IGEIA
Integration of Geothermal Energy into Industrial Applications

> Deliverable 8

> ENERGY NEED FOR A STANDARDIZED SUPERMARKET: HEATING, COOLING, REFRIGERATION

With the support of :

Intelligent Energy Europe

November 2007

UBeG Dr. E.Mands & M. Sauer GbR
Zum Boden 6
D-35580 Wetzlar
Tel. +49 6441 212910 – Fax +49 6441 212911
www.**ubeg**.de

UBeG
Umwelt Baugrund Geothermie Geotechnik

Table of contents

1. Conventional system for Heating, Cooling and Refrigeration

In a typical supermarket, heat and cold is required in the following areas:

- Space heating for the market area, offices and storage
- Space cooling for the market area, offices and storage
- Heat for hot water in offices and social rooms (DHW)
- Cold for cold display cases in market area and for cold storage
- Cold at low temperature for deep freezers in market area and storage

The classical energy supply layout is shown in fig. 1. This schematic does not include DHW (there is typically a minor demand only, which can best be covered by a small electric boiler near the kitchen sink in social rooms), and also does not include the deep freezer chests in the market area (those are independent units, each with own condenser; they are plugged to the electric main and the net energy balance of evaporator, compressor and condenser results in an internal heat load to the building, like lights, cashiers, etc.). In summertime, individual refrigeration equipment is used for space cooling and for cold for display, storage and deep freeze storage. In winter, space heating is provided by natural gas boilers (sometimes fuel oil boilers), while the refrigeration equipment for cold and deep freezing continues running.

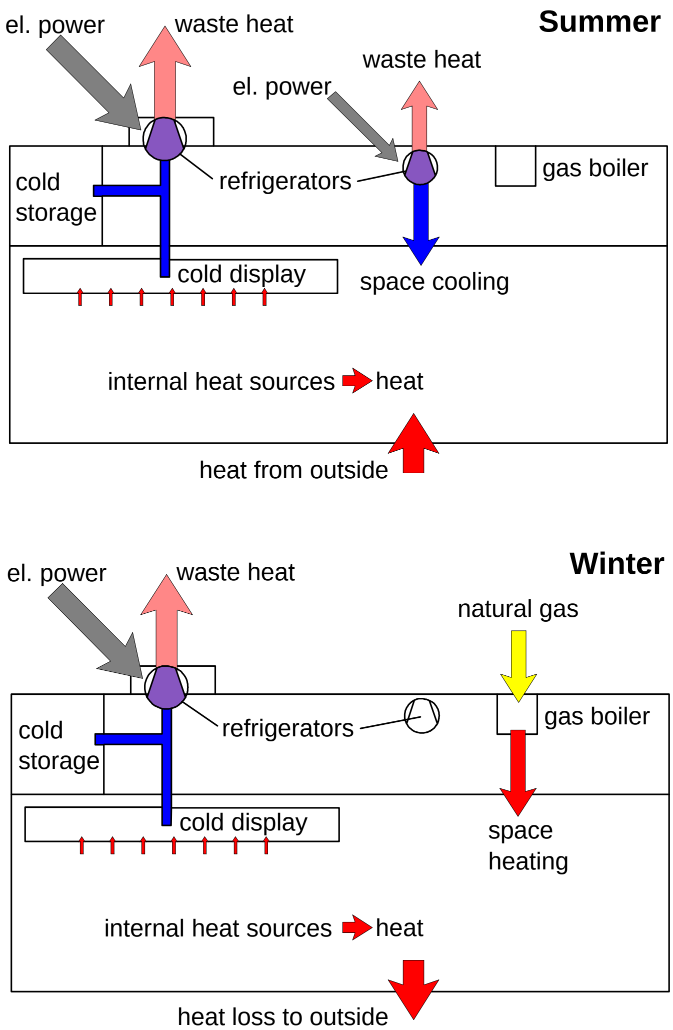


Fig. 1: Schematic of a conventional heat and cold supply for standardized Supermarket

