SUSTAINABLE ENERGY SYSTEMS

Feasibility study for thermal cooling system

Organisation name of lead contractor for this deliverable: **SWE**

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1 Results of heating and cooling calculations

The company Elektror plans to build an office building with attached laboratory in the area Scharnhauser Park. The constructor wants to realize a sustainable coverage of the cooling demand. The energy for heating will be provided by the biomass power plant.

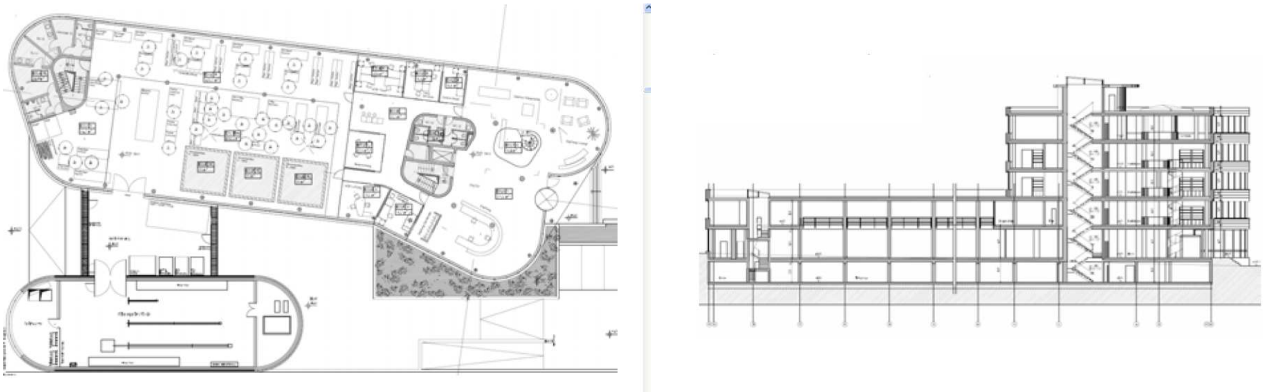


Fig. 1: Plan view on the new Elektror building

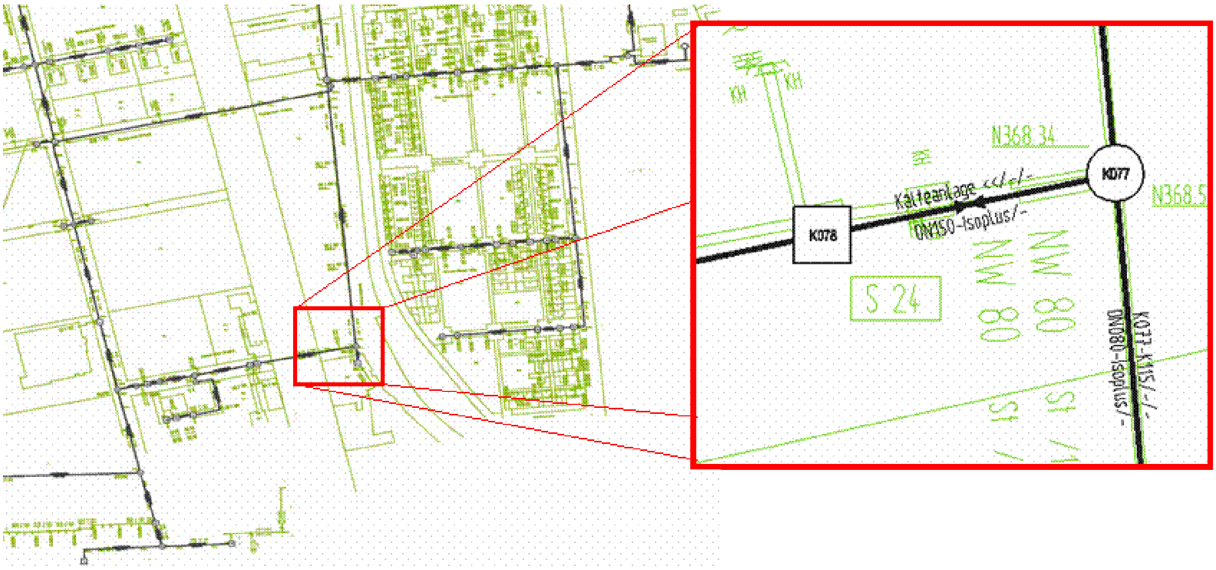
Elektror building	Main building	Laboratory
Heated area	3280 m²	280m²
Heated volume	11620m³	1540m³
persons	200 (10 h per day)	8 (10 h per day)
PC	150 (10 h per day)	8 (10 h per day)
Lighting	13 W/m² (2 h per day)	13 W/m² (10 h per day)
Other internal loads	-	8 kW (10 h per day) 2 kW (24 h per day)
Natural air change	0.2 1/h	0.2 1/h
Mechanical air change	0.6 1/h	0.6 1/h
Cooling set temperature	24 °C	24°C
Heating set temperature	20°C (night lowering 15°C)	20°C (night lowering 15°C)

