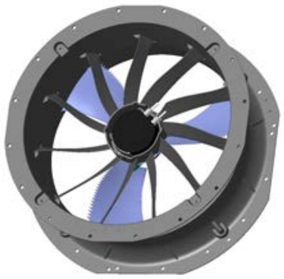
Optimized fan system design for the one-year cycle of a Heat Pump



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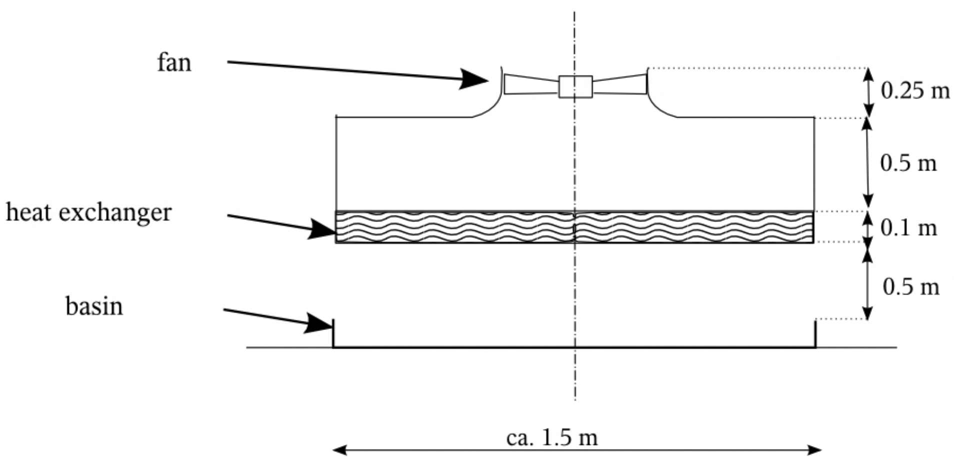
Outline

- Targets for the energetical optimization of fan unit
- Numerical optimization procedure
- Results with experimental validations
- Investigation: optimization of tonal noise
- Comparison of two designs for two different EC motors
- Conclusions

Framework: Evaporator design (air side)

- In a first phase of the greenHP project, framework conditions for the different components have been worked out in the consortium
- Evaporator HEX is approximately square shaped 1.5 m x 1.5 m, plane, and horizontally aligned. Complexer HEX geometries (for example, bent) have been discussed but discarded
- Fan is arranged in suction mode. Main reasons: risc of thermal shortcut in pushing mode; more homogenuous velocity distribution on the HEX in suction mode
- Distance fan plate – HEX 0.5 m, which was worked out by preliminary CFD studies considering a fan of diameter 630 mm



depth of HEX: ca. 1.5 m (extruded)

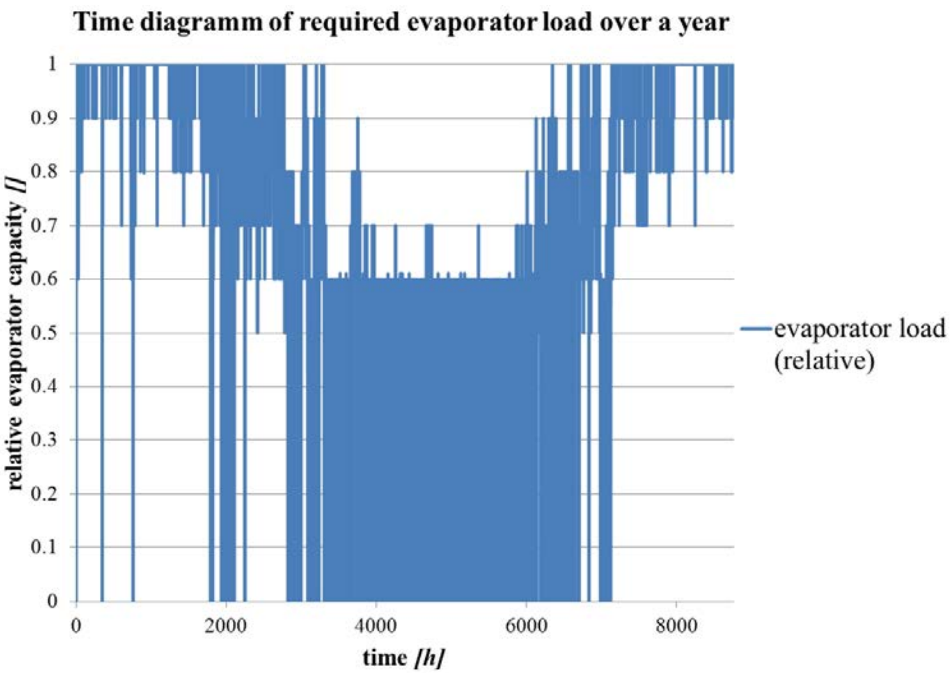
Targets for fan design of the present work

