

# Energy Efficiency Through Thermal Interaction Between Production Machines, Building & Building Services

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Barcelona



Facilitator

# The ETA-Factory



TECHNISCHE  
UNIVERSITÄT  
DARMSTADT



Supported by:



Federal Ministry  
for Economic Affairs  
and Energy



Projektträger Jülich  
Forschungszentrum Jülich



on the basis of a decision  
by the German Bundestag



Federal Ministry  
for Economic Affairs  
and Energy



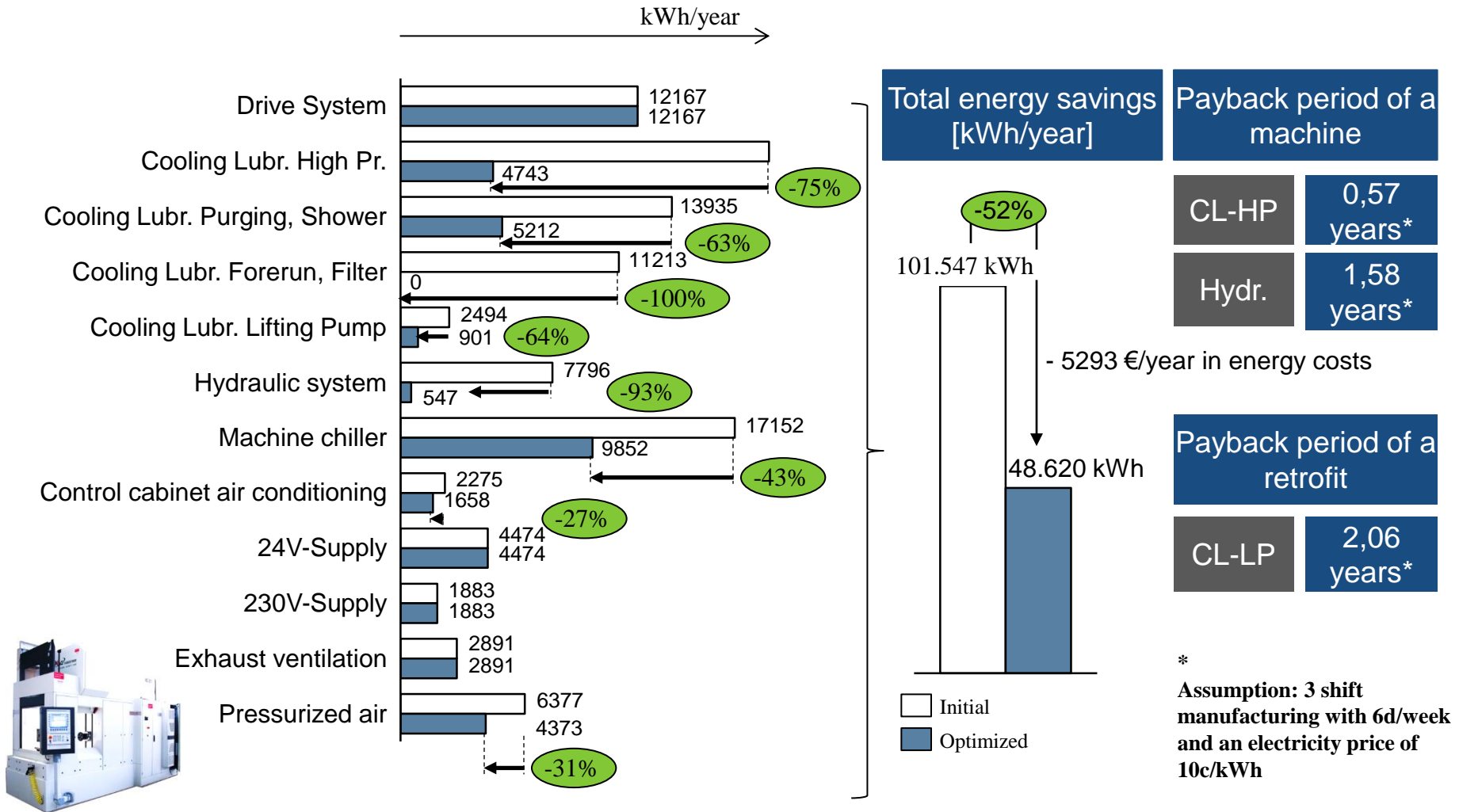
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# Starting point: energy efficiency of machine tools (MAXIEM 2012)



# The idea: holistic increase of energy efficiency

**Today:** isolated optimization of different sub-systems of a factory

## Building

25%



Source: Prof. Dipl.-Ing. J. Eisele

## Building services

20%



## Machine

30%



Maximum  
savings  
**< 30 %**

**Our vision:** holistic factory optimization including all sub-systems



Potential  
**~ 40 %**

Interaction of:

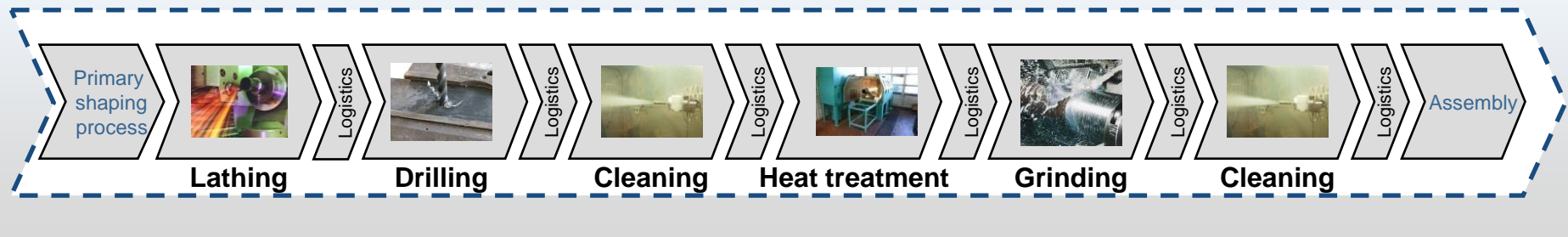
- machines
- building services
- buildings

