Mutah University
College of Graduate Studies

Managing the thermal impact of green walls on internal spaces of Aqaba buildings

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Dedication

to my first inspirer, my mother.. None of my achievements would have been possible without your motivation and inspiration

to the constant source of support and encouragement in my life, my great father.. You have taught me to work hard for the things I desire

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List of Abbreviations

ASEZA	Aqaba Special Economic Zone Authority
A1	Internal air of the plain room
A2	Internal air of the green room
ES1	External wall surface of the plain room
ES2	External wall surface of the green room
GF	Green façade
GR	Green room
Sig	statistical significance
IC0	In-between sub climate
IS1	Internal wall surface of the plain room
IS2	Internal wall surface of the green room
LAI	Leaf area index
OUT0	Outdoor ambient environment
PR	Plain room
PV System	Photovoltaic System
UHI	Urban heat island
VGS	Vertical greenery system
α	Alpha

Abstract

Managing the thermal impact of green walls on internal spaces of Aqaba buildings

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Green wall systems have been introduced around the world as a sustainable solution to reduce impact of urban heat islands and global warming. It is used to combat the hot environment within buildings, provide thermal comfort by improving the thermal efficiency of the building envelope, and as a result, lower building operating costs.

This study aims to find out whether green walls can be used to manage the inside thermal conditions of Aqaba buildings. It is intended to lessen the impact of Aqaba's harsh warm climate on internal building spaces achieving the thermal comfort level.

A physical live experiment was used to detect the thermal impact of green walls on internal spaces of Aqaba buildings. The researcher made a comparison between two identical real-scale test rooms. Both were built in the same way as local Aqaba buildings. One of test rooms had a green facade fixed, a free-standing structure where plants are to be climbed and fixed to the main wall. The external wall surface temperature, the internal wall surface temperature and internal air temperature and humidity have been being recorded during the hot summer for both rooms. The thermal performance of both rooms was compared by analyzing and assessing the observations. The data measurements were examined using Microsoft Excel and SPSS software.

The main conclusion demonstrated that green facades have a significant potential to promote buildings' thermal behavior in the hot summer in Aqaba achieving the thermal comfort level. It reduces the temperature of the internal air, the internal wall surface, and the external walls surface. It can be utilized as a passive system to minimize energy consumption in buildings.

الملخص

إدارة التأثير الحراري للجدران الخضراء على الفراغات الداخلية لمباني العقبة

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يتوجه العالم اليوم لاستخدام نظام الجدار الأخضر"Green Wall System" كحل مستدام لظاهرة الإحتباس الحراري وظاهرة الجزر الحرارية الحضرية التي تلازم المدن المكتظة، حيث يعالج هذا النظام البيئة الحرارية داخل المباني من خلال تعزيز كفاءة الأداء الحراري للمبنى لخفض تكاليف تشغيل المبنى.

تهدف الدراسة إلى معرفة ما إذا كان يمكن استخدام نظام الجدار الأخضر لإدارة الظروف الحرارية الداخلية لمباني العقبة، بالإضافة إلى تقليل تأثير المناخ شديد الحرارة لمدينة العقبة على الفراغات الداخلية للمباني وتحقيق مستوى الراحة الحرارية.

أجرت الباحثة تجربة حية واقعية في مدينة العقبة عن طريق بناء غرفتين متماثلتين تماماً بمقياس حقيقي في منطقة مفتوحة خالية من الأشجار والمباني للكشف عن التأثير الحراري لنظام الجدار الأخضر على الفراغات الداخلية لمباني العقبة. وقد تم بناء غرفتي اختبار متطابقتين بمقياس حقيقي بحيث تحاكي طريقة البناء المحلية، مع تثبيت شبك معدني على الواجهة الجنوبية الغربية لإحدى الغرفتين بحيث تنمو عليه نباتات متسلقة مكوّناً بذلك جداراً أخضراً لهذه التجربة. وباستخدام أجهزة خاصة تم تسجيل درجة حرارة سطح الجدار الخارجي ودرجة حرارة سطح الجدار الداخلي ودرجة حرارة ورطوبة الهواء الداخلي لكلا الغرفتين خلال أيام الصيف الحارة، بالإضافة لتسجيل درجة حرارة ورطوبة الهواء الخارجي في البيئة المحيطة، وبعد جمع البيانات من الموقع تمت مقارنة الأداء الحراري لكلا الغرفتين، وذلك من خلال تحليل هذه البيانات واختبارها وتقييمها باستخدام برمجيتي Microsoft Excel Software و SPSS Software.

توصلت الدراسة إلى أن الجدران الخضراء لديها إمكانات كبيرة لتعزيز السلوك الحراري للمباني في فصل الصيف الحار في مدينة العقبة لتحقيق مستوى الراحة الحرارية؛ حيث أنها تقلل من درجة حرارة الهواء في الفراغات الداخلية وكذلك تقلل درجة حرارة الجدار الداخلي والخارجي للواجهة الجنوبية غربية، وبالتالي يمكن استخدام هذا النظام لتقليل استهلاك الطاقة في المباني. كما بينت الدراسة أن تهوية الفراغات الداخلية يساعد في تعزيز قدرة الجدار الأخضر.

Chapter One
Introduction

1.1 Background

Large amounts of concrete, asphalt, buildings, pavements, and other solid surfaces have been built at the expense of green areas around the world as a result of fast population increase and urbanization. Thermal conductivity, heat capacity, and surface emissivity of the urban environment are all directly impacted by this modification. This ultimately enhances the urban heat island (UHI) and the effects of global warming (Wong et al., 2010). As a result, urban districts adopting sustainable design that incorporates greenery systems are being seriously explored as a green solution. Such examples include green walls, public gardens, and green roofs (Wong et al., 2009). Green walls or Vertical Gardening, commonly referred to as Vertical Greenery Systems (VGSs), is the structure where plants and vegetation are allowed to cover vertical structural components manually or naturally (Loh, S., 2008). These systems are installed on building facades, fences, or surrounding balconies in the exterior. However, inside buildings, they can be built as or internal walls, partitions or standalone bio sculptures (Wong et al., 2010).

Wong et al. (2010) asserted that the term "vertical greenery system" can refer to any method for utilizing plants to cover a building's façade. This system can often be classified into two categories: green façade and living wall which sometimes known as eco walls. Climber plants are typically utilized to create a green façade, using the building's façade as support where the plants climb up it (Wong et al., 2009). While the modern method tends to separate the vegetation from the building façade, it is possible that the main structure could experience issues if living objects are linked directly to a building's façade. In the green façade, the vegetation is planted at the base of the structure in the ground and grows vertically, covering the wall surface, whereas the growth medium is positioned vertically on the facade itself in the case of a living wall (Jaafar B. et al., 2013). According to the researcher, the verticality of green walls over other greenery systems gives architects additional possible areas and allows them to use vertical walls when horizontal land is limited.

When used at the building scale, green wall improves the building's energy efficiency and reduces the buildings' internal spaces and wall temperatures, which lowers the building's cooling capacity. Additionally, green wall produces an attractive, welcoming, motivating, and inspirational environment that enhances the psychological health of its inhabitants. They will feel a sense of loyalty and belonging, which increases output and productivity. Green wall primarily work as a passive system involving four mechanisms: the foliage's ability to cast shadows, the evaporative cooling provided by plants' evapotranspiration, the insulation created by the plant and substrate, and the wind-barrier impact (Pérez G, et al., 2011). Many factors influence building thermal efficiency and energy savings in terms of using the green wall in architectural spaces. Such factors are the classifications of green wall, the climate, the utilized plant type and the earlier mentioned mechanisms that operate the green wall.

Discussing the use of Vertical Greenery Systems to fight global warming, that gives us a suggestion for how to handle the harsh warm climate conditions of Aqaba. Aqaba has a desert climate since its summer is hot and dry and its winter is warm (weather spark, 2022). The internal spaces of Aqaba buildings are impacted by the hot climate and become warmer. The use of concrete blocks as the primary building material in Aqaba, where the walls have a high thermal conductivity, further complicates the situation and lowers the building's thermal efficiency. This means that it is challenging to achieve the "thermal comfort zone" in Aqaba buildings' internal spaces without artificial cooling systems on hot summer days. This study examines if green façade may considerably lower the temperature inside buildings in Aqaba using a live experiment and empirical comparison between two test real- scale rooms.

1.2 Research Problem

The harsh warm climate conditions of Aqaba force us to find a solution to reach the thermal comfort level in the internal spaces of the buildings and reduce the energy consumption in the buildings. On the other hand, the entire world tends to introduce the green wall as a sustainable solution to reduce the temperature significantly inside the buildings and make them more comfortable.

A lot of studies have proved that green facade system is an efficient solution in hot regions in general. But could it be considered as an efficient solution for Aqaba in particular?

This study aims to find out whether green facades can be used to manage the inside thermal conditions of Aqaba buildings by analyzing, assessing, and comparing the thermal performance between both buildings with and without green facades.

1.3 Research Importance

This study is significant because it demonstrates the thermal impact of green wall implementation as a preliminary phase, laying the groundwork for their widespread construction on buildings. As a result, the process can be managed and evaluated in the experimental phase rather than the actual application phase, which involves lesser risk, efforts, and mistakes. This research is the first step in identifying a green solution that may be used to address the hot environment within buildings, provide thermal comfort by enhancing the thermal efficiency of the building envelope, and consequently lower building operating costs.

Applying the concept of the study and establishing Aqaba's green wall system on a broad scale will green the city vertically and compensate for the lack of horizontal plant cover. That would definitely reduce the impact of urban heat island and produce an impressive urban setting. As a step toward transforming Aqaba into a green city, the study will also strongly persuade the relevant authorities to include a green wall system in the local building codes.

1.4 Research Objectives

This research is intended to achieve these main goals:

1. Reduce the temperature inside buildings during the summer at Aqaba using green facade system.
2. Determine if green facade could be an efficient thermal solution of high temperature in Aqaba.
3. Determine if ventilation affect the impact of green facades.
4. Persuade the relevant authorities to develop a regulation for green walls that includes a mandatory percentage of vertical greenery systems in local buildings, similar to the horizontal green percentage.

1.5 Research Hypotheses

The following hypotheses were developed in consideration of the problem and the research questions:

The first main hypothesis ($H_0$1) There is no statistically significant effect of green facades on the internal temperature and humidity of Aqaba buildings during the summer season-Period C at ($\alpha <0.05$) level. This hypothesis generates the following related hypotheses:

Hypothesis ($H_0$1.1) There is no statistically significant difference between the external wall surface temperature of Aqaba buildings and those with green facades during the summer season-Period C at ($\alpha <0.05$) level.

Hypothesis ($H_0$1.2) There is no statistically significant difference between the internal wall surface temperature of Aqaba buildings and those with green facades during the summer season-Period C at ($\alpha <0.05$) level.

Hypothesis ($H_0$1.3) There is no statistically significant difference between the air temperature inside Aqaba buildings and the air temperature inside those with green facades during the summer season-Period C at ($\alpha <0.05$) level.

Hypothesis ($H_0$1.4) There is no statistically significant difference between the air humidity inside Aqaba buildings and the air humidity inside those with green facades during the summer season-Period C at ($\alpha <0.05$) level.

Hypothesis ($H_0$1.5) states: There is no statistically significant difference between the temperature of the in-between sub-climate (between main wall and the green façade) of Aqaba buildings and the outdoor ambient temperature during summer season-Period C at (α <0.05) level.

Hypothesis ($H_0$1.6) states: There is no statistically significant difference between the humidity of the in-between sub-climate (between main wall and the green façade) of Aqaba buildings and the outdoor ambient humidity during summer season-Period C at (α <0.05) level.

The second hypothesis ($H_0$2) There is no statistically significant effect of green facades on the internal temperature and humidity of Aqaba buildings in the case of preventing buildings from ventilation during the summer season-Period D at (α <0.05) level. This hypothesis generates the following related hypotheses:

Hypothesis ($H_0$2.1) There is no statistically significant difference in the internal wall surface temperatures between Aqaba buildings and those with green facades in the case of preventing buildings from ventilation during the summer-Period D at (α <0.05) level.

Hypothesis ($H_0$2.2) There is no statistically significant difference between the air temperature inside Aqaba buildings and the air temperature inside those with green facades in the case of preventing buildings from ventilation during the summer season-Period D at (α <0.05) level.

Hypothesis ($H_0$2.3) There is no statistically significant difference between the air humidity inside Aqaba buildings and the air humidity inside those with green facades in the case of preventing buildings from ventilation during the summer season-Period D at ($\alpha \leq$0.05) level.

1.6 Research Limitations

The study had some difficulties and restrictions. The most significant to note are the following:

1. Time consuming growth of plants is a critical issue because the plants took a long time to fully cover the trellis of the green façade and an extended period were required. In addition, the plants became extremely sensitive in extreme temperatures and after they were relocated, causing them to overheat and die during the initial trials.
2. A long-term experiment of about a year requires a lot of effort, time, and money to keep all of the experiment conditions steady and under control, preventing any unexpected issues. It is necessary to make frequent visits to the experiment site.

   During several site visits, for example, devices were found to be fallen or the sensor was touching another surface. As a result, the researcher is forced to exclude the observations from that time period. Another issue was that once a day, the devices were discovered to be out of operation due to battery loss and external weather conditions, and all observations from that time period were lost.

3. Human mistake for instance, when watering the plants, the workers sometimes sprayed water over the exterior fixed devices and the green room's main façade. Unexpected observations resulted from this, forcing the researcher again to exclude the data from this time period.
4. Four walls and a roof, which are all exposed to external thermal factors including direct sunlight, warm ambient air, wind speed, and humidity, have a major impact on the internal air temperature. The green facade effect is minimized as a result of the huge heat gain in all of these surfaces. Compared to local buildings, which gain less heat because the majority of rooms in a building have one or two exposed surfaces. The roof also accumulates a huge amount of heat due to its perpendicular orientation to the sun in the summer.
5. There is a significant thermal leakage from the window and the door, indicating that their insulating properties are inadequate and that they reduce the effect of the green facade.

1.7 Thesis Layout

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Chapter Two
Literature Review and Theoretical Framework

2.1 Introduction

This section describes the literature review and theoretical foundation of the green wall system and its thermal impact when used in buildings. It is a sustainable strategy to promote the thermal performance of the building and reach the thermal comfort in hot climate. Figure 2.1 illustrates the problem of this research that affected the structure of the theoretical framework.

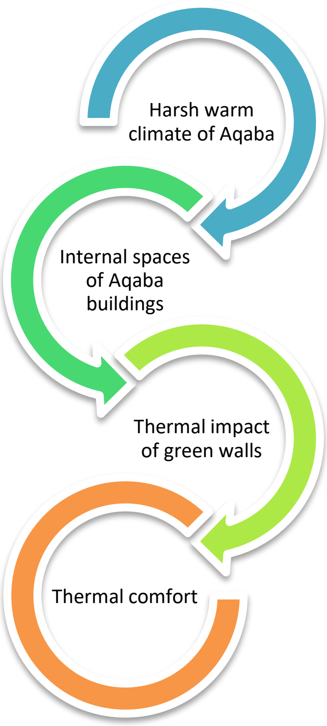


Figure 2.1
Managing the thermal performance of Aqaba buildings

2.2 Aqaba Climate

Climate is the beginning point for this research, as the research problem was caused by climate issues in Aqaba buildings. This section explains the climate characteristics of Aqaba.

Aqaba, which is located in the far southwest of Jordan on the Red Sea's Gulf of Aqaba (Britannica, 2022), is classified as BWh (arid; desert; hot arid) by the Koppen-Geiger climate classification (Kottek et al., 2006).

2.2.1 Temperature Averages

According to weatherspark website (2022), summers in Aqaba are long, hot, arid, and clear, while winters are cool, dry, and often clear. The temperature typically ranges from 10°C to 40°C throughout the year, rarely falling below 7°C or rising above 42°C. Figure 2.2 and table 2.1 illustrate the monthly high and low average temperature at Aqaba. Summer lasts four months, from May 23 to September 23, with daily high temperatures averaging more than 36°C. July is the hottest month in Aqaba, with average peaks of 39°C and valleys of 27°C. Winter lasts 3.1 months, from December 1 to March 4, with daily high temperatures averaging less than 24°C. January is the coldest month in Aqaba, with average lows of 10°C and peaks of 20°C. The sunrise is at its earliest on March 31 at 5:31 AM and its latest on October 27 at 6:49 AM, which is 1 hour, 18 minutes later. Figure 2.3 illustrates the hourly high and low average temperature at Aqaba. The sunset is at its earliest on December 1 at 4:40 PM and its latest on July 1 at 7:44 PM.

The year 2022 will see the implementation of DST (daylight saving time), which already has begun in Aqaba on Feb 25 and will finish on October 28 in the autumn.

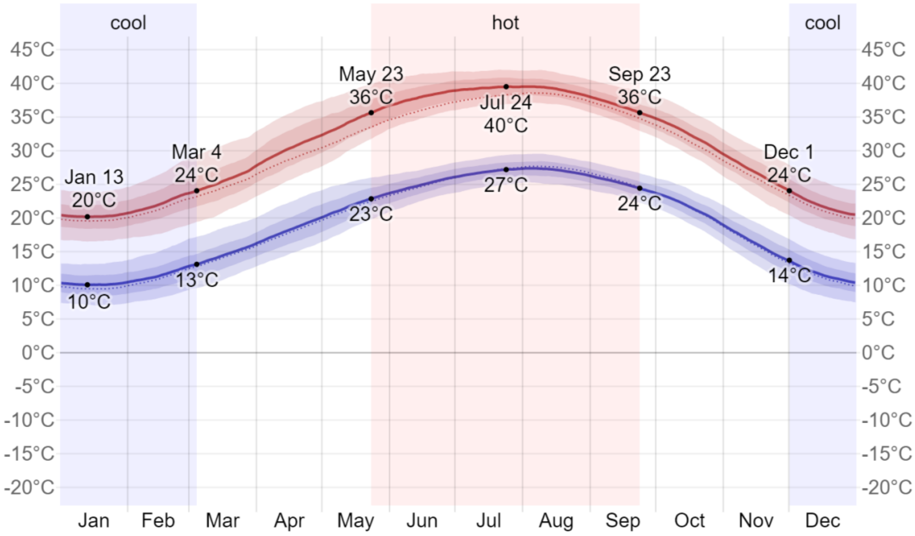


Figure 2.2
Monthly high and low average temperature at Aqaba (weatherspark, 2022)

Table 2.1
Monthly high and low average temperature at Aqaba (weatherspark, 2022)

Average	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
High	20°C	22°C	26°C	30°C	35°C	38°C	39°C	39°C	36°C	32°C	27°C	22°C
Temp.	15°C	17°C	20°C	24°C	29°C	32°C	33°C	33°C	31°C	27°C	21°C	16°C

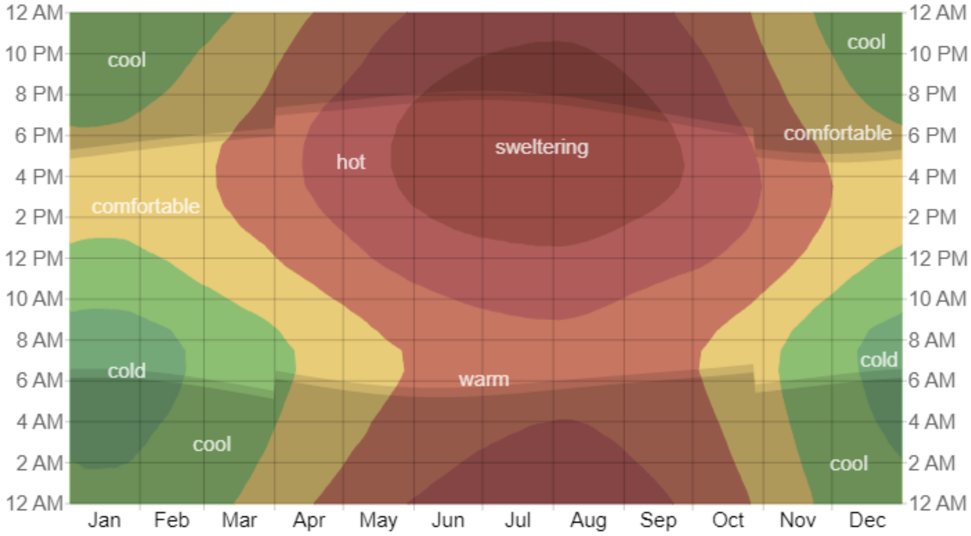


Figure 2.3

Hourly high and low average temperature at Aqaba (weatherspark, 2022)

2.2.2 Humidity

The dew point is used to determine whether perspiration evaporates from the skin, cooling the body which provides the humidity comfort level. Higher dew points feel more humid, while lower dew points feel drier. Unlike temperature, which drops at night, dew point varies slowly between night and day, and a muggy night usually follows a muggy day. August has the muggiest days in Aqaba, with four days classified as muggy or worse, and January has the fewest muggy days in Aqaba, with a total of zero muggy days (weatherspark, 2022). Figure 2.4 shows the comfort levels of humidity at Aqaba according to weatherspark, 2022.

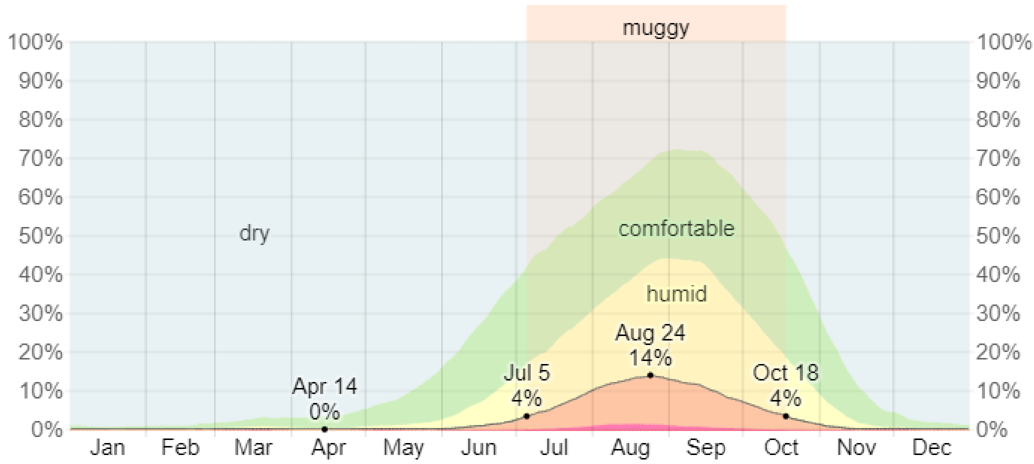


Figure 2.4

Comfort levels of humidity at Aqaba (weatherspark, 2022)

2.3 Internal Spaces of Aqaba Buildings

The internal spaces of Aqaba buildings are impacted by the hot climate and become warmer. The use of concrete blocks as the primary building material in Aqaba further complicates the situation. The concrete walls have a high thermal conductivity. This means that it is challenging to achieve the "thermal comfort zone" in Aqaba buildings' internal spaces without artificial cooling systems in summer days.

Buildings usually need a lot of energy on construction and operation (Radwan et al, 2015). In hot regions where the ambient temperature rises, cooling the building requires a significant amount of the building's operational energy (Satumane A., 2018). Aqaba is one of the cities with a high temperature. According to the researcher, it is difficult to live in Aqaba without employing artificial cooling systems in local buildings. In addition to the extreme heat, the principal building material, concrete, and the lack of insulation increase the conductivity of the envelope, lowering the building's thermal efficiency. The cost of cooling loads at Aqaba buildings is a source of concern for the general public. Jordan's energy costs are especially high. This scenario inspires the researcher to consider a green solution which is the first world solution to global warming and urban heat islands (UHI). Vertical greenery systems that concern with covering the facades of the building with vegetation are such examples (Satumane A., 2018).

2.4 Vertical Greenery Systems (Green Walls)

The vertical greenery system, which the researcher chose to call "Green Wall," is illustrated in this section. Its definition, history, benefits of application, types, energy saving factors, mechanisms and plant types and selection, all were described.

2.4.1 Definition of Vertical Greening System (Green Walls)

This part displays many researchers' definitions of the vertical greenery system (VGS).

VGS refers to the employment of plants to green vertical surfaces of a structure, such as walls, facades, partition walls, blind walls, and other surfaces, as well as the growing of plants on, up, and within a building's wall. VGS can be classified into three primary categories based on plant species, growing media, and method of construction. Wall-climbing, hanging-down, and module are the three categories of vertical greenery system (Tarboush O., 2019).

According to AA.VV. (2008), VGS is the common name for all types of vegetated wall surfaces. Wong et al. define VGS as any method of spreading plants on a building façade. Traditionally, these installations have used climber plants that grow directly on the main façade. These technologies, in a more modern manner, detach the plants from the main surface, minimizing any problems associated with integrating the building with living organisms. This requires the installation of support structures to enable successful development of plants across the façade surface. Achieving this goal, various designs have been evolved in recent years, resulting in various construction systems (Wong et al., 2010).

Like Tarboush O. (2019); AA.VV. (2008), and other studies, the researcher chose to refer to VGS as "Green Wall". In fact, the word is used by some researchers like Pérez G, et al. (2014), to refer to the living wall.

2.4.2 History of Green Walls

Green wall system is not a modern concept. The Hanging Gardens of Babylon, one of "The Original Seven Wonders of the World", are an early example of such systems. They were built around 600 BC. by the Chaldean King, Nebuchadnezzar (Wong et al., 2010).

Traditional green wall techniques have been employed since the Roman and Greek eras as well as the Babylonian Hanging Gardens. Vine was extensively utilized in Mediterranean regions to shade the building envelope, on building walls, or to cover pergolas, cooling the building duri ng the summer (AA.VV., 2008). Climbing plants have been used to cover building walls from the 17th and 18th centuries, primarily in the United Kingdom and Central Europe (Newton J. et al., 2007). Woody climbers were extensively used as aesthetic parts of building envelopes in European and North American communities in the nineteenth century (Dunnett N., and Kingsbury N., 2008). The first studies on green façade focused on botanical features (Kohler M., 2008). However, since the 1980s, another concept of green facades as contributors to city ecological enhancement has emerged. The garden city movement of the late nineteenth century saw the integrating of greening into urban planning. The German Jugendstil (Art Nouveau) movement of the early twentieth century advocated the merging of the house and the garden. Several incentive programs for the development of green façade occurred during this time period. Furthermore, Berlin is a noteworthy example, with approximately 245.584 m2 of green facades constructed between 1983 and 1997 (Kohler M., 2008).

2.4.3 Benefits of Green Walls Application in Architecture

Green walls have a lot of benefits in architectural applications. This part summarizes the primary advantages.

Green walls give significant economic, environmental, psychological, and social benefits for local citizens while also improving building structure (Radic et al., 2019). They improve the health of the environment by filtering dust from the air and providing fresh air by using carbon dioxide and returning oxygen through the photosynthesis process, minimizing the effects of "sick building syndrome" (Ambius, 2011). They also help to minimize noise levels in residential areas, along roadways, and between buildings. The green walls have been widely employed to enhance the aesthetic and pleasant qualities of buildings. However, with today's technology, the plants functional benefits to building performance may be maximized. The shade provided by plants and their ability to evapotranspiration control the building temperature. Consequently, vertical greenery systems reduce global warming and urban heat islands (Radic et al., 2019). Green walls reduce the building's cooling loads by lowering the wall and ambient temperatures, resulting in a noticeable reduction in the building's operating expenses (Wong et al., 2010).

2.4.4 Types of Green Walls

You may have become confused when researching the various types of green walls. There are numerous categories and subcategories. This section highlights and organizes the most common types.

The majority of classifications divide VGS into two major categories: green facades and living walls. Green facades focus on climbing plants that climb along the wall that covers it, whereas living walls support a range of plants and serve to generate consistent growth along the surface (Manso and Castro-Gomes, 2015). Figure 2.6 shows pictures of direct/ indirect green façade and continuous living wall. Pérez, G. et al. apply the same categories in their researches based on construction method, climate influence, plant species, and other operational processes, which will be mentioned later (Pérez G, et al., 2014). Figure 2.5 shows the basic classification as mentioned in (Manso and Castro-Gomes, 2015). Table 2.2 illustrates the categories and subcategories of this classification and set the advantage and disadvantages of each.

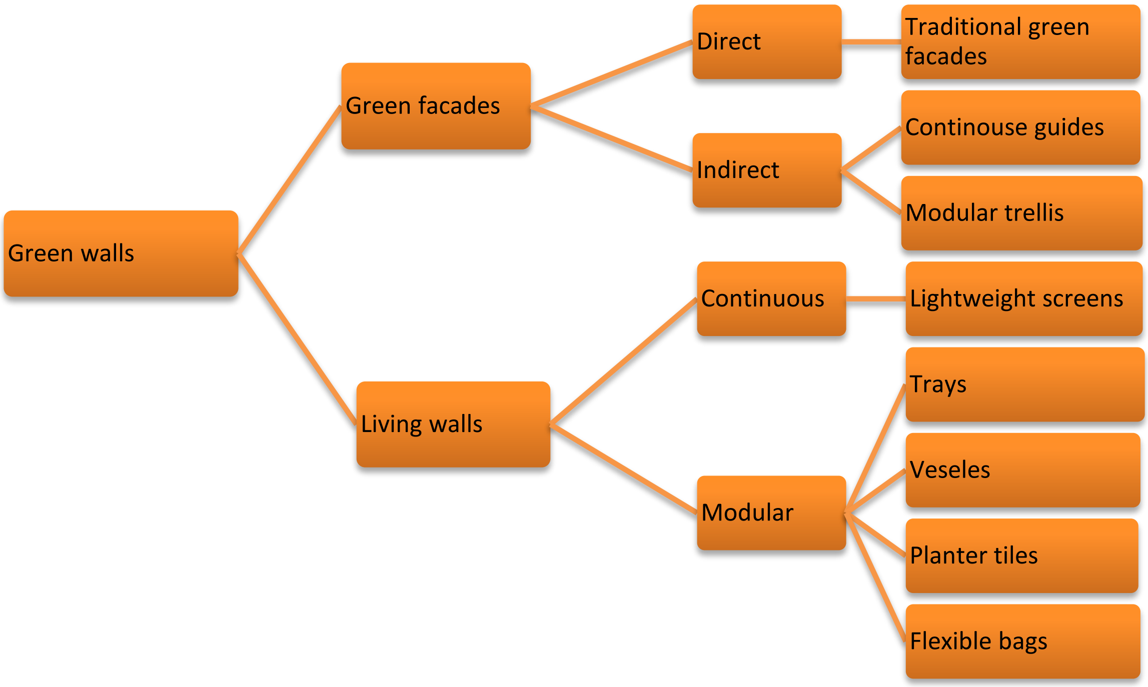
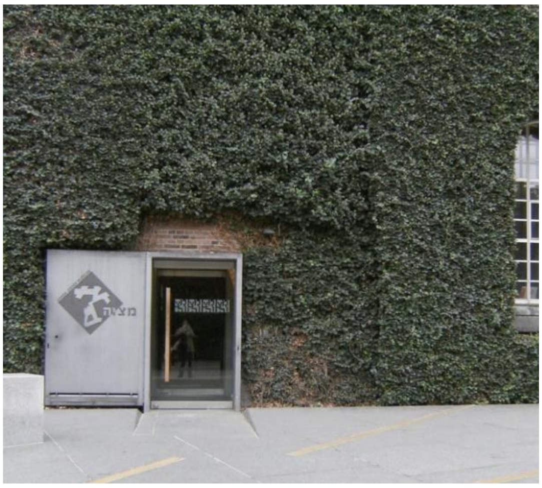
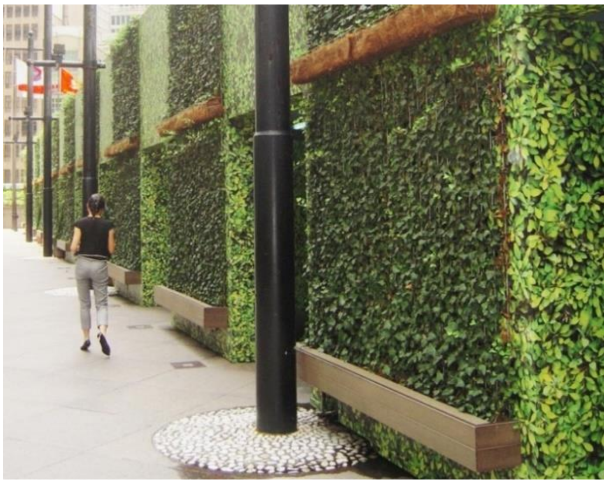


Figure 2.5
The classification of green wall systems (Manso and Castro-Gomes, 2015)

Table 2.2
The advantages and disadvantages of green wall systems (Manso and Castro-Gomes, 2015)

System	Category	Sub-category	Advantages	Disadvantages
Green facades	Direct greening	Traditional green facades	No materials involved (support, growing media, irrigation) Low environmental burden Low cost	Limited plant selection/climate adaptability Slow surface coverage Scattered growth along the surface Surface deterioration/plants detachment Maintenance problems
	Indirect greening	Continuous guides	Vegetation development guidance Low water consumption	Limited plant selection/climate Adaptability Slow surface coverage Scattered growth along the surface High environmental burden of some materials
		Modular trellis	Lightweight support Vegetation development guidance Controlled irrigation/drainage Easiness to assemble and disassemble for maintenance Plants replacement	Limited plant selection/climate adaptability High environmental burden of some materials High installation cost
Living walls	Continuous systems	Felt pockets vertical gardens	Uniform growth Flexible and lightweight Increased variety of plants/aesthetic potential Uniform water and nutrients distribution	Complex implementation High water and nutrients consumption Frequent maintenance Limited space for root development High installation cost
	Modular systems	Trays	Easily disassembled for maintenance Increased variety of plants/aesthetic potential Controlled irrigation/drainage	Complex implementation Heavier solutions Surface forms limited to trays dimensions High environmental burden of some materials High installation cost
		Planter tiles	Increased variety of plants/aesthetic potential Attractive design of modules	Complex implementation Limited space for root development Surface forms limited to tiles dimensions High installation cost
		Flexible bags	Adaptable to sloped surfaces Increased variety of plants/aesthetic potential	Complex implementation Heavier solutions due to growing media/ limited to buildings maximum load High installation cost


a)


b)


c)

Figure 2.6
a) Direct green façade b) Indirect green facade c) Continuous living wall (Manso and Castro-Gomes, 2015)

2.4.5 Green Façade

This research experiment used the green façade, which is a main type of green walls. This section is about its subtypes and installation.

The system of green façade consists of two main forms of plants, Climber plants that grow up on vertical surfaces, similar to traditional examples, and plants hanging along the wall that grow downward on vertical surfaces while suspended at a specific height (Kohler M., 2008). Green facades are divided into two types: direct and indirect. Plants grow immediately on the wall in direct green facades, like in traditional green facades, where they are planted directly in the ground at the structure base or in different heights pots of the façade. At indirect green facades the plants climbs and cover the wall, where a supporting structure is existed to support the plants, this supporting structure is fixed to the main structure forming a space between both structures and doubling the façade. This gives it the name of double-skin green façade or green curtain (Pérez G, et al., 2011). The goal of the supporting structure is to prevent the main wall from plant issues as a new development of the system (Perini *et al.*, 2013). Moreover, the support structure stabilizes the plants and prevents it from falling in areas where resistance to natural elements like as rainfall and wind is greater. On the other hand, Climbing plants in the direct green façade are generally not supported by the building wall, putting the plants at risk of falling (Elgizawy, 2016).

In double-skin green façade, modular trellises, wires, and mesh structures are implemented (Pérez G, et al., 2011). Modular trellises are relatively light metal trellis modules that are installed on the main wall or on separate structures and serve as climbing plant supports. In wired structures, the elements of steel cables, separators, anchorages, and others are used to create a light structure that acts as support for climbing plants. Mesh framework is a very light structure constructed of steel mesh fixed to the main wall or to the structure of the building that offers support for climbing plants (Pérez G, et al., 2011).

There is a third form of green façade mentioned in some studies which is a perimeter flowerpots (Figure 3), where hanging plants grow around the building help to create the façade composition forming a green curtain (Pérez G, et al., 2011).

Although the installation of climbers of green façade is highly cost-effective, this form of VGS has difficulties in maintaining vegetation sustainability. Guidance is required in some climbers during their growth to achieve maximum coverage of the surface. It is desirable to set the plants at various altitudes on the facade so that their load will distribute across the facade and damaged plants can be replaced. (Manso and Castro-Gomes, 2015; as cited at Tarboush O., 2019)

2.4.6 Energy Savings Factors

This section discusses the factors that affect the VGS role in managing the thermal efficiency.

Many factors influence building thermal efficiency and energy savings in terms of using the VGS in architectural spaces. They all have strong impact on temperature reduction. The first earlier-discussed factor is **the classifications** of VGS that describes how plants are positioned vertically and the construction type of the used system (Pérez G, et al., 2014). **The climate**, which is the second factor, is directly influences the thermal performance and indirectly influences the plant type selection and their growth. Climate, according to Zarandi and Pourmousa (2018), is the most important parameter in VGSs. Greening of surfaces aids in the absorption of more solar radiation, resulting in a greater reduction in temperature and thus, leading to significant savings (Zarandi and Pourmousa, 2018).

The third factor, that will be mentioned later, is the physical characteristics of **the utilized plants** and their types, whether they are deciduous or evergreen, climbers or shrubs, with high density of foliage or not and other characteristics that affect the volume of reduction in temperature.

The final aspect to take into account is **the mechanisms** of the next following section. These mechanisms operate the VGS and govern how it functions as means of reducing the amount of thermal energy (Pérez G, et al., 2014); (Radic et al., 2019).

