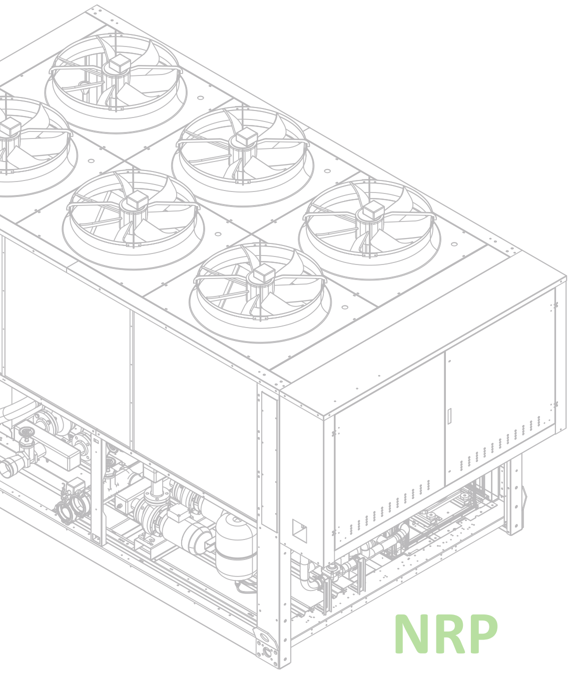
TECHNICAL FOCUS

ENERGY SAVING IN YEAR ROUND AIR-CONDITIONING BY USING SIMULTANEOUS LOADS OF OPPOSITE SIGN

COMFORT SOLUTIONS

Energy saving and energy recovery for heating and cooling: plant-engineering application of the multipurpose units NRP for 4-pipe hydronic systems.



In order to grant the better comfort conditions, while climate conditions are changing, of the buildings characteristics and of different applications and utilizations, the concept of all year round air conditioning is more and more actual. The 4-pipe plant-engineering solution certainly represents one of the best possibilities, which are able to satisfy the request when demand is changing all year long and to treat also thermal loads of opposite sign, which could require to be satisfied in a simultaneous and independent way. This phenomenon is becoming over the years more and more marked, due to the increasing variability of use of different areas in the same building and to the reduction of leakage thanks to the increasing insulations used. The use of multipurpose centralized units for the contemporary and independent production of heating and cooling energy, based on heat pump technology, are an excellent opportunity to give an answer to this need. For this plant-engineering evolution, Aermec presents, with this document, the advantages in terms of energy and economic savings resulting from multipurpose units for 4-pipe hydronic plants. The analyzed case demonstrates that in the examined commercial building the energy saving could arrive at 33%.
Consequently the obtained energy, has as immediate effect, the marked reduction of the polluting emissions, associated to the air-conditioning of the property, and also the reduction of the operating costs for the user and to offer to the owners and constructors a life-cycle cost of the plant extremely convenient compared to traditional solutions.

Technical Sales Support Department

SUMMARY

WHY MULTIPURPOSE UNITS ARE SUCCESSFUL IN AIR-CONDITIONING MARKET?

The reasons why these units are entering the market are the following:

- More attention to energy efficiency themes and savings of building-system designing
  → Valorization in heating and cooling energy recovery.

- Technological evolution of the refrigerant circuit in general as far as components, design and regulation is concerned
  → enlargement of the operating ranges of the units (outside temperatures and produces water temperature).

- Greater knowledge of the criticalities, which may concerned multipurpose units operation, adoption of appropriate design features and of regulations by manufacturers, more attention to plant requiements to be recommended to designers.
  → achieving high levels of reliability.

- Increased supply on the market of this tyoe of product.
  →improving the competitiveness of manufacturers in terms of performance and price positioning.

Chapter 1
INTRODUCTION

Multipurpose units are present in the air-conditioning market for more than 20 years. They had and increasing spread, above all in the last years, arousing growing among the thermal engineering designer and installers.

We define multipurpose unit a chiller with heat pump, with total recovery and particular architecture of the refrigerant circuit, and of specific and dedicated management logics, **is able to satisfy at the same time and independently** different plant functions.

Multipurpose units are different accordingly to the system typology for which they are designed. In particular the logic of management could be:

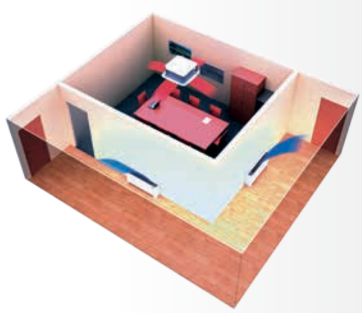
- Multipurpose units for 4-pipe system, able to deliver in the same time heating **and** cooling energy on the circuits of the system and with any partialization required;

- Multipurpose units for 2-pipe system, able to deliver heating **or** cooling energy in a 2-pipe system, and at the same time, when required heating energy at one intermediate hydronic circuit subjected to Domestic Hot Water preparation (the type with intermediate exchanger and downstream boiler, with accumulation of technical water and instantaneous downstream exchanger).

