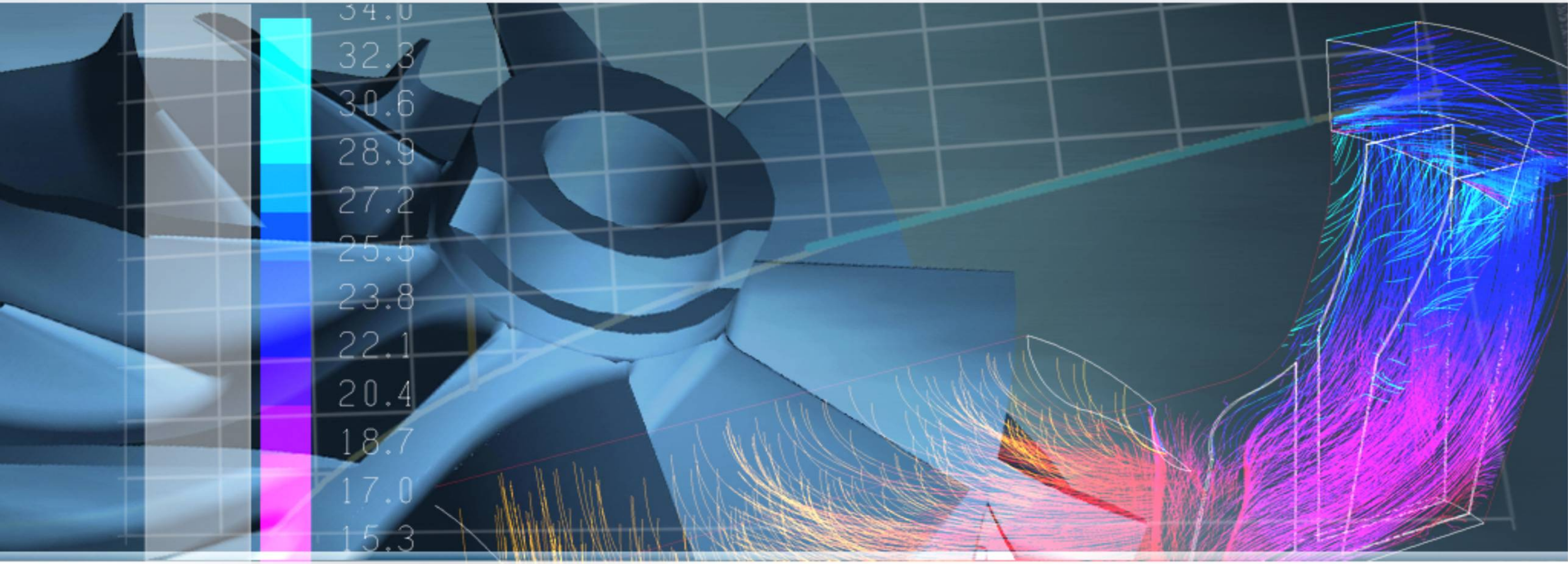
ILK Dresden



Institute of Air Handling and Refrigeration ILK Dresden

Ongoing developments in SolarSplit – sub project: Integration of Ice Storage in to Mono-Split-Units

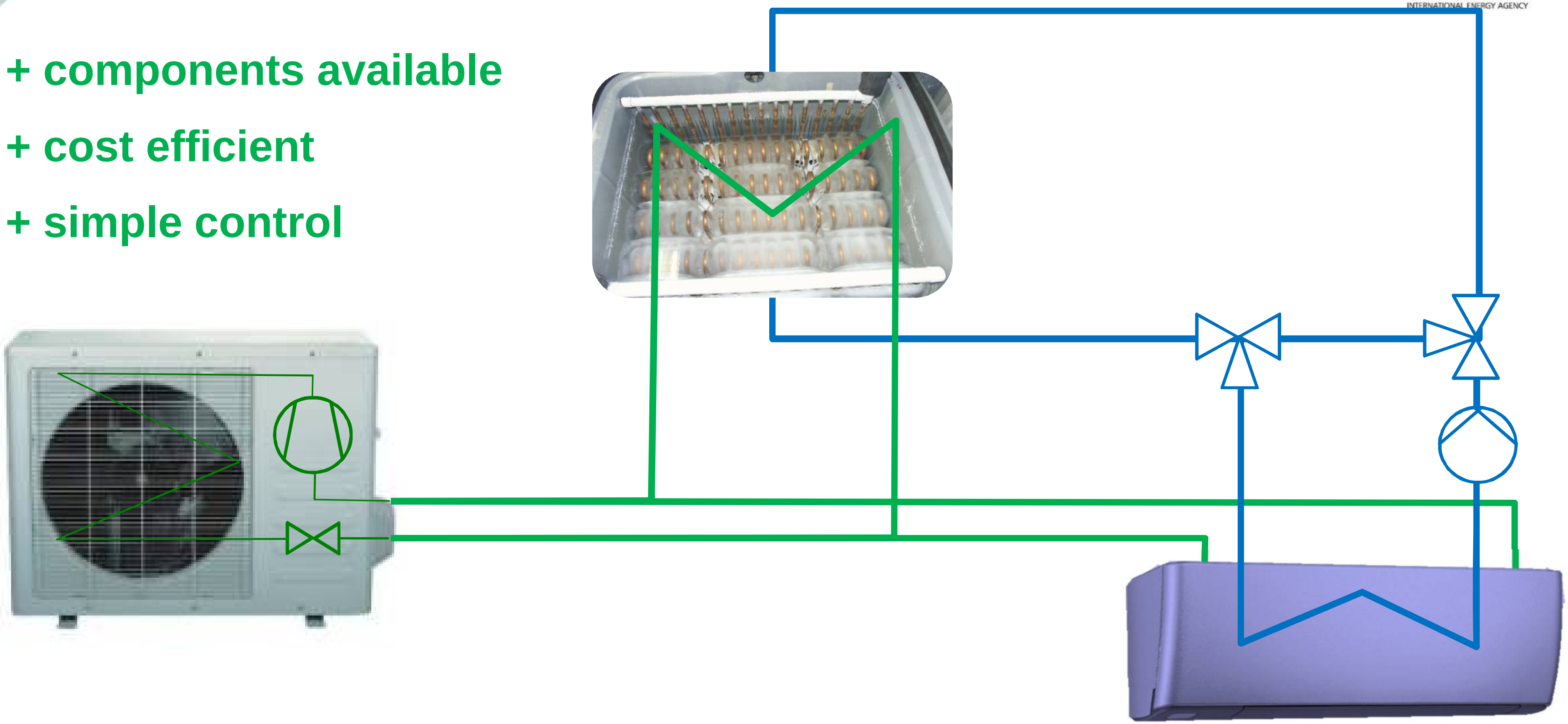
Carsten Heinrich

Integrating an Ice Storage
Option 1

+ components available

+ cost efficient

+ simple control



- poor direct cooling efficiency

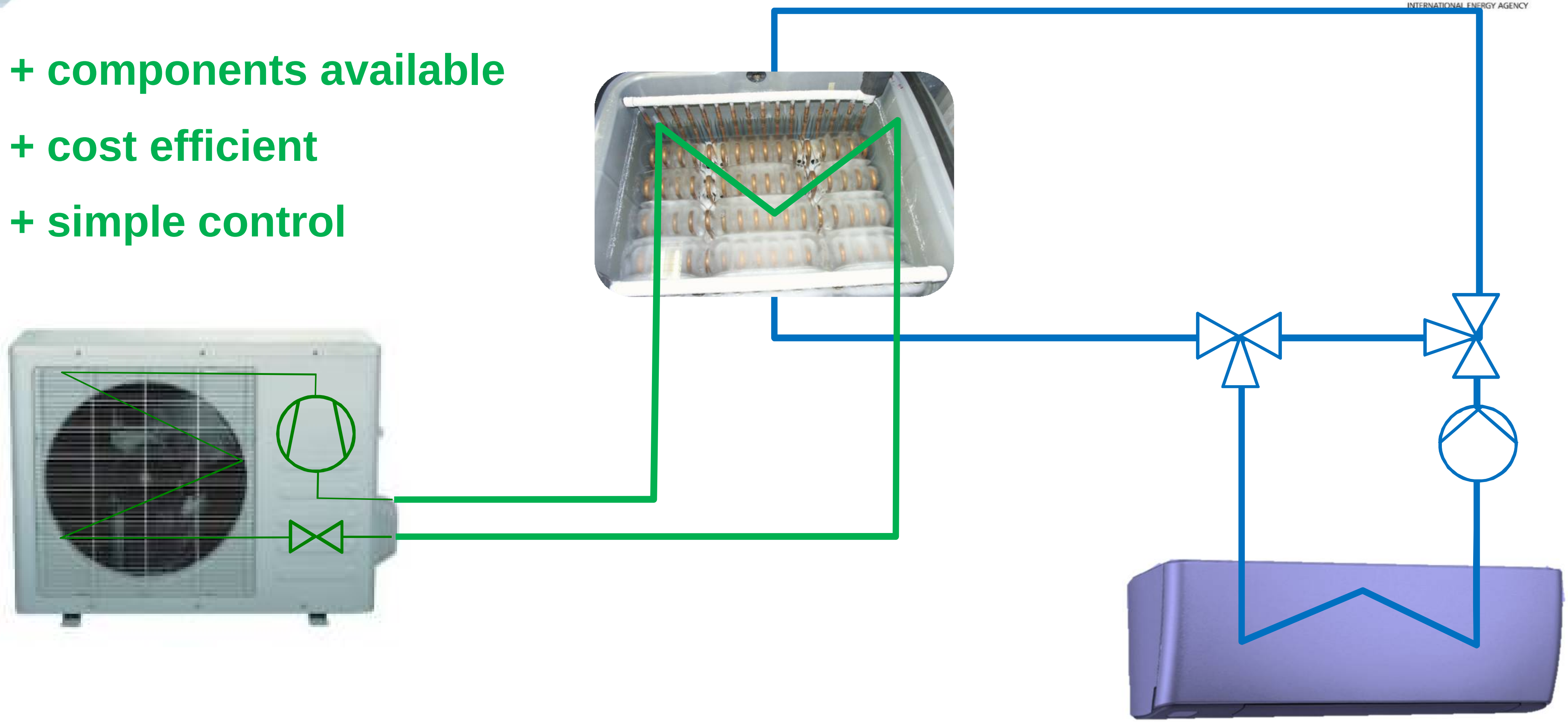
- high thermal inertia during initial cooling

