Evaluating the Appropriateness of Double Skin Glass Facade System, within the Context of Sustainability, for North Cyprus (TRNC)

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Approval of the Institute of Graduate Studies and Research

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ABSTRACT

The current study aimed to investigate the appropriateness of Double Skin Glass Facade (DSGF) systems for Large Scaled Glazed Facade Commercial and Office Buildings (LSGFCOB), within the context of sustainability for North Cyprus (NC), since there are no DSGF systems in NC. To accomplish this aim, observation of 15 LSGFCOB (having more than 120m GF), were analyzed according to the types of glazed facade system, facade's orientation, construction cost per m^2, shading device and ventilation system. Secondly, perceptions of 23 stakeholders, in construction sectors as well as educational sector, regarding DSGF systems and sustainability in GF systems as well as existing reasons of not using DSGF systems for LSGFCOB in NC, were identified.

The major research techniques used in this study were in the form of semi-structured interviews, based on quantitative method, and personal observations, based on descriptive methodology, with the application of qualitative data analysis.

In order to gather information about the existing LSGFCOB in NC, visual data were collected (photographs of 15 analyzed buildings). In addition, the stakeholders of the buildings were interviewed in order to collect further information of the glazed facade systems. Interviews were conducted also to find out the knowledge and opinions of the stakeholders about the advantages and disadvantages of using DSGF system as well as their future strategies and expectations, for using these systems, from the governmental authorities in construction sectors in NC.

The study concluded that, since there is not enough client demand, mainly because of the high cost in the market for DSGF systems to be used in LSGFCOB, there is a barrier to develop the sector which will apply these kinds of DSGF systems in NC. It is most likely that in the nearest future, due to the high cost and customer demand in the market, DSGF systems might not be sustainable to be applied in LSGFCOB in NC. For now, it can be recommended to use proper shading devices, in appropriate direction where it is needed, with careful design and selection of appropriate materials for existing LSGFCOB. On the whole, there is a need of government to encourage the society, customers and stakeholders to use these systems for backing the worldwide demand of Sustainable Construction and Development.

Key words: Sustainability, Sustainable Glass Facade System, Double Skin Glass Facade System, Glazed Curtain Wall System, North Cyprus.

ÖZ

Kuzey Kıbrıs (NC) için sürdürülebilirlik bağlamında Çift Cilt Cam Cephe (DSGF) Büyük Ölçekli Sırlı Cephe Ticari ve Ofis Binaları (LSGFCOB) için sistemlerinin uygunluğu araştırıldı çalışmada,) Bütün olarak bakıldığında, toplum, müşteriler ve paydaşlar Sürdürülebilir İnşaat ve Kalkınma dünya çapında talep destek için bu sistemleri kullanmaya teşvik etmek için hükümet bir ihtiyaç vardır. NC hiçbir DSGF sistemleri olmadığından. (Fazla 120 GF olan) 15 LSGFCOB gözlenmesi Bu amaçla gerçekleştirmek için, camlı cephe sistemi, cephe oryantasyon, m2 başına inşaat maliyeti, gereçlerin ve havalandırma sistemi türlerine göre analiz edildi. Ikinci olarak, inşaat sektöründe 23 paydaşların algılamaları gibi eğitim sektöründe, ilgili DSGF sistemleri ve GF sistemlerde sürdürülebilirlik yanı sıra NC LSGFCOB için DSGF sistemleri kullanarak değil mevcut nedenleri, tespit edilmiştir.

Bu çalışmada kullanılan başlıca araştırma teknikleri nitel veri analizi uygulaması ile, açıklayıcı metodolojisine dayalı kantitatif yöntemine dayalı yarı yapılandırılmış görüşme formu ve kişisel gözlemler vardı.

NC mevcut LSGFCOB hakkında bilgi toplamak amacıyla, görsel veri (15 analiz binaların fotoğrafları) toplanmıştır. Ayrıca, binaların paydaşların camlı cephe sistemleri hakkında daha fazla bilgi toplamak amacıyla görüşme yapıldı.

Görüşmeler NC bilgi ve avantajları hakkında paydaşların görüş ve dezavantajları inşaat sektörlerinde hükümet yetkililerinden, bu sistemleri kullanarak, DSGF

sisteminin yanı sıra gelecekteki stratejilerini ve beklentilerini kullanarak öğrenmek için de yapılmıştır.

Anahtlar Kelemeler:

DEDICATION

To my beloved mother, Pooran (Zahra) Targi, for supporting me and giving me opportunity to come all the way from Iran to Cyprus to complete my studies. I am so thankful to my beloved sister and brother for encouraging and motivating me during the whole time…I LOVE YOU ALL SO MUCH…

ONE LOVE!

ONE SAMANEH!

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LIST OF ABBREVIATION

AA: Aesthetic and Appearance

AC: Air Conditioning

AI: Acoustic Insulation

ArI: Architectural Identity

CC: Climatic Condition

COB: Office Buildings

DBT: Dry Bulb Temperature

DSGF: Double Skin Glass Facade

EDS: Environmental Dimension of Sustainability

EcD: Economic Dimension

EE: Energy Efficiency

EnD: Environmental Dimension

EP: Environmental Dimension and Performance

GCW: Glass Curtain Wall Systems

GF: Glass Facade

HVAC: Heating, Ventilating, and Air Conditioning

ICC: Investment and Construction Cost

IE: Indoor Environment

LCA: Life Cycle Assessment

LC: Life Cycle

LCC: Life Cycle Cost

LSCOB: Large Scale Commercial and Office Buildings

LSGFCOB: Large Scale Glazed Facade Commercial and Office Buildings

NC: North Cyprus

ND: Natural Daylight

NV: Natural Ventilation

OMC: Operational and Maintenance Cost

PV: Prevailing Wind

SD: Social Dimension

SGF: Sustainable Glass Facade

ThP: Thermal Performance

ThC: Thermal Comfort

TVC: Transparancy and Visual Comfort

TRNC SPO: Turkish Republic of North Cyprus State Planning and Organization

VC: Visual Comfort

Chapter 1

INTRODUCTION

1.1 Background Knowledge

As being one of the recent focused subjects in architecture and building construction industry, protecting the environment, reducing building's energy consumption, cost efficiency, developing buildings, sustainability and sustainable development have been widely considered for building designers and engineers.

The word "Sustainability" is a wide and complex topic with different aspects and definitions (Graber, and Dailey, 2003: 11-12). The main dimensions of sustainability are environment, society and economic in a world wide scale and local scale, and in many different sectors such as construction, industry, tourism, etc (Hoşkara, 2009: 3). Sustainability mainly is well-being of environmental, economic and social comfort for human beings and satisfactory of their essential basic needs to have a better quality of life for today and tomorrow without compromising the future generation's well-being for their needs (Brundtland, 1987).

In construction sector, (especially in LSCOB) for the past 2 decades, sustainability has been one of the important issues in design concepts. Buildings are one of the harmful belongings for the society and environment in terms of sustainability. They have high energy consumption and they are a huge producer of harmful gasses to the air. On the other hand they consume high amount of energy, and thus cost in order to be facilitated for the users. So the buildings not environmentally and socially nor economically are sustainable (Graber and Dailey, 2003: 1-89). While considering sustainability principles in construction sector, building's facade systems, especially GF systems, are one of the critical issues in terms of design, manufacture and construction.

Major advancement in GF technologies has given the architects and specialists opportunity to integrate the AA of the building envelope within sustainability principles (environmental, social, and economical) while maintaining a high level of facility. That is why it is important that GF systems construction and materials should be properly designed and installed to provide an interesting living environment, while maintaining a sustainable system for the environment and the society (Winxie, 2007: 3).

In the last 20 years the use of glass as building material has been increased because of the developments of steel framing systems and curtain wall cladding techniques in LSCOB (horizontally and vertically developed) and it has been used as one of the main components of building's envelope since then. Some examples can be fully glazed facade of Victoria Life Insurance buildings, which has DSGF system, in Cologne (Germany), designed by Van den Valentyn and A. Tillmann (Compagno, 1999: 122). ARAG 2000 Tower is also a good example of highly glazed office building with DSGF system, completed in 2000, in Düsseldorf (Germany), by architects Foster and Partners, and Rhode Kellermann Wawrowsky. The other example is SysOpen Tower in Finland, built by architect Tommila Oy in 2001. Bloomberg Tower in New York is a good example of GCW system. This building was completed in year 2005 by Cesar Pelli & Associates Architects. However, over the last 2 decades some changes has been made in GF systems in terms of technological approaches, energy performance and AA of the facades as well as construction systems and materials. Due to these developments new types of GF systems, such as DSGF systems, have become popular to be used for LSGFCOB, in building construction technology (Patterson, et al, 2008: 2-3).

In LSGFCOB the main problem is unwanted heat loss in winter and heat gain in summer. This is because of both transparency of the glass and, that, it is a conductor of heat. That is why recent developments in GF systems have become more functional, and they provide designers flexibility to create high performance solutions such as energy efficiency, NV, reduction of heat loss in winter and heat gain in summer, maximum use of ND and etc. Some of these developments include different systems used for the GF such as DSGF systems, advanced GCW systems and etc. Although transparency has been one of the important issues to be considered in GF systems in order to have maximum ND and view, sustainability has become the main scope of the architects and engineers projects.

Recent studies on GF systems in LSGFCOB and their sustainable performance in different environmental conditions have proved that DSGF systems (also called climate facades, active integrated facades, supply air windows, and etc.) have resulted to be highly successful GF technologies, for designers and users and the environment. There are many research studies conducted in different countries under different climatic conditions, which investigated these types of facades; “Investigation on Energy Performance of Double Skin Facade in Hong Kong” by Chan, A.L.S, and others, (2009) which studied the energy performance of DSGF system applied to a typical OB under the climatic (hot and humid) condition in Honk Kong (Chan, et al, 2009: 1-8). As the authors mentioned, in this research the gap was that wide usage of fully glazed facade in Singapore caused higher energy consumption and thermal discomfort due to higher solar gain, and the suggested solution was using DSGF system with ventilation system (Chan, et al, 2009: 1-2). Another example is "Double Skin Facades for Warm Climate Regions: Analysis of a Solution with an Integrated Movable Shading System", which explains the optimization of the facade's energy performance both in winter and summer. A model was developed for a facade oriented towards the south and taking into account the climatic data of central Italy (Baldinelli, 2008: 1-13). "Experimental Evaluation of a Climate Facade: Energy Efficiency and Thermal Comfort Performance" is another work by Serra V., and others, (2009) which investigated the result of an extensive experimental campaign on a DSGF system with a mechanically ventilated air gap. According to the authors, measurements were performed utilizing the "*TWINS (Testing Window Innovative System)*" test facility. The result was achieving the ability to pre-heat the ventilation air in the winter and the ability to remove part of the solar load during the summer by changing the air flow rate, the shading device and the internal glazing (Serra, et al, 2009: 1-13).

Moreover, in studies mentioned above, which were made in different countries under different climatic conditions, mainly, energy performance and reduction of building's energy consumption in LSGFCOB was studied and discussed.

1.2 Statement of the Problem

According to the observations made by the researcher, the number of LSGFCOB (tall or elongated COBhaving more than 120m^2 glazed facade) are limited in NC, and the existing GF (Glass Facade) systems are mostly GCW (Glass Curtain Wall) systems. The term sustainability for buildings in NC has been defined in terms of energy saving which is only providing domestic hot water by using solar collector panels outside of the buildings. Other than that, some natural cross ventilation has been seen in houses but not in LSGFOB.

However, recently there is a worldwide trend towards using LSGF systems in commercial and office buildings. Nowadays the same approach can be observed in NC. In these buildings the problem is high energy consumption. Suggested solution in the world is using DSGF systems, in directions where it is needed, with variable external or internal elements (shading devices, air gaps, and etc) and different ventilating cavity to reduce the energy consumption of the building, under different climatic conditions. So far, there are no DSGF systems, in NC. Therefore, this thesis is discussing if DSGF systems are appropriate to be used in LSGFCOB, within the context of sustainability, in NC.

1.3 Aim of the Study and Research Questions

The aim of this study is to discuss the appropriateness of DSGF Systems for LSGFCOB, within the context of sustainability, in NC. In this case the main research question is: Is DSGF system appropriate for NC within the context of sustainability?

In order to answer this question there is need of answering the following sub questions:

- What are GF Systems?
- What is DSGF System?
- What is sustainability?

- What is the relation of GF system with sustainability and what is SGF system?
- What are the conditions of NC?
- What are the conditions of construction sector of NC?
- What types of GF systems are already used for LSGFCOB in NC?
- Evaluation of sustainability of GF systems in NC; what are the problems? Can DSGF system solve these problems?

1.4 Methodology

The present study is designed as a qualitative and descriptive research study. Major techniques used were personal building observations, semi-structured interviews, literature survey and textbook evaluation. Specifically, data analysis of observations were descriptive qualitative, and interviews were qualitative and quantitative.

The interview participants were stakeholders (architects, engineers, suppliers, contractors, and users) from Chamber of Architects, Construction Council manager and architects, and City Planning Council architects, KAM-TEK Yapı ve Kaplama Sistemleri, DAREM Trading Company, Korman Construction Company, LEVENT Construction Company, and universities (EMU, GAU, CIU, LIU, NEU) in NC.

To accomplish the aim, the researcher conducted interviews including definite questions with 23 participants (as mentioned above), who volunteered to contribute to this study. Due to the fact that there are not many LSGFCOB and not many GF construction companies existing in NC, the number of stakeholders related to this system is quiet limited, the researcher could only get in touch with 17 of them. Out of 17 stakeholders 5 were selected from Chamber of Architects, Construction

Council manager and architects, and City Planning Council architects in order to identify possible limitations or existing laws related to application of DSGF systems in NC. Moreover, the researcher aimed to find out if these stakeholders have knowledge about DSGF systems both technical and theoretical. In addition the researcher interviewed 5 participants which are the Heads of the Department of Architecture in 5 universities in NC (Eastern Mediterranean University, Cyprus International University, Near East University, Girne American University, and Lefke International University) to obtain knowledge about whether DSGF systems are taught to prospective architects.

In data collection procedure, first of all, observation of 16 LSGFCOB (with more than 120 m^2 GF) were carried out in order to identify the type of existing GF systems used in NC. Then, interviews were conducted with the 23 stakeholders.

For data analysis, observational data was analyzed by identifying 15 LSGFOB according to the name of the building, height of the building and number of floors, orientation of the glazed facade, type of facade system, facade support structure, glass type and size, glazing type, ventilation type, shading device (if exists), function of the openings (if exists), GF m^2, and construction cost of GF per m^2.

The data obtained through the interviews was analyzed by looking at how each individual responded to each question to find out differences, common points and comments provided by the interviewees. Then, common points and comments as well as different responses (as additional comments) were categorized and the percentages were calculated.

1.5 Limitations

This research is limited by LSGFOB having minimum 120 m^2 GF both vertically and horizontally because for case of NC, “large scale building” is defined as a building having minimum 6 floors. This study considered only two types of GF systems; because the other types of GF systems are not the scope of the investigation. Specifically there are only GCW systems used, and the researcher attempted to find out whether DSGF systems are known and used in NC.

1.6 Significance of the Study

This study is a survey to give design aid about appropriateness of DSGF systems to be used for LSGFCOB in NC, and under which condition these systems can be used in NC. It is also a document to give idea to stakeholders and decision makers for using DSGF systems in NC.

Chapter 2

GLASS FACADE (GF) SYSTEMS

GF systems are transparent walls which are used for building exterior cladding. The main parts of these systems are the glass pane and support structural elements which attach the cladding (including glass panes, framing system, and etc) to the building. In this section of the thesis, firstly, a short history about GF systems is described and types of glass which are used in GF systems are categorized accordingly. In this chapter GCW systems and DSGF systems and their types are categorized and explained.

2.1 Historical Background of GF Systems

As Michael Wigginton (Wiggington, 1996) stated in his book, "Glass in Architecture", that, glass is a remarkable material and it presents a significant challenge to the design of the buildings (Wiggington, 1996: 6). It is used mostly in building's facade as a transparent cladding material. Glass is a partially natural material because the first fundamental and essential material for producing glass (base glass) is sand. Sand always has some impurities, usually iron oxide, which causes the color tints in the glass (Compagno, 1999: 11).

The first use of glass in architecture, as window glass, dates back to approximately the 1st century AD. Glass was used in various colors and transparency in different cultures. It was traded as a prized material among kings and emperors of the lands. (Patterson, 2008: 14). In that time glass was used in building mostly in windows and size of glass pane was very limited and the thickness was difficult to control until the 11th century that Germanic and Venetian craftsmen refined processes for producing sheet glass in cylinder and blown ball shape and this processes become common in Western Europe (Wigginton, 1996: 13).

According to Michel Wigginton, (1996) the first true glass architecture was seen in Northern European Gothic Style where the glass was used in small pieces and in many different colors for large openings in arches, vaults and in-between flying buttresses to admit light in to the building (Wigginton, 1996: 14). As shown in Figure 2-1, Chartres Cathedral is the good example for Northern European Gothic Style.

Figure 2-1: Chartres Cathedral; in France, 1194-1260 (URL 1; and URL 2).

This so called "structural masonry frames with glass membrane" was continued to be used in a similar manner in buildings around Paris from the 12th through the 14th centuries (Patterson, 2008: 16). Late 16th century and early 17th century was the time that the major use of glass in buildings was started. The type of glass used in buildings was flat glass sheets. Cast and rolled plate glass were types of flat glass which were used for windows in buildings for the first time in France since 1688 till 1702. Further development in flat glass manufacturing can be seen in 18th century with plentiful use of flat glass in glazed doors and windows and mirrors. An example can be the Crystal Palace by Joseph Paxton built in 1851 which is a good evidence of glass being an architectural material (W-Harvey, 2008: 83).

Following that, the word “Architectural Glass” found its way into architecture and building industry when major use of glass started in buildings in early 18th century. Architectural glass plays an important role in buildings’ IE comfort by providing ND, views of the surrounding, ThC and AA of the building (Allen, 1997: 146). Till mid and late 18th century mostly facades were constructed as massive load-bearing walls with small size of windows and openings. So, communication between users with outdoor environment was less and there was not enough income ND into the building and not a proper way of having natural air ventilating system (Sivanerupan, et al, 2008: 1; and Selkowitz, 1999: 2).

In mid 18th century increase in number and size of windows and large glazed wall could be seen in several European and American buildings. These changes were the first steps of technology of GCW systems. Wanamaker’s Department Store in 1859, in New York, could be count as one of the primary leaders in such buildings. In 19th century the new architecture was emerged, in which the size of windows and opening increased and consequently the proportion of glass to solid was increased in facade of the buildings. A fine example can be seen in the late 19th century in the work of Louis Sullivan and others in which large glass sheets were used in infill to the new multi-story steel framing the facade of the building (see Figure 2-2), (Patterson, 2008: 16).

Figure 2-2: Carson Pirie Scott Building; in Chicago 1898, Louis Sullivan architect (URL 3; and URL 4).

By development in glass productions and facade construction techniques, starting from 19th century, the new innovation of facade technology encouraged the architects and engineers to come up with a new facade construction system design such as GCW systems in which glass was the mostly used material in such facade systems (Sivanerupan, et al, 2008: 1; and Selkowitz, 1999: 2). An example which can be counted as second big step toward GCW system is Empire State Building by Shreve, Lamb and Harmon in 1929 in New York (see Figure 2-3). In this building they used aluminum spandrels which were a new step of using aluminum and glass (Allen, 1997: 147).

Figure 2-3: Empire State Building; in New York (URL 5; and URL 6).

A lavish use of large glass sheets and aluminum extrusion can be seen in Peter Jones's building in London by William Crabtree which is a good example of stylish GCW built in year 1930 (see Figure 2-4), (Allen, 1997: 147).

Figure 2-4: Peter Jones's Building; in London (URL 7; and URL 8).

In 1950s criticism about the increase of energy consumption in fully GF buildings started (Compagno, 1999: 8). Good examples of such buildings can be the development of the curtain wall as a high-rise cladding system and milestones in the Seagram Building, New York, 1954-8 (see Figure 2-5), and 860 Lake Shore Drive, Chicago, 1948-51(see Figure 2-6), both by Mies van der Rohe, and the Lever House, New York, 1951-2 (see Figure 2-7), by Skidmore Owings and Merrill (Patterson, 2008: 29).


Figure 2-5: The Seagram Building; by Mies van der Rohe and Philip Johnson, 1954, New York (URL 9; and URL 10).


Figure 2-6: 860 Lake Shore Drive; in Chicago, 1948-51 (URL 11; and URL 12).

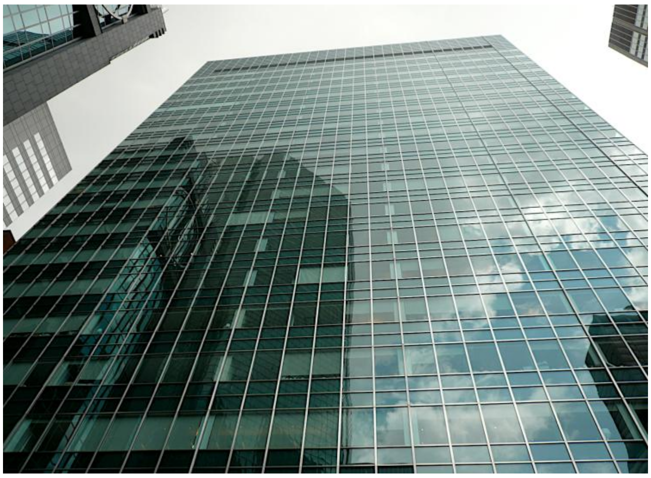



Figure 2-7: The Lever House; in New York, 1951-2 (URL 13; and URL 14).

In 1969, Reyner Banham in "The Architecture of the Well-Tempered Environment" shared his ideas about the separation of architecture from local climatic and regional conditions in opposition to high energy consumption of AC systems for the buildings. Due to oil crisis in 1973/74, a pressure of finding an urgent solution for reducing energy consumption of GF buildings forced architects and engineers to search for more utilize GF considering reduction of building's EE performance (Compagno, 1999: 8). The facade for the Willis Faber & Dumas is the good sample in which the GF is not about transparency, but reflection, at least during the daytime. A solid, uninterrupted reflective exterior face is presented by the use of bronze solar control coated glass. The glass panes were attached by weather seal which was provided by a minimal field applied silicone joint (see Figure 2-8). (Patterson, 2008: 29).

Figure 2-8: Willis Faber & Dumas Building; in Ipswich, by Foster and Associates, 1972 (URL 15; URL 16; and URL 17).

Development of GF and glass architecture continued growing and became more significant in 1980s while the pressure of ecological and environmentally-friendly design was quiet high (Compagno, 1999: 8).

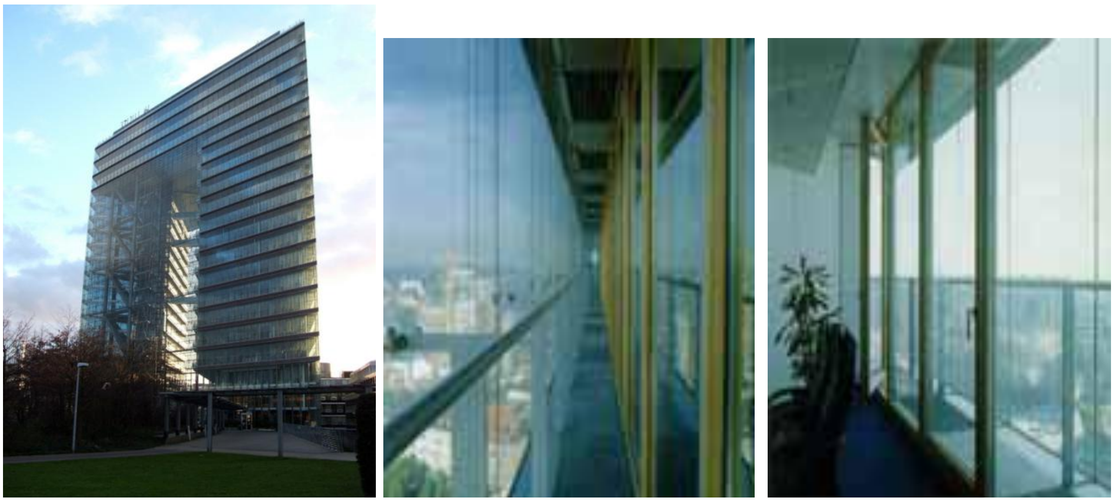
In building construction sector, facades are one of the critical issues in terms of design, manufacture and construction. Facades are the first aesthetical feature of a building that distinguishes one building from another (Winxie, 2007: 17-27). No other building system can play a major role both in building performance and AA as facade (Patterson, et al, 2008: 1) Facades, as one of the main systems of buildings play a very significant role in building construction industry by enabling users to interface with the outside environment and also by providing adequate amount of ND and NV to have better quality of IE (Sivanerupan, et al, 2008: 1).

In a building with large scale GF one of the problems is not just heat losses, but the energy which is consumed for ventilating, cooling and lighting the building. By maximum usage of ND and NV, the energy consumptions for such facilities can be reduced effectively. In the last 20 years building with GF have become the feature of Modern Architecture and by increase of building with GF disadvantages of this facade (overheating and heat loss) has been realized (Compagno, 1999: 7).

Development in facades can be more functional, providing designers with the flexibility to create high performance solutions both internally and externally. Major advancement in facade technology has given architects and engineers the opportunity to vary the AA of the buildings envelope, create an integrate grid system with all of their ideas, such as, windows, large glass panes, ventilation elements, aluminum features, etc. (Winxie, 2007: 1-5). The highly GCW system of New Beijing Poly Plaza, in Beijing, China, designed by SOM architect in year 2007, is a good example of such buildings (see Figure 2-9).

Figure 2-9: New Beijing Poly Plaza; by SOM architect, 2007, China. Cable net support system with rocker arm detail (right) (URL 18; URL 19; and Patterson, 2008: 241).

After 60 years of curtain wall systems, 30 years of element facade systems, at the end of 19th century, DSGF systems have come to the building construction and industry (Knaack, n.d: 1) as GF systems which obtain sustainability principles in terms of environmental performance (energy saving). The facade of Düsseldorf City Gate (Düsseldorfer Stadttor) in Germany (Figure 2-10), Sanomatalo in Finland (Figure 2-11), ABB Business Center in Sweden (Figure 2-12), Helicon Finsbury Pavement in London (Figure 2-13), and Seattle Justice Centre in United States of America (Figure 2-14), are the good examples of DSGF systems built around the world during the last 2 decades.



a) b) c)

Figure 2-10: DSGF of Düsseldorf City Gate (Düsseldorfer Stadttor); by Petzinka architect, in 2007, in Germany: a) South face of the “City Gate” (URL 20); b) View of the D.S.F. cavity; c) View of the interior glazing (Poirazis, 2004: 77).

a) b) c)

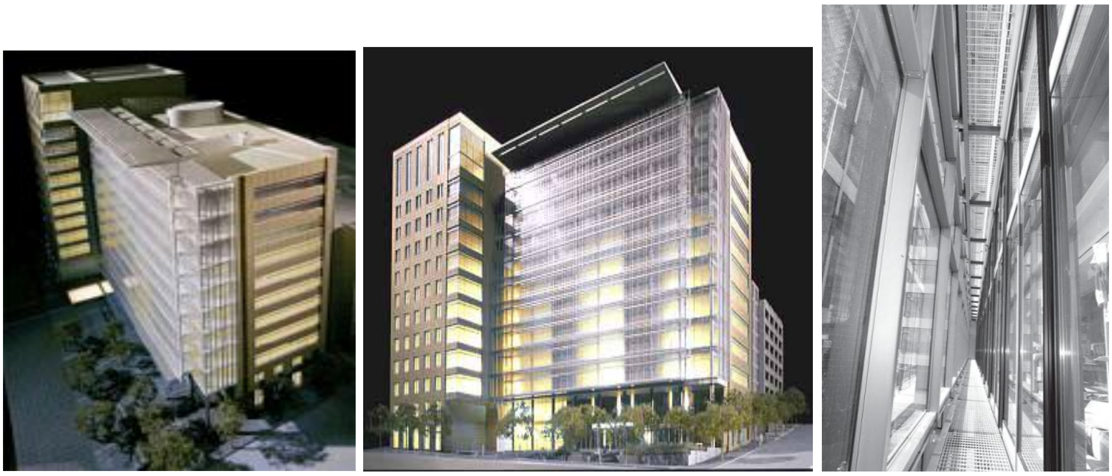
Figure 2-11: DSGF of Sanomatalo Building; in Helsinki, Finland, by Jan Söderlund & Co. Oy Architect, in 1997-1999. a) View of Sanomatalo (URL 21); b) View of the Facade (URL 22); c) View of the cavity (Uuttu, 2001, appendix A. In: Poirazis, 2004: 111).

a) b)

Figure 2-12: DSGF of ABB Business Center; in Sweden, by Architect: BSK after ideas from Archus-Arosia, in 2002: a) View of ABB (URL 23); b) View of the cavity (Poirazis, 2004: 134).

a) b) c)

Figure 2-13: DSGF of Helicon Finsbury Pavement; in London, by architect Sheppard Robson: a) View of Helicon Finsbury Pavement; b) Shading devices located in the cavity; c) View through the cavity from down (URL 24).



a) b) c)

Figure 2-14: View of Seattle Justice Centre; in USA, by architect Hegedus. a & b) View of Seattle Justice Center Building (URL 25; Poirazis, 2004: 153); c) View of the cavity (U.k, 2002: 2).

However, these examples illustrates that in global scale how affectively architects and engineers attempt has been toward growing and developing modern architecture at the same time considering sustainable principles and challenging with EE as the biggest problem of GF systems.

During the same period of time, as one of the results for using natural resources for building EE, solar radiation was seen as the ideal form of energy because of its advantages such as not polluting the environment, available everywhere in more or less quantities during daytime et al times of the year. Although in winter, in spring, and in autumn solar radiation is a good resource to provide required heat and light for the buildings with fully GF, but in summer it causes serious problems (green house effect in hot and humid climates) due to overheating the interior space of the building. In order to control the overheating, different types of shading devices should be used to control the heat gain of the space. Light-deflecting elements can be used for controlling the lighting which is high in summer and is a reason for the large part of the cooling load of the space. So these requirements for buildings with GF have caused the building construction and material industry to develop both new glass products for a high quality building facade and advanced building energy performance concepts to assure the interaction of the facade with the building services. That is why building planning and design stages have become quiet complex and it can be resolved only with comprehensive and integrate planning (Compagno, 1999: 9).

2.2 Glass types Used in GF Systems

Many types of glasses and many different glass systems have been used in GF systems to attain more advantages such as controlling solar radiation transmittance, reducing heat transfer, redirecting solar radiation, and etc. Below, main types of these glasses are explained and categorized in Table 2-1.

Annealed Glass

It is a glass pane without heat treatment. Annealed glass is weak in thermal resistance. Failure by thermal stress can occur on annealed glass due to partial shading. This type of glass is mostly used in glass fins. Annealed glass should not be used under direct partly shaded sunlight (Chan, n.d: 158).

Tempered glass

Tempered glass is achieved when a glass pane is heat treated. Tempered glass has good resistance against tension and breakage. When it is broken it will not fall down and hurt people. To produce tempered glass, first the glass is cut into desired pieces, then it is put into an oven and finally it is heated consistently to 621ºC. After that, the glass is cooled rapidly and at this time the outer surfaces of the glass are under compression and the inner parts are under tension and cooling process gets faster. Usually the thickness of the compression zone is about 0.2 of the total thickness and the thickness of the inner tension zone is about 0.6 of the total thickness (Chan, n.d: 153). Tempered glass is about 4 times stronger than annealed glass (without heat treatment) against bending and it has much more resistance against thermal stress as well and it is more expensive. Tempered glass is mostly used for facades which are exposed to heavy wind pressures or intense heat or cold (Allen, and Iano, 1938: 648-649).

Tinted and Coated Glass

In facades which have large area of glass, although the best way to block unwanted sunlight is using fixed shading devices, tinted glass and reflective coated glass are the glass productions which are designed to reduce glare and solar heat gain. Tinted glass or heat-absorbing glass is made by adding colorant to normal glass. Colorant is added to the molten glass and it has variety of tones such as grays, bronzes, blues, greens, and golds. For tinted glass, depending on color and thickness, light transmittance varies from 14% (in a very dark gray) to 75% (in lightest tints) and 85% which is clear glass (Allen, and Iano, 1938: 652). For tinted glass usually heat-strengthened glass (it is made with the same way as tempered glass but with less surface compressive stress) is used (Chan, n.d: 158). By inserting layers of coatings onto the glass surfaces, coated glass is produced. The main two types of coated glasses are the reflective coated glass, which controls the solar radiant, and the low emissivity (low-e) glass, which can reduce the emissivity of the surface of the glass from e ~ 0.87 to e ~ 0.04, thus reducing infrared radiation to 20%, without low down the light transmittance below 0.77 (Chan, n.d: 158; and Compagno, 1999: 42).

Insulating Glass

Insulating glass pane is a good insulation against sound and heat transmittance. It is made of two or more panes of glass with air gap in-between, which provides a good insulation. The gap can be filled by hexafluoride which is a good sound insulator. It can be made of reflective and low-e glass. It is mostly used with metallic spacer of roll-formed aluminum, stainless steel, coated steel or galvanized steel, sealed with polysulfide, polyurethane or hot-melt butyl etc. materials (Chan, n.d: 161).

Laminated Glass

It is made by bonding two or more layers of glass by interlayer such as PVB (polyvinyl butyral) or resin. The thickness of the interlayer is usually 0.38mm, 0.76mm 1.52mm etc (Chan, n.d: 159). This type is one of the most common types of glass used in LSGFB because when it is broken, the soft interlayer keeps the shards of glass together and reduces the risk of injury to people by falling in case of breakage. However, it is not as strong as annealed glass (Allen, and Iano, 1938: 649). Laminated glass is a good sound barrier after insulating glass. The interlayer can be colored or patterned to produce extensive variety of visual effects in laminated glass (Allen, and Iano, 1938: 650).

Table 2-1: Types of Glass Used in GF Systems

Type of Glass	Properties	Production Process
Annealed Glass	- Weak in thermal resistance	- It is a glass pane without heat treatment
Tempered glass	- Good resistance against tension and breakage - Is about 4 times stronger than annealed glass (without heat treatment) against bending and it has much more resistance against thermal stress as well and it is more expensive.	- Produced by heat treating a glass pane
Tinted & Coated Glass	- Reduce glare and solar heat gain - The main two types of coated glasses are the reflective coated glass, which controls the solar radiant, and the low emissivity (low-e) glass, which can reduce the emissivity of the surface of the glass	- Tinted glass or heat-absorbing glass is made by adding colorant to normal glass - Coated glass is produces By inserting layers of coatings onto the glass surfaces
Insulating Glass	- Good insulation against sound and heat transmittance	- Consist of two or more panes of glass with air gap in-between
Laminated Glass	- Is a good sound barrier after insulating glass - It is not as strong as annealed glass - when it is broken, the soft interlayer keeps the shards of glass together and reduces the risk of injury	- Made by bonding two or more layers of glass by interlayer

Thickness of the Glass

Glass, depending on the manufacturer, is typically manufactured in a series of thicknesses ranging from approximately 2.5 mm, which is called single-strength, through 3 mm, called double-strength, to a maximum o as much as 25.4 mm. for large scale buildings, where wind velocities are high at higher altitudes, thicker glass is generally required (Allen, and Iano, 1938: 648). Thickness of the glass also affects the transmittance of solar radiation as well as the type of the glass pane is total transmittance of the base glass which depends on thickness of the glass. For example, transmittance value for a 4mm thickness base glass is τ 0.09 and g 0.87 (Compagno, 1999: 32).