**Synergies by energy controlling and recovery measures**



# The idea: holistic increase of energy efficiency

## Building up an energy-efficient production process with our ETA-Partners



## Energy efficiency research based on a realistic production chain in an innovative factory building

- Original process is used to define the demands on **quality and functionality**
- **Energy efficiency** research based on a **realistic production chain** in an **innovative factory building**
- **Interdisciplinarity** for reducing the energy demand in industrial companies

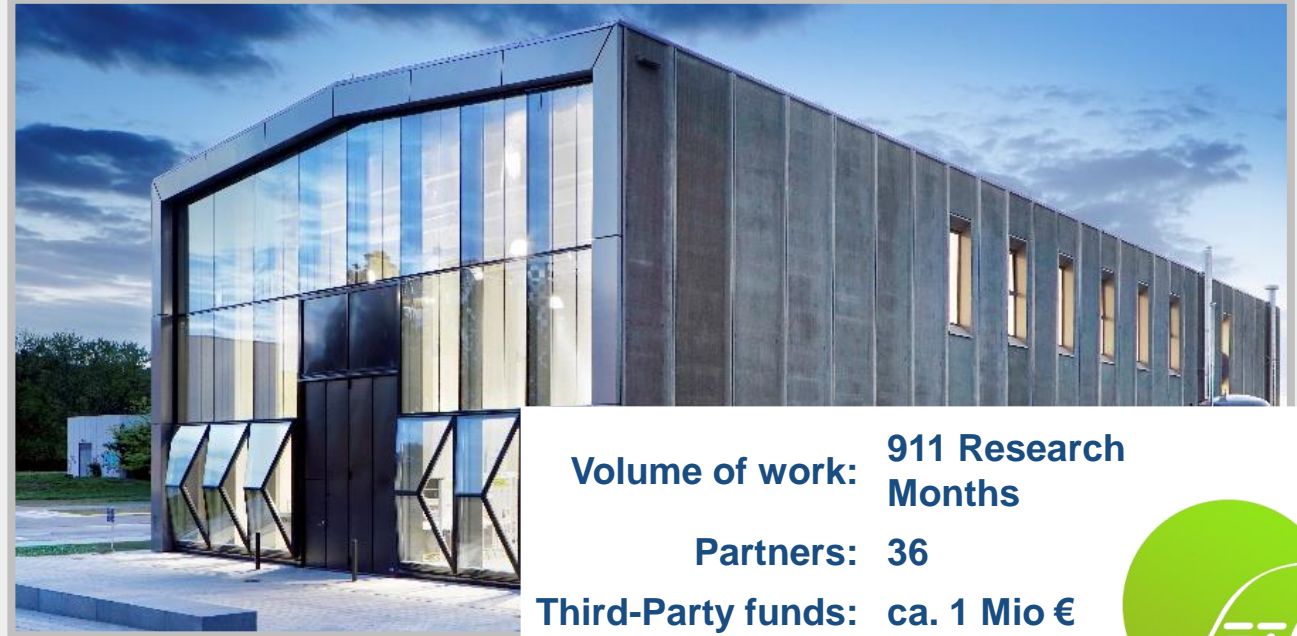
# The partners

## The ETA-Project

Gefördert durch:  
 Bundesministerium  
 für Wirtschaft  
 und Technologie  
 aufgrund eines Beschlusses  
 des Deutschen Bundestages

Betreut vom:  
 PTJ  
 Projektträger Jülich  
 Forschungszentrum Jülich

Unterstützt durch:  
 HESSEN



**Volume of work:** 911 Research  
Months

**Partners:** 36

**Third-Party funds:** ca. 1 Mio €

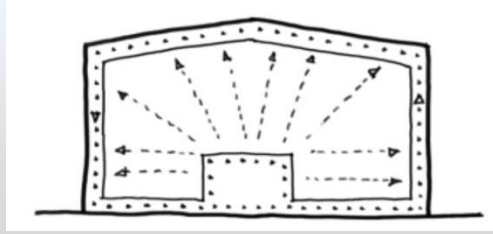
**Own funds:** ca. 3.7 Mio €

**Total volume:** ca. 15 Mio €

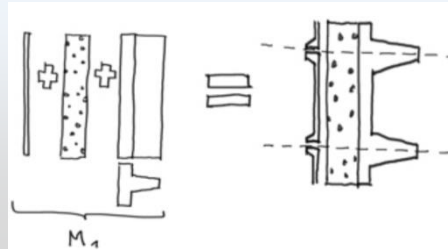


# Key innovations in the ETA-Factory

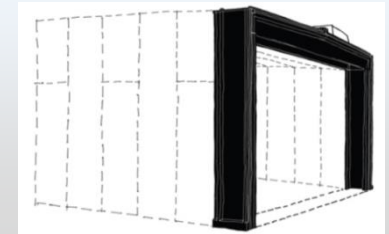
## Energetic interaction



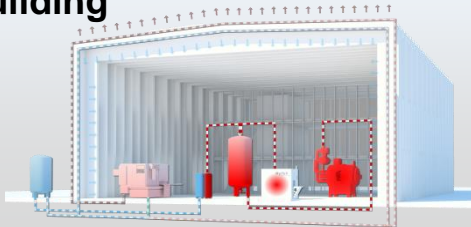
## One material: concrete



## Modular structure



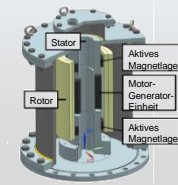
## Energetic combination of machines, building services & building



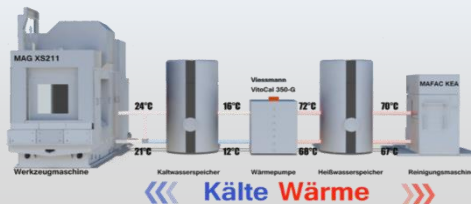
## Holistic energy controlling



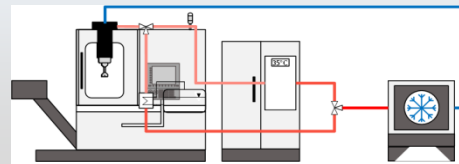
## Smoothing of load peaks by means of kinetic energy storage



