Heat recovery with decentralized hybrid ventilation

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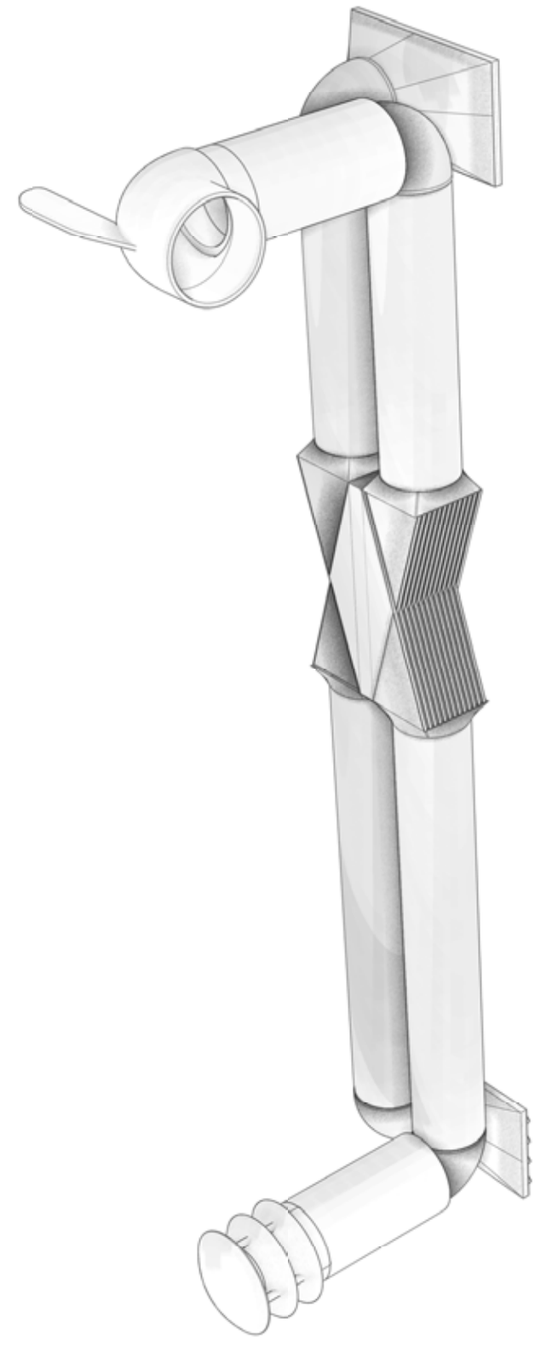


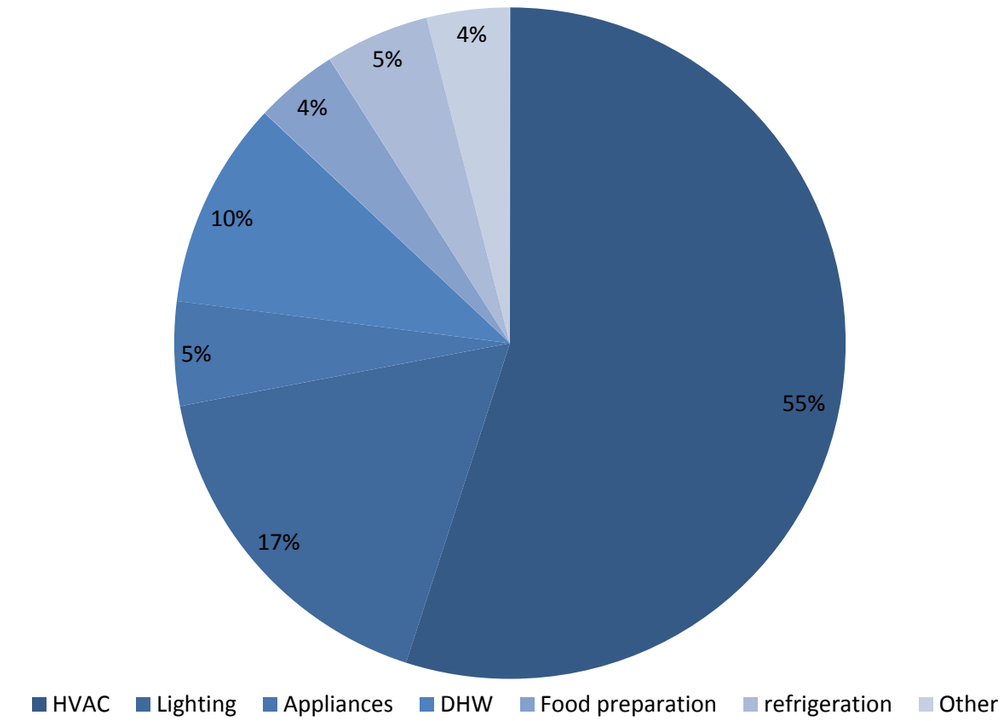
Problem Statement

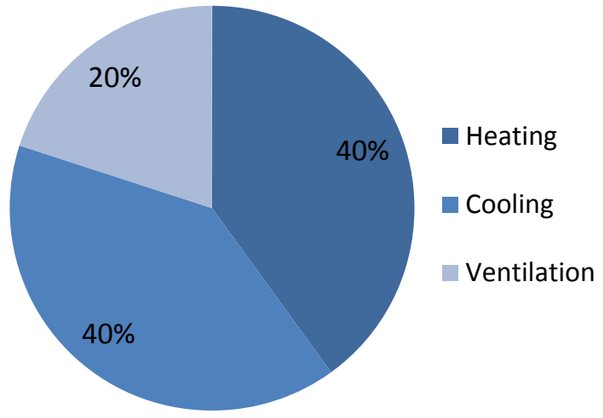
50% mechanically ventilated offices

HVAC systems use 55% of energy costs
- Ventilation 11% of total

One size fits all approach

Large centralized systems





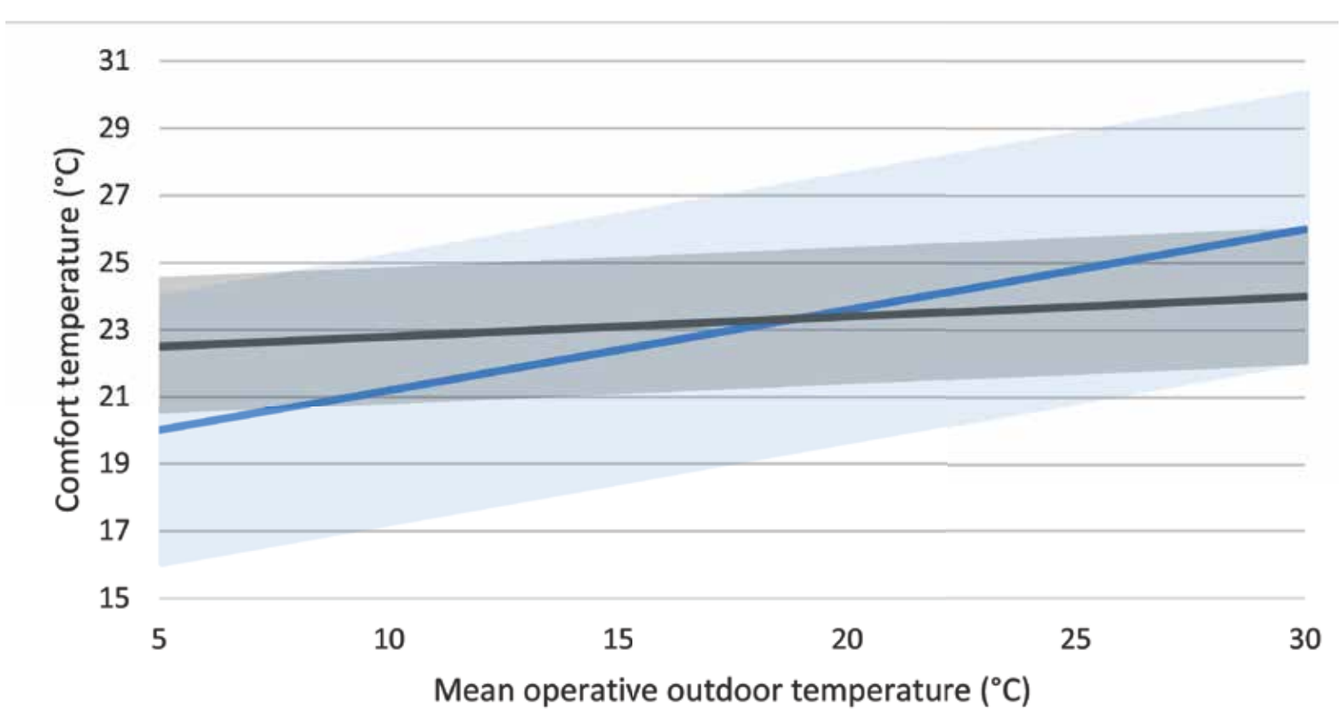
Sources:
Wood, A., & Salib, R. (2013)
Pérez-Lombard, L., Ortiz, J., & Pout, C. (2008)

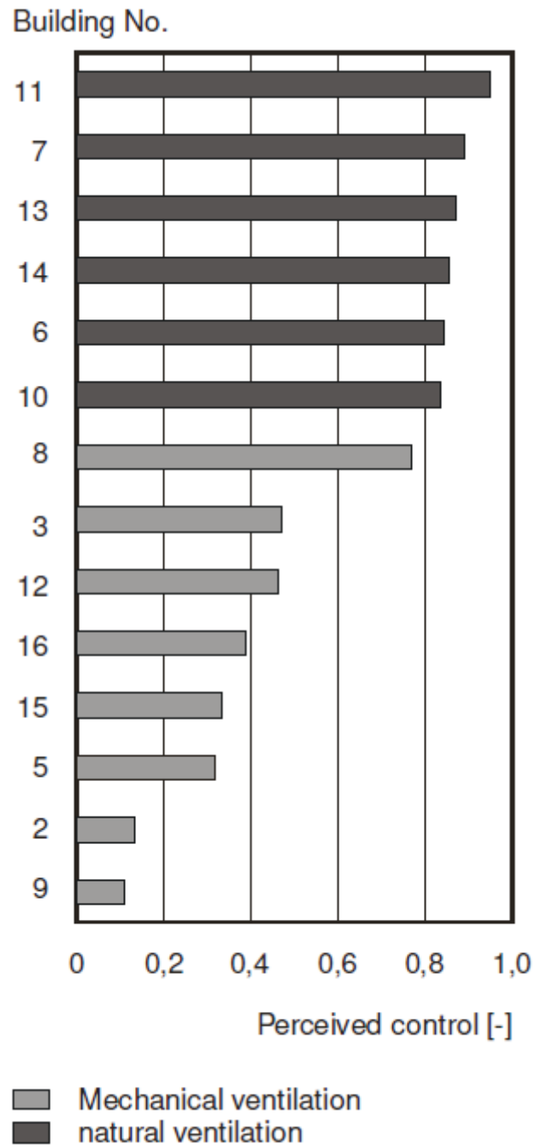
Problem Statement

Natural/hybrid ventilation

- Higher temperature acceptance

- More perceived control and satisfaction





Sources:
Hellwig, R., Brasche, S., & Bischof, W. (2006)

Research Question

How can a decentralized mechanical ventilation system be redesigned to make use of natural ventilation principles?