According to the literature, the mostly used glasses in GF systems have been low-e glass, tempered glass, and laminated glass. Mostly insulating glass units (double glazing units) were used for the GCW systems and also for the inner skin of DSGF systems, which usually had one glass layer (inner layer) of coated low-emissivity (low-e) glass to reflect heat radiation from interior spaces back inside and excessive sun heat back outside. The outer glass layer of the insulating unit has also often been coated solar control glass to reflect the unwanted part of the sun spectra back outwards (Tenhunen, et al, n.d: 7).

2.3 Types of GF Systems

In this section 2 types of GF systems, which are used in order to achieve highly glazed facades, are explained. First type is GCW systems and second type is DSGF systems.

2.3.1 Glass Curtain Wall Systems (GCW systems)

As Saldano L. M., (1998) described that "*Curtain wall systems are attached to the structural frame with angles or sub-framing. The most prevalent curtain wall systems are metal or metal and glass walls. These systems are used on many of today's skyscrapers. Curtain wall systems may also be constructed of natural stone, precast concrete, or either combinations of materials. Today, the curtain wall option is selected most often in enclosure systems*" (Saldano, 1998: 12).

GCW systems resist wind forces acting on the building, seismic forces, air and water infiltration and its own self weight; glazed curtain wall systems are recently the common type of curtain walls which mainly consist of aluminum framing (the early curtain walls were made of steel) with mullions and transoms. The glass panes are fitted into the aluminum frames and fixed by pressure plate and screws. Designing a GCW systems includes analysis, design of the glass panels and their framing systems, the connection between the panels with frames and building itself, in order to resist the out-of-plane wind pressures, and to accommodate in-plane deflections which are due to wind induced building drift, long term floor deflections, thermal movement, and earthquake loads (Sivanerupan, et al, 2008: 2).

Since mid 19th century, GCW systems have been widely used in modern buildings because of their essential specifics such as AA, increase of ND usage and their sustainability issues. The materials for framing and glazing may differ according to design concepts and principles. It can be steel, wood, aluminum, and etc. For glazing, it can have different glazing systems such as structural silicone-bonded system, point fixing system, suspended glazing system and etc. (Sivanerupan, et al, 2008: 2).

Figure 2-15: View of Bloomberg Tower. Designed by the renowned Cesar Pelli & Associates Architects, in New York. Bloomberg Tower is a 54-story, 1.4 million square feet, mixed-use building encompassing retail, commercial and residential space. The GCW has aluminum framing system with silicone sealant glazing to provide an excellent weather-resistant and waterproof seal that can offer long-lasting performance as well as a clean, neat AA (Momentive Performance Materials, 2007; URL 26; URL 27; and URL 28).

The GCW system can be classified into two main types, namely; frame GCW and frameless GCW systems as explained below:

2.3.1.1 Framed GCW Systems

Framed GCW systems are the types that framing system is used as one of the support structural elements for the facade and are in-fitted by glass panels. Although the early frames in framed GCW systems were made of steel but nowadays they are typically designated with extruded aluminum members that are typically in-filled with glass. The glass panes with extruded aluminum frames provide an impressive AA for the building’s facade plus allowance of ND into the building. Framed GCW systems are used to cover multiple floors as a facade system with significant performance resisting thermal expansion and contraction, building bend and movement, water diversion. These systems provide thermal efficiency for cost-effective heating, cooling, and lighting in the building as well (Sivanerupan, et al, 2008: 2).

The framed GCW systems are categorized into three common types, namely: stick system, semi-unitized system and unitized system.

A: Stick Wall System

Stick wall systems are counted as the earliest design for curtain wall systems. They were extensively used in metal curtain wall systems and nowadays they are still used in greatly superior versions. Installation of the wall is piece by piece and usually first the mullion members (which are the vertical elements) are installed and then transom members (which are the horizontal members). However, depending on design emphasis in some cases that horizontal lines are more preference the installation process may modify and the larger transoms might be first installed and then the mullions. No matter how the installation process is, but in both cases the transom and mullion members are designed mostly as long sections and they are interrupted or extended through at their intersections. Low shipping and handling costs of this system, which is due to low bulk and allowance for dimensional adjustment according to the site conditions, are the advantages of this system. These advantages for some contractors are the reasons to consider this system superior than other systems (Winxie, 2007: 20).

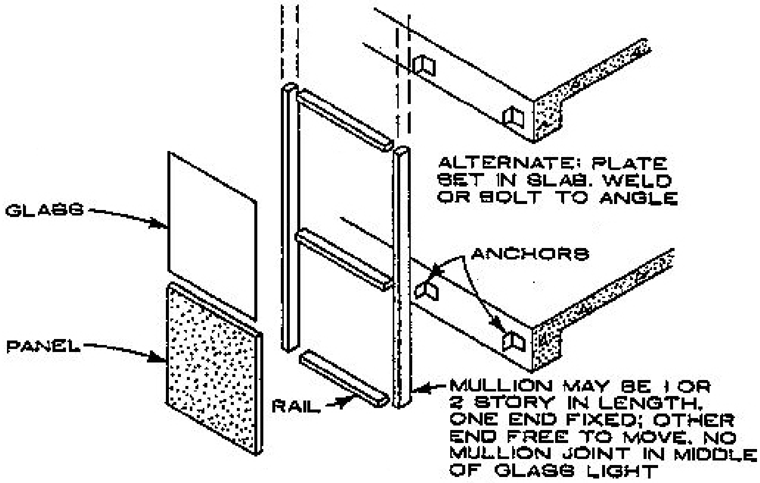


Figure 2-16: Diagram to Illustrate the Stick Wall System (Winxie, 2007: 21).

Impossibility of pre-glazing and pre-assembling (assembling and glazing should be done in the construction site) are the disadvantages on this system (Winxie, 2007: 21).

B: Semi-unitized Curtain Wall (Hybrid System)

After stick wall system, semi-unitized curtain wall method was the new design in the technology of curtain wall systems. In this system, first the mullion members are separately installed and then pre-assembled framing units are fitted between them. These units can be full story height, or they can be divided into a spandrel unit and vision glass unit. This system is suitable to be used for long spans, height of two floors, and it can be reinforced by steel (Sivanerupan, et al, 2008: 2).

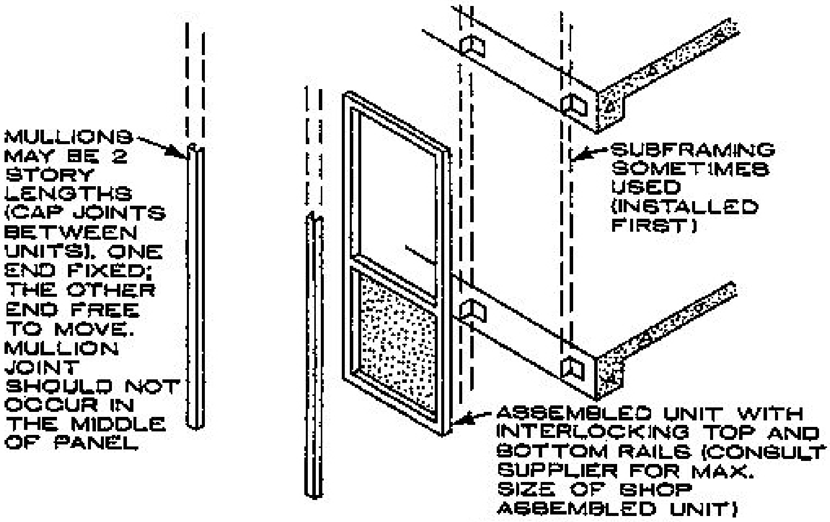


Figure 2-17: Diagram to Illustrate Semi-Unitized Curtain Wall System (Winxie, 2007: 22).

Semi-unitized system requires large amount of effort for field jointing work and the time needed for assembling is quite more in compare with stick wall system. (Winxie, 2007: 21).

C: Unitized Curtain Wall System

Unitized curtain wall system is the most contemporary method and it is designed for modern technology. In this system, the units of large glass sheets fitted in aluminum frames are fabricated in the factory where the process is under control and tested. In unitized curtain wall system, the top and bottom of each mullion member is connected to a transom member and with a glazed glass panel. According to the facade engineers, installing a unitized curtain wall is a fast process with a minimum work in the construction site and relatively few joints. This system is the most sealed and weather resistant cladding and exterior wall system available (Sivanerupan, et al, 2008: 3).

The unitized system is assembled on the building in form of panels. The structural section around the panel is fabricated as half sections (female and male) instead of a whole section, which eases the erection and to facilitate relative movement through articulation. The installation of the panels may start either from the top or bottom of the building and go around each floor until the whole building is dressed up (Winxie, 2007: 21; and Kawneer White Paper, 1999: 3).

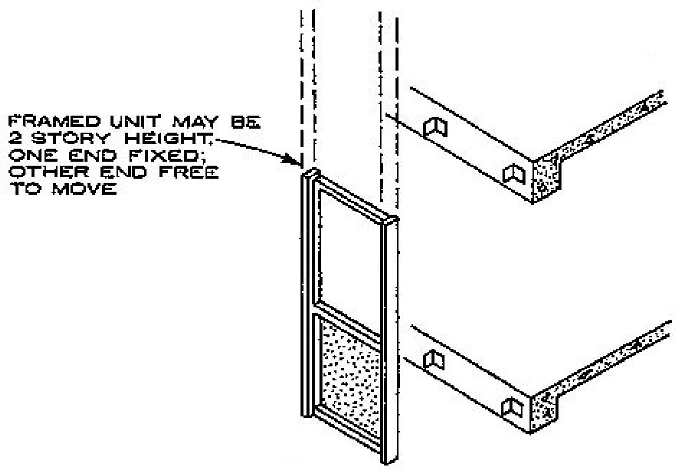


Figure 2-18: Diagram to Illustrate Unitized Curtain Wall System (Winxie, 2007: 23).

The structural section around the panel is fabricated as half sections (female and male) for ease of erection and relative movement through articulation. The panels are installed in shingle fashion, starting either from the bottom or top of the building and going around each floor until the whole building facade is complete (Sivanerupan, et al, 2008: 3).

Unitized curtain wall system is the most popular framed GCW systems according to many architects and engineers and it has performed satisfactorily when installed correctly (Winxie, 2007: 25).

In these systems mentioned above, all types of glazing such as single glazing, double glazing, triple glazing and multiple glazing can be used. But in order to increase the sustainable principles in these systems, such as EE, double glazing system has been used consisting of two sheets of glass installed into a frame with an air insulation gap in between to form a sealed unit (Sivanerupan, et al, 2008: 3).

2.3.1.2 Frameless GCW Systems

Frameless GCW systems are the types which many architects and engineers prefer to use them instead of framed GCW systems. The reason is that these unconventional glass wall systems, if well designed, can help the EE of the building by providing maximum usage of ND due to less support structural elements (such as mullions and transoms and aluminum/metal profiles). They have different types all aim at achieving maximum transparency by reducing the support structure (Sivanerupan, et al, 2008: 3). There are different types of frameless glazed systems available to be used in GFs such as:

A: Point Fixed Glass Supported by Steelwork

In point fixing systems or bolted glazing system the glass itself can function as a bearing element and is used even to support the mullions and beams. In these systems, there are no frames or mullions in the support structure systems. The support structure systems are simple posts, trusses and fins (Vyzantiadou, and Avdelas, 2004: 2). If the height of glazed wall is more than 4.0 m, trussed posts made of steel, in different forms, are used to support the glazing wall (Sivanerupan, et al, 2008: 3).

In point fixing systems, that there are no holes on the glass panes, fixtures are placed on the sides of the panes either at the joints between the panes or at the corner of the panes. The good example of this type of glazing can be the atrium in Hotel Kempinski at Municch Airport, built in 1994 by Murphy/Jahn architects (Vyzantiadou, and Avdelas, 2004: 2).

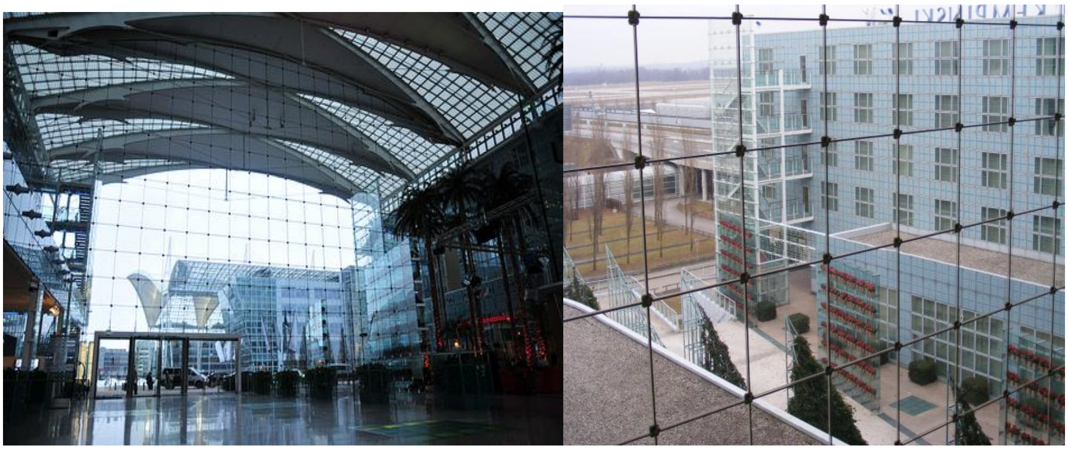


Figure 2-19: Point Fixing for the GF of Hotel Kempinski at Municch Airport (URL 29; and URL 30).

In point fixing systems with holes on the glass panes, the holes are drilled in the panes and bolts are put in the holes. The variety of this type are based on the holes, which in some cases the head of the bolts are hidden in the holes and gives a flat surface on the panes, whereas in other cases the end head of the bolt is not hidden and it’s visible. A good example of this type is planar system, used for the first time for the facade of the Renault Center by Foster and partners in Swindon, England, in 1982. The size of the glass panes are 4*1.8 m and the thickness is 10 mm. the type of the glass is toughened glass. The glass panes are attached to the spring plates by bolts and the spring plates are attached to the transoms of the structure. These spring plates are made of stainless steel. Other type of this system is the case where the glass panes are suspended from the facade structure by pins which are connected to the mullions of the facade structure. In this type bolts are in a cylindrical shape (Compagno, 1999: 17).

Figure 2-20: View of Renault Center; by Foster and Partners in Swindon, England, built in 1982 (URL 31, and URL 32).

In this system the metal part of the small bolts are visible and they cover a very small portion of the glass. In some types of bolting and fixing systems the fixing holes can be drilled into the glass pane so that the bolts are fixed in the thickness of the glass. For small and medium glazing which the height is less than 7m and the length is less than 50 m rigid bolted system is preferred to be used (Garg, 2009: 2).

In this system, glass panels and the structure are attached with rigid bolts and steel plates. In modern types of this system, Knockled bolts are used instead of common fixed bolts. By using Knockled bolts, the glass panes which carry the wind pressure become flexible and they make a continuous carve instead of a double curvature. It also prevents the extra tension in the glass at suspension points. It has self-lubricant and special coating against wear and tear and. This new type of bolt is designed for roofs, it can be used also for the facades and be rotated up to 7 degrees. From inside this bolt has to rings which protect it from wind and water. Bolted glasses are mostly used for the main facade of the LSGFB because they provide the maximum transparency (Garg, 2009: 2). The difference of point fixing system with conventional framing systems is that the bolts which are used to attach the glass panes give a point support to the glazed glass panes but in conventional framing the type of support is a continuous linear edge support. Point fixing system is applicable for small simple structures for shops and also for multistory buildings with complete GF. Glass panes are attached to glazing support attachments by bolt fixings and these support attachments are connected to the support structures. So this systems which does not have framing support system, consists of group of elements connected to each other and they transfer the loads and movements to the main structure of the facade. The main components of this system are glazing panels (glass panes), bolted fixings, glazing support attachments and the main support structure. The advantage of point fixing systems is that steel used in this system will have less corrosion and also the glass panes will get damaged by wind stresses less (Garg, 2009; and Compagno, 1999).

In modern style of frameless glazing systems, bolt on steel support structures are used which are counted as one of the important architectural elements and they help the better AA of the GF. These systems are applicable for simple structures such as shop windows and settlers, and also for complex structures such as LSGFB and atria. Bolted fixings commonly connect the glass panels to each other at their corners and if the glass panel is large there will be an additional bolted fixing in the middle of its edge as well. By this way the panels are connected to the glazing support attachments as well and glazing support attachments in turn are connected to the support structures. In this case considering the movement of glazing panels and support structures, due to thermal effects and applied loads, is an essential issue. If glazing panels and support structures resist the movements then stresses can be developed in the system. Therefore, the pre-consideration, is first for bolted fixings and glazing attachments to prevent the rotation and movement. In bolt fixing system, connection of the glass panels can be done either by bolting through the glass that bears on the glass or by friction plates that are clamped on to the glass panels by bolts. In some cases friction plates can be used for connecting metal brackets or plates to a piece of glass or for connecting glass sheets by using patch plates which cover both pieces of glass. Metal plates are clamped together and are fitted on both sides of the glass in order to generate a normal force and a corresponding frictional load capacity in the plane of the glass. To provide required flatness and coefficient of friction between the glass panes and metal plates, an interface such as a soft metal (pure aluminum) or fiber-reinforced plastics are normally used (Sivanerupan, et al, 2008: 3).

B: Point Fixed Glass Supported by Cable Systems

Support structures can be almost entirely from tension elements, such as rods or wires. This provides a lightweight structure with less visual barriers. Loads are transferred trough both ends of the cables to boundary support structures. The weight of the vertical glazing is either supported by a tie rod hanger system or by each panel being suspended from the above panel (Vyzantiadou, and Avdelas, 2004: 3).

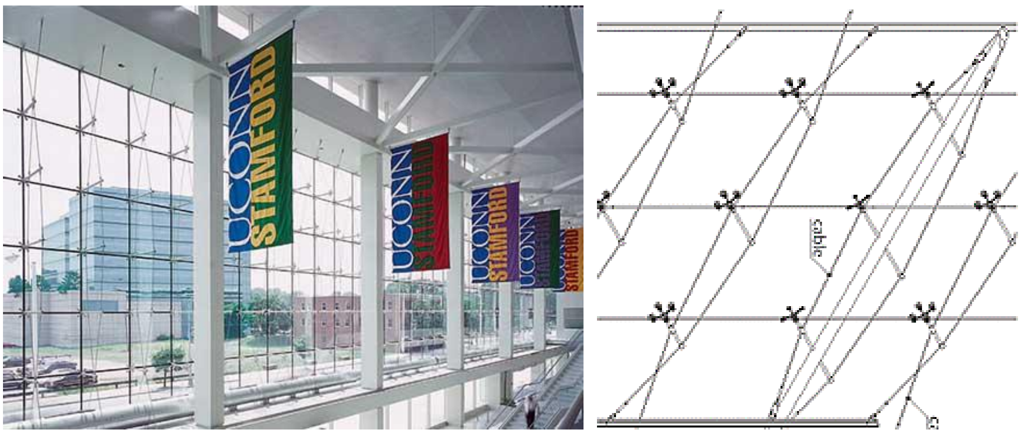


Figure 2-21: University of Connecticut, Stamford, CT; by architects Perkins & Eastman. Cable tension trusses help create the exceptional transparency of the facade (URL 132; and URL 33).

C: Glass Fin Support System

In fin supported glazing, the glass wall is supported with glass beams or fins on its edge. Soft silicone sealant is used to attach the glazing to the fins or it is connected to the fins discontinuously by using bolted connections. This system is not suitable to be used for tall buildings employing GF system (Sivanerupan, et al, 2008: 3).

In this system, glass fins are used to reach the maximum transparency. In structuralizing the glazing system, principles of designs and installation should be considered. Size, thickness and safety should be included in glass fin supported systems. In addition bolted joints are used in designing glass fin supported systems. Different fittings are applied to support the structure in which they absorb forces applied to the glass under load to provide secure bond between the glass fins and the support structure. Greater visibility and high level of ND in interiors is achieved by glass fin supported systems.

Figure 2-22: GF of Sony Center in Berlin; Murphy/Jahn Architects; 1992-1999. Facade is supported by glass fins, also for wind bracing (URL 34; URL 35; and Compagno, 1999: 22).

D: Suspended Glazing Support System

Deflection of glass on the facade is a major problem and one of the solutions for preventing such problem on a GF is using glass panels suspended from top of the building instead of inserting them to the building's body itself. These systems are excluded of mullions and transoms and there is no frames used to hold the glass panes. The glass panes are hung and suspended from the structure and they create a matrix, allowing large openings on the facade which provide maximum transparency and view for the building. Suspended glazing support system is created for the need of large glazed portions in the buildings. This system is mainly used for tall glass panes which are weak against bending and buckling due to their height (Entrepreneur, 2009; and Compagno, 1999: 4). Following pictures are the examples of this system.

Figure 2-23: Suspended GF of Banque Populaire de l' oust et de l' Armorique; located in Rennes, France, built in 1989 by architects Odile Decq and Benoit Cornette, with RFR, and Peter Rice. In the suspended GF the upper row of glass panes is attached to the roof edge via spring assemblies at the center. The next rows are suspended below them via cross-shaped bolted fixing. The types of glass used are toughened single panes and insulating glass panes. The facade provides ND, maximum transparency with less visual barriers (Compagno, 1999: 99), (URL 35; URL 36).

In suspended glazing system, a similar system of hanging curtains inside the houses is used but in larger scale in which the top tier panels are connected by regulate-able hanger brackets to the structure. Following lower panels are connected to the corners by special fittings. All the glass joints are sealed with silicone and they are all located in a same linear form of fittings which are from inside providing smooth exterior facade surface. Also, facades are located in special sliders to be connected to the support structure or ground. Stabilizing the hanging mechanism is necessary for avoiding any damage due to wind forces plus reducing the weight upon the lower glass panels. Because of the size, using tongs on monolithic glass panes are necessary to suspend. Tongs are useful due to their double sides holding mechanism. On double glazed panels which are not capable of handling sustaining pressure, using tongs is not the option. In this case, the available option is using hooks. This system works with special processed and toughened glass panes bolted together, at the corners, by metal patch fitting tools. Due to lateral forces of wind loads, pane-to-pane joints are fixed by synthetic sealing and toughened glass stabilizers and used on each vertical joint to provide lateral rigidity. Assembly system is suspended from the top part of the building's structure by attached hangers which are bolted to the top edge of the structure. None-setting mastic or neoprene strips are used for sealing those panes in the sliders. Concept of the design guarantees that facade is looking stable and rigid because of the potential problems of differential movements between the components of the facade system. Therefore, having a rigid system will avoid those problems such as vibration or wind force based problems (Garg, 2009: 4).

2.3.2 Double Skin Glass Facade (DSGF) Systems

Types of facade system in 19th century, which were framed non-load bearing walls, gave the opportunity to the architects and engineers to create an envelope for buildings only with glass. A good example can be the facade of Hallidee Building in San Francisco in 1918 by Willis Polk. This building is counted as one of impressive facade in early curtain wall system which opened the road to the modern glass architecture (see Figure 24). However, at the beginnings stages there was not extensive usage of glass in facades because of the problems that glass can cause for internal comfort condition such as ThC (Andreotti, n.d: 71).

Figure 2-24: Facade View of Hallidee Building (URL 37).

By Willis Carrier's work, Scackets-Wilhelms printing company in New York in 1902, which was the first building with fan coil dehumidifying system, these problems were solved and all the buildings that were equipped with this system could provide a good internal environment system and also a building with lightweight structure and envelope became possible. The biggest disadvantage of fan coil dehumidify system was its high level of energy consumption and because of that and the energy crisis in 1973, usage of glass in architecture was not preferred by people unless combined by exploitation of renewable energy sources for heating, cooling, lighting and ventilating a building. This caused the architects and engineers to improve the use of solar energy and NV and ND in the buildings (Andreotti, n.d: 71). Such improvement can be seen in Corrales House of Steve Bear in Mexico in USA, the St. George School of A. E Morgan in Liverpool, England, and the house in Odeillo in France, all designed by Jacques Michel and Felix Trombe.

In 1978, Richard Rogers, about future target for glass research stated that: "*A building becomes a chameleon which adapts. A properly equipped and responsively clothed building would monitor all internal and external variables, temperature, hygrometry and light levels, solar radiation etc, to determine the best energy equation given these conditions and modify the building and its internal systems* *accordingly. It is not too much to ask of a building to incorporate, in its fabric and its nervous system, the very basic vestiges of an adaptive capability*" (Rogers, 1978. In: Andreotti, n.d: 72).

The idea of a building have an envelope which can adapt to different climate condition to provide the best internal and external environment condition is not new. Its basic ideas can be seen in old traditional method of providing a thermal buffer zone with removable glazed skin such as buildings which have temporary glazed balconies or if the buildings are located in hilly regions they have Box-type windows. In fact, these old tradition methods are the inventive form of new facades such as recent DSGF systems (Dickson, n.d: 7). Good examples are Energieversorgung Schwaben in Stuttgart (Germany) and the DB Cargo building in Mainz (Germany), both built in 1998. DSGF system has been seen as a combination between the innovative structure of the modern GCW facades and the old principles of the 'bioclimatic architecture' (Andreotti, n.d: 72).

Back in 1980, Occidental Chemical Center at the Niagara Falls (Canada) by Helmuth, Obata and Kassabaum, was the first modern version of double skin facade. In 1984, the 'Briacliff House' in Farnborough (England) by Ove Arup Associates, is a further example of double skin facade. In these 2 examples, the facade does not have cavity NV system and the DSGF mostly acts as an acoustic barrier against the noise of the aircrafts but it also integrates the heat recovery and solar control systems, whereas Richard Roger developed a new facade solution for the Lloyd's Insurance Company in London in 1984 but the cavity in DSGF was ventilated mechanically with a down-ward air flow to achieve the best possible ThC near the internal surface of the GF (Andreotti, n.d: 73).

In 1981, Mike Davies in his article, “A Wall for All Seasons”, proposed a development of multi-performance glazing, called Polyvalent Wall as one of the innovative facade systems, which could dynamically regulate the energy from outside to inside and vice versa and may offer the best energy equation. Invention of DSGF as a smart facade, have proved that DSGF can be the response to the Polyvalent Wall which could automatically change its performances according to the outside weather condition. Back in 1903, an early example of DSGF was already built for the east facade of the Margarethe Steiff Factory in Geingen, Germany (Compagno, 1999: 8).

Figure 2-25: Aerial View of the Steiff Factory, 1910 (Historical Archive of the Steiff Factory, Giengen. In Fissabre, and Niethammer, n.d: 2).

In short it can be said that, DSGF systems, if well designed, can satisfy all the requirements of the occupants in terms of cooling, heating, lighting and using as much as possible natural renewable energy sources (Fissabre, and Niethammer, n.d: 601).

The facade of the Business Promotion Center in Disburg (England) built in 1993 by Foster and Partners in collaboration with Kaiser Bautechnik may be counted as the first example of DSGF with naturally ventilated cavity. In this facade system, the air entering the cavity rises up for stack effect and it removes the heat, which are absorbed by the louvers from the external surface of the internal layer of glass, untill it reaches the roof edge where it is ejected out (see Figure 2-25), (Andreotti, n.d: 73).

a) b)

Figure 2-26: Business Promotion Center; in Disburg (England). a) View of the facade at night (URL 38), b) view of the facade during daytime (URL 39).

Facade of the Victoria-Ensemble in Cologne (Germany) has the similar design concept but it has a deeper cavity with scaffolds located at every floor just purpose of maintenance and cleaning. Nevertheless, the mentioned 2 buildings are equipped with full AC system and the air flowing in the cavity is not used for NV of the building (see Figure 2-26) (Andreotti, n.d: 73).

However, as mentioned above, there are many buildings designed in the last 20 years around the world, which are the result of previous studies about improving the performances of the DSGF systems. Indeed, this system has become the symbol of architectural and technological innovation/ design concept.

Figure 2-27: View of Victoria-Ensemble; in Cologne, Germany, by Architect Thomas Van Den Valentyn, in 1997 (URL 40; and URL 41).

Definition and Characteristics of DSGF Systems

According to Harris Poirazis, (2004) DSGF system is a European architectural trend driven mostly by: *"• the aesthetic desire for an all glass facade that leads to increased transparency; • the practical need for improved indoor environment*; *• the need for improving the acoustics in buildings located in noise polluted areas*; *• the reduction of energy use during the occupation stage of a building"* (Poirazis, 2004: 12).

There are different definitions for DSGF systems explained by famous authors. Some of these definitions are mentioned in this section in order to define DSGF systems. Harrison and Boake, (2003) in the Tectonics of the Environmental Skin, described the DSGF system as "*essentially a pair of glass "skins" separated by an air corridor. The main layer of glass is usually insulating. The air space between the layers of glass acts as insulation against temperature extremes, winds, and sound. Sun-shading devices are often located between the two skins. All elements can be arranged differently into numbers of permutations and combinations of both solid and diaphanous membranes*" (Harrison, and Boake, 2003. In: Poirazis, 2004: 15).

According to Arons, (2001) DSGF is "*a facade that consists of two distinct planar elements that allows interior or exterior air to move through the system. This is sometimes referred to as a twin skin.*" (Arons, 2001. In: Poirazis, 2004: 15). Compagno, (2002) defines the DSGF as "*an arrangement with a glass skin in front of the actual building facade. Solar control devices are placed in the cavity between these two skins, which protects them from the influences of the weather and air pollution a factor of particular importance in high rise buildings or ones situated in the vincity of busy roads*" (Compagno, 2002). In general, DSGF systems are the facade systems consisting of 2 glass skin (exterior fully glazed and interior not fully glazed) with a layer of air insulating in between.

In order to understand the concept of DSGF systems, there is need to understand different sections and elements of this system. DSGF systems are mainly characterized according to the types, ventilation, and air flow concepts of the cavity of the facade.

Type of Cavity in DSGF systems

According to the type of cavity, DSGF systems are categorized into 4 groups as listed below:

2.3.2.1 Multistory Facade System

In this type, the cavity is not divided and it has opening only at the top and bottom of the facade. It provides a good sound insulation and strong thermal insulation (see Figure 28). In buildings with multistory facade, usually the cavity is ventilated mechanically and the openings on the internal layer of the facade are just for maintenance and cleaning purposes (Andreotti, n.d: 74).

Figure 2-28: Example of Multistory DSGF; GSW headquarters, Berlin, Sauerbruch Hutton Architects (URL 42).

2.3.2.2 Box-window Facade System

In this type, the cavity is closed horizontally and vertically at each floor to prevent the transmission of sounds and smells from room to room (Andreotti, n.d: 74).

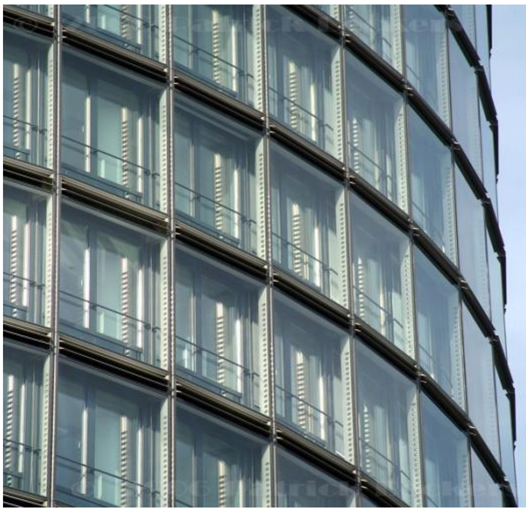


Figure 2-29: Example of Box-Window DSGF; Victoria Insurance, Dusseldorf; Architects: Hentrich, Petschnigg and partners (URL 43).

2.3.2.3 Corridor Facade System

In this type, the cavity is separated horizontally at each floor which allows good NV of the cavity, but it could cause some sound transmission problems from room to room (Andreotti, n.d: 74).

Figure 2-30: Example of Corridor DSGF; Dusseldorfer Stadttor Building, Dusseldorf, Germany; Architects: Petzinka Pink and Partners (URL 44).

2.3.2.4 Shaft-box Facade System

In this type, box window systems are connected with a vertical shaft (has stronger thermal uplift) which improves the ventilation of the facade, provides a better sound insulation and it has less openings on the external skin (Andreotti, n.d: 74).

Figure 2-31: Example of Shaft-Box DSGF; ARGA Insurance, Dusseldorf; Architects: Rhode Kellermann Wawrosky and Partners (RKW) in cooperation with Foster and Partners (URL 45).

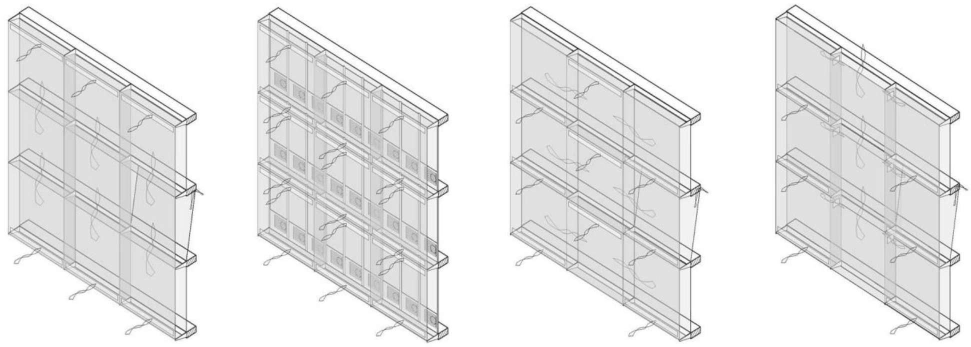


Figure 2-32: Example of DSGF systems(from left to right): Multistory Facade, Box-window Facade, Corridor Facade and Shaft-box facade (Knaack, n.d: 2).

Table 2-2 is a summary of what have been explained above about types of DSGF systems according to type of their cavity.

Table 2-2: Classification of DSGF Systems According to Type of the Cavity

Name of the DSGF System	**Type of the Cavity**	**Properties**
Multistory Facade System	- Cavity is not divided and it has opening only at the top and bottom of the facade - Cavity is ventilated mechanically	- Provides a good sound insulation and strong thermal insulation - openings on the internal layer of the facade are just for maintenance and cleaning purposes
Box-window Facade System	- Cavity is closed horizontally and vertically at each floor	- Prevents the transmission of sounds and smells from room to room
Corridor Facade System	- Cavity is separated horizontally at each floor	- Allows good NV of the cavity - Causes some sound transmission problems from room to room
Shaft-box Facade System	- Box window systems is connected with a vertical shaft - Cavity has less openings on the external skin	- Improves the ventilation of the facade - Provides a better sound insulation

2.3.2.5 Ventilation Type of the Cavity in DSGF Systems

Due to extensive usage of DSGF systems and consequent increase in variety of modified solutions, DSGF systems include a large group of systems that can visually be similar but completely different in performance. DSGF systems are different mainly in type of ventilation of the cavity. The air cavity between the two skins can be totally natural, fan supported or mechanically ventilated, as categorized below:

- The type in which the air cavity is ventilated mechanically which works as sound insulation but also dynamically controls the ThP of the facade (Aber, 2007: 5).
- The type in which the air cavity is completely closed and it works as a thermal buffer zone or acoustic barrier (Aber, 2007: 5).
- The type in which the cavity is open both from bottom and top and provides NV for the facade. In this type the openings of the inner skin can be used in order to ventilate the interior spaces (Aber, 2007: 5).
- The type in which the air cavity is open either from top and bottom or from sides or both in order to allow NV of the facade. In this system, ThP and AI are changeable (Aber, 2007: 5) The last system of DSGF system is the most innovative type of this facade system because it provides NV of the building which reduces the use of AC system plus it provides ThC for the occupants. (Andreotti, n.d: 74).

Table 2-3 is a summary of what have been explained above about ventilation type of the cavity of DSGF systems.

