Site Environmental Sustainability Achievements at Avago Technologies, Fort Collins, CO

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ABSTRACT
Despite the intense use of chemicals, energy, and water associated with wafer manufacturing and the exacting requirements for control, fabs can reduce inefficiencies and reduce their impact on the environment. This paper explores some of the ways this can be accomplished.

INTRODUCTION

Avago Technologies Ft Collins strives to find ways to lower its impact on the environment as a result of fab operations. It is important to behave responsibly not only with respect to local impacts on our community but also to preserve the environment in general whenever possible. Avago employees live in the community of Fort Collins and want to be good stewards of the local environment. This responsibility is managed by the Work Place Services Group (WPS) with the support of Manufacturing Management.

Those who embark on this path must obtain that support because all projects to improve sustainability require two valuable resources - time and money. Management support and focus also provides motivation for individual contributors by the assignment and acknowledgement of projects or process improvements and the associated results. Given time, individuals see the merit in putting forward ideas of their own which further promotes progress and can result in the creation of a list of projects that can be prioritized and completed as time and money become available.

Management of Programs

Avago facilitates the development of ideas and manages progress through our Pollution Prevention Team (P2) which is sponsored by the Manufacturing Manager and Chaired by the WPS manager and meets monthly. Through this team assignments are made to design solutions and/or to implement ideas.

Focus has been separated into four major areas:

Reduction of hazardous waste
Reduction of energy consumption
Reduction of water consumption
Reduction of solid waste heading to our landfill

Avago also uses the EHSMS (ISO 14000) management system to track significant aspects and associated resulting projects or process improvements. This system of organization is essential to placing some rigor to the many reporting requirements manufacturers have and the improvements that can be made to either meet or exceed regulations as determined by local jurisdictions. Avago strives to ensure we meet the basics of regulatory reporting through process control and then goes beyond this through project identification to improve our sustainability each year.

As an example; our permit allows a certain amount of Arsenic to be released into our waste water stream (in the ppb levels) but our goal is to release zero. We have identified and implemented processes that help us achieve this goal. In the matter of release of hazardous byproducts, zero is a good number regardless of legal limits.

In addition to the utilization of the EHSMS system Avago created an Environmental Sustainability Report based on the widely accepted GRI (Global Reporting Initiative) index. The advantages of creating this report are as follows. First, it forces the consolidation of all efforts into one place in order to create the report. Second, it forces a look from outside through the eyes of NGO's and environmentally-minded individuals to ensure that you have not gotten stuck in an activity trap but can show real results and real improvement. Use of the GRI forces a rigor that otherwise would not be created. Creating this report each year forces a look backwards to assess effectiveness.

Prioritization of projects

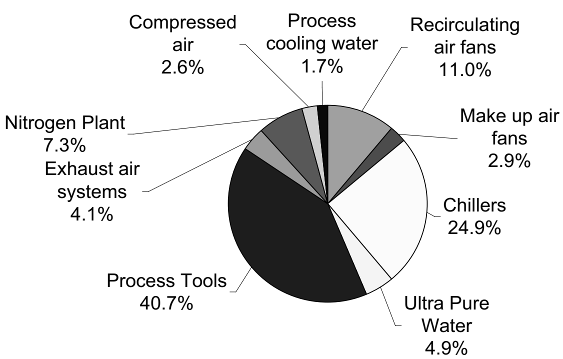
Avago's method of prioritization has been to look at those projects that have the greatest return on financial investment and fit with in the budget, believing that impacting both budgets and the environment are the most efficient and usually end up saving the most resources. This method of prioritization has resulted in a focus on projects in the following order:

- Recycling of solvents (that would otherwise have become hazardous waste)
- Energy efficiency or reduction of wasteful consumption
- Water efficiency
- Reduction of solid waste
- Renewable energy

To date, reductions in wasteful practices have been far more cost effective (highest reduction in use of natural resources) than has the more popular renewable energy solutions.