2. Simulation of heat and cold demand for standardized supermarket

To investigate the thermal energy needs (heating, cooling, refrigeration) in a standardized supermarket, a simulation of the heating and cooling loads of the building was done. The energy needs of the refrigeration and food cooling system were taken from manufacturer´s data. The following target temperatures first had been asked for:

zone	winter	summer
• market area	min. 19 °C	max. 25 °C
• cashier area	min. 21 °C	max. 25 °C
• storage area	min. 17 °C	max. 17 °C
• office and social rooms	min. 21° C	max. 24 °C

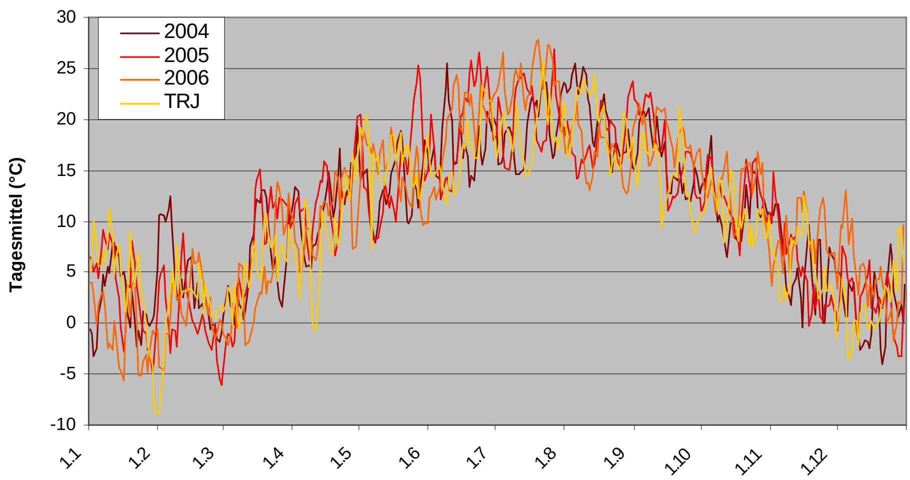
other boundary conditions:

- no space heating from June 1 to September 15
- no space cooling from November 1 to March 31
- no explicit standards for air exchange (fresh air)
- internal loads from persons, lighting, etc. are considered, and opening and closing times of the market are distinguished
- Deep freezer chests only have a net heating impact (condenser in the market area, beneath each chest; ca. 450 W net heating per unit)
- Cold display cases only have a net cooling impact (part of the central refrigeration system, condenser to the outside air; ca. 1500 W net cooling per m case length)

Fig. 2: Deep freezer chest (left) and cold display case (right), generic photos

The climatic conditions of the site have been taken from a standard meteorological file (TRJ, hourly temperature values for long-term average) for the Rhein-Main-area, one of the trade centres of Germany. The validity of the standard file for the recent years has been checked with data of the German Geological Service (Deutscher Wetterdienst, DWD) for Frankfurt airport for the years 2004-2006 (fig. 3). The standard file represents the actual temperatures quite well, in the limits of normal variation of annual weather development.

The results in the following calculations are set to an arbitrary energy value (EV) for kWh, and for an arbitrary power unit (PU) for kW, in order to allow easy comparison.



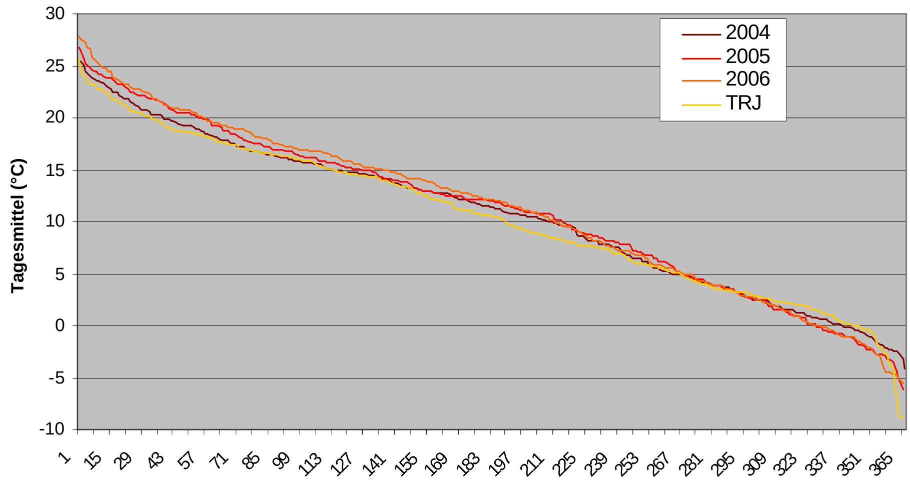


Fig. 3: Comparison of the daily mean temperature in the standard meteorological file (TRJ) with the actual data for daily mean temperature at Frankfurt airport (data from DWD for 2004-2006), as development over the year (top) and as sorted curve (bottom)

