Enabling New Horizons

M+W GROUP


# Sustainable, Cost-Efficient Semiconductor Facilities Design Trends

**Hartmut Schneider (VP Technology)**

**Green High-Tech Facility Forum**
**SEMICON China, 2017**

# 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 2015

| | |
|---|---|
| Order Intake: | € 3 bn |
| Sales: | € 3 bn |
| Employees: | 6,000 |

## 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.”**

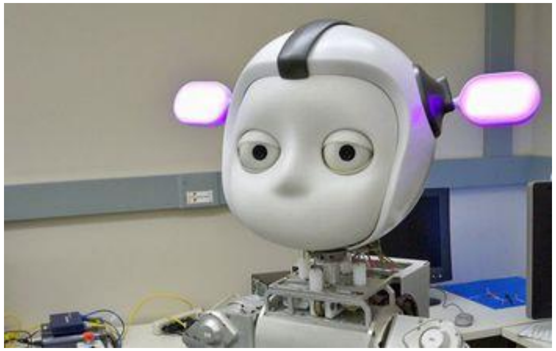


Source: M+W Group

# Challenges in a Changing Industry...
## And More Sustainability

M+W GROUP

- The trend of “Nanoelectronics Everywhere” has created new high volume semiconductor consumer markets which drive:
  - Diversification of process technologies & applications
  - Flexible manufacturing
  - Corporate social responsibilities
  - Environmental-friendly green products



Source: US National Robotics Initiative

- The protection of the environment and natural resources is of highest priority for China
  - China has signed the Paris Agreement within the United Nations Framework Convention on Climate Change (UNFCCC) in 2015
  - China is the largest investor in green energy globally
  - New environmental protection law established in 2015

Source: SINA Corporation

**Challenge: Sustainability while maintaining cost-efficiency.**

# Evaluation of Waste Reduction Measures
## Life Cycle Assessment (LCA) Modeling

M+W GROUP

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

Defined in ISO 14040 and ISO 14044

**Calculate the environmental performance**

- How big is the carbon footprint?
- How much water is used?
- What are my KEPIs?

**Identify environmental hotspots**

- Where is the environmental impact coming from?
- What is the biggest impact?

**Assess, compare, optimize design options**

- Which option is more sustainable?
- How can I improve my environmental performance?