Among many reasons of the affirmation of 4-pipe systems, prevail the followings:

- Building development in the tertiary sector oriented to architechtural solutions with wide with large glass surfaces and lightweight walls, characterized by low thermal inertia;
- Increasing demand for flexibility in the use of rooms that generates a random component in the definitions of loads;
- Flexibility of performance, with the possibility to extend the number of terminals and consequently the potentiality of the system;
- High wellness and environmental comfort;
- Low energy consumptions with the possibility with use of high performance thermal recovery generators or multipurpose units.

Rooms with opposite sign thermal load, served by 4-pipe fan coil system.



Chapter 2
APPLICATIONS AND PLANT REQUIREMENTS

In modern systems and equipements for buildings for commercial use, the more frequent system-typology consists of fresh air system and fancoils.
These configurations allows an individual control of room temperature in every single room, independently from the others, and present considerable flexibility of use and elasticity of working. In this area, the possible hydronic solutions are divided into 2-pipe and 4-pipe systems.

In 2-pipe system, fancoils, always equipped with a single coil, are fed with chilled water in summer period and hot water in winter period. With this system there is no possibility to compensate thermal loads with opposite sign, that could occur in different environments and in the same period of time.

4-pipe systems are normally equipped with fan coils equipped by double heat exchanger to answer to the request for heating and cooling in a single room all year long, maintaining both chilled and hot water circuits simultaneously active. Recently Aermec developped a more convenient alternative solution (with reference to Technical Focus n°1), based on the use of a unique coil for both circuit. In both cases, upstream of 4-pipe system, two generators must be necessarily present (a chiller and a generator of thermal energy, burner or heat pump), or alternatively a unique generator able to satisfy simultaneously the request of both circuits (multipurpose heat pump).

NRP 1250 A4

Multipurpose units NRP
Units designed for 4-pipe system, able to deliver contemporarily heating and cooling energy, answering with any partialization required by users.

Examples of application:

- Shopping mall
- Multi-use buildings
- Hotels
- Business centres

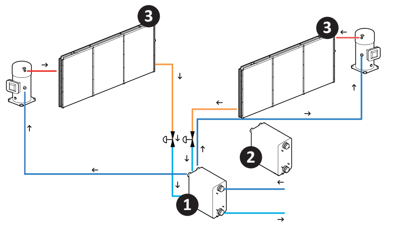
Monoblock solution with multipurpose units

This type of system, as well as lend itself to application for office buildings, finds its place also in solutions for commercial use, in particular shopping centres where also during cold season, thermal loads of opposite sign are present.

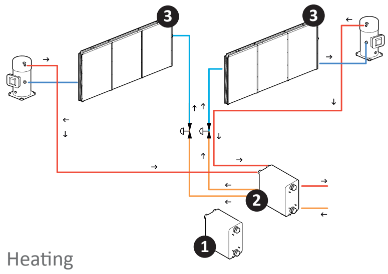
The architecture of the refrigerant circuit of multipurpose units for 4-pipe system, and the dedicated logic of regulation are designed to satisfy the thermal and cooling loads, whatever could be the load factor on heating and cooling; they transfer heat from the cold circuit to hot circuit when and if it is possible, and provide to integrate the thermal and the cooling power, which may be required in accordance to the needs.
These are machines equipped with a water-cooling condenser and a water-cooling evaporator, which remain so during the functioning in every period of the year and in every load condition, and with a heat-exchanger between cooling and the external equipment (for the air/water units with fins heat exchanger) which could work as a condenser or as evaporator depending on load condition on both circuit.

Multipurpose units are generally equipped of more refrigerant circuits, each of which could work independently from the other.
Following you could find the functional schemes of 4-pipe multipurpose units.

