Greenhouse Gas Reduction and Energy Efficiency – Opportunities for Equipment Suppliers

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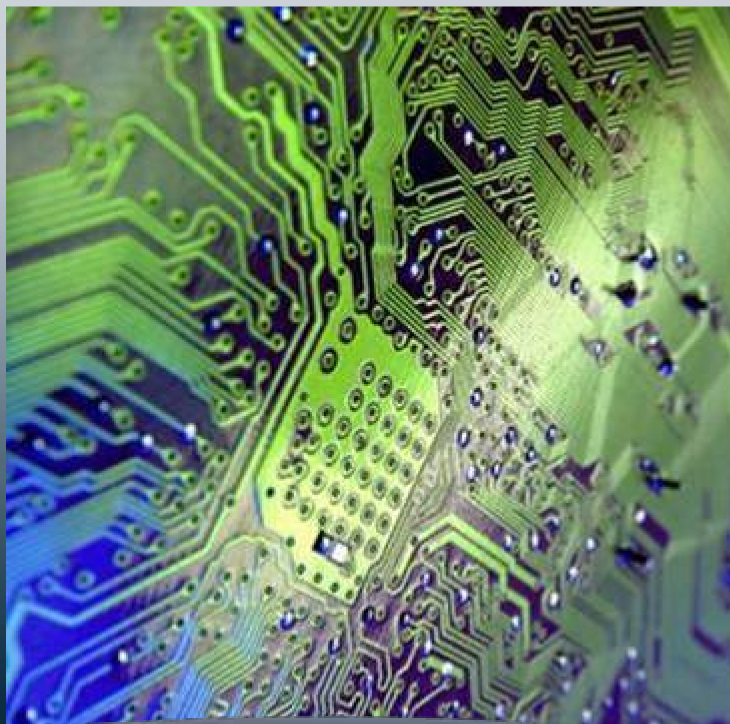
PLASMA ETCH USERS GROUP, May 15, 2008

think it. apply it.™

APPLIED MATERIALS.

Sustainability is essential

- Meeting the needs of today without jeopardizing the ability of future generations to do so
  - People, Planet, Profit
  - Economy, Environment, Equity



APPLIED MATERIALS.

Growing Importance of Sustainability

- Evidence of human caused global warming "unequivocal", says IPCC
- Water usage, fuel efficiency, erosion, preserving bio-diversity, pollution becoming important issues
- Changing weather patterns, drought, water shortage, floods, hurricanes etc.
- The BBC reported $100B spent worldwide in 2007 on clean tech research and funding

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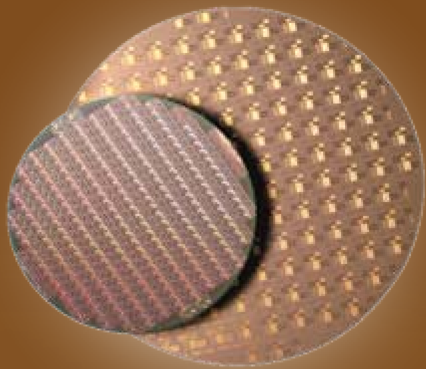
High-Tech Industries Play a Big Role

- Worldwide electricity consumption for servers in 2005 ~ 14 one GW power plants
- 2% of the world's CO_2 emissions from IT equipment
- 70-80% of energy used by IT is in manufacturing and transportation
- Overall manufacturing accounts for one third of world's global energy use

Source: IT News, The Wall Street Journal

Enabling Growth by Driving Cost Reduction….