Other plant related factor is the effect of **Leaf Area Index** (LAI). It is the leaf cross-sectional meter square area per meter square covered area is described as LAI, which is a dimensionless quantity. It is used to compare various plants' types utilized in green facades, to monitor the growth of plant and maturity, and to assess seasonal variance in energy savings (Pérez G, et al., 2017); (Pérez G, et al., 2022).

Wong et al. (2009) discovered a linear relationship between LAI and shading ratio for various VGSs. This indicates that higher LAI values can lead to better thermal performance at building. According to Bakhshoodeh et al., (2022), the external surface of a plant-covered wall becomes colder when LAI increases when compared to a direct exposed wall to solar radiation. Pérez G, et al. (2017), employed LAI of plants in a GF to evaluate the potential shadow impact, which is thought to be the most important measure for producing energy savings in buildings. They developed a simple method for assessing LAI and then matched it to the energy savings from GF (Pérez G, et al., 2022).

2.4.7 The Mechanisms of VGSs

Many studies mention the four mechanisms that operate the vertical greenery systems and make them act as passive energy-saving systems. These mechanisms include: the plants' shadow on building facades, the insulation from the plants' layer and substrate layer in the case of living wall, the evapotranspiration process that produced from plants and cools the temperatures, and the wind barrier effect (Pérez G, et al., 2011).

Most analyzed studies have shown that the shadow influence has the most significant impact on lowering the building wall temperature and, as a result, on the reduction of energy consumption that the plants provide solar radiation interception (Pérez G, et al., 2011). Similar results have been determined using simulations (Stec W.J, et al., 2004). However, it is obvious that it is difficult to determine the exact contribution of each mechanism in energy savings (Coma *et al.*, 2014).

According to some studies, the cooling impact is referred to as the evapotranspiration effect, while other studies consider shade and the evapotranspiration process to be the cooling effect. Regarding the cooling effect, it should be noted that the only factor that has a significant impact on the thermal behavior on a green facade is plant transpiration, not the evaporation from the substrate. Plant species type, the irrigation system (The greater the irrigation amount, the greater the transpiration ratio), and the façade orientation influence the transpiration effect (Pérez G, et al., 2014).

The insulation effect is determined by the insulation characteristics of the various layers, which varies based on the system's composition, including air in the vegetation layer, thickness and materials of the substrate layer (in the case of living wall), and other possible intermediary air layers, among others (Pérez G, et al., 2014).

Finally, the wind barrier effect, that reduces air velocity due to greenery, make a reduction in air infiltration between the interior and exterior and heat flux of a building, thus lowering energy consumption Saleh et al. 2017).

2.4.8 Plant Types and Selection

This part explains the earlier mentioned factor that affected energy savings in buildings in terms of using green wall systems.

The plants' type is an important parameter to consider regarding energy savings produced by VGS. The deferent systems utilizes different sorts of plants. In Green Façades it is common to utilize climbing plants whereas in living Walls herbaceous plants and shrubs are more frequent. As a result, plants for Green Façades might be evergreen or deciduous, but plants for living Walls are almost always evergreen. This may have a significant role in the thermal behavior of the façade. The facade will be affected in all periods of the year when using evergreen plants, but just the hot period when using deciduous plants because sun radiation passes through during the leafless period (Pérez G, et al., 2014).

When employing deciduous plants, however, solar gains effect in the building throughout spring and autumn must be considered. During the spring, different species' leaves grow at different times and at varying speeds, and not all plants lose their foliage at the same time and at the same speed rate during the autumn (Pérez G, et al. 2010).

Vegetation is affected by the previous factors mentioned regarding the energy savings in VGS, the system type, plant type and the climate. In addition Vegetation is affected also by the building characteristics where the VGS is applied, the surrounding conditions. All these factors play a role in the lifespan of the plant. In fact, climbing plants are the most common, they are cheap green solution. It can be, according to leaves type, evergreen or deciduous plants. Evergreen plants sustain their leaves during the year. Deciduous plants shed their leaves in the autumn, causing an optical shift throughout the year (Adams, 2009).

To achieve the sustainability goals of a greening system, local plants suitable to climatic circumstances and vegetation with low watering needs should be used (Inkmason, 2015).

Because the plants in an outdoor garden are frequently exposed to insects and pests, it is important to protect the vegetation and surrounding environment from them. Plants can live for a while if they are healthy, but they cannot be protected indefinitely. As a result, plants should be checked and examined on a regular schedule, and when necessary, pesticides should be used, with natural pesticides being preferred over chemical pesticides (Lush living walls, 2018).

VGS plants require a lot of water, so undrinkable water should be utilized for irrigation. Plant water demands are estimated based on plant type, plant density, and climate. Due to the environment and facade exposure to the sun, highly dense plants require a fast frequency watering at least during high-temperature seasons, if not all year. As a result, as much recycled water as possible should be used in irrigation. Water drainage system should be efficient in filtering the groundwater and the surface to protect the structural integrity of the structure, and the vegetation must not be adversely impacted by the rise in water (Loh S., 2008).

2.5 Thermal Comfort Zone

This research aims to manage and reduce the temperature inside the buildings of hot areas, and reach the thermal comfort zone. Li (2018), explains it as the state of mind in which an occupant is satisfied with the thermal conditions and feels at ease. It is measured by the range of climatic circumstances that would be thermally comfortable for the majority of people. It is the combination between humidity and temperature. Figure 2.7 illustrates the zone of thermal comfort.

It is challenging to achieve the "Thermal comfort zone" in Aqaba buildings without artificial cooling systems in the summer. However, this study is providing us a sustainable solution limiting the dependency on these systems.

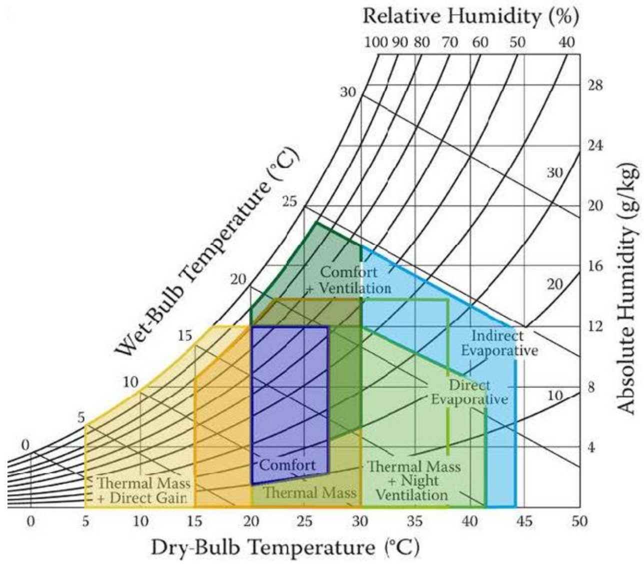


Figure 2.7
Thermal comfort zone (Li, 2018)

2.6 Previous Studies

Recent years have seen a rise in interest in the usage of vertical greenery systems as elements of sustainable green structures, and numerous studies have been carried out to assess the advantages of the VGS and how it can be utilized particularly to fight high temperatures in hot climates. Other researches explore the various types of VGSs and their classifications, definitions and characteristics. This section of the study covers important studies that are connected to the issue of the current study, and it was defined the purpose of each investigation, the methodology, and the most notable reached results.

Pérez et al., (2014), Spain, is one of the names that are now mentioned frequently in the field. The researchers in this group put a lot of effort into the field. Pérez et al. addressed certain important mechanisms when working with VGS, such as classification systems, the plants employed, climatic influence, and operation mechanism by reviewing the reviewed literature in the research: ***"Vertical Greenery Systems (VGS) for energy saving in buildings*****"**. It summarized the main conclusions of the reviewed literature such as the potential of the *VGS* in reducing energy, the distribution of the researches all over the world, the lack of heating periods researches and the aspects to be studied deeply; such as which species are best suited for each climate, air layer presence, how the orientation of the façade affects energy savings, the thickness of the foliage and finally in the case of green walls, the composition and thickness of the substrate layer. These results are based on wall construction type (green walls and green facades) and regional climate.

Radic et al., (2019), also did a scoping review study titled with **"*Green Facades and Living Walls—A Review Establishing the***

Classification of Construction Types and Mapping the Benefits", providing a construction-based classification consisting of nine kinds of living walls and four kinds of green facades and analyzing the environmental, educational, social, aesthetical, and economic benefits of them. The results showed that the most extensively empirically investigated benefit of VGS is thermal performance. However, there is a lack of some topics and methodologies, such as additional qualitative research, those on people's perceptions of thermal comfort, empirical evidence of the educational and social VGSs' benefits and finally empirical studies of noise reduction, better air quality, visual benefits and beneficial effects on hydrology, as the supporting data is primarily descriptive at this time and depending on the similarity between VGSs and green roofs.

For the field to develop, a particular VGS categorization method must be used, as well as additional qualitative and quantitative imperial investigations of the advantages. To allow cross-comparison of research, these tests should be formally linked to a certain VGS construction type.

In Portugal, 2015, a same methodology in another review study by Manso, and Castro-Gomes' ***"Green wall systems: A review of their characteristics"*** reviewed, examined, identified, and systematized the VGS characteristics and technology involved. That will help researchers to establish the main differences between them in terms of construction and composition. To promote the use of VGS in buildings, researchers must continue to assess their impact on buildings performance. Construction type, climatic constraints, and the environmental effect of VGS components and related expenses over their full lifespan must all be considered when selecting the kind of VGS.

There are a lot of studies which investigated empirically the thermal efficiency of the VGSs. A recently completed study by Jaradat N. et al. (2022), aimed to improve the shading and thermal performance of green walls on buildings in hot, dry areas. The research was carried out on a university campus using field experiment measurements and simulation in Jordan, the same country as the current study, titled ***"Optimizing Shading and Thermal Performances of Vertical Green Wall on Buildings in a Hot Arid Region"***, 2022.

Both study approaches, field experiment measurements and simulation, demonstrated that the thickness of the air cavity and the percentage of leaf covered had a significant influence on the performance of the green wall system. They also demonstrated that green wall could be used as an effective natural shading solution because they reduced outside wall surface temperatures by 6 to 11 degrees Celsius and the interior surface temperature of the investigated southern façade by an average of 5 degrees Celsius on different days as compared to the base case without a VGS.

In Spain, 2017, Coma et al.'s paper ***"Vertical greenery systems for energy savings in buildings: A comparative study between green walls and green facades"*** compares the thermal performance of green wall and green facade systems in experimental house-like cubicles for both cooling and heating periods on a real scale. In the first cubicle, a double-skin green facade made of deciduous creeper plants has been placed, while the second cubicle contains green walls made of evergreen species. Finally, as a reference, a third identical cubicle is used with no green coverage.

This group "the same Pérez et al. group that mentioned earlier" carried out the experiment was at a controlled internal ambient temperature, with heating and cooling provided as needed to ensure optimal comfort levels. To examine the thermal response of the building system, the house-like cubicles were tested once more in a free-floating condition, without any heating, ventilation, or air conditioning systems. In comparison to the reference system, the results showed that green walls (58.9%) and double-skin green facades (33.8%) had great potential for energy savings throughout the summer season. However, because of the thermal stability provided by the polyethylene modules, both systems deliver savings of up to 4.2% throughout the winter season.

In addition, *American Journal of Engineering Research* also published a research paper under a title of ***"Analysis of Possible Savings Impacts of Green Walls on Urban Dwellings in Bangladish"***. Saleh et al. (2017), aimed to study the saving energy efficiency on urban dwellings using green walls on Dhaka, Bangladesh during summer days. The authors estimate the evapotranspiration of the used plants by two analytical methods. The result shows that it could save energy consumption by 16% to 31% when using three sides green façade of a typical building canopy, while 64% to 100% could be saved if considering only energy consumed from ventilation and cooling.

Some academics investigate an essential parameter known as the Leaf Area Index (LAI) and its impact on building green facade performance. One of them is Convertino F.et al., (2022), aimed at determining the cooling effect of an evergreen, south-facing green facade in a Mediterranean environment throughout the summer and to see what occurs when the LAI varies. The cooling impact of the facade was calculated using experimental data where the relevant cooling effect was established by simulations with various LAI values were run. The outcomes of this study, ***"Effect of Leaf Area Index on Green Facade Thermal Performance in Buildings",*** can help to close gaps in the energy performance of green façade and the energy modeling of buildings with them.

The ***"Field measurement on the model of green facade systems and its effect to building indoor thermal comfort*** study by Widiastuti et al., (2020), was undertaken in a tropical country in 2020 to investigate the effect of green facade technology on building thermal comfort. Three experimental investigations using three types of green facade systems with varying leaf covering areas were mounted to the facade of a scaled building model in this investigation. The findings of the experiments showed that green facades can reduce building temperature. However, they raise relative humidity, resulting in poor indoor thermal comfort.

Various studies looked into the impact of each mechanism. Bakhshoodeh et al., (2022) from the University of Western Australia, Australia, conducted a similar study dubbed ***"Exploring the evapotranspirative cooling effect of a green façade"***, which established an experimental study comparing shade sails and GF to measure the relative impacts of shading and evapotranspiration.

The gap temperatures and the external wall behind the green façade were cooler than the gap and external wall behind the shade sail, demonstrating the efficiency of GF. The green façade's thermal advantages showed that they might successfully contribute to the building design sustainability and serve as an efficient, natural solution for the city-scale urban heat island effect and building energy use.

Jaafar B. et al. (2013), investigated the effect of vertical greenery on the thermal performance of building corridors using an experiment. Temperature, humidity & wind velocity were measured using specialized instruments for the experiment. This study - titled ***"Impact of Vertical Greenery System on Internal Building Corridors in the Tropics"*** revealed how VGSs significantly reduced energy consumption by reducing corridor temperature, and this reduction is even greater with higher air velocity. The study also revealed that a low temperature and high intermediate climate was created.

Green facades enhance the thermal performance of the envelope, allowing for energy savings for air conditioning. More research has been done on the GF's energy behavior during warm seasons than during cold ones. Therefore, the paper by Convertino F. *et al.*, (2022), ***"Thermal behaviour of green facades in winter climatic conditions"*** investigated GF's wintertime energy performance. The evaluations were made using experimental data from two green facades and a control bare wall under Mediterranean climatic conditions in Bari (Italy). Then a statistical and energy analyses were made to the data collected to assess the heating effect. The results demonstrated that GF improves winter thermal efficiency by minimizing energy losses at night.

The team from Universiti Teknologi Malaysia, Malaysia, conducted a small-scale experiment to simulate the actual conditions and challenges faced by various vertical greenery systems in tropical climes. Safikhani et al. (2014), conducted a study ***"Thermal Impacts of Vertical Greenery***

Systems" in order to better understand how vertical greenery systems operate thermally in hot and humid areas. In fact, this study inspires the researcher to conduct the ongoing investigation using an experimental methodology. The findings demonstrated that both systems lowered the temperature inside and on the outside. Additionally, they lower the temperature in the intermediary space. As a result, the living wall was more successful at lowering the temperature in hot areas.

2.6.1 Commentary on Previous Studies

Pérez, G. et al. (2014), Radic et al. (2019), Manso and Castro-Gomes (2015), and others performed their studies based on reviews of the literature in order to come to their conclusions. These studies gather, arrange, classify, and identify the literature's key characteristics. Additionally, it offers a base of classifications for the vertical greenery systems, assisting the researcher in selecting the appropriate classification. They also support comprehension of the current study's theoretical foundation.

Comparing to scoping review and simulation studies, the current study has an advantage. The field experimental studies provide academics with data for constructing and refining computer simulation programs, promoting the use of green wall systems in buildings.

Saleh et al. (2017), used analytical methods to examine how using green walls can save energy. This approach provides us with theoretical data as opposed to field experimental approaches that are adapted to the nature of organisms.

The evapotranspirative mechanism, one of the green wall mechanisms, was studied by Reza and Oldham in 2022. Since the data from such research is just partial, it cannot be directly used in energy calculations. In contrast, the data from the current research is comprehensive and realistic.

Convertino F. et al., (2022), studied the effect of Leaf Area Index on green facade thermal performance, which is a primary parameter. However, at the current study, it is focused on the difference between the room with green façade and without green façade.

Like the current research, Jaafar B. et al. (2013), and Convertino F. et al. (2022), studied the ability of a green façade to control heat transfer and maintain temperature level inside spaces. Jaafar B. et al. focused on corridors while the current research focused on real scale rooms. While Convertin F. et al. concentrated on the winter, the current research concentrated on the issue of extremely hot weather, which is causing people to suffer in Aqaba.

Safikhani et al. (2014) carried out an experimental study with a comparable goal, but the material used in the experiment was wood rather than concrete. Because the u-value of the local concrete buildings differs significantly from the u-value of the wood, using concrete in the experiment construction in Aqaba is more representative. Moreover, whereas the current study uses test rooms that are real scale, the Safikhani et al. experiment uses smaller test rooms. Both differences boost the reliability of the current research.

Coma et al. (2016); Jaradat N. et al. (2022); Widiastuti et al. (2020) and Safikhani et al. (2014), all have experimental studies, and all confirmed the ability of a green façade to lower temperatures and raise the humidity like the current research.

While the current study and Coma et al. study used test rooms, the experiment by Jaradat N. et al. (2022) was carried out in a student accommodation building. Even though the students were on vacation, test rooms are more specialized for this type of research because it is difficult to control how they are used in the lodging building.

Table 2.3 summarizes the main points of the previous studies.

Table 2.3
The summery of previous studies

Researcher name	Year	Research title	The aim	Methodology	Results
Pérez, G. et al.	2014	"Vertical Greenery Systems (VGS) for energy saving in buildings"	To summarize and organize the literature review in th1e field	Reviewing the reviewed literature	Asses a summary of main conclusions of the reviewed literature about the categories of the VGSs, the potential of the VGS in reducing energy, the distribution of the researches all over the world, the lack of heating periods researches and the aspects to be studied deeply in further studies.
Radic et al.	2019	"Green Facades and Living Walls—A Review Establishing the Classification of Construction Types and Mapping the Benefits"	To provide a construction-based classification of the VGSs and to map the benefits of them	A systematic scoping literature review	The study establishes a construction-based classification, assessed the benefits of the VGSs and evaluates the current situation of the field regarding the related literature and their methodologies identifying the lack of some methodologies and topics in the field.
Manso and Castro-Gomes	2015	"Green wall systems: A review of their characteristics"	To review all forms of VGSs in order to identify and categorize their key attributes and the technologies they include will help you establish the main differences between them in terms of construction and composition.	Scoping literature review	-To promote the use of VGS in buildings, researchers must continue to assess their impact on buildings performance. -Construction type, climatic constraints, and the environmental effect of VGS components and related expenses over their full lifespan must all be considered when selecting the kind of VGS.

……Continue

Researcher name	**Year**	**Research title**	**The aim**	**Methodology**	**Results**
Jaradat N. et al.	2022	"Optimizing Shading and Thermal Performances of Vertical Green Wall on Buildings in a Hot Arid Region"	To improve the shading and thermal performance of green walls on buildings in hot, dry areas.	Field experiment measurement and simulation method	The thickness of the air cavity and the percentage of leaf covered had a significant influence on the performance of the green wall system. They also demonstrated that green wall could be used as an effective natural shading solution because they reduced outside wall surface temperatures by 6 to 11 degrees Celsius and the interior surface temperature of the investigated southern façade by an average of 5 degrees Celsius compared to the base case of VGS.
Coma et al.	2016	"Vertical greenery systems for energy savings in buildings: A comparative study between green walls and green facades"	To Compare between the thermal performance of green wall and green facade systems	Experimental study	In comparison to the reference system, the results showed that green walls (58.9%) and double-skin green facades (33.8%) had great potential for energy savings throughout the summer season. However, because of the thermal stability provided by the polyethylene modules, both systems deliver savings of up to 4.2% throughout the winter season.
Saleh et al.	2017	"Analysis of Possible Savings Impacts of Green Walls on Urban Dwellings in Bangladish"	To study the saving energy efficiency on urban dwellings using green walls on Dhaka, Bangladesh during summer days.	Two analytical methods	It could save energy consumption by 16% to 31% when using three sides green façade of a typical building canopy, while 64% to 100% could be saved if considering only energy consumed from ventilation and cooling.
Convertino F. et al.	2022	“Effect of Leaf Area Index on Green Facade Thermal Performance in Buildings”	At determining the cooling effect of an evergreen south-facing GF in a Mediterranean environment throughout the summer and to see what occurs when the LAI varies.	Field experiment measurement and simulation method	The outcomes of this study can help to close gaps in the energy performance of green façade and the energy modeling of buildings with them.

……Continue

Researcher name	Year	Research title	The aim	Methodology	Results
Widiastuti et al.	2020	"Field measurement on the model of green facade systems and its effect to building indoor thermal comfort"	To investigate the effect of green facade technology on building thermal comfort.	Three experimental investigations	Green facades can reduce building temperature. However, they raise relative humidity, resulting in poor indoor thermal comfort.
Bakhshoodeh et al.	2022	"Exploring the evapotranspirative cooling effect of a green façade”	At comparing shade sails and GF to measure the relative impacts of shading and evapotranspiration	Experimental study	The gap temperatures and the external wall behind the green façade were cooler than the gap and external wall behind the shade sail, demonstrating the efficiency of GF.
Jaafar B. et al.	2013	"Impact of Vertical Greenery System on Internal Building Corridors in the Tropics"	To investigate the effect of vertical greenery on the thermal performance of building corridors.	Experimental study	Revealed how VGS significantly reduced energy consumption by reducing corridor temperature and this reduction is even greater with higher air velocity. The study revealed that a low temperature and high humidity intermediate climate was created.
Convertino F. et al.	2022	"Thermal behavior of green facades in winter climatic conditions"	To investigated GF's wintertime energy performance under Mediterranean climatic conditions	Experimental study	GF improves winter thermal efficiency by minimizing energy losses at night.
Safikhani et al.	2014	"Thermal Impacts of Vertical Greenery Systems"	To better understand how vertical greenery systems operate thermally in hot and humid areas.	Experimental study	The findings demonstrated that both systems lowered the temperature inside and on the outside. Additionally, they lower the temperature in the intermediary space. As a result, the living wall was more successful at lowering the temperature in hot areas.

2.6.2 What Distinguished the Current Study

This study is laying the groundwork for green wall widespread construction on buildings of hot arid areas. It is also providing academics with data for constructing and refining computer simulation programs, promoting the use of green wall systems in buildings.

In addition, the study will also strongly persuade the relevant authorities to include a green wall system in the local building codes, as a step toward transforming Aqaba into a green city.

The current research is the first research of such type, which studied the effect of green walls, in Aqaba city. It also the first study that analyze the orientation of the buildings in terms of solar angles at Aqaba, which can be utilized in a lot of applications such as green wall system design, sun breakers and shading devices design, PV system design and architectural spaces design.

Most of green wall studies conducted the experiment and recorded temperature observations for one day or three days as a maximum. However, the current research used data logger devices that recorded temperature every ten minutes during the whole summer. That gave the experiment an extra level of reliability and gave the researcher flexibility to choose the best period to study. Any doubt in circumstances and observations of any day, it was excluded from the period. In fact, the data loggers have been recording the temperature during the whole year until now. That gave the researcher the experience in dealing with the plants, the weather, the devices and all other elements giving a greater capacity in understanding mistakes and correcting them early.

Moreover, the type of green wall used in this study sets it apart from others. Combining two different kinds of double-skinned green façades with climbing up and hanging down plants would cut down on the amount of time needed for experiment setup.

Chapter Three
Research Design and Methodology

3.1 Introduction

In terms of determining the thermal impact of green façade on internal spaces used in a hot, arid region of Aqaba, a physical live experiment has been carried out.

Because of the various mechanisms—shading, insulation, evaporative cooling, and wind barrier—that affect the behavior of green facades, the researcher used an experimental approach to give the study a practical, realistic reality. It is difficult to determine the exact contribution of each mechanism in energy savings in GF (Pérez G, et al., 2014).

Rather than other approaches, this experimental approach could assess the contribution of all of these mechanisms in the thermal behavior of GF. A review of the literature also led the researcher to the approach of field experiments. In reality, the majority of vertical greenery system research approaches are experimental, computer simulation, or literature review driven. According to the researcher's perspective, the field studies provide academics with data for constructing and refining computer simulation programs. The building construction type, the greenery system type, the climatic conditions, the specifications of the region's plants, the leaf area index (LAI), the way to deal with the plants, the way to maintain the structure, and the gap between the main wall and the VGS, all of these variables must be thoroughly investigated in the field before they can be used to improve the precision of the programming process at simulation method.

3.2 The Experiment Design

To meet the aim of this research and investigate the impact of green facades, the researcher made a comparative experimental study between two identical real test rooms that have the same construction style as local buildings.

The experiment has been conducted in a clear and open place at Aqaba since 2021, July. A double skin green façade has been installed at one of them at the south-west elevation, while the other room remained plain representing the current situation and conditions of local buildings and representing the reference of this experiment. The comparison between the two test rooms is based on the variables: the external wall surface temperature, the internal wall surface temperature, the internal air temperature and the internal air humidity for both rooms; and the temperature and humidity of the in-between sub-climate. This comparison was done after the data and measurements have been collected from the site. Special thermal and humidity devices have been used in the experiment. The researcher started to analyze the data measurements using Microsoft Excel as the main software in which give the ability to draw mathematical curves and to study relationships between the previous variables. SPSS software was also utilized to analyses the data and run the statistical tests that help define the relationships and produce the results in such a comparative quantitative study.

This intensive study brings us important conclusions that could help to improve the concept of applying the green façade system in Aqaba buildings as well as other buildings around the world in such a climate.

Many details concerning the experiment design must be thoroughly discussed. The topics below demonstrate this.

3.2.1 The Experiment Location

The experiment actually took place in the nursery of Aqaba Special Economic Zone Authority (ASEZA), Aqaba, Jordan. It is in the far southwest of the country, on the Red Sea's Gulf of Aqaba (Weatherspark, 2022) at Latitude: 29.566589625 and Longitude: 34.997752759 (Latitudelongitude, 2022). Figure 3.1 shows the experiment location. The place is open and clear from any object that may works as wind barrier, sun reflector, heat collector or any other obstacle may overshadow the target elevation of both test rooms. The accuracy of experiment measurements and results will be impacted by these and other factors, if any exist. For the same reason the researcher made a wide distance between both rooms avoiding one room to overshadow or blocking air from the other room.

Aqaba climate is discussed earlier in chapter two.

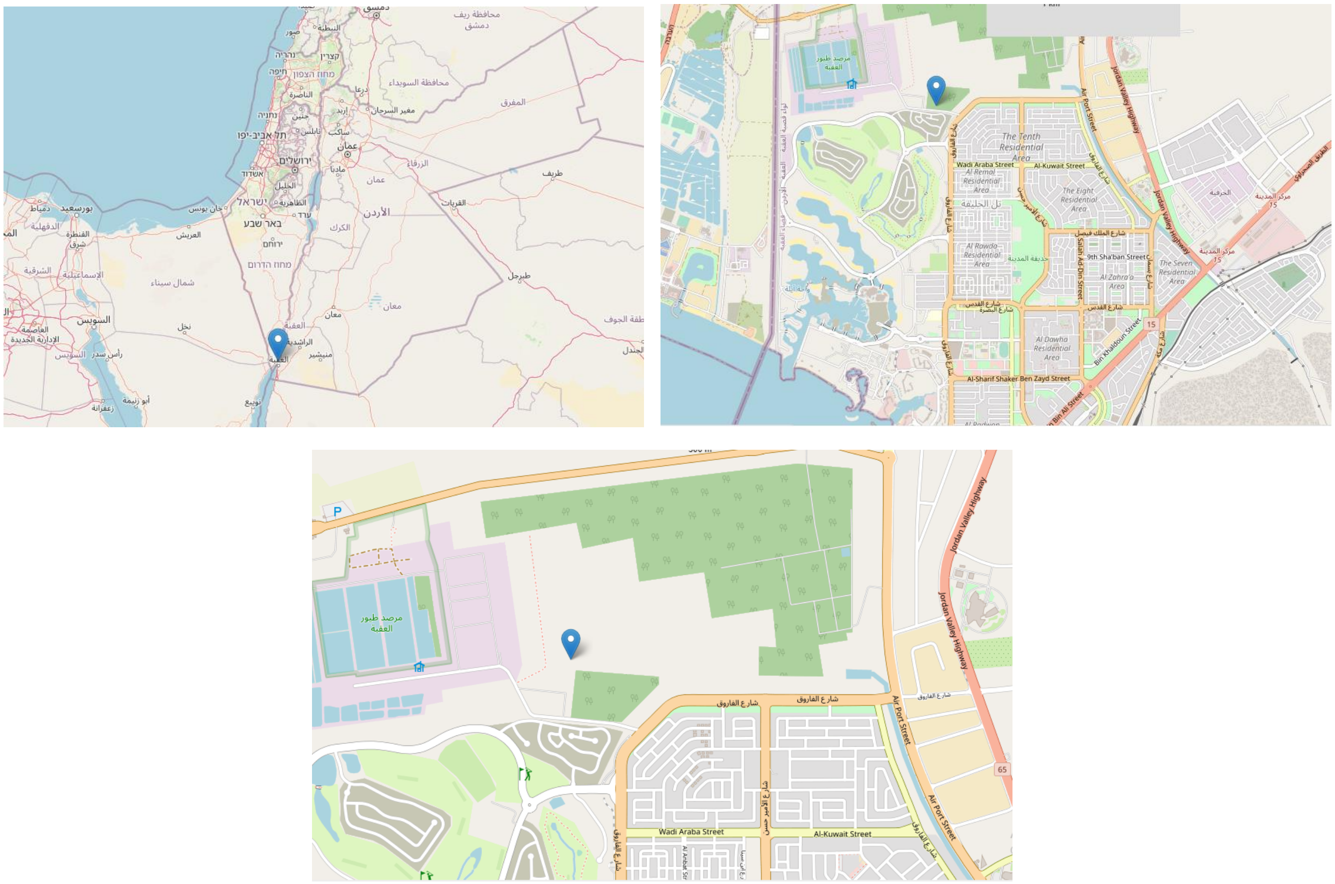


Figure 3.1

The experiment location: ASEZA nursery, Aqaba, Jordan (Marsh A., 2020)

3.2.2 Orientation

Both rooms are oriented towards the south-west after the researcher has studied the orientation factor carefully because of the importance of exposure to solar radiation. Choosing the optimal orientation, providing the most sun exposed elevation, was based on three considerations. Based on these considerations, the greatest reduction elevation of temperature degrees has been achieved.

Consideration One: studying the sun path and its thermal measurements using the website: http://andrewmarsh.com/apps/staging/sunpath3d.html. The options of it were experienced to analyze the provided thermal measurements and the sun path related to the experiment location. Figure 3.2 illustrates the sun path during the four seasons. The animation of sun path and its data show that the sun rays come from south because of the location of Aqaba on the northern hemisphere and the sun rays cannot arrive from true north.

Therefore, south was taken into consideration as the target elevation as an initial conclusion.

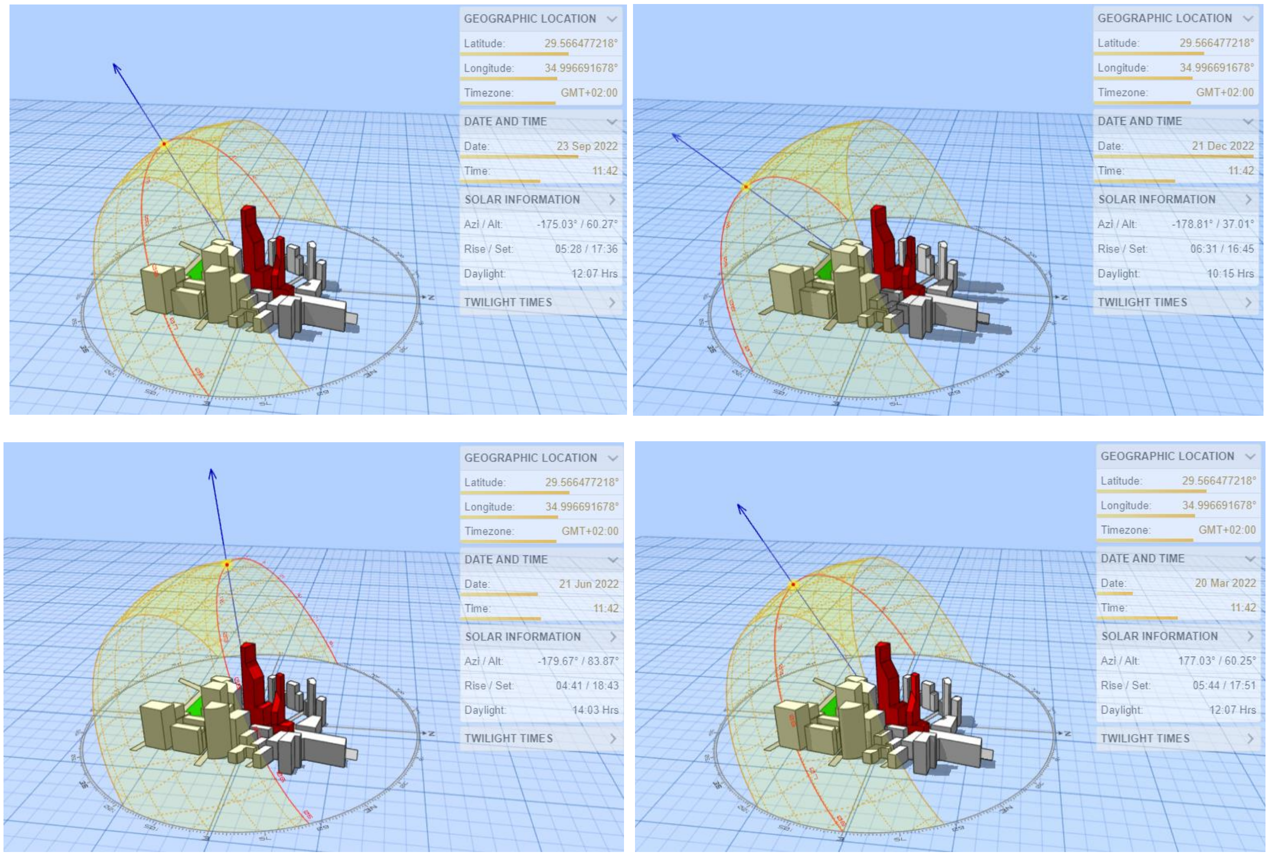


Figure 3.2
Sun path during the four seasons (Marsh A., 2020)

Table 3.1illustrates the solar data of experiment location during the year according to Marsh A. (2022), while table 3.2 illustrates the solar data of the experiment location during 21 Jun 2022.

Table 3.1
Solar data of experiment location during the year (Marsh A., 2022)

Date	Solar Noon		Sunrise		Sunset		Day Length	
	Time	Altitude	Time	Azimuth	Time	Azimuth	Hours	Change
21-Jan	11:52	40.58Â°	6:35	112.52Â°	17:08	-112.52Â°	10:33:37	0:01:08
21-Feb	11:54	49.92Â°	6:15	101.68Â°	17:34	-101.68Â°	11:19:20	0:01:41
21-Mar	11:47	60.70Â°	5:43	89.26Â°	17:52	-89.26Â°	12:08:44	0:01:48
21-Apr	11:39	72.32Â°	5:07	75.85Â°	18:10	-75.85Â°	13:02:35	0:01:38
21-May	11:36	80.65Â°	4:44	66.11Â°	18:29	-66.11Â°	13:44:34	0:01:06
21-Jun	11:42	83.90Â°	4:41	62.26Â°	18:43	-62.26Â°	14:02:25	0:00:02
21-Jul	11:47	80.93Â°	4:54	65.78Â°	18:40	-65.78Â°	13:46:04	-00:01:01
21-Aug	11:43	72.57Â°	5:11	75.56Â°	18:15	-75.56Â°	13:03:46	-00:01:36
23-Sep	11:32	60.39Â°	5:28	89.62Â°	17:36	-89.62Â°	12:07:19	-00:01:46
21-Oct	11:24	49.78Â°	5:44	101.83Â°	17:03	-101.83Â°	11:18:41	-00:01:40
21-Nov	11:25	40.57Â°	6:08	112.53Â°	16:42	-112.53Â°	10:33:33	-00:01:09
21-Dec	11:38	37.04Â°	6:30	116.68Â°	16:45	-116.68Â°	10:14:50	-00:00:03

Table 3.2
Solar data of the experiment location during 21 Jun 2022 (Marsh A., 2022)

Time	Solar Position			Shadow Projection	
	Altitude	Azimuth	Hor.Angle	Hor.Angle	Length
5:00	1.72Â°	65.40Â°	24.60Â°	-155.40Â°	33.33314
6:00	13.62Â°	72.21Â°	17.79Â°	-162.21Â°	4.12689
7:00	26.21Â°	78.43Â°	11.57Â°	-168.43Â°	2.0316
8:00	39.10Â°	84.63Â°	5.37Â°	-174.63Â°	1.2307
9:00	52.12Â°	91.62Â°	-1.62Â°	178.38Â°	0.77786
10:00	65.08Â°	101.49Â°	-11.49Â°	168.51Â°	0.46469
11:00	77.22Â°	123.70Â°	-33.70Â°	146.30Â°	0.22682
12:00	81.78Â°	-156.32Â°	-113.68Â°	66.32Â°	0.14446
13:00	71.69Â°	-110.12Â°	-159.88Â°	20.12Â°	0.33089
14:00	58.97Â°	-96.20Â°	-173.80Â°	6.20Â°	0.60148
15:00	45.95Â°	-88.13Â°	178.13Â°	-1.87Â°	0.96745
16:00	32.97Â°	-81.66Â°	171.66Â°	-8.34Â°	1.54181
17:00	20.20Â°	-75.53Â°	165.53Â°	-14.47Â°	2.71801
18:00	7.84Â°	-69.09Â°	159.09Â°	-20.91Â°	7.26427

Consideration Two: using the temperature measurement readings from Ibn Hayyan weather station/ ASEZA, which located three kilometers south of the experiment site. The station collects temperature, humidity, and wind velocity readings. Based on temperature readings, we can conclude that the hottest hour of the day is almost 5:00 PM during the summer. At this time, the sun is facing west. Figure 3.3 illustrates the temperature of one day of June, 23, 2021 according to Ibn Hayyan weather station. In general, this elevation is not recommended in architectural opening- needed spaces in hot areas. **Therefore, the researcher considered the west elevation to prevent the building from heat and reduce the temperature inside spaces.**

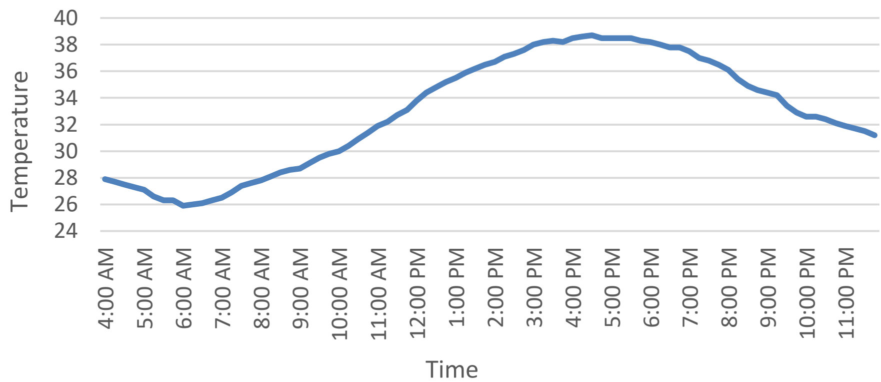


Figure 3.3
Temperature of June, 23, 2021

Consideration Three: using PVsyst software which allows users to design and sizing a complete PV system by solar simulation. It also provides analyzed data of the PV system according to the site location and sun angles effect. In order to conclude the impact of solar radiation on various elevations and orientations, the software has been used to investigate the particular reports and calculations that are generated by solar systems simulation.

