Enabling New Horizons

Sustainability in Semiconductor Facilities

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Motivation for Sustainability
Driving Megatrends and Challenges

Driving Megatrends:

- Globalization of Value Chains
- Demographic Change
- Climate Change
- Urbanization

Challenges:

- Climate Protection
- Productivity, Growth and Prosperity
- Efficient use of Resources
- Infrastructure & Mobility
- Renewable Energy Production
- Technology & Innovation
- Information- & Knowledge-Technologies
- Healthcare

Megatrends and their challenges are shaping the future of our society
Motivation for Sustainability
Challenges and M+W Group Portfolio

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<th>Challenges</th>
<th>M+W Group Portfolio:</th>
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<tbody>
<tr>
<td>Climate Protection</td>
<td>Advanced Technology Facilities</td>
</tr>
<tr>
<td>Productivity, Growth and Prosperity</td>
<td>Life Sciences &amp; Chemicals</td>
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<tr>
<td>Efficient use of Resources</td>
<td>Energy</td>
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<tr>
<td>Infrastructure &amp; Mobility</td>
<td>High Tech Infrastructure</td>
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<td>Renewable Energy Production</td>
<td>Solar</td>
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<tr>
<td>Technology &amp; Innovation</td>
<td>Waste-to-Energy</td>
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<td>Information- &amp; Knowledge-Technologies</td>
<td>Conventional Power Plants</td>
</tr>
<tr>
<td>Healthcare</td>
<td>Nuclear Systems</td>
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</tbody>
</table>

Megatrends and their challenges for our business
M+W Group at a Glance

- Leading global engineering and construction company
- Unique skillset in the delivery of complex technology-intensive factories and facilities
- Special expertise in cleanroom technology and controlled environments
- Established in Germany in 1912
- Figures 2014
  - Order Intake: € 2.7 bn
  - Sales: € 2.5 bn
  - Employees: 7,050

Mission Statement

“M+W creates customer value through a unique combination of lean and sustainable, high-technology engineering and project management solutions in an injury-free environment.”
Sustainability – Three Strategic Principles that are Implicit in everything we do

As a frontrunner in sustainability, M+W Group aims to challenge the balance of responsibility for people, the environment and the value creation.
# Sustainability in Semiconductor Facilities

## Influencing Factors, Challenges and Solutions

### Influencing Factors

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<tr>
<th>Economy</th>
<th>Ecology</th>
<th>Social</th>
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<tr>
<td>Bulk Gases</td>
<td>Special Gases</td>
<td>Safety Requirements</td>
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<td>Natural Gas</td>
<td>Exhaust</td>
<td>Operators</td>
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<tr>
<td>Electrical Power</td>
<td>Waste Water</td>
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</table>

### Challenges

- Schedule
  - Time to Market
  - Costs
- Environmental Protection
  - Fab Complexity
- Process Requirements
  - Product Contamination

### Solutions

- Site Selection
- Design Process
- Innovations
  - Water Efficiency
- Energy Efficiency
- Material Efficiency
Sustainability in Semiconductor Facilities
High Complexity and Challenges

- Production equipment for a wafer fab require over 200 various facility supply and disposal systems.
- Effluents and byproducts of the manufacturing process need appropriate and sophisticated treatment systems.
- Utility systems as well as the entire fab complex are supported by secondary facility systems such as chilled water, hot water, make-up air etc.
- Holistic resource management approach is mandatory to optimize the sustainability of a wafer fab.
Sustainability in Semiconductor Facilities
Materials in Manufacturing

Growing quantity of elements used in semiconductor industry

New materials need to be evaluated with regard to minimize hazards, environmental impacts (production, discharge) and CO2 footprint

Source:
Article from Dr. Mike Cooke
"Semiconductor chemistry comes to the force", Fabtech;
09/18/2008, own estimates
Design Impact on Sustainability Integrated Project Delivery (IPD)

More efficient project execution
= More sustainability – lower demand of energy, material and staff

Enhanced by our coordinated range of inhouse services
Design Impact on Sustainability Green Building Certification Systems

GB certification systems are predominantly non-process related

- **Sustainable Sites (SS Credits)**
  - Site Selection
  - Development Density & Community Connectivity
  - Brownfield Redevelopment
  - Alternative Transportation: Public Transportation Access
  - Site Development: Maximize Open Space
  - Stormwater Design: Quantity and Quality Control
  - Heat Island Effect: Non-Roof / Roof
  - Light Pollution Reduction

- **Water Efficiency (WE Credits)**
  - Water use reduction, Irrigation etc.
  - Innovative Wastewater Technologies

- **Energy and Atmosphere (EA Credits)**
  - Minimize Energy Performance
  - Refrigerant Management
  - On-Site Renewables
  - Enhanced Commissioning
  - Green Power

