# ENVIRONMENTAL VALUE (EnV) ANALYSIS

S. Thurwachter[1], J. Schoening[2], P. Sheng[1]

[1]Department of Mechanical Engineering, University of California at Berkeley

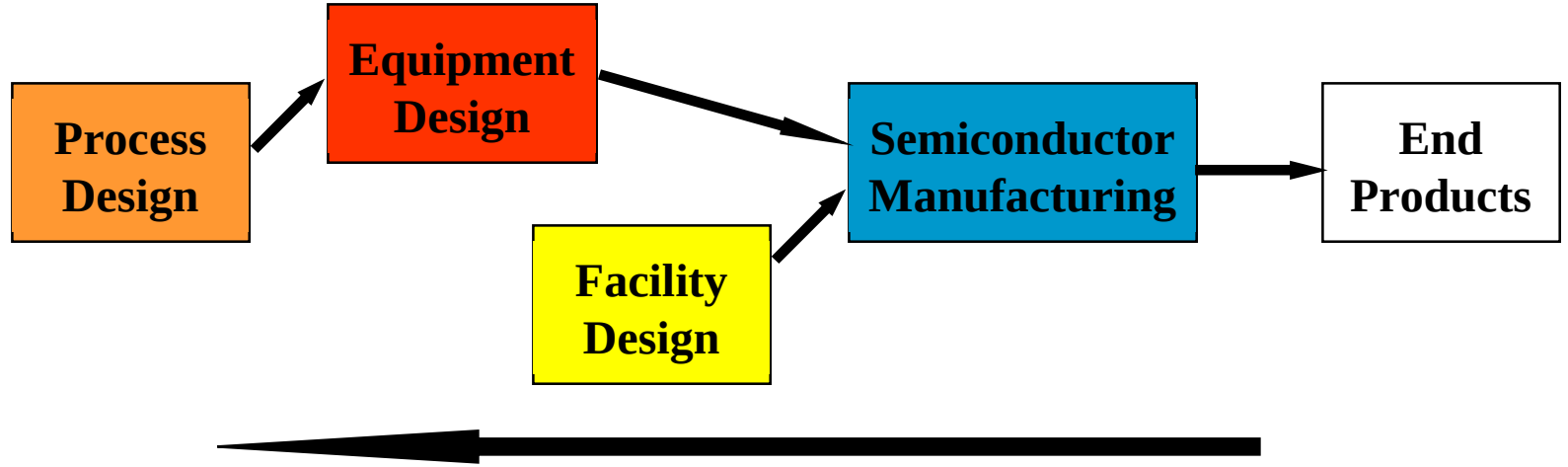
[2]Environmental Technologies and Services, Applied Materials Inc.

# OVERVIEW


- Problem Statement
- EnV Framework
- Case Study Demonstration
- Future Directions