Initially, a PV system project with a capacity of 4400 Wp and a 20-meter square area was designed as a matter of assumption using PVsyst software. The location was selected in the program on exact site of real experiment in ASEZA nursery, Aqaba, Jordan. In the first case of the virtual experiments, the PV panels were installed on the south elevation of a room built in the software. Four further cases were done; on the west elevation, east elevation, south-west elevation, and south-east elevation. These five cases represent the options on which the rooms might be oriented. As mentioned earlier, the north orientation was excluded because we are on the northern hemisphere, thus the sun rays cannot arrive from true north. The east orientation is also excluded because the ambient temperature in morning is low and it is recommended in architectural design to take advantage of the east elevation and design openings, not to prevent the east elevation from sun rays.

Appendix II is the report of the PVsyst simulation. The analytical figure 3.4 is extracted from the report for case 1. The report concludes the same for all cases.

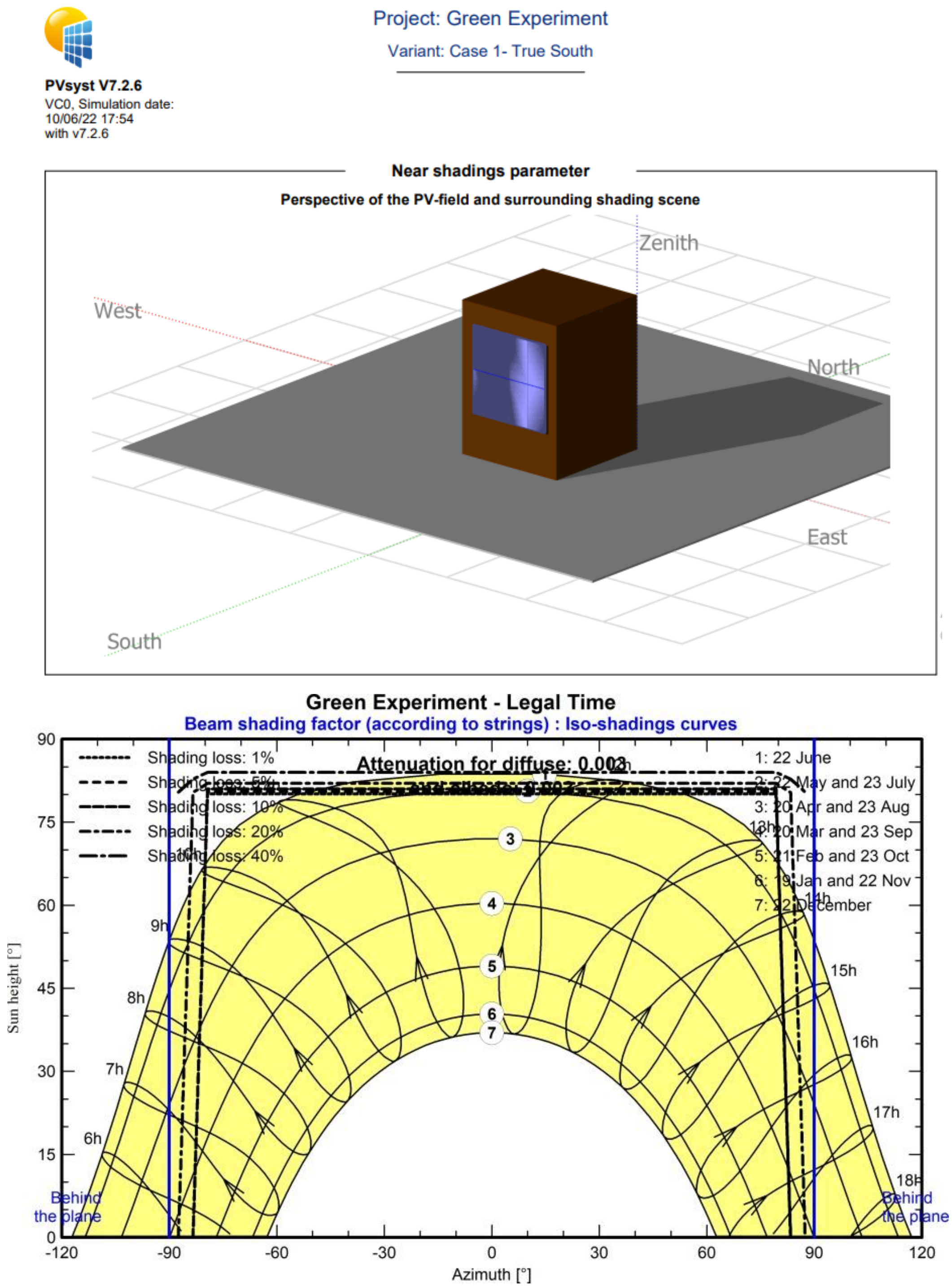


Figure 3.4

Analytical figures from PVsyst report- case 1

Table 3.3
Balances and main results of the five cases from PVsyst report (Appendix II)

Case 1- True South

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray kWh	E_Grid kWh	PR ratio
January	121.3	28.59	15.70	173.2	165.7	634.9	611.5	0.803
February	130.8	38.17	17.88	142.0	134.1	518.4	499.8	0.800
March	186.7	47.42	21.85	139.2	127.0	490.6	385.1	0.629
April	212.9	55.60	25.61	98.3	85.2	330.2	295.4	0.683
May	240.9	62.51	30.29	70.1	58.6	225.7	215.1	0.697
June	251.5	46.59	32.93	54.7	44.9	171.4	162.2	0.675
July	253.6	48.49	34.97	61.4	50.4	190.4	180.6	0.669
August	232.1	51.26	34.75	86.8	73.4	276.0	264.0	0.692
September	195.8	44.42	31.70	121.4	107.9	404.1	389.0	0.728
October	165.9	37.33	28.30	160.1	149.6	555.6	535.5	0.760
November	129.5	24.54	22.39	173.1	165.5	614.5	592.1	0.777
December	113.0	25.70	17.37	175.5	168.5	638.3	615.0	0.796
Year	2234.0	510.62	26.19	1455.8	1330.7	5050.0	4745.4	0.741

Case 2- True West

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray kWh	E_Grid kWh	PR ratio
January	121.3	28.59	15.70	76.2	69.4	274.3	262.9	0.784
February	130.8	38.17	17.88	80.0	73.6	288.3	276.9	0.786
March	186.7	47.42	21.85	105.8	98.7	375.6	303.6	0.652
April	212.9	55.60	25.61	117.9	110.7	414.1	369.9	0.713
May	240.9	62.51	30.29	131.7	123.8	453.0	435.2	0.751
June	251.5	46.59	32.93	131.1	123.2	443.1	425.6	0.738
July	253.6	48.49	34.97	136.8	128.5	456.6	438.4	0.728
August	232.1	51.26	34.75	131.6	123.7	442.8	425.3	0.735
September	195.8	44.42	31.70	110.9	104.3	377.9	362.9	0.744
October	165.9	37.33	28.30	98.9	92.4	343.7	329.9	0.758
November	129.5	24.54	22.39	79.4	73.6	281.2	269.6	0.771
December	113.0	25.70	17.37	69.7	63.7	250.7	240.4	0.784
Year	2234.0	510.62	26.19	1270.1	1185.5	4401.4	4140.6	0.741

Case 3- True East

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray kWh	E_Grid kWh	PR ratio
January	121.3	28.59	15.70	77.7	71.1	286.0	274.2	0.802
February	130.8	38.17	17.88	78.4	71.9	285.9	274.5	0.796
March	186.7	47.42	21.85	107.3	99.3	385.0	312.0	0.661
April	212.9	55.60	25.61	115.3	107.5	408.4	359.9	0.709
May	240.9	62.51	30.29	130.1	121.8	455.0	437.1	0.764
June	251.5	46.59	32.93	133.6	125.0	459.5	441.5	0.751
July	253.6	48.49	34.97	137.9	129.0	469.5	450.9	0.743
August	232.1	51.26	34.75	123.3	115.0	418.0	401.3	0.740
September	195.8	44.42	31.70	113.3	106.2	391.4	375.8	0.754
October	165.9	37.33	28.30	102.1	95.8	362.3	347.8	0.774
November	129.5	24.54	22.39	76.5	70.6	275.1	263.7	0.783
December	113.0	25.70	17.37	72.3	66.4	265.8	255.0	0.801
Year	2234.0	510.62	26.19	1267.7	1179.7	4462.2	4193.7	0.752

Case 4- South-West

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray kWh	E_Grid kWh	PR ratio
January	121.3	28.59	15.70	134.3	126.5	482.1	463.5	0.785
February	130.8	38.17	17.88	118.6	111.9	427.2	411.1	0.788
March	186.7	47.42	21.85	131.9	123.5	465.8	371.8	0.641
April	212.9	55.60	25.61	119.0	110.8	418.1	374.0	0.714
May	240.9	62.51	30.29	111.7	102.2	384.6	369.4	0.752
June	251.5	46.59	32.93	101.6	91.9	343.5	329.7	0.737
July	253.6	48.49	34.97	109.4	99.5	367.1	352.3	0.732
August	232.1	51.26	34.75	121.6	112.7	411.6	395.5	0.739
September	195.8	44.42	31.70	126.6	118.5	430.1	413.6	0.743
October	165.9	37.33	28.30	138.3	130.1	474.1	455.8	0.749
November	129.5	24.54	22.39	137.3	129.7	477.2	458.7	0.760
December	113.0	25.70	17.37	132.4	125.2	473.5	455.6	0.782
Year	2234.0	510.62	26.19	1482.6	1382.5	5154.8	4850.9	0.744

Case 5- South-East

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray kWh	E_Grid kWh	PR ratio
January	121.3	28.59	15.70	135.7	128.0	494.7	475.5	0.796
February	130.8	38.17	17.88	117.1	110.4	426.7	410.5	0.797
March	186.7	47.42	21.85	132.2	124.0	474.8	379.4	0.652
April	212.9	55.60	25.61	117.7	109.4	418.3	370.2	0.715
May	240.9	62.51	30.29	110.1	101.0	385.4	370.2	0.764
June	251.5	46.59	32.93	102.6	92.4	350.3	336.3	0.745
July	253.6	48.49	34.97	109.1	99.3	372.2	357.3	0.744
August	232.1	51.26	34.75	116.8	107.9	398.9	383.2	0.746
September	195.8	44.42	31.70	128.2	120.1	442.4	425.4	0.754
October	165.9	37.33	28.30	141.5	133.3	492.5	473.6	0.761
November	129.5	24.54	22.39	133.7	126.1	471.2	453.0	0.770
December	113.0	25.70	17.37	135.6	128.1	490.5	472.0	0.791
Year	2234.0	510.62	26.19	1480.3	1379.7	5218.1	4906.5	0.753

Legends

GlobHor: Global horizontal irradiation

DiffHor: Horizontal diffuse irradiation

T_Amb: Ambient Temperature

GlobInc: Global incident in coll. Plane

GlobEff: Effective Global, corr. for IAM and shadings

EArray: Effective energy at the output of the array

E_Grid: Energy injected into grid

PR: Performance Ratio

The data in the table 3.3 is extracted from the PVsyst simulation reports (Appendix II). Making a comparative analysis between the cases according to Pvsyst reports, it can be concluded that:

1. **Global Incident in Coll. Plane (kWh/m²)**

It is the total amount of irradiance that the tilted plane has received. It is influenced by the solar geometry and, by extension, by the geographical location. It is derived from the hourly values of the Global horizontal and diffuse irradiances (Mermoud A., 2013). This measurement is very important consideration to determine the powerful of each orientation according to collected irradiances. Comparing between the five cases from the table 0, it is obvious that case four, south- west, collects the greatest amount of irradiance. **It indicates that using this elevation to apply and enhance the effectiveness of the green façade is advantageous because it is the elevation that receives the maximum solar exposure.**

2. **Near Shadings: Irradiance Loss**

How much irradiance is stopped by other objects before it hits the photovoltaic module is determined by near shading losses (Opie N., 2022). Retaining to the comparison table 3.4, it can be noticed that the least shading losses is case four. Accordingly, south-west elevation experiences the fewest losses and gains the greatest radiation due to near-shading. **This once again advantages the south-west elevation when applying and maximizing the effectiveness of the green façade.**

Table 3.4
Comparison between the five cases

Cases	Tilt/Azimuth Angle	Produced Energy (kWh/year)	Specific production (kWh/kWp/year)	Perf. Ratio PR%	Global horizontal irradiation (kWh/m²)	Global incident in coll. Plane (kWh/m²)	Near Shadings: irradiance loss
Case 1- True South	90° / 0 °	**4745**	1079	74.09%	2234	1455.8	-0.48%
Case 2- True West	90° / 90 °	**4141**	941	74.09%	2234	1270.1	-1.17%
Case 3- True East	90° / -90 °	4194	953	75.19%	2234	1267.7	-1.43%
Case 4- South-West	90° / 45 °	4851	1102	74.36%	2234	**1482.6**	**-0.21%**
Case 5- South	90° / -45 °	4907	1115	75.33%	2234	1480.3	-0.29%

3. Heat Losses

Table 3.5
Temperature losses on the five cases

Cases	Due temperature losses
Case 1- True South	**9.37 %**
Case 2- True West	**11.15 %**
Case 3- True East	**9.51 %**
Case 4- South-West	**10.95 %**
Case 5- South-East	**9.70 %**

Losses data provided by PVsyst simulation show that west elevation has heat losses (losses due temperature) more than the east elevation (Table 3.5). This is the reason why the PV panels on east elevation produced more energy (Produced Energy (kWh/year)) than west elevation. Furthermore, greater heat losses in west elevation means it is experienced more heat around the year. The same concept is regarding south-east and south-west elevation. Therefore, West elevation is given priority over east elevation and south-west over south-east elevation when thinking of prevents the building from heat and installs a green façade. Due to this, from most to least priority, this could be: south-west elevation, south-east elevation, south elevation, west elevation, and finally, east elevation. **We can conclude from all considerations that south-west elevation is the most optimal elevation in our case. Therefore, both rooms are oriented towards the south-west to install the green façade on this elevation.** Furthermore, the present expansion of the urban planning of Aqaba city is oriented toward the south-west, which directed the researcher once more to think of the south-west elevation.

Valid note: Returning to consideration three, the researcher compared between the five cases according to the total irradiance reached during the whole year. However, from another perspective, the data of PVsyst reports show the produced energy (kWh/year) in every month for every case. If we focused analysis on summer months (May, June, July, and August) and exclude winter months, we will notice that west elevation collects greater amount of energy than south-west elevation in hot season. It deserves to be looked into in more detail in further studies. The goal of this study is to introduce the green façade as a building tool in Aqaba. The researcher might therefore have to cope with the existing urban planning expansion scenario in Aqaba.

3.2.3 The Construction of the Test Rooms

Two identical concrete rooms have been constructed (240cm, 240cm, and 220cm) in length, width, and height, respectively with 20cm parapet (Figure 3.5). The typical materials used in the test rooms as well as Aqaba local buildings are concrete and blocks. From the inside out, the wall layers are: paint, plaster, 20cm block, plaster with a texture coat. The foundations are made of concrete and reinforcing steel bars. The roof is a solid slab conventional flat roof (15 cm reinforced concrete) with 2 cm of thermal insulation. Both test rooms used in this research are identical except the green façade that has been installed at the south-west elevation of one of them, providing the experiment with:

1. Plain Room (PR) or reference room: represents the ordinary conditions and envelope performance of local Aqaba buildings.
2. Room with green facade (GR): represents the new conditions experienced by green façade.

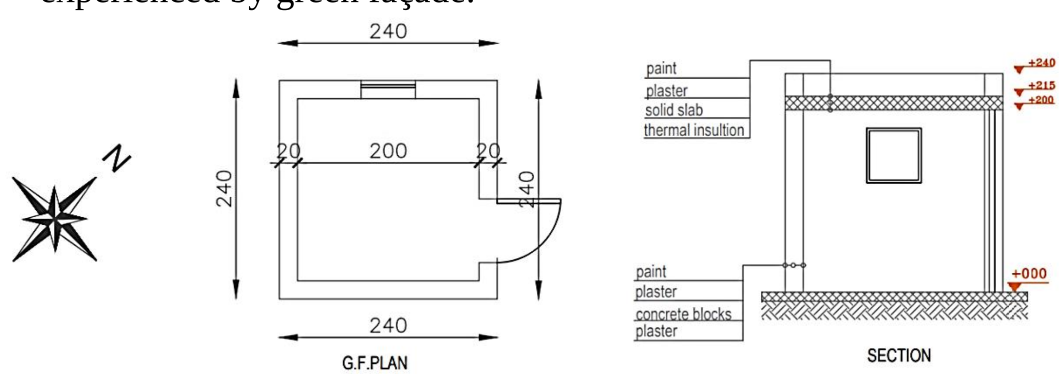


Figure 3.5
Test room plans

3.2.4 Installing the Green Façade (Trellis and Plants)

This study employs double-skin green façades that allude to a separate structure (metal trellis) supporting the hanging plants, resulting in a green curtain, as a means of avoiding issues caused by the plants' attachment to the main wall surface (Pérez et al., 2011).

3.2.4.1 Trellis

To perform this experiment a metal trellis of (240cm x 180cm) has been mounted with anchors to the west southern elevation, which is the optimal elevation, to install a green façade at Aqaba (Figure 3.6). A twenty centimeters gap was left between the main elevation and the mounted trellis. It consists of a 5cm metal frame with a metal wire inside in a (11cm x 11cm) grid design. This trellis guided the creeping plant to grow and cover the whole elevation in fast and regular way.

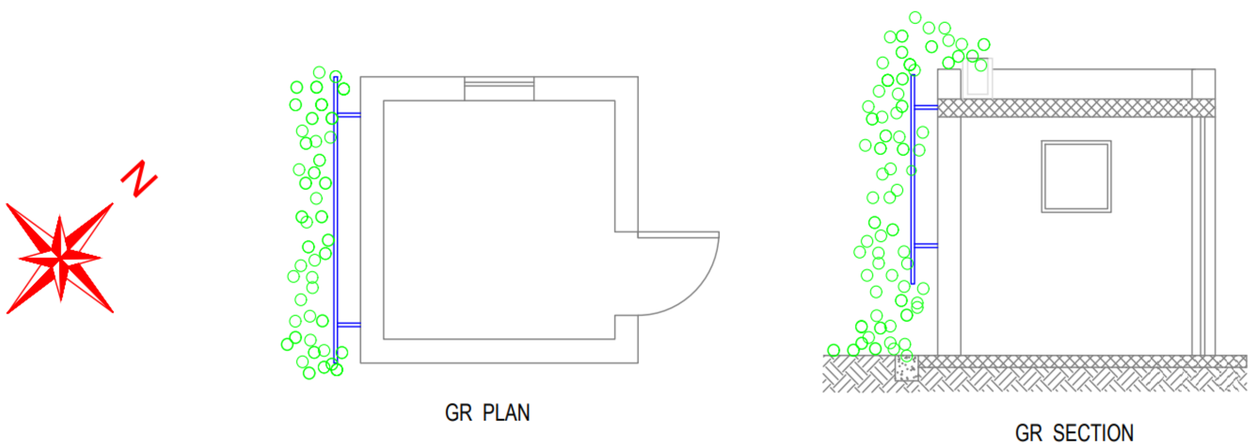


Figure 3.6
GR plans

3.2.4.2 Plant Selection

In the first step, in June 2021, the researcher analyzed the local plants to determine the best plant for the study regarding the Aqaba climate and coastal location, foliage density, plant care and maintenance, growth style and speed of the plant, which was a challenging issue for the researcher. In the ASEZA nursery, four types of creeping plants that, according to agricultural engineers, are all suitable for the climate in Aqaba, were tested (Appendix III). The plants were planted first in large plant pots in a green house in the nursery, and then they were transferred to the ground in the middle of July 2021, after the rooms' construction was completed. Unfortunately, after three days of severe weather (17th-19th July), all of the plants were overheated and died in early August. According to temperature readings from Ibn-Hayyan weather station, these days were the worst three days of the year. Moreover, it is observed that plants became extremely sensitive in the days following its relocation. The researcher immediately searched about another plant or another way that could make the green façade preparation complete fast in such weather.

The researcher tried a new climbing perennial plant called *Bayhops,* or *Ipomoea pes-caprae,* which is a salt-tolerant herbaceous climbing vine (figure 3.7). It grows on the coasts of tropical and subtropical regions. Flowers bloom in the summer and autumn, opening early in the morning and closing before noon on a regular basis, giving the plant the name beach morning glory. Seedpods appear shortly after the flowers fade.

On the 12th of August, 2021, the plant worker of the nursery took a lot of cuttings from another huge Bayhops and set the dry stiff cuttings into the moistened soil of the ground basin of the GR, while setting the green soft cuttings into water. A third group of cuttings were set into pots in the green house of the nursery. After few days, the internodes sent out roots and little leafs. The group in pots in the green house seems to be the fastest and the strongest, while the weakest was the group in water. It took a month before the pots have been put on a liner arrangement on the south-west roof edge let the branches falling down covering a good part of the target elevation (Appendix IV). The researcher reasoned that combining the two types of GF, climbing up plants and hanging down plants, would decrease the time required for experiment setup. The ground planted branches also climbing up meeting the branches from roof edge and covering about half the elevation. On October 10, 2021, the south-west elevation was covered by foliage to a degree of about 75%. By the end of June 2022, 100% coverage was achieved. Figure 3.8 gives an idea of the growth progress of the plants from 6.9.2021 to 26.6.2022, while appendix IV provides the detailed stages. The foliage coverage percentage of the GF over the time is shown in figure 3.9.

This plant experience directed the researcher to rely on *Ipomoea pes-caprae* climbing plant to perform the experiment and cover the trellis. It is well-adapted specie in Aqaba climate with less maintenance, high salt-resistant, high dense foliage and very fast to grow.

Moreover, this experiment showed that plants grew faster in cooler months than they did in the hottest. See plant characteristics table on appendix III.

Figure 3.7
Ipomoea pes-caprae

Figure 3.8
The growth progress of the plants from 6.9.2021 to 26.6.2022

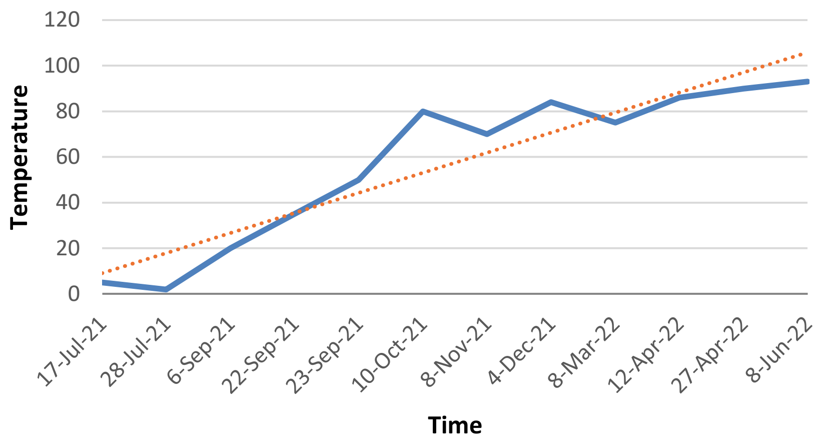


Figure 3.9
Foliage Coverage % of the GF over time

3.2.5 Measuring Points and Devices

To make the comparison between both rooms in regards to thermal behavior, These points have been measured: internal air temperature and humidity for both rooms, Internal and external surface temperature of the south-west wall for both rooms, temperature and humidity for the in-between space, the gap between the GF and main wall, and the air temperature and humidity of the ambient environment.

Temperature and humidity have been measured and recorded up using special detective devices for both rooms at the eight located points (Figure 3.10): the center of both rooms, the center of in-between space of the GR, the south-west internal surface of both, south-west external surface of both and outside shaded location.

Eight Elitech RC-4HA/RC-4HC temperature and humidity data loggers were used in the experiment, they were calibrated with (± 0.5°C temperature accuracy for the range -20~40°C and ± 1.0°C for others), where for humidity the accuracy is (± 3%RH for the range 20~80%RH and ± 5%RH for others). These devices have been continuously measuring and documenting temperature and humidity data. Devices were positioned about 140 cm above the ground. At 10-min intervals, the data were automatically recorded by a computer. They have been recording from August 2021 to July 2022 (almost one year). The experiment is still active, and recordings are being made right now.

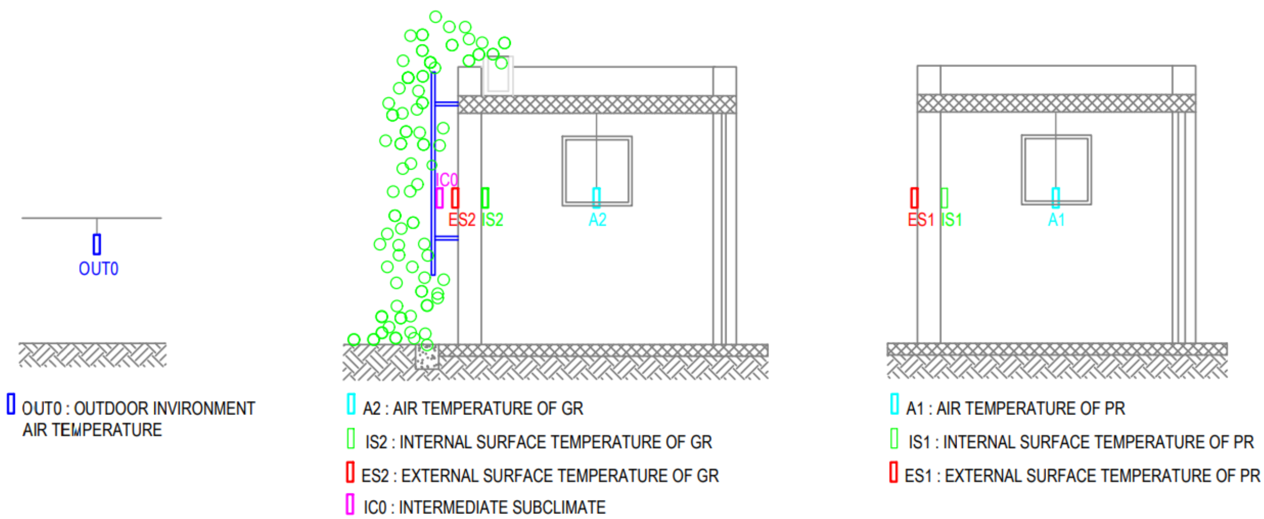


Figure 3.10
Measured locations

In order to maintain airflow throughout the day and night, the window and door in each room were left open for the duration of the experiment at a fixed two-centimeter distance.

The data were transformed from 10-minute points to 30-minute averages. Using Microsoft Excel, the maximum and minimum temperature of each day was determined. Two main intervals from the continuous entire duration were selected to focus on the previous factors. These periods were chosen to correspond with the summer in different conditions, with and without ventilation, in Aqaba:

C: From 27.6.2022 to 1.7.2022 which represents hot summer season. The foliage coverage ratio of this period is about 100% and the average temperature is 41oC. This is the main period of the study because the aim of it is to set out the effect of green façade on thermal behavior of Aqaba buildings in hot days.

D: From 8.7.2022 to 12.7.2022 which represents hot summer season but without ventilation inside both rooms. The foliage coverage ratio of this period is about 100% and the average temperature is 41^{o}C.

After the data and measurements have been collected from the site, they were tabulated, analyzed, compared, examined and shaped variables relationships to determine the results. Appendix I shows the spreadsheets of the variables of both periods before analyze them using Microsoft Excel and SPSS software.192 observations for every variable in period C and 240 observations for every variable in period D were studied. Figure 3.11 gives an idea of the main measured variables of the experiment.

				OUT0 En	OUT0 En	ES2 GF	ES2 GI	A2 GI	A2 GI	IS2 GI	IS2 GR	C0 In-betwe	C0 In-betwe	ES1 P	ES1 P	A1 PI	A1 PI	IS1 P	IS1 P
Date	time	an Temper	ayyan Humi	Temperature°C	Humidity%	Temperature°C	Humidity%	Temperature°C	Humidity%	Temperature°C	Humidity%	Temperature°C	Humidity%	Temperature°C	Humidity%	Temperature°C	Humidity%	Temperature°C	Humidity%
6/27/2022	12:00:00 AM	30.8	31	29.8	28.4	30	29	32.3	26	32.5	28.1	29.5	30.7	30.2	28.1	33.3	23.8	35	23.5
6/27/2022	12:30:00 AM	30.5	31	29.1	29.1	29	29.9	32	26.2	32.3	28.3	28.7	32.2	29.6	29.7	32.9	24	34.7	23.6
6/27/2022	1:00:00 AM	29.5	33	28.2	30.3	28.4	30.8	31.7	26.9	32.1	28.5	28	32.8	29.1	29.4	32.5	24.3	34.3	23.8
6/27/2022	1:30:00 AM	29.5	33	28.1	30.4	28.5	31.1	31.4	26.9	31.8	28.4	27.8	33.2	28.7	29.7	32.2	24.4	33.9	24
6/27/2022	2:00:00 AM	29	33	27.8	30.8	27.7	32.3	31	27.1	31.7	28.5	27	34.3	28.3	30.2	31.7	24.9	33.5	24.4
6/27/2022	2:30:00 AM	28.6	34	27.7	31	28.2	31.3	30.5	27.3	31.4	28.5	27.5	33.7	28	30.6	31.4	25.1	33.1	24.4
6/27/2022	3:00:00 AM	28.2	34	27.3	31.4	27	32.7	30.3	27.6	31.1	28.6	26.5	34.7	27.5	30.9	31	25.4	32.8	24.7
6/27/2022	3:30:00 AM	28.4	34	26.4	32.1	27	32.8	30	27.6	30.9	28.6	26.3	35.1	27.1	31.6	30.7	25.4	32.4	24.8
6/27/2022	4:00:00 AM	28.4	33	26.1	32.5	26.2	33.9	29.7	27.8	30.6	28.7	25.4	36.3	26.7	31.9	30.3	25.6	32	24.9
6/27/2022	4:30:00 AM	28.4	34	26.2	32.8	26.4	34.6	29.3	28.2	30.4	29.1	25.4	37.1	26.4	32.3	30	26	31.6	25.1
6/27/2022	5:00:00 AM	28.5	34	26	33.3	26.4	35	29.2	28.6	30.1	29.4	25.7	37.5	26.2	33.4	29.7	26.3	31.3	25.3
6/27/2022	5:30:00 AM	28.4	34	26	33.5	26.1	35.2	29	29	29.9	29.8	25.7	38.1	26	33.3	29.5	26.8	30.9	25.6
6/27/2022	6:00:00 AM	28.2	34	24.2	35.9	24	38.7	28.8	29.7	29.6	30.5	24.1	40.1	25.2	36.4	29.2	27.3	30.5	26.1
6/27/2022	6:30:00 AM	28.4	34	23.9	37.1	24.3	40.2	28.5	30.6	29.5	31	23.7	41.9	25.2	35	28.9	27.9	30.3	26.7
6/27/2022	7:00:00 AM	28.7	35	25	35.7	25.4	37.7	28.4	30.4	29.3	31	24.5	40.5	25.5	33.7	28.7	27.7	29.9	26.4
6/27/2022	7:30:00 AM	29.4	34	26.2	34.5	26.6	37.2	28.5	30.4	29.1	31.2	25.4	39.7	26.1	32.6	28.7	27.9	29.6	26.6
6/27/2022	8:00:00 AM	30	32	27.8	33.2	27.8	35	28.6	30.4	29	31.7	26.9	38	27	31.3	28.8	28.1	29.5	26.8
6/27/2022	8:30:00 AM	30.5	31	29.8	30.2	29.2	34.3	29	30	28.9	31.5	28.4	36	28	29.2	29.2	28.1	29.4	27.1
6/27/2022	9:00:00 AM	31.2	30	31.1	27.4	30.2	30.2	29.5	29.3	29	31.1	29.8	33.6	29.1	27.1	29.5	27.7	29.4	27.2
6/27/2022	9:30:00 AM	32	29	31.8	26.1	30.9	28	30	28.6	29.1	30.9	30.6	31.3	30	26	30	27.2	29.4	27.2
6/27/2022	10:00:00 AM	32.8	28	33.2	24.8	31.9	27.6	30.6	27.8	29.3	30.5	31.5	29.9	31	24	30.6	26.5	29.6	27
6/27/2022	10:30:00 AM	33.5	26	35.1	22.2	32.7	25.5	31.3	26.6	29.5	29.6	32.3	29.2	32	22.8	31.3	25.5	29.9	26.6
6/27/2022	11:00:00 AM	34.1	25	35.6	20.8	33.6	25.5	32	25.8	29.9	29.5	33.2	27	33.1	21.4	32.1	24.6	30.3	26

Figure 3.11
The main measured variables of the experiment

Each variable in the GR was compared to its equivalent in the PR. Each pair of variables was tabulated in a single sheet for analysis. The following chapter explains how the researcher analyzed these variables.

Chapter Four
Results, Discussion, Conclusions and Recommendations

4.1 Introduction

After recording and transferring temperature and humidity observations to the computer, they were combined and organized into a single Excel data sheet. Appendix I shows the data of both periods' observations of 30-minutes intervals. Four or five continuous days under identical conditions were selected for both. The observations refer to the experiment's eight thermal devices, which are described further down. The measures' excel data sheet has 16 columns to handle the measurements of these variables (Appendix I):

The air temperature and humidity inside the PR (A1)
The air temperature and humidity inside the GR (A2)
The internal wall surface temperature of the PR (IS1)
The internal wall surface temperature of the GR (IS2)
The external wall surface temperature of the PR (ES1)
The external wall surface temperature of the GR (ES2)
The air temperature and humidity of the in-between sub-climate for GR (IC0)
The outdoor ambient environment temperature and humidity (OUT0)

A comparative quantitative analysis was conducted regarding the hypotheses of the study. Experiment observations were analyzed to identify the differences between the variables in both rooms. The external wall surface temperature, the internal wall surface temperature, the internal air temperature and the internal air humidity of the GR were all compared and analyzed with those of the PR, which represents the reference for the study. The air temperature and humidity of the in-between sub-climate of GR were also compared to the outdoor ambient temperature.

Descriptive statistics and **statistical tests** were used to assess the data of each variable in both rooms. The researcher began with descriptive statistics, using Microsoft Excel as the main software to analyze the data measurements, drawing mathematical curves to support in the discovery of variations between the analyzed variables. Along with that, means, maximums, minimums, intervals of maximum impact, intervals of minimum impact, etc. were explored. On the other hand, SPSS software was utilized to analyze the data by run the statistical tests that help define the results. The comparison was mainly based on independent samples T-test at ($\alpha \leq 0.05$) level.

4.1 Analyzing the Variables in Hot Summer by Descriptive Statistics

This part of the study uses descriptive statistics to analyze the variables with respect to the hypothesis for two summertime periods. According to the problem statement, the study's target season is the hot summer in Aqaba. To evaluate the earlier variables, two summertime periods were chosen. Period C is the main period with ventilation, and period D is the secondary period without ventilation.

4.1.1 Analyzing the Variables in Hot Summer-Period C

The first main hypothesis ($H_0 1$) examines the variations in interior temperature and humidity of buildings with green facades in Aqaba during the summer - Period C.

