ISMI Conference October 2006 - Abstract

Title:	Worksheet Used to Identify Energy Conservation Opportunities
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Purpose:

The purpose of developing this worksheet was to improve the energy efficiency of future Applied Materials' products by adding consideration of equipment energy consumption to our product life cycle process. Reducing energy consumption is clearly of interest to many Applied Materials' customers, and reduced energy consumption is becoming more valuable as a differentiator for Applied Materials products. Increased regulatory interest, higher energy costs, and the higher cost of capital equipment required to provide basic utilities in a facility are all increasing industry focus on energy consumption. Energy consumption is now frequently included in equipment specifications, often by requiring compliance with SEMI™ S23-0705, the semiconductor industry standard for equipment energy conservation.

Design processes have not historically required consideration of energy consumption in the product specification and early design phases. The analysis tool described by this paper is a worksheet which leads design teams (users) through a process for setting energy consumption goals for a new product or the improvement of any part thereof. This provides a method for considering energy consumption and for setting consumption goals within the process. The process and worksheet satisfy, in part, the SEMI S23 requirement for an energy consumption continuous improvement program.

Description of Approach:

The worksheet is an interactive tool. The user enters wafer size, throughput, and utility consumption information for a predecessor product (if any). Embedded calculations convert consumption in engineering units to annual and per-cm^2 equivalent electrical usage. Default SEMI S23 assumptions are used in calculations, but they can be modified.

The user is asked to look for aspects of the new product design in which energy consumption can be reduced. Suggestions applicable to a wide range of products are built into the worksheet. After opportunities are identified, the user enters wafer size, throughput and utility consumption estimates for the new product.

Energy consumption results for the new product are displayed alongside those for the predecessor equipment. The results of design tradeoffs are seen immediately and directly represent energy costs. Finally, the user must state an energy consumption goal for the new product as an absolute value or as a percentage change.

Stakeholders who require energy improvement (perhaps a product EHS group in the company) and those who are asked to deliver the improvements (typically the product design group) all sign the worksheet to acknowledge the common goal of improvement.

Evaluation of Results:

Applied Materials has recently launched a worksheet of this design internally. While it is still too early to present definitive data on how effective the worksheet has been, it is clear that it has, in general, raised awareness of customer interest in energy efficiency within our design groups and provided some paradigm shift in design focus. Examples can be provided of some typical worksheet entries and process considerations.

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Highlights from an Example Energy Conservation Improvement Worksheet

Table 3 – Energy Efficiency Improvement Analysis

Component, Module or Service	Present on this System?	If Yes ▶	Description of High-efficiency Alternate (if available)	Decision, and Reason for "No Change" Decision or Decision Date if "Study Further"
Electric Motors *Consider higher efficiency, redesigning to reduce loads, pneumatic actuators, etc.*	☐ Yes ☐ No	☐ High-Efficiency Alternate Not Available		Decision: --- --- Study Further No Change Use Alternate
Fan Filter Units *Consider higher efficiency motors, minimizing requirements with local FFUs, etc.*	☐ Yes ☐ No	☐ High-Efficiency Alternate Not Available		
Robots *Consider robots with faster handling speed, high efficiency motors, etc.*	☐ Yes ☐ No	☐ High-Efficiency Alternate Not Available		Decision: ---
Abatement Devices *Consider idle modes or off states, select highest efficiency units, etc.*	☐ Yes ☐ No	☐ High-Efficiency Alternate Not Available		Decision: ---
Wafer Loadlock	☐ Yes	☐ High-Efficiency Alternate Not Available		Decision: ---

Table 4 – Estimated Utility Consumption of New Product

If the new product processes wafers or controls the processing of wafers, what is the size? *Enter 300 if both 200 and 300; enter 0 if wafers are not processed.*	mm	= 0 cm²
If the new product processes wafers or limits throughput, what is the maximum throughput? *Enter 0 if throughput does not apply.*	wfr / hr	= 0 cm² / yr