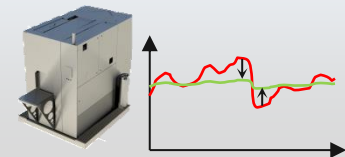
## Energetic combination of machines



## Energetic machine improvement



## Smoothing of load peaks by means of innovative control concepts



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# Renewable energies – points of contact

- **Energy demand reduction** to reduce the effects of fluctuating energy prices and availability
- **Small temperature differences** (e.g. capillary tube mats) for heat exchange to enable the use of environmental energy (e.g. with sprinkler systems, night cooling,...)
- Integration of **storage units** for load shifting to react to fluctuating energy prices and buffering of non-simultaneous availability of energy flows of heat sources and sinks in the factory (e.g. night cooling, heat-pumps)

## Thermal storages

### Vacuum Super Insulated Thermal Stratified Storage Tank (90 ° C)



Source: ZAE Bayern

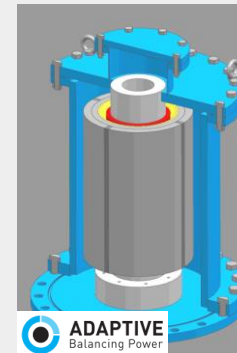
### High Volume Fly Ash Storages



Source: Finger Beton

## Electrical storages

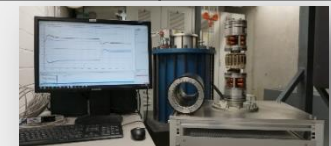
### Flywheel Storage (load peak reduction)



**ADAPTIVE**  
Balancing Power

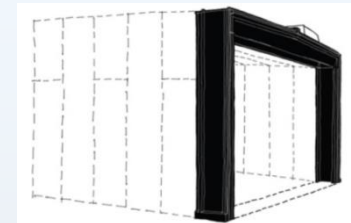
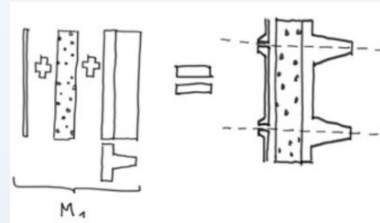
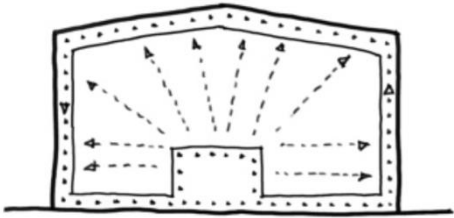
Source: IMS Darmstadt

Capacity	1,4 kWh
Power	60-110 kW
rpm	7500 - 15000 rpm (+)
Material	Fibrous synthetics
Diameter of rotor, height	300 mm, 500 mm
Mass of rotor	50 kg





