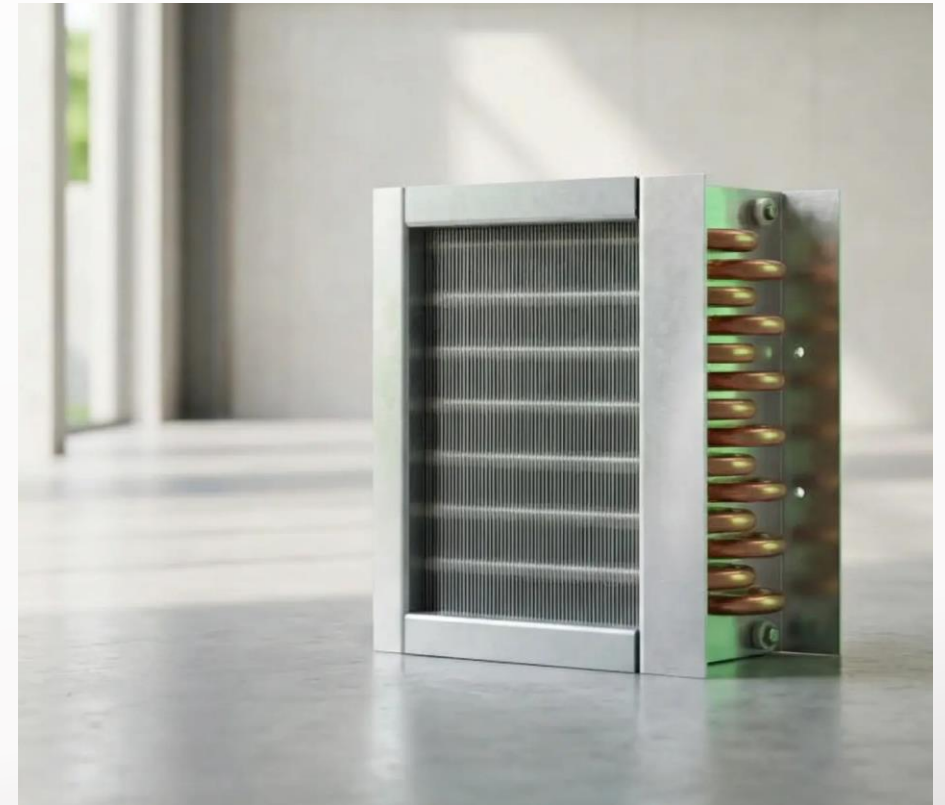


# Geometry-Based Performance Enhancement of Finned-Tube Heat Exchangers

→ More performance with the same or lower material usage

Technology offering for differentiation in the OEM market

- ✓  $\geq 25\%$  reduction in **tube material**
- ✓ approx. 14% savings in fin material
- ✓ Advantages in frosting behavior
- ✓ No new manufacturing technology required
- ✓ Geometric optimization of the air inlet zone



# Increasing performance demands – an inefficient system

## Competitive pressure in the heat exchanger market

- OEMs demand higher efficiency
- Increasing price pressure
- Volatile material costs
- Differentiation is becoming more difficult