# PROBLEM STATEMENT

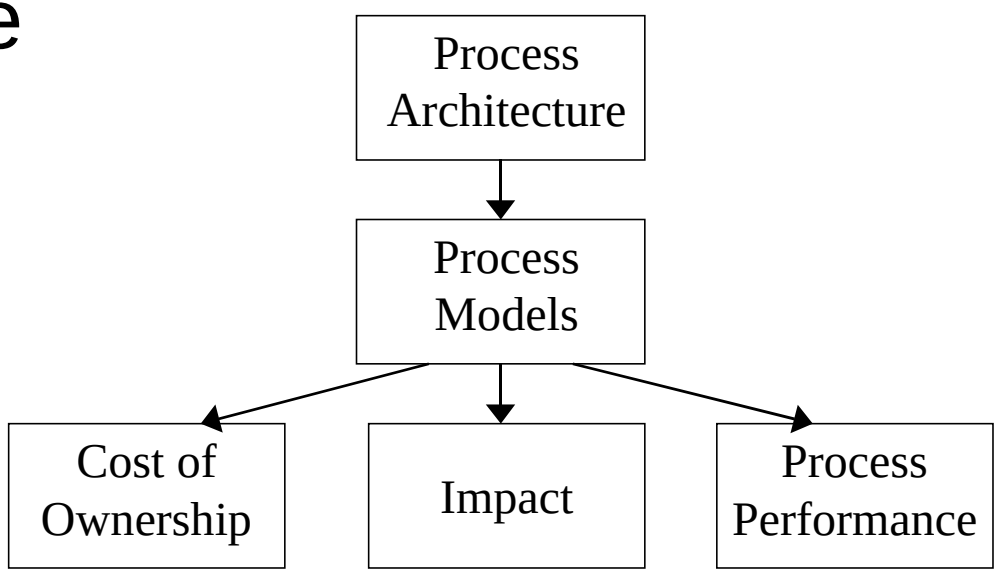
- Evaluate Semiconductor Manufacturing



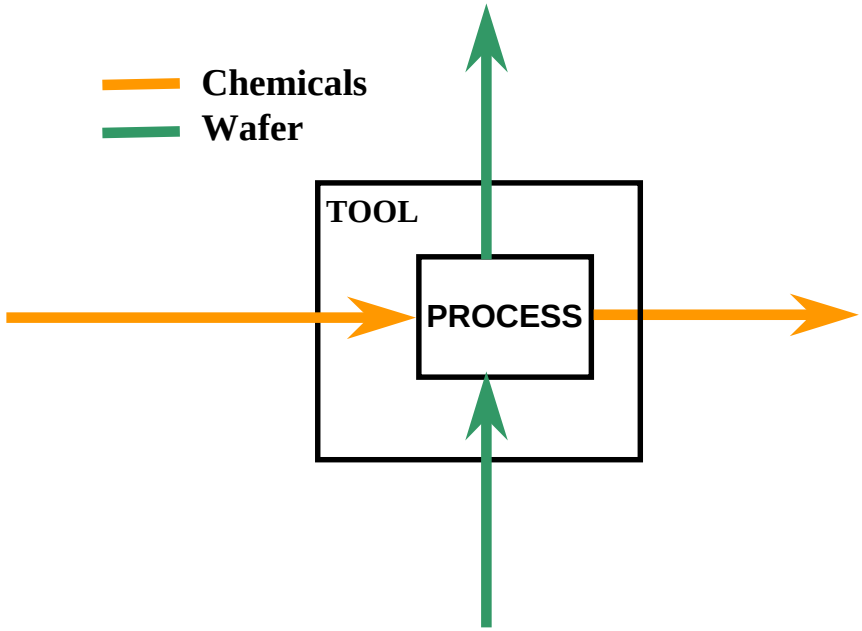

- Influence Equipment/Process/Facility Design
- Requirement - Tool that captures impacts of manufacturing and links to design parameters

