

# How to reduce energy consumption of built-in refrigerators?

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## Background and motivation

- 29 % of electrical energy in private households used to operate refrigerators and freezers
  - Great efforts to reduce this consumption
  
- Problematic case: built-in refrigerators and freezers
  - Standardised niche measures
  - Insulation limited to a certain extent
  - Additional insulation material decreases refrigerator's net volume
  - Sensitive to deviations in air vents
  - Seldom graded into the highest energy efficiency classes

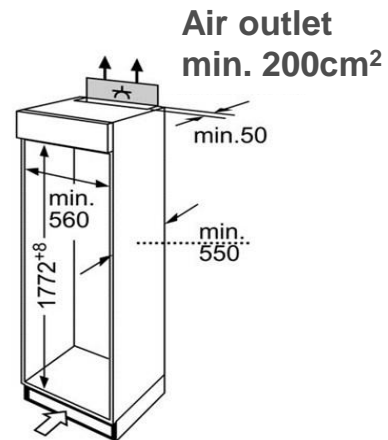
## State of the art

- Installation instructions have remained unchanged for many years
- Over this period, efficiency was improved and heat dissipation reduced

→ Do modern refrige together?

→ How do installatio consumption?

→ Is it possible to rec by modifying ins



conditions still fit

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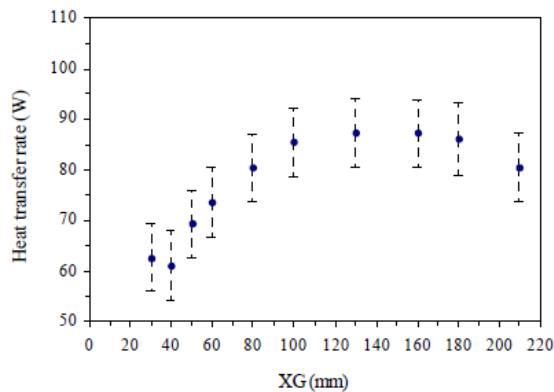
Air inlet in the socket  
min. 200cm<sup>2</sup>

Measures in mm

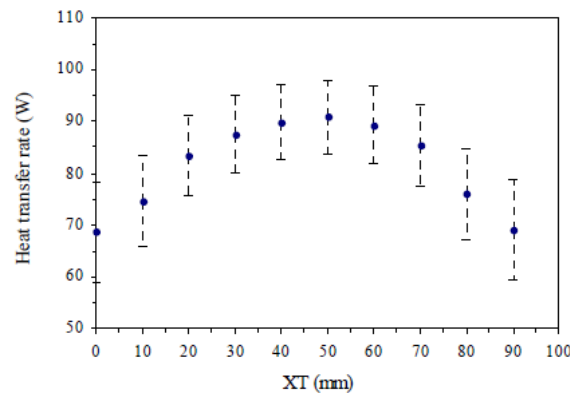
# State of research

- Melo et al. (2004): Study on performance of wire-and-tube condensers (special experimental apparatus) dependent on:
  - Geometry
  - Distance to adjacent walls

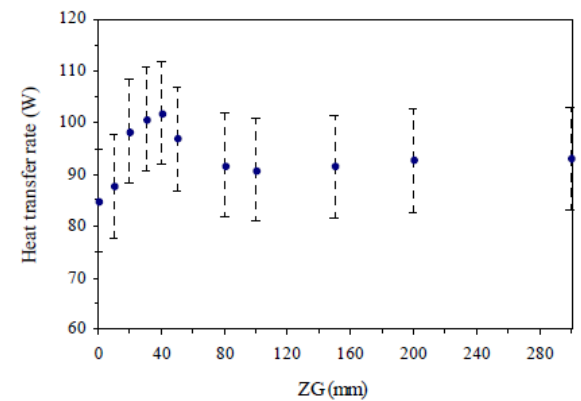
**Gap: refrigerator – rear wall**



**Position of condenser**



**Gap: refrigerator – side wall**



Figures: Melo et al. (2004)

