mechanical engineering

DESIGN

efficiency is its own reward

by Jeffrey Winters, Associate Editor

Building a green factory was intended to be a neighborly gesture, but it wound up making fundamental business sense.

It isn't difficult to focus on the dark clouds hovering over the American manufacturing sector. The United States has lost millions of manufacturing jobs in the past five years, and its trade deficit in manufactured goods runs into the billions every year.

Economists like to talk about nations exploiting their relative advantages—factors such as proximity to market or cost of labor. And in a world that's increasingly knit together by long-distance communication and containerized shipping, it is harder and harder to justify making things in the United States.

The answer to this line of reasoning, however, is about to be completed just northeast of Dallas. Texas Instruments calls it the RFAB. It is a state-of-the-art semiconductor factory that TI is building. When fully operational, the $3 billion fabrication plant will make TI's most advanced digital signal processors, destined for cell phones, disk drives, and anti-lock brakes.

These long, straight ducts and pipes below the clean rooms carry utilities and waste more efficiently than smaller, curved pipes

"One of the keys to getting it built in the U.S. was cutting back on capital costs," said Paul Westbrook, a mechanical engineer who is the sustainable development manager at Texas Instruments. And it turned out that energy efficiency and environmental friendliness were in harmony with slashing capital costs. From the point of view of Texas Instruments or any company, it doesn't really matter where manufacturing takes place. In a global free market, the important thing is to get the highest quality product for the lowest cost. Thanks to technological advances in Asia over the past two decades, facilities in China, Korea, or Japan can turn out high-tech devices that are virtually indistinguishable from those made in the U.S. or Europe. And with labor and construction costs running at a fraction of those in the West, the lion's share of recent fabrication facilities have been built in Asia.

Profits at Home

The challenge for Westbrook, then, was to make it profitable for TI to build near its Texas hometown.

The first order of business was trying to find a way to bring down capital costs—to make the entire plant cheaper to build. "That's what most companies are concerned with," Westbrook said. "But once we started tackling that, we realized that if we were going to be redesigning this fab and really thinking about everything, then we also would need to be sure we're thinking about operating costs at the same time."

The white roof of the RFAB (above) under construction in Richardson, Texas, reflects away some 85 percent of incoming sunlight, reducing cooling loads. Daylight reflected off of window shelves in the administrative wing (below) reduces the need for artificial lighting, while the Ergolights hanging from the ceiling are designed with sensors and will shut off automatically when no one is in the office.

For instance, there was an intense effort made at cutting cooling loads, which are a major factor not only in operating costs, but in upfront capital costs as well. After all, the more heat you need to remove from the environment, the more ventilation equipment and chillers you have to install. After a while, building the space to house the mechanical systems becomes expensive.

So Westbrook and his team looked at every area where they could cut sources of heat. The largest, in a sense, was the roof. The building covers 220,000 square feet, or five acres. And the relentless Texas sun irradiates that area with an average of nearly 100 megawatt-hours of energy a day. To combat that, the TI team designed a roof covered with an enormous white plastic sheet. The membrane reflects away about 85 percent of the incoming radiation, which could make for more than a 20° difference on a hot summer's day. "We cut over 100 tons of cooling just from our roof reflectivity," Westbrook said.

Another area where incoming heat was eliminated was in the windows, which were designed not only to help insulate the building, but to provide as much natural daylight as possible to the interior. That's of critical importance, because lighting is one of the largest sources of heat inside an office; a typical office environment generates about one watt per square foot just from lights.

Shelves in the windows reflect natural light from the windows deep into the interior of the building. Special sensors adjust the artificial lighting to account for that reflected daylight. Other sensors keep track of whether a room is occupied, and shut off some of the lights when no one is there. Westbrook said that he actually had the lights go out on him when he worked in an office equipped with such a system, "but I leaned away from the computer screen and they popped back on."

By keeping the need for lights to a minimum, Westbrook's team was able to reduce the heat from lighting by a factor of four.

Making It Cost Effective

There are dozens of other clever little things that the team thought up—from micro-hydroelectric turbines in the bathroom drains to using solar panels to help heat water—and no one thing contributed enormously to driving down cooling loads. "But if you keep finding 50 tons of cooling load here and 100 tons there," Westbrook said, "what happens is that it eventually added up to one entire 1,600-ton chiller that we didn't have to buy.

"The way you make it cost effective is that you make a conscious decision to spend that million dollars on the roof and the windows and so on. And you eliminate that chiller, so that net capital cost is pretty much a wash—and you have a perpetual operating savings. Plus, taking into account that we knew in advance we needed one less chiller means we had to build less space for the mechanical plant. When you start adding in those savings, you may actually find that you made a little profit on the capital side and you've lowered your operating costs."

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Other efficiencies played a part in driving down costs. Relying on water too impure for wafer manufacturing to run the cooling system and rainwater to irrigate the landscaping helped drive down water usage. Fly ash was used as aggregate in the concrete—with the added benefit of making the material more durable.

Although Westbrook confesses that very few of the designs in the building are groundbreaking, it's rare to see them incorporated in any building on this scale, let alone one with manufacturing as its primary function.

"One reason we don't do more things like this is that we are too myopic when we're doing our payback calculations," Westbrook said. "We stop too early." For example, his team used heat recovery from large air compressors and chillers, which helped eliminate five boilers. Not only did this reduce energy use, but it also cut back on the plant's emissions. "The emissions were gravy," Westbrook said, but it's just the kind of savings one can uncover in the pursuit of efficiency.