# ENVIRONMENTAL VALUE (EnV) ANALYSIS

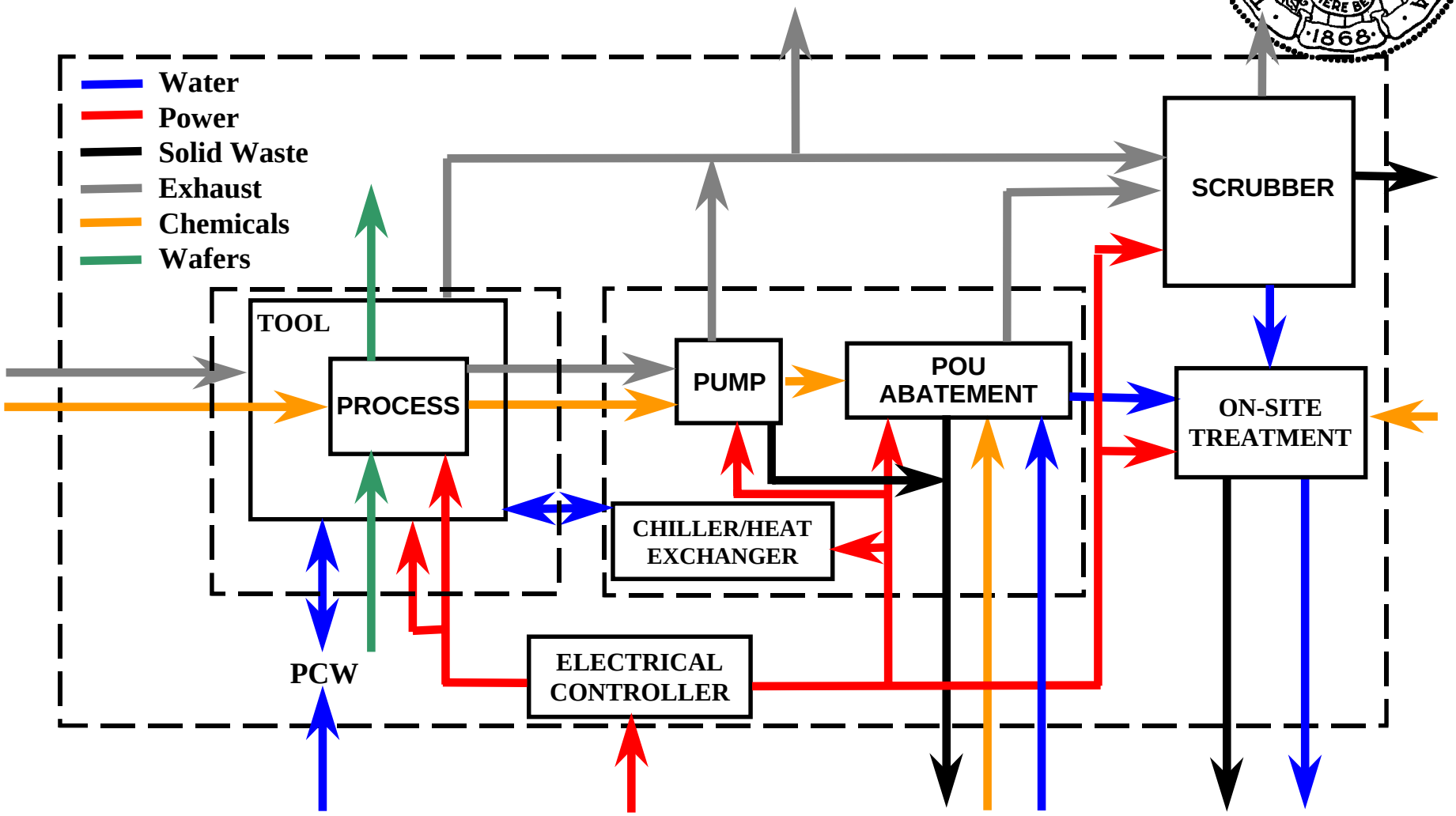
- Process Architecture
- Process Models
- Characterization
  - Cost of ownership
  - Health and environmental impacts
  - Process performance



# PROCESS ARCHITECTURE



# PROCESS ARCHITECTURE



# EnV CHARACTERIZATION
## Cost


- Facility data
- System data
- Equipment data
- Production data

- Capital Costs
- Operation Costs
- Treatment Costs

# EnV CHARACTERIZATION
## Impacts

- Human Health Impacts
  - Multi-criteria hazard (MCH) evaluation
  - Incorporates 6 toxicity/physical safety categories
- Environmental Impacts
  - LCA classification approach
  - Several regional and global indicators
- Under Development

