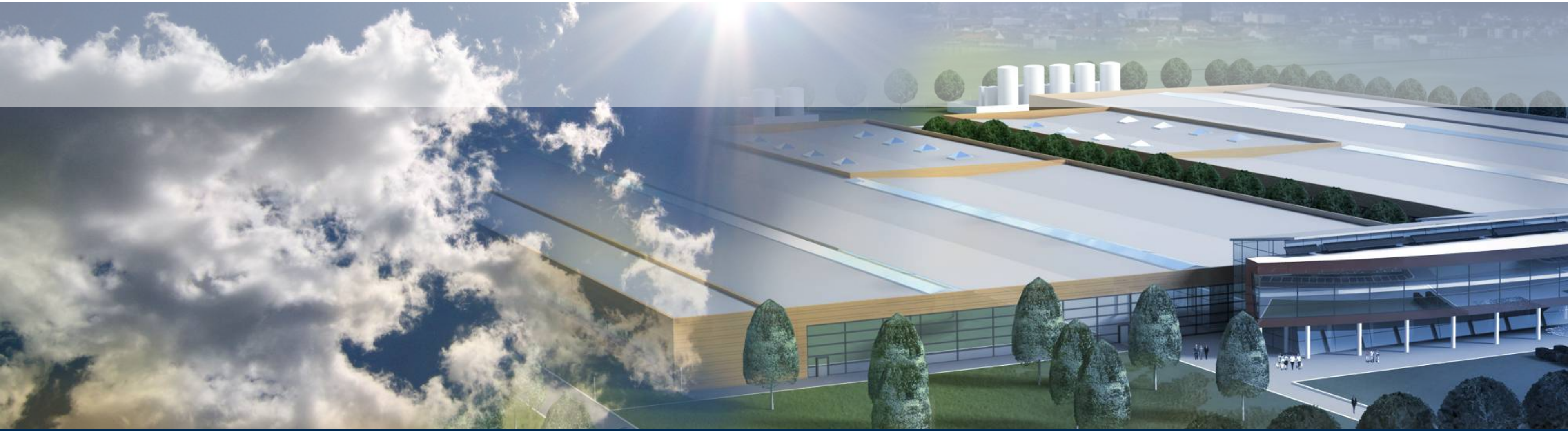

Eco-Factories and PV Manufacturing

Sustainability aspects for terawatt scale PV

European PV Technology Platform & PVSEC

Hamburg, September 8th 2011

M+W Group
Dr. Klaus Eberhardt

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M+W GROUP

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M+W Group at a Glance

EHS as core value

Know-how of over
5,000 technical experts

Global presence

The leading global engineering and project company ….

- more than 6,000 employees worldwide
- world class EHS records and awards
- technical expertise in process and automation

…. for high-tech production facilities, mission critical infrastructure and energy & environmental solutions ….

- more than 200 Semiconductor Fabs realized
- More than 10 GWp Photovoltaic Fab capacity realized
- largest Nanotechnology Research Center built
- over 300 successfully completed turnkey projects

…. committed to deliver customer value

Proven capability
to manage
complex projects

Energy-efficient &
environmentally friendly
solutions

Integrated solutions
focused on
customer value

Recognitions and Strategic Initiatives

The Top 20 International Design Firms
Based on Revenue from Projects Outside Home Country

Rank 2010	Rank 2009	Type of Firm	Firm	Revenue $ bn
1	1	E	FUGRO, The Netherlands	2.67
2	2	EC	WORLEYPARSONS, Australia	2.58
3	6	EA	AECOM TECHNOLOGY CORP., U.S.A.	2.39
4	4	EC	FLUOR CORP., U.S.A.	2.12
5	3	E	AMEC PLC, UK	1.95
6	7	E	ARCADIS, The Netherlands	1.90
7	5	EAC	JACOBS, U.S.A.	1.88
8	8	EC	SNC-LAVALIN INTERNATIONAL, Canada	1.72
9	10	EA	DAR AL-HANDASAH CONSULTANTS, Egypt	1.63
10	9	EC	KBR, U.S.A.	1.50
11	-	EC	M+W GROUP, Germany	1.24
12	13	EC	TECNICAS REUNIDAS, Spain	1.21
13	11	EC	BECHTEL, U.S.A.	1.11
14	15	E	MOTT [illegible]	[illegible]
15	19	EC	HOCH [illegible]	[illegible]
16	–	EC	TECH [illegible]	[illegible]
17	26	EAC	CH2M [illegible]	[illegible]
18	21	EAP	LOUIS [illegible]	[illegible]
19	17	E	ARUP [illegible]	[illegible]
20	18	E	HATCH GROUP, Canada	0.78

2010 ranking is based on revenue for design services performed in 2009.
Key to Type of Firm: A architect; E engineer; C contractor; P planner