Period C represents four hot summer days (from 27.6.2022 to 1.7.2022) in Aqaba according to Weatherspark website, (2022). The foliage coverage ratio of this period is about 100%. The daily average temperature of the environment during this period was 33.6^{o}C, while the daily average of relative humidity of the ambient environment was 28.8%. According to the experiment observations during this period, the hottest time of the day (the curve peaks) was from 1:00 PM to 8:00 PM, with temperatures averaging 35^{o}C to 43^{o}C.3, while the coolest time of the day (the curve valleys) was from 2:00 AM to 8:00 AM , with temperatures averaging 25^{o}C to 29^{o}C.
The first main hypothesis generates the following related hypotheses:

4.1.1.1 Analyzing the External Wall Surface Temperature-Period C

Hypothesis ($H_0 1.1$) examines the difference between the external wall surface temperature of Aqaba buildings and those with green facades during the summer season-period C.

Descriptive statistics was initially used to present and analyze the main statistical figures of this variable. It was compared between the observations of the south-west external wall of both rooms. Referring to figure 4.1, it is obvious that the external wall surface temperature of the GR (ES2) is less than the temperature of the external wall surface of the PR (ES1) by (1.4-5.4)^{o}C at the hottest time of the day with a daily average of 1.4 ^{o} C during this period. This reduction is due to shadow factor in which the GF prevents the external wall from direct sunrays. However, the measurements show that ES2 is approximately equal ES1temperature during the coolest time of the day. The reason is that the south-west wall surface of PR loses heat faster than GR's does because of the insulation effect of the GF, which reduces heat loss and controls the rate of heat transfer rate.

This important finding, concerning hypothesis **$H_0$1.1**, means that GF affects the thermal conditions of the GR in the hottest hours of summer days at Aqaba.

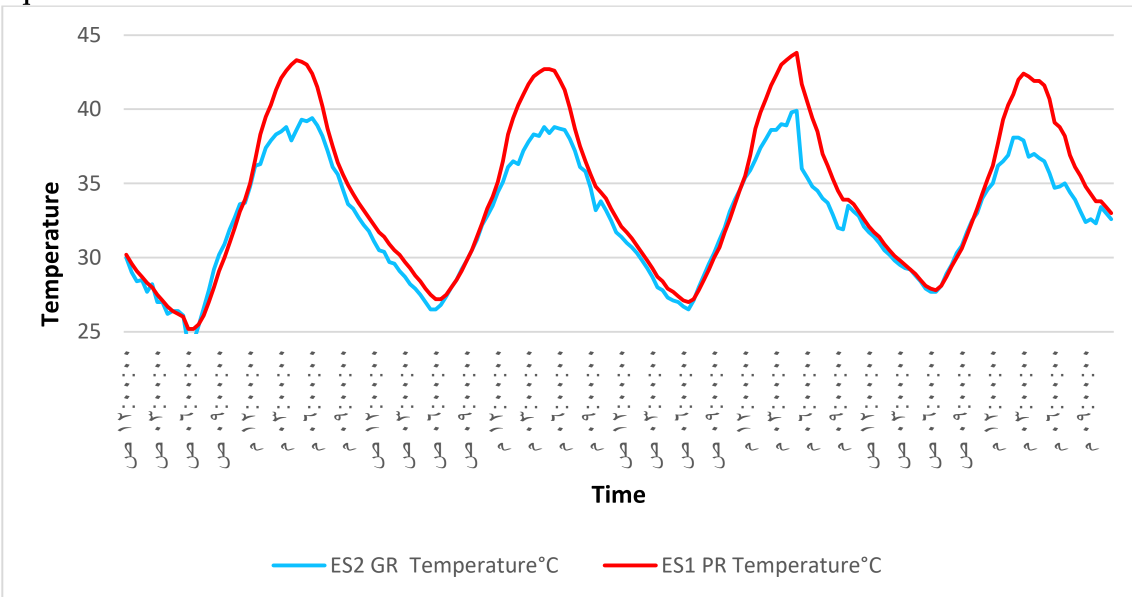


Figure 4.1
The differences between external wall surface temperature in GR and PR from June 27 to July 1

Furthermore, Comparing the previous ES1 and ES2 graph with the outdoor temperature (OUT0), it was noticed that ES2 is also less than the OUT0 at the hottest time of the day and almost they are equal at the coolest time of the day. At the peak, the ES1 has a little greater temperature than the OUT0, and both are nearly equal at the valley. Figure 4.2 illustrates the compared observations between the OUT0, ES1 and ES2.

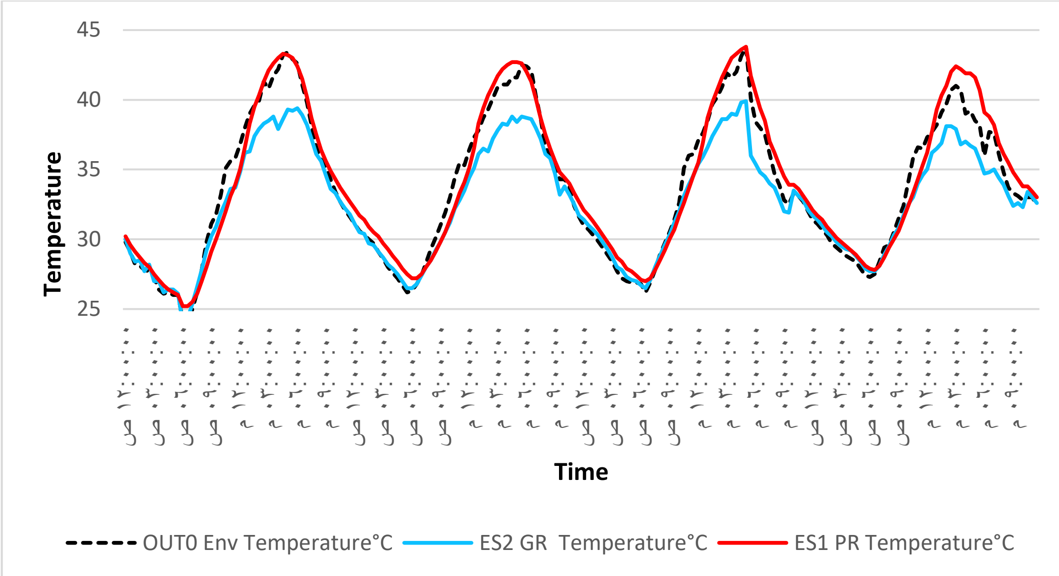


Figure 4.2
The differences between GR and PR according to external wall surface temperature from June 27 to July 1

4.1.1.2 Analyzing the Internal Wall Surface Temperature-Period C

Hypothesis ($H_0$1.2) investigates the difference in internal wall surface temperatures between Aqaba buildings and those with green facades during the summer. Regarding this hypothesis, the observations for the internal wall surface temperature were initially evaluated for both rooms using descriptive statistics.

Findings show that the most thermally influenced hours during the day regarding the internal surface temperature are from 4:00 PM to 11:00 PM. During this hours, the internal surface temperature differences at their maximum. IS2 temperature is less than IS1 by (0.3-3.4) during the whole day with an average of 1.6 ^{o}C during this period (figure 4.3). This reduction is due to the insulation effect of the GF as a direct impact, which reduces heat loss and controls heat transfer rate. Shadow effect of the GF also prevents the wall from direct sun rays reducing the gained heat by the wall itself. Between 6:00 AM to 11:00 AM, IS1 and IS2 temperature differences are at their lowest.

Notice that there is a three hours delay in maximum temperatures between the internal surface temperature and the outdoor temperature due to thermal resistance of the materials.

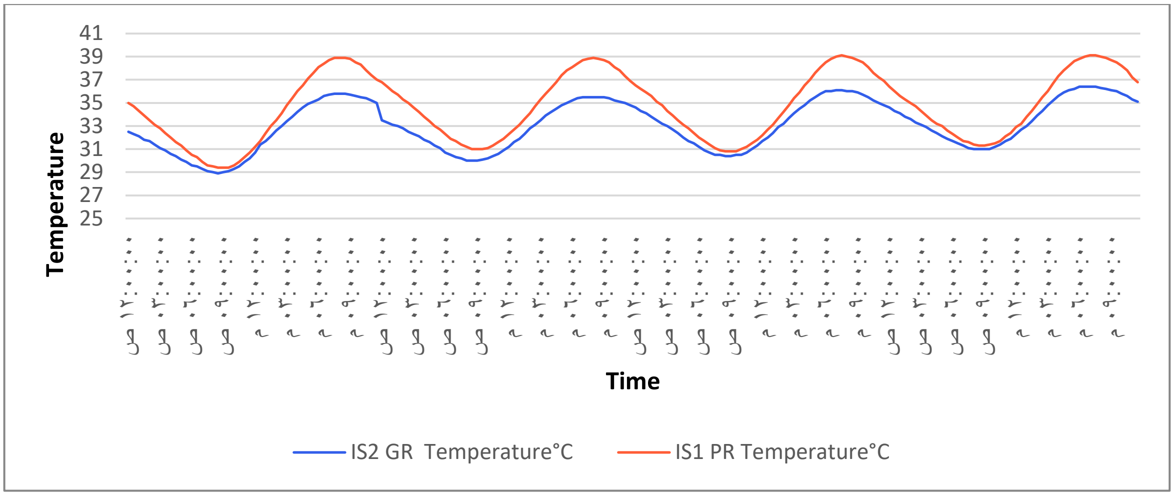


Figure 4.3
The differences between GR and PR according to internal wall surface temperature from June 27 to July 1

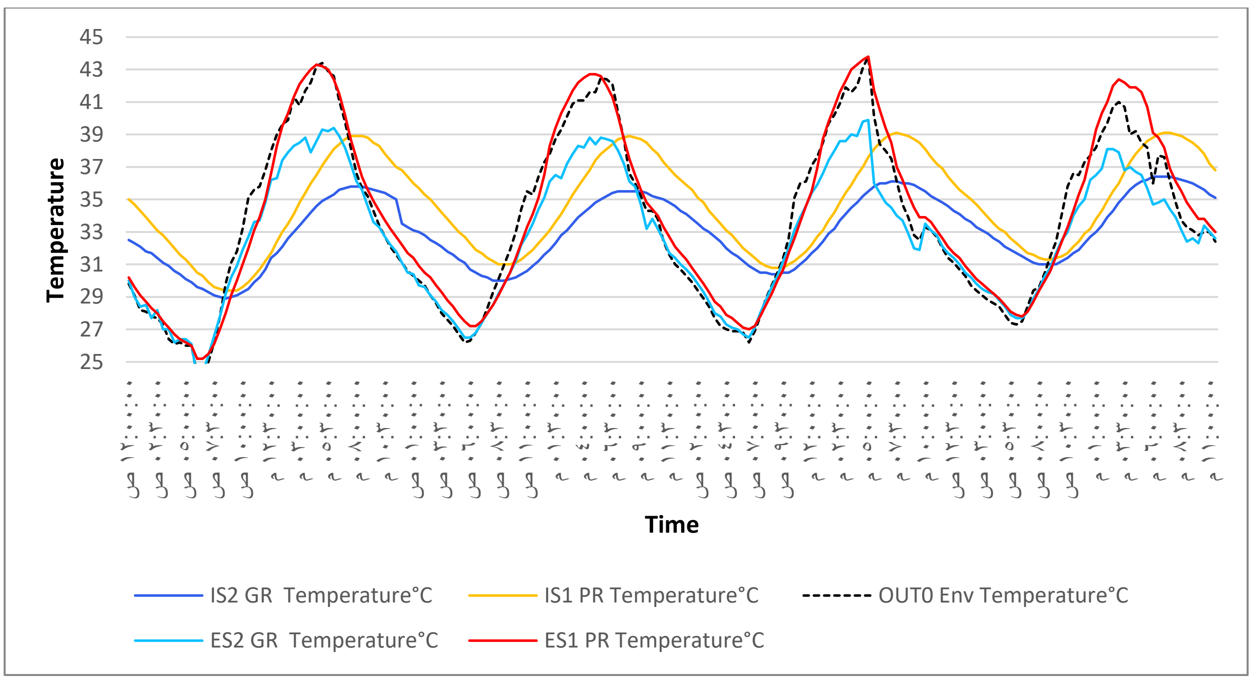


Figure 4.4
The differences between GR and PR according to external and internal wall surface temperature from June 27 to July 1

For a thorough comparison, graph 4.4 displays all five variables together. This graph displays the impact of GF on the south-west wall of the GR's internal and external surface temperatures and provides an indication of the thermal behavior of the GR's south-west wall when compared to the PR. The following are the variables' temperatures in order of highest to lowest

throughout the hottest time of these period days: ES1, OUT0, ES2, IS1 and the lowest temperature of all these variables is IS2.
Regarding the coolest hours of the day, the order of coolest to the warmest in this period is almost the same: ES1, OUT0, ES2 and IS1 PR are almost the same level, and the warmest temperature of all these variables is IS2.

4.1.1.3 Analyzing the Internal Air Temperature- Period C

Hypothesis ($H_0$1.3) investigates the difference between the air temperature inside Aqaba buildings and the air temperature inside those with green facades during the summer.

Descriptive statistics was initially used to study and analyze the main observations and figures for this variable in both rooms. Findings show that the internal air temperature at GR (A2) is slightly cooler than the internal air temperature in PR (A1) by (0.3-1.4) from 6:00 PM to 7:00 AM of this period, in which the internal air temperature differences are apparent. The daily average of the differences is about 0.49°C during this period. Figure 4.5 shows that there appear to be no temperature differences between 10:00 AM and 3:00 PM because the gained heat during daytime in PR is faster to lose than GR in the night and early morning. This indicates that GF act as an additional insulation layer to the main wall reducing heat loss and heat transfer rate.

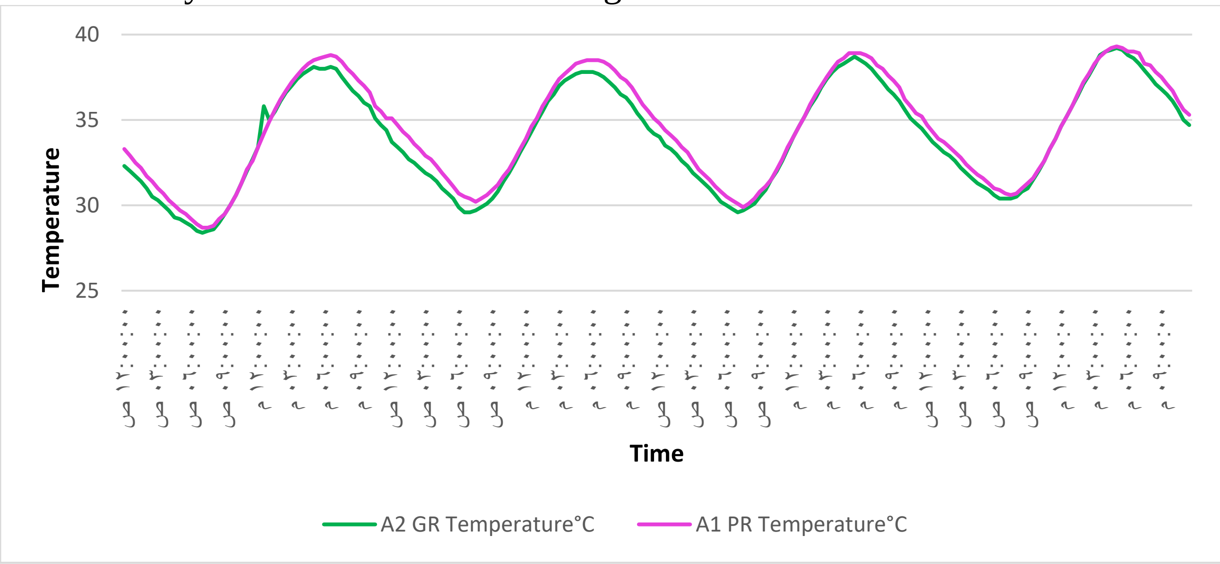


Figure 4.5
The differences between Air Temperature in GR and PR from June 27 to July 1

4.1.1.4 Analyzing the Internal Air Humidity- Period C

Hypothesis ($H_0$1.4) investigates the difference between the air humidity inside Aqaba buildings and the air humidity inside those with green facades during the summer. Air humidity was studied to detect the effect of GF on internal humidity. The study found a clear increase in the humidity inside the GR with a daily average of 1.8%. According to graph 4.6, temperature and humidity have an inverse relationship: the higher the temperature, the lower the humidity.

In fact, a high humidity ratio makes the space uncomfortable (figure 2.4); this is one of the obvious drawbacks of using GFs in residential buildings.

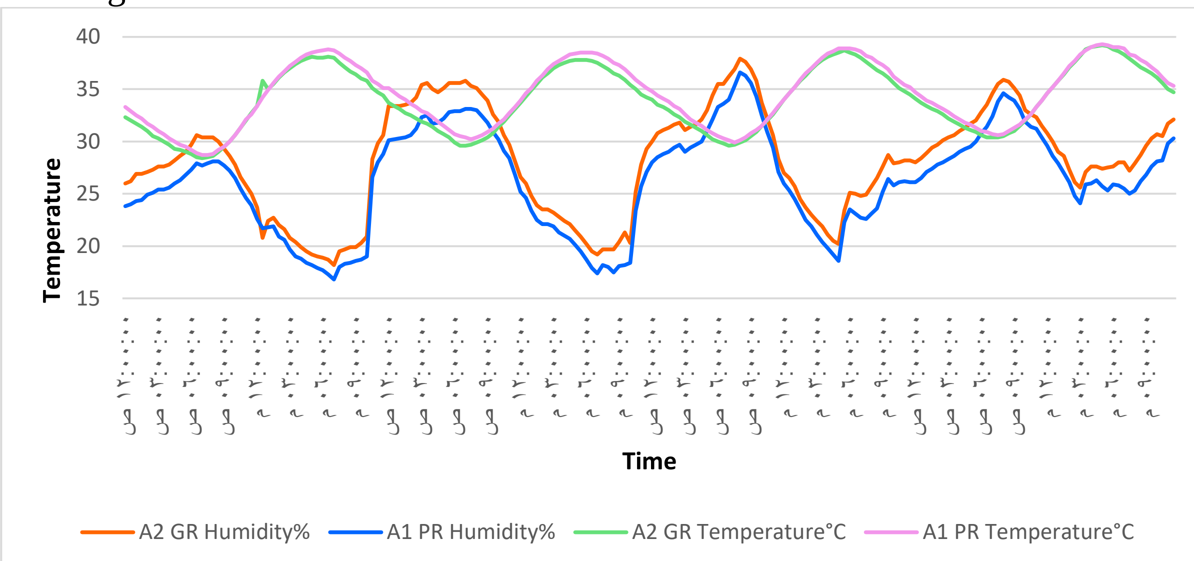


Figure 4.6
The differences between Air Temperature and humidity in GR and PR from June 27 to July 1

4.1.1.5 Analyzing the In-between Sub Climate Temperature- Period C

Hypothesis ($H_0$1.5) investigates the effect of the use of green facades on the temperature of the in-between sub-climate (between main wall and the green façade) of Aqaba buildings in summer season.

The findings of the experiment show a new sub climate, differs from the outdoor temperature and the inside air temperature, in the space between the south-west wall of GR and the GF. The figure 4.7 compares between the in-between sub climate temperature (IC0) and the internal air temperature of GR. It is shown that the range of air temperature inside GR is shorter than in-between climate temperature; slightly lower in the peaks and much higher in the valleys. Outdoor environment temperature is the widest range of the curves like most of the graphs. The in-between temperature is lower than the environment temperature between 9:00 AM to 9:00 PM, by (0.6 to 4.7) ^{o} C with a daily average of 1.4^{o}C, and almost equal in the night and early morning.

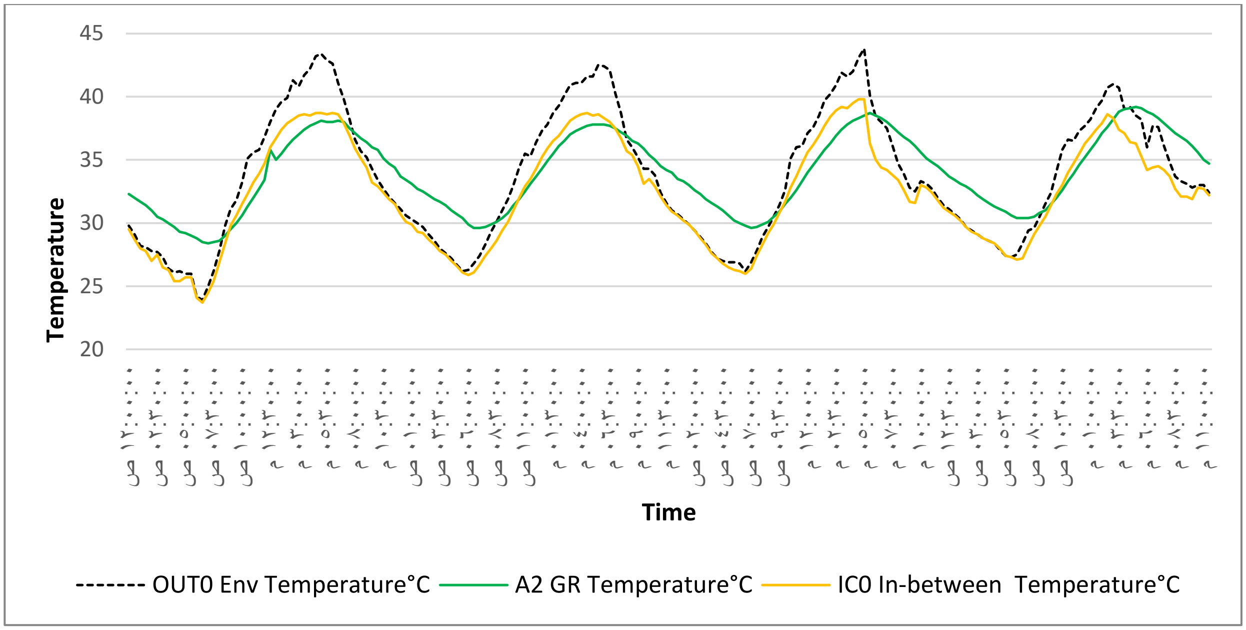


Figure 4.7
The temperature of in-between sub climate from June 27 to July 1

4.1.1.6 Analyzing the In-between Sub Climate Humidity- Period C

Hypothesis ($H_0$1.6) investigates the effect of the use of green facades on the humidity of the in-between sub-climate (between main wall and the green façade) of Aqaba buildings in summer season.

The same inverse relationship is detected between temperature and humidity of the outdoor environment and in-between sub climate. It is discovered that the humidity of IC0 is higher than that of OUT0 during the day, with a 3.7 % increase on average. Thus, using GF in a building creates a new sub climate with lower temperatures and more humidity (figure 4.8).

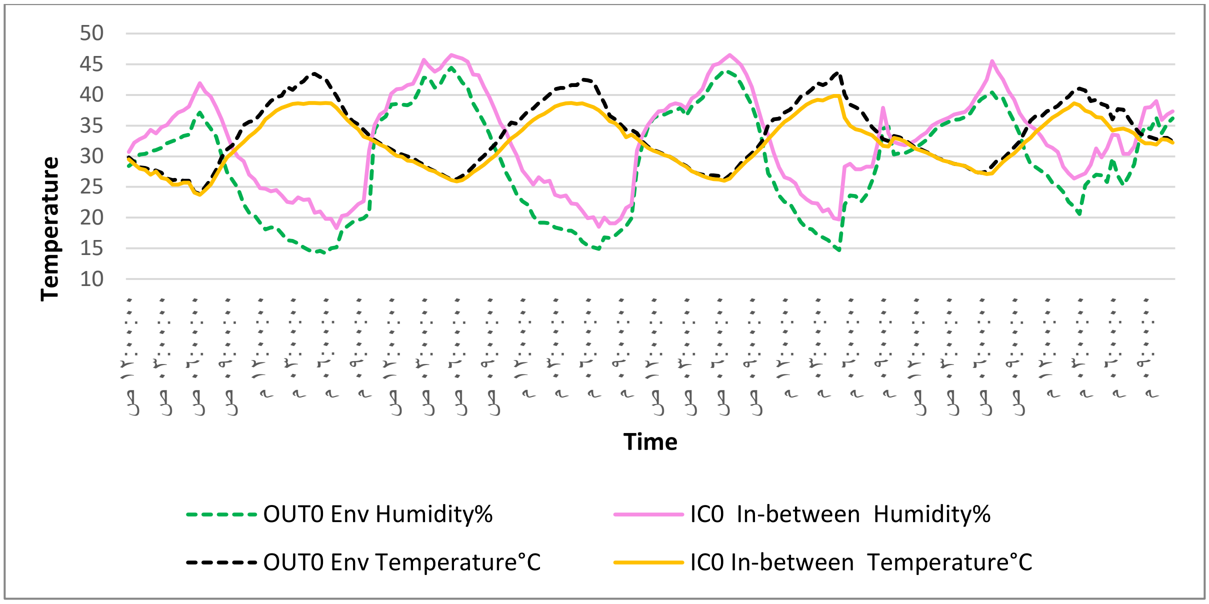


Figure 4.8
The temperature and humidity of in-between sub climate from June 27 to July 1

4.1.1.7 Explanations of the GF Thermal Behavior

Analyzing the variables in hot summer-Period C shows variations in internal temperature and humidity of buildings with green facades in Aqaba. That is due to the mechanisms of how GF affects thermal behavior of a building. This part explains that through heat transfer process.

According to a mechanical explanation, the GF has impacted the GR's external wall surface and decreased its temperature by around 1.4 ^{o}C daily average due to the ability of green facades to intercept solar radiation (shadow factor) during the hottest time of the day.

Three hours delay, the internal surface of the GR experienced a 1.6 ^{o}C drop in temperature due to thermal conduction process. Accordingly, the air inside GR is affected by this reduction due to radiation and convection process reducing its temperature of 0.49 ^{o}C.

When adding the internal air temperature curves for GR and PR to figure 4.4 and evaluating all the variables at once, it becomes clear that GR's internal surface temperature still has the narrowest range of all the variables for this time period. The external wall surface temperature decrease has been considered the most important variable in the comparison because it is the most noticeable and influenced of all the variables. See figure 4.9.

That indicates that under the experiment's conditions of full plant coverage, the GF has an effect on the thermal behavior of the wall, which in turn has an effect on the overall thermal change inside the GR during the summer in Aqaba.

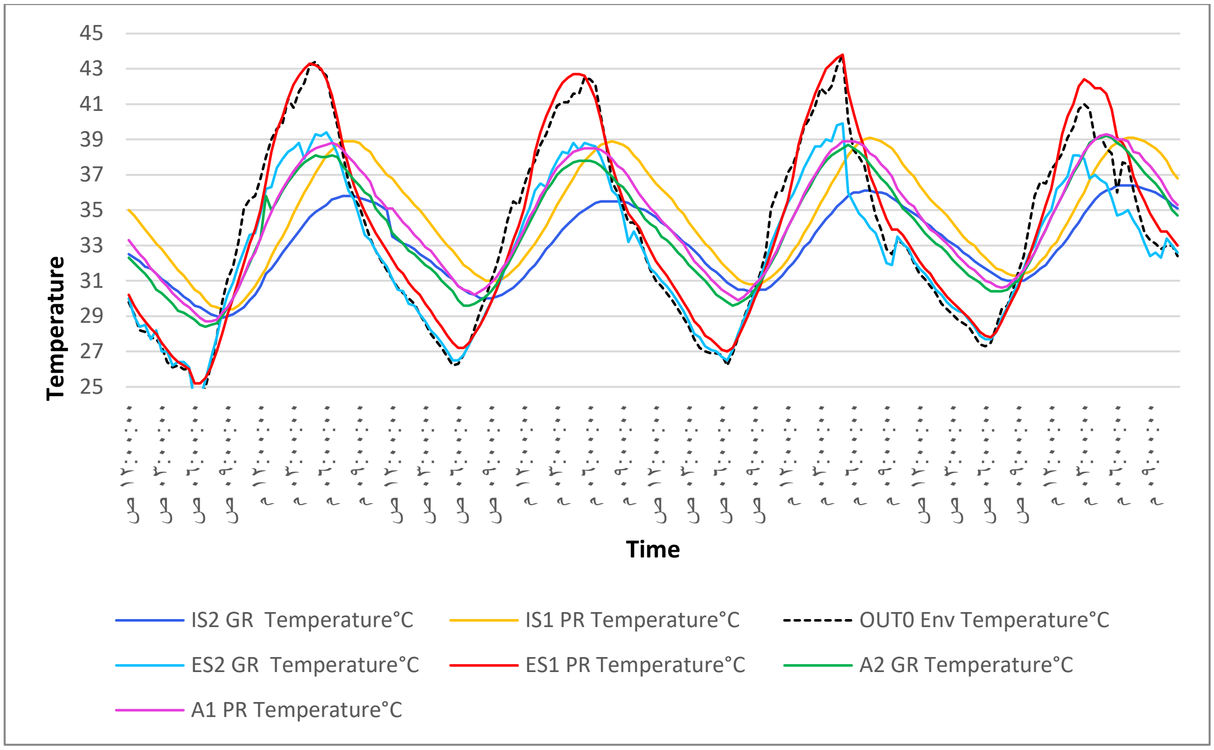


Figure 4.9

The differences between GR and PR according to external and internal wall surface temperature and air temperature from June 27 to July 1

The Graph below (figure 4.10) shows how the temperature changes when it is transferred from the outdoor to the indoor of GR through the wall layers. The outdoor ambient environment temperature is the greatest temperature in the peaks, the external surface temperature of GR is the next greatest, the internal air temperature is the third variable and the coolest temperature of GR is the internal surface temperature. According to GF, this behavior is explained by the earlier mentioned mechanisms, which reduces the impact of direct sunlight in daytime. Therefore, the temperature of the external surface is lower than the environment temperature in daytime. Accordingly, the internal surface temperature will be lower than the external surface temperature because of the heat loss during transferring and the cooling mechanism of the GF. This variable, the internal surface temperature, is the coolest in the daytime, while the internal air temperature is the second least cold variable.

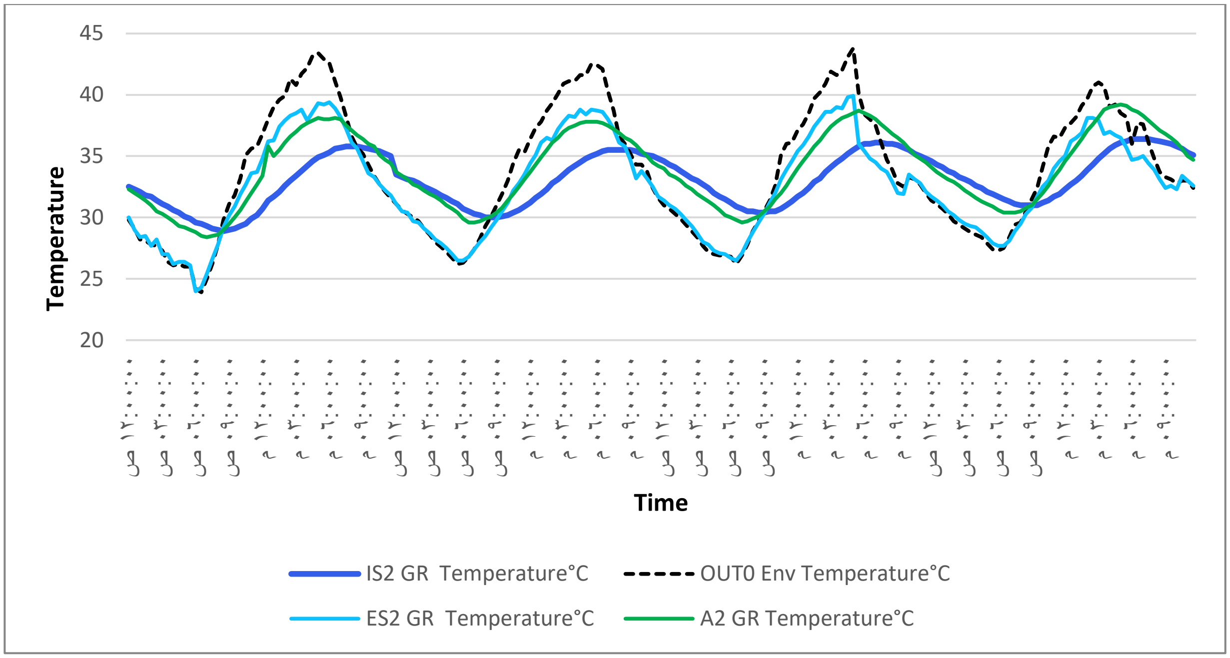


Figure 4.10

The shift in temperature in GR from June 27 to July 1

4.1.2 Analyzing the Variables in Hot Summer in the Case of Preventing the Buildings from Ventilation –Period D

The second hypothesis ($H_0 2$) examines the variations in interior temperature and humidity of buildings with green facades in Aqaba during the summer in the case of preventing the test rooms from ventilation- Period D.

Period D represents five hot summer days (From 8.7.2022 to 12.7.2022) in Aqaba according to Weatherspark website, (2022). The foliage coverage ratio of this period is about 100%. The daily average temperature of the ambient environment was 34°C, while the daily average of relative humidity of the ambient environment was 29.4%. According to the experiment observations during this period, the hottest time of the day (the curve peaks) was from 12:00 PM to 8:00 PM, with temperatures averaging 36 °C-44°C. The coolest time of the day (the curve valleys) was from 2:00 AM to 8:00 AM, with temperatures averaging 25°C-30°C.

The only difference between this period and the previous one is that the experiment in this period was designed to limit ventilation in both rooms. During this time, the minor gaps in the door and window in both rooms were closed, blocking airflow into the spaces. The goal of this part is to assess how ventilation affects the interior air in the GR. Internal wall surface temperature, internal air temperature and internal air humidity were analyzed to achieve this goal as follow:

4.1.2.1 Analyzing the Internal Wall Surface Temperature-Period D

Hypothesis ($H_0$2.1) investigates the difference in internal wall surface temperatures between buildings in Aqaba and those with green facades during the summer in the case of preventing buildings from ventilation.

The internal wall surface temperature observations were also studied for both rooms, regarding this hypothesis, using descriptive statistics. Findings show that IS2 temperature is less than IS1 by (0.1-3.4) ^{o}C during the whole day with an average of 1.4 ^{o}C of this period (figure 4.11). This reduction, with blocked ventilation, is smaller than the case with ventilation. That means the internal wall surface of GR is warmer in the case of blocked ventilation.

According to this finding, ventilation affects the thermal behavior of internal wall surface and blocking it reduces the effect of GF.

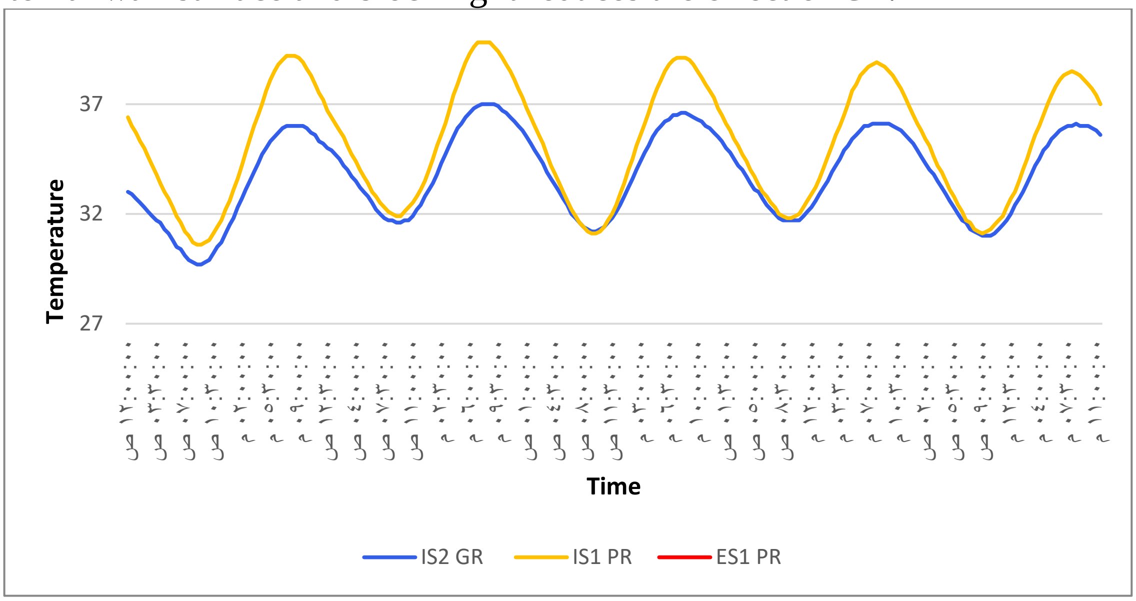


Figure 4.11

The differences between GR and PR according to internal wall surface temperature from July 8 to July 12

4.1.2.2 Analyzing the Internal Air Temperature-Period D

Hypothesis ($H_0$2.2) investigates the difference between the air temperature inside Aqaba buildings and the air temperature inside those with green facades during the summer in the case of preventing buildings from ventilation.

Descriptive statistics was initially used to study and analyze the main observations and figures for this variable in both rooms. The analysis of the observations at period D shows that the internal air temperature at GR is slightly cooler than the internal air temperature in PR by (0.3-1.4) ^{o}C from 6:00 PM to 7:00 AM, in which the internal air temperature differences are significant. The daily average of the differences is about 0.46°C during this period. Figure 4.12 shows that there appear to be no temperature differences between 8:00 AM and 3:00PM.

It is found that GF affected the temperature of internal spaces even without ventilation. However, it is noticed that the daily average of the reduction in internal air temperature during period D is, 0.46°C, less than it during period C, 0.49°C. That indicates that when ventilation is blocked, the temperature of the air inside a GR is higher.