# Innovations in building technology – thermal activation and modular structure

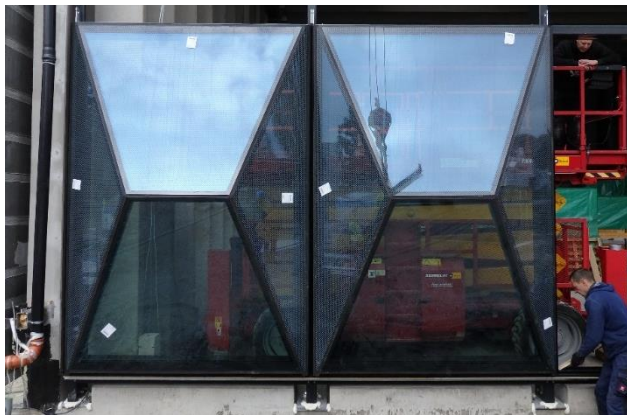


# Innovations in building technology – glass facade



Source: Hessen Agentur, Jan Hosan

South  
facade



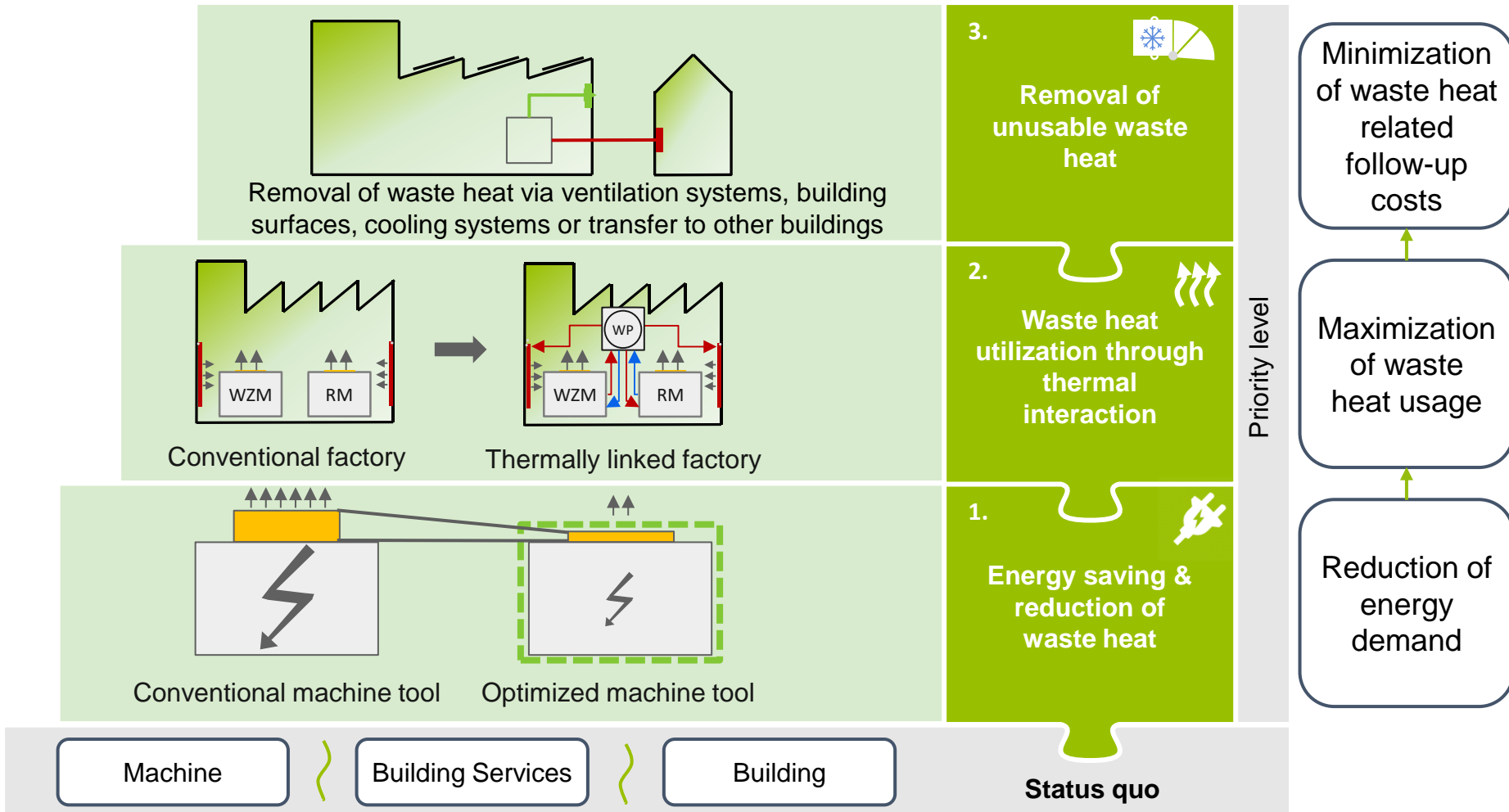
Sunlight without  
thermal input

Reflection of  
sunlight into  
the building



Source: Eibe Soennecken, Darmstadt

# The method: holistic increase of energy efficiency





# Innovations in production machine technology



- Demand-based control of pumps and compressors
- Minimizing of leakage
- Energy efficient cooling systems
- ...

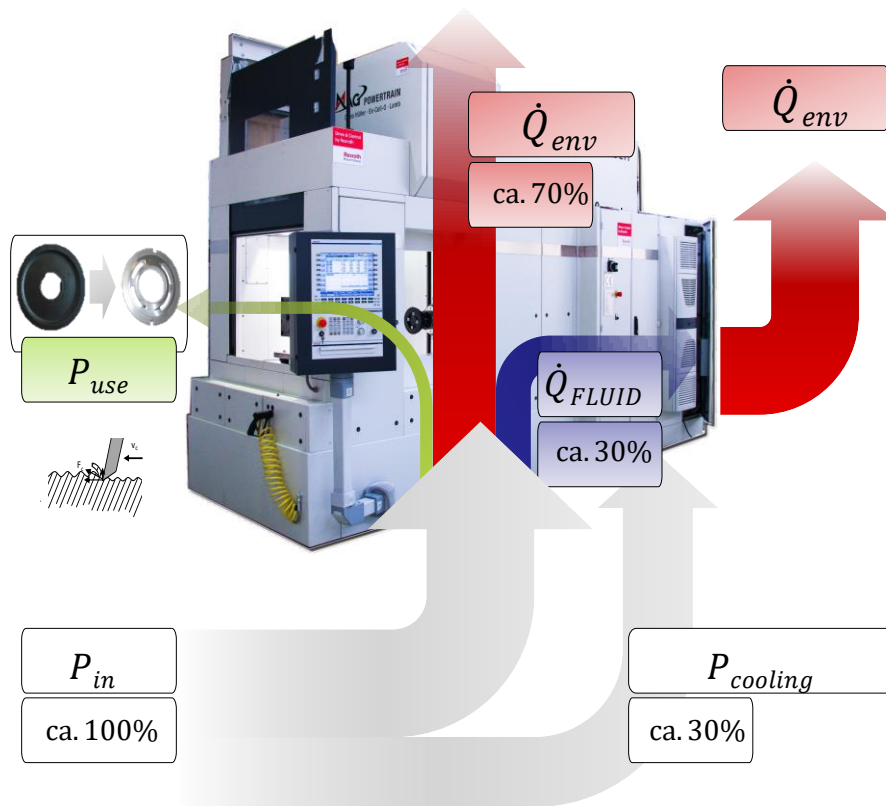


- Individual cleaning program for each component
- Insulation
- Recuperation of energy
- Integration of waste heat of other processes
- ...



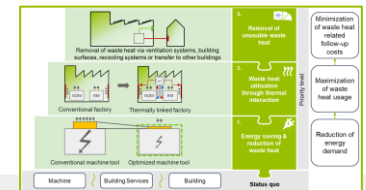
- Insulation
- Recuperation burner
- Using lightweight construction
- Optimizing process
- Recuperation of waste heat
- ...

