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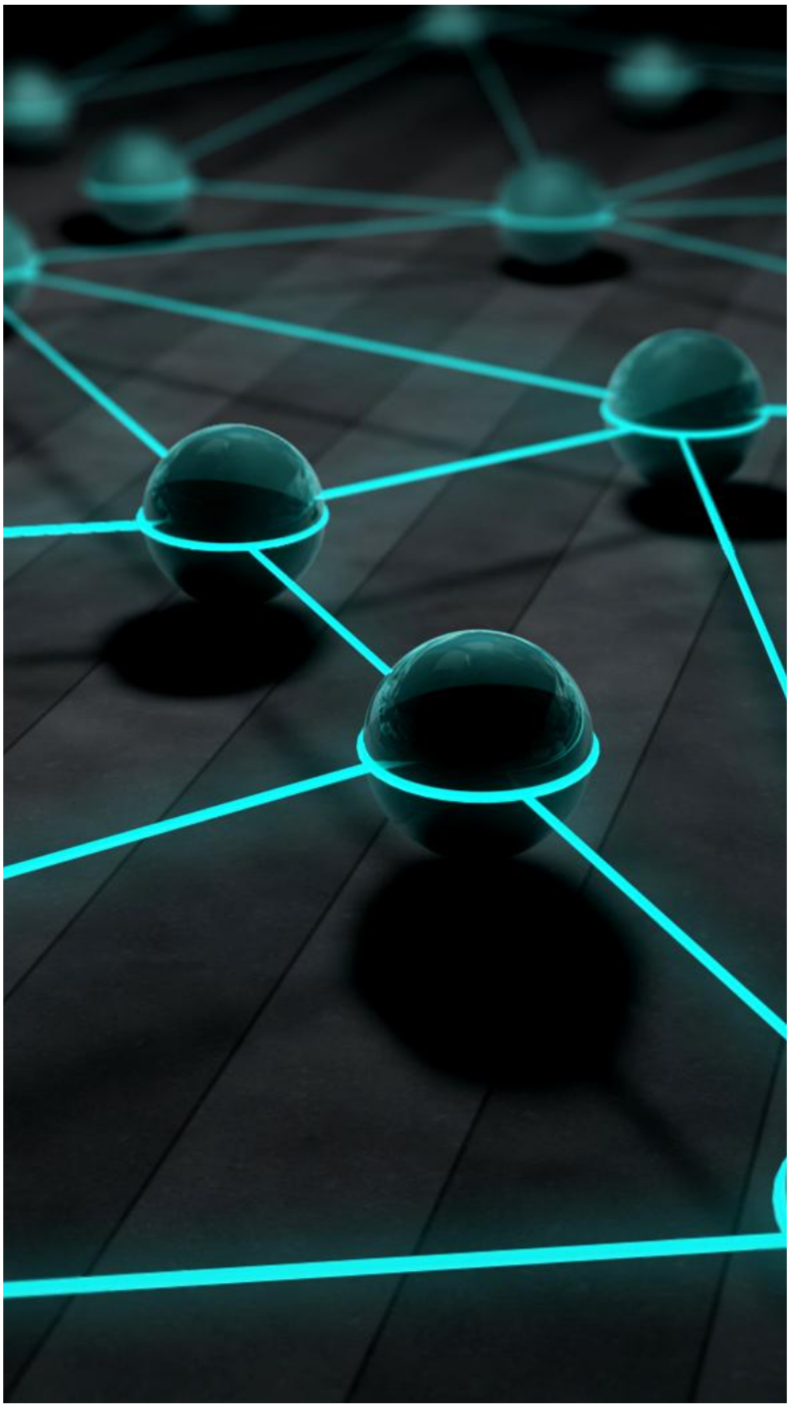

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OVERVIEW OF SOLAR ENERGY CONVERSION IN TURKEY

İsmail KARALI[1], Mehmet Ali ÖZÇELİK[2*], Ahmet KABUL[3]

[1,2] Gaziantep University, Technical Sciences, Department of Electricity and Energy, Turkey

[3]Süleyman Demirel University, Department of Energy Systems Engineering, Isparta, Turkey

*Corresponding author; ozcelik@gantep.edu.tr

Abstract

According to global energy statistics, the amount of energy consumed increased from 8557 Million Tons of Equivalent oil (mtep) in 1990 to 13509 mtep in 2016. Research has shown that life span of 200 years of coal, 40 years of oil and 60 years of natural gas. Therefore, it is foreseen that fossil fuels will not be able to respond to the increase in energy needs and will fall behind energy consumption. because of this reason, it has been considered important to search for new energy sources to prevent future energy crises. Today, it can be said that this searching mostly focuses on renewable energy sources.

Research suggests that renewable energy will constitute approximately 40% of total energy in the future. Although the importance of hydroelectric and wind energy from renewable energy sources has been understood much earlier, it is seen that the importance of solar energy has been realized in recent years. It is estimated that the highest increase in renewable energy sources between 2018 and 2050 in electricity generation will be in solar energy. Based on the years 2010 and 2018, while in 2010 was obtained 40,871 MW energy from the solar and 180,854 MW energy from the wind, but in 2018 was obtained 485,826 MW energy from the solar and 563,726 MW energy from the wind. According to these results, the energy obtained from the solar has increased approximately 12 times in the last nine years, while the energy obtained from the wind has increased approximately 4 times.

Keywords: *Solar energy and its potential, Renewable Energy, Energy conversion*

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1. Introduction

Energy is the ability to do business briefly. Therefore, countries also need energy to do business and to have an independent future. But, beside the increase in demand for energy increases day by day, energy costs increase, environmental factors and scarcity of resources bring about energy concerns.

According to the global energy statistics, the amount of energy consumed worldwide increased from 8557 million tons of oil (mtep) in 1990 to 13509 million tons of oil (mtep) in 2016 [1]. Research shows that fossil resources will be insufficient to respond to the increase in energy needs. These researches show that there is a life span of coal of 200 years, oil of 40 years and natural gas of 60 years. In addition, this study reveals that fossil fuel formation around the world lags behind energy consumption [2]. In parallel with the increase in the world population, the current level of energy use is foreseen to increase by 50-60% in the future [3]. In this context, the search for new energy sources is inevitable. The main criteria of this energy search are continuity, environmentalism, accessible and cheaper energy [4].

It is a well-known fact that renewable energy sources are accepted by the broader community in which they overlap with the above mentioned criteria. International energy companies anticipate that the share of renewable energy in total energy production will increase around 40% in the future [5]. Although the importance of hydroelectric and wind energy from renewable energy sources has been understood much earlier, it is seen that the importance of solar energy has been realized in recent years. It is estimated that the highest increase in renewable energy sources between 2012-2040 to electricity generation will be solar energy [6]. Figure 1 shows the distribution of all countries' investments in renewable energy sources by years.

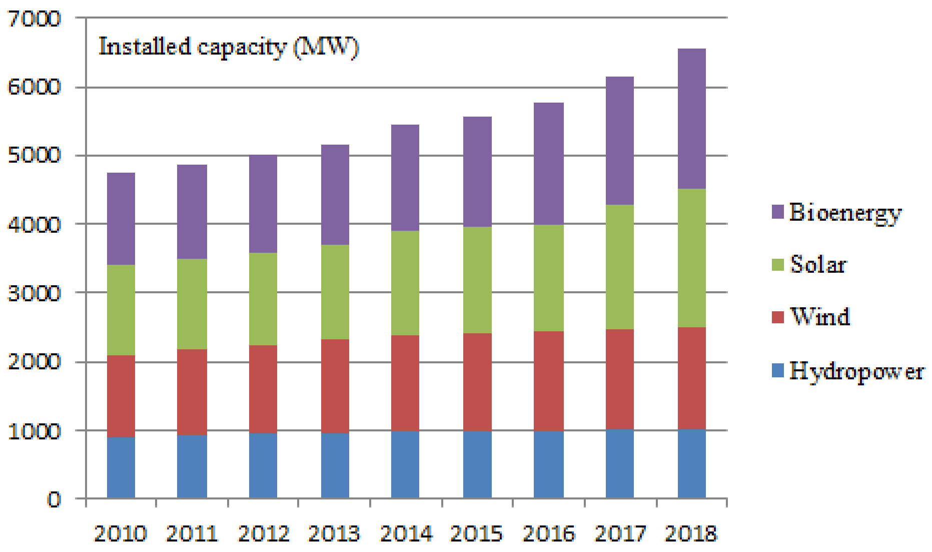

Figure 1. Renewable Energy Installed Power Capacity in World[16].

It can be seen from the graph that while the high capacity increase is seen in the solar and wind energy, the capacity increase in other renewable energy sources is lower. Based on the years 2010 and 2018, while in 2010 was obtained 40,871 MW energy from the solar and 180,854 MW energy from

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the wind, but in 2018 was obtained 485,826 MW energy from the solar and 563,726 MW energy from the wind. According to these results, the energy obtained from the solar has increased approximately 12 times in the last nine years, while the energy obtained from the wind has increased approximately 4 times. In the light of these values, it is seen that the investments made in solar energy in recent years are much more than the investments made in other renewable energy sources and therefore the importance given to solar energy has increased. According to the estimates of the International Energy Agency (IEA), investments in solar energy are expected to reach an installed power capacity of 1721 GW by 2030, not to slow down in the near future [7].

2. Solar Energy Installed Power Capacity of European Union Countries

One of the most important reasons for the interest in renewable energy sources is the harmful emissions resulting from the combustion of fossil fuels. European Union countries and other countries that want to reduce their emissions value think that the solution of the problem is in solar and other renewable energy sources. At this point, EU countries plan to increase the share of renewable energy to 34 percent by 2030, according to the values of the report of 2016 which published by the International Renewable Energy Agency IRENA in Brussels [8]. In this way, it is thought that the targeted emission values will be achieved and in addition to the emergence of new business areas, it will contribute positively to the revival of the national economies. Figure 2 shows the distribution of investment in renewable energy sources of the European Union countries by years.

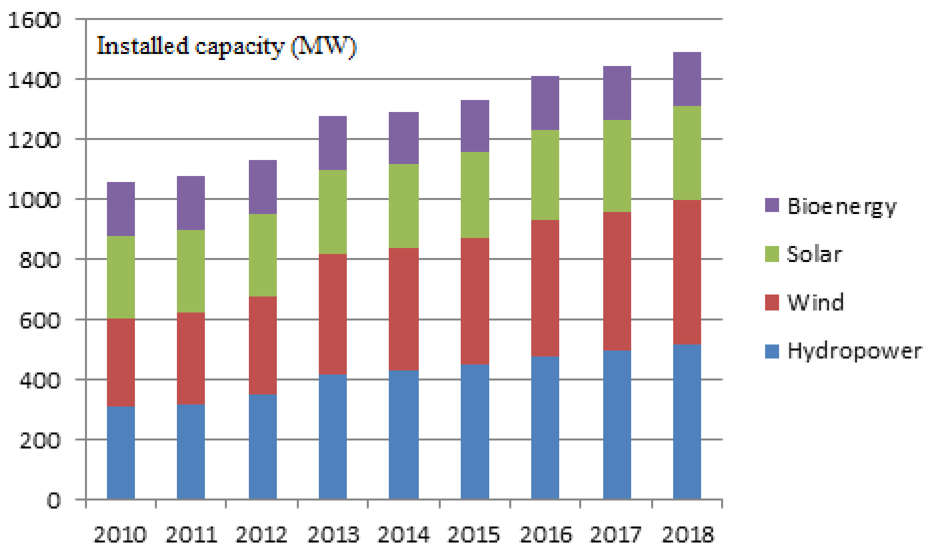

Figure 2. Renewable Energy Installed Power Capacity Across European Union Countries[16].

While the high capacity increase in the European Union is observed in solar and wind energy, it is observed that the capacity increase in other renewable energy sources is much lower. Considering the last nine-year process in EU countries, while in 2010 was obtained 30,857 MW energy from the solar and 84,922 MW energy from the wind, but in 2018 was obtained 121,692 MW energy from the solar and 182,491 MW energy from the wind. According to these results, while the energy obtained from the sun increased by 4 times in nine years, the energy obtained from the wind increased by 2 times. Although the European Union's investment in solar energy showed a rapid increase, it remained below the rate of increase in the world average. Reason of this can be attributed to the fact that other EU countries except Germany and Italy do not invest enough in solar energy, and in addition, China's high investment in solar energy raises the world average.