Table 2-3: Ventilation Type of the Cavity of DSGF Systems

Type of Ventilation	Properties
Mechanically Ventilated Cavity	- Cavity works as sound insulation but also dynamically controls the ThP of the facade
Completely Closed Cavity	- Cavity works as a thermal buffer zone or acoustic barrier
Open Cavity (both from bottom and top)	- Cavity provides NV for the facade
Open Cavity (either from top and bottom or from sides or both)	- Cavity provides NV of the facade

The width of the cavity can vary as a function of the applied concept between 10 cm to more than 2m. This width influences the way that the facade is maintained (BBRI, 2002. In: Poirazis, 2004: 16). In some cases, in order to provide the cleaning facilities of whole facade, which may not be possible from inside and outside of the building, the width of the cavity has to be about 80 cm to allow the cleaning personnel to access the cavity. Thus, in such a case the airflow in the cavity has less flow resistance and therefore can be higher compared to a narrow gap. However, in this case more space is occupied by the cavity which is loss of space in the interior of the building (Aber, 2007: 5).

However, the size of the cavity can also affect the ventilation. As Stec & Paasen, (2003) claimed that, "*It is difficult to claim in general if the thin or deep cavities will perform better because in one case the cavity temperature and in other case temperature of the blinds will be Higher"* (Stec & Paasen, 2003. In: Poirazis, 2004: 43). For example, in cold climates it is more suitable to use thin cavities to limit the flow and increase the cavity temperature. In hot climates the DSGF should work as a screen for the heat gains from radiation and conduction (Poirazis, 2004: 43).

2.3.2.6 Air Flow Concept of the Cavity in DSGF Systems

As explained in "BEST FACADE: Best Practice for Double Skin Facades", (2008) "*the ventilation mode refers to the origin and the destination of the air circulating in the ventilated cavity.*" The air flow into the cavity is independent from the type of ventilation of the cavity. "*Not all of the facades are capable of adopting all of the ventilation modes described here. At a given moment, a facade is characterised by only a single ventilation mode. However, a facade can adopt several ventilation modes at different moments, depending on whether or not certain components integrated into the facade permit it (for example operable openings).*" (Schiefer, et al, 2008: 44) below different type of air flow of the cavity are categorized:

1) Outdoor Air Curtain: in this type, the circulated air inside the cavity enters from outside and it is immediately rejected towards the outside. In this system, the cavity forms an air curtain enveloping the outer facade (see figure 2-32) (Haase, and Dr. Amato, 2006: 6-7).

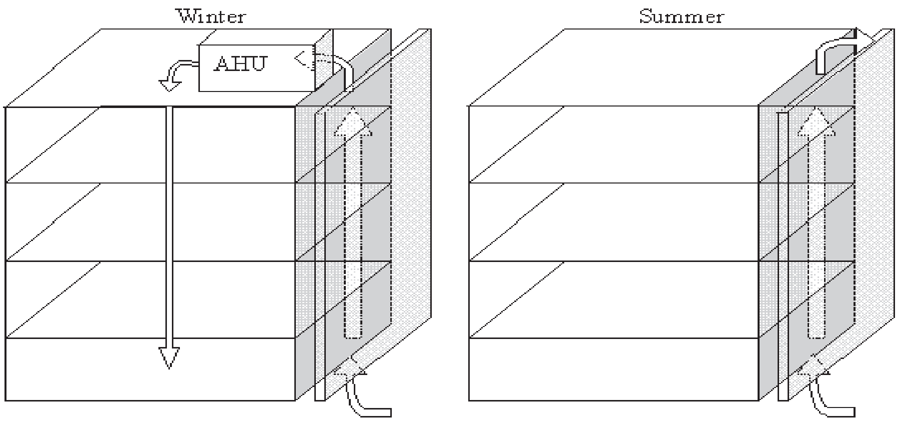


Figure 2-33: DSGF System as a Central Direct Pre-Heater of the Supply Air (Poirazis, 2004: 45).

Figure 2-34: Telus-William Farrell Building; in 2000, located in Vancouver, British Columbia; Busby and Associates Architects. a) View of the facade (URL 46); b) View of the cavity; (URL 47). The facade is the first triple-skinned system in Canada. Suspended from the existing building face approximately 90cm, a new double glazed fritted glazing system, including openable windows, was hung. The air space acts as the main mechanism to help regulate the building's internal temperature, contributing in both cold and warm weather. The cavity is both naturally and mechanically ventilated in which in winter it is closed from top and bottom and it insulates the building. In summer the cavity is open and in order to increase the air movement in the cavity, mechanical fan might be used (Gilson, n.d).

2) Indoor Air Curtain: in this type, the air comes from the interior spaces and it is returned to the interior spaces, sometimes by ventilation system (See Figure 2-34) (Schiefer, et al, 2008: 45).

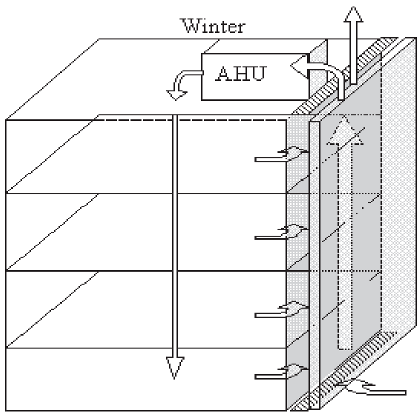


Figure 2-35: DSGF System as a Central Exhaust Duct for the Ventilation System (Poirazis, 2004: 47).

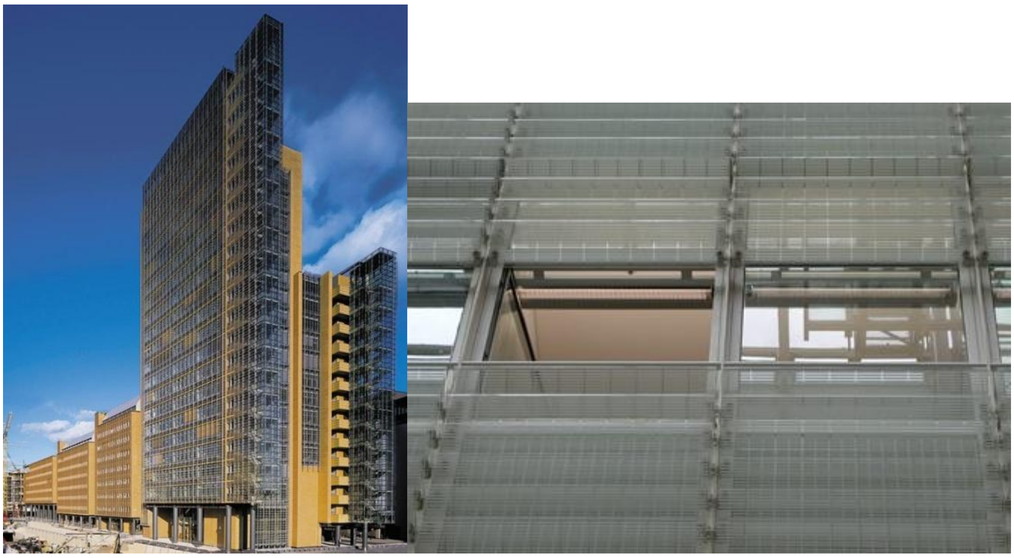


Figure 2-36: Debis-Building; Located in Berlin, Germany; in 1998; Architect Renzo Piano. a) View of the facade (URL 48); b) detail of the DSGF system (URL 49); the Window system is used with timber made louver blinds in the void between interior facade and exterior skin. The facade is composed of prefabricated terra-cotta elements and glass. The second skin of the facade reduces ND, even when designed for maximum transparency. The interior spaces are equipped with openable windows, but a mechanical system controls the ventilation as well (IBUS, n.d).

3) Supply Air: in this type, the ventilation of the facade is by outdoor air in which the outdoor air comes inside the cavity and thus the interior spaces or into the ventilation system. So, in this type supply of the outer air is possible for the ventilation of the building. The cavity is open to the interior spaces from the top and it is open to the outside from bottom of the facade (see Figure 2-36) (Haase, and Dr. Amato, 2006: 6-7).

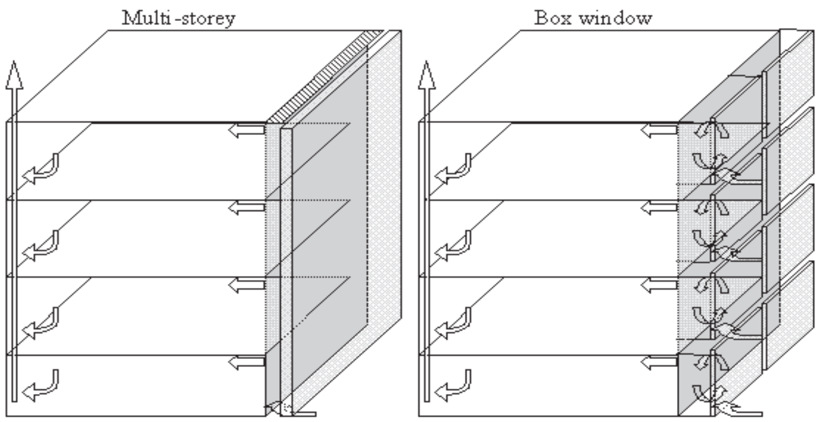


Figure 2-37: DSGF System as an Individual Supply of the Preheated Air (Poirazis, 2004: 46).

a) b) c)

Figure 2-38: View of Tjibaou Cultural Centre; in New Caledonia, in 1998; by Renzo Piano; a) View of the building (URL 50); b) detail of the outer skin of the facade (URL 51); c) Detail of the inner skin; The DSGF uses the PW, coming from the ocean side, for the NV of the system. The inner skin of the facade is from glass louvers which open or close according to wind speed, allowing wind to flow through the building for passive ventilation. The outer skin, on the ocean side, is equipped with horizontal wood slats composed of iroko wood (a type of wood that is impervious to rot and can withstand cyclone-force winds) filter the wind into a second layer of skin. The double layer of skin also filters the warm air upward functioning similar to a chimney (URL 52).

4) Exhaust Air: in this type, the air comes from interior spaces and it is moved towards the outside. The evacuation of the interior air is possible with the ventilation of the facade. In this type, the cavity is open to the interior spaces from the bottom and it is open to the outside from top of the facade (see Figure 2-39) (Haase, and Dr. Amato, 2006: 6-7).

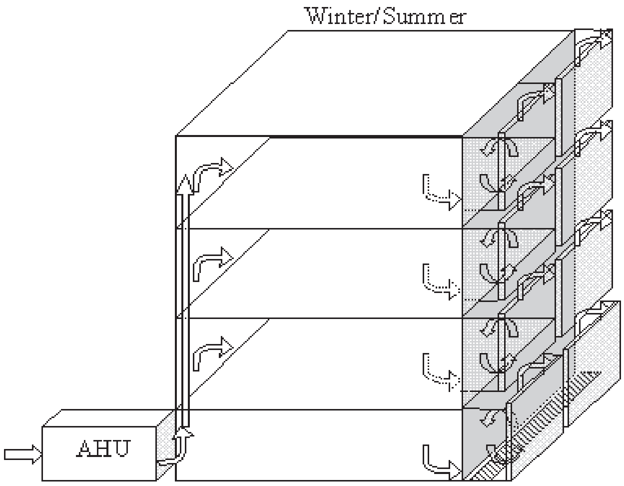


Figure 2-39: DSGF System as an Exhaust Duct (Poirazis, 2004: 45).

a) b)

Figure 2-40: View of Helicon Building, in London; in 1997; Architect Sheppard Robson International. a) View of the facade (URL 53); b) detail of the facade with louvers located in cavity (URL 54). The building has a triple glazed facade that integrated adjustable shading devices allowance for maximum transparency while minimizing heat gain and providing a temperature buffer in cold weather. Chilled ceiling and floor based air supply are used to increased user comfort while decreasing the long-term energy use of the building (Sharma, n.d: 2-3).

5) Static Air Buffer: in this type, the cavity is open neither to the interior spaces nor to the outside. The cavity acts as an air tight layer and form a buffer zone between the inside and the outside in which the ventilation of the cavity is not possible (Haase, and Dr. Amato, 2006: 6-7). The buffer facade consists of two layers of glazing mounted approximately 250 to 750mm (10” to 30”) apart, with the air space between the two layers sealed. This is the oldest typology; it has been in use for nearly 100 years. The buffer facade was developed before insulating glazing was invented to increase sound and heat insulation without reducing the amount of ND entering the building (Andreotti, n.d: 75).

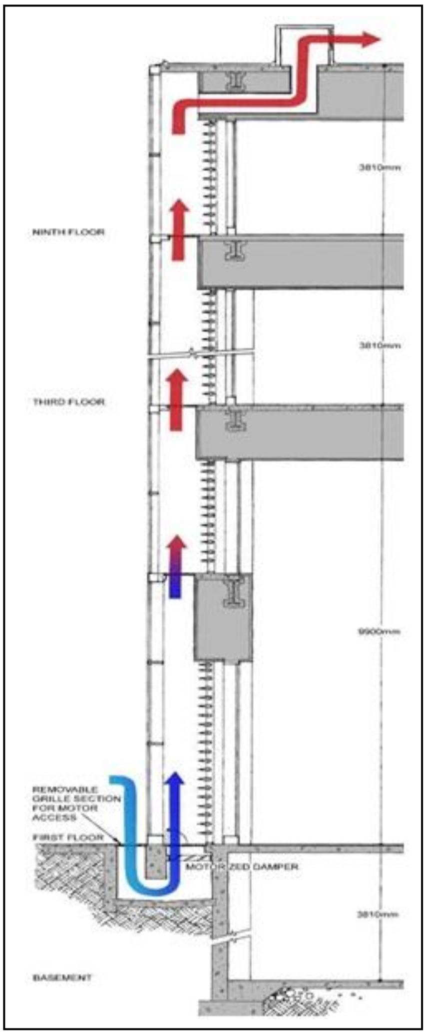


Figure 2-41: View of Occidental Chemical Centre, in Niagara Falls, New York, in 1998; Architects Cannon Design Inc., Principal, and Mark R. Mendell. a) View of the building; b) Detail view of the cavity; c) detail of ventila- tion of the cavity; the building has buffer facade with an undivided air space continuous over the entire building with moto-rized dampers for air intake at grade and vents at the top. The building is comprised of two different air-handling systems; one for the facade and the second for the conditioning of the interior spaces. This design allows the warm air within the wall cavity to temper the outside air on the exterior skin and act as a “buffer” for the interior layer of glass. The cavity is equipped with metal louvers and the occupants cannot access the inside of the cavity. The louvers in the air cavity are controlled by an “intelligent” light sensor system that responds according to weather, time of day and season (Harrison, Meyer-Boake, n.d).

Table 2-4: Air Flow Concept of the Cavity in DSGF Systems

Type of Air Flow	Air Flow Concept	Cavity Type	Properties
Outdoor Air Curtain	- Air enters from outside and it is immediately rejected towards the outside	- Cavity forms an air curtain enveloping the outer facade	- Cavity is open in summer and reduces the temperature of the air inside the cavity. In winter cavity is closed from top and bottom and pre-heat the air inside the cavity (sometimes mechanical fans are used to increase the air movement
Indoor Air Curtain	- Air comes from the interior spaces and it is returned to the interior spaces, sometimes by ventilation system	- Cavity forms an air curtain enveloping the indoor facade	- Cavity acts as a central exhaust duct for the ventilation system
Supply Air	- Outdoor air comes inside the cavity and thus the interior spaces or into the ventilation system	- Cavity is open to the interior spaces from the top and it is open to the outside from bottom of the facade	- Evacuating the air from the building is possible by ventilation of the facade
Exhaust Air	- Air comes from interior spaces and it is moved towards the outside	- Cavity is open to the interior spaces from the bottom and it is open to the outside from top of the facade	- Cavity helps the ventilation of the interior spaces
Static Air Buffer	- Air does not enter the cavity and it is not ejected out of the cavity	- Cavity is open neither to the interior spaces nor to the outside	- Cavity acts as an air tight layer and form a buffer zone between the inside and the outside in which the ventilation of the cavity is not possible

In addition to above categorization of DSGF systems, kind of glass used in the inner and outer layers, percentage of transparent and opaque surfaces, depth of the intermediate space between the inner and outer layers, and type and position of the sun protection systems can cause the difference of DSGF systems from one to another (Andreotti, n.d: 75).

2.3.2.7 Glazing and Support Structural Systems in DSGF Systems

The exterior glazing of DSGF system can be fully glazed and it is usually a hardened single glazing. The interior glazing of DSGF system usually is not completely glazed and it is insulating double glazing unit (clear, low E coating, solar control glazing, etc can be used). If the interior skin has openings, they can be opened by the occupants. This can provide NV for the interior spaces. Automatically controlled solar shading can be integrated inside the air cavity. As a function of the facade concept and of the glazing type, heating radiators can be installed next to the facade (BBRI, 2002. In: Poirazis, 2004: 16).

Painted steel, hot dip galvanized steel, stainless steel, weather-resistant steel, aluminum, and etc. can be used for supporting structures in DSGF systems. Aluminum is light, corrosion resistant and easy to work accurately, but it has large coefficients of thermal expansion and thermal conductivity and low elastic modulus and fire-resistance. Stainless steel is a long-life material, easy to maintain and it has a good fire resistance, but its purchase price is somewhat high. Hot dip galvanized steel is difficult to work at site and does not have high corrosion resistant, but economic as well as painted steel. Weather-resistant steel can be used in only few subjects. Usually many different metals have been used in one structure giving problems in heat expansion, deflection, staining, corrosion, fasteners and maintenance (Tenhunen, et al, n.d: 6).

2.3.2.8 Shading Devices and Glass Pane in DSGF Systems

While designing a DSGF system, the main attention should be on type of glass pane (clear glass, solar control glass, low E coating, etc), and shading devices (venetian blinds, louvers, etc).

According to Oesterle, et al, (2001) "*Determining the effective characteristics of the sun-shading in each case poses a special problem at the planning stage since the properties can vary considerably, according to the type of glazing and the ventilation of the sun-shading system. The sun-shading provides either a complete screening of the area behind it or, in the case of the louvers it may be in a so-called "cut-off" position*" (Oesterle, et al, 2001. In: Poirazis, 2004: 33). As the authors concluded "*for large-scale projects it is worth investigating the precise characteristics of the combination of glass and sunshading, as well as the proposed ventilation of the intermediate space in relation to the angle of the louvers*" (Oesterle, et al, 2001. In: Poirazis, 2004: 33).

Shading devices can be located inside the cavity for protection. Usually Venetian blinds are used in the cavities. The type, characteristics, position (external/internal/intermediate) and orientation of the blinds influence the physical behavior of the cavity; because the blinds absorb and in some cases (depending on the material) reflect the energy from radiation. Indeed, the selection of the shading devices should be made after considering the proper combination between the pane type, the cavity geometry and the ventilation strategy. Selection of shading devices has a high impact on the ND situation within the interior spaces. The geometry (mainly width and height of the cavity) and the properties of the shading devices (absorbance, reflection and transmission) may also affect the type of air flow in the cavity (Aber, 2007: 5).

The choice of the proper pane type and shading device is crucial for the function of the DSGF system. Different panes can influence the air temperature and thus the air flow in the case of a naturally ventilated cavity. In most of the literature the most common glass pane types used for DSGF systems are ventilated with outdoor air, for internal skin is, usually, a ThI double or triple pane is used (Schiefer, et al, 2008: 23). For the external skin, usually a toughened (tempered) single pane is used. Sometimes it can be a laminated glass as well (Poirazis, 2004: 31). In a case that facade is ventilated with indoor air, an insulating pane is usually placed in the external skin and the single glazing is placed in the internal skin. Sometimes if there are opening in the internal skin, they can be open and close by the users in order to have NV for the internal spaces (Schiefer, et al, 2008: 23).

In addition some famous authors have claimed different strategies such as:

Lee, et al., (2002) claim that, mostly a heat- strengthened safety glass or laminated safety glass is used for the exterior skin of DSGF systems. Usually, the interior skin of the facade consists of fixed or operable, double or single-pane, casement or hopper windows. According to the author, Low-emittance (low-e) coatings on the interior glass facade reduce radiative heat gains to the interior (Lee, et al, 2002: in Poirazis, 2004: 31).

Oesterle, et al., (2001) suggest that flint glass can be used as the exterior layer in order to obtain higher degree of transparency. But the high cost of flint glass should be considered to compare with normal one. While the number of the layers and the thickness of the panes are greater than in single skin construction, it is really important to maintain a clear facade. In a case, the specific safety is desired (i.e. bending of the glass or regulations requiring protection against falling glass), then the toughened, partially toughened or laminated safety glass can be used (Oesterle, et al, 2001. In: Poirazis, 2004: 31).

2.3.2.9 Heating, Ventilating, and Air Conditioning (HVAC) Strategy in DSGF Systems

HVAC is the system that maintains ThC (desired environmental conditions) indoor spaces of the buildings. In almost every application, several options are available to satisfy this basic goal. The integration of DSGF systems in LSGFCOB is crucial for ThP and energy use of the building in order to provide ThC during the occupation phase (Schiefer, et al, 2008: 23-25).

In a building with DSGF system, there are 3 different approaches of ventilating the building with HVAC. The first one is when a building has its own separate heating, cooling and ventilating system. In such building the cavity of the DSGF is only ventilated with outdoor air and it aims to reduce noise and solar shading and light redirection devices are placed inside the cavity. The second approach is when a building has the heating, cooling and ventilating system and this system is integrated into the DSGF system. In this case, ventilation of the building is also by the cavity and the DSGF can play the role of the pre-heater for the ventilation air, ventilation duct, and pre-cooler (mostly for night cooling). The second option is more cost-effective option compare to the first option (Aber, 2007: 6). In addition, Stec, et al, (2003) describes a third option in which the building does not have HVAC. In this case, the DSGF fulfills all the requirements of an HVAC system. This is the most energy-effective option (Stec, et al, 2003. In: Poirazis, 2004: 31).

As a result, the geometry and type of the facade, the choice of the glass panes and shading devices and the size and position of the interior and exterior openings determine the use of DSGF system and the heating, ventilation and HVAC strategy that has to be followed in order to succeed in improving the IE and reducing energy use.

Chapter 3

Sustainability

As one of the aims of this study is to investigate the SGF system, the first stage is to study the term sustainability and its dimensions. This chapter is going to study the concept and meaning of sustainability, sustainable development, sustainable construction, SGF system and contribution of DSGF systems to sustainability principles.

3.1 Definition and Dimensions of Sustainability

For the past 20 years human life style has been growing through all sectors such as industrial, medical, production, educational, construction and etc. The way that people live, satisfy their needs, and attempt for a better quality of life has been dominating the importance of environment and society, and subsequently, the economic situation of the community and the culture. Thus, in order to satisfy people needs related to the environment there is need of using natural and manmade resources (Graber, and Dailey, 2003: 11-12; and CIOB, n.d: 2).

Definition of sustainability is changeable according to the context in which it is used or proposed. One of the common definitions of sustainability is meeting the needs of the present without compromising the ability of future generations to meet their own needs. For example, if there is a say that "something" or "someone" or "a phenomena" is sustainable, it means that the "something" or the "someone" or the "a phenomena" should be able to sustain itself and continue till the infinity (Brundtland, 1987: 5).

By these explanations, then sustainability cannot be a thing. It is a kind of a process which should continue forever. Thus, sustainability is a process or an adaptable characteristic which never finishes (Brundtland, 1987: 4-6). Moreover, the importance of sustainability concepts and the reason of why it has been rapidly growing in the world should be stressed, that because of wide growth of the population in the world, their needs and activities, natural resources are reducing, the world and the nature is getting harmed by this huge growing population. This can be the main reason of recent strong interpretation of sustainability principles in almost all the sectors such as medical, industrial, construction, and etc.

Sustainability has three dimensions: economic dimension (EcD), environmental dimension (EnD) and social dimensions (SD), to be considered for different subjects (see Figure 3-1). It has also different scales, from global to local and many different implementation areas and sectors such as tourism, construction, industrial, and etc (Brundtland, 1987: 5).

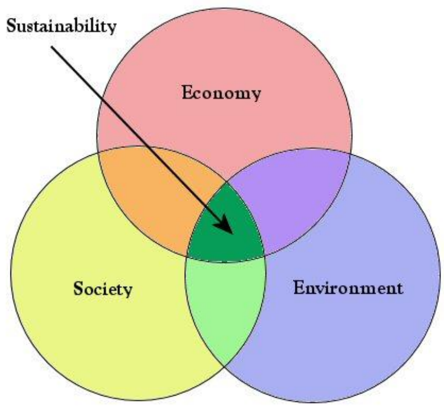


Figure 3-1: Dimensions of Sustainability, Example of the Venn diagram (URL 55).

3.2 Sustainable Development (SD)

According to the World Commission on Environment and Development, (1987) SD is "*path of progress which meets the needs and aspirations of the present generation without compromising the ability of future generations to meet their own needs.*" (Brundtland, 1987: 5).

Optimizing the relationship between people, environment, and their infrastructure is the purpose of sustainable development. For this purpose, considering the needs of both present and future people generation is required (Graber, and Dailey, 2003: 14).

3.3 Sustainable Construction (SC)

Achieving SD principles needs development of policies at all scales and in every specific sector (tourism, construction, and etc.) (Hoskara, 2009: 1). The Brundtland Report recommends that: "the principles of sustainable development must be built into all activities". Construction sector is one of the areas of implementation of sustainability principles. As CIB & UNEP-IETC (2002) defines, "*construction is the broad process/mechanism for the realization of human settlements and the creation of infrastructure that supports development. This includes the extraction and beneficiation of raw materials, the manufacturing of construction materials and components, the construction project cycle from feasibility to deconstruction, and the management and operation of the built environment*." (CIB & UNEP-IETC, 2002: 4).

The main reason of its importance is that in this sector construction materials are directly drown from natural resources with using highly energy intensive processes. This sector uses the land, sometimes takes the lands from other uses, and it is responsible for designing and providing construction developments which have a lasting effect on the needs of their users (CIOB, n.d:1).

In this sector, buildings materials and construction methods are integrated for supporting and benefiting social, economical and environmental quality at all stages of the buildings LC (Graber, and Dailey, 2003: 15). That is why LCA (Life Cycle Assessment) of a building is the key issue to determine the sustainability principles of the building. Accordingly, it can be said that sustainability principles should be met when designing, planning, assembling and constructing a building. In this case, SC concept is the key issue to be considered and added into the agenda. The construction industry and its activities have many environmental impacts and they are responsible for a significant amount of global resource use and waste emissions. Socio-economic developments and quality of life are other important implementation areas of construction industry, which plays an important role (CIB & UNEP-IETC, 2002: iii).

However, as CIB & UNEP-IETC (2002) summarized the terminology on sustainability, SD, and SC: "*The objective is to sustain the species homo sapiens. That is to support it and keep it alive. Sustainability is the condition or state which would allow the continued existence homo sapiens, and provide a safe, healthy and productive life in harmony with nature and local cultural and spiritual values. It is the goal we would like to achieve. Sustainable development is than the kind of development we need to pursue in order to achieve the state of sustainability. It is a continuous process of maintaining a dynamic balance between the demands of people for quality, prosperity and quality of life, and what is ecologically possible. It is what we need to do. Sustainable human settlements are those cities, towns, villages* *and their communities that enable us to live in a manner that supports the state of sustainability and the principles of sustainable development. Sustainable construction means that the principles of sustainable development are applied to the comprehensive construction cycle from the extraction and beneficiation of raw materials, through the planning, design and construction of buildings and infrastructure, until their final deconstruction and management of the resultant waste. It is a holistic process aiming to restore and maintain harmony between the natural and built environments, while creating settlements that affirm human dignity and encourage economic equity*." (CIB & UNEP-IETC, 2002: 5-8). Moreover, according to Houvila and Koskela (1998), SC is the response of construction industry to SD. Similarly, in CIB (1999), it is stated that SC is "*a way for the building industry to respond to the achievement of sustainable development*" (CIB, 1999: 54. In: Hoskara, 2009: 25).

However, from the statements above, it can be inferred that to achieve SC, all building elements and materials must be assessed in terms of EnD, EcD, and SD. Facade, as a building element, plays a very crucial role for achieving sustainable principles in a building. This fact is vital for the case of fully glazed facades.

3.4 Sustainable Glass Facade (SGF) Systems

A SGF system, mainly deals with EE and IE quality of a building. DSGF systems are known as SGF systems in terms of EnD. A definition or concept of SGF is minimum use of non renewable resources matching with the functions that the facade has to provide. In fact, this means that sustainability can be claimed only after a LCA because those concepts should be applied to all the LC of the facade's material and to the facade itself (Butera, n.d: 166).

EE and ThC in LSGFCOB are often questioned. However, nowadays more and more fully glazed buildings are built for the following reasons: "*There is a growing tendency on the part of architects to use large proportions of glass that lead to higher transparency; Users (who do not take into account the risk of visual and thermal discomfort that can occur due to this construction type) often also like the idea of increased glass area, relating it to better view and more pleasant indoor environment; Companies who want to create a distinctive image for themselves (e.g. transparency or openness) often like the idea of being located in a glazed office building*" (Poirazis, 2005: 11).

The performance parameters of a GF and environment interact with each other. In SGF systems design, the integration of solar technologies is a delicate matter. Good performance of passive or active solar systems cannot be achieved unless the integration of the solar technologies is considered in the early design stage. EE in GF systems is highly connected with the location and use of the building which is directly influenced by the building's shape and orientation as well. It has impacts on the LCC (Life Cycle Cost), on the environmental profile, and it is crucial for the IE quality (Poirazis, 2005: 15).

3.4.1 Systematic Approach to SGF Systems

Before any other issue, it is necessary to talk about sustainability issues of glass, itself, and its affect on EE in buildings. As Allen E and Iano J (1938) described, there are some factors to be considered about the sustainability issues of glass as explained below: *"The major raw materials for glass-sand, limestone, and sodium carbonate, are finite but abundant minerals; the high embodied energy of glass, 6750 to 7500 BTU/pound, can be reduced by 30 to 65 percent as new manufacturing technologies are introduced; although glass bottles and containers are recycled into new* *containers at a high rate, there is little recycling of flat glass at the present time with little degradation of quality, much longer than any other component of a building; the impact of glass on energy consumption can be very depending on how intelligently it is used; if badly used, it can contribute to summertime overheating from unwanted solar gain, excessive wintertime heat loss due to inherently low R-values, visual glare, wintertime discomfort caused by radiant heat loss from the body to cold glass surfaces, and excessive condensation of moisture that destroys nearby components of the building; well used, it can bring solar heat into a building in winter and exclude it in summer, with attendant savings in heating and cooling energy. It can bring daylight into a building without glare, reducing the use of electricity for lighting; these benefits accrue over the entire life of the building and payoffs can be huge; Thus, glass is a key component of every energy-efficient building, and a chief accomplice to the ill-informed designer in most energy-wasting buildings*" (Allen, and Iano, 1938: 648).

Going into details about SGF systems design, embodied energy of construction materials for a GF is an important factor which must be considered as well. Many researchers criticize the glass, as the main material for a GF, which has a relatively high embodied energy. Table 3-1 shows the embodied energy of construction materials for buildings (Hilmarsson, 2008: 29).

Table 3-1: Embodied Energy of Building Material (Hilmarsson, 2008: 29).

Material	Embodied energy MJ/Kg	Material	Embodied Energy MJ/Kg
Aggregate	0.10	**Glass**	**15.9**
Stone (local)	0.79	Fiberglass insulation	30.30
Concrete	1.3	Steel	32.0
Concrete precast	2.0	Zinc	51.0
Brick	2.5	PVC	70.0
Cellulose insulation	3.3	Copper	70.6
Aluminum (recycled)	8.1	Paint	93.3
Steel (recycled)	8.9	Linoleum	116.0
Plywood	10.4	Polystyrene insulation	117.0
Mineral wool insulation	14.6	Aluminum	227.0

As shown is table 3-1, glass, with embodied energy of 15.9, takes place almost in the middle of the other construction materials; but, for designing a SGF system still there is need of investigation about whether recycling glass is easy and efficient or not. If yes, then it can reduce the embodied energy of glass significantly (Hilmarsson, 2008: 28).

Glass and Energy

Due to energy crisis in 1970s, there was a setback to the use of glass in buildings. Wide usage of glass in that period of time caused unwanted heat loss in winter and overheating in interior spaces in summer. Because of these problems, using AC systems was necessary for heating and cooling demands for the buildings. Additionally, different types of glass, which were designed for solar control, blocked the admittance of ND into the interior spaces of the buildings and caused high electricity consumption for powering artificial lightings. However, this caused the reduction in use of glass in buildings, in spite of all its transparency and translucency, there was a need for a new GF system that can be more sustainable.

As shown in Figure 3-2, shortly SGF aims to improve air quality by providing NV, and IE for the occupant's comfort, by providing ThC, and to help reducing energy consumption of building by dropping the cooling load down, when it is hot, providing ND, as much as possible, and thus reducing the operational cost.

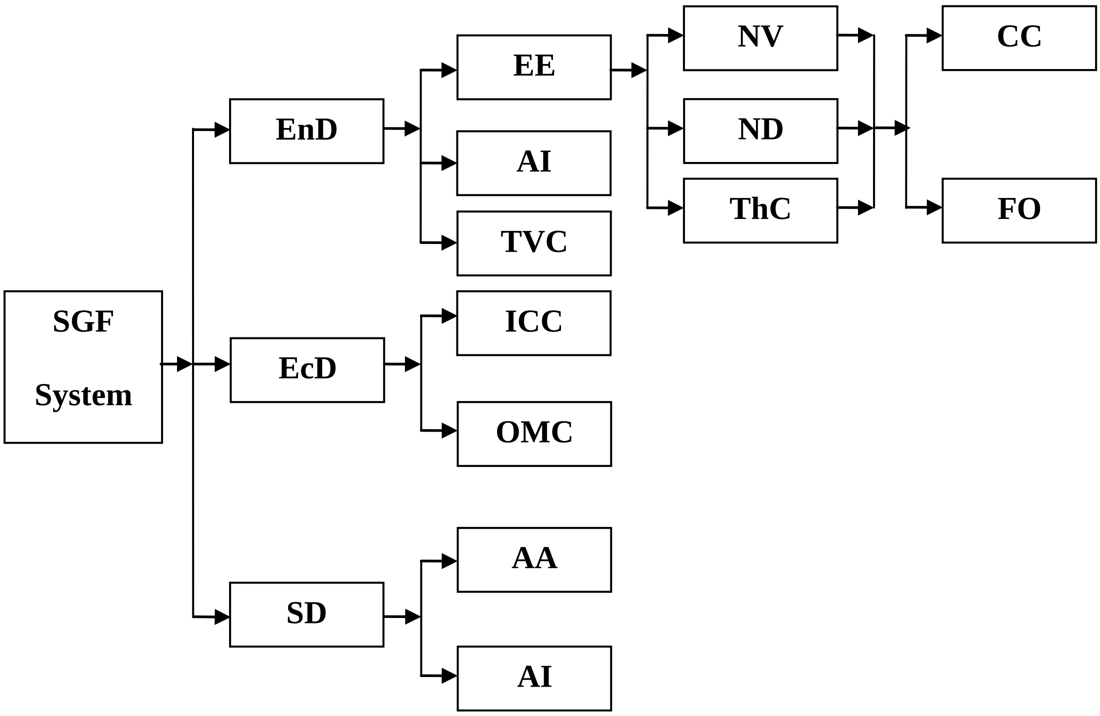


Figure 3-2: Principles of Sustainability for GF System

In Figure 3-2, consequential relationships between the factors are shown. Each of these factors is explained in this chapter. The series of factors in this Figure can be continued to many other factors, but this research is limited by the ones mentioned in Figure 3-2.

3.4.1.1 Environmental Dimension (EnD)

EnD for SGF systems deals with maximum usage of natural renewable resources. In this case, it is necessary to stress the factors which a GF should deal with the environment to optimize the natural renewable resources in order to save energy; factors such as ND, NV, ThC, AI, TVC.

