Environmental Value Systems (EnV-S) Analysis for Semiconductor Manufacturing

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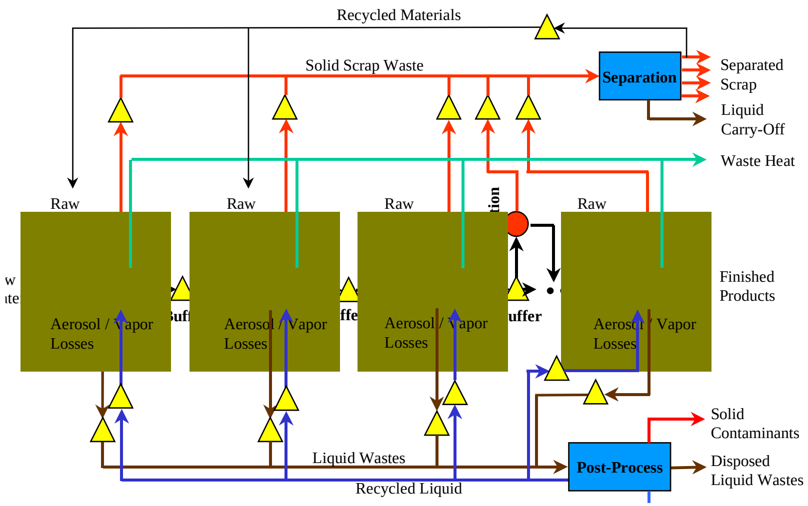
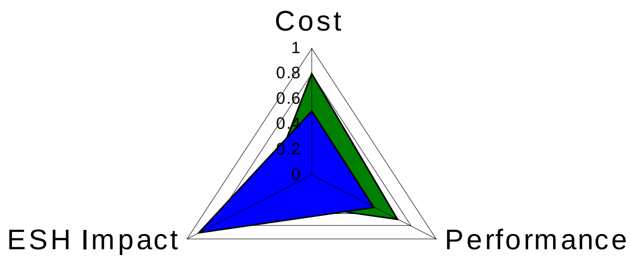
Overview of the Consortium's work in DfE



Modeling and Sequencing

Accounting of Process and Environmental Flows (Manufacturing Systems modeling in Machining)

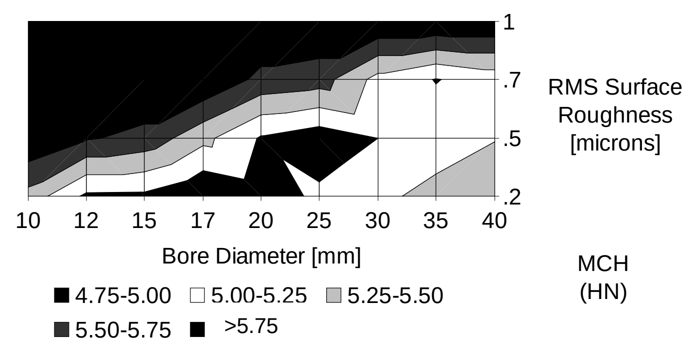


System Characterization

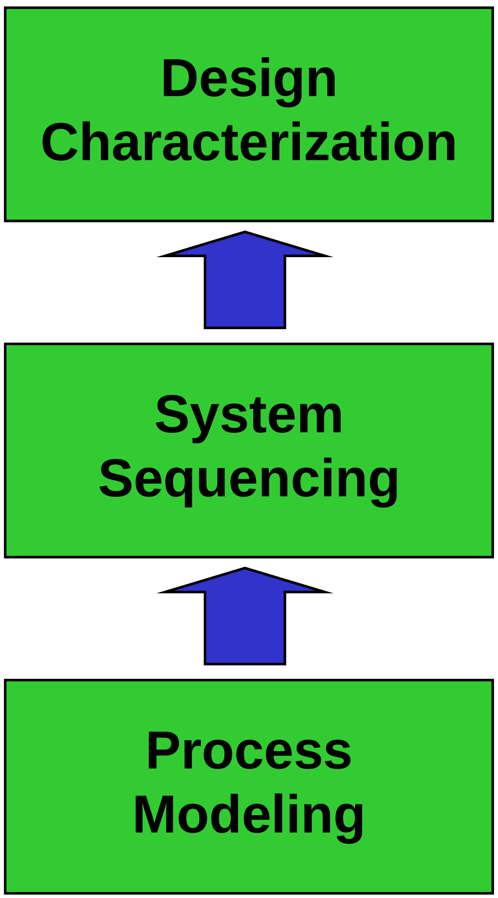
Multidimensional Endpoints (Environmental Value Analysis)

Design and Decision Analysis

Integration of Functional and Environmental Characterization (Bearing Design and Surface Finish)



EnV-S Framework



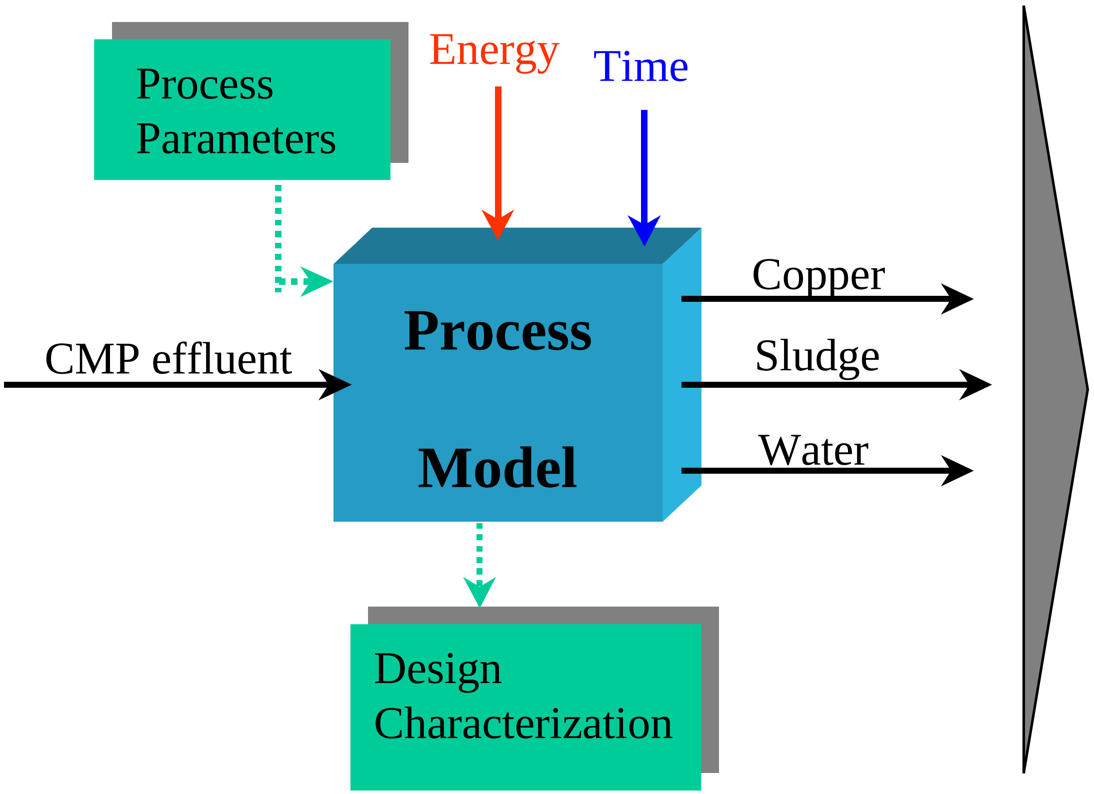
Objectives

- Specify tool objectives or trade-offs in terms of performance, cost and environmental parameters
- Identify absolute constraints imposed by industry standards or regulatory requirements

- Identify the processes within the system
- Define process sequences or modules
- Define the bounds of analysis through specification of system to be modeled