3. Germany's Solar Power Installed Power Capacity

Germany ranks first in the world in terms of PV system power per capita [6]. When Compared to other countries of the EU, Germany has shown rapid growth in solar and other renewable energy investments and is the leading country in the European Union. Germany, which is expected to invest more than 200 billion euros in renewable energy sources, is expected to provide jobs to about 500,000 people by 2020 [9]. Figure 3 shows the distribution of Germany's investment in solar energy by years.

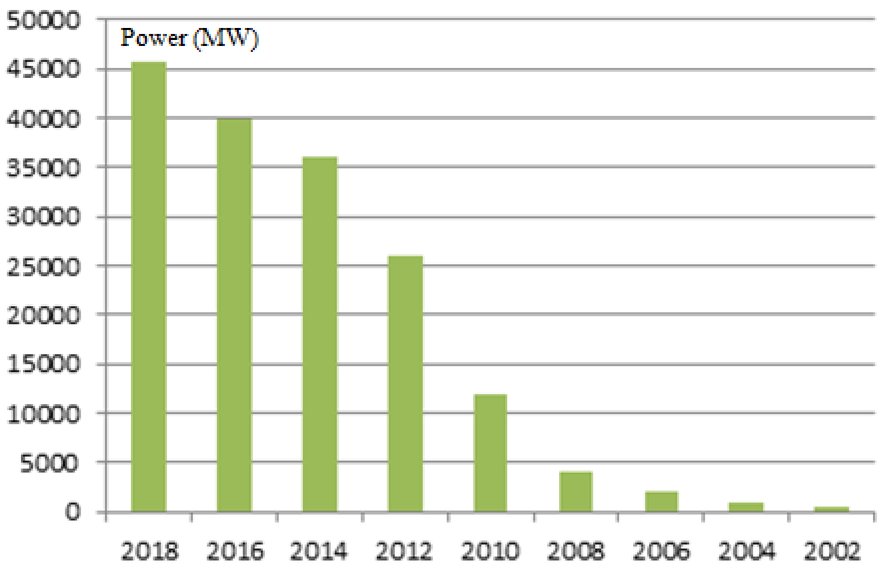

Figure 3. Germany's solar power installed power capacity [17].

As it is seen in the graph, Although The Germany have worse climate than Turkey in particular by making the necessary investments in solar energy in recent years has become a leader in the region and because of this reason has been a role model to many countries. The power which Germany generated 47,780 MW from the solar energy is approximately 38% of the power which European Union obtained from solar energy.

4. China's Solar Power Installed Power Capacity

China, which has surpassed success of Germany in solar energy investment, has the largest solar panel fields in the world and is the leading country in this field with the technologies which they have developed in this field. As of 2018, China alone produced about 1.5 times the total PV power

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produced by all European countries (121,692 MW). Moreover, China which produced approximately 36% of the power generated by all countries (485,826 MW) with 174,630 MW of solar power, It is expected that by 2030 it will increase its solar energy investment capacity to 200 GW [10]. But, considering the year-end gains of 2018, it can be foreseen that this country will reach its 2030 targets much earlier. China, which is also the world's largest producer of solar panels, produces more than 60 percent of total panel production, according to data from the International Energy Agency (UEA) [11]. This situation has created a serious business area in China with the increasing interest in solar energy in recent years [11]. According to the International Energy Agency (IEA) data, China reached their targets of 2020 three years ago in 2017. Table 1 shows the distribution of China's solar power over the years.

Table 1. China's Solar Power Installed Power Capacity [18]

SOLAR POWER INSTALLED POWER / MW										
YEAR	2009	2010	2011	2012	2013	2014	2015	2016	2017	**2018**
INSTALLED POWER/ YEAR	160	500	2.50	5.00	9.50	10.560	15.130	34.540	52.830	**44.38**
TOTAL CAPACITY	300	800	3.30	8.30	17.8	28.199	43.180	77.420	130.25	**174.6**

As can be seen from the graph, China has made a very rapid development in investments of solar power in recent years. Of course, the increase in industrial production in China and the increase in oil prices in recent years can be said to be the reasons for this rapid development.

5. Turkey's Solar Power Installed Power Capacity

In particular, China, Germany and other developed countries have shown their successful breakthrough in solar energy also can serve as a positive example for Turkey's renewable energy policy. Turkey has a very high solar energy potential due to its geographical location is located. According to Solar Energy Potential Atlas to (GEPA), Turkey's total annual sunshine duration of 2,741 hours, 7.5 hours per day and an annual total incoming solar energy 1,527 kWh / m^2.year, the daily average is 4.18 kWh / m^2.day [12]. In 2017, total solar collectors area in Turkey reached to 20.000.000 m^2 and 823.000 tons of petroleum heat energy was obtained [12]. In 2017, in addition that, 2.9 billion kWh of electricity was generated from solar energy [12]. According to the researches of the Vienna technical University - Energy Economics Group, the distribution of the Solar Energy Technical Potential according to European countries is shown in Figure 4.

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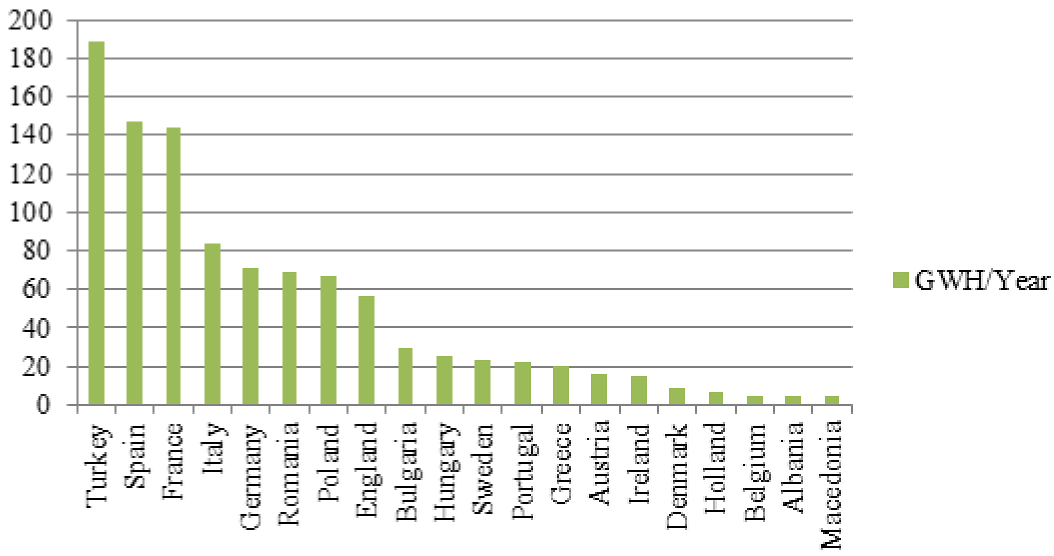

Figure 4. Distribution Of Solar Energy Technical Potential By European Countries (GWh/Year) [19]

As shown in the figure, Turkey, which has 189 GWh / year solar energy potential is in first place in Europe. Result of this information, solar energy potential of Turkey is greater than about 2.5 times the solar energy potential possessed by Germany.

Total installed capacity of solar power in Turkey is planned 5 thousand MW as target of 2023 [13]. But, as shown in Table 3, in the end of 2018. Turkey 4.981 MW unlicensed and 81 MW licensed solar PV power has an installed capacity of 5.062 MW in totaly. In this informations light, Turkey have reach in 2018 for target of 2023. Turkey has increased investment in solar energy in recently. Table 2 shows the total installed capacity of solar energy in 2018 and the total installed capacity of solar energy until 2018 on a global scale.

Table 2. Top 10 Countries in World By 2018 And Total Solar Power Installed Capacity Power [20]

	Investment for 2018			**Total investment including Year 2018**	
1	China	45.0 GW	1	China	176.1 GW
2	India	10.8 GW	2	India	62.2 GW
3	American	10.6 GW	3	American	56.0 GW
4	Japan	6.5 GW	4	Japan	45.4 GW
5	Australia	3.8 GW	5	Australia	32.9 GW
6	Germany	3.0 GW	6	Germany	20.1 GW
7	Mexico	2.7 GW	7	Mexico	13.0 GW
8	Korea	2.0 GW	8	Korea	11.3 GW
9	Turkey	1.6 GW	9	Turkey	9.0 GW
10	Netherlands	1.3 GW	10	Netherlands	7.9 GW

As can be seen in the Table 2, Although Turkey has in recent years invested in solar energy and has entered into the top 10 countries in recent years, it could not enter into the top 10 countries in total.

In this context, when we look at the gains of the top 10 countries as a result of the investments they have made, it can be said that we are still far from the target. As shown in Table 3, investments in solar energy have increased. However, Turkey needs more energy because of the growing economy and increasing production. Therefore, Turkey should be increase much more investments of solar energy.

Table 3. Turkey's Solar Power Installed Power Capacity[21]

SOLAR POWER INSTALLED POWER / MW		
RESOURCES	AS OF END OF 2018	AS OF END OF 31 JANUARY 2019
Solar Energy(Unlicensed))	4.981,20	5.098,50
Solar Energy	81,7	81,7
Wind Energy	6.942,30	6.946,80
Wind Energy (Unlicensed)	63,1	63,1
Hydropower (Dam)	20.536,10	20.567,50
Hydropower (Streamıng)	7.747,10	7.783,70
Geothermal	1.282,50	1.302,50

The investments made in Turkey in 2017 and 2018 has increased significantly compared to previous years. As of the end of 2007, was obtained 3 MW from solar energy, up to 250 MW in 2015 and up to 5,062 GW by the end of 2018 [16]. It is now and also coming century, solar energy will continue to take important role in terms of energy resources [22]-[23].

6. Conclusion

In particular, the rise in energy costs in recent years, the difficulties in supplying energy and political pressures over energy have made the value of energy quite important today. Turkey have not high potential in terms of energy resources and especially fossil resource. In this reason, Turkey dependent on foreign countries, the use of all domestic resources and the assessment of all possibilities are necessary to break addiction. The fossil fuels of the country should be used such as coal. Moreover, in the medium term, it should increase its energy diversity by completing nuclear power plants in order to reduce or eliminate energy dependence with other countries. However, the general projection that the energy future is in renewable energy sources in the long term should not be ignored. Because of this and the case of China and Germany examples, Turkey needs to energy much more should be investment from renewable energy sources and primarily solar energy. Developing more technology in this direction are high importance for Turkey.

Countries like China and Germany did not produce energy only in solar power. Thanks to the experience gained in these countries, they have also produced and exported the technology needed for the installation and operation of solar energy systems. China produces 60% of PV panels produced worldwide [11]. Similarly, according to 2010 data in Germany there are approximately 10 thousand companies, including assembly and suppliers, and more than 200 companies producing PV cells and modules, it is explained that the number of full-time workers in these companies is about 133

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thousand [9]. However, If considering that Germany has increased its investments in solar energy more than doubled from 2010 to 2018, it can be estimated that the number of workers working in the same period has increased approximately fourth period. Therefore, both countries have created an important business area for the citizen of the country and contributed to the economy.

As of the end of December 2018, total installed power of 4981 MW unlicensed and 81 MW licensed solar power plant in Turkey has been increased to 5,062 GW. Turkey has an aboriginal rate of more than 50 percent on PV panel basis and more than 75 percent on solar energy system basis [14]. Currently, panels, Transformers, cutters, steel structures and cables are manufactured in the country. However, cell production, which is the most important part of solar energy systems, has still not been indigenized as of 2018[14]. Taking into account the unemployment and current account deficit problems experienced in the country, it will be an important opportunity all parts needed in solar energy systems to be produced immediately in our country.

Orientation to solar energy systems on a global scale is fast, moreover it is estimated that it will reach 1721 GW by 2030 [7]. As a result of this rapid development, the PV panels, which are known to have a useful life of 25-30 years, are projected to generate 9.57 million tons of waste by 2050[15]. As a result, it is already foreseeable that PV panels and other parts used in solar energy systems will pose a waste problem in the near future. Therefore, in order to prevent future environmental problems due to these wastes and to turn this problem into an opportunity, the necessary studies should be carried out at the point of recycling of wastes occurring in part of solar energy systems.