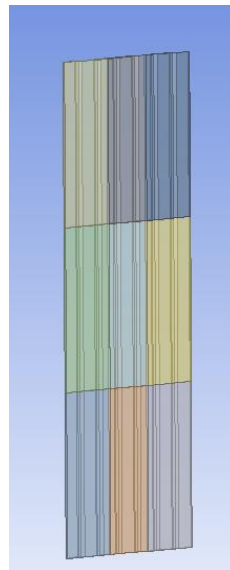
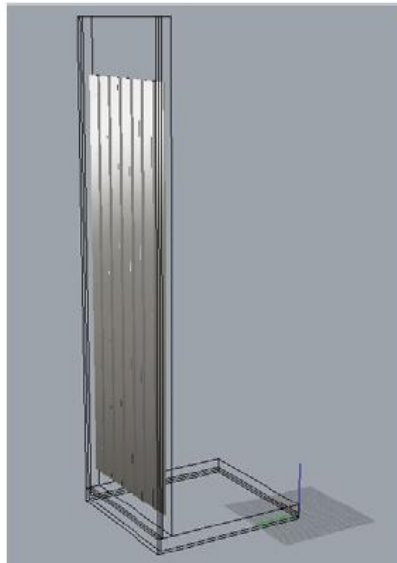
## Objectives

Is it possible to reduce energy consumption of built-in refrigerators and freezers by modifying installation conditions or by using additional features without impairing safety and quality of stored food?

- Accelerating heat removal from the condenser
- Reducing the condenser's temperature, which is the most crucial factor for refrigerators' energy consumption

## Material and methods – *Numerical simulation (CFD)*

- Geometry of condenser simplified (nine equal parts)
- Each part was assigned a constant temperature (deduced from IR thermography)

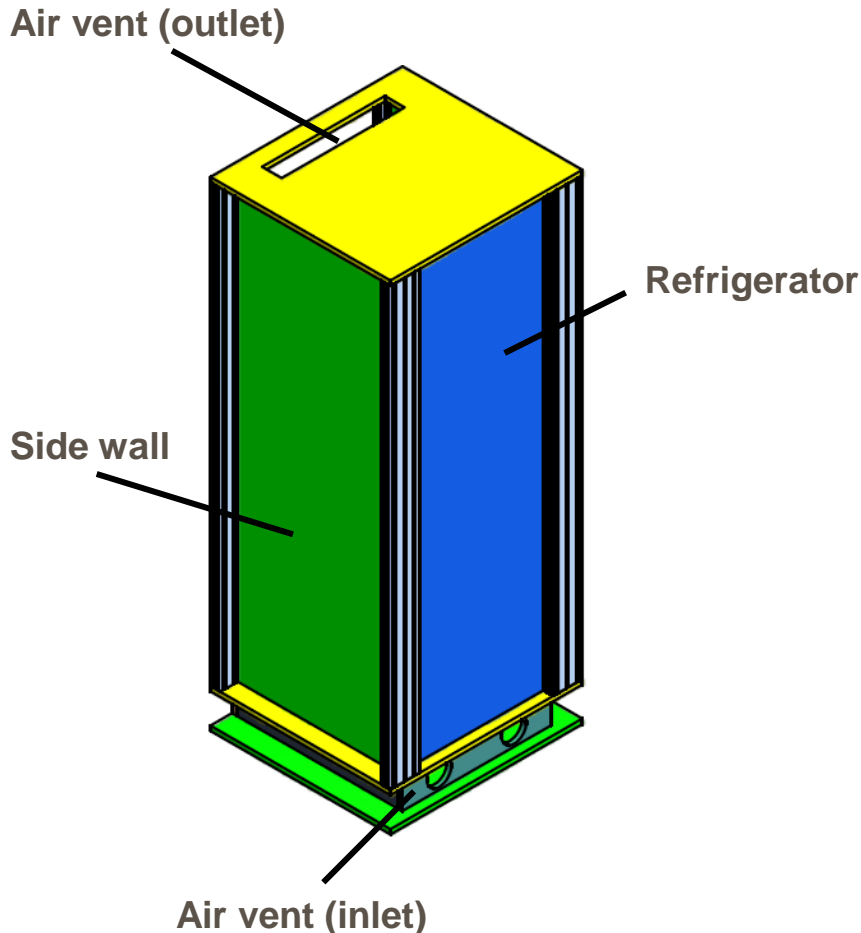


Figures: Transsolar Energietechnik GmbH

## Material and methods – *Numerical simulation (CFD)*

- Assumptions/ simplifications to reduce computational efforts:
  - Walls are adiabatic
  - Radiation neglected
  - Heat transfer and airflow were examined at a discrete and representative point of time

## Material and methods – *Experiments*



- Test enclosure made of 20 mm dull black-painted plywood
- Positions of side walls and rear wall variable
- Air vents variable
  
- Measured parameters:
  - Internal fridge temperature (3 positions)
  - Condenser temperature (9 positions)
  - Air velocity (near inlet and outlet)
  - Ambient temperature and humidity
  - Energy consumption