2.1 Energy Simulation following exactly the temperature requests

A first simulation was done with an approach to strictly meet the temperature targets as given above, in particular the following:

- Temperature in the market area, always and at each point, 19 °C or higher during winter
- Room temperature in summertime maximum 25 °C

Air exchange volume was set to a high level for increased comfort.

A relatively high annual heating load results, with ca. 68’300 EV per year at a maximum heating output of 41.5 PU. The annual space cooling demand is much lower, totalling 4’000 EV per year at 13.8 PU maximum cooling capacity. The development of heating and cooling load over the year can be seen in fig. 4. The scale of figures 4- is kept the same, to allow easy comparison

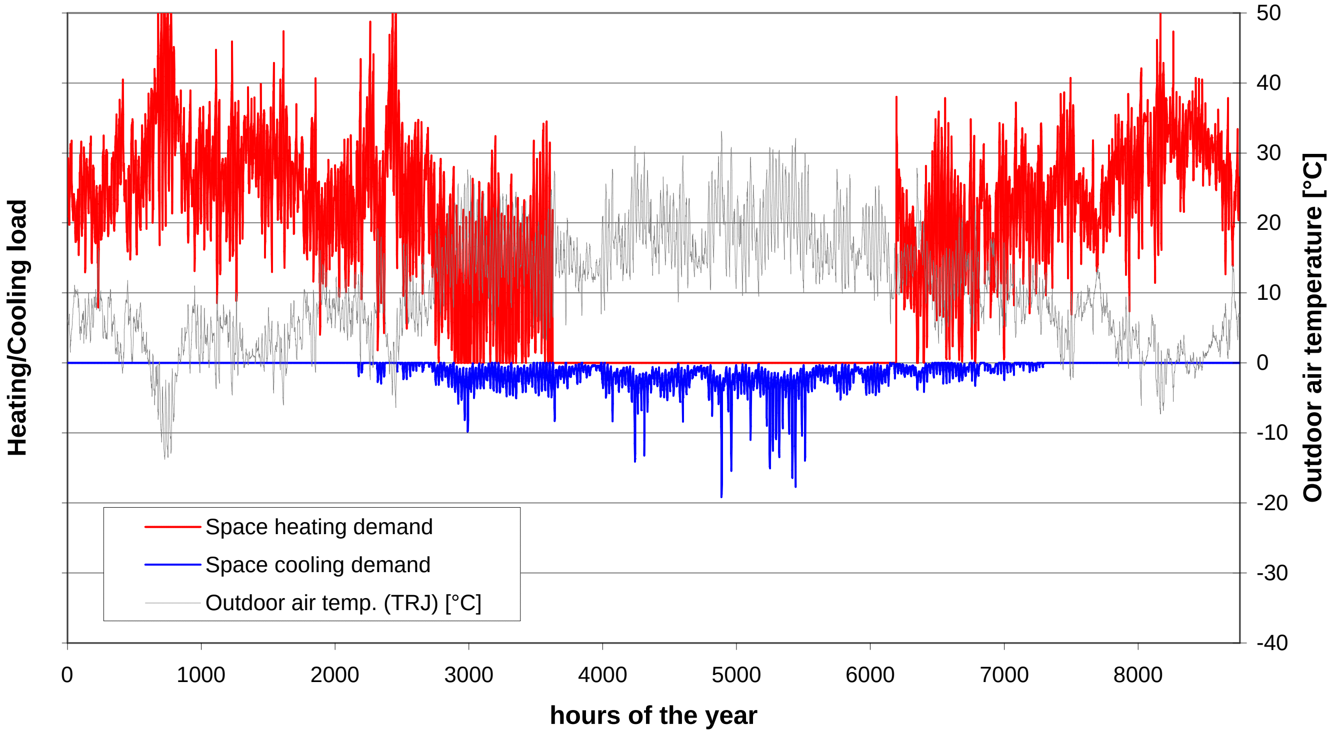


Fig. 4: Development of space heating and cooling load over an average year, with high ventilation air volume, meeting target temperatures strictly and considering thermal impact of cold display cases