**LCA enables one to make environmentally sound decisions.**

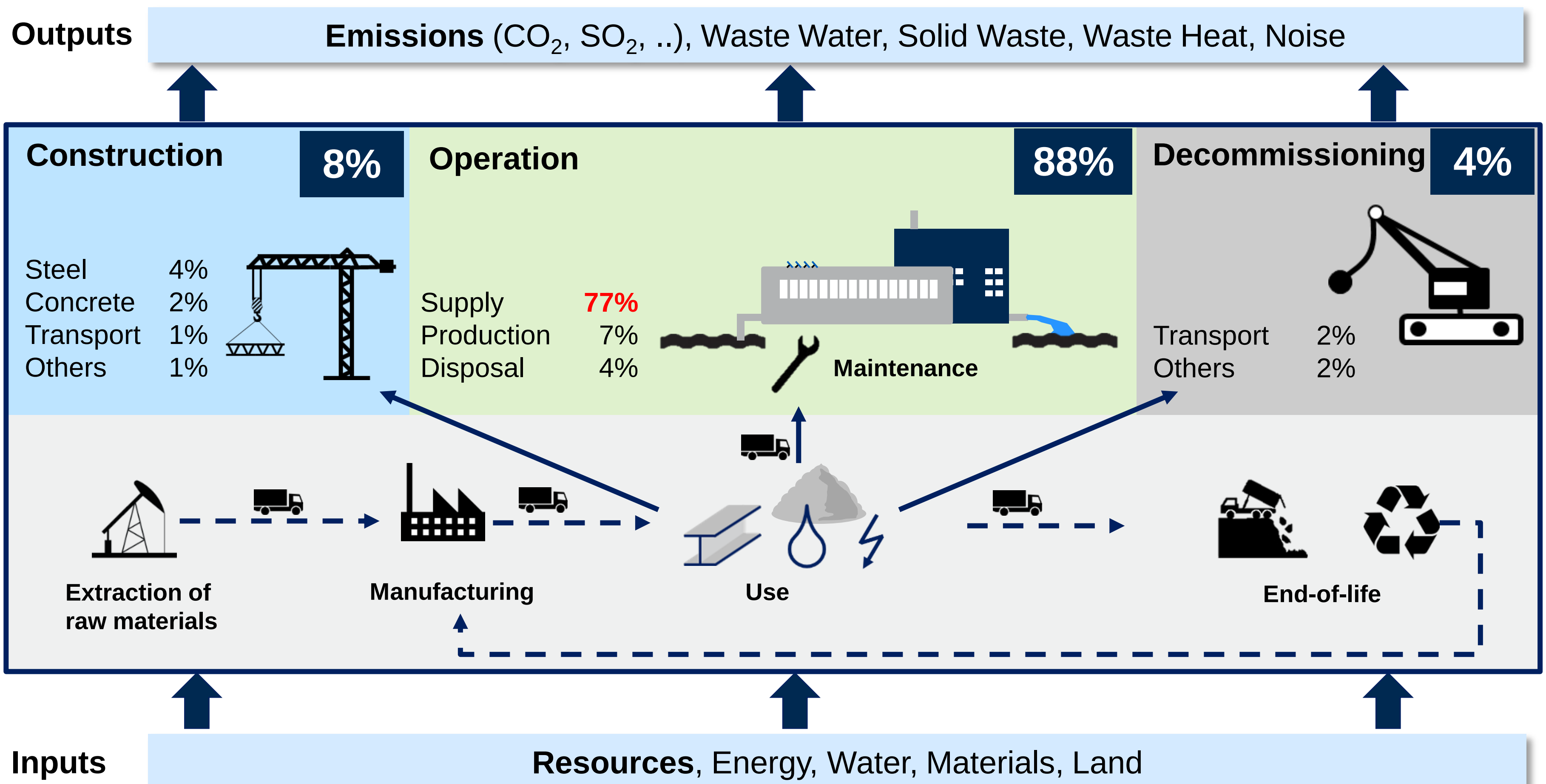


Source: M+W Group

# Life Cycle Assessment (LCA) Modeling
## Operation Phase Dominates CO2 Footprint

M+W GROUP

## Calculated Relative Contribution to Wafer Fab Life Cycle CO2 Footprint

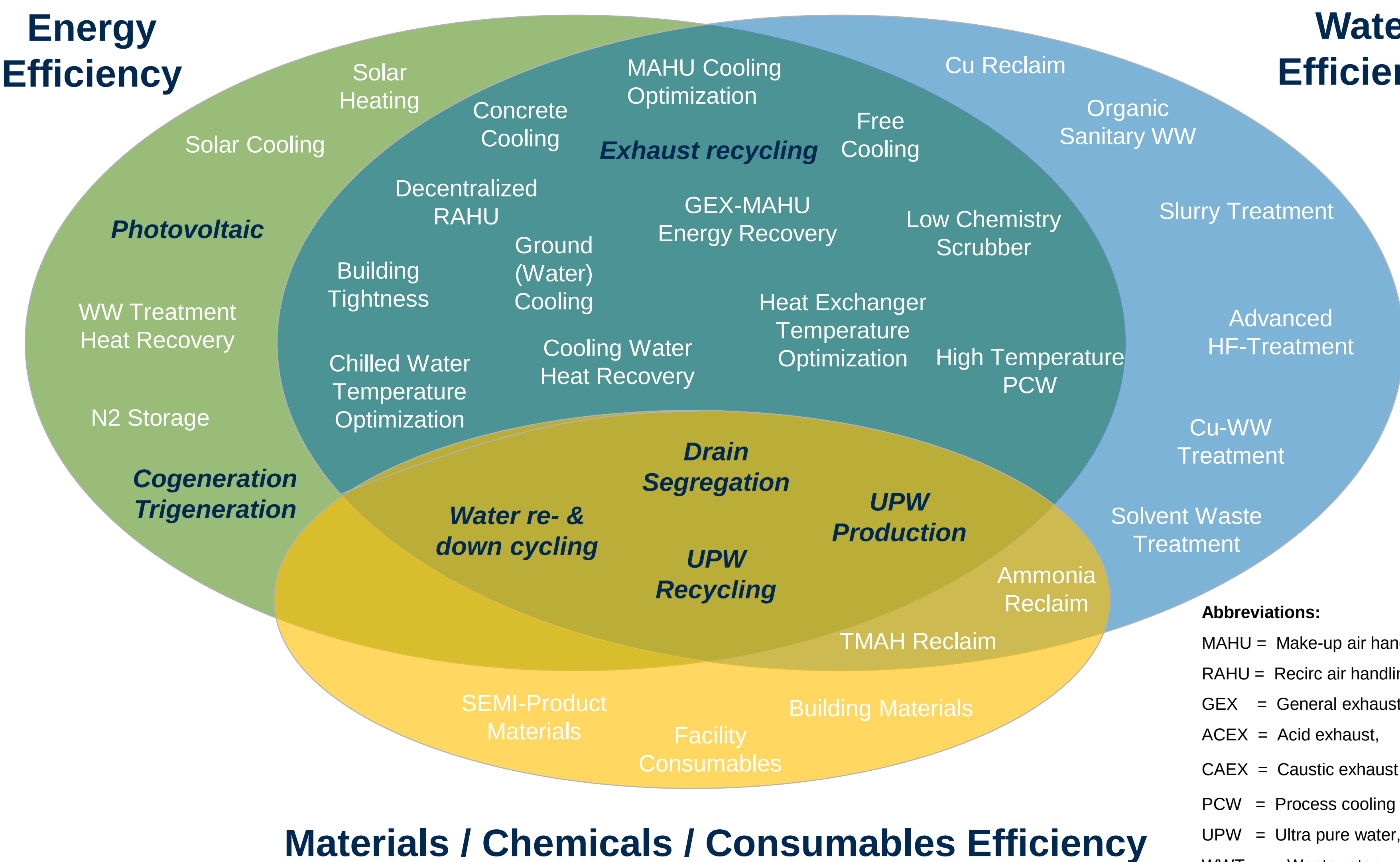




March 2017
Source: M+W Group

