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THE IMPORTANCE OF DAYLIGHT SAVING TIME FOR ENERGY SAVINGS IN BELGRADE LATITUDE AND CLIMATE

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ABSTRACT

The idea of Daylight Saving Time (DST) was introduced before electrification era in order to prolong diurnal use of daylight during summer. DST has been imposed in European legislation since year 2000, but the legislation left open a back door for its suspension if the overall effect did not show positive results. During past decade it has been debated very often about effects of DST. Although many studies have concluded that DST has positive effect on energy savings in buildings in middle latitudes, there are still arguments that DST is causing loses in other areas of economy.

Many literature surveys have concluded that positive effect of DST on energy consumption in buildings is very small and highly dependable on latitude. This paper investigates how the application of DST in Belgrade climate and latitude influences the change of energy demand in highly glazed office spaces. Office buildings are used for work mainly during daytime, so it might be assumed that the influence of clock shift during summer period has high potential for change in utilisation of environmental energy resources.

Keywords: DST, Daylight Saving Time, lighting energy, cooling energy

INTRODUCTION

Daylight Saving Time, or DST, also called Summer Time in some European countries, represents a social arrangement in which local Standard Time[2] (ST) is shifted forward by one hour during summer time, precisely from spring to fall[3]. The idea of time shift during summer derived in 19th century. The intention was to prolong working hours during daylight. This arrangement was first time officially introduced in Germany during World War I, in 1916 (Seize the Daylight, 2020). The intention of German government was to achieve some savings in energy resources during war time. Soon, other countries followed German example.

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[2] Standard Time (ST) (also called the Winter Time) – refers to time synchronised with the local mean time at meridian that passes through the region (the meridian should be near the centre of the region). This means that in that region at noon the Sun has its highest altitude. The time arranged on particular meridian is referred to as *solar time* or *sun clock*.

[3] Since both Daylight Saving Time and Standard Time are products of social arrangement in one society, in many studies both times are referred to as *social time* or *social clock*.

Since the World War I the idea of DST has been evoked and revoked many times in legislation of many European countries. Immediately after World War I, DST was revoked, but after the outbreak of World War II, DST was reintroduced. It was evoked in the 1960s, and especially during the Oil embargo of 1973. Each country evoked and revoked DST as it pleased. Also, the duration of DST differed in each country. This caused a lot of confusion. In 1996, the European Union enforced DST and in 2000 EC unified its duration by adopting the time shift from the last Sunday in March to the last Sunday in October. As in EU countries, Serbia has adopted the same scheme of DST. This means that our social time is adapted to seven months in Summer time and five months in Winter (or Standard) Time.

Today, some countries worldwide enforce DST, some don’t. Less than 40% of countries worldwide use DST (Time and Date, 1995). DST is characteristically used in countries in middle latitudes where one hour shift in daytime can have some impact on energy demand during working time. In equatorial countries there is no significant deviation in daylight change during one year, so the impact on energy demand would be negligibly small or not occur at all. At high latitudes, there are extreme seasonal differences in duration of daylight, so the energy benefits from one hour time shift almost don’t exist.

There are numerous studies about the enforcement of DST. Its application has been intensively studied during past decade from many different aspects of human life. From medical standpoint, the results of numerous studies are very different – some studies concluded that DST has positive effect on human health, but the other studies concluded the opposite. There is a very convincing study (Roenneberg, *et al.*) which shows that deviation from sun time (or sun clock at meridian) causes sleep disturbance and thus many consequences on human health, wellbeing and efficiency at work. From aspect of energy efficiency in buildings there is also a huge difference in study results and there are many pros and cons considering application of DST. A survey of the literature concerning the effects of DST on energy demand (Havranek *et al.*, 2016) concluded that the design of a study has a crucial effect on its results.