It is important to consider that EnD of a GF, in one side, is related to both the energy use for the production of the GF materials, and to the environmental impacts of producing energy for heating, cooling and lighting the building (Poirazis, 2005: 35).

Energy Efficiency (EE)

In GF systems, solar radiation is collected from the sun. The heat is also collected in order to heat the internal spaces and to generate electricity to reduce the energy consumption of the building for heating, cooling and electricity consumption. Below, factors which affect the EE of LSGFCOB are explained:

Natural Daylight (ND)

ND is the visible radiation of sunlight which penetrates through the glass with the wavelengths from 380 to 780 nm. ND plays a crucial role in illuminating internal space of buildings employing GF system, in addition to the size of the glazed surface. The arrangement of the glazed surfaces and reflectivity of the interior surfaces affect the amount of ND the space (Schittich, et al, 1999: 114).

A SGF system should let ND enter the space as much as possible. But, it should not be forgotten that ND, itself, is a form of energy and after being absorbed it is converted to heat. In this case, solar technologies, such as shading devices with solar panels, are used on the facade in order to collect the solar radiation of the sunlight. Using solar technologies strongly depends on the facade’s orientation and shape.

These technologies affect the OMC of the facade as well as ThC of the inner spaces, as Poirazis (2005) stated that, in a building "*Since the energy use is directly connected with the life cycle cost, it is obvious that the integration of solar systems can be environmentally friendly and cost efficient at the same time.*" (Poirazis, 2005: 35). In addition, in "Sustainable Building Technical Manual" it is mentioned that, "*day lighting creates healthier and more stimulating work environments than artificial lighting systems and can increase the productivity up to 15%*." (Poirazis, 2005: 27).

Natural Ventilation (NV)

One of the important issues for a building is ventilation of its inner spaces; how the exhaust air is drain out and how fresh air is supplied into the building. Facade, as a building element, can affect this issue as well. In conventional GF systems, by using the openings and windows, fresh air is supplied into the inner spaces but for draining out the exhaust air, and heating and cooling demands AC system is used. This can be useful in small scale buildings where cross ventilation is a possible way of providing NV for internal spaces, but in large scale buildings, especially highly glazed ones, this solution is not working. Considering sustainability principles, according to the literature, conventional GF systems, barley can provide appropriate NV for the internal spaces. However, it should not be forgotten as well, that glass type, glazing type, and their materials also affect the ventilation. CC (especially wind pressure and speed) and FO can affect this issue as well. Moreover, in order to provide NV, all these issues should be considered and calculated for a better result.

Thermal Comfort (ThC)

As a barrier, which separates the indoor and outdoor climate in a building, GF systems should act as ThI against unwanted heat loss in winter and extra heat gain in summer, in order to provide a pleasant IE and ThC for the occupants as much as possible. Glass, as a material, is a conductor of heat. In order to enhance the resistance of GF against heat transfer, condensation and frost, several layer of glass should be used with spaces in between which can be filled with air or gas (Schittich, et al, 1999: 116).

A SGF system should let the sun heat in when it is cold (in winter) and keep the sun heat out when it is hot (in summer). This affects the ThC of the IE which can affect the occupant's health as well.

The most important thing that should be considered during designing a SGF, in terms of ThI, is amount of U-value/thermal transmittance (the measure of the rate of heat loss through a material) of solar radiation into the inner space (Schittich, et al, 1999: 75). This is strongly affected by type of glazing (single or double, glazing material), and type of glass (tempered, reflective and coated, absorptive, and etc.) as well as FO and CC. For instance, in a case which Low-e glass is used in a double glazing unit, thermal transmittance is much less than a case with float glass in a single glazing unit. But, still absorption of solar heat or solar gain can cause the problem of overheating. In such a case, there is need of shading devices on the facade to control the solar radiation (Schittich, et al, 1999: 133).

Climatic Condition (CC) and Facade Orientation (FO)

As Allen W, (1997) mentioned, "*Heat from the sun arrives at the earth as direct radiation travelling line-of-sight, and as diffuse radiation from the atmosphere and clouds warmed by the sun. Heat is also radiated out into space at different wavelengths by everything on the surface of the earth, with loss of heat being greatest on cloudless nights. When cloud cover is available to act as a screen and* *insulator, this heat loss is much reduced*" (Allen, 1997: 18). The climate changes; sometimes gets warmer, sometimes with wetter winters, hotter and drier summers and many other different conditions. GF systems are exposed to the outdoor environment and that is why any changes in climate can affect the performance of the facade. SGF systems can get adapted to such changes. For instance, if the weather is windy, it helps to have better NV, and in summer acts as a ThI to reduce the cooling load. Designing SGF systems differs for different country with different climates.

As much as CC can affect the performance of GF, FO has a crucial role in performance of the GF especially when sustainability principles are demanded. For example if facade is oriented toward the South, it has the potential of receiving solar radiation to reduce heating load in winter and to reduce the electricity consumption for providing hot water as well. On the other hand, because of the high number of hours that the sun is radiating, too much heat might get into the building through the glass panels. If GF is facing North, there is no need for sun shading devices because there is no direct sunlight radiating into the building. For instance, if it is facing East or West, again there is need of shading devices (vertical shading devices) on the facade. FO also affects the internal spaces of the building as Allen E, and Iano J (1938), described "*Winter dining rooms and bathrooms should have a southwestern exposure, for the reason that they need the evening light, and also because the setting sun, facing them in all its splendor but with abated heat, lends a gentler warmth to that quarter in the evening. Bedrooms and libraries ought to have an eastern exposure, because their purposes require the morning light…. Dining rooms for Spring and Autumn to the east; for when windows face that quarter, the sun, as he goes on his career from over against them to the west, leaves such rooms at the* *proper temperature at the time when it is customary to use them.*" (Allen, and Iano, 1938: 670).

Acoustic Insulation (AI)

In order to provide the IE (for occupants comfort) minimum affection of outer noises, especially in crowded areas with high traffic, all above mentioned factors and their impacts on IE must be considered carefully in design stage of a GF. Productivity, level of communication and social interaction of occupants are affected as well by the level of AI and acoustic privacy in a building (Poirazis, 2005: 30).

Both external and internal sounds transmittance, especially external sounds, have become one of the problems of LSGFB. In this case the location of the buildings is also important. In GCW systems, architects by using sound barriers inside the walls or in between the glazing frames could partly control the problem, but in LSGFB this problem is solved (according to the literature) by having a second skin glass in front of the facade. The space between the two skin acts as a barrier against external sounds and the occupants can use the openings (if existed) without getting disturbed by the external sounds.

Internal sounds are also important to be noted for AI of buildings. Internal sounds mostly are controlled by locating sound insulation materials inside the internal walls. However, as it is stated by Butera F M (n.d), "*Also acoustic performances need to be carefully evaluated since if it is indubitable that the second skin is a good sound screen for the noise coming from outside, it is also evident that during the periods in which natural ventilation is used and the windows of the inner skin are open, room to room or floor to floor sound transmission will take place enhanced by the cavity (IEA, 2000).*" (Butera, n.d: 166).

Transparency and Visual Comfort (TVC)

For a LSGFB, visibility and VC for the occupants is noticeable issue while deigning the facade. According to Poirazis H, (2005) using ND may not impressively (compared, for example, to energy saving for heating and cooling) help saving energy used for generating electricity, but at the same time it may not provide a pleasant IE for the occupants. Correct distribution of light may create a better IE, and thus improve the mood and productivity of the occupants (Poirazis, 2005: 27).

The amount of transparency and visibility differs from one design concept to another and thus it differs from building to building. For LSGFB transparency and visibility creates problem due to the low U-value of glass. Thus, in such buildings, in one side, high level of transparency is desired which may cause visual discomfort and on the other side because of high level of glazing, overheating is occurred in IE. VC depends on amount of glazing, type, and function of the building. As Poirazis H, (2005) claimed "*the comfortable visual environment depends on vision, perception and what we want to see in different room configurations and for different activities. The absence of sensation of physiological pain, irritation or distraction is the main aim when the visual properties of an indoor environment are optimized.*" (Poirazis, 2005: 28). Similarly, Christoffersen J, (1995) explains in his PhD thesis that "*visual perception is an active, information-seeking process, partly conscious and partly unconscious, involving many mechanisms in a cognitive process interpreted by the eye and the brain*". Thus, in design stage of a SGF system, percentage and way of transparency should be strongly noticed in order to provide the best possible TVC for the occupants (Christoffersen, 1995. In: Poirazis, 2005: 28).

3.4.1.2 Economic Dimension (EcD)

EcD of SGF systems cover the issues related to the economic values of the GF in total which includes the ICC and OMC of the GF. In order to achieve sustainability principles in terms of EcD in a GF system, there is a need for a careful design which has to consider many different parameters connected both with the use of building (building scheme and type, orientation, occupancy schedule, equipment etc) and its location (climate, ND availability, temperature, site & obstructions, latitude, atmospheric conditions etc) (Oesterle et al, 2001. In: Hilmarsson, 2008: 7-10).

As a building component, when a GF system is going to be designed for a large scale building, the first issue for deciding whether or not this new component is a feasible alternative is cost efficiency issue. So far, in the literature, there are three ways of calculating the cost of a building or a facade system: ICC (consideration of the investment cost only); LCC (Cost for the whole life of a building/ facade); and Total Economic Value which is more comprehensive than LCC, because it includes more "hidden" costs related to the building/facade or profits, such as the productivity of the occupants in the building (Poirazis, 2005: 32). However, for evaluating cost efficiency of GF system to be applied in a large scale building, ICC, and OMC of the facade should be evaluated.

Investment and Construction Cost (ICC)

In this thesis, because of the situation of NC, which most of the materials for building construction sector should be import to the country (this cause an additional cost) side issues which can affect the ICC of the GF systems will not be argued.

However, for investors, a building will always be evaluated with its life durability and its ICC and OMC. Thus, in this case if the ICC for SGF system is high, then there should be some significant advantages of this system to encourage the investors to choose this system. In most literature and case studies the overall cost of the building is evaluated with OMC. According to the literature, not all the researchers agree on such result. For example, Straube and Straaten, (2001) claimed that, there is a reduction of ICC and OMC if glazing area is reduced and quality of the glazing is increased. In this research, Straube referred to 3 layers of glass panes which were optimized possibly with some improved components. However, still this case has comparable environmental influences (Straube, and Straaten, 2001. In: Hilmarsson, 2008: 7-8).

Operational and Maintenance Cost (OMC)

Compared with conventional GF Systems, the cost of SGF system is one of the aspects where the systems have the upper hand due to its complex design. At this point the basic idea is to reduce the service installations and mechanical service systems in the building by enhancing the properties of the GF system. As it claimed in literature that DSGF systems are known as SGF systems in the world, it is more complicated to evaluate whether OMC for a building with DSGF system is actually lower. This is because of many different types and functions of the DSGF systems. It should be noticed that reduction in heating and cooling loads can directly affect the operational load. Due to this point, mostly researches focus on if DSGF systems are more EE and therefore environmentally friendly. In this case, optimal EE facades by reducing heating and cooling load as well as providing NV for the building become the main aim of the SGF systems. In fact, this means that if these aims are achieved, then automatically OMC will be lower as well (Hilmarsson, 2008: 10).

The other important issue to be considered is how much is gained in capital by lowering OMC for a GF system. If OMC is too high, then it will not be the expected benefit for the investors. Although in many cases researches have shown good results in lowering OMC, many practitioners do not agree on if reduction in OMC is beneficial or not; as Harris Poiraziz, (2006) claimed that “*Comparing the double skin façade and the single type of façade, one can easily see that the double skin type has higher cost regarding construction, cleaning, operating, inspection, servicing, and maintenance*” (Poirazis, 2006. In: Hilmarsson, 2008: 11).

3.4.1.3 Social Dimension (SD) in SGF Systems

As long as SD is a wide area of study for different sectors, in this study, AA and AI aspects of SD and their impacts on SGF systems are explained and discussed.

Aesthetic & Appearance (AA) and Architectural Identity (ArI) in SGF Systems

What comes to the eyes first, while looking at a building, is the AA of the building. In fact, most of the people get affected by the AA of the building. The outer AA of a building is mostly defined by its facade. As it is stated in Design Guide for Interiors, “*aesthetic appreciation is both expressed and influenced by the environment. To define aesthetic qualities, the designer needs to understand that the concept of beauty differs with time and place, purpose and context.*” (Poirazis, 2005: 30). However, according to some survey, highly glazed buildings have a pleasant AA for the society and occupants. Some of the researches claimed that, maximum transparency of the facade is an excellent property and in many cases that sustainability and EE principles are required, DSGF systems are the feasible alternative. However, some others stressed that in a case of GF system the diversity of what type of facade can be used for a building is limited. Because as they claimed, the AA of the facade will always mainly be glass panes and steel frames.

However, although AA of GF systems mostly depend on the taste of the designer and occupants and society, it much strongly depends on the CC and desired functions of the building as well.

3.4.2 Contribution of DSGF Systems to Sustainability Principles

As resulted in many recent researches, when the word “sustainability” is used for GF system, according to literature review, the words such as DSGF or “multiple skin envelope”, “twin skin”, “airflow window”, “ventilated facades”, “Double skin facade”, etc, are mentioned and discussed. The main goals of these new glazed facades are: to improve energy saving by reducing cooling loads in summer and heat losses in winter, to improve ThC (avoiding radiant temperature problems), to optimize the use of ND and to improve AI (Corgnati, et al, 2006: 1). In this thesis, the performances of DSGF systems are studied in order to underline sustainability principles in these systems.

In this section existing literature about environmental performance of DSGF systems and contribution of these systems to SD and SC are assessed and analyzed. In this study, cost issue for DSGF systems is also discussed by the help of extensive assorted previous researches related to sustainability principles in GF systems.

3.4.2.1 Contribution of DSGF systems to SD and SC

Often, when the conventional insulation of the exterior wall LSGFCOB is poor, the savings that can be obtained with the additional skin is quiet high. This causes energy savings and reduces environmental impacts. This savings are achieved when the DSGF systems make window ventilation possible or where they considerably extend the period in which NV can be utilized, and when low solar factor and low U Value are provided, the cooling load will be minimized. By preventing a mechanical air supply, electricity costs for air supply can be reduced (Poirazis, 2004: 63). Similarly, Andreotti G, (n.d) claims that, in climates in which a SGF is demanded, DSGF, if designed properly, is the most feasible alternative to be used for both hot climates and cold climates (Andreotti, n.d: 1-7).

In order to understand the exact advantages and disadvantages of DSGF system, all the technical, economical and architectural aspects which are related to its design, construction, and performance should be considered. The main advantages of DSGF systems, compared to conventional GF systems are shortly categorized below:

- Allowance of NV (or fan supported) in different climates, orientations, locations and building types; with operable windows (wind or stack effect), independent or dependent from wind and weather conditions, mainly during sunny winter days, the intermediate seasons (spring and autumn), and hot summer days.
- Reduction of heating demand due to preheating of outdoor air. According to the literature, it is stressed that it is possible to reduce the AC system by using a ventilated DSGF. In some other studies the practitioners claimed, that if a DSGF system is well designed in a building, some parts of HVAC systems, such as internal ventilation system or the cooling system, could be eliminated. But these methods are not confirmed without thought, in the case when a DSGF is compared with a single skin facade fitted with external shading devices, and when comparing a DSGF with a single skin facade fitted with internal shading devices. In some cases the building has DSGF and there is no heating system. Therefore, the heating demand is satisfied by other internal and solar gains.
- Night time ventilation of the building (during hot summer) is possible by opening the internal windows, if the facade is well ventilated. In this case, the indoor

temperatures will be lower during the early morning hours providing ThC and improved air quality for the occupants. At the same time, the use of natural night time ventilation affects the heat storage of the surrounding materials (furnishing, ceilings, walls, etc) (Poirazis, 2005: 63-64).

- Low U-Value and g-value: the low thermal transmission (U-Value) and the low solar heat gain coefficient (g value) are the main advantages of DSF system (Kragh, 2000: in (Poirazis, 2004: 65).

- Providing greater ThC due to the outer skin, both in winter and in summer. During winter, the external additional skin provides improved insulation by increasing the external heat transfer resistance. The reduced speed of the air flow and the increased temperature of the air inside the cavity lower the heat transfer rate on the surface of the glass, which leads to reduction of heat loss. During summer, the warm air inside the cavity can be extracted when it is ventilated (naturally or mechanically). Re-radiation from absorbed radiation is emitted into the intermediate cavity, and thus a natural stack effect results which causes the air to rise, and rejected out with its additional heat (Poirazis, 2004: 62-63). The air is warmer inside the cavity (compared to the outdoor air temperature) during the heating period, so, the interior part of the facade can maintain temperatures that are more close to the ThC levels (compared to the single skin facades). Cavity should be well designed so that, the temperature inside the cavity will not increase dramatically (for example: the deeper the cavity is, the less heat is transmitted by convection when the cavity is closed) (Poirazis, 2005: 52). Similar to this, Butera. F M mentioned in his article, that "*As far as thermal comfort is concerned, double skin façade systems have an indubitably good performance in winter, since the inner glass is warmer that it would be without the outer. The opposite may happen in summer, since the high* *glass temperature may cause discomfort especially to people close to the glass surfaces, as it has been documented for the building in Turin and unofficially admitted in other double skin buildings.*" (Butera, n.d: 166).

- Better sound proofing by reducing both the transmission from room to room (internal noise pollution) and the transmission from external noise sources (especially at locations with heavy traffic) (Aber, 2007: 5). This issue is critically affected by the type of the DSGF system (width of the cavity should be 1m) and the number of openings (Poirazis, 2005: 51). In the case of LSGFB employing DSGF system (if designed properly), it provides sound insulation for internal sounds by the cavity which acts as a sound barrier both for internal and external sounds (Hilmarsson, 2008: 26). In some studies, it is claimed that the DSGF also has problems with providing sound insulation for the IE against internal sounds. To support this, Hilmarsson J G, (2008) explained that "*Oestele et al. identify two main problems with internal sound transmission when dealing with a double skin façade. The first one is that rooms side by side bring up the problem of sound to transferring in the cavity space and affecting each other. One could assume that the affects would be the same as sound transferring through the corridor between the rooms. But corridors usually have greater acoustic damping and that absorbs the sound. Glass is not a good material to absorb sound and that creates a significant difference. Another factor is that windows have a psychological factor for the occupier. The person in the room will not expect to hear people on the next room via the window and it does disturb more than hearing something from the corridor. The second problem with sound transmission is when the sound travels between rooms from floor to floor. This is often a problem when dealing with a corridor façade. In* *situations where the double skin façade does not have a horizontal partition, the risk of internal sound transmission will always be greater."* (Hilmarsson, 2008: 27).

- Reduction of the wind pressure affect: The use of DSGF is advisable if the building is exposed to a high wind pressure and high level of external noise as well as if there is need of NV for the building. Short-term pressure fluctuations caused by wind facilitated by the buffer effect of the cavity. Constant pressure of the wind can spread into the cavity and if the windows are open, into the interior spaces (Andreotti, n.d: 76).
- Protection of exterior shading devices: exterior shading devices are protected from outdoor environment by the second skin and can operate properly during windy days (Aber, 2007: 6).
- Lower construction cost: compared to solutions that can be provided by the use of electrochromic, thermochromic or photochromic panes (their properties change according to climatic or environmental conditions) in conventional G systems (Poirazis, 2005: 51).
- Transparency – Architectural design and better AA: In almost all the literature sources, in spite of the problems of fully glazed facades in terms of energy performance and IE, transparency in architecture has always been desirable for architects and occupants. DSGF systems fulfill this desire with better AA and energy performance (Poirazis, 2004: 64).
- Possibility of protecting the existing facade in a case of renovation (Aber, 2007: 6).
- Fire escape: the cavity can be used as fire escape if designed accordingly (Poirazis, 2005: 52).

Although DSGF systems have advantages, which are mentioned above, they have some disadvantages as categorized below, which should be considered during the design stage:

- Overheating problems: if the DSGF system is not properly designed, the air temperature in the cavity may increase and causes the overheating of interior space. To support this, Jager, (2003) claimed that, to avoid this, the minimum width of the cavity should be 2 m (Jager, 2003: in Poirazis, 2004: 69). Hot summer/spring/autumn days can lead to high temperatures in interior spaces as a result of window ventilation (Schiefer, et al, 2008: 24).
- Increased air flow velocity inside the cavity: may occur mostly in multi storey-high types. During windless periods, poorer cross ventilation and inadequate ejection of heat from the interior spaces might happen, mainly when NV is provided (Schiefer, et al, 2008: 24).
- AI: if the facade is not designed properly, cross talk via cavity of the facade may happen from one office to another with open windows (Schiefer, et al, 2008: 24).
- Higher ICC and OMC compared to conventional GF: higher ICC due to the construction of second skin and the cavity (Schiefer, et al, 2008: 24). These systems have higher OMC due to cleaning, operating, inspection, servicing, and maintenance (Aber, 2007: 7). Oesterle et al, (2001) claims that, still there is not a efficient way to estimate the costs (Poirazis, 2005: 55). This means that, in one hand, DSGF systems reduce the cost by saving energy, on the other hand, cleaning and maintenance of these systems is less than conventional GF systems, but it is different. This can cause differences in the cost as well. The high cost of a second glass skin can be refunded by the high quality performance of DSGF in terms of providing ThC, solar

protection, NV, optimization of ND, energy saving (Schiefer, et al, 2008: 71-73). ICC and OMC of DSGF systems are not very often described in the existing literature. As, Oesterle et al, (2001) mentioned, "*as yet, neither comprehensive, conclusive cost calculations, nor generally applicable methods of assessing cost effectiveness exist*". However, there are impressive clashing opinions from different authors. In some of the documents, DSGF system may be mentioned as "Energy Saving Facade" whereas in some other ones the energy consumption during the occupation stage and consequently the cost is noted as the main disadvantage. There is no doubt that ICC of a DSGF is higher than a single skin one. But, the good thing is that if the facade is designed properly, it is possible to reduce the energy consumption mainly from heating, cooling and ventilating the building which causes the reduction of OMC in long time use. As, Straube, (2001) in "The technical Merit of Double Skin Facades for Office Buildings in Cool Humid Climates" claimed,that "*Double facades are merely one approach to overcoming the large energy consumption and comfort problems that are created by the use of excessive glazing areas of interior performance. The most environmentally sound and least expensive construction and operating cost solution avoid the problems that Double Facades are intended to solve by reducing glazing area and increasing the quality of the glazing product*" (Straube, 2001. In: Hilmarsson, 2008: 7). Similarly, Oesterle et al, (2001) agreed that, it is usually irrelevant which method is used for comparing alternatives. Therefore, a cost-efficiency ranking will be independent of the method of calculation. The authors affirm that, in general, economic analyses of façade alternatives should take account of both ICC and OMC (Oesterle et al, 2001. In: Hilmarsson, 2008: 8). In addition, Schiefer, (2008) presented ICC and OMC for single GF and DSGF. According to him: "*Investments (in Central Europe) for:*

Standard façade 300 to 500 Euro/ m²; Double Skin Standard 600 to 800 Euro/ m²; Double Skin with adjustable air in and outlet 700 to 1000 Euro/ m²; Double Skin with openable exterior sashes 800 to 1300 Euro/ m² . Running Costs (in Central Europe) for: Standard façade 2.5 to 3.5 Euro/ m² and cleaning operation; Double Skin façade 4 to 7.5 Euro/ m² and cleaning operation" (Schiefer, et al, 2008: 73).

- Reduction of interior space: the width of the intermediate cavity of a Double Skin Facade can vary from 20 cm to several meters. This, results to the loss of useful space (Poirazis, 2004: 67).
- Increased weight of the structure: due to the additional skin (Poirazis, 2004: 69).
- Fire protection: it is not yet very clear whether the DSGF systems can be positive or not, concerning the fire protection of a building. However, some authors mention possible problems caused by the room to room transmission of smoke in case of fire (Poirazis, 2005: 53). So, in case of fire, the cavity can cause the reduction of ejecting the smoke out, due to the second skin.

3.4.2.2 Environmental Performance (EP) of DSGF Systems

In recent years, a number of experimental, numerical and theoretical investigations have contributed to a better understanding of the SGF systems. According to the recent studies about design of sustainable transparent building envelopes, various publications have been distributed; Post Tower, published by Helmut Jahn (Huckemann, et al, 2009). "*These publications emphasized ideas in such that these facades are ''the maximum, nowadays, that can be reached in office and administration buildings''* (Dassler, et al, 2002. In: Huckemann, et al, 2009: 1-7) *and they contained unenlightened comments, calling these glass buildings* *“sustainable transparent buildings” or ‘‘ecological skyscrapers’’* (Rozynski, et al, 2006. In: Huckemann, et al, 2009: 1-7).

Among these publications some experimental works, related to performances of DSGF systems have been done. For instance, Pasquay T, (2004) in his article “Natural ventilation in high-rise building with double facade, saving or waste of energy, Energy and Buildings” monitored three buildings with DSGF. Three types of building were studied in this research. In the first building, Siemens building in Dortmund, all the AC facilities were removed and ventilation of whole building was by the DSGF. As a results, it was proved that although the temperature in facade space was increased up to 10 ºC above outdoor temperature, the inside temperature stayed in middle acceptable limits. Second building, which was Victoria Insurance Company in Dusseldorf, had cooling system without mechanical ventilation. In this building, even though the temperature in the facade cavity was increased up to 8ºC above outside temperature, and for the whole year only for 46h the temperature exceeded 26ºC. RWE Tower in Essen, which was the third building, had both cooling system and mechanical fan. The average temperature in the cavity was increased up to 15ºC above the outside temperature. However, the temperature in the cavity of the facade, slightly affected the inside temperature (Pasquay, 2004: 1-9).

In another work by Manz H, (2004) named as “Total Solar Energy Transmittance of Glass Double Facades with Free Convection”, a spectral optical model and a computational fluid dynamic model was used to simulate the total solar energy transmittance to the interior. The influence of layers of the DSGF and ventilation properties on the ThP was discussed in detail. A spectral optical model combined with a CFD (computational fluid dynamic) model that includes convection, conduction and radiation, was therefore recommended for analyzing and optimizing the DSGF system. It was proved that the secondary internal heat transfer factor can be reduced by 2% and total solar energy transmittance values could be reduced by 10% if the DSGF is well-designed with free convection (Manz, 2003: 1-10).

In another research project, “Optimal Operation of a South Double-Skin Facade”, by Gratia and Herde, (2003) ThPs of the building between DSGF system and single glazed facade was compared by using software. The authors recommended operating the DSGF system according to the climatic conditions (Gratia, and Herde, 2003: 1-20). In addition, Gratia and Herde in another article named as “Natural Ventilation in a Double-Skin Facade” analyzed the DSGF system behavior with respect to facade orientation, wind orientation and degree of wind protection (Gratia, and Herde, 2003: 1-10). At the same time Balcoo C, (2003) in his article, “A Non-Dimensional Analysis of a Ventilated Double Facade for Energy Performance”, proposed a non-dimensional analysis for energy and ThP study for a natural ventilated DSGF system. The results of the analysis were confirmed with experimental and computational fluid dynamic simulation results. According to the author, the method can be applied to all natural ventilated facade typology (Balcoo, 2003: 1-6). At the same time, some of these publications were stressing that buildings with transparent facades called “sustainable transparent buildings” or “ecological skyscrapers” were neither energy efficient nor comfortable in relation to buildings with a smaller window to wall ratio. This discussion first was argued, in 1999, by Gertis, (1999) with a special focus on DSGF system and claimed that “*instead of a great number of descriptive reports*’’, there is need of ‘‘*measurements under real conditions*’’ (Gertis, 1999. In: Gratia, and Herde, 2003: 1-2). This discussion, by an article named as ‘‘Life in the sweatbox’’ (Schulz, et al, 2004. In: Gratia, and Herde, 2003: 2) reached a new and highly technically questionable point. This article clearly showed that the ‘‘big experiment’’ with glazed OCBfailed without a combined and complete basis. The article was a typical discussion about innovative buildings in which numerous ‘‘experiences,’’ ‘‘opinions’’ and quoted data could be found; exactly what Gertis, (1999) had criticized before (Gertis, et al, 1999. In: Herde, 2003: 2). At this stage, determining scientifically reliable data from DSGF systems and confirming concepts was started to be a matter for researchers (Huckemann, et al, 2008. In: Herde, 2003: 2). However, to understand this, some experimental studies are explained in details. These studies are categorized and summarized in table 5 and 6 as below:

Table 3-2: Studies Based on Comparison of DSGF systems with GCW Systems in Terms of ThP

Category	Topic	Method	Objectives	Conclusion
A	"Thermal Behavior of a Ventilated Double Skin Facade in Hot Arid Climate"	a building with DSGF in Tehran was monitored for 2 weeks in summer and 2 weeks in winter in the hot arid climate of Iran	To observe the behavior of the facade both in hot and cold conditions	Nevertheless, both heating and cooling loads are reduced in a building with DSF in comparison to the same building with normal facade
A	"Empirical Thermal Comfort Evaluation of Single And Double Skin Facades"	A long-term monitoring was performed in 280 office rooms distributed over 28 buildings in Germany	operative temperature, vertical gradient temperature, draught rate, radiation asymmetry, and relative humidity and carbon dioxide concentration	buildings with DSGF have slight advantages in relation to buildings with single skin facade
A	"Effects of Double Glazed Facade on Energy Consumption, Thermal Comfort and Condensation for a Typical Office Building in Singapore"	3 models were studies: building with full single glazed facade system, a building with DSGF system with stack effect ventilation, a building with DSGF system with mechanical fan ventilation	effects of double glazed facade with ventilation system on the energy consumption, ThC and condensation and compare to single glazed facade system	Double glazed facade is a good approach to enhance ThC in a multistory office building whereas ThC is achieved for almost all floors and zones except for the sixth floor during June

“Thermal Behavior of a Ventilated Double Skin Facade in Hot Arid Climate” is a research by Hashemia, Fayazb, and Sarsharc, (2010) in Tehran, IRAN (Hashemia, et al, 2010: 1-10). According to the authors, “*In this paper a building with double skin facade in Tehran was monitored for 2 weeks in summer and 2 weeks in winter in the hot arid climate of Iran, in order to observe the behavior of the facade both in hot and cold conditions. Additionally, simulations were performed on the case study building with and without double skin facade, to assess the effectiveness of the facade.”* (Hashemia, et al, 2010: 1).

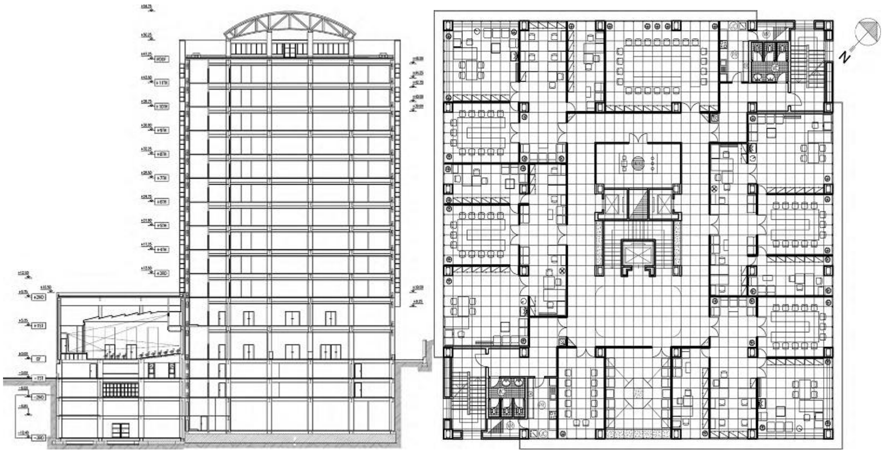


Figure 3-3: Cross-section of the Case Building, view from south with DSGF on east and west sides (left); Typical floor plan of the case building (right) (Hashemia, et al, 2010: 2-3).

As the authors described, *“The building under study is the “Supreme Audit Court” in Tehran, which is 11 storeys high and has DSF on all four sides of it. The 7th and 11th floors were monitored from 6th to 21st of July and 5th to 13th of January in 15 min intervals. The building was simulated with Energy-plus Version 2.1 with and without DSF. The performance of the two buildings considering the thermal loads and the temperature on the facade surface are compared with the results of the field measurements.”* (Hashemia, et al, 2010: 2).

As results mentioned in the research, *"The results revealed that the temperature difference between the outer skin, the inner skin and the cavity can significantly save heating energy in winter. To reduce the cooling loads in summer it is essential to introduce additional techniques such as night ventilation and installation of shading devices for the cavity"* (Hashemia, et al, 2010: 10). According to comments by authors in conclusion part, in countries such as Iran with hot arid climate which there is high solar incidence (especially in summer), high outdoor temperature, and increase of the air temperature in the cavity during night, cooling demand is higher. "*Nevertheless, both heating and cooling loads are reduced in a building with DSF in comparison to the same building with normal facade*." (Hashemia, et al, 2010: 10).

In another research named as "Empirical Thermal Comfort Evaluation of Single And Double Skin Facades", done by Volker Huckemann, and others, the aim was "*to determine the individual sensory perception of the indoor environment and compare it to the actually measured indoor climate in buildings with double skin facades and single skin facades*" (Huckemann, et al, 2009: 1). According to the authors "*A long-term monitoring was performed in 280 office rooms distributed over 28 buildings in Germany. The survey methods were based on sensor measurements and data simultaneously gathered from questionnaire given to office users. The authors take into consideration the operative temperature, vertical gradient temperature, draught rate, radiation asymmetry, and relative humidity and carbon dioxide concentration*" (Huckemann, et al, 2009: 1). In this research several buildings with DSGF systems were analyzed in terms of energy efficiency, comfort and functionality. The research aimed to study and analyze the potential of optimization for the case studies during their operation. "*The research project compared the planning objectives with characteristics and operating experiences in DSF, which built the basis for a* *comprehensive assessment of the functionality of DSF and energy concepts*" (Huckemann, et al, 2009: 1-2). All the case studies which include building with single skin GF and DSGF were evaluated and compared according to their ThP as well. As a result, buildings with DSGF have slight advantages in relation to buildings with single skin facade. According to the authors in conclusion part, "*In the course of the project it was proven that close cooperation with building operators is a very important point in achieving user comfort*" (Huckemann, et al, 2009: 7).

"Effects of Double Glazed Facade on Energy Consumption, Thermal Comfort and Condensation for a Typical Office Building in Singapore" which investigated the effects of DSGF with ventilation system on the energy consumption, ThC and condensation and compare to single GF system in Singapore (Hien, et al, 2004: 1-10). As authors described, "*Basically, three models were developed for this study. The first model is a six-storey building with full single glazed facade system. The simulation was run from 2nd to 6th story. The second model is double glazed facade system with stack effect ventilation. External heat absorption glazed layer was added 1 m away from inner facade. The third model is double glazed facade system with mechanical fan ventilation. The mechanical fans were installed on the top of the double facade space to accelerate the air movement*" (Hien, et al, 2004: 2).

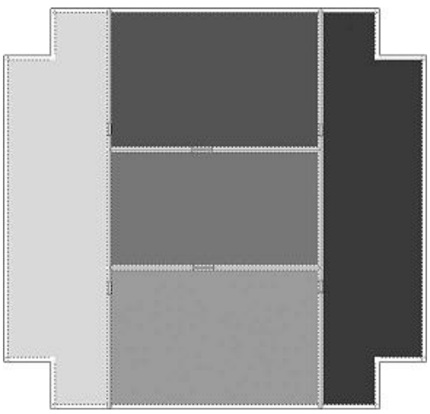


Figure 3-4: Zone Layout for Single Glazed Facade (Hien, et al, 2004: 2).