- Ensure required heat transfer from ambient air to evaporator at any operating condition of interest
- Ensure this heat transfer with pre-selected, small EC drive (EC090). Alternative design for bigger EC drive (EC116, higher torque available) was generated additionally
- Minimize, under these conditions, the integral annual energy consumption of the fan

Approach

- Built up a fan system geometry from geometrical parameters
- Generate a virtual model (based on CFD simulations) for the required electrical fan power for a given fan geometry, a given a required heat transfer to the evaporator, and a given icing condition
- Use this model to sum up the annual fan energy consumption for a given annual load profile of the evaporator heat transfer with corresponding icing conditions
- Minimize the annual fan energy consumption by optimizing the fan geometry parameters

Load profile of the heat pump



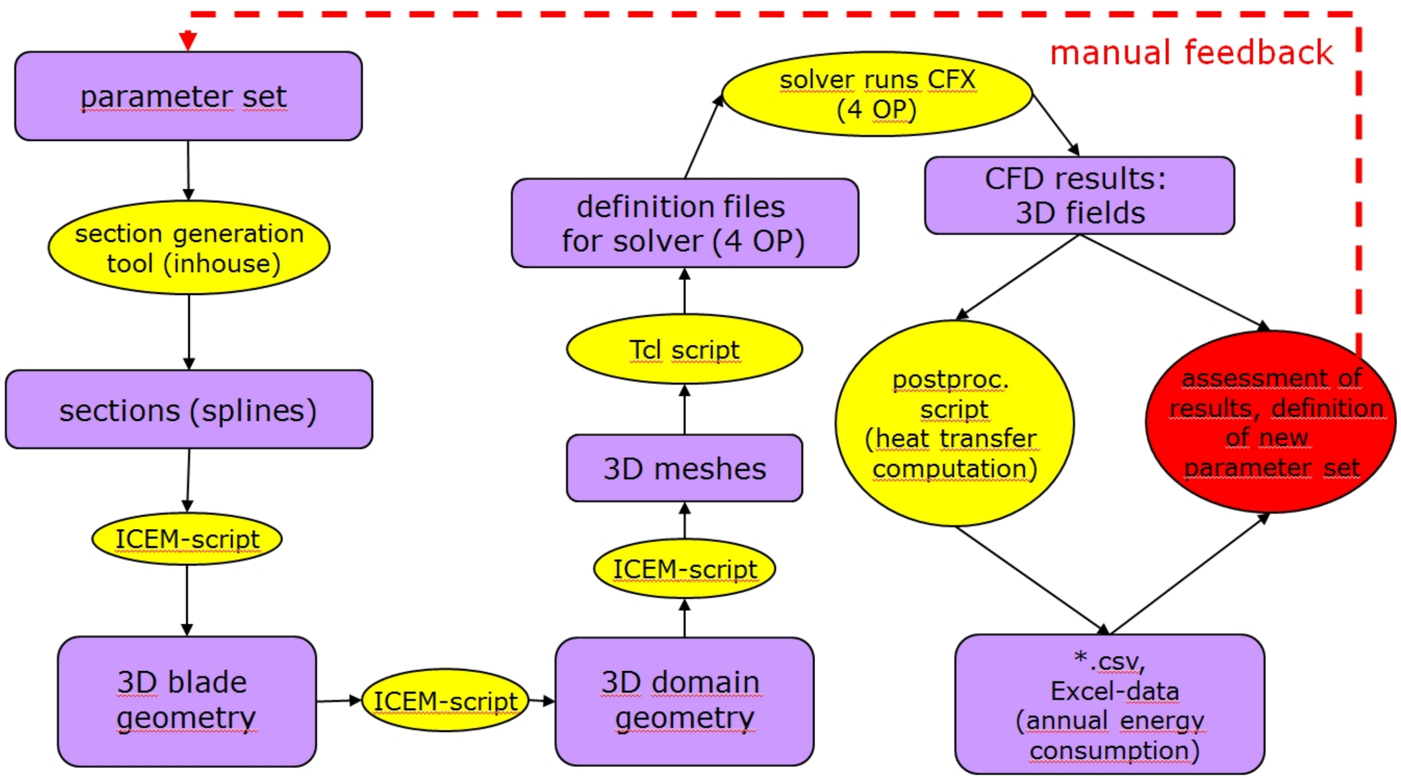
- At full capacity: 18 kW heat transfer to evaporator, air flow at dry condition about 2.8 m/s ↑3
- 4 representative operation points for annual load profile with associated annual runtime defined in an energy-conservative way
- Icing conditions are taken into account