# Waste heat generation of a machine tool



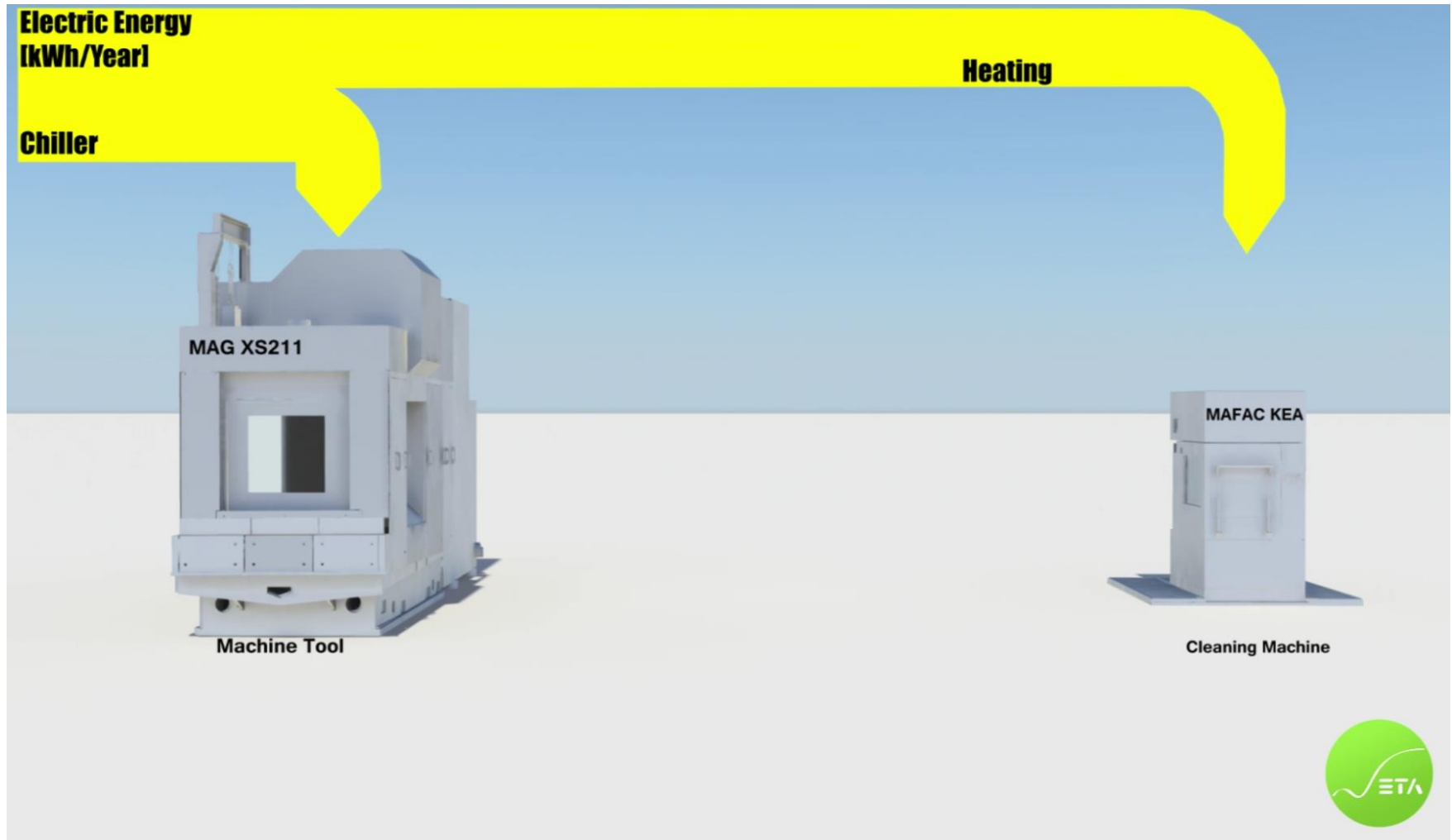
## Potentials

1. **Reduction of energy demand**
  - Dimensioning
  - Energy efficiency of components
  - Efficient operation (e.g. speed control)
2. Waste heat **utilization** in the overall factory system
3. Cost-effective **heat dissipation**