COOLING AND HEATING WITH OUTWARD HEAT DISPOSAL

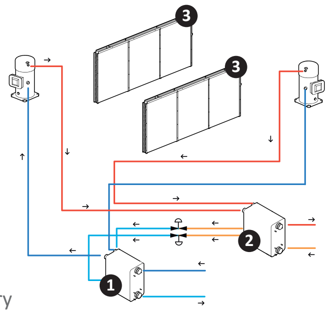


Cooling



Heating

HEAT RECOVERY WITH HEAT TRANSFER FROM ONE CIRCUIT TO THE OTHER

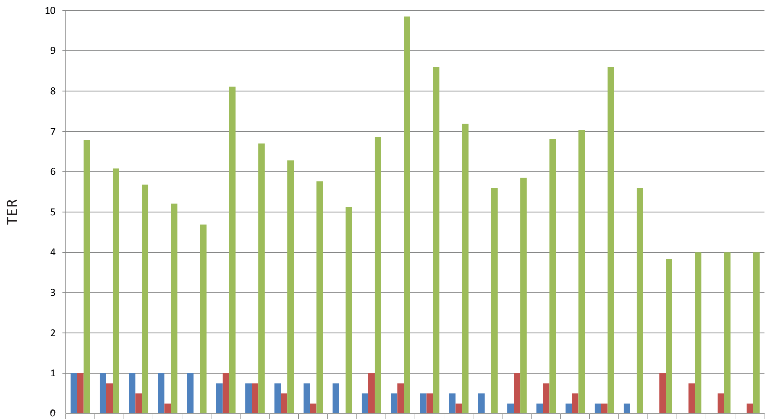


Recovery

LEGEND

1. Plant side heat exchanger chilled water
2. Plant side heat exchanger hot water
3. Source side heat exchanger

STATE OF TER INDEX OF MULTIPURPOSE NRP IN VARIOUS LOAD CONDITIONS



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
P. cooling	100%	100%	100%	100%	100%	75%	75%	75%	75%	75%	50%	50%	50%	50%	50%	25%	25%	25%	25%	25%	0%	0%	0%	0%
P. heating	100%	75%	50%	25%	0%	100%	75%	50%	25%	0%	100%	75%	50%	25%	0%	100%	75%	50%	25%	0%	100%	75%	50%	25%
TER	6,79	6,08	5,68	5,21	4,69	8,11	6,70	6,28	5,76	5,13	6,86	9,85	8,60	7,19	5,59	5,85	6,81	7,03	8,60	5,59	3,83	4,00	4,00	4,00

Please note:
State of TER for multipurpose NRP for 4-pipe system with various load conditions (produced water 7°C e 45°C external air temperature 15°C).

TER: Total **E**fficiency **R**atio is the connection between the useful effect (sum of output thermal and cooling powers) and the power required.
The TER is higher in case of balanced loads.

USER INTERFACE pGD[1] for multipurpose units of NRP series .

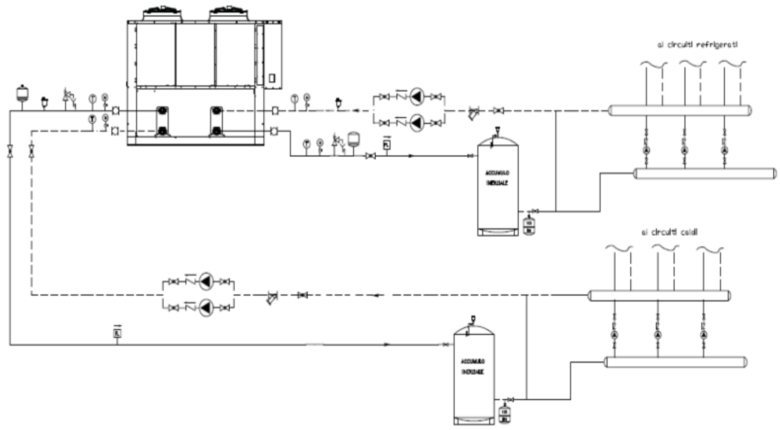
Setting of multipurpose units

The setting which manages the units satisfy loads in the proportions required, making refrigerant circuits work duly differenciated in time.
In function of the set point temperature of the hot hydronic system and on the chilled hydronic system , and of the detected temperature from water probes circulating in such systems, the management logic states which one has the higher load factor, and according to it, it determines the number of active compressors or the degree of partialization of any modulating compressors;
in function of the load on the other hydronic system, it is managed the state of operation of the refrigerant circuits and of the timing between the switching status of the same.
In order to limit the frequency in which these commutations occurr, hydronic systems connected to both plate heat exchangers (user side hot/cold) must be equipped with an adequate water content; in this way it is obtained the result of protecting the unit containing also the swings in temperatures of hot and chilled water.
The use of multipurpose units also requires attentions which increase the confort.
Unlike the case of simple chillers, it should be provided on both hydronic circuits a higher water quantity with inertial function, and the fractionation of the power on a higher number of scroll compressors, or the use of modulating compressors doesn't help to reduce the volume of water required.