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ASSESSING AND IMPROVING RECOMMENDATIONS FOR LOCAL POWER QUALITY EFFICIENCY FOR INDUSTRIAL PLANTS WITH THE HELP OF REAL DATA

Levent Kılıç

Şişecam Science, Technology and Design Center, Turkey

lkilic@sisecam.com

Abstract

The Turkish grid system is under big dynamic changes. Renewables are continuously increasing, distribution privatization was completed. There are many participants of electricity system of Turkey. To synchronise all these needs scientific rules and regulations to be obeyed.
On the other hand, although many rules, there is no any statistical data about how system operates effectively. What are the industrial plants faced with? Industrial plants connected to the national distribution or transmission grid at medium voltage level are really exposed to various grid events that affect firstly production efficiency, equipment, system failure and unexpected malfunctioning.
Without data, there is no way to analysis and make clear definition of grid events. Recorded data for a long time in the point of common coupling will be used to evaluate existing status and to estimate next ones.
In this paper, comparative power quality comparison will be analysed for 12 industrial plants distributed localized at five different industrial grid points. It is aimed to the seven different regions of our country compared to the facilities connected to the national system and compare them with a point from abroad. With this study, Turkish power quality intensity is realized by site data for next care of private sectors, private electric companies and industrial plants, and to give numerical data to literature.

Keywords: power, quality, grid, events, statistic, sag

1. Introduction

In order to achieve objectives as continuity and security of the supply, some problems have to be issued together by system operators and the other users based on real data. Some countries have issued dedicated grid codes for connecting the all kind of plants to the electrical grid addressed to transmission or distribution system. Turkish grid code is based particularly European ones in conjuction with The Institute of Electrical and Electronics Engineers (IEEE). In Turkish grid code these requirements haven't focused on power quality and fault ride through

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capability of industrial plants. Grid disturbances have deeply negative impact on industrial plants.

There are a variety of events in the grid, most of them related to the grid voltage. These events are characterized by a change in amplitude and durations from milliseconds to hours. Based on these amplitude and duration, voltage events are classified in different ways by standard methods [1].

There are a number of power quality problems in the present-day fast-changing electrical systems. The main causes of these power quality problems can be classified into natural and man-made in terms of current, voltage, frequency, and so on. The natural causes of poor power quality are mainly faults, lightning, weather conditions. However, loads or system operations are the man-made ones. The causes related to the loads are nonlinear loads such as saturating transformers and other electrical machines, or loads with solid-state controllers such as vapor lamp-based lighting systems.

The power quality problems affect all concerned utilities, customers, and manufacturers directly or indirectly in terms of major financial losses due to interruption of process, equipment damage, production loss, wastage of raw material, loss of important data, and so on. There are many instances and applications such as automated industrial processes, namely, semiconductor manufacturing, pharmaceutical, glass industries, and banking, where even a small voltage dip/sag causes interruption of process for several hours, wastage of raw material, and so on. Some power quality problems affect the protection systems and result in mal-operation of protective devices. These interrupt many operations and processes in the industries and other establishments. These also affect many types of measuring instruments and metering of the various quantities such as voltage, current, power, and energy. Moreover, these problems affect the monitoring systems in much critical, important, emergency, vital, and costly equipment [2].

The EN 50160 standard [3] indicates that there is no such limitation on the voltage values in the IEEE 1159 [4] standard power system, while concentrating on the voltage characteristics of the low and medium voltage grids. A few seconds of transient voltage disturbances are classified in the IEEE 1250 standard [5]. Although the same voltage drop event is based on the same standard between EN 50160 and IEEE 1159 standards, the amplitude of the event is defined differently in these standards. This is shown in Table 1 for both standards [6]. This classification method, based on the magnitude and duration of events in the electricity grid, has several advantages and drawbacks. When this method is used, the following items are expressed [2]:

The effective value (rms) of the voltage at the time of the event is not constant, which may lead to an uncertainty when describing the amplitude and duration of the event. Rapid events that are shorter than a period cannot be defined very well because the value of the voltage may not be fully calculated. Repeated events can give erroneous results. In this case, the number of events may be missing or overestimated [7].

The voltage will be reduced to 0,1 pu or less and will focus on immediate events up to 1 second. Short interruptions and voltage drops events are characterized by this amplitude and duration [1]. These events mainly concern short circuits in the electricity grid.

In this study, the answers to the following questions will be tried to be answered according to the actual field / measurements.

• Why does a distribution grid fail?
• What is the effect of grid faults on the production facility?
• Is there a difference between organizing industry connection, direct 154 kV system connection, distribution system output connection?

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- Is it necessary to link the national grid to the same criteria for all installations?
- What is needed to ensure the same reliability?
- Does the load characteristic affect the connection point selection?

2. Investigation of the Grid Events

Grid events have been effectively introduced in the literature and standards [8]. In this respect, various studies including measurement and long-term studies have been carried out in countries such as USA, France [6]. In Turkey, there is no study which will contribute to the national system based on the actual measurement results, which is reflected in the literature in this respect. This system, which is thought to be radial, seems to be efficient, providing very effective solutions when examining the various regions of our country. However, it is seen that this positive effect on the transmission system does not continue in the distribution system in the same way due to the structural differences, and therefore some obligations like measurement, recording have to be applied and and not standardized.
3 years events were recorded according to EN 50160 standard. These are based on short and long interruptions, voltage sags and swells that fall below 0.9 -1.1 pu, which is considered to lead to production failures. Voltage unbalance, flicker and harmonics will not be considered here. Plants' locations are seen in Figure 1. Distribution companies are different for all locations.

Figure. 1. Distributed localized industrial plants on Turkish map

The power quality (PQ) problems due to power distribution systems's disturbances are not just the power quality problems but also affect the energy efficiency of the plant. As far as energy efficiency is concerned in an industrial plant power quality events will create negative sequence components causing power losses in conductors and electrical motors and malfunctioning of entire system like relays. Even more, these they can damage the system components [9].
There are major reasons for the concerning events: Newer load equipment with microprocessor based controls and power electronic devices is more sensitive to PQ variations. Adjustable speed motor drives and shunt capacitors for power correction to reduce losses need to high overall power system efficiency. System capacity has impact on increasing reliability.

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Now, end users have an increased awareness of power quality events by monitoring. End users are becoming better informed about such issues as interruptions, sags, switching transients and need power quality issues to be improved. Integrated processes and connections to grid mean that the failure of any plants has much more impact on grid.

2.1. Voltage Interruptions

The origins of the voltage interruptions in general are "faults" which caused by grid or industrial plants and broken connection pieces. An interruption is the supply voltage or load current decreases to less than 0.1 pu for a period of time less than 3 minutes. Interruptions can be the result of power system faults, equipment failures, and control malfunctions and misoperation. The interruptions are measured by duration of the voltage magnitude less than 1 percent. The duration of an interruption due to a fault on the grid is determined by the operating time of utility and plant protective devices [10]. Reclosing and/or delayed reclosing of the protective devices can limit the interruption caused by a fault. The duration of an interruption due to equipment malfunctions or loose connections can be irregular.

Table 1. Definion of Interruptions.

Standard	Definition	Magnitude	Duration	Applicability
EN 50160	Short interruption	< %1	< 3 minutes	LV and MV (<35 kV)
IEEE Std 1159-1995	Momentary interruption	< %10	10 ms – 3 sec	LV, MV, HV
IEEE Std 1250-1995	Instantenous interruption	Complete loss of voltage	10 ms – 0,5 sec	LV, MV, HV
	Momentary interruption		10 ms – 2 sec	LV, MV, HV

Tables 2-3-4 are numbers of event occurred. These PQ events are monitored by localized sensitive equipment.

Table 2. 2016 Events' Statistics.

Plant	Year	Recording duration (Hours/Year)	Short Interruptions of the supply voltage	Long Interruptions of the supply voltage	Supply voltage dip	Supply voltage swell	Sum of all events
AB	2016	8760	0	4	144	8	156
AE	2016	8760	0	1	98	7	106
AF	2016	8760	1	3	59	1	64
PE	2016	8760	4	4	102	13	123
PK	2016	8760	0	2	387	394	783
TF	2016	8516	0	0	335	358	693
TM	2016	8760	0	1	215	59	275
TN	2016	8760	0	2	148	14	164
TP	2016	8760	0	7	1588	1243	2838
SO	2016	8760	2	9	409	408	828
SD	2016	8760	9	14	95	28	146
KR	2016	8760	3	0	2	0	5

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Table 3. 2017 Events' Statistics.

Plant	Year	Recording duration (Hours/Year)	Short Interruptions of the supply voltage	Long Interruptions of the supply voltage	Supply voltage dip	Supply voltage swell	Sum of all events
AB	2017	8760	1	4	102	2	109
AE	2017	8760	0	0	64	6	70
AF	2017	7392	2	1	31	2	36
PE	2017	8760	1	2	65	6	74
PK	2017	8760	1	4	348	351	704
TF	2017	4560	2	1	184	177	364
TM	2017	8760	1	1	272	132	406
TN	2017	8760	0	0	7	0	7
TP	2017	8760	28	8	898	522	1456
SO	2017	8760	0	11	357	355	723
SD	2017	8760	1	7	79	1	88
KR	2017	8760	1	7	238	1	247

Table 4. 2018 Events' Statistics.

Plant	Year	Recording duration (Hours/Year)	Short Interruptions of the supply voltage	Long Interruptions of the supply voltage	Supply voltage dip	Supply voltage swell	Sum of all events
AB	2018	8760	0	1	102	0	103
AE	2018	8760	0	9	185	19	213
AF	2018	8760	1	3	23	2	29
PE	2018	6744	2	8	185	20	215
PK	2018	8760	0	3	491	513	1007
TF	2018	8760	2	4	633	661	1300
TM	2018	8760	0	3	175	42	220
TN	2018	8396	4	1	13	4	22
TP	2018	8760	2	7	1092	867	1968
SO	2018	8760	0	10	659	672	1341
SD	2018	8760	0	3	55	0	58
KR	2018	8760	0	3	34	0	37

AE plant amplitude – duration statistics data is given Table 5. These tables are available for all but not will be given more for other plants and years.

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Table 5. Events' Amplitude and Times Characteristics

Res. voltage			Duration (s)			
u (%)	0.01 ≤ t ≤ 0.2	0.2 ≤ t ≤ 0.5	0.5 ≤ t ≤ 1	1 ≤ t ≤ 5	5 ≤ t ≤ 60	t > 60
90 ≥ u ≥ 80	102	5	7	5	0	0
80 ≥ u ≥ 70	22	4	6	0	0	0
70 ≥ u ≥ 40	14	0	1	0	0	0
40 ≥ u ≥ 5	16	1	0	1	1	0
5 ≥ u	0	0	0	0	0	9

2.2. Voltage Sags

Table 6 shows voltage sags terminology as standardized. The reason of voltage sags may be short circuits, overloads, and starting of large motors. Distance to fault, line/cable characteristics, transformers connection, grid status, short circuit impedance, etc. are deterministic parameters for voltage sags.

Table 6. Definion of Voltage Sags

Standard	Magnitude	Duration	Applicability
EN 50160	%1 – 90%	0.5 cycles to 1 min	LV and MV (up to <35 kV)
IEEE Std 1159-1995	%10 – 90%	0.5 cycles to 1 min	LV, MV, HV
IEEE Std 1250-1995	Reduction of voltage	0.5 cycles to few seconds	LV, MV, HV

As seen in Table 2-3-4, there are huge amount voltage sags that are uncontrollable.
This survey of power quality has run for 3 years 12 industrial plants which have been monitored at their point of common coupling. Some plants are connected to the grid at the same bar but different cubicles.
Power quality intensity (all events occurred one day/one year) is seen in Table 7.

Table 7. Power Quality Intensity

PQ Event Intensity	2016	2017	2018	3 Years Average
AB	0,018	0,012	0,012	0,014
AE	0,012	0,008	0,024	0,015
AF	0,007	0,005	0,003	0,005
PE	0,014	0,008	0,032	0,018
PK	0,089	0,080	0,115	0,095
TF	0,081	0,080	0,148	0,092
TM	0,031	0,046	0,025	0,034
TN	0,019	0,001	0,003	0,008
TP	0,324	0,166	0,225	0,238
SO	0,095	0,083	0,153	0,110
SD	0,017	0,010	0,007	0,011
KR	0,001	0,028	0,004	0,011

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Industrial plants connections to the national grid/substations are defined in Table 8.

Table 8. Substation Connection With Electrical Parameters

Ind. Plant Code	City	154/36 kV Substation Name	3 phase shortcircuit [kA]	1 phase - earth shortcircuit [kA]
AB	Yenisehir	Yenisehir	8,93	5,51
AE	Eskisehir	Eskisehir 3	20,39	15,72
AF	Mersin	Yakakoy	13,67	9,94
PE	Eskisehir	Eskisehir 3	20,39	15,72
PK	Kirklareli	Buyuk Karistiran	16,59	12,06
TF	Kirklareli	Buyuk Karistiran	16,59	12,06
TM	Mersin	Nacarli	19,87	15,81
TN	Yenisehir	Yenisehir	8,93	5,51
TP	Polatli	Beylikkopru	5,20	3,30
SO	Kirklareli	Buyuk Karistiran	16,59	12,06
SD	Mersin	Mersin 2	13,50	10,42
KR	Mersin	Mersin 3	13,50	10,42

Table 8 is of Turkish grid operator, Turkish Electricity Transmission Company (TEIAS), data. It is seen here that, 3 phase and 1 phase-earth shortcircuits' ratios are correlated with each other. However, power quality intensity given above does not correspond to this. Some special situations must be investigated for reliability analysis. Table 9 is of same substation connections of industrial plants.

