efficient systems, installing water softeners, upgrading restrooms with low-flow fixtures, and installing smart sensors to optimize landscaping irrigation. According to Lockheed, in 2012 the company spent over $2 million on water conservation initiatives, with an estimated collective water savings of greater than 43 million gallons per year (CDP 2013). The Boeing Santa Susana facility installed a biofiltration system which acts simultaneously a pollinator species habitat and stormwater treatment system (Boeing 2014).

While US Government production is much rarer now than it was in World War II the US Navy still conducts manufacturing processes work at maintenance facilities, dry docks, and depots. A relevant example of water conservation at one of these facilities was when the U.S. Navy implemented processes to conserve water at their Fleet Readiness Center Southwest in San Diego, California. A highly efficient sub-surface irrigation system was installed at the Center that, according to reports in the DOD SSPP (2012), reduced outdoor water use by 30-40%. Savings were also realized at the Center's manufacturing and painting facilities by installing a Mini-Max waterless steam cleaning system and low-water steam assist rinse and by retrofitting the aircraft washing hoses to be utilized at a lower water volume. The cost savings are estimated at $151,000 per year based on a savings of over 110,000 gallons of water and the reduction of treatment and disposal of industrial wastewater. (p. II-30)

Waste

Waste reduction, simply preventing or reducing the generation of waste, is a third major component of sustainable manufacturing (EPA Waste Wise). Approximately 7.6 billion tons of solid waste are generated each year by U.S. industrial facilities (Guide for Industrial Waste Management, EPA 2015). The foundation of any waste reduction program involves reducing waste at the source, recycling waste, and treating waste (EPA Waste Wise). Reducing waste translates into lower disposal and material costs, improved operating efficiency, and reduced regulatory burden (Sitarz 2008). Waste reduction and management practices include, but are not limited to, reducing packaging, composting, printing double-sided, purchasing remanufactured office equipment, using rechargeable batteries where possible, installing reusable furnace and air conditioner filters, implementing an improved inventory system, using less toxic or nontoxic substitutes for products such as inks, paints, and cleaning solvents, and using reusable or recyclable containers for shipping products. Converting waste to energy is another method to eliminate waste disposal. Lean manufacturing is a business model that aims to reduce waste by eliminating non-value added activities and delivering products at the least cost and most efficiency (EPA Lean Manufacturing and the Environment). The EPA makes the point that "while the focus of lean manufacturing is on driving rapid, continual improvement in cost, quality, service , and delivery, significant environmental benefits typically 'ride on the coattails' or occur incidentally as a result of these production-focused efforts" (ibid). These benefits include reduction in the use of materials, energy, water, space, and equipment per unit of production (ibid).

OEMs have established waste management practices, particularly with regard to chemical use. The Boeing Product Chemical Profile System is a tool the company uses to identify and record the chemicals in their products. One example of steps being taken to replace products with less toxic substitutes is taking place at Boeing, where they have developed chrome-free paints and primers which are used on various military products including the AH-64 Apache, V-22 Osprey, F-15E Strike Eagle, Chinook, F/A-18E/F Super Hornet, and EA-18G Growler (Boeing 2014). Partnering with ConcordBlue USA, Lockheed Martin is developing an advanced waste-to-energy conversion system which uses a gasification process to convert waste products to electricity, heat, and synthetic fuels. According to their sustainability report, Lockheed has implemented recycling and reuse programs for products such as paper, cardboard, scrap metal, wood, construction materials, computers, batteries, tires, fluorescent light tubes, mercury thermometers, and cables (LM 2013).