FIRST



Cost per transistor

1974	2004
4 trillion	1,400,000 trillion
10 cents	5 nano-dollars

20,000,000x Cost Reduction

Source: SIA, IC Knowledge LLC

THEN

Cost per area

1995	2005
0.3 million m^2	25 million m^2
$30,000 / m^2	$1,500 / m^2

20x Cost Reduction

Source: Display Search, Nikkei BP, Applied Materials

NEXT

Cost per watt

2007	2010	2012
300MW	2GW	4GW
$1.45/W	<$1.00/W	<$.75/W

2x Cost Reduction

Applied Materials is accelerating Solar by reducing production costs

Setting Aggressive Goals

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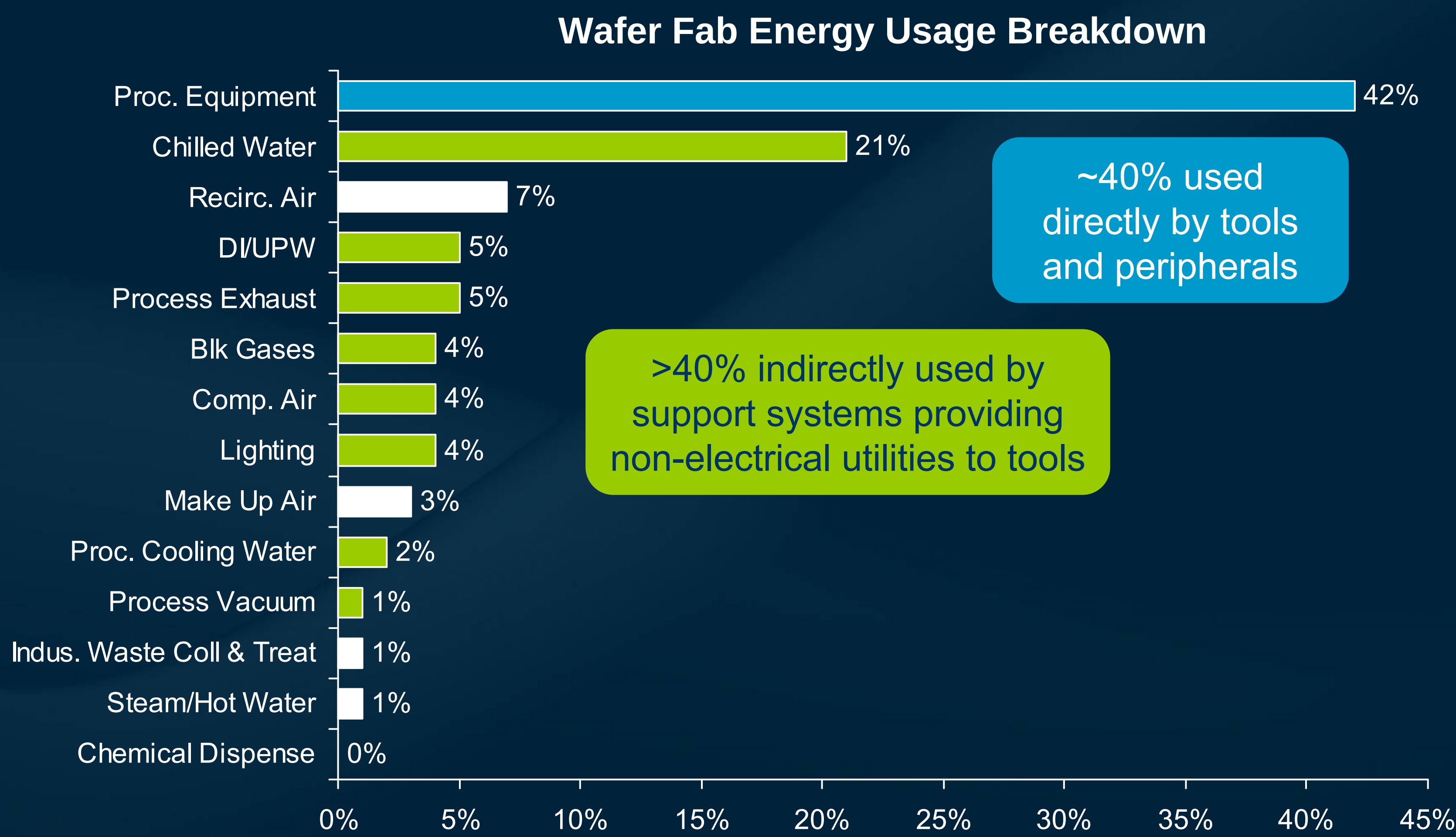
CORPORATE GOAL