This result reveals how limiting GR's ventilation has a negative impact on the temperature of the internal air. This is because heat doesn't escape from the GR via blocked ventilations.

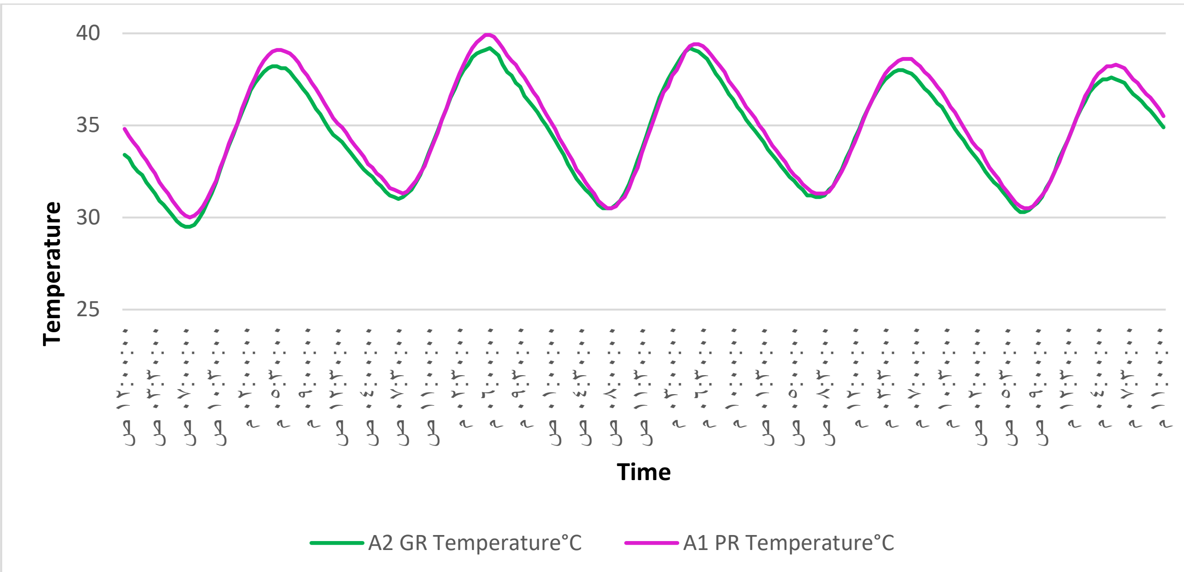


Figure 4.12

The differences between Air Temperature in GR and PR from July 8 to July 12

4.1.2.3 Analyzing the Internal Air Humidity-Period D

Hypothesis ($H_0$2.3) investigates the difference between the air humidity inside Aqaba buildings and the air humidity inside those with green facades during the summer in the case of preventing buildings from ventilation.

Air humidity in this period also studied inside both rooms, using descriptive statistics, to detect the effect of blocking ventilation into the space in the research on internal humidity in GR. The study found a clear increase in the humidity inside the GR with a daily average of 2%. Temperature and humidity have an inverse relationship: the higher the temperature, the lower the humidity. It is noticed that the daily average of the reduction in internal air humidity during period D is, 2%, greater than it during period C, 1.8%.

The findings show that preventing GR from ventilation affects the internal air humidity negatively in addition to the temperature. That is due to the room's accumulation of water vapors.

The figures in tables 4.1 and 4.2 summarize the effects of GF on GR thermal behavior during periods C and D.

Table 4.1
The effect of GF on GR thermal behavior during period C

	ES2 Temp	IS2 Temp	A2 Temp	IC0 Temp	A2 Hum	IC0 Hum
Daily average reduction	1.4 ^{o} C	1.6 ^{o}C (0.3-3.4) ^{o}C	0.49^{o}C	1.4 ^{o}C	X	X
The period of significant reduction	The hottest time of the day 1:00 PM-8:00 PM	All the day The most significant 4:00 PM- 11:00 PM The least significant 6:00 AM- 11:00 AM	6:00 PM- 7:00 AM	9:00 AM to 9:00 PM	X	X
The significant reduction	(1.4-5.4)^{o}C	The most significant (1.7-3.4) ^{o}C The least significant (0.3-1.4) ^{o}C	(0.3-1.4)^{o}C 0.72^{o}C	(0.6 to 4.7) ^{o} C	X	X
	ES2 Temp	**IS2 Temp**	**A2 Temp**	**IC0 Temp**	**A2 Hum**	**IC0 Hum**
The period of no significant effect	The coolest time of the day 2:00 AM-8:00 AM	X	10:00 AM- 3:00 PM	at night and early morning	X	X
The period of significant increase	X	X	X	X	All the day	All the day
The significant increase	X	X	X	X	(0.6-3.3)% with a 1.8% daily average increase	3.7 % daily average increase

Table 4.2
The effect of GF on GR thermal behavior during period D

	IS2 Temp	A2 Temp	A2 Hum
Daily average reduction	1.4 °C (0.1-3.4) °C	0.46°C	X
The period of significant reduction	All the day	6:00 PM to 7:00 AM	X
The significant reduction	(0.1-3.4) °C 1.4 °C	(0.3-1.4)°C 0.7°C	X
The period of no significant effect	X	8:00 AM and 3:00 PM	X
The period of significant increase	X	X	All the day
The significant increase	X	X	(0.4-4.3)% with a 2% daily average increase

4.2 Analyzing the Variables in Hot Summer Using Independent Samples T-Test

Statistical tests were also used in the analysis to verify the results in terms of statistical theories. The Independent Samples T-Test was used to statistically test the earlier mentioned hypotheses. By comparing the means of two groups of samples, this test automatically calculates the T test effect Size. In an ideal situation, the subjects would be randomly assigned to two groups for this test, ensuring that any differences in reaction are due to the therapy and not to extraneous circumstances (IBM, 2021).

The main outcome of this test is the statistical significance (sig.), which is a probability measure of the null hypothesis that being true relative to the acceptable degree of uncertainty about the true answer.

Alpha (the significant level) was pre-specified of 0.05 by the researcher. It represents the level of tolerance for error in decimal form. That is implying that before the researcher rejected the null hypothesis, he agreed its chance to be less than 5%. As a result, the researcher who needs to be 95% confident in the results of the study must be willing to be mistaken about those results 5% of the time (Tenny S. and Abdelgawad I., 2021). The following are the hypotheses tests according to independent samples T- test:

4.2.1 The First Main Hypothesis ($H_0 1$)

There is no statistically significant effect of green facades on the internal temperature and humidity of Aqaba buildings during the summer season-Period C at ($\alpha \leq 0.05$) level. This hypothesis generates the following related hypotheses:

4.2.1.1 Hypothesis ($H_0 1.1$)

states: There is no statistically significant difference between the external wall surface temperature of Aqaba buildings and those with green facades during the summer season-Period C at ($\alpha \leq 0.05$) level. Table 4.3 and table 4.4 illustrate the main figures of the sample T-test.

Table 4.3

Group Statistics- $H_0 1.1$

home		N	Mean	Std. Deviation	Std. Error Mean
degree	PR	192	34.0219	5.29216	.38193
	GR	192	32.6307	4.00354	.28893

Table 4.4

Independent Samples Test- $H_0 1.1$

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
degree	Equal variances assumed	20.729	.000	2.905	382	**.004**	1.39115	.47891	.44953	2.33277
	Equal variances not assumed			2.905	355.681	**.004**	1.39115	.47891	.44930	2.33299

The result for the test ($H_0 1.1$) is that we reject the null hypothesis because the statistical significance is less than 0.05 (sig=0.004). That means that there is a statistical significant difference between the external wall surface temperature of Aqaba buildings and those with green facades during the summer season at ($\alpha \leq 0.05$) level.

4.2.1.2 Hypothesis ($H_0 1.2$)

states: There is no statistically significant difference between the internal wall surface temperature of Aqaba buildings and those with green facades during the summer season-Period C at ($\alpha \leq 0.05$) level. Table 4.5 and table 4.6 illustrate the main figures of the sample T-test.

Table 4.5
Group Statistics- $H_01.2$

home		N	Mean	Std. Deviation	Std. Error Mean
degree	PR	192	34.6630	2.91809	.21059
	GR	192	33.0479	2.15020	.15518

Table 4.6
Independent Samples Test- $H_01.2$

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
degree	Equal variances assumed	29.956	.000	6.174	382	**.000**	1.61510	.26159	1.10076	2.12944
	Equal variances not assumed			6.174	351.185	**.000**	1.61510	.26159	1.10062	2.12959

The result for ($H_01.2$) test is that we reject the null hypothesis because the statistical significance is almost zero, which is less than 0.05. This indicates that, at (α <0.05) level, there is a very strong, statistically significant difference between the internal wall surface temperature of Aqaba buildings compared to those with green facades during the summer.

4.2.1.3 Hypothesis ($H_01.3$)

states: There is no statistically significant difference between the air temperature inside Aqaba buildings and the air temperature inside those with green facades during the summer season-Period C at ($\alpha \leq 0.05$) level. Table 4.7 and table 4.8 illustrate the main figures of the sample T-test.

Table 4.7
Group Statistics- $H_01.3$

home		N	Mean	Std. Deviation	Std. Error Mean
degree	PR	192	34.4401	3.09252	.22318
	GR	192	33.9594	3.07942	.22224

Table 4.8
Independent Samples Test- $H_01.3$

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
degree	Equal variances assumed	.000	.991	1.526	382	**.128**	.48073	.31496	-.13855	1.10000
	Equal variances not assumed			1.526	381.993	**.128**	.48073	.31496	-.13855	1.10000

The result for ($H_01.3$) test is that we accept the null hypothesis because the statistical significance (sig=0.128) is greater than 0.05. That means that there is no statistically significant difference between the internal air temperature of Aqaba buildings and the internal air temperature of those with green facades during the summer season- Period C at ($\alpha \leq 0.05$) level.

4.2.1.4 Hypothesis ($H_01.4$)

states: There is no statistically significant difference between the air humidity inside Aqaba buildings and the air humidity inside those with green facades during the summer season-Period C at ($\alpha \leq 0.05$) level. Table 4.9 and table 4.10 illustrate the main figures of the sample T-test.

Table 4.9
Group Statistics- $H_01.4$

home		N	Mean	Std. Deviation	Std. Error Mean
degree	PR	192	26.2880	4.82062	.34790
	GR	192	28.1188	5.05825	.36505

Table 4.10
Independent Samples Test- $H_01.4$

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
degree	Equal variances assumed	.555	.457	-3.630	382	**.000**	-1.83073	.50427	-2.82223	-.83923
	Equal variances not assumed			-3.630	381.119	**.000**	-1.83073	.50427	-2.82224	-.83922

The result for ($H_0$1.4) test is that we reject the null hypothesis because the statistical significance is almost zero, which is less than 0.05. This indicates that, at ($\alpha \leq 0.05$) level, there is a very strong, statistically significant difference between the internal air humidity of Aqaba buildings and the internal air humidity of those with green facades during the summer season-Period C.

4.2.1.5 Hypothesis ($H_0$1.5)

states: There is no statistically significant difference between the temperature of the in-between sub-climate (between main wall and the green façade) of Aqaba buildings and the outdoor ambient temperature during summer season-Period C at ($\alpha \leq 0.05$) level. Table 4.11 and table 4.12 illustrate the main figures of the sample T-test.

Table 4.11
Group Statistics- $H_0$1.5

home		N	Mean	Std. Deviation	Std. Error Mean
degree	IC0	192	32.3443	4.22816	.30514
	OUT0	192	33.6969	5.17474	.37345

Table 4.12
Independent Samples Test- $H_0$1.5

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
degree	Equal variances assumed	12.828	.000	-2.805	382	**.005**	-1.35260	.48226	-2.30083	-.40438
	Equal variances not assumed			-2.805	367.404	**.005**	-1.35260	.48226	-2.30095	-.40426

The result for ($H_0$1.5) test is that we reject the null hypothesis because the statistical significance is less than 0.05 (sig=0.005). This indicates that, at ($\alpha \leq 0.05$) level, there is a statistically significant difference between the temperature of the in-between sub-climate of Aqaba buildings and the outdoor ambient temperature during the summer season-Period C.

4.2.1.6 Hypothesis ($H_0$1.6)

states: There is no statistically significant difference between the humidity of the in-between sub-climate (between main wall and the green façade) of Aqaba buildings and the outdoor ambient humidity during summer season-Period C at ($\alpha \leq 0.05$) level. Table 4.13 and table 4.14 illustrate the main figures of the sample T-test.

Table 4.13
Group Statistics- $H_0$1.6

home		N	Mean	Std. Deviation	Std. Error Mean
degree	IC0	192	32.5771	7.79240	.56237
	OUT0	192	28.8677	8.69729	.62767

Table 4.14
Independent Samples Test- $H_0$1.6

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
degree	Equal variances assumed	5.693	.018	4.401	382	**.000**	3.70938	.84275	2.05236	5.36639
	Equal variances not assumed			4.401	377.480	**.000**	3.70938	.84275	2.05230	5.36645

The result for ($H_0$1.6) test is that we reject the null hypothesis because the statistical significance is almost zero, which is less than 0.05. This indicates that, at ($\alpha \leq 0.05$) level, there is a very strong, statistically significant difference between the humidity of the in-between sub-climate of Aqaba buildings and the outdoor ambient humidity during the summer season-Period C.

4.2.2 The Second Hypothesis ($H_0$2)

states: There is no statistically significant effect of green facades on the internal temperature and humidity of Aqaba buildings in the case of preventing buildings from ventilation during the summer season-Period D at ($\alpha \leq 0.05$) level. This hypothesis generates the following related hypotheses:

4.2.2.1 Hypothesis ($H_0$2.1)

states: There is no statistically significant difference in the internal wall surface temperatures between Aqaba buildings and those with green facades in the case of preventing buildings from ventilation during the summer-Period D at ($\alpha \leq 0.05$) level. Table 4.15 and table 4.16 illustrate the main figures of the sample T-test.

Table 4.15
Group Statistics- $H_0$2.1

home		N	Mean	Std. Deviation	Std. Error Mean
degree	plan	240	35.1742	2.70376	.17453
	green	240	33.7879	1.97166	.12727

Table 4.16
Independent Samples Test- $H_0$2.1

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
degree	Equal variances assumed	40.236	.000	6.418	478	**.000**	1.38625	.21600	.96182	1.81068
	Equal variances not assumed			6.418	437.154	**.000**	1.38625	.21600	.96172	1.81078

The result for ($H_0$2.1) test is that we reject the null hypothesis because the statistical significance is almost zero, which is less than 0.05. This indicates that, at ($\alpha \leq 0.05$) level, there is a very strong, statistically significant difference between the internal wall surface temperature of Aqaba buildings compared to those with green facades in the case of preventing buildings from ventilation during the summer-Period D.

4.2.2.2 Hypothesis ($H_0$2.2)

states: There is no statistically significant difference between the air temperature inside Aqaba buildings and the air temperature inside those with green facades in the case of preventing buildings from ventilation during the summer season-Period D at ($\alpha \leq 0.05$) level. Table 4.17 and table 4.18 illustrate the main figures of the sample T-test.

Table 4.17
Group Statistics- $H_0$2.2

home		N	Mean	Std. Deviation	Std. Error Mean
degree	plan	240	34.9450	2.84688	.18377
	green	240	34.4892	2.73599	.17661

Table 4.18
Independent Samples Test- $H_0$2.2

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
degree	Equal variances assumed	.698	.404	1.788	478	**.074**	.45583	.25487	-.04498	.95664
	Equal variances not assumed			1.788	477.247	**.074**	.45583	.25487	-.04498	.95664

The result for ($H_0$2.2) test is that we accept the null hypothesis because the statistical significance (sig=0.074) is greater than 0.05. That means that there is no statistically significant difference between the internal air temperature of Aqaba buildings and the internal air temperature of those with green facades in the case of preventing buildings from ventilation during the summer season- Period D at ($\alpha \leq 0.05$) level.

4.2.2.3 Hypothesis ($H_0$2.3)

states: There is no statistically significant difference between the air humidity inside Aqaba buildings and the air humidity inside those with green facades in the case of preventing buildings from ventilation during the summer season-Period D at ($\alpha \leq 0.05$) level. Table 4.19 and table 4.20 illustrate the main figures of the sample T-test.

Table 4.19
Group Statistics- $H_0$2.3

home		N	Mean	Std. Deviation	Std. Error Mean
degree	plan	240	26.2829	6.95397	.44888
	green	240	28.3192	6.99343	.45142

Table 4.20
Independent Samples Test- $H_0$2.3

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
degree	Equal variances assumed	.007	.933	-3.199	478	**.001**	-2.03625	.63661	-3.28715	-.78535
	Equal variances not assumed			-3.199	477.985	**.001**	-2.03625	.63661	-3.28715	-.78535

The result for ($H_0$2.3) test is that we reject the null hypothesis because the statistical significance is less than 0.05 (sig=0.001). This indicates that, at ($\alpha \leq 0.05$) level, there is a strong, statistically significant difference between the internal air humidity of Aqaba buildings and the internal air humidity of those with green facades in the case of preventing buildings from ventilation during the summer season-Period D.

4.3 Findings Discussion of the Descriptive Statistics and the Independent Samples T-Test

This part links and compares the findings between the descriptive statistics and the independent samples T-test. It allows us to draw clear comprehensive conclusions.

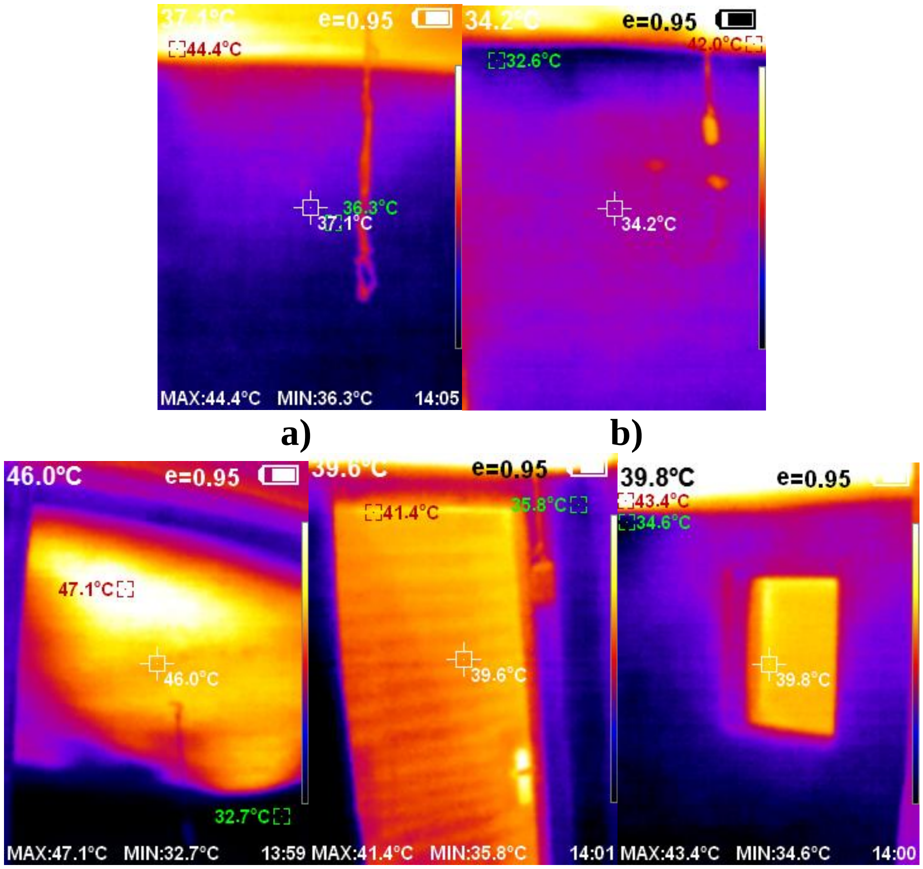
Discussion 1.1: regarding hypothesis ($H_0$1.1), the descriptive statistics demonstrate that there is a difference in the temperature between GR's external wall surface and that of PR in Aqaba during the summer season at the experiment conditions. The statistical tests prove that this difference is statistically very significant at 0.05 level. This finding is consistent with the findings of Jaradat N. et al. (2022). Green walls were shown to be an effective natural shading solution because they effectively reduce outside wall surface temperatures. However, it was discovered that the reduction in daylight hours is (6-11)^{o}C, whereas the reduction in the current research's significant hours is (1.4-5.4)^{o}C. Widiastuti et al. (2020) and Safikhani et al. (2014) also demonstrated that green walls reduce the temperature of the external wall surface.

Discussion 1.2: regarding hypothesis ($H_0$1.2), the descriptive statistics demonstrate that there is a difference in the temperature between GR's internal wall surface and that of PR in Aqaba during the summer season at the experiment conditions. The statistical tests prove that this difference is statistically very significant at 0.05 level. This finding agrees with Widiastuti et al. (2020); Safikhani et al. (2014) and Coma et al. (2016), demonstrating that green walls reduce the internal wall surface temperature.

Discussion 1.3: regarding hypothesis ($H_0$1.3), although the descriptive statistics show a clear difference in the temperature of internal air in Aqaba in the GR comparing with that of PR during summer season at the experiment conditions, the independent samples T-test prove that this difference does not statistically significant at 0.05 level. This finding agrees with Safikhani et al. (2014), Widiastuti et al. (2020), and Coma et al. (2016). However, Safikhani et al. (2014) discovered a reduction in air temperature inside the space of up to 2.5^{o}C, whereas the current study found a reduction of up to 1.4^{o}C.

The drop of the air temperature in GR in the current study is less than expected. The reason for this is due to the rooms' thermal conditions. While the GF prevents the GR from heat gain, the internal air temperature is primarily influenced by four walls and a roof, all of which are exposed to external thermal factors like direct sunrays, warm ambient air, wind speed, and humidity. The layers of these elements indeed have high u values, which increase the rate of heat transfer through each layer and result in high thermal conduction. The areas that gain the most heat as a result are increased, and the GF effect is dropped. Additionally, due to its perpendicular orientation to the sun during the summer, the roof accumulates a huge amount of heat. The thermal imaging of roof illustrates that in figure 4.13. The thermal imaging also reveals a significant thermal leakage from the window and the door, indicating that their insulation is inadequate (figure 4.13).

All of this reduces the south-west internal wall surface's cooling effect on the GR internal air and brings it closer to the PR internal air. Thus, the researcher is eager to make some adjustments to the insulation and material of the building layers and openings' u values and examine the new findings in follow-up further research.



a) b)

c) d) e)

Figure 4.13

Thermal images of a) IS1, b) IS2, c) the roof of the GR, d) the door in the GR, e) the window of the GR.

Discussion 1.4: regarding hypothesis ($H_0$1.4), the descriptive statistics demonstrate that there is a clear difference between the air humidity inside Aqaba buildings and the air humidity inside those with green facades during the summer season at the experiment conditions. The statistical tests prove that this difference is statistically very significant at 0.05 level. This finding supports the findings of Jaradat N. et al. (2022), Widiastuti et al. (2020), Safikhani et al. (2014), and Coma et al. (2016), which show that green walls increase the air humidity of internal spaces.

Discussion 1.5: regarding hypothesis ($H_0$1.5), the descriptive statistics demonstrate that there is a clear difference between the temperature of the in-between sub-climate of Aqaba buildings and the outdoor ambient temperature during the summer season at the experiment conditions. The statistical tests prove that this difference is statistically significant at 0.05 level. This study is in line with Jaafar B. et al. (2013) and Safikhani et al. (2014) regarding the effect of green façade in creating a new sub-climate with lower temperatures.

Discussion 1.6: regarding hypothesis ($H_0$1.6), the descriptive statistics demonstrate that there is a clear difference between the humidity of the in-between sub-climate of Aqaba buildings and the outdoor ambient humidity during the summer season at the experiment conditions. The statistical tests prove that this difference is statistically very significant at 0.05 level. This study is in line with Jaafar B. et al. (2013) and Safikhani et al. (2014) regarding the effect of green façade in creating a new sub-climate with higher humidity.

Discussion 2.1: regarding hypothesis ($H_0$2.1), the descriptive statistics demonstrate that there is a difference in the temperature between GR's internal wall surface and that of PR in Aqaba, in the case of preventing buildings from ventilation during the summer-Period D at the experiment conditions. The statistical tests prove that this difference is statistically very significant at 0.05 level.

Discussion 2.2: regarding hypothesis ($H_0$2.2), although the descriptive statistics show a clear difference in the temperature of internal air in Aqaba in the GR comparing with that of PR in the case of preventing buildings from ventilation during the summer season-Period D, the independent samples T-test prove that this difference does **not** statistically significant at 0.05 level. The findings of Safikhani et al. (2014) agree with this finding in that both demonstrated the ability of GF to reduce the temperature inside spaces when ventilation is blocked. However, the current research found that the reduction in the case of blocked ventilation is greater than it in the case of being ventilation, whereas, the opposite is true according to Safikhani et al. This could be related to the amount of ventilation allowed to circulate in both experiments.

Discussion 2.3: regarding hypothesis ($H_0$2.3), the descriptive statistics demonstrate that there is a clear difference between the air humidity inside Aqaba buildings and the air humidity inside those with green facades, in the case of preventing buildings from ventilation during the summer season-Period D at the experiment conditions. The statistical tests prove that this difference is statistically very significant at 0.05 level.

As a result, in the case of preventing buildings from ventilation, the GF is still affecting the thermal behavior of Aqaba buildings. However, the effect of GF in this case is less than it with ventilation according to temperature. Internal humidity in this case is more affected negatively.

4.4 Conclusions

It was analyzed and compared between the external wall surface temperature, internal wall surface temperature, internal air temperature and internal air humidity in two similar test rooms. The intermediate sub climate's temperature and humidity were also compared to those of the outdoor ambient environment.

Based on these parameters' analysis, findings and discussion, and in relation to the previous hypotheses and objectives, this study finds out that:

1. Concerning the findings of Hypothesis ($H_0$1.1), it is concluded that the external wall surface temperature of GR can be reduced by up to 5.4 °C in warm weather with a daily average of 1.4 ^oC. That is due to the excellent ability of green facades to intercept solar radiation (shadow factor). During the hottest time of the day in the summer, the external wall surface temperature of the GR is less than that of the PRs' by (1.4-5.4) ^oC. However, the external wall surface temperature of GR and PR is approximately equal during the coolest time of the day. The reason is that the south-west wall surface of PR loses heat faster than GR's does because its green façade controls the rate of heat transfer and reduces heat loss. According to the figures discovered, this parameter is regarded as the most effective of all tested parameters. It can be also used as a natural shading device to protect the building from direct sun rays efficiently.
2. Regarding the findings of Hypothesis ($H_0$1.2), it is concluded that green facades have a significant impact on internal wall surface temperature during summer season due to the idea of insulation, which minimizes and controls heat transfer through the wall layers via conduction. A green facade can lower the internal surface temperature of up to 3.4 ^oC at its highest points, around 8:00 PM, with a daily average reduction of 1.6 ^oC. The reduction during the morning is at its lowest because PR's internal surface losses gained heat faster than GRs'.
3. Concerning the findings of Hypothesis ($H_0$1.3), it is concluded that the green façade has a strong potential for cooling the spaces during summer season; it functions as an insulating extra layer, slowing down heat transfer with the internal air and reducing heat loss. It shortens the range of internal air temperatures. In the peaks of the internal air temperature curve, green facade can reduce the internal air temperature of up to 1.4 ^oC with a daily average reduction of 0.49 ^oC, but in the valleys of the internal air temperature curve, 10:00 AM - 3:00 PM, there are no temperature differences between the air in both rooms. That because the air in PR losses heat faster, while GR maintains heat inside.

4. Concerning the findings of Hypothesis ($H_0$1.4), it is concluded that the GR's internal relative humidity is significantly impacted by the green façade, which raises the ratio up to 3.3% with a daily average of 1.8% during the summer season. A high humidity ratio makes the space uncomfortable, which is one of the clear disadvantages of adopting green façades in residential buildings.
5. Concerning the findings of Hypothesis ($H_0$1.5), it is discovered that between the main wall and the green façade, a new sub-climate is created. It is different from the outdoor ambient climate and the internal air climates. The range of the in-between climate temperature curve is narrower than that of the outdoor environment temperature curve; it is less between 9:00 AM and 9:00 PM by (0.6 - 4.7) ^{o}C, and it is almost equal at night and early morning with a daily average reduction of 1.4 ^{o}C during summer season. This decrease is caused by the potential of GF in shading mechanism.
6. Concerning the findings of Hypothesis ($H_0$1.6), it is revealed that humidity of in-between sub-climate is higher than that of the outdoor ambient environment during the day, with a 3.7 % increase on average. Thus, using GF in a building creates a new sub climate with lower temperatures and more humidity.
7. Concerning the findings of Hypothesis ($H_0$2.1), it is revealed that the green facade affected the temperature of internal wall surface even without ventilation during the summer. The internal wall surface's thermal behavior is influenced by ventilation, and preventing the buildings from ventilation minimizes green facade effect. Compared to the ventilation period (C), the temperature of the internal wall surface of the GR is 0.2 ^{o}C warmer in the case of blocked ventilation (D).
8. Concerning the findings of Hypothesis ($H_0$2.2), it is revealed that the green facade affected the temperature of internal air even without ventilation. However, limiting GR's ventilation has a slightly negative impact on the temperature of the internal air during the summer season. The daily average of the reduction in internal air temperature during the blocked ventilation period (D) is less by 0.03 ^{o}C than that during the ventilation period (C). That indicates that when ventilation is blocked, the temperature of the air inside a GR is higher. This is because heat doesn't escape from the GR via blocked ventilation.
9. Concerning the findings of Hypothesis ($H_0$2.3), it is revealed that preventing GR from ventilation affects the internal air humidity negatively during the summer season. The daily average reduction in internal air humidity during the blocked ventilation period is greater by 0.2% than it is

during the ventilation period (C). That is due to the room's accumulation of water vapors.

10. An additional conclusion is that the temperature and humidity have an inverse relationship as a general rule: the higher the temperature, the lower the humidity.

This study concludes that green facades have a significant potential to improve buildings' thermal behavior in the hot summer months in Aqaba. It had an impact on the temperature of the internal air, the internal wall surface, and the external walls surface. It can be utilized as a passive system to minimize energy consumption in buildings.

The effect of the green façade on increasing the relative humidity inside the structures is a drawback that calls for a solution.

The thermal behavior of a building is influenced by ventilation. Blocking buildings from ventilation has a slightly negative impact on the temperature and humidity of buildings. It minimizes green facade effect on the internal temperature during the summer season keeping the spaces warmer. However, it maximizes the green facade effect on internal humidity keeping the spaces more humid.

4.5 Recommendations

This thorough investigation revealed significant findings that help to promote the idea of implementing the green façade system in buildings of Aqaba and other hot, arid climates worldwide. These are some recommendations based on the study's objectives and conclusions:

1. It is recommended to apply green façade system:
   I. as a natural shading device to protect the building from direct sun rays in hot arid areas like Aqaba. West or south-west elevation is recommended to mountain the green façade, in cities of same latitudes.
   II. when there is no horizontal plant cover and the horizontal areas are limited.
   III. in downtown cities where urban heat islands exist. It would definitely reduce the impact of urban heat islands while also creating an impressive urban environment.
2. The researcher recommends the relevant authorities to create a green wall regulation that includes a mandatory percentage of vertical greenery systems in local buildings, similar to the horizontal green percentage.
3. Natural ventilation is required to control indoor humidity when applying a green wall system. It can minimize the impact of a vertical greenery system on temperatures but it enhances the comfort of the indoor environment.

4. In hot temperature regions like Aqaba, the researcher advises architectural designers to incorporate VGS as a design element.
5. In order to promote the usage of green wall systems in buildings, the researcher recommends academics to use the results and figures of this experimental study in developing and refining computer simulation software.
6. To make the environment more pleasant and turn Aqaba into a green city, the researcher recommends *Aqaba Special Economic Zone Authority* to implement the green wall system along all main streets.

4.6 Future Works

Regarding the study's objectives, limitations, conclusions and recommendations, these are some suggestions and treatments for additional research:

1. It is suggested to duplicate the experiment in further studies and remove the hanging down plants from the green façade, by remove the plants' pots from the roof edge of the green room, and maintain the climbing up plants to eliminate the mistakes of watering and spoil the elevation of water. After that, compare the results to the current research.
2. It is suggested to repeat the experiment in future research with the u values of the roof and wall layers being reduced by adding an insulating layer to lessen heat gain from the roof and walls. Furthermore, the door and window are suggested to be replaced with high insulating properties. Then, in order to investigate into the insulation factor, compare the findings to current research.
3. It is suggested to carry out the experiment once more in future research, with a third test room constructed with a true west orientation. The results should then be compared to current research in order to investigate the impact of the orientation factor.

5 It is suggested in future research to investigate the impact of wind factor in the same experiment conditions.

6 It is suggested in future research to investigate the impact of building temperature reduction on energy savings and CO_2 emissions.

7 It is suggested to analyze the observations in the spring and winter, to determine if green façade can thermally affect Aqaba buildings during the spring and winter seasons.

