ILK Dresden

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(Summary)

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(Summary)

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Key

Symbols

Δ	Difference
$\dot{V}$	Air Volume flow rate
w	Velocity

Abbreviations

East	Façade facing East
South	Façade facing South
West	Façade facing West
North	Façade facing North

1 Introduction

Modern office buildings are smaller, new considerations for the modern office include flexible room layout and effective thermal mass storage. Modern architecture uses more glass for external walling, which increases the solar gains. The thermal load in the area is also substantially increased by the technology used in the modern office. Bearing this in mind the critical comfort requirements of air quality and space temperature can only be achieved in new buildings by employing the latest air conditioning technology. At the same time there is also pressure for cost reduction imposed by rising energy prices and government controls to limit primary energy consumption.

Due to the changing requirements a trend in space and building air conditioning is to have decentralised air conditioning or partial conditioning. These approaches, which have been developed in the last few years, provide solutions for both heating and cooling. This is now proving popular in the latest modern offices. The main arguments for this technology are the high degree of flexibility, the individual control as well as the local energy monitoring and the small spatial requirements. Disadvantages of this system are e.g. increased inlet temperatures from outside, condensation removal and above all maintenance. The advantages and disadvantages, which arise as a result of decentralised air conditioning compared with centralised plant, are evaluated in this report.

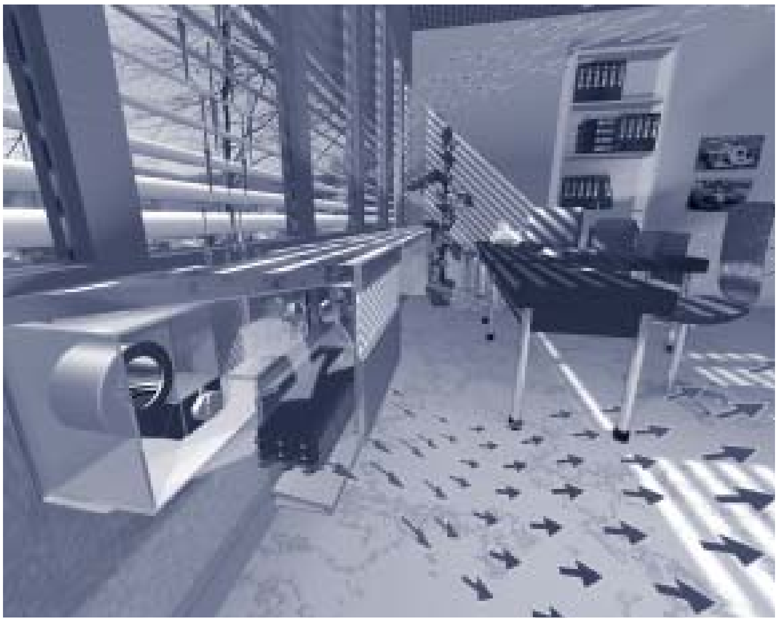

Figure 1 Example of Decentralised Air Conditioning

2 Heating and Cooling Capacity required in Different Seasons

2.1 Sample Building

For the investigations a sample office Tower with 30 occupied floors was selected. The orientation of the façades has crucial influence on the heat loads from solar radiation and hence on the cooling load required. Thus in the interests of producing generalised results the sample tower building was assumed to be square with the same percentage glazing on each façade. It was assumed the office floor was open plan and that the required temperature was the same over the whole floor.

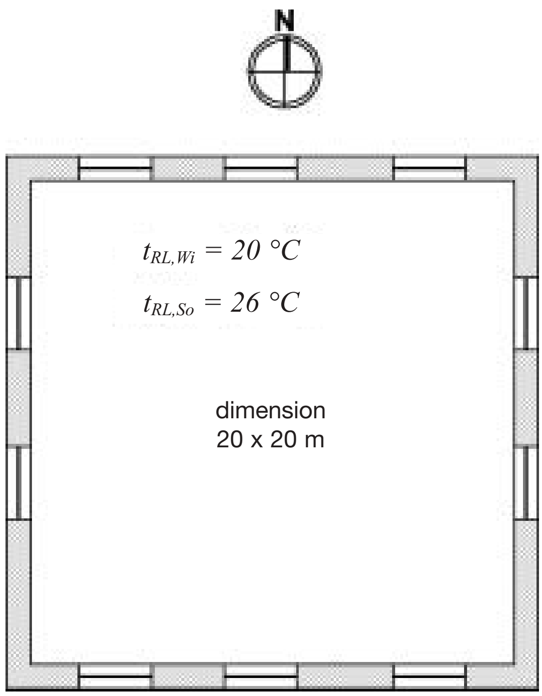

Figure 2 Building sketch and orientation

Building:

Building Construction-Weight Class:	Mean (no secondary false ceiling); Light (with secondary false ceiling)
External Wall:	k = 0.36 W/m^2 K
Climatic data:	Frankfurt am Main
Glazing percentage:	36 %
Glazing:	Solar Control Glass k = 1.3 W/m^2 K Transmission Factor g = 0.4
Solar Protection:	Horizontal blinds where there is direct radiation

Use:

Occupants:	40 People working from 8.00 until 18.00 hours
Fresh Air:	60 m^3/h per Person (Open Office Plan DIN 1946)
PC:	40 PC's at 225 W from 8.00 until 18.00 hours (Diversity 0.8)
Lighting:	10 W/m^2 from 8.00 until 18.00 hours
Required Temperature Winter:	20°C
Required Temperature Summer:	22..26°C (in accordance with DIN 1946 T2)