- **Materials and Resources (MR Credits)**
  - Storage & Collection of Recycleables
  - Building Reuse
  - Construction Waste Management
  - Material Reuse
  - Regional Materials
  - Rapidly Renewable Materials
  - Certified Wood

- **Indoor Environment Quality (EQ Credits)**
  - Minimum IAQ Performance
  - Environment Tobacco Smoke Control
  - Outdoor Air Monitoring
  - Increased Ventilation
  - Materials (Paints, Sealing’s, etc.)
  - Indoor Chemical/Pollution Control
  - Thermal Comfort
  - Daylight Utilization

- **Innovation & Design Process (ID Credits)**
  - Innovation in Design
  - Accredited Professional

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### GB Certification Systems Share

- **Sustainable Sites**
  - 20.3% of total
- **Water Efficiency**
  - 24.6% of total
- **Energy and Atmosphere**
  - 7.2% of total
- **Materials and Resources**
  - 21.7% of total
- **Indoor Environment Quality**
  - 7.2% of total
- **Innovation and Design Process**
  - 18.8% of total
Energy Conservation & Efficiency in Green Building Certification Systems

- GB certification systems focus on component & individual system efficiencies
- No consideration is given to actual process (specifications) and process-specific supply & disposal systems

Energy Conservation and Efficiency has to consider the overall concept, system and components, as well as the core process requirements into account.

Energy Management complements Green Building Certification Systems
Sustainability in Semiconductor Facilities
Energy Management

- Investment plays an important role on overall project economics
  - Difficult to recover high investments through operational cost savings

- But excessively low investment plans result in:
  - “Design to Budget“
  - Less efficient facility systems
  - Little implementation of energy conservation & efficient concepts
  - Each discipline reduces construction cost without consideration of other systems

Low Investment VS. Energy Efficiency

How to achieve an optimum?

ENERGY MANAGEMENT
Energy Management/Efficiency During Design
The Five Step “Inside – Out” Approach

Step 5
- Alternative Energy Supply Systems (Renewables)

Step 4
- Heating and Cooling Generation Systems (Renewables)

Step 3
- Thermal Energy Supply & Distribution System Optimization

Step 2
- HVAC and Process Supply Systems (PCW, CDA)

Step 1
- Production Energy Efficiency

Improvement and Optimization from Inside to Outside
Sustainability in Semiconductor Facilities
Life Cycle Assessment

LCA is a systematic technique for the evaluation of (potential) \textbf{environmental impacts} associated with products, processes or services over their \textbf{entire} life cycle.

**Direct impacts**

- Acidification
- Global Warming
- Resource depletion
- Eutrophication

**Indirect impact sources**

- Utility generation, distribution
- Extraction of raw materials
- Manufacturing of (intermediate) products
- Transportation
- Waste treatment

\textbf{LCA} is a systematic technique for the evaluation of (potential) \textbf{environmental impacts} associated with products, processes or services over their \textbf{entire} life cycle.
Sustainability in Semiconductor Facilities

LCA - Advantages & Results

- Calculate, track and benchmark environmental performance
- Analyze environmental hot-spots in the manufacturing process or supply chain
- Identify effective measures to reduce environmental footprint
- Basis for making environmentally sound decisions
- Involve stakeholders
- Show your commitment to sustainable development
- Reduce risks

Carbon footprint breakdown [%] of a semiconductor R&D site in Europe
Sustainability Enhancements
General Overview & Examples

Energy Efficiency
- Solar Heating
- Concrete Cooling
- GEX Recycling
- MAU Cooling Optimization
- Ground (Water) Cooling
- GEX-MAU Energy Recovery
- Heat Exchanger Temperature Optimization
- MAU Cooling Optimization
- Photovoltaic
- Concrete Cooling
- Decentralized RAHU
- GEX Recycling
- Low Chemistry Scrubber
- Energy Recovery
- Free Cooling
- Building Tightness
- Chilled Water Temperature Optimization
- High Temperature PCW
- Concrete Cooling
- Decentralized RAHU
- Heat Exchanger Temperature Optimization
- WT – WWT Heat Recovery
- Solar Cooling
- Concrete Cooling

Water Efficiency
- Organic Sanitary WW
- Slurry Treatment
- Low Chemistry Scrubber
- Advanced HF-Treatment
- Cu-WW Treatment
- Chilled Water Heat Recovery
- Slurry Treatment
- Heat Recovery
- Organic Sanitary WW
- Solvent Waste Treatment
- Drain Segregation
- Cooling Water Heat Recovery
- Heat Recovery
- Heat Recovery
- Drain Segregation

Materials / Chemicals / Consumables Efficiency
- Ammonia Reclaim
- TMAH Reclaim
- TMAH Reclaim
- Cu Reclaim
- Organic Sanitary WW
- Cu Reclaim
- Organic Sanitary WW
- Ammonia Reclaim
- TMAH Reclaim
- Organic Sanitary WW
- Organic Sanitary WW