2.2 Energy Simulation without consideration of cold display cases

In another simulation run the influence of the cold display cases on the space heating demand was investigated. So the net cooling impact of these elements has been switched off for this simulation, while keeping all other boundary conditions as before.

In practical case this approach would mean that temperatures in the market area can drop below 19 °C in winter, in particular directly in front of the cold display cases. Experience from visits to supermarkets proves that this is typically the case in reality, with relatively low temperatures in front of the cold display.

Now the annual space heating load is reduced substantially to ca. 35'800 EV at about 34.6 PU maximum heating capacity. The space cooling loads are merely unchanged, with 4’000 EV per year at 13.8 PU maximum cooling capacity. The development of heating and cooling load over the year can be seen in fig. 5.

2.3 Energy Simulation with reduced air exchange

The results of the first two simulation scenarios were much higher than measured energy consumptions in similar supermarkets. Another simulation was done with reduction of ventilation air to the minimum value required to ensure acceptable indoor air quality. Everything else was kept as in chapter 2.2.

The annual space heating load is further reduced to less than ca. 18'400 EV at about 18 PU maximum heating capacity. The space cooling load decreases slightly to 3’800 EV per year at 7 PU maximum cooling capacity. The development of heating and cooling load over the year can be seen in fig. 6.

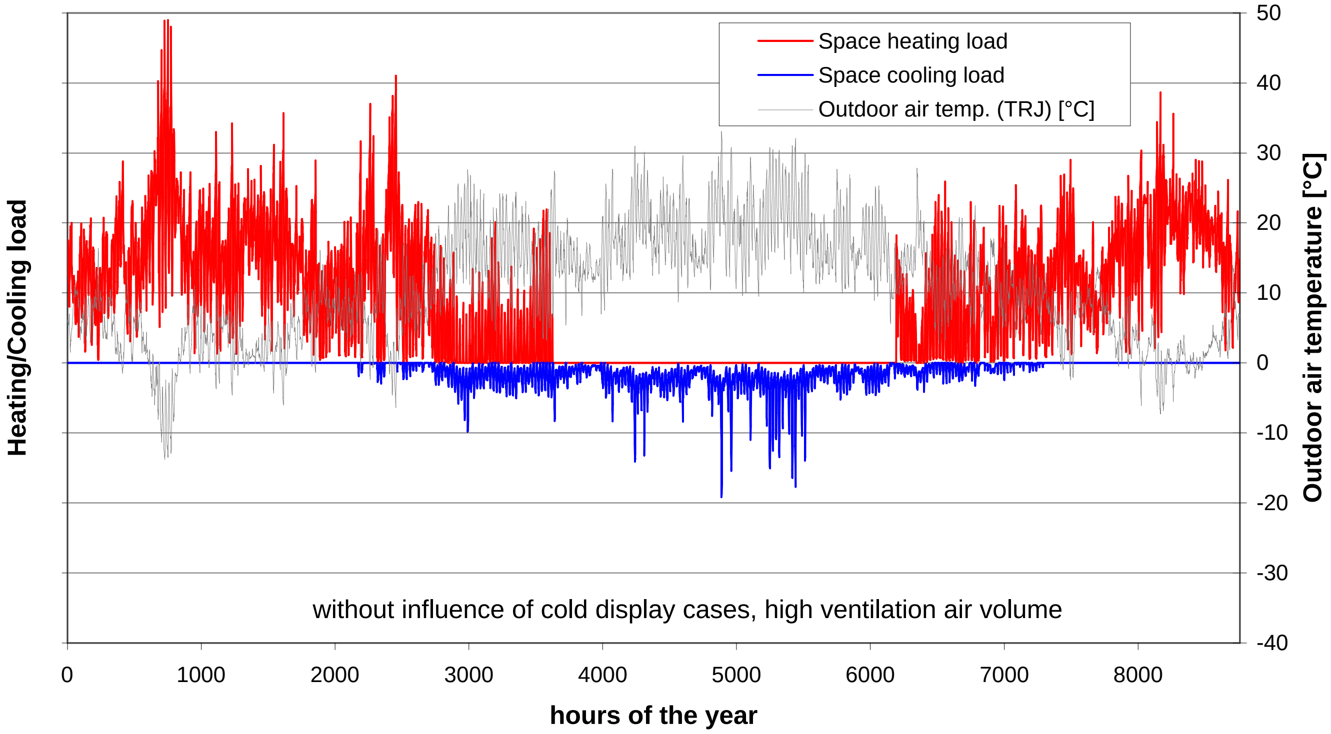


Fig. 5: Development of space heating and cooling load over an average year, with high ventilation air volume, without considering thermal impact of cold display cases (see 2.2)

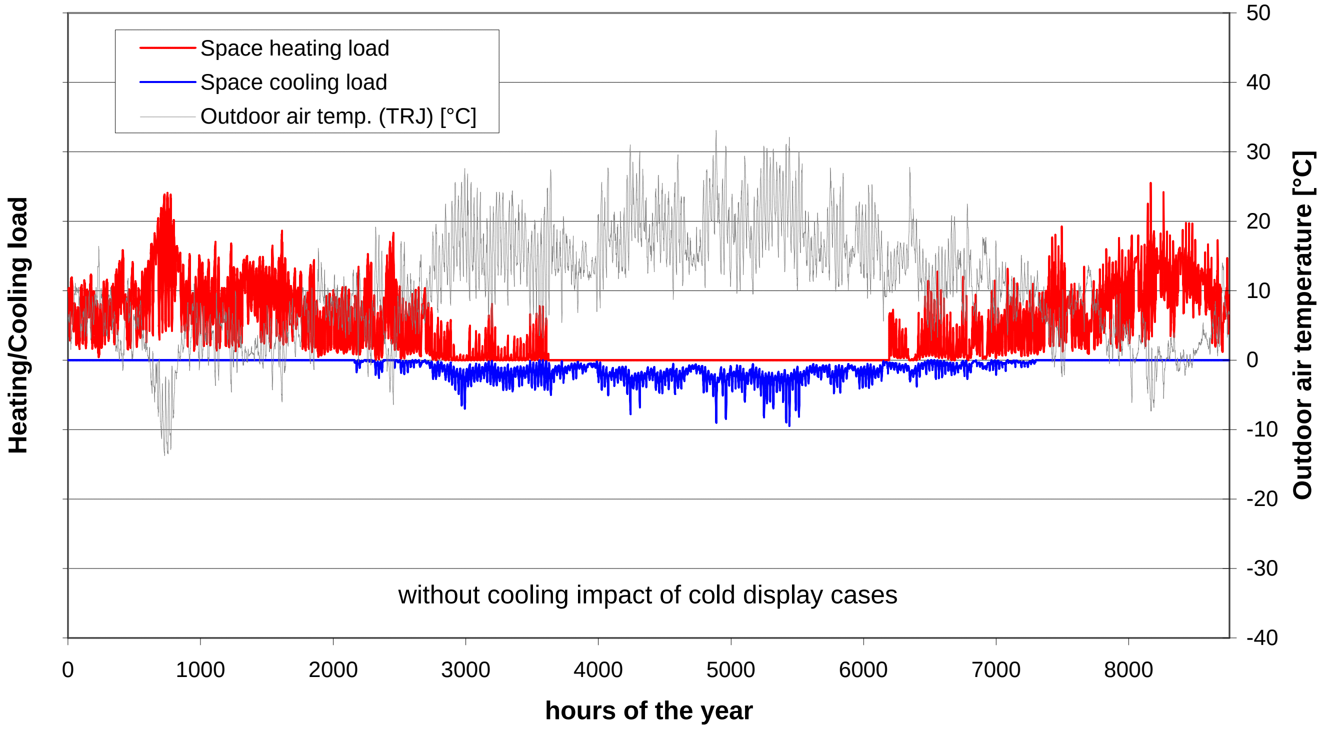


Fig. 6: Development of space heating and cooling load over an average year, with reduced ventilation air flow, mostly meeting target temperature 19 °C, without thermal impact of cold display cases (see 2.3)

2.4 Energy Simulation with decreased temperature

It is rather improbable that in a room like the super market sales area a temperature of 19 °C is actually kept at all time. So the next scenario allows a decrease of the temperature within the sales are, where costumers typically move around, to a minimum of 17 °C, and possibly even lower directly in front of the cold display cases. The temperature in the cashier area, where personal is sitting while working, is always kept above 19 °C. All other boundary conditions, including reduced ventilation air, stay unchanged to the previous simulation.