Table 3: Representative operation points and their required runtime

	Heat Power Q [kW]	Icing	Annual runtime [h]	Annual Heat Transfer [kWh]	Air Density [kg/m^3]
OP 1	18.4	Dry	1425	25650	1.3
OP 2	18.4	Medium	1062	19116	1.33
OP 3	18.4	Max	908	16344	1.33
OP 4	11.04	Dry	2334	25207	1.2

Analysis of one fan system geometry

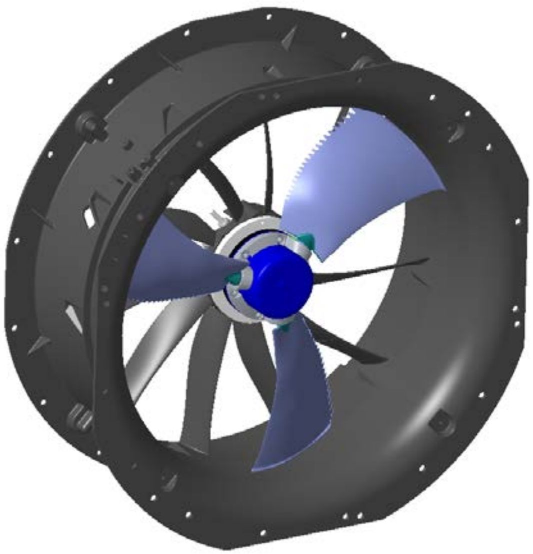
- Setup of CFD simulation from parameter set for fan geometry
- Compute, for each of the 4 representative OPs, the required rotation speed and the required electrical power
- Sum up annual energy consumption



Results: Comparison of different fan geometries (EC090 drive)

Table 4: comparison of best performance fans at isolated duty points

Annual cons. [kWh]	**SUM**	**OP 1**	**OP 2**	**OP 3**	**OP 4**
Best Fan	2061	570	524	670	297
Best OP 1	2256	544	522	890 (?)	290
Best OP 2	2234	564	518	850 (?)	302
Best OP 3	2087	599	525	655	308
Best OP 4	2269	551	537	850 (?)	288
Best efficiency	2282	555	520	915 (?)	292