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Appendix I

The Temperature and Humidity Observations- Period C and Period D

The Temperature and Humidity Observations-Period C

Date	Time	OUT0 Env Temperature °C	OUT0 Env Humidity%	ES2 GR Temperature °C	ES2 GR Humidity%	A2 GR Temperature °C	A2 GR Humidity%	IS2 GR Temperature °C	IS2 GR Humidity%	IC0 In-between Temperature °C	IC0 In-between Humidity%	ES1 PR Temperature °C	ES1 PR Humidity%	A1 PR Temperature °C	A1 PR Humidity%	IS1 PR Temperature °C	IS1 PR Humidity%
27-06-22	12:00 AM	29.8	28.4	30	29	32.3	26	32.5	28.1	29.5	30.7	30.2	28.1	33.3	23.8	35	23.5
27-06-22	12:30 AM	29.1	29.1	29	29.9	32	26.2	32.3	28.3	28.7	32.2	29.6	29.7	32.9	24	34.7	23.6
27-06-22	1:00 AM	28.2	30.3	28.4	30.8	31.7	26.9	32.1	28.5	28	32.8	29.1	29.4	32.5	24.3	34.3	23.8
27-06-22	1:30 AM	28.1	30.4	28.5	31.1	31.4	26.9	31.8	28.4	27.8	33.2	28.7	29.7	32.2	24.4	33.9	24
27-06-22	2:00 AM	27.8	30.8	27.7	32.3	31	27.1	31.7	28.5	27	34.3	28.3	30.2	31.7	24.9	33.5	24.4
27-06-22	2:30 AM	27.7	31	28.2	31.3	30.5	27.3	31.4	28.5	27.5	33.7	28	30.6	31.4	25.1	33.1	24.4
27-06-22	3:00 AM	27.3	31.4	27	32.7	30.3	27.6	31.1	28.6	26.5	34.7	27.5	30.9	31	25.4	32.8	24.7
27-06-22	3:30 AM	26.4	32.1	27	32.8	30	27.6	30.9	28.6	26.3	35.1	27.1	31.6	30.7	25.4	32.4	24.8
27-06-22	4:00 AM	26.1	32.5	26.2	33.9	29.7	27.8	30.6	28.7	25.4	36.3	26.7	31.9	30.3	25.6	32	24.9
27-06-22	4:30 AM	26.2	32.8	26.4	34.6	29.3	28.2	30.4	29.1	25.4	37.1	26.4	32.3	30	26	31.6	25.1
27-06-22	5:00 AM	26	33.3	26.4	35	29.2	28.6	30.1	29.4	25.7	37.5	26.2	33.4	29.7	26.3	31.3	25.3
27-06-22	5:30 AM	26	33.5	26.1	35.2	29	29	29.9	29.8	25.7	38.1	26	33.3	29.5	26.8	30.9	25.6
27-06-22	6:00 AM	24.2	35.9	24	38.7	28.8	29.7	29.6	30.5	24.1	40.1	25.2	36.4	29.2	27.3	30.5	26.1
27-06-22	6:30 AM	23.9	37.1	24.3	40.2	28.5	30.6	29.5	31	23.7	41.9	25.2	35	28.9	27.9	30.3	26.7
27-06-22	7:00 AM	25	35.7	25.4	37.7	28.4	30.4	29.3	31	24.5	40.5	25.5	33.7	28.7	27.7	29.9	26.4
27-06-22	7:30 AM	26.2	34.5	26.6	37.2	28.5	30.4	29.1	31.2	25.4	39.7	26.1	32.6	28.7	27.9	29.6	26.6
27-06-22	8:00 AM	27.8	33.2	27.8	35	28.6	30.4	29	31.7	26.9	38	27	31.3	28.8	28.1	29.5	26.8
27-06-22	8:30 AM	29.8	30.2	29.2	34.3	29	30	28.9	31.5	28.4	36	28	29.2	29.2	28.1	29.4	27.1
27-06-22	9:00 AM	31.1	27.4	30.2	30.2	29.5	29.3	29	31.1	29.8	33.6	29.1	27.1	29.5	27.7	29.4	27.2
27-06-22	9:30 AM	31.8	26.1	30.9	28	30	28.6	29.1	30.9	30.6	31.3	30	26	30	27.2	29.4	27.2
27-06-22	10:00 AM	33.2	24.8	31.9	27.6	30.6	27.8	29.3	30.5	31.5	29.9	31	24	30.6	26.5	29.6	27
27-06-22	10:30 AM	35.1	22.2	32.7	25.5	31.3	26.6	29.5	29.6	32.3	29.2	32	22.8	31.3	25.5	29.9	26.6
27-06-22	11:00 AM	35.6	20.8	33.6	25.5	32	25.8	29.9	29.5	33.2	27	33.1	21.4	32.1	24.6	30.3	26
27-06-22	11:30 AM	35.8	20.4	33.7	21.6	32.7	25	30.2	28.6	33.9	26.2	33.9	20.2	32.6	23.9	30.7	25.6

Date	Time	OUT0 Env Temperature °C	OUT0 Env Humidity%	ES2 GR Temperature °C	ES2 GR Humidity%	A2 GR Temperature °C	A2 GR Humidity%	IS2 GR Temperature °C	IS2 GR Humidity%	IC0 In-between Temperature °C	IC0 In-between Humidity%	ES1 PR Temperature °C	ES1 PR Humidity%	A1 PR Temperature °C	A1 PR Humidity%	IS1 PR Temperature °C	IS1 PR Humidity%
27-06-22	12:00 PM	36.8	19.2	34.8	21.6	33.4	23.7	30.7	27.4	34.7	24.8	35	18.8	33.4	22.6	31.2	24.7
27-06-22	12:30 PM	38	18.1	36.2	21.8	35.8	20.8	31.4	26.2	36	24.7	36.6	17.4	34.2	21.7	31.7	24.1
27-06-22	1:00 PM	39	18.4	36.3	20.6	35	22.4	31.7	27.3	36.7	24.3	38.3	18	34.9	21.8	32.4	24.1
27-06-22	1:30 PM	39.6	18.4	37.4	23.1	35.5	22.7	32.1	27.4	37.4	24.5	39.5	17.5	35.6	21.9	33	24.2
27-06-22	2:00 PM	39.9	17.4	37.9	21.7	36.1	22	32.6	26.8	37.9	23.6	40.3	16.4	36.2	20.9	33.5	23.8
27-06-22	2:30 PM	41.3	16.3	38.3	21.3	36.6	21.6	33	26.3	38.2	22.6	41.3	15.2	36.7	20.6	34.1	23.6
27-06-22	3:00 PM	40.8	16.2	38.5	20.7	37	20.8	33.4	26	38.5	22.4	42.1	14.5	37.2	19.7	34.8	22.8
27-06-22	3:30 PM	41.7	15.8	38.8	21.2	37.4	20.4	33.8	25.6	38.6	23.3	42.6	13.7	37.6	19	35.4	22.3
27-06-22	4:00 PM	42.2	15.2	37.9	22	37.7	19.9	34.2	25.4	38.5	22.9	43	13.7	38	18.8	36	21.7
27-06-22	4:30 PM	43.2	14.7	38.6	20.4	37.9	19.5	34.6	24.5	38.7	23	43.3	13.8	38.3	18.4	36.5	21.3
27-06-22	5:00 PM	43.4	14.4	39.3	18	38.1	19.2	34.9	24.4	38.7	20.8	43.2	13.6	38.5	18.2	37.1	20.9
27-06-22	5:30 PM	42.9	14.6	39.2	17.8	38	19	35.1	23.8	38.6	21	43	14.1	38.6	17.9	37.6	20.5
27-06-22	6:00 PM	42.6	14.2	39.4	18.4	38	18.9	35.3	23.9	38.7	19.8	42.4	14.2	38.7	17.7	38.1	20
27-06-22	6:30 PM	41.1	15	38.9	17.2	38.1	18.7	35.6	23	38.6	19.8	41.5	14.6	38.8	17.3	38.4	19.6
27-06-22	7:00 PM	39.8	15.2	38.2	17.1	38	18.2	35.7	22.4	37.9	18.3	40.2	15.1	38.7	16.8	38.7	19.1
27-06-22	7:30 PM	38.2	17.9	37.2	19.3	37.5	19.5	35.8	23.9	36.9	20.3	38.7	17.9	38.4	18	38.9	19.6
27-06-22	8:00 PM	36.6	18.6	36.1	19.4	37.1	19.7	35.8	24.5	35.9	20.5	37.5	18.1	38	18.3	38.9	19.3
27-06-22	8:30 PM	35.7	19.3	35.6	20	36.7	19.9	35.8	25.1	35.1	21.3	36.4	18.9	37.7	18.4	38.9	19.3
27-06-22	9:00 PM	35.2	19.6	34.6	20.9	36.4	19.9	35.7	25.5	34.4	22.2	35.6	19.4	37.3	18.6	38.8	19.1
27-06-22	9:30 PM	34.3	19.9	33.6	21.4	36	20.3	35.6	24.3	33.2	22.7	34.9	19.7	37	18.7	38.5	19.2
27-06-22	10:00 PM	33.4	20.7	33.3	30.5	35.8	20.9	35.5	26.6	32.9	30.9	34.3	29.7	36.6	19	38.3	19.3
27-06-22	10:30 PM	32.7	34.3	32.7	35.7	35.1	28.3	35.4	30.2	32.4	35.1	33.7	34.3	35.8	26.6	37.8	26.7
27-06-22	11:00 PM	32.1	35.8	32.2	36.5	34.7	29.8	35.2	31.1	31.9	36.8	33.2	35.1	35.5	28	37.4	28
27-06-22	11:30 PM	31.6	36.5	31.8	37.4	34.4	30.6	35	31.6	31.5	37.4	32.7	35.8	35.1	28.8	37	28.9
29-06-22	12:00 AM	31.1	38.4	31.1	39.4	33.7	33.4	33.5	35.3	30.7	40.2	32.2	37.2	35.1	30.1	36.8	30.4

Date	Time	OUT0 Env Temperature °C	OUT0 Env Humidity%	ES2 GR Temperature °C	ES2 GR Humidity%	A2 GR Temperature °C	A2 GR Humidity%	IS2 GR Temperature °C	IS2 GR Humidity%	IC0 In-between Temperature °C	IC0 In-between Humidity%	ES1 PR Temperature °C	ES1 PR Humidity%	A1 PR Temperature °C	A1 PR Humidity%	IS1 PR Temperature °C	IS1 PR Humidity%
29-06-22	12:30 AM	30.6	38.5	30.5	39.9	33.4	33.4	33.3	35.3	30.1	40.9	31.7	37.3	34.7	30.2	36.4	30.5
29-06-22	1:00 AM	30.3	38.4	30.4	39.7	33.1	33.4	33.1	35	29.9	41	31.4	37.3	34.3	30.3	36	30.5
29-06-22	1:30 AM	30	38.3	29.7	40.2	32.7	33.5	33	35	29.3	41.6	30.9	37.3	34	30.4	35.7	30.6
29-06-22	2:00 AM	29.7	38.8	29.6	40.5	32.5	33.7	32.8	35.2	29.2	41.8	30.5	37.9	33.6	30.6	35.3	30.8
29-06-22	2:30 AM	29.1	40.5	29.1	42.5	32.2	34.2	32.5	35.7	28.7	43.5	30.2	39.7	33.3	31.2	35	31.3
29-06-22	3:00 AM	28.6	42.8	28.7	45.2	31.9	35.4	32.3	36.6	28.3	45.7	29.7	42.3	32.9	32.3	34.6	32.5
29-06-22	3:30 AM	28	42.7	28.2	43.1	31.7	35.6	32.1	36.6	27.8	44.6	29.3	40.3	32.7	32.5	34.2	32.3
29-06-22	4:00 AM	27.6	41.2	27.9	41.9	31.4	35	31.8	35.9	27.5	43.8	28.8	39.4	32.3	31.7	33.8	31.3
29-06-22	4:30 AM	27.2	41.7	27.5	42.6	31	34.7	31.6	35.6	27	44.3	28.4	40.4	31.9	31.8	33.4	31.4
29-06-22	5:00 AM	26.7	43.4	27	44.1	30.7	35.1	31.3	35.9	26.6	45.5	27.9	41.8	31.5	32.2	33	31.7
29-06-22	5:30 AM	26.2	44.4	26.5	45.1	30.4	35.6	31.1	36.2	26.1	46.5	27.5	42.5	31.1	32.8	32.7	32.3
29-06-22	6:00 AM	26.3	43.4	26.5	44.4	29.9	35.6	30.7	36	25.9	46.2	27.2	41.4	30.7	32.9	32.3	32.4
29-06-22	6:30 AM	26.8	42	26.8	43.8	29.6	35.6	30.5	36.1	26.1	45.9	27.2	40.6	30.5	32.9	31.9	32.3
29-06-22	7:00 AM	27.4	41.2	27.4	43.7	29.6	35.8	30.3	36.4	26.7	45.4	27.5	40	30.4	33.1	31.7	32.3
29-06-22	7:30 AM	28.3	38.6	28	40.2	29.7	35.3	30.2	36.1	27.4	43.3	28	36.9	30.2	33.1	31.4	32
29-06-22	8:00 AM	29.3	37.1	28.5	40.6	29.9	35.1	30	36.3	28	43.2	28.5	36.1	30.4	33	31.2	31.8
29-06-22	8:30 AM	30.1	35.5	29.2	39.1	30.1	34.5	30	35.9	28.6	41.3	29.1	33.9	30.6	32.4	31	31.6
29-06-22	9:00 AM	31	33.6	29.8	37.9	30.4	33.9	30	35.6	29.4	39.6	29.8	33	30.9	31.8	31	31.3
29-06-22	9:30 AM	31.9	31.3	30.5	35.2	30.8	32.6	30.1	34.9	30.1	37.6	30.5	30.5	31.2	30.9	31	30.8
29-06-22	10:00 AM	33	29.6	31.2	31.7	31.4	31.9	30.2	34.5	31	35.4	31.4	28.6	31.7	30.2	31.1	30.4
29-06-22	10:30 AM	34.4	27.4	32.2	30	31.9	30.6	30.4	33.9	32	34.1	32.3	27	32.1	29.1	31.3	29.9
29-06-22	11:00 AM	35.5	25.8	32.8	28.5	32.5	29.7	30.6	33.6	32.9	31.9	33.3	25.9	32.7	28.4	31.6	29.3
29-06-22	11:30 AM	35.3	23.8	33.5	28.8	33.1	28.1	30.9	32.4	33.5	30.2	34.1	24.6	33.3	26.8	31.9	28.5
29-06-22	12:00 PM	36.4	22.7	34.4	25.3	33.7	26.6	31.2	31.5	34.3	27.7	35.1	21.5	33.9	25.2	32.3	27
29-06-22	12:30 PM	37.3	22.1	35.1	26.6	34.3	26	31.6	30.5	35.2	26.6	36.5	19.8	34.6	24.6	32.7	26.6

Date	Time	OUT0 Env Temperature °C	OUT0 Env Humidity%	ES2 GR Temperature °C	ES2 GR Humidity%	A2 GR Temperature °C	A2 GR Humidity%	IS2 GR Temperature °C	IS2 GR Humidity%	IC0 In-between Temperature °C	IC0 In-between Humidity%	ES1 PR Temperature °C	ES1 PR Humidity%	A1 PR Temperature °C	A1 PR Humidity%	IS1 PR Temperature °C	IS1 PR Humidity%
29-06-22	1:00 PM	37.8	20.3	36.1	23	34.9	24.8	31.9	29.8	35.9	25.4	38.3	18.6	35.1	23.4	33.1	25.8
29-06-22	1:30 PM	38.7	19.2	36.5	23.3	35.5	23.9	32.3	29	36.5	26.6	39.4	17.2	35.8	22.5	33.6	25.1
29-06-22	2:00 PM	39.3	19.2	36.3	24.5	36.1	23.5	32.8	28.7	36.9	25.8	40.3	17.1	36.3	22.1	34.1	24.9
29-06-22	2:30 PM	40.1	19.1	37.2	21.9	36.5	23.5	33.1	29	37.5	26	41	17.6	36.9	22.1	34.7	24.7
29-06-22	3:00 PM	40.9	18.4	37.8	22.1	37	23.2	33.5	28.5	38.1	23.7	41.7	16.9	37.4	21.9	35.3	24.6
29-06-22	3:30 PM	41.1	18.2	38.3	20.6	37.3	22.8	33.9	28	38.4	23.4	42.2	16.5	37.7	21.3	35.8	24
29-06-22	4:00 PM	41.1	17.9	38.2	22.2	37.5	22.4	34.2	27.6	38.6	23.6	42.5	16.3	38	21	36.3	23.8
29-06-22	4:30 PM	41.6	17.9	38.8	20.3	37.7	22.1	34.5	26.7	38.7	22.3	42.7	16.1	38.3	20.7	36.8	23.4
29-06-22	5:00 PM	41.6	17.3	38.4	21.7	37.8	21.5	34.8	26.6	38.5	22.2	42.7	15.8	38.4	20.1	37.4	22.6
29-06-22	5:30 PM	42.5	16.1	38.8	20.5	37.8	20.9	35	25.7	38.6	21.1	42.6	14.5	38.5	19.5	37.8	21.9
29-06-22	6:00 PM	42.4	15.5	38.7	19.1	37.8	20.2	35.2	24.9	38.3	19.9	42	13.9	38.5	18.7	38.1	21
29-06-22	6:30 PM	42.1	15.2	38.6	18.9	37.7	19.5	35.4	24.6	38	20.1	41.3	14.9	38.5	17.9	38.4	20
29-06-22	7:00 PM	40.3	14.9	38	17.1	37.5	19.2	35.5	23.4	37.5	18.5	40.1	14.3	38.4	17.4	38.7	19.5
29-06-22	7:30 PM	38.7	16.8	37.2	18.5	37.2	19.7	35.5	24.5	36.7	20	38.7	16.9	38.2	18.2	38.8	19.5
29-06-22	8:00 PM	36.6	16.7	36.1	18	36.9	19.7	35.5	24.5	35.7	19.1	37.5	16.5	37.9	18	38.9	18.7
29-06-22	8:30 PM	36	17.1	35.8	18	36.5	19.7	35.5	24.4	35.4	19.1	36.5	17.1	37.5	17.5	38.8	18.1
29-06-22	9:00 PM	35.2	17.9	34.7	19	36.3	20.4	35.5	25.8	34.5	19.8	35.6	17.8	37.3	18.1	38.7	18.2
29-06-22	9:30 PM	34.3	18.6	33.2	20.7	35.9	21.3	35.4	25.4	33.1	21.6	34.8	18.5	36.9	18.2	38.5	18.3
29-06-22	10:00 PM	34.3	19.9	33.8	21.4	35.4	20.3	35.2	24	33.5	22.1	34.4	20.3	36.4	18.4	38.1	18.7
29-06-22	10:30 PM	33.8	28.1	33.2	32.1	35	25.2	35.1	28.1	32.9	30.9	34	30.5	35.9	23.4	37.8	23.1
29-06-22	11:00 PM	32.4	31.9	32.5	33.5	34.5	27.8	35	29.4	32.1	33.4	33.3	32.3	35.5	25.7	37.3	25.6
29-06-22	11:30 PM	31.6	34.7	31.7	35.7	34.2	29.3	34.8	30.5	31.4	35.1	32.7	34.4	35.1	27.1	36.9	26.9
30-06-22	12:00 AM	31	36.2	31.4	36.5	34	30	34.6	31.1	30.9	36.3	32.1	35.3	34.8	28	36.5	27.7
30-06-22	12:30 AM	30.7	36.7	31	37.2	33.5	30.8	34.3	31.6	30.6	37.3	31.7	35.9	34.4	28.5	36.2	28.3
30-06-22	1:00 AM	30.3	36.8	30.7	37.1	33.3	31.1	34.1	31.8	30.2	37.4	31.3	36	34.1	28.8	35.9	28.6

Date	Time	OUT0 Env Temperature °C	OUT0 Env Humidity%	ES2 GR Temperature °C	ES2 GR Humidity%	A2 GR Temperature °C	A2 GR Humidity%	IS2 GR Temperature °C	IS2 GR Humidity%	IC0 In-between Temperature °C	IC0 In-between Humidity%	ES1 PR Temperature °C	ES1 PR Humidity%	A1 PR Temperature °C	A1 PR Humidity%	IS1 PR Temperature °C	IS1 PR Humidity%
30-06-22	1:30 AM	29.9	37.2	30.3	37.5	33	31.3	33.8	32.1	29.9	38.3	30.8	36.5	33.8	29	35.6	28.8
30-06-22	2:00 AM	29.4	37.4	29.8	38	32.6	31.6	33.5	32.3	29.4	38.6	30.3	36.9	33.4	29.4	35.1	29.1
30-06-22	2:30 AM	28.9	37.9	29.3	37.5	32.3	31.8	33.2	32.1	28.8	38.4	29.8	36.3	33.1	29.7	34.8	29.3
30-06-22	3:00 AM	28.4	36.6	28.7	36.9	31.9	31.1	33	31.5	28.3	37.8	29.3	35.7	32.6	29	34.3	28.5
30-06-22	3:30 AM	27.7	38.1	28	39	31.6	31.4	32.7	31.9	27.6	39.4	28.7	37.3	32.1	29.4	33.9	29.1
30-06-22	4:00 AM	27.2	38.8	27.8	39.3	31.3	31.6	32.4	32.1	27.2	40	28.4	37.8	31.8	29.7	33.5	29.4
30-06-22	4:30 AM	27	39.5	27.3	40.4	31	32.1	32	32.5	26.8	41	27.9	38.7	31.5	30	33.1	29.7
30-06-22	5:00 AM	26.9	40.8	27.1	41.8	30.6	33	31.7	33.4	26.5	43.3	27.7	40.1	31.1	31	32.8	30.7
30-06-22	5:30 AM	26.9	42.3	27	44	30.2	34.4	31.5	34.4	26.3	44.8	27.4	41.8	30.8	32.1	32.4	31.6
30-06-22	6:00 AM	26.8	43.1	26.7	44.3	30	35.5	31.2	35.1	26.2	45.1	27.1	42.6	30.5	33.3	32	32.7
30-06-22	6:30 AM	26.2	44	26.5	45.2	29.8	35.5	30.9	35.4	26	45.8	27	42.8	30.3	33.6	31.7	32.9
30-06-22	7:00 AM	26.9	43.6	27.1	45.8	29.6	36.2	30.7	36.1	26.4	46.5	27.2	42.7	30.1	34	31.4	33.1
30-06-22	7:30 AM	27.8	43.1	28	44.4	29.7	36.9	30.5	36.8	27.4	45.7	27.8	41.7	29.9	35.3	31.1	34
30-06-22	8:00 AM	28.9	41.8	28.8	43.9	29.9	37.9	30.5	37.8	28.3	44.9	28.5	41	30.1	36.6	30.9	34.9
30-06-22	8:30 AM	29.7	40	29.6	41.6	30.1	37.6	30.4	37.9	29.2	43.3	29.2	38.8	30.4	36.3	30.8	34.8
30-06-22	9:00 AM	30.5	38.3	30.3	39	30.5	36.9	30.4	37.7	29.9	41.3	30	36.5	30.8	35.6	30.8	34.4
30-06-22	9:30 AM	31.4	35.7	31.2	35.2	30.9	35.8	30.5	36.7	30.8	38.2	30.7	33.7	31.1	34.3	30.8	33.9
30-06-22	10:00 AM	32.6	32.1	32	33.2	31.5	33.7	30.5	35.7	31.7	35.2	31.7	30.7	31.5	32.5	31	32.6
30-06-22	10:30 AM	35.1	27.2	33.1	30.3	32	32.2	30.7	34.9	32.8	33.5	32.6	28.3	32.1	30.9	31.2	31.6
30-06-22	11:00 AM	36	25.8	33.9	28.7	32.6	30.6	31	33.8	33.7	30.6	33.6	25.5	32.7	29.4	31.5	30.6
30-06-22	11:30 AM	36.1	23.6	34.6	25.2	33.3	28.3	31.3	32.1	34.7	28.2	34.6	23	33.4	27.1	31.8	28.9
30-06-22	12:00 PM	37.1	22.6	35.4	25.1	34	27	31.7	31.7	35.6	26.6	35.5	22.4	34	26	32.2	27.7
30-06-22	12:30 PM	37.6	22.3	35.9	23.6	34.6	26.5	32	31.1	36.2	26.3	36.9	20.5	34.6	25.3	32.7	27.5
30-06-22	1:00 PM	38.5	20.8	36.6	23.5	35.2	25.7	32.4	30.1	36.9	25.6	38.7	19.5	35.2	24.5	33.1	26.9
30-06-22	1:30 PM	39.7	19.3	37.4	22	35.8	24.5	32.9	29.5	37.7	23.8	39.8	18.1	35.9	23.5	33.7	26

Date	Time	OUT0 Env Temperature °C	OUT0 Env Humidity%	ES2 GR Temperature °C	ES2 GR Humidity%	A2 GR Temperature °C	A2 GR Humidity%	IS2 GR Temperature °C	IS2 GR Humidity%	IC0 In-between Temperature °C	IC0 In-between Humidity%	ES1 PR Temperature °C	ES1 PR Humidity%	A1 PR Temperature °C	A1 PR Humidity%	IS1 PR Temperature °C	IS1 PR Humidity%
30-06-22	**2:00 PM**	**40.2**	**18.3**	**38**	**22.9**	**36.3**	**23.7**	**33.2**	**28.5**	**38.4**	**23**	**40.7**	**17**	**36.5**	**22.5**	**34.2**	**25.3**
30-06-22	**2:30 PM**	**40.9**	**18.1**	**38.6**	**23**	**36.9**	**23**	**33.7**	**28.4**	**38.9**	**22.4**	**41.6**	**15.8**	**37**	**21.9**	**34.8**	**24.9**
30-06-22	**3:00 PM**	**41.9**	**17.2**	**38.6**	**21.7**	**37.4**	**22.4**	**34.1**	**27.8**	**39.2**	**22.3**	**42.3**	**15.5**	**37.5**	**21.1**	**35.4**	**24.3**
30-06-22	**3:30 PM**	**41.6**	**16.8**	**39**	**20**	**37.8**	**21.9**	**34.5**	**27.3**	**39.1**	**21**	**43**	**15**	**38**	**20.4**	**35.9**	**23.8**
30-06-22	**4:00 PM**	**42**	**16.3**	**38.9**	**20.8**	**38.1**	**21.1**	**34.8**	**26.8**	**39.5**	**21.4**	**43.3**	**14.3**	**38.4**	**19.8**	**36.5**	**23.1**
30-06-22	**4:30 PM**	**43.1**	**15.4**	**39.8**	**19.4**	**38.3**	**20.5**	**35.2**	**25.2**	**39.8**	**19.9**	**43.6**	**13.9**	**38.6**	**19.2**	**37**	**22.5**
30-06-22	**5:00 PM**	**43.8**	**14.7**	**39.9**	**17.3**	**38.5**	**20.2**	**35.5**	**24.8**	**39.8**	**19.7**	**43.8**	**13**	**38.9**	**18.6**	**37.6**	**22.1**
30-06-22	**5:30 PM**	**40.1**	**22.1**	**36**	**29.6**	**38.7**	**23.4**	**35.8**	**28.6**	**36.3**	**28.3**	**41.7**	**22.3**	**38.9**	**22.3**	**38.1**	**24.1**
30-06-22	**6:00 PM**	**38.4**	**23.6**	**35.4**	**29**	**38.5**	**25.1**	**36**	**29.4**	**35**	**28.8**	**40.5**	**21.1**	**38.9**	**23.5**	**38.5**	**25.8**
30-06-22	**6:30 PM**	**38**	**23.5**	**34.8**	**28.5**	**38.3**	**25**	**36**	**29.5**	**34.4**	**27.9**	**39.4**	**21.1**	**38.8**	**23.1**	**38.8**	**25.5**
30-06-22	**7:00 PM**	**37.5**	**22.6**	**34.5**	**27.6**	**38**	**24.8**	**36.1**	**29.2**	**34.2**	**27.9**	**38.5**	**22.3**	**38.6**	**22.7**	**39**	**24.5**
30-06-22	**7:30 PM**	**36.1**	**23.7**	**34**	**27.9**	**37.6**	**24.9**	**36.1**	**29.6**	**33.8**	**28.3**	**37**	**24.5**	**38.2**	**22.6**	**39.1**	**24.1**
30-06-22	**8:00 PM**	**34.7**	**26**	**33.7**	**28.1**	**37.2**	**25.7**	**36**	**30.2**	**33.4**	**28.3**	**36.2**	**24.5**	**38**	**23.1**	**39**	**24.2**
30-06-22	**8:30 PM**	**33.9**	**28.9**	**32.9**	**32**	**36.8**	**26.5**	**36**	**31**	**32.6**	**32**	**35.3**	**29.5**	**37.6**	**23.6**	**38.9**	**24.6**
30-06-22	**9:00 PM**	**32.8**	**34.5**	**32**	**36.4**	**36.5**	**27.6**	**35.9**	**32**	**31.7**	**37.9**	**34.5**	**34.6**	**37.3**	**25.2**	**38.7**	**26.8**
30-06-22	**9:30 PM**	**32.5**	**34.8**	**31.9**	**36.4**	**36.1**	**28.7**	**35.7**	**31.7**	**31.6**	**33.7**	**33.9**	**28.7**	**36.9**	**26.4**	**38.5**	**27.7**
30-06-22	**10:00 PM**	**33.3**	**30.3**	**33.5**	**30.8**	**35.6**	**27.9**	**35.5**	**30.4**	**33**	**32.3**	**33.9**	**29.8**	**36.2**	**25.8**	**38.1**	**26.1**
30-06-22	**10:30 PM**	**33.1**	**30.5**	**33.1**	**31.1**	**35.1**	**28**	**35.2**	**30.2**	**32.8**	**32**	**33.6**	**30.2**	**35.8**	**26.1**	**37.6**	**26.2**
30-06-22	**11:00 PM**	**32.7**	**30.5**	**32.8**	**30.9**	**34.8**	**28.2**	**35**	**30.1**	**32.4**	**31.8**	**33.1**	**30.2**	**35.4**	**26.2**	**37.2**	**26.1**
30-06-22	**11:30 PM**	**32**	**30.9**	**32.1**	**31.3**	**34.5**	**28.2**	**34.8**	**29.9**	**31.8**	**32.1**	**32.6**	**30.5**	**35.2**	**26.1**	**36.9**	**26.2**
01-07-22	**12:00 AM**	**31.4**	**31.4**	**31.7**	**31.8**	**34.1**	**28**	**34.6**	**29.7**	**31.2**	**32.6**	**32.1**	**31**	**34.7**	**26.1**	**36.4**	**26.1**
01-07-22	**12:30 AM**	**31.1**	**32**	**31.4**	**32.5**	**33.7**	**28.4**	**34.3**	**29.9**	**30.9**	**33.3**	**31.7**	**31.7**	**34.3**	**26.5**	**36**	**26.5**
01-07-22	**1:00 AM**	**30.7**	**32.7**	**31**	**33.3**	**33.4**	**28.9**	**34.1**	**30.1**	**30.6**	**33.9**	**31.4**	**32.4**	**33.9**	**27.1**	**35.6**	**26.9**
01-07-22	**1:30 AM**	**30.3**	**33.7**	**30.5**	**34.5**	**33.1**	**29.4**	**33.8**	**30.6**	**30.2**	**35**	**30.9**	**33.9**	**33.7**	**27.4**	**35.3**	**27.3**
01-07-22	**2:00 AM**	**29.7**	**34.7**	**30.2**	**34.9**	**32.9**	**29.7**	**33.6**	**30.8**	**29.7**	**35.5**	**30.5**	**34.1**	**33.4**	**27.8**	**35**	**27.6**

Date	Time	OUT0 Env Temperature °C	OUT0 Env Humidity%	ES2 GR Temperature °C	ES2 GR Humidity%	A2 GR Temperature °C	A2 GR Humidity%	IS2 GR Temperature °C	IS2 GR Humidity%	IC0 In-between Temperature °C	IC0 In-between Humidity%	ES1 PR Temperature °C	ES1 PR Humidity%	A1 PR Temperature °C	A1 PR Humidity%	IS1 PR Temperature °C	IS1 PR Humidity%
01-07-22	2:30 AM	29.4	35.2	29.8	35.2	32.6	30.1	33.3	30.9	29.3	35.9	30.1	34.4	33.1	28	34.7	27.8
01-07-22	3:00 AM	29.1	35.6	29.5	35.7	32.2	30.4	33.1	31.2	29.1	36.3	29.8	34.9	32.8	28.3	34.3	28
01-07-22	3:30 AM	28.8	35.9	29.3	36.2	31.9	30.6	32.9	31.4	28.8	36.8	29.5	35.4	32.4	28.6	33.9	28.3
01-07-22	4:00 AM	28.6	36	29.2	36.1	31.6	31	32.6	31.6	28.6	37	29.2	35.6	32.1	29	33.5	28.6
01-07-22	4:30 AM	28.4	36.4	28.8	36.5	31.3	31.3	32.4	31.8	28.4	37.2	28.9	36	31.8	29.3	33.2	28.8
01-07-22	5:00 AM	27.9	37	28.4	37.5	31.1	31.7	32.1	32.2	28	38.1	28.5	36.8	31.6	29.5	33	29
01-07-22	5:30 AM	27.4	38.4	27.9	38.8	30.9	32	31.9	32.7	27.4	39.6	28.1	37.7	31.3	30	32.6	29.7
01-07-22	6:00 AM	27.3	39.3	27.7	39.9	30.6	32.8	31.7	33.3	27.3	40.9	27.9	38.7	31	30.8	32.3	30.3
01-07-22	6:30 AM	27.5	39.9	27.7	41.4	30.4	33.5	31.5	33.9	27.1	42.5	27.8	38.9	30.9	31.4	32	30.7
01-07-22	7:00 AM	28.4	40.4	28.1	44.5	30.4	34.6	31.3	35	27.2	45.5	28.1	39.4	30.7	32.4	31.7	31.4
01-07-22	7:30 AM	29.4	39.2	28.9	42.5	30.4	35.5	31.1	35.7	28.2	43.8	28.7	39	30.6	33.8	31.6	32.5
01-07-22	8:00 AM	29.6	39.4	29.5	40.4	30.5	35.9	31	36.2	29.1	42.5	29.4	38	30.7	34.6	31.4	33.2
01-07-22	8:30 AM	30.5	37.4	30.3	38.9	30.8	35.7	31	36.4	29.8	40.6	30	36.3	31	34.2	31.3	33.1
01-07-22	9:00 AM	31.5	35.6	30.8	38.1	31	35.1	31	36.2	30.5	39.2	30.6	34.7	31.3	33.9	31.3	33
01-07-22	9:30 AM	32.4	33.6	31.7	35.7	31.5	34.4	31	36	31.4	37	31.5	31.7	31.6	33.1	31.4	32.7
01-07-22	10:00 AM	34.1	30.7	32.5	33.5	32	33	31.2	35.5	32.3	35.7	32.4	30	32.1	31.9	31.5	32
01-07-22	10:30 AM	35.8	28.7	33	33	32.6	32.6	31.4	35.5	33	34.9	33.3	29.5	32.6	31.4	31.7	31.9
01-07-22	11:00 AM	36.6	28.2	34	32.2	33.3	32.3	31.7	35.8	34	34.3	34.3	28.3	33.3	31.2	32.1	32.1
01-07-22	11:30 AM	36.5	27.6	34.6	31.3	33.9	31.5	31.9	35.5	34.7	33.2	35.3	27.4	33.9	30.4	32.4	31.9
01-07-22	12:00 PM	37.3	27	35	29.1	34.6	30.8	32.3	35.1	35.5	31.8	36.2	25.7	34.6	29.6	32.9	31.5
01-07-22	12:30 PM	37.7	25.7	36.2	30.6	35.2	30	32.7	34.5	36.3	31.4	37.7	23.6	35.2	28.6	33.2	31
01-07-22	1:00 PM	38.2	25.2	36.5	29.5	35.8	29	33	34.3	36.8	30.7	39.3	22.2	35.8	27.9	33.8	30.5
01-07-22	1:30 PM	39.1	24.2	36.9	25.8	36.4	28.6	33.4	33.5	37.4	28.3	40.3	20.9	36.5	27	34.3	30.2
01-07-22	2:00 PM	39.7	22.6	38.1	26.1	37.1	27.3	33.9	32.5	37.9	27.2	41	20.5	37.2	26.1	34.9	29.7
01-07-22	2:30 PM	40.7	21.8	38.1	24.7	37.6	26.1	34.3	32	38.6	26.4	42	18.1	37.7	24.8	35.5	28.5

Date	Time	OUT0 Env Temperature °C	OUT0 Env Humidity%	ES2 GR Temperature °C	ES2 GR Humidity%	A2 GR Temperature °C	A2 GR Humidity%	IS2 GR Temperature °C	IS2 GR Humidity%	IC0 In-between Temperature °C	IC0 In-between Humidity%	ES1 PR Temperature °C	ES1 PR Humidity%	A1 PR Temperature °C	A1 PR Humidity%	IS1 PR Temperature °C	IS1 PR Humidity%
01-07-22	3:00 PM	41	20.6	37.9	24.3	38.2	25.6	34.8	31	38.3	26.8	42.4	18.3	38.3	24.1	36	28.1
01-07-22	3:30 PM	40.7	25.3	36.8	30.5	38.8	27.1	35.2	32.4	37.4	27.2	42.2	20.2	38.7	25.9	36.7	28.6
01-07-22	4:00 PM	39	26.3	37	29	39	27.6	35.6	32.8	37.1	28.6	41.9	22.1	39	26	37.3	29.5
01-07-22	4:30 PM	39.2	27	36.7	30.9	39.1	27.6	35.9	33.2	36.4	31.3	41.9	21.8	39.2	26.3	37.8	29.5
01-07-22	5:00 PM	38.5	26.9	36.5	29.9	39.2	27.4	36.1	32.4	36.3	29.8	41.6	22.5	39.3	25.7	38.2	29.1
01-07-22	5:30 PM	38.2	25.8	35.7	30.6	39.1	27.5	36.2	32.3	35.3	31.3	40.7	23.1	39.2	25.3	38.6	28.9
01-07-22	6:00 PM	36	29.7	34.7	33	38.8	27.6	36.4	32.7	34.2	33.5	39.1	26.5	39	25.9	38.8	28.6
01-07-22	6:30 PM	37.7	26.8	34.8	32.4	38.6	28	36.4	32.8	34.4	33.4	38.8	25.7	39	25.8	39	28
01-07-22	7:00 PM	37.6	25.3	35	29.6	38.3	28	36.4	32.5	34.5	30.4	38.2	23.8	38.9	25.5	39.1	27.1
01-07-22	7:30 PM	36.1	26.8	34.4	30.1	37.9	27.2	36.4	32.3	34.2	30.4	36.9	27.1	38.3	25	39.1	26.4
01-07-22	8:00 PM	34.8	28.7	33.9	30.8	37.5	27.9	36.3	32.8	33.7	31.6	36.1	28.7	38.2	25.3	39	26.4
01-07-22	8:30 PM	33.7	33.1	33.1	33.6	37.1	28.7	36.2	33	32.7	34.7	35.5	30.5	37.8	26.2	38.9	27.8
01-07-22	9:00 PM	33.3	34.8	32.4	36.8	36.8	29.6	36.1	33.9	32.1	37.9	34.8	34.1	37.5	26.8	38.7	28.2
01-07-22	9:30 PM	33.1	34.4	32.6	36.5	36.5	30.3	36	34.5	32.1	38	34.3	33.1	37.1	27.6	38.5	28.5
01-07-22	10:00 PM	32.8	36.3	32.3	37.9	36.1	30.7	35.8	35.2	31.9	39	33.8	35.3	36.7	28.1	38.2	28.9
01-07-22	10:30 PM	33	33.8	33.4	34.7	35.6	30.5	35.6	33.1	32.8	35.9	33.8	33.5	36.1	28.2	37.8	28.5
01-07-22	11:00 PM	33	35.3	33	36	35	31.7	35.3	33.6	32.7	36.8	33.4	35.1	35.6	29.8	37.2	29.7
01-07-22	11:30 PM	32.4	36.2	32.6	36.7	34.7	32.1	35.1	33.8	32.2	37.3	33	35.7	35.3	30.3	36.8	30.2
	Average	33.69	28.86	32.63	31.20	33.95	28.11	33.04	30.98	32.34	32.57	34.02	27.92	34.44	26.28	34.66	27.08

