Renewable Energy Case Challenge

Stephen Cannizzaro was looking out the window across the river near his large manufacturing plant in the heart of Scranton, Pennsylvania. "We've been consistently applying sustainability practices to all aspects of plant operations," he thought, "including energy efficiency, recycling, and water conservation. Our plant has become a sustainability leader and a great example for manufacturing installations of all types and sizes. But we still use a huge amount of energy generated by fossil fuel to meet our production needs. I wonder how much we could reduce our greenhouse gas emissions by using renewable energy?"

Background

Mr. Cannizzaro's plant is owned by the US Department of Defense and operated by his company, General Dynamics (GD), a longstanding government contractor. The plant is located on 14.2 acres in the heart of downtown Scranton, the largest city in the Scranton/Wilkes-Barre metropolitan area, with a population of about 76,000. The plant's capabilities include metal forging, heat treating, machining, finishing, as well as some research, development, testing, and evaluation.

The GD plant provides considerable employment and community support to the area. With a staff of 250 it is the area's largest employer. It also consumes a huge amount of energy; about one-tenth as much as the entire city of Scranton. Its water effluent can have a major impact on the water quality in nearby rivers, which feed into the Chesapeake Bay. Its facilities total over 500,000 square feet and occupy landmark buildings originally built in 1907 that are part of an historic district (see photo 1). The plant operators take great pride in its national significance and historical setting, and regularly work to preserve and protect the natural and built environment in which it resides.

GD faces significant challenges in incorporating sustainability initiatives into its urban industrial setting. The plant is so close to residential and commercial buildings that space to expand is limited, and GD must largely work with the existing infrastructure. It must also be mindful of established standards for historic buildings. In addition, the lack of surrounding green space means the installation has to come up with innovative green solutions to include as part of its sustainability plan, its commitment to the community, and to environmental stewardship.

Recent Sustainability Initiatives

GD has made environmental compliance and conservation a key part of modernizing its facility. During the past several years, the company has introduced several key technologies and best practices to increase energy efficiency, reduce and reuse water, improve air emissions in its production facility, and reduce hazardous materials in production. Furthermore, it has participated in multiple Chesapeake Bay initiatives, maintained an active recycling program, and continued to promote green procurement in the installation's acquisition process. For its efforts, the plant has achieved certifications for environmental and energy management systems.

Energy Conservation and Utilities Savings

GD's efforts to promote energy conservation and efficiency at the plant include: Extensive refurbishment of its furnaces (see photo 2) have yielded a 25% reduction in natural gas consumption, moving the plant toward reaching its greenhouse gas reduction goals; Modernization of its forge presses (see photo 3) have lowered its electrical intensity and resulted in a 15% reduction in utilities costs; Modernization of its boilers (see photo 4) have reduced natural gas consumption by 20% and brought about an overall 30% reduction in greenhouse gas emissions.

Water Conservation and Reuse

GD has installed a large rainwater collection system using facility roof space (see photo 4). Thousands of gallons per year of rainwater are captured and diverted to large storage tanks and tapped for cooling water for production operations. This allows the facility to reduce the demand for city water and lessens storm water discharge. Since installation, GD has reduced expenses for city water, chemical treatment and city sewer discharge by tens of thousands of dollars per year.

Another ongoing initiative is reducing wastewater discharge to the municipal sewer authority by installing a filtration system that allows the facility to successfully recycle all its wastewater and re-use it for the facility's cooling system. This system saves million gallons of oily wastewater from the forging operation. Hundreds of thousands of dollars in total economic savings have been realized from this sustainability investment. Environmental benefits include the reduction in municipal water used for cooling towers and reduced volumes released to the municipal sewer and potable water supply.

In addition, GD SCAAP has been an active participant in local, regional, and Army efforts aimed at preserving the Chesapeake Bay.

Material Substitution, Elimination, and Recycling

GD's solid waste management program aims to divert, reuse, and eliminate materials wherever possible in its operations processes. Materials recycled include steel, mixed metals, scrap wood, wood pallets, lead-acid batteries, miscellaneous equipment, chemical constituents, cardboard, paper products, and electronics. Proceeds from recycling are used to support and maintain the facility's recycling program. In addition to traditional recycling, GD continues to invest in technologies to minimize the total waste stream and allow for improved collection of recyclable byproducts.

As part of a pollution prevention program, GD also introduced state of the art technology to reduce the amount of paint and solvent required to apply protective coating to its metal products. This greatly reduced the facility's overall emissions of regulated volatile organic compounds from the coatings operation.

Case Challenge

The plant executives now want to examine the feasibility of significantly lowering green-house gas emissions by creating renewable energy sources to reduce the plant's current reliance on fossil-fuel generated energy. You are asked to recommend the best mix of renewable-energy options to meet the executives' goals. To inform and support your recommendations, please consider the following:

Plant Energy Requirements

The plant currently purchases about 40,000,000 kilowatt hours (40,000 MWh or 40 GWh) of electricity from the "grid" each year. The cost of energy plus transmission fees total about $4,900,000 per year, which averages to about $0.12/KWH).