# EnV CHARACTERIZATION
## Performance


- Metrics are process/equipment dependent

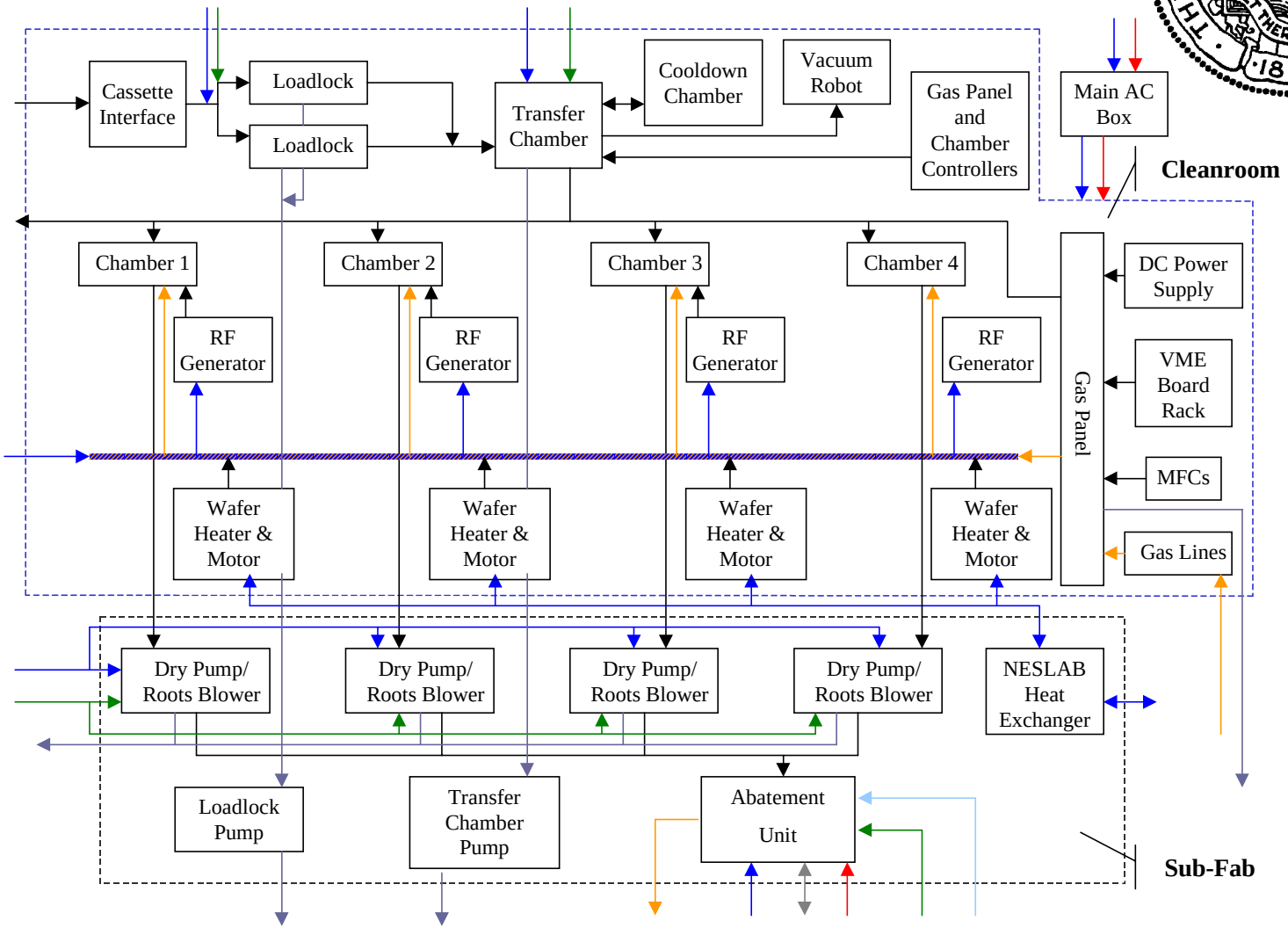
- Examples for semiconductor manufacturing:
  - Wafer to wafer uniformity
  - Stress drift
  - Gas utilization
  - Abatement efficiency
  - Regulatory compliance

