

TRIGENERATION SYSTEM FOR THE UNIVERSITY CAMPUS OF RIJEKA

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Abstract: *By the Decision of the Government of the Republic of Croatia (of December 2003), the territory of the former Trsat Army Barracks in Rijeka was awarded to the Town of Rijeka to be used expressly for the needs of healthcare and higher education. In the Detailed Plan of Urban Development (DPUD) for the area of the Sušak Clinical Hospital Centre and the future University Campus Trsat, the thermo-technical and thermal energy systems for the intended usage of this area are separated and prejudged in the levels of engineering solutions. This detailed defining of the thermo-technical and thermal power infrastructure, without a preliminary justification study for the construction of two separate power systems, was shown to be a wrong solution as early as the design stage of the building projects of Phase One of construction of the University Campus. To no useful purpose, the plan foresees two autonomous systems – the hospital system at the cogeneration/trigeneration level, and the system for the Campus area at the conventional warm water/hot water heating plant. The fact that these systems are located in close proximity of each other further brings into doubt the solution proposed and adopted by the plan. That the power and thermo-technical systems were needlessly and erroneously defined became obvious during the elaboration of the first building projects and infrastructure projects for the University Campus. The new structures to be built in the first construction phase of the campus will have air-conditioning systems. The housing section of the student complex is designed for year-round use, as the complex will be used during the summer months to accommodate visiting professors, students, participants in summer sports activities and others (use as a hostel)*

This paper presents the results of a preliminary study justifying the application of a joint complex municipal thermal power system powered by natural gas for the areas the DPUD covers. The combined thermal power system will serve for heating, steam production, cooling and electrical energy production, primarily for the DPUD area. There is a possibility of increasing the power-producing capacity of this combined system for the needs of town consumers, which would make the system more efficient. An analysis has been made based on the guidelines for the thermo-technical and thermal power system adopted by the DPUD, the actual state of the distance heating system, and the need for heating, cooling and electrical energy within and outside the zone covered by the plan. Results point to the need to combine the two systems in order to reach an improved technical solution. The solution proposed will help to increase the efficient use of natural gas, the primary energy source, while reducing operating costs and abating environmental pollution.

Key words: urban planning, municipal infrastructure, thermal power system, heating, cooling, natural gas, cogeneration, trigeneration, heating plant/thermal power plant

1. INTRODUCTION

The Detailed Plan of Urban Development (DPUD) of the area of the Sušak Clinical Hospital Centre and the future University Campus Trsat in Rijeka (Figure 1) plans for two heating plants/power plants, located in the immediate vicinity of each other. For the needs of the University Campus, the heating plant foreseen is equipped with a hot water system intended for distant heating, as well as with a steam system for use by the technological systems of the student complex. The heating plant is situated in the Campus's eastern side, immediately next to the Clinical Hospital Centre. Natural gas is the primary energy source. A space has been designated for reservoirs of liquid fuel to serve as the heating plant's auxiliary energy source. For the University Campus, the DPUD does not foresee space cooling from the central system.

The power producing facility of the Clinical Hospital Centre (CHC) is more complex, and in addition to a system for heating and steam production for technological needs, it also has a work-media cooling system and electrical energy generation system. This is a cogeneration level system, with waste heat being used for cooling (trigeneration). This power plant will be located in the immediate vicinity of the existing Emergency Tract and the Polyclinics building, about 150 metres from the heating plant of the Campus. Natural gas is the power plant's primary energy source. The thermo-technical systems of the buildings to be constructed according to the DPUD, and the existing CHC buildings will require: the preparation of the work media – water for hot water or warm water systems, warm-water preparation, steam production for kitchen and laundry technologies, cooling-media preparation for cooling and air-conditioning, and electrical energy.

Based on these facts, the question arises: Why does the DPUD plan for two similar thermo-technical/thermal power systems located in the immediate vicinity of one another?