Location

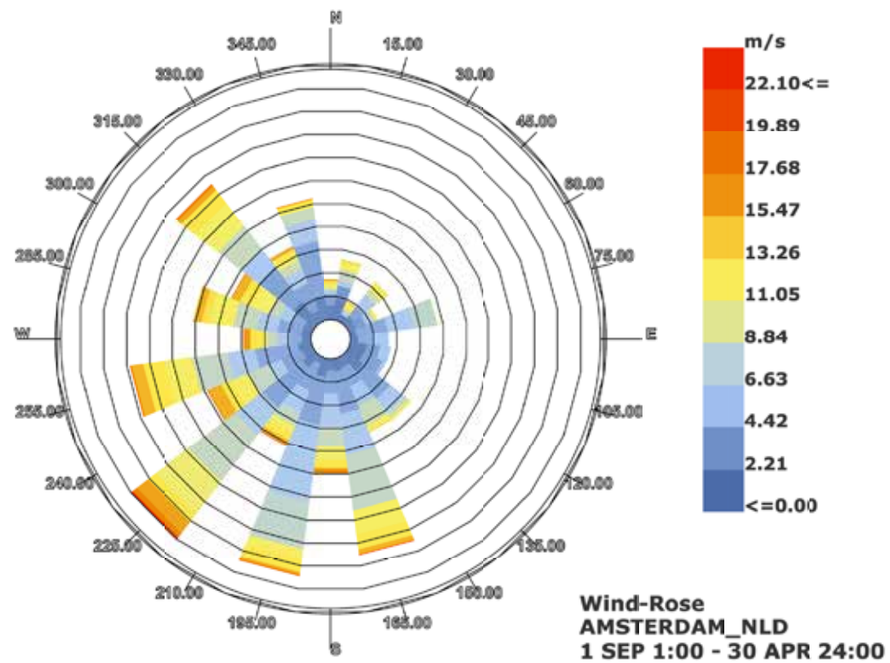
Amsterdam

70's Dutch office building typology

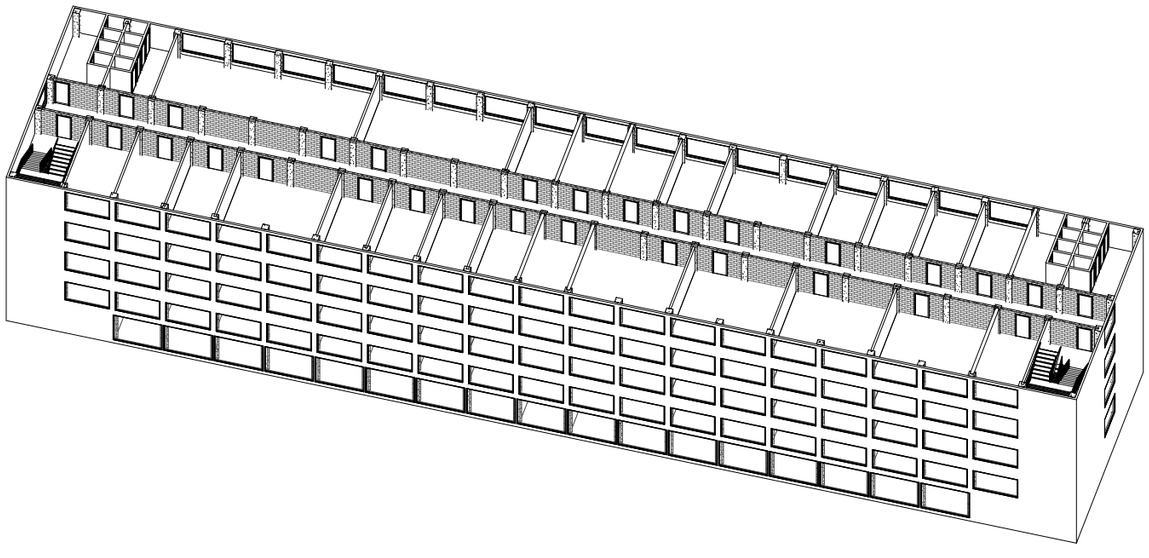
10 stories high

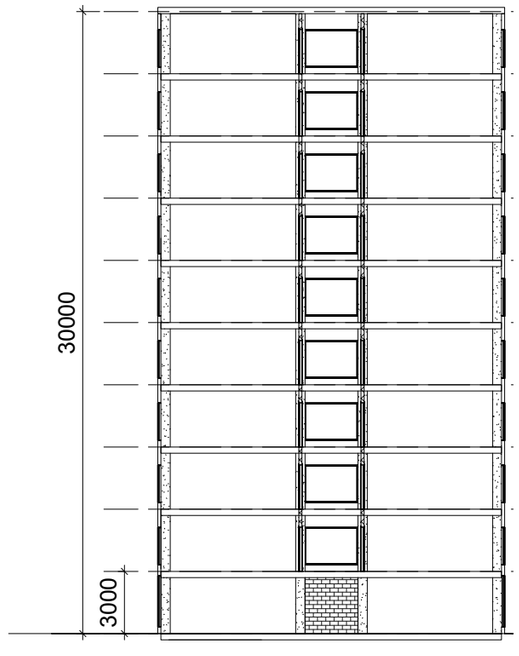
Office depth of 6.5 m with corridor of 3 m

Main wind direction is SW



Single sided office





Driving forces

Total Pressure difference

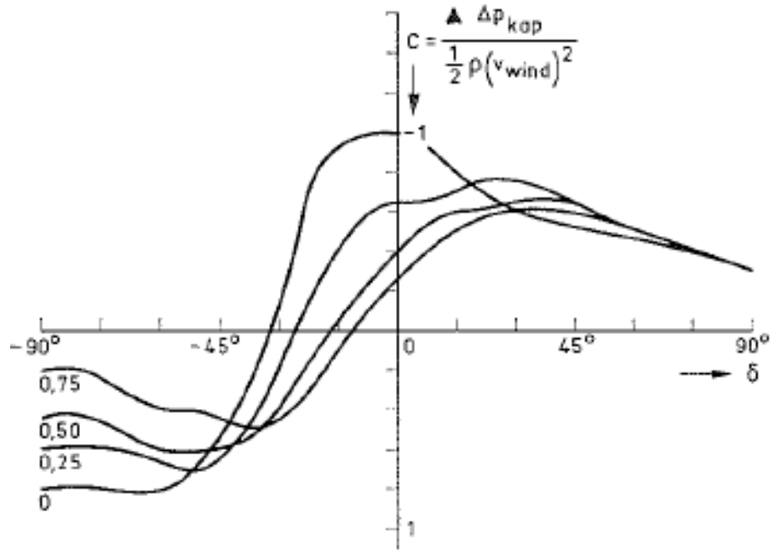
$$\Delta P_{total} = \Delta P_{ath} + \Delta P_{cp} + \Delta P_{temp} + \Delta P_{in/out}$$

No pressure difference due to Cp value

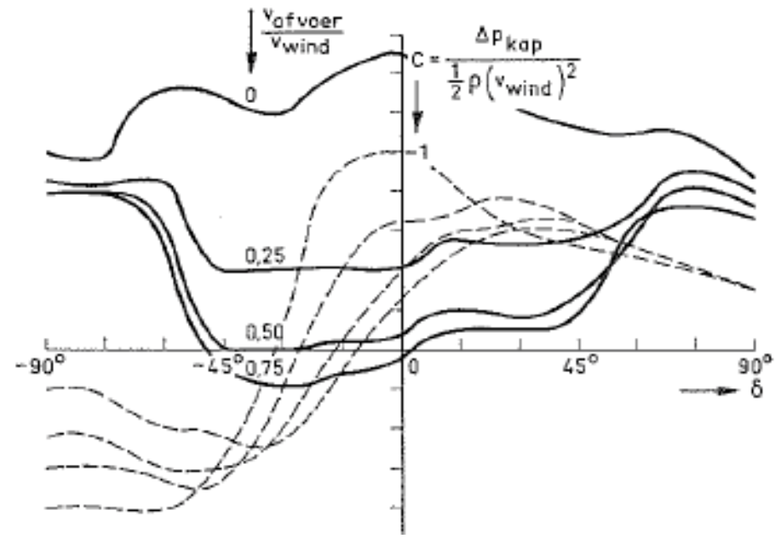
0,4 Pa pressure difference due to temperature difference

Correction factors for wind velocities

Correction factors in- and outlet vents



Open pipe



Venturi shape (de Gids & den Ouden, 1986)

Wind around the building

3D model

Box environment

Wind velocity of 6 m/s (4 Bft)