Table 1 Results of the cooling load and capacity requirement calculations for an office floor

	Centralised Air Conditioning With False Ceilings Construction Weight Class L	**Decentralised Air Conditioning** Without False Ceilings Construction Weight Class M
max Cooling Load	21.0 kW	20.3 kW
max Specific Cooling Load	52.5 W/m^2	51 W/m^2
Annual Energy Requirement Heating	14.4 MWh	14.1 MWh
Annual Energy Requirement Cooling	7.5 MWh	7.4 MWh

It must be noted that the impact from the heat absorbed by the floor/ceiling slab was low with respect to the overall cooling load. Other influencing structural factors such as window surface area or the type of solar protection have a significant effect on the cooling requirements of the building.

2.2 Comparison of Energy required for Central Air Conditioning compared with Local Perimeter Systems

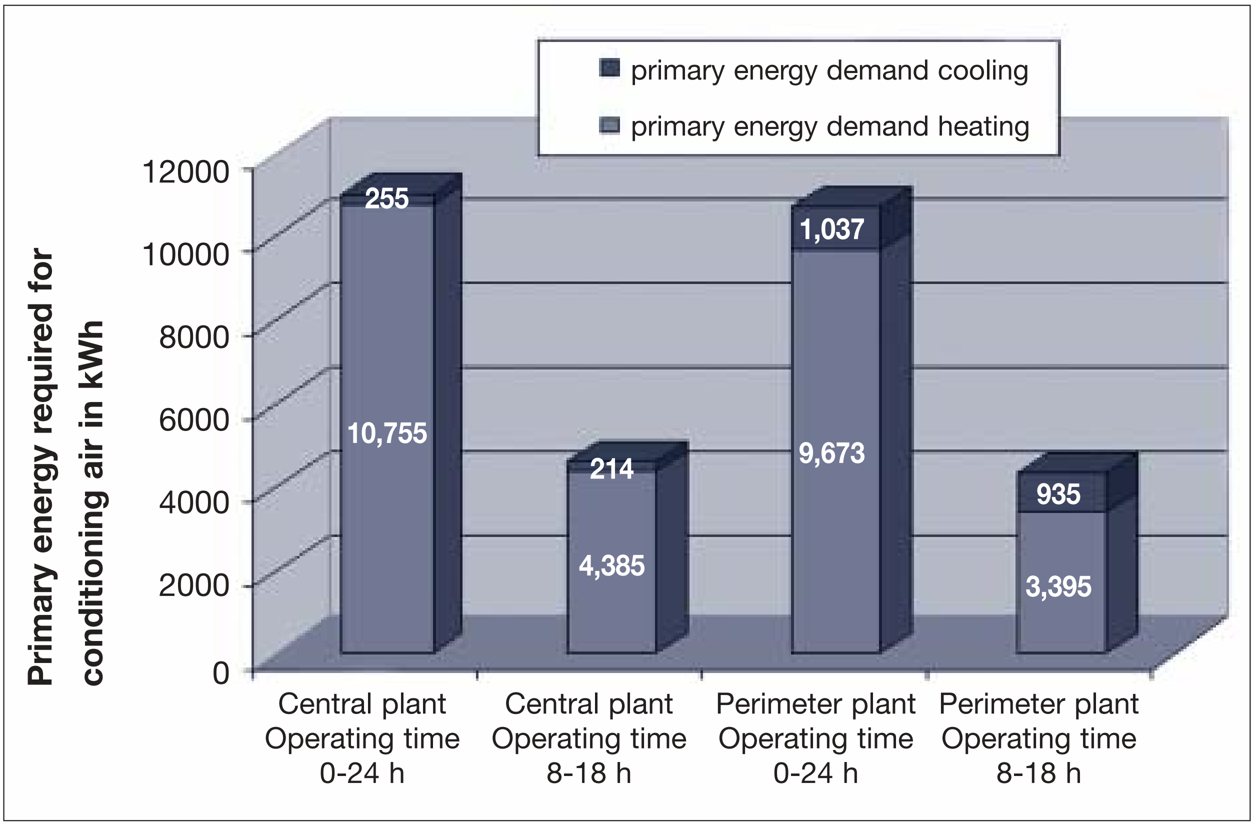

Figure 3 Yearly primary energy requirements to condition the external air (external air quantity 300 m^3/h; without condensation, without fan energy)

With the central air processing plant option the outside air can be drawn from high level using for example, roof top pent house louvres, whereas perimeter systems by their very nature must draw air in from specific areas of the façade. This can result in summer in higher inlet temperatures and hence higher energy demands for perimeter systems. However many central plant systems also draw air in from the sides of the building.

In this case the yearly energy requirements for conditioning of the air are the same for both systems. Figure 4 shows the primary energy required for perimeter ventilation equipment to condition outside air in comparison with a centralised system (with air inlet at high/roof level). The primary energy demand of both systems is almost equivalent. Figures 3 and 4 also show that shutting down the systems outside of normal working periods results in substantial energy-saving.

With an office complex rented out to different companies, working times can vary significantly from company to company depending on the type of business involved. Centralised ventilation equipment must be working for the entire duration in which people are in the space. As a result areas can be conditioned when they are not in use. The individual control abilities of decentralised ventilation systems are clearly an advantage. In these circumstances shutting down or reducing the provision of fresh air to non occupied spaces will result in substantial operating cost reductions when using perimeter ventilation equipment.