The annual space heating load is further reduced to less than ca. 12'000 EV at only 15 PU maximum heating capacity. The space cooling load remains at 3'800 EV per year at 7 PU maximum cooling capacity. The development of heating and cooling load over the year can be seen in fig. 7.

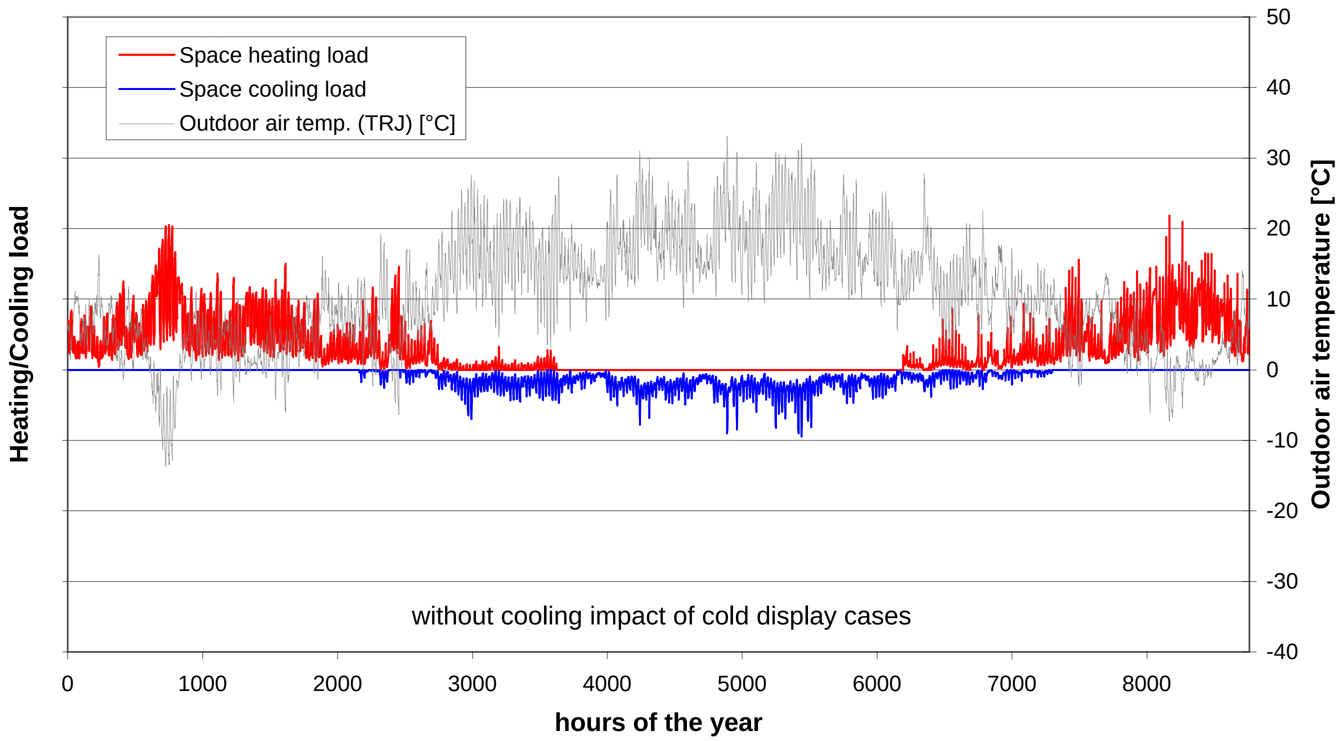


Fig. 7: Development of space heating and cooling load over an average year, with reduced ventilation air flow, mostly meeting reduced target temperature 17 °C, without thermal impact of cold display cases

2.5 Comparison to measured data and Energy Simulation with calibrated data

The industrial partner provided energy consumption data (natural gas consumption for heating) for seven super markets in comparable climatic conditions (Central Germany). Table 1 lists these data, and an average consumption of heat is calculated. Furthermore, the expected natural gas consumption for the scenarios from chapter 2.3 and 2.4 are calculated; these are close to the measured data, in contrary to the higher heat loads calculated in the first scenarios.