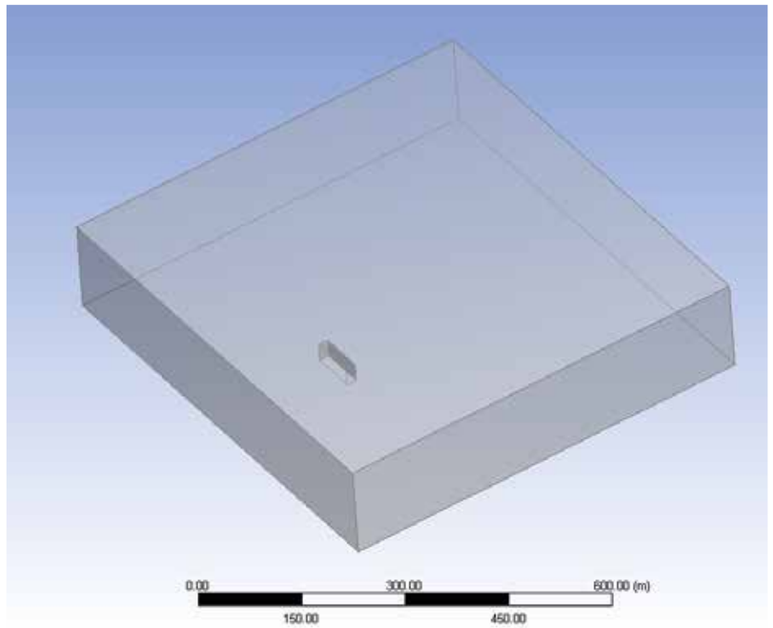
Denser mesh at the facade

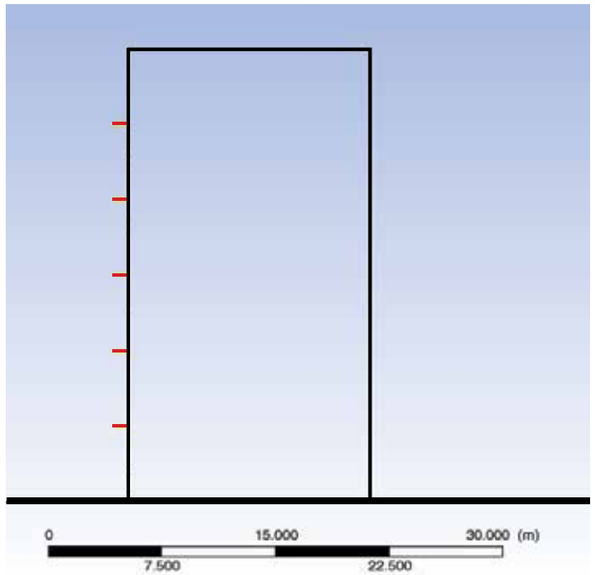
Horizontal lines at facade

Angle of building 0, 30, 60 and 90 degrees

Ansys Fluent

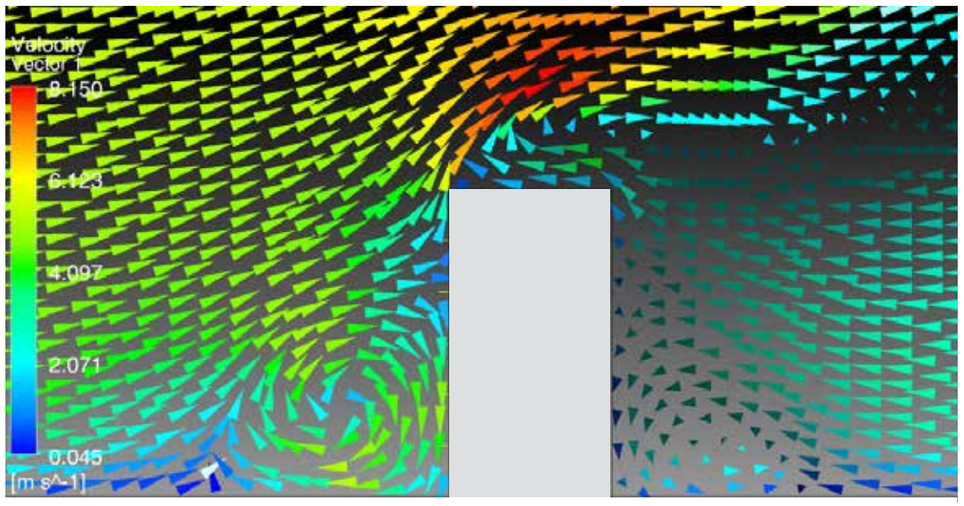
Input

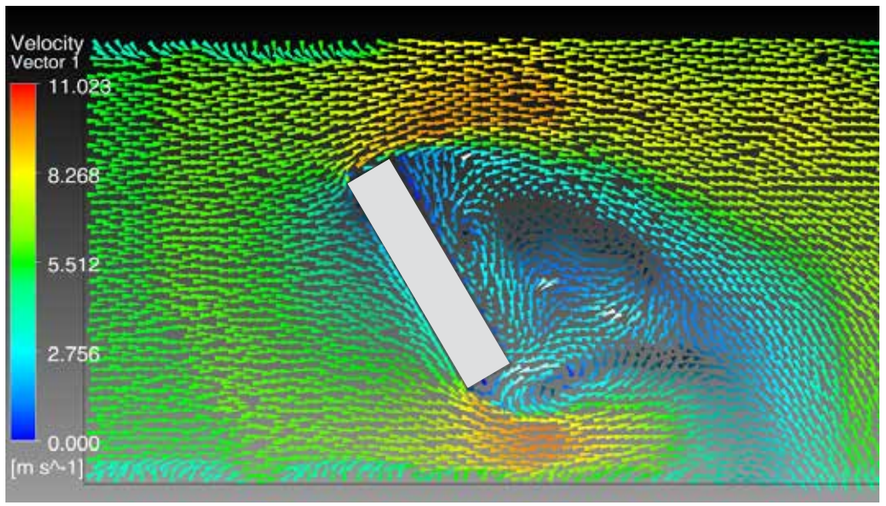


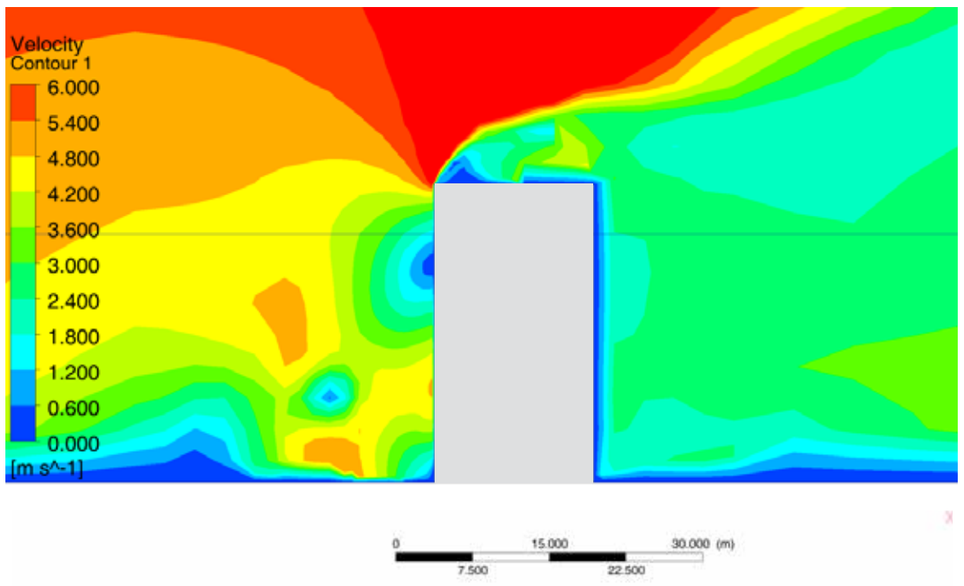


Wind around the building

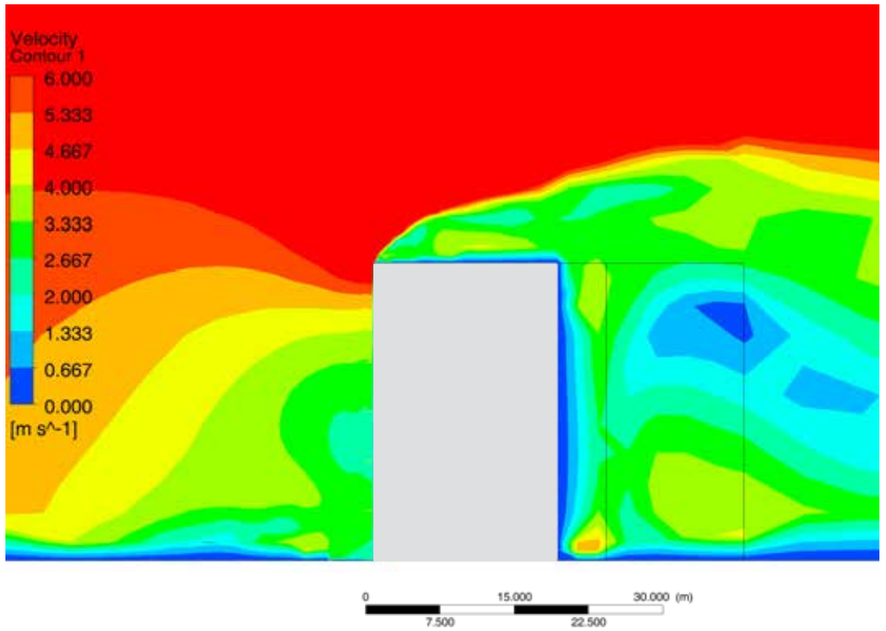
Visualisation of the results





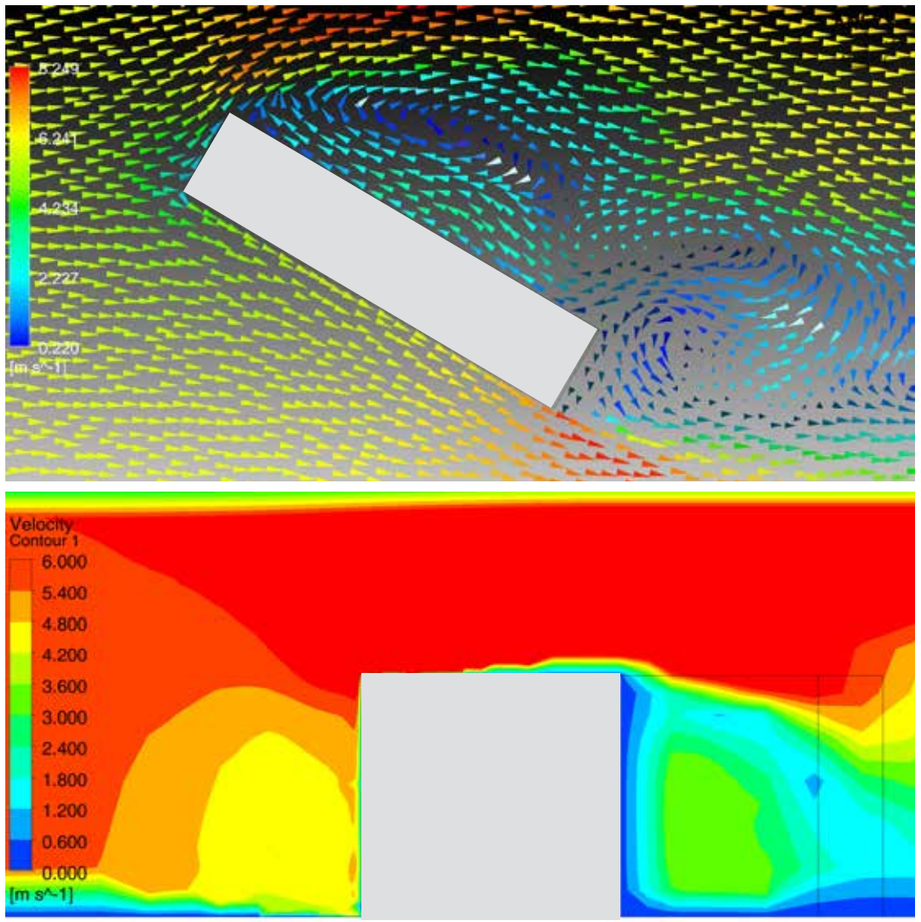


Wind 0 deg section. Vector (top), contour (bottom)