Source: Engineering News Record / Company Annual Reports

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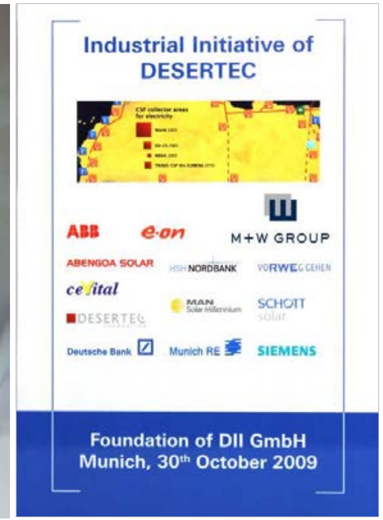
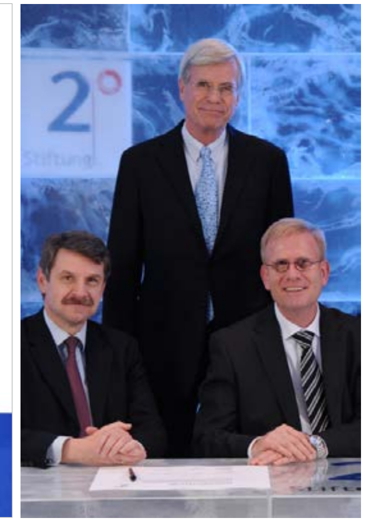
"Top 20" of the Leading International Design Firms, Bruce Shaw Handbook 2011

"Top 100" of Germany's World Market Leaders

"Turnkey Company of the Year" Award by Solar PV Management Magazine & Turnkey Company of the Year 2011



Founding Member of Desertec Industrial Initiative Dii



Founding Donor of Trust '2 Degrees' for Climate Protection

M+W Group – Business Divisions

M+W Group is the leading global engineering and construction company for high tech projects.

Advanced Technology Facilities

- Semiconductor
- Flat Panel Display
- Photovoltaics
- Battery Cells

Life Science Industries

- Pharmaceutical
- Biotechnology
- Medical Devices
- Food & Beverages
- Consumer Care
- Chemical
- Fine Chemical

Energy & Environment Technologies

- Renewable Energy
- Waste to Energy
- Power Plants
- Green Buildings

High Tech Infrastructure

- Science & Research
- IT & Telecom
- Space & Security
- General Industries

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Cost Matters – Potential for PV

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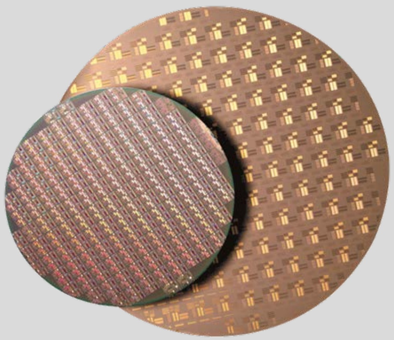
FIRST	THEN	NEXT



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

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

Cost per Watt

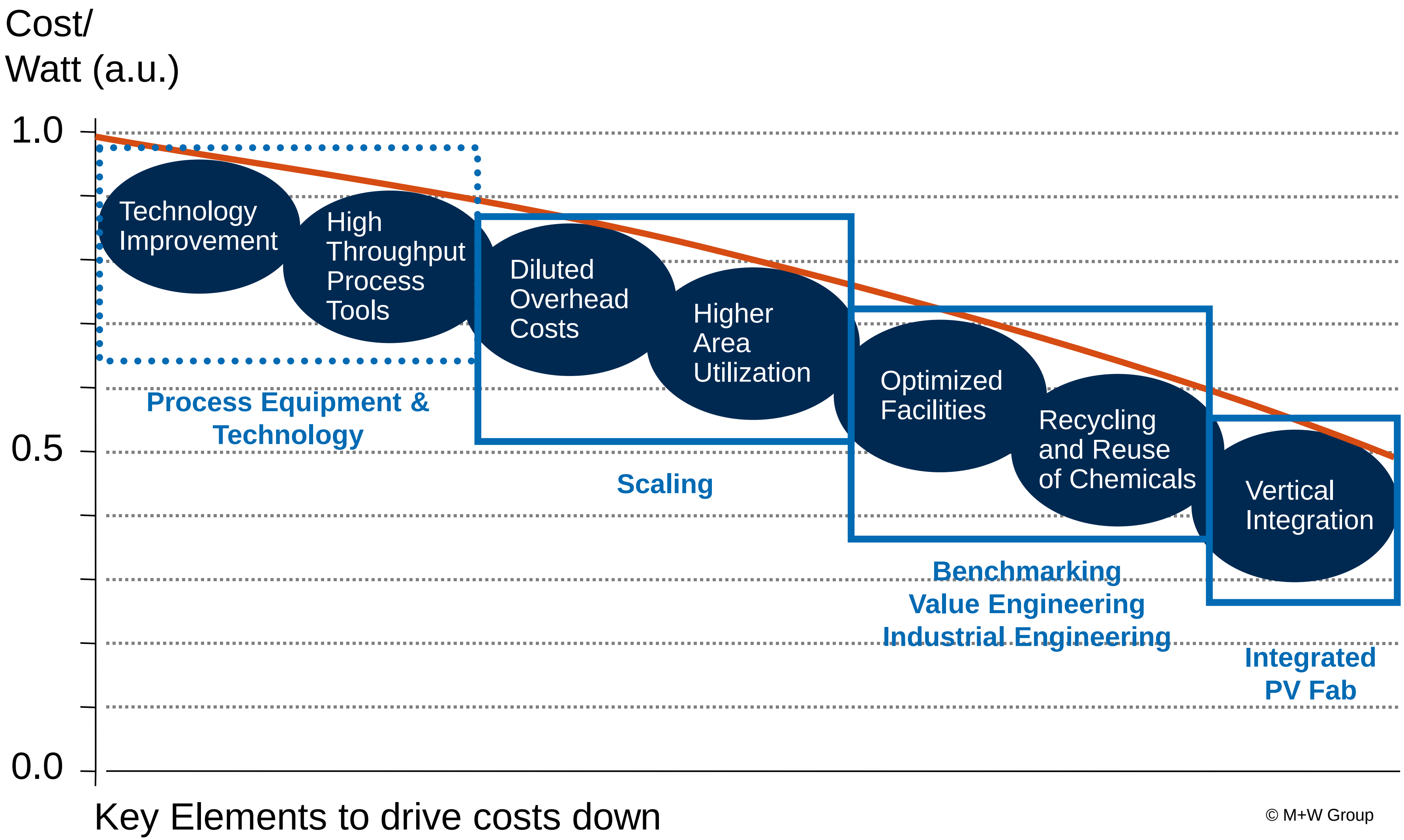
2000	2010	2015
280 MW	17 GW	44 GW
$1.50/W	$1.00/W	<$.75/W

