

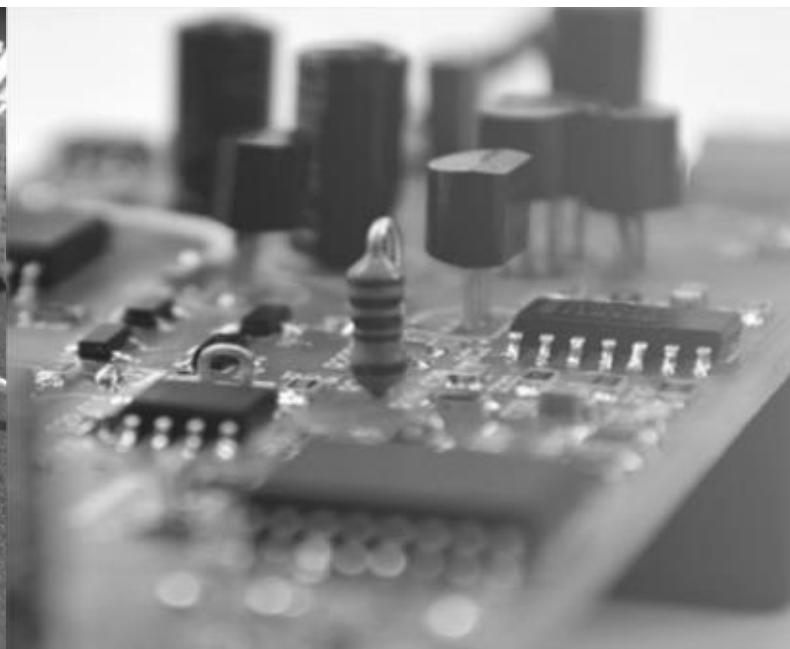
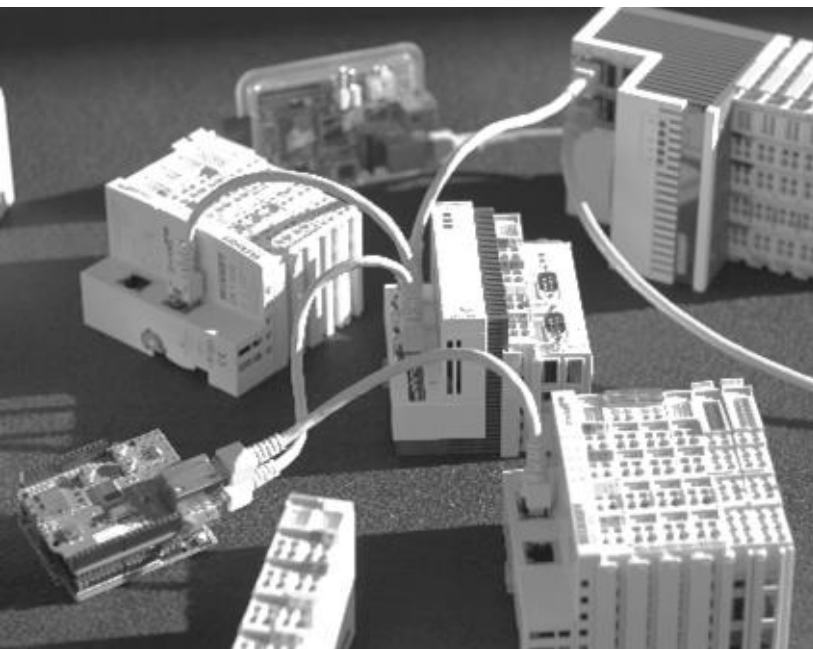
# Technische evaluatie van duurzame koeltechnieken in woningen en industriële gebouwen



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Sustainable cooling in industrial buildings  
Thursday, 20. May 2021





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## 1 Introduction of the University of Bayreuth

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2 SCools: Project description

3 Cooling in industrial buildings

3.1 Data acquisition

3.2 Development of the cooling tool

# University of Bayreuth



- Founding year: 1975
- 13.000 Students
- 7 faculties
  - Mathematics, Physics and Computer Science
  - Biology, Chemistry and Earth Sciences
  - Law, Business & Economics
  - Languages & Literatures
  - Humanities & Social Science
  - **Engineering Science**
  - Life Sciences: Food, Nutrition & Health

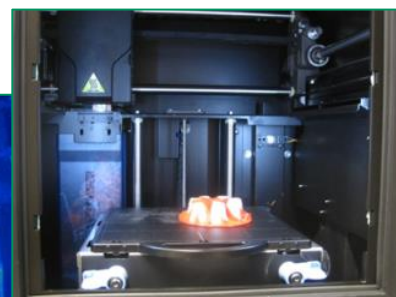
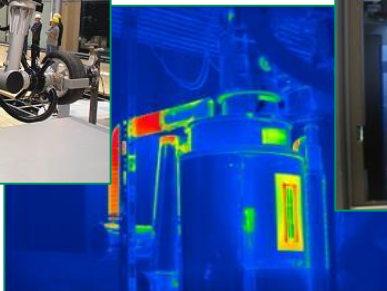
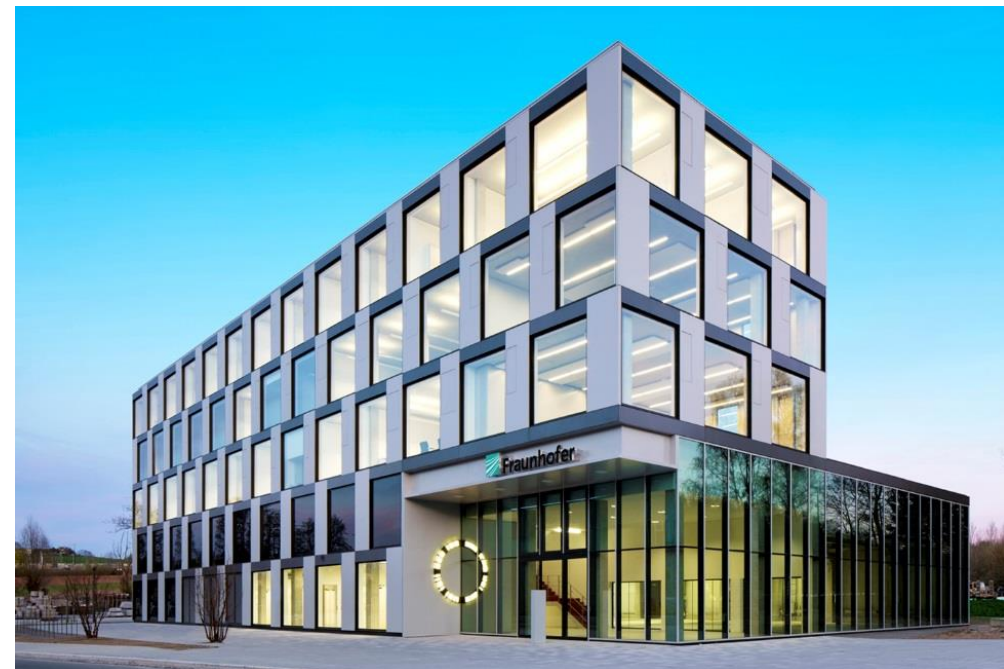
# Chair Manufacturing and Remanufacturing Technology