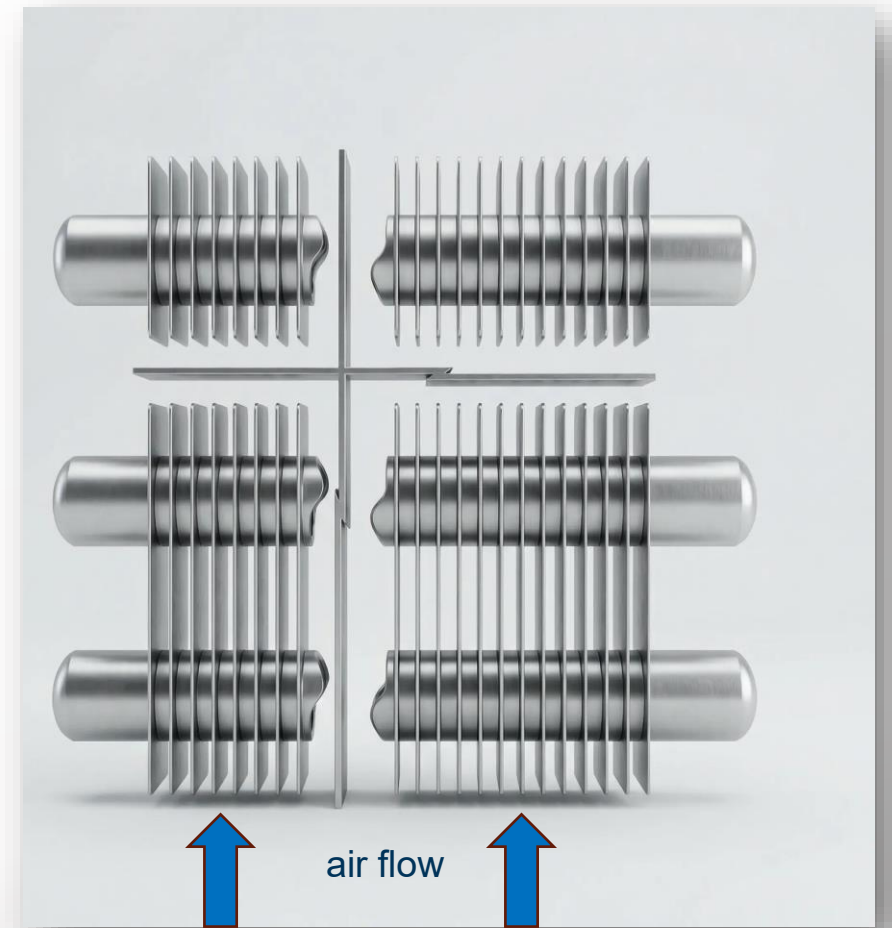
**The next efficiency level is geometric**

# Old technology – known limitations.

## Physical background

### Conventional fin geometry

- Parallel airflow
- Limited turbulence
- Standard fin block
- Scaling performance requires:
  - More air
  - More material
  - More volume

