**15B.7** ENVIRONMENTAL ASPECTS OF ENERGY USE IN HVAC SYSTEMS IN HOTEL FACILITIES

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**ABSTRACT**

Being one of the fastest growing sectors of industry, tourism is rapidly gaining in influence on energy consumption worldwide. At many travel destinations, the accelerating and inefficient use of energy and other resources is causing serious environmental damage, thus jeopardizing the very basis of sustainable tourism development. The hotel industry is a particularly energy-intensive branch of the tourism industry, and about 50% of the energy consumption in this sector is due to the use of HVAC systems for space conditioning. The environmental impacts of HVAC-system operation can be partially described by the TEWI factor, which considers parameters including the emission of environmentally hazardous refrigerants, and system-related $CO_2$-emission. The ODP factor can be additionally used to describe the effects of CFC and HCFC refrigerant emission on ozone depletion.

This paper discusses the use of advanced types of HVAC systems for hotel facilities in the Mediterranean, designed to provide comfortable indoor environments at substantially reduced environmental impacts, by incorporating measures of energy efficiency and using renewable energy resources. An energy and environmental impact analysis of typical systems is presented. Possibilities for $CO_2$-trading in this sector are additionally discussed

## 1. INTRODUCTION

Hotels and tourism accommodation facilities are tertiary commercial buildings and high energy density consumers. It is estimated that that building sector (residential and tertiary) accounts for about 40% of the energy consumption worldwide. Plans of European Union, agreed by Kyoto Protocol, to meet their commitment to reduce green house gasses - GHG ($CO_2$, $CH_4$, $N_2O$, HFCs, PFCs and $SF_6$) emissions by 8% and 5% respectively by 2008-2012 is in among other measures, utilization of cost-effective technologies of the building energy performance that already exists. It is estimated that by 2010, energy consumption of buildings can be reduced by 22% using advanced technologies [1].

Therefore, tourism accommodation facilities as high energy density consumers can contribute to emission savings.

Analysis of energy consumption in a hotel must take into account the geographical location, local environment. These factors determine the design of the hotel and many of the characteristics affecting the energy consumption of equipment and plant. Important considerations are the availability of conventional and renewable energy sources and the climatic and environmental conditions of the location.

Energy consumption of HVAC systems in tourism accommodation accounts for about 50%, but including systems for domestic hot water it accounts about 62% of total energy consumption [2]. Since these systems are high-energy consumers and consequently produce high $CO_2$ emission, sustainability in their design will contribute to the sustainability of tourism sector in general.

Alternative refrigerants as well as alternative cycles can contribute to sustainability of the cooling systems. These systems should be both, energy efficient and environmentally friendly.

## 2. SYSTEM MODELING

In order to show how utilization of renewable energy sources in HVAC systems can contribute to environmental protection three cooling and heating systems were designed and analyzed. Environmental analysis for the cooling systems will be presented in details. Case study is made for the Eco complex, the four-star apartment complex (400 beds) of total area 6300 $m^2$, located in Mediterranean, on Croatian coast. Advanced cooling system, as a high temperature cooling system, utilizes seawater of $15^oC$ and radiant heat transfer for building cooling (SWC system). This system and solar cooling absorption system (ABSOL) are compared with conventional one, vapor compression (VC) system for the same cooling load which is 210 kW. None of the systems utilizes fresh water as a heat sink. For this purpose seawater is utilized. In that way water conservation measure is accomplished and coefficient of performance (COP) of cooling systems is increased. Environmental analysis is obtained converting results from the energy analysis that is the result of simulation process in Trnsys simulation program.

## 3. ENVIRONMENTAL ANALYSIS

Environmental analysis of HVAC system comprises analysis of green house gasses emission, ozone depletion substance emission and water consumption and pollution. Environmental impact of energy use in HVAC systems can be measured by kg of greenhouse gasses emitted per kW/h of consumed energy.

Cooling and heating equipment might release greenhouse gases into the atmosphere in two ways. Refrigerant, if used, may be directly released into the atmosphere during equipment installation, normal operation, decommissioning, or eventual disposal. Secondly, air-conditioning equipment "releases" greenhouse gas during electricity generation from different fossil fuels, nuclear power and water, necessary to operate the system. The combustion of fossil fuels produces, among other gases, carbon dioxide – a dominant greenhouse gas. The extent of the carbon dioxide emissions for a given carbon content in the fuel and for a given generation efficiency, depends primarily on the energy efficiency of the HVAC equipment. The amount of generated carbon dioxide is directly proportional to the amount of used energy.

Analysis that can determine overall contribution to global warming from energy using equipment over its operating lifetime (20 years) is Total Environmental Warming Impact (TEWI) analysis. TEWI factor is expressed in terms of equivalent kg $CO_2$ direct and indirect emissions.

$$TEWI = \text{direct } CO_2 \text{ emission equivalent} + \text{indirect } CO_2 \text{ emission equivalent}$$

Two of three cooling systems that are designed for Eco complex are utilizing alternative refrigerants. SWC system utilizes seawater as a renewable source of cold energy, while ABSOL system utilizes mixture $H_2O$-LiBr. Both systems do not have direct emission of $CO_2$, but only indirect due to energy utilization. Third system, VC is vapor compression system that as a working fluid utilizes refrigerant R404A, that is HFC with global warming potential GWP =3260.