# Integrated Waste Reduction for Facility Systems
## General Overview & Examples

M+W GROUP




**Abbreviations:**

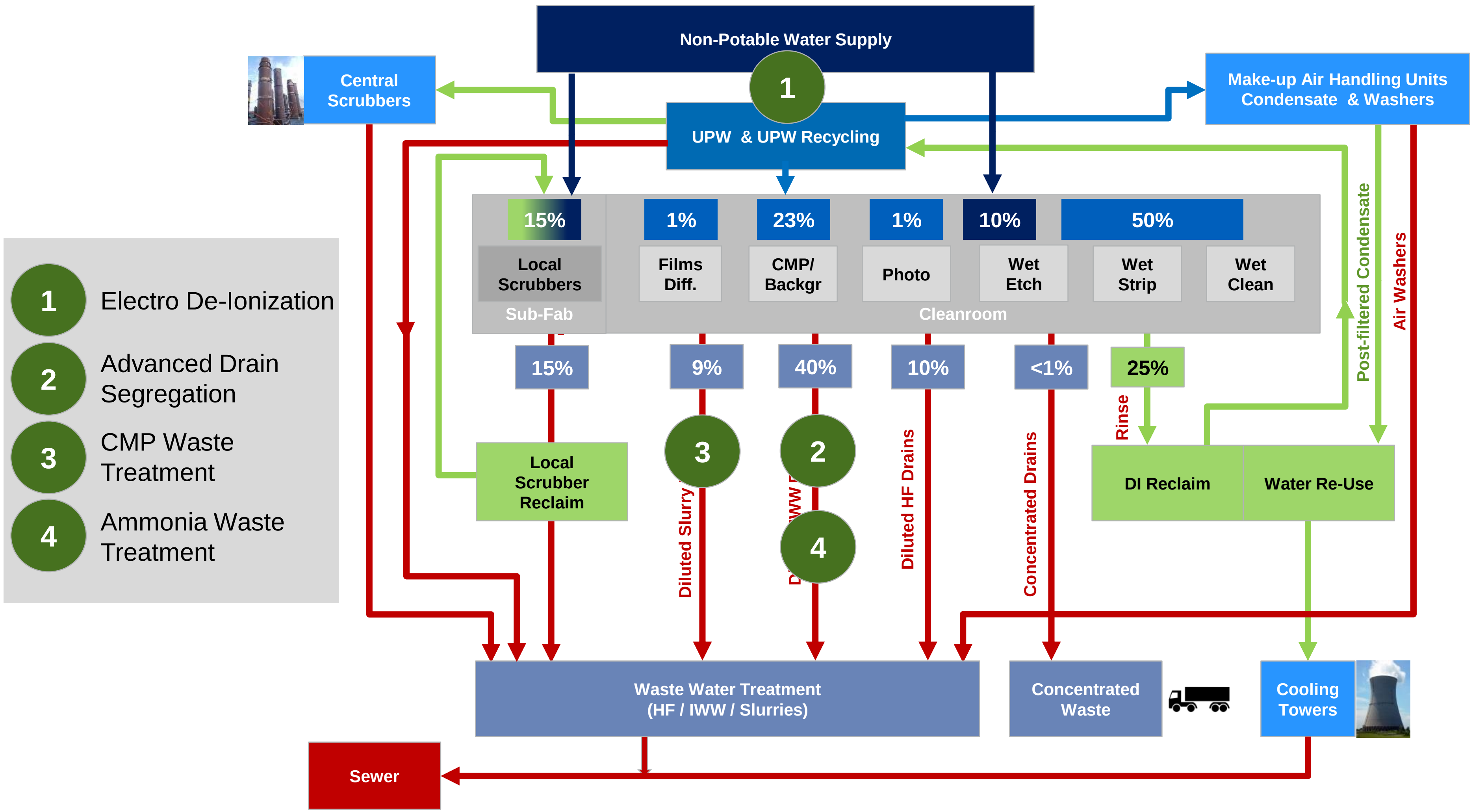
MAHU = Make-up air handling unit,
RAHU = Recirc air handling unit
GEX = General exhaust,
ACEX = Acid exhaust,
CAEX = Caustic exhaust
PCW = Process cooling water,
UPW = Ultra pure water,
WWT = Wastewater