It also consumes 3,500,000 ccf (100 cubic feet) of natural gas, equivalent to 358,000 MMBTUs (million BTUs) of natural gas, at $0.53/ccf. This equates to an additional 1,025,749 KWH of energy used at an average cost of $0.16/KWH (using a conversion factor of 1 ccf to .293 kWh, or 3412 BTU to 1 KWH).

NOTE: For the purposes of the case, here we are only considering the electricity requirement.

Potential Renewable-Energy Options that the Plant Could Use:

1. **Installing solar panels a) on or b) near the facility site**
2. **Constructing wind turbines a) on or b) near the facility site**
3. **Installing a) a small-sized or b) a medium-sized low-impact hydroelectric generation system in a nearby river (the Roaring Brook)**

The table below shows for each source:

A) The system's size ("Nameplate MW")
B) Installation costs per watt
C) Total installation costs
D) Acres of space required for installation
E) Time to build the system (considering all factors)
F) The capacity factor reflecting percent of time the system actually generates electricity
G) The annual amount of energy actually generated in KWH
H) The percentage of current plant energy needs the system would meet
I) The delivered operating costs per KWH of the system
J) The energy cost savings per year
K) The metric tons of CGH gas (CO_2) emitted per year
L) The metric tons of CGH gas (CO_2) *reduced* per year by the renewable option.

It is important to note that many of the GD plant's production processes (e.g., forging) require a continuous and 100% reliable supply of energy. Some of the renewable energy options only produce energy intermittently (e.g. when the sun is shining or the wind is blowing). Further, space limitations at GD's site mean that it may need lease nearby land to install some of the larger renewable-energy systems, and build transmission lines to its facilities. Such expenses are already factored in to the total system construction costs shown in the table.

Which renewable energy options do you recommend (you may choose whichever and as many as you think are advisable)?

Data Table for GD Renewable Energy Decisions

[See notes and links below table]

Type of System	System Size (Nameplate MW)	Cost per watt Installed	Total Cost	Space Required	Time to build	Capacity Factor	kWh Used / Produced	% of plant needs	Price per kWh	Delivered cost of Electricity	Cost Savings per Yr.	Metric tons of CO_2 Emissions per Yr	Annual metric tons CGH Reduced
Plant's current electricity use (Grid-supplied)							40,000,000		0.12	$4,920,000		27,571	
Solar Photovoltaic													
On-site Solar PV 1MW	1	$3.45	$3,450,000	5 ac.	6mos	14%	1,226,400	3%	0.11	$138,000	-$12,847	42.27	-803
Off-site Solar PV 5MW	5	$2.60	$13,000,000	25 ac.	1 yr	14%	6,132,000	15%	0.12	$722,356	-$31,880	211.33	-4,015
Wind													
On-site Single Turbine	1.6	$1.15	$1,840,000	10 ac.	3mos	25%	3,504,000	9%	0.02	$73,600	-$357,392	120.76	-2,294
Off-site Five turbines	8	$1.05	$8,400,000	50 ac.	1yr	25%	17,520,000	44%	0.05	$914,160	-$1,240,800	603.80	-11,472
Low-Impact hydro													
Small System Off site	1	$1.95	$1,950,000	10 ac.	1-2yrs	92%	8,059,200	20%	0.04	$343,954	-$647,328	277.75	-5,277
Medium System Off site	4	$1.95	$7,800,000	40 ac.	1-2yrs	92%	32,236,800	81%	0.04	$1,375,814	-$2,589,312	1,111.00	-21,109

NOTES FOR TABLE COLUMNS

Type of Renewable Energy System

Solar PV Systems [see photos 6 & 7]

Sources: http://newscenter.lbl.gov/news-releases/2013/08/12/installed-price-of-solar-photovoltaic-systems-in-the-u-s-continues-to-decline-at-a-rapid-pace/; http://solaresystems.com/faqs.

Based on the 15.3 acre size of the property, we assumed a 1 MW solar array could be created by covering parking lots and open space, using 4.8 acres (based on the NC SAS solar farm fact sheet). A 5 MW array, requiring about 25 acres, would need to be off-site. Leasing and transmissions expenses are factored in to total costs.