2x Cost Reduction

Source: EPIA, M+W Assumptions

Further Potential for PV?

Key Elements to Drive Down Cost for PV Manufacturing



Drivers towards Sustainability

- Future PV Manufacturing will be largely influenced by:
  - Legislature
  - Availability and cost of energy
  - A voluntary commitment by the industry to reduce energy consumption as well as CO2 discharge

Legislature as well as public pressure due to global warmimg as well as the limited availability of fossil-based fuels will pave the route towards „Green PV Fabs“

„Green“ certification systems

- BREEAM (UK)
- LEED (Green Building Council, U.S.)
- Estidama (UAE)

- The common objective of all certification systems is the reduction of energy and CO2 emissions through improved efficiency during design & operation
- The possible introduction of compulsory Carbon trading will not only trigger the reduction of energy consumption, but also the type of energy source being used to supply power to each PV manufacturing facility

Initial focus towards public and commercial buildings, but increasingly for electronincs and PV manufacturing

References – Designed & Build according to LEED

Globalfoundries

Malta NY

USA

2007 - 2012

GLOBALFOUNDRIES

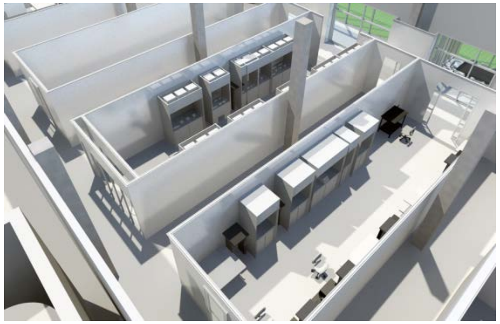
Fab 8

Design + Build

39 000 WSPM 28nm on 300mm Wafer

Production Area: 19 500 m²

- Most technologically advanced manufacturing facility
- Largest leading-edge semiconductor foundry in the US
- Designed to LEED® certification



University of Utah

Salt Lake City UT

USA

2007 - 2012

Neuroscience & Biomedical Research Building

Design

Total Building Area: 18 900 m²

- Research hub for the entire Rocky Mountain and Western Great Plains region of the US
- Integrates nanotechnology and materials sciences with biological and medical research
- Designed to LEED® Gold certification

Roche

Shanghai

China

2007 - 2011

Roche

Roche RoSE

EPCM

Production Area: 23 000 m²

- LEED "Gold"
- cGMP QA/QC Laboratory Facility for sterile biological manufacturing QA/QC functions. Decontamination & Waste Treatment Plant, Warehouse, Offices, Utility Building, Grounds & Landscape, Cafeteria etc.