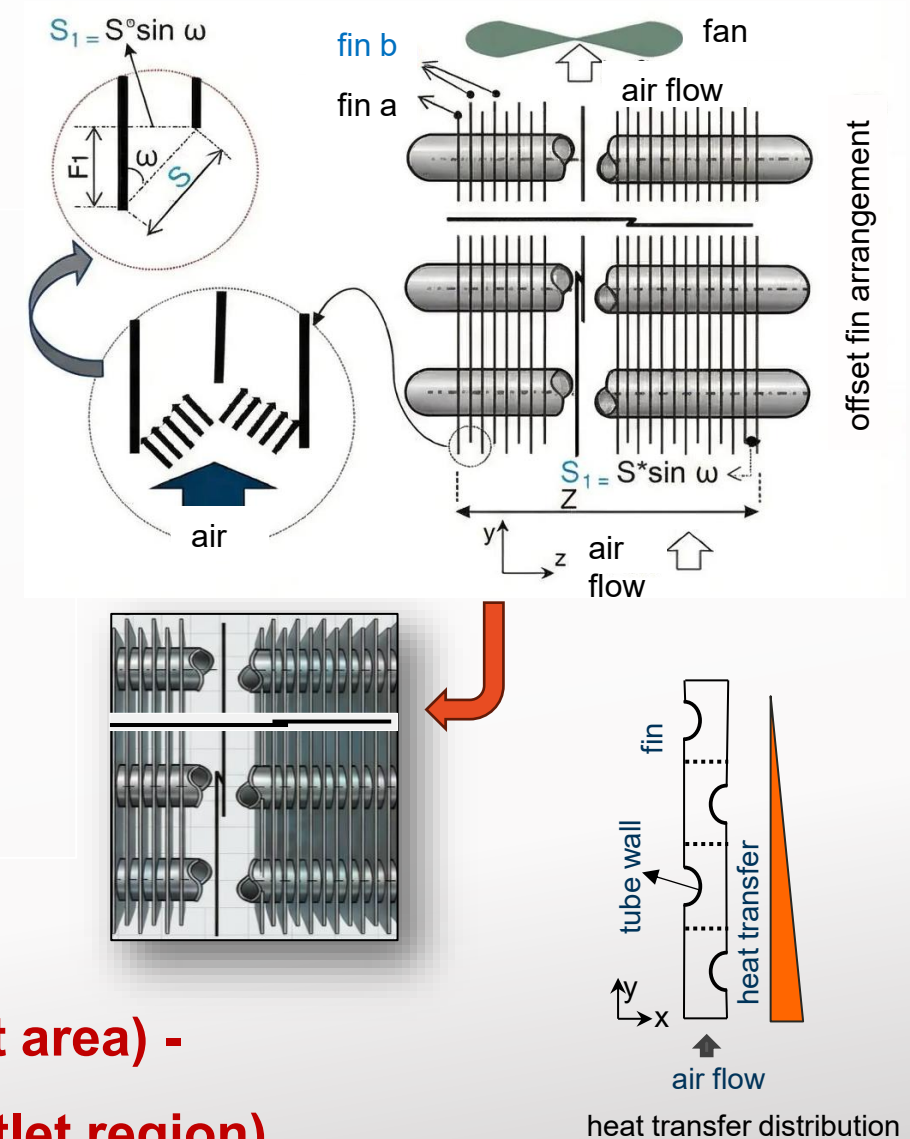


**Higher costs for every additional kW of performance**

# Patented alternating fin displacement

## Geometric intervention

- Air no longer flows parallel to the fins  
 → increased turbulence
- Air inlet areas are larger than the spaces between fins  
 → increased local air velocity
- Higher number of fins within the same or **smaller** space  
 → lower fin height and fewer tube rows  
 → increased efficiency  
 → higher performance **without increasing fin surface area**



**More surface where it is effective (air inlet area) -  
 less surface where it contributes little (air outlet region)**

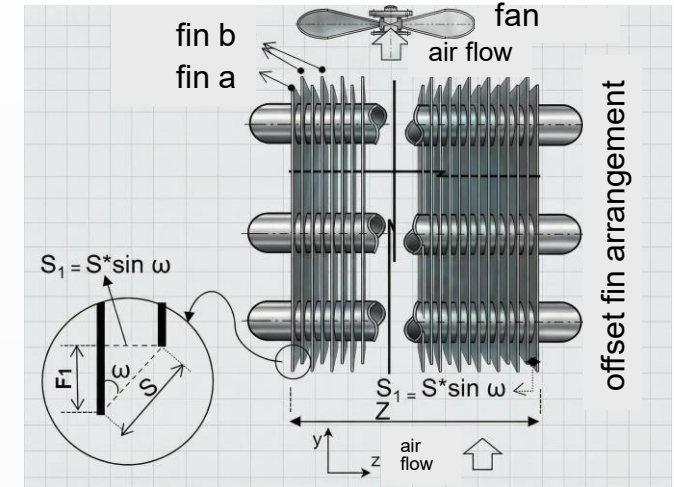
# Higher efficiency without additional complexity

## Technical comparison: Conventional vs. patented geometry

- **With identical air inlet areas:**
  - Inlet area > free inter-fin area
  - Higher local air velocity
- **With identical fin spacing:**
  - Targeted turbulence increase with higher airflow
  - Improved heat transfer with controlled pressure drop

### ❖ $F_1$ und $S_1$ as key optimization parameters:

- |                        |                                    |
|------------------------|------------------------------------|
| ▪ Reynolds number      | ▪ Extended design freedom          |
| ▪ Turbulence intensity | ▪ Increased optimization potential |
| ▪ Pressure drop        | ▪ Greater geometric flexibility    |