Table 9. Local Categorization

Ind. Plant Code	City	154/36 kV Substation Name	PQ Intensity 3 Years Average
AB	Yenisehir	Yenisehir	0,014
TN	Yenisehir	Yenisehir	0,008
AE	Eskisehir	Eskisehir 3	0,015
PE	Eskisehir	Eskisehir 3	0,018
PK	Kirklareli	Buyuk Karistiran	0,095
TF	Kirklareli	Buyuk Karistiran	0,092
SO	Kirklareli	Buyuk Karistiran	0,110
AF	Mersin	Yakakoy	0,005
TM	Mersin	Nacarli	0,034
SD	Mersin	Mersin 2	0,011
KR	Mersin	Mersin 2	0,011
TP	Polatli	Beylikkopru	0,238

There is 5 area including 7 substation and 12 plants. The second best value is, 0,008 by TN and the second worst is 0,110 by SO. Reliabilities (R) by this assumption are 99.2% and 89.00% sequentially. By using Bernoulli (Binomial) equation, for 99.20% Table 10 is created for reliability map according to industrial plants connected to substations.

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Reliability is the ability of the power system to supply energy within accepted standards and in the amount desired. For industril plants, the availability Table 10 is often stated as being the adopted reliability.

Table 10. Reliability Impacts of New Plants/Cubicles

n	1	2	3	4	5	6	7	8	9
R	0,9920	0,9841	0,9762	0,9684	0,9606	0,9529	0,9453	0,9377	0,9303

From a grid service perspective, a power supply is delivered with a reliability in the range of 1 to 2 column, while end customers typically experience a low reliable power, in the range of 8 to 9 ones. Reliability is measured using various indices characterising duration, and magnitude of adverse effects on the power-quality issues (such as voltage-dip and swell disturbances) that are becoming increasingly significant in sustainable production. For critical-process information services contemporary thoughts on this topic are quite differently focused; modern power-system reliability relates more reliability, quality, security and redundancy.

3. Conclusion and Suggestions

In this study, the data obtained for the link states from different connection points to the national grid in different regions of our country are examined.
Based on the presented records regarding events on the electrical grid can be drawn the following conclusions:
• The industrial plants that have individual feeder at the substation and less plants have good reliability that is the most important for product quality.
• The installations connected to the Organize Industrial Zone (OIZ) seem to have the second best connection.
• Industrial plants connected to the distribution system feeders have the worst conditions.
• In the same busbar, as the plant itself collapses, the voltage decreases to less than 0.5 pu voltage amplitude that causes the other plants collapse and loss of production.
• In this case, it is important to standardize the maintenance that the facilities have done or have done. This is because the failures in the distribution seem to originate mainly from the facilities connected to the busbar.
• It is especially important that the transformer center and the OIZ or the individual feeder plants are fed by double circuit. Man-made failures of long-distance events leave the whole system without backup.
• It will be beneficial to standardize this distance and to provide 154 kV if necessary.
• The definition of consumer and producer linkage published in the Official Gazette dated 30.07.2016 should be assessed taking into consideration the load characteristics and dynamics. For example, a facility with a 5 MW moment load input / output, such as the SO, should not be considered as a facility with a total load of 2.5 MW.
• As the number of consumers connected to the bus increases, it is seen that the failures experienced are also linear. In this case, the facilities do not have the same service quality. There is a difference between the power quality provided in Mersin and the power quality provided in Thrace.
• The fact that transformer substations have standard power and number of consumers will increase the quality of the power.
• It appears that there are a significant number of voltage surges in the grid.
The national grid is integrated with producers, transmitters, distributors and consumers. The negativity experienced in one of these will adversely affect the others.

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Equipping the factories with a monitoring system that allows the evaluation of the quality of the power in the standard building, such as the meters that are the basis for the invoice, will be beneficial in terms of prioritizing system improvements.

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ASSESMENT OF ENERGY PERFORMANCE AND THERMAL BEHAVIOR OF A SINGLE-FAMILY RESIDENTIAL BUILDING

Ayse Zelal Tugrul

Building &Architectural Engineering, Politecnico di Milano, Lecco, Italy

aysezelal.tugrul@mail.polimi.it

Abstract

This study provides a comprehensive analysis on the impacts of passive and active design strategies with regard to energy efficiency and thermal comfort of a building in three different climate conditions, over a case study. A single-family building has been simulated to determine energy consumption and internal thermal comfort based on static (ISO 7730:2005) and adaptive thermal comfort (EN 15251:2007) criteria. A serious of simulations were conducted to optimize the building envelope by using Trnsys 17. The study carried out the results of different design options by the implementation of varied thermal mass, natural ventilation, shading, plant system and heat exchanger options for Lystrup, Paris and Rome climates. The results of simulations point out that a single building strategy without a promoter energy-driven strategy, is not enough to obtain an energy efficient building.

Key words*: Thermal Comfort; Building Envelope; Low-energy Residential Building*

1. INTRODUCTION

Buildings, as the keystones of cities, have an important role for the sustainable development. According to European Commission, buildings are responsible for 40% of global energy consumption. [1] Considering this major impact of the buildings within the context of future climate change, it is crucial to understand the energy performance of a building and to take required actions for prevention of the waste of energy. There are also many studies can be found about the impact of climate change on the energy performance of a building since they are linked to each other. Wang et al. [2], analyzed the effect of climate impact on the change of heating and cooling demands of residential buildings. The study shows up to 120% and 530% in total heating and cooling energy requirements depending on the increase in the global temperature for 2°C and 5°C. In this regard, the optimization of the building envelope, in other words the improvement of the building energy performance has become an important step during the design stage to minimize the cooling and heating energy demands, thereby the reduction of energy consumption. To improve the energy performance of a building considering the thermal comfort of the envelope, different building strategies are implied to the building envelope. Pfafferott et al. [3] carried out an experiment aiming the reduction of primary energy consumption of office buildings by utilizing the natural heat sinks such as ambient temperature, ground water, etc. An another study showed that the ventilated roof system can be used to improve the thermal performance of a building by reducing the heat flux up to 50%. [4]. The

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building strategies can be classified under the two title; passive design strategies and active design strategies. The direct usage of natural energy, appropriate building orientation, optimized window to wall ratio (WWR), etc. are some of the examples to the passive building strategies [5] and optimization of HVAC system, energy efficient lightening systems can be shown as examples to the active design strategies. However, all the simulations, the energy calculations and energy performance evaluations have no meaning without a building standard. The evaluation of a building makes a sense when the results are acquainted with the specified design criteria. [6]

In this study, a series of energy simulations have been operated to better understanding of impact of building technologies, climate conditions, passive and active design strategies on the energy performance of a building. A sustainable single-family building from a real case study, has been analyzed by usage of Trnsys, building energy simulation (BES). Moreover, the study provides the sensitivity analysis of different parameters aiming the most efficient energy performance of the building, such as climate conditions, building technologies (wood, brick, concrete, etc.) with different thermal mass and thermal transmittance, shading devices (intensity and control), ventilation (intensity and use), etc. Evaluation of thermal condition and energy use are the main two stages of the method of work of the study. The building performances and the thermal comfort classes are evaluated according to EN 15251:2007 (adaptive approach) and to the ISO 7730:2005 (static approach) [7], [8].

The building simulations were carried out for both summer period (1st May - 30th September) and winter period (15th October 15th April). According to UNI EN ISO 6946:2008 the thermal mass is described as the mass per unit area of the opaque wall. Thermal mass can also be considered as a passive system because the building components are capable of storing heat, thereby they can provide the heat that is needed for the active systems. For example, walls and floors in the building components are assumed as thermal masses. [9], [10]. This heat storage system can be determined by usage time lag (ϕ) and decrement factor (f) [11]. In this study, the mentioned utilization factors referring the internal behavior for the assigned building technologies are evaluated regarding to UNI-EN-ISO-13786. [12]

2. MODEL PREPERATION

The model preparation consists of three steps. Firstly, the required information about the case building was collected. Then the building was divided into the thermal zones which is required for a proper thermal comfort study or sizing of HVAC system. Lastly, the implemented building technologies were defined.

2.1. Building information

The case study building was built in city of Lystrup, 10 km north of Aarhus, Denmark, in 2009. The 190 m2 home is distributed over one and a half story, with a total window area (façade windows and roof windows) is equivalent to 40% of the floor area. The building has been modelled in SketchUp. The next step was to import the 3d model into Trnsys tool with Simulation Studio and using TRNBuild.

2.2. Thermal Zone

The model was divided into a sufficient number of thermal zones and shading objects (Fig. 1). Each of thermal zone represents a space that simulates the energetic behavior of a part of the

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home. In other words, the areas in the same zone share the same load profile. The thermal zones of the building are detailed for each floor respectively:

- The first thermal zone is on the ground floor and mostly oriented to the north. It has one large window on the south facade, two windows on the west facade, five windows on the north facade and two windows on the east facade.
- The second thermal zone is on the south oriented part of the building. It has one window facing to south, one window each the west and the east facades, and it has two roof-windows facing to the south.
- The third thermal zone is on the first floor of the building. It has one window facing to the south, two windows on the west, two windows on the east, one window on the northern part and six windows on the north oriented roof.
- The building has some external shading elements. Balcony and console part of the roof are used to shade the south side of the home. On the east side, the garage, shades one of the two windows of the east side.

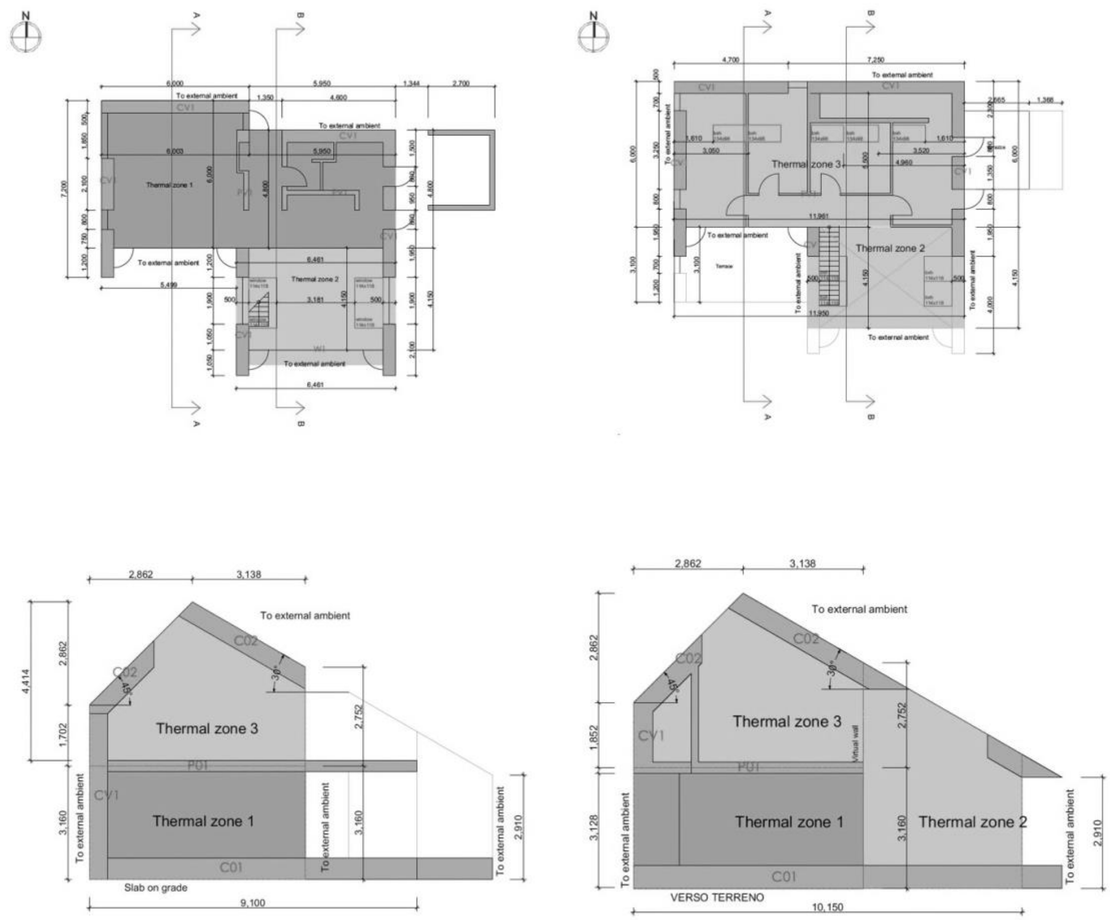

Fig. 1. Ground floor and section A-A on the left and second floor and section B-B on the right

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2.3. Building Technology

The behavior of the building was studied considering the three different building technologies listed below with the constant thermal transmittance, U-value seen in

Table 3 and

Table 3, in order to evaluate different building materials' behavior and to compare the thermal masses.