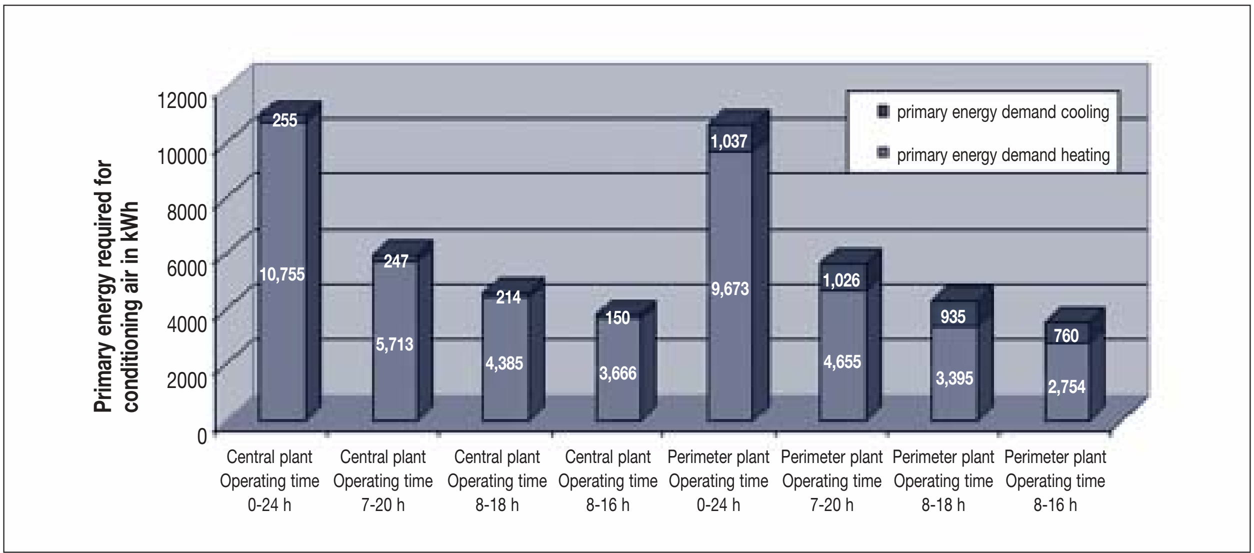

Figure 4 Yearly energy required to condition external air as a function of the period of operation (external air quantity 300 m^3/h; without condensation, without fan energy, location Frankfurt/M)