- Quantify the primary material, ancillary material, and energy flows within each process through analytical or empirical models
- Define key parameter sensitivities which drive the process environmental performance

Process Modeling



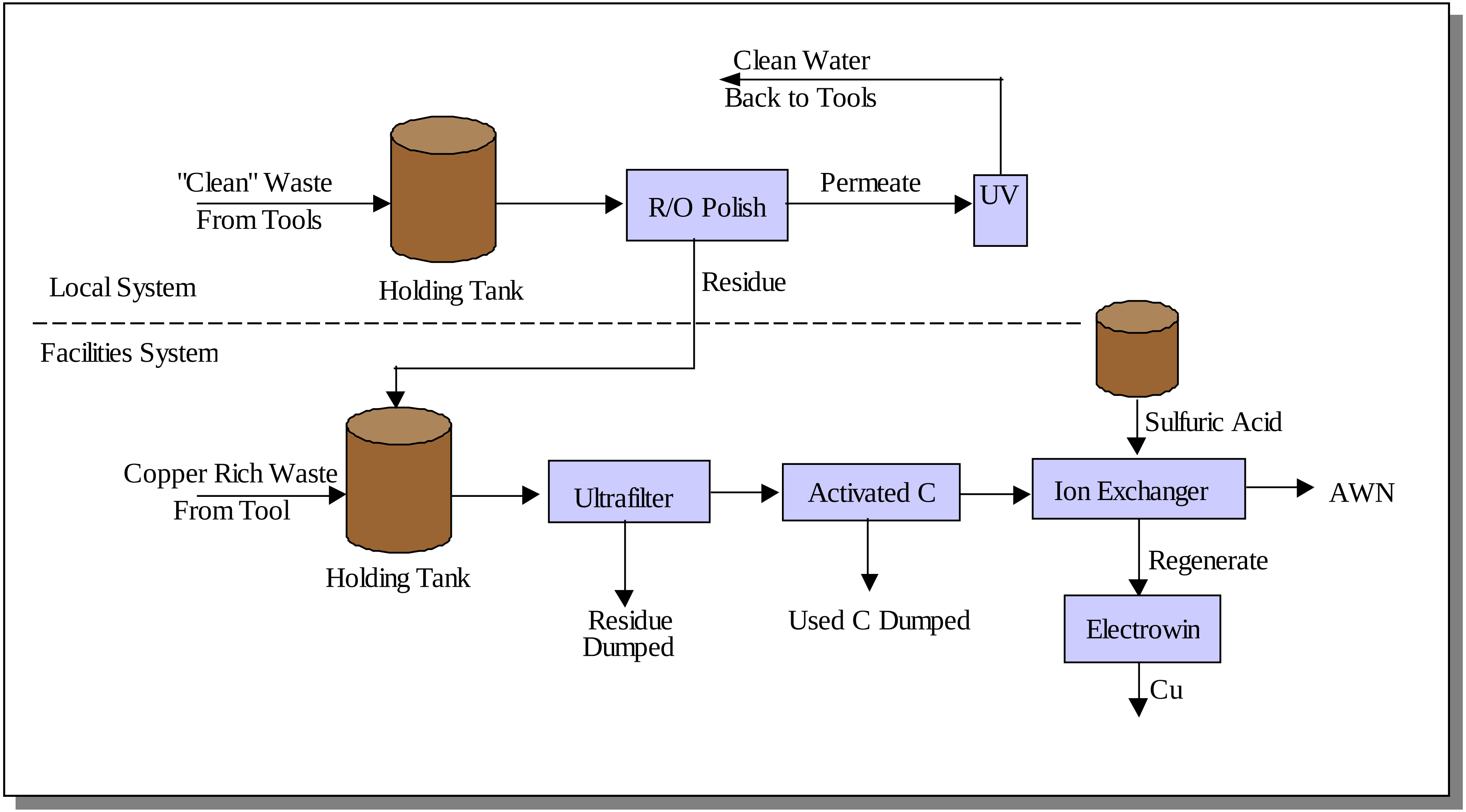
A set of analytical/empirical process models are used to describe the process.

Output parameters include energy utilization, waste masses (including mixed waste), process rate.

Information flows are captured in two ways:

- Input - process parameter influence
- Output - cost, impact, and performance characterization

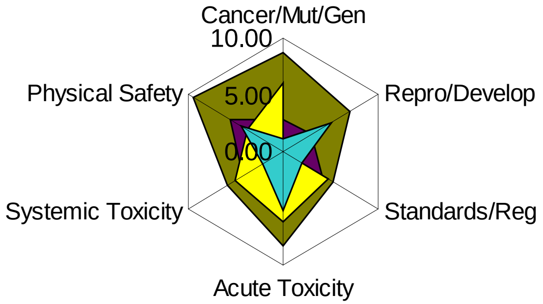
System Sequencing:
Cu CMP wastewater treatment system



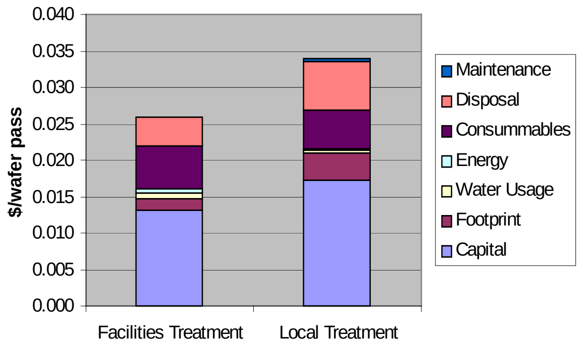
System Characterization: Environmental Value (EnV) Analysis

Environmental Value Analysis

Environmental hazards
Interpreted through Multi-Criteria Hazard (MCH) analysis



Cost of ownership
Interpreted through Environmental Value Analysis (EnV CoO)

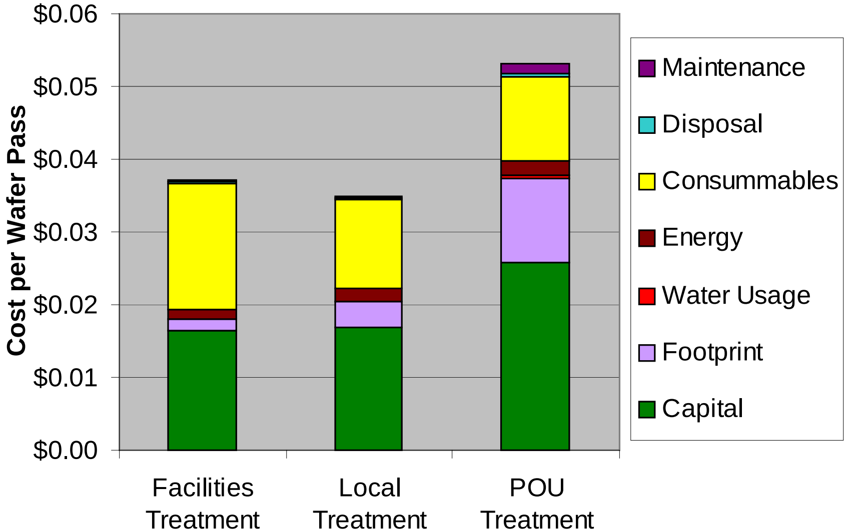


Process Performance
Interpreted through Engineering objectives

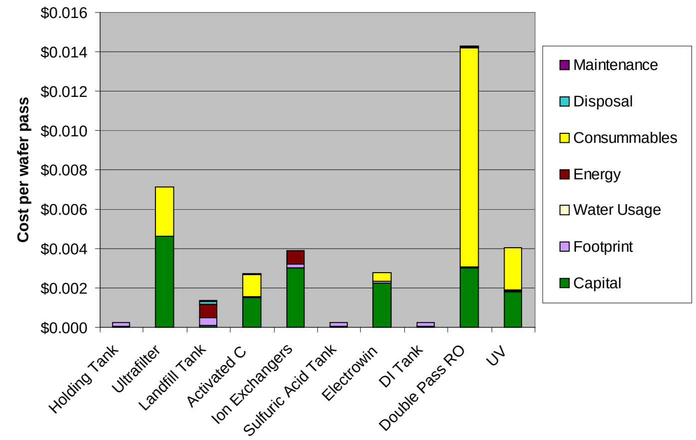
	System 1	System 2
Throughput	X wph	Y wph
Availability	X%	Y%
Treatment Efficiency	X%	Y%