# APPLICATION: CASE STUDY


- Tool Mainframe Evaluation
  - 4 chamber Centura and 2 twin Producer
  - 0.75 m PECVD TEOS process
  - RF $C_2F_6$ clean vs. Remote Clean™ $NF_3$
- EnV Analysis
  - Established process architecture models
  - Collected data
  - Characterized systems

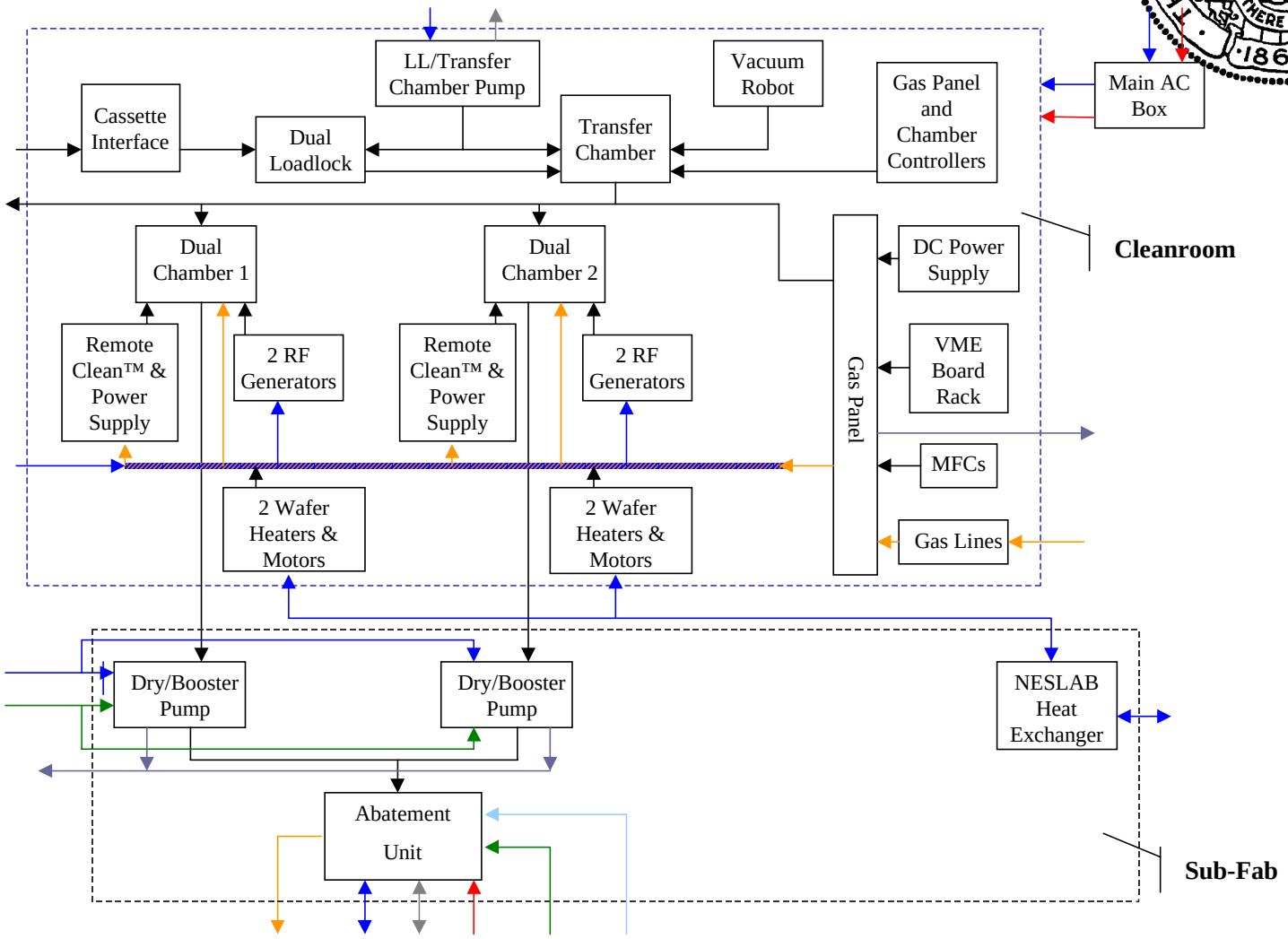
# PROCESS ARCHITECTURE

## Centura



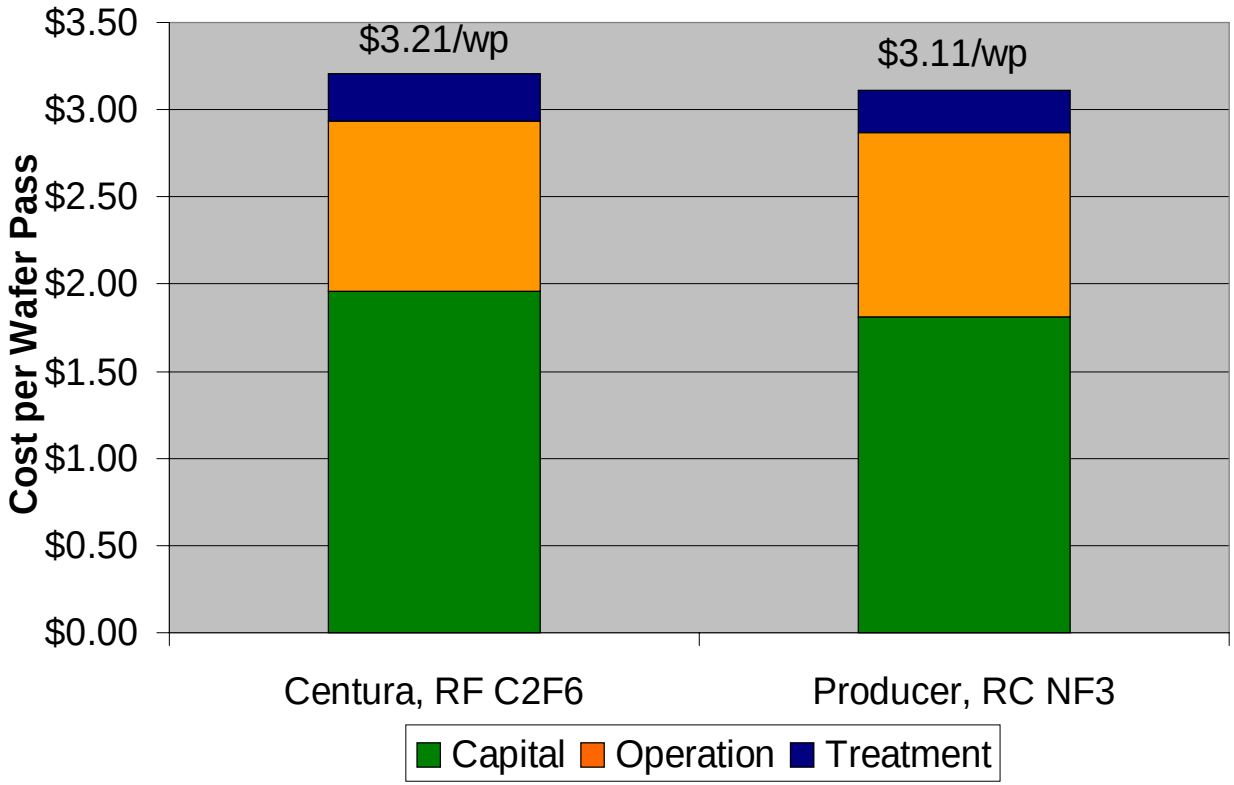