Since leakage of refrigerants during the lifetime of the system is small, and only one system utilizes refrigerant having certain GWP value. Systems will be compared according to indirect $CO_2$ emission due to electricity utilization.

Emissions of $CO_2$ are calculated with the average $CO_2$ emission factor from the electricity power plants in Croatia, where Eco complex is located. As in Croatia 40-49% of total energy production is obtained from hydropower plants, green house gasses emission is quite low. Average value for $CO_2$ emission is 308g $CO_2$/kWh of produced electric energy, [3].

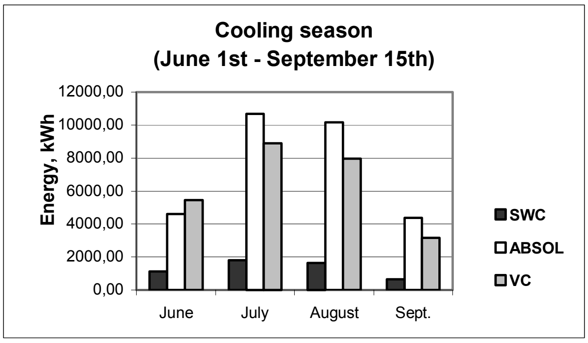


**Figure 1**. Energy consumption during cooling season

Figure 1 represents results of energy analysis, where one can see that system that consumes the smallest amount of electric energy for the same cooling load, is SWC system.

Since kg $CO_2$ emitted from the system is directly proportional to kWh of consumed electrical energy, SWC system will be the most environmentally friendly producing significant emission savings for the same cooling load, while ABSOL system that utilizes highest amount of electric energy would be the worst one.

### Cooling season /June 1st – September 15th

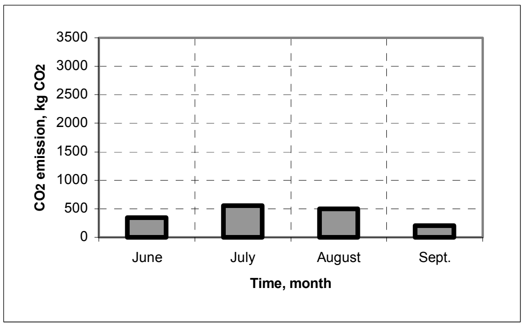


**Figure 2**. *$CO_2$ emissions during the cooling season from SWC system*

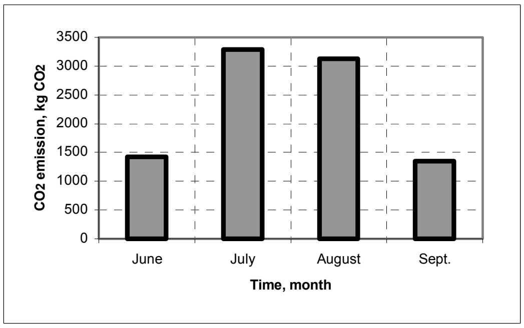


**Figure 3.** *$CO_2$ emissions during the cooling season from ABSOL system*

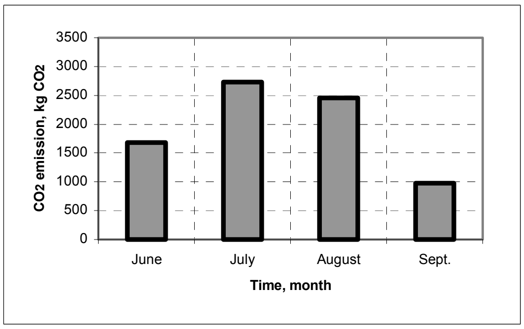


**Figure 4.** *$CO_2$ emissions during the cooling season from VC system*

On the Figures 2-4 calculated $CO_2$ emissions in kg are given for each system and each month during the cooling season.

$CO_2$ emission savings realized by SWC system during the cooling season is 83% compared to ABSOL system and 80% compared to VC system (Table 1).

Hydropower in Croatia is limited, what leads to the conclusion that each new kW of installed power in HVAC equipment would utilize electricity from the thermal power plants in Croatia or from export. Since $CO_2$ emissions from the thermal power plants are 3 times larger than average emission in Croatia, emissions from the new HVAC equipment on the Adriatic coast would contribute much more to the global warming. Comparisons for the cooling systems are given in Table 1, where ratio of the renewable energy sources can be seen as well. SWC system during the cooling season operates using 97% of renewable energy sources, while ABSOL system utilizes 85%.