Applied Materials will cut CO_2 equivalents by 20% or 50k tons by 2012

PRODUCT DESIGN GOAL

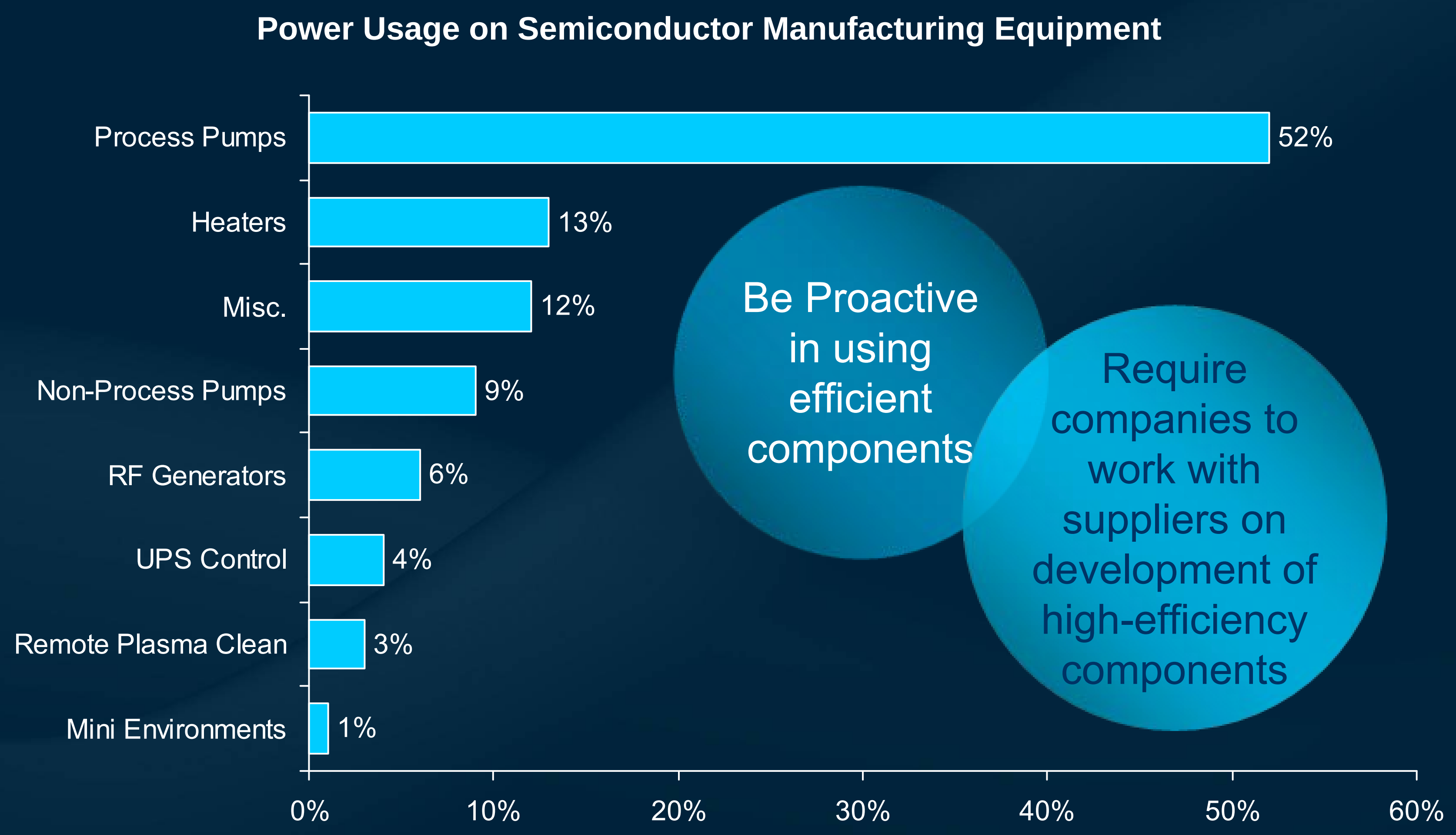
Applied Materials will reduce energy and resource consumption in overall product set by 20% by 2012

Tool Efficiency = GHG/Energy Opportunity



Source: 1997, 2000, 2002 SEMATECH Energy Research, presented at SEMICON Europa 2005

Engineers Designing Efficiency In



Source: 1997, 2000, 2002 SEMATECH Energy Research, presented at SEMICON Europa 2005

Drive DfE Through Product Life Cycle

Tasks have been added to the PLC to achieve the product energy efficiency objective:

Φ	PLC
1	Determine Market Requirements
2	
3	Specification
4	Product Development
5	Verification

Design for Energy Efficiency Activities

- Include energy efficiency in the Statement of Market Requirements.
- Establish baseline energy consumption based on an existing product.
- Analyze existing product designs.
- Include SEMI S23 energy consumption in the specification.
- Design and test to the specification.
- Fully characterize the new product according to SEMI S23 protocol.
- Plan to maintain competitiveness

SEMI S23 Evaluation of New Products

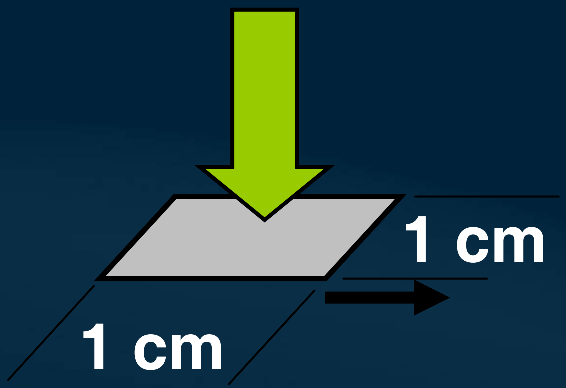
Applied Materials has adopted SEMI S23 as the protocol for measuring and reporting energy consumption of semiconductor manufacturing equipment.