This paper presents the results of a preliminary study justifying the merging of the two proposed power systems into a single, compound thermal power system. Natural gas would be the primary energy source of the proposed system. The system will primarily serve the needs of the new buildings planned by the DPUD, although the possibility of using the system outside of this area is not ruled out. The project assignments in designing the Phase One buildings of the University Campus plan for a higher level of micro-climate conditions in rooms, that is, cooling, thus making the level of climate conditions in university rooms at par with that of hospital rooms. This fact, as well as the fact that neither the University nor the CHC are registered for selling energy, together with the complexity of the plant and its maintenance, provides additional incentive to analyse the option of a combined thermal power system. The combined thermal power system would serve for heating, steam production, cooling and electrical energy generation in the area the DPUD covers.



Figure 1. Area of the University Campus of Rijeka and buildings included in Phase One of construction

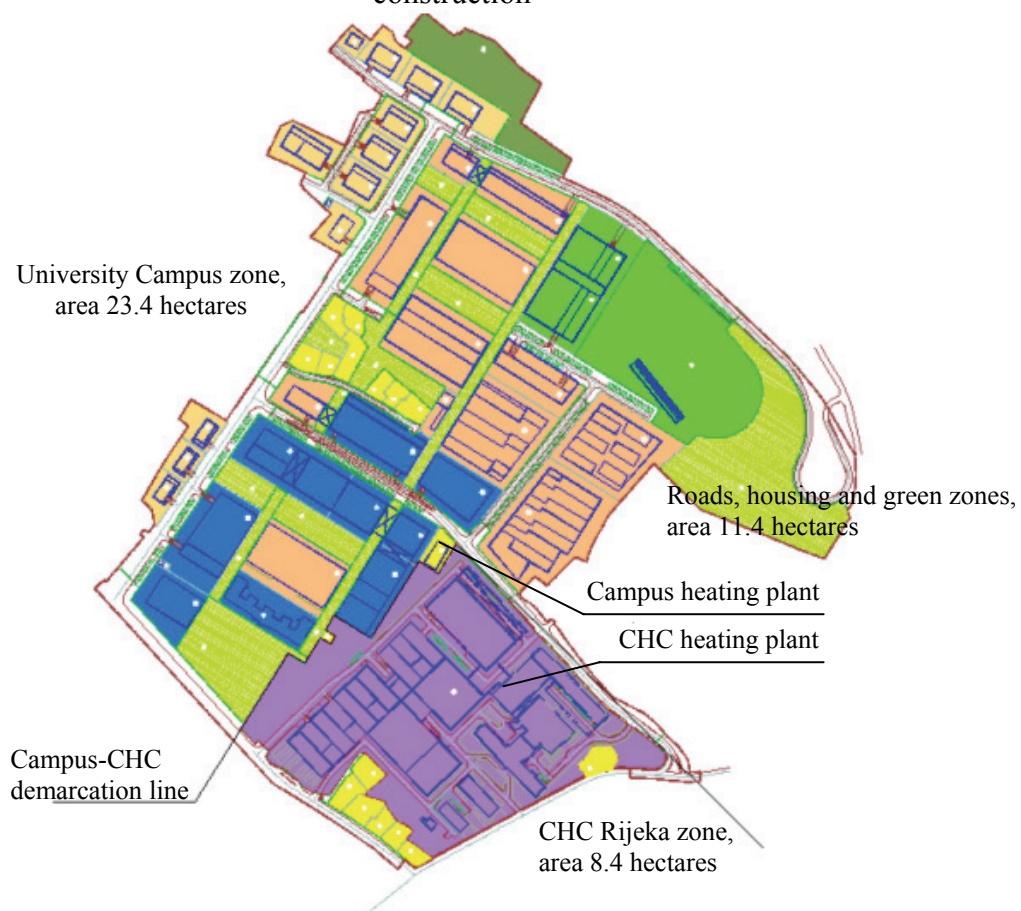


Figure 2. Area covered by the *DPUD Campus Trsat – CHC Sušak* of Rijeka.

2. DPUD OUTLINE

The DPUD for the University Campus and the Sušak Clinical Hospital Centre covers an area of 43.2 hectares, divided into two parts: the first part in the western wing with an area of 23.4 hectares is intended for the University Campus Trsat, while the second, smaller part in the eastern section with an area of 8.4 hectares is intended for the spatial expansion of the CHC. Roads within the DPUD area, and housing, pedestrian and green areas amount to 11.4 hectares.