References – Designed & build according to LEED

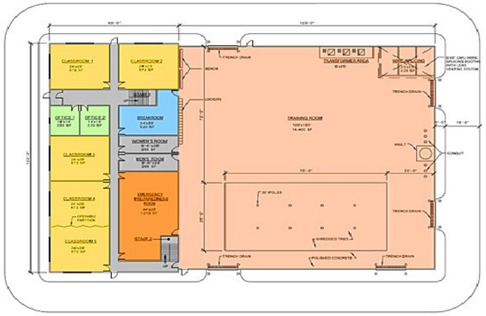
Mead Johnson
Guangzhou
China
2010 - 2010

Nutritional Products R&D Institute

Design

Total Building Area: 5 000 m²

- The new Institute including R&D, medical affair, nutrition science, product development, process engineering and sensory analysis.
- LEED "Silver“ Certification



Exelon Business Services
Rockford IL
USA
2008 - 2008

Com-Ed Training Facility

Feasibility Study

Total Building Area: 3 000 m²

- Prototype facility to train electrical service workers
- Designed to LEED® Silver certification
- Command center to track electrical grid restoration

Genzyme
Beijing
China
2007 - 2010

Biotech R&D Center

Engineering

Production Area: 1 000 m²

- LEED "Platinum" & "Gold“
- Engineering of BSL-2 cGMP R&D laboratory facility for boutique biotech pharmaceutical products

References – Designed & build according to LEED

NASA
Greenbelt MD
USA
2004 - 2006

NASA Goddard Space Flight Center
Design
Total Building Area: 24 500 m²
- Consolidates personnel from 6 buildings into single building
- Multiple purpose areas: Chemistry, Electronic Instrument, Cleanrooms, High Bay Assembly
- Designed to LEED® Silver certification

Argonne National Laboratory
Argonne IL
USA
2004 - 2006

Center for Nanoscale Materials (CNM)
Design + Construction Management
Total Building Area: 8 500 m²
- Multiple cleanroom research laboratories
- Hard-X-ray nanoprobe beamline
- 2007 Excellence in Engineering Award
- Designed to LEED® Silver certification

Hitachi
San Jose CA
USA
2004 - 2006

Research & Development Center
Design
Total Building Area: 32 500 m²
- Rapid, cost effective reconfiguration of lab spaces
- Cleanroom laser lab
- Designed to LEED® certification

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CO2 footprint

- CO_2 emissions differ significantly when comparing fossile with renewable energy sources
- Crystalline Silicon based modules exhibit a slightly higher emission rate due to the high energy flux to produce Poly Si and the ingots
- Thin film based modules exhibit fairly low CO_2 footprint. Slightly higher if fluorinated gases are used for chamber cleaning

- Strong dependency on the operational phase of most facilities (excluding the manufacturing of the process equipment)
  - Any analysis must therefore focus on the overall energy consumption and the identification of key users

Estimated CO2 emissions generated by Energy Source

		Range $g\ CO_2/kWh$		
Conventional[1]				
	Lignite	850	-	1,200
	Black Coal	750	-	1,100
	Natural Gas	400	-	550
	Nuclear	10	-	30
Renewables				
	Wind[1]	10	-	40
	CSP[1]	10	-	14
	PV[2]	**Solar Irradiation**		
		2,000 kWh/KW		**1,000 kWh/KW**
	Si-based	30	-	60
	CdTe	15	-	30
	CIS	20	-	40
	Thin Film (a/µ)	25	-	50

Source: 1) IEE, BWK 59 (2007)) Nr. 10**; 2) M+W Group**

Life Cycle CO2 Footprint - Operation Phase Dominates

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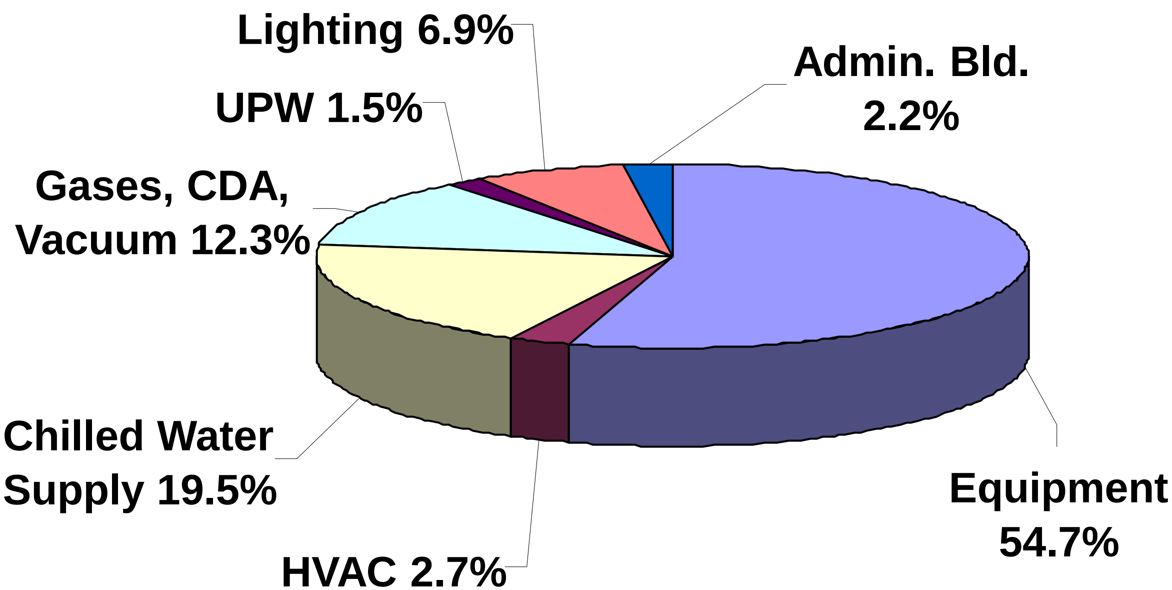
Calculated Relative Contribution to Life Cycle CO_2 Footprint