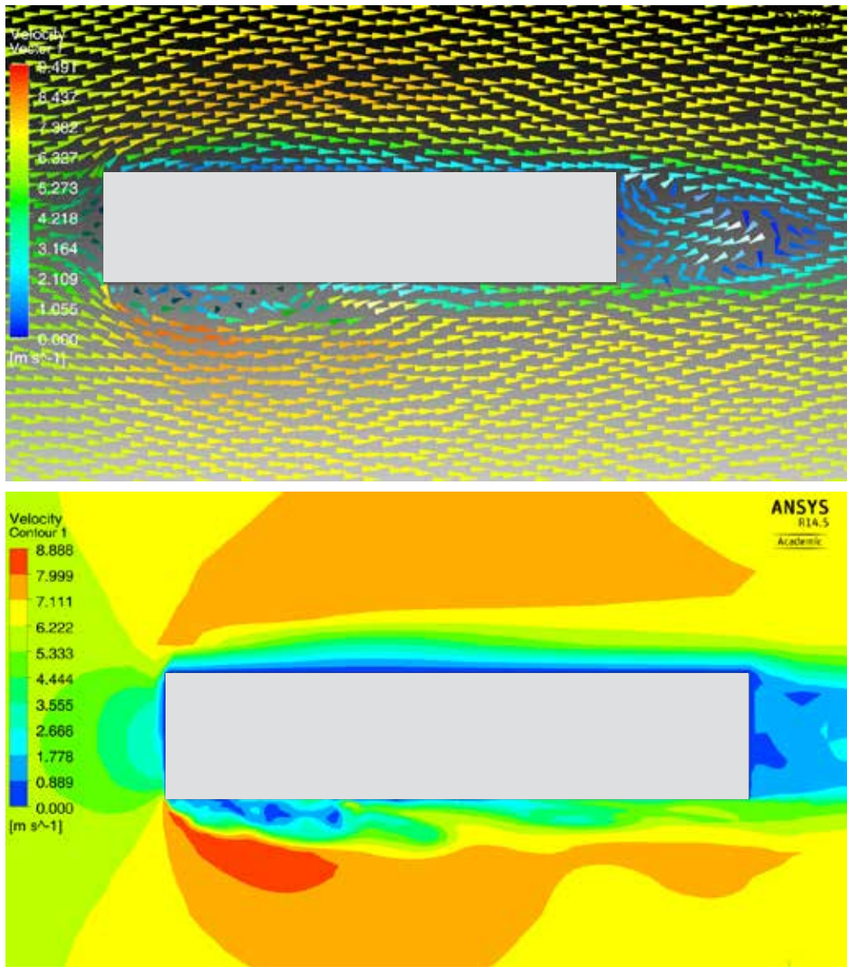


Wind 30 deg. h = 15 m Vector (top), contour (bottom)

Wind around the building



Wind 60 deg. Vector h = 15 m (top), contour (bottom)



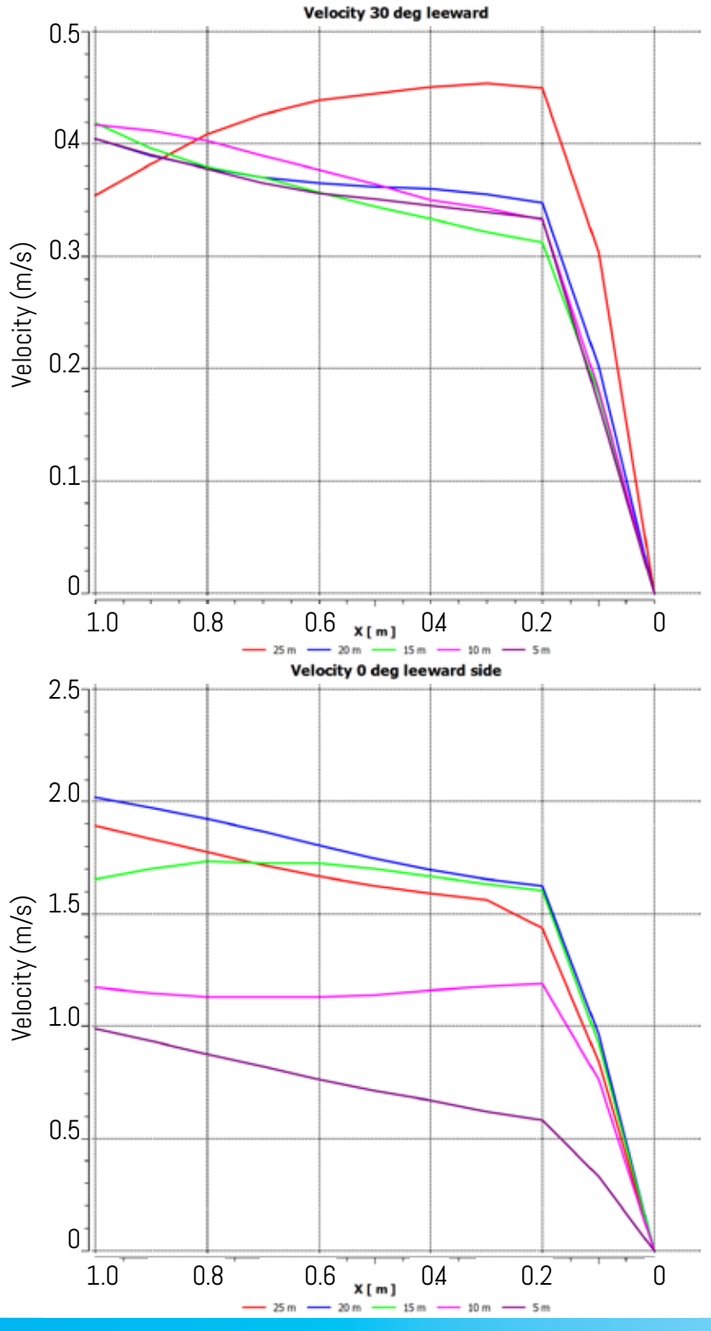
Wind 90 deg. h = 15 m Vector (top), contour (bottom)