Cost Avoidance

Mission Resources

Research has proven that responsible, sustainable manufacturing is needed in order to sustain economic development (Madu C.N., 2001). This is especially true in large scale defense manufacturing within the United States. Every resource that is not used for the procurement process can be used to operate or sustain the weapon when needed during mission critical times. The Department of Defense budget is undergoing strenuous budget cuts and scrutiny (Estimated Impacts of Sequestration Level Funding, 2014); in order to optimize the available budget, considerations should be taken to reduce energy consumed in the investment phase of weapons acquisition. In reports issued by the President's Council of Advisors on Science and Technology in July of 2012 and October of 2014, detailed plans were outlined on how to capture and maintain America's domestic competitive advantage in advanced manufacturing. The 2012 report specifically calls out sustainable manufacturing and reducing waste in processes by saying:

> A major area of focus will be energy efficient manufacturing— where high energy-consuming manufacturing processes need to be substituted by lower energy-consuming alternatives. Areas such as re-manufacturing (i.e., using recycled components) also need to be researched. In addition to savings in energy consumption and higher profitability, many accompanying benefits can aid the competitiveness of industry (p. 19).

The 2014 draft DOD Sustainability Analysis Guidance describes the three areas that should be of interest to the Department of Defense including: mission resources, environmental and human health. Resources needed for mission success directly impact mission readiness and, if depleted, would negatively impact the ability of Armed service men and women to complete the intended mission. These resources needed to complete the mission include fossil/liquid fuel used for operations, mineral and metal use, water, and land (p. 8). Figure 1 which was taken from the report details the flow of elements starting as inputs on the left, entering the process/system and their effect on mission resources, environmental health and human health and impact on costs.

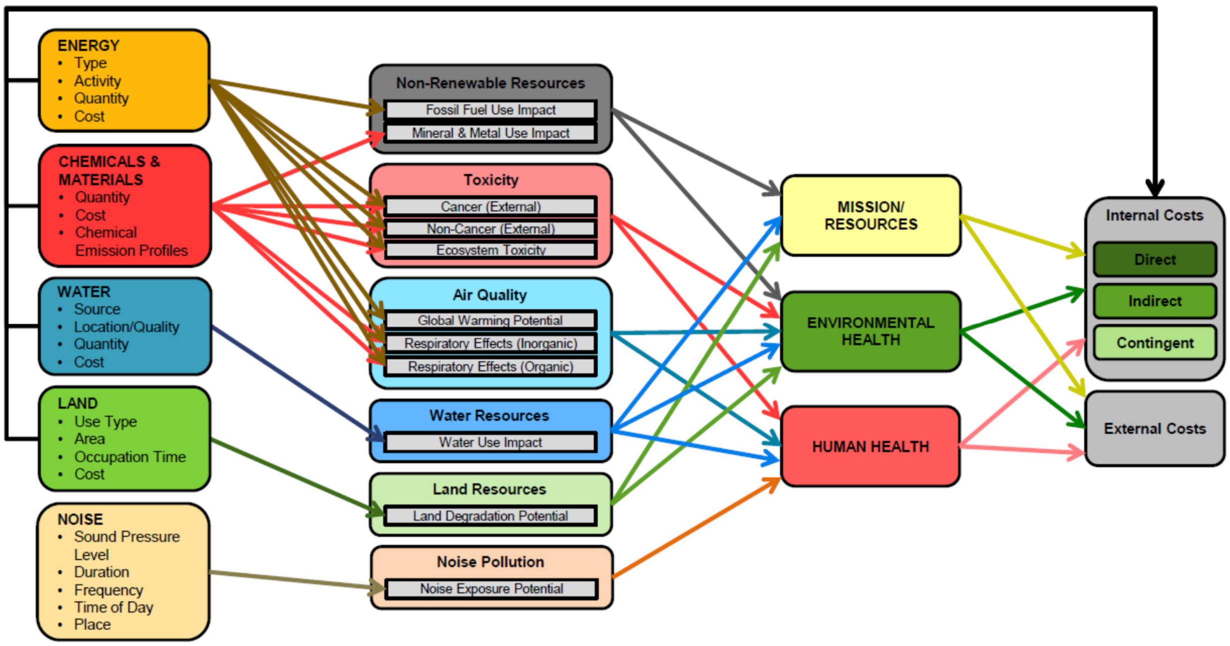

Figure 1 Sustainability Analysis Framework from DOD Analysis Guidance Draft (2014, p. 10)