As authors described, "*TAS and CFD simulation have been used for this study. TAS is a multi-zone simulation software for energy consumption, thermal comfort issue, and condensation problems. In order to obtain the precise air change rate for facade space, CFD simulation has been implemented to calculate airflow field of the double facade*" (Hien, et al, 2004: 1). The results of this study showed that DSGF with stack effect (NV) is effective to extract the solar heat gain inside the cavity whereas using mechanical fans increase the air movement but there is not much difference for energy saving to compare to its cost. According to the authors in conclusion part, "*Double glazed facade is a good approach to enhance thermal comfort in a multistory office building whereas thermal comfort is achieved for almost all floors and zones except for the sixth floor during June*" (Hien, et al, 2004: 9). This is the result of high temperature in the cavity which is because of higher solar gain at higher stories. "*During high humidity night, temperature differences between ambient and glass surface become the major cause of condensation. By operating fans when condensation happens, it can prevent the moisture to build up and condense. Therefore, operations of mechanical fans are recommended to remove the condensation. The speed of mechanical fans can be adjusted according to the rate of condensation in different time to minimize the energy used*" (Hien, et al, 2004: 9). However, DSGF is effective solution to exhaust the solar heat gain in the facades cavity, towards East and West orientations. But, in high floors solar gain is increased so that ThC is less for the occupants.

Table 3-3: Studies Based on Energy Saving, Heat Transfer and ThP of the Facade and its Effect on IE

Category	Topic	Method	Objectives	Conclusion
B	"Greenhouse Effect in Double-Skin Facade"	An Office building with DSGF system was monitored	solar radiation level, orientation and shading devices use, opaque wall/window proportion of the interior facade, wind speed, color of shading devices and of interior facade, depth of the cavity of the double-skin, glazing type in the interior facade and openings in the DSGF	The first element which influences the greenhouse effect is the solar radiation quantity. Orientation of DSGF affects the green house affect
B	"Analysis of Variables that Influence Electric Energy Consumption in Commercial Buildings in Brazil"	A computer simulation program was used to explore the electrical energy consumption pattern of a typical office building, simulating its dynamic ThP	Built volume with internal partitions and outside openings, and dimension; Installed power densities for lighting and equipment; Geographic orientation of the construction and the existing external shading elements, trees, other constructions, braise soleil, etc; Timetable of working hours, usage intensity of equipment and lighting facilities, AC system data; Hourly meteorological data for Rio de Janeiro	It is very important to select an adequate glass, especially in buildings that have glass panels, where the glass area is large, as the impact in the electric energy consumption is actually strong. The greenhouse effect has to be avoided and, whenever possible, the direct solar radiation must be blocked before it penetrates the glass.
B	"Strategic Decision-Making for Intelligent Buildings: Comparative Impact of Passive Design Strategies and Active Features in a Hot Climate"	computer energy modeling was used to evaluate energy performance and VC in three parametric series, for a prototype office unit	influence of incorporating intelligence in buildings in hot climates, through the perspective of energy consumption and user comfort with an emphasis on lighting Firstly the result of the integration of active features alone; secondly intelligent passive design strategies, thirdly the combination of both approaches	A successful intelligent building, as seen from the results, cannot be just a collection of smart active features. It needs to be a product of a design process that incorporates intelligence in all its stages, including the schematic, early ones, while taking advantage of technological innovations

B	"Double Skin Facades for Warm Climate Regions: Analysis of a Solution with an Integrated Movable Shading System"	3 different modeling were used which were optics of materials, fluid dynamics of the DSGF and building energy balance	analyzed a DSGF system which had moveable shading devices in the cavity	the thermodynamic behavior of the facade was studied and it proved a good performance both in winter conditions as well as in the warm season, where traditional DSGF shows weak performance because of gap overheating
B	"Investigation on Energy Performance of Double Skin Facade in Hong Kong"	an experimental setup was established and the measured data were used to verify the theoretical model developed via the Energy-Plus simulation program	optimal selection of glazing types and configuration for a DSGF in a fully air-conditioned building in Hong Kong	a double skin facade system with single clear glazing as the inner pane and double reflective glazing as the outer pane can provide an annual saving of around 26% in building cooling energy, as compared to a conventional single skin facade with single absorptive glazing. However, the long payback period of 81 years makes the double skin facade system economically infeasible. Support and motivation are needed from the local government in order to foster successful and widespread application of the double skin facade system in buildings
B	"A Parametric Study of Multiple Skin Facades for Warm Climates"	a test building was set up and the accuracy of the simulation program was checked	width of the cavity between the double skins, area of the openings, height of the buildings, the height of the transparent chimney added to the top of the south double facade, arrangements of open and closed openings	DSGF system provides ThC, for most of the time, during winter season and for the rest of the time it contributes to the heating of the buildings. But as the authors mentioned, although DSGF can provide some ventilation in summer, but still there is need of more research to be done upon this factor

“Greenhouse Effect in Double-Skin Facade” by Gratia and Herde, (2006) discusses the greenhouse effect in DSGF and the factors that influence the greenhouse effect. This research studied the impact of these factors. Factors such as solar radiation level, orientation and shading devices use, opaque wall/window proportion of the interior facade, wind speed, color of shading devices and of interior facade, depth of the cavity, glazing type in the interior facade and openings in DSGF (Gratia, and Herde, 2006: 1-13).

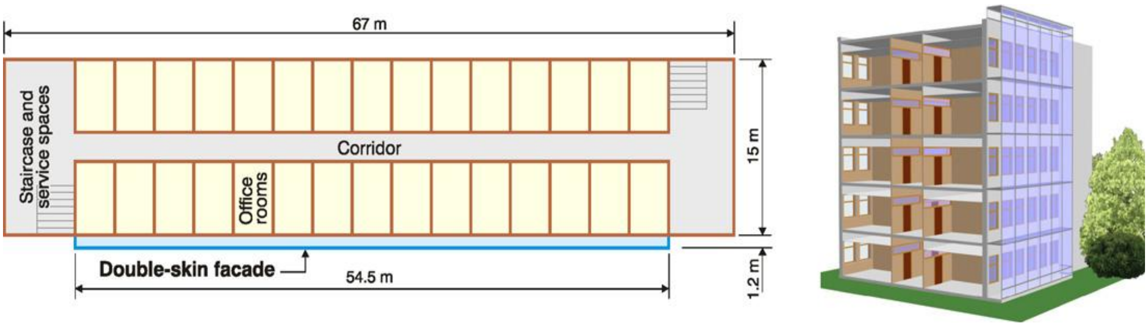


Figure 3-5: View of the Office Building (Gratia, and Herde, 2006: 3).

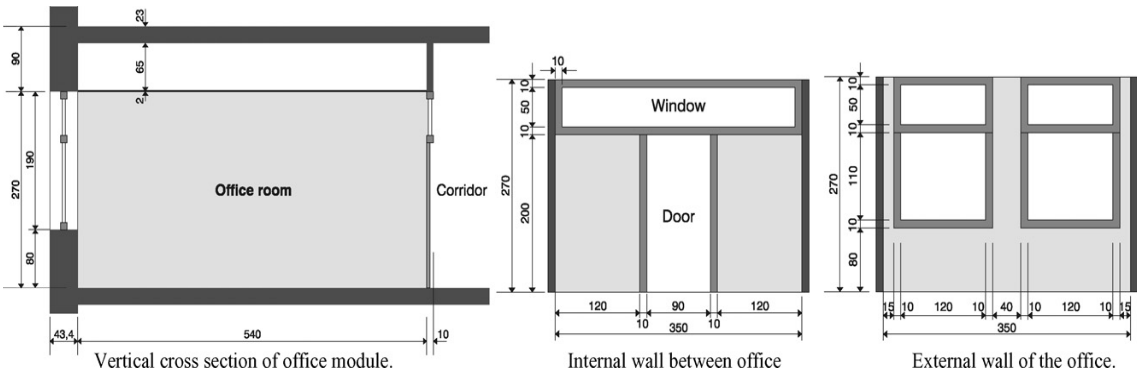


Figure 3-6: Geometrical Data of the Office Building (Gratia, and Herde, 2006: 3).

As authors described, “*The first element which influences the greenhouse effect is the solar radiation quantity which penetrates in the double-skin. It is directly proportional to the solar radiation level, to the glazing percentage of the external skin (generally near to the 100%), to the solar factor of the external glazing, function* *of the orientation and the slope of the external skin and to the solar masks generated by environment and building itself.*" (Gratia, and Herde, 2006: 2).

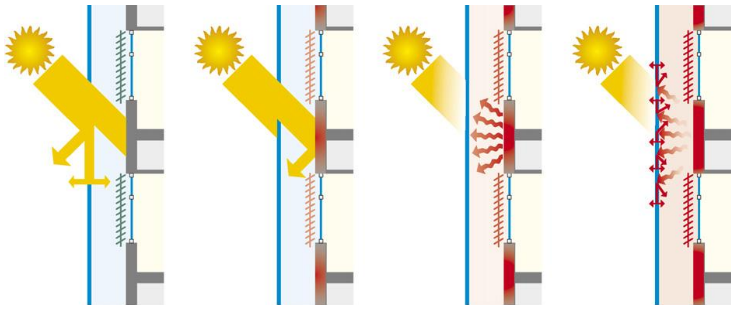


Figure 3-7: Greenhouse Effect in a DSGF (Gratia, and Herde, 2006: 2).

At the end, one of the results proved the answer of "*is greenhouse effect favorable?*" which was, "*If natural cooling strategies are not used, greenhouse effect must be decreased. If natural cooling strategies are used: - Greenhouse effect is favorable if double-skin is south oriented; - Greenhouse effect has no impact if double-skin is north oriented; -Greenhouse effect is de-favorable if double-skin is east or west oriented.*" (Gratia, and Herde, 2006: 12).

Another study "Analysis of Variables that Influence Electric Energy Consumption in Commercial Buildings in Brazil" by Carvalho M M Q, and others, (2010) described how energy performance of the building is considerably influenced by the facade protection and shows the impact that decisions related to the top-level and facades have on the energy consumption of the building (Carvalho, et al, 2010: 1-7). According to the authors, in Brazil the number of buildings with fully glazed facade and fully AC systems, is high and there was a need of energy conservation and sustainable design in buildings. As the authors mentioned, a computer simulation program named as "Visual DOE 2.61" was used to fully integrate the various factors, mentioned above, to determine hourly building energy loads and specific loads for end users, such as external lights and others (Carvalho, et al, 2010: 1-2). This program was used "*to explore the electrical energy consumption pattern of a typical office building, simulating its dynamic thermal performance.*" (Carvalho, et al, 2010: 2).

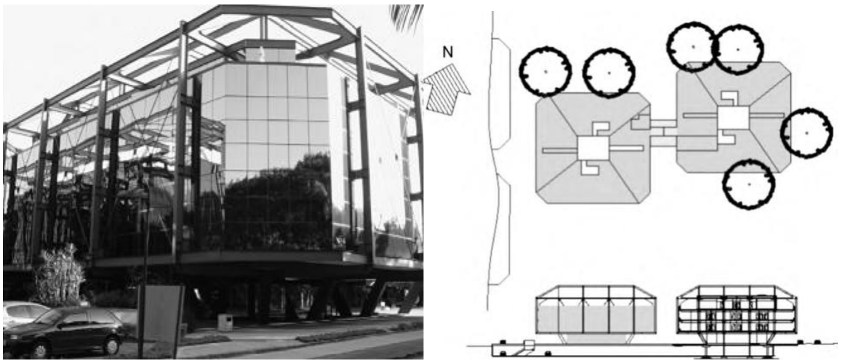


Figure 3-8: External View of the Facades (right), section and plan of a typical floor with zone layout and existing shading provided by trees and surrounding building (left) (Carvalho, et al, 2010: 3).

As explained in the research, "*The following items were taken into consideration: Built volume with internal partitions and outside openings, described in terms of materials as well as its thermal characteristics, use (office, toilet, etc.) and dimension; Installed power densities for lighting and equipment; Geographic orientation of the construction and the existing external shading elements – trees, other constructions, brise soleil, etc; Timetable of working hours, usage intensity of equipment and lighting facilities, air conditioning system data, and others; - Hourly meteorological data for Rio de Janeiro*" (Carvalho, et al, 2010: 2). By using the computer software a building model was created and based on this model architectural modifications were simulated. This building energy-use simulation software used its own climate data file. In this paper, the consumption portion relative to AC facilities was analyzed as well. According to the authors "*The* *methodology used to study the building consisted in checking the effects of altering certain parameters in the architectural design when comparing them to the base case. After this initial analysis with the purpose of evaluate the building sensitivity as to the changes in the envelope, which are, in this case, specifically related to facade and top-level floor. After this analysis, different situations were simulated, such as glass exchange, use of external protections, and replacement of glass curtain by masonry in the windows, etc. At this stage, the building energy behavior is evaluated, which is the purpose of this paper*" (Carvalho, et al, 2010: 2). In this research, 3 scenarios were developed as listed below: 1) Existing building model, do-nothing (standardization of the existing building model); 2) Roofing alterations in the existing building; 3) Facade alterations in the existing building. As a result, solar radiation was the main heat source gain in buildings. Also results show that in order to avoid extra heat gain in the buildings, shading devices, thermal efficient glass, external light colors, construction material with low U-factors and an adequate geographic orientation are needed. Among all these, using external shading devices is one of the most important ones in Brazil, because it can block direct solar radiation. Also, because the buildings are not too high, the use of trees outside the buildings is the most convenient solution for providing external shading (Carvalho, et al, 2010: 2-4). As the authors described in conclusion part, "*It is very important to select an adequate glass, especially in buildings that have glass panels, where the glass area is large, as the impact in the electric energy consumption is actually strong. The greenhouse effect has to be avoided and, whenever possible, the direct solar radiation must be blocked before it penetrates the glass. Comparing the use of a double clear SS08 Argon glass – which is the most efficient glass tested – with the single 6 mm colorless glass, it was noticed that the energy efficiency improved by* *around 12%. Therefore, choosing the right glass is a very important measure, when weather is taken into consideration. Efficient glass has the advantage of relatively fast thermal response and low thermal inertia. It can also reduce the lighting energy consumption by making full use of daylight and provide a large external view, increasing comfort sensation*" (Carvalho, et al, 2010: 6-7). At the end, according to this research the best results are, when shading elements are used outside the building, as architectural solutions, in a harmonious and EE way.

"Strategic Decision-Making for Intelligent Buildings: Comparative Impact of Passive Design Strategies and Active Features in a Hot Climate" is a research by Carlos Ernesto Ochoa, and Isaac Guedi Capeluto, (2007) explored "*the influence of incorporating intelligence in buildings in hot climates, through the perspective of energy consumption and user comfort with an emphasis on lighting. The paper will show how decisions taken in the early design stages can affect those of later ones. Moreover, it will try to clarify how much building performance depends on early smart architectural design decisions (passive design strategies) or if it can be left exclusively to later intelligent technological devices (active features)*" (Ochoa, and Capeluto, 2007: 1). In this research, computer energy modeling was used to evaluate energy performance and VC in three parametric series, for a prototype office unit. The first parameter was the result of the integration of active features alone. The second parameter was showed by intelligent passive design strategies, and the third parameter was the combination of both approaches. According to the authors, "*This article begins by contrasting design strategies under hot climate conditions, and the influence they can have on the building design process. It is followed by an inventory of suitable elements that can be used as components for an intelligent facade for a hot climate. Then, it examines through computer modeling if it is enough only to add* *active features, depend only on intelligent passive design strategies, and what happens when both are combined throughout the design process*” (Ochoa, and Capeluto, 2007: 2).

Figure 3-9: Photograph of ‘‘Zim–Opher House’’; in Haifa, used as case study (Ochoa, and Capeluto, 2007: 5).

As authors mentioned in conclusion, “*Results show that a truly intelligent building needs to be the product of a design process that incorporates intelligence in all its stages while taking advantage of technological innovations. Dependence on the performance of individual active features to solve one or some climatic design strategies brings energy savings that range from just 8% up to 40%, depending on the combination used. This makes them unreliable for constant savings in all situations. Passive design strategies that used low-sophistication devices achieved between 20% to 60% energy savings, but some of these strategies might not be applicable to all cases (for example, depending on south-facing orientations only). However, combining active features and correct passive design strategies gives consistent savings of around 50–55% for most cases when compared to a conventional situation. Such sensibly planned intelligent buildings offer flexibility* *and convenience that exclusively passive buildings cannot give, such as rapid temporary changes, options to open individual windows or operate specific blinds.*" (Ochoa, and Capeluto, 2007: 5-11). According to results of this research, all the climatic design strategies are equally important while designing a building. According to the climate situation, any of climatic design strategies may have higher priority than the other ones. However, because of the high number of products available in the market, it is advisable for architects to use tools in order to choose the best combination for any specific situation. "*A successful intelligent building, as seen from the results, cannot be just a collection of smart active features. It needs to be a product of a design process that incorporates intelligence in all its stages, including the schematic, early ones, while taking advantage of technological innovations*" (Ochoa, and Capeluto, 2007: 11).

In April 2008 a research, "Double Skin Facades for Warm Climate Regions: Analysis of a Solution with an Integrated Movable Shading System" by G. Baldinelli, (2008) in University of Perugia, Italy, analyzed a DSGF system which had moveable shading devices in the cavity. For this analysis, 3 different modeling were used which were optics of materials, fluid dynamics of the DSGF and building energy balance. This research was done on case studies located in central Italy which has warm climate. As the author said, the aim of this research was "*to optimize both winter and summer energy performance. The model is developed for a facade oriented towards the south and taking into account the climatic data of central Italy; the solar radiation path with its multiple reflections at the different interfaces have been taken into account employing a ray tracing method. Simulations have been validated by the comparison with data of a similar experimental apparatus and they show that the winter configuration of the proposed façade allows a satisfactory solar* *heat gain in spite of the presence of shading systems. In summer, the solar heat is mainly absorbed by the external part, and even if a natural convection occurs, there is no significant influence on the inner skin and on the internal environment, thus reducing building cooling requirements. The façade performance was compared with traditional enclosures such as glazed and opaque walls in an office room in central Italy, showing that in the entire year the façade proposed significantly improves the building energy behavior, especially compared to opaque walls and when the configuration with air recovery is considered"* (Baldinelli, 2008: 1).

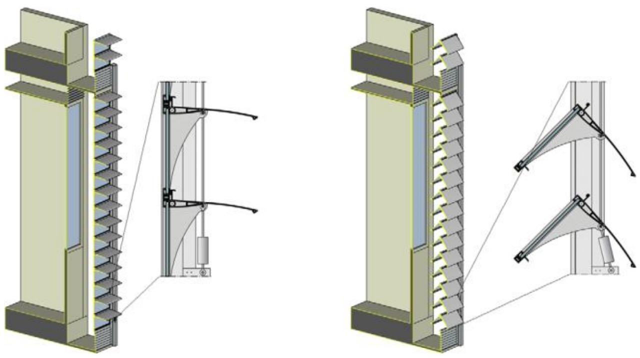


Figure 3-10: DSGF Investigated in Winter and Summer Configurations (Baldinelli, 2008: 2).

According to the research "*A detailed analysis of the new facade is carried out through an approach that combines experimental spectro-photometric movements for characterizing the optical properties of materials with a three dimensional computational fluid dynamics code, validated with data gathered form an experimental apparatus, and used as a tool for simulation models that evaluate the building energy consumption*" (Baldinelli, 2008: 1-2). As the author explained in conclusion part, the thermodynamic behavior of the facade was studied and it proved a "*good performance both in winter conditions as well as in the warm season, where traditional double skin façades show weak performance because of gap overheating"*

(Baldinelli, 2008: 12). The analysis of energy performance of the facade showed the "*strong effect of the spectral properties of each component: the high reflection shading devices allow a satisfactory solar gain in winter and a considerable cooling load reduction in summer. The simulation of façade performances with a Computational Fluid Dynamic model for the winter configuration (shading closed) showed the instauration of a buoyancy induced flow inside the gap, producing the doubly beneficial effect of diminishing the heat dispersion through external walls and preheating the air for ventilation purposes.*" (Baldinelli, 2008: 12). Simulations for summer season showed good system behavior because of the high shading level and the open configuration that inhibits overheating, which is one of the main problems of DSGF when it is used in warm climate countries. "*The façade performance was compared with traditional enclosures such as glazed and opaque walls in an office room in central Italy; results showed that in the entire year the façade proposed significantly improves the building energy behavior, especially when the configuration with winter forced convection is considered. In this case, in fact, the joint contribution of air preheating and gap thermal resistance enhancement makes the performance of the double skin façade particularly interesting: the comparison with opaque walls showed an energy saving up to 60 kWh per year per façade square meter. When differences with a standard glazed surface solution are analyzed, energy improvements result weakened, but the indoor comfort improves significantly because of smoother mean radiant temperature.*" (Baldinelli, 2008: 12). According to the author regarding employing shading devices in the facade, "*The movable configuration of the facade proposed implies a detailed design case by case and a higher investment costs, making difficult a wide and quick diffusion; besides, additive maintenance matters have to be taken into account, especially if the motion* *mechanism is automatic. Difficulties deriving from the need of implementing a different project for each different building analyzed could be overcome through the use of the simulation model proposed. On the other hand, when quick variations of external climatic parameters are found, the steady state hypothesis is no more applicable; therefore, it will be useful to extend the analysis to unsteady conditions"* (Baldinelli, 2008: 12-13). Future works and studies, as the author suggested, "*should deal with the extension of the analysis to different sites, with a greater number of days investigated each month and assessing the performance of the façade proposed with the variation of geometric parameters such as the shading shape and tilt. It will be also useful to analyze the effect of the facade in the natural lighting of inner rooms, since the shading system is not removable and its configuration in winter conditions is fixed"* (Baldinelli, 2008: 13).

"Investigation on Energy Performance of Double Skin Facade in Hong Kong", by Chan A.L.S et al, (2009) in City University of Hong Kong, Hong Kong, is a very good work for SGF concept. This research "*reports the findings on the energy performance of double skin facade applied to a typical office building under the climatic condition in Hong Kong*" (Chan, et al, 2009: 1-8). As the authors said in the research, the gap was that there was no LCA for economic-evaluation of DSGF systems in Hong Kong, which has subtropical climate (hot summer and relatively warm winter). The research also reported an investigation of optimal selection of glazing types and configuration for a DSGF in a fully AC building in Hong Kong. The methodology of this research contains "*an experimental setup was established and the measured data were used to verify the theoretical model developed via the Energy-Plus simulation program*" (Chan, et al, 2009: 1). Then this model was used to evaluate the energy performance of DSGF with different configurations including glazing type (clear, absorptive or reflective glass), glazing position (inner or outer pane) and glazing layers (single or double glazing material).

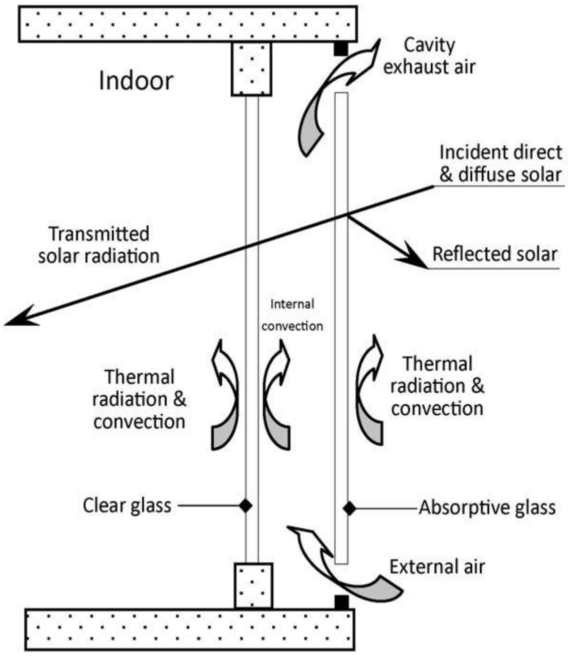


Figure 3-11: Airflow and Heat Transfer within the DSGF System (Chan, et al, 2009: 3).

As the authors mentioned in conclusion part of the research, "*the application of double skin facade in buildings can reduce the heat transmission as well as the electricity consumption of the air-conditioning system, especially for the buildings located in subtropical area. The results indicate that a double skin facade system with single clear glazing as the inner pane and double reflective glazing as the outer pane can provide an annual saving of around 26% in building cooling energy, as compared to a conventional single skin facade with single absorptive glazing. However, the long payback period of 81 years makes the double skin facade system economically infeasible. Support and motivation are needed from the local government in order to foster successful and widespread application of the double skin facade system in buildings*" (Chan, et al, 2009: 1-7).

One of the most important researches about DSGF, related to this thesis, for NC, is "A Parametric Study of Multiple Skin Facades for Warm Climates" by Mesut B. Ozdeniz, and Halil Z. Alibaba, (2010) in EMU, in NC. As written in the research, "*In this study the authors selected to do a parametric study for warm climates on multi-storey type double skin facade, in order to provide a design aid for architects and designers. The same approach will also be very useful for the other climates. Parameters studied are the width of the cavity between the double skins, area of the openings, height of the buildings, the height of the transparent chimney added to the top of the south double facade, arrangements of open and closed openings . The effects of these parameters on air flow within the building, heating and cooling loads, predicted mean vote (PMV) and percentage of people dissatisfied (PPD) were analyzed"* (B.Ozdeniz, and Alibaba, 2010: 1). According to the authors, as the first step for this research "*a test building was set up and the accuracy of the simulation program was checked. The test house has 4.70 m width, 12.20 m length and 3.53 m height. The long axis of the test house is on the east-west axis so the long facades are looking to south and north. Three 1.30 x 2.40 m size box type double skin facades were fixed to the window openings on the south and one on the north side. The width of the air cavities are flexible that could be changed between 30-120 cm. In the first run 30 cm width was tested. Each open-able window, at the top and bottom of each floor and the cavity, can be opened up to 1800 cm² at maximum. On the external surface 6mm thick reflective type and on the inner surface 4+12+4 mm double glazing was used.*" (B.Ozdeniz, and Alibaba, 2010: 3).

For testing process, surface temperature, air temperatures, relative humidity and air velocity, at different points of the test house (both inside and outside), were measured.

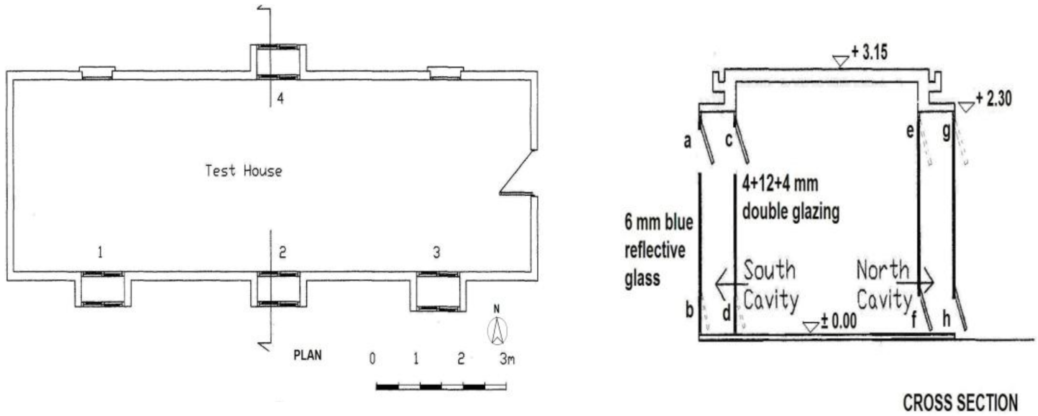


Figure 3-12: Plan and Cross Section of the Test House (B.Ozdeniz, and Alibaba, 2010: 4).

Figure 3-13: The Case Study Building: Pictures from outside (left), and inside (right) of the south facade of the test house (B.Ozdeniz, and Alibaba, 2010: 4).

As the authors mentioned in the conclusion part and according to the results of measurements by simulations, *"For year round performance of the double skin facade it is necessary to open and close the windows. This could be made manually. However, the best result is obtained if it is done automatically. Sometimes direction and velocity of wind affect the results. A mechanism to open and close the windows, which is connected to an environmental measurement center, will provide a better* *solution. However, the extra cost of this should be considered against the benefits*" (B.Ozdeniz, and Alibaba, 2010: 7). As result of this research, DSGF system provides ThC, for most of the time, during winter season and for the rest of the time it contributes to the heating of the buildings. But as the authors mentioned, although DSGF can provide some ventilation in summer, but still there is need for more research to be done upon this factor and the effects of blinds in the south cavity, the effect of corridor facade type of DSGF, the effect of cavity width, the effect of shorter office depth, the effect of wider openable windows (B.Ozdeniz, and Alibaba, 2010: 7-8).

Table 3-4: Studies Based on Ventilation Performance of the Facade with or without HVAC System.

Category	**Topic**	**Method**	**Objectives**	**Conclusion**
C	"Total Solar Energy Transmittance of Glass Double Facades with Free Convection"	Comprising a spectral optical and a computational fluid dynamic (CFD) model is described for modeling a DSGF with free convection.	the influence of the layer sequence and ventilation properties on the ThP	With a well-designed DSGF with free convection, the secondary internal heat transfer factor can be reduced to values below 2%. Low secondary internal heat transfer factors are obtained if: Total solar absorption is low and mainly in layer number 1; Ventilation is efficient (large ventilation openings, etc.); Thermal transmittance (U-value) of insulating glazing unit is low; Reflectance of shading screen is high (within the wavelength interval where layer number 1 is transparent)
C	"Experimental Assessment of the Performance of an Active Transparent Facade During Actual Operating Conditions"	temperatures, heat fluxes and air velocities in the ventilated facade were continuously monitored, over a period of 2 years, using a monitoring system with 34 sensors	a transparent mechanically ventilated facade integrated with an HVAC system	the radiative heat transfer between the solar shading device and the inner glass pane is significantly reduces by optimizing the shading devices (low-emittance, double reflective screen, etc.), to correctly choose the glass type and to create a proper air flow path of the air inside the air gap

C	"Experimental Evaluation of a Climate Facade: Energy Efficiency and Thermal Comfort Performance"	Measurements were performed utilizing the TWINS (Testing Window Innovative Systems) test facility, which consists of two outdoor cells, one used for reference purposes, and the other which adopts different active facade configurations. extensive experimental operation on a DSGF equipped with mechanically ventilated air gap.	EE of the facade and the ThC implications have been evaluated considering the ability to pre-heat the ventilation air in the winter season, and the ability to remove part of the solar load during the summer season; the normalized daily energy passing through the facade and the normalized surface temperature of the inner glass were analyzed.	DSGF showed a better performance in each season for different configurations, in terms of EE and ThC issues. However, DSGF is not comparable with performance of opaque facades.

A study, "Total Solar Energy Transmittance of Glass Double Facades with Free Convection" for DSGF, with a ventilated mid-pane shading device and the key significance for the cooling load of the building and ThC of its occupants, has been done by Heinrich Manz, (2003) in Swiss Federal Laboratories for Materials Testing and Research (EMPA), Switzerland (Manz, 2003: 1-10). In this research, comprising a spectral optical and a computational fluid dynamic (CFD) model is described for modeling a DSGF with free convection. Also, the influence of the layer sequence and ventilation properties on the ThP are studied and discussed in this research. The results of this model are compared with data derived from an experimental investigation of a single-story DSGF with free convection, incorporated in an outdoor test facility. The results show that "*for a given set of layers, total solar energy transmittance can easily vary by a factor greater than five.*" (Manz, 2003: 7-9)

Figure 3-14: Outdoor Test Facility for Facade Elements: The test element (right) and the sensors for outside air temperature, wind speed, global and diffuse solar radiation (left) are visible (Manz, 2003: 4).

As the author mentioned in conclusion part, "*It was shown that alterations to the sequence of a given set of layers in a Glazed Double Facade or to its ventilation properties can easily change the total solar energy transmittance by a factor greater than 5. With a well-designed GDF element with free convection, the secondary* *internal heat transfer factor can be reduced to values below 2%. Low secondary internal heat transfer factors are obtained if: Total solar absorption is low and mainly in layer number 1; Ventilation is efficient (large ventilation openings, etc.); Thermal transmittance (U-value) of insulating glazing unit is low; Reflectance of shading screen is high (within the wavelength interval where layer number 1 is transparent)*" (Manz, 2003: 9-10). In this research, another important issue was resulted which is the direct relationship between the height of the building with increase of temperature of the cavity and solar energy transmittance of the DSGF system. The temperature increase as a function of height might be reduced by wind. In this case, if the inlet and outlet openings are not vertically and they are horizontally is beneficial. "*It was observed in the experimental investigations that short-term wind fluctuations can reverse the direction of airflow in the façade cavities by 180◦ and increase the air change rate. Yet, provided they are limited to short periods, such changed airflow patterns are likely to have only a minor impact on energy flows. A windless situation should be assumed as a worst-case scenario for overheating*" (Manz, 2003: 10). In this paper, the measured and calculated temperature distribution resulted in the maximum air temperature is occurred on the top, in the cavity of DSGF, where electric motors are located for the shading devices. "*Depending on the quality of the optical and thermal design of the construction and the façade orientation, air temperatures of more than 80 ◦C may occur on days with high solar irradiation and high outside temperatures. This has to be considered when choosing and locating electric motors for the shading devices*" (Manz, 2003: 10).

A good research about performance of DSGF system is "Experimental Assessment of the Performance of an Active Transparent Facade During Actual Operating Conditions" by Corgnati S.P, et al, (2007) which aimed "*to assess the actual facade* *performance, both in terms of energy savings and enhanced comfort conditions, to obtain more detailed knowledge of its thermo fluid dynamic behavior and to highlight the weak points of this relatively new technology that still requires further improvement. The analyzed component consists of a transparent mechanically ventilated facade integrated with an HVAC system. The facade is used as the exhaust outlet of the HVAC system. The temperatures, heat fluxes and air velocities in the ventilated facade were continuously monitored, over a period of 2 years, using a monitoring system with 34 sensors. In the paper, attention is focused on the measurement techniques that were adopted and on the critical analysis of the experimental data*" (Corgnati, et al, 2006: 1-3).

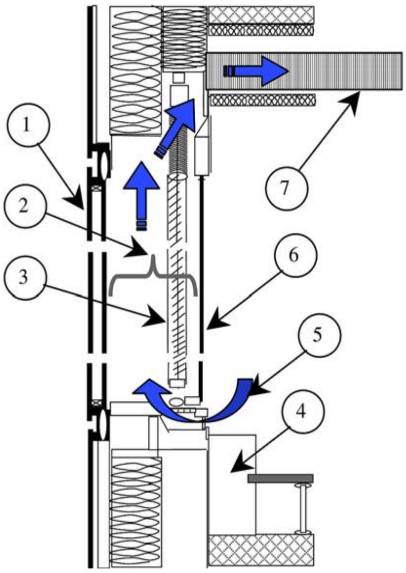


Figure 3-15: Structure of the Ventilated Facade: 1, external glazing; 2, air gap; 3, venetian blind; 4, aluminum frame; 5, scheme of the air flow path; 6, internal gazing; 7, exhaust air duct to the HVAC system (Corgnati, et al, 2006: 3).