Characterization Results:

Comparison of Different Process Options



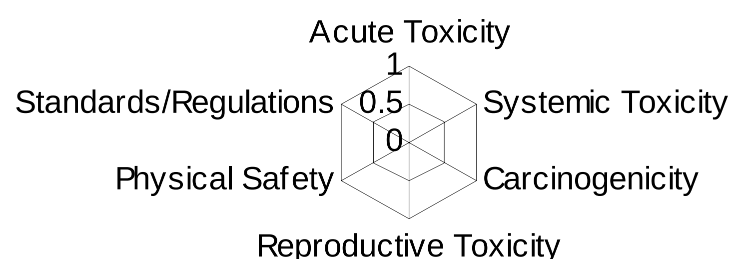
Cost breakdown of a facility level Cu CMP wastewater treatment system



Performance, Environmental and Health Hazard Metrics

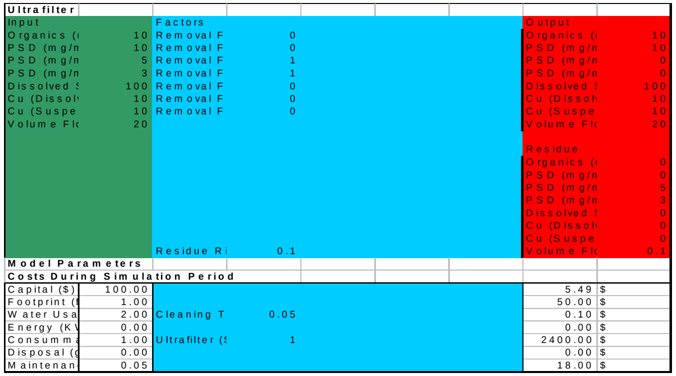
	Facilities Treatment	Local Treatment
Performance Metrics		
Water Recycling Efficiency (%)	98	64
Copper Extraction Efficiency (%)	100	100
Final Copper Concentrations (mg/L)	0	0
Total Dissolved Solids (mg/L)	0.05	0.08
Total Suspended Solids (mg/L)	0.003	0.004
Water Quality (Mega Ohms)	15	14
Environmental Metrics		
Waste Stream Cu/Discharge Limit	0	0
Water Recovered per Wafer (gal)	0.18	0.12

Health Hazard Metrics

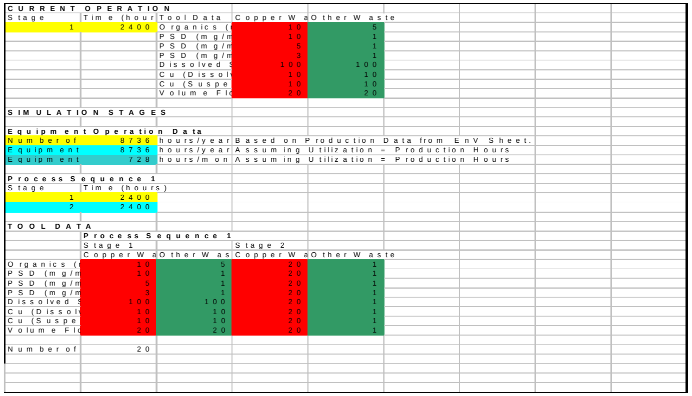


Current Project Implementation

1. Compile process model information*

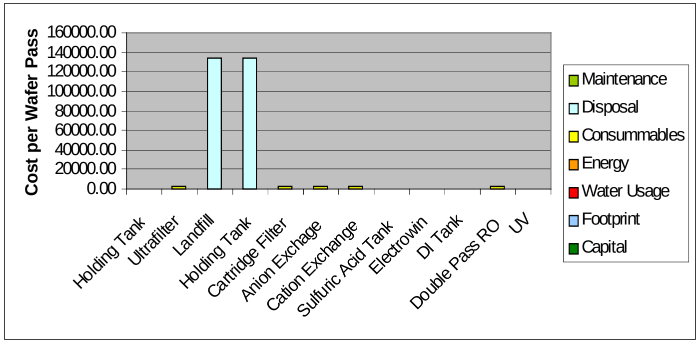


2. Link desired models to process sequence



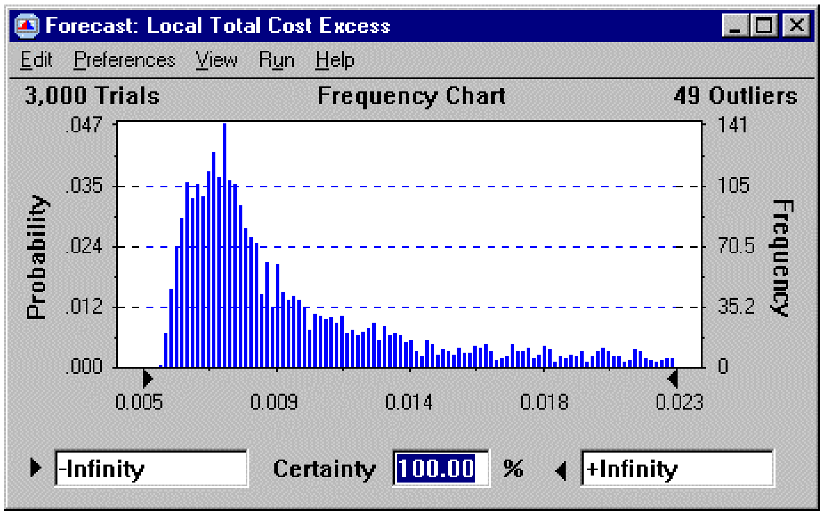
3. Select variables and run sensitivity analysis

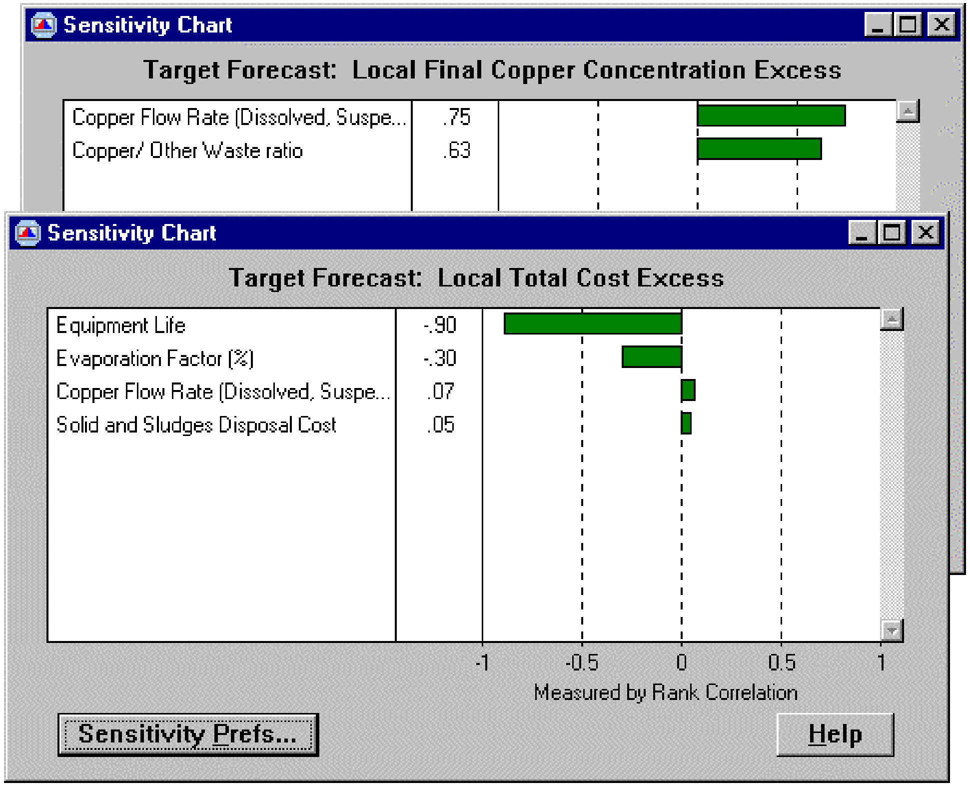
4. Determine trade offs in design characterization