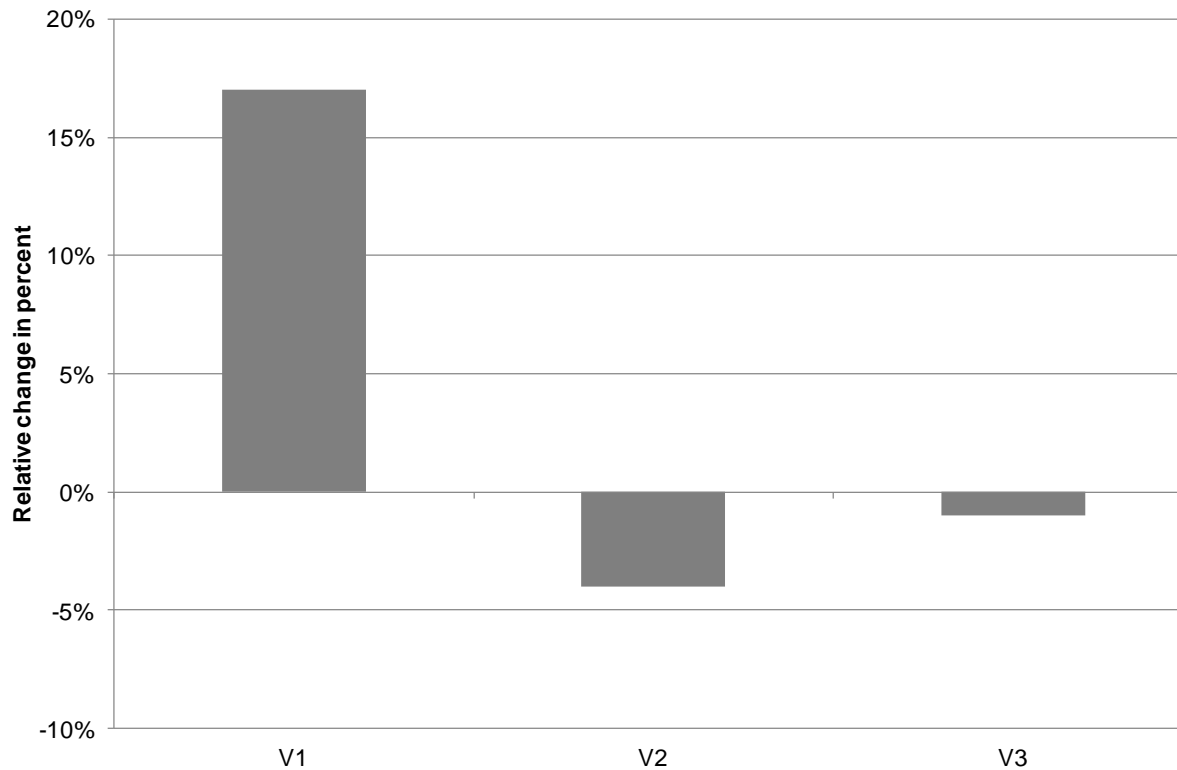


## Material and methods – *Experiments*

- Climatically controlled test conditions
- Ambient temperature 21 °C
- Test period: at least 24 h under steady state conditions (following EN ISO 15502:2005)
  
- Reference point: according to installation instructions
  - Gap between condenser and rear wall: 50 mm
  - Area of air vents: 200 cm<sup>2</sup>