2.2.1 Comparison of Energy required for Central Air Conditioning compared with Local Perimeter Systems in Warm Climates

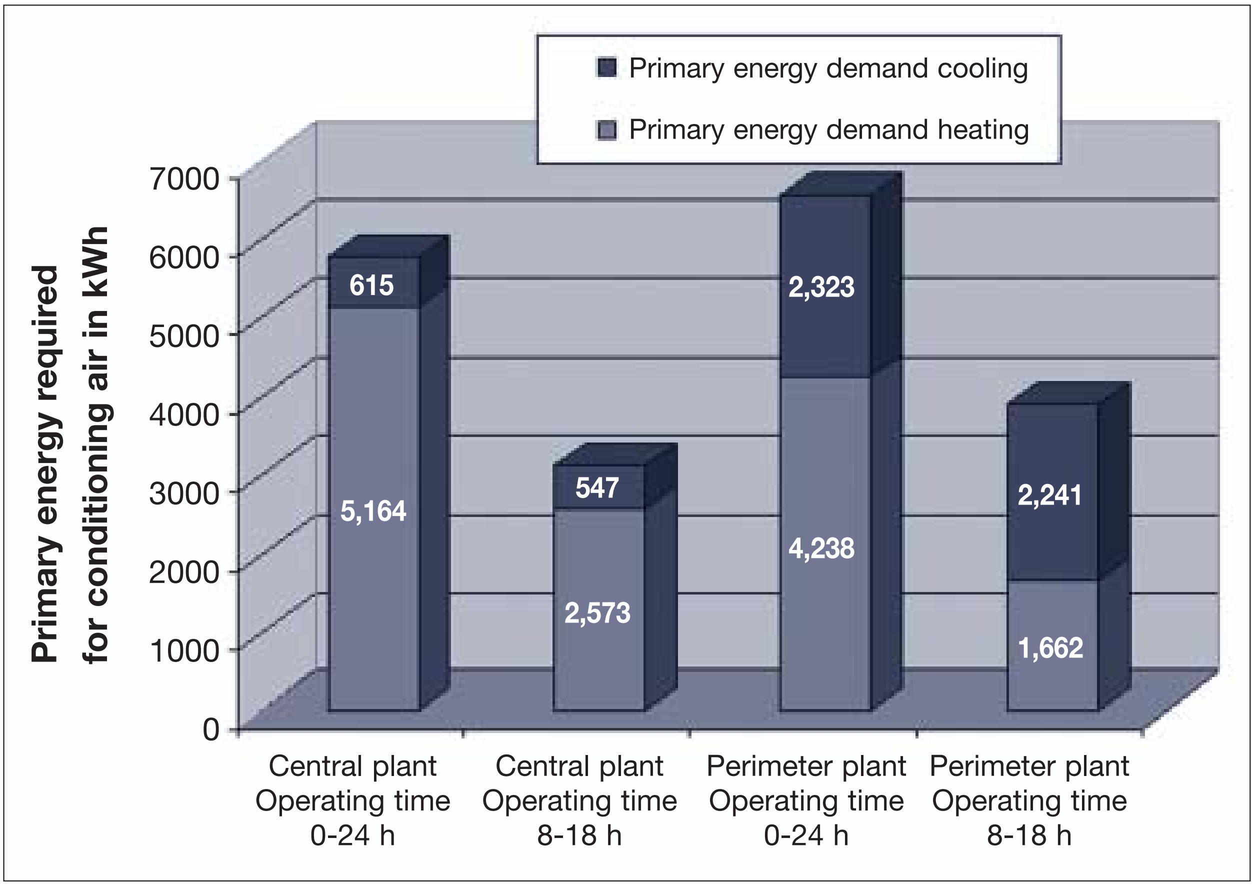

Figure 5 Yearly energy required to condition external air for climate conditions in Lisbon / Portugal (external-air quantity 300 m^3/h; without condensation, without fan energy)

As shown in figure 5 the conditioning of external air in the case of centralised plant (with roof mounted intakes) offers primary energy advantages. In the case of perimeter systems when considering office hours between 8.00 and 18.00 hours, the cooling energy required exceeds that for heating. Thus decentralised systems can offer energy savings if the usage periods for individual offices are concentrated in early and late shifts.

3 Comparison Centralised vs. Decentralised Systems

Advantages of Centralised System (Traditional Air Conditioning)	**Advantages of Decentralised System**
• Energy Efficient Conditioning of Outside Air (with roof mounted intakes)	• Easy Distribution of Cooling Capacity
• Heat Recovery at Lowest Possible Costs	• Individual Use results in Lower Costs
• Alternative Air Conditioning possible (sorption-supported air conditioning)	• Individual Room Temperature and Fresh Air Volume Flow Adjustment
• Full Air Conditioning with Low Costs	• Low Structure Costs (smaller area required, less fire protection required)

3.1 Technical Concepts

3.1.1 Centralised System

When comparing the two options the centralised solution for office air conditioning is less suitable due to its higher energy and space requirements. Because of this, the comparison of the two systems is primarily based on conditioning the outside air and meeting the local internal temperature requirements by the distribution of conditioned air to the occupied spaces. The energy transfer to cool a space in both cases uses water as the prime source. In the central plant situation cold air is produced centrally and ducted to the individual rooms. With this solution local/room temperature control and local system shut down can be provided but is not essential.

3.1.2 Decentralised System

In order to have flexibility of space layout the floor plan is crucial. To provide a high degree of layout flexibility decentralised perimeter based systems offer major advantages. In the past, this type of system has only been used for ventilation and heating. In the last few years, the provision of cooling, dehumidification and air filtration have been introduced. Modern perimeter ventilation units also offer the possibility of heat recovery. Apart from the flexibility of the decentralised air conditioning systems, an individual can easily change the local temperature as required. The decentralised air conditioning system issues include concerns of acoustics, heat recovery, maintenance and the auxiliary power supply and return system, all of which have to be considered.

3.2 Space required for Decentralised Conditioning of Air

Table 2 Space required for centralised and decentralised conditioning of air

	Centralised System	Decentralised System
Room Height	2.65 m	2.65 m
Slab to Slab Height	3.60 m	3.00 m
Slab Thickness	350 mm	350 mm
False Ceiling Void	600 mm	
Place for Vent	86 m^2	
Central Unit	34 m^2 – 69 m^2 (VDI 3808)	
Central Air Plant	275 m^2	
Total Floor Area	361 m^2	
	The space required for the air supply, exhaust silencer and chillers are not included.	

It is to be considered that the decentralised system has the advantage with respect to constructional complexity. The decentralised systems do not require the costs of the air distribution ducts, and the fire protection dampers that have to be fitted throughout the distribution duct system. The space requirement for the risers, a necessity with centralised air conditioning, is not needed with the decentralised system.

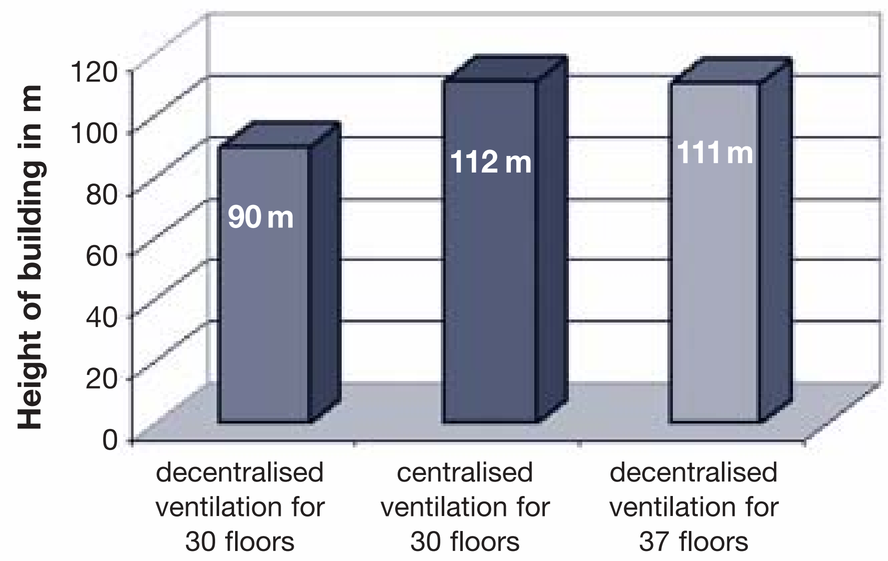

Figure 6 Height of a building with decentralised air conditioning compared with a building with centralised air conditioning and distribution

By saving the false ceiling void and hence the resulting smaller slab to slab height the overall height of the sample building can be reduced approx. 22 m whilst maintaining the same letable floor area. As the construction costs of a building increase linearly with building height the benefit of this saving is approximately 20 % when comparing decentralised with centralised systems.