Integrating an Ice Storage
Option 1

+ components available

+ cost efficient

+ simple control

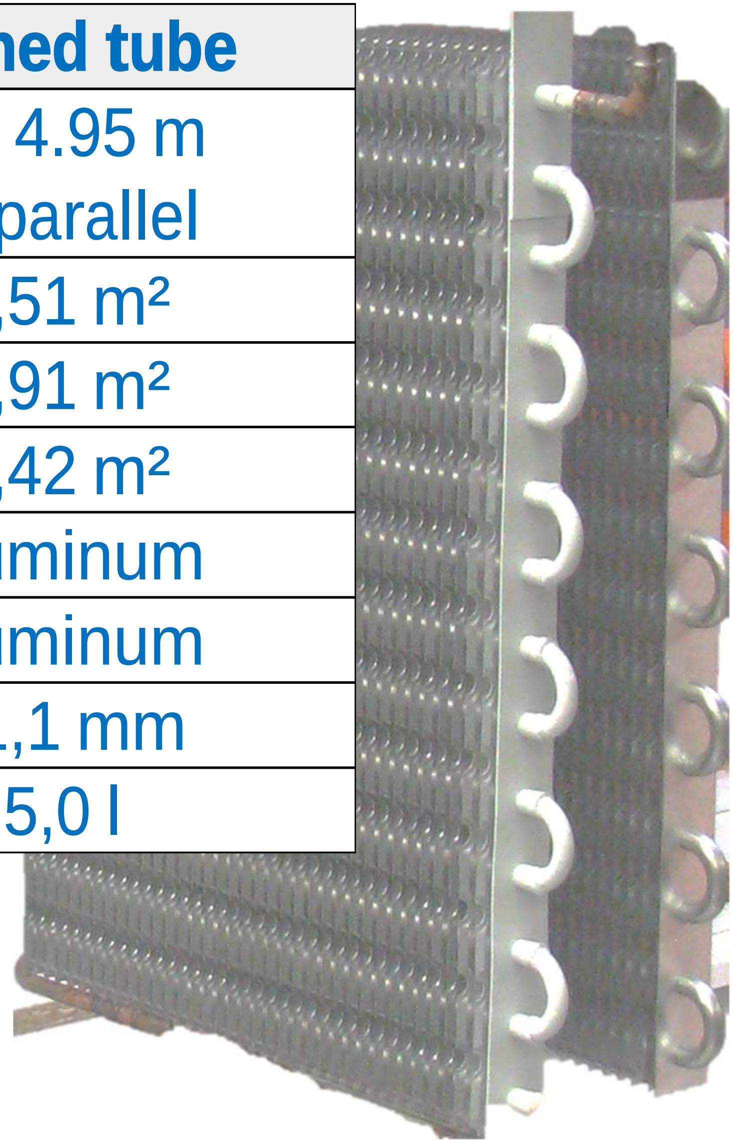


- poor direct cooling efficiency

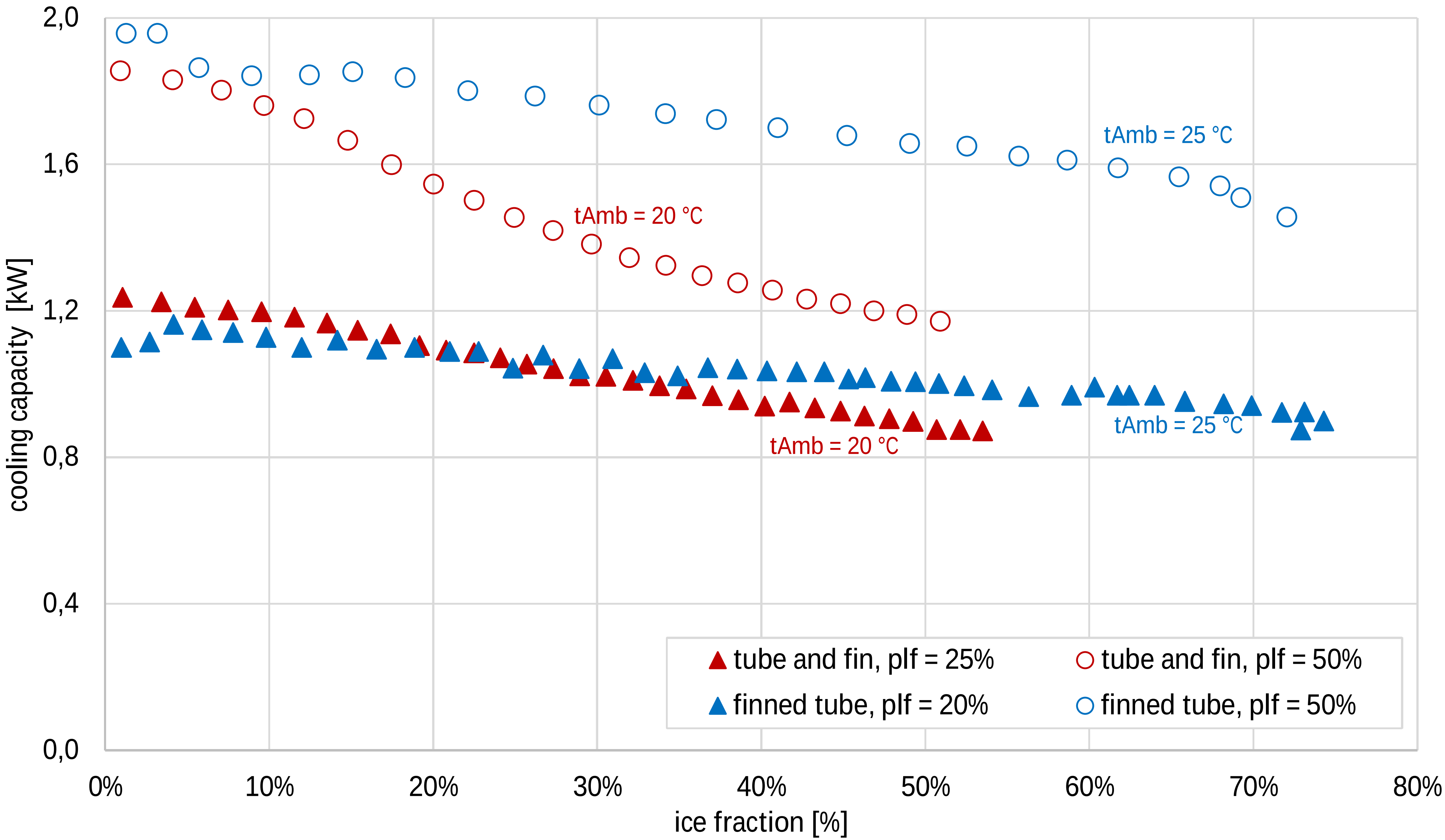
- high thermal inertia during initial cooling