Construction	Steel	4%	8%
	Concrete	2%	
	Transport	1%	
	Others	1%	
Operation	Supply	77%	88%
	Production	7%	
	Disposal	4%	
Decommissioning	Transport	2%	4%
	Others	2%	

Typical Fab Electrical Energy Consumption Process Equipment is Dominant



Process equipment also directly impact facility system capacities and energy consumption

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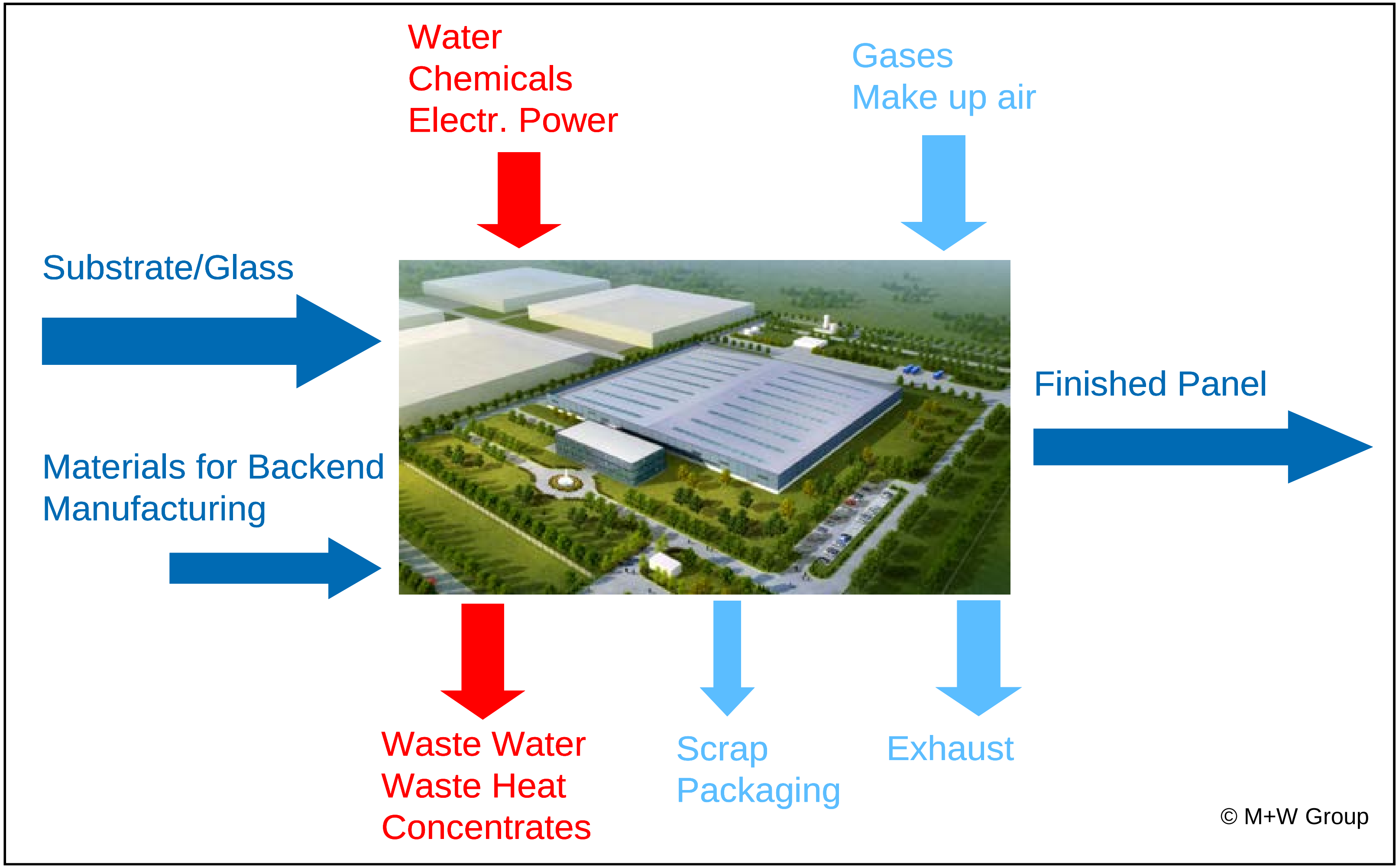
Facility Systems and electrical Power consumption