A way to quantify cost savings to the mission by implementing sustainable manufacturing practices is by calculating and tracking certain metrics. Data that should be collected include: the energy of fossil fuel resources that were saved in mega joules (MJ), the mass of minerals/metals reduced in kilogram (kg), volume of water conserved in cubic meters (m^3), and area of arable land equivalents per year (ha.yr arable eq) of additional land that was not utilized for manufacturing purposes. Any increase to previously undeveloped arable land usage during the manufacturing stage should be considered in the cost of a weapons system. By quantifying this data, the OEMs and US Government can better understand the cost savings associated with sustainable manufacturing. Reducing these resources at the present time will prolong the current lifespan of reserves for future generations and allow the technology to advance to improve extraction processes and alternative energy sources (Department of Defense Guidance Integrating Sustainability into DOD Acquisitions, 2014).

Environmental Health

Businesses often quantify savings from sustainable manufacturing in terms of electricity and water use reduction and cost savings from lower electric and water bills. While quantified cost savings in terms of reduced utility bills stemming from sustainable manufacturing practices is amply available in the literature, measuring cost avoidances due to sustainable manufacturing is less straightforward. Risk associated with a previous manufacturing practice that is now lessened or avoided entirely due to the substitution of a sustainable manufacturing practice can be considered cost avoidance. This particularly pertains to environmental litigation from exposure to hazardous waste. Actual litigation cases can provide insight into cost avoidances from preventing such exposure. In 2014, the Tennessee Clean Water Network (TCWN) filed a federal lawsuit against the Army and BAE Systems for discharging explosive chemicals into the Holston River from its Holston Army Ammunition Plant. The lawsuit is based on failure to comply with water permits set by the Tennessee Department of Environment and Conservation and seeks a payment from BAE of $37,500 per day for each violation of the Clean Water Act; the Army was liable to fines as well (Nelson 2014).

Human Health

The most intangible and hardest to quantify the cost avoidance of sustainable manufacturing is the impact on human health. This includes the health impacts to the workers, engineers and others OEM/defense personnel or surrounding local community with the manufacturing process. Impacts of sustainable manufacturing may include a reduction of toxicity (cancerous and non-cancerous), improved air quality (inorganic/organic respiratory effects), and a decrease of water and noise pollution of the surrounding area.

The largest metric tied to tracking the impact of sustainability practices in manufacturing is Disability Adjusted Life Year (DALY). Defined in the DOD Sustainability Analysis Guidance Draft (2014) as "a measure of the overall disease burden, expressed as the number of person-years lost due to ill-health, disability, or early death. The DALY relies on an acceptance that the most appropriate measure of chronic illness impact is time; both time lost due to a premature death and time spent disabled by disease" (p. 103). Human health is tied to worker productivity so this data can be used to determine the time lost by injury, and cost can be associated with the lost time.

Acquisition Recommendations

The case has been made for the benefits provided by implementing sustainable manufacturing in the weapons acquisition process, for the warfighter, taxpayer, manufacturer, environment, and the health and safety of workers. How does the Department of Defense ensure that these benefits and cost savings are realized?

The authors propose that language should be added to the Federal Acquisition Regulation (FAR) Sustainable Acquisition Policy section 23.103 to include weapons systems, which is under existing policy, an exception. Currently, the policy reads that "Federal agencies shall advance sustainable acquisition by ensuring that 95 percent of new contract actions for the supply of production and for the acquisition of services (including construction) require that products are –

1) Energy-efficient (ENERGY STAR® or Federal Energy Management Program (FEMP)-designated);
(2) Water-efficient;
(3) Biobased;
(4) Environmentally preferable (*e.g.*, EPEAT®-registered, or non-toxic or less toxic alternatives);
(5) Non-ozone depleting; or
(6) Made with recovered materials (FAR, 2014, p. 23.1-1).