3.3 Energy Required for Outside Air

Electrical power consumption is generally similar when comparing centralised and decentralised systems, despite of the lower efficiencies associated with the decentralised fan motors. In the case of comparing air transport power required there is no clear demarcation. By the use of EC-fan motors (electronically commutated direct current type) with an efficiency of > 20 %, a significant energy saving can be achieved. Furthermore, there is a possible energy-saving potential with the decentralised system with its possibility of demand oriented de-activation (see 2.2).

Table 3 Computation values for an approximate performance determination for the centralised air conditioning

Size	**Amount**
$\Delta p_{V,\ RLT^*}$	500 Pa
$\Delta p_{V,\ duct\ system}$	450 Pa
$\dot{V}$	9600 m^3/h
η_{total}	0.6
P_{Fan}	4.2 kW

Table 4 Computation values for an approximate performance determination for the decentralised air conditioning

Size	**Amount**
$\Delta p_{V,\ RLT^*}$	220 Pa
$\Delta p_{V,\ duct\ system}$	0 Pa
$\dot{V}_{unit}$	100 m^3/h
n_{unit}	96
η_{total}	0.15
P_{Fan}	3.9 kW

* RTL = room air control system

The air balance is very expensive and complicated with the decentralised air supply. Wind pressure at the façade of the building leads to variable pressure ratios between inside and outside, which results in the fan operating point to changing. This effect can only be avoided by appropriate engineering.

3.4 Possibilities of Heat Recovery

The energy-saving potential from heating and/or cooling recuperation is a possibility for cost reduction. The possibility of using such an energy recovery depends on the relationship between use and expenditure. From an energy view point, heat recovery (WRG) is possible, which then leads to energy saving. However, the possible additional energy cost must be less than the energy quantity, which can then be saved. A net reduction of the energy used is thus reflected by reducing operating costs. If the reduced expenditure for the operating cost can cover the additional capital and maintenance costs, a heat recovery is economic.

3.4.1 Evaluation of the Results

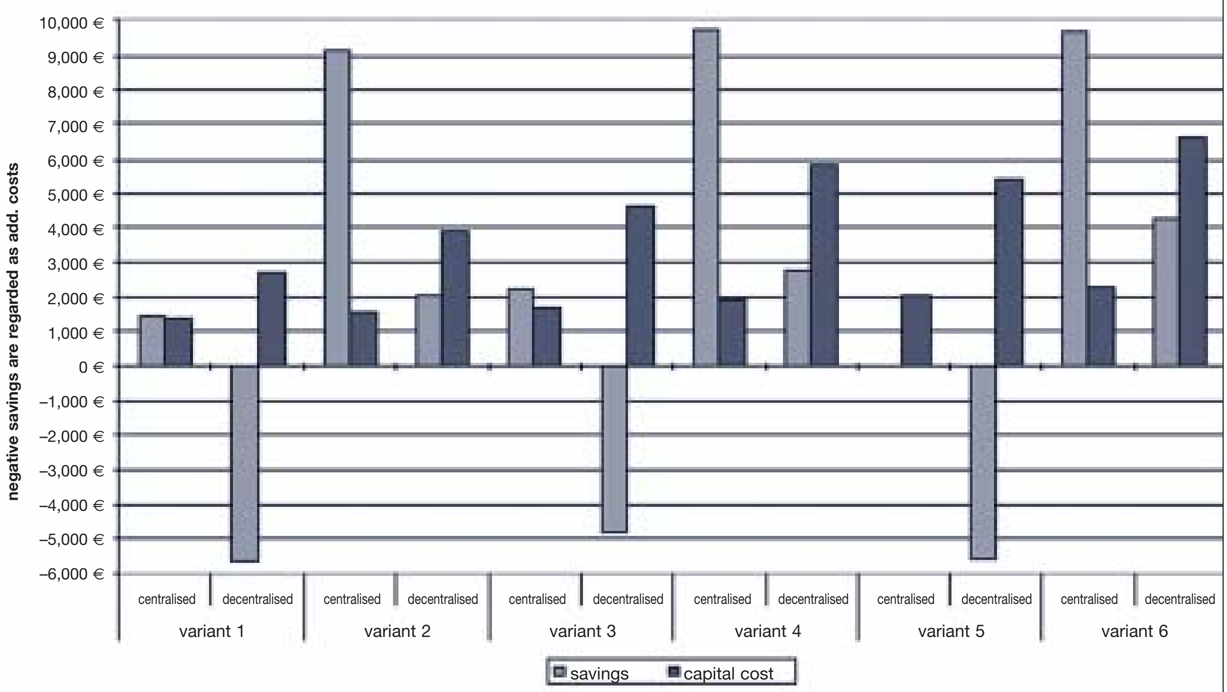

Figure 7 Economic comparison using the annual equivalent annuity method

Variant 1	Variant 2	Variant 3	Variant 4	Variant 5	Variant 6
WRG with plate-type heat exchanger heater/cooler	Preheater WRG with plate-type heat exchanger final heater/cooler	WRG – Regenerator with rotary mass storage heater/ cooler	Preheater WRG – Regenerator with rotary mass storage heater/ cooler	As Variant 1, but with 1.5-times outside air flow rate	As Variant 2, but with 1.5-times outside air flow rate