- Emphasis must be placed on the reduction of the operational energy demand of the process equipment and the capacity of the associated facility systems

Manufacturing Area	Support Area	Utilities	Gas Farm	Office
Equipment	Equipment	Mechanical Chillers	Compressors	HVAC
Lighting	Lighting	Pumps for Chilled Water	Others	Lighting
Rec. Air Fans	Rec. Air Fans	Pumps for Cooling Water		PC's
Make-Up Air Fans	Make-Up Air Fans	Fans for Cooling Towers		Others
Exhaust Air Fans	Exhaust Air Fans	Pumps for Cooling Towers		
PCW Pumps	PCW Pumps	UPW Plant		
UPW Pumps	UPW Pumps	Compressors for Dry Air		
Others	Others	W.W. Treatment		

Major battery limits for mass and energy flow



Mass & Energy flow modelling

- Traditionally high temperature process operations such as diffusions, vacuum coating… consume more electrical power than wet processes
- Examples in order to reduce overall energy consumption
  - Increase throughput, uptime and yield of process equipment
  - Minimize idle mode status
  - Introduce cluster equipment (smaller equipment and area footprint, reduced cooling and reheating of the substrates)
  - Reduce utility flows for exhaust, gases, chemicals and water
  - Improve energy efficiency of process equipment
  - Reduce heat dissipation to the environment, increase heat removal vis process cooling water and permit the use of higher cooling water temperatures

Assuming a reduction of 10% in the process equipment energy demand, the potential annual saving for the total site is

- **Electrical consumption: 8%**
- **Water consumption: 3%**
- **Wate water discharge: 1%**

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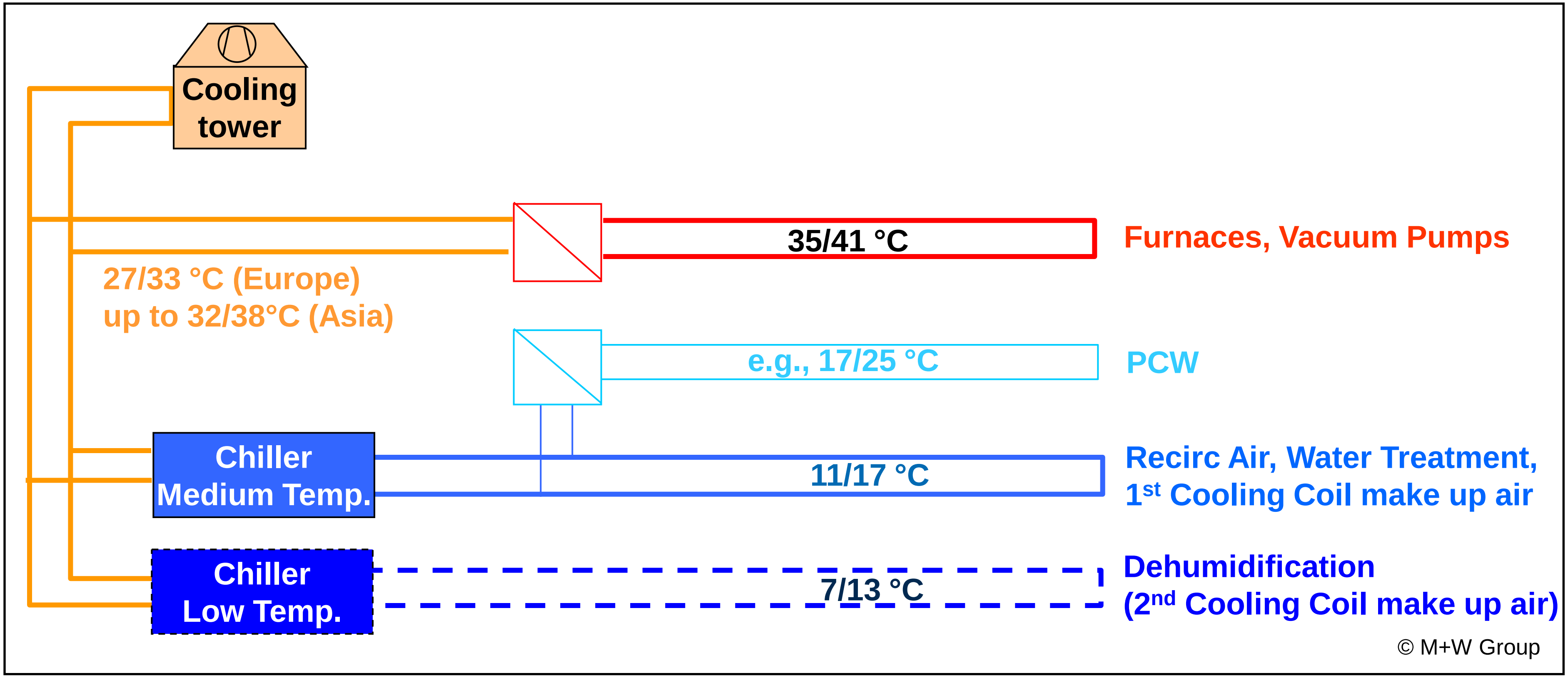
Potential enhancements in Facility system design