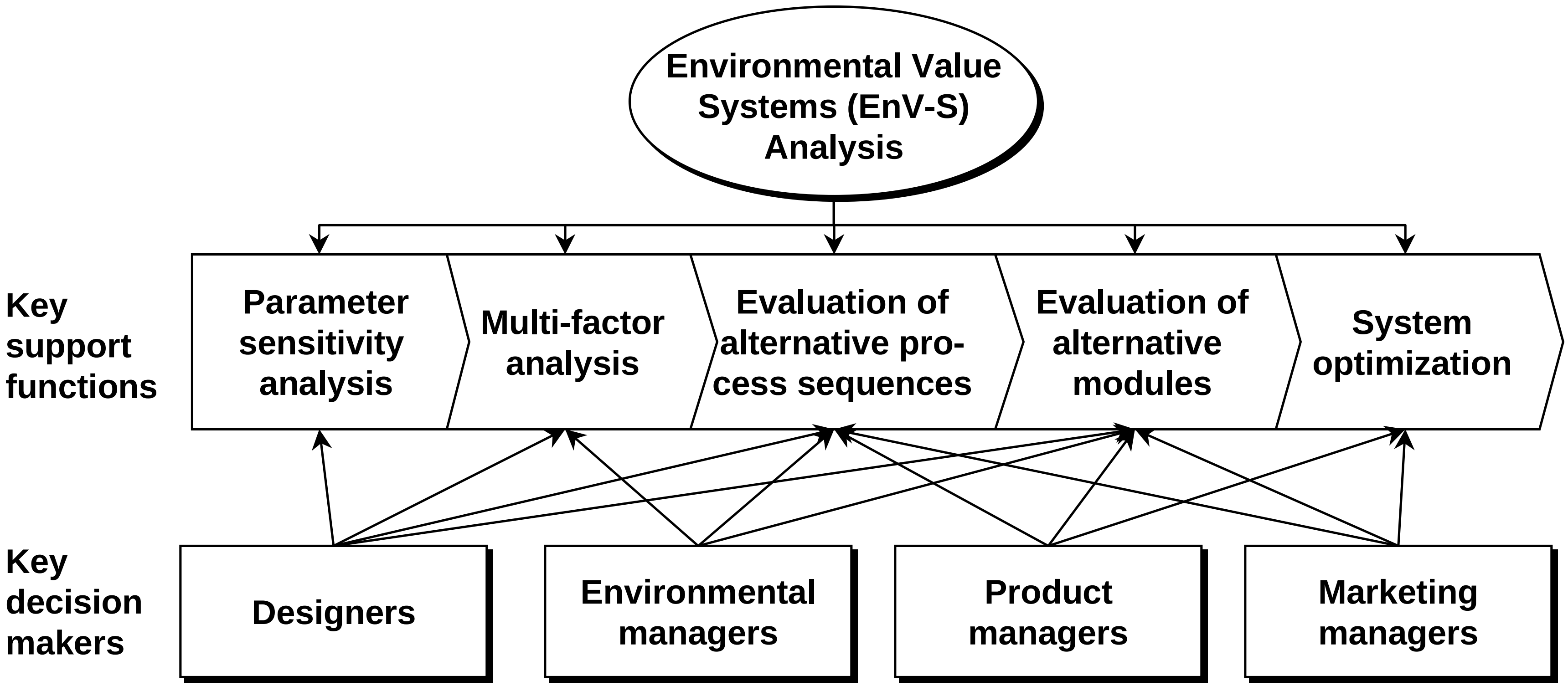
*M. Schmotzer and F. Shadman, U of A

Design Analysis





Design and Decision Applications



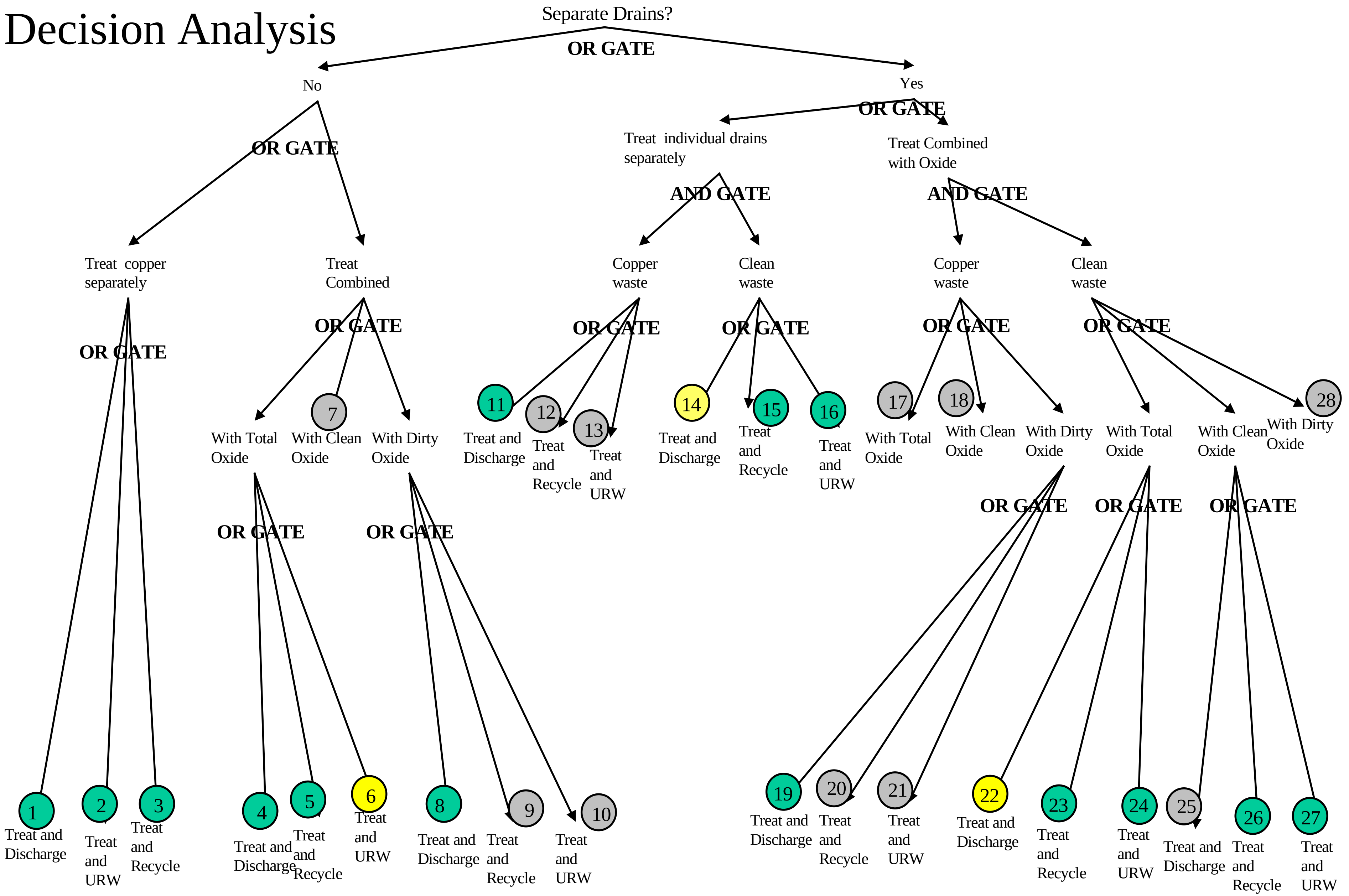
- Equipment process design
- Process optimization