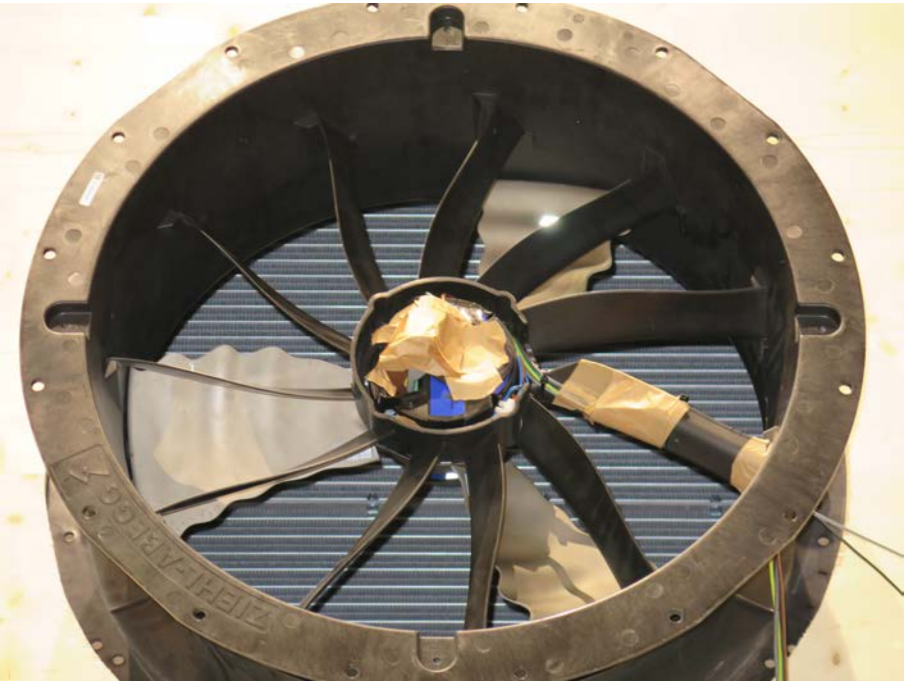


- Optimal design for small motor (EC090)
- Annual energy consumption 2061 kWh
- Important to take into account different operating points

Optimization tonal noise

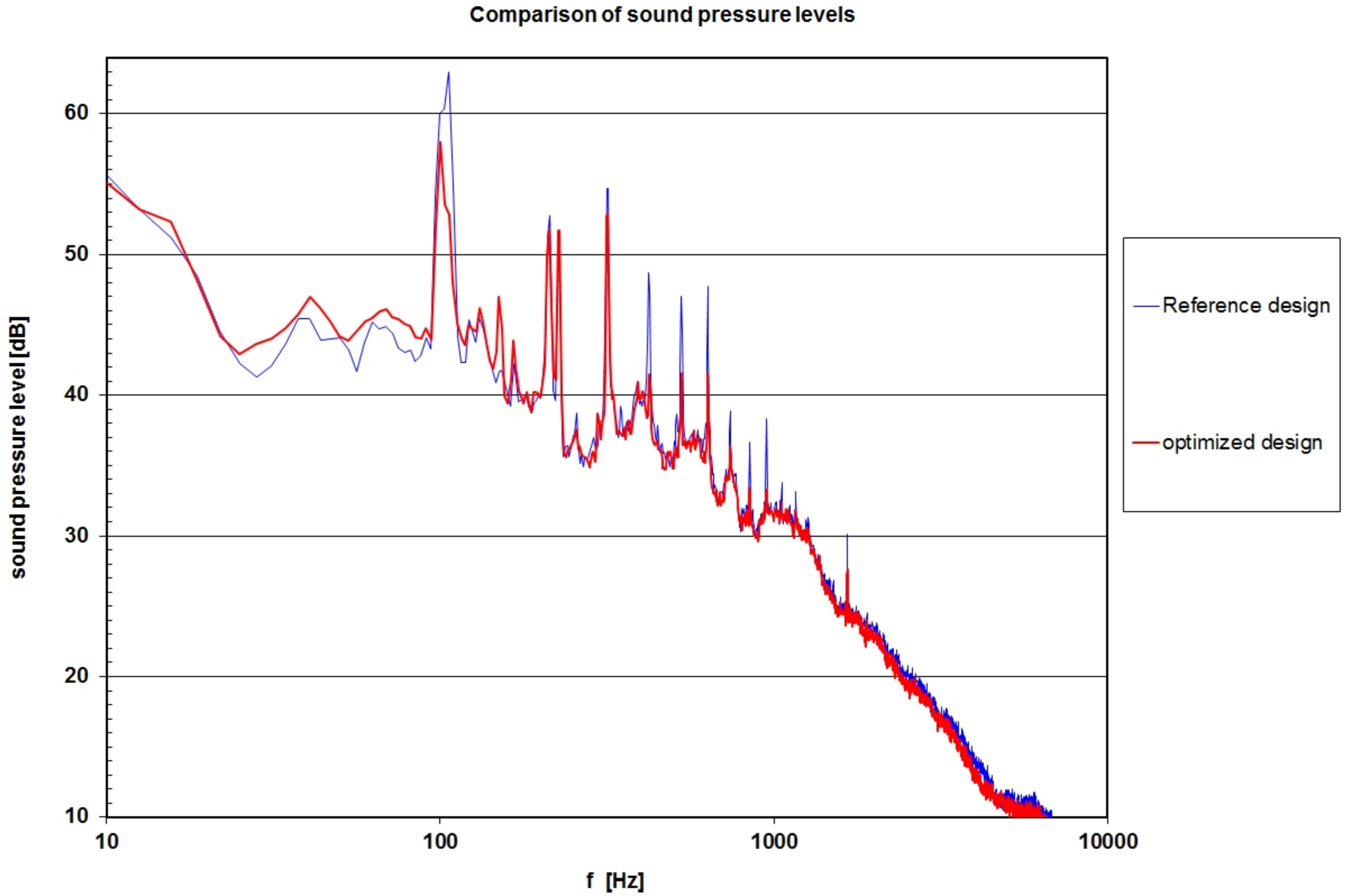
prototype without wavy structure (for EC090)