The area the DPUD covers is subject to strong streams of wind blowing from the northern and eastern quadrants (the bora wind). The DPUD plans the construction of two major roadways: the four-lane University Avenue running vertical to Slavko Krautzek Street and exiting in the area's outermost, northern part; and the Vjekoslav Dukić Street that cuts across the central part of the DPUD area. It is planned that all power lines will be laid in these two streets and in sidewalks. The Campus and CHC will be supplied with natural gas coming from Slavko Krautzek Street that runs along the southern edge of the project zone. The CHC power plant and the Campus heating plant are located directly along the south side of Vjekoslav Dukić Street.

Table 1. Estimated DPUD power requirements

Power requirements for the DPUD area			
	Campus	CHC	Total
Primary power source natural gas m ³ /h	3 900	1 320	5 220
Thermal power requirements in MW	33	8	41
Cooling power requirements in MW	11.8	5.2	17
Consumer warm-water requirements in MW	1	2	3
Steam requirements t/h	1	2.5	3.5 (5)
Electrical energy requirements in MW	7.2	2.5	12.4
Electrical energy generation in MW		1.7 + 0.8	2.5

3. GAS SUPPLY

The University Campus will be supplied with natural gas coming from the direction of Slavko Krautzek Street (running along the southern border of the DPUD area) in which a high-pressure gas line has been provided with a connection for the needs of the Campus. Gas pressure will be reduced from high pressure (4 – 6 bars prepressure) to moderate pressure (up to 1 bar prepressure) at the gas measuring and regulation station to be located in the University Campus area, east of the Applied Arts Academy building. The intended capacity of the station is 5,500 m³/h of natural gas, which fully meets the total requirements of the Campus and the CHC. A secondary network for moderate-pressure gas will be developed throughout the entire area the DPUD covers.

4. UNIFIED POWER SYSTEM FOR THE DPUD AREA

Thermo-dynamic and economic analyses point to the need of merging the two power systems by making the heating plant of the University Campus the joint power plant of the area. The outputs of three typical cogeneration systems were analysed: the first cogeneration system, dimensioned according to the DPUD, has a nominal output of 1.7 MW in electrical energy generation; the second system is dimensioned according to the required output of cooling power in the DPUD area; and in the third system, the amount of waste heat should be sufficient to meet the thermal output needed to heat the DPUD area. Based on the analyses conducted, a fourth system – the optimum system for the DPUD area – is also presented in Table 2. The data in this table are based on nominal outputs that were the groundwork for the analyses. The table clearly indicates that in the first cases, the dimensioning of the system for an electrical output of 1.7 MW requires a parallel, conventional thermo-technical plant, a heating plant for winter heating, because the amount of waste heat available is in the order needed for preparing hot consumer water. The cooling power generated would amount to only 10 percent of the required output for the project area. In the second case, investments are higher, and the cooling power available is capable of meeting all the area's needs. There is enough power for the entire preparation of consumer water, and the surplus of electrical energy generated is taken over by the external grid. The waste heat available in the winter period covers 75 percent of the heating requirements of buildings. The third system is the most expensive, in terms of investment, and its waste heat can fully meet the heating needs of buildings in the DPUD zone. The surplus of electrical energy generated is taken over by the external grid, and the waste heat available for preparing water for the cooling system is greater than needed for the DPUD zone.

The above analysis indicates that an optimum system would have a nominal output of 6 MW in electrical energy generation. The system would be capable of generating enough electrical energy for the entire project zone, while the surplus generated would be transferred to the external grid. It would also ensure a sufficient amount of waste heat to meet a third of the needs for cooling output, as well as for the preparation of warm consumer water. It is a fact that some of the buildings of Phase One of the Campus under construction have an in-built autonomous cooling system. Waste heat for heating covers only a quarter of the declared requirements, calling for a parallel, conventional heating system.