## ■ Chair:

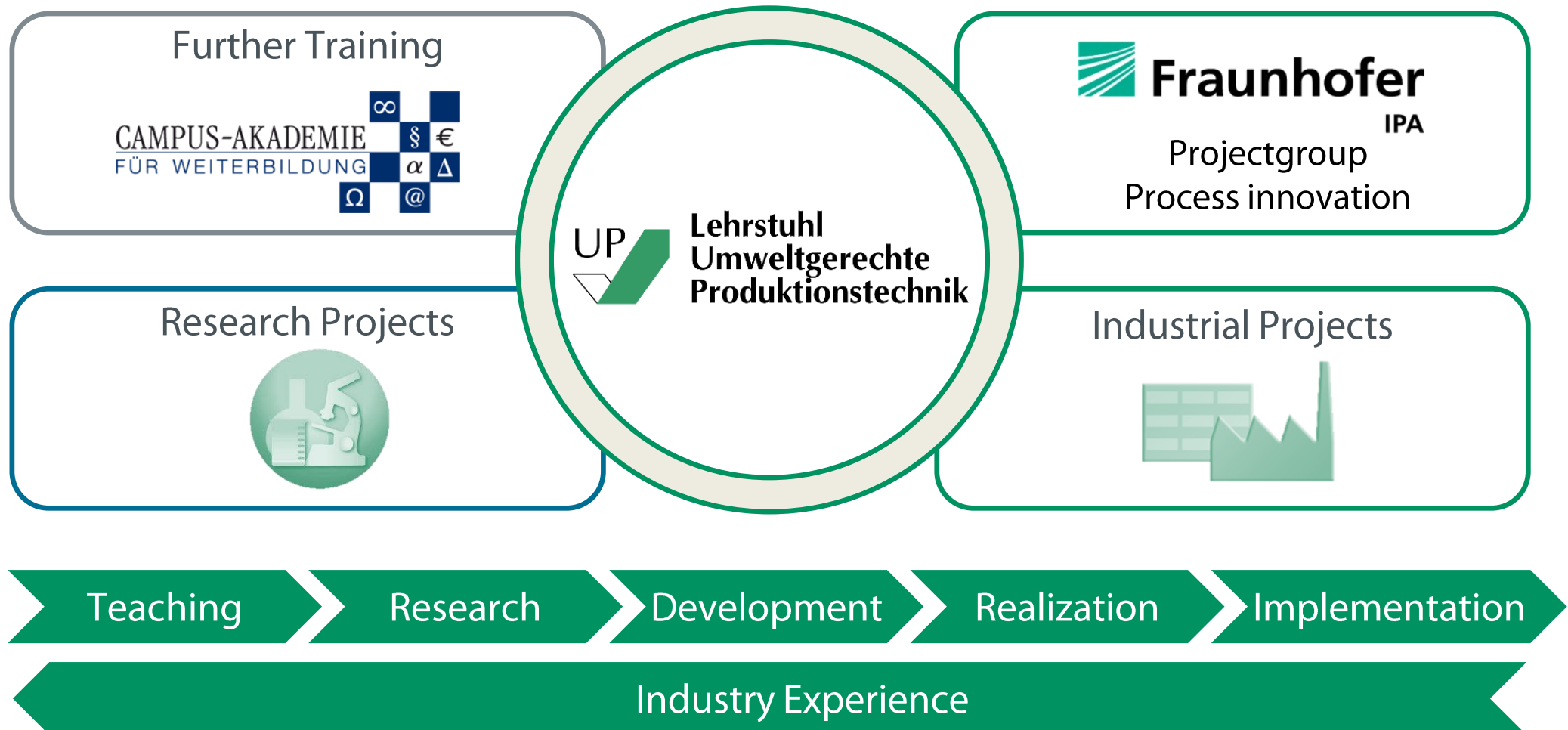
- 2017: Handover to Prof. Dr.-Ing. Frank Döpfer

## ■ Research and Teaching

- Remanufacturing
- Circular Economy
- Factory planning and operation
- Additive Manufacturing
- Innovation and technology management
- Maintenance and service engineering



# Networking of science and practice



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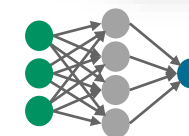
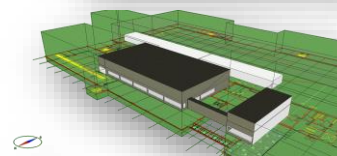
# SCoolS: Project description

## Initial situation and problem definition

- Lack of knowledge about sustainable cooling systems in industrial environment
- Barriers: Acceptance, Unawareness, Inefficient operating points

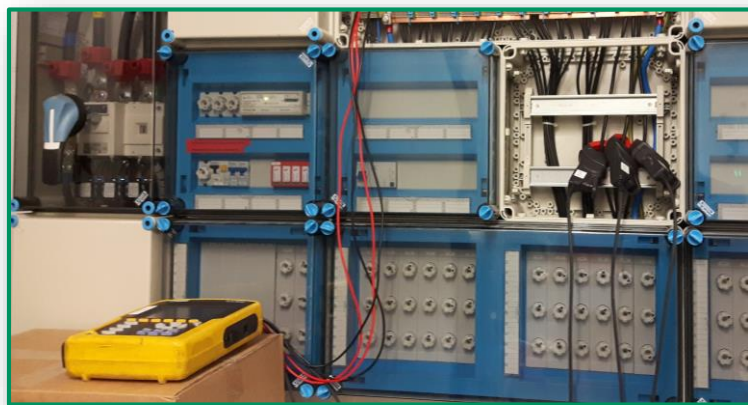
## Aim and procedure

- Initial situation
  - Identification and description of cases for industrial buildings
- Data collection procedure
  - Measuring and Analysis
- Simulation model and case studie
  - Development and verification of simulation models
  - Creation of a Design of experiment
  - Implementation and analysis
- Development of a eassy-to-use tool