Wind around the building

Wind speeds at the facades

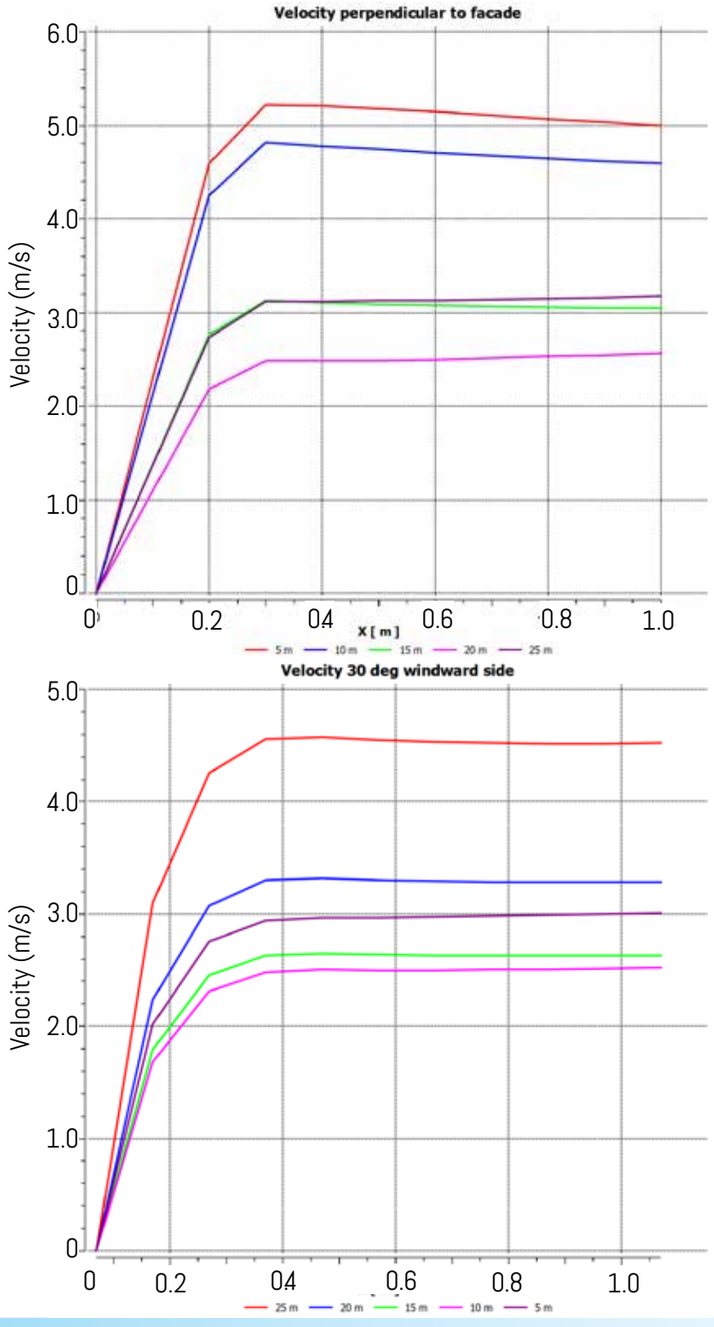
Leeward side

Wind 0 deg



Wind 30 deg

Windward side side



Wind around the building

Result analysis

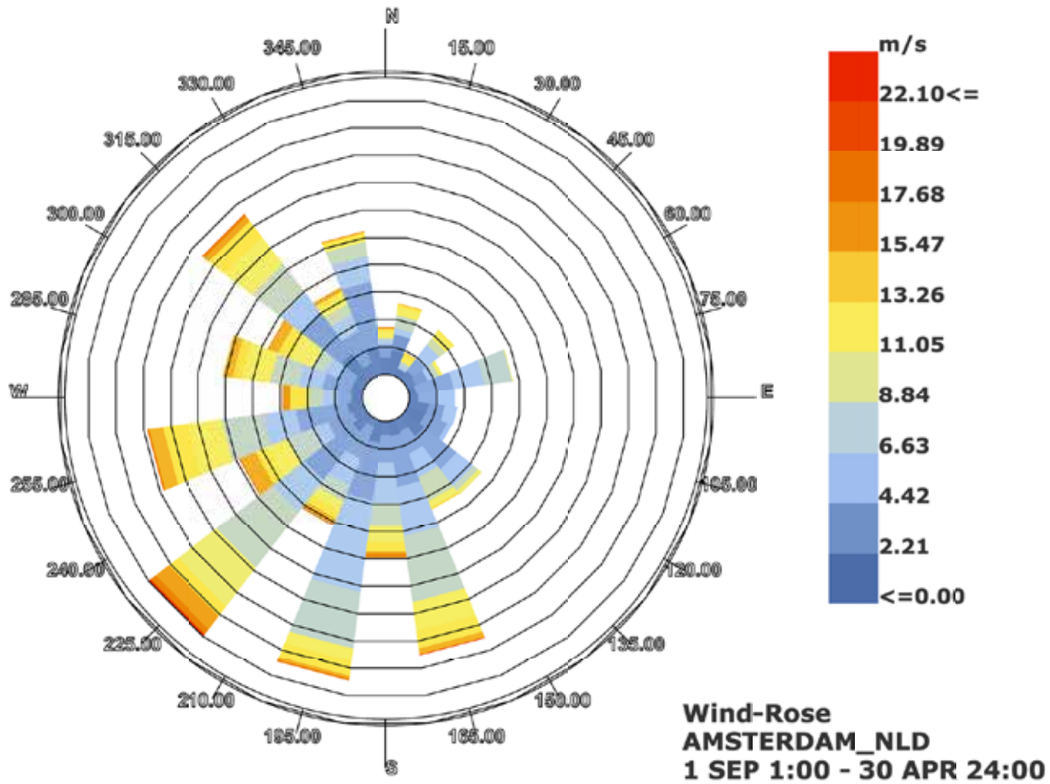
Wind speed Leeward side not sufficient

Hybrid ventilation as a result of low wind speeds

Orientation to the W for optimal use of wind direction

Design boundary conditions

- Wind velocity facade 2,4 m/s
- Max velocity 0,2 m/s in office
- Different wind directions on the facade