prototype with wavy structure (for EC090)



Optimization tonal noise

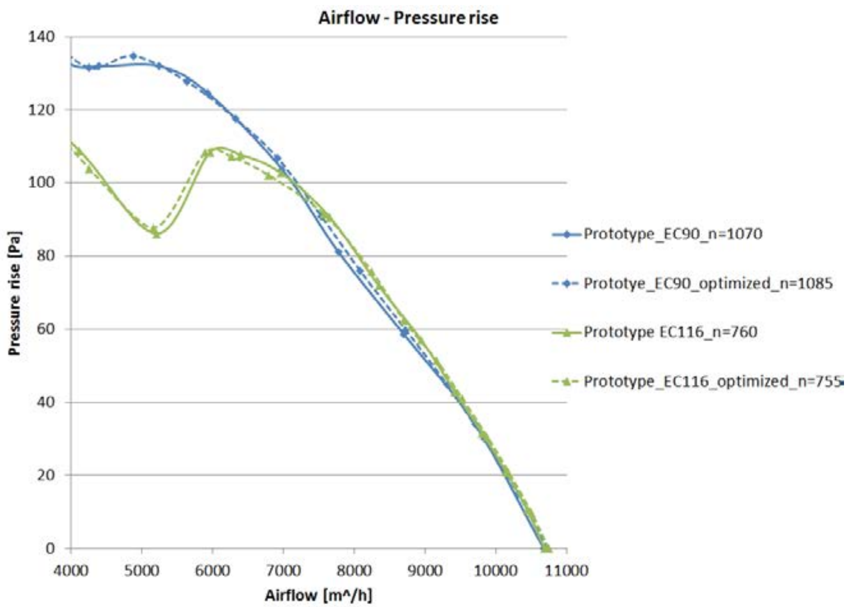
Improvement for tonal components in heat pump configuration
(EC090, pressure side, design point)