# Results

# Changes in convective heat dissipation compared to reference (*numerical simulation*)

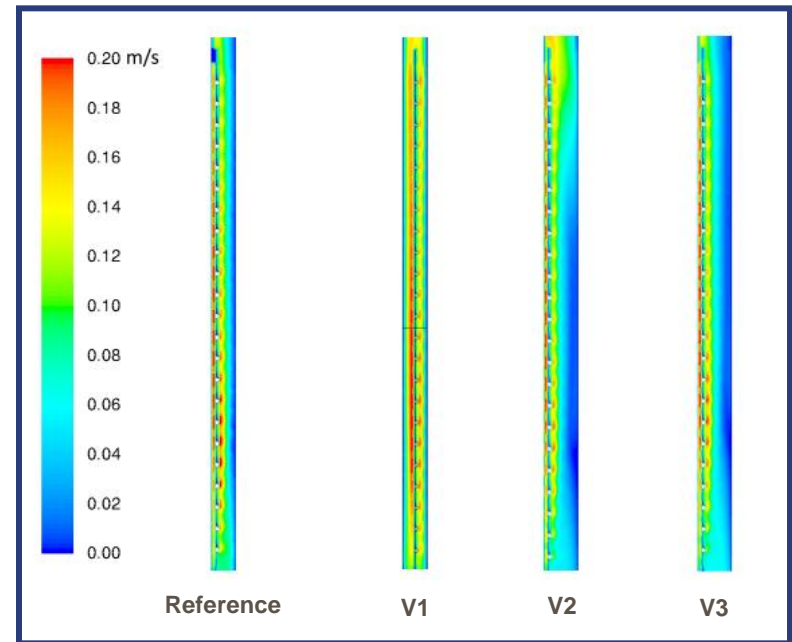
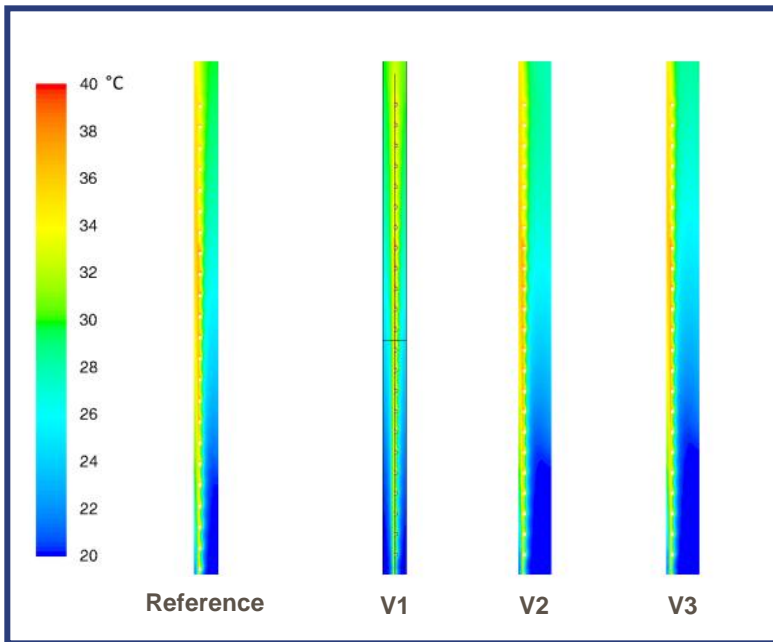


**V1:** condenser centrally arranged

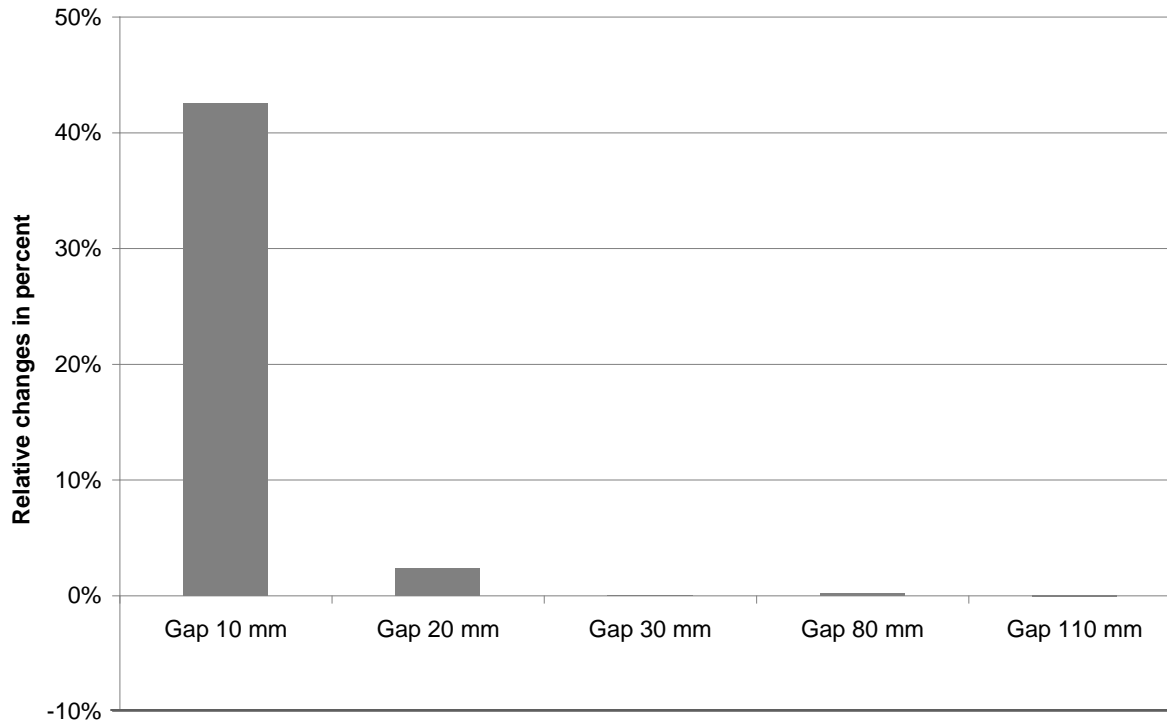
**V2:** gap between refrigerator and rear wall and air vents increased

