# Data-Driven Prediction of Compressor Efficiency for High Temperature Heat Pumps

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## Motivation

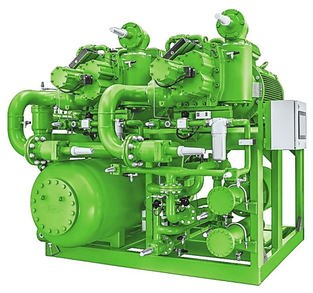
- **Industrial HTHPs operating above 100℃ are highly sensitive to compressor performance.**
- **Most studies still assume fixed isentropic efficiency ($\eta_{is}$ = 0.70-0.85) across all conditions.**
- **In reality, $\eta_{is}$ varies strongly with pressure ratio, suction state, refrigerant type, and temperature lift.**
- **These simplifications distort predictions of COP, electricity demand, cost, and optimal stage distribution.**
- **A fast and realistic $\eta_{is}$ predictor is required for technoeconomic screening, and optimization of superstructure models.**

**Goal: Developing a data-driven, physically grounded model for accurate prediction of $\eta_{is}$ for early-stage HTHP design.**

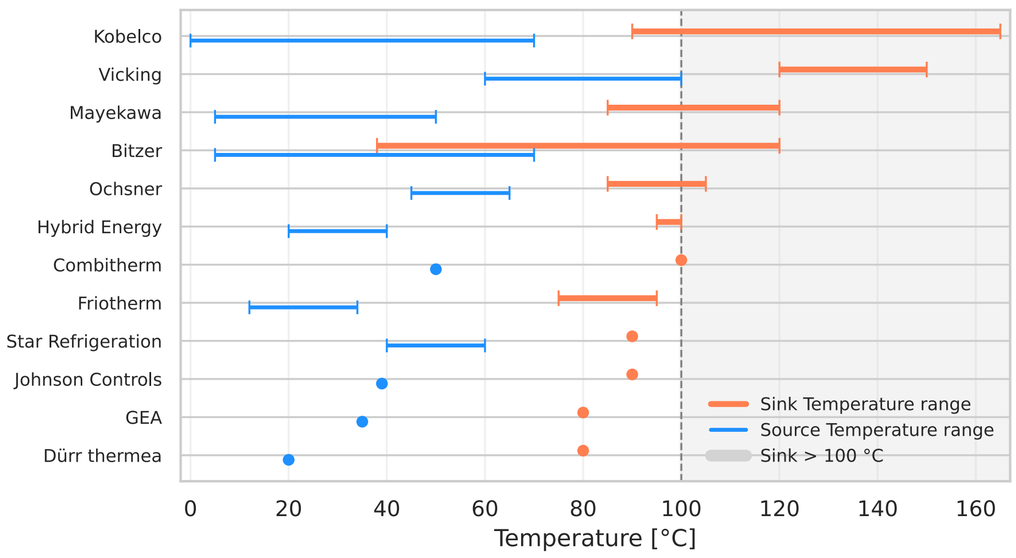
## Dataset

**~4000 operating points collected from major manufacturers and system integrators:**

**BITZER, GEA, Mayekawa, Johnson Controls, Kobelco, Star Refrigeration, Friotherm, Ochsner.**


- **Source: 0-100℃, Sink: 38-165℃, PR ~1.5–10.**
- **~2000 points above 100℃ (steam/drying range).**
- **Broad refrigerant coverage: HFC/HFO, Hydrocarbons, $NH_3$, $CO_2$, Water.**




## Method

**Early-stage features:**

• Inlet density, pressure ratio, temperature lift, evaporator/condenser temperatures.

**ANN architecture:**

• 64–32–1 MLP with BN, dropout, ReLU.

• Sigmoid-bounded output for physical limits.

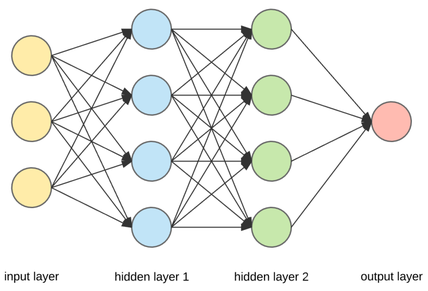
• Adam optimizer + early stopping + LR scheduler.

**Hybrid ANN + kNN:**

• ANN predicts $\eta_{is}$.

• kNN retrieves 10 nearest real compressors.

• Provides interpretability and engineering validation.




## Conclusions

- **Accurate, data-driven prediction of compressor $\eta_{is}$ across refrigerants and pressure ratios.**
- **Hybrid ANN + kNN approach ensures both reliability and engineering interpretability.**
- **Suitable for early-stage design and high-temperature (>100℃) HTHP applications.**
- **Improves accuracy in COP and TAC estimation within the ASTRA HTHP superstructure.**

## Results

**Predictive accuracy:**

• $R^2$ = 0.975, MAE = 0.0093, RMSE = 0.018

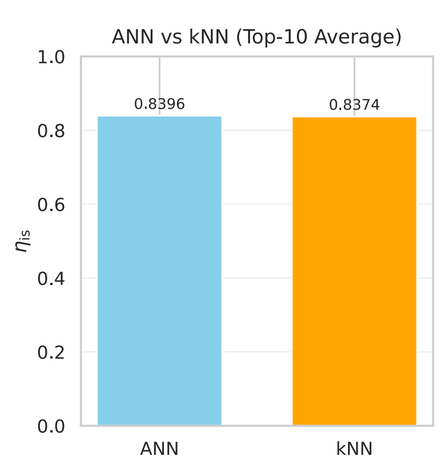
• Error <0.02 for nearly all test points

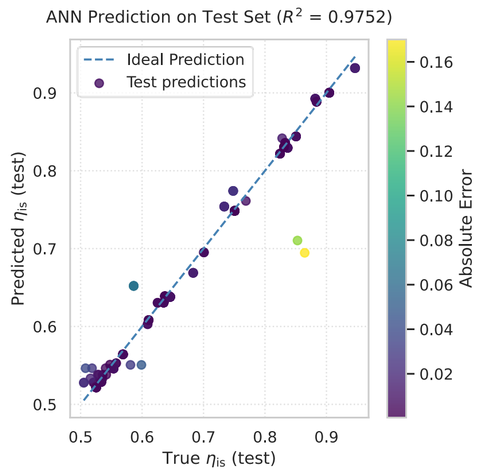
• Uncertainty = ±1 percentage point

**Example:**

• ANN $\eta_{is}$ : 0.8396 ($NH_3$, 50/85℃)

• Mean of retrieved compressors: 0.8374




| Model | Fluid | $T_{evap}$ (°C) | $T_{cond}$ (°C) | *PR* | $\eta_{is}$ | $\dot{V}_{in}$ (m³/h) |
|---|---|---|---|---|---|---|
| 6hs | r717 | 50.00 | 85.00 | 2.27 | 0.88 | 543.06 |
| 4hs | r717 | 50.00 | 85.00 | 2.27 | 0.83 | 362.75 |
| 6hk | r717 | 50.00 | 85.00 | 2.27 | 0.83 | 170.70 |
| 4hk-p | r717 | 50.00 | 85.00 | 2.27 | 0.81 | 113.61 |
| 6hs | r717 | 48.00 | 85.00 | 2.39 | 0.87 | 529.01 |
| 6hk | r717 | 48.00 | 85.00 | 2.39 | 0.82 | 166.28 |
| 4hs | r717 | 48.00 | 85.00 | 2.39 | 0.82 | 352.96 |
| 4hk-p | r717 | 48.00 | 85.00 | 2.39 | 0.79 | 110.64 |
| 6hs | r717 | 45.00 | 85.00 | 2.59 | 0.89 | 531.71 |
| 6hk | r717 | 45.00 | 85.00 | 2.59 | 0.83 | 166.90 |

## Abbreviations

| | |
|---|---|
| **ASTRA:** | AI-based superstructure thermal system automated design |
| **HTHP:** | High temperature heat pump |
| **COP:** | Coefficient of performance |
| **TAC:** | Total annual cost |
| **ANN:** | Artificial neural network |
| **kNN:** | k-nearest neighbors |
| **MLP:** | Multilayer Perceptron |
| **BN:** | Batch Normalization |
| **ReLU:** | Rectified Linear Unit |
| **LR:** | Learning Rate |

For more information

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