Design

Double system

20 cm thick wall element

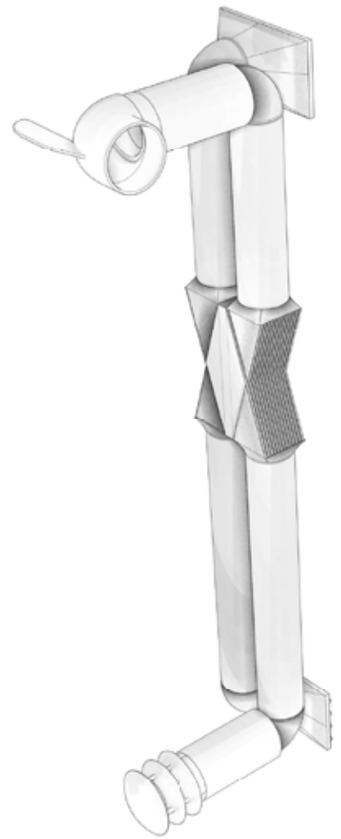
User control

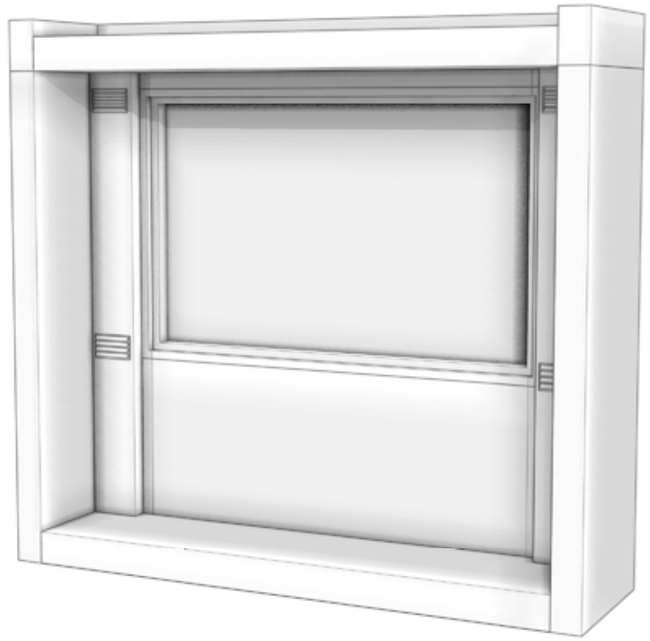
Inlet interior at 1m height

Outlet interior near ceiling

Fiwihex heat exchanger

Inlet Temperature of 18 deg





Fiwihex

Air to air and air to liquid

Low pressure resistance

Compact, 480x240x100 mm

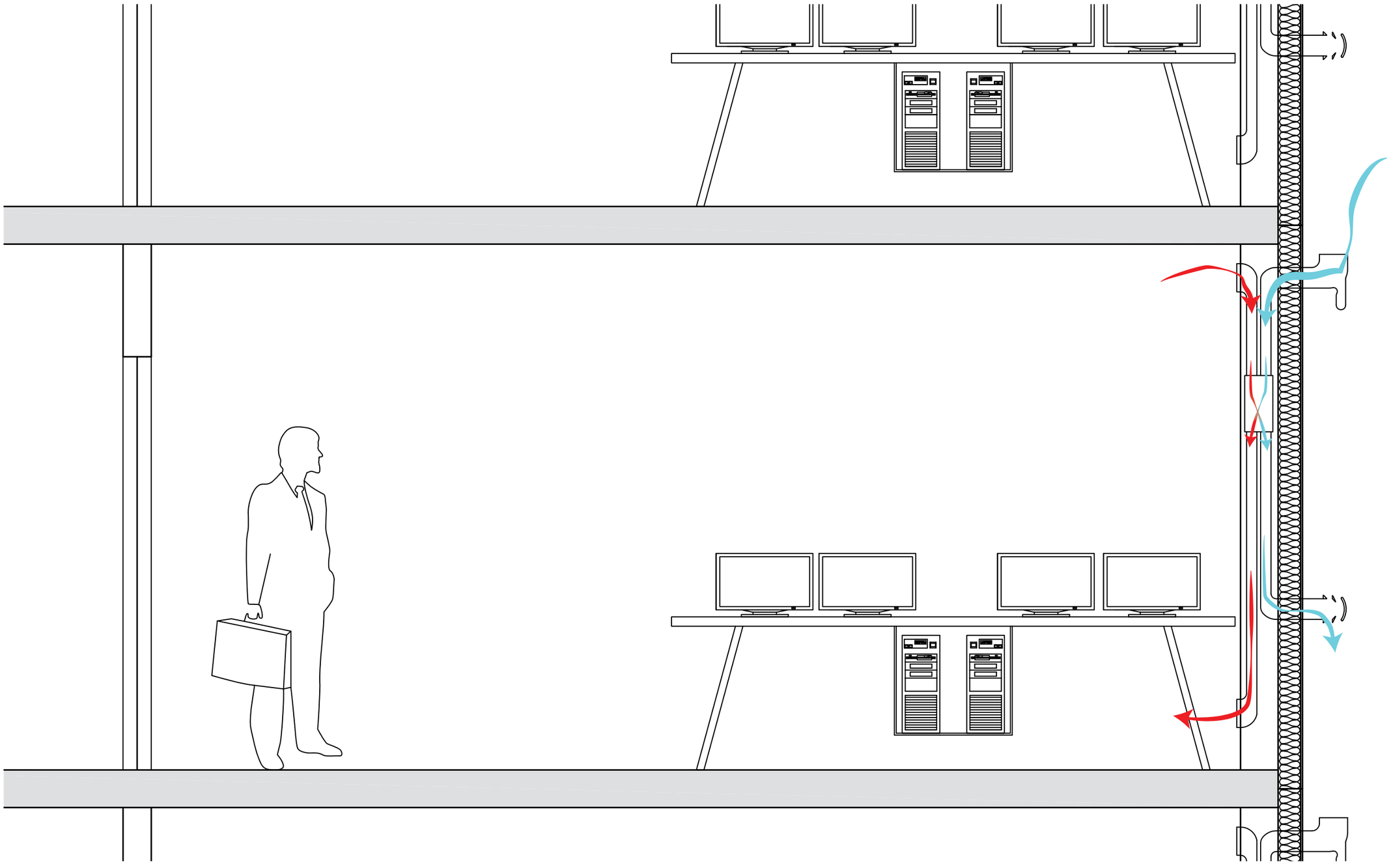
Small pressure drop: 4 Pa at 100 m^3

Optimal at 100 m^3/h

85-90 % Efficiency

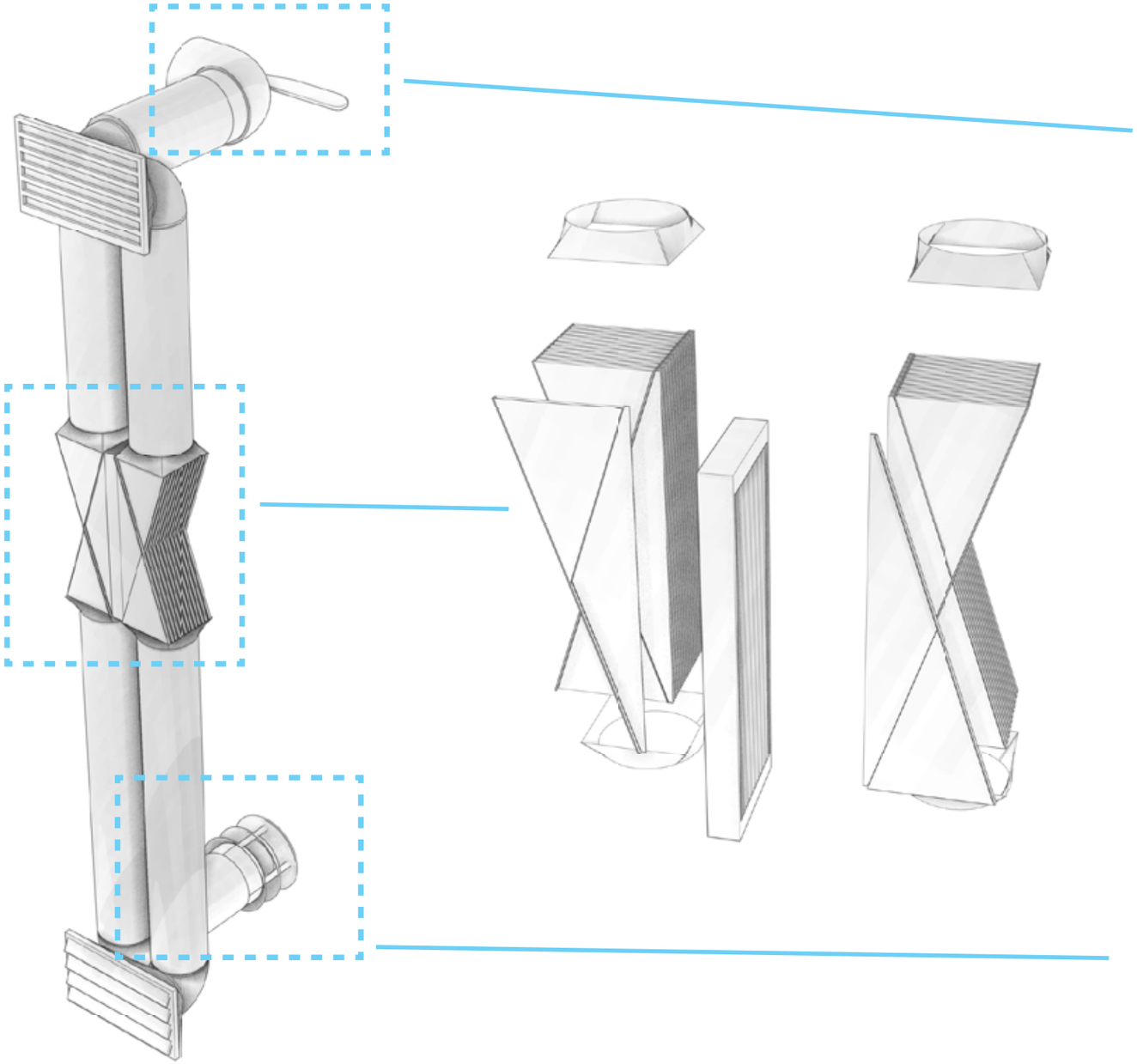
Design

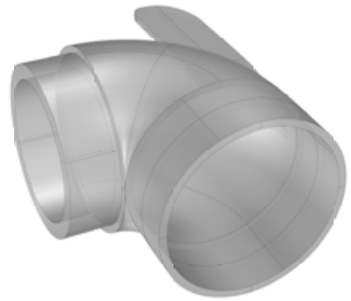
Principle



Design

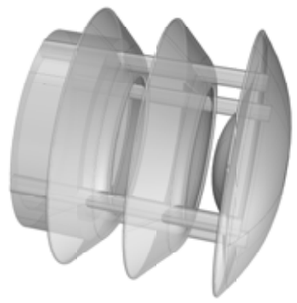
Elements





Rotating inlet cowl

Heat exchanger



Venturi outlet

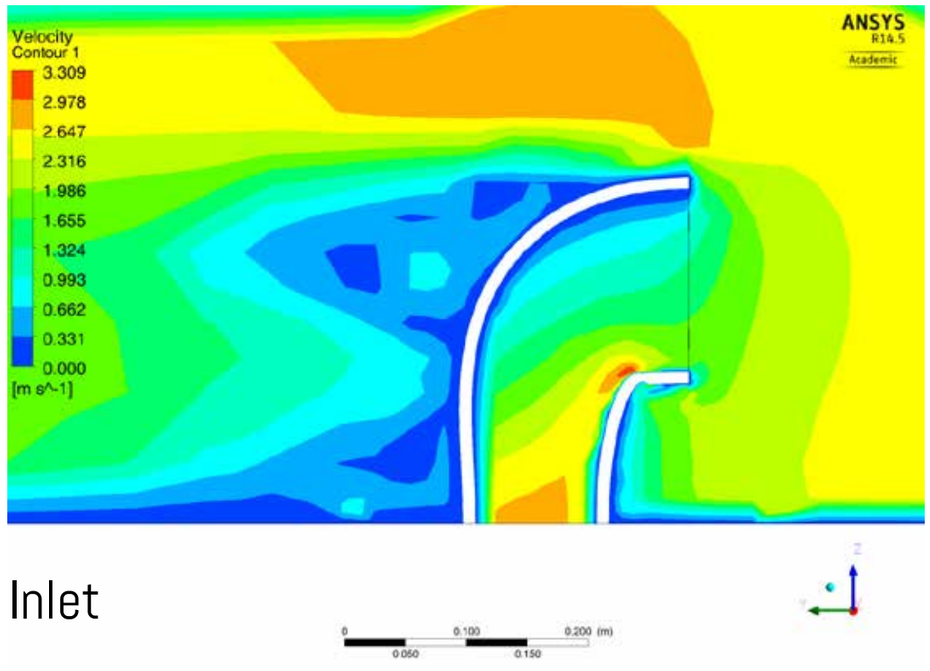
Design

Nozzles

Inlet: redirecting wind into the ventilation system

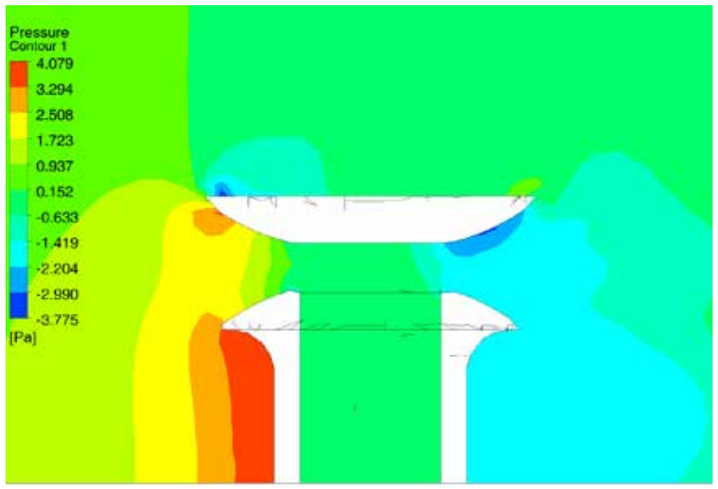
Outlet: Creating negative pressure at the outlet
- Venturi shapes
- Hill shaped

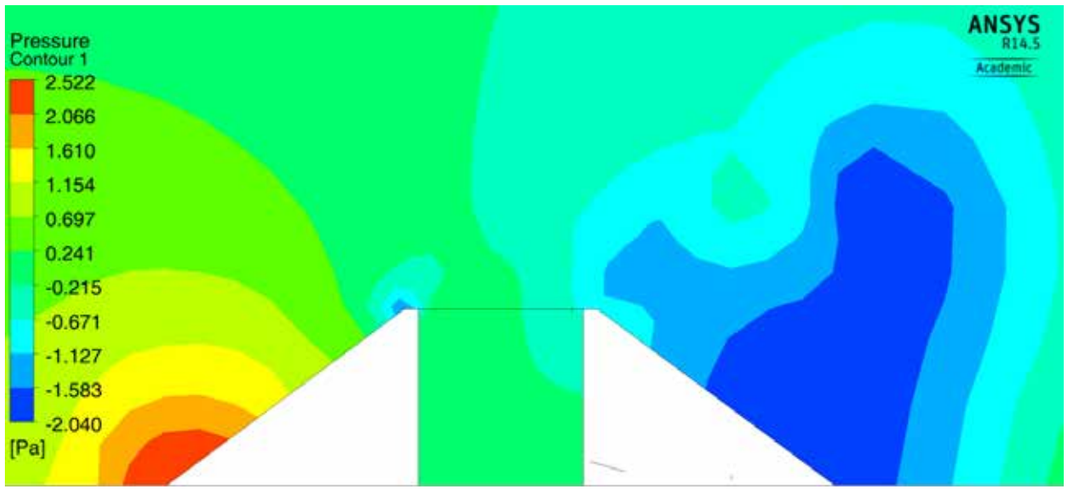
Wind velocity of 2,4 m/s



Inlet

Outlet





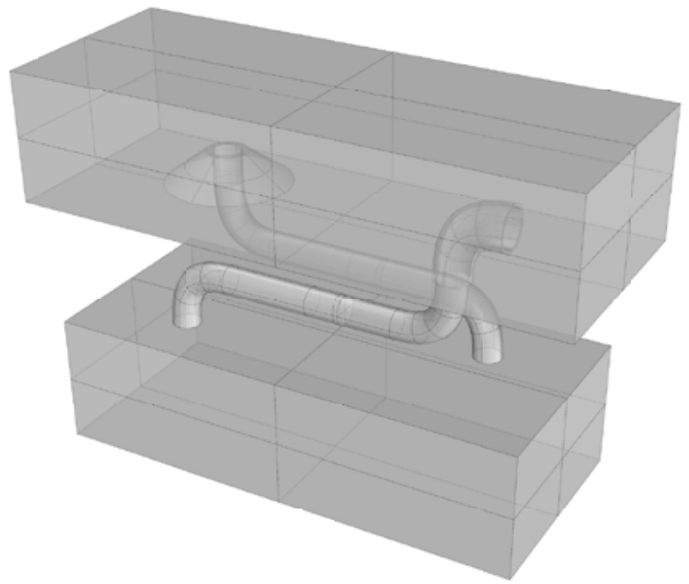
Design

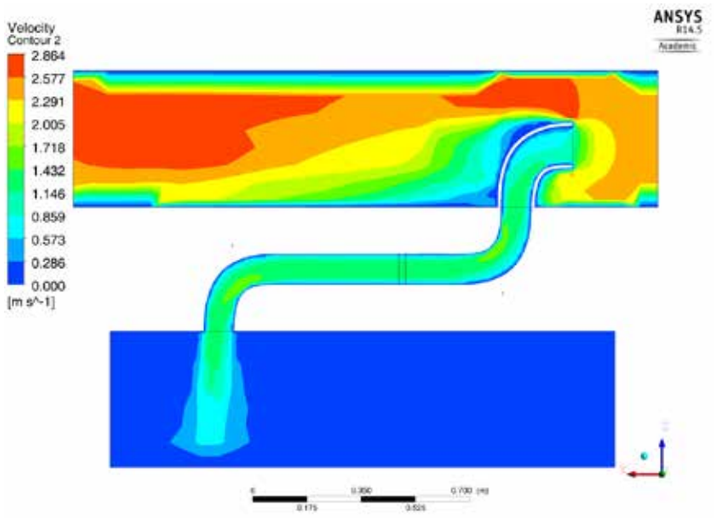
Inlet velocity 2,4 m/s

1,4 m/s air velocity for 50 m^3/h

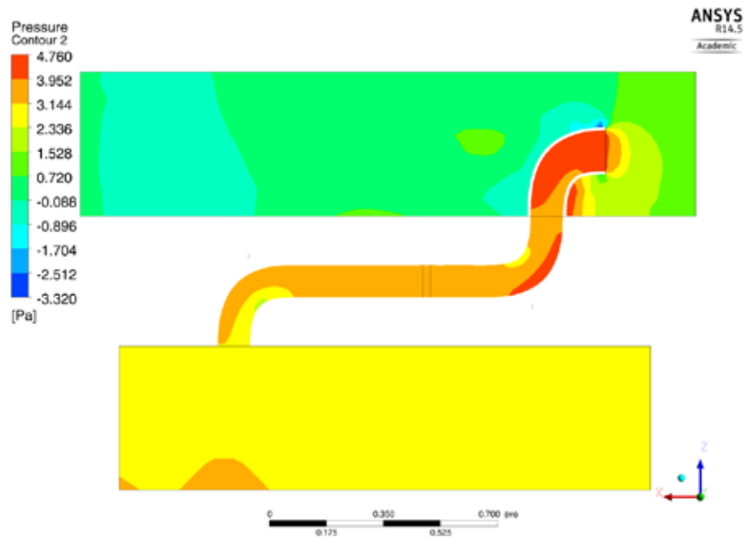
Low presure drop due to heat exchanger
- Calibrated at 4Pa at 100 m^3/h