- Case 1: Light technology
- Case 2: Medium technology
- Case 3: Heavy technology

3. ANALYSIS OF THE DYNAMIC PROPERTIES

The dynamic thermal behavior of the building is analyzed based on UNI-EN-ISO-13786. Verified dynamic-state conditions are utilized to understand the behavior of opaque envelope components taking into consideration the influence of the time in thermal exchanges, between internal spaces and external ambient. According to the Italian code, the building performance is classified in relation to summer operation (Table 1). The analyze of the two important parameters, thermal lag and attenuation factor, can be considered as the fundamental for the thermal performance analyze, especially when the opaque elements are considered as storage in hot seasons. The attenuation factor is analyzed to determine the relationship between the external temperature variation and the heat flow from outside to inside (Fig. 3). The thermal lag is analyzed to determine the time delay for transmitting the heat between the walls.

3.1. Results

Maintaining a constant thermal transmittance, U-value, and analyzing the dynamic properties gave the following indications. It has been observed that the thermal mass value increase causes to decrease of the attenuation factor. In contrary to that, the time shift increases in parallel with the thermal mass value. Comparison of the thermal lag values (Fig. 2) shows that the stratigraphic correlation of the medium technology has a higher value of the time delay. While the thermal lag difference between heavy and medium technologies is around 3 to 4 hours, the difference between light and medium technologies is almost 6 to 7 hours. Overall the medium and heavyweight technologies show a higher level of time shift (>12), compared to the lightweight technologies. The medium and heavyweight technologies in comparison to the lightweight one, have a low decrement factor (< 0.15); which means a higher indoor thermal comfort. The increasing trend is proportional to the increment of the thermal mass. The classification table is used as an instrument of thermal analysis of opaque components, to verify the behavior of the different building technologies' elements as summarized in the

Table 5. The medium construction satisfies the requirements to be classified in the first classes of performance. The analysis proved that the lower thermal transmittance alone is not enough to guarantee the optimum indoor thermal comfort considering the utilization factors.

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Table 1. Classification of building performance on the basis of Italian regulation (Ministero dello Sviluppo Economico, 2009)

Time Lag [φ]	Decrement factor [f_a]	Performance	Performance quality
φ > 12	f_a < 0,15	Excellent	Excellent
12 > φ > 10	0,15 < f_a < 0,30	Good	Good
10 > φ > 8	0,30 < f_a < 0,40	Middle	Fair
8 > φ > 6	0,40 < f_a < 0,60	Satisfactory	Satisfactory
6> φ	0,60 < f_a	Poor	Poor

Table 2. Window properties

Transparent envelope components	U_w [W/m2K]	g *value* [%]
Vertical windows	1.0	0.45
Roof facing South windows	1.0	0.3
Roof facing North windows	1.0	0.45

Table 3. U-value [W/m2K] of different building technologies

Element	Lightweight	Medium	Massive
External wall	0.38	0.39	0.40
Horizontal slab	1.04	0.55	0.76
Slab on grade	0.21	0.23	0.31
Roof	0.65	0.14	0.14
Party wall	0.24	0.29	0.28

Table 4. Building physic characteristics of the simulation model

Case Study	Building Component	Thickness [m]	Heat capacity (kJ/m2K)	Attenuation Factor [F]	Thermal Lag [φ]
Case 1	External wall (CV1)	14.60	23.46	0.92	3.25
	Horizontal slab (PO1)	14.00	46.18	0.83	3.88
	Slab on grade (CO1)	14.60	46.82	0.11	17.33
	Roof (CO2)	57.40	31.18	0.69	5.74
	Party wall (PV1)	26.60	48.20	0.49	8.19
Case 2	External wall (CV2)	32.20	32.35	0.08	16.80
	Horizontal slab (PO2)	27.00	47.46	0.21	12.52
	Slab on grade (CO3)	116.50	51.12	0.10	12.52
	Roof (CO4)	48.10	31.52	0.21	12.92
	Party wall (PV2)	24.60	47.90	0.22	10.84
Case 3	External wall (CV3)	60.10	120.80	0.17	7.18
	Horizontal slab (PO3)	31.50	36.44	0.44	6.20
	Slab on grade (CO5)	66.50	34.33	0.42	6.97
	Roof (CO6)	50.10	121.63	0.28	8.96
	Party wall (PV3)	41.60	78.40	0.34	10.00

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Table 5. The building performance rating according to the Italian regulation (Ministero dello Sviluppo Economico, 2009)

Element	Lightweight		Medium		Massive	
	φ [h]	fd [-]	φ [h]	fd [-]	φ [h]	fd [-]
Vertical wall	3.25	0.92	16.80	0.08	7.18	0.17
Horizontal slab	3.88	0.83	12.52	0.21	6.20	0.44
Slab on grade	17.33	0.11	14.52	0.10	6.97	0.42
Roof	5.74	0.69	12.92	0.21	8.96	0.28
Party wall	8.19	0.49	10.84	0.22	10.00	0.34

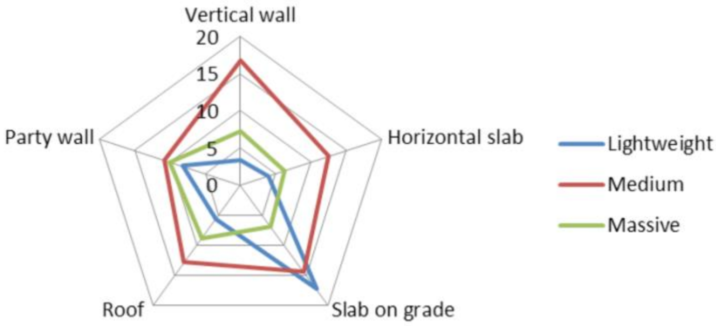

Fig. 2. Thermal time shit

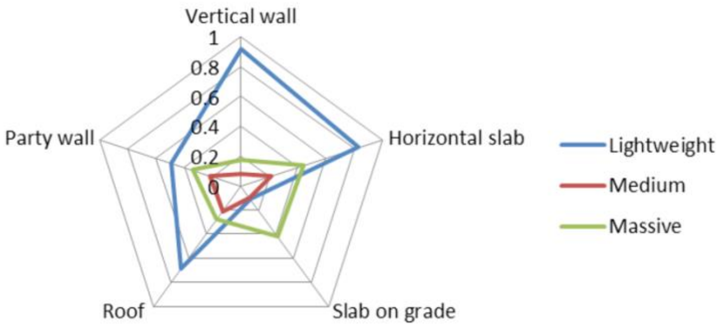

Fig. 3. Decrement factor

4. CLIMATE ANALYSIS

Preliminary design solutions considering the orientation and the aspects related to the building form can be deduced by analysing the annual/seasonal distribution of solar radiation, air temperature, wind direction and relative humidity. The defined building technologies were assigned in the simulations of TRNBuild and TRNEdit. The different climate properties were added the model through the Simulation studio. The climate data was collected by using the Meteonorm software which generates the accurate database from the weather station of a demanded location. The simplified Trnsys model was conducted with the input database of the different cities. In this study, the air temperature (°C), relative humidity (%), direct solar radiation (kWh/m2), wind velocity (m/s) and wind direction (orientation) were used as database.

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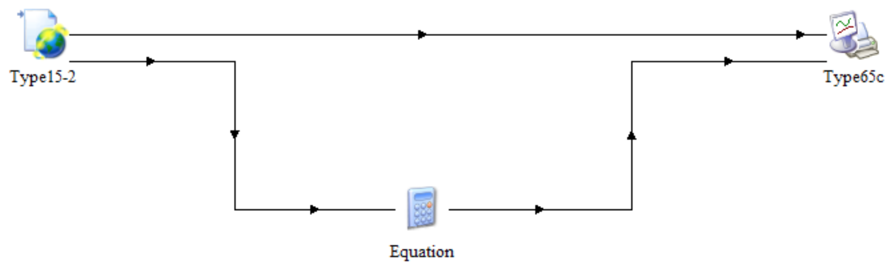

Fig. 4. The scheme of climate analysis

To verify the behaviour of the building performance with different sets of external conditions, three different climate conditions were analysed. The purpose of this step was to determine the most efficient technology and climate that is consistent with Air temperature and Relative humidity values.

4.1. Climate type

The locations were decided so as to be analysed for hot climate, mild climate and cold climate conditions. The cities were selected as listed below.

- Lystrup climate data for cold climate condition
- Paris climate data for mild climate condition
- Rome climate data for hot climate condition.

The maximum and minimum temperature values of the three cities can be followed from Fig. 5. The maximum ambient temperature value highlights the fact that the range of variation is almost parallel for the Paris climate and the Lystrup climate. But on the other hand, the minimum average temperature can be tracked for the Lystrup climate. Given that the thermal comfort depends on the external climate conditions. In every location, the variation of the temperature causes the similar difficulties from the design point of view. The following indications can be deduced from the monthly average temperature graph in

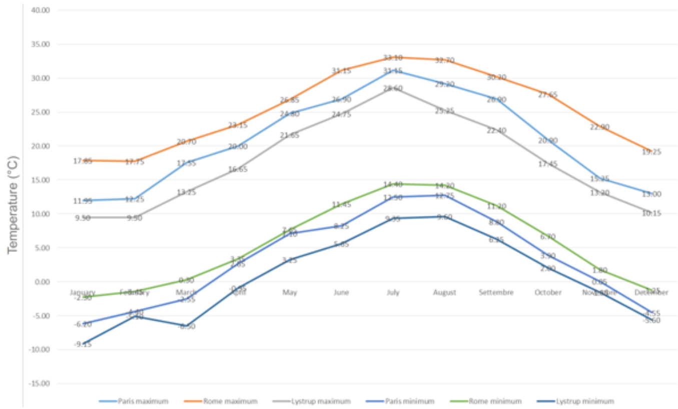

Fig. 6. Among of the three cities, the Rome represents the warmest climate in overall and the Lystrup represents the coldest climate throughout a year. The information of minimum and maximum temperature values and monthly average temperature values clue in about the cooling and heating demands (caused by the climate condition) of the building.

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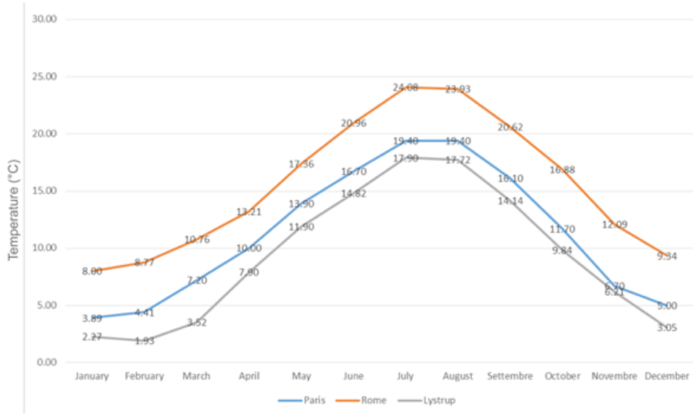

Fig. 5. Ambient temperature - Minimum and maximum values

Fig. 6. Ambient temperature - Month average

The humidity and temperature have different ranges of variation for the three cities (Fig. 7, Fig. 8 and Fig. 9). It is observed that while the hot summer is in Rome where the average temperature is 23°C and relative humidity is 74.7%, the driest summer is in Paris where the average is temperature 18.5°C and relative humidity is 70.3%. Also, a variety of intermediate conditions between the hot, dry and cold climate conditions are traced for the two cities. The situation for Lystrup climate is also similar with a different range of variations. In winter period, the coldest climate is in Lystrup with the average temperature 2°C and relative humidity 85.5%. The minimum relative humidity is seen in Paris with 36% in April. Lystrup has more humid climate than others. The maximum relative humidity (100%) can be seen for the all three cities.