- Hazard characterization
- Standard evaluation approach
- Communications format

- Equipment selection
- System configuration
- Life-cycle cost

- Competitive assessment
- Value communication to the customer

Decision Analysis



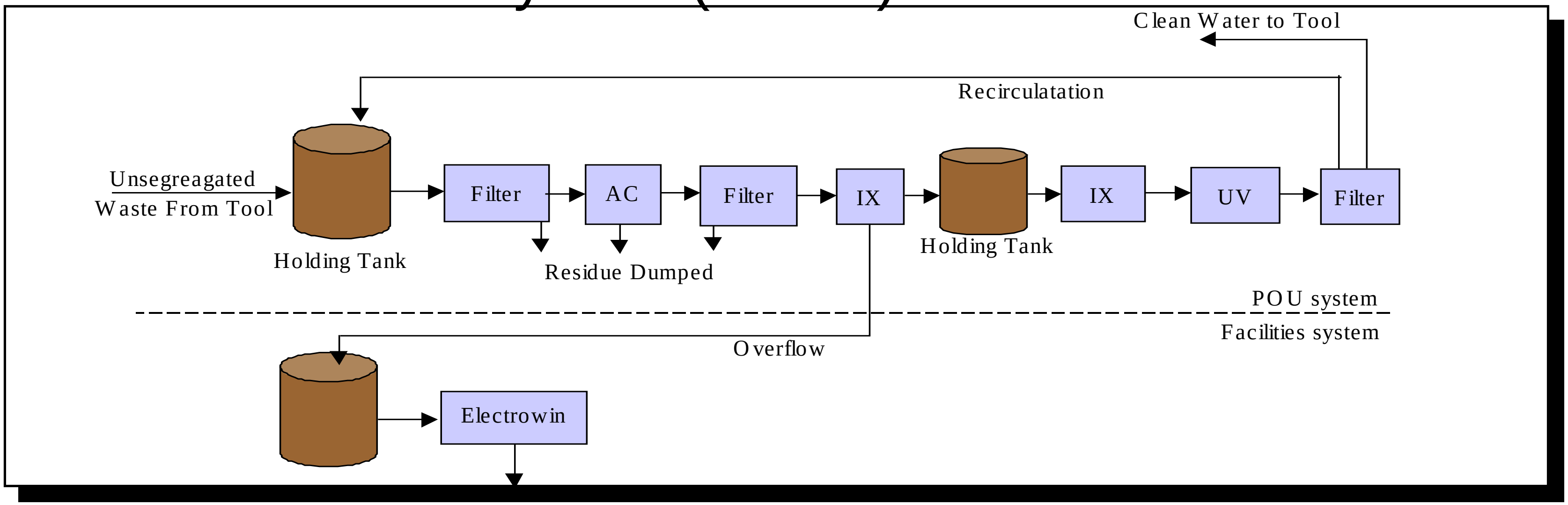
x Possible

x Unlikely

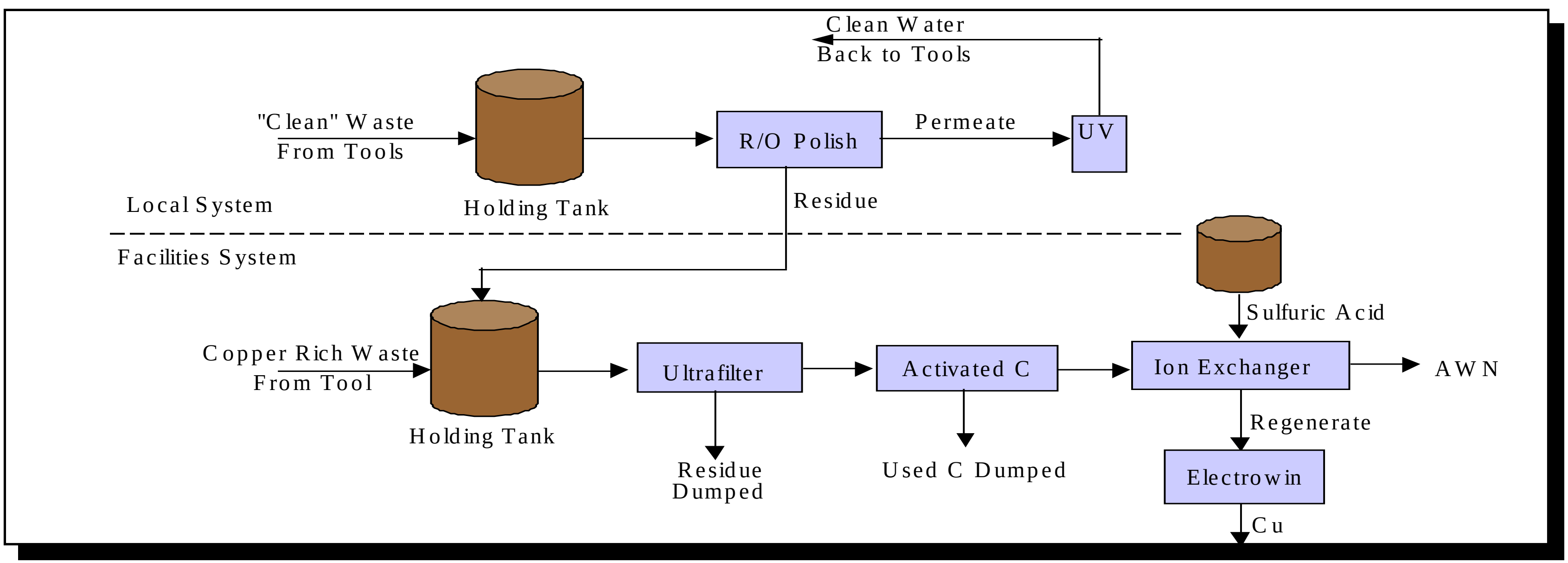
x Technically impossible or logically flawed

Cu CMP Treatment Case Study

POU Treatment System (1 Tool)