Simulation





Velocity contour, Vin = 2,4 m/s

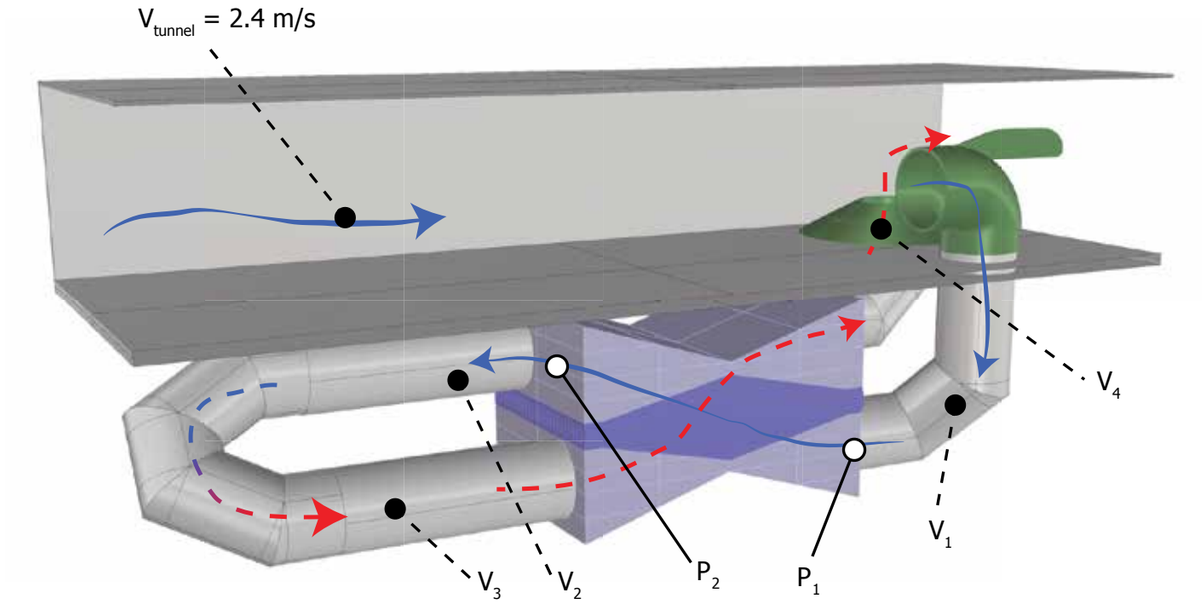


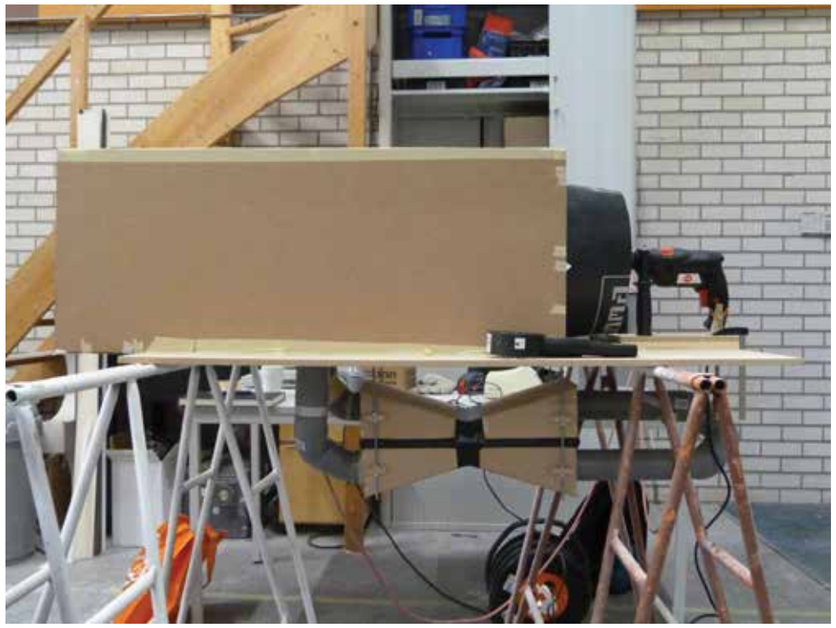
Pressure contour, Vin = 2,4 m/s

Test setup

Wind tunnel test
- Extraction of the air by fan
- Heat exchanger

Measurements
- 4 locations in the system
- Pressure difference over heat exchanger



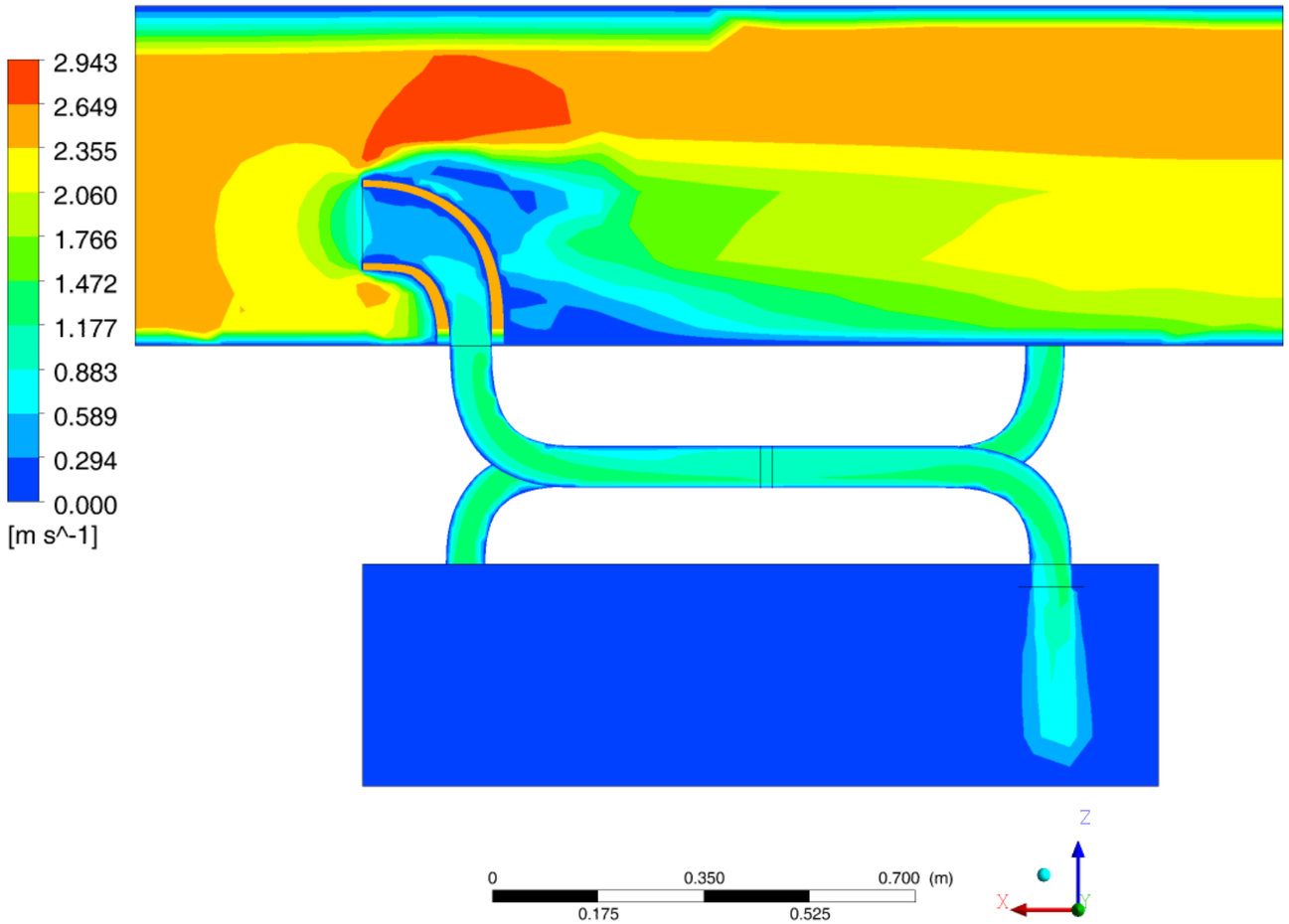


Test setup

Test vs simulation
- Wind velocity inside the system
- 0.22 m/s tested - 0.28 m/s simulated
- 0.87 m/s tested - 1.07 m/s simulated

Accuracy of the system

1.5 Pa pressure difference at 2,4 m/s



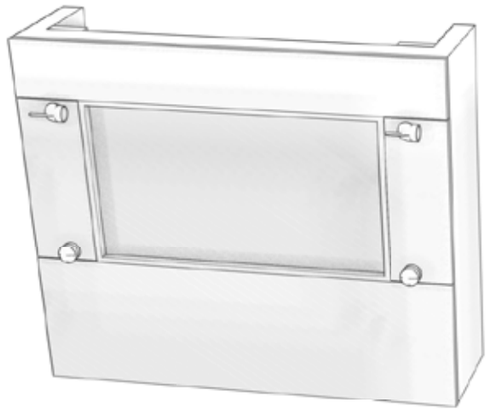
Design possibilities

Facade design boundary conditions:

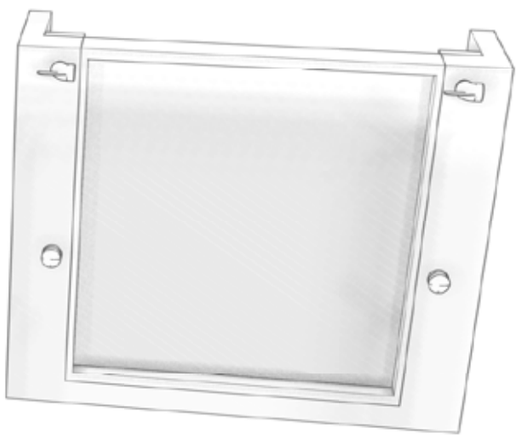
- Distance inlet-outlet min 1 m
- Center of opening at 0,15 m of the facade
- Dimensions internal box 0,3x0,2x1m