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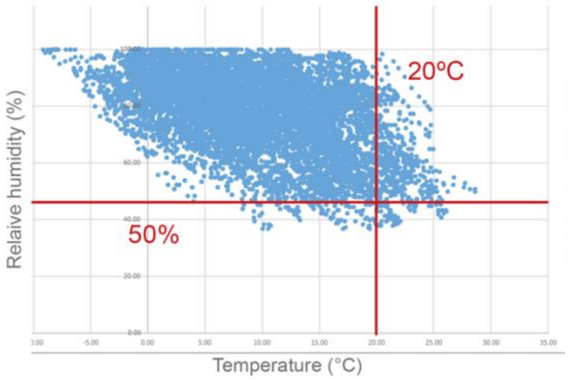

Fig. 7. Lystrup, Denmark

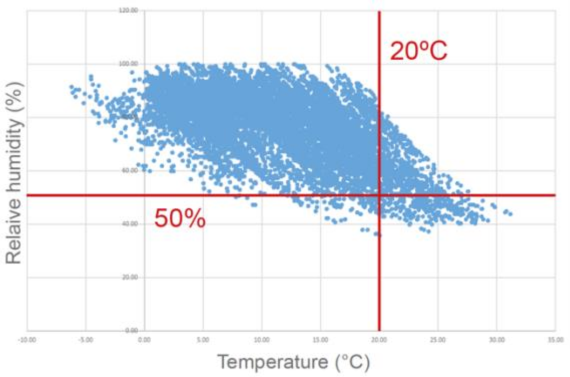

Fig. 8. Paris, France

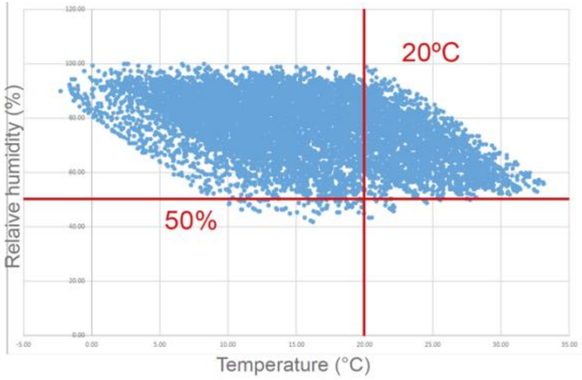

Fig. 9. Rome, Italy

5. SOLAR RADIATION

The monthly average of the Direct Solar Radiation for the mentioned cities can see tracked from the Fig. 11. Considering that all the cities are located in the boreal hemisphere, the direct solar radiation trend for each location seems similar. It is interesting to observe that the monthly average direct solar radiation is the lowest in Paris while it is expected to be seen in Lystrup. Regarding the maximum direct solar radiation, it has been observed that for each location, the result shows a rather constant value during the year (Fig. 10). However, the maximum values are relatively close for all three locations and eventually the solar system installed in this location would provide a rather constant gain at an energetic level. The highest direct solar

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radiation values are seen for Rome climate. The result of the solar radiation analyse was utilized to evaluate the efficiency of the eventual solar and shading system.

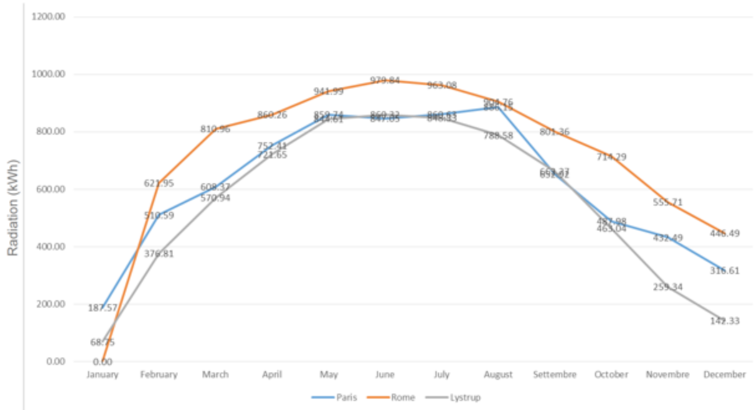

Fig. 10. Solar radiation - Maximum per month

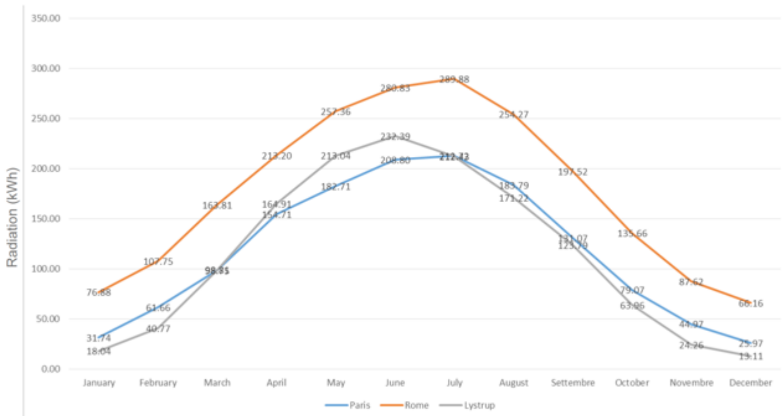

Fig. 11. Solar radiation - Monthly average

Considering all the climatic analyses so far, some specific conclusions could be drawn regarding the influence of the climate shift. From the series of comparative analysis previously illustrated, substantial differences emerged between the climates taken into consideration. The hypothetical displacement of the building in the three different cities shows that the climate change has a high influence on the subsequent analysis results.

6. IMPACT OF CLIMATE ON THE DIFFERENT BUILDING TECHNOLOGIES

The main purpose of the following simulations is to test the building with all the possible combinations of applicable passive strategies, in order to obtain the best combination in terms of energy efficiency and thermal behavior. The best combination is used as a base case to implement, where needed, the all necessary active strategies.
After creating the model on SketchUp and opening it in Simulation studio component of Trnsys, it was necessary to set up some starting point conditions that were kept fixed in all the simulations as shown in Table 6, Table 7 and Table 8. The TRNBuild component of Trnsys was used for giving the initial inputs of the simulation. The tool was conducted to define the different layering and to set the parameters.

Table 6. Initial point conditions

Thermal zones	Schedule	Internal heat gains (light and appliances) [W/m2]
Thermal zone 1	7:00-8:00; 11:00-13:00; 17:00-22:00	4
Thermal zone 2	7:00-8:00; 11:00-13:00; 17:00-22:00	4
Thermal zone 3	7:00-7:30; 22:00-23:00	1.5

Table 7. Initial point conditions

Thermal zones	Schedule	Internal heat gains (persons) [W/m2]
Thermal zone 1	7:00-8:00; 11:00-13:00; 17:00-22:00	2
Thermal zone 2	7:00-8:00; 11:00-13:00; 17:00-22:00	1
Thermal zone 3	22:00-7:00	2
Air infiltration [ACH]	0.1	

Table 8. Initial point hygrometric values

Thermal zones	Starting point temperature [°C]	Relative humidity [%]
Thermal zone 1, 2, 3	5	50

The comfort is evaluated for each thermal zone separately with the three building technologies for three different climate conditions. The analyses have been done to understand how the operative temperature changes depending on the building technology correlated with the ambient temperature for the different climate conditions. From the annual simulation, it was seen that the three thermal zones present some differences in terms of behaviors. For thermal zone 1 and thermal zone 3, the maximum temperature was tracked around 40°C in Rome. Moreover, for all three climates thermal zone 2 presents higher values of maximum temperatures. The most efficient performance for the building technology was massive technology, namely C type for all types of climates as it allows slightly higher temperatures in cold days and lower temperatures in hot days. In Fig. 12 shown as an example, an accurate zooming for Paris climate on the hottest month over a typical year (July) narrowed the result down by the purpose of emphasizing the role of building technologies in determination of the internal operative temperatures. The same procedure was implemented for Rome and Lystrup climate data as well. Considering the hottest month (July), the lightweight and medium technologies perform similar in comparison to the massive technology. The massive technology showed a better performance than the other two technologies as it permits the presence of sensible lower temperatures in the hotter days for all climate conditions.

As the conclusion of the impact of the climates and technologies on the building performance, the following results were observed.

- The preferable technology for Lystrup climate is the massive technology;
- The preferable technology for Paris climate is the massive technology;
- The preferable technology for Rome climate is the massive technology.

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Regarding the simulation results, the massive technology is used as the best solution for the all chosen climates. The following simulations were done by using the massive technology strategy.

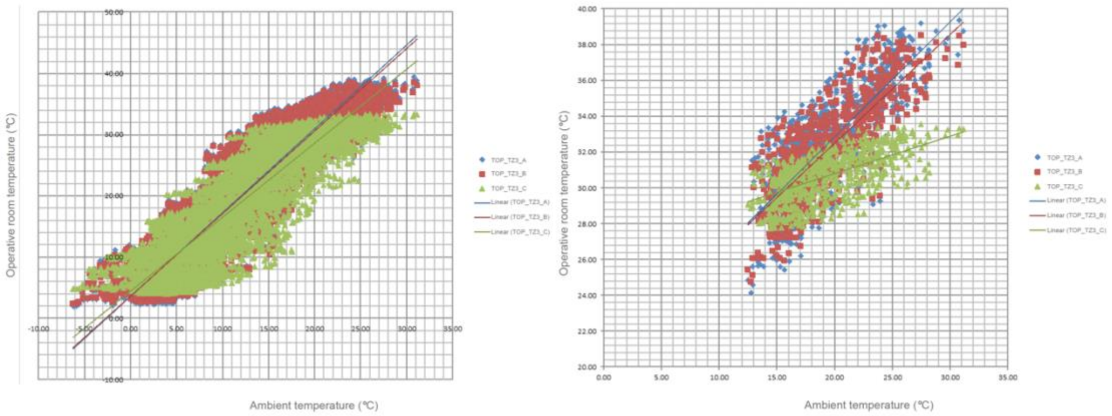

Fig. 12. Paris - Influence of technologies - Thermal zone 3 - Annual Simulation on the left and July on the right

- ***TOP_TZ1,2,3_A - operative room temperature [°C] for thermal zone 1,2,3 with lightweight technology;***
- ***TOP_TZ1,2,3_B - operative room temperature [°C] for thermal zone 1,2,3 with medium technology;***
- ***TOP_TZ1,2,3_C - operative room temperature [°C] for thermal zone 1,2,3 with massive technology;***
- ***Linear (TOP_TZ1,2,3_A,B,C) – interpolation of the TOP_TZ1,2,3_A,B,C data.***

7. IMPACT OF SHADING STRATEGIES

In this part of the study, the influence of shading devices on the building performance are analyzed. The different shading strategies were applied to the simulation model and observed the results. Proceeding in that way, three types of shading strategies were introduced. The shading strategies were defined by the percentage of shading factor and applied to the glazed components of the envelope.

Initially, 0.6 Vol/h ventilation rate was adopted through the building envelope as a constant value. All the simulations were performed considering the summer behavior (July) of the building since it is the most variational parameter and the simulations were strictly related to the solar radiation for every single context introduced in this study. The data analyzed is related to the operative room temperature, since it is considered as the most relevant energy data for defining the thermal comfort conditions of the inside envelope of the building. The simulation results with the different shading strategies, following the order of Table 9 were evaluated. The operative room temperature of each three zones was obtained with the different shading options for the climates of Lystrup, Paris and Rome.

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Table 9. Shading strategies

Location	Thermal zone	Shading strategy	Percentage of shaded surface
Lystrup, Paris, Rome	Thermal zones 1, 2, 3	Low shading strategy	20%
		Medium shading strategy	50%
		Hight shading strategy	80%

7.1. Results

Proceeding in this way, the remarkable changes on the operative room temperatures were obtained with the mentioned percentages of the shaded surface. The following deductions were made for all types of climate conditions. The peak operative room temperatures have been decreased to 20°C to 25°C from 30°C to 38°C for the thermal zone 2 by adopting to the 80% shading strategy. In the case of 20% and 50% shading strategies, the operative room temperature of the three thermal zones varies between 23°C and 38°C. The highest uncomfortable temperature was obtained with 20% shading strategy for all thermal zones. The 80% shading strategy shows the best results with regard to the comfort temperature in July. The analysis confirmed the strong relationship between the operative room temperature of each thermal zone including the roof windows and incident solar radiation. In case of Rome, the comfortable operative room temperature could not be achieved for most of the analysis period, even though the high shading strategy (80%) was adopted for each thermal zone. The analyses can be summarized as that adaptation of shading solutions alone on the glazed components of the envelope is not enough to obtain desired results in terms of internal thermal behavior. The strategies were chosen to follow for the further steps are listed below.