Figure 7 shows the economic comparison using the annual equivalent annuity method. The yearly maintenance and capital costs, which relate to heat recovery are compared with the achieved savings of heat recovery. The negative savings for decentralised systems in the variants 1, 3 and 5 have to be regarded as additional costs when compared with air conditioning without heat recovery. That is when heat recovery is used in these variants there is no cost saving rather that additional costs arise. Thus, the variants 1, 2, 3, 4 and 6 in combination with a centralised heat recovery are economic. The minimal operational cost savings in comparison with the significant capital costs show that variant 5 is not an economic solution. With decentralised systems heat recovery can only be considered as economic in restricted applications.

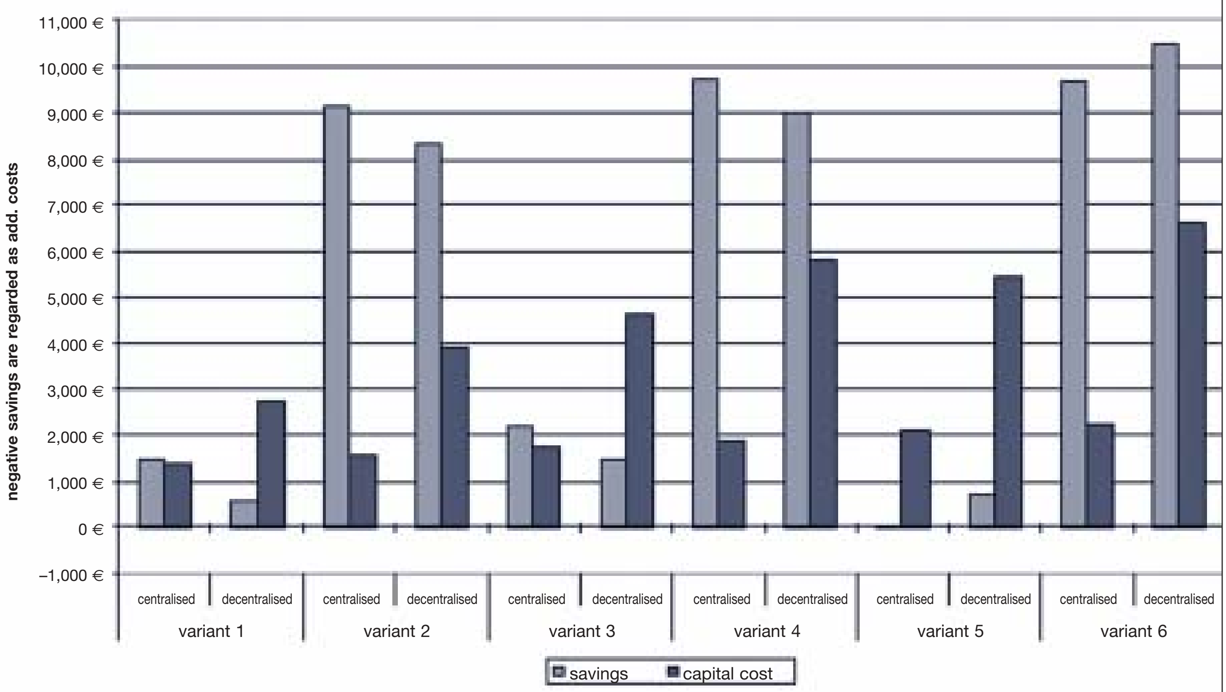

Figure 8 Economic comparison with reduced maintenance costs

Variant 1	Variant 2	Variant 3	Variant 4	Variant 5	Variant 6
WRG with plate-type heat exchanger heater/cooler	Preheater WRG with plate-type heat exchanger final heater/cooler	WRG – Regenerator with rotary mass storage heater/ cooler	Preheater WRG – Regenerator with rotary mass storage heater/ cooler	As Variant 1, but with 1.5-times outside air flow rate	As Variant 2, but with 1.5-times outside air flow rate

The influence of these costs on the profitability has been separately examined. The time required for maintenance of each piece of equipment was reduced from 10 min/a to 2 min/a. The results are plotted in figure 8. The decentralised systems with preheaters (variants 2, 4 and 6) require the least amount of time and energy. A further investigation based on a maximum allowed maintenance time of 6 min/a for each piece of equipment has yet to be evaluated. In practice, to achieve these low time rates maintenance can only take place once a year and it must therefore cover filter change, dust removal from the heat-transfer equipment and heat recovery devices at the same time.

In the summer with an assumed exhaust temperature of 24 °C and an outside ambient of 20 °C, the operation of the heat recovery system will result in an additional cooling load of 1,096.3 kWh/a. To avoid this increase in energy requires a bypass of the heat recovery system which is necessary to enable free cooling to be used.

The heat recovery provides no energy conservation, but results in an increased demand and is therefore bypassed. This can be achieved with a suitable control system. With the use of a centralised system the high air flow rates and lengthy distribution systems result in high energy transportation costs, in this respect decentralised system variants offer favourable solutions. High maintenance costs compared with the centralised variants do not result in an economic advantage for decentralised heat recovery with low outside air flow rates. These costs for decentralised systems can be reduced in terms of annual maintenance if filter changes, cleaning dust from the heat-transfer elements and heat recovery devices are all done at the same time. This can result in the economic application of heat recovery to these systems.