Abbreviations:
MAU = make-up air,
GEX = general exhaust,
ACEX = acid exhaust,
CAEX = caustic exhaust,
PCW = process cooling water,
UPW = ultra pure water,
WW = wastewater

Materials / Chemicals / Consumables Efficiency
Sustainability Enhancements
Water Efficiency

UPW Recycling / Re-Claim / Re-use up to 90% realized in existing projects

- Last rinse recycling
- Re-claim in facility systems
  - Waste water supply to cooling tower
    - Waste water from UPW plant (with low salt concentration) supplied cooling tower
  - 30% make-up water savings

- Water treatment
- Production
- WWT
- Facilities

Non recyclable Waste water

Treatment type: Reduction of TOC contamination

Reduction of Water Consumption up to 40 %
Sustainability Enhancements
Energy Efficiency & Management - Example

- **Energy Efficiency Management** done for R&D semiconductor facility during complete design phase

- Energy (electrical power, natural gas) & water consumption reduction of all facility systems

  → **Operational cost savings**

- Capacity reduction of changed system & all surrounding and successive systems

  → **Investment cost savings**
  Lower capacity

  → **Operational cost savings**
  Lower power provision fee

<table>
<thead>
<tr>
<th>Subject</th>
<th>Electrical Power Saving in MWh/a</th>
<th>Natural Gas Saving in MWh/a</th>
<th>Water Saving in m³/a</th>
<th>Energy + Water Cost Saving in €/a</th>
<th>Additional Investment in €</th>
<th>Payback Period in Years</th>
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<tbody>
<tr>
<td>Distillation + Cogeneration</td>
<td>-4,284</td>
<td>305,914</td>
<td>900,000</td>
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<td>Heat Recovery</td>
<td>215</td>
<td>11,670</td>
<td>23,018</td>
<td>479,037</td>
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<td>Extended Heat Recovery</td>
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<td>16,097</td>
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<td>658,946</td>
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<td>PCW Free Cooling</td>
<td>2,320</td>
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<td>9,373</td>
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<td>PCW Generation with 12°C</td>
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<td>Heat Recovery + Free Cooling</td>
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<td>11,670</td>
<td>30,648</td>
<td>613,271</td>
<td>1,700,000</td>
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Sustainability Enhancements
General Exhaust Recycling & Re-Use

- **Discharge of risk-free General Exhaust** into subfab or support areas (add. system “Recycling Exhaust”)

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<th>Assumption: 25,000 m² Fab (Europe)</th>
<th>= Investment saving</th>
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<tr>
<td>GEX-Recycling</td>
<td>290,000 m³/h (30% of total GEX)</td>
<td></td>
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<tr>
<td>Electrical Power</td>
<td>1,970 MWh/a</td>
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<tr>
<td>Natural Gas Savings</td>
<td>284,000 m³/a</td>
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<tr>
<td>CO2 Emission Savings</td>
<td>1,500 t/a</td>
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<tr>
<td>Operation Cost</td>
<td>300,000 €/a</td>
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<tr>
<td>Chiller &amp; Cooling</td>
<td>3,000 kW</td>
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</tr>
</tbody>
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**Reduction of investment & operational costs**

**Assumption:**
- 25,000 m² Fab (Europe)
- GEX Recycling: 290,000 m³/h (30% of total GEX)
- Electrical Power Saving: 1,970 MWh/a
- Natural Gas Savings: 284,000 m³/a
- CO2 Emission Savings: 1,500 t/a
- Operation Cost Savings: 300,000 €/a
- Chiller & Cooling Tower Capacity Savings: 3,000 kW

= Investment saving
Sustainability Enhancements
Alternative Energy Supply Concept

Trigeneration Plant:
Base load covering of electrical power, hot and chilled water

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<tr>
<td>Alternative Energy Supply Concept</td>
<td></td>
</tr>
<tr>
<td>Electrical power saving</td>
<td>17,000 MWh/a</td>
</tr>
<tr>
<td>Higher natural gas demand</td>
<td>49,600,000 m³/a</td>
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<tr>
<td>CO2 emission reduction</td>
<td>26,800 t/a</td>
</tr>
<tr>
<td>Energy &amp; Water cost reduction</td>
<td>5,480,000 €/a</td>
</tr>
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Assumption: 25,000 m² Fab (Europe)
Sustainability in Semiconductor Facilities

Summary

- Sustainable technologies are becoming more and more important for our clients

- “Good design & construction” should include consideration of all green building aspects as well as process requirements

- Overall knowledge & experience of the process, facility systems and energy supply sources is essential

Sustainability = Protection of the Environment

...is our motivation and implicit in everything we do
THANK YOU!

Enabling New Horizons

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