Wind Turbines [see photo 8]

Sources: Pennsylvania Mehoopany Wind Farm Completed, http://cleantechnica.com/2013/01/14/pennsylvania-mehoopany-wind-farm-completed/; http://en.wikipedia.org/wiki/Wind_power; http://www.pawindenergynow.org/wind/facts.html

Studies show excellent wind potential in the Scranton area. Based on the 15.3 acre size of the property, we assumed a single 1.6 MW turbine could be erected on site. A 5-turbine, 8 MW wind farm, requiring about 25 acres, would need to be off-site. Leasing and transmissions expenses are factored in to total costs

Low-Impact Hydroelectric Systems

Sources: http://www.brookssolar.com/microHydro.asp; http://www.exeloncorp.com/energy/generation/hydro.aspx; http://www.lowimpacthydro.org

The nearest river to the DG facility, *the Roaring Brook*, has excellent hydroelectric generation potential. *Building a new damn is NOT being considered*. This option assumes there are *existing dams* on this river that can be adapted for hydroelectric generation (see Photo 9), or *new "run of river" systems* can be installed (involving short bypass pipes through which some of the river's water runs and drives turbines to produce electricity; see Figure 1). There are thousands of hydropower dams in the United States located on many of our most important rivers and streams. These dams can create pollution-free energy, but they can also produce significant adverse impacts on fish and wildlife and other resources. Run-of-the-river hydroelectricity (ROR) projects are dramatically different in design and appearance from conventional hydroelectric projects. Traditional hydro dams store enormous quantities of water in reservoirs, necessitating the flooding of large tracts of land. In contrast, most run-of-river projects do not require a large impoundment of water, which is a key reason why such projects are often referred to as environmentally friendly, or "green power."

Certification program help identify hydropower dams that are minimizing their environmental impacts. Such certification can help facilitate construction permitting. In order to be certified, a hydropower facility must meet criteria in eight areas: river flows, water quality, fish passage and protection, watershed protection threatened and endangered species protection, cultural resource protection, recreation, and facilities recommended for removal. We believe the options considered here would not encounter problems in securing certification.

Sizing energy generation systems and estimating capacity

Generating facilities are typical sized in MW, called the "nameplate capacity," i.e., the capacity of the system at peak production per hour. The power produced is typically cited in kWh (kilowatt hours); 1000 kWh equals 1 MWh (megawatt hour). It's important to recognize, however, that different systems have different "capacity factors," based on when they can generate power and how much. A conventional power plant is typically operating at about 90% of capacity (based on maintenance, etc.), while a solar system rarely gets more than 15% of its rated capacity (based on sun hours, angle, etc.). A wind turbine is typically capable of producing 25% of its rated capacity, and a hydroelectric facility as much as 92% (based on the fact that it is normally operating 24/7, unless the water source is frozen or the flow diminished).

Cost Estimates

Costs are best-guess estimates

Time to build

Estimates the time needed to obtain leases, construct the system and transmission lines (if needed), and secure regulatory approval.

Greenhouse Gas Emissions

1. The figure of 27,571 metric tons of GHG emissions was calculated using the EPA calculator (http://www.epa.gov/cleanenergy/energy-resources/calculator.html)
2. Emissions calculated on the basis of .000069 metric tons of CO2 per KWH
3. The lifecycle GHG emissions of renewables, whether solar, wind, or hydro, were estimated at 1/20th of the amount for grid-supplied electricity, as per the NREL fact sheet.

See illustrative photos and figures on next pages

Photo 1: Arial view of GD Scranton facilities (November 2007).

Photo 2: Erie 1 Rotary Hearth Furnace

Photo 3: Erie 1 Forge Press Line

Photo 4: Keeler Boiler

Photo 5: Array of SCAAP Rainwater Collection System.
From top left – Rooftop collection basins.
Top Right – Collection storage tanks.
Bottom – Plant view of collection system in production area.

Photo 6: Solar canopies in parking lot

Photo 7: Solar farm (Bradford 5 MW farm):

Photo 8: GE 1.5 MW Wind turbines

Photo 9: Low-Impact Hydro on existing dam
Milford Hydroelectric Project, on the Penobscot River, ME (certified low-impact — http://www.lowimpacthydro.org/lihi-certificate-113-milford-hydroelectric-project-on-the-penobscot-river-me.html)

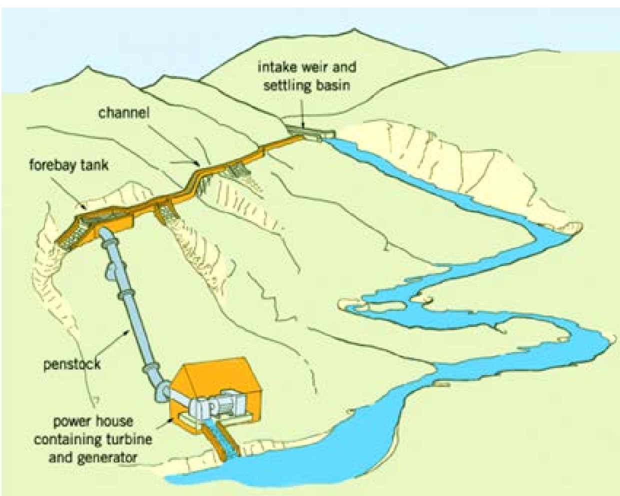

Figure 1: Run-of-river hydro (http://www.worldwatch.org/hydropower-central-america-renewable-sustainable-and-without-alternatives)