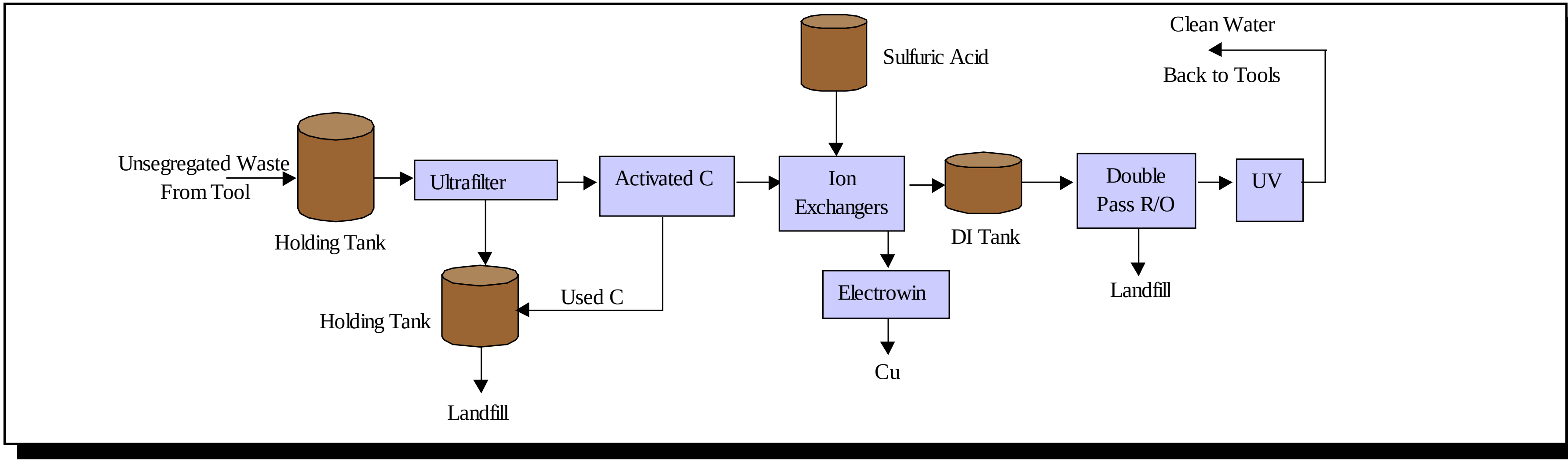


Local Treatment System (5 Tools)

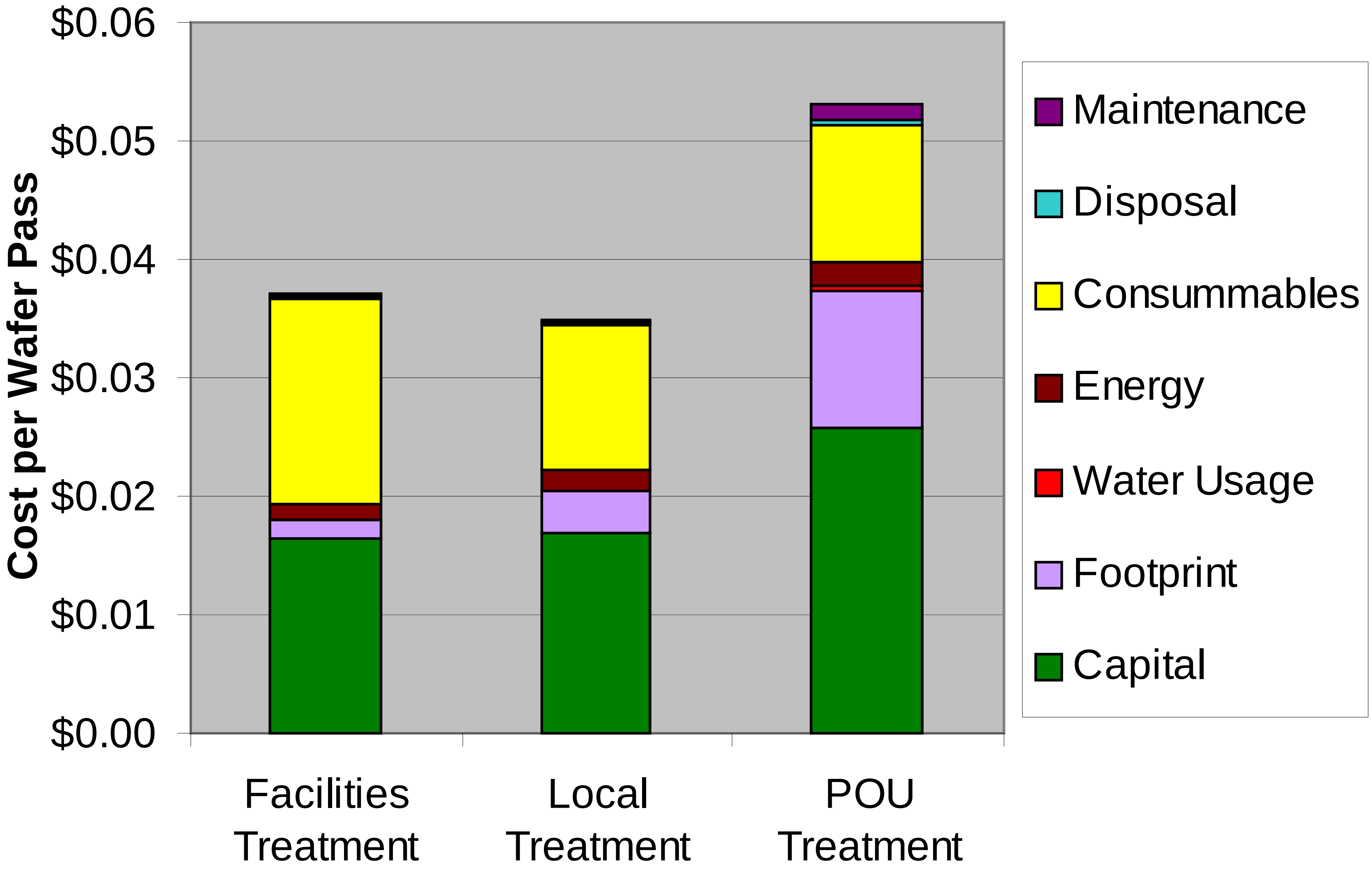


Cu CMP Treatment Case Study (2)

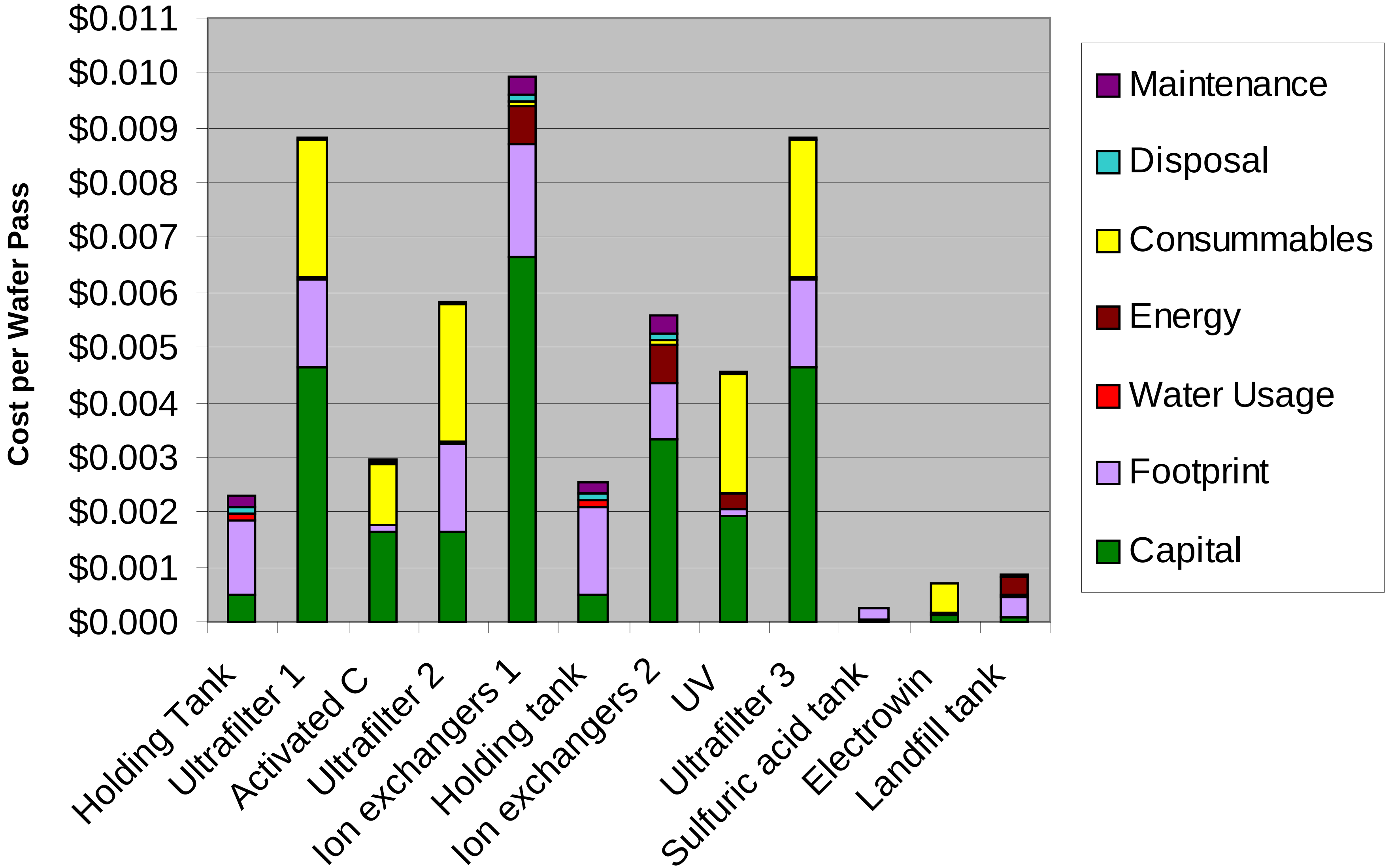
Facility Treatment System (20 Tools)