Evaporators Data

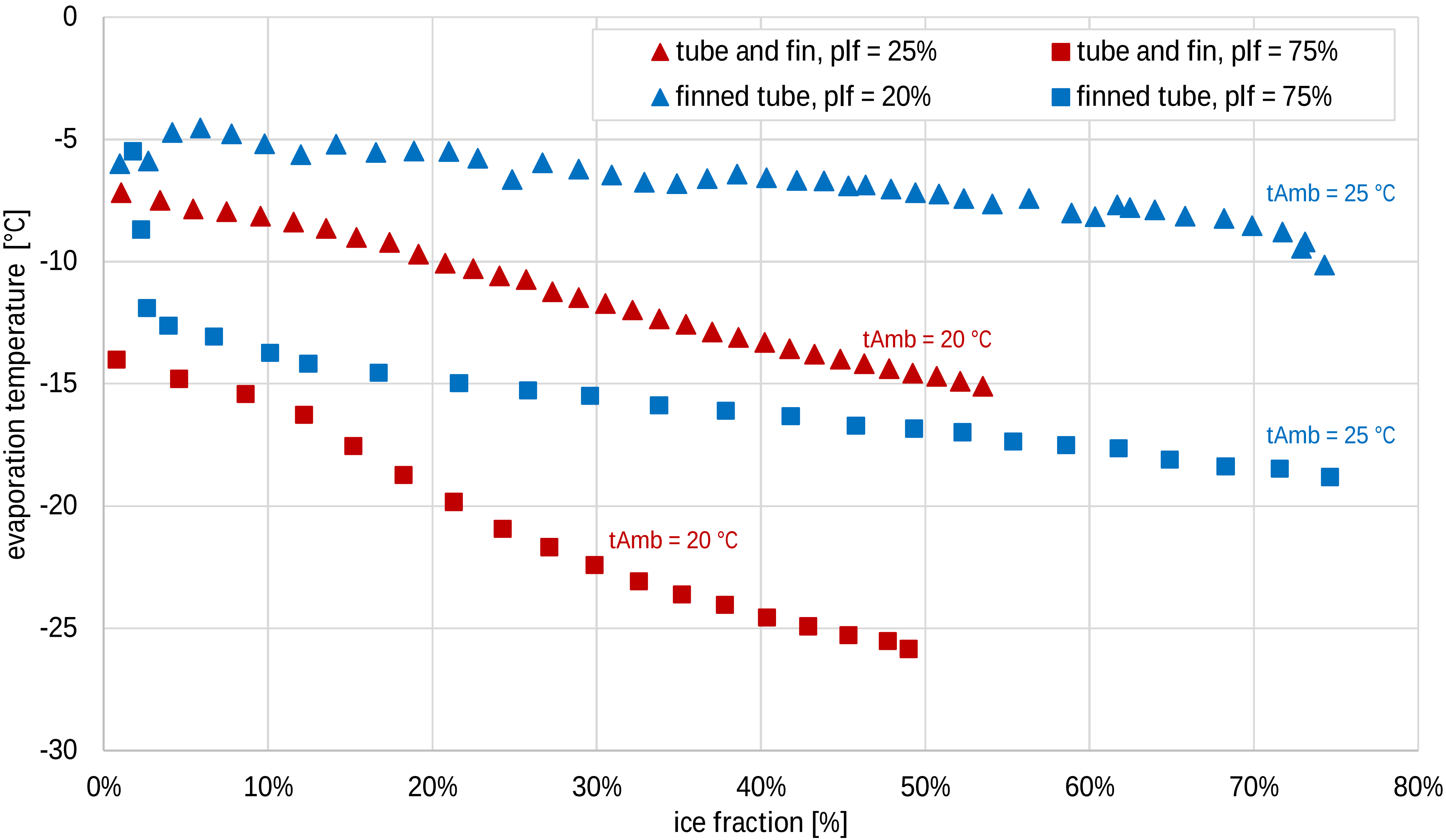
	tube and fin	finned tube
tube length	2 x 6.2 m in series	4 x 4.95 m in parallel
tube outside surface	0,39 m²	0,51 m²
fin water side area	2,32 m²	0,91 m²
total water side area	2,71 m²	1,42 m²
tube material	copper	aluminum
fin material	aluminum	aluminum
mean fin length	9,8 mm	11,1 mm
refrigerant volume	5,8 l	5,0 l



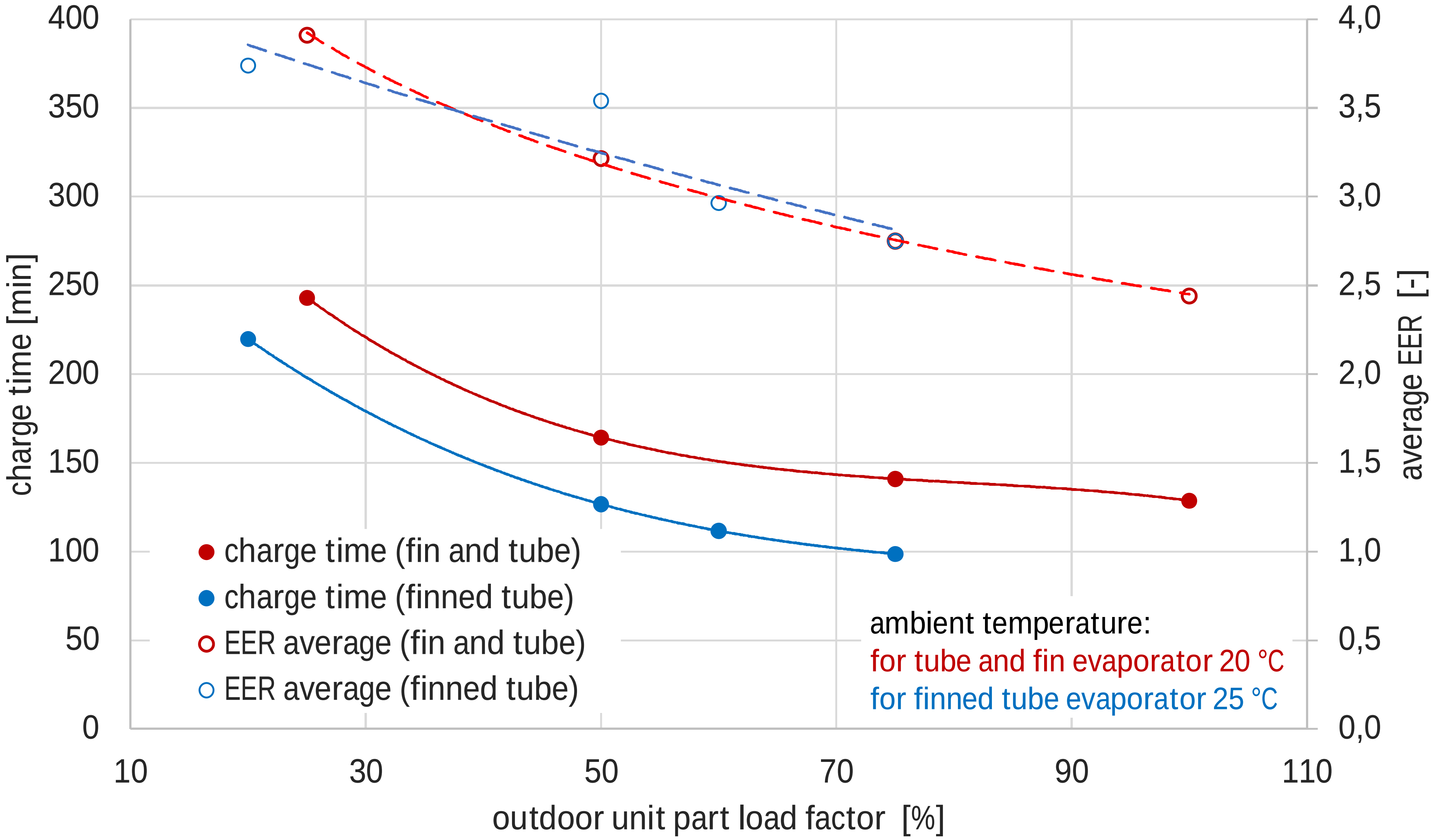
Storage Charging
Cooling Capacity vs. Ice Fraction