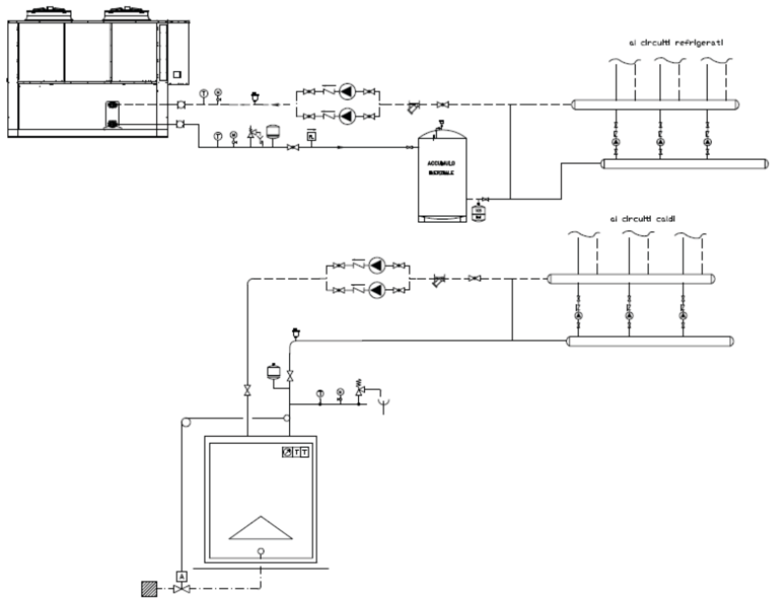
Sizing of storage tanks

Approximately the minimum required water quantity in the hot and chilled circuit place itself in a range of 7÷10 l/kW referred to the nominal cooling capacity.
This value has to be verified according to precise technical specifications of the manufacturer. Higher water quantities, if present, could contribute to reduce any further oscillation of circuit temperatures. It is however essential that in the calculation of water quantity, which constitutes the thermal flywheel, one has to consider the one circulating on the unit, or the water contained in the primary circuit and on eventual derivations on the secondary that integrate this content.

PRINCIPLE DIAGRAM
Heating-cooling unit with 4-pipe multipurpose unit.



PRINCIPLE DIAGRAM
Heating-cooling unit with condensing boiler and chiller.



Chapter 3

ENERGY AND COSTS SAVINGS

University of Orenburg
Orenburg [Russian Federation]

Building Canary Wharf
London [Gran Bretagna]

The choice to employ a multipurpose unit as generator of thermal and cooled energy to serve a 4-pipe system represents an important investment in enrgy efficiency, with the result of reducing the management costs of the system, the CO_2 emissions, and the demand of primary energy.
Now we evaluate the advantage of such an investment from all point of views, considering that in one case the choice of generators of thermal and cooling energy for 4-pipe system to serve a glass building for office use.

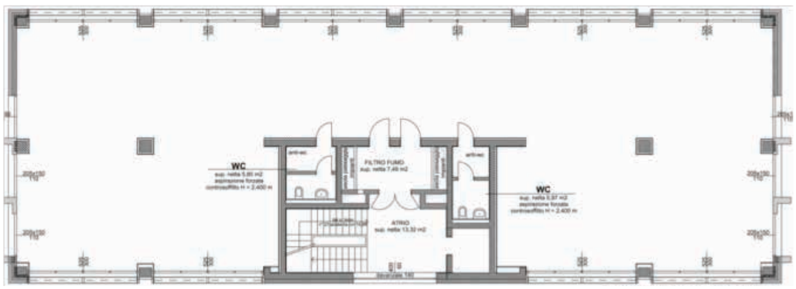
The following analysis compares the more traditional solution which provides a thermal power plant with condensing boiler and a chiller and the solution of a multipurpose unit for 4-pipe systems.

The system considered consists of a typical installation for 4-pipe fan coil units and fresh air supply plant serving an externally glazed office building. To provide a complete overview the energy analysis has been made with the same type of design (building/system), simulated in three different European locations:

- Stockholm (climatic zone **Colder**)
- London (climatic zone **Average**)
- Rome (climatic zone **Warmer**)

The three reference locations allow us to analyse the building/system using three different climatic zones, as suggested in the standard EN 14825:2011:

- Colder
- Average
- Warmer



The characteristics of the building are as follows:

- Each floor area is 576m^2 (16x36m^2)
- Each floor is 3 metres high
- There are 4 floors
- The building total gross air conditioned volume is 7000m^3
- The building total floor area is 2300m^2
- Each floor is constructed with 2 rows of offices
- All spaces are air conditioned.