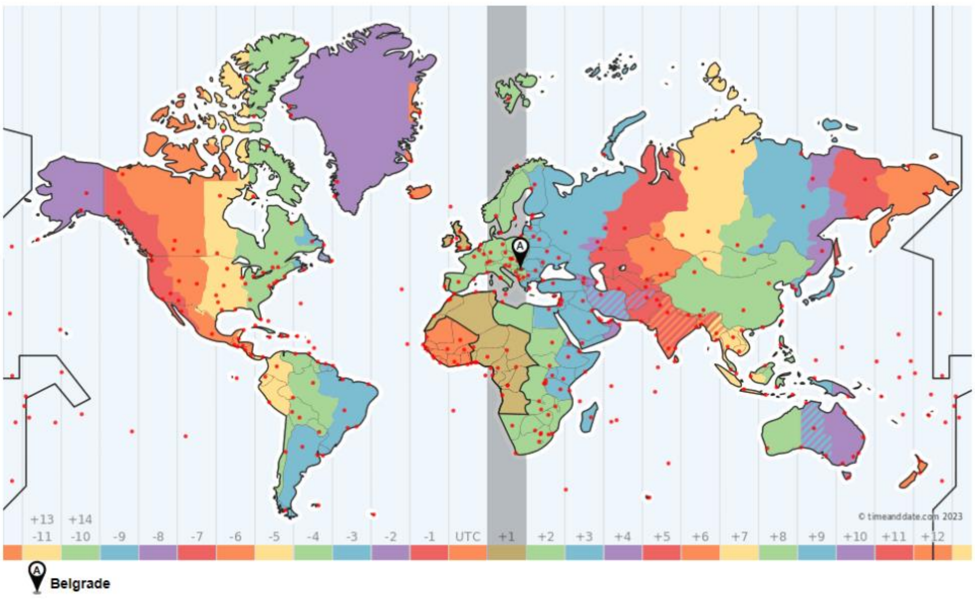

Figure 1: Coordinated Universal Time (UTC) for Belgrade and Serbia in time zone world map for Standard Time (ST) (Source: Time and Date. 1995b)

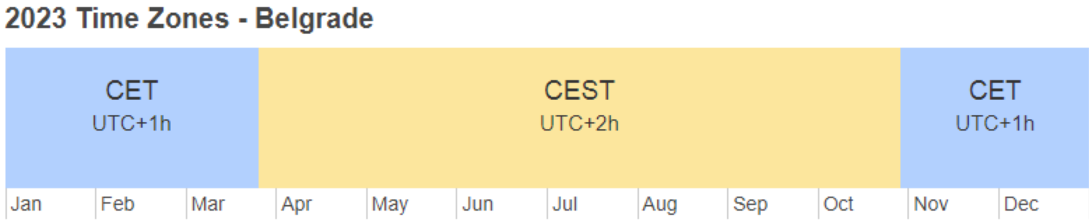

Figure 2: Coordinated Universal Time (UTC) for Belgrade and Serbia for Standard Time (ST) and Daylight Saving Time (DST) (Source: Time and Date. 1995c)

In EU there was a study upon which European Commission in 2019 suggested that DST should be suspended. It was left open for every state member to choose appropriate Standard Time. Covid 19 pandemic followed and this question stayed open and unanswered. In Serbia, as a state candidate for European Union, there was a lot of discussion on DST subject. There is no official proposal yet, but some suggestions can be found in media. Medical profession is claiming that one hour shift in time during summer is causing a period of adaptation in humans during which there are negative consequences on human health and wellbeing (Euronews Srbija, 2023). The other researchers proposed that it is more appropriate to adopt DST (UTC+2h)[4] (Figure 1 and 2) as Standard time (Tanjug, 2022), because geographical position of Serbia is more suitable to Eastern European time zone. That way we can get more daylight in buildings during work hours and use more daylight throughout the year, and thus we can better synchronize our social time and biological clock with the solar time we live in. Similar proposals are that we keep existing Standard Time, and move the beginning of working hours to an hour earlier – the situation that existed during Yugoslavian period (Tanjug, 2023).

DESIGN OF THE STUDY

This research was part of an earlier, more elaborated study, primarily focused on daylight analysis in single office spaces with highly glazed façade. The simulation of energy demand was carried out using Diva for Rhino software (Solemma, 2015). The analysis was carried out for typical Belgrade climate data (IWEC2 data file) (White Box Technologies – ASHRAE, 2011).