Utility	Electricity	UPW_{PRES}	UPW_{ATM}	$PCW_{T\leq25°C}$		$PCW_{T>25°C}$		N2		Process Exhaust		Cooling Exhaust		CDA	Vac.
	kW	ℓ / min	ℓ / min	ℓ / min	ΔT °C	ℓ / min	ΔT °C	ℓ / min	psig	ℓ / min	ΔT °C	ℓ / min	ΔT °C	ℓ / min	ℓ / min
Processing															
Idle															

ΔT for PCW = T outlet – T inlet ● ΔT for Exhaust = T outlet – T ambient ● N2 and CDA volumes should be measured at supply pressure ● "Vacuum" is House Vacuum

Comments on Estimates:

Table 5 - Calculated Annual Equivalent Energy Consumption

		Utility →	Electricity	UPW	PCW	N2	Exhaust	CDA	Vac.	Sub Total	Heat Air	Heat H_2O	Burden	Total
kWh / yr	Predecessor (grand total [0])	Processing	0	0	0	0	0	0	0	0	0	0	0	0
		Idle	0	0	0	0	0	0	0	0	0	0	0	0
		Total	0	0	0	0	0	0	0	0	0	0	0	
	New Product (grand total [0])	Processing	0	0	0	0	0	0	0	0	0	0	0	0
		Idle	0	0	0	0	0	0	0	0	0	0	0	0
		Total	0	0	0	0	0	0	0	0	0	0	0	
mWh / cm²	Predecessor	*Processing only*	0	0	0	0	0	0	0	0	0	0	0	0
		Processing + Idle	0	0	0	0	0	0	0	0	0	0	0	0
	New Product	*Processing only*	0	0	0	0	0	0	0	0	0	0	0	0
		Processing + Idle	0	0	0	0	0	0	0	0	0	0	0	0

UPW = UPW_{PRES} + UPW_{ATM} ● PCW = $PCW_{T\leq25}$ + $PCW_{T>25}$ ● N2 is based on equivalent N2 volume at atmospheric pressure ● CDA is based on CDA volume at supplied pressure
Heat Burden expresses how heat generated from equipment burdens the air-conditioning system of the fab.

Table 7 - Conversion Factors & Utilization *These values are from SEMI S23 and are used for the calculations in this worksheet. For a worksheet with different values, contact corporate product EHS.*

Processing Time			**Idle Time**			**Down Time**			*All times are per year*
	6,132	hr		2,190	hr		438	hr	
	367,920	min		131,400	min		26,280	min	

Utility	Electricity kWh / kWh	UPW_{PRES} kWh / m³	UPW_{ATM} kWh / m³	$PCW_{T\leq25°C}$ kWh / m³	$PCW_{T>25°C}$ kWh / m³	N2 (Vatm)* kWh / m³	Exh. kWh / m³	$Heat\text{-}out_{air}$ kWh / m³ °C	$Heat\text{-}out_{water}$ kWh / m³ °C	Heat burden kWh / kWh	CDA kWh / m³	Vacuum kWh / m³
S23 factor	1.00	10.2	10.0	1.78	0.25	0.25	0.004	3.24E-4	1.16	0.382	0.147	0.075
... per ℓ		1.02E-2	1E-2	1.78E-3	2.5E-4	2.5E-4	4E-6	3.24E-7	1.16E-3		1.47E-4	7.5E-5
Conditions	Vrms • Irms • t	28.4 psig	not under pressure	71 psig 20-25 °C	71 psig 32-37 °C	115 psig	0.29 psia	Heat Burden** = Electric Power – ($Heat\text{-}out_{air}$ + $Heat\text{-}out_{water}$)			71 psig	0.85 psia

*Before the conversion factor is applied, N2 volume must be determined at atmospheric pressure and 20°C. Convert supplied volume Vsup to atmospheric volume Vatm at 20 °C (293 °K) and 1 atm (14.5 psia) using supplied pressure Psup (in psig) and supplied temperature Tsup (in °K; = °C+273) with the following formula: Vatm = Vsup (293 / 14.5) ((Psup+14.5) / Tsup). Note: It is assumed that Tsup = 20°C (293°K) so the formula simplifies to Vatm = Vsup • Psup / 14.5
** This model assumes all heat arises from electrical equipment and does not include other heat sources.