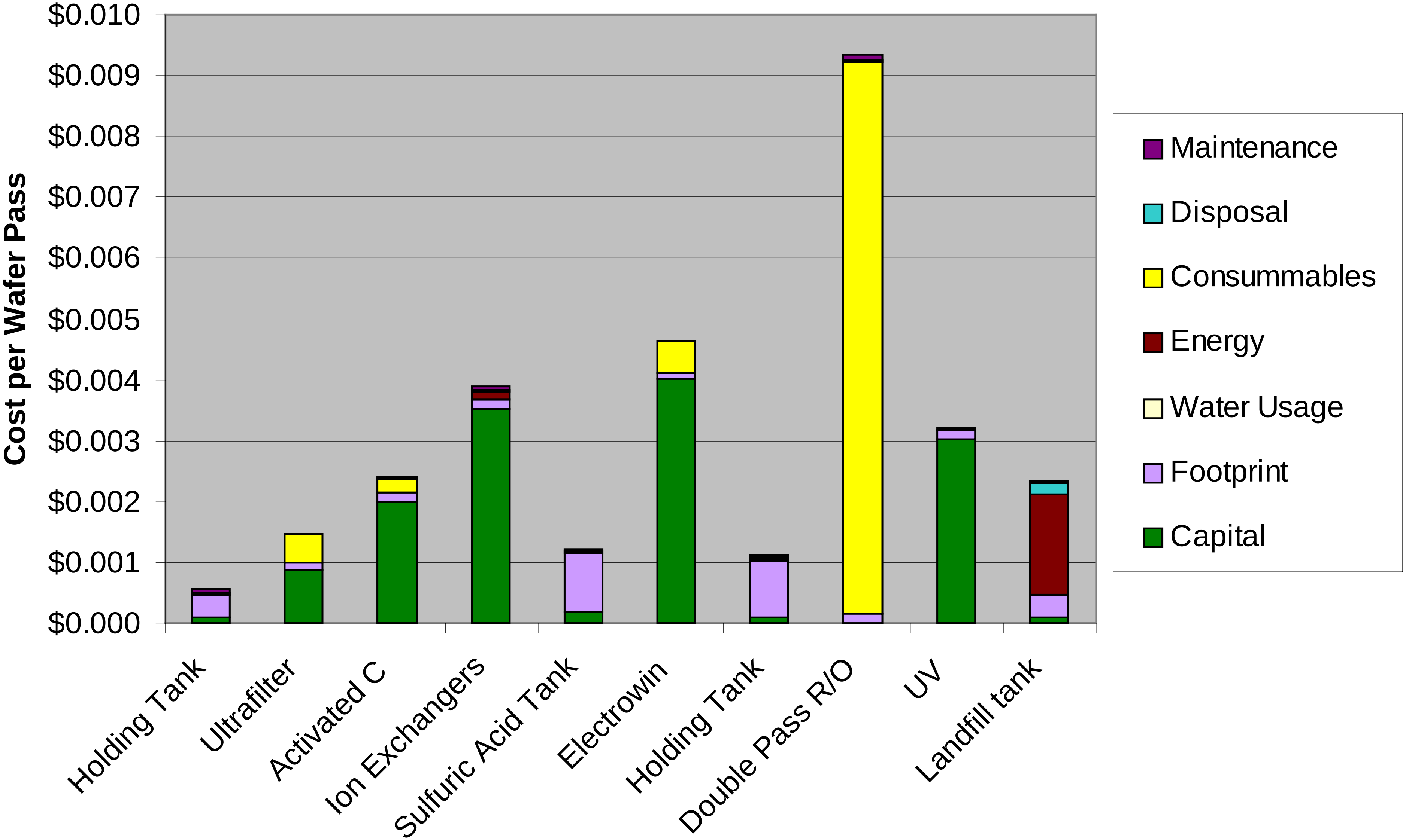
Comparison of systems



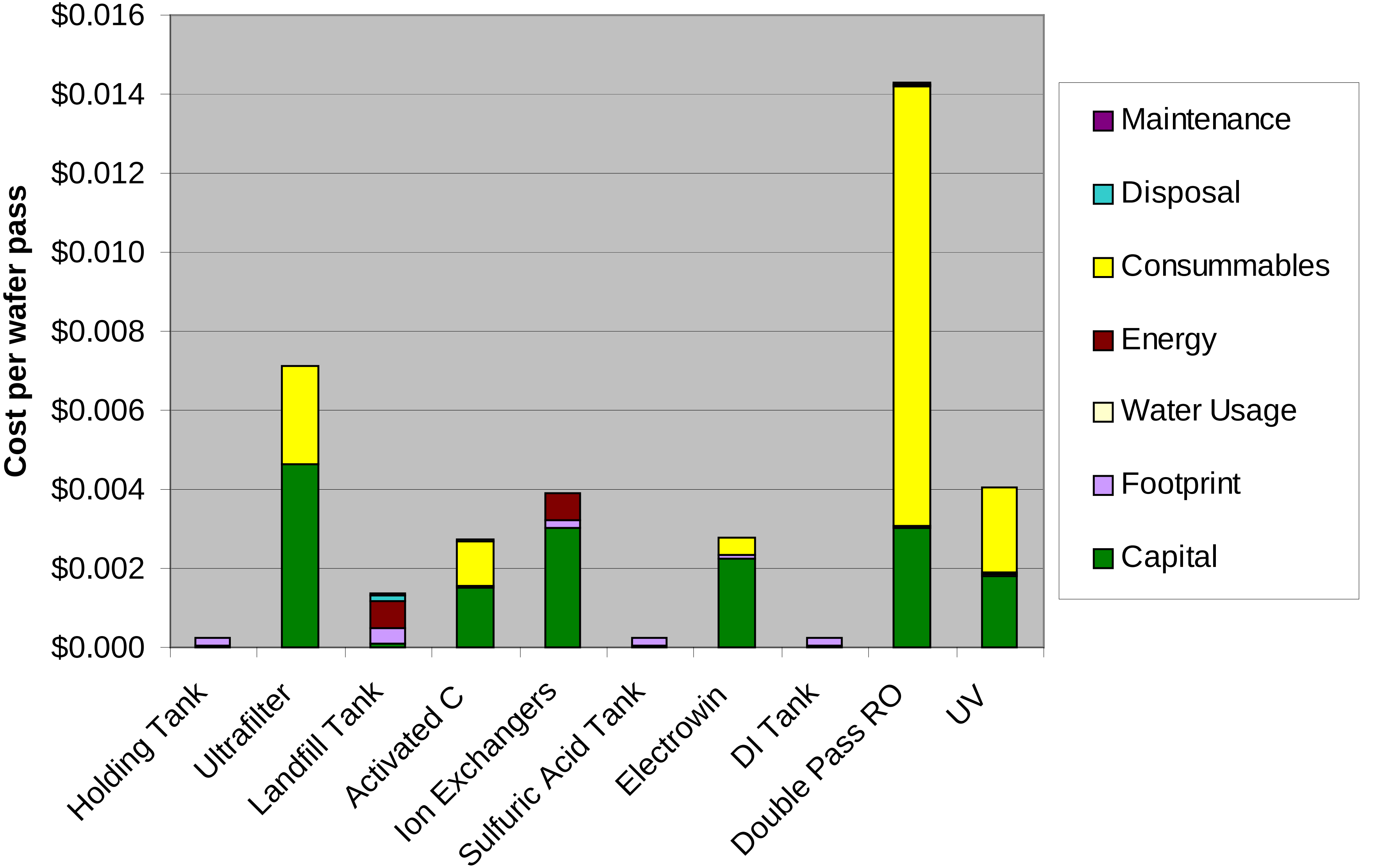
Characterization results - POU system



Characterization results - local svstem



Characterization results: facilities system



Performance metrics

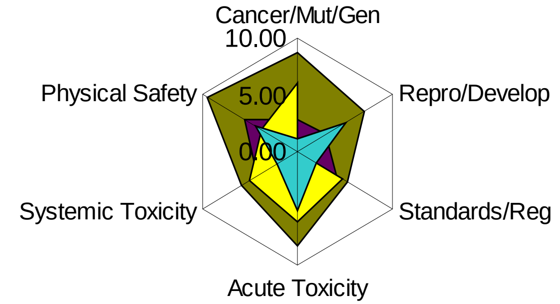
	Facilities Treatment	Local Treatment	POU Treatment
Water Recycling Efficiency (%)	72.7	69.5	72.7
Copper Removal Efficiency (%)	99.5	99.9	99.5
Final Copper Concentrations (mg/L)	0.002	0.0005	0.003

Conclusions

- *Local treatment system is the most cost effective solution with*
  - high particle removal performance.
  - most useful cost reduction efforts should be focused on the reverse osmosis consumable costs.
- *If the primary process could use all of the recycled water*
  - a facility-level solution would be more cost effective
- *If there are compelling reasons to install POU systems*
  - cost per wafer pass must be reduced by $0.016 per wafer
  - Reducing filter costs would be an effective way to meet this requirement.

Future Work

- NSF/SRC ERC Collaboration
- Sensitivity Analysis
  - isolation of model and process parameters that influence the results the most.
- The natural expansion of the CMP analysis is into the primary process.
  - Effects of slurry free CMP processes
  - Different rinse cycles on the interactions with the treatment and recycling processes.

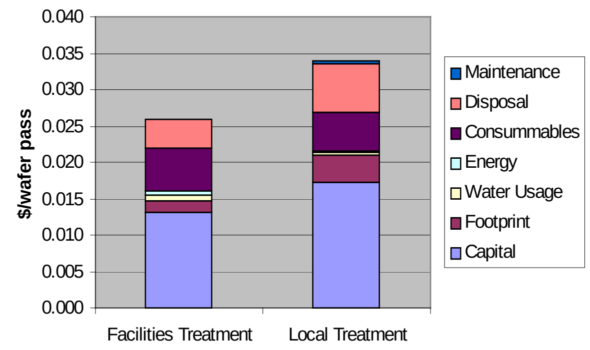


ESH Impacts

- 6 Toxicity and Physical Safety Categories
- Based on Logarithmic Hazard Scale
- Normalized to Reference Compounds

	Carcinogenicity/Mutagen/Genotox				Acute Toxicity					
Score	**EPA WOE**	**IARC WOE**	**TDL**	**TCL**	**LD50**	**LC50**	**TDL**	**TCL**	**ID (eye)**	**ID (skin)**
0	E	-	-	-	-	-	-	-	-	-
1		4	>10 g/kg	> 100 g/m^3	>1 kg/kg	> 10 kg/m^3	>100 g/kg	> 1 kg/m^3	>100 mL,100 g	>1 L,1 kg
2	D	3	< 10 g/kg	< 100 g/m^3	< 1 kg/kg	< 10 kg/m^3	< 100 g/kg	< 1 kg/m^3	<100 mL,100 g	<1 L,1 kg
3			< 1 g/kg	< 10 g/m^3	< 100 g/kg	< 1 kg/m^3	< 10 g/kg	< 100 g/m^3	<10 mL,10 g	<100 mL,100 g
4			< 100 mg/kg	< 1 g/m^3	< 10 g/kg	< 100 g/m^3	< 1 g/kg	< 10 g/m^3	<1 mL,1 g	<10 mL,10 g