The Temperature and Humidity Observations-Period C

Date	time	OUT0 Env Temperature °C	OUT0 Env Humidity%	ES2 GR Temperature °C	ES2 GR Humidity%	A2 GR Temperature °C	A2 GR Humidity%	IS2 GR Temperature °C	IS2 GR Humidity%	IC0 In-between Temperature °C	IC0 In-between Humidity%	ES1 PR Temperature °C	ES1 PR Humidity%	A1 PR Temperature °C	A1 PR Humidity%	IS1 PR Temperature °C	IS1 PR Humidity%
08-07-22	12:00 AM	31.2	25.9	31.4	27	33.4	23.6	33	25.9	31	27.8	NO DATA	NO DATA	34.8	20.9	36.4	21
08-07-22	12:30 AM	30.2	27.3	30.5	27.6	33.2	23.8	32.9	26.3	30.4	28.5	NO DATA	NO DATA	34.4	21.1	36	21.1
08-07-22	1:00 AM	30	27.2	30.3	28	32.8	24	32.7	26.3	29.9	28.8	NO DATA	NO DATA	34.1	21.1	35.7	21.3
08-07-22	1:30 AM	29.4	27.7	29.8	28.3	32.5	24.2	32.5	26.2	29.5	29	NO DATA	NO DATA	33.8	21.4	35.3	21.4
08-07-22	2:00 AM	28.9	28.4	29.3	29.1	32.3	24.5	32.3	26.4	29	29.9	NO DATA	NO DATA	33.4	21.6	35	21.6
08-07-22	2:30 AM	28.9	28	29.4	28.8	31.9	24.7	32.1	26.3	28.8	30	NO DATA	NO DATA	33.1	21.9	34.6	21.8
08-07-22	3:00 AM	28.5	27.4	28.8	29.2	31.6	24.8	31.9	26.4	28.7	30.1	NO DATA	NO DATA	32.7	22.1	34.2	21.9
08-07-22	3:30 AM	27.7	30.8	27.8	32	31.3	25.4	31.7	26.5	27.5	32.3	NO DATA	NO DATA	32.4	22.3	33.8	22.4
08-07-22	4:00 AM	27.5	31.1	27.6	33.5	30.9	26.2	31.6	27.1	27	33.9	NO DATA	NO DATA	31.9	23.3	33.4	23.3
08-07-22	4:30 AM	27	30.8	27.6	31.8	30.7	26.2	31.3	27.1	27.1	33.1	NO DATA	NO DATA	31.6	23.5	33	23.4
08-07-22	5:00 AM	27.1	30.3	27.7	31	30.4	26.1	31.1	27	27.2	32.5	NO DATA	NO DATA	31.3	23.6	32.7	23.4
08-07-22	5:30 AM	26.7	30.1	27.1	31.1	30.1	25.9	30.8	26.9	26.8	32.1	NO DATA	NO DATA	30.9	23.6	32.3	23.4
08-07-22	6:00 AM	26	30.7	26.2	31.8	29.8	26	30.5	26.9	26.1	32.6	NO DATA	NO DATA	30.6	23.6	31.9	23.3
08-07-22	6:30 AM	26.3	30.5	26.1	32.8	29.6	26.1	30.4	27	25.7	33.5	NO DATA	NO DATA	30.3	23.6	31.6	23.4
08-07-22	7:00 AM	27.4	29.1	26.8	32.5	29.5	26.1	30.1	27.2	25.9	34	NO DATA	NO DATA	30.1	23.7	31.2	23.5
08-07-22	7:30 AM	28.4	27.5	28.1	30.1	29.5	25.9	29.9	27.3	27.1	32	NO DATA	NO DATA	30	23.7	31	23.5
08-07-22	8:00 AM	29.9	25.8	29.1	29.1	29.6	25.7	29.8	27.3	28.2	30.2	NO DATA	NO DATA	30.1	23.6	30.7	23.5
08-07-22	8:30 AM	31.3	25	30	27.8	29.9	25.7	29.7	27.3	29.3	28.8	NO DATA	NO DATA	30.3	23.7	30.6	23.7
08-07-22	9:00 AM	32.1	24.1	30.8	27.4	30.3	25.8	29.7	27.6	30	28.4	NO DATA	NO DATA	30.6	23.9	30.6	24
08-07-22	9:30 AM	33.1	24	31.4	27.4	30.8	26.1	29.8	28.2	30.8	28.2	NO DATA	NO DATA	31	24.2	30.7	24.4
08-07-22	10:00 AM	34.5	23.1	32.4	27.3	31.3	26.1	29.9	28.5	31.6	28	NO DATA	NO DATA	31.5	24.4	30.8	24.6
08-07-22	10:30 AM	35.5	22.5	33.2	26.6	31.9	26.2	30.2	29	32.6	27.7	NO DATA	NO DATA	32	24.6	31.1	24.9
08-07-22	11:00 AM	36.7	19.7	34	23.6	32.6	25	30.5	28.4	33.6	24.4	NO DATA	NO DATA	32.7	23.6	31.4	24.2
08-07-22	11:30 AM	37.1	18.4	35.2	22.7	33.3	23.5	30.7	27.6	34.5	22.8	NO DATA	NO DATA	33.3	22.3	31.7	22.9
08-07-22	12:00 PM	37.5	18.1	35.8	22	33.9	22.6	31.1	26.8	35.1	22.1	NO DATA	NO DATA	34	21.2	32.2	22.3

Date	time	OUT0 Env Temperature °C	OUT0 Env Humidity%	ES2 GR Temperature °C	ES2 GR Humidity%	A2 GR Temperature °C	A2 GR Humidity%	IS2 GR Temperature °C	IS2 GR Humidity%	IC0 In-between Temperature °C	IC0 In-between Humidity%	ES1 PR Temperature °C	ES1 PR Humidity%	A1 PR Temperature °C	A1 PR Humidity%	IS1 PR Temperature °C	IS1 PR Humidity%
08-07-22	12:30 PM	38.1	16	36.3	19.4	34.5	21.8	31.5	26.2	35.8	20.6	NO DATA	NO DATA	34.6	20.5	32.6	21.5
08-07-22	1:00 PM	39.1	14.9	37.3	18.5	35.1	20.7	31.8	25.3	36.4	19.2	NO DATA	NO DATA	35.1	19.3	33.1	20.6
08-07-22	1:30 PM	40.2	14.2	37.8	18.2	35.7	19.8	32.3	24.9	37.1	18.1	NO DATA	NO DATA	35.9	18.3	33.6	19.8
08-07-22	2:00 PM	40.8	12.8	38.3	17.4	36.3	18.9	32.7	23.8	37.6	18.7	NO DATA	NO DATA	36.5	17.5	34.2	18.9
08-07-22	2:30 PM	42	12.1	38.8	16.1	36.9	18.1	33.1	22.9	38.4	17	NO DATA	NO DATA	37.1	16.5	34.8	18.3
08-07-22	3:00 PM	42.3	11.6	39.2	15.7	37.3	17.5	33.5	22.3	39	15.2	NO DATA	NO DATA	37.6	15.9	35.4	17.7
08-07-22	3:30 PM	42.4	11.3	39.4	14.3	37.6	16.8	33.9	21.8	39.2	14.8	NO DATA	NO DATA	38.1	15.2	36	17
08-07-22	4:00 PM	43	10.9	39.7	13.9	37.9	16.1	34.3	20.8	39.6	14.7	NO DATA	NO DATA	38.5	14.6	36.5	16.5
08-07-22	4:30 PM	44	10.2	40.1	14.6	38.1	15.5	34.7	20.1	39.8	14.1	NO DATA	NO DATA	38.8	14.1	37	15.7
08-07-22	5:00 PM	43.9	10.1	40.3	13.1	38.2	15.1	35	19.7	39.9	14.4	NO DATA	NO DATA	39	13.8	37.6	15.2
08-07-22	5:30 PM	43.2	10.2	40.2	13.2	38.2	14.9	35.3	19.2	39.8	13.4	NO DATA	NO DATA	39.1	13.4	38.1	14.8
08-07-22	6:00 PM	43.7	9.8	40.1	13	38.1	14.8	35.5	18.8	39.6	13.2	NO DATA	NO DATA	39.1	13.2	38.5	14.4
08-07-22	6:30 PM	43.3	9.7	39.7	12.7	38.1	14.3	35.7	18.4	39.2	13.6	NO DATA	NO DATA	39	12.8	38.8	13.8
08-07-22	7:00 PM	41.8	10.1	39.4	12.6	37.9	14.4	35.9	18.4	38.9	12.7	NO DATA	NO DATA	38.9	12.7	39	13.7
08-07-22	7:30 PM	39.3	10.7	38.4	12.5	37.6	14.3	36	18.5	38.2	12.9	NO DATA	NO DATA	38.7	13	39.2	13.7
08-07-22	8:00 PM	37.5	11.9	37.4	12.4	37.3	14.4	36	18.9	37.4	12.8	NO DATA	NO DATA	38.4	13.4	39.2	13.9
08-07-22	8:30 PM	36.7	12.3	36.4	13.3	37	15	36	19.8	36.3	13.7	NO DATA	NO DATA	38	13.9	39.2	14.2
08-07-22	9:00 PM	35.8	12.7	35.9	13.6	36.7	15.7	36	21.1	35.6	14.2	NO DATA	NO DATA	37.7	14.3	39.1	14.4
08-07-22	9:30 PM	35.4	12.7	35.6	13.8	36.3	15.4	36	20.8	35.2	14.3	NO DATA	NO DATA	37.3	14.3	38.9	14.4
08-07-22	10:00 PM	34.3	13.1	34.4	14.3	35.9	15.8	35.9	19.6	33.7	14.9	NO DATA	NO DATA	37	14.5	38.6	14.5
08-07-22	10:30 PM	33.5	13.9	33.6	15	35.6	16.4	35.7	19.4	33.5	15.6	NO DATA	NO DATA	36.6	14.6	38.3	14.7
08-07-22	11:00 PM	33.1	13.6	33.2	14.7	35.2	16.6	35.6	19.4	33	15.3	NO DATA	NO DATA	36.2	14.7	37.9	14.8
08-07-22	11:30 PM	32.6	15.5	33	14.6	34.8	15.9	35.3	18.4	32.3	15.5	NO DATA	NO DATA	35.8	14.3	37.5	14.2
09-07-22	12:00 AM	32	28.1	32	25.7	34.5	19.7	35.2	20.7	31.9	24.1	NO DATA	NO DATA	35.4	16.4	37.2	17.7
09-07-22	12:30 AM	31.6	35.4	31.9	34.4	34.3	24.7	35	24.8	31.6	34.4	NO DATA	NO DATA	35.1	21.3	36.7	21.9

Date	time	OUT0 Env Temperature °C	OUT0 Env Humidity%	ES2 GR Temperature °C	ES2 GR Humidity%	A2 GR Temperature °C	A2 GR Humidity%	IS2 GR Temperature °C	IS2 GR Humidity%	IC0 In-between Temperature °C	IC0 In-between Humidity%	ES1 PR Temperature °C	ES1 PR Humidity%	A1 PR Temperature °C	A1 PR Humidity%	IS1 PR Temperature °C	IS1 PR Humidity%
09-07-22	1:00 AM	31.2	39.4	31.6	38.5	34.1	28.2	34.9	27.9	31.4	39.1	NO DATA	NO DATA	34.9	23.9	36.4	24.6
09-07-22	1:30 AM	30.6	41	31.1	41.2	33.8	30.4	34.7	30.1	30.9	41.9	NO DATA	NO DATA	34.6	26.3	36.1	26.6
09-07-22	2:00 AM	30.3	42	30.5	43	33.5	32	34.5	31.4	30.4	42.7	NO DATA	NO DATA	34.2	28.3	35.8	28.9
09-07-22	2:30 AM	29.7	43.4	30.2	44	33.2	32.9	34.2	32.4	30	44.2	NO DATA	NO DATA	33.9	29.9	35.5	29.7
09-07-22	3:00 AM	29.2	45.1	29.7	44.7	32.9	33.6	34	33.1	29.6	45.5	NO DATA	NO DATA	33.6	30.2	35.1	30.2
09-07-22	3:30 AM	29.3	43.7	29.9	44.1	32.6	34.3	33.7	33.6	29.4	45.5	NO DATA	NO DATA	33.3	31	34.7	30.8
09-07-22	4:00 AM	29.1	44	29.7	44.4	32.4	34.9	33.5	34.1	29.3	45.5	NO DATA	NO DATA	32.9	31.8	34.4	31.6
09-07-22	4:30 AM	28.8	44.6	29.3	44.9	32.2	35.3	33.2	34.6	29.1	45.7	NO DATA	NO DATA	32.7	32.5	34	32.2
09-07-22	5:00 AM	28.4	45.7	29	45.4	31.9	35.7	33	35	28.7	46.5	NO DATA	NO DATA	32.4	32.9	33.7	32.7
09-07-22	5:30 AM	27.9	46.9	28.5	47.2	31.7	36.2	32.8	35.5	28.3	47.9	NO DATA	NO DATA	32.2	33.2	33.4	32.8
09-07-22	6:00 AM	27.7	48.1	28.3	48.2	31.4	36.7	32.5	36	28	48.9	NO DATA	NO DATA	31.9	33.9	33	33.4
09-07-22	6:30 AM	27.9	48.6	28.2	49.5	31.2	37.4	32.2	36.6	27.8	50.1	NO DATA	NO DATA	31.6	34.5	32.8	34.2
09-07-22	7:00 AM	28.8	47.4	28.4	50.6	31.1	38.4	32	37.3	28	51	NO DATA	NO DATA	31.5	35.3	32.5	34.9
09-07-22	7:30 AM	29.6	46	29.1	49.7	31	39.2	31.8	38.2	28.5	50.8	NO DATA	NO DATA	31.4	36.3	32.3	36
09-07-22	8:00 AM	30.5	43.9	29.7	47.7	31.1	39.4	31.7	38.7	29.2	49	NO DATA	NO DATA	31.3	37.4	32.1	36.7
09-07-22	8:30 AM	31	42.6	30.3	45.6	31.3	39.3	31.7	39	29.8	47.2	NO DATA	NO DATA	31.4	37.3	32	37
09-07-22	9:00 AM	31.9	40.5	31	44.1	31.5	39.2	31.6	39.6	30.5	45.5	NO DATA	NO DATA	31.7	37.4	31.9	37
09-07-22	9:30 AM	32.8	38	31.7	42.4	31.9	38.1	31.6	39.6	31.1	43.8	NO DATA	NO DATA	32	36.8	31.9	36.2
09-07-22	10:00 AM	33.9	35.6	32.6	39.5	32.3	37	31.7	39	31.8	40.5	NO DATA	NO DATA	32.4	35.5	32.1	35.5
09-07-22	10:30 AM	35.8	32	33.3	36.9	32.9	36.1	31.7	38.8	32.8	38.8	NO DATA	NO DATA	32.8	35	32.3	34.9
09-07-22	11:00 AM	36	29.7	34.2	34.1	33.5	34.3	31.9	37.7	33.7	35.2	NO DATA	NO DATA	33.4	33.2	32.5	33.5
09-07-22	11:30 AM	36.4	27.6	35.2	31.1	34.1	32.7	32.2	36.9	34.6	32.9	NO DATA	NO DATA	34	31.5	32.8	32.2
09-07-22	12:00 PM	37.6	25.4	36.2	28.3	34.7	30.5	32.4	35.3	35.5	29.3	NO DATA	NO DATA	34.6	29.6	33.1	30.4
09-07-22	12:30 PM	38.6	23.5	36.7	26.1	35.3	29.2	32.8	34.3	36.7	28	NO DATA	NO DATA	35.3	28	33.5	29.1
09-07-22	1:00 PM	39.5	21.1	37.7	23.8	35.9	27.6	33.1	33.1	37.7	25.4	NO DATA	NO DATA	35.9	26.3	34	27.8

Date	time	OUT0 Env Temperature °C	OUT0 Env Humidity%	ES2 GR Temperature °C	ES2 GR Humidity%	A2 GR Temperature °C	A2 GR Humidity%	IS2 GR Temperature °C	IS2 GR Humidity%	IC0 In-between Temperature °C	IC0 In-between Humidity%	ES1 PR Temperature °C	ES1 PR Humidity%	A1 PR Temperature °C	A1 PR Humidity%	IS1 PR Temperature °C	IS1 PR Humidity%
09-07-22	1:30 PM	40.8	19.2	39.1	22.1	36.5	25.9	33.4	31.2	38.3	23.9	NO DATA	NO DATA	36.6	24.8	34.5	26.3
09-07-22	2:00 PM	41.6	17.8	39.7	20.1	37	24.5	33.8	29.9	39	21.6	NO DATA	NO DATA	37.2	23.1	35.1	24.8
09-07-22	2:30 PM	42.2	18.7	40	20.3	37.6	24.3	34.3	29.7	40	21.5	NO DATA	NO DATA	37.8	22.7	35.6	24.7
09-07-22	3:00 PM	42.9	18.2	40	20.8	38	24.2	34.7	29.5	40.1	21.9	NO DATA	NO DATA	38.3	22.9	36.1	24.5
09-07-22	3:30 PM	43.2	18.5	40.9	20.9	38.3	24.3	35.1	29.5	40.4	22.1	NO DATA	NO DATA	38.8	22.8	36.7	24.5
09-07-22	4:00 PM	43.3	18.8	41.1	20.7	38.7	24.1	35.5	29.1	40.8	22.3	NO DATA	NO DATA	39.2	22.5	37.4	24.2
09-07-22	4:30 PM	43.5	18.3	41.3	20.6	38.9	23.8	35.9	28.8	40.7	21.9	NO DATA	NO DATA	39.5	22.2	37.9	23.8
09-07-22	5:00 PM	42.6	19	41.2	21	39	23.7	36.1	28.4	40.8	21.2	NO DATA	NO DATA	39.7	21.7	38.4	23.5
09-07-22	5:30 PM	42.6	19.1	41.1	21	39.1	23.8	36.4	28.3	40.5	21.8	NO DATA	NO DATA	39.9	21.7	38.9	23.4
09-07-22	6:00 PM	41.5	18.3	40.3	20.7	39.2	23.3	36.6	27.8	40.1	21.5	NO DATA	NO DATA	39.9	21.1	39.3	22.5
09-07-22	6:30 PM	40.6	17	39.4	18.7	39	21.7	36.8	26.3	39.3	19.3	NO DATA	NO DATA	39.8	19.9	39.6	21
09-07-22	7:00 PM	39.4	17.9	38.8	19.2	38.8	21.4	36.9	25.9	38.6	19.8	NO DATA	NO DATA	39.5	19.4	39.8	20.3
09-07-22	7:30 PM	37.8	19	37.8	19.8	38.3	21.4	37	26.1	37.6	20.5	NO DATA	NO DATA	39.2	19.5	39.8	19.9
09-07-22	8:00 PM	36.8	19.7	36.9	20	37.9	21.3	37	26.1	36.7	20.5	NO DATA	NO DATA	38.8	19.3	39.8	19.8
09-07-22	8:30 PM	36.2	20.1	36.3	20.5	37.7	21.7	37	27	36	21.1	NO DATA	NO DATA	38.5	19.7	39.8	20
09-07-22	9:00 PM	35.6	22.2	35.8	22.1	37.3	22.5	37	27.1	35.6	22.8	NO DATA	NO DATA	38.3	20.1	39.6	20.5
09-07-22	9:30 PM	34.7	27.8	34.9	27.3	37.1	24.4	36.9	28	34.9	27.8	NO DATA	NO DATA	37.9	21.4	39.4	22.1
09-07-22	10:00 PM	34.1	28	34.1	29.3	36.6	25.6	36.7	28.2	33.9	29.9	NO DATA	NO DATA	37.6	23	39.1	23.3
09-07-22	10:30 PM	33.5	28.4	33.7	29.4	36.3	26	36.6	28.1	33.4	30.3	NO DATA	NO DATA	37.2	23.4	38.8	23.6
09-07-22	11:00 PM	32.6	28.4	33.1	28.9	36	26.3	36.4	28.1	32.9	29.9	NO DATA	NO DATA	36.8	23.5	38.5	23.5
09-07-22	11:30 PM	31.8	27.2	32.3	27.5	35.7	26.3	36.2	28	32.3	28.6	NO DATA	NO DATA	36.5	23.2	38.1	23.2
10-07-22	12:00 AM	31.4	25.7	32	26.6	35.3	25.6	36	27.4	31.8	27.8	NO DATA	NO DATA	36	22.6	37.7	22.6
10-07-22	12:30 AM	30.7	24.5	31.2	26	35	25.5	35.8	27	31.3	27.3	NO DATA	NO DATA	35.6	22.4	37.3	22.3
10-07-22	1:00 AM	30	24.2	30.3	26.7	34.6	25	35.5	26.6	30.5	27.3	NO DATA	NO DATA	35.2	22	36.8	22
10-07-22	1:30 AM	29.5	23.3	30	24.7	34.2	24.9	35.2	26.6	30.1	25.9	NO DATA	NO DATA	34.8	21.9	36.4	21.7

Date	time	OUT0 Env Temperature °C	OUT0 Env Humidity%	ES2 GR Temperature °C	ES2 GR Humidity%	A2 GR Temperature °C	A2 GR Humidity%	IS2 GR Temperature °C	IS2 GR Humidity%	IC0 In-between Temperature °C	IC0 In-between Humidity%	ES1 PR Temperature °C	ES1 PR Humidity%	A1 PR Temperature °C	A1 PR Humidity%	IS1 PR Temperature °C	IS1 PR Humidity%
10-07-22	2:00 AM	29.3	24	30	24.7	33.8	24.5	34.9	25.8	29.8	26	NO DATA	NO DATA	34.3	21.3	36	21.2
10-07-22	2:30 AM	28.6	23.9	29.4	23.6	33.4	24	34.6	25.3	29.3	25	NO DATA	NO DATA	33.9	20.7	35.6	20.7
10-07-22	3:00 AM	28.1	26.8	28.6	28.2	32.9	24.1	34.3	25.3	28.4	28.5	NO DATA	NO DATA	33.5	21	35.2	21.1
10-07-22	3:30 AM	27.9	27.9	28.6	28.9	32.5	24.5	33.9	25.4	28.2	29.9	NO DATA	NO DATA	33.1	21.7	34.7	21.7
10-07-22	4:00 AM	27.7	30.6	28.3	30.8	32.1	25.2	33.6	25.7	27.9	31.4	NO DATA	NO DATA	32.6	22.2	34.2	22.4
10-07-22	4:30 AM	26.9	33.8	27.5	33.8	31.8	26.2	33.3	26.5	27.4	34.2	NO DATA	NO DATA	32.3	23.3	33.8	23.4
10-07-22	5:00 AM	26.9	34.3	27.4	35.3	31.5	27.1	33	27.3	27.1	35.8	NO DATA	NO DATA	31.9	24.3	33.4	24.2
10-07-22	5:30 AM	26.3	35.3	26.9	35.9	31.3	27.6	32.7	27.8	26.8	36.5	NO DATA	NO DATA	31.6	24.8	33	24.6
10-07-22	6:00 AM	25.6	38.4	25.9	39.2	31	28.3	32.4	28.4	26	39.7	NO DATA	NO DATA	31.3	25.3	32.6	25.1
10-07-22	6:30 AM	26.1	40.1	26.1	42.4	30.7	29.2	32	29	25.9	42.8	NO DATA	NO DATA	30.9	25.9	32.2	25.7
10-07-22	7:00 AM	27.2	38.9	26.6	43.9	30.5	30.1	31.8	29.8	26.2	44.5	NO DATA	NO DATA	30.7	26.4	31.9	26.2
10-07-22	7:30 AM	28.7	36.3	27.7	42.7	30.5	30.8	31.6	30.5	26.8	43.9	NO DATA	NO DATA	30.5	27.4	31.6	27.1
10-07-22	8:00 AM	29.9	34.1	28.8	38.9	30.5	31.2	31.4	31.2	28.1	41.5	NO DATA	NO DATA	30.5	28.5	31.4	28.2
10-07-22	8:30 AM	30.5	32.7	29.8	36.2	30.7	31.1	31.3	31.5	29.1	38.9	NO DATA	NO DATA	30.6	28.9	31.2	28.6
10-07-22	9:00 AM	31.5	31.7	30.4	35.2	30.9	31.3	31.2	32.2	29.9	37.7	NO DATA	NO DATA	30.9	29	31.1	28.7
10-07-22	9:30 AM	32.5	30.7	31.4	35	31.3	31	31.2	32.4	30.5	36.4	NO DATA	NO DATA	31.1	28.8	31.1	28.6
10-07-22	10:00 AM	33.6	27.2	31.7	31.9	31.8	30.2	31.3	32.4	31.3	34.5	NO DATA	NO DATA	31.6	28.4	31.2	28.4
10-07-22	10:30 AM	35.5	23.3	32.8	29.9	32.4	28.7	31.4	31.9	32	32.2	NO DATA	NO DATA	32.2	27.2	31.4	27.4
10-07-22	11:00 AM	36.1	21.3	33.7	26.4	33.1	27.1	31.6	30.5	32.9	27.9	NO DATA	NO DATA	32.7	25.6	31.7	26.2
10-07-22	11:30 AM	36.5	21.4	34	25.5	33.7	26.2	31.8	30.2	33.8	28	NO DATA	NO DATA	33.5	24.5	32	25.4
10-07-22	12:00 PM	37.5	19.9	35.6	24.2	34.4	25.8	32.1	30	34.7	26	NO DATA	NO DATA	34.2	23.9	32.4	25.1
10-07-22	12:30 PM	37.9	19	35.7	23.9	35.1	25.4	32.4	29.9	35.4	25.1	NO DATA	NO DATA	34.8	23.2	32.9	24.6
10-07-22	1:00 PM	38.5	23.7	36.8	22.8	35.8	25	32.8	29.3	36.4	22.9	NO DATA	NO DATA	35.5	22.1	33.4	24.2
10-07-22	1:30 PM	36.4	24.9	35.9	26.1	36.5	26.4	33.2	31.6	35.9	28.6	NO DATA	NO DATA	36.2	24.8	34	25.6
10-07-22	2:00 PM	37.6	21.2	35.9	23.6	37	25.3	33.6	31	35.6	26.1	NO DATA	NO DATA	36.8	23.5	34.5	24.8

Date	time	OUT0 Env Temperature °C	OUT0 Env Humidity%	ES2 GR Temperature °C	ES2 GR Humidity%	A2 GR Temperature °C	A2 GR Humidity%	IS2 GR Temperature °C	IS2 GR Humidity%	IC0 In-between Temperature °C	IC0 In-between Humidity%	ES1 PR Temperature °C	ES1 PR Humidity%	A1 PR Temperature °C	A1 PR Humidity%	IS1 PR Temperature °C	IS1 PR Humidity%
10-07-22	2:30 PM	37.8	22.2	36.4	24.7	37.5	25.1	34	30.3	35.9	25.3	NO DATA	NO DATA	37.1	22.9	35.1	24.4
10-07-22	3:00 PM	39	20.1	36.9	23.6	37.9	25.4	34.4	30.2	36.4	25.2	NO DATA	NO DATA	37.7	22.7	35.6	24.2
10-07-22	3:30 PM	38.8	20.7	36.6	22	38.3	24.2	34.8	29.4	36.8	24	NO DATA	NO DATA	38	21.9	36.1	23.5
10-07-22	4:00 PM	41.1	16	38.6	20.4	38.7	23.4	35.1	28.6	38.2	22.8	NO DATA	NO DATA	38.5	21	36.6	22.8
10-07-22	4:30 PM	42.3	14.5	40	16.9	39	20.5	35.5	26	39.9	18.2	NO DATA	NO DATA	39	18.4	37.2	20
10-07-22	5:00 PM	41.8	14.7	39.9	17.4	39.2	19.2	35.8	24.5	39.6	17.6	NO DATA	NO DATA	39.3	17.7	37.7	19.2
10-07-22	5:30 PM	41.3	15.5	39.9	17.3	39.1	19.4	36	24.4	39.5	17.7	NO DATA	NO DATA	39.4	17.6	38.1	19
10-07-22	6:00 PM	41.1	16.1	39.4	18.6	39	19.6	36.2	24.1	39.1	18.4	NO DATA	NO DATA	39.4	17.6	38.5	19.1
10-07-22	6:30 PM	40.1	17.5	39.1	19.1	38.8	20.6	36.3	24.7	38.7	19.6	NO DATA	NO DATA	39.3	18.3	38.8	19.5
10-07-22	7:00 PM	38.9	18.7	38.2	20	38.6	20.9	36.5	24.9	38	20.5	NO DATA	NO DATA	39.1	18.8	39	19.8
10-07-22	7:30 PM	37.4	20.7	37.3	21.1	38.2	21.5	36.5	25.4	37.1	21.6	NO DATA	NO DATA	38.8	19.3	39.1	20.3
10-07-22	8:00 PM	36.7	22.4	36.6	22.3	37.8	22.4	36.6	26.2	36.4	22.9	NO DATA	NO DATA	38.5	20.1	39.1	20.9
10-07-22	8:30 PM	36.2	23.4	36.2	23.6	37.5	23.3	36.6	27.2	36	24.4	NO DATA	NO DATA	38.2	20.7	39.1	21.4
10-07-22	9:00 PM	35.4	27.1	35.6	26.2	37.1	24.3	36.5	27.6	35.4	26.5	NO DATA	NO DATA	37.9	21.3	39	22.5
10-07-22	9:30 PM	34.3	28	34.8	28.2	36.7	25.5	36.4	28.3	34.6	29.2	NO DATA	NO DATA	37.4	23.4	38.8	23.9
10-07-22	10:00 PM	33.7	28.9	34	29.2	36.4	25.8	36.3	28.3	33.8	30	NO DATA	NO DATA	37.1	23.8	38.5	24.1
10-07-22	10:30 PM	33	30.8	33.4	30.8	36	26.4	36.2	28.5	33.3	31	NO DATA	NO DATA	36.8	24.2	38.2	24.6
10-07-22	11:00 PM	32.4	32.5	32.8	32.4	35.7	27.3	36	29	32.7	32.9	NO DATA	NO DATA	36.4	25	37.9	25.4
10-07-22	11:30 PM	31.9	34.8	32.4	34.2	35.3	28.2	35.9	29.6	32.1	34.7	NO DATA	NO DATA	36	25.8	37.6	26.1
11-07-22	12:00 AM	31.4	37.1	31.9	36.5	35	29.6	35.7	30.6	31.7	36.9	NO DATA	NO DATA	35.7	26.9	37.3	27.2
11-07-22	12:30 AM	31	37.5	31.6	37.4	34.7	30.5	35.5	31.2	31.3	38.1	NO DATA	NO DATA	35.4	27.8	36.8	27.9
11-07-22	1:00 AM	30.6	39.2	31.1	39.2	34.4	31.2	35.3	31.9	30.9	39.9	NO DATA	NO DATA	35	28.7	36.5	28.7
11-07-22	1:30 AM	30.3	41.4	30.7	41.3	34.1	32.4	35	32.7	30.5	41.4	NO DATA	NO DATA	34.7	29.7	36.1	29.8
11-07-22	2:00 AM	29.9	43.6	30.3	43.7	33.7	33.7	34.8	33.8	30.1	43.6	NO DATA	NO DATA	34.3	31.3	35.8	31.5
11-07-22	2:30 AM	29.4	45.3	29.8	46.3	33.4	35.2	34.5	35	29.7	46	NO DATA	NO DATA	33.9	32.9	35.4	32.9

Date	time	OUT0 Env Temperature °C	OUT0 Env Humidity%	ES2 GR Temperature °C	ES2 GR Humidity%	A2 GR Temperature °C	A2 GR Humidity%	IS2 GR Temperature °C	IS2 GR Humidity%	IC0 In-between Temperature °C	IC0 In-between Humidity%	ES1 PR Temperature °C	ES1 PR Humidity%	A1 PR Temperature °C	A1 PR Humidity%	IS1 PR Temperature °C	IS1 PR Humidity%
11-07-22	3:00 AM	29	45.8	29.5	46.8	33.1	35.7	34.2	35.4	29.3	46.6	NO DATA	NO DATA	33.6	33.6	35.1	33.4
11-07-22	3:30 AM	28.6	48.3	29.2	47.7	32.8	36.5	34	36.1	29	48.5	NO DATA	NO DATA	33.3	34.2	34.7	33.9
11-07-22	4:00 AM	28.3	49.7	28.8	50	32.5	37.7	33.7	36.9	28.6	50	NO DATA	NO DATA	33	35.2	34.4	35.2
11-07-22	4:30 AM	28.1	50.5	28.5	50.9	32.2	38.3	33.4	37.5	28.3	51	NO DATA	NO DATA	32.6	36	34	35.7
11-07-22	5:00 AM	27.9	53.2	28.3	53.3	32	39.8	33.1	38.6	28.1	53.7	NO DATA	NO DATA	32.3	37.2	33.7	36.9
11-07-22	5:30 AM	27.5	54.4	28.1	54.6	31.7	40.6	33	39.5	27.9	55.1	NO DATA	NO DATA	32.1	38.5	33.3	37.9
11-07-22	6:00 AM	27.3	56.9	27.8	56.4	31.5	41.8	32.7	40.5	27.6	56.7	NO DATA	NO DATA	31.8	38.9	33	38.6
11-07-22	6:30 AM	27.4	58.4	27.8	57.5	31.2	43.4	32.4	41.6	27.5	58.9	NO DATA	NO DATA	31.6	40.2	32.8	39.8
11-07-22	7:00 AM	27.7	58.3	28.1	58.2	31.2	44	32.2	42.3	27.8	58.8	NO DATA	NO DATA	31.4	41.3	32.5	40.9
11-07-22	7:30 AM	28.3	56.2	28.5	57.2	31.1	44.7	32	43.3	28.1	58.3	NO DATA	NO DATA	31.3	41.8	32.3	41.4
11-07-22	8:00 AM	28.7	52.9	29.2	54.6	31.1	44.6	31.8	43.6	28.7	56.4	NO DATA	NO DATA	31.3	42.1	32	41.6
11-07-22	8:30 AM	29.5	50.7	29.6	51.3	31.2	43.7	31.7	43.2	29.1	52.8	NO DATA	NO DATA	31.3	41.5	31.9	41.2
11-07-22	9:00 AM	30.3	47.9	30.4	49.1	31.5	43.2	31.7	43.3	29.8	51	NO DATA	NO DATA	31.4	41.3	31.8	40.9
11-07-22	9:30 AM	30.9	45.9	30.9	47	31.7	42.5	31.7	43.4	30.5	49	NO DATA	NO DATA	31.7	40.8	31.8	40.4
11-07-22	10:00 AM	32.2	41.4	31.5	44	32.2	41.3	31.7	43.2	31.2	46	NO DATA	NO DATA	32.1	39.8	31.9	39.5
11-07-22	10:30 AM	33.5	36.9	32.6	40	32.6	39	31.7	42.2	32.1	42.1	NO DATA	NO DATA	32.5	38.1	32	37.9
11-07-22	11:00 AM	34.2	36.3	33.1	38.2	33.2	37.5	31.9	41	32.6	40.1	NO DATA	NO DATA	33	36.5	32.3	36.8
11-07-22	11:30 AM	34.8	35.2	33.5	37.6	33.7	37.2	32.1	41.5	33.5	39.6	NO DATA	NO DATA	33.6	36.2	32.6	36.7
11-07-22	12:00 PM	35.4	34.1	34.7	36.1	34.3	36.3	32.3	41	34.2	37.5	NO DATA	NO DATA	34.1	35.4	32.9	36
11-07-22	12:30 PM	36.6	31.7	34.9	33.9	34.8	35.1	32.6	39.9	35	35.4	NO DATA	NO DATA	34.7	34.1	33.2	35
11-07-22	1:00 PM	37.8	29.7	35.4	31.9	35.4	33.9	32.9	39.4	35.9	33.9	NO DATA	NO DATA	35.3	32.9	33.6	33.9
11-07-22	1:30 PM	37.9	28.2	36.4	30.6	35.9	32.9	33.2	38.6	36	32.6	NO DATA	NO DATA	35.9	31.7	34.1	32.9
11-07-22	2:00 PM	38.9	26.1	37	28.6	36.4	31.5	33.5	37.6	36.9	30.6	NO DATA	NO DATA	36.4	30.4	34.6	31.6
11-07-22	2:30 PM	39.8	25.8	38.2	28.9	36.8	30.6	33.9	36.7	37.4	29.9	NO DATA	NO DATA	36.9	29.2	35.1	30.8
11-07-22	3:00 PM	40.3	24.7	38.2	26.2	37.2	29.7	34.2	35.8	38.5	27.4	NO DATA	NO DATA	37.4	28.5	35.6	30

Date	time	OUT0 Env Temperature °C	OUT0 Env Humidity%	ES2 GR Temperature °C	ES2 GR Humidity%	A2 GR Temperature °C	A2 GR Humidity%	IS2 GR Temperature °C	IS2 GR Humidity%	IC0 In-between Temperature °C	IC0 In-between Humidity%	ES1 PR Temperature °C	ES1 PR Humidity%	A1 PR Temperature °C	A1 PR Humidity%	IS1 PR Temperature °C	IS1 PR Humidity%
11-07-22	3:30 PM	40.5	24.4	38.5	25.6	37.5	29.1	34.5	35	38.8	27	NO DATA	NO DATA	37.8	27.8	36	29.3
11-07-22	4:00 PM	40.3	24.6	39.2	25.9	37.7	28.8	34.9	34.6	38.7	27.1	NO DATA	NO DATA	38.1	27.3	36.5	28.8
11-07-22	4:30 PM	41.2	23.1	38.8	25.1	37.9	28.2	35.1	33.7	38.9	26.3	NO DATA	NO DATA	38.3	26.7	37	28.1
11-07-22	5:00 PM	41.3	22	39.1	24.6	38	27.3	35.4	32.9	38.9	25.1	NO DATA	NO DATA	38.5	25.7	37.6	27.3
11-07-22	5:30 PM	41	22.1	39.1	24.7	38	26.9	35.6	32.3	38.8	25.1	NO DATA	NO DATA	38.6	25.3	37.9	26.7
11-07-22	6:00 PM	40.6	21.7	38.9	24.2	37.9	26.5	35.8	31.4	38.5	24.8	NO DATA	NO DATA	38.6	24.6	38.3	25.7
11-07-22	6:30 PM	40.1	21.8	38.4	24.2	37.8	26	36	30.8	38.2	24.5	NO DATA	NO DATA	38.6	24.3	38.5	25.3
11-07-22	7:00 PM	39.1	22.7	37.8	24.5	37.6	26	36	30.7	37.6	25.1	NO DATA	NO DATA	38.4	24.2	38.7	25.1
11-07-22	7:30 PM	37.3	24.5	37.2	25.4	37.3	26.2	36.1	30.6	36.9	25.7	NO DATA	NO DATA	38.2	24.4	38.8	25.1
11-07-22	8:00 PM	36.2	25.6	36.4	25.9	37	26.4	36.1	30.7	36.2	26.3	NO DATA	NO DATA	37.9	24.7	38.9	25.2
11-07-22	8:30 PM	35.4	26.9	35.6	27.4	36.8	26.8	36.1	31.3	35.4	27.6	NO DATA	NO DATA	37.7	25	38.8	25.4
11-07-22	9:00 PM	34.8	29.2	35.1	27.9	36.5	27.4	36.1	31.7	35	28.1	NO DATA	NO DATA	37.4	25.1	38.7	25.7
11-07-22	9:30 PM	34.1	31.2	34.4	30.7	36.2	28.5	36.1	32.3	34.2	31.2	NO DATA	NO DATA	37.1	26.1	38.5	26.5
11-07-22	10:00 PM	33.6	32.9	34	32.7	36	29.6	36	32.4	33.8	32.7	NO DATA	NO DATA	36.8	26.8	38.3	27.2
11-07-22	10:30 PM	32.8	34.9	33.3	34.2	35.6	30.4	35.9	32.7	33.3	34.5	NO DATA	NO DATA	36.4	27.6	38	27.9
11-07-22	11:00 PM	32.1	36.5	32.6	36.2	35.2	31	35.8	32.9	32.5	36.8	NO DATA	NO DATA	36	28.6	37.7	28.9
11-07-22	11:30 PM	31.4	38.3	31.8	38	34.8	31.9	35.6	33.2	31.8	38.3	NO DATA	NO DATA	35.7	29.3	37.3	29.5
12-07-22	12:00 AM	30.6	40	31.2	39.6	34.5	32.6	35.4	33.6	31	40.2	NO DATA	NO DATA	35.3	30.1	36.9	30.2
12-07-22	12:30 AM	30.1	41.4	30.6	41	34.2	33.2	35.2	34	30.4	41.4	NO DATA	NO DATA	34.9	30.7	36.5	30.7
12-07-22	1:00 AM	29.7	42.2	30.2	41.9	33.8	33.7	34.9	34.3	30	42.6	NO DATA	NO DATA	34.5	31.2	36.1	31.3
12-07-22	1:30 AM	29.3	43.3	29.7	43.1	33.5	34.4	34.6	34.7	29.5	43.7	NO DATA	NO DATA	34.1	31.8	35.8	31.7
12-07-22	2:00 AM	28.8	44.4	29.5	43.9	33.2	34.9	34.3	35.1	29.2	44.5	NO DATA	NO DATA	33.8	32.3	35.4	32.1
12-07-22	2:30 AM	28.3	45.4	28.9	45.5	32.9	35.3	34	35.5	28.8	45.4	NO DATA	NO DATA	33.6	32.6	35.1	32.4
12-07-22	3:00 AM	28.1	45.6	28.5	45.9	32.5	35.8	33.8	35.7	28.4	46	NO DATA	NO DATA	33.1	33.3	34.6	33.1
12-07-22	3:30 AM	27.8	46.4	28.3	46.2	32.2	36.1	33.5	35.9	28.1	46.7	NO DATA	NO DATA	32.7	33.8	34.2	33.5