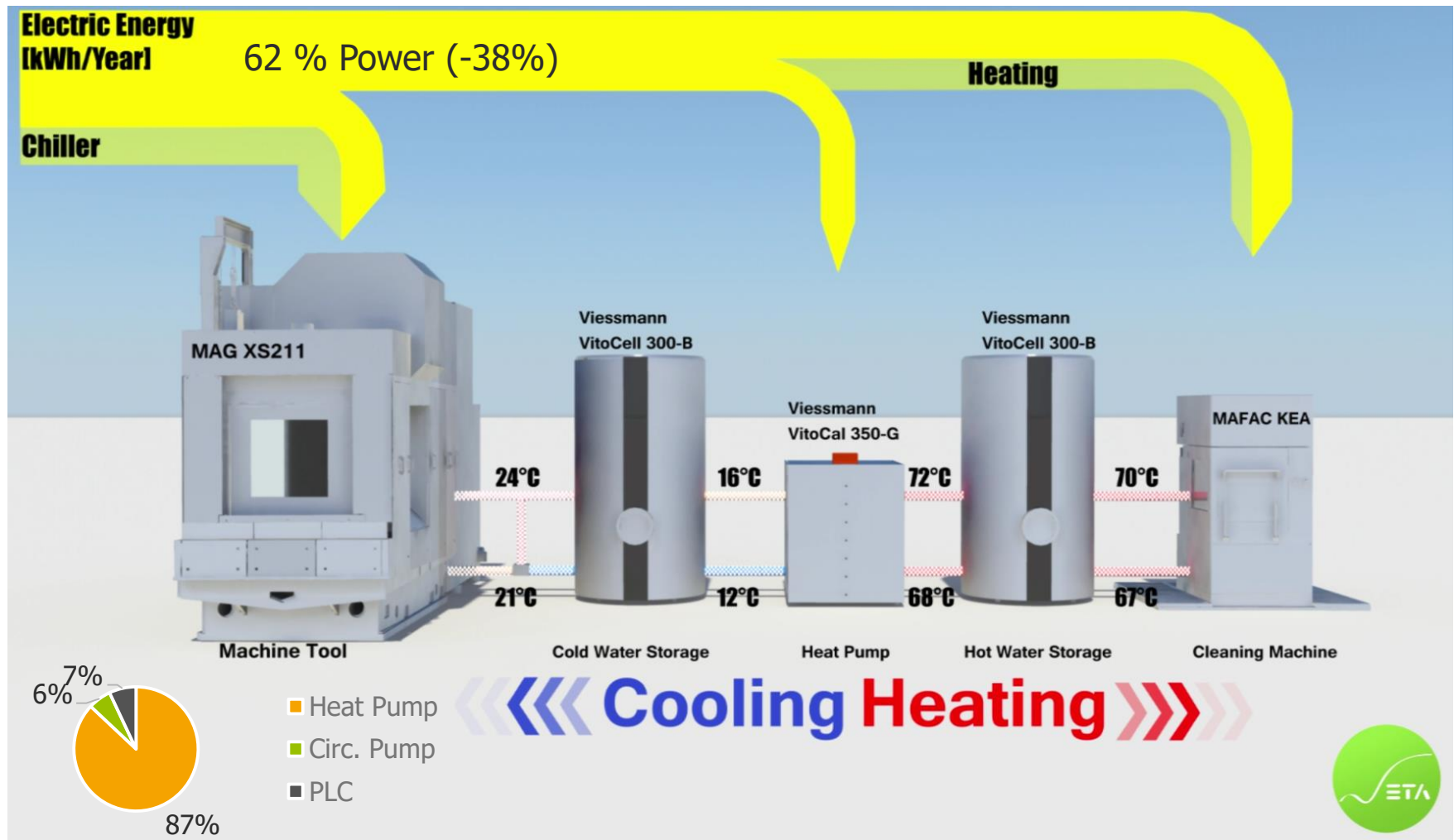




# Thermal interaction (machine tool – cleaning machine)



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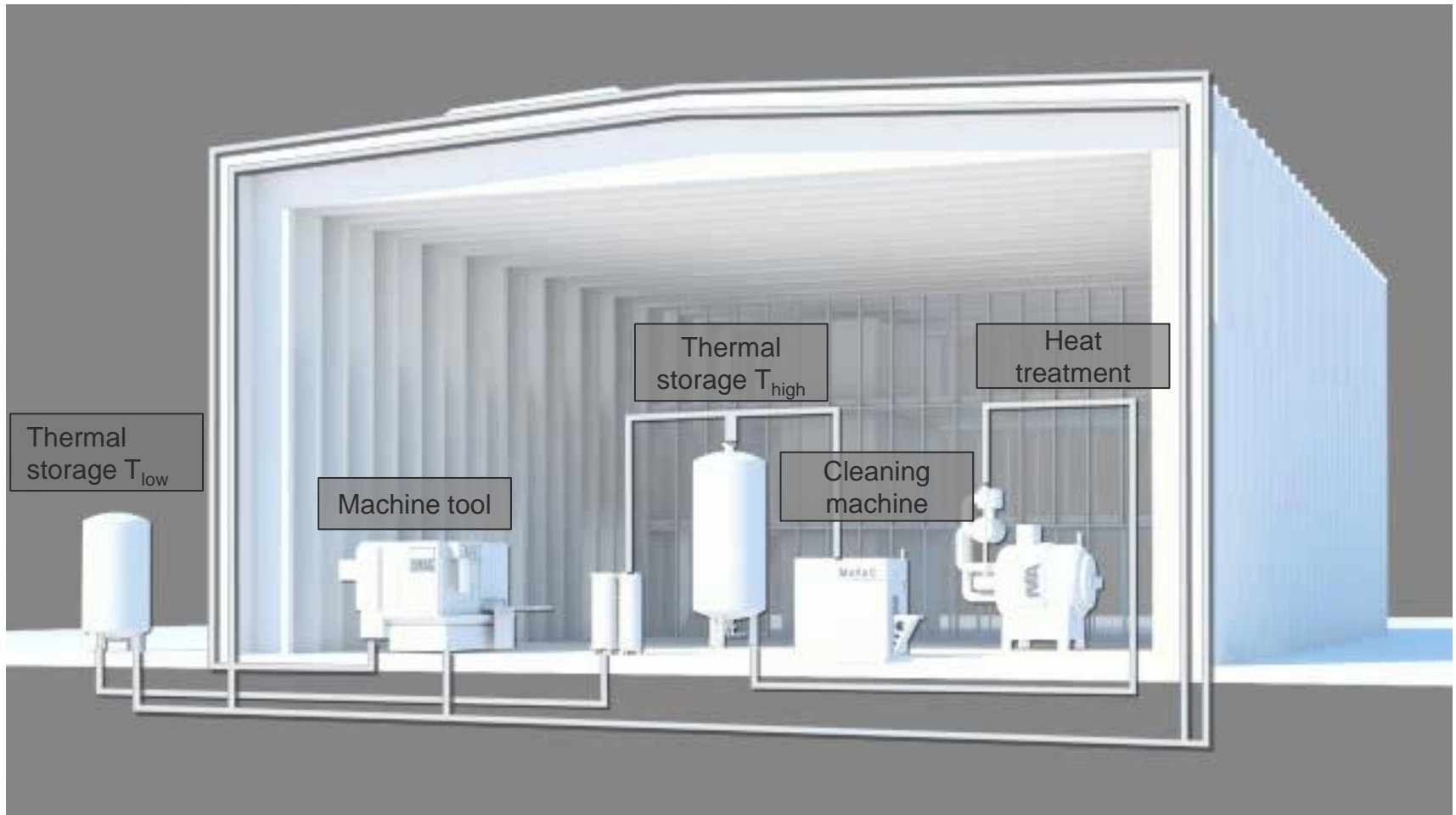


[illegible]

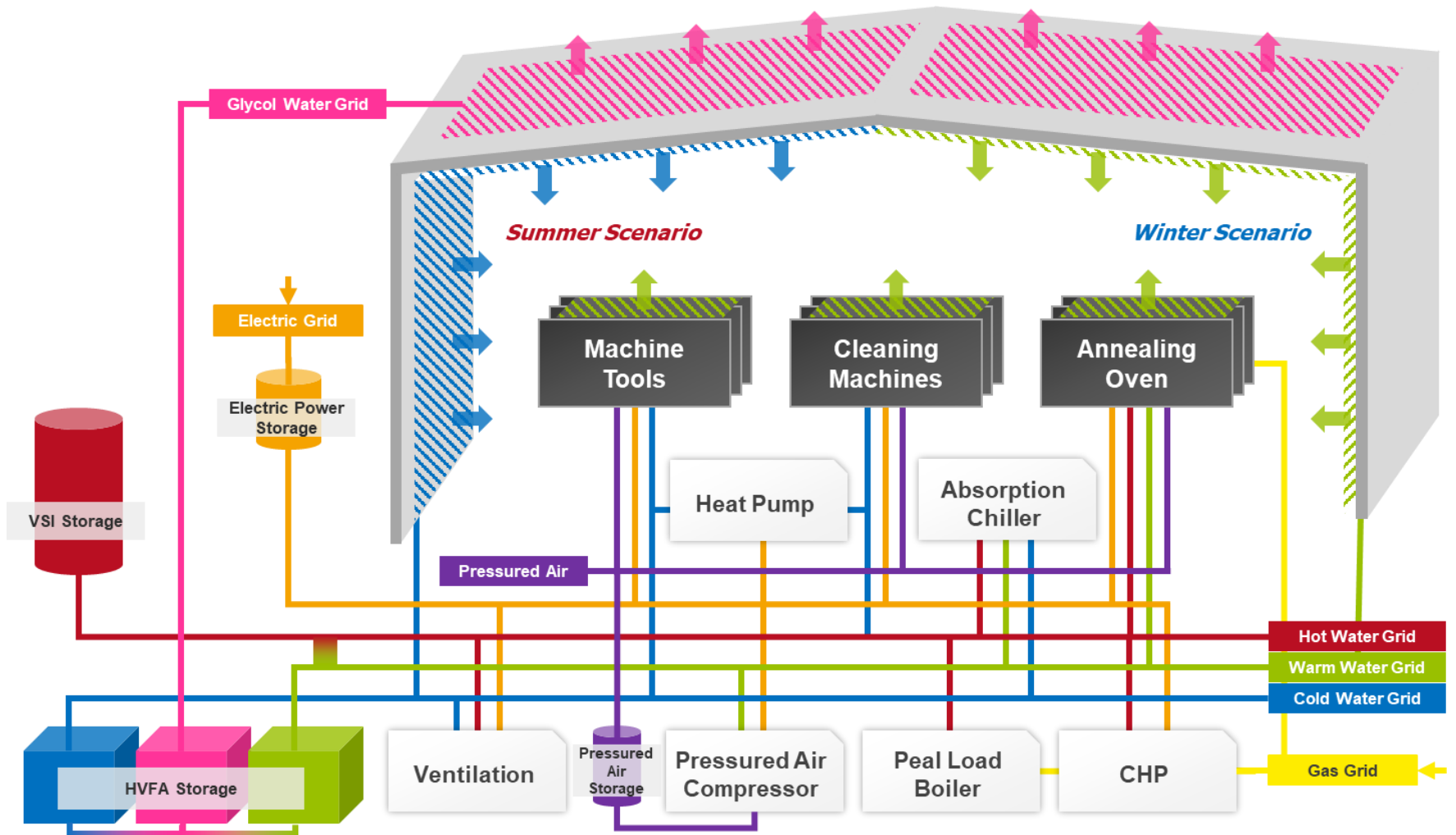
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# Thermal interaction in the ETA-Factory