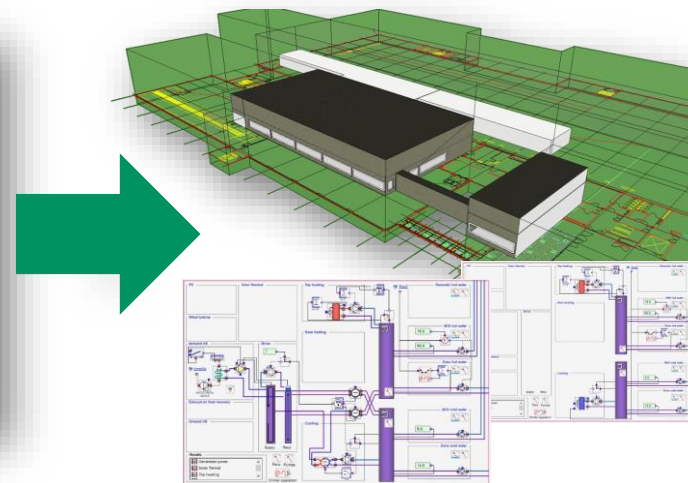
# Development of the tool

Measurements of real building data



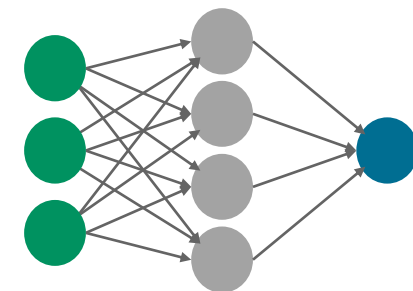
?

results of the IDA ICE simulation



?

prediction with ANN



Prediction

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2 SCools: Project description

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**3 Cooling in industrial buildings**

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3.1 Data acquisition

3.2 Development of the cooling tool

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- 2 SCools: Project description
- 3 Cooling in industrial buildings

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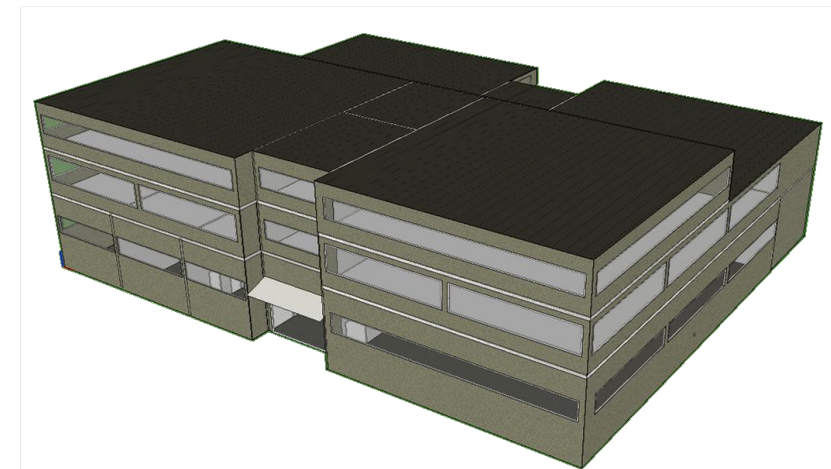
### 3.1 Data acquisition

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### 3.2 Development of the cooling tool

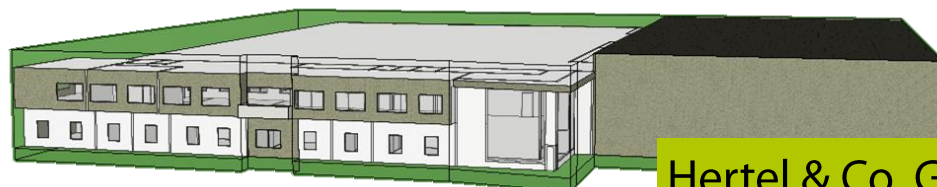
## Initial situation - case studies

- **elektron** Systeme und Komponenten GmbH & Co. KG  
Production hall for electronic assemblies
- **BM Green Cooling** GmbH  
Server room

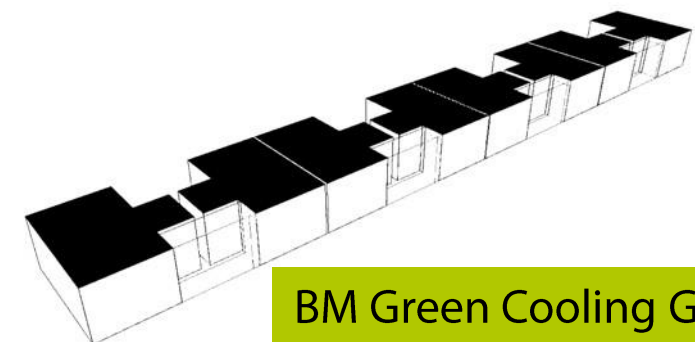


elektronic systems and components GmbH & Co. KG

- **hertel & Co. GmbH**  
Production hall for the manufacture and printing of packaging materials