Date	time	OUT0 Env Temperature °C	OUT0 Env Humidity%	ES2 GR Temperature °C	ES2 GR Humidity%	A2 GR Temperature °C	A2 GR Humidity%	IS2 GR Temperature °C	IS2 GR Humidity%	IC0 In-between Temperature °C	IC0 In-between Humidity%	ES1 PR Temperature °C	ES1 PR Humidity%	A1 PR Temperature °C	A1 PR Humidity%	IS1 PR Temperature °C	IS1 PR Humidity%
12-07-22	4:00 AM	27.6	46.4	28.2	46.5	31.9	36.5	33.2	36.3	28	46.8	NO DATA	NO DATA	32.4	34.1	33.9	33.8
12-07-22	4:30 AM	27.4	46.8	27.9	47	31.7	36.8	32.9	36.5	27.7	47.1	NO DATA	NO DATA	32.1	34.5	33.5	34.3
12-07-22	5:00 AM	27	47.4	27.6	47.7	31.4	37.2	32.6	36.8	27.4	47.7	NO DATA	NO DATA	31.7	34.9	33.1	34.5
12-07-22	5:30 AM	26.6	47.9	27.1	48.6	31.1	37.4	32.3	37	26.9	48.2	NO DATA	NO DATA	31.4	35.1	32.8	34.8
12-07-22	6:00 AM	26.5	48.5	27	49.4	30.8	37.9	32	37.4	26.7	49.2	NO DATA	NO DATA	31.1	35.6	32.4	35.2
12-07-22	6:30 AM	26.9	48.2	27	49.5	30.5	38.4	31.7	37.7	26.7	49.5	NO DATA	NO DATA	30.8	36.3	32.1	35.8
12-07-22	7:00 AM	27.9	45.9	27.7	48.2	30.3	38.8	31.6	38.1	27.2	48.6	NO DATA	NO DATA	30.6	36.8	31.7	36.3
12-07-22	7:30 AM	28.4	44.6	28.3	46.2	30.3	38.8	31.3	38.4	27.8	47	NO DATA	NO DATA	30.5	36.9	31.6	36.5
12-07-22	8:00 AM	28.9	43.9	28.9	44.9	30.4	39	31.2	38.8	28.5	46	NO DATA	NO DATA	30.5	37.5	31.3	36.9
12-07-22	8:30 AM	29.6	43.1	29.3	44.2	30.6	39.3	31.1	39.3	28.9	45.5	NO DATA	NO DATA	30.6	37.7	31.2	37.3
12-07-22	9:00 AM	30.6	41.2	29.8	42.8	30.8	39.1	31	39.6	29.6	43.8	NO DATA	NO DATA	30.9	37.7	31.1	37.4
12-07-22	9:30 AM	31.4	38.9	30.6	40.4	31.1	38.4	31	39.9	30.3	41.7	NO DATA	NO DATA	31.2	37.1	31.2	36.8
12-07-22	10:00 AM	32.4	36.6	31.6	38.4	31.6	37.5	31	39.5	31.1	39.7	NO DATA	NO DATA	31.5	36.4	31.3	36.3
12-07-22	10:30 AM	33.5	35	32.3	37.3	32	37	31.1	39.5	31.8	39	NO DATA	NO DATA	32	35.9	31.5	35.9
12-07-22	11:00 AM	34.6	32.3	33	36	32.5	36.3	31.3	39.3	32.7	37	NO DATA	NO DATA	32.5	35.3	31.7	35.5
12-07-22	11:30 AM	35.2	31.5	34.2	33.8	33.2	35.2	31.5	38.9	33.6	35.3	NO DATA	NO DATA	33	34.3	31.9	34.7
12-07-22	12:00 PM	36.1	30.1	34.9	31.8	33.7	34	31.7	38.1	34.4	33.4	NO DATA	NO DATA	33.6	33.2	32.3	33.9
12-07-22	12:30 PM	37	27.2	35.8	29.5	34.2	32.3	32	37.4	35.4	30.7	NO DATA	NO DATA	34.2	31.9	32.7	32.6
12-07-22	1:00 PM	38.1	25.7	36.3	26.6	34.8	30.7	32.4	35.8	36.2	28.5	NO DATA	NO DATA	34.8	29.9	33	31.1
12-07-22	1:30 PM	38.9	24.9	37.4	26.6	35.4	30	32.7	35.5	36.8	27.7	NO DATA	NO DATA	35.4	29.2	33.5	30.4
12-07-22	2:00 PM	39.5	23.2	38.2	24.3	35.9	28.8	33	34.2	37.7	25.3	NO DATA	NO DATA	36	27.8	34	29.3
12-07-22	2:30 PM	40.1	22.1	38.4	23.4	36.3	27.8	33.4	33.3	38.3	24.4	NO DATA	NO DATA	36.6	26.7	34.5	28.3
12-07-22	3:00 PM	40.7	21.2	38.9	22.3	36.8	26.8	33.8	32.3	38.9	23.6	NO DATA	NO DATA	37	25.7	35.1	27.4
12-07-22	3:30 PM	41	20.1	39.5	21.5	37.1	25.6	34.2	31	39.2	22.5	NO DATA	NO DATA	37.5	24.7	35.6	26.3
12-07-22	4:00 PM	41.3	19.7	39.4	20.9	37.3	25	34.5	30.3	39.3	21.6	NO DATA	NO DATA	37.8	24	36	25.6

Date	time	OUT0 Env Temperature °C	OUT0 Env Humidity%	ES2 GR Temperature °C	ES2 GR Humidity%	A2 GR Temperature °C	A2 GR Humidity%	IS2 GR Temperature °C	IS2 GR Humidity%	IC0 In-between Temperature °C	IC0 In-between Humidity%	ES1 PR Temperature °C	ES1 PR Humidity%	A1 PR Temperature °C	A1 PR Humidity%	IS1 PR Temperature °C	IS1 PR Humidity%
12-07-22	4:30 PM	41.4	18.5	39.6	20.2	37.5	24.1	34.9	29.1	39.3	20.9	NO DATA	NO DATA	38	22.9	36.5	24.4
12-07-22	5:00 PM	42	17	39.7	19.2	37.5	22.9	35.1	28.1	39.3	19.6	NO DATA	NO DATA	38.2	21.7	37	23.4
12-07-22	5:30 PM	41.4	16.9	39.7	19.1	37.6	22.2	35.4	27.3	39.1	19.3	NO DATA	NO DATA	38.2	20.9	37.4	22.3
12-07-22	6:00 PM	41.2	17.3	39.1	18.9	37.5	22	35.6	26.8	38.9	19.3	NO DATA	NO DATA	38.3	20.4	37.8	21.8
12-07-22	6:30 PM	40.3	18	38.8	19.5	37.4	22.1	35.8	26.6	38.5	19.5	NO DATA	NO DATA	38.2	20.4	38.1	21.6
12-07-22	7:00 PM	39.1	19.3	38.1	20.7	37.3	22.6	35.9	27	37.9	20.8	NO DATA	NO DATA	38.1	20.8	38.3	21.9
12-07-22	7:30 PM	37.2	21.1	37.3	21.5	37	22.9	36	27.4	37.1	21.7	NO DATA	NO DATA	37.8	21.3	38.4	22.1
12-07-22	8:00 PM	36.2	21.6	36.4	22.1	36.7	23	36	27.5	36.2	22.3	NO DATA	NO DATA	37.5	21.6	38.5	22.2
12-07-22	8:30 PM	35.4	22.7	35.6	23.2	36.5	23.7	36.1	28.3	35.5	23.3	NO DATA	NO DATA	37.3	22	38.4	22.5
12-07-22	9:00 PM	35	28.8	35.3	26.6	36.3	25	36	28.4	35.1	25.8	NO DATA	NO DATA	37	22.5	38.3	23.8
12-07-22	9:30 PM	34.3	30.2	34.5	29.8	36	27.2	36	29.9	34.4	30.1	NO DATA	NO DATA	36.7	25	38.1	25.6
12-07-22	10:00 PM	33.5	31.5	33.9	31	35.8	28.1	36	30.5	33.8	31	NO DATA	NO DATA	36.5	25.7	37.9	26
12-07-22	10:30 PM	33	33.1	33.4	32.4	35.5	28.9	35.9	30.9	33.3	32.5	NO DATA	NO DATA	36.2	26.4	37.7	26.6
12-07-22	11:00 PM	32.6	34.2	33	34.2	35.2	29.9	35.8	31.3	32.9	34.2	NO DATA	NO DATA	35.9	27.3	37.4	27.5
12-07-22	11:30 PM	32.2	36	32.6	35.9	34.9	30.8	35.6	31.9	32.4	35.9	NO DATA	NO DATA	35.5	28.1	37	28.4
	Average	34.11	29.46	33.46	31.02	34.49	28.33	33.79	30.89	33.15	31.85	NO DATA	NO DATA	34.95	26.26	35.18	26.72

Appendix II

The Report of the PVsyst Simulation

Version 7.2.6

PVsyst - Simulation report

Grid-Connected System

Project: Green Experiment

Variant: Case 1- True South
Building system
System power: 4400 Wp
Aqaba - Jordan

Maryam Khlof

Signature

Project: Green Experiment

Variant: Case 1- True South

PVsyst V7.2.6
VC0, Simulation date:
10/06/22 17:04
with v7.2.6

Project summary

Geographical Site	**Situation**		**Project settings**	
Aqaba	Latitude	29.07 °N	Albedo	0.20
Jordan	Longitude	35.00 °E		
	Altitude	30 m		
	Time zone	UTC+2		

Meteo data
Aqaba
Meteonorm 8.0 (2005-2011), Sat=100% - Synthetic

System summary

Grid-Connected System — **Building system**

PV Field Orientation		**Near Shadings**		**User's needs**
Fixed plane		According to strings		Unlimited load (grid)
Tilt/Azimuth	90 / 0 °	Electrical effect	100 %	

System information

PV Array		**Inverters**	
Nb. of modules	8 units	Nb. of units	1 Unit
Pnom total	4400 Wp	Pnom total	4000 W
		Pnom ratio	1.100

Results summary

Produced Energy	4745 kWh/year	Specific production	1079 kWh/kWp/year	Perf. Ratio PR	74.09 %

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10/06/22 PVsyst Licensed to Page 2/9

PVsyst V7.2.6
VC0, Simulation date:
10/06/22 17:54
with v7.2.6

General parameters

Grid-Connected System

Building system

PV Field Orientation

Orientation
Fixed plane
Tilt/Azimuth 90 / 0 °

Sheds configuration

Models used
Transposition Perez
Diffuse Perez, Meteonorm
Circumsolar separate

Horizon
Free Horizon

Near Shadings
According to strings
Electrical effect 100 %

User's needs
Unlimited load (grid)

PV Array Characteristics

PV module

Manufacturer	Longi Solar
Model	LR5-72 HPH 550 M
(Original PVsyst database)	
Unit Nom. Power	550 Wp
Number of PV modules	8 units
Nominal (STC)	4400 Wp
Modules	2 Strings x 4 In series
At operating cond. (50°C)	
Pmpp	4021 Wp
U mpp	150 V
I mpp	27 A

Inverter

Manufacturer	ABB
Model	UNO-DM-4.0-TL-PLUS
(Original PVsyst database)	
Unit Nom. Power	4.00 kWac
Number of inverters	2 * MPPT 50% 1 unit
Total power	4.0 kWac
Operating voltage	90-580 V
Pnom ratio (DC:AC)	1.10

Total PV power

Nominal (STC)	4 kWp
Total	8 modules
Module area	20.4 m²
Cell area	18.5 m²

Total inverter power

Total power	4 kWac
Nb. of inverters	1 Unit
Pnom ratio	1.10

Array losses

Array Soiling Losses
Loss Fraction 3.0 %

Thermal Loss factor
Module temperature according to irradiance
Uc (const) 15.0 W/m²K
Uv (wind) 0.0 W/m²K/m/s

DC wiring losses
Global array res. 93 mΩ
Loss Fraction 1.5 % at STC

Serie Diode Loss
Voltage drop 0.7 V
Loss Fraction 0.4 % at STC

LID - Light Induced Degradation
Loss Fraction 2.0 %

Module Quality Loss
Loss Fraction -0.3 %

Module mismatch losses
Loss Fraction 2.0 % at MPP

Strings Mismatch loss
Loss Fraction 0.1 %

IAM loss factor
Incidence effect (IAM): User defined profile

0°	25°	45°	60°	65°	70°	75°	80°	90°
1.000	1.000	0.995	0.962	0.936	0.903	0.851	0.754	0.000

PVsyst V7.2.6
VC0, Simulation date:
10/06/22 17:54
with v7.2.6

System losses

Unavailability of the system

Time fraction	2.0 %
	7.3 days,
	3 periods

AC wiring losses

Inv. output line up to injection point

Inverter voltage	230 Vac mono
Loss Fraction	1.00 % at STC

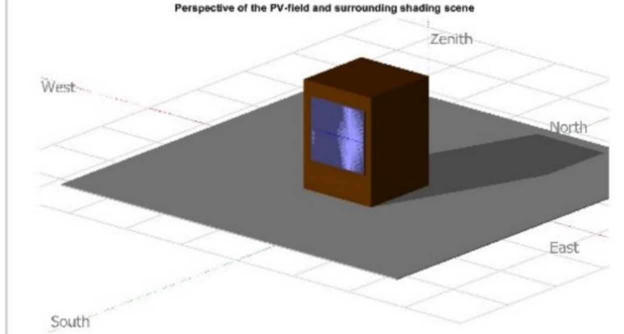
Inverter: UNO-DM-4.0-TL-PLUS

Wire section (1 Inv.)	Copper 1 x 2 x 3 mm²
Wires length	8 m

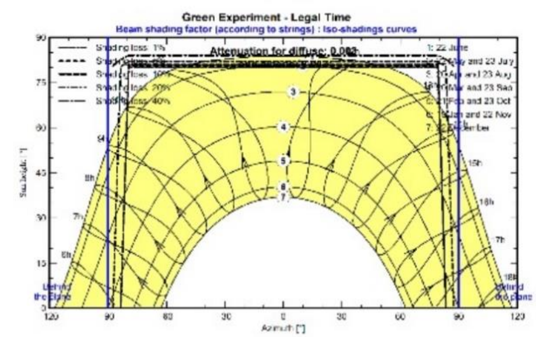
PVsyst V7.2.6
VC0, Simulation date:
10/06/22 17:54
with v7.2.6

Near shadings parameter

Perspective of the PV-field and surrounding shading scene



Iso-shadings diagram



PVsyst V7.2.6
VC0, Simulation date:
10/06/22 17:34
with v7.2.6

Main results

System Production

Produced Energy	4745 kWh/year	Specific production	1079 kWh/kWp/year
		Performance Ratio PR	74.09 %

Normalized productions (per installed kWp)

Performance Ratio PR

Balances and main results

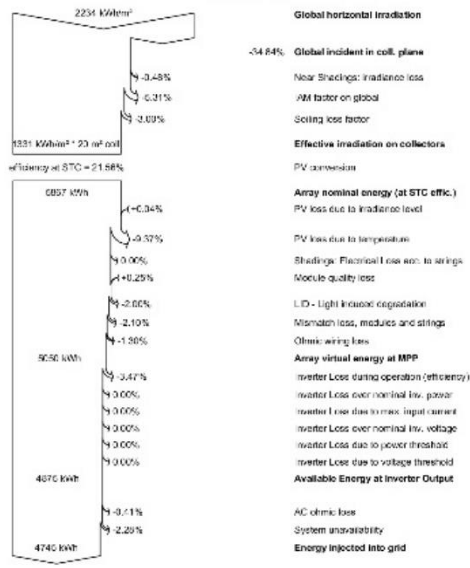
	GlobHor	DiffHor	T_Amb	GlobInc	GlobEff	EArray	E_Grid	PR
	kWh/m²	kWh/m²	°C	kWh/m²	kWh/m²	kWh	kWh	ratio
January	121.3	28.59	15.70	173.2	165.7	634.9	611.5	0.903
February	130.8	38.17	17.86	142.0	134.1	518.4	499.8	0.800
March	188.7	47.42	21.85	139.2	127.0	480.8	385.1	0.829
April	212.9	66.60	25.51	98.3	85.2	330.2	295.4	0.583
May	240.9	62.51	30.29	70.1	58.6	226.7	215.1	0.607
June	201.5	46.59	32.93	54.7	44.9	171.4	162.2	0.675
July	253.6	48.49	34.97	51.4	50.4	190.4	180.6	0.669
August	232.1	51.26	34.75	86.8	73.4	276.0	264.0	0.692
September	196.9	44.42	31.70	121.4	107.9	404.1	389.0	0.728
October	166.9	37.33	28.30	160.1	149.6	566.5	535.5	0.760
November	129.5	24.54	22.39	173.1	166.5	614.5	592.1	0.777
December	113.9	26.73	17.37	175.6	168.6	638.3	615.0	0.796
Year	2234.0	618.62	25.19	1435.6	1330.7	5068.9	4745.4	0.741

Legends

GlobHor	Global horizontal irradiation	EArray	Effective energy at the output of the array
DiffHor	Horizontal diffuse irradiation	E_Grid	Energy injected into grid
T_Amb	Ambient Temperature	PR	Performance Ratio
GlobInc	Global incident in coll. plane		
GlobEff	Effective Global, corr. for IAM and shadings		

PVsyst V7.2.6
VC0, Simulation date:
10/06/22 17:54
with v7.2.6

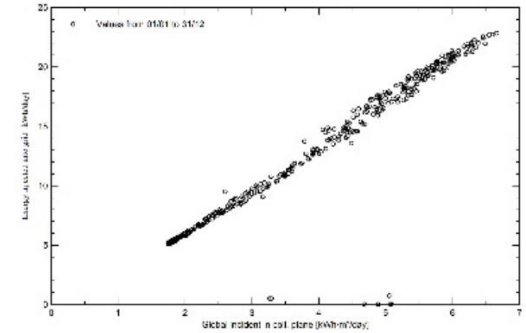
Loss diagram



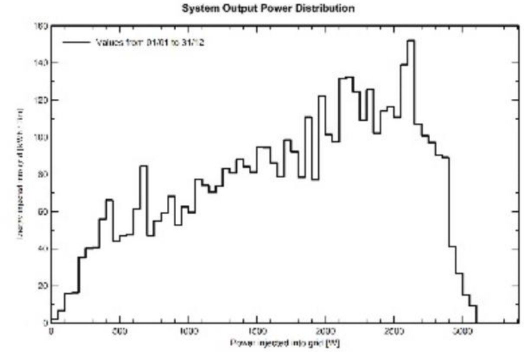
PVsyst V7.2.6
VC0, Simulation date:
10/06/22 17:54
with v7.2.6

Special graphs

Daily Input/Output diagram



System Output Power Distribution



Version 7.2.6

PVsyst - Simulation report

Grid-Connected System

Project: Green Experiment

Variant: Case 2- True West
Building system
System power: 4400 Wp
Aqaba - Jordan

Maryam Khlof

Signature

PVsyst V7.2.6
VC1, Simulation date:
10/06/22 18:04
with v7.2.6

Project summary

Geographical Site		**Situation**		**Project settings**	
Aqaba		Latitude	29.57 °N	Albedo	0.20
Jordan		Longitude	35.00 °E		
		Altitude	30 m		
		Time zone	UTC+2		

Meteo data
Aqaba
Meteonorm 8.0 (2006-2011), Sat=100% - Synthetic

System summary

Grid-Connected System — **Building system**

PV Field Orientation		**Near Shadings**		**User's needs**	
Fixed plane		According to strings		Unlimited load (grid)	
Tilt/Azimuth	90 / 90 °	Electrical effect	100 %		

System information

PV Array		**Inverters**	
Nb. of modules	8 units	Nb. of units	1 Unit
Pnom total	4400 Wp	Pnom total	4000 W
		Pnom ratio	1.100

Results summary

Produced Energy	4141 kWh/year	Specific production	941 kWh/kWp/year	Perf. Ratio PR	74.09 %

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Main results ____ 6
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General parameters

Grid-Connected System

Building system

PV Field Orientation

Orientation

Fixed plane	
Tilt/Azimuth	90 / 90 °

Sheds configuration

Models used

Transposition	Perez
Diffuse	Perez, Meteonorm
Circumsolar	separate

Horizon
Free Horizon

Near Shadings

According to strings	
Electrical effect	100 %

User's needs
Unlimited load (grid)

PV Array Characteristics

PV module

Manufacturer	Longi Solar
Model	LR5-72 HPH 550 M
(Original PVsyst database)	
Unit Nom. Power	550 Wp
Number of PV modules	8 units
Nominal (STC)	4400 Wp
Modules	2 Strings x 4 In series
At operating cond. (50°C)	
Pmpp	4021 Wp
U mpp	150 V
I mpp	27 A

Inverter

Manufacturer	ABB
Model	UNO-DM-4.0-TL-PLUS
(Original PVsyst database)	
Unit Nom. Power	4.00 kWac
Number of inverters	2 * MPPT 50% 1 unit
Total power	4.0 kWac
Operating voltage	90-580 V
Pnom ratio (DC:AC)	1.10

Total PV power

Nominal (STC)	4 kWp
Total	8 modules
Module area	20.4 m²
Cell area	18.5 m²

Total inverter power

Total power	4 kWac
Nb. of inverters	1 Unit
Pnom ratio	1.10

Array losses

Array Soiling Losses

Loss Fraction	3.0 %

Thermal Loss factor

Module temperature according to irradiance	
Uc (const)	15.0 W/m²K
Uv (wind)	0.0 W/m²K/m/s

DC wiring losses

Global array res.	93 mΩ
Loss Fraction	1.5 % at STC

Serie Diode Loss

Voltage drop	0.7 V
Loss Fraction	0.4 % at STC

LID - Light Induced Degradation

Loss Fraction	2.0 %

Module Quality Loss

Loss Fraction	-0.3 %

Module mismatch losses

Loss Fraction	2.0 % at MPP

Strings Mismatch loss

Loss Fraction	0.1 %

IAM loss factor
Incidence effect (IAM): User defined profile

0°	25°	45°	60°	65°	70°	75°	80°	90°
1.000	1.000	0.995	0.962	0.936	0.903	0.851	0.754	0.000

System losses

Unavailability of the system

Time fraction	2.0 %
	7.3 days,
	3 periods

AC wiring losses

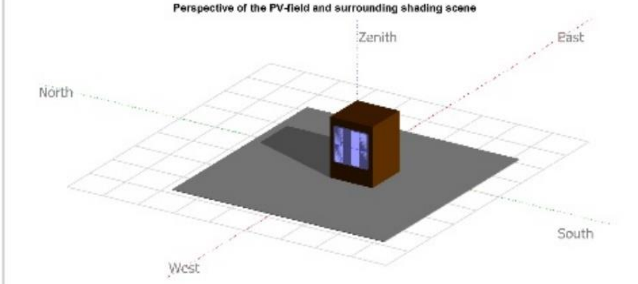
Inv. output line up to injection point

Inverter voltage	230 Vac mono
Loss Fraction	1.00 % at STC
Inverter: UNO-DM-4.0-TL-PLUS	
Wire section (1 Inv.)	Copper 1 x 2 x 3 mm²
Wires length	8 m

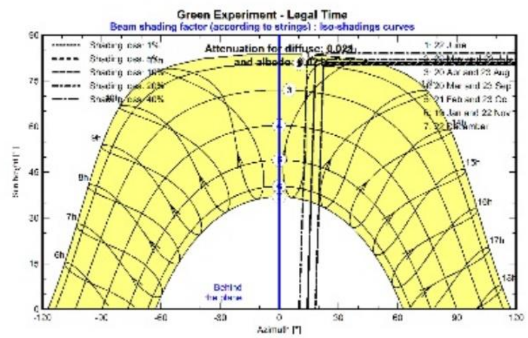
PVsyst V7.2.6
VC1, Simulation date:
10/06/22 19:04
with v7.2.6

Near shadings parameter

Perspective of the PV-field and surrounding shading scene



Iso-shadings diagram



Project: Green Experiment
Variant: Case 2- True West

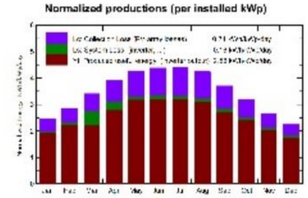
PVsyst V7.2.6
VC1, Simulation date:
10/06/22 19:04
with v7.2.6

Main results

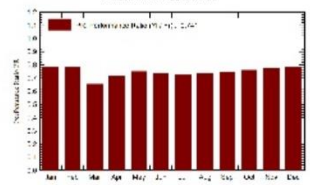
System Production

Produced Energy	4141 kWh/year	Specific production	941 kWh/kWp/year
		Performance Ratio PR	74.09 %

Normalized productions (per installed kWp)



Performance Ratio PR



Balances and main results

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray kWh	E_Grid kWh	PR ratio
January	121.3	28.09	16.70	76.2	69.4	274.3	262.9	0.784
February	133.8	38.17	17.88	80.0	73.6	288.3	276.9	0.785
March	188.7	47.42	21.85	105.8	98.7	375.6	303.6	0.652
April	212.8	55.60	25.61	117.9	110.7	414.1	368.9	0.713
May	240.8	62.51	30.29	131.7	123.8	453.0	435.2	0.751
June	251.6	46.69	32.93	131.1	123.2	443.1	425.6	0.738
July	253.8	48.49	34.97	136.8	128.6	456.6	438.4	0.728
August	232.1	51.26	34.75	131.8	123.7	442.8	425.3	0.735
September	195.8	44.42	31.70	110.9	104.3	377.5	362.9	0.744
October	165.9	37.35	28.30	98.9	92.4	343.7	328.9	0.758
November	129.5	24.64	22.39	79.4	73.8	281.2	269.6	0.771
December	113.0	25.70	17.37	69.7	63.7	250.7	240.4	0.784
Year	2234.0	510.62	26.19	1270.1	1185.6	4401.4	4140.5	0.741

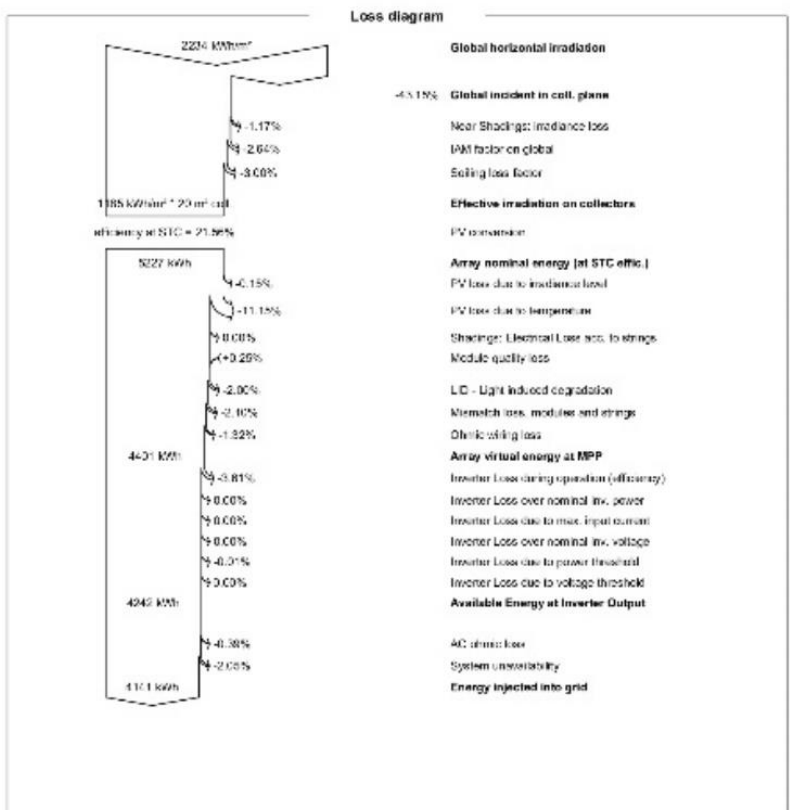
Legends

GlobHor	Global horizontal irradiation	EArray	Effective energy at the output of the array
DiffHor	Horizontal diffuse irradiation	E_Grid	Energy injected into grid
T_Amb	Ambient Temperature	PR	Performance Ratio
GlobInc	Global incident in coll. plane		
GlobEff	Effective Global, corr. for IAM and shadings		

PVsyst V7.2.6
VC1, Simulation date:
10/06/22 10:04
with v7.2.6

Project: Green Experiment

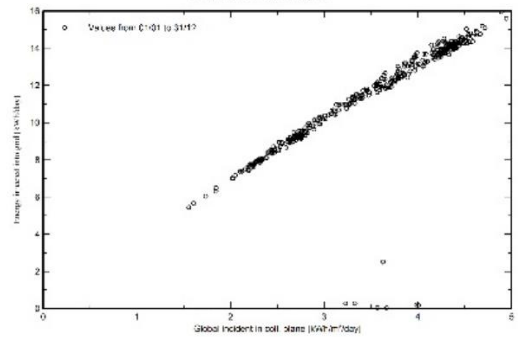
Variant: Case 2- True West



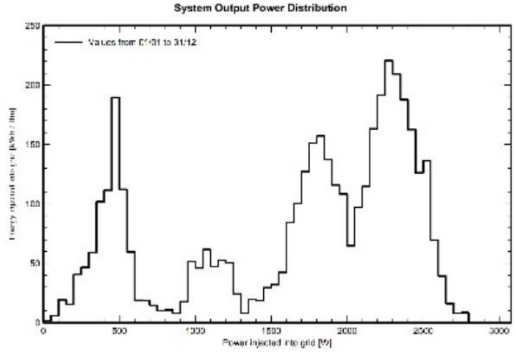
10/06/22 PVsyst Licensed to Page 7/8

Special graphs

Daily Input/Output diagram



System Output Power Distribution



Version 7.2.6

PVsyst - Simulation report

Grid-Connected System

Project: Green Experiment

Variant: Case 3- True East

Building system

System power: 4400 Wp

Aqaba - Jordan

Maryam Khlof

Signature

Project summary

Geographical Site
Aqaba
Jordan

Situation

Latitude	29.57 °N
Longitude	35.00 °E
Altitude	30 m
Time zone	UTC+2

Project settings
Albedo 0.20

Meteo data
Aqaba
Meteonorm 8.0 (2006-2011), Sat=100% - Synthetic

System summary

Grid-Connected System

Building system

PV Field Orientation
Fixed plane
Tilt/Azimuth 90 / -90 °

Near Shadings
According to strings
Electrical effect 100 %

User's needs
Unlimited load (grid)

System information

PV Array

Nb. of modules	8 units
Pnom total	4400 Wp

Inverters

Nb. of units	1 Unit
Pnom total	4000 W
Pnom ratio	1.100

Results summary

Produced Energy	4194 kWh/year	Specific production	953 kWh/kWp/year	Perf. Ratio PR	75.19 %

Table of contents

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Main results 6
Loss diagram 7
Special graphs 8

General parameters

Grid-Connected System

Building system

PV Field Orientation
Orientation
Fixed plane
Tilt/Azimuth 90 / -90 °

Sheds configuration

Models used

Transposition	Perez
Diffuse	Perez, Meteonorm
Circumsolar	separate

Horizon
Free Horizon

Near Shadings
According to strings
Electrical effect 100 %

User's needs
Unlimited load (grid)

PV Array Characteristics

PV module

Manufacturer	Longi Solar
Model	LR5-72 HPH 550 M
(Original PVsyst database)	
Unit Nom. Power	550 Wp
Number of PV modules	8 units
Nominal (STC)	4400 Wp
Modules	2 Strings x 4 In series
At operating cond. (50°C)	
Pmpp	4021 Wp
U mpp	150 V
I mpp	27 A

Inverter

Manufacturer	ABB
Model	UNO-DM-4.0-TL-PLUS
(Original PVsyst database)	
Unit Nom. Power	4.00 kWac
Number of inverters	2 * MPPT 50% 1 unit
Total power	4.0 kWac
Operating voltage	90-580 V
Pnom ratio (DC:AC)	1.10

Total PV power

Nominal (STC)	4 kWp
Total	8 modules
Module area	20.4 m²
Cell area	18.5 m²

Total inverter power

Total power	4 kWac
Nb. of inverters	1 Unit
Pnom ratio	1.10

Array losses

Array Soiling Losses
Loss Fraction 3.0 %

Thermal Loss factor
Module temperature according to irradiance
Uc (const) 15.0 W/m²K
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DC wiring losses
Global array res. 93 mΩ
Loss Fraction 1.5 % at STC

Serie Diode Loss
Voltage drop 0.7 V
Loss Fraction 0.4 % at STC

LID - Light Induced Degradation
Loss Fraction 2.0 %

Module Quality Loss
Loss Fraction -0.3 %

Module mismatch losses
Loss Fraction 2.0 % at MPP

Strings Mismatch loss
Loss Fraction 0.1 %

IAM loss factor
Incidence effect (IAM): User defined profile

0°	25°	45°	60°	65°	70°	75°	80°	90°
1.000	1.000	0.995	0.962	0.936	0.903	0.851	0.754	0.000

PVsyst V7.2.6
VC2, Simulation date:
10/06/22 18:09
with v7.2.6

System losses

Unavailability of the system

Time fraction	2.0 %
	7.3 days,
	3 periods

AC wiring losses

Inv. output line up to injection point

Inverter voltage	230 Vac mono
Loss Fraction	1.00 % at STC

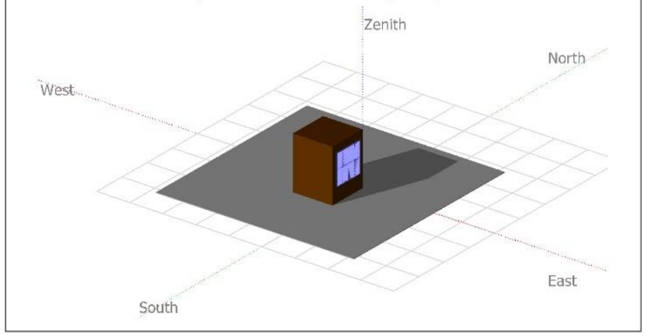
Inverter: UNO-DM-4.0-TL-PLUS

Wire section (1 Inv.)	Copper 1 x 2 x 3 mm²
Wires length	8 m

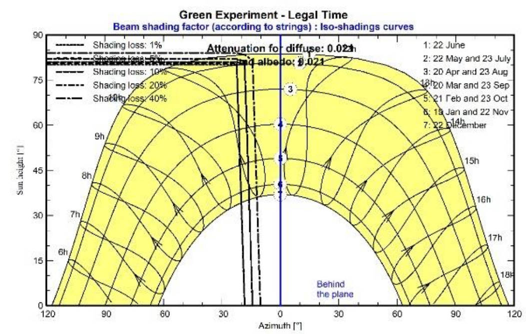
PVsyst V7.2.6
VC2, Simulation date:
10/06/22 18:09
with v7.2.6

Near shadings parameter

Perspective of the PV-field and surrounding shading scene



Iso-shadings diagram

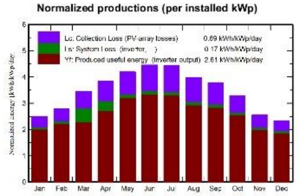


Main results