Source: M+W Group

# High Leverage Waste Reduction Measures
## UPW and Waste Water Systems

M+W GROUP




**Additional measures can substantially improve overall site water recycling ratios from 50% to >75%.**

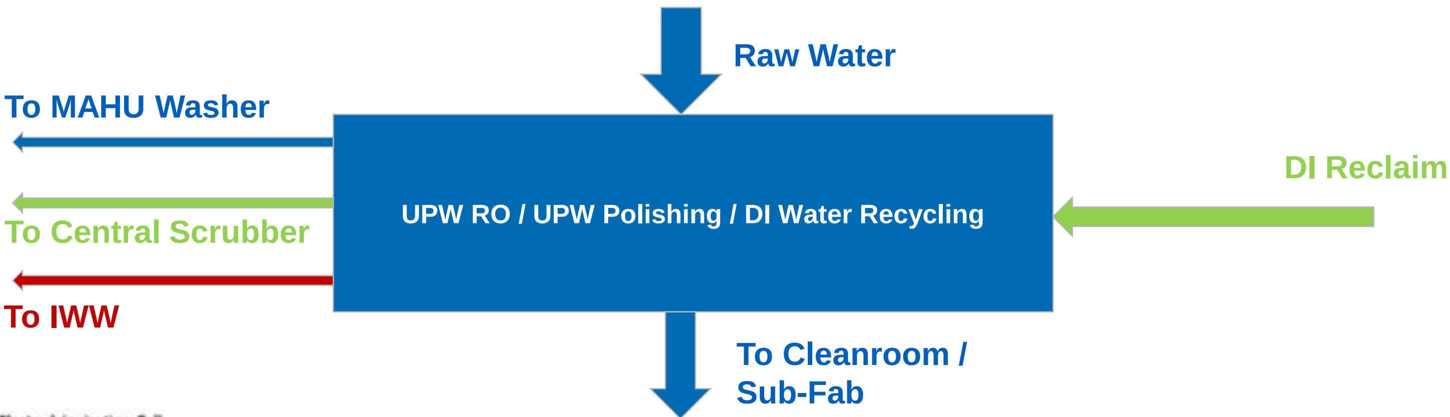


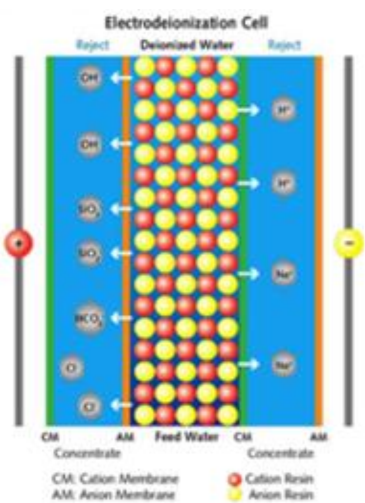
Source: M+W Group

# Low-Chem UPW Make-Up
## Electro De-Ionization

- Comparison based on installed systems for a major semiconductor facility, similar raw water inlet quality and UPW specifications