In contrast, one could look at data showing the largest pareto items and attempt to beat down that category or the top few in the hopes this would provide the biggest gains. Fig. 1 would suggest that attacking fab tools would be the highest priority. This category proves to be much broader and much more complex as well as being somewhat "hands off" for fear that one might spoil the recipe by changing processing. Despite this, by breaking this category down Avago has identified load lock pumps as an item within this category that can be attacked by replacement of older pumps with new more efficient models. This will be a long slow change over ten years which can run on its own once set up as a standard.

Fig. 1 Contribution to total electric consumption in fab facilities by system.



This is not to say that everything Avago does has to have an ROI. Most solid waste recycling and composting for instance does not have any appreciable return yet we continually strive to increase ways to not only reduce the amount we use but look for opportunities for reuse and only use recycling as a last resort. The overused adage that one man's waste is another man's gold turns out to be true.

A brief overview of our focus by area follows.

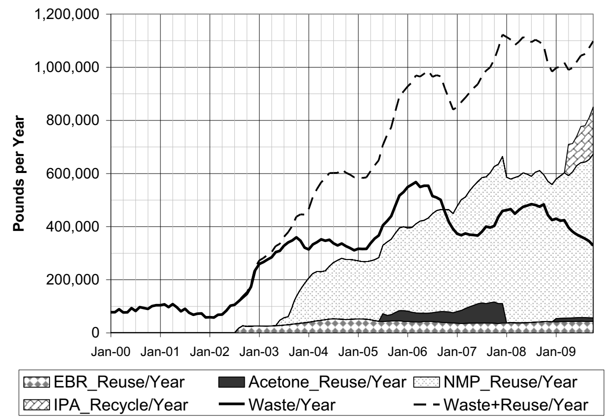
Reduction of Hazardous Waste:

Avago continually strives to increase both the types and the amount of chemicals / byproducts recycled. To date solvent recycle systems constructed include: EBR, NMP, and Acetone.

IPA recycle has proven to be complicated and as a final clean, undesirable. Instead, used IPA is collected and sold to a second source whose purity requirements are not as stringent as those of the IC industry. Fig. 2 below shows the amount of each of the solvents we recycle and the progress made in recycling each of them.

At this point Avago is saving approximately $1.7M per year in solvent purchases as a result of this recycle effort. The cost of these systems is approximately $200K each and there are 4 systems.

Fig. 2 Solvent Waste Shipped vs. re-used 2003 to 2009 in pounds per year



Spent sulfuric acid can be used as a source chemical in waste water treatment systems in order to avoid buying virgin chemical.

Vendors exist that will extract metals like Gallium, Copper, and Gold from waste streams, thus keeping this material from being incinerated or land filled. Reclaimed metals can be returned for reuse indirectly as those materials make it back to high purity metal suppliers.

As a result of these efforts Avago now uses about 75% recycled solvents in our process instead of buying new material that we must then dispose of. The goal is to get to 95% over the next few years.

Reduction of energy consumption

This focus area is concerned with usage of electricity and natural gas. Avago looks for opportunities to increase efficiencies of operation, shut off systems, and take advantage of energy already generated for secondary uses. Through this emphasis Avago has been able to identify sustained year over year reductions in consumption. Through a long slow road of electrical savings, multiple projects have been able to reduce electrical consumption by 2% per year for the last 5 years (Fig. 3). Reductions in natural gas consumption by 20% over the last 3 years have also been achieved through multiple projects (Fig. 4).

Reduction of water consumption

This focus area is concerned with usage of domestic and irrigation water. We look for opportunities to lower water usage via fixture replacements or by seeking opportunities to reuse water before sending it back to our municipal supplier. Over the last 4 years we have been able to reduce water consumption by 20%. Examples of these projects are listed in Fig. 5 below.