5	C	2B	< 10 mg/kg	< 100 mg/m^3	< 1 g/kg	< 10 g/m^3	< 100 mg/kg	< 1 g/m^3	<100 uL,100 mg	<1 mL,1g
6			< 1 mg/kg	< 10 mg/m^3	< 100 mg/kg	< 1 g/m^3	< 10 mg/kg	< 100 mg/m^3	<10 uL,10 mg	<100 uL,100 mg
7	B2		< 100 ug/kg	< 1 mg/m^3	< 10 mg/kg	< 100 mg/m^3	< 1 mg/kg	< 10 mg/m^3	<1 uL,1 mg	<10 uL,10 mg
8			< 10 ug/kg	< 100 ug/m^3	< 1 mg/kg	< 10 mg/m^3	< 100 ug/kg	< 1 mg/m^3	<100 nL,100 ug	<1 uL,1 mg
9	B1	2A	< 1 ug/kg	< 10 ug/m^3	< 100 ug/kg	< 1 mg/m^3	< 10 ug/kg	< 100 ug/m^3	<10 nL,10 ug	<100 nL,100 ug
10	A	1	< 100 ng/kg	< 1 ug/m^3	< 10 ug/kg	< 100 ug/m^3	< 1 ug/kg	< 10 ug/m^3	<1 nL,1 ug	<10 nL,10 ug

Cost of Ownership



- Detailed cost categories calculate process driven costs
- Database holds regional and platform specific data

Facility Parameters

Scheduled Production
Burdened Salary/Labor Rates
Annual Space Rates
Depreciation Life
Equipment Life
Depreciation Method
Inflation Rate
Tax Rate

Process Chemicals

Deposition Liquids
Deposition Gases
Chamber Clean Gases
Slurries

Treatment/Disposal

Industrial Water Disposal
Scrubbed Exhaust
Solids and Sludges
Solid Acid Waste
Solid Solvent Waste
Handling/Disposal Waste
Facility Treatment Expenses
Recovery of By-Products

For Process and Abatement Equipment

Uptime/Throughput

% Utilization Scheduled Maintenance
Unscheduled Maintenance

Equipment Data

Original Cost/System
Training Required/System
System Operation Costs
Floor Space/System

Utility Usage/System

Electricity Requirements
Industrial City Water
Partially Treated Water
Ultra Pure Water
High Purity Nitrogen
Utility Nitrogen
Clean Dry Air

Consumable Costs/System

Consumables
Non-Consumable Spares
ESH Supplies

	System 1	System 2
Throughput	X wph	Y wph
Availability	X%	Y%
Treatment Efficiency	X%	Y%

Process Performance

- Performance measured through engieering objectives
- Table displays example of process tool objectives
- Qualitative overall results

Estimated Tool Downtime	
Throughput (wafers/hour)	
Wafer Uniformity	
Wafer to Wafer Uniformity	
Film Stress	
Refractive Index	
Particles/Wafer	
Wafers/Dry Clean	
Wafers/Wet Clean	
Estimated Abatement Downtime	
Gas Utilization/Dissociation %	