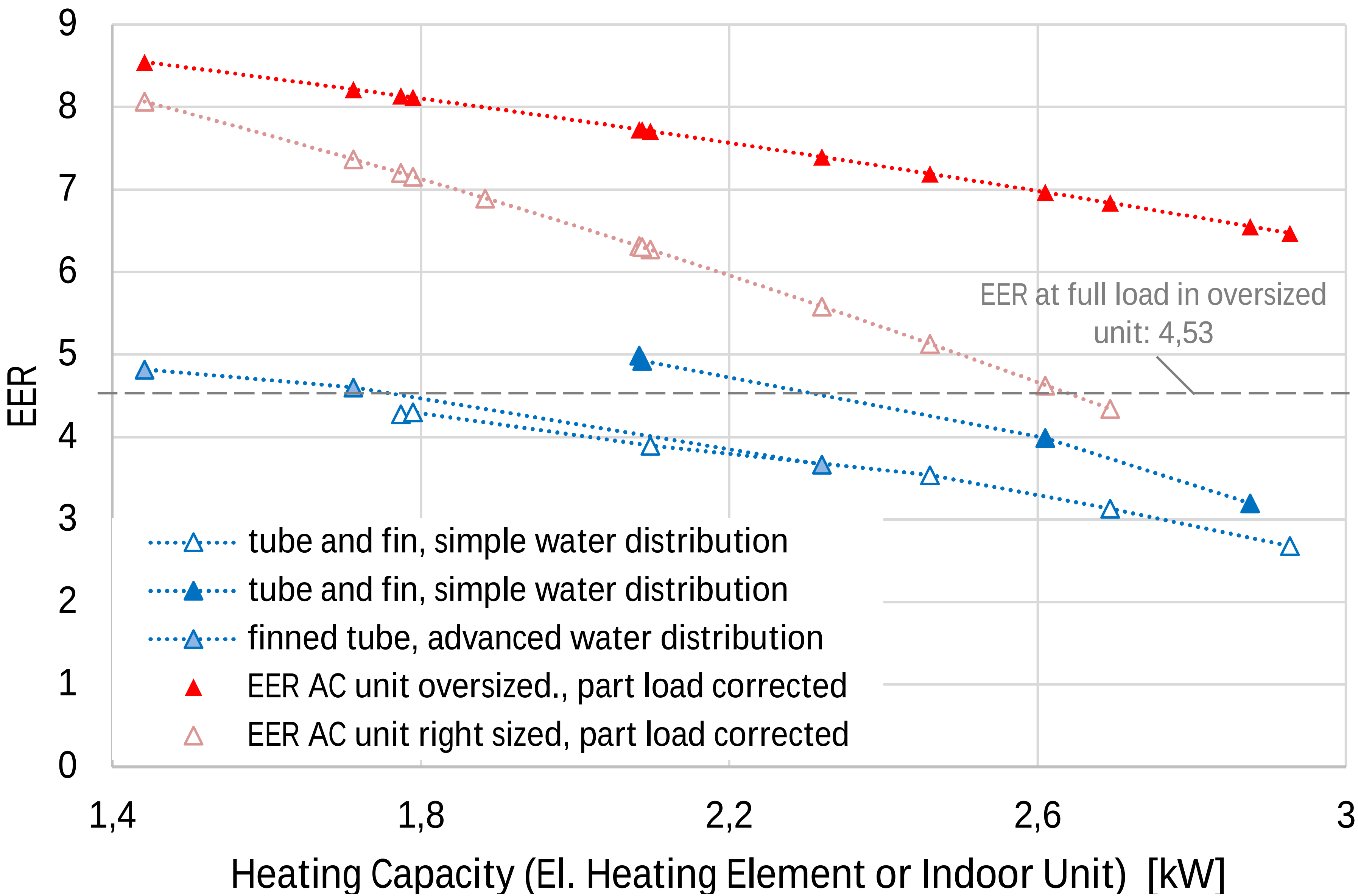
Storage Charging
Evaporation Temperature vs. Ice Fraction

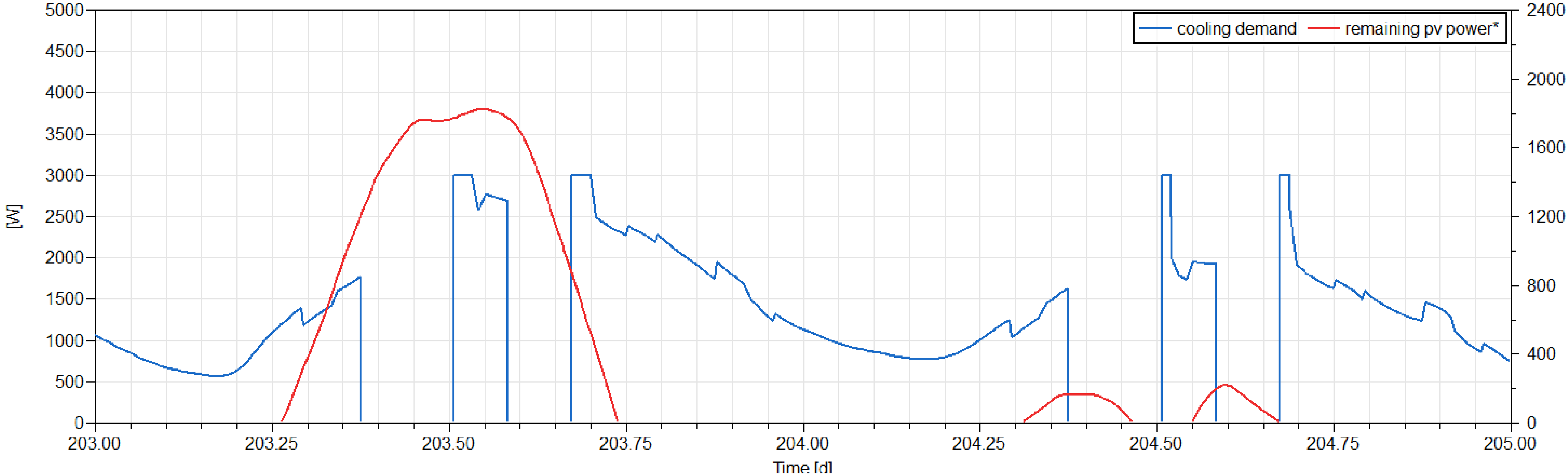


Charge time and EER vs. Outdoor Unit PLF for charging process 15 °C to 50 % ice fraction