Overall variants 2 and 4 with centralised systems offer the greatest advantages. The decentralised options are attractive based on the criteria mentioned above. Basically, variants with preheaters, heat recovery with bypass and final heaters offer the best results.

4 Air Hygiene Considerations

With air-hygiene, the following factors show the goals for providing physiologically perfect air:

Table 5: Air-hygiene aspects of centralised and decentralised ventilation units

Units with Centralised Air Conditioning		Decentralised Ventilation Units	
Problem	Counter measure	Problem	Counter measure
Ducts Contaminated	Use High Quality Filtration	Equipment Casing Contaminated	Clean Regularly
Contamination of heat-transfer elements due to induction	Filter stage, regular cleaning (6 months)	Contamination of heat-transfer elements	Filter stage, regular cleaning (6 months)
Quality of the outside air	Suitable selection of intake air, multi stage filters	Quality of outside air; Short-circuit effects	Requires individual solution
Moisture content in the outside air filters	Constructional, generally problem free	Moisture content in the outside air filters	Requires individual solution
Filter change	Standard product, problem free	Filter change	Requires individual solution

Table 6 Comparison of the annual maintenance costs for centralised and decentralised air conditioning

	Centralised air conditioning 1 central unit 9600 m³/h	**Decentralised air conditioning** 96 perimeter ventilation devices each 100 m³/h
Cleaning	1 unit at 120 min/unit twice a year 4 h at 35 EUR/hr **140 EUR**	Twice a year complete 96 devices at 10 min/device Twice a year sampling 12 devices at 10 min/device Total 36 h at 35 EUR/hr **1,190 EUR**
Change of filter	1 device at 520 EUR 4 times a year* 1 device at 30 min (efficiency) 4 x 0.5 h at 35 EUR/hr **2,150 EUR**	96 devices at 7 EUR/device (material) 4 times a year* 96 devices at 2 min/device (efficiency) 4 x 3.2 h at 35 EUR/hr **3,136 EUR**
Inspection of fire dampers	18 pieces at 6 min/unit 1.8 h at 35 EUR/hr annually **63 EUR**	0 pieces at 6 min annually **0 EUR**
Cleaning of air duct system and air diffusers	Cleaning of the supply system through an air duct cleaning service. Cleaning of 350 m^2 duct at 10 EUR/m^2, 48 air diffusers (5 min each) and 24 return air devices (10 min each) 8 h at 40 EUR/hr every two years **1,910 EUR/year**	Is included in the device cleaning costs
Annual maintenance	**4,263 EUR**	**4,396 EUR**

* for polluted outside air (basis: hygiene requirements of VDI 6022)

5 Conclusions and Summary

A new trend in office air conditioning which is considered to be the new requirement for modern offices, is decentralised air conditioning. The functions include air conditioning and space cooling, and it is accomplished directly into the occupied zone. Simple ability to identify local energy usage, control of the system by the individuals as well as a high degree of flexibility and limited space requirements are the main arguments that speak for this new technology.

During this study investigations were undertaken into the economic factors of the decentralised air conditioning compared with centralised RLT plants. This included structural considerations and specifically looking into the energy and hygienic issues. For the decentralised system we have chosen perimeter ventilation devices, and for a centralised plant we selected an air and water based system. Only air conditioning systems are suitable for the high thermal loads of a modern office building, since these offices use 30-times more distributed power than previously, resulting in additional heat loads. Additionally, there are much greater demands for a good working environment.

Assuming that for centralised air systems the intake air is from roof level (pent house louvers) then the decentralised system appears to have a higher energy requirement for conditioning of the intake air in summer conditions. This is due to the perimeter systems being exposed to the potentially higher air temperatures on the building façade due to solar exposure. Whereas for the centralised system the air intake location can be selected to avoid this, i.e. roof top pent house louvers. It is known, however, that in the case of perimeter systems this additional expenditure in the summer is compensated by heating energy savings in the winter period. Both systems were compared for year round use. This is based on the relationship between yearly heating energy demand and yearly cooling load requirement for a typical place in Central Europe. In climatic regions with a higher yearly cooling load more energy is saved using a decentralised system. However, in many cases the air inlets for central plants are not ideally located, i.e. on the sides of buildings, in which case the differences between the two systems are small. Decentralised systems also offer energy advantages if adjacent areas of an office block are used at different times of day as with centralised plants all areas would be conditioned continuously. The ability of the local user to control the on/off of local units and regulate air flow rate and temperature can lead to substantial energy conservation, however, it does also create other major costs. Since perimeter ventilation units are usually not integrated into the central building management system, management of these units will have higher costs.

Further possibilities were examined regarding heat recovery with perimeter ventilation units. Due to the comparatively high intake temperatures and the additional necessary regulation and maintenance costs, only in few cases can economic advantages be shown for heat recovery systems. The focus of energy saving should rather be toward intelligent unit controls (quality control of room air).

Looking at the hygiene standards for the decentralised and the centralised systems, both have proven unsatisfactory. The design of the systems, even with filter changes, creates a substantial cost to achieve the required hygiene standards. It should not be forgotten that pollutants and odours can spread using the decentralised units. For each case with perimeter units the acceptability of short circuiting should be examined. Toilets, kitchens and extract from smoking areas should each have an individual solution for the extract air. When higher degrees of thermal comfort are desired, centralised air conditioning systems are preferred. The control of room air moisture content (dehumidification and humidification) is not economic with decentralised systems when complying with hygiene requirements.