Fig. 3 Electric consumption Jan 2005 to Dec 2009 in KWh per month

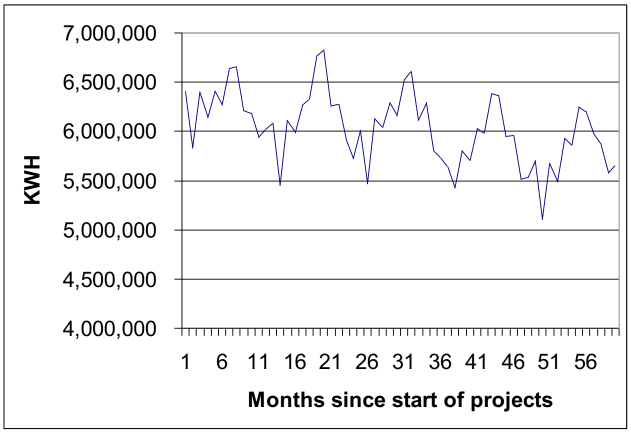


Fig. 4 Natural Gas consumption Jan 2007 to Dec 2009 in DTh per month

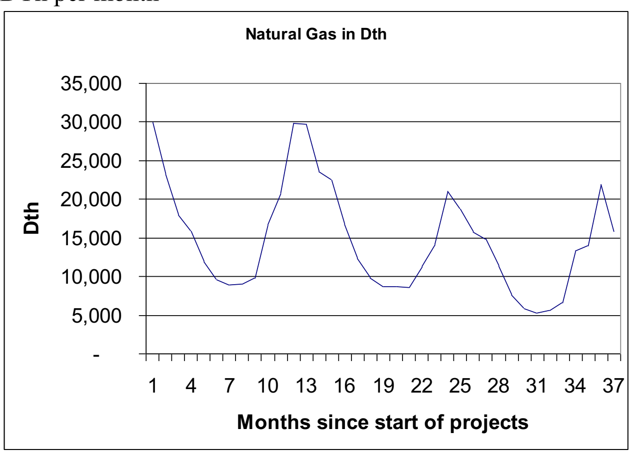
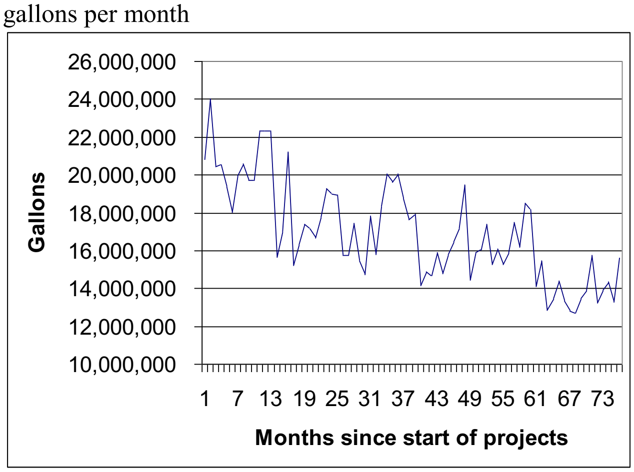


Fig. 5 Water consumption Sept. 2003 to Dec 2009 in gallons per month



Reduction of the amount of waste heading to our landfill

This is a broad area that encompasses many activities and is best described by the individual solutions we have listed below. Our current diversion rate is 77% and rising due to the diligence of our employee Green Team and support from our facilities and procurement teams.

Solid Waste

1. Started getting actual weights on trash dumpsters to more accurately calculate our diversion rate.
2. Implemented plastic bag recycling.
3. Composted 12,131 pounds of food waste and restroom paper towels.
4. Replaced all battery operated paper towel dispensers (~80) with manual dispensers.

Other Efforts

1. Created our first Environmental Sustainability Report. Report focuses exclusively on Fort Collins Fab facility and reports on activities in 2006 and 2007. Each year from here forward we will add each year's results to the report to show our long term progress.
2. Replaced 88 sq. ft. of blinds with energy efficient shades. R-Value 7.86 SHGC rating - 1.5. UV blockage 99%

Following is a brief listing several projects completed over the last few years that show capital outlay and annual savings. Savings were calculated with that year's energy costs. Given the rising cost of energy, these projects will look more and more attractive in the coming years.