SEMI S23 ANNUAL EQUIVALENT ENERGY CONSUMPTION							Per Wafer	
	IDLE		PROCESSING		TOTAL		Proc	Proc+Idle
	Total m3	Equiv kWh	Total m3	Equiv kWh	Total m3	Equiv kWh	Equiv Wh	Equiv Wh
Electricity		175,638		1,134,420		1,310,058	2,984	3,446
HVAC Heat Burden		58,033		334,606		392,639	880	1,033
Ultrapure Water (UPW, DI)	394	4,021	5,519	56,292	5,913	60,313	148	158
Process Cooling Water (PCW) <25°C	0	0	0	0	0	0	0	0
Process Cooling Water (PCW) >25°C	8,410	2,102	36,792	9,198	45,202	11,300	24	30
Nitrogen (Utilities N2)	763	191	7,358	1,840	8,121	2,031	5	5
Clean Dry Air (CDA)	2,365	348	37,896	5,571	40,261	5,919	15	16
Exhaust	591,615	2,366	1,656,523	6,626	2,248,138	8,992	17	24
House Vacuum	0	0	8,462	635	8,462	635	2	2
TOTAL		242,699		1,549,188		1,791,887	4,075	4,714

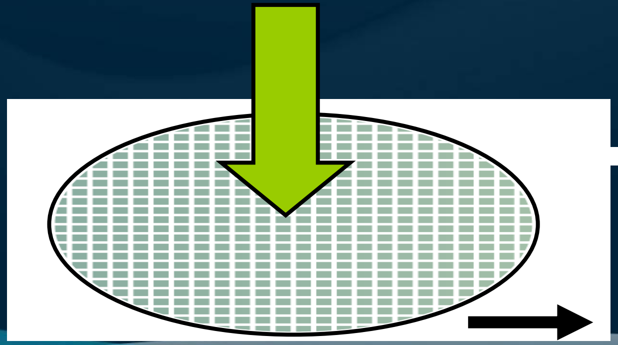
Energy per Unit Processed

Applied Materials evaluates product energy consumption on a equivalent energy (S23) per unit processed basis.

Wh / cm^2-pass



kWh / wfr-pass



- **Simplifies comparison of product generations or dissimilar equipment performing similar functions**
- **Recognizes throughput improvement**
- **More consistent with ITRS kWh / cm^2 out**
- **Per-unit-area metrics are applicable to most Applied Materials products**
- **Basic SEMI S23 protocol is being tested on non-semiconductor products**

Simple S23 Energy Calculator

- Enter Utilization and Consumption for up to two cases

Throughput in wafers per hour:	62
Percentage of time processing:	70.00%
Percentage of time in "standby 1":	15.00%
Percentage of time in "standby 2":	
Percentage of time in "standby 3":	

Utility Consumption Rate for Case 1

Utility	Electricity Real kW	UPW (pres) ℓ / min	UPW (atm) ℓ / min	PCW (T ≤ 25 °C) ℓ / min	PCW (T ≤ 25 °C) ΔT (°C)	PCW (T > 25 °C) ℓ / min	PCW (T > 25 °C) ΔT (°C)
Processing	185	15				100	6
Standby 1							

N2 ℓ / min @ STP	Process Exhaust ℓ / min	Process Exhaust ΔT (°C)	Cooling Exhaust ℓ / min	Cooling Exhaust ΔT (°C)	CDA ℓ / min @ STP	Vacuum ℓ / min

- See Energy Consumption:

fer Pass | Energy per cm2 | Energy per mm

Energy Consumption per cm² Processed

Utility	mWh / cm²								
	Electricity	UPW	PCW	N2	Exhaust	CDA	Vacuum	Heat Burden	Total
Processing Only	4,221.31	209.47	34.23	6.85	24.66	20.73	2.36	1,245.11	5,764.71

- and the cases compared:

PERCENT CHANGE CASE 1 TO CASE 2 (CELLS ARE GREEN IF CASE 2 IS A REDUCTION FROM CASE 1):

Utility	Electricity	UPW	PCW	N2	Exhaust	CDA	Vacuum	Heat Burden	Total
Processing Only	1.43%	27.06%	4.26%	-0.29%	22.04%	-6.23%	44.50%	9.85%	4.27%
Total*	6.08%	28.68%	8.29%	2.63%	22.04%	-2.37%	39.97%	14.19%	8.69%