Characteristic energy values:

	Max. heating power [kW]	Max. cooling power [kW]	Quantity of heat energy [MWh/a]	Quantity of cooling energy [MWh/a]
Main building	180 (55 W/m²)	90 (28 W/m²)	72 (22 kWh/m²a)	129 (39 kWh/m²a)
Laboratory	8 (29 W/m²)	15 (53 W/m²)	1 (3,5 kWh/m²a)	10 (36 kWh/m²a)

2 Description of the supply concept

The building’s heat supply is covered by the biomass heat-net. The heat transfer takes place in the transfer station. The cooling process is decentralized and realized by an absorption cooling machine driven by hot water out of the heat net.



Within the building heating and cooling is distributed via a water-based tube net that supplies a low-temperature heating/cooling system, consisting either of combined floor heating/cooling devices or an activated building part system in addition with radiators/ convectors for the heating.

The cooling machine is a lithium bromine-based absorption chiller with a cooling power of 105 kW which will be installed in the cellar of the building.

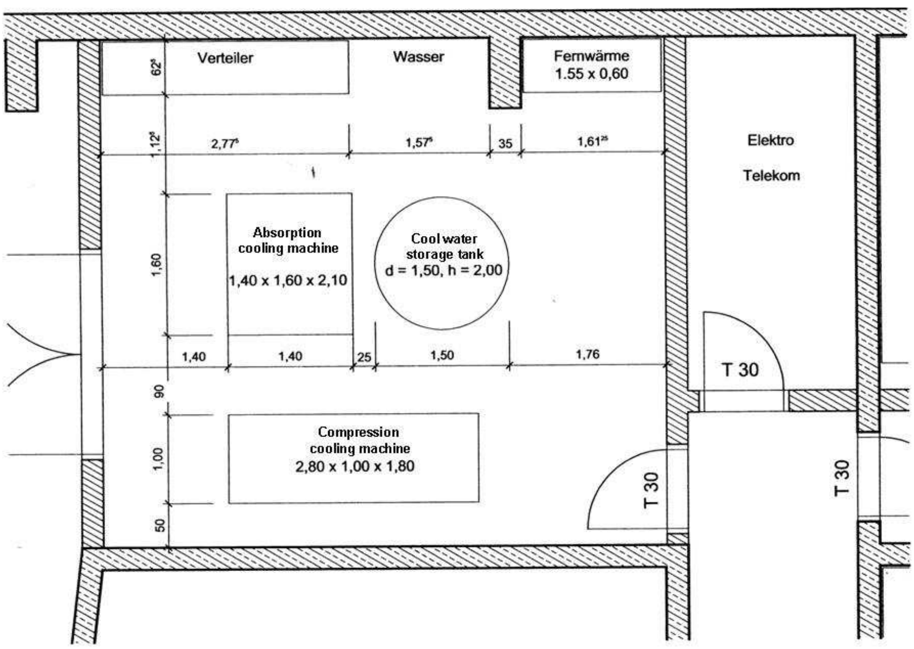


Fig. 2: Floor plan of the central heating room in the Elektror building

A contracting model in which the cooling machine remains in property of the supply company Stadtwerke Esslingen helps to ensure a save supply of cooling energy (maintenance is carried out by SWE) prevents the customer from incalculable cost raisings by a long term contract.

Due to the fact that the absorption cooling machine needs a feed water mass flow of 7.2 kg/s and produces a temperature spread of only 5K, the common connection between feed and return of the heat net would lead to high return temperatures in the heat net in the summertime, and would probably have an impact on the electrical performance of the CHP plant. One way to solve that problem is the integrated connection of the cooling machine within the feed line of the heat net.