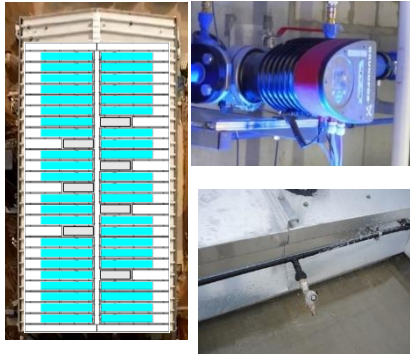


# Thermal interaction in the ETA-Factory





# Thermal interaction: energy-efficient cooling concepts

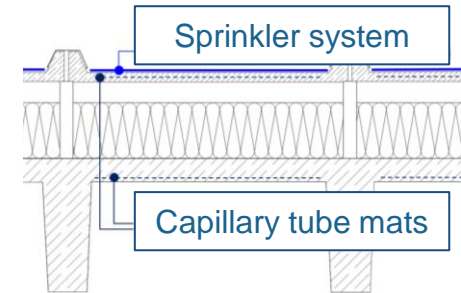


## Capillary tube mats (roof surface)

- $43 \times 7 \text{ m}^2 = 301 \text{ m}^2$
- power consumption of pumps  $< 0.4 \text{ kW}$

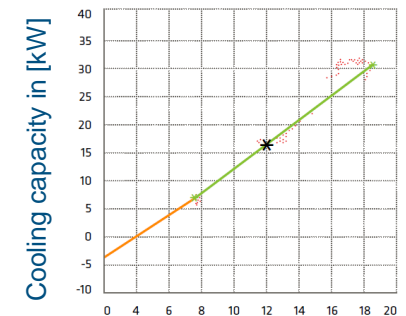
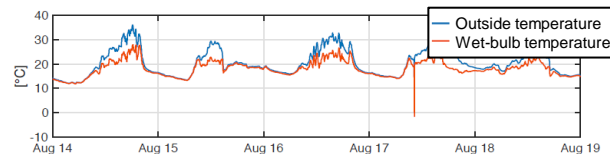
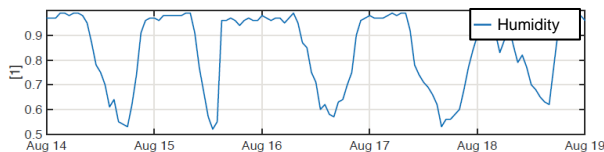
## Sprinkler system (roof surface)

- power consumption of pumps  $< 0.8 \text{ kW}$



## Achievement potential of adiabatic evaporative cooling

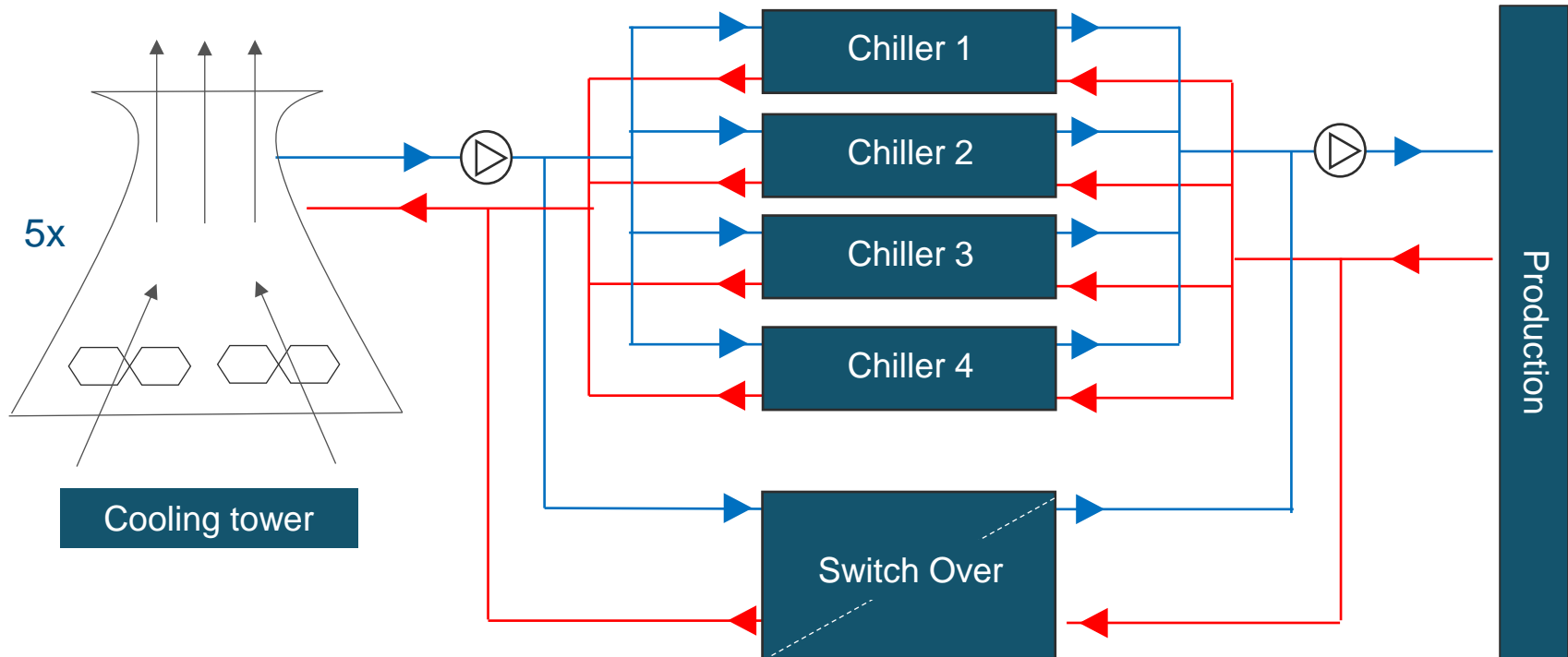
- Cooling capacity: up to 30 kW (during summer)
- Energy Efficiency Ratio:  $\text{EER} \approx 30$