**Table 1**. $CO_2$ emissions from systems due to electric energy consumption – cooling season

| Cooling system | SWC | ABSOL | VC |
|---|---|---|---|
| $Q_{cool}$ | 153829,44 | 152444,44 | 154797,22 |
| $Q_{el}$ | 5208,38 | 29828,31 | 25481,01 |
| $\eta_c$ | 29,54 | 5,11 | 6,08 |
| RET (%) | 97% | 85% | / |
| g CO2/kWh (average in Cro) | 308 | 308 | 308 |
| kg CO2 | **1604,18** | **9187,12** | **7848,15** |
| g CO2/kWh (thermal) | 910 | 910 | 910 |
| kg CO2 | **4739,62** | **27143,77** | **23187,72** |

Besides $CO_2$ as a major green house gas (GHG), there are other gasses that contribute to global warming and acid rains, like $SO_2$ and $NO_x$. Emissions expressed in kg $SO_2$ and $NO_x$ due to the electricity consumption in HVAC systems in Eco complex are given in Table 2.

**Table 2.** *$SO_2$ and $NO_x$ emissions from systems due to electricity consumption – cooling season*

| Cooling system | SWC | ABSOL | VC |
|---|---|---|---|
| $Q_{el}$ | 5208,38 | 29828,31 | 25481,01 |
| g $SO_2$/kWh (average in Cro) | 1,74 | 1,74 | 1,74 |
| kg $SO_2$ | **9,06** | **51,9** | **44,34** |
| g $NO_x$/kWh (average in Cro) | 0,68 | 0,68 | 0,68 |
| kg $NO_x$ | **3,54** | **20,28** | **17,33** |
| g $SO_2$/kWh (thermal) | 3,6 | 3,6 | 3,6 |
| kg $SO_2$ | **18,75** | **107,38** | **91,73** |
| g $NO_x$/kWh (thermal) | 2,02 | 2,02 | 2,02 |
| kg $NO_x$ | **10,52** | **60,25** | **51,47** |

Neither of systems utilizes ozone-depleting substances (ODS) as a working fluid. They are chlorine free and ozone depleting potential of the systems equals zero. Therefore these cooling systems do not contribute to the ozone depletion.

Designed HVAC systems do not utilize fresh water as a heat sink or source. Therefore, they contribute to the water conservation that is important natural resource in coastal areas.

## 4. ENERGY CONSUMPTION

Energy consumption in hotels and accommodation facilities is measured and calculated as energy consumption in kWh per sq meter or kWh per guest and night. It is estimated that average energy consumption per sq meter is 365 – 550 kWh/$m^2$year in efficient and non-efficient hotels respectively, [4]. If it were considered that energy for air conditioning and heating represent 48% of total energy consumption in hotel, average consumption for HVAC systems would be depending of efficiency of hotel system 175 – 264 kWh/$m^2$year. When energy consumption per sq meter is calculated, obtained values were 25 kWh/$m^2$ for cooling season and 80 kWh/$m^2$year for heating season. Heating load analysis is based on the simulation of the heating solar systems and heat pump system for the same building. Total energy consumption in Eco complex (area 6300 $m^2$) for HVAC systems would be 105 kWh/$m^2$year, what has proved sustainable building structure. Energy consumption for HVAC system is decreased for 40% - 60% depending of the hotel efficiency.

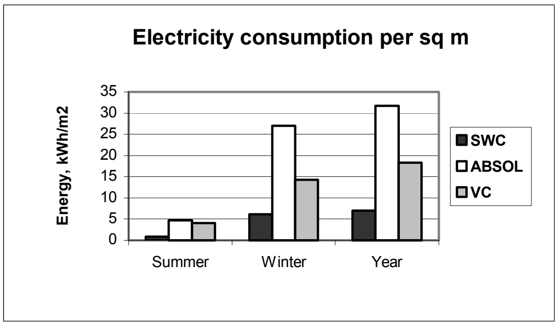


**Figure 5.** *Comparison of electricity consumption per sq m during the whole year*

Ratio of the electrical energy consumed for HVAC systems in Eco complex is showed on Figure 5, while numerical values are given in Table 3. One can see that consumption of electrical energy in all systems is significantly low, compared to data for estimated average values in hotels worldwide. Even ABSOL system, that has showed worst energy results considering electricity back up system, consumes only 31,73 kWh/$m^2$year of electrical energy for HVAC systems. That proves sustainability of the systems utilizing renewable energy sources and importance of sustainable building design that primary decrease needs for energy.

**Table 3**. *Electricity consumption per sq m of Eco complex*

| $Q_{el}$, kWh/$m^2$ | SWC | ABSOL | VC |
|---|---|---|---|
| **Summer** | 0,83 | 4,73 | 4,04 |
| **Winter** | 6,15 | 27 | 14,31 |
| **Year** | 6,98 | 31,73 | 18,35 |

## 5. CONCLUSIONS

The case study of Eco complex was showed that assuming the sustainable building design, with passive architecture elements and better building materials is possible to reduce loads in the building for 40-60%. Secondly, design of efficient energy systems that would utilize renewable energy sources will provide electricity and environmental savings. Beside energy savings that are expressed in kWh of saved electricity or in EUR/kWh of cooling or heating load and environmental savings expressed in kg $CO_2$, $SO_2$ and $NO_x$ saved emissions, beneficial is the fact that low electricity consumption of this system can contribute to sustainability of the regions with not developed electricity distribution network.

## 6. REFERENCES


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