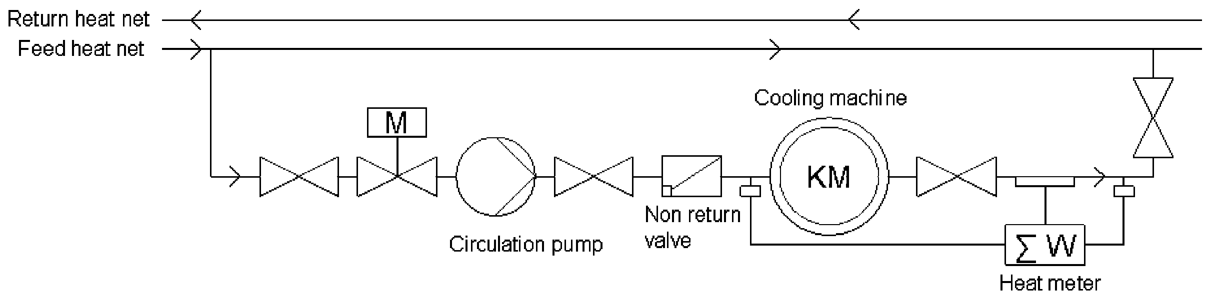


Fig. 3: Direct connection of the cooling machine to the district heat net

3 Heat- and cooling distribution devices

There are two basic concepts for the layout of the heat- and cooling distribution system.

Concept 1 Activated building parts for cooling and additional convectors for heating

In this concept the supply with cooling energy is provided by the heavy ceilings of the building, in which synthetic pipe coils are concreted. Those activated ceilings can provide between 35 and 90 W/m² of cooling power and could also be used for heating in winter, but for reasons of comfort heating power in this system should not exceed 50 W/m² and additional convectors or radiators have to be installed.

Advantages of this concept compared with standard solutions

- The cooling machine can be dimensioned 30-40% smaller than it would be possible in conventional systems, because cooling power can be stored in the volume of the ceiling.
- High thermal comfort because of small temperature spread between the surrounding surfaces.
- Significant lower installation cost

Disadvantages of this concept compared with standard solutions

- Cooling control within separated rooms is not possible, but in most cases not necessary anyway.
- Billing the amount of cooling energy is possible only via m² floor space.

Concept 2: Combined floor heating- / cooling-system with uncased ceiling

In this concept a special patented heating-/cooling-screed (system Behr) is used to transfer the heat /cooling energy into the rooms. This system has a lower storage volume so that a separated control of single rooms is possible. With this system cooling feed temperatures in the summertime can be lowered down to 12°C what leads to a cooling power up to 47 W/m² with cased, and 75 W/m² with uncased ceiling.

Advantages of this concept compared with standard solutions

- The cooling machine can be dimensioned 30-40% smaller than it would be possible in conventional systems
- High thermal comfort because of small temperature spread between the surrounding surfaces.
- Significant lower installation cost

Disadvantages of this concept

- Thermal- and acoustic insulation measures have to be enhanced

After simulating the building with a dynamic building simulation software, the requests heating and cooling power and the power of the heat-transferring surfaces shows as following:

- **Cooling**

  Office building with attached laboratory and production

- Cooling power required: 90 kW with activated building parts
  130 kW with standard systems
- Cooling surfaces: 3400 m² (concept 1 = ceiling space)
  (concept 2 = floor space)
- Cooling power: 28 W/m² active / uncased ceiling
  38 W/m² floor cooling with uncased ceiling

Realization

Concept 1: Building part activation 35 - 90W/m²
Concept 2: Floor cooling 22 W/m² (17°C feed temperature)
47 W/m² (12°C feed temperature)

- **Heating**

  Office part with laboratory and production

- Heating power required: 188 kW or 55 W/m²

Realization

Concept 1: Activated building parts + convectors

- 25% via activated building parts 3400² with 25°C feed temperature 14W/m² 49 kW
- 16 % via air-handling system with air refreshing rate 0.6 and 35°C feeding air temperature 9W/m² 30 kW
- 58% via convectors at the facades, height: 20cm, heating Temperature: 55/45°C 32W/m² 109 kW

Concept 2: heating-/cooling-screed (system Behr)

- heating-/cooling-screed 3400² with 30°C feed temperature 30-70 W/m² 102-238 kW
- 16 % via air-handling system with air refreshing rate 0.6 and 35°C feeding air temperature 9W/m² 30 kW

4 Table of total cost approximation

Approximation of the Heating and Cooling production

- Estimation of heating costs

The connection to the heat net is compulsive, so there are no other solutions for the heat supply. The costs for the installation of the transfer unit with control devices, building supply line and a building cost subsidy add up to 28.000 Euros for a connected power of 200 kW.