In this study, the monitoring was performed on a common type of ventilated facade installed in an office building in Turin (North-West Italy) and the research aimed to assess the performance of this facade in terms of energy savings and enhanced ThC during normal operation of the building. To do so, a measurement system made up of

34 sensors was used. "*Surface and air temperatures, heat fluxes, solar radiation (incident and transmitted) were measured for two consecutive years with a scan rate of 15 min. The performances of the facade were analyzed in terms of: heat fluxes entering the indoor environment, losses/ gains of monthly thermal energy and surface temperatures of the internal glass pane. In order to assess the capacity of the facade to recover energy during heating periods and to reduce the heat loads in the room during the cooling periods, two types of efficiency were assessed: Pre-heating efficiency, g, introduced by Van Paassen and Stec (2001); and Dynamic insulation efficiency, which was on-purpose introduced and defined"* (Corgnati, et al, 2006: 2-4). As the results of this paper, "*the radiative heat transfer between the solar shading device and the inner glass pane is an important phenomenon to determine indoor comfort concerns during the summer and mid seasons. An upper limit exists which is represented by the nominal flow rate prescribed by IAQ standards (it would not be energy efficient to adopt larger values). As seen in the previous sections, the entity of these flow rates proved to be insufficient to provide a suitable cooling of the solar shading device. The only way of significantly reducing this phenomenon is to optimize the shading devices (low-emittance, double reflective screen, etc.), to correctly choose the glass type and to create a proper air flow path of the air inside the air gap*" (Corgnati, et al, 2006: 18- 20). These were the main fields for further research for achieving benefits of transparent ventilated facades in terms of energy and comfort issues.

Another useful research, "Experimental Evaluation of a Climate Facade: Energy Efficiency and Thermal Comfort Performance", by Valentina Serr, et al, (2009) in University of Politecnico di Torino, Italy, studied an extensive experimental operation on a DSGF equipped with mechanically ventilated air gap. "*Measurements* *were performed utilizing the TWINS (Testing Window Innovative Systems) test facility, which consists of two outdoor cells, one used for reference purposes, and the other which adopts different active facade configurations. The energy efficiency of the facade and the thermal comfort implications have been evaluated considering the ability to pre-heat the ventilation air in the winter season, and the ability to remove part of the solar load during the summer season; the normalized daily energy passing through the facade and the normalized surface temperature of the inner glass were analyzed. The improvement in performance obtained by varying the configuration and operative conditions (changing the air flow rate, the shading device and the internal glazing) has been investigated.*" (Serra, et al, 2009: 1-2).

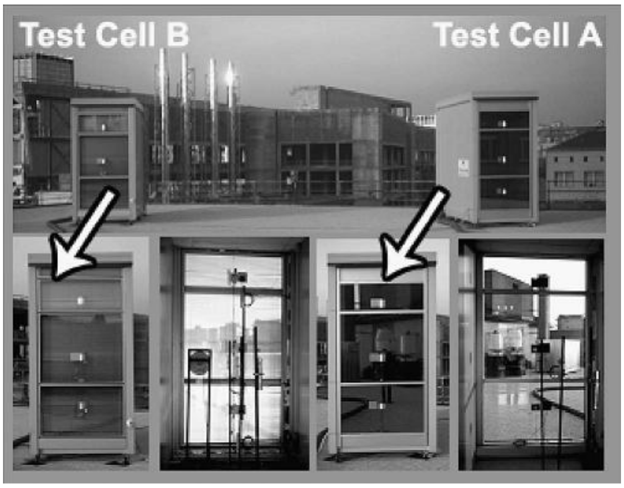


Figure 3-16: A View of the Overall System (above), test cell B (bottom left) and test cell A (bottom right) (Serra, et al, 2009: 3).

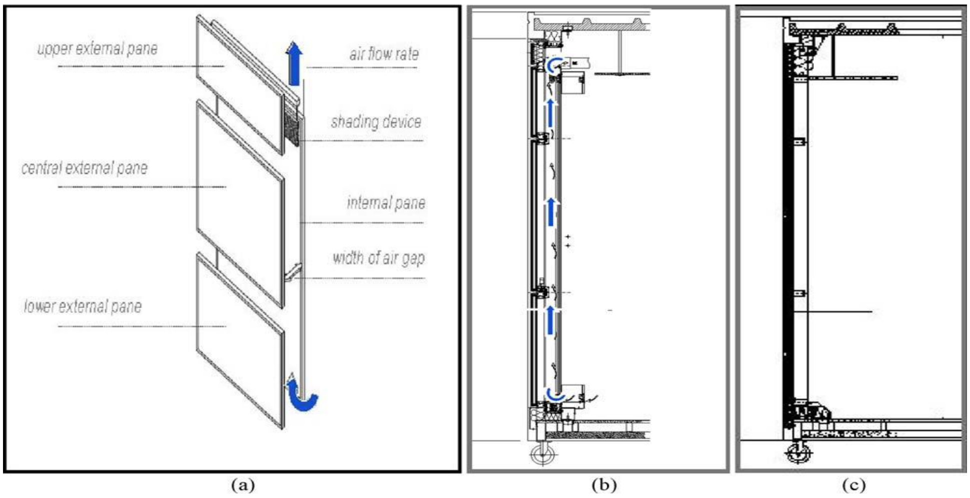


Figure 3-17: Schemes of the Monitored Facades: (a) the climate facade; (b) section of the climate facade and of test cell B and (c) section of the reference facade and of test cell (Serra, et al, 2009: 3).

As the authors mentioned, the main goal of this research was to evaluate the performance of DSGF in terms of energy saving and ThC and to improve these performances by changing its configurations and operative conditions such as the air flow rate, the shading device and the glazing system. According to the authors, "*As far as the energy efficiency in the winter period is concerned, the analysis of the pre-heating efficiency has shown that it is negative for at least 50% of the operative time: this means that, for most of the time, the facade cools the air flowing in the gap. It is therefore important to control the temperature of the air exhausted by the facade if it is used in a heat recovery system*" (Serra, et al, 2009: 12). As it is mentioned in the research, if an additional insulation such as shading devices is added to the facade, "*there is an inverse influence of the air flow rate: an increase in the ventilation air flow rate lowers the facade efficiency. The use of a venetian blind leads to a higher ability to pre-heat the ventilation air than a reflecting roller screen*" (Serra, et al, 2009: 12). As it is written in the conclusion part of the research, analysis of the normalized ''*long wave*'' heat fluxes and daily energy showed that "*if solar radiation is low or absent, the climate facade allows a reduction in heat losses. When solar radiation is present, the climate facade allows a heat gain instead of a heat loss, and the thermal and visual comfort problems that can be present when solar radiation directly enters the indoor environment can be avoided. During the cooling season, the active facade limits the loads entering the indoor environment: it removes part of the loads entering the facade from the outdoor environment through of the air flowing in the ventilated gap. The dynamic insulation efficiency rises according to the air flow rate. The use of a reflecting roller screen always leads to* *higher efficiency values, with respect to the venetian blind, probably because of the different fluid dynamic behavior of the facade with the two shading devices. With the roller screen, the air cavity is divided into two different air flow channels. The external one collects most of the radiation absorbed and reflected by the shading device, and the air in the internal one has a more effective insulating and cooling effect. This does not occur with the venetian blind, whose higher air permeability allows a higher mixing of the air in the cavity. At a medium ventilation rate (56 m3/h) and with the reflecting roller screen, the entering heat load is reduced by about 50% for more than 85% of the operational time*" (Serra, et al, 2009: 12). The results showed that in summer conditions, there is a reduction of the entering loads, with respect to the reference facade, of at least 37%. This proved that using roller screen is "*more effective at low air flow rates, whereas the difference between the two shading devices is very low at medium low rates*" (Serra, et al, 2009: 12). The analysis of the normalized temperature of the inner glass showed that the temperature of the inner glass of the DSGF and radiant effect towards the indoor space of the active facade was higher to compare with the reference facade. Ventilation reduced the temperature difference between two facades and the radiant effect of the active facade. An increase in the ventilation rate, in winter, causes the lower performance of the facade in terms of EE and ThC. In summer time there was an overheating in the cavity and increase of temperature of the inner glass as function of the overheating which caused discomfort problems. *"The analysis of the spatial distribution of the PMV and PMV values over the floor area showed a good performance of the active facade. Considering the PMV index distribution, the percentage of floor area in comfort varies from 67.0%, in the case of class A, to 99.7%when comfort class C is considered. Considering the effect of the entering solar radiation, about 20% of the* *floor is in class A comfort conditions, but the performance still remains good for classes B and C, with a percentage of comfort area that is always above 80%. The reference facade did not provide such good results, especially considering the presence of solar radiation, with the whole floor surface in discomfort conditions when considering class A, and with significantly larger floor areas in discomfort, according to class B and class C. The analysis of the normalized surface temperature in summer conditions showed that a lower temperature of the inner glass can be achieved by increasing the air flow rate and that better results can be achieved adopting the reflecting roller screen. An air flow rate in summer therefore improves both the energy efficiency and the thermal comfort performance of the facade*" (Serra, et al, 2009: 12). At the end, the authors claimed that in comparison of performance of the active facade and the reference facade, the DSGF showed a better performance in each season for different configurations, in terms of EE and ThC issues. However, DSGF is not comparable with performance of opaque facades. "*This technology needs further improvement to avoid overheating in cooling periods and to use its ability to behave as a solar collector in the heating period more effectively*" (Serra, et al, 2009: 13).

From the studies discussed above, it is shown that most of the researchers studied the DSGF systems as SGFS in terms of EDS and consider the cost issue of DSGF system as a disadvantage of these systems. So far, SD of sustainability in DSGF was not discussed. This can be due to the reason that, however, like any other type of facade system, DSGF system can be adapted by most of the societies.

Furthermore, most of the studies investigated and compared different types of DSGF system with conventional GF systems. However, DSGF systems, environmentally, showed much better performances in different CC, even in NC. But yet, in order to achieve the better result of environmental performance of DSGF systems, there is need of using shading devices, especially when the facade is facing south. However, this can be true as well while using conventional GF systems.

Chapter 4

Evaluation of Appropriateness of DSGFs:

Case of NC

This chapter presents environmental and socio-economic condition of NC, as well as affect of social and cultural factors on AI of facades in NC. Then, discussion of observations and interviews are explained and analyzed.

4.1 Environmental Condition of NC

In environmental scanning multi-factors, which affect the GF and DSGF construction within the context of sustainability, positively or negatively, are explained.

4.1.1 Location and Population of NC

Cyprus is the third largest island in Mediterranean after Sicily and Sardinia. It situated between 30.33^0 N and 35.41^0 N latitudes and 32.23^0 E and 34.55^0 E longitudes. The Turkish Republic of Northern Cyprus (TRNC) covers an area of 3,242 square kilometers with population of 315,000. TRNC is a developed independent country with its borders and all democratic institutions of a democratic country (URL 56).

4.1.2 Climatic Condition (CC) of NC

According to Meteorology Office of TRNC, NC has Mediterranean climate with hot and dry summer season and warm and wet winter. Figure 4-1shows the hot periods of the year and amount of heat.

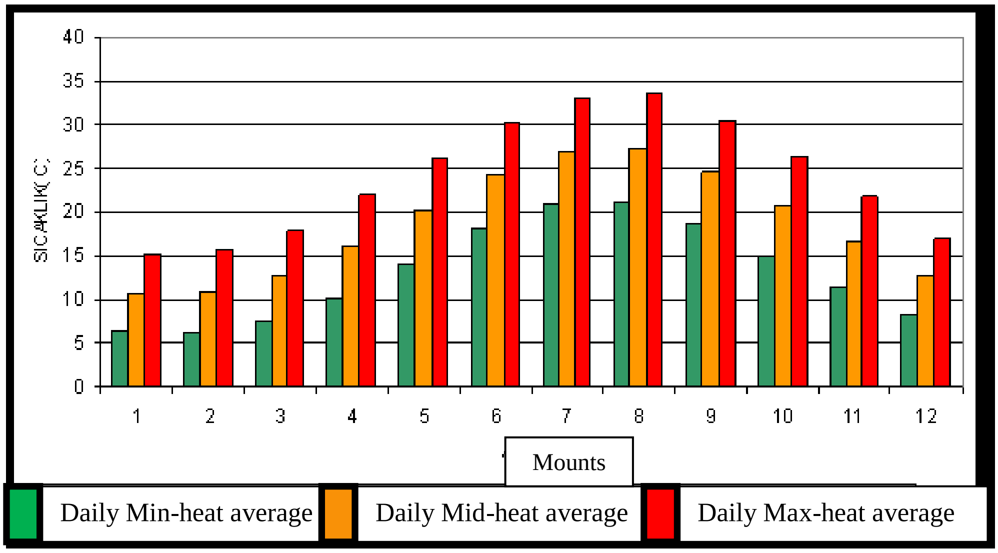


Figure 4-1: Monthly Amount of Heat During a Year (URL 56).

According to the data in Figure 4-1, in NC the average yearly heat temperature is 19.0 °C. The hottest month in the year is July. In July the air temperature during day is (in shaded) 37 °C -40 °C. The coldest month is January in which the air temperature during day is 9.0 °C-12°C. The coldest nights of the year is in month of January. In these nights freezing happens due to decrease of earth's temperature down to 0.0 °C.

4.1.2.1 Solar Radiation in NC

In NC due to its latitude, there is sunlight for 12 hours of a day in summer and 5 hours a day in winter.

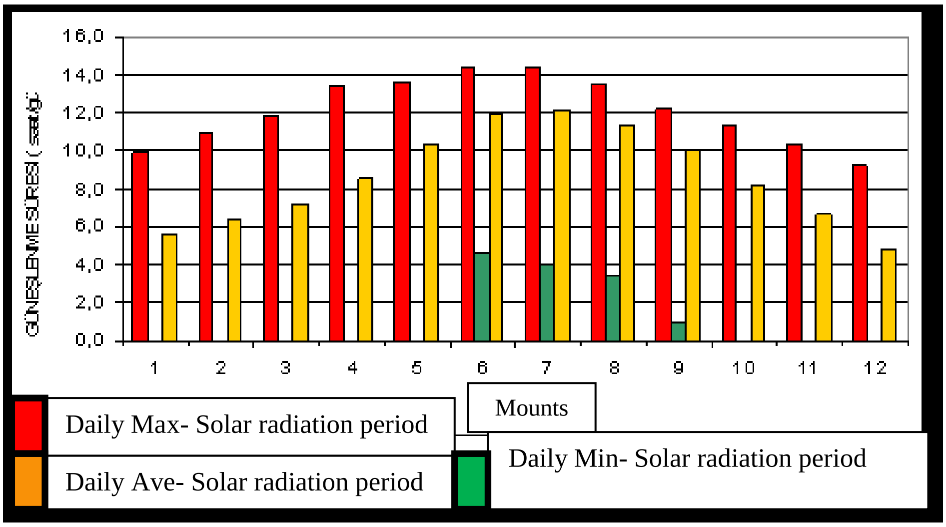


Figure 4-2: Monthly Solar Radiation Period in a Year (URL 56).

As it is shown in Figure 4-2, in June and July daily maximum hours of sunlight is the highest and in June and July daily average sunlight is the highest as well. The minimum daily sunlight is in months of June, July, August and September. Figure 4-2 shows that in all the months of the year there is daily maximum and minimum sunlight but average daily sunlight period is in summer seasons which are June, July, August and September. The solar energy in TRNC is strongly high. The yearly average solar energy is 417.3 cal/cm^2. The maximum solar energy is in month of July which is 622.2 cal/cm^2 and minimum solar energy is in month of December which is 214.5 cal/cm^2.

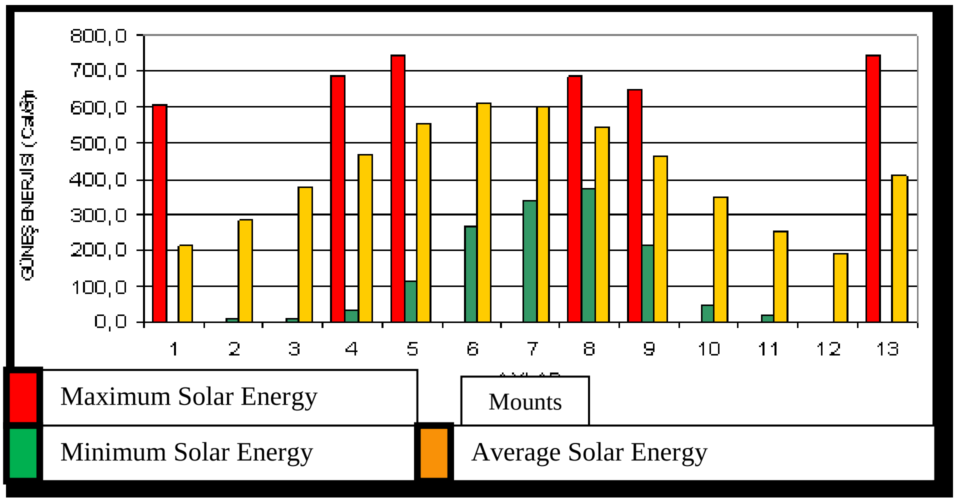


Figure 4-3: Monthly Amount of Solar Energy in a Year (URL 56).

According to Figure 4-3, maximum solar energy is in May and it is less in April, August, September and January. Minimum solar energy in August is the highest and in February is the lowest and average solar energy in June is the highest and in December is the lowest.

4.1.2.2 Wind and Moisture in NC

As an environmental factor, wind can affect the NV performance of the air cavity of DSGF (as explained in chapter 3). For this reason it is necessary to know the wind direction of the region. In NC wind blows from many different directions and this is because of the topography of the land and also that NC is an island (URL 56).

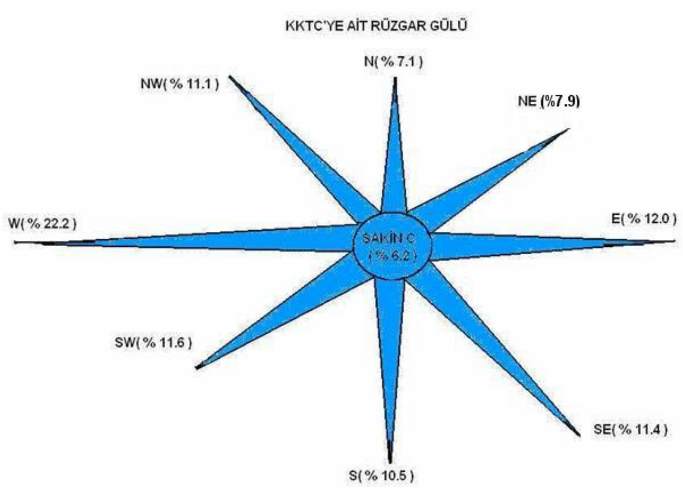


Figure 4-4: Wind Direction in NC (URL 56).

In Figure 4-4, it is shown that the maximum wind blow which is 22.2% is from west direction. Wind direction in design of DSGF helps the configuration of the air cavity.

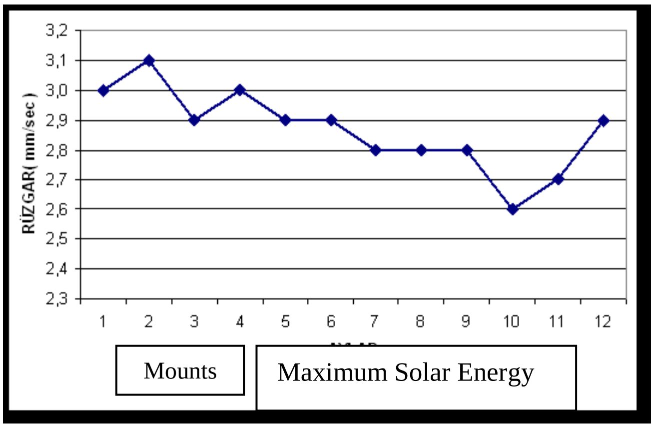


Figure 4-5: wind Speed in NC (URL 56).

As it is shown in Figure 4-5, average wind speed is 2.8 m/sc, which is mostly blowing in the middle of July, and in August and September.

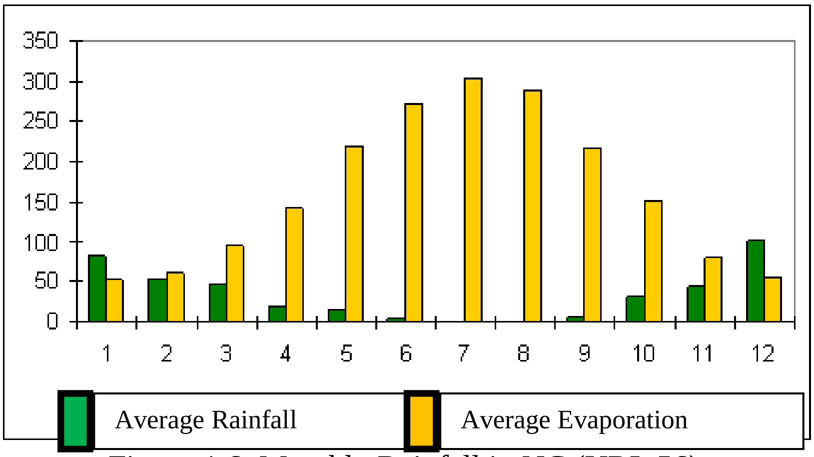


Figure 4-6: Monthly Rainfall in NC (URL 56).

According to Figure 4-6, the driest months of the year in NC are July and August and the wettest month is December. Average rainfall period in the year is between November and March.

4.1.3 Bioclimatic Analysis of Cities Based on Issues Affecting DSFs Performance in NC

This section presents web based climatic data combined with Turkish Cypriot Meteorological Organization, which were collected in order to specify the climatic characteristics of the Island.

According to Meteorology Office of NC, climate data in detail is shown for 4 main cities in NC. Important issues which affect the performance of DSGF system, such as speed and amount of wind, daily sunshine period, total solar radiation, solar radiation intensity, dry bulb temperature, mean-maximum and mean-minimum relative humidity, ThC zone, amount of rainfall are analyzed:

a) Nicosia (Lefkoşa):

Climate of Nicosia shows less mild characteristics of Mediterranean climate. This is because of being close to the North by a range of mountains. There are no days with snow. The number of days with strong wind is the highest in January and December and it is the least in June, July and August. In Nicosia, the PW comes from North and North-West, but the most consistent directions for wind are South-West and West. Daily sunshine period is increasing from its minimum, which is 5 hours a day in December and January, up to its maximum, which is 13 hours in July, and again it is reducing continuously down to its lowest minimum in December and January. In average, in 7 months of the year there is sunshine more than 9 hours a day. Total solar radiation in Nicosia is rapidly increasing from its minimum level, which is 9 MJ/m2 in December and January, up to its maximum level, which is 29MJ/m2 in June and July, and it again reduces till December. Solar radiation intensity in Nicosia continuously increases from its minimum, which is 110W/m2 in December, up to its maximum, which is 350W/m2 in June and July. Mean Max. DBT varies between 15.34 ºC and 36.23 ºC, while Mean Min. DBT changes between 5.43 ºC and 21.54 ºC .Maximum DBT may reach up to 44ºC in summer, which occurs in August and minimum DBT may drop down to -6 ºC in winter that happens in February. The relative humidity, which is another climatic factor, is varying between 25% and 86% in summer. In winter the differences are from 41% to 92%. Relative humidity is highest in February and March which is about 91.58% in the morning and lowest in August in the afternoon which is 24.7%. Although the relative humidity is high in winter, the rainfall is quiet low. For Nicosia, maximum 7:00hours relative humidity, which is 84%, is from middle of February till middle of March and minimum 7:00hours relative humidity, which is 83%, is at the end of the April and beginning of May. Maximum mean relative humidity, which is 74%, is at the end of December and minimum mean relative humidity, which is 51%, is in the middle of the June and middle of August. Maximum 14:00hours relative humidity, which is 51%, is at the end of December and beginning of January and minimum 14:00hours relative humidity, which is 24%, is in the middle of June till middle of July. In January, which is the most raining month, it rains only 60 mm/month normally. There is no rainfall in July and August. Even in December the falling rate is 7mm/month, which is less than in September (Figure 4-7) (B. Özdeniz, 2010: 10-80).

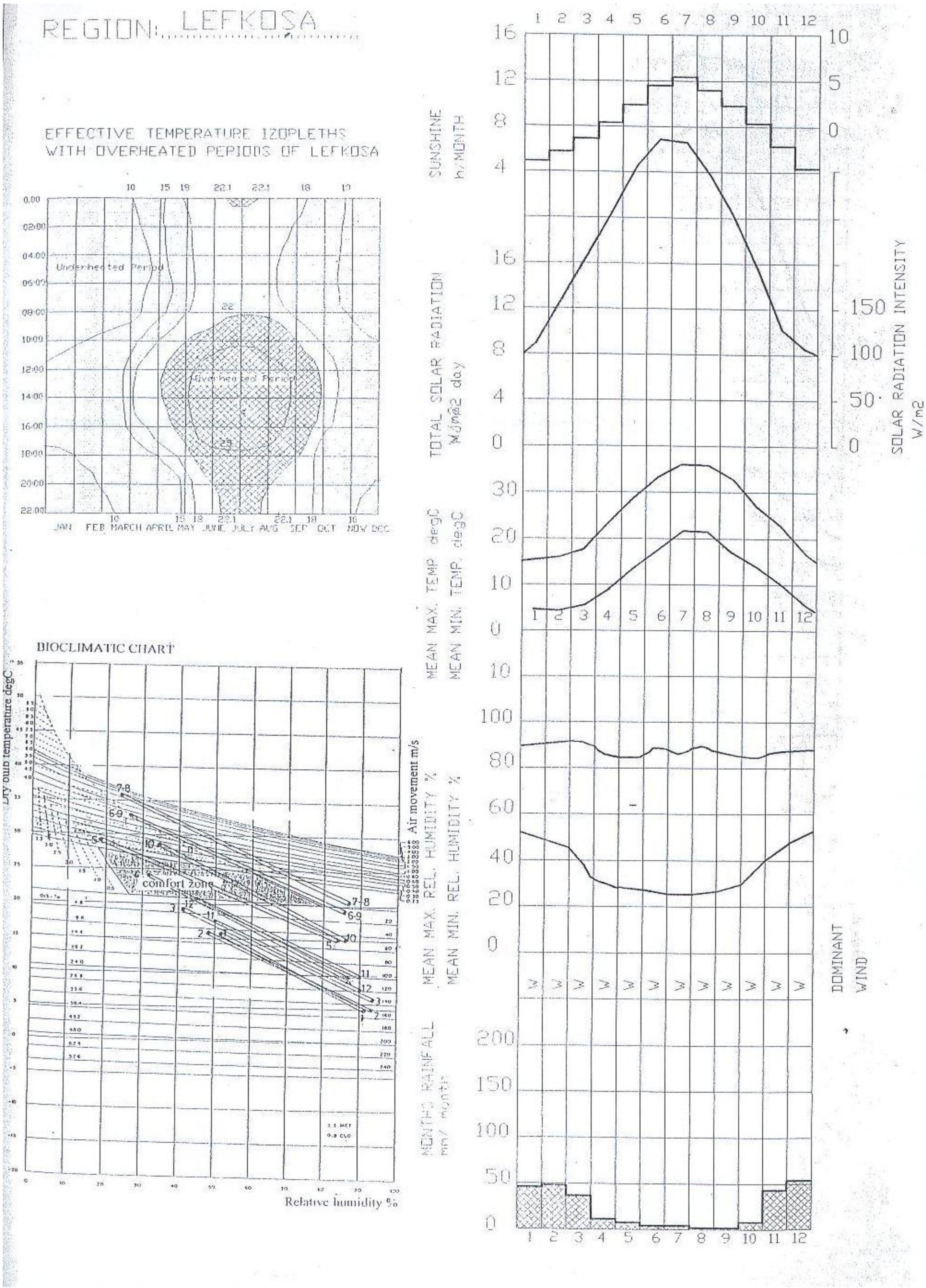


Figure 4-7: Meteorologic Data for Nicosia (Lefkoşa), (TRNC Meteorology Office).

b) Famagusta (Gazimağusa):

Climate of Famagusta shows mild characteristics of Mediterranean climate. There are no days with snow. In the month of December the numbers of days with strong wind is the highest, in January and February it is less and it continuously reduces till month of July and August when there is no wind during the month. The PW (PW is the most frequent wind), in January, February, March, April, May, September, October, November and December is from West and in June, July and August it is from South West. Daily sunshine period is the maximum level in June, July and August which is 12 and 13 hours and it is the minimum in December and January which is 5 hours. In average, in 7 months of the year there is sunshine more than 9 hours a day. Total solar radiation in Famagusta is rapidly increasing from its minimum level, which is 6 MJ/m^2 in December, up to its maximum level, which is24 MJ/m^2 in June and July. Solar radiation intensity in Famagusta continuously increases from its minimum, which is 70W/m^2 in December, up to its maximum, which is 280 W/m^2 in June and July. Maximum DBT may reach up to 42ºC in summer, which occurs in August and minimum DBT may drop down to -6 ºC in winter that happens in January. Mean Min. DBT changes between 6.8 ºC and 22.3 ºC while Mean Max. DBT varies between 33.3 ºC and 16.3 ºC. The relative humidity, which is another climatic factor, is varying between 88% and 47% in summer. In winter the difference is from 88% to 60%. Relative humidity is highest in April and May, which is about 90%, in the morning and lowest in July in the afternoon which is 46%. Although the relative humidity is high in winter, the rainfall is quiet low. Maximum 7:00hours relative humidity, which is 90%, is in middle of May and minimum 7:00hours relative humidity, which is 84%, is in middle of March; Maximum 14:00hours relative humidity, which is 60%, is from January till middle of

February and at the end of December and Minimum 14:00hours relative humidity, which is 44%, is in July. In December, which is the most raining month, it rains 110 mm/month. There is no rainfall in July and August (Figure 4-8) (B. Özdeniz, 2010: 10-80).

c) Kyrenia (Girne):

The city of Kyrenia is the most humid region in NC. This city is open to the Mediterranean Sea from North and it is located at the skirts of the Beşparmak (Pentadaktilos) Mountain Range. In city of Kyrenia, number of days with strong wind is mostly in December, January and February, and it is the lowest in months of November, March, October and April. The direction of PW, in January, February, March, November and December, is from South and in April, May, June, July, August and September it is from West and in October it is from South-West. Daily sunshine period is the maximum level in June and July, which is 13 and 12 hours, and it is the minimum in December and January which is 5 hours. In average, in 7 months of the year there is sunshine more than 9 hours a day. Total solar radiation in Kyrenia is rapidly increasing from its minimum, which is 7.8MJ/m^2 in December, up to its maximum level, which is 26 MJ/m^2 in June and July. Solar radiation intensity in Kyrenia continuously increases from its minimum, which is 90W/m^2 in December, up to its maximum, which is 320 W/m^2 in June and July. Mean Max. DBT changes between 32.43 ºC and 15.84 ºC, while Mean Min. DBT varies between 22.93 ºC and 8.06 ºC. Maximum DBT may reach up to 41 ºC in summer, which may occur during June, July and August. Minimum DBT may drop down to -1 ºC very rarely. However, usually DBT is above the freezing point in winter. Usually, January and February are the coldest and August is the hottest month for this region.

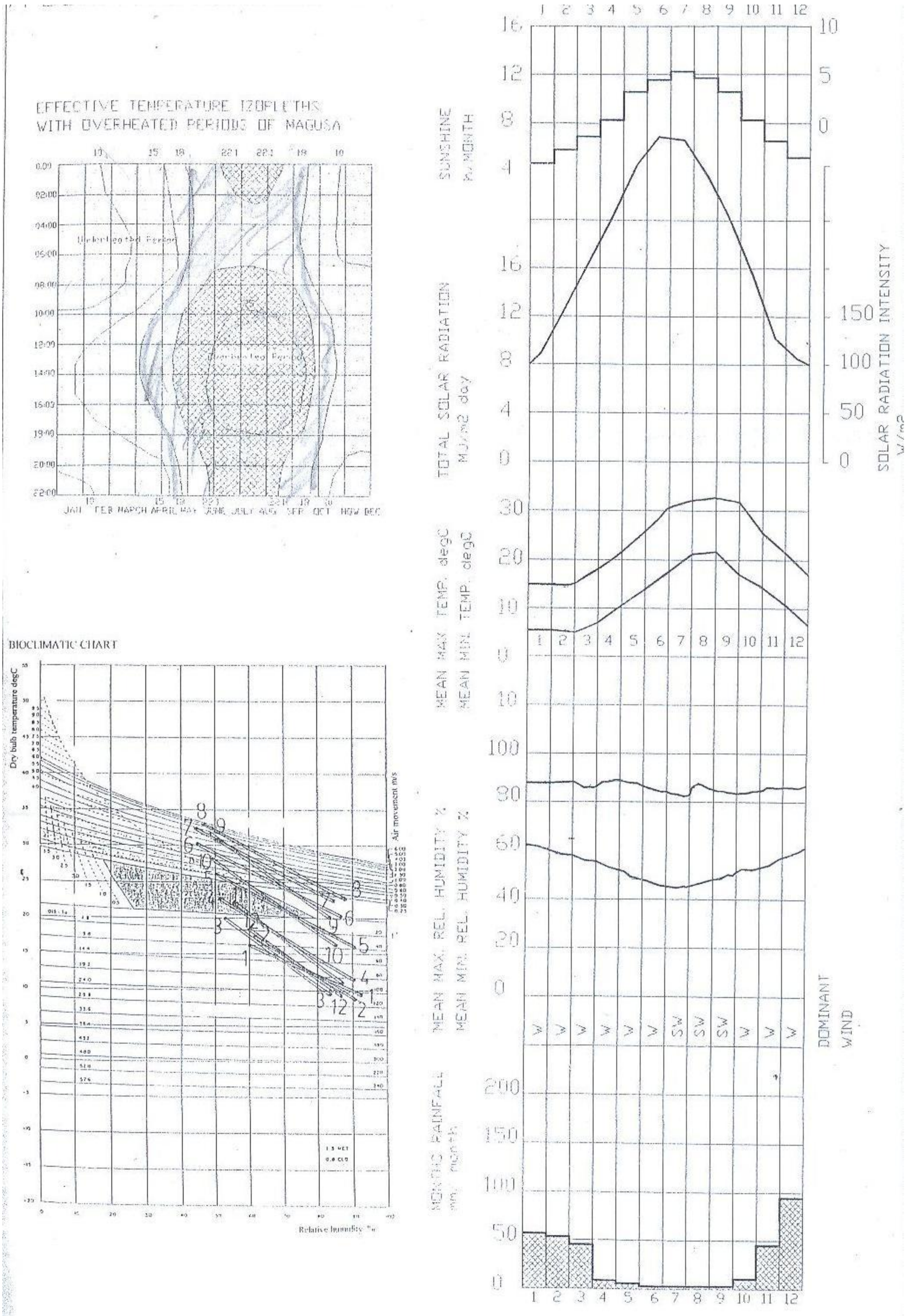


Figure 4-8: Meteorologic Data for Famagusta (Gazimağusa), (TRNC Meteorology Office).

The relative humidity is varying between 46% and 88% in summer. In winter the differences is from 56% to 90%. Relative humidity is the highest in May, in the morning, and the lowest in July in the afternoon, which is 89.84% and 46.34%. In afternoons relative humidity never drops less than 85% in whole year. It only changes 5 or 6 percent in whole year. For Kyrenia, maximum 7:00hours relative humidity, which is 91%, is in May and minimum 7:00hours relative humidity, which is 86%, is in December. Maximum 14:00hours relative humidity, which is 61%, is from January till middle of February and at the end of December. Although the relative humidity is high in winter, the rainfall is not high. However, Kyrenia is the rainiest city of NC. It may reach up to 135mm/month in December and 537mm/month totally in a year. There is no rainfall in July and August (Figure 4-9) (B. Özdeniz, 2010: 10-80).

d) Morphou (Güzelyurt):

The climate of Morphou shows dryer characteristics from the other coastal climates, due to being between the mountains on both South and North sides and a bit far away from the sea. For the city of Morphou, the days with strong wind are in December and it is less in February and January. There are almost no days with strong wind in July and June. The PW in January, February, March, October, November and December is from East, and it is from North-West in June, July, August, September, and April.