1




Source: Waterworld, April 2016

| Description | Standard | Low Chem | Pros & Cons |
|---|---|---|---|
| Chemical Usage | Higher | Lower | 80% Reduction |
| Energy Cons. | Lower | Higher | 35% Increase |
| Water Demand | Higher | Lower | 10% Reduction |
| Footprint | Larger | Smaller | 25% Reduction |
| CAPEX | Higher | Lower | 5% Reduction |
| OPEX | Higher | Lower | 3.5% Reduction |

Source: M+W Group. Actual comparison for a semiconductor facility based on same raw water inlet quality and UPW specifications

# Process Exhaust
## Waste Reduction Opportunities

M+W GROUP

| Opportunity | Description | Status | Potential Waste Red. | Considerations |
|---|---|---|---|---|
| **Heat exhaust recycling** | Non-toxic exhaust discharged into recirculation airstream | In Operation | **Medium** | Non-hazardous exhaust only. CAPEX saving potential (MAHU, chillers, boilers etc.) |
| **PFC recycling** | Etch/CVD chamber cleaning gases | Prototype | **High** | Reduced global warming gases. High purification requirements. |
| **Dynamic Exhaust Volume Control** | Multiple actuated dampers at process tools | Concept | **Medium** | Increased CAPEX for dampers & FMCS system |
| **Scrubber heat recovery** | Pre-cooling of MAHU air (~16ºC => 1 MW) | Concept | **Medium** | Regional dependent. Reduced chiller capacity, plus heat recovery system CAPEX |
| **EXVO heat recovery** | Approx. 200ºC available for pre-heating hot water (~0.4MW) | Prototype | **Low** | Reduced boiler capacity, plus heat recovery system CAPEX |
| **Reclaimed Scrubber Chemicals** | Process waste water containing $H_2SO_4$ and $NaOH$ | Concept | **Low** | Low potential waste streams and additional segregation |
| **Solvent waste reuse** | Fuel for EXVO (solvent exhaust treatment) or boilers | Other industries | **Low** | Low concentrated solvent waste discharge volumes. |

**Example:**
**Heat Exhaust Recycling**

| | |
|---|---|
| GEX-Recycling | 290,000 m$^3$/h (30% of total GEX) |
| Electrical Power Saving | 1,970 MWh/a |
| Natural Gas Savings | 284,000 m$^3$/a |
| $CO_2$ Emission Savings | 1,500 t/a |
| Operation Cost Savings | 300,000 €/a |
| Chiller & Cooling Tower Capacity Savings | 3,000 kW |



Source: M+W Group

# Waste Reduction during Construction
## Pre-Assembly and Modularization

M+W GROUP

**Traditional Stick Build Construction → Design for Manufacturing/Assembly**

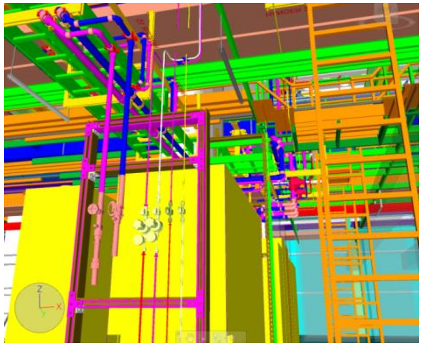
### Benefits

- Reduced materials, space and resources wasted on site (safety)
- High labor productivity through efficiency & less interface management
- Continuous manufacturing with less set-ups
- Established pre-qualification testing off-site
- Electronic records of as-builts
- Fast ramp-up of installation phase

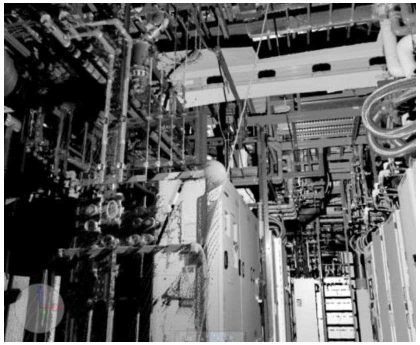
### Pre-Requisites

- Collaborative & experienced supply chain
- Early contractor engagement
- Detailed engineering and BIM/4D platform implementation

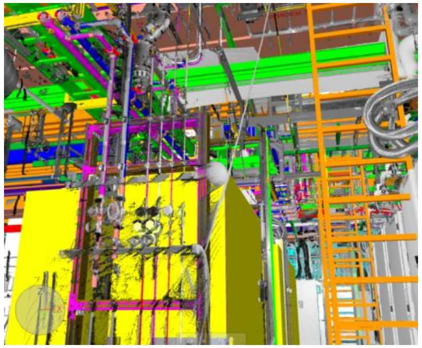
**Scan of actual sub fab area**



**BIM Model development**



**Scan of actual sub fab area**



**Overlay of scan with model**



Source: M+W Group

# Sustainable Energy Supply Options
## Renewable Energy

M+W GROUP

- Renewable energy sources are site-dependent
- 100% renewable energy supply to a fab is unlikely
  - Space requirements
  - Remote locations inevitable
  - Energy storage required for high quality power supply