By including weapons systems in this requirement, or by adjusting these constraints to better suit the nature of weapons procurement, the Department of Defense and the US Government can ensure that future and current contracts meet environmentally sound standards. Consideration has to be given to the burden that this will add to the already understaffed acquisition professionals in the Department of Defense. A framework and processes need to be developed to assist with the evaluation of proposals and source selection process and the incorporation of these requirements.

Recently on Thursday, March 19, 2015, the President signed an executive order to set new goals for reducing GHG emissions from federal agencies (Davis, 2015). In conjunction with the executive order, the Obama administration released a new scorecard for federal suppliers to report their emissions and track their reductions (n.p.). The tracking of OEM's greenhouse gas emissions and their reductions being submitted to the Government and cataloged in an accessible data repository will allow analysis to be performed in evaluating the OEM's impact and progress towards sustainability goals. This information can be used during the acquisition decision making process. This data should especially be considered in the Life Cycle Cost Estimate (LCCE) of the weapon system, which is defined by the International Society of Cost Estimators and Analyst's Cost Estimating Body of Knowledge as "a cost estimate that covers all of the costs projected for a system's life cycle, and which aids in the selection of a cost-effective total system design, by comparing costs of various trade-offs among design and support factors to determine their impact on the total system acquisition and ownership costs. This includes the cost of development, acquisition, support and disposal" (2014, p. 103). In the article "NCDMM Sustainable Military Manufacturing" in the Live Better Magazine (2012) the author discussed the challenges associated with measuring sustainability at the manufacturing level. Sustainability metrics can be collected at the individual manufacturing cell level, facility, and the supply chain. As stated in the article "Accurate data will drive intelligent decisions that will improve sustainability and profitability of the manufacturing process" (n.p.). Along with the required GHG emission tracking, Lu et al in their 2010 article proposed the following list of potential manufacturing process metrics to collect in order to assess sustainability in the manufacturing facility:

- Environmental impact
  - GHG emissions (kg CO2 eq./unit)
  - Ratio of renewable energy used (%)
  - Total water consumption (kg/unit)
- Energy consumption
  - In-line energy use (kWh/unit)
  - Energy use for maintaining working environment (kWh/unit)
  - Energy consumption for material handling (kWh/unit)
- Economic cost
  - Labor cost ($/unit)
  - Energy cost ($/unit)
  - Maintenance cost ($/unit)
- Worker safety
  - Exposure to corrosive/toxic chemicals (incidents/person)
  - Injury rate (injuries/unit)
  - Near misses (near misses/unit)
- Worker health
  - Chemical contamination of working environment (mg/m3)
  - Mist/dust level (mg/m3)
  - Physical load index (dimensionless)
- Waste management
  - Mass of disposed consumable (kg/unit)
  - Consumables reuse ration (%)

- Ratio of recycled chips and scrap (%)

(Lu et al, 2010, p. 4)

Along with including requirements in the FAR for sustainability in the weapons acquisition process and collecting data in order to make informed decision analysis; contracts, cost analysts and acquisition officials within the Department of Defense should consider the cost savings of implementing sustainable initiatives during the proposal evaluation process. During the proposal assessment period of the contract award/source selection process the proposal evaluation team should include cost savings to the proposed manufacturing price. If decrements were not recommended by the contractor/OEM the Government team should recommend a reduction in costs for the negotiations team. This will ensure that the cost savings are passed on to the taxpayer, allowing for more usage of the Government's money and Program Office's budget. This also complies with the guidance set forth by Frank Kendall in the 2012 Memorandum for Defense Acquisition Workforce regarding Better Buying Power 2.0 for Defense Spending.

In 2009, as part of the Recovery and Reinvestment Act, a new tax credit was available for manufacturing facilities that incorporated new clean energy technologies. Called the 48C Advanced Manufacturing Tax Credit, it provided $2.3 billion to 183 domestic manufacturing facilities. In 2013, the Internal Revenue Service (IRS) announced an additional $150 Million of tax credits available on a competitive basis dependent on the technologies implemented, impact on reduction of air pollution, job creation, innovation and the timeline of project completion. Twelve manufacturers were awarded the tax credit for a total of approximately $150,228,397. None of these twelve companies who received the tax credits in 2013 were the main military/weapon system OEMs. As an incentive to encourage clean energy in weapon system manufacturing facilities the authors recommend another similar tax credit be utilized specifically for the defense industry (US Department of Energy, 2013, n.p.).