Facade

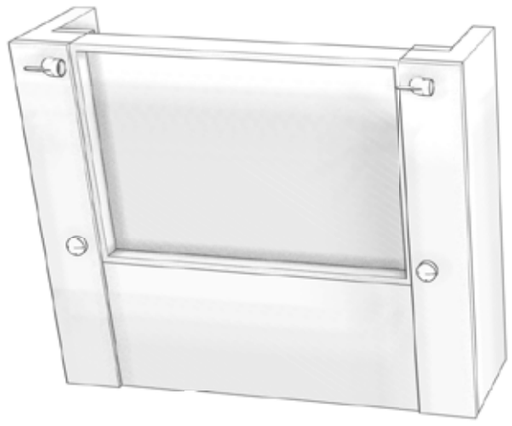
Exterior



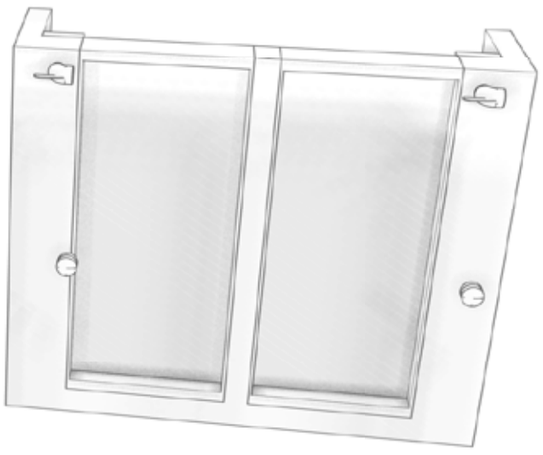
Standard option



Floor/floor glass



Vertical accent



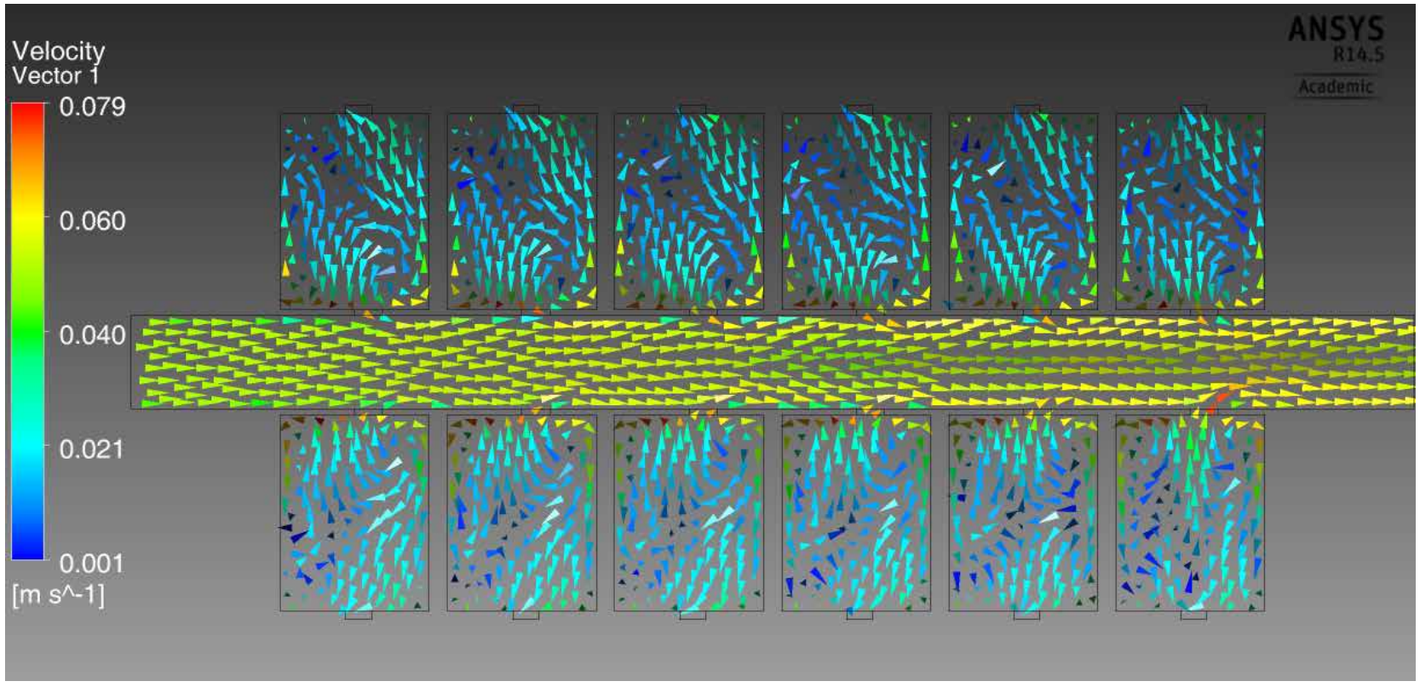
Double glass

Design possibilities

Floor plan

Floor layout
- Enclosed offices
  - Overpressure in hallway

- Open plan offices
  - Mechanical system at opposing facade
  - Additional rooms and toilets must be located at a facade



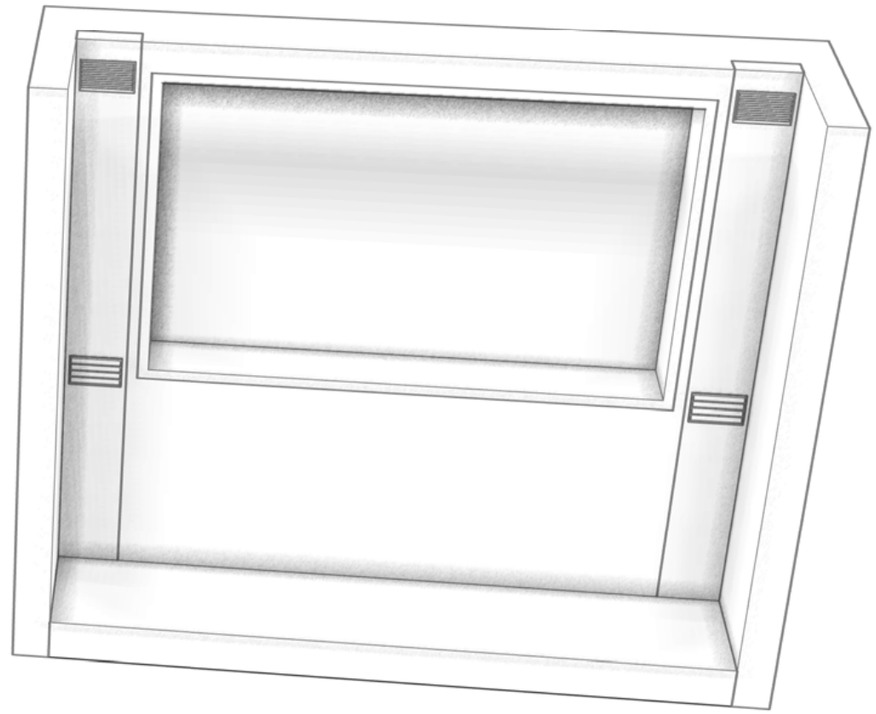
Enclosed office

Advantages

Small dimensions: 0,3x0,2x1m
- Simple to integrate in facade panel

More temperature acceptance due to natural principle
- 18 deg, during outside temperatures of -5 deg

Easy maintenance
- Few components



Advantages

Energy savings

Energy savings compared 6 mechanical ventilation systems

- Climarad
- Trox Schoolair-V
- Smartbox
- V4E - Smart ventilation (fiwihex)
- inVENTer
- Sonair A+

Energy saving up to 5% on total energy consumption

- Average annual energy consumption office building: 35.65 €/m^2
- € 0.39 to € 1.87 per m^2
- € 40,48 for a 21,6 m^2 office
- € 13763,- for the entire building

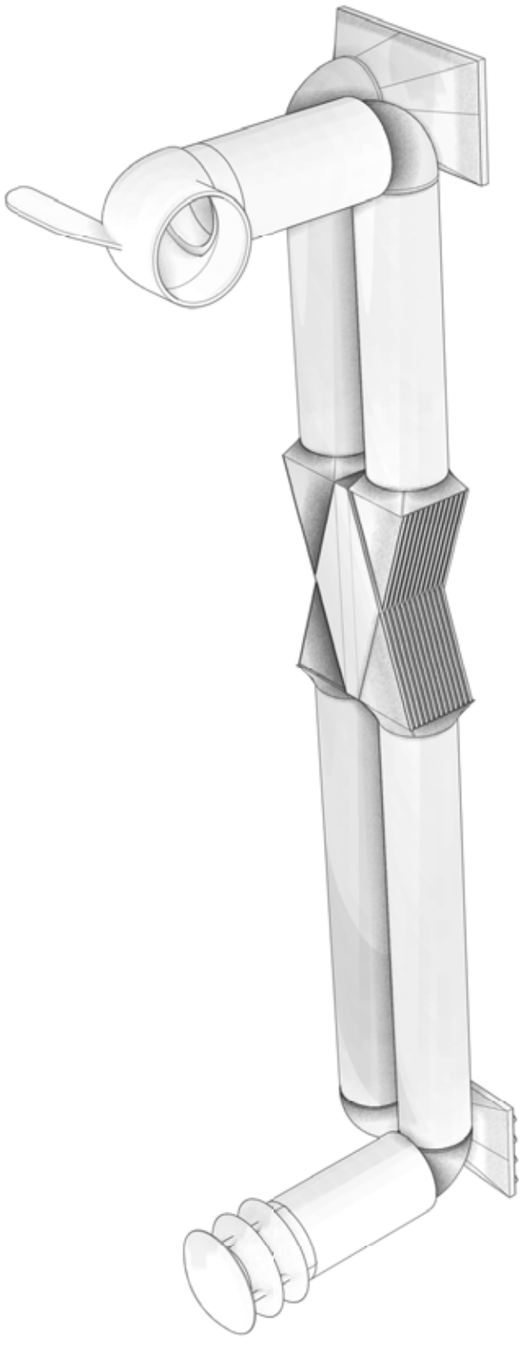
Conclusion

Natural ventilation with heat recovery is possible
- Wind induced ventilation
- High efficiency of the HE

Mechanical backup needed due to low winds on leeward side

Energy savings of 5% on total energy usage of the building

Increased user comfort



Recommendations

Study about wind velocities at the facade
- Influence of facade elements on air flow

Environmental influences

Optimizing the Inlet and the Outlet of the ventilation system

Bypass of the heat exchanger during the summer

Relation between the simulation and the real-life tests

Heat recovery with decentralized hybrid ventilation