Technical Focus Vol. 1

"The new way to provide comfort in 4-pipe systems application"

The system which serves the entire building is the type of fresh air, and in function of the peak loads in the offices, sizes of fan coil units with double coil are selected (main coil with three rows, connected to refrigerated circuit with project water temperature 7°C / 12°C, and additional coil with 1 row, connected to hot circuit with project water temperature 45°C / 40°C); the same temperatures feed the heating coil, cooling and after-heating of the fresh air handling unit appropriately sized, whereby they coincide with the temperatures of the set of generators.
We remind you that next to this solution, more traditional and therefore more widespread, it is now possible to use fancoils equipped with single coil (3 rows or 4 rows) and with one double outlet valve, which connects the above mentioned coil alternatively with both hot and cold circuits (Technical Focus Vol. 1: “The new way to provide comfort in 4-pipe system applications”); the greater available heat exchange hot surface permits in this case, with same size fan, to feed the heating terminals with low water temperature, and to achieve advantages in terms of energy and cost savings, both with traditional generators (condensing boilers) which, in am more accentuated way, with heat pumps and multipurpose units. The use of low temperature hot water and of higher temperature chilled water to give power to the fresh air handling unit, will make necessary to create, in it, coils with a higher number of rows.
This modification negligibly affects the overall costs and it doesn't imply substantial technical changes in the system.

Continuing with the technical discussion, we defined the sizes of generators used in simulations dimensioning them in function of the maximum loads of the building, situated in the three location examined:

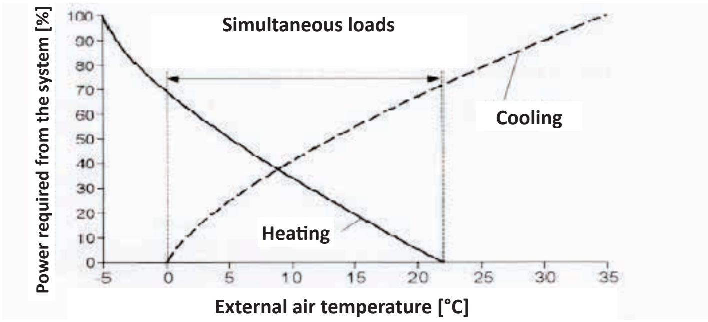
ENERGY SOURCES HEATING-COOLING

City	P cooling kW	P heating kW	Traditional solution	High efficiency solution
Stockholm	161	191	NRL 0650 A + boiler	NRP 0650 A4
London	168	116	NRL 0700 A + boiler	NRP 0700 A4
Rome	209	93	NRL 0800 A + boiler	NRP 0800 A4

The further calculation assumption and the references to the base of the carried out simulations are reported below:

- 14 power-on hours, 5 days per week
- Natural gas unit cost: see below the "opearting costs table"
- Electric kWh unit cost: see below the "opearting costs table"
- 1,968 kg CO2 issued for combustion of 1 Nmc natural gas (soruce IEA "International Energy Agency")
- 0,442 kg CO2 issued for 1 kWh electric consumed (soruce IEA "International Energy Agency")

We underline that in the calculation of the maximum thermal loads and at the various intermediate conditions it has been also computed the power of fresh air handling unit, and the used coils for the last one have been dimensioned with the same temperature kit used for fan coils.
The cost of energy, the emission of CO_2 and the demand for primary energy, of the three compared solutions, was estimated evaluating the variable tharmal and cooling load, against maximum loads, in a way depending on temperature, as reported in the following graphic.



Note:
The graph is from "Air conditioning with radiant system" - Author "M. Vio"

Following are listed the results of the carried out simulations, where the comparison was conducted in two working conditions:

- with traditional fan coil unit with double-coil, feeded with water 7°C / 12 °C e 45°C /40°C
- with fan coil unit with more powerful single coil, with 4 rows and water temperature 9°C / 14°C e 35°C / 30°C

OPERATING COSTS (SOURCE EUROSTAT)
For the calculation of annual operating costs it is mainly energy costs that have been considered. In the calculation the following values were used:

	€/Nm³	€/kWh
Stockholm	0.598	0.083
London	0.299	0.104
Rome	0.374	0.167

Note:
In the case of Stockholm, given the possibility of reaching extremely low external temperatures (-20°C), for the high efficiency solution it is necessary to provide a boiler, to be used in replacement of the multipurpose unit on the heating circuit. Such "HYBRID" system is used to optimise efficency, operating the boiler in place of the multipurpose unit with external temperatures below 0°C (at which values there is no cooling load).