Industry members might be on the fence for implementing sustainable manufacturing practices into their facility. There is a significant capital investment to implement clean technologies and best practices discussed in the section above. Cost analysts can utilize Economic Analysis (EA) techniques such as Benefit Cost Analysis (BCA) to build a business case and help calculate a Return on Investment (ROI) for upper management, decision makers, and shareholders. Quantifying the costs and benefits will present a challenge as the tangible and intangible benefits are still being realized by early adopter manufacturers embracing sustainably and green practices, but as more research is conducted and more converts are made the case for sustainable manufacturing will be easier to make and justify.

The final recommendation for the Department of Defense in order to best utilize sustainable manufacturing practices in the acquisition process is to encourage and support professional conferences and working groups between the Government and Industry. By encouraging a forum for best practices, research and new ideas to be shared between the Department of Defense, Government Think-Tanks, Universities with funded research, and the OEMs, a flow of information can be encouraged. A cross functional team, including members from each service branch, can inspire communication and promote innovation that will enable advancement.

Conclusions and Future Study

After reviewing all the information presented in this paper, members of the cost analysis community might be wondering how they can support this important issue. The first step is to become educated on the Department of Defense’s current policy and guidance associated with sustainability. Next, is understanding the impact that implementing sustainable manufacturing techniques will have on the military industrial base and costs. In a brief by Ralph Resnick of the National Center for Defense Manufacturing and Machining he details the benefits of sustainable manufacturing including cost savings, competitive advantage, doing more with less (budget cuts/sequestration), a positive image for the Government and manufacturer and responsibility for our limiting supply of resources. (p. 8). Cost Analysts are the primary party responsible for creating the Life Cycle Cost Estimate (LCCE) or the Total Ownership Cost (TOC) for a weapons system or program. In a 2011 brief by Paul Yaroschak he details the need for better Total Ownership Cost estimates and a more consistent and practical methodology for incorporating sustainability into life cycle cost (p. 3).

The foundation and work horse of any good cost estimate is data collection – a model or estimate is only as good as what you put into it (CEBoK, 2013). In order to evaluate the cost savings associated with sustainable manufacturing, analysts and estimators need to do a better job of collecting the necessary data. Since currently there is not much data available this will present a challenge and will require working with the prime contractor and tiered suppliers to gather the necessary information in order to perform the analysis.

During the analysis period the analyst needs to be cognitive of the implications of sustainability and how it influences the entire life cycle of the system, and how to properly include it in the estimate and supporting documentation. Additional research is needed to fully understand how to quantify these tangible and intangible benefits.

This paper is just a scratch on the surface regarding the topic of sustainable manufacturing within the Department of Defense. There is a plethora of research and future work that can and needs to be conducted on this topic. Hopefully, this paper will serve as a starting point for discussion and consideration of the DOD including sustainable manufacturing in their future policies and requirements for weapon system acquisition. The benefits are great, but there needs to be a better understanding and methodology of how to successfully implement practices that will benefit the OEM, Government, and American taxpayer.

In conclusion, more attention is needed on sustainable manufacturing in the sustainability guidance set forth by the individual service branches and the Department of Defense. The cost analysis community has an important role to play in assisting with improving the way data is collected and used to understand cost avoidances and how these cost savings can correctly be incorporated into the Total Ownership Cost of the system. However, cost effectiveness should not always be the overriding criterion for switching to sustainable manufacturing practices, other criteria include improved environmental awareness, employee morale and community relationships. As protectors of the United States, and its interests both foreign and domestic, the Department of Defense has an obligation to conserve, protect, and be good stewards of our natural resources and environment for future generations of Americans.

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