**Potential $CO_2$ reduction in case of 100% utilization of renewable energies is approx. 540,000 t/a***

* Assumes $CO_2$ emission of 0.578 kg/kWh elec. For a 25k m² Fab with power demand of ~ 420 GWh/a

**Photovoltaic**

**PV Park 350 MWp**
**~ 5 km² ***

* Related to global irradiation of 1,300 kWh/m²/a

**Wind**

**Wind Park 22x 6 MW units**
**~ 15 to 20 km² ****

** Depending on annual and maximum wind conditions

**Biomass**

**Agriculture Area**
**Short Turnover Plantation ~ 330 km²**
**Crop Straw ~ 700 km²**

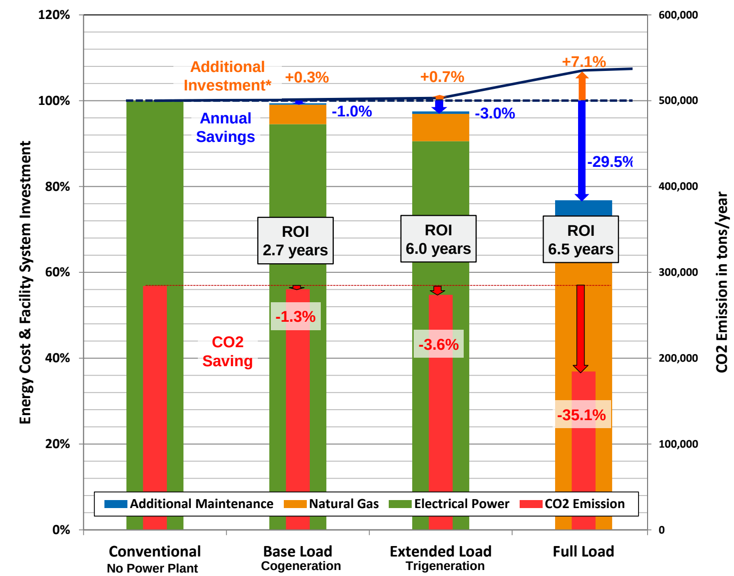


Source: M+W Group

# Sustainable Energy Supply Options
## Cogeneration & Trigeneration Plant Scenarios

- Alternative sustainable energy supply strategies effect CAPEX and ROI periods

| Scenario | Type | Scope |
|---|---|---|
| Base Load | Cogeneration | Provision of base load of hot water (summer) & corresponding electrical power capacity |
| Extended Load | Trigeneration | Provision of higher load of hot & chilled water & corresponding electrical power capacity<br>Winter: Hot Water (up to 100%)<br>Summer: Base Load of Hot Water & Share of Chilled Water |
| Full Load | Trigeneration | Provision of full load of electrical power & hot and chilled water<br>Winter: 100% Hot Water & Share of Chilled Water<br>Summer: Base Load of Hot Water & 100% Chilled Water |




**Example: 25k m² Wafer Fab in Asia, Electrical Power 80 €/MWh, Natural Gas 25 €/MWh(LHV)**



Source: M+W Group

# Integrated Waste Reduction
## Summary

- An Integrated Waste Reduction Program considers multiple interactions and dependencies by utilizing LCA methods

- Waste reduction focuses on fab operations
  - New water treatment technologies and advanced drain segregation can improve a site's overall reclaim ratio >75%
  - A reduction in process exhaust treatment volumes has a significant leverage on fab power and water demand.

- Improvements during fab construction include modular or pre-assembled building & facility systems or elements.

- Alternative energy supply concepts can further reduce energy demand and the $CO_2$ footprint of the wafer fab.
  - Tri-generation requires acceptance of ROI periods > 6 years, pending power to gas price ratio

**Resource efficiency and waste reduction have become major considerations for wafer fab design / operation.**





Source: M+W Group

# THANK YOU

Hartmut Schneider
Phone: +49 711 8804-1431
Mail: hartmut.schneider@mwgroup.net

M+W Group
Lotterbergstraße 30
70499 Stuttgart, Germany

www.mwgroup.net