Synthesis of the results

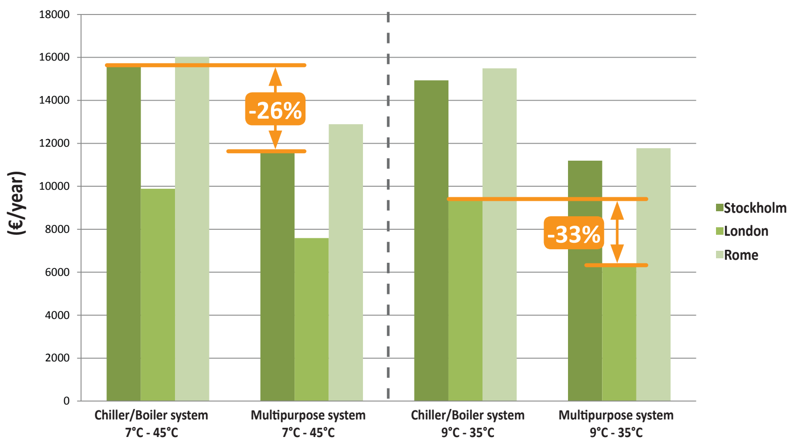
Below we resumed graphically the main results of the carried out simulations. The multipurpose solution, in economic terms, implies a reduction of costs related to yearly medium energy consumption up to 33%, in comparison to the the traditional solution chiller/boiler. These savings are more consistent in correspondance to climate conditions which promote the simultaneous presence of thermal loads of opposite sign (TER index).
We underline that the more consistent savings are reached in London, climatic zone Average, while the more restricted are reached in Rome, climatic zone Warmer, though such savings are of the same order of magnitude in all three locations examined.
If we analyse the costs related to the use of generators with modified set points, therefore increasing the cold set from 7 to 9°C and reducing the hot set from 45 to 35°C as shown in the following graphic, it is obtained a further increase of efficiency and then a decrease of energy cost.

The energy efficiency which derives from the choice to use a multipurpose unit is highlighted also from a significant reduction of emissions of CO_2 of which the estimations are reported.

With NRP the average yearly energetic cost is reduced up to 33% compared to the traditional solution.

ENERGY COST EURO/YEAR
For the services of room air conditioning.

ESTIMATION OF OPERATING COSTS (€/YEAR)

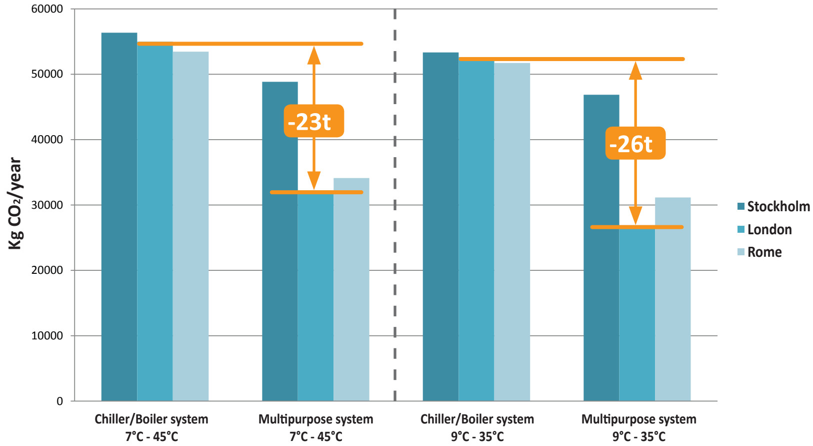


Note:
In the example were examined multipurpose units NRP for high efficiency 4-pipe system and high efficiency chillers of the NRL series with condensing boilers.
The working conditions on which the yields are compared are:
- chilled water 7°C / heated water 45°C, fan coil unit with double valve and double coil (comparison left side of the graph).
- chileld water 9°C / heated water 35°C, fan coil unit with 4 rows single coil and VCF_X4 valve (comparison right side of graph).

EMISSIONS Kg CO_2/YEAR
Graph relative to the various examined solutions.

With NRP the emissions of CO_2 are reduced up to 45% compared with traditional solutions.

EMISSIONS Kg CO_2/YEAR

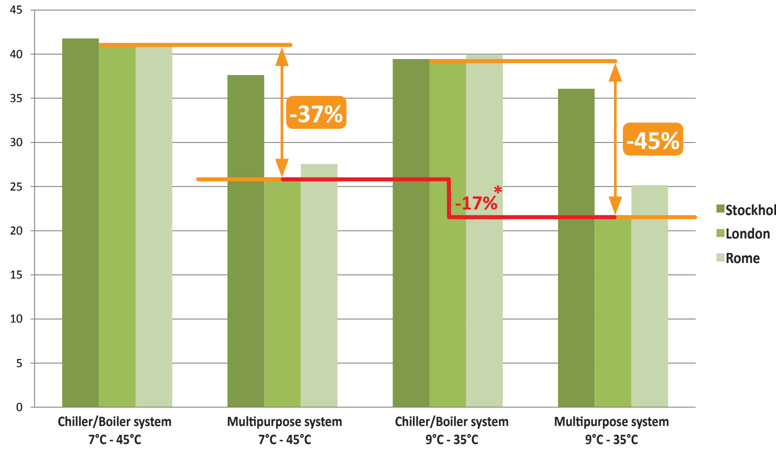


LOWER POLLUTING EMISSIONS MEANS ENVIRONMENTAL PROTECTION.