Table 2. Four optional cogeneration system for the DPUD area; in MW

DPUD	Electrical energy	Cooling power	Thermal power	Optimum system	Summer	Winter
Gas output	5.00	55.35	73.21	17.60	17.60	17.6
Electrical energy generated	1.70	18.81	25	6.00	6.00	6.00
Waste heat (for heating)	2.80	31	41.00	10.00	9.85	9.85
Cooling power (for cooling)	1.55	17.00	23	5.32	5.32	-
Losses	0.50	5.54	7.30	1.76	1.76	1.76

Figure 3 illustrates the primary power savings ensured by the cogeneration plant relative to conventional power generation.

The savings on primary power sources in the cogeneration plant could amount to 38 percent. In addition to savings on primary power sources, this type of power generation also provides the following advantages:

- Efficient utilisation of fuel, lower cost of generating electrical and thermal energy
- Environmental protection, as the same quantity of useful power generated produces less harmful pollution
- Electrical energy generated at the site of consumption helps to reduce losses during transfer and distribution, and to increase the safety and flexibility of power supply.

Such an analysis, based solely on output, cannot be complete and may lead to wrong conclusions. This makes it necessary to include into the analysis the amount of power used relative to the requirements during year-round operation. The detailed analysis should be based on the incoming micro-climate conditions of the area and on knowledge of the real hourly micro-climate values of the ambient air (temperature, humidity and enthalpy). Furthermore, spatial usage plays a decisive role: there will be no students on the Campus during the summer months, at the end of July and throughout August. Capital investments, as well as the purchase price of electrical energy, also have vital roles. The subject analysis is based on the following thermal-energy prices: natural gas at 0.25 HRK/kWh and electrical energy at 0.7 HRK/kWh (for single rate electricity), and 0.74 HRK/kWh and 0.39 HRK/kWh (for dual rate electricity— high tariff and low tariff, respectively) or at an average price of 0.59 HRK/kWh. For comparison purposes, if this electrical energy were used for heating in a heat pump, the corresponding prices would be 0.28, 0.30, 0.61 and 0.24 HRK/kWh (in the analysis, for the purpose of comparison, the prices of fuel oil are: 0.5 HRK/kWh for extra light and 0.29 HRK/kWh for light).

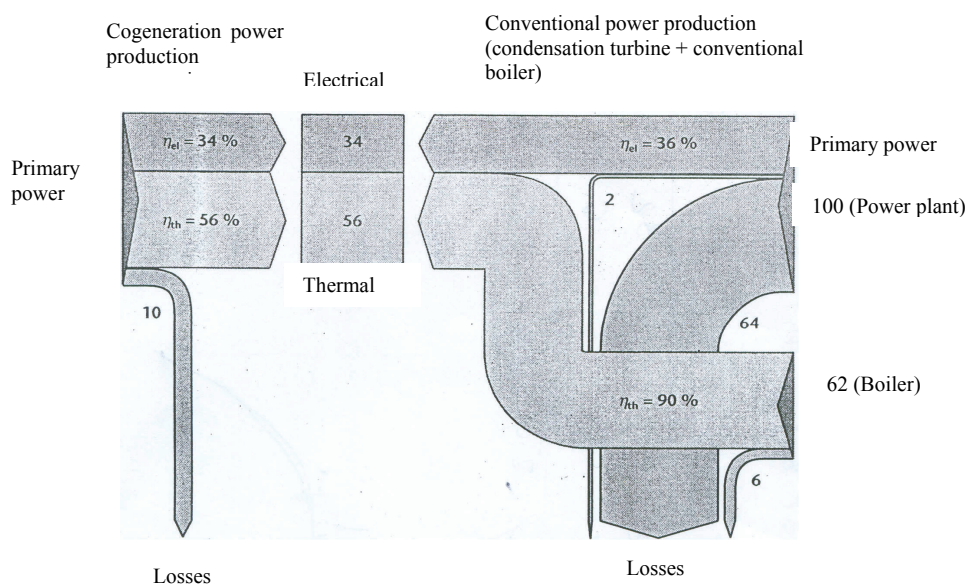


Figure 3. Savings on primary power sources in the cogeneration plant relative to conventional power generation, shown in %.