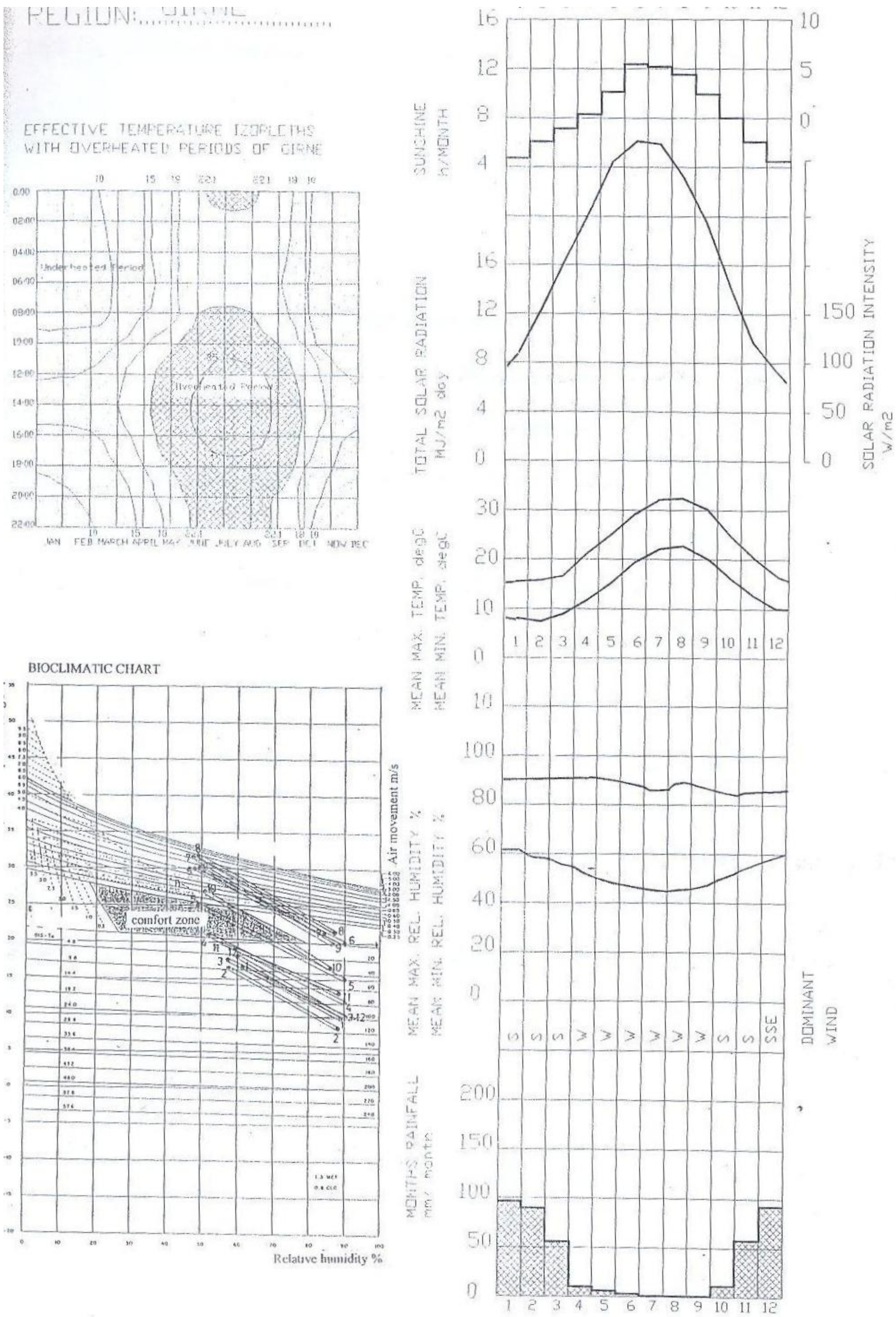


Figure 4-9: Meteorologic Data for Kyrenia (Girne), (TRNC Meteorology Office).

Daily sunshine period is the maximum in June and July, which is 11 and 12 hours and it is the minimum in December, which is 5 hours. In average, in 7 months of the year there is sunshine more than 9 hours a day. Total solar radiation in Morphou is rapidly increasing from its minimum, which is 7.9MJ/m^2 in December, up to its maximum, which is25.5MJ/m^2 in June and July. Solar radiation intensity in Morphou continuously increases from its minimum, which is 80W/m^2 in December, up to its maximum, which is 280 W/m^2 in June and July. Maximum DBT may reach up to 44 ºC in summer, which occurs in August as in Nicosia. Minimum DBT may drop down to -3 ºC in winter which happens in January and February. Mean Min. DBT changes between 4.4 ºC and 18.3 ºC while Mean Max. DBT varies between 34.2 ºC and 16.2 ºC. The relative humidity is varying between 87% and 36% in summer. In winter the difference is from 91% to 46%. Relative humidity is the highest in december, 91% in the morning, and the lowest in July in the afternoon which is 36%. Maximum 7:00hours relative humidity, which is 90%, is at the end of December till the beginning of January. Minimum 7:00hours relative humidity, which is 83%, is in June. Maximum mean relative humidity, which is 74%, is from end of December till beginning of January and minimum mean relative humidity, which is 64%, is at the end of June and beginning of July. Maximum 14:00hours relative humidity for this city, which is 58%, is at the end of December and beginning of January and minimum 14:00hours relative humidity, which is 39%, is at the end of April. For Morphou, December is the rainiest month, when normally it rains 70mm/month in this month. There is no rainfall in July and August (Figure 4-9) (B. Özdeniz, 2010: 10-80).

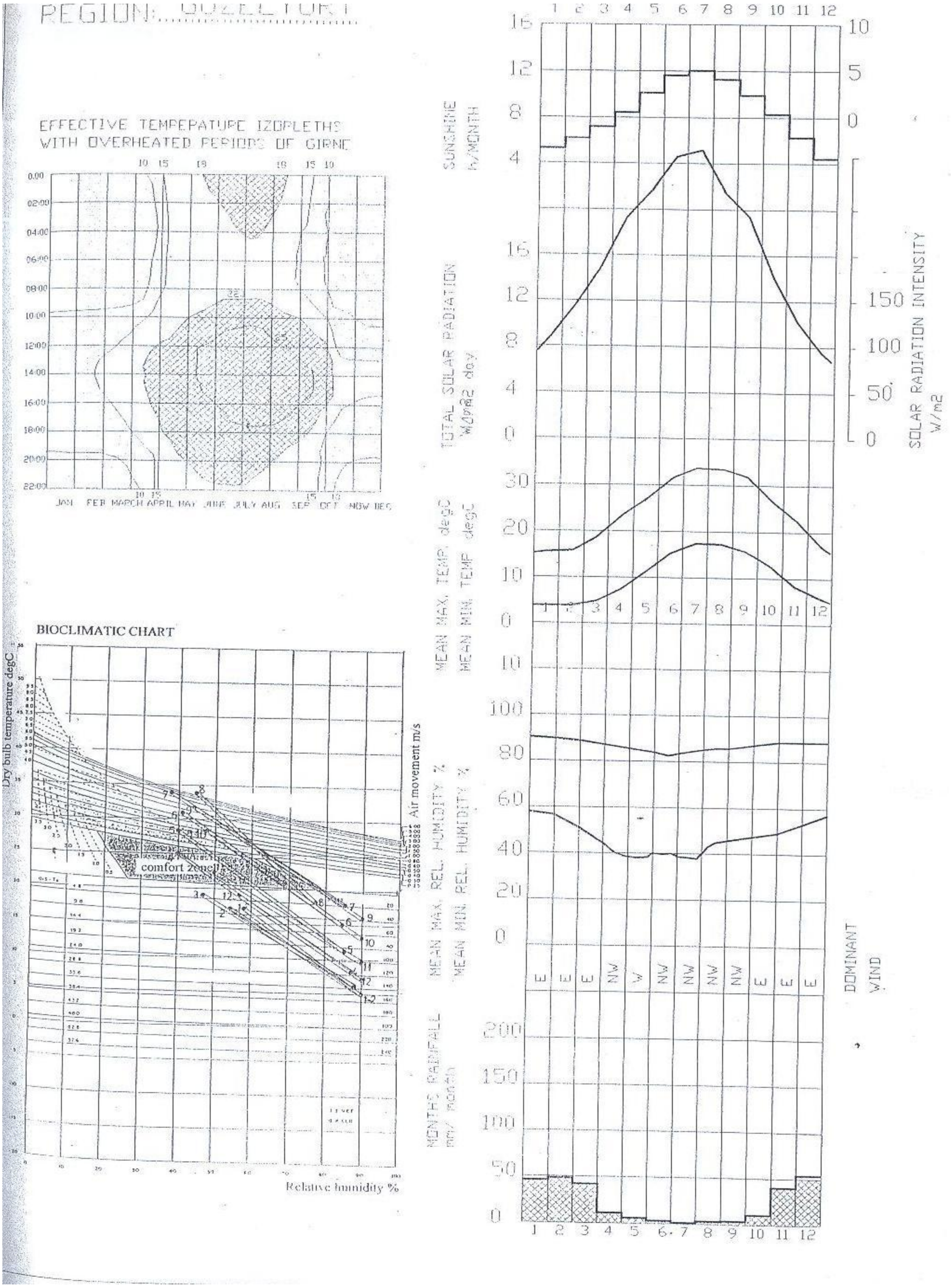


Figure 4-10: Meteorologic Data for Morphou (Güzelyurt), (TRNC Meteorology Office).

As it is explained above, the number of hot seasons in the year that is, the number of days with high solar radiation is high in most of the regions of NC. The wind direction and amount of wind blow is very effective for the air cavity of DSGF and for ventilation of the building and reduction of cooling load in summer, as well. According to literature, to maintain sufficient ventilation for cooling down the skin of the building in summer it is recommended to calculate the optimum width of any type of DSFs and the proper area for its openings.

4.2 Socio-economic Condition of NC

NC has economy of a small island which needs a great amount of imports for increasing balance to the growth of the economy. In addition, NC has a limited sources such as energy, and natural sources. However, energy problems will increase the operating and investment cost. Construction cost is also relatively high in NC due to economic situation and political embargo of the island.

According to the free-market economic system adopted by the government since 1987, the advancement of the private sector with limited government involvement, rational use of natural resources, encouragement of investments in priority sectors such as tourism, industry, trade, construction, transportation and higher education, keep their priority and importance (Business Policy Group 1, 2004). On the other hand, since 1974, although lack of recognition caused political difficulties for NC, but its economy has experienced a rapid change and a reasonably high-growth trend (Business Policy Group 2, 2004: 11-12). In that period exports showed an increase of 62% and reached US $ 70.5 million, while imports increased by 27.7% and reached US $ 318.4 million. Due to these developments, the trade shortage reached US $ 247.9 million (Business Policy Group 1, 2004). At the same time, the most recent economic cooperation protocol out of several was signed between the governments of Turkey and NC, in order to set up an economically self-sufficient NC. The aim of this protocol was to improve the economic balance which was harmed by unfavorable conditions faced recently, to realize the structural adjustment required for rapid development and thus to enhance the standards of living. According to this protocol, the Turkish government agreed to provide support up to US $ 250 million. Affecting the construction sector, some of the most important issues included in the protocol were: to adjust the banking, money foreign exchange and foreign investment regulations; to increase the privatization process; and to realize the infrastructure projects, the major ones being energy, water and tourism; to provide the same credit conditions for the Turkish and Turkish Cypriot investors in tourism, industry, agriculture, construction, education and artisans; to provide cooperation between the two countries in trade, tourism and agriculture (Business Policy Group 1, 2004). In addition to all these, covering budget expenses by local incomes and demanding foreign aid and loans, like most developing countries, have been the difficulties that NC faces with. Although local incomes have shown rising tendency over the years and reached 62% of expenses in 1995 (this information not available for recent years), they are still far from covering the budget shortage (Business Policy Group 1, 2004).

Moreover, the main aims of the economic development policy of NC are to achieve the highest possible rate of growth for economic stability, more reasonable distribution of national income, and to enhance the life standards by improving the financial and social structure (Business Policy Group 2, 2004: 11-12).

Construction companies have to import some equipments and materials from other countries due to the weaknesses in industry sectors of NC. For example, the maintenance fee will be high because company cannot find local GF systems equipments manufacturing suppliers. The construction market demand is also limited, although the market demand has been increasing in the past 10 years, due to the increase of number of foreign investors and immigrants settled in the island and the increase of numbers of investors coming back from UK to the island. Political embargo is still a limitation and in some ways it influences the construction sector. However, if these problems can be solved during project life time, the market demand for GF system and thus DSF systems will be rapidly increased.

In new construction of GF systems for LSCOB, both around the world and in NC, the conventional envelope of buildings, have been tending to be replaced by highly glazed envelopes. This is because of the demand of both occupants and architects for a pleasant visual IE, more ND, view and also other advantages of GF systems. In NC, according to observations and interviews, this trend can be seen in recent buildings with GCW systems. Thus, according to these evidences, GF systems has been accepted, recognized and demanded by the stakeholders.

In NC the education level is very high, so people try to invest their money with high return. As a result, people mostly invest their money either in construction sector or in banks. The other fact is that, since the unemployment is too low, people earn well. This also can affect people's attention to invest their money in construction sector. On the other hand, the population of NC is low, which can affect this issue negatively (Business Policy Group 1, 2005: 53).

According to Business Policy Group 1, (2005) "*the per capita income is 5949 $ in TRNC. It could be low in comparison with EU countries. However, it is quite fine* *when it is compared with most of the Middle East and African countries. This shows us that people's welfare is high."* (Business Policy Group 1, 2005: 53). This can show that people's income is higher than medium level, so people can accumulate higher investments in construction sector as well as tourism and other sectors. Analysis of the data about sectoral investments and growth in TRNC SPO website showed that, although the population of NC is relatively small comparing with other giant countries, its interest in construction is above medium level (TRNC SPO website). In addition, due to emigration of foreign investors and immigrants, construction sector has gained more and more attention. This increase in population has brought more opportunities and development for construction sector; but yet, there are some factors which can be seen as a threat for the investors in NC. For instance, the financial crisis, particularly construction sector crisis, and dramatic exchange rate fluctuation lower the stakeholders' motivation to make a long-term investment. The import of construction material, particularly for GF systems, is another factor that affects the stockholders' decision. There is another important factor which should be considered. The exchange rates of TL to US $ and Euro have been increasing since early of 1990s and fluctuate dramatically until present (Business Policy Group 1, 2004 :). However, the construction of GF systems in NC as well, got relatively affected by these factors and the developments in construction sector have been mostly in low density settlements such as villas and houses and less in LSCOB, especially the ones with GF system.

4.3 Construction Sector in NC

The roots of construction sector in NC can be traced back to the British period (1878-1960). In 1960 regulatory bodies in construction sector was established for the first time in NC (Hoskara, et al, 2009. In: Hoskara, 2009: 51). As a result, it brought massive construction in the beach resort areas in Famagusta and Kyrenia due to the increased number of tourists in the late 1960s. Political conflict in the period of 1963-1968 decreased the construction flow of Turkish Cypriots. There was a geographical division of the island into two in 1974, which moved Turkish Cypriots from South to North and Greek Cypriots from North to South. After that, reconstruction process has started. Influenced by growing number of settlements in the North side of the island, there was a decrease in the construction movements. By the end of 1980s, the development of housing construction sectors has increased. There were local citizens and students demand for housing construction. The government and private sectors supported this construction process by providing investments. As indicated by the sector of developments, between 2002-2006 construction sector has experienced the highest growth rate (TRNC SPO, 2007b). As the infrastructural investments grew, the share in economy of construction sector leveled up. Moreover, growing local and foreign demand for settlement investments and public infrastructural investments led to a rapid increase in the sector (TRNC SPO, 2007a: 4).

Due to the evidence of growing number of constructors, which increased from 171 in 2003 to 378 in 2007, and increase in sales of cement from 168.300 tons in 2002 to 493.100 in 2007, there have been increasing trends in the construction sector in NC (TRNC SPO, 2007b: 85).

According to TRNC SPO, buildings construction cost and chain index for different types of buildings are calculated. Here, only office buildings are considered since the data regarding other commercial buildings is not availabe. In construction sector, according to the available data, with the effect of positive expectations and high foreign demand and as the result of the highest increase in construction investments, annual average growth rate has been realized as 19.1 % despite of the estimated decrease in 2007 (Limason Turk Cooperative Bank, 2008).

Table 4-1: 2007 Urban Office Building Statistics in TRNC (TRNC SPO).

Building type A: Number of Buildings C: Value (YTL)		**Total**	**Nicosia**	**Famagusta**	**Kyrenia**	**Morphou**	**Iskele**
Offices	**A**	**20**	**7**	**4**	**3**	**4**	**2**
	B	**4,308,400**	**1,828,460**	**611,917**	**598,650**	**467,850**	**801,523**

According to TRNC SPO, office buildings receive the 3rd rank among other type of buildings. Maximum construction cost expended for office building is in year 2007 which was 760 TL/m^2. The collected data show that since 1980 to 2007, there is a noticeable growth in construction sector for office buildings. This growth can be seen (according to the observations) the most, after 2007 until present, there has been a high increase in construction of LSCOB employing GF systems. There are number of office buildings built both in urban and rural scales of NC. In a smaller scale, these data are categorized according to the urban and rural context in different cities in NC, in different years (TRNC website).

In year 2007, major office buildings, 7 buildings, were built in Nicosia, 4 office buildings in Famagusta, 4 in Morphou, 3 office buildings in Kyrenia, and 2 offices building in Iskele. The highest construction cost for these office buildings firstly belongs to the ones in Nicosia (1,828,460 YTL), secondly to Iskele (801,523 YTL), thirdly to Famagusta (611,917 YTL), fourthly to Kyrenia (598,650 YTL) and lastly to Morphou (467,850 YTL). This shows that although the number of office buildings in Famagusta and Morphou is higher than the ones in Iskele, the expended construction cost for office buildings in Iskele is more than the ones in Famagusta and Morphou. Again this can be affected by the area m^2 of the buildings and type of material used for the office buildings.

Table 4-2: 2007 Rural Office Building Statistics in TRNC (TRNC SPO)

Building type **A: Number of Buildings** **C: Value (YTL)**		**Total**	**Nicosia**	**Famagusta**	**Kyrenia**	Morphou	**Iskele**
Offices	**A**	**6**	**1**	**-**	**2**	**1**	**2**
	B	**780,125**	**339,500**	**-**	**115,405**	**105,000**	**220,220**

In NC some office buildings are built in rural areas. Comparing the number of rural office buildings to urban, the highest number of office buildings is in Kyrenia and Iskele which is 2 for each city, then in Nicosia and Morphou which is 1 for each city. The highest construction cost belongs, orderly, to the rural office buildings built in Nicosia (339,500 YTL), Iskele (220,220 YTL), Kyrenia (115,405 YTL) and Morphou (105,000YTL). According to Table 4-2, there are no office buildings in rural areas of Famagusta. Although there are 2 office buildings built in the rural area of Iskele and Kyrenia and 1 in rural area of Nicosia, the construction cost for one office in rural area of Nicosia is much higher than construction cost of office buildings in rural area of Iskele and Kyrenia.

Table 5: 2006 Urban Public Building Statistics in TRNC (TRNC SPO)

Building type A: Number of Buildings C: Value (YTL)		Total	Nicosia	Famagusta	Kyrenia	Morphou	Iskele
Offices	A	37	25	7	4	1	-
	B	10,643,046	8,868,442	804,733	926,370	105,000	-

Comparing the number of office buildings in urban scale, in year 2006, the highest number belongs, orderly, to Nicosia which is 25, Famagusta which is 7, Kyrenia which is 4, Morphou which is 1 and none for Iskele. Comparison of construction cost for urban public building shows that the highest construction cost belongs, orderly, to Nicosia (8,868,442 YTL), Kyrenia (926,370 YTL), and Famagusta (804,733 YTL). Although the number of office buildings built in urban scale in Famagusta is more than the ones built in Kyrenia, the construction cost of the ones in Kyrenia is more than the construction cost for the ones in Famagusta.

Table 4-4: 2006 Rural Office Buildings Statistics in TRNC (TRNC SPO)

Building type A: Number of Buildings C: Value (YTL)		Total	Nicosia	Famagusta	Kyrenia	Morphou	Iskele
Offices	A	12	4	-	8	-	-
	B	4,431,750	741,560	-	3,690,190	-	-

According to the record of the number of office buildings built in rural scale in year 2006, the highest number belongs, orderly, to Kyrenia which is 8, then Nicosia which is 4. As shown in Table 4-4, there are no office buildings built in rural areas of Famagusta, Morphou and Iskele, in year 2006. Construction cost of the office buildings built in Nicosia (741,560 YTL) is much higher than the construction cost of the office buildings built in Kyrenia (3,690,190 YTL).

As discussed in Tables 4-1, 4-2, 4-3, 4-4, and according to TRNC SPO, mostly the office buildings are the building types, after apartment blocks and villa houses, having highest construction rate in NC. According to the observations, some of these office buildings have large scale GF systems and they are mostly located in Nicosia and some in Kyrenia.

Due to growing number of constructions explained above, in NC, there have been social environmental damages such as social costs, and loss in natural resources (Yorucu and Keles, 2007. In: Hoskara, 2009: 56). LSGFCOB have had individual private, and in some case public market. According to the interviews, there are no rules and regulations in construction sector in NC about usage of specific material or systems in the facade of office buildings and no limitations and restrictions for amount of using glass in the facade of these buildings. Similarly, there are no rules and regulations for considering sustainable principles in not only office buildings, but all type of buildings.

On the whole, developments in LSCOB employing GF system are based on clients and users desire as well as private construction sector preference in NC.

4.4 Affect of Socio-cultural Factors on Architectural Identity (ArI) of Facades in NC

Socio-cultural issue is a wide topic to be discussed. However, this study focuses on socio-cultural factors in terms of ArI and AA of building facades. In terms of AI of facade types and systems in NC, as long as DSGF systems are mostly used for LSCOB, they will have different expression due to their function and facade systems. According to the observations and interviews, although some of the buildings in NC have the identity of traditional and historical facade types such as Ottoman, and Venetian facade style, recently commercial buildings, mainly office buildings, banks, hospitals and some educational buildings in NC, are called “modern buildings” (by local people and stakeholders) due to their GS systems.

4.4.1 Historical Background

Since ancient time social and cultural factors of a region, which can change through time, have had influences on AI. Önal, (1997) mentioned that architecture is a subset of culture (Önal, 1997. In: O.Türker, 2002: 34) and according to Özlem Olgac Türker, (2002) the cultural aspects affect the formation of the architectural environment in many different ways, so the reflection of these affects and cultural ideas of the society influence the architectural environment (O. Türker, 2002: 35). People’s life style and living environment changes and develops according to their culture which includes their religion, their needs, and the society which they live in and also the government and political condition. This means that changes in culture can affect the architecture and thus the facade design of the buildings as well as building form and architectural details, building size and proportion, building plan and special arrangements, and construction techniques. For example, religion and beliefs, as well as climate condition, can affect the orientation and size/type of the openings on the facade. According to Önal (1997) there is a possibility of seeing different physical/ architectural characteristics in buildings for 2 separate regions but located in the same country or geographical land with same climatic condition. These differences can be seen in terms of cultural environment as well (Önal 1997. In:

O.Türker 2002: (Onal, 1997). These developments and changes are mainly because of demand of a more comfortable living space and this demand is the most important factor affecting the buildings. The influences of changes in socio-cultural factors have had impacts on building's facades as well as building planning which can be observed clearly in NC in traditional and conventional buildings more than contemporary and so-called "modern" ones.

As Hifsiye Pulhan said in her PhD thesis, "*the island of Cyprus has been the home of people from different cultural backgrounds for ages. Traces of this multi-cultural social structure are still found in the built environment.*" (Pulhan, 2002: 94). Ibrahim Numan and Özgur Dinçyürek mentioned that because of strategic location of Cyprus many different societies were always coming and settling in the island. These societies were mainly from Gothic to Ottoman and British Colonial cultures (Numan, and Dinçyürek, n.d: 1-3). According to Hill G, (1972) different rulers and societies living in the island had been primarily Phoenicians, Egyptians, Assyrians, Persians, Helens, Romans, Byzantines, Arabs, Frankish, Genovese, Venetians, Ottomans, the British and religious men and merchants with their families and followers (Hill, 1972. In: Numan, and Dinçyürek, n.d: 2). During this period Architectural development of the island had contribution of Roman, Egyptian, Hellenistic, Roman, Islamic, Byzantine, Lusignan, Gothic, Renaissance, Frankish, Italian nobles, Ottoman Turkish and British Colonial Styles (Numan, and Dinçyürek, n.d: 2). This multi-cultural society, because of differences in their needs, religion, has brought many different architectural solutions for various buildings and their facade systems, in different regions of NC, over the years. These happened for offices and administrative buildings as public buildings, as well as houses as private buildings (See Figure 4-11). Sometimes these architectural solutions were adding some parts, elements or opening to the façade of the buildings which were built by the previous societies living in the island. Example of this can be the transformation of Armenian Church and Monastery, built during Lusignans, to a Kindergarten in Ottoman period (See Figure 4-12).

Figure 4-11: Traditinal Facade Style in NC: Venetian Palace, located in walled city, Famagusta, NC (left). The building was built by local stones and materials, by venetians on the ruins of a palace built by the Lusignans (URL 57). Post Office Building located in Nicosia, NC (right). The building was built by British. After the establishment of the republic of Cyprus in 1960, the post office was moved, and the building had several uses, including at one time that of a Radio station (URL 58).

Figure 4-12: Armenian Church and Monastery, located in Nicosia, at the border of NC and South Cyprus. The building is Gothic in style built during Lusignan for the Lusignan King, Henry II. In Ottoman period a small bell tower was added on the north eastern wall, and convent buildings were constructed north of the church (URL 59).

During the period of all these societies and architectural identities/styles, available material and construction techniques have had major influences on designing the buildings. During the history, in NC, local materials were the only alternative for designing and building the buildings, however materials for religious, royal, municipal or other monumental buildings could be transport in bulk by shipping to the island. For instance, buildings during Venetians times in Cyprus were mainly made of local stones with small rectangular or arched opening on the facade.

The other example, as the privacy was important in traditional buildings during religion periods, can be the buildings during Ottomans which had Jumba, serving as a covered balcony, in front facade for privacy and traditional Turkish houses having courtyards served for purpose of privacy, beside its other functions (see Figure 4-13).

Figure 4-13: Historical Facades in NC: a) Jumba on building's facade during Ottoman period, Nicosia, NC (URL 60); b & c) Traditional Turkish house with Gothic and Lusignan style, during Ottoman period, Nicosia, NC (URL 61).

As Özlem Olgac Türker (2002) described, traditional materials and techniques, compared to contemporary materials and techniques, had many affects on buildings and their facades such as limiting the wall heights; ordered span of floors and roofs; which led to modular coordination and thus restriction of size/type of the opening on the facades. Beside all these traditional architecture insists on the importance of human scale (Ö. Turker, 2002: 32-33). During any period of history in NC, with any ArI, architects and engineers designed the buildings according to the available materials, construction techniques, and knowledge, so that the AI of the region in that period of time could be defined.

4.4.2 Contemporary AI of Facades in NC

Over time, with the emergence of invention of new materials, people’s way of living and their needs, buildings, cities and countries had to undergo through occurred changes. Due to Modern Movement, current architecture and architects, designers, planners, facade designers, structural designer, urban designers, etc. have been influenced. For a very long time, old buildings and cities were replaced by new ones and so ground level has got higher and higher. On the other hand, social and technological changes were the other facts that architects and designers were challenged with. By the emergence of Modern movement, new and modern buildings, similar to each other, were constructed mainly by concrete, metal and recently with glass, with less traditional values (Oktay, 1996: 32).

Recent construction and facade types in NC are usually made of reinforced concrete. In last 15 years, Aluminum and GF also have been appearing in facade design. The example of these buildings can be seen in the Table 12. All these buildings were not comfortable and suitable enough for climate condition of NC. The designs of these contemporary buildings mostly did not take into account the environmental condition of NC. Another important noticeable factor beside environment condition, is the social and AI of the buildings in small scale, and the cities in larger scale.

Influences of the impacts of Modern movement on buildings in NC have been expressed by the pioneer domestic architects who graduated from universities in NC such as EMU, GAU, CIU, NEU, LIU as well as from other international universities, and have come back to their country to practice their architectural profession. By new design ideas and methods, the new modern work style and lifestyle was imitated to the both society and AI (essentially in terms of facade design) of the cities (specially in Nicosia and Kyrenia and rarely in Famagusta) representing the modernism principles, but not sustainable principles yet, in architecture in worldwide scale. Because of these changes, lifestyle and desires of the community got affected and modified in different aspects as well as buildings function, construction materials and technologies. Among these changes, developments in construction materials and technologies are much more obvious due to recent buildings with reinforced concrete, GF and aluminum claddings. Among these materials, reinforced concrete (according to the observations) are the most preferred ones but GF has gained a "modern" value, the more pleasant AA, and it enhances the prestige to its owner and, in larger scale, to the city and the country. At the same time it has higher cost, less availability and lack of traditional values. GF systems are nowadays both preferred and not preferred by the domestic stakeholders and it strongly depends on demand of investors, building owners and users. By these preferences, traditional buildings and traditional facades mostly are left aside. But, there are still many users and owners desiring their old traditional architectural style.

In social point of view, because of these changes and because GF systems are used for LSGFCOB, the opportunity of participation for the occupants in social environment has been reduced. But it should not be forgotten that such activities and participations differ by variety of individuals with same locality and cultural identity.

4.5 Observation Results: Analysis of Existing large scale GF Systems in NC

Information regarding existing observed LSGFCOB in NC is categorized according to area m^2 of the facade, from the largest to the smallest, and presented in Table 4-5. According to Table 4-5, the largest GF belongs to the Hospital of Near East University, located in Near East University Campus in Nicosia. The building, in total, has 12000 m^2 glazed facade, covering 38 m height, including 8 floors. The stakeholders of the building are from KAM-TEK Yapı ve Kaplama Sistemleri Company in Nicosia, NC. The building has GCW system with cold mirror coated and low emisivity glass type. The size of the glass panels is 1*1.80. The support structure for the facade is aluminum framing system and the glazing units are double glazing. Ventilation of the building is by central heating and cooling system. There are vertical shading devices on the East and West facades but there is no shading device on the south facade (see Figure 4-15). There are open-able parts on the facade for the aim of maintenance and ventilation. The approximate construction cost for per m^2 of the glazed facade is about 180 GBP.

Figure 4-14: View of Yakin Doğu Hastanesi

The next building is Lefkoşa Türk Belediyesi (located in Nicosia) which is 1130 m^2 and the stakeholders of this building are also KAM-TEK Yapı ve Kaplama Sistemleri Company in Nicosia, NC. This building has GCW system employing cold mirror coated glass and tempered glass with sizes of 0.80*1 m and 0.80* 0.80 m with double glazing system. The GF is facing north (see Figure 4-15). Support structure of the GF is aluminum framing, which is covering 17m height, including 6 floors. Ventilation of the building is by AC system. The openings on the facade are for the aim of maintenance, NV, ND, and view for the building and occupants. The GF is not equipped with any shading device and this is because of its orientation towards North. The approximate price of per m^2 the GF is 140 GBP.

Building's info	Height of the building & floors	Orientation of the Glazed Facade	Type of facade system	Facade Support Structure	Glass type/size	Glazing type	Ventilation system	Shading device	Function of the Openings	GF m^2	Construction Cost of glass façade per m^2
1) Yakin Doğu Hastanesi Location: N.E.U, Nicosia	36 m 8 floors	Facing East, West, South	GCWS	AFS	CMCG. Low-E/ 1*1.80	DG	CHCS	Yes	M&V	~ 12000 m^2	~ 180GBP
2) Name: Lefkoşa Türk Belediyesi Location: Nicosia	17 m 6 floors	Facing North	GCWS	AFS	CMCG.TG/ 0.80*1 m CMCG.TG/ 0.80* 0.80 m	DG	ACS CHCS	No	M& V	~ 1130 m^2	~ 140 GBP
3)Name: Eziç Restaurant Location: Girne	5 m & 7.5 m 2 floors	Facing North, North West, and East	GCWS	GFSS & SSBS AFS	TG/2.80*2.50 m	SG	ACS	No	N.O	~707 m^2	~ 180 GBP ~ 215 GBP
4) Name: Golden Tulip Hotel Location: Nicosia	30 m 12 floors	Facing South	GCS	AFS	CMCG.TG/ 0.60* 0.60 m	DG	ACS & CHCS	No	M& V	~ 435 m^2	~ 150 GBP
5) Name: Milli Eğitim Gençlik ve Spor Bakanlığı Location: Nicosia	26 m 8 floors	Facing North	GCWS	AFS	BTG –TG/1 *0.80 m	DG	ACS	No	M& V	~ 300 m^2	~ 140 GBP
6) CIU, Sport Center Location: Nicosia Road	8 m 2 floors	Facing West , South, and East	GCWS	AFS & SBSS & STS	TG/1*0.80 m	DG	ACS	No	N.O	~ 300 m^2	~ 150 GBP
7)Name: GAU Location: Girne	10 m 3 floors	Facing East	GCWS	AFS	CMCG.TG/0.80*0.80 m & 0.80*1.60 m	DG	ACS CHCS	No	M& V	~ 285 m^2	~150 GBP
8)Name: Selin Tourism Location: Girne	14 m 4 floors	Facing South	SGFS	SC & Ch S with PSCT	TG LTG	SG & DG –PFGS	ACS	No	M&V	~ 280 m^2	~ 257.14 GBP
9) CIU, Super Market Location: Nicosia Road	10.50 m 2 floors	Facing North East and South East	GCWS	AFS & STS	TG/1.60 *0.80 m	DG – AF + SGS	CHCS	Yes	N.O	~ 180 m^2	~ 140 GBP
10) Name: Limason Türk Kooperatif Bankasi LTD. Location: Nicosia	16 m 6 floors	Facing North	GCWS	AFS	BTG –TG/1 *0.80 m	DG	ACS	No	M& V	~ 180 m^2	~ 140 GBP
11) Name: Saray Aliminyum Location: Nicosia	9.50 m 2 floors	Facing South and East	GCWS	AFS	BTG –TG/1.20 *0.80 m	DG	ACS	No	N.O	~ 180 m^2	~ 140 GBP
12) Name: Kaner Group of Companies Location: Nicosia	16 m 6 floors	Facing South, East, and West	GCWS	SBSS	BTG.TG/ 0.80* 1.20 m	SG -SSBGS	ACS	Yes	M& V	~ 155 m^2	~ 140 GBP
13) Name: Atakom Ulker Location: Nicosia	10 m 2 floors	Facing South, South East, and South West	GCWS	AFS	BTG.TG/ 0.80*1 m	DG –SSBGS	ACS CHCS	No	M& V	~ 150 m^2	~ 140 GBP
14)Name: Credit West Bank ltd Location: Nicosia	42 m 8 floors	Facing North, East, West, South	GCWS	AFS	BTG –TG/1.20*1 m	DG	ACS CHCS	No	M&V	~ 150 m^2	~140 GBP
15)Name: Ofton Location: Girne	9.5 m 3+ half floor	Facing North	GCS	AFS & Ch. S	LTG -TG/2.80*1.5 m BTG–TG/0.70*1.5 m	SG – PFGS–DG	ACS	No	N.O	~ 125 m^2	~ 175 GBP

Table 4-5: Analysis of Existing GF Buildings in NC

-AF= Aluminum Framing System	-CMCG= Cold Mirror Coated Glass	-GCWS= Glass Curtain Wall System	-M= Maintenance	-SBSS= Steel Bracing Support System	-SSBS= Structural Silicone-Bonded Glazing System
-ACS= Air Conditioning System	-Ch S= Chrome Spider	-GFSS= Glass Fin Supported System	-N.O= No Openning	-SC= Steel Cable	-STS= Support Truss System
-ACS= Aluminum Cladding System	-DG= Double Glazing	- GCS= Glass Cladding System	-PFGS= Point Fixing Glazing System	-SG= Single Glazing	-TG= Tempered Glass
-BTG= Body Tinted Glass	-DSFS= Double Skin Façade System	-LTG= Laminated Tempered Glass	- PSCT= Pre-Stressed Cable Truss	-SGFS= Suspended Glass Façade System	-V= Ventilation
-CHCS= Central Heating & Cooling System	-FG= Float Glass	-Low-E= Low Emissivity Glass			

Figure 4-15: View of Lefkoşa Türk Belediyesi Building

The next building with large GF is Eziç Restaurant (located in Kyrenia). Total GF area is about 710 m2. The stakeholder of the building is a company from Istanbul, Turkey. The type of facade of this building is GCW system which has glass fin supported system, with aluminum framing and structural silicone bonded system, in different parts of the building (see Figure 4-16). The facade is facing North, North West and East, covering 7.5 m in one part of the building and 5 m in another part of the building. The building has 2 floors. Type of glass used in the facade is tempered glass with the size of 80*2.50 m, with single glazing. There are no openings and no shading devices on the facade and the ventilation of the building is by central heating and cooling system. The approximate price for per m2 of the GF is between 180 GBP and 215 GBP.