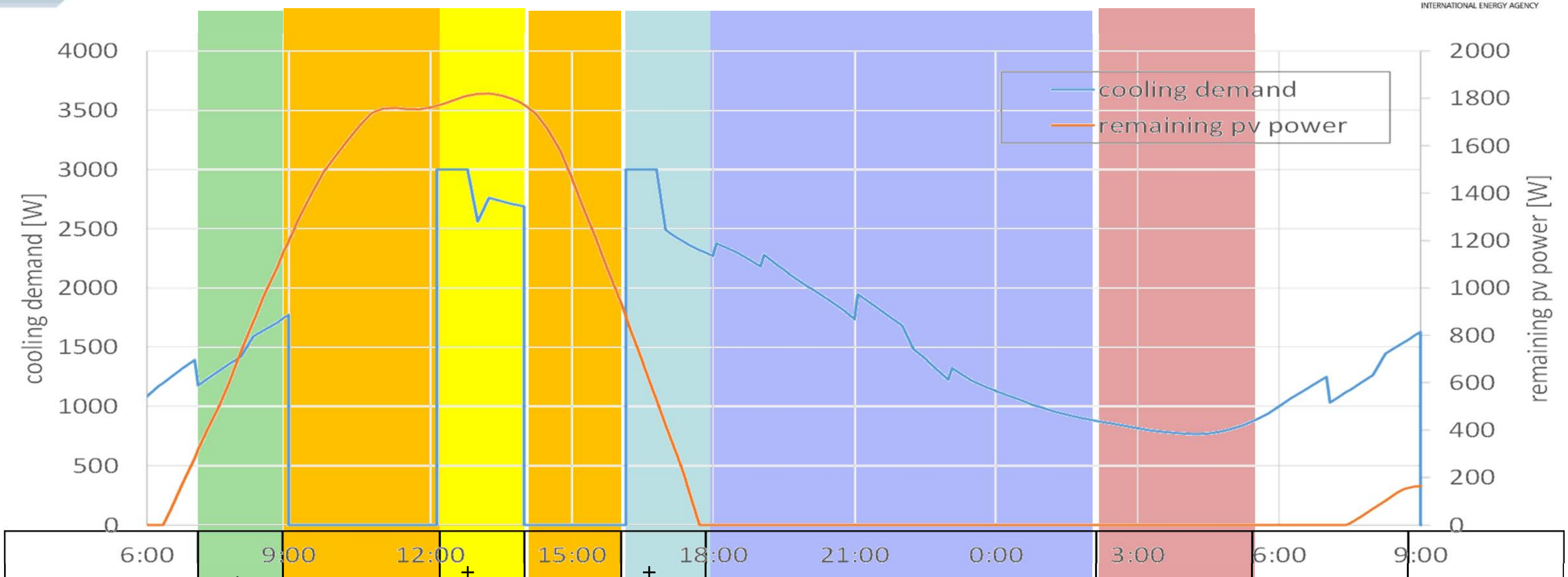
Efficiency in Direct Cooling Mode





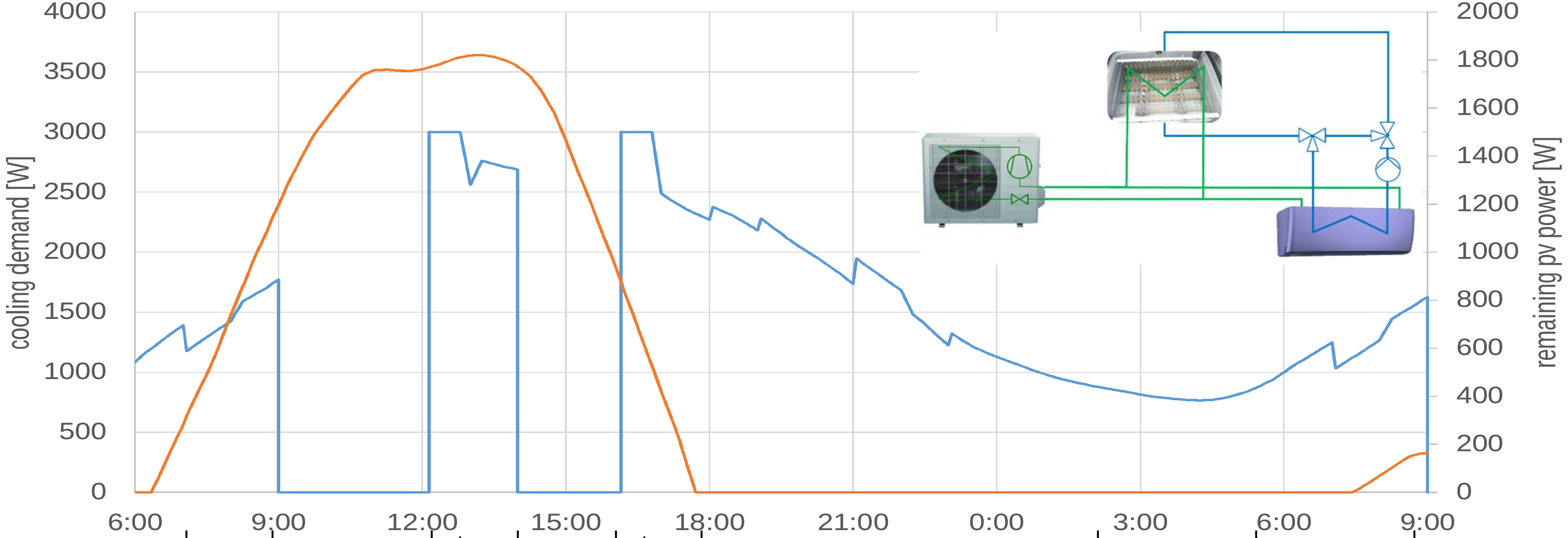
possible									
efficient									
simple control									

Possible Operations Modes Depending on Cooling Demand and Remaining PV Power



	cooling on pv	charging	cooling on pv + charging		cooling on pv + discharging	discharging	cooling by electricity from grid		
possible									
efficient									
simple control									

Possible Operations Modes – Option 1



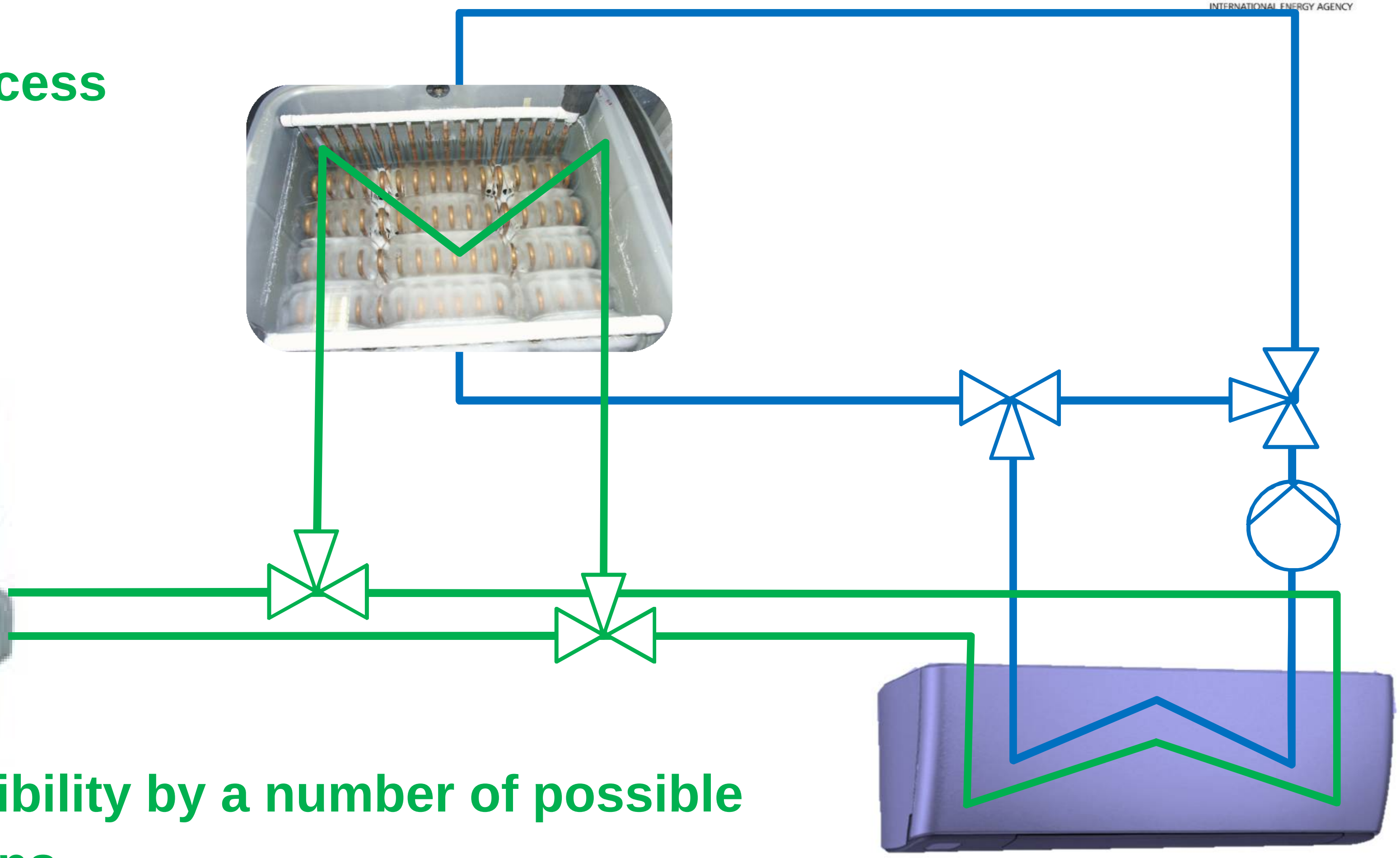
	cooling on pv	charging	cooling on pv + charging		cooling on pv + discharging	discharging	cooling by electricity from grid		
possible	✓	✓	✓		✓	✓	✓		
efficient	👎	👍	👉		👎	👍	👎		
simple control	👉	👍	👍		👍	👍	👉		