5. CONCLUSION

This paper gives a preliminary analysis of a unified cogeneration (trigeneration) system for the production of steam and electrical energy, as well as thermal and cooling energy for heating and cooling needs. The initial analyses indicate that there is no justification in building two similar thermo-technical and thermal energy systems located close to one another in a relatively small urban area. The requirements for both usages are similar, and this is an additional argument for combining the two systems. Investment in a cogeneration plant will be cost-effective providing waste heat is utilised alongside the generation of electrical energy. The mechanical thermo-technical system needs to have power consumers throughout the entire year. By combining the two systems, the utilisation of waste heat is increased and, in turn, the efficiency of the system. Having a nominal electrical output of 6 MW, the proposed optimum cogeneration/trigeneration system will continuously generate 10 MW of thermal power. The analysis shows that this thermal output is capable of meeting the thermal-power needs of the DPUD zone for a period of five months. When the DPUD zone's requirements for electrical energy are lower than the amount of power generated, the surplus of electrical energy will be transferred to the external grid.

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TRIGENERACIJSKI SUSTAV ZA SVEUČILIŠNI KAMPUS U RIJECI

Sažetak: Odlukom Vlade RH (od prosinca 2003. godine) prostor bivše Vojarne na Trsatu u Rijeci dodijeljen je Gradu Rijeci s izričitom namjenom za potrebe zdravstva i visokog obrazovanja. Detaljnim planom uređenja (DPU) područja Kliničkog bolničkog centra na Sušaku i budućeg Sveučilišnog kampusa na Trsatu termotehnički i energetski sustavi su za predviđene namjene prostora razdvojeni i prejudicirani u razinama tehničkih rješenja. Ovako detaljno definiranje termotehničke i energetske infrastrukture, bez prethodne studije opravdanosti izgradnje dva izdvojena energetska sustava, pokazalo se već kod razrade projekata zgrada I. faze izgradnje Sveučilišnog kampusa krivim rješenjem. Nepotrebno su planom zacrtana dva autonomna sustava od kojih je bolnički razine kogeneracije/trigeneracije, a na području namijenjenom za Kampus je razine konvencionalne toplovodne/vrelovodne toplane. Sustavi su u neposrednoj blizini što dodatno čini upitnim predložena i planom usvojena rješenja. Tijekom razrade prvih projekata zgrada i projekata infrastrukture za Sveučilišni kampus uočen je planom nepotrebno i krivo definiran energetski i termotehnički sustav. U I. fazi izgradnje kampusa nove zgrade imaju sustave za klimatizaciju, a smještajni dio studentskog naselja zamišljen je za cjelogodišnje korištenje jer će naselje tijekom ljetnih mjeseci biti korišteno za potrebe gostujućih profesora, studenata, učesnika ljetnih sportskih aktivnosti i drugih, (mogućnost korištenja hostela).

U radu su prikazani rezultati prethodnog istraživanja opravdanosti primjene zajedničkog složenog komunalnog termoenergetskog sustava pogonjenog prirodnim plinom za područje obuhvaćeno detaljnim planom uređenja prostora. Objedinjeni termoenergetski sustav služi za grijanje, proizvodnju vodene pare, hlađenje i proizvodnju električne energije, prvenstveno za područje obuhvaćeno planom. Postoji mogućnost povećanja kapaciteta proizvodnje energije ovakvog objedinjenog sustava dijelom na gradske potrošače čime se stvara sustav učinkovitijim. Temeljem smjernica za termotehnički i termoenergetski sustav usvojenog detaljnog plana, činjeničnog stanja sustava za daljinska grijanja i potreba za grijanjem, hlađenjem i električnom energijom u zoni i izvan zone zahvata planom izvršene su analize te ukazano na potrebu objedinjavanja dva sustava čime se dobiva bolje tehničko rješenje. Predloženim rješenjem povećava se učinkovito korištenje osnovnog energenta prirodnog plina, smanjuju se pogonski troškovi i zagađenje okoliša.

Ključne riječi: prostorno planiranje, komunalna infrastruktura, termoenergetski sustav, grijanje, hlađenje, prirodni plin, kogeneracija, trigeneracija, toplana/energana