- Estimation of cooling costs

Option 1: Conventional electrical driven compression cooling machine
Option 2: Thermal absorption cooling machine driven by the heat net
Option 3: Contracting solution with SWE running an absorption cooling machine in the Elektror building

For an economical comparison the cooling cost of each option is calculated with the annuity method according to VDI 2067 page 1 over a period of 14 years. The actual cooling costs include all arising expenses like investment including cooling tower, installation and maintenance, and all costs of operation including electricity, heat and water.

The yearly annuity a [€] of the investment K [€] is determined by the invest loan z [%/100] and the service lifetime n over the factor of annuity AF like the following equations:

$$a = K \cdot AF$$

$$AF = z\frac{(z+1)^n}{(z+1)^n - 1}$$

The yearly overall-costs GK are calculated out of the sum of annuity, the maintenance costs WT and the operation costs for electricity SK, heating energy WK and costs for water WaK:

$$GK = a + WT + SK + WK + WaK$$

The specific cooling costs SpezK result from the division of the yearly overall cost GK with the yearly cooling demand $Q_{Kühl}$:

$$SpezK = \frac{GK}{Q_{Kühl}} \qquad [€/kWh]$$

The specific cooling costs were determined for each option as displayed in the figures 4 and 5. For the calculation the following energy and water prices were used.

Costs of heating:	0.0500€ / kWh (for the absorption chiller)
Costs of electricity	0.1326€ /kWh (price for electricity for industrial customers)
Increase of prices:	4%
Costs of water:	1.77 € / m³ for fresh water
	1.98 € /m³ for effluent water

ELECTRICAL COOLING	Approximation of costs and system layout		
		Eingabespalte:	
cooling power	Cooling power required	105	kW
demand of cooling power	Yearly demand of cooling energy	140	MWh
hours of use	Yearly runtime	3000	h
	Yearly full load hours	1333	h
COP	COP of the planned cooling machine	4.0	--
	service life time	14.0	
Investment cooling machine	specific investment per kW cooling power	300	EUR/kW
	net investment of the cooling machine	31,500	EUR
	Percentage for installation and tubing etc. in % of the net investment	35	%
	Gross investment of the cooling machine	42,525	EUR
Investment cooling tower	Recooling power necessary	131	kW
	Specific investment for cooling tower per kW cooling power	45	EUR/kW
	Net investment cooling tower	5,895	EUR
	Percentage for installation and tubing etc. in % of the net investment	80	%
	Gross investment of the cooling tower	10,611	EUR
Overall investment cooling machine	investment including installation ect.	53,136	Euro
	yearly interest rate in percent	5.0	%
Costs of operation	Yearly maintenance costs in percent of investment	3.0	%
	Alternatively: yearly maintenance costs:		Euro
Costs of consumption	Costs of electicity (in Euro/kWh, z.B."0,12" Euro)	0.1326	Euro/kWh
	Yearly price increase electricity	4.0	%
	Yearly electricity demand cooling machine	35,000	kWh
	Electrical power cooling tower	2.0	kW
	Yearly demand of electricity cooling tower	2,667	kWh
	Electrical power cooling-circuit-pump	2.0	kW
	Yearly demand of electricity cooling-circuit-pump	2,667	kWh
	Yearly overall demand of electricity	40,333	kWh
	costs of water	1.98	Euro/m3
	Cooling water demand max. performance	0.30	m³/h
	yearly demand of cooling water	400.00	m3
Factor of annuity (is calculated)	0.101		
Annuity	5,368.01 Euro		