Integrating an Ice Storage Evolution Stage

direct cooling process

+ high efficient

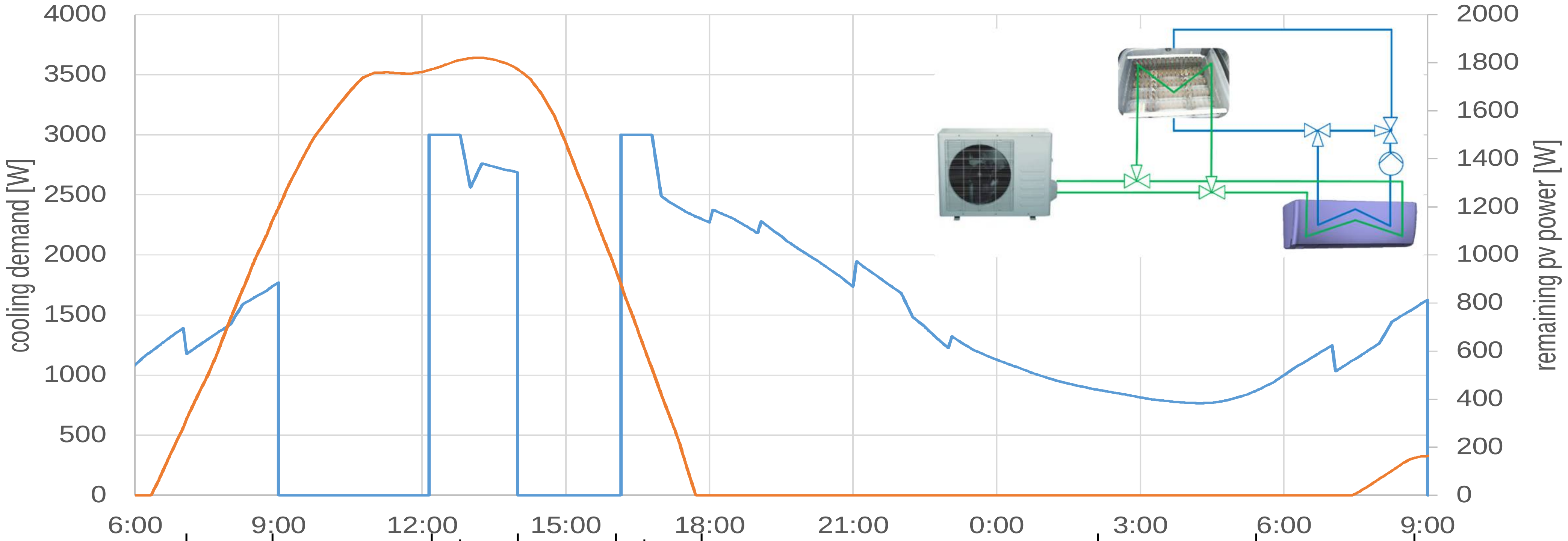
+ fast response



+ we increase flexibility by a number of possible parallel operations

- **complex control required**
- **expensive indoor unit and installation**

Possible Operations Modes – Option 2



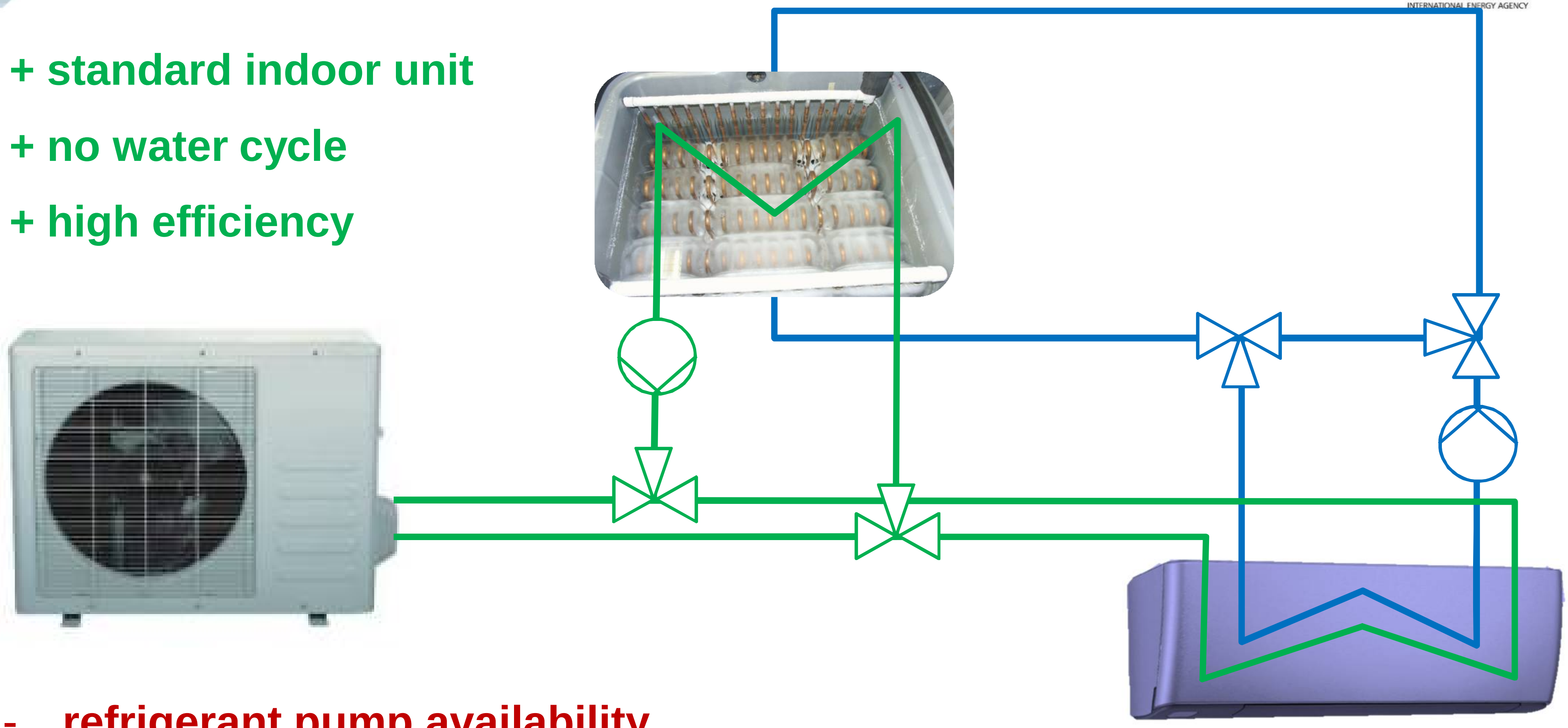
	cooling on pv	charging	cooling on pv + charging		cooling on pv + discharging	discharging	cooling by electricity from grid		
possible	✓	✓	✓		✓	✓	✓		
efficient	👍	👍	👎/👍		👍	👍	👍		
simple control	👍	👍	👉 👎		👉	👍	👍		

Integrating an Ice Storage Alternative

+ standard indoor unit

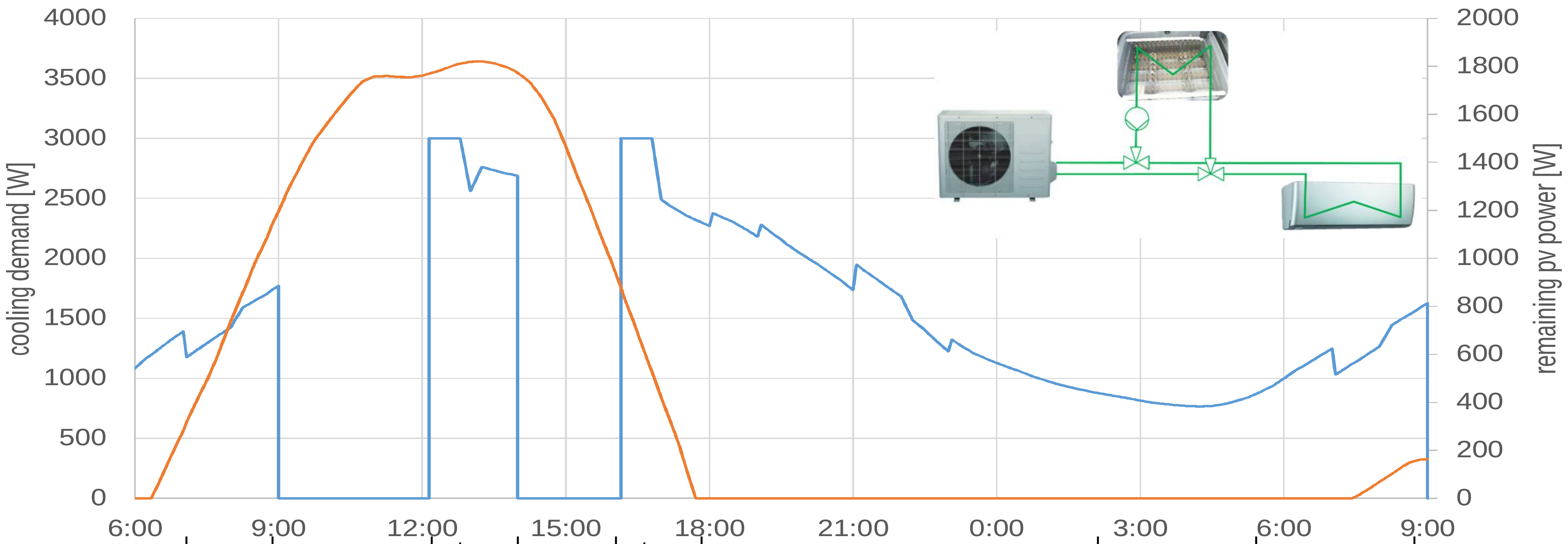
+ no water cycle

+ high efficiency



- refrigerant pump availability
- complex control (refrigerant location)
- discharge process might be less efficient