Note:
Calculations were obtained by considering:
1,968 kg CO_2 emitted for the combustion of 1 Nmc of natural gas;
0,442 kg CO_2 emitted for 1 kWh electric absorbed.
Soruce IEA "International Energy Agency"

With NRP the primary energy requirements are reduced up to 45%

ESTIMATION OF THE PRIMARY ENERGY USE kWh/YEAR



RESULTS:
The % reduction of primary energy could be considered for the purposes of defining a hypothetical improvement of the energy class of the building.

Note:
Conversion factors of the considered energy vectors: 1kWh electric = 2,5kWh of primary energy; 1Nm³ of methane = 9,943kWh of primary energy.

* It is enphasized that the temperature variation of energy vectors, is possible using one coil of the fan coil unit with greater exchange surface and the relative valve accessory (VCF_X4 - with reference to Technical Focus Vol. 1), allows to reduce up to **17%** the demand of primary energy. This result was obtained keeping as a reference base always the same multipurpose unit NRP and evaluating the increase of efficiency caused by the temperature variation.

OPERATION WITH MULTIPURPOSE SYSTEM:
The practical effect which is obtained in the transition from:
7°C to 9°C (system side cold)
45°C a 35°C (system side hot)
allows to reduce up to 17% the demand of primary energy.

Chapter 4

LCC ANALYSIS OF THE TWO SOLUTIONS IN COMPARISON

To obtain an evaluation of the overall economic convenience of the choice of solution with a multipurpose unit compared with the more traditional solution, we consider not only the energy cost, but also all the main items which contribute to determine the cost of a solution, through the method LCC (Life Cycle Cost).

Carrying out this analysis we consider, in addition to energy cost, the purchase costs, installation and the estimated costs of maintenance of the units and of the components, which differentiates the two solutions; we won't consider, in other words, purchase costs, installation and maintenance of such components and of those parts of the system that are common to both cases (and that obviously don't influence in any way the convenience of one solution compared to the other).

Market interest rate $r = 5\%$

Real inflation rate $i = 3{,}3\ \%$

Real interest rate $r_i = (r-i)/(1+i) = 1{,}64\%$

System life cicle lenght $n = 15$ years

Annual costs discounting back factor $f_{pv} = (1-(1+r_i)^{(-n)})/r_i = 13{,}2$

LCC = Life Cicle Cost = $I + f_{pv}\,(C_o+C_m)$

I = initial cost

C_o = energy annual cost

C_m = annual maintenance cost

STOCKHOLM

SOLUTION 1: CHILLER + BOILER

Chiller NRL0650°°°°A°°°00 supply including charges and medium mark-up of the installer	25654 €
Condensing thermal unit with heating capacity 189 kW, complete with fumes exhaust devices gas supply and safety devices for thermal power plant	18680 €
Estimated annual maintenance cost	1295 €

SOLUTION 2: MULTIPURPOSE UNIT FOR 4-PIPE SYSTEM

Multipurpose unit NRP0650A4°°°0000 supply including charges and medium mark-up of installer	40619 €
Condensing thermal unit with heating capacity 189 kW, complete with fumes exhaust devices gas supply and safety devices for thermal power plant (used for the hybrid system)	18680 €
Estimated annual maintenace cost	1670 €

	Chiller+boiler 7°C 45°C	Multipurpose unit 7°C 45°C	Chiller+boiler 9°C 35°C	Multipurpose unit 9°C 35°C
I €	44334	59299	44334	59299
Co € / year	15641	11634	14932	11190
Cm € / year	1295	1670	1295	1670
LCC €	267889	234911	258530	229051

LONDON

SOLUTION 1: CHILLER + BOILER

Chiller NRL0700°°°A°°°00 supply including charges and medium mark-up of the intsaller	29288 €
Condensing thermal unit with heating capacity 112 kW, complete with fumes exhaust devices, gas supply and safety devices for thermal power plant	12182 €
Estimated annual maintenance cost	1159 €

SOLUTION 2: MULTIPURPOSE UNIT FOR 4-PIPE SYSTEM

Multipurpose unit NRP0700A4°°°0000 supply including charges and medium mark-up of installer	48101 €
Estimated annula maintenance cost	1005 €