Selected parameters for physical model and its properties

Selected model of typical individual office space has a very narrow rectangular floor plan and fully glazed façade. The floor plan of modelled office space is 3,0 m net wide on façade wall, with unusually elongated space depth of 9,8 m, which corresponds to measure of 3,5 net height of the space. The adopted height of the space is 2,8 m, as this height is usual net height used in Serbia for office spaces. Elongated depth of office space was adopted in order to avoid the influence of back wall reflected daylight on horizontal and vertical illuminance in space. The **useful** area of the selected office model is 5,6 m depth of space, which represents standard depth of real single office spaces and corresponds to 2 times net space

[4] UTC – Coordinated Universal Time (*UTC*) is the primary time standard by which the world regulates clocks and time. The time in the Earth is ajusted acoording to mean solar time at the Reference Meridian as the currently used prime meridian (at 0° longitude). it is not adjusted for daylight saving time. It is effectively a successor to Greenwich Mean Time (GMT).

height. Daylight and energy analysis ware carried out only for useful area of selected model (figure 3).

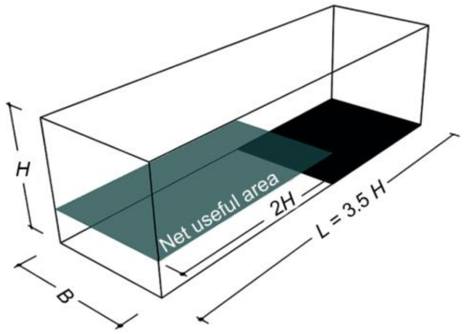

Figure 3: Proportions of modelled individual office space

For the purpose of this research only one model of façade was used. Façade wall is fully glazed with windows in aluminium frame and triple glazings filled with mixture of 10% air and 90% argon gas. Only 1/3 of glazed surface is operable (windows can be opened), so this façade model has window-to-wall ratio (*WWR*) of 85%. Selected properties of glazing model has visible transmittance (τ_v) 72%, solar factor (g) 62% and U-value (U_g) 0,7 W/m²K. The selected glazing has neutral colour. No shading was selected since the purpose of this analysis is to investigate the potentials of DST application. Accordingly, no comfort control was established within the selected model in this study.

Scenarios for office occupancy profile and social time

The analysis of energy demand in buildings usually includes one hour before and after working time. Comfortable thermal conditions for working environment should be established before working time starts and also there must be some time when workers come and leave their offices. Based on these assumptions, ten working hours per day ware selected. No holidays and weekend breaks ware calculated. In this analysis office occupancy profile counts 3650 hours annually (ten hours per day through whole year).

All selected scenarios have the same number of occupancy hours, but the beginning and end of working hours are different. Working hours in Serbia in most administrative buildings officially start at 7:30, lasts 8 hours and ends in 15:30. Since selected software and climate data file have time interval of one hour, real working time in Serbia needed to be calculated at full hour interval, so tree different working times ware selected: (1) working hours from 7:00 to 15:00 (scenario for ten hours 6:00 – 16:00) (2) working hours from 8:00 to 16:00 (scenario for ten hours 7:00 – 17:00) and (3) working hours from 9:00 to 17:00 (scenario for ten hours 8:00 – 18:00) (Table).

The variable parameter in this analysis is also a selected social time which have only two options: with DST and without DST (perennial standard time (ST)).

Combination of tree working time variants and two social time options resulted seven different scenarios presented in Table 1.

Table 1: Selected scenarios – office occupancy profiles within different working and social times

		SOCIAL TIME		
		perennial ST* (no DST)**	**with DST**	**perennial DST**
WORKING TIME	**1** **from 9 am to 5 pm**	8:00 – 18:00 	8:00 – 18:00 (7:00 - 17:00) 	
	2 **from 8 am to 4 pm**	7:00 – 17:00 	7:00 – 17:00 (6:00 – 16:00) 	
	3 **from 7 am to 3 pm**	6:00 – 16:00 	6:00 – 16:00 (5:00 – 15:00) 	5:00 – 15:00 