Feed CDA from Building 4 (B4) to Building 2 (B2)

- Combined two separate Compressed Dry Air (CDA) systems into one. B4 has two 350 HP compressors and B2 has three 150 HP compressors
- Installed 700' of 4" pipe through a connecting tunnel to connect the systems together
- B2 system is still functional to provide safe supplies (N+1) but is removed from full time service due to lower efficiency than the B4 compressor rack.
- Project utilized the Platte River Power Authority (PRPA) Energy Efficiency Program (EEP) to supplement the installation cost and improve the ROI.
- Project Cost $46K and saves 471,000 KWH or $20K annually

Feed Process Vacuum from B4 to Buildings 2 and 1

- Combined three separate process vacuum systems into one. B4 has two units that were designed to handle more load than we ended up having. B2 had 4 units and B1 had 3 units using 55 KW peak load.

- Ran 1400' of pipe through a connecting tunnel into B2 and then on into B1
- Project utilized the PRPA EEP to supplement the installation cost and improve the ROI.
- Project Cost $37K and saves 481,000 KWH or $20K annually

B2 Free Cooling Process Cooling Water Loop 1
- Utilized existing cooling tower for off season free cooling.
- Install new 300 ton heat exchanger and sand filter, and pump header to connect in free cooling
- PRPA EEP funded to improve ROI. (approx $42K)
- Project cost $175K and saves 750,000 KWH or $32K annually

B4 Free Cooling
- Utilized existing cooling tower for off season free cooling.
- Installed new 600 ton heat exchanger, sand filter and pump.
- PRPA EEP funded to improve ROI. (approx $54K)
- Project Cost $165K and saves 1,070,000 KWH or $46K annually

B1 Free Cooling
- Utilized existing cooling tower for off season free cooling
- Install new 600 ton heat exchanger and sand filter
- PRPA EEP funded to improve ROI. (approx $48K)
- Project cost $150K and saves 700,000 KWH or $29.4K annually

B2 Free Heating
- Utilize existing chiller reject heat to heat up our incoming water to 70 deg before cleaning it up and using it in the fab as Ultra Pure Water. Incoming water varies between 38 and 50 deg F.
- Install new heat exchanger and pipe
- Project cost $14K and saves 32,850 MMBTU or $350K annually. This represents almost 2,000 Tons of CO_2e per year.

B4 Heating water boiler right size
- Provide matched boiler capacity to meet the base load and average demands without using the two 800 boiler-horsepower boilers to meet N+1. The large boilers were experiencing failures due to very frequent on off cycles. Base load is less than 50 boiler-horsepower and average is about 140
- Provide controls to switch over and only utilize large boilers in the coldest conditions when full 800 hp are needed.
- Utilize 200 hp steam boilers to create a small steam loop to heat water. Installed a new steam to water heat exchanger, de-aerator and pump to provide base load heating
- Project cost is $220K
- Annual savings $21K in electricity due to changes in pumping strategy and $12K per year in Nat. Gas. It also saves $8K per year in maintenance and reduces repair costs.

B4 Base Load Chiller
- Building 4 utilizes two chiller systems to provide chilled water and glycol chilled water
- Both systems utilize chillers that are oversized for the base load
- Move 500 ton chiller from glycol system to chilled water system to support CHW base load
- Purchase new 350 ton chiller and pump to support glycol system base load
- Project cost $270K, will save 680,000 KWH or saves $40K total including $4K in maintenance. (6+yr ROI !)
- Costs have gone up extensively since this was defined and approved. Piping came in at 2X expected despite several discussion on how to reduce scope. Chiller and pump also came in high.
- PRPA EEP funded to improve ROI. (approx $44K)

B2 Heating Plant Reconfiguration
- Project reduced operational costs for natural gas and electrical energy usage and electrical peak demand. It does this by improving the efficiency of the B2 heating plant during minimum load conditions, which occurs for more than 4200 hours/year. The yearly energy savings is about 7,220 dekatherms of natural gas, and about 175,000 KWHs per year. This represents about $81,000/year. There will also be a reduction of maintenance costs by about $3,100/year.
- Project cost was $230K
- We now operate one load-matched condensing boiler where two over-sized boilers were needed (one steam and one hydronic), thereby increasing overall system efficiency by about 10% during the warmest 3200 hours of operation.
- This also reduced load on the campus heating loop due to reduced pipe losses due to reduced loop temperature.