Applied's Strategies to Reduce Carbon footprint

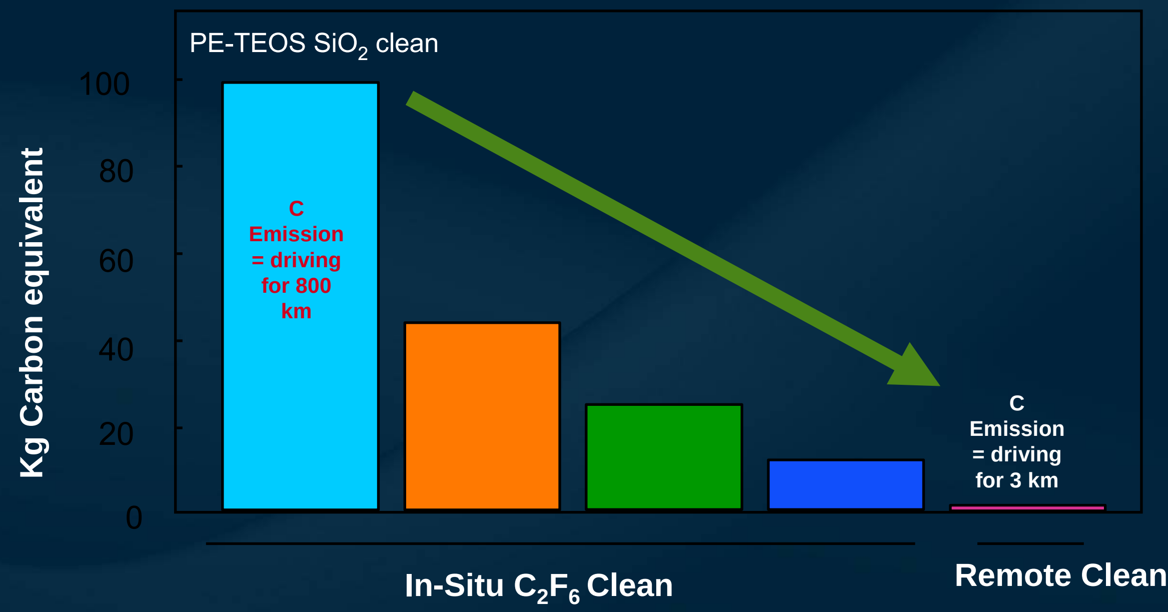
Strategy	Approaches
Optimize	1. Optimized Hardware (System Enhancements; Remote Clean)
Substitute	2. Alternate Chemistries (Fab consulting process optimization)
Abate	3. Convert/Destroy PFCs (Abatement Technology: Combustion-Wet, Plasma etc.)

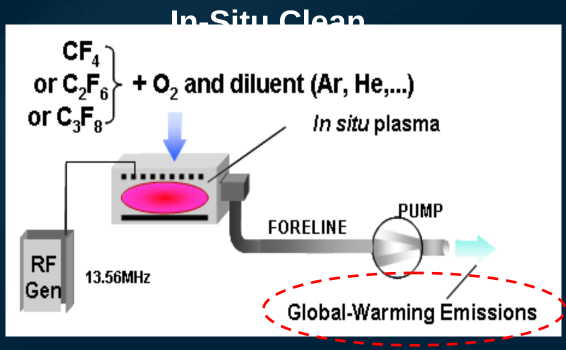
Multiple Offerings In Place to Reduce Carbon Footprint

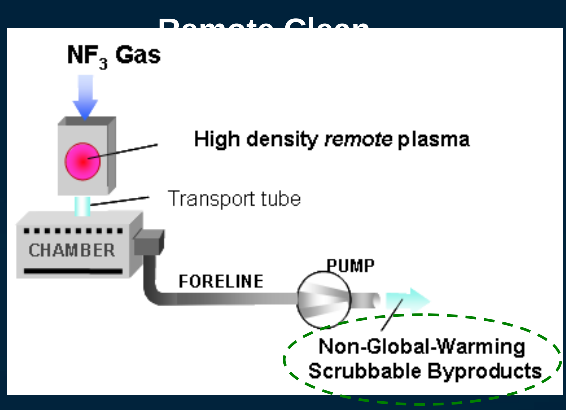
Environmental impact of Remote Clean

- **Global warming emissions from CVD chamber cleaning were reduced by two orders of magnitude by switching from in-situ clean to remote cleans**
  - In-situ clean: One clean = 800 km (100 Kg Carbon equivalent)
  - Remote clean: One clean = 3 km (2 Kg Carbon equivalent)

Global Warming Emissions (100 years ITH)