* ST – Standard Time
** DST – Daylight Saving Time

RESULTS

In energy breakdown for heating, cooling and lighting in selected office model, lighting energy demand accounts only up to 9% of energy demand. The reason for this is that no visual control was included in the analysis and no shading was applied. As we move working and social time through presented scenarios the change in relative energy demand for lighting is going up to 50%. Interesting is that the peaks in energy demand are in scenarios with working time as early as possible and as late as possible. The amount of available daylight is time and orientation dependable, so there is increase and decrease depending on orientation and time of the day that office space is orientated toward the Sun. If control of visual comfort would be included in this analysis (in form of shadings) daylighting conditions would deteriorate and lighting energy demand would rise up to 25% in energy breakdown. Also, visual conditions in such office space would not be so orientation dependable, as with shadings applied the visual conditions almost equalise for all orientations.

In energy breakdown half of energy demand is for heating and the rest is for cooling. Of course, heating and cooling energy demand are highly orientation dependent. For example, in energy breakdown for south orientations, energy demand for heating can be 40%, and cooling demand can be higher (above 50%).

In this study, first idea was to analyse just energy demand for cooling and lighting, since the one hour shift is happening during summer period. It was assumed that heating energy demand would not influence the results. But, in Belgrade climate, DST period includes period of late spring and early fall, when there is a need for heating the buildings. Belgrade climate is heating dominated climate and heating represents the highest energy demand in heating-cooling-lighting energy breakdown. The results of this analysis show that heating energy demand during late spring and early fall can be a deciding factor in results.

The results of this study are presented in Table 2 and the same results are graphically presented in diagram in Figure 4.

Table 2: Results of energy demand for different scenarios and orientations

		LIGHTING	HEATING	COOLING	TOTAL	difference compared to the minimum
	scenario	[kWh]	[kWh]	[kWh]	[kWh]	[%]
EAST	8-18	121	471	457	1048	8,07%
	8-18 (7-17)	103	472	421	997	3,35%
	7-17	86	472	421	979	1,52%
	7-17 (6-16)	***80***	***475***	***409***	***964***	***min***
	6-16	78	516	409	1003	3,91%
	6-16 (5-15)	83	521	373	977	1,34%
	5-15	96	496	373	965	0,10%
SOUTH	8-18	94	261	417	771	8,39%
	8-18 (7-17)	78	262	395	735	3,91%
	7-17	64	269	394	727	2,85%
	7-17 (6-16)	***65***	***274***	***368***	***707***	***min***
	6-16	68	298	367	733	3,61%
	6-16 (5-15)	85	302	348	735	3,82%
	5-15	102	284	349	734	3,74%
WEST	8-18	89	540	428	1057	6,44%
	8-18 (7-17)	85	542	412	1039	4,84%
	7-17	76	526	412	1015	2,51%
	7-17 (6-16)	***84***	***530***	***375***	***989***	***min***
	6-16	89	570	375	1034	4,32%
	6-16 (5-15)	109	575	360	1044	5,22%
	5-15	128	535	360	1023	3,31%
NORTH	8-18	125	728	154	1007	5,37%
	8-18 (7-17)	113	733	141	987	3,45%
	7-17	102	713	141	956	0,33%
	7-17 (6-16)	***103***	***724***	***126***	***953***	***min***
	6-16	105	770	126	1001	4,80%
	6-16 (5-15)	120	770	110	999	4,60%
	5-15	133	729	110	971	1,89%
OVERALL (total for four orientations)	8-18	429	2000	1455	3884	6,99%
	8-18 (7-17)	380	2010	1370	3759	3,89%
	7-17	328	1981	1368	3677	1,75%
	7-17 (6-16)	***331***	***2003***	***1279***	***3613***	***min***
	6-16	340	2154	1277	3771	4,20%
	6-16 (5-15)	396	2167	1191	3754	3,77%
	5-15	458	2043	1191	3693	2,18%

The main rule in the results of this analysis is that as we move working time one hour later – heating is reduced and cooling is higher. This is understandable, since moving working hours one hour in warmer zone of the day is producing higher energy gains which are beneficial for period of heating and non-beneficial for cooling period. As we move working hours one hour into the cooler part of the day (earlier time) energy gains through glazing are lower and it results in reduction of cooling energy demand and rise of heating energy demand.