Water Projects
- Convert B4 Vertex scrubbers to acid waste water, saving 10GPM or 5M GPY and saving 19.3K per year.
- Acid waste water to B4 scrubber makes up saving 12 GPM or 6.3M GPY and saving $34.7K per yr.
- Acid waste water to B4 scrubber make up saving 18 GPM or 9.5M GPY and saving $34.3K per year

- RO reject to RO feed water tank saving 60 GPM or 31.5M GPY and saving $114K per yr.
- Reprogram B4 tower water sand filter to pressure not time, saving 3 GPM or 1.6M GPY and saving $1.4K per yr.

Miscellaneous Projects

- Use chiller reject heat to preheat incoming water before sending through RO units. Installed a heat exchanger and intercepted both the chiller tower water line and the incoming industrial water line. Project cost only $14K to complete because we owned the exchanger and saves us $350K per year in natural gas costs.
- Replaced most of our urinals and water closets with the lowest flow units we could find that fit our existing piping racks. Cost was $32K for 123 fixtures and saves around $8K per year depending on site occupancy.
- Placed timers and motion sensors in a host of support locations through out our facility (basements, mezzanines, utility rooms, etc) where people traffic is limited. Cost was $12.5K and saves about $28K per year.
- Turned off a CRAC unit in a computer room and instead use house air. This allows utilization of the more efficient chiller and takes advantage of winter time free cooling discussed above. Cost was $3K and savings is estimated at about $4K.

In addition we have upgraded lighting, placed variable frequency drives (VFD's) on fans and subsequently turned them down to match actual need, upgraded fan seals on transfer fans, eliminated gas bottle coolers and instead used house chiller water, widened temperature objectives in support areas and even in office areas, and created winter set points and summer set points. All these projects save energy and have ROI's that are less than 3 years. Most projects have less than one year and some are virtually free if one has a building automation system.

Conclusions

Despite the very exacting controls fabrication facilities must operate under in order to make good die, there are many opportunities available to reduce the footprint. Senior management directives in this area are essential to making real progress despite the fact that many opportunities exist in most facilities. The concepts are not difficult and the applications can be very easy to implement. The most difficult step seems to be in making the leap from viewing sustainability as a bothersome diversion that requires lip service so it can be included in marketing brochures to an acknowledgement that being sustainable is good for the bottom line as well as for the environment. Fabs that engage in this activity will improve their bottom line. Fabs that engage in this can have huge impacts on their community as well. Typically energy and water saving project results can be listed in terms of having saved energy equivalent to the annual usage of dozens of average homes and it is not hard to rack up numbers that equal hundreds of homes' worth of savings.

It is unfortunate that many fabs limit their ROI tolerance for energy saving to 1 year or less payback. While it is likely that many projects can be found that fall into this constraint, it does prevent larger projects from being developed and thus larger savings from being realized.

With the proper focus on sustainability and long term perseverance fabrication facilities can expect to realize 10% to 20% reductions in their impact on the environment and an equal reduction in the cost of their energy costs within a decade.

ACKNOWLEDGEMENTS

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ACRONYMS

CRAC – Computer room air conditioner
EBR – Ethyl Lactate
DTh- Decatherm - heat equivalent to 100,000 BTU
N+1 – Number of units required to service need plus one extra in case of failure or maintenance
NGO – Non-governmental organization
NMP – N-Methylpyrrolidone
ROI – Return on investment
SHGC - Solar heat gain coefficient
UV – Ultraviolet (light)
VFD – Variable Frequency Drive