Upgrading chamber with remote clean reduces environmental impact ☺

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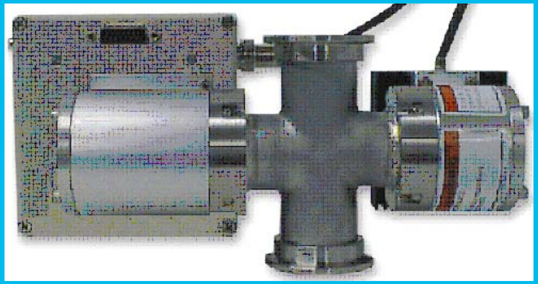
Hardware Optimization – System Enhancements

Remote Plasma Clean for 200mm Dielectric CVD

- Lower particle count
- Higher Throughput, less frequent cleans
- Longer process kit and consumable lifetime
- Higher Uptime, longer interval between PMs
- 98% reduction PFC emissions vs In-situ RF clean
- **Annual CO_2 emissions reduction: 13,300 tons**

Infrared Chamber Diagnostic Sensor (IRCDS)
Dynamic Endpoint System



- Improved and consistent particle performance
- Enhanced process kit life
- Higher throughput with greater MWBC
- Available for 200mm DxZ; Ultima HPCVD
- Reduced NF3 usage
- **Annual CO_2 emissions reduction: 104 tons***

* RPC efficiency included

Assumes 50K WSPM, 1μ TEOS application, GWP 1g NF3 = 10970 g CO2 Equivalent

Hardware Optimization – System Enhancements

1kW and 3kW Thermoelectric Chillers

- Compact size (1kW unit shown)
- Reduced power consumption
- Reduce CO2 emissions
- High reliability, exceptional temp stability, high ramp rates.
- Available for 200mm MxP and DPS Etch
- **Annual CO_2 emissions reduction: ~11 tons/system**