**V3:** gap between refrigerator and rear wall increased

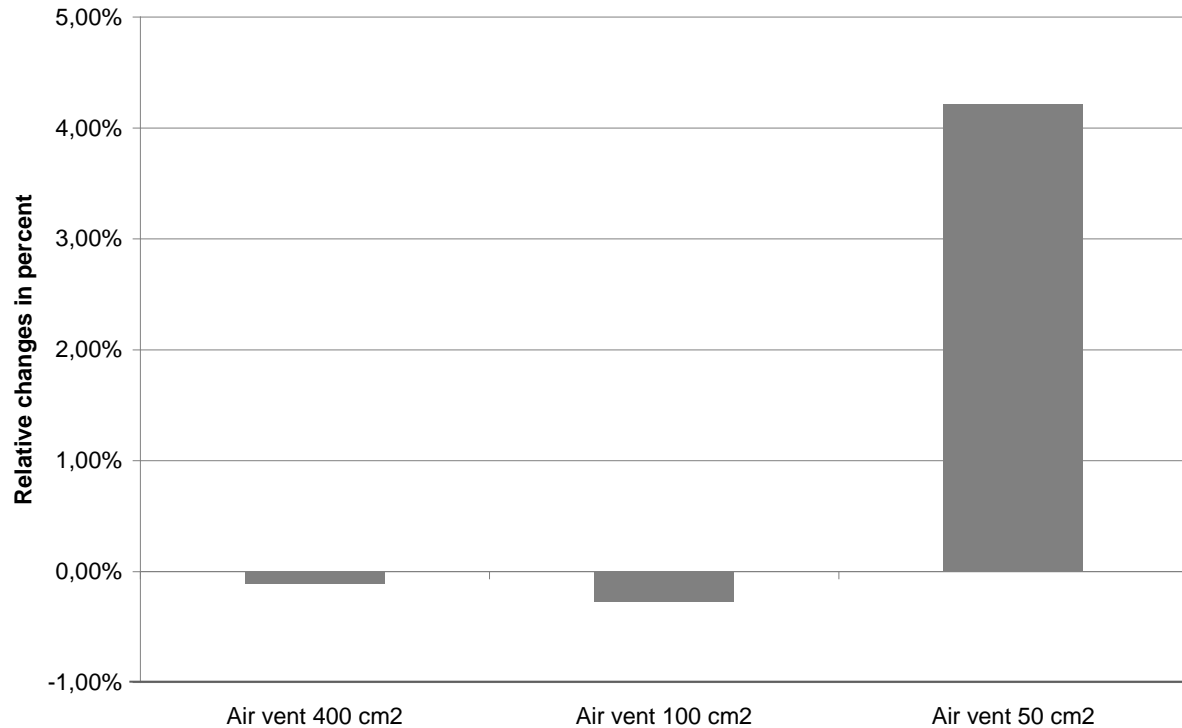
# Air temperature/ velocities inside the gap between refrigerator and rear wall (*numerical simulation*)



# Changes in energy consumption by modifying gap between refrigerator and rear wall compared to reference (*experiments*)



# Changes in energy consumption by modifying air vents (air inlet/ outlet) compared to reference (*experiments*)



## Conclusion

- Gap between refrigerator and rear wall has highest impact on energy consumption
- Energy consumption decreases with increasing gap, reaching a minimum at 30 mm
  - Gap can be reduced by 20 mm compared to actual instructions (50 mm) without negative effects for energy consumption
  - Additional space might be used to extend insulation layer
- Optimal position of the condenser is half the distance between refrigerator and rear wall
- Effect of air vents is vanishingly low

## Outlook

- Further experiments and simulations needed:
  - Gap between refrigerator and side walls
  - Forced ventilation
  - Material of rear wall (increased thermal conductivity)
  - Additional features (e.g. drawers inside the refrigerator)
  - ...
  
- Results applicable to other refrigerators/ freezers?



# Thank you for the attention!

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