Hertel & Co. GmbH

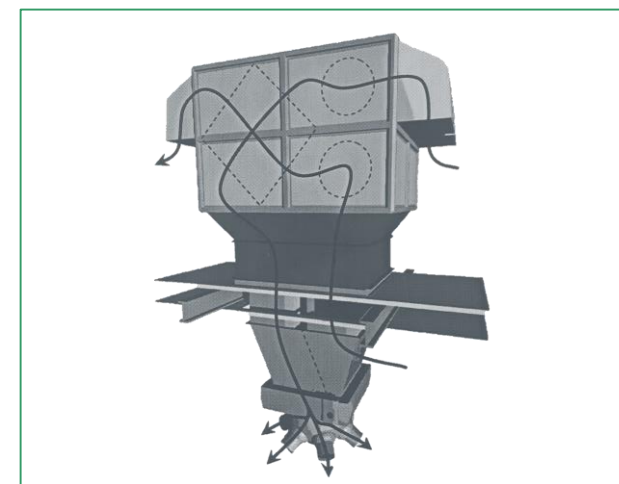


BM Green Cooling GmbH

# Data collection procedure - hertel

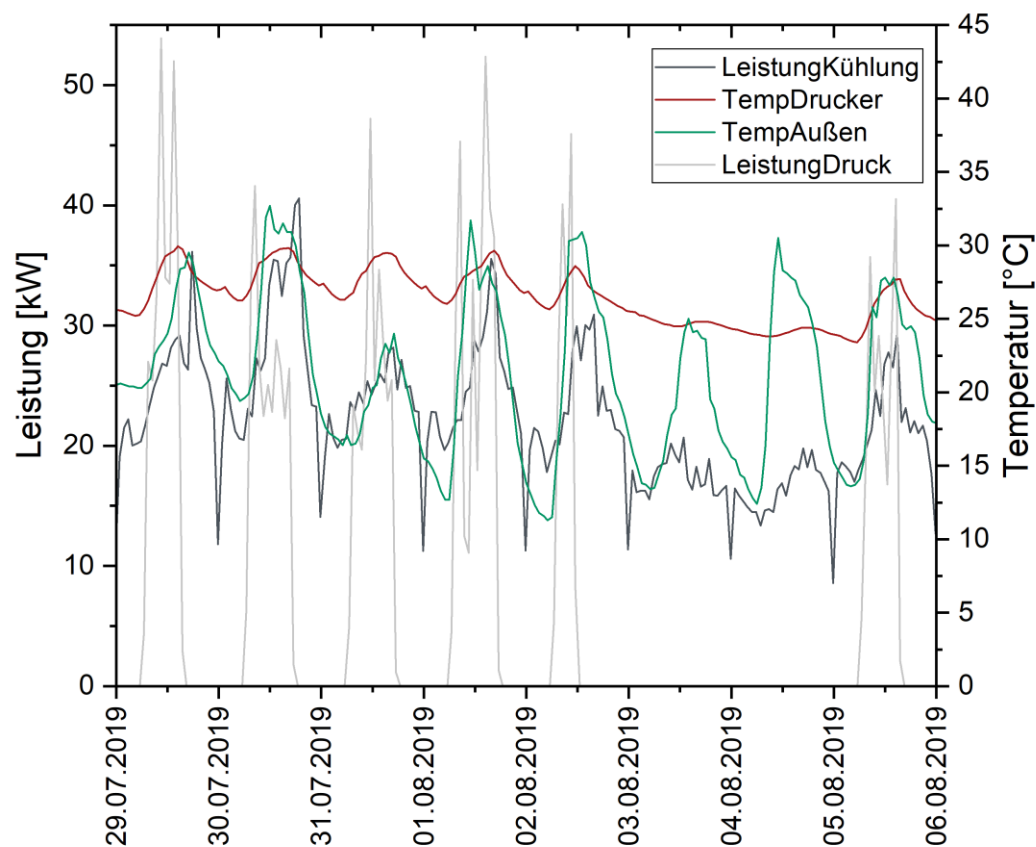
## ■ Description of cases

- Largest heat load in production: printing machine
- 8 heat pumps for cooling and heating ( $\varnothing 17,6$  MWh/Month;  $\varnothing 32$  % Total demand)
- Decentralized distribution to different areas in the production
- The solar power covers more than 70 % of the heating and cooling demand



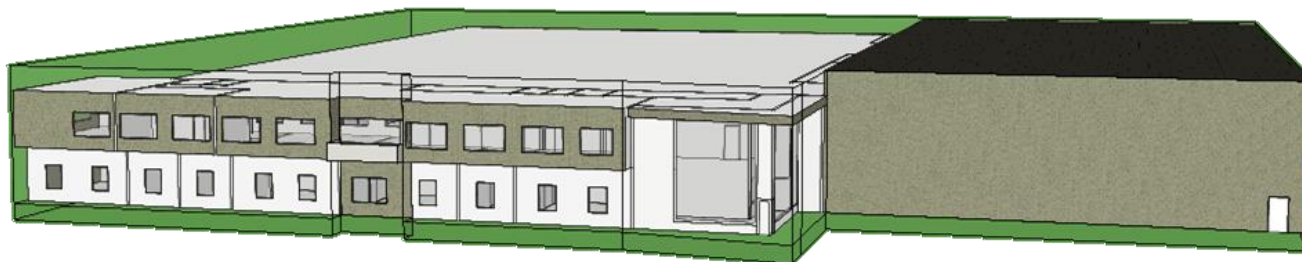
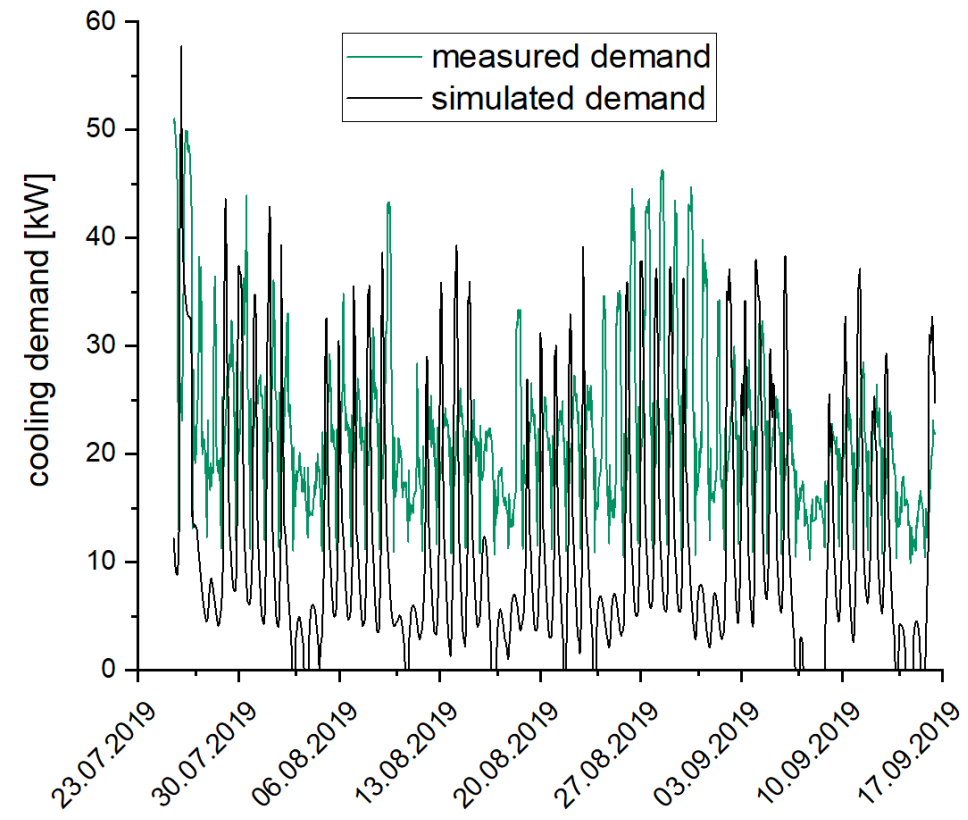
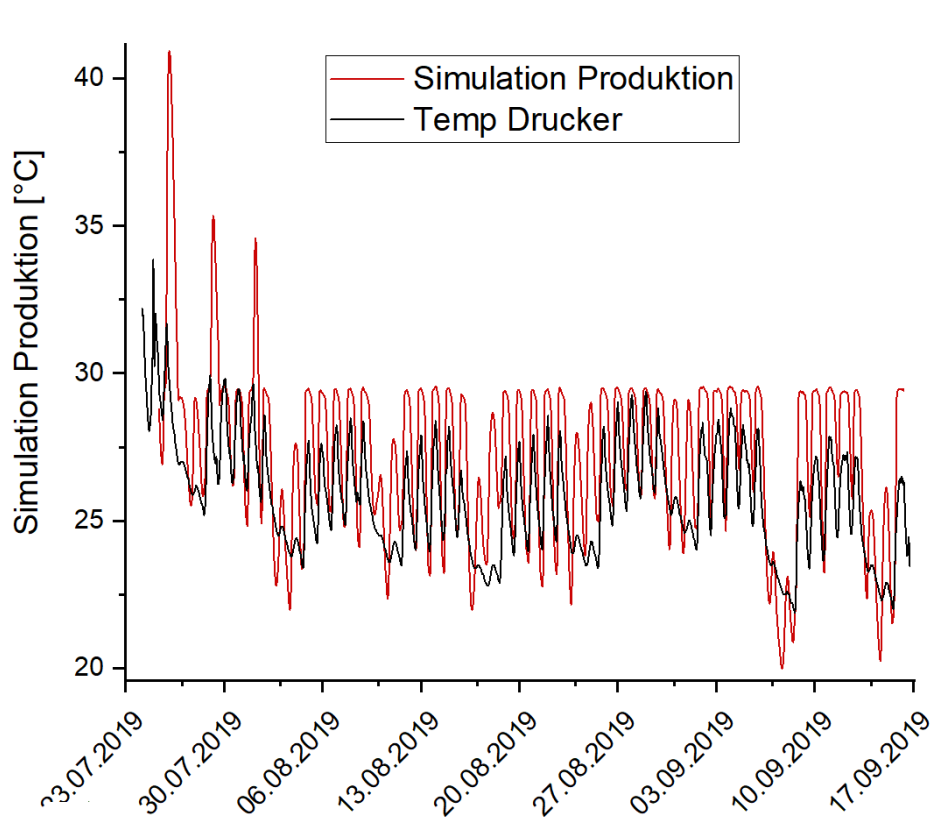
# Data analysis - hertel