- The preferable shading strategy for Lystrup is medium (50%);
- The preferable shading strategy for Paris is medium (50%);
- The preferable shading strategy for Rome is high (80%).

8. IMPACT OF VENTILATION STRATEGIES

The ventilation systems provide the passive cooling in buildings and correspondingly the thermal comfort and improved of energy performance. In this step the ventilation strategies were performed by TRNbuild component of TRNSYS simulation tool. The strategies were applied on the three thermal zones. All the strategies were associated to a schedule shown in Table 10. The data used in this section are the operative room temperature and the outside temperature since they are considered as the most relevant energy drivers to determine the comfort condition inside the building. All the simulations were performed for the summer season (July) as the most variable results were obtain in summer season for the previous simulations too.

8.1. Results

The study mostly focuses on thermal zone 2 and thermal zone 3 for the all climates in the context of ventilation strategy since the impact of ventilation system is more crucial when the temperature ranges are considered. Regarding behavior of thermal zone 2 in Rome case (Fig. 13), the high ventilation strategy shows the most effective operative room temperature range, in comparison to the other cases. In Paris climate, implementation of the high ventilation strategy shows a reasonable solution, as it permits to maintain an intermediate range for the

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comfort temperature which varies between 22°C and 30°C. For the analysis of thermal zone 3 in the Rome climate, the lowest mean operative temperature was obtained when the ventilation rate was the highest. To sum up, the analyses proves that with introducing the appropriate ventilation system to the building envelope reduces the demand for a cooling system, therefore decreases the overall energy consumption of the building without activation of a plant system. As a conclusion of the analyses, the following strategies have been chosen:

- The preferable ventilation strategy for Lystrup case is high (1.5 Vol/h);
- The preferable ventilation strategy for Paris case is high (3 Vol/h);
- The preferable ventilation strategy for Rome case is high (3 Vol/h).

Table 10. Ventilation strategies

Location	Thermal zone	Schedule	Ventilation strategy	
Lystrup, Paris, Rome	Thermal zones 1, 2, 3	7:00-18:00	Low ventilation	0.6 Vol/h
			Medium ventilation	1.5 Vol/h
			High ventilation	3.0 Vol/h

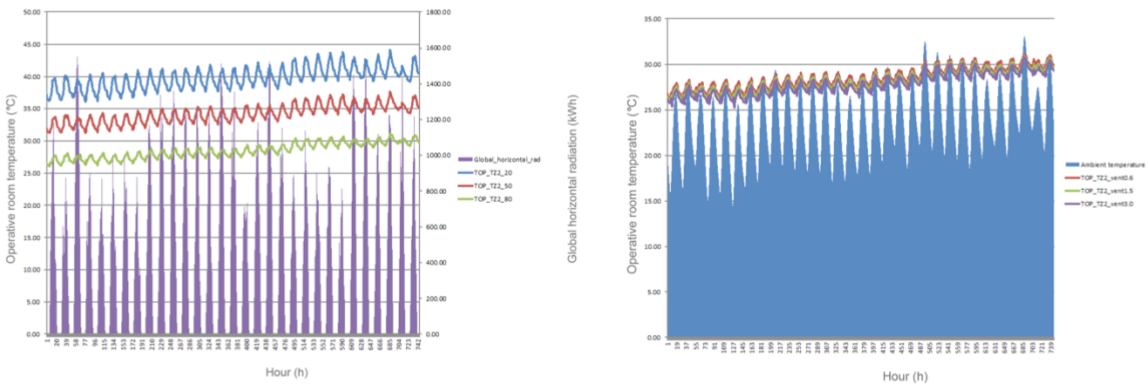

Fig. 13. Implementation of shading and ventilation strategies on thermal zone 2 for Rome climate, as an example

9. COMFORT ANALYSIS

In this section, the hygrothermal comfort of internal spaces of the building is analyzed. The study so far determined the simulation results with the intent of energy consumption reduction by selecting the best strategy. The analysis and the evaluations till this section were done mainly by considering the operative room temperature and ambient temperature. To obtain a robust analysis, in this section the building is analyzed according to the static comfort and the adaptive comfort analysis since both are crucial for comfort rating. The following analyses in this section were done to find out the best building technology among of the ones described in the previous sections (lightweight, medium, massive) with the fixed building strategies for ventilation and shading as indicated in the Table 11, by making use of the static and adaptive comfort criterion.

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Table 11. Scheme of best solutions

Location	Shading strategy	Ventilation strategy
Lystrup	Medium (50%)	High ventilation (1.5 Vol/h)
Paris	Medium (50%)	High ventilation (3.0 Vol/h)
Rome	High (80%)	High ventilation (3.0 Vol/h)

9.1. Static Model (UNI EN ISO 7730) and Adaptive Comfort Model

Both the static thermal comfort model and adaptive model were used to evaluate the percentage of occupants satisfied with thermal environment according to ISO 7730 and UNI EN 15251respectively. The adaptive comfort categories is shown in Table 12. The charts below for Lystrup case are shown as an example. The same evaluations were done for each climate conditions separately. The colored dots for both charts represent the zone temperatures of the hours for the related thermal zone, grey the lines show the upper limits and the dark grey lines show the lower limits classes (Fig 14).

Table 12. Thermal comfort categories by UNI EN 15251

Category	Applicability/Level of expectancy	Limit equations
I	High: Buildings with high expectancy for sensitive occupants	Upper limit: θi,max = 0.33×θrm+18.8+2 Lower limit: θi,max = 0.33×θrm+18.8-2
II	Normal: New buildings and renovations	Upper limit: θi,max = 0.33×θrm+18.8+3 Lower limit: θi,max = 0.33×θrm+18.8-3
III	Acceptable: Existing buildings	Upper limit: θi,max = 0.33×θrm+18.8+4 Lower limit: θi,max = 0.33×θrm+18.8-4
IV	Low: Expectancy only for short periods	-

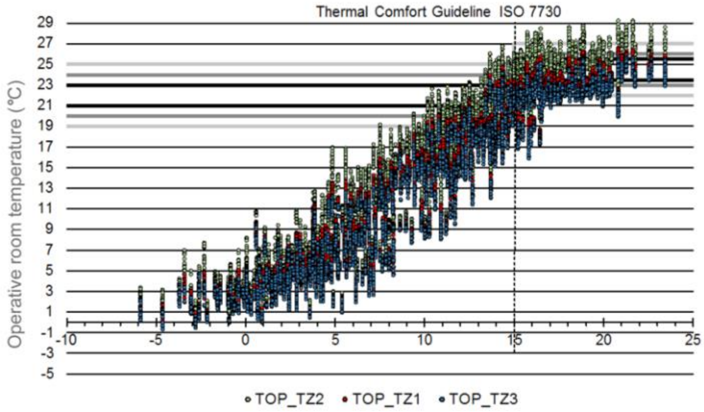

Fig 14. The static thermal comfort model based on ISO 7730 for medium

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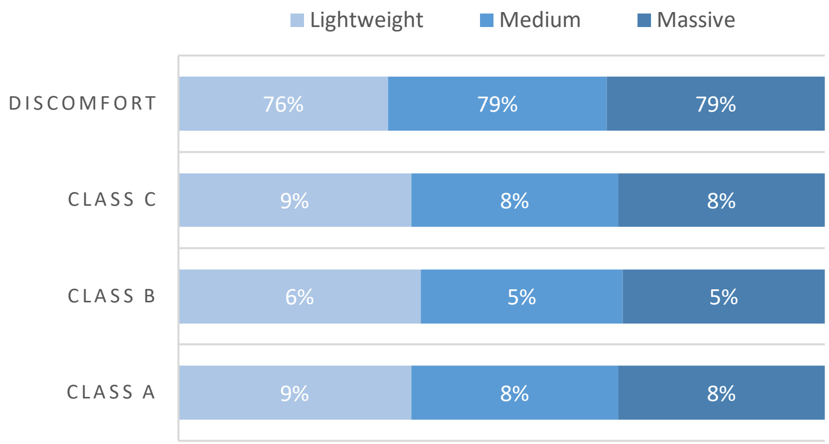

Fig. 15. Static comfort analysis result for Lystrup technology in Lystrup

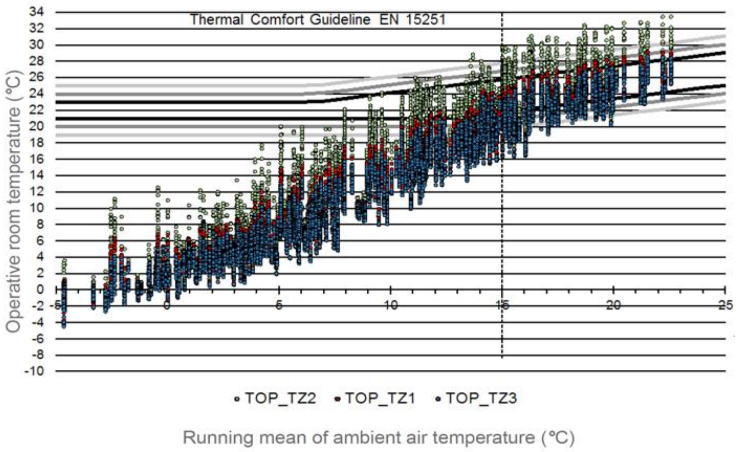

Fig. 16. The adaptive thermal comfort chart based on UNI EN 15251

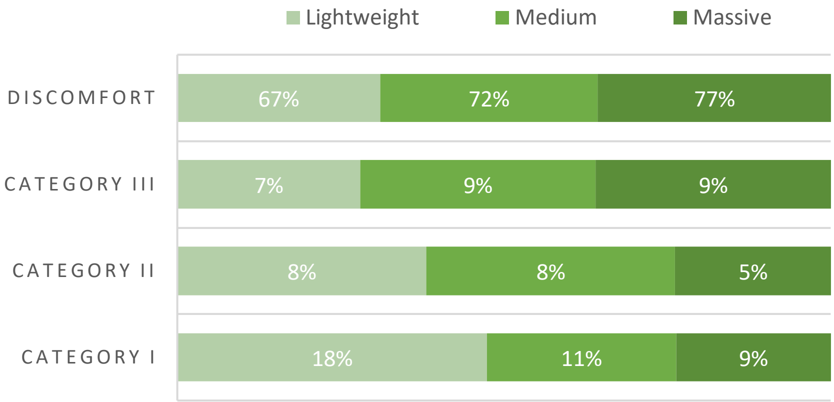

Fig. 17. Adaptive comfort analysis result for Lystrup medium technology for Lystrup

9.1.1 Lystrup Climate

Regarding the static comfort analysis, the largest number of unsatisfied users was defined as 76% when the lightweight technology was adopted. The medium technology and massive technology presented a similar trend with 79% occupants satisfied. From the comparison analyses, the operative room temperature of thermal zone 2 was higher than other two thermal zones. In the case of adaptive model, the operative room temperature trend was similar in the case of lightweight and medium technologies. Thermal zone 1 provided a better overall behavior in comparison to the other two thermal zones. Considering the two comfort models, the results showed that the highest efficient performance solution was for the lightweight technology justified by the fact that it provided an increase as twice much, in the percentage of the satisfied users in category I.

9.1.2 Paris Climate

In the Paris case, the range of operative room temperatures was obtained between -3°C and 30°C. Due to the location and the zone geometry, thermal zone 2 represented a higher operative room temperature range between 30°C and 35°C. Regarding the static comfort analysis, the percentages of satisfied users were similar for the lightweight and the medium technologies. The least number of unsatisfied users was defined as 74% in the case of the massive technology. According to adaptive comfort model, the massive and medium technologies showed similar percentages of discomfort category. The lightweight technology appears as the most performing one, as in summer period the operative room temperatures are totally in comfort class range. The lightweight technology has been chosen for Paris climate as solution because of the least percentage of unsatisfied users (65%) shown in the adaptive model.

9.1.3 Rome Climate

The range of operative room temperatures for Rome climate was obtained between 2°C and 28°C. It is deduced from the evaluations, the passive strategies applied for the climate of Rome are effective mainly in summer season. Comparing the previous context for the Rome climate, the operative room temperatures are less scattered and thermal zone 3 has the highest values for the operative room temperature. The largest number of unsatisfied users was obtained in the case of the lightweight and medium technologies as 79%. According to static comfort analysis, the massive building technology is the one with highest efficiency among the other technology options for Rome climate.