Since for perimeter systems the supply air discharge is sill mounted, with very high cooling capacities (heat loads > 50 W/m^2) the local supply air temperatures can lead to levels of discomfort. The specific conditions of these situations should be investigated by computer simulation (CFD) and/or by full scale laboratory mock up tests. If the supply air terminals of the perimeter ventilation units can be installed in the ceiling or be combined with other cooling systems (e.g. chilled ceilings), these systems can then also be suitable for air conditioning with high heat loads.

Considering the additional expenditure for the fire protection regulations, decentralised units are an advantage, since supply air does not have to be transported through different designated fire zones (omission of fire dampers). However, the avoidance of fire transmission around the face of the building must be considered when dealing with decentralised systems. Further, a more efficient utilisation is achieved for the available floor area by lack of area requirements for the air duct risers and the central plant room. Also the costs of a false ceiling, which often hides the distribution ductwork systems, can be avoided with decentralised systems. By the omission of a false ceiling void with the same room height there is a reduction in overall building height i.e. lower construction costs.

Due to the numerous decentralised ventilation openings in the façade of the building, the effects of the wind pressure on the building cannot be ignored. For this reason control systems for perimeter ventilation units are required to avoid drafts being generated and for the compensation in the shift of the fan operating point.

If the building has a perimeter chilled water system near the façade and the necessary openings in the façade are pre-engineered, then the building can be equipped progressively. In rental situations the direct building costs can be reduced by this methodology, since the equipment requirements (product configuration) of the individual users can be very different.

Concerning the technology of air conditioning, new situations arise as a result of decentralised systems. Since the decentralised ventilation systems must be integrated into the façade of the building, the main partner and decision maker for the system is the architect. For example, it is also conceivable to provide the entire supply utilities for the ventilation units at the perimeter. Since the perimeter ventilation systems are mainly completed as far as possible in the manufacturers factory, only limited assembly is required on the building site. The main share of the cost is associated with the manufacture of the complete units. A close co-operation between façade manufacturers and equipment manufacturers is necessary and can also lead to an improved market share for both parties.

Table 7 Comparison of the various parties that contribute to costs (manufacturers and trades)

Centralised System	Perimeter Ventilation Units
Central plant manufacturer	Façade manufacturer
Component manufacturer (air diffusers, fire dampers …)	Manufacturer of perimeter ventilation units
Chilled water production and chilled water system	Chilled water production and chilled water system
HVAC contractor	
Measurement and control	Measurement and control
Chilled water production and chilled water system	

6 Review of the factors considered in the decision process

Criteria	Centralised System	Decentralised System
Equipment	Large area requirements for central plant	Small area requirements
Pressure loss in the distribution system	High	Not applicable
Efficiency of fans	High	Low
Area requirements for air distribution system	High	Not applicable
Technical expenditure for fire protection	High (distribution ductwork passing through fire protection compartments)	Small
Expenditure for the weather protection of inlet and exhaust air openings (avoidance of the moisture penetration into the filters)	Small	Higher
Condensate removal	Easily achievable	Not easy to achieve, costly
Energy costs	• In the summer smaller than decentralised solution • In winter higher than decentralised	• In summer higher than centralised • In winter smaller than centralised
Structural costs	• Higher space requirement for air conditioning and distribution • False ceiling to hide the distribution system	• Large effect on the façade design • Less assembly of components ducting etc.
Interference to the façade	Little	High
Air conditioning comfort	Full air conditioning possible	At justifiable expenditure only thermal air treatment possible
Air quality	High (centralised outside air intake at selected points)	Very different (dependent on the air quality at the inlet locations)
Pollutant transmission from other spaces	Negligible	Possible by transmission across the face of the façade
Function control (examination of the required fresh-air ratio, functions of the energy-demanding components)	Possible	Very expensive, complex due to the large number of units
Maintenance costs	Moderate	High – maintenance of the units distributed around the building
Use of the ducting system for mechanically driven smoke removal	Possible	Not possible

Criteria	Centralised System	Decentralised System
Use of the building mass for storage of cooling / heating	Not possible because of the false ceiling void	Concrete core activation possible
Construction time – assembly/installation on site	High	Low (due to modular construction)
Behaviour in the case of fire	Smoke sensor in the supply air. Plant shuts down	Smoke entry from other areas cannot be excluded
Ventilation effectiveness	High	Lower due to possible short circuiting between supply and exhaust air points on building façade
Consumer allocation/account	Air conditioning costs can only be apportioned on an overall basis	User based account easily possible
Operation/shut down	For the entire conditioned space –> long duration	For the respective area –> smaller actual operating time possible
Progressive development / refit	Very difficult, expensive	Easily achievable with appropriate preplanning
Acoustic influence on space (road noise, fans)	Avoidable at small expenditure	Expensive
Heat recovery	Inexpensive	Expensive
Regulation expenditure for basic functions	Small	Small
Expenditure for parameter monitoring for energy management	Small	High
Local required default value	• Temperature	• Temperature • Period of operation (outside air supply)
Acceptance of the users	Moderate	High due to availability of individual adjustment of parameters
Plant safety (possible estimate)	Very large functional areas	Only local functional areas