Possible Operations Modes – Option 3

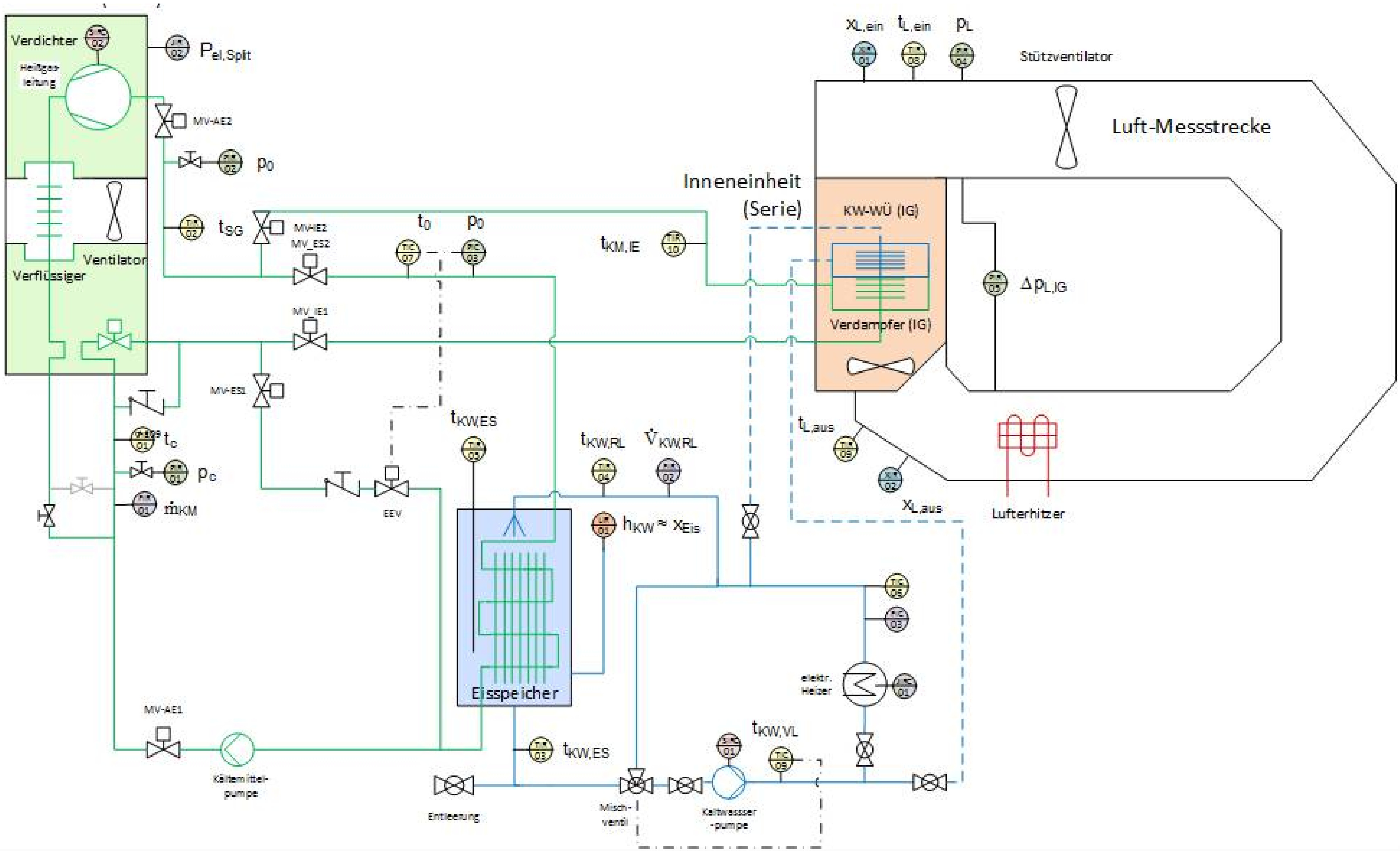


	cooling on pv	charging	cooling on pv + charging		cooling on pv + discharging	discharging	cooling by electricity from grid		
possible	✓	✓	✓		✓	✓	✓		
efficient	👍	👍	👉		👍	👍	👍		
simple control	👍	👍	👎		👎	👍	👍		

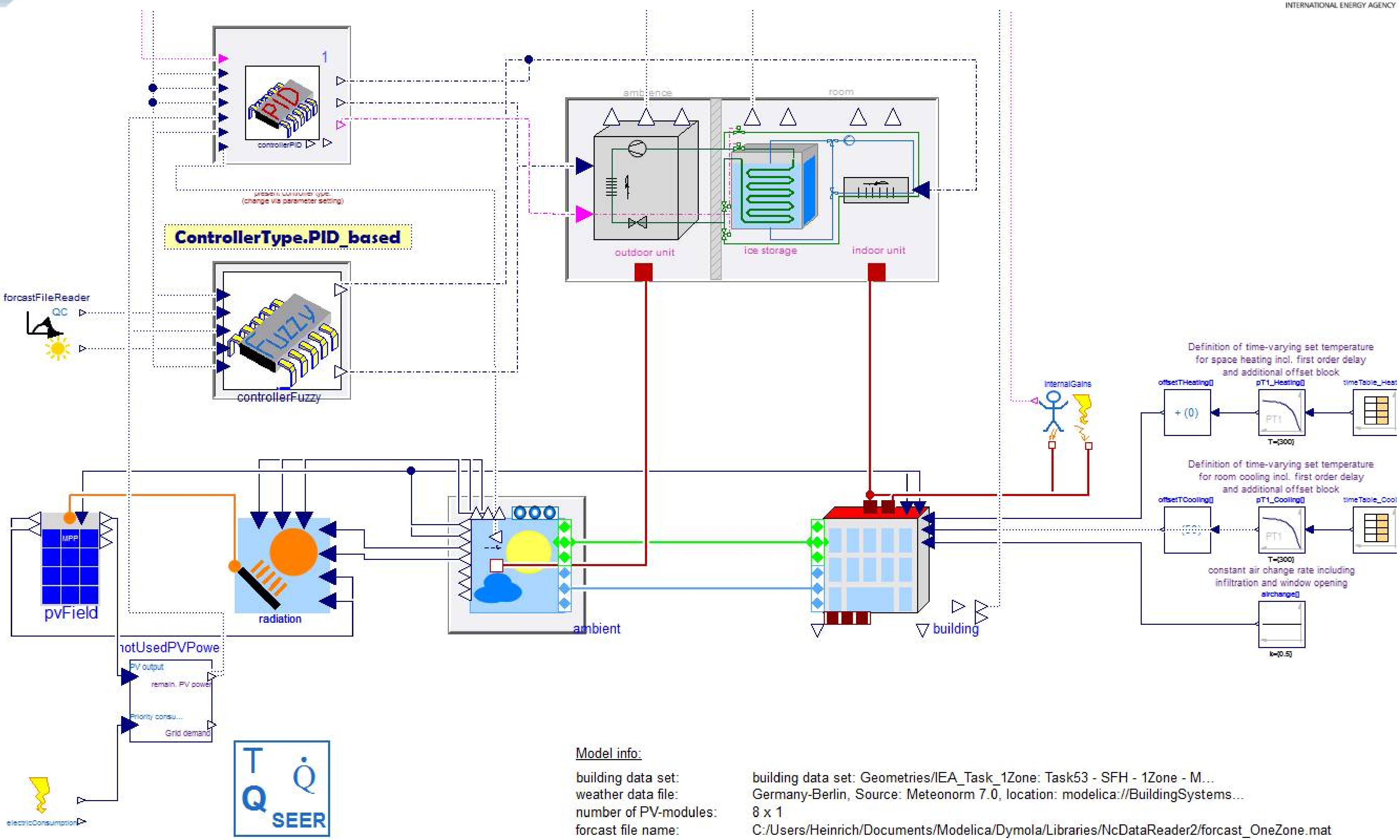
Refrigeration Pumps Tests

- **no pumps for liquid refrigerants are available in the required range**
- **compared to application of available pumps conditions differ in…**
  - viscosity of refrigerants is lower than of other media (diesel, gasoline)
  - pressure increase is low
  - absolute pressure level is high (up to 40 bar and higher)
  - refrigerant state is near to saturation (pressure decrease leads to vaporization)
- **cooperation with a German pump manufacture**
  - first promising results in a test cycle
  - right now installed in the test rig

Test Rig Extension



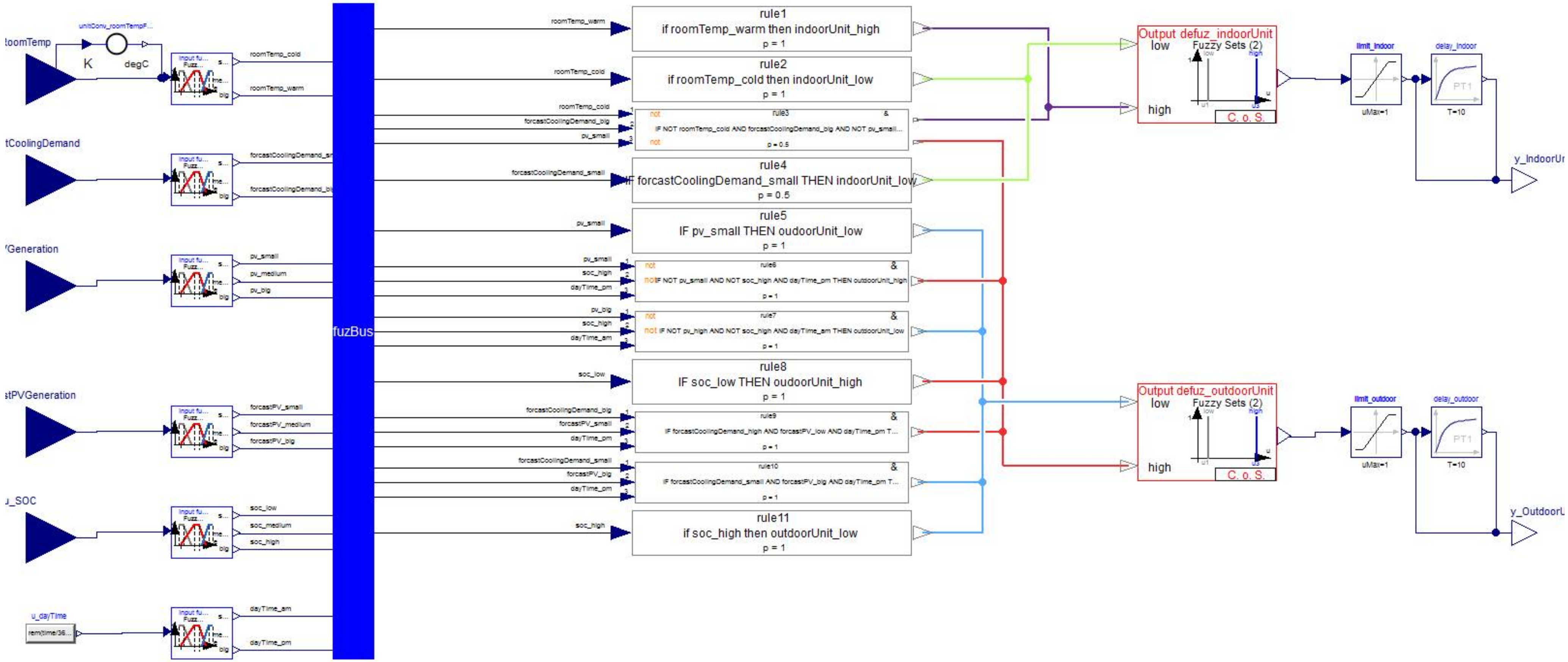
Controller Development using Modelling / Simulation