With data calibrated as given in Table 1, a heating load of ca. 14'600 EV at about 14 PU maximum heating capacity is obtained. The space cooling load decreases to 940 EV per year at 7 PU maximum cooling capacity. The development of heating and cooling load over the year for this final scenario can be seen in fig. 8.

Table 1: Measured natural gas consumption of several supermarkets, and calculated from simulation

Supermarket No.	Natural Gas consumption [EV/m²] Year 2004	Year 2005	Average
1	9,5	10,5	10,0
2	6,1	6,5	6,3
3	5,5	5,6	5,5
4	7,7	8,2	7,9
5	6,9	6,8	6,8
6	7,4	7,6	7,5
7	7,4	9,3	8,3
Mean	7,2	7,8	7,5

	Heating [EV]	Nat. Gas [EV]	Nat. Gas [EV/m²]
Simulation 2.3	18280	19242	12,4
Simulation 2.4	11906	12533	8,1
calibrated simul.	14690	15463	10,0

Natural gas consumption calculated with 95 % efficiency

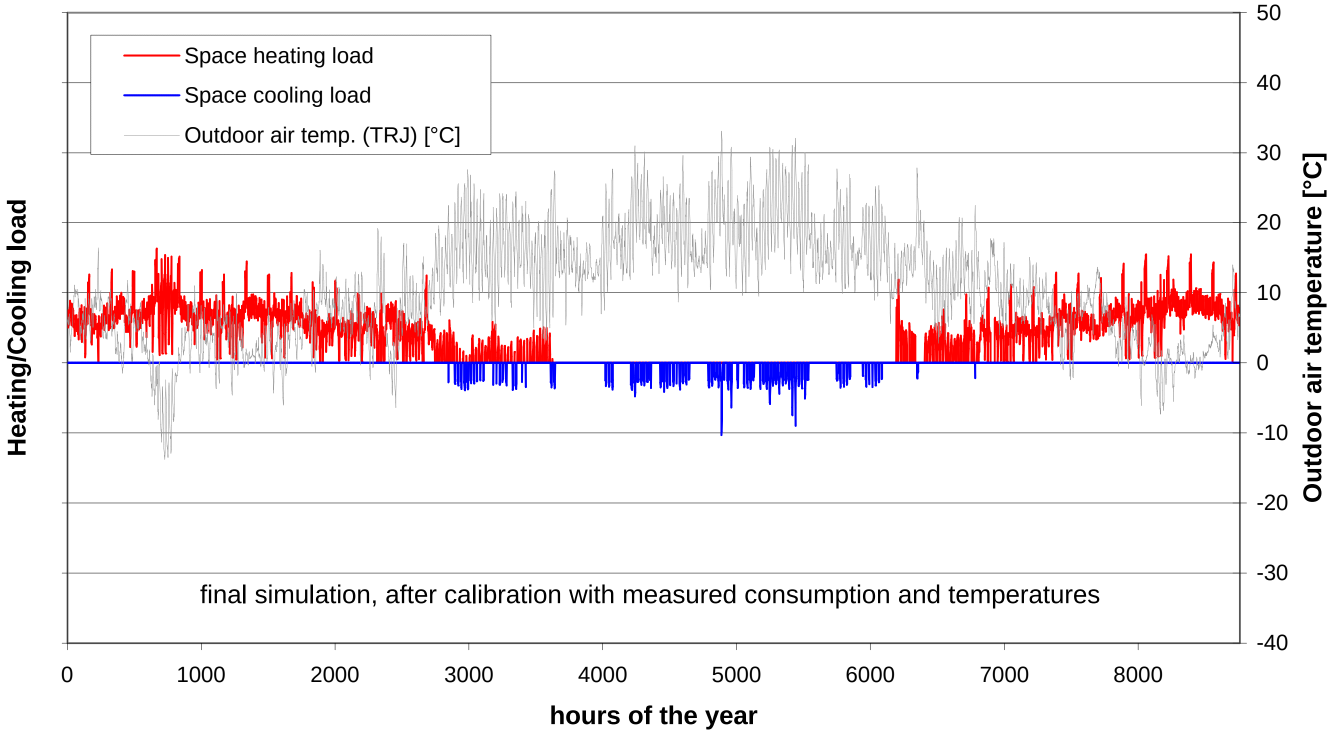


Fig. 8: Development of space heating and cooling load over an average year, final scenario calibrated with average measured consumption and temperature data

3. Summary of thermal energy demand for standardized supermarket

In chapter 2, the energy requirement for space heating is calculated. As was said in chapter 1 and can be seen from fig. 1, this is only a part of the overall energy need for heating, cooling and refrigeration in the building. The most important energy consumer in a supermarket is the cooling for food storage, consisting mainly of the following items:

- Cold for cold display cases in market area
- Cold for cold storage cells in storage area

- Cold at low temperature for deep freezers in market area
- Cold at low temperature for deep freezing storage in storage area

The heat and cold required, and the necessary electricity input as well as natural gas input for all of the thermal energy needs in the standardized supermarket is listed in table 2. Figure 9 shows the energy flow diagrams for the different energy needs.

Table 2: Summary of thermal energy need for conventional supply of standardized supermarket (in arbitrary energy values EV for heating/cooling work (instead of kWh or MWh), and arbitrary power units PU for heating/cooling capacity (instead of kW).

	Annual work	Momentary output
Space heating requirement	14’690 EV per year	13.8 PU
Natural gas for space heating	*15’460 EV per year*	*14.6 PU*
Space cooling requirement	942 EV per year	6.9 PU
Electricity for space cooling	*314 EV per year*	*2.3 PU*
Food cooling, storage, freezing	73’370 EV per year	18.1 PU
Electricity for food cooling etc.	*24’260 EV per year*	*6.0 PU*

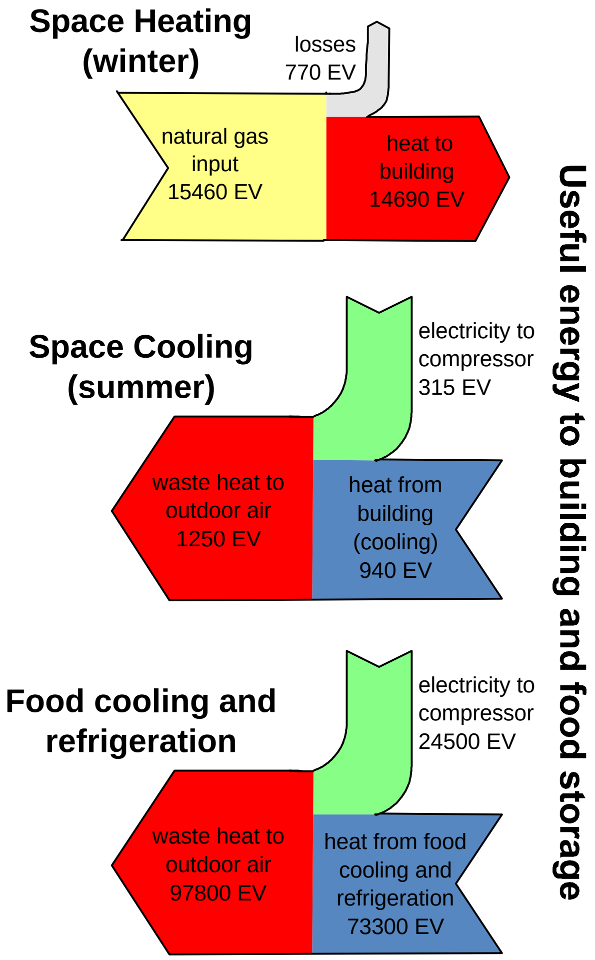


Fig. 9: Energy flow diagrams for standardized supermarket, conventional energy supply