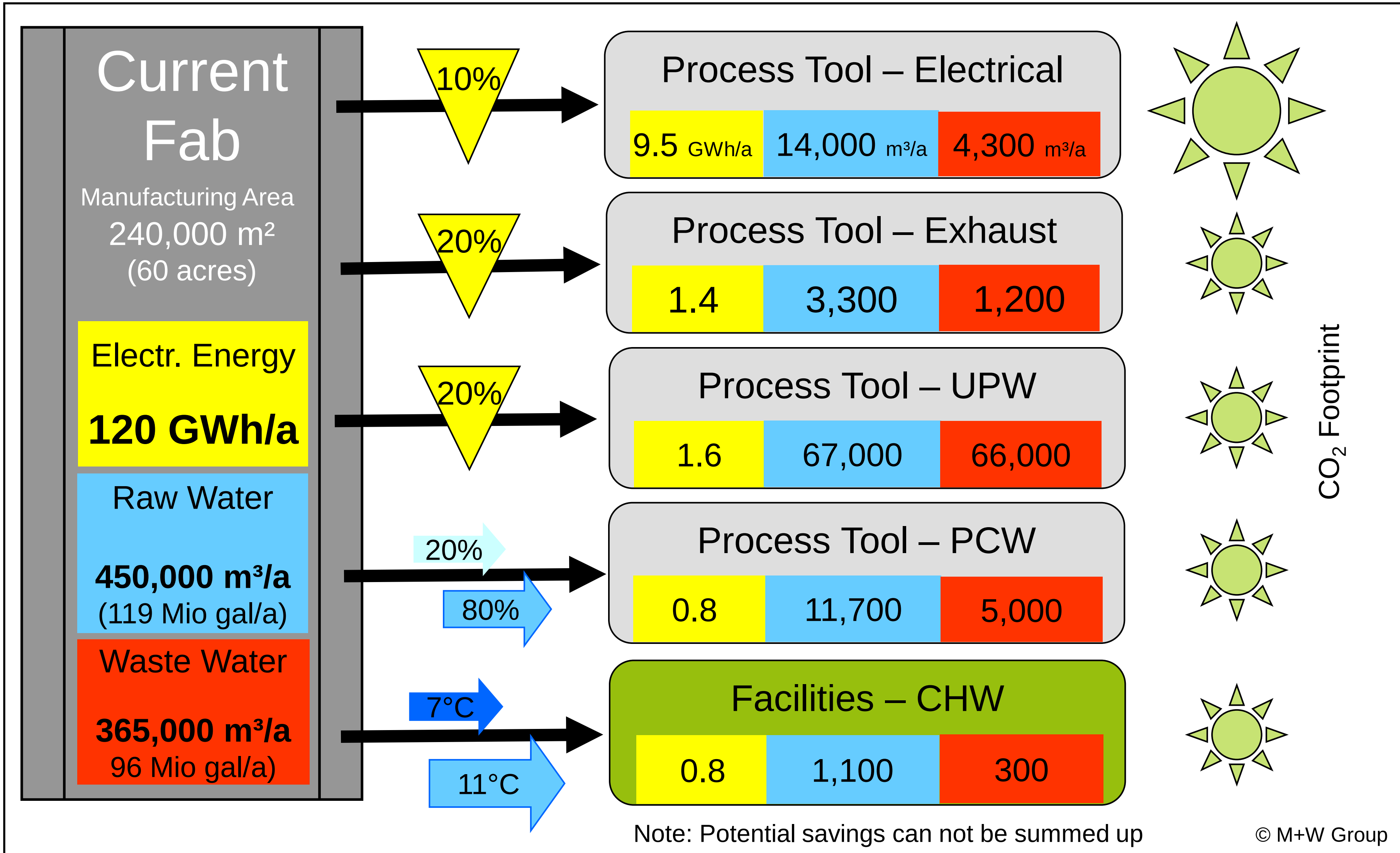
- In addition to reductions in facility system capacities through optimization utility consumptions, alternative facility system design should be considered
  - Dual temperature chilled water system
  - High temperature process cooling water system
  - Free cooling
  - Heat recovery
  - Reclaim / Recycle and reuse of chemicals

Alternative Facility system concepts will increase the initial investment, but offer an attractive return on investment and decrease the life cycle cost calculation