Fig.4: Approximation of cooling costs for option 1

THERMAL COOLING	Approximation of costs and system layout		
		Eingabespalte:	
cooling power	Cooling power required	105	kw
demand of cooling power	Yearly demand of cooling energy	140	MWh
hours of use	Yearly runtime	3000	h
	Yearly full load hours	1333	h
COP	COP of the planned cooling machine	0.7	--
	service life time	14.0	
Investment cooling machine	specific investment per kW cooling power	453	EUR/kW
	net investment of the cooling machine	47565	EUR
	Percentage for installation and tubing etc. in % of the net investment	25	%
	Gross investment of the cooling machine	59456.25	EUR
Investment cooling tower	Recooling power necessary	255	kW
	Specific investment for cooling tower per kW cooling power	31	EUR/kW
	Net investment cooling tower	7905	EUR
	Percentage for installation and tubing etc. in % of the net investment	60	%
	Gross investment of the cooling tower	12648	EUR
Overall investment cooling machine	investment including installation ect.	72104	Euro
	Advancement in percent	0	%
	Investment less advancement	72,104.25	Euro
	yearly interest rate in percent	5.0	%
Costs of operation	Yearly maintenance costs in percent of investment	3.0	%
	Alternatively: yearly maintenance costs:		
Costs of consumption	Costs of electicity (in Euro/kWh)	0.1326	Euro/kWh
	Yearly price increase electricity	4.0	%
	Electical power cooling machine	0.50	kW
	Yearly electricity demand cooling machine	1,500	kWh
	Electrical power cooling tower	3.0	kW
	Yearly demand of electricity cooling tower	3,999	kWh
	Electrical power cooling-circuit-pump	2.0	kW
	Yearly demand of electricity cooling-circuit-pump	2,666	kWh
	Yearly overall demand of electricity	8,165	kWh
	Costs for heating	0.05	Euro/kWh
	Yearly demand of heating power cooling machine	199,950	kWh/a
	costs of water	1.98	Euro/m3
	Cooling water demand max. performance	0.60	m³/h
	yearly demand of cooling water	799.80	m3
Factor of annuity (is calculated)	0.101		
Annuity	7,284.26 Euro		