## ■ Measuring of performance



- Printing presses contribute significantly to the temperature increase
- The recooling unit works accordingly when the printing press is running
- Room temperature more influenced by presses than by outside temperature
- Increased use of night cooling possible

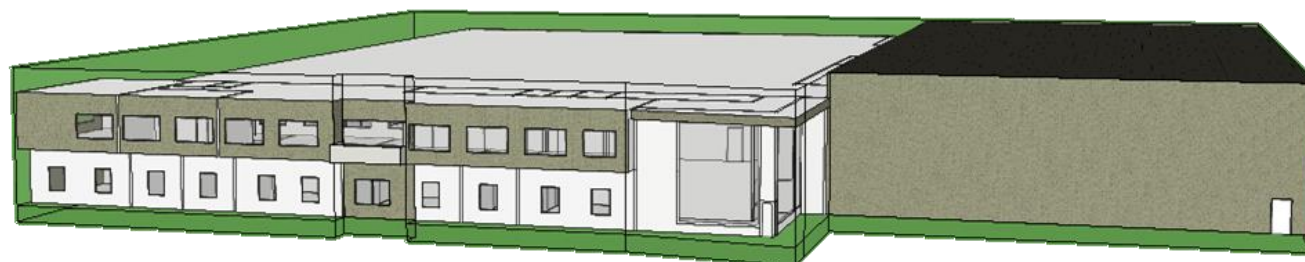
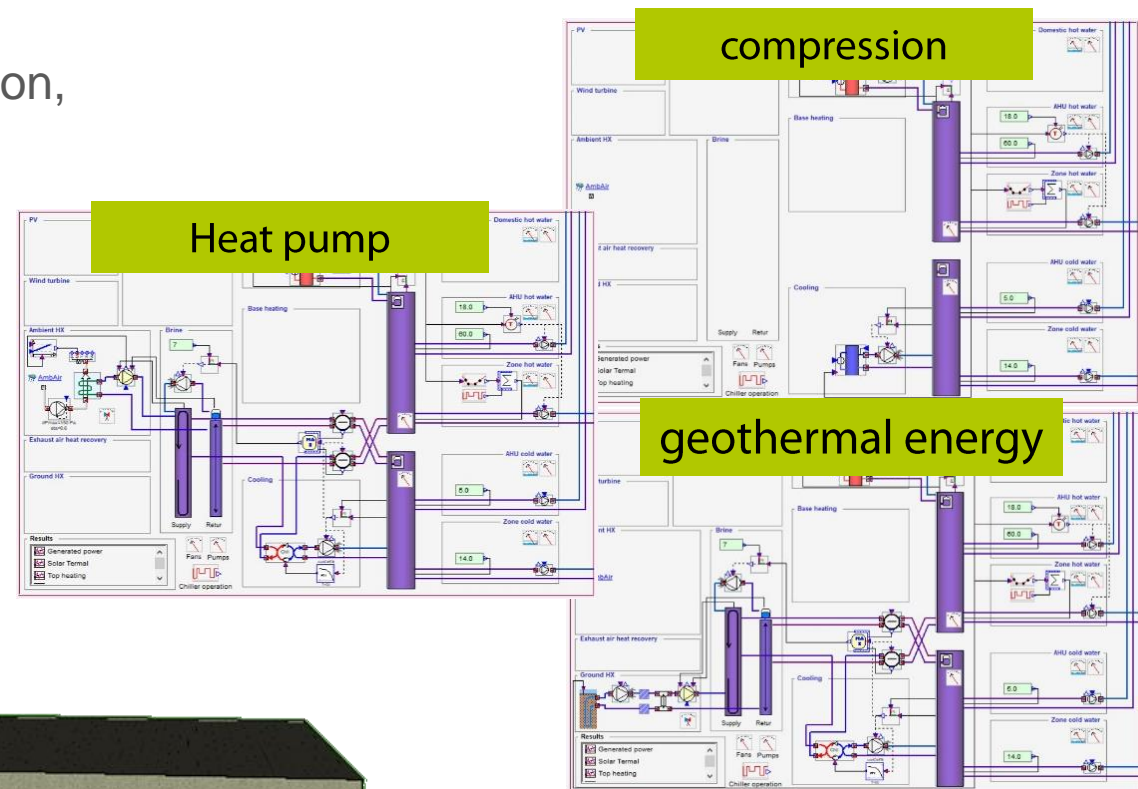
# Simulation model and parameter studie - hertel