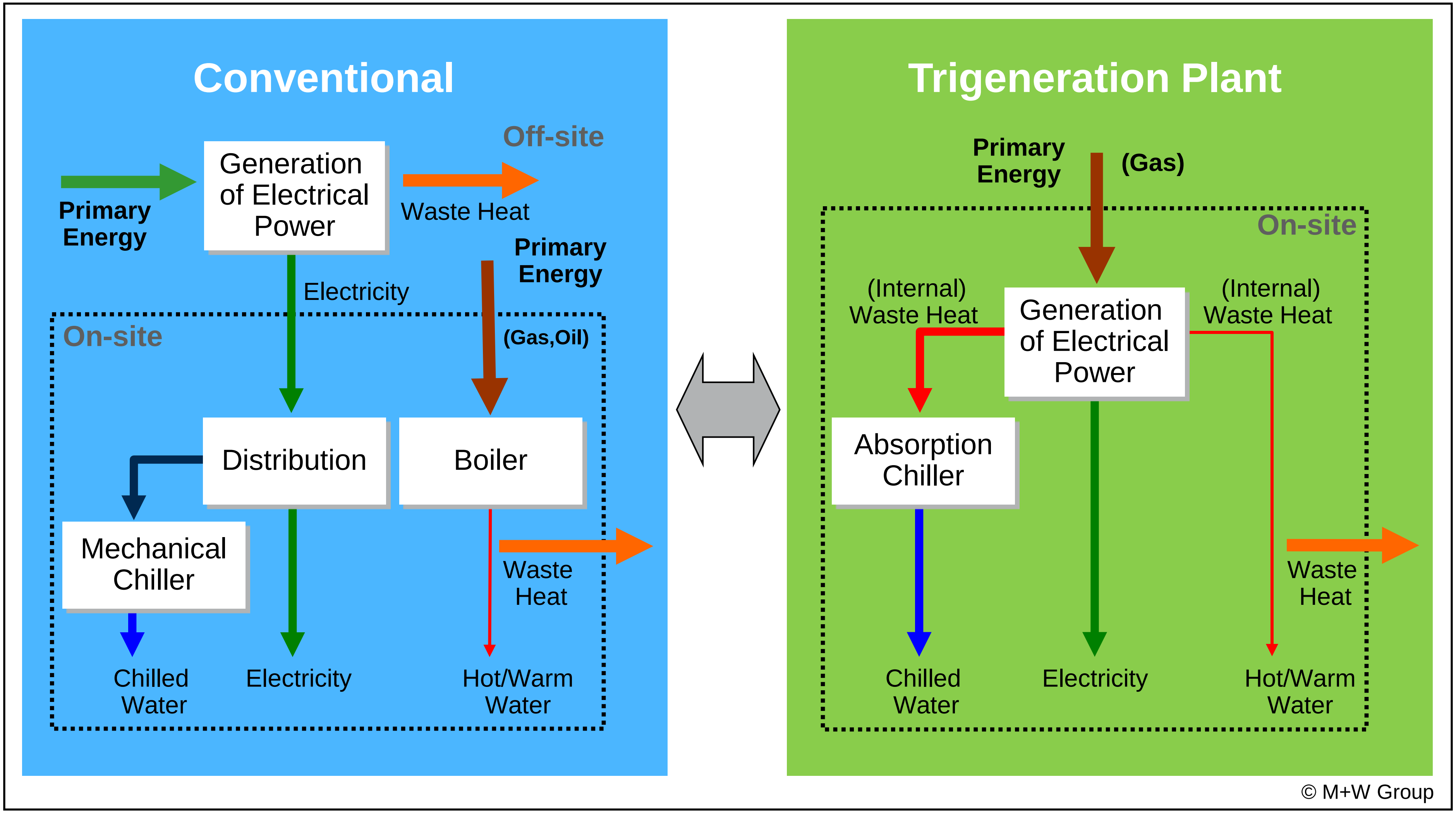
Schematic and users of a multi-level Temperature Chilled Water System



Energy saving Potential in a Reference PV Production Facility



Alternative Energy Supply Concepts - Conventional vs. Cogeneration



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Renewable Energy Supply Sources

- A mix of renewable energies can offer an attractive supplementary energy source to the conventional grid solution
  - CSP (Concentrated Solar Power)
  - Wind
  - PV Power Plant

Renewable Energy Supply sources will require additional property to accomodate the renewable energy plant.
It is assumed that each option would fully cover the energy requirements of the PV production plant assuming excessive or insufficient power can be fed into and from the public grid, making no storage necessary

Supplementary Energy Supply through Sustainable Energies

1.7 km²

44 units; 13 km²

2.9 km²

7x

54x

12x

17 MW (24/7)
State-of-the-Art
500 MW PV Fab
Site Area ~0.24 km²

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Conclusions

- Sustainability will play an ever-increasing role in the legislative compliance, manufacturing competitiveness and corporate image of PV production facilities
- A key methodology to optimize the possible scenarios is by conducting energy and mass flow modelling to determine and evaluate new approaches
- Any achievable improvement in energy reduction not only decreases electrical capacity, but also annual raw water demand and waste water discharge volumes
- High efficient co-/trigeneration should be evaluated as energy supply strategy
- The use of renewable energy sources will be beneficial to the overall life cycle cost of a PV production facility

Thank You

Visit us at Hall B3, Ground Floor, B6

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