Energy-Saving Heat Exchanger

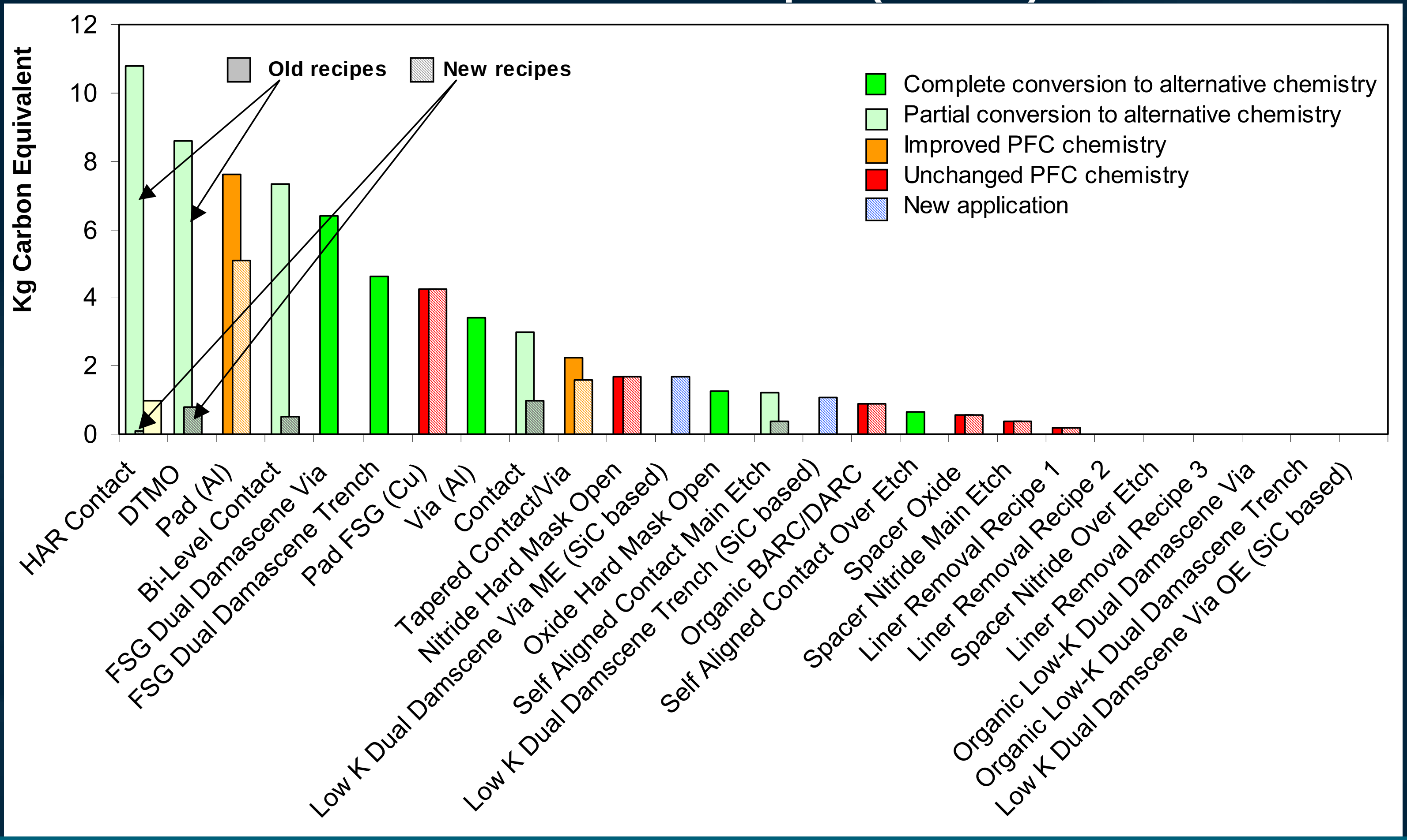
Heat Exchanger **Controller**

- Compact size (W:158mm, D:335mm, H:494mm)
- Lamp heating module for quick temperature control
- Built-in purge function
- Available for 200mm MxP, DPS Etch
- **Annual CO_2 emissions reduction: ~2.5 tons/system**

Assumes CO2=0.4kg/KWH (from JEITA)

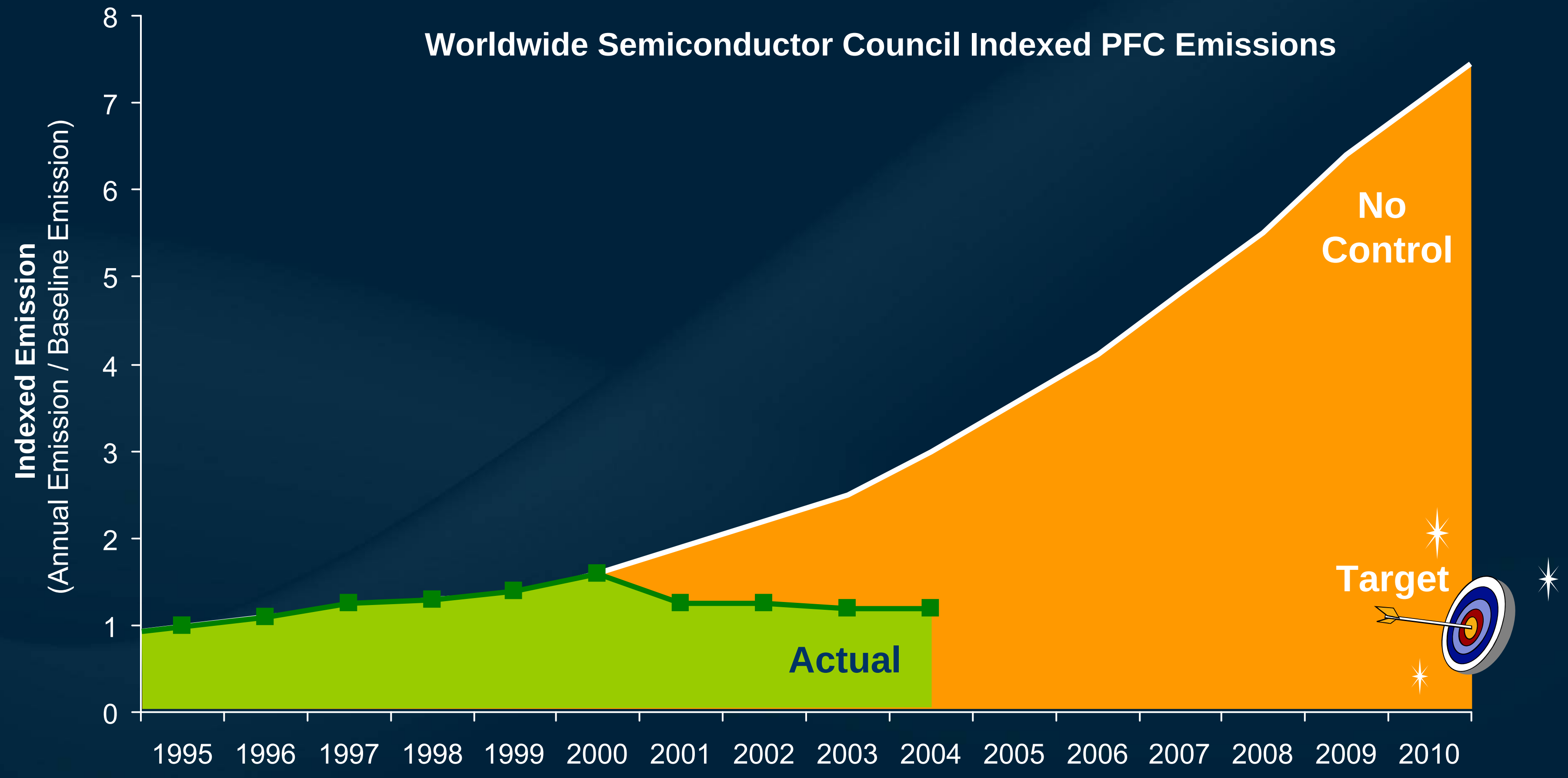
Process Optimization – Fab Consulting Services