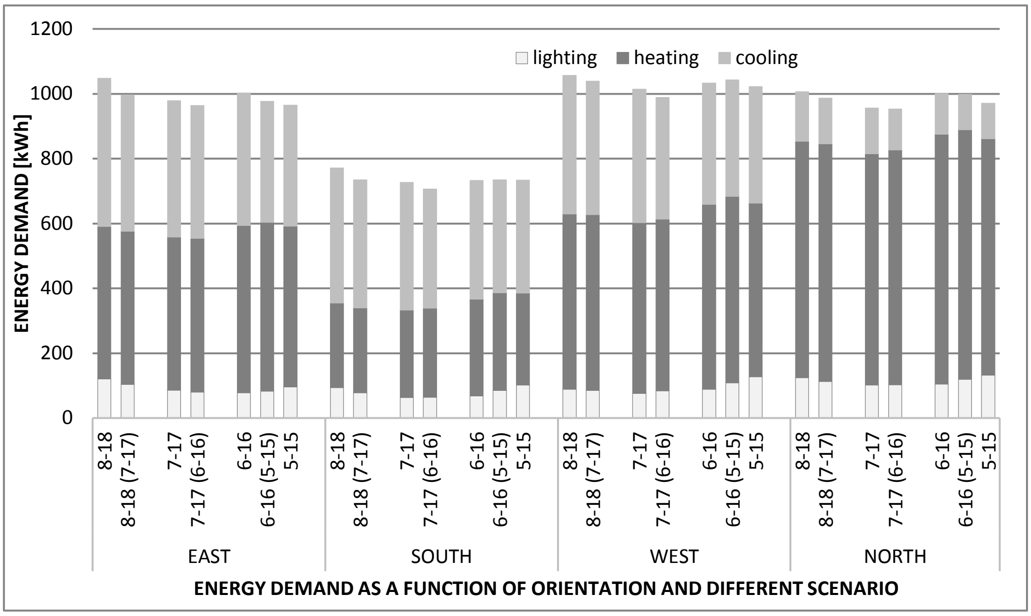

Figure 4: Results of the study presented in diagram – Energy demand for different scenarios and orientations

Working time from 8:00 to 16:00 with applied DST (scenario named ***7-17 (6-16)***) seems to result in most favourable balance between positive effects of energy gains for heating and negative effects of energy gains for cooling. For all orientations separately and for summarised energy demand for all orientation together, the result is the same – minimal energy demand is with application of DST and working time from 8:00 to 16:00.

For all three scenarios with different beginning and end of working time there is a reduction in energy demand with applied DST, as shown in Table 3. The reduction in energy demand is small and dependent on design of the study. Also the accuracy of the results is highly dependent on design of the study.

Table 3: Results of energy demand for different selected worktime scenarios

		LIGHTING	HEATING	COOLING	TOTAL	**reduction with DST**
	scenario	[kWh]	[kWh]	[kWh]	[kWh]	[%]
OVERALL (total for four orientations)	8-18	429	2000	1455	3884	
	8-18 (7-17)	380	2010	1370	3759	**- 3,22%**
	7-17	328	1981	1368	3677	
	7-17 (6-16)	***331***	***2003***	***1279***	***3613***	***- 1,75%***
	6-16	340	2154	1277	3771	
	6-16 (5-15)	396	2167	1191	3754	***- 0,45%***

CONCLUSIONS

It can be concluded that in Belgrade climate conditions there can be reductions in energy demand in offices with application of Daylight Saving Time. The best results in energy savings with application of DST are in the current official working time – from 8:00 to 16:00. Even if the beginning and end of working time is shifted by an hour up or down, there is still reduction in energy demand with application of DST. The reduction in this study is small, up to 3%. It can be argued that with control of thermal and visual comfort the reduction in energy demand with application of DST would be even smaller.

It is not important how small the reduction in energy demand was shown in this study. The importance of the results in this study is to ensure the continuation of tuning the energy efficiency system by applying small reductions in energy demands in buildings. At the building level savings of 1% to 3% are very small, but at the level of all administrative buildings in Serbia a serious amounts of energy can be saved.

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