In the context of adaptive model, the envelope solutions can be considered as similar. The medium technology appeared as the highest efficient technology with 59% occupants satisfied with the thermal environment, as in summer period the operative room temperatures for most of the days were in comfort class range limit.

9.2. Results for Static and Comfort Analysis

According the hard data of the comfort analyses, the numerical outputs were deduced. The results showed the necessity of a plant system, providing both heating and cooling services aiming to increase the internal comfort conditions. The working on the performance of envelope components alone was not enough to guarantee acceptable comfort conditions, especially in winter period for all the climates. The further simulations were conducted by adopting following technologies:

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- Lystrup - Lightweight technology;
- Paris - Lightweight technology;
- -Rome - Medium technology.

10. IDEAL PLANT SYSTEM

After the optimizations with the passive strategies i.e. envelope technologies, natural ventilation and solar shading, there was still a percentage of discomfort inside the building. Therefore, plant systems i.e. heating and cooling systems, are introduced to the model aiming to improve in the indoor thermal comfort. Type 91 was inserted to the simulation as an air ventilation system and heat exchanger combined. The plant system is set by taking in consideration the boundary climatic conditions of each location (Lystrup, Paris, and Rome). The heating schedules depending on degree days parameters (HDD) are defined based on Italian regulations (Table 13). Lystrup and Paris are located in climate zone E and Rome is located in climate zone D. The performed simulations are indicated step by step in Table 14 for the following analyses.

Table 13. Schedule of heating and cooling systems

Climate zone	Location	Degree days	Heating schedule		Cooling schedule	
			Days	Daily schedule	Days	Daily schedule
E	Lystrup	2100-3000	15th Oct-15th April	07:00-12:00 16:00-19:00	1st May-30th Sep	10:00-18:00
E	Paris	2101-3000	15th Oct - 15th April	07:00-12:00 16:00-19:00	1st May-30th Sep	10:00-18:00
D	Rome	1401-2100	1st Nov – 15th April	07:00-12:00 16:00-19:00	1st May-30th Sep	10:00-18:00

Table 14. Scheme of the performed simulations

Type of simulation	Location	Active strategy	Passive strategy	
			Shading/Surface Percentage	Ventilation Rate
Step 1. Heating and cooling systems	Lystrup, Paris, Rome	Heating (20°C) Cooling (26°C)	-	0.3 Vol/h
Step 2. Heating and cooling systems	Lystrup, Paris, Rome	Heating (21°C) Cooling (26°C)	-	0.3 Vol/h
Step 3. Heating and cooling systems + Shading strategies	Paris	Heating (21°C) Cooling (26°C)	20% 80% Adaptive (South, West-50%, East-20%)	0.3 Vol/h
	Rome	Heating (21°C) Cooling (26°C)	20% 80% Adaptive shading (South, West-50%, East-20%) Adaptive shading (South, West-80%, East-20%)	0.3 Vol/h

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Step 4. Heating and cooling systems + Passive strategies	Rome	Heating (21°C) Cooling (26°C)	20% for Thermal zone_1,3 + Adaptive shading (South, West-50%, East-20%) for Thermal zone_2	0.3 Vol/h (08:00-22:00) 1.5 Vol/h (22:00-08:00)
	Rome	Heating (21°C) Cooling (26°C)	20% for Thermal zone_1,3 + Adaptive shading (South, West-50%, East-20%) for Thermal zone_2	0.3 Vol/h (08:00-22:00) 3.0 Vol/h (22:00-08:00)

10.1. Step 1. Heating and cooling systems

Implementation of a plant system decreased the percentage of unsatisfied users. By observing the quantitative definition, it is possible to derive that in Rome case the number of unsatisfied users is decreased from 59.94% to 30%. It is seen also in Lystrup and Paris with 50% and 48% respectively, for unsatisfied users. In Paris and Lystrup cases the comfort level depended on the heating system. For this reason, the energy consumption of the building was heavily influenced by the winter energy demand. On the other hand, the need of cooling system in Rome climate plays a fundamental role in defining the comfort level and at the same time causes a higher energy consumption during summer season. It is important to see that the 90% of heat gains were associated to solar so the cooling system. The losses were associated to infiltration through the envelop. The total energy consumption for heating and cooling was 53.13 kWh/m2 for his step.

10.2. Step 2. Heating and cooling systems

The same strategies implied for step 1, here the heating system set to 21°C to improve the energy performance. That was resulted with increase on the number of occupied satisfied with thermal environment according to adaptive comfort analysis. 12%, 14% and 2% decreases on the percentage for the number of occupants in discomfort, were deduced for Lystrup, Paris and Rome cases respectively. The heating and internal gains was 17% less comparison to the previous simulations due to the increase of heating set point temperature. Total energy consumption for heating and cooling for this step was 55.94 kWh/m2.

10.3. Step 3. Heating and cooling systems with Shading strategies

In this step, the building performance was improved by combination of passive strategies with the idealized plan system. Addition to the 20% and 80% shading strategies, different adaptive systems were introduced to minimize the cooling load. The shading systems were tested with different percentages for south, east and west facades. The scheme of performed strategies can be followed from Table 15.

Table 15. Scheme of performed simulations in the Step 3.

Location	Thermal zones	Shading strategy	Percentage of shaded surface
Paris	Thermal zones 1, 2, 3	Low shading strategy	20%
		High shading strategy	80%
		Adaptive shading strategy 1	South, West 50%, East 20%
		Low shading strategy	20%

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Rome	Thermal zones 1, 2, 3	High shading strategy	80%
		Adaptive shading strategy 1	South, West 50%, East 20%
		Adaptive shading strategy 2	South, West 80%, East 20%

In the Paris case, adopting the fixed shading devices with 20% of the covered glazed resulted with a better performance than 20% of shading as increasing the number of satisfied users: Thermal zone 1; Category I from 0% to 30.11%; thermal zone 2: Category I from 0.91% to 31.10%; thermal zone 3: Category I from 0% to 24.34% increased by transferring the 80% shading to %20 shading. The results from adaptive shadings showed efficient results in thermal zone 2, but for thermal zone 1 and 3, 20% of shading was a better solution. From the analysis of energy demand on Paris case, the solution of fixed shading elements with 80% of the covered glazed surface resulted with the least performing solution, as it caused an increase in the sensible heat in winter means the amount of energy needed to increase the indoor temperature. The low shading and the adaptive strategy were resulted as the best performing strategy, since it reduced the winter energy demand from 11399.45 kWh, to 10587.39 kWh and 11399.45 kWh, respectively. In the Rome case, reduction of the glazing percentage was a better option as in the case of Paris. The number of satisfied users in Rome case increased as; thermal zone 1: Category I from 0.43% to 62.15%; thermal zone 2: Category I from 16.8% to 33.4%; thermal zone 3: Category I from 13.36% to 51.53%. The results from adaptive shadings strategy showed a similar result with the Paris case. The adaptive shade strategy 1 showed 5096.19 kWh energy demand while the adaptive shade strategy showed 6947.02 kWh energy demand. In comparison to the low shading strategy and the adaptive shade strategy 1, the energy demands obtained as 6947.02 kWh, to 3866.36 kWh respectively. In conclusion, the following shading strategies have been chosen taking into account the results related for both to comfort and energy consumption.

- The preferable shading strategy for Thermal zone 1 - Low (20%);
- The preferable shading strategy for Thermal zone 2 - Adaptive (South, West facades-50%, East facade-20%);
- The preferable shading strategy for Thermal zone 3 - Low (20%).

10.4. Step 4. Heating and cooling systems with passive strategies

The previous step proved that the most efficient climate for the building results were obtained for the Rome climate conditions. Hence, the further steps were conducted with the Rome climate data. In addition to that, the optimum shading strategy was defined for each zone separately. The performed simulations are listed in Table 16. The purpose of this stage to deduct the optimum ventilation strategy that would work efficiently with the ideal plant system. For this purpose, different ventilation rate values are introduced; 0.3 Vol/h, 1.5 Vol/h and 3.0 Vol/h.

Table 16. Scheme of performed simulations in the Step 4.

Location	Thermal zones	Strategies		Ventilation strategies
		Active strategies	Shading strategies	
Rome	Thermal zones 1, 3	Heating (21°C)	Low shading strategy (20%)	0.3 Vol/h (08:00-22:00)

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	Thermal zone 2	Cooling (26℃)	Adaptive shading strategy (S, W-50%, E-20%)	1.5 Vol/h (22:00-08:00)
Rome	Thermal zones 1, 3	Heating (21℃) Cooling (26℃)	Low shading strategy (20%)	0.3 Vol/h (08:00-22:00)
	Thermal zone 2		Adaptive shading strategy (S, W-50%, E-20%)	3.0 Vol/h (22:00-08:00)

The results showed that optimization of natural ventilation system regarding the thermal zone increased the number of satisfied occupants. The comfort level increased to 53% in Category I with introducing 1.5 Vol/h rate of ventilation to the thermal zone 2 while the other option also represented a good amount of satisfied occupant with 51%. For the energy the demand analysis, the results determined for the summer season. The energy demand analysis showed 3.0 Vol/h ventilation rate as the most efficient solution. Total energy consumption for heating and cooling was 41.43 kWh/m2.

11. HEAT EXCHANGER

In this section, the impact of the heat exchanger, classified as a hybrid device, was investigated for the climate data of Rome aiming the reduction of energy demand for plant system. The heat exchanger was introduced into the TRNSYS simulation model. The ground heat exchanger is an underground heating that can work as passive heating and cooling system. By introducing the controlled ventilation, the contribution of the natural ventilation and infiltration were neglected. Initially, the main parameters of ground heat exchanger were optimized. The relationship between ground heat exchanger efficiency and the depth, length and diameter of the exchanger system was evaluated (Table 18) by determining the load side outlet temperature. Firstly, the depth of the duct was investigated to find the appropriate depth in terms of the load out temperature for both winter and summer seasons. The 60 m duct length and the 0.3 m duct diameter were used initially. As result, the 6 m and 10 m duct depths showed similar temperature trends. Both duct depths provided 10°C temperature difference between load outlet and ambient temperature in the summer season. Due to the constructive reasons, 6 m length has been chosen. Secondly, the duct diameter was simulated for 0.2 m, 0.3 m and 0.6 m with the 6 m duct length and 60 m duct length. The highest temperature difference (12°C) was obtained with 0.3 m duct diameter. As third and the last step, the duct length was simulated for 20 m, 40 m and 60 m. The 14°C temperature difference was obtained with 60 m duct length. As final result, the following duct characteristics have been chosen.

- The preferable depth of the duct - 6 m;
- The preferable diameter of the duct - 0.3;
- The preferable length of the duct - 60 m

By introducing the heat exchanger to the building envelope, total energy consumption for heating and cooling was obtained 35.53 kWh/m2.

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Table 17. Parameters of Ground Model (Type 77)

Amplitude of surface temperature [°C]	Time shift [day]	Soil thermal conductivity [kJ/hmK]	Soil density [kg/m3]	Soil specific heat [kJ/kgK]
5	30	8.72	2000	0.84

Table 18. Options for defining the depth of the duct

Location	Duct length [m]	Duct diameter [m]	Duct depth [m]
Rome	20 40 60	0.2 0.3 0.6	1.5 3.0 6.0 10.0

12. CONCLUSION

The main purpose of this research is investigation of the thermal behavior buildings depending on the passive and active strategies implemented to the building envelope. With this aim, a building energy simulation tool was conducted for a case study building constructed in Lystrup, Denmark. The research study determines the thermal lag and the attenuation according to Italian code, to evaluate internal thermal behavior of the building.
The results of the study show that with the right passive strategy, the amount of the energy consumption can be considerably reduced. In particular, controlled shading system minimized the solar gains. The impact of thermal mass over the different building technologies are analyzed with combining the passive strategies. It was important to consider the different climate conditions during the analysis. Therefore, the study was carried out for three cities; Lystrup, Paris and Rome. Even though the initial analyses showed the massive strategy as the most effective design strategy, the further simulations, when the building technologies were combined with the other passive design strategies, showed the lightweight technology for the Lystrup and Paris climate and the medium technology for Rome climate. The building with free running (only with passive strategies) represented only 40% thermal comfort in the category III for Rome case as the highest result. The lowest comfort conditions were observed for the Lystrup case. The study showed that the passive strategies was not enough to achieve for the different climate conditions. The analysis was conducted for whole year with taking into account occupied hours.
The energy benchmarks used in this research to determine how efficiently the building used the energy, are not discussed in this paper. The energy benchmarking method as an effective tool to identify the building properties, will be analyzed in a further research paper.

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