Example: Evolution of PFC consumption per wafer pass in Dielectric Etch - Old vs. new recipes (300mm)



Applied Materials Fab Consulting Service Can Help Identify and Implement Solutions

Industry Is On track To Meet the Challenge to Reduce PFC's



Source: World Semiconductor Council

Applied Material's Fab-wide Process Exhaust Solutions

PFC Abatement Technologies

Marathon
Combustion-wet
(High Flow Capacity)

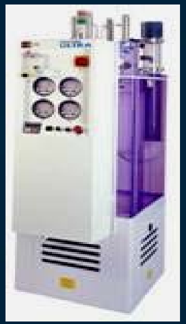
Litmas
Plasma
(Zero Footprint)

CDO
Thermal-wet Abatement

Nova Series
Dry Abatement

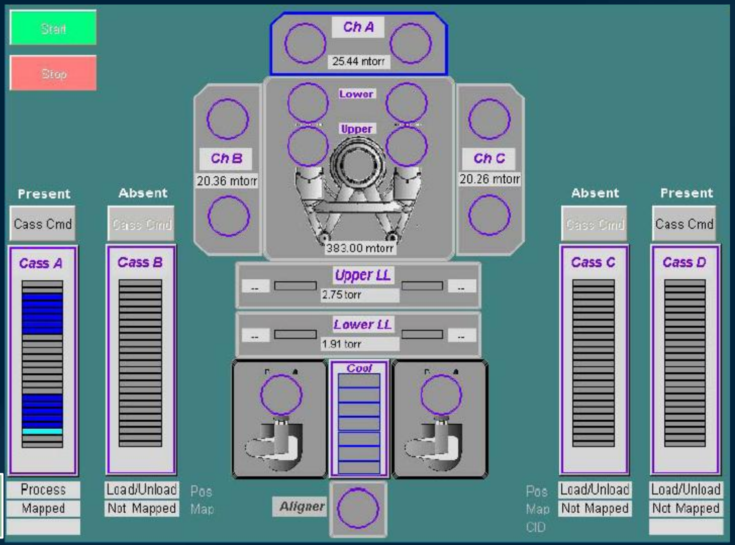
Guardian
Combustion Abatement

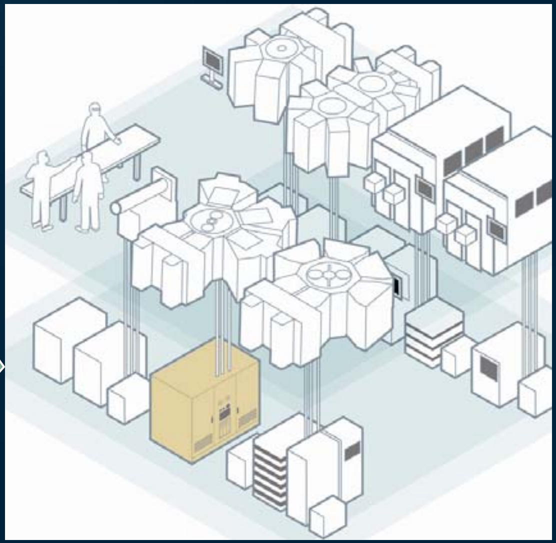
Vector
Wet Abatement



Integrated Process and Abatement Solution

- Interface for Integrated control of abatement systems by process tool based on process operational conditions
- Umbilical cord links wafer position to subfab operation, matching energy consumption to need.
- Potential Idle Mode Savings:
  - CDA >44%
  - Fuel > 90%
  - PCW >70%
  - Utility = Energy = Cost
  - (For example:
  - 1 liter/minute DI water usage represents 3,752 kWh/year*)





Summary

- Reduction of our carbon footprint is one of the great challenges for the sustainability of the semiconductor industry
  - Applied Materials is now implementing strategies to significantly reduce its carbon footprint and incorporating steps to lower the environmental impact of new tools
- Aggressive goals for carbon reduction are required
- Sustainability and DfE need to be incorporated into the product release process
- PFC emission reduction and energy saving solutions can help device manufacturers meet their environmental goals:
  - Optimized Hardware
  - Alternate Chemistries
  - Convert/Destroy PFCs - Abatement technologies

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