	Chiller+boiler 7°C 45°C	Multipurpose unit 7°C 45°C	Chiller+boiler 9°C 35°C	Multipurpose unit 9°C 35°C
I €	41470	48101	41470	48101
Co € / year	9884	7587	9414	6335
Cm € / year	1159	1005	1159	1005
LCC €	187238	161515	181034	144989

ROME

SOLUTION 1: CHILLER + BOILER

Chiller NRL0800°°°A°°°00 supply including charges and medium mark-up of the intsaller	39123 €
Condensing thermal unit with heating capacity 88 kW, complete with fumes exhaust devices, gas supply and safety devices for thermal power plant	12180 €
Estimated annual maintenance cost	1536 €

SOLUTION 2: MULTIPURPOSE UNIT FOR 4-PIPE SYSTEM

Multipurpose unit NRP0800A4°°°0000 supply including charges and medium mark-up of installer	61998 €
Estimated annual maintenance cost	1369 €

	Chiller+boiler 7°C 45°C	Multipurpose unit 7°C 45°C	Chiller+boiler 9°C 35°C	Multipurpose unit 9°C 35°C
I €	51303	61998	51303	61998
Co € / year	16023	12890	15491	11790
Cm € / year	1536	1369	1536	1369
LCC €	283082	250217	276059	235697

The installation cost has not been considered, being very variable depending on circumstances; the differences in the cost of installation of a chiller and of a multipurpose unit, on equal terms are however limited and do not move significantly the comparison results.

With NRP the LCC is reduced up to 20% compared to the traditional solution.

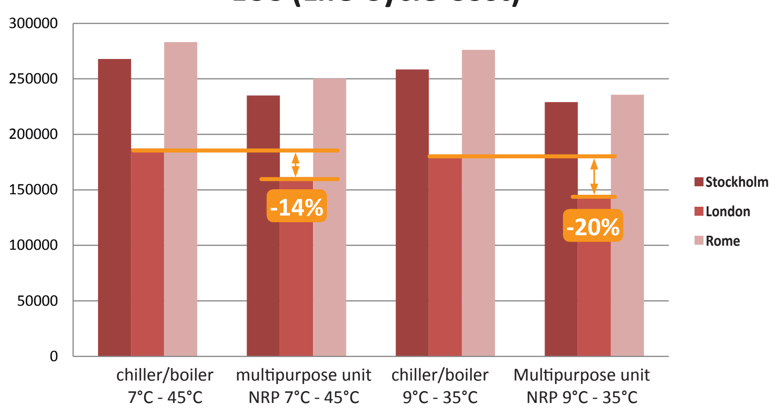
LIFE CYCLE COST

Comparison of the test solution.

ENERGY SAVING = COST SAVINGS

- Lower management costs.
- Lower LCC (Life Cycle Cost).

LCC (Life Cycle Cost)



Chapter 5
CONCLUSIONS

Reduction of life cycle cost (LCC) of the system

The realized analysis permitted to observe that the solution with 4-pipe multipurpose unit allows savings up to **20%** on plant life cycle compared with traditional solution chiller/boiler. For the preparation of the compared plants we did the same considerations: in the traditional solution it was decided for condensing boiler and high efficiency chiller unit (gruppo frigo); same consideration was done in the alternative plant proposal, choosing the high efficiency NRP multipurpose unit.
Here is therefore that the true saving is essentially linked to cost reduction of energy determined from heat recovery, which is possible to obtain only with the multipurpose unit NRP.

Operating cost reductions

The reduction of operating costs, related to energy saving that the solution with multipurpose NRP ranks until **33%** compared with the traditional solution chiller/boiler. It is underlined also that this result is much more higher, when the TER index, which characterize the efficiency on multipurpose unit recovery, is high, therefore in correspondence of climatic conditions which promotes the simultaneity of the loads of opposite sign. The influence of irradiation in the considered buildings is also significant in correspondence of climatic zones with rather rigid winters, making the solution extremely advantageous on whole Europe .

Building energy class improvement

The solution with multipurpose unit permits to obtain a primary energy saving up to **45%** compared with traditional application chiller/boiler.
This aspect may result in a lower year-round primary energy demand for the considered building for office use.

Reduction of CO_2 emissions

In terms of environmental impact the solution with multipurpose unit NRP, implies a reduction of emitted CO_2 placeable up to **45%** compared with the traditional solution chiller/boiler.

Less floor spaces

The possibility to use the multipurpose for the entire production of thermal energy permits to prevent the realization of a thermal power plant and makes spaces available (inside the building , or in its appliances) which could be usefully employed in another way (e.g. construction of a parking).

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