# Simulation model and parameter studie - hertel

## variable parameters for the IDA ICE simulation

- cooling system (heat pump, compression, geothermal energy)
- location (Bayreuth, Munich, Brussels)
- shading
- cool setpoint
- internal load
- storage of the cooling system



# Simulation model and parameter studie - hertel

create a test plan

**Mehrstufiger faktorieller Versuchsplan** test plan

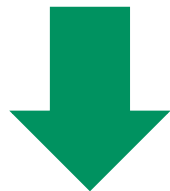
Übersicht des Versuchsplans

Faktoren:	6	Replikationen:	1
Basisdurchläufe:	729	Durchläufe gesamt:	729
Basisblöcke:	1	Blöcke gesamt:	1

number of simulation runs

#	C1	C2	C3	C4	C5-T	C6-T	C7-T	C8	C9	C10
StdRfolge	DlaufRfolg	Punkttyp	Blöcke	Cooling system	Location	Shading	Cool Setpoint	Internal Load	Storage of the cooling system	
1	1	701	1	1 Wärmepumpe	Brüssel	ohne	25	0,6		0
2	2	365	1	1 Wärmepumpe	Brüssel	ohne	25	0,6		6
3	3	728	1	1 Wärmepumpe	Brüssel	ohne	25	0,6		10
4	4	284	1	1 Wärmepumpe	Brüssel	ohne	25	0,8		0
5	5	312	1	1 Wärmepumpe	Brüssel	ohne	25	0,8		6

variable parameters  
→ Input



modelling the different cases and simulate



results of the IDA ICE simulation

No.	elektronic cooling [KWh]	HVAC aux [KWh]
1	8103,1	11526,0
2	8262,9	9578,3
...	...	...
729	6129,9	483,1

energy output  
→ Label

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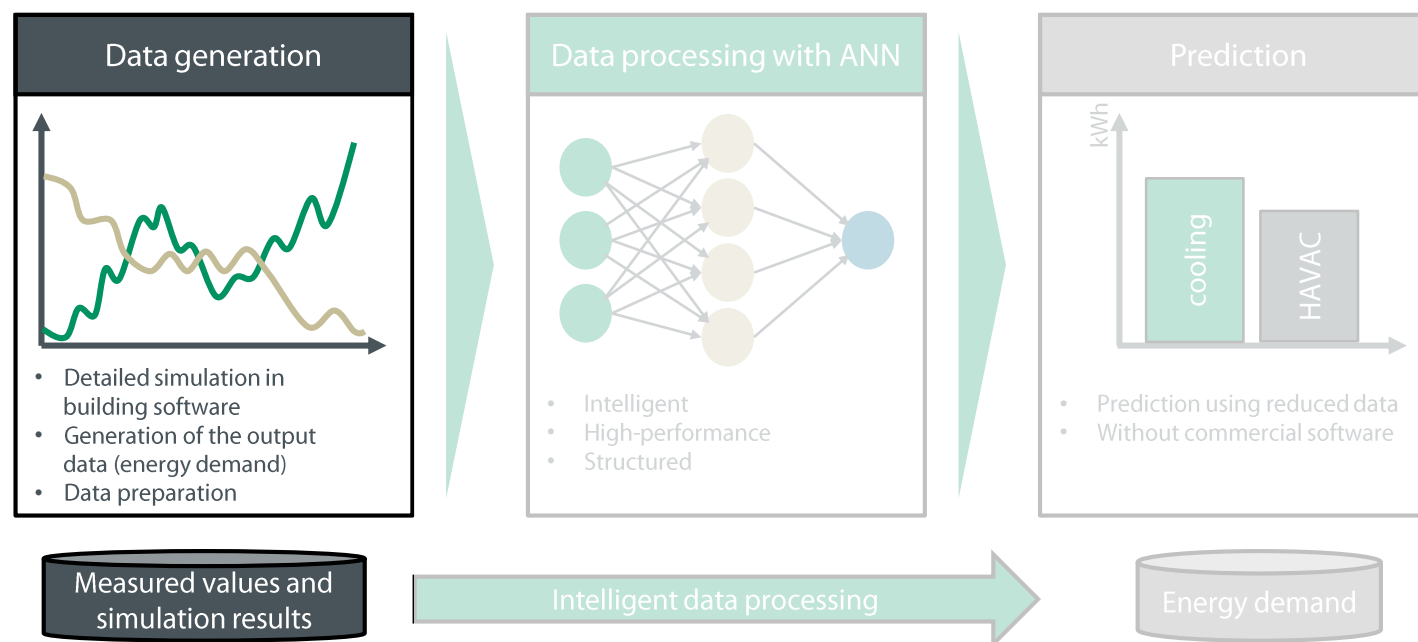
## 3.2 Development of the cooling tool

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# Development of the tool – data processing

Data generation:

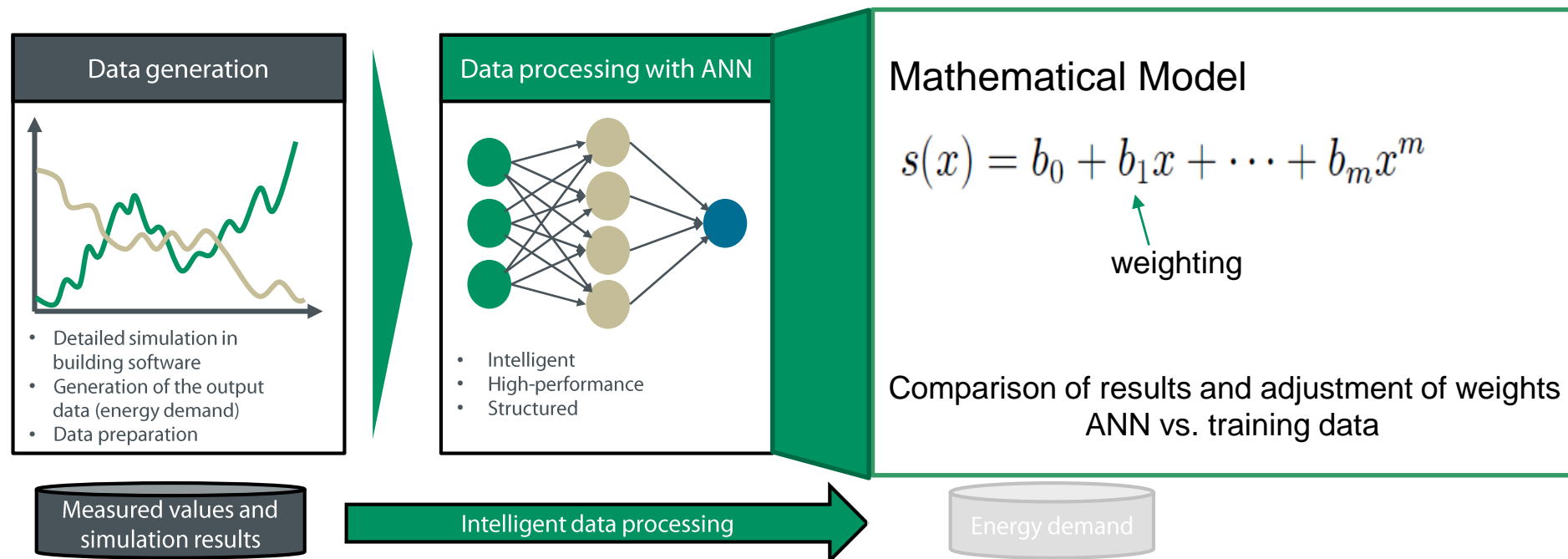
- Modelling of a detailed simulation model based on real measured data and building parameters
- Validation of the model based on measurements of the energy demand of the cooling system
- Implementation of a parameter variation based on defined scenarios



# Development of the tool – data processing

Data processing:

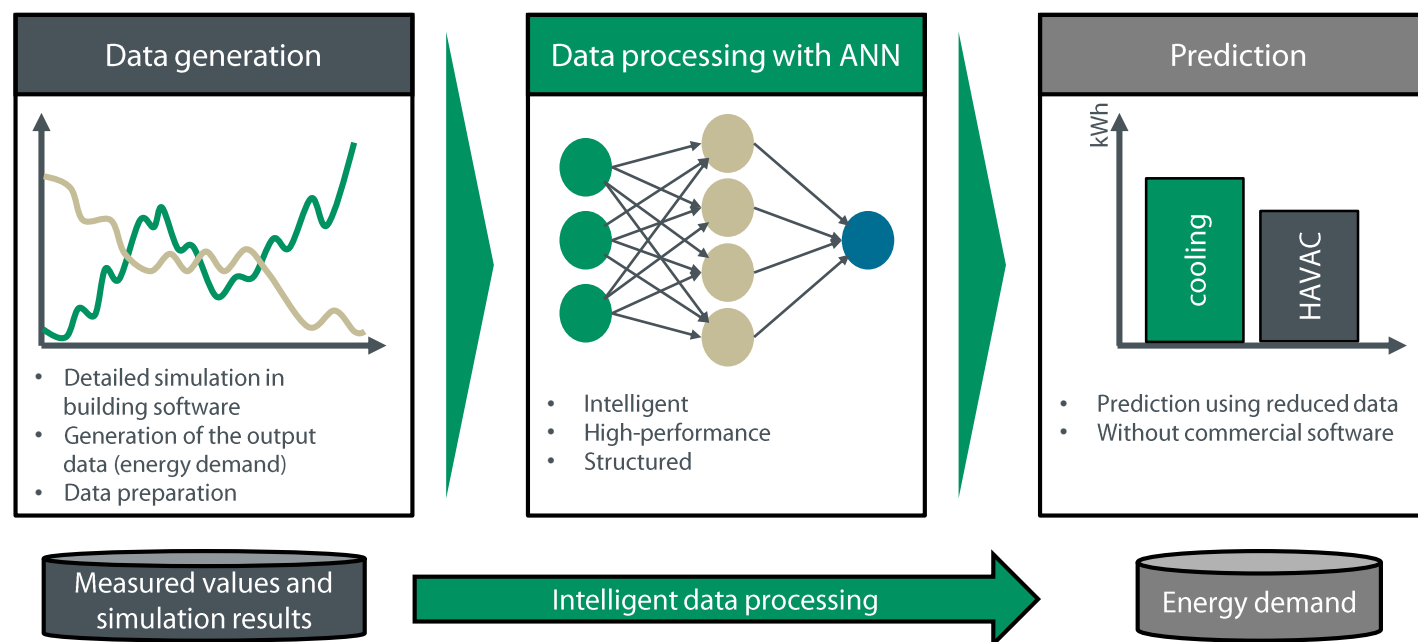
- Parameters and simulation results of the cooling demand serve as training data for the ANN
- Mathematical Model calculates energy demand as an output
- Output accuracy can be improved with more and more data (e.g. from simulations)