# PROCESS ARCHITECTURE

## Producer



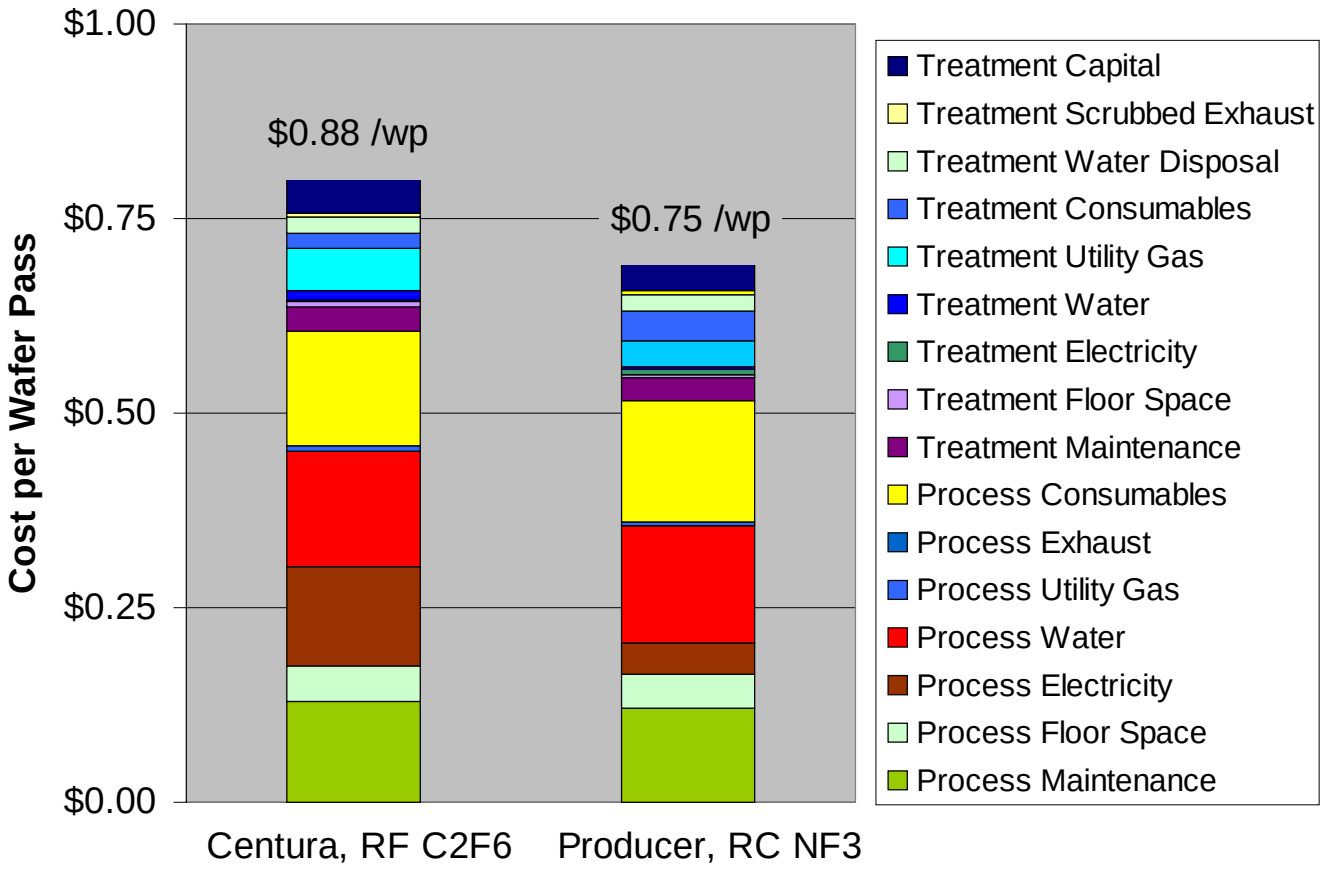
# EnV RESULTS
## Cost

- Δ=$0.10/wp
- ≈$175,000 per 6000 wspw fab



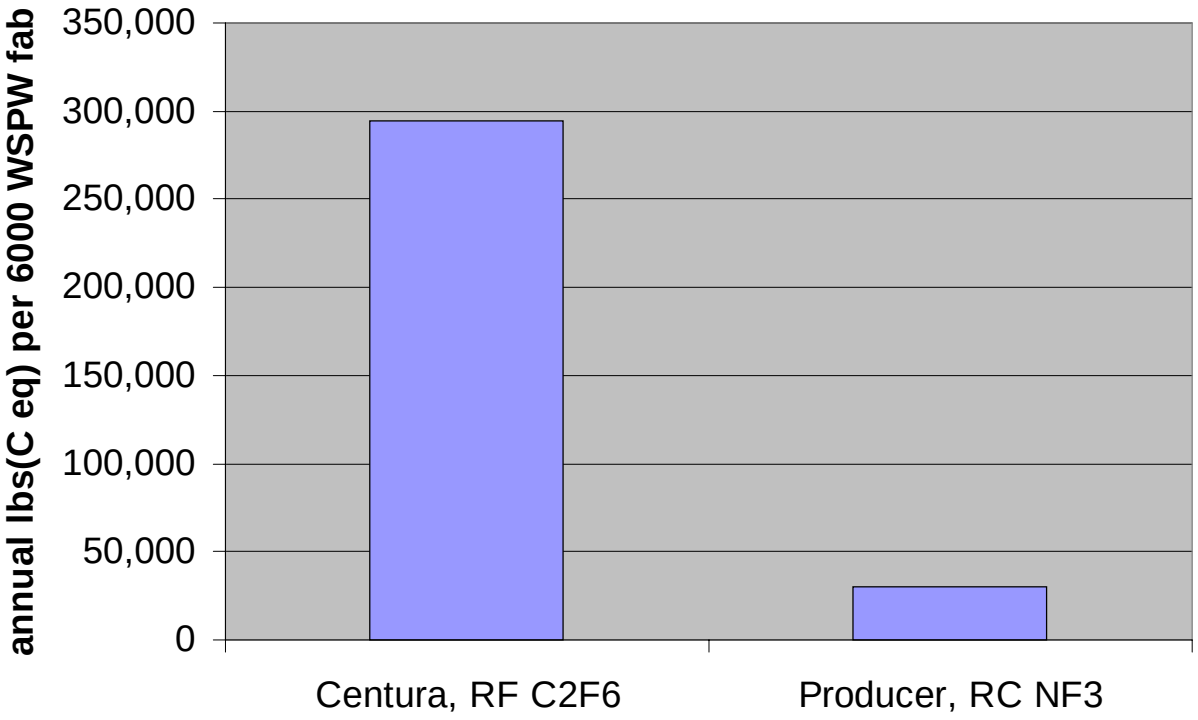
# EnV RESULTS
# Cost

- Operation and treatment costs %'s
- Power and abatement reductions



# EnV RESULTS
## Impacts

- Order of magnitude drop in GWP
- 4.5 lb. ⬆ in HAPs
  - ➞ 0.025% of site limit



# EnV RESULTS
## Performance

- Producer processing superior to Centura
- Variety of performance indicators used

| |
|---|
| 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 % |

# RESULTS
## Performance


- $NF_3$ clean performance was superior or statistically insignificant to the $C_2F_6$ clean

| | $C_2F_6$ | $NF_3$ |
|---|---|---|
| Gas Utilization | 50% | 92-99% |
| Abatement Efficiency | 30% | 50% |
| Equipment Downtime | | ⬇ |
| Wafer Throughput | | ⬆ |
| Wafer Properties | statistically insignificant | |

# DISCUSSION

- Conclusions
  - Quantification of trade-offs
  - Decisions are value-based
  - Boundaries critical ➡ wider boundaries important
- Future Work
  - Expand impact characterization
  - Sensitivity analysis
  - Develop facility level model from the processes