Heat Exchanger with Offset Fins

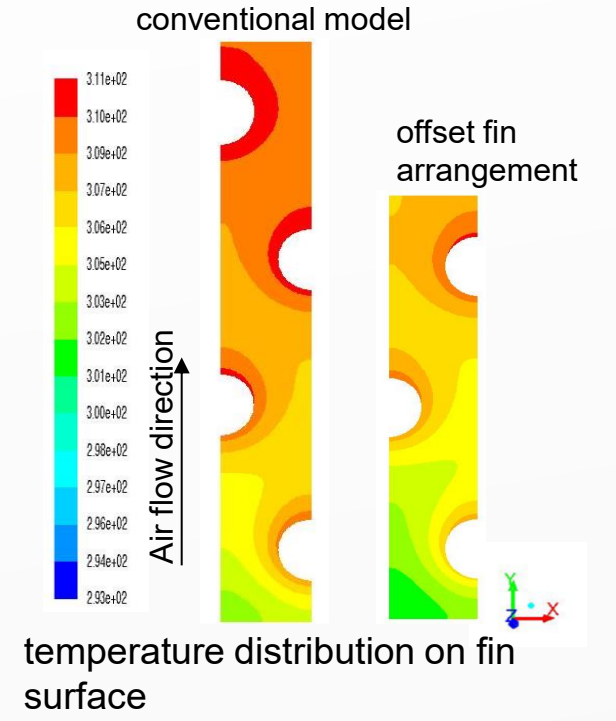
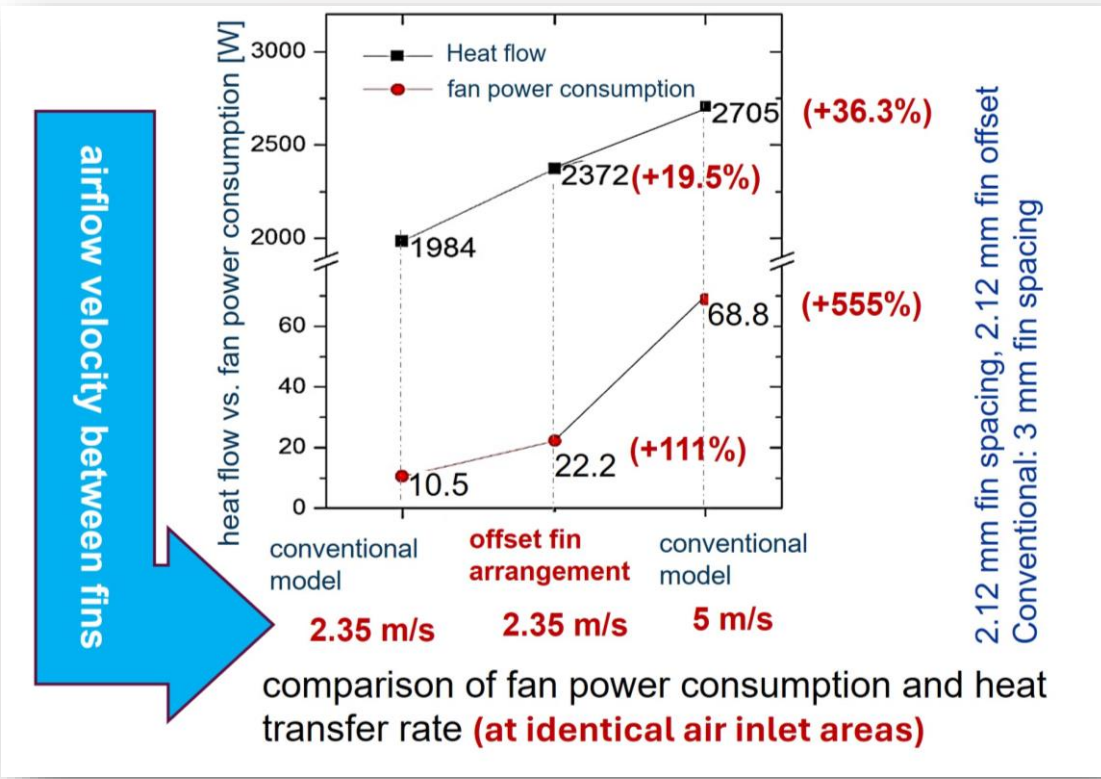
Allows precise adaptation to:

- Noise limits
- Fan characteristics
- OEM requirements



# Quantitative effects (experimental results)

## Heat transfer vs. fan power



**Conventional design\*\*:**  
+36 % heat transfer | +555 % fan power

→ **doubled airflow**

**Patented geometry:**  
+19.5 % heat transfer | +111 % fan power

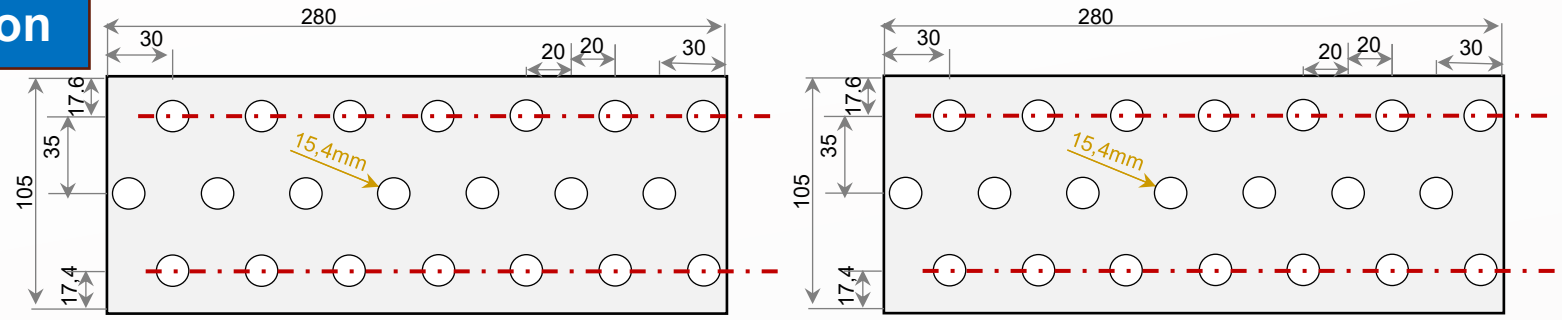
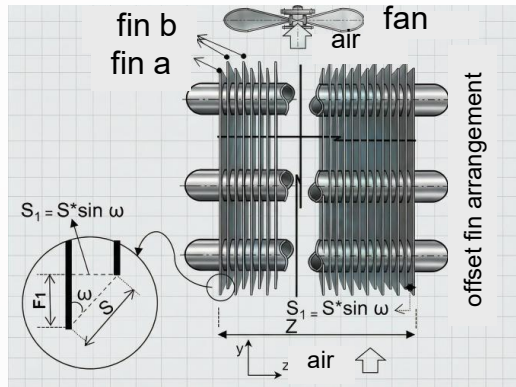
→ **same airflow level**

noise	efficiency
↑	↑
↑	↑

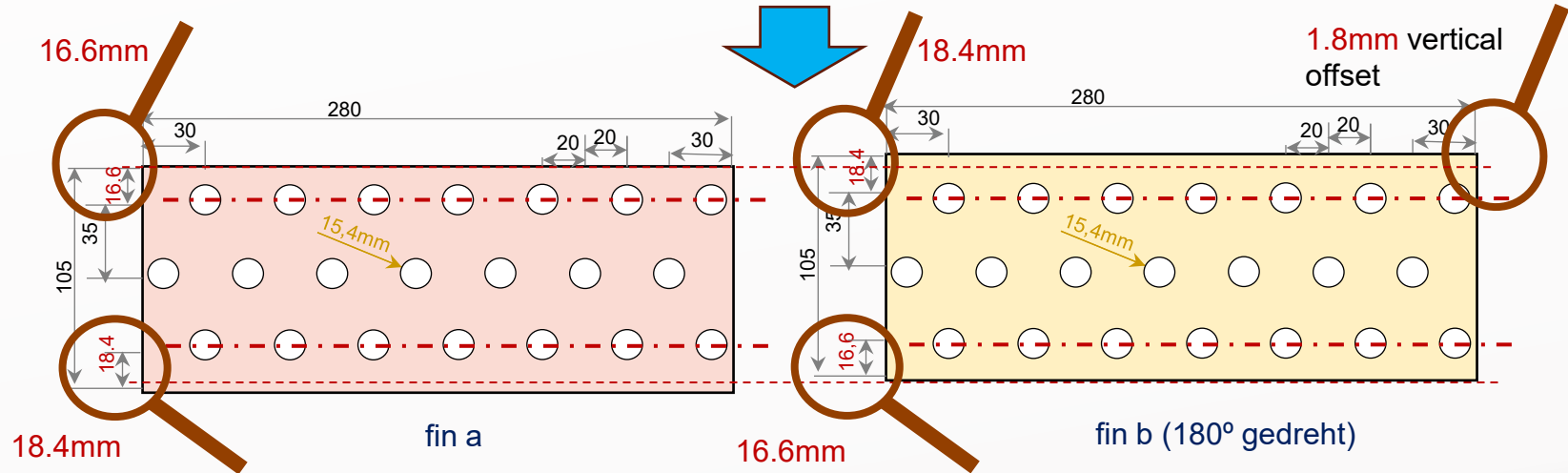
\*\*The study focused on comparing heat transfer and power demand with identical material usage.

# Manufacturing process. Same costs. Same production.

## Manufacturing integration



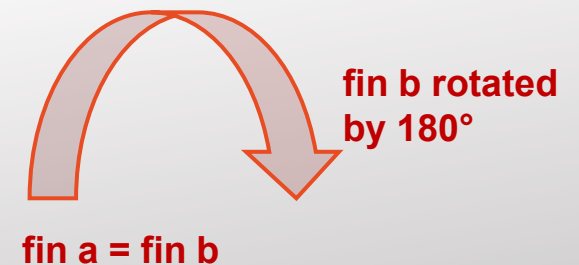
Standard fins in a conventional heat exchanger



Fin a and fin b are identical

### Example implementation:

- Vertical tube hole offset: 1 mm per fin
- Every second fin rotated by 180° before assembly (Result:  $F_1 = 1.8$  mm)
- Production steps remain unchanged.



# Frosting Behavior: Conventional Fins vs. Staggered Fin Arrangement

## Further considerations for reducing frost formation in finned heat exchangers

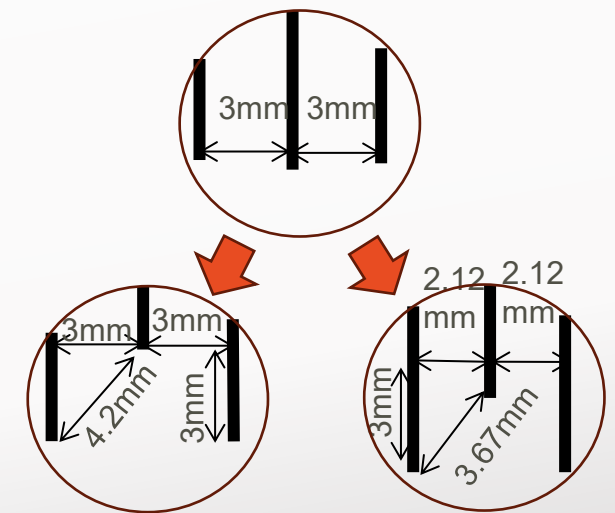
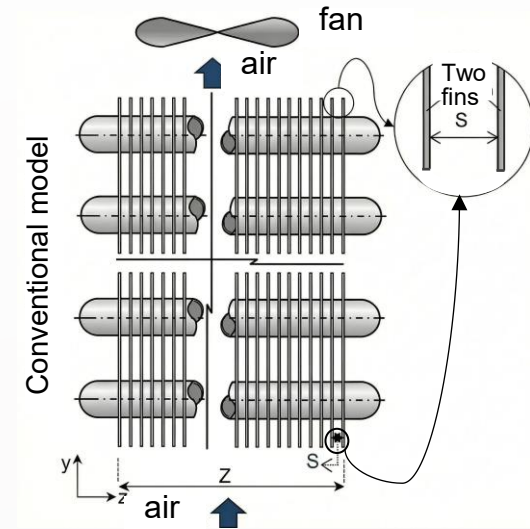
### Conventional Heat Exchanger

- Uniform frost formation on both fin surfaces, especially at the edges
- Rapid formation of ice bridges between adjacent fins
- Early channel blockage increases pressure drop and defrost frequency

### Offset Fin Arrangement:

- Increased effective distance between critical fin edges can delay direct ice bridge formation
- Non-uniform airflow over adjacent fins allows more frost growth on the longer fin edge (fin A) without early blockage of the flow channel
- Higher heat transfer at lower airflow demand enables the same performance with reduced air volume flow and potentially lower moisture input
- Targeted local coatings applied only on the longer fin edges can further reduce ice adhesion.

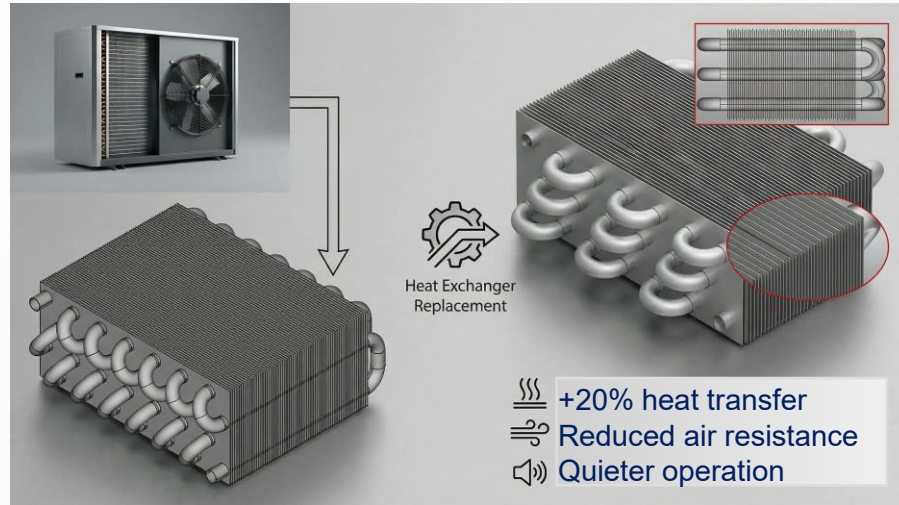
**Offset fins can delay ice bridge formation and extend the time until airflow channel blockage occurs.**



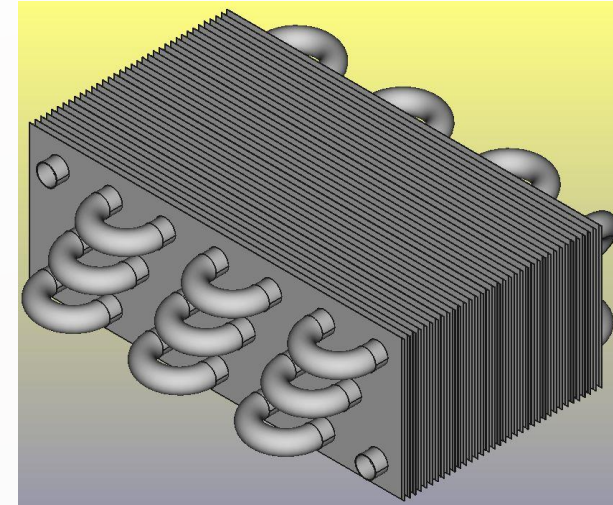
**Extended design flexibility:** Variable F1 and S1 enable increased air inlet area and larger fin spacing.

# Measurable efficiency gains with minimal system modification

## Competitive advantages



and/or



Up to **20%** energy savings

Up to **14% fin** material reduction and up to **38% tube** reduction

### Additional manufacturer perspective:

- Ability to offer higher efficiency to OEM customers
- Competitive advantage in tenders
- Potential for premium product lines
- Higher value creation per heat exchanger

- Less copper / aluminum required
- Reduced weight
- Lower logistics costs
- Potentially higher margins

**Not a new process – a new principle**

# From idea to granted patent – ready for market

## Patent development

- **Granted German patent**
  - DE102012007570B4 “*Finned-tube heat exchanger with improved heat transfer through fin offset*” (German: Lamellen-Rohr-Wärmetauscher mit verbesserter Wärmeübertragung durch Lamellenversatz); Granted in 2022
  - Current patent holders (inventors): Dr.-Ing. Diala Karmo & Dr.-Ing. Ayman Al Khateeb (since 2023)
- Original patent applicant: Technische Universität Ilmenau, Germany (April 2012)
- Professional patent drafting with PATON | State Patent Center Thuringia
- **Licensing model individually negotiable**



# Scientifically founded – technically validated

## Research-driven Technology Development

- Developed during several years of scientific research at Technische Universität Ilmenau (Department of Thermo- and Magnetofluidynamics)
- **Dissertation** “Contributions to Increasing the Effectiveness of Finned-Tube Heat Exchangers” University Press Ilmenau, 2016
- **Prototype and multiple design variants developed**
- Energy efficiency scientifically demonstrated
- More information: <https://www.innovative-heat-exchanger.de>
- **Patent reference DE102012007570B4:**  
<https://worldwide.espacenet.com/patent/search/family/049231983/publication/DE102012007570B4?q=pn%3DDDF102012007570B4>





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