# Development of the tool – data processing

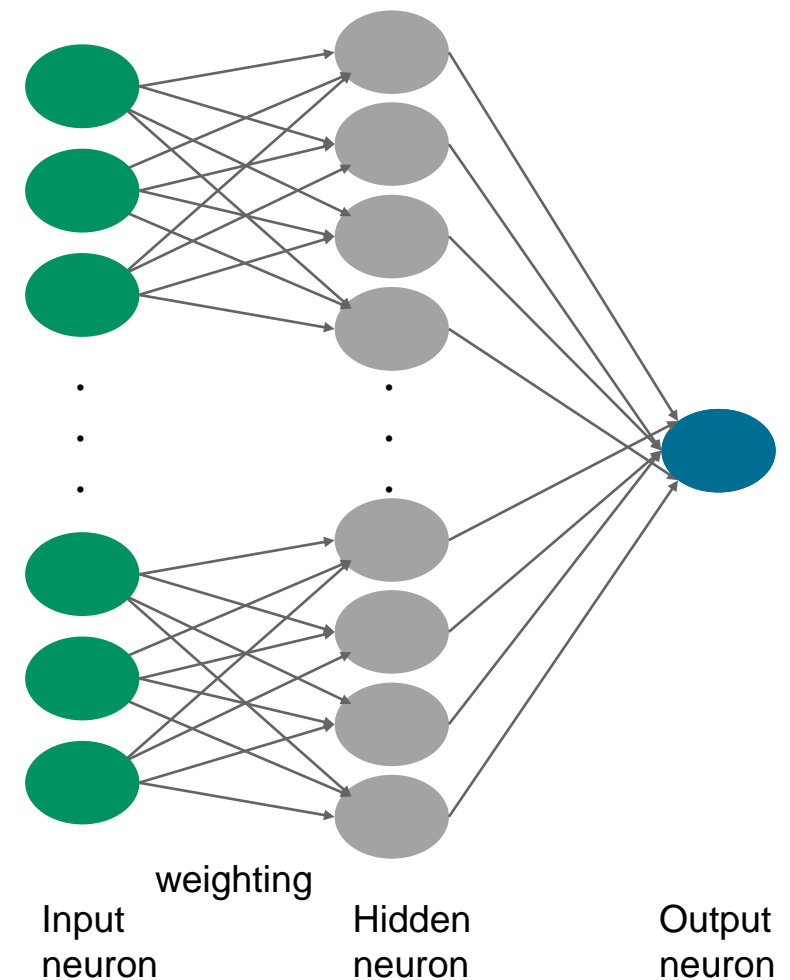
Prediction:

- ANN can be used to predict energy demands, even for unknown input parameters.
- The result / output is the most probable cooling demand for the given input parameters.
- The trained model can be used for predictions of cooling demand with a minimal knowledge.



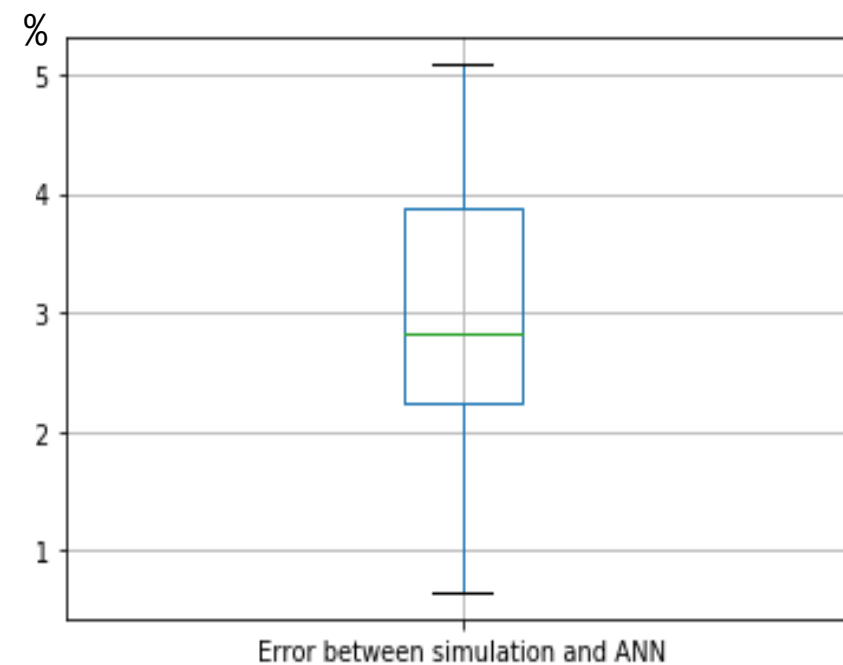
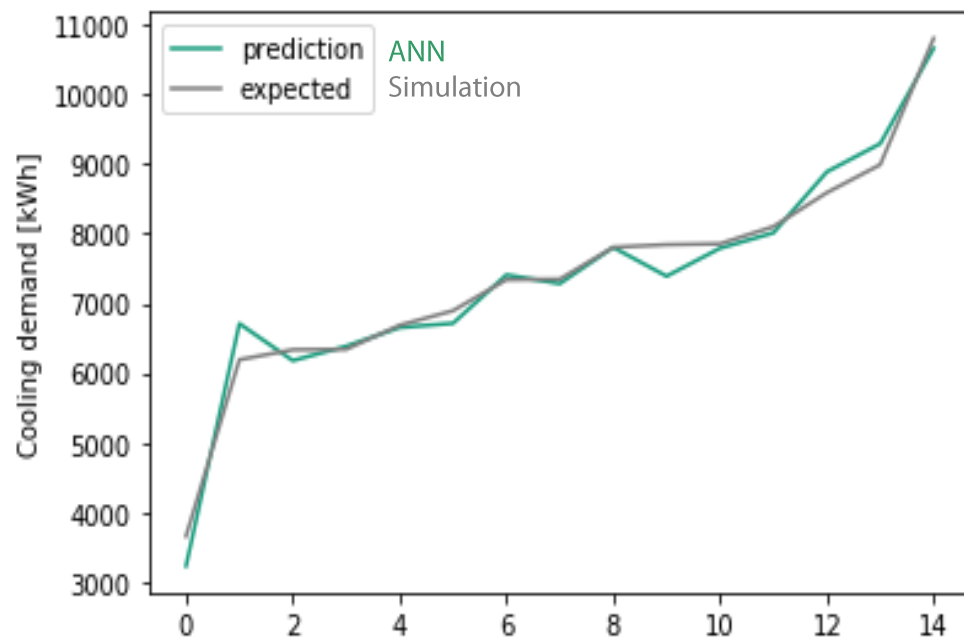
# Development of the tool – model development

- 12 neurons inputlayer  
(Denselayer)
- 25 neurons first hiddenlayer  
(Denselayer, activation: ReLU, activity regularizer: L2(e-4))
- 20 neurons second hiddenlayer  
(Denselayer, activation: ReLU)
- 1 neuron outputlayer  
(Denselayer)
  
- Early stopping (1e-3)
- Batchsize: 10
- Max. epochs: 2000



# Development of a tool – model development

- RMSE for unknown data : 3.2%



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