Difference of wet bulb temperature  
& required temperature in [K]

→ High Energy Efficiency Ratios for waste heat removal of machine tools throughout the year

# Transfer project: energy efficient cooling systems (use case)



# Transfer project: energy efficient cooling systems (use case)

Planning process

1  
2  
3  
4

Determination of the cooling demand according to nameplate data

5.46 MW

Definition of required temperature levels

Flow: 16° C

Return: 22° C

Dimensioning of the central cooling system

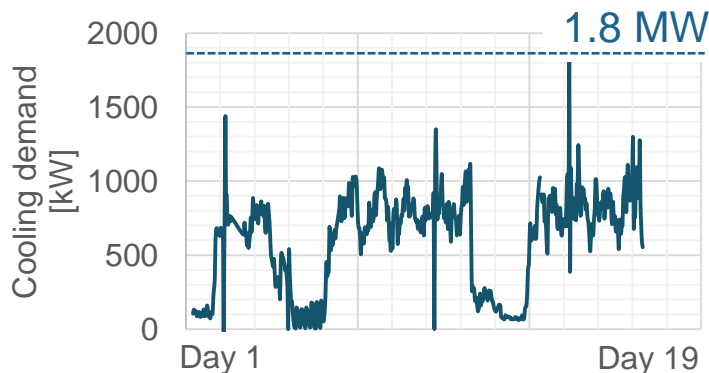
> 6 MW

Definition of permanent control parameters

Switch over: 12 °C

....

Reality



- Max. Cooling demand: 1.8 MW
- Required temperature levels: 18 ° C / 24 ° C
- Required switch over temperature: 14 ° C

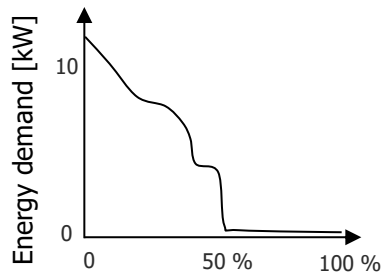


- Overdimensioning
- High investment costs (5 cooling towers, 4 chillers)
- High energy costs due to partial load of cooling towers, chillers & pumps

# Transfer project: energy efficient cooling systems (use case)

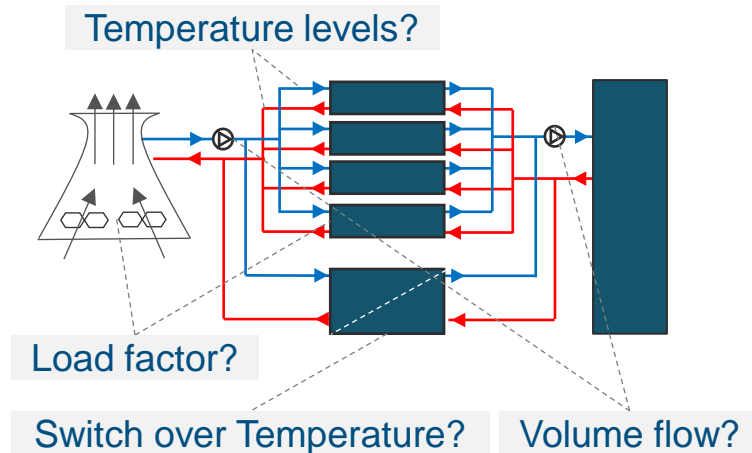
## 1 Measurement

Duration line (machine tool)



- Which components are liquid-cooled?
- Time shares?
- Cooling demand?
- Simultaneity of cooling demand?

## 2 Modelling



Energy demand	953,487 kWh/a	
Energy demand (optimized)	782,204 kWh/a	-18%

## 3 Evaluation

## 4 Optimization

### Measures

- Demand-oriented dimensioning
- Control strategy depending on outside temperature & humidity
- Increase of switch over temperature

### Savings

- Energy costs: > 25,700 €/a
- Investment costs: > 1,000,000 €

# Monitoring and controlling of energy flows

## Energy flows are

- usually invisible
- ubiquitously
- partly highly dynamic
- distorted by influences
- partly controllable

Over 3000 data points!



# Conclusions

- There is a high potential for energy efficiency measures, especially in a holistic approach.
- Most measures from the ETA-Project can be transferred to different industries.
- Energy Monitoring is an essential part of energy efficiency, but it also gives us the opportunity to think further → Energy 4.0!
- The high complexity of systematic energy efficiency optimizations requires an interdisciplinary approach and a consideration from the beginning of planning processes.



# Contact us

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