Model info:

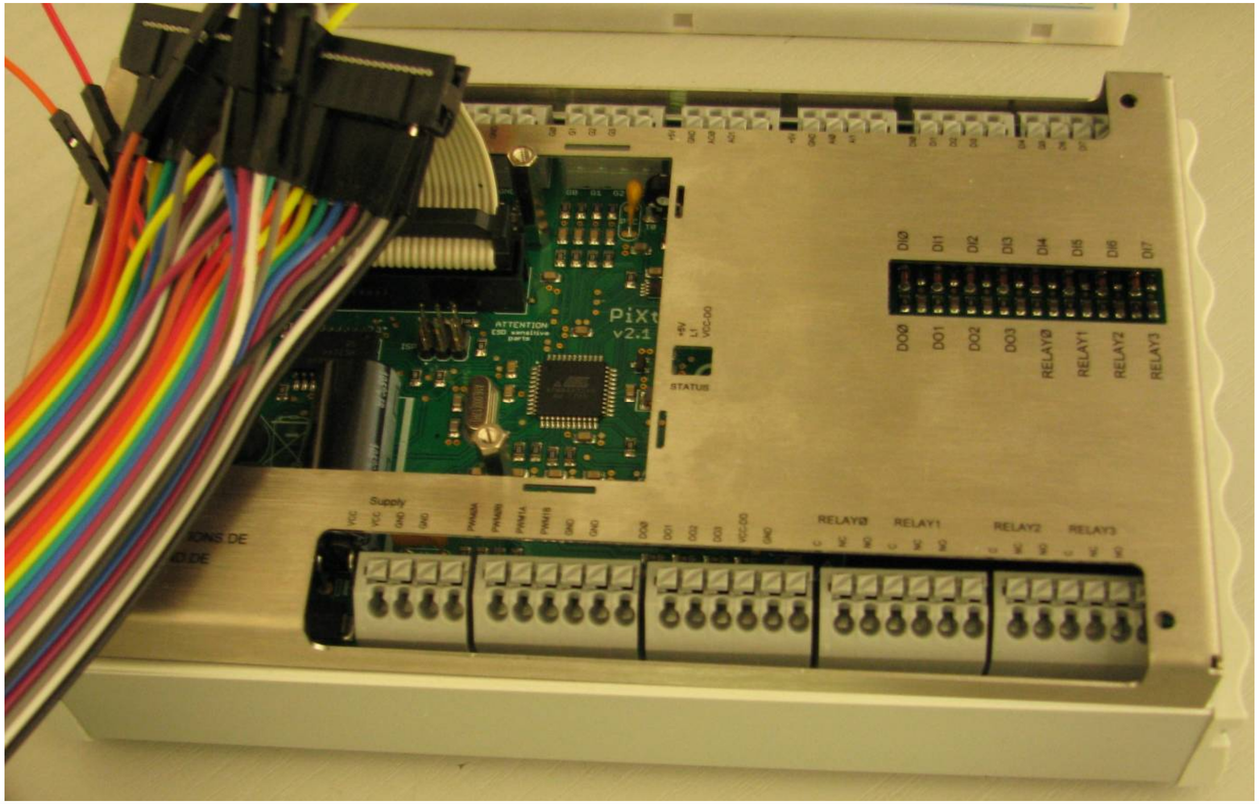
building data set:	building data set: Geometries/IEA_Task_1Zone: Task53 - SFH - 1Zone - M...
weather data file:	Germany-Berlin, Source: Meteonorm 7.0, location: modelica://BuildingSystems...
number of PV-modules:	8 x 1
forcast file name:	C:/Users/Heinrich/Documents/Modelica/Dymola/Libraries/NcDataReader2/forcast_OneZone.mat

Controller Development using Modelling / Simulation

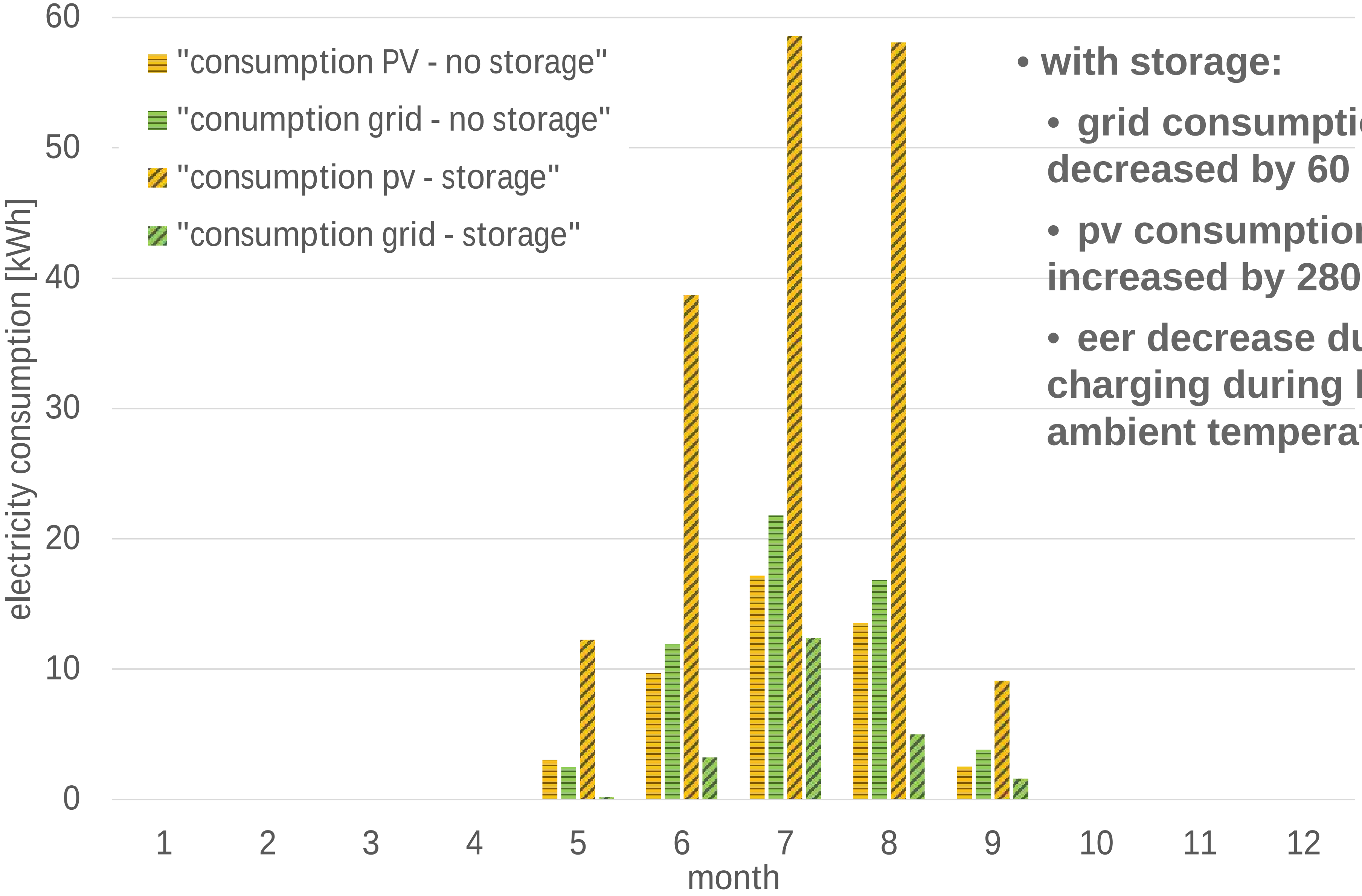


Controller Implementation

- **Controller implementation in Arduino / Pi – based controllers**
  - both variants (PID based and fuzzy based)
  - forcast for pv-production and cooling demand based on web-queries and simple calculation models
- **Controller test on test rig**
  - hardware controller
  - using real forcast data
  - using current pv-electricity generation from ILK-pv-system
  - using current weather data and building model to generate heat load



Simulation Results using Models based on the Test Rig Results



- **with storage:**
  - **grid consumption is decreased by 60 %**
  - **pv consumption is increased by 280%**
  - **eer decrease due to charging during high ambient temperatures**