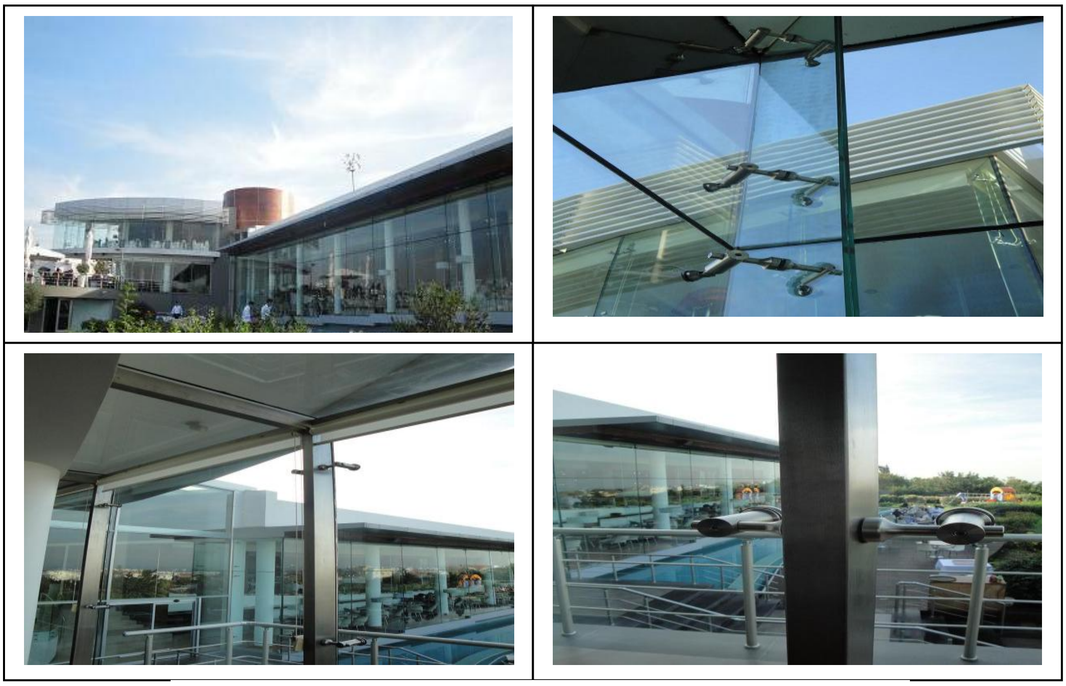


Figure 4-16: View of Eziç Restaurant Building

The next rank belongs to the facade of Golden Tulip Hotel (located in Nicosia) with area of about $435m^2$, oriented towards south. As shown in Table 12, facade type of this building is glass cladding System supported by aluminum framing system. Stakeholder of this building is also a company from Istanbul, Turkey. Type of glass used in this facade is cold mirror coated glass and tempered glass with the size of 0.60* 0.60 m and with double glazing system and, covering 30m building height including 12 floors (see Figure 4-17). Ventilation of the building is by AC system, and central heating and cooling system. There are no shading devices on the facade and the purpose of the openings is for maintenance, NV, ND, and view. Approximate price for per m^2 of this facade is 150 GBP. Although coating method is used for the glass panels of the facade of Golden Tulip Hotel to reduce the income solar radiation, but due to the direction of the facade (facing south) and climate condition of NC, amount of solar transition into the buildings is high and there is need of shading devices, but since the glass panes are used just for the purpose of cladding, there is no need of shading devices.

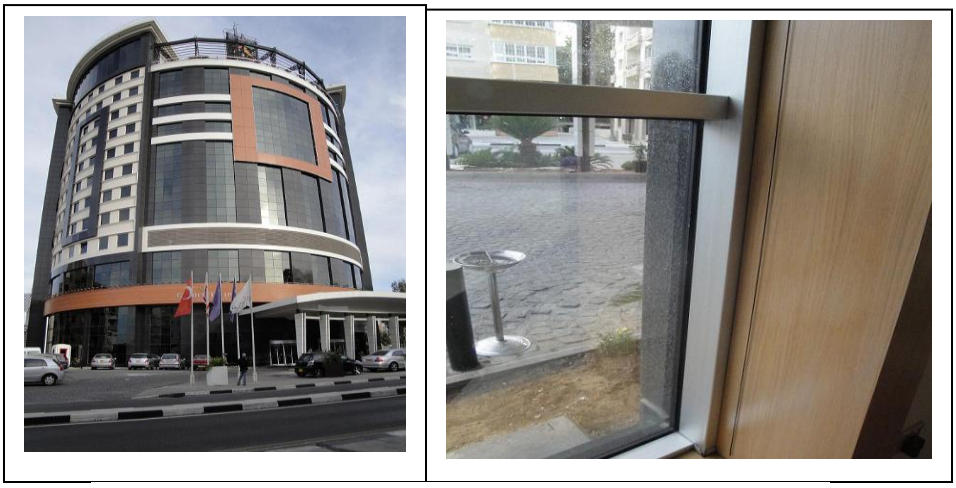


Figure 4-17: View of Golden Tulip Hotel Building

As shown in Table 4-5, the next building is Milli Eğitim Gençlik ve Spor Bakanlığı (located in Nicosia). The building has GCW system, facing south, covering 26m height, including 8 floors (see Figure 4-18). The GF is supported by aluminum framing system and has opening for purpose of maintenance, NV, ND, and view. The total area of the GF is 300 m^2 and there are no shading devices on the facade, because by using tempered and body tinted glass panels, with double glazing system, with the size of 1 *0.80 m, and the orientation of the facade towards north, the solar radiation is controlled. The ventilation of the building is by AC system. The approximate price of per m^2 of the GF is 135 GBP.

Figure 4-18: K.K.T.C Milli Eğitim Gençlik ve Spor Bakanlığı

The next buildings is Sport Center of CIU (located in Nicosia Road) having 300 m^2 area of GCW system, covering 8m height, including 2 floors. The building is constructed by Levent Construction Company in Nicosia. The facade is facing West, South and East, without openings. There are no shading devices on the facade and this can cause overheating in the interior spaces during the hot seasons (see Figure 4-19). The GF is supported by aluminum framing system and steel bracing support system. Type of glass panels are tempered glass with the size of 1*0.80 m and with double glazing. Ventilation of the building is by central heating and cooling. Approximate construction cost for per m^2 of the GF is about 150 GBP.

The next building, as shown in Table 12, is GAU (located in Kyrenia) with GCW system with the area of 285 m^2, covering 10m height, including 3 floors. The facade is oriented towards East and has opening with the purpose of maintenance, NV, ND and view (see Figure 4-20). Although the facade is facing East and South directions, there are no shading devices on the facade.

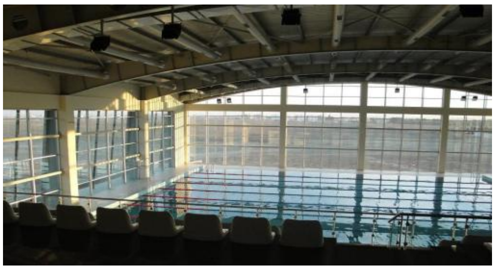


Figure 4-20: View of CIU, Sport Center Building

The type of glass panels is tempered and cold mirror coating glass, with double glazing system, and with the sizes of 0.80*0.80 m and 0.80*1.60 m, which can barely control the solar radiation penetrating into the building. Ventilation of the building is by AC and central heating and cooling systems. The approximate price for per m^2 of the GF is about 150 GBP.

Figure 4-21: View of GAU Building

The next building is Selin Tourism (located in Kyrenia) having suspended GF system with the area of 280m^2 covering 14m height, including 4 floors. The facade system is designed by Arch-line Company in Kyrenia, NC. Support structures of the facade are steel cables and chrome spiders with pre-stressed cable truss system (see Figure 4-21). Although the facade is oriented towards South, there are no shading devices on the facade; the type of glass panels are tempered glass and laminated tempered glass, but they are not enough for controlling solar transition into the building and these can cause the problem of overheating of the interior spaces. Ventilation of this building is by AC system and the function of the openings is for maintenance, NV, ND, and view. The approximate construction cost for per m^2 of the GF is about 257.14 GBP.

Figure 4-22View of Selin Tourism Building

The next building is the Super Market of CIU (located in Nicosia Road). Construction Company of this building is also Levent Construction Company in Nicosia. The building has GCW system with the total area of 180 m^2 covering 10.50 m height, including 2 floors. The GF is facing North East and South East (see Figure 4-22). Support structure of the facade is aluminum framing system and support truss system. There are shading devices on the facade which controls the solar radiation penetrating into the building. There are no openings on the facade and ventilation of the building is by central heating and cooling system. Approximate construction cost of per m^2 of the facade is about 140 GBP.

Figure 4-0-23: View of CIU, Super Market Building

As shown in Table 4-5, the next building is Limason Türk Kooperatif Bankasi LTD. The building is built by Korman Construction Company in Famagusta. This building has GCW system with the total area of 180 m^2 covering 16m height, including 6 floors. The GF is oriented towards North and there is no need for having shading devices on the facade (see Figure 4-23). The openings on the facade are used for maintenance and NV of the interior spaces. Support structure of the GF is aluminum framing system. The type of glass panels are body tinted and tempered glass with size of 1 *0.80 m and with double glazing system. The building is equipped by AC system for the purpose of ventilation. Approximate construction cost for per m^2 of the GF is about 140 GBP.

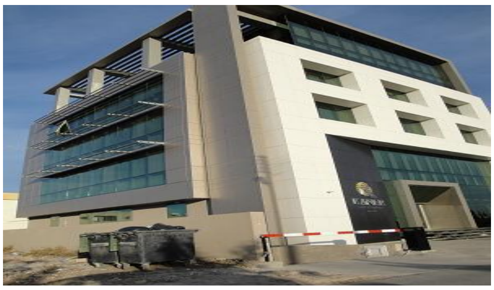
Figure 4-24: View of Limason Türk Kooperatif Bankasi LTD Building

Figure 4-25: View of Saray Aliminyum LTD Building

The next building is Saray Aluminum (located in Nicosia) having GCW system with the total area of 180 m^2 covering 9.50 m height, including 2 floors. The facade is facing South and East without opening and shading device (see Figure 4-24). Support structure of the facade is aluminum framing system. The type of the glass used in the facade is tempered and body tinted glass with double glazing system. Ventilation of the building is by AC system. Approximate construction cost for per m^2 of the GF is about 140 GBP.

As shown in Table 4-5, the next building is Kaner Group of Companies (located in Nicosia) which is 155 m^2 and the stakeholder of this building is the company itself. This building has GCW System employing body tinted Glass and tempered glass with sizes of 0.80*1.20 m, with double Glazing and single glazing. The GF is facing South, East and West support structures of the GF are in East and West facade, aluminum framing system and in South facade structural silicone-bonded system (see Figure 4-25). The GF covers 16m height, including 6 floors. Ventilation of the building is by AC system. The openings in the facade are for the aim of maintenance and NV of the building. The GF is equipped with horizontal shading device on the East and West side which instead should be equipped with vertical shading devices on the East and west direction. There is no shading device on the south facade which receives the maximum solar radiation. The approximate price of per m^2 the GF is 145 GBP.

Figure 4-26: View of Kaner Group of Companies Building



The next building in the table is Atakom Ulker (located in Kyrenia). Total GF area is about 150 m^2. The facade of this building has GCW system with aluminum framing and structural silicone bonded system, in different parts of the building (see Figure 4-26). The facade is facing South, South West and South East covering 10m height building including 2 stories. Type of glass used in the facade is body tinted glass and tempered glass with the size of 0.80*1 m, with double glazing. Although the facade is towards South which gains maximum solar radiation, there are no shading devices on the facade. The openings on the facade are for the purpose of maintenance and NV. The ventilation of the building is by central heating and cooling system. The approximate price for per m^2 of the GF is 140 GBP.

Figure 4-27: View of Atakom Ulker Building

As shown in Table 4-5, the next building is Credit West Bank Ltd (located in Nicosia) having 150 m^2 area of GCW system covering 42m height, including 8 floors. The building is constructed by a Turkish construction company. The facade is facing North, West, South and East. There are no shading devices on the facade and the openings are for the aim of maintenance and natural air ventilating of the building (see Figure 4-27). The GF is supported by aluminum framing system. Type of glass panels are body tinted and tempered glass with the size of 1.20*1 m and with double glazing. Ventilation of the building is by AC system and central heating and cooling system. Approximate construction cost for per m^2 of the GF is about 140 GBP.

Figure 4-0-28: View of Credit West Bank ltd Building

The next building is Ofton building which is built by Arch-Line Company in Kyrenia. The building has glass cladding system with the total area of 125 m^2, covering 9.5 m height, including 3 and half floors. The GF is oriented towards North and there is no need for having shading devices on the facade (see Figure 4-28). There are no openings on the facade. Support structure of the GF is aluminum framing system. The type of glass panels are body tinted, tempered, and laminated tempered glass with the size of 2.80*1.5 m and 0.70*1.5 m, with single and double glazing and point fixing glazing systems. The building is equipped by AC system for the purpose of NV. Approximate construction cost for per m^2 of the GF is about 175 GBP.

Figure 4-29: View of Ofton Builing

4.6 Analysis of Interview results

This section presents interview results which are categorized according to dimensions of sustainability (EnD, EcD, SD).

4.6.1 The Use of Wide GF Systems for Commercial and Office Buildings (COB) in NC

Among the interviewees, 78% (18 out of 23) of the interviewees, including architects, engineers, suppliers, users, and owners reported that they prefer to use Wide GF Systems because:

1) They are modern cladding facade system, and they make the work easier in terms of design and installation

2) They last long, and they have less maintenance cost in long-term use which can refund the construction cost partially

3) They are not complex and it’s easy to select materials for them, and they provide flexibility for designing interior spaces

4) They have better resistance against humidity which is high in NC

5) They have good AA which advertises construction companies

6) They provide more ND light for inner spaces

7) They require proper technical design and appropriate direction for the facade and the use of these systems depend on the project.

Out of 78%, 21% (5 out of 18) of the participants, including architects and suppliers, added that for NC they should be used with shading devises. In addition, out of 78%, 8% (2 out of 18) participants, who were architects, owners, and users, said that these systems give positive feeling to people and occupants and increase the productivity of users. The example is Sport center of Cyprus International University (CIU). However, 13% out of 78% (3 out of 18) said that these systems are flexible to be designed for any type of climate. Moreover, 17% (4 out of 23) of the participants, who were architects and owners, reported that they do not prefer using wide GF systems in NC because of the following reasons: 1) hot climate of NC, 2) high reflection of the sun into the building, 3) high construction cost.

4.6.2 Problems of Using Wide GF Systems in NC

In terms of EnD, to avoid problems:

- 34% (8 out of 23) of interviewees, who were architects, engineers and suppliers, said that there is need of selection of the right direction and material for the facade.
- 21% (5 out of 23) of interviewees, who were architects, engineers and suppliers, said that there is need of controlled insulation and day lighting.
- 17% (4 out of 23) of interviewees, who were architects and engineers, said that there is need of qualified techniques.

Problems mentioned by the interviewees are:

- 47% (11 out of 23) of the interviewees, who were architects and users, said that they cause heat loss and heat gain.
- 21% (5 out of 23) of the interviewees, who were architects and users, said that they cause extra sunshine into the building.
- 4% (1 out of 23) of the interviewees, who were architects, said that the cause dirt on the facade due to weather conditions (rain, dust).
- 17% (4 out of 23) of the interviewees, who were suppliers, engineers and architects, said that they cause penetration of water to the building if not designed properly.
- 4% (1 out of 23) of the interviewees, who was an architect, said that, these systems are usually less feasible and harder to do passive control environmentally.

In terms of EcD:

- 65% (15 out of 23) of the interviewees, who were architects, owners and users, said that these systems have high construction cost and electricity consumption.
- 4% (1 out of 23) of the interviewees, who was an owner, said that they have cleaning cost and problems.

In addition, 13% (3 out of 23) of the interviewees, who were architects and suppliers, claimed that these systems do not cause problem for heat loss and heat gain.

In terms of SD:

- 34% (8 out of 23) of the interviewees, who were architects, suppliers, owners and users, claimed that these systems are suitable for NC because there is no architecture identity.

- 21% (5 out of 23) of the interviewees, who were architects and owners, claimed that, these systems are suitable to be used in city centers (5).
- 21% (5 out of 23) of the interviewees, who were architects and suppliers, claimed that these systems are applicable for any type of building (residential and commercial).
- 4% (1 out of 23) of the interviewees, who was an architect, said that there is problem of access to good quality material and workmanship of these systems for NC.

Additional opinions related to the question 1 in the interview:

Asaf Özkara (architect/supplier in KAM-TEK Yapı ve Kaplama Sistemleri), said that there is a need to aware people about EE of wide GF systems by applying right insulation. Balkiz Ozdemir (architect and Chair of the Department of Archietcture, GAU), and Zeynep Onur (Architect of GAU), stated that "*since this type of design is not my choice, I would not know any of the problems this system might prevail in design*".

4.6.3 Awareness of Sustainability in GF System in NC

In general terms, 78% (18 out of 23) of the participants, who were architects, suppliers and owners have awareness about the sustainability of GF. The remaining 22% of the participants are not aware of the sustainability of GF.

In terms of EnD:

- 26% (6 out of 23) of the interviewees, who were architects and suppliers, said that SGFs need less maintenance.
- 21% (5 out of 23) of the interviewees, who were architects and owners, said that GFs are not sustainable.

- 30% (7 out of 23) of the interviewees, who were architects and suppliers, said that SGF systems provide AI.
- 65% (15 out of 23) of the interviewees, who were architects and suppliers, said that SGFs provide ThC.
- 8% (2 out of 23) of the interviewees, who were an architects and a supplier, said that GF systems are sustainable.
- 34% (8 out of 23) of the interviewees, who were architects and suppliers, said that SGF systems use natural resources.
- 52% (12 out of 23) of the interviewees, who were architects, suppliers and owners, said that SGF systems are long lasting.

In terms of EcD:

- 60% (14 out of 23) of the interviewees, who were architects, engineers and suppliers, said that SGF systems are economical.

In addition, 17% (4 out of 23) of the interviewees, who were architects and suppliers, do not have knowledge about economical dimension of sustainability in GF systems.

In terms of SD:

- 4% (1 out of 23) of the interviewees, who was an architect, do not have knowledge about SD of sustainability in GF systems.
- 39% (9 out of 23) of the interviewees, who were architects, suppliers and owners, said that SGF systems are feasible in different types of architectural contexts.
- 17% (4 out of 23) of the interviewees, who were architects and suppliers, said that SGF systems are not applicable in all architectural contexts.

In addition, Ali Kamaci (the owner of KAM-TEK Yapı ve Kaplama Sistemleri), mentioned that all types of GF systems are sustainable because around the world, especially Europe, GF systems widely. Therefore, it is surely sustainable for all types of climates within all sustainability dimensions. Apart from this, Ali Kodan and Emine Azimli (head architects in City Planning Council of NC), claimed that all types of GF systems are sustainable because they have completely different design, concept and technique. They are modern type of design and every country/every architect/every engineer should improve towards modern movement. Only in NC the only usage of natural resource is the solar radiation for domestic hot water. However, Fevzi Özersay (architect of CIU Sport Center building), said that "*I do not think a glass facade is by nature sustainable*". He also added that "*even if we can convince the customers to the benefits and long term feasibility of such material, the initial cost and economy is becoming the main reason why they cannot be used.*"

Another additional opinion by Ekrem Bodamyalizade (head architect in Chamber of Architect in NC) was that, GF systems are not sustainable for NC because of CCand problems of maintenance, supplying, and availability of the material.

Besides, Tanju Gultekin (Head of Architecture dept, Lefke University) said that, the glass itself is not sustainable because it does not consist of many natural ingredients. If GF is assembled by aluminum framing it is sustainable due to recycle of aluminum. Natural resources are used in NC in conventional facade systems even without having GF systems.

Furthermore, Hasan Dincer (civil engineer of Supermarket building and Sport Center of CIU) reported that, in order to save energy, natural energy resources should be used in GF systems. It was highlighted by Huseyin Tazaoglu (Manager of City Planning and Construction Council in NC) that, GF systems have advantage of short time of installation and construction. However, Burhan Atun (Architect of Credit West Bank) claimed that, in NC wide GF systems can be used and sunlight can be easily controlled by shading devices.

4.6.4 Knowledge about DSGF Systems in NC

Among interviewees, 56% (13 out of 23), who were architects, engineers, and suppliers, have knowledge about DSGF systems; 30% (7 out of 23), who were architects and suppliers, have lack of technical knowledge; and 26 % (6 out of 23), who were architects and suppliers, do not have knowledge about this system. Specifically, Aziz Elagoz (Civil Engineer and contractor for Limasol Bank) claimed that, he has knowledge about ThP of DSGF systems.

In addition, Senal Sarper (head architect in City Planning and Construction Council in NC) said that, in economical terms it seems difficult to apply the DSGF systems. Furthermore, DSGF systems are completely environmental friendly and ecological facade systems, but it is difficult to make it feasible for governmental projects in NC. On the other hand, Ekrem Bodamyalizade (head architect in Chamber of Architect in NC) claimed that, these systems are not economical and sustainable for NC, however, Murat Muratoglu (Contractor for CIU Supermarket and Sport Center buildings) claimed that, although DSGF systems have high construction cost, they are much more feasible and sustainable for NC than GF systems which have spider systems, high level of heat loss and heat gain. Simirarly, Burhan Atun (Architect of Credit West Bank) claimed that, DSGF systems have very good ThP and NV performance. He also stated that, both in residential and commercial buildings minimum amount of energy should be used. As it can be seen in traditional building, for instance, in NC, English people had used bricks or natural stones in the buildings located in Lefkoşa. DSGF systems are very good for energy saving concept.

4.6.5 Preferences and Reasons of Using DSGF Systems in NC

Among the interviewees, 60% (14 out of 23), who were architects, engineers, and suppliers, stated that they prefer to use DSGF systems in NC because of its advantages in terms of EnD. In addition, 26% (6 out of 22) of the interviewees, reported that they do not prefer to use DSGF systems in NC.

In terms of EnD:

- 86% (20 out of 23) of the interviewees, who were architects, engineers, and suppliers, said that DSGF systems have good AA.
- 56% (13 out of 23) of the interviewees, who were architects and suppliers, said that DSGF systems provide AI.
- 56% (13 out of 23) of the interviewees, who were architects, engineers, and suppliers, said that DSGF systems use natural resources.
- 56% (13 out of 23) of the interviewees, who were architects and suppliers, said that DSGF systems provide ThC;
- 56% (13 out of 23) of the interviewees, who were architects, engineers, and suppliers, said that DSGF systems are long lasting.

In terms of EcD:

- 52% (12 out of 23) of the interviewees, who were architects, engineers, and owners, said that DSGF systems are not economical.
- 65% (15 out of 23) of the interviewees, who were architects, engineers, and suppliers, said that DSGF systems have less maintenance cost.
- 21% (5 out of 23) of the interviewees, who were architects and suppliers, said that DSGF systems are economical.

In terms of SD:

- 60% (14 out of 23) of the interviewees, who were architects, engineers, suppliers, and owners, said that DSGF systems are suitable for ArI in NC.
- 13% (3 out of 23) of the interviewees, who were architects, said that DSGF systems are not suitable for ArI in NC.

The related comment is by Fevzi Özersay (architect of CIU Sport Center building), who claimed that, "*there are very limited number of buildings we (and the potential of Cyprus) have found appropriate to use glass facade. Also, there are very limited numbers of companies importing, supplying and installing proper glass façade and DSGFs materials. As a designer, we are usually restricted with the materials available in the island. When these are imported as special materials and systems, opposed to the materials and systems already existing in North Cyprus, they tend to cost more than the usual portfolio materials available. Even the installation of these systems could become a problem due to the lack of proper workmanship and qualified installation teams. Turkey has been a good source for these materials and workmanship but even the use of these companies has proved to be more expensive due to travel expenses of materials and qualified workers.*"

In addition, 21% (5 out of 23) of the interviewees, who were architects and suppliers, stated that their preference of DSGF systems depends on the customers' desire. However, 39% (9 out of 23) of the interviewees, who were architects, engineers, and suppliers, stated that although the first construction cost of these systems is high, in the long term use the cost can be refund by its energy saving performance.

When interviewees were additionally asked whether they offer DSGF systems to their customers:

- 4% (1 out of 23) of the interviewees, who were architects and suppliers, stated that they offered DSGF systems to their customers, however they rejected.
- 17% (4 out of 23) of the interviewees, who were architects and suppliers, did not offer DSGF systems to their customers because of lack of technical knowledge and high cost of these systems in NC.

4.6.6 Future Intention/Strategy for Using DSGF Systems in NC

The interviewees provided different responses about their future intention/strategy for using DSGF systems in NC.

The interviewees reported that they expect different kinds of support from government to develop DSGF systems in NC as listed below:

- 60% (3 out of 5) of the interviewees, who were architects, stated that they prefer DSGF systems to be developed and used in NC with the help of government.
- 60% (3 out of 5) of the interviewees, who were architects and engineers, reported that the technical knowledge of this system should be announced to the stakeholder in this field as a law.
- 40% (2 out of 5) of the interviewees, who were architects, reported that because the cost of this system is high for economical condition in NC, it can become feasible by time, in future. However, if the cost of this system can be reduced to a lower price, close to the cost of conventional GF systems in NC, it would be affordable.

- Heads of the Department of Architecture in 5 main universities, 50% (3 out of 6), do not have any intention or strategy for development of this system in NC.
- 20% (1 out of 5) of the interviewees, who was an architect, does not have any intention or strategy for development of this system in NC.

However, strategies and intentions were given mostly by the interviewees who were architects. Fevzi Özersay (architect of CIU Sport Center building) said that, "*to be honest, I haven't had such an intention or strategy till now. Unless I know more about the system and unless there is a local or international supplier/installer introducing these to us, it will be a matter of chance to use it. But, now that I have been questioned about it, I will probably look into it sooner than expected.*"

- 8% (1 out of 12) of the interviewees, who was an architect, reported that there is no any future intention and strategy related to the use of this system in NC.
- 25% (3 out of 12) of the interviewees, who were architects and engineers, reported that technical construction details, materials and financial support should be provided by the government.
- 33% (4 out of 12) of the interviewees, who were architects and suppliers, reported that they strongly support the use of these systems. There should be seminars and conferences in hotels or other public places offered by government in order to introduce these systems to stakeholders and to highlight their advantages and disadvantages.
- 16% (2 out of 12) of the interviewees, who were architects and suppliers, reported that not much is expected from the government and if there is a chance to develop this system in NC it will be by private construction

companies. However, if the governmental buildings such as Lefkoşa Türk Belediyesi could employe this system, it would be a very good example for the stakeholders.

- 16% (2 out of 12) of the interviewees, who were suppliers, reported that there is an expectation from the governmental sectors to provide log-term financial credit with low interest rate for stakeholders to construct this system. Furthermore, the government should encourage the private construction companies to build these systems.
- 8% (1 out of 12) of the interviewees, who was an architect, reported that if these systems and any other factors for buildings, which support energy saving and use of natural resources concept, are confirmed as a law for the stakeholders by the government in NC, the stakeholders will have to consider using this system and related factors to energy saving and use of natural resources concept.
- 16% (2 out of 12) of the interviewees, who were an architect and a supplier, reported using this system, in which the DSGF systems has one skin with glass and the second skin is aluminum cladding, has already started in NC, but due to its high cost, it is not feasible for all customers.
- 16% (2 out of 12) of the interviewees, who were suppliers, reported that the price for these systems is not fixed and it differs from project to project, but the average price for per m^2 of these systems is approximately 500 € in NC.

Chapter 5

CONCLUSION

In this study the appropriateness of DSGF systems for LSGFCOB, for NC, within the context of sustainability, has been evaluated. As the main aim was to evaluate the appropriateness of DSGF systems in terms of environmental, social, and economical dimensions, the main research question of this study was: Is DSGF systems appropriate for LSGFCOB, within the context of sustainability, in NC?

In order to answer this question, the following sub-questions have been answered in this thesis, to support the main research question:

- What are GF Systems?
- What is DSGF System?
- What is sustainability?
- What is the relation of GF system with sustainability and what is SGF system?
- What are the conditions of NC?
- What are the conditions of construction sector of NC?
- What types of GF systems are already used for LSGFCOB in NC?
- Evaluation of sustainability of GF systems in NC; what are the problems? Can DSGF system solve these problems?

These particular questions were asked in order to fill the gap concerning the appropriateness and use of DSGF systems, as SGF systems, for LSGFCOBin the case of NC. Furthermore, this study was a contribution to the knowledge of considering the usage of DSGF systems in NC.

By using the related literature in the field, observational and interview data, the analysis revealed the following conclusions.

The observation of the buildings in NC (15 analyzed LSGFCOB), have shown that the existing GF are GCW systems, with different glazing systems, such as single or double glazing, including different types of glass panels (mostly tempered, laminated, and tinted glasses), and with different support structure systems, such as aluminum framing, glass fin supported glazing, point fixing glazing, steel bracing support system, suspended glass system, structural silicone-bonded system, and support truss system.

Regarding the cost issue, the average cost of the existing GCW systems is about 150 GBP/ m^2, which can change according to materials used and meter square of the glazed facade. According to the owners of KAM-TEK Yapı ve Kaplama Sistemleri, and DAREM Trading Company, the estimated price for DSGF systems is approximately 415 GBP, if desired to be used, in LSGOCB, in NC. The given price is more than twice the price for existing GCW systems, which is quiet high price for stakeholders in NC.

DSGF systems have not been used in NC, the preference for using these systems have been mentioned by the stakeholders. However, due to the economical barriers which cause the lack of customer demand, the usage of these systems is restrained.

As for the EnD, as the evaluation results have shown, there seems to be a misapplication: some of the observed buildings used inappropriate shading device direction (horizontal instead of vertical), and in some other ones there is a need to use shading devices. Even though, using shading devices was offered and designed by the architects (for Credit West Bank building, and CIU Sport Center building), the owners neglected having the shading devices on the facades where it was necessary, due to additional cost. However, all these buildings were fully equipped with mechanical ventilation systems, which are high consumers of electricity. Evaluation results have also shown that, energy consumption for heating and cooling, in DSGF systems are less compared with existing GF systems in LSGCOB. Although DSGF systems provide better acoustical insulation for outside sounds, but there is need of detailed analysis regarding this issue for the case of NC. It can be suggested that with the use of DSGF systems in LSGCOB, in appropriate facade direction where it is necessary, there would be less electricity consumption. Considering the literature, it can be suggested that the appropriate type of DSGF system for LSGFCOB, for the facade towards South, can be multistory DSGF system in which the cavity is not divided and it has opening at the top and bottom of the facade. Shading devices, as solar collector panels with a size which will not block a large portion of the glazed facade, should be used on this facade. These devices can be opened and closed manually, during summer and winter according to the weather condition. In this case, DSGF system, with the help of shading devices, can provide ThC for most of the time during winter season. For summer seasons, it can provide some NV for the building, and help the reduction of cooling load. This idea is also supported by the literature reviewed.

Regarding the SD of sustainability of DSGF systems, it was reported by the stakeholders that these systems can be used in any area but preferably it is more appropriate in city centers than in historical regions of NC. Generally, as these systems are widely used in the world in different architectural contexts, they can also be used in NC. However, in every period of time, with the developments, innovations, improvements of technologies and materials, new types of facade systems were adopted to the buildings. Therefore, it can be said that, DSGF systems seem to be sustainable in terms of SD for LSGCOB in NC.

According to the stakeholders, who were architects and engineers, there were no limitations existing with regard to the use of DSGF systems in LSGCOB in NC. Moreover, most of the stakeholders, who were architects, engineers, suppliers, owners and users, required financial support as well as theoretical and technical guidance in the form of conferences.

Although theoretical knowledge is provided for the prospective architects by universities (EMU, GAU, CIU, NEU, LIU) in NC, there is a need for detailed technical knowledge about DSGF systems. In the words of one of the architects: "Architecture is Art, but a great part of it is Science".

In conclusion, since there is not enough demand, mainly because of the high cost, there is a barrier to develop the sector which will apply these kinds of DSGF systems. It is most likely that in the nearest future, due to the high cost and lack of customer demand in the market, these systems might not be sustainable to be applied in LSGFCOB. However, DSGF systems will be used in NC, eventually. For now, it can be recommended to use proper shading devices with careful design and selection of appropriate materials for the existing LSGFCOB.

As for the educational sector (universities), it can be recommended to teach the prospective architects about the technical knowledge of DSGF systems in order to gain awareness in using DSGF systems in future, in NC.

Although the government of NC has no restriction of using DSGF systems or any other type of GF systems in NC, there is a need of encouraging stakeholders by government, to use these systems for backing the worldwide demand of SC and SD.

4.1 Implications

This study is meant to serve as a resource for future GF projects within the context of sustainability for architects and designers in NC. In this research the existing GF systems in LSCOB are assessed in terms of sustainability, in order to attain more detailed knowledge of SGF systems, their performance, and to highlight the weak points of these systems which still require further improvement. Also, it attempts to suggest more possible solutions to improve the usage of SGF systems such as DSGF systems in NC.

Future studies can focus on the technical area of appropriate construction method of DSGF systems for the case of NC. Moreover, the scope of inquiry could be expanded by including more participants and buildings available in NC.

APPENDIXES

Appendix 1: Interview Questions

Q: Do You Prefer to Use Wide Glass Facade Systems for Large Scale Commercial and Office Buildings in North Cyprus? Why? (Ticari ve Ofis Binalarda geniş cam cephe sistemleri kullanmayı tercih ediyor musunuz? Neden?)

Q: According to your opinion, is there any problem to use wide glass façade systems? (Sizce geniş cam cephe sistemleri kullanmanın yaratacağı sorunlar var mıdır?)

Q: What Do You Know about Sustainability in Glass Facade? (Cam cephe sistemlerinin sürdürülebilirliği hakkında bilginiz var mı bu konuda ne düşünüyorsunuz?), (ekonomik, sosyal (estetik, mimari kimlik, kültürel değerler…)ve çevresel boyutu ile ilgili sorular da eklenecek)

Q: Do You Know Double Glass Skin Facade Systems? (Çift yüzeyli cephe sistemleri hakkında bilginiz var mı?)

Q: Do You Prefer to Use Double Skin Glass Facade System in North Cyprus? Why? (Çift yüzeyli cephe sistemlerini kullanmayı tercih eder misiniz Kuzey Kibrisda? Neden?)

Q: Do You Have an Intention / Strategy for Using Double Skin Facade Systems in North Cyprus? Why? (İlerde, çift yüzeyli cephe sistemlerinin kullanılması için bir niyetiniz veya stratejiniz var mı Kuzey Kibrisda? Neden?)

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