Fig. 5: Approximation of cooling costs for option 2

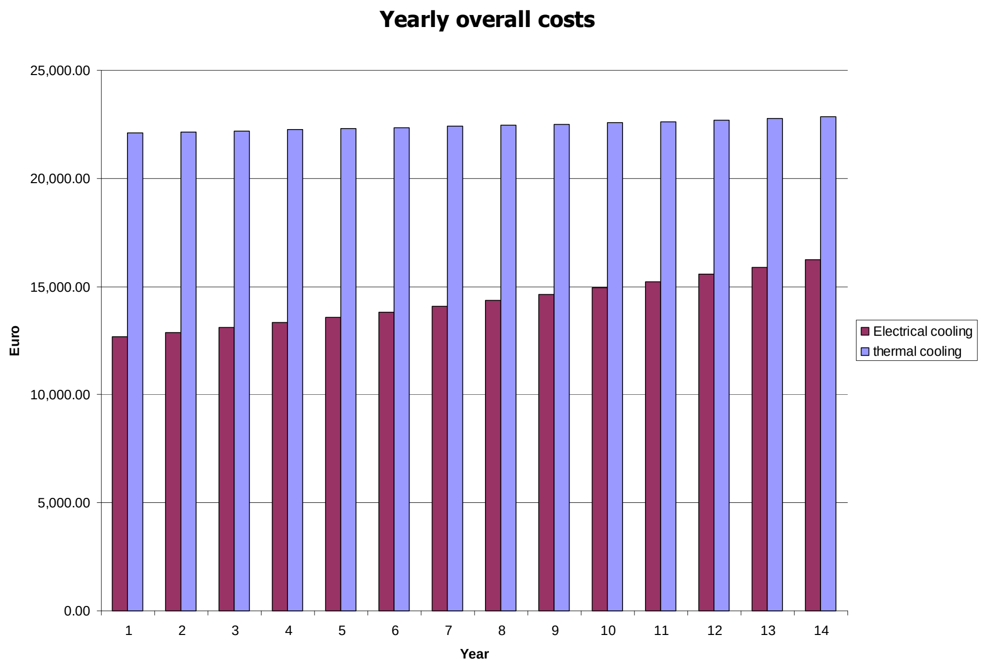


Fig. 6: Comparison of the yearly overall costs

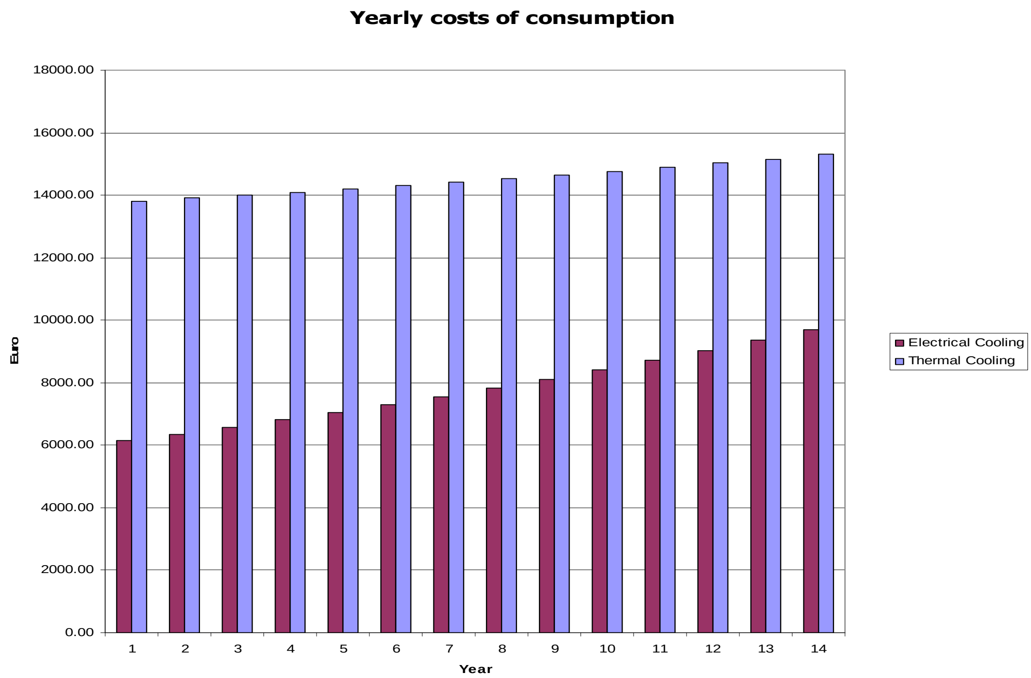


Fig. 7: Comparison of the yearly costs of consumption

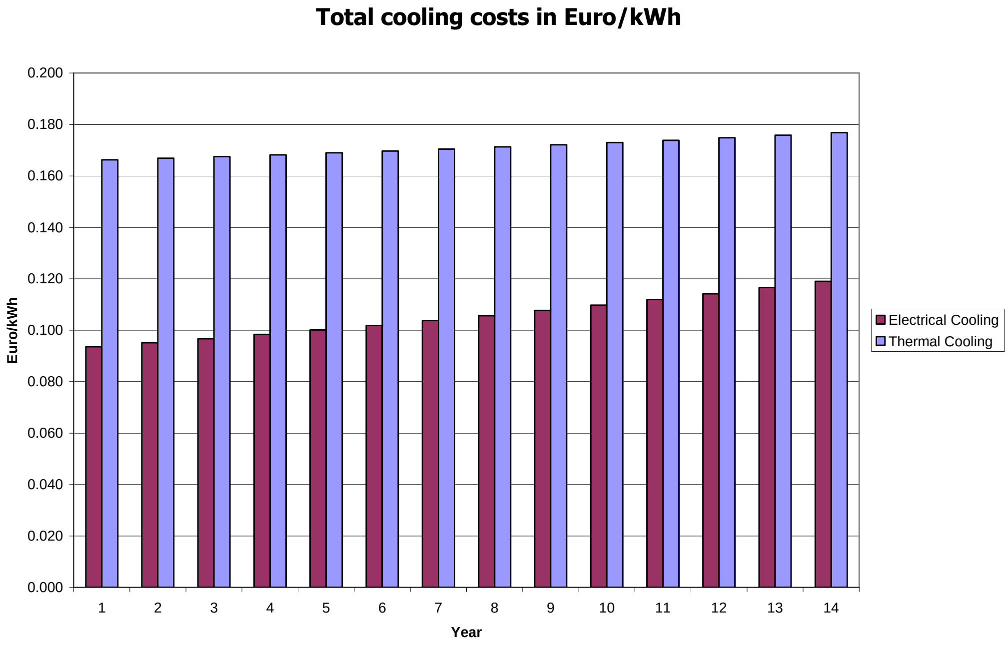


Fig. 8: Comparison of the total cooling costs

As Fig. 8 shows, total cooling costs over a period of 14 years result as following:

- Absorption cooling machine:	0.153- 0.162	€/kWh cooling energy
- Electrical compression cooling machine	0.104- 0.130	€/kWh cooling energy

This shows that a supply of cooling power with an absorption cooling machine is more expensive than a conventional electrical compression cooling machine, as long the machine is prosecuted by the Elektror company. This is mainly due to the heat costs calculated with 5ct/kWh during the whole year. The difference between the two options is decreasing because auf the increasing costs of electricity and the constant prices for heat.

A different study using a different type of electrical cooling machine with integrated re-cooling device results in a price of 0.11 ct/kWh for the Elektror building.

The company Stadtwerke Esslingen will offer a price slightly below the price of a conventional compression cooling machine if the absorption cooling machine is delivered in the contracting model. A definite price will be set after a more detailed and reliable study, being conducted by the zafh.net institute.

Estimated yearly energy costs for heating and cooling

The yearly energy costs displayed in Fig.4 are based on the following data:

Costs for heating - yearly demand of heating energy 73000 kWh/a
- price for district heat 0.05 €/kWh

Costs for cooling - yearly demand of cooling energy 140000 kWh/a

- price for cooling energy

Option1:
Absorption cooling machine
Operator: Elektror ~ 0.16 €/kWh

Option2:
Compression cooling machine
Operator: Elektror ~ 0.11 €/kWh
Option3:
Absorption cooling machine
Operator: SWE ~0.11 €/kWh
(temporary statement)

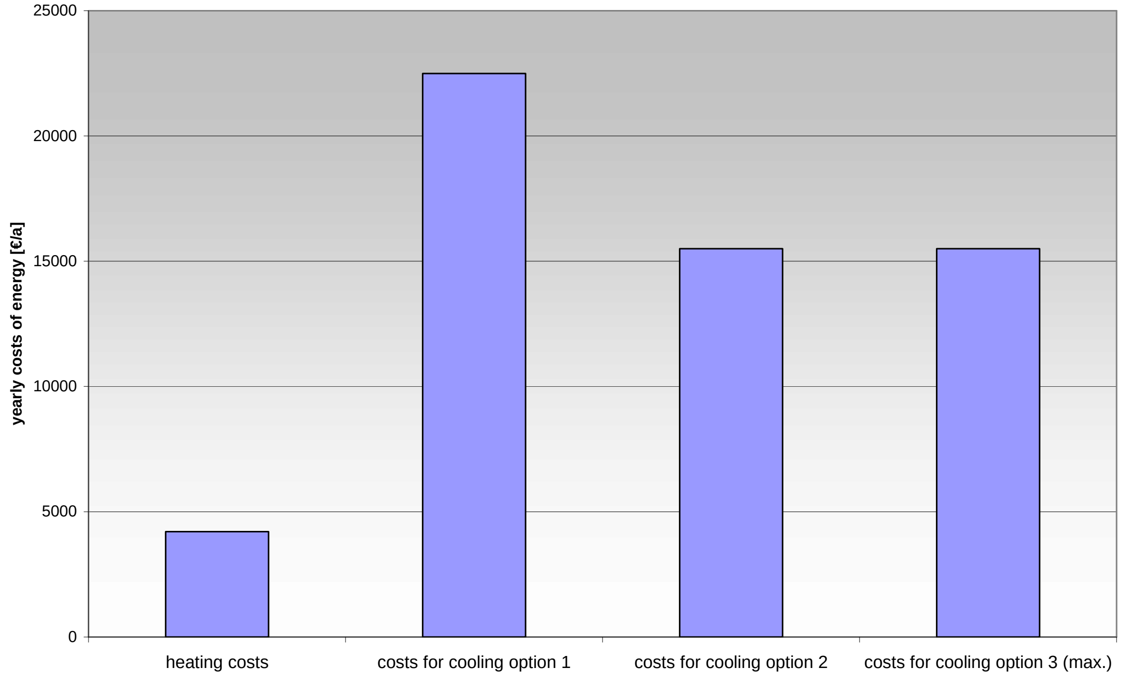


Fig. 9: Estimated yearly energy costs for all tree options