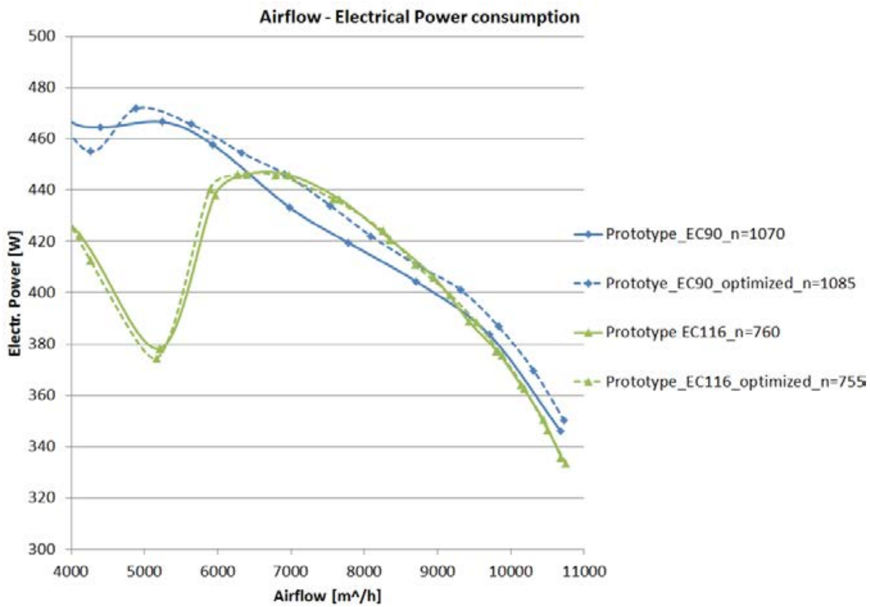


Fan Design for bigger motor „EC116“

- Fan design developed for EC116 (same approach than for EC090, annual energy consumption minimized)
- Prototype as FDM part available
- Higher torque possible -> run at lower rotational speed
- Additionally, prototypes with new development for tonal noise reduction technique also for the EC impeller have been designed and investigated

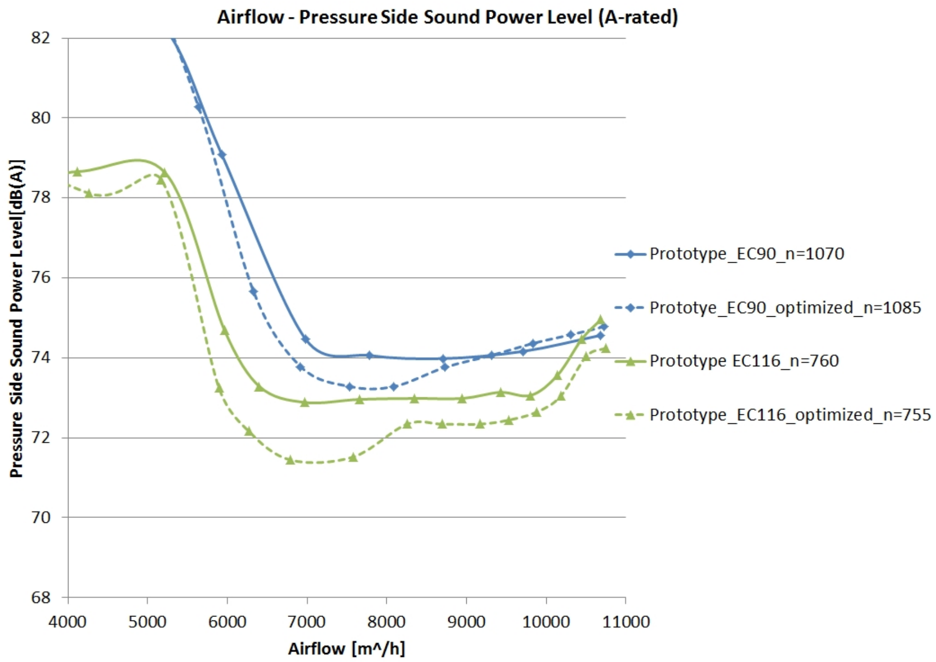
Fan Design for bigger motor „EC116“, experimental results in Evaporator





- Fan designed for EC116 needs lower rotational speed
- More pressure reserves towards stall for smaller prototype due to higher rotational speed
- Power consumption similar

Fan Design for bigger motor „EC116“, experimental results in Evaporator



- At design rotational speed, the EC116 fan has lower sound power (lower rotational speed)
- Improvement by wave structure in both cases

Conclusions

- Fan designs taylored for the „greenHP“ carried out for two EC motors
- Objective: minimize annual energy consumption of the fan in the heat pump
- The annual load profile was condensed to 4 representative operation points
- Virtual model generated as tool: for a given fan geometry, the functional of the annual energy consumption in application is approximated numerically.
- Semi-automatic optimization for given heat pump has been carried out, about 100 fan geometries have been considered
- Experimental validation under dry conditions: fan alone, fan in evaporator, velocity distribution on HEX; good agreement observed
- Consideration of different operating points, especially those under icing, turned out to be important in order to find best fan geometry
- Investigation on tonal noise reduction technique carried out
- Comparison of designs for two different motors: the bigger motor can achieve the required airflow at lower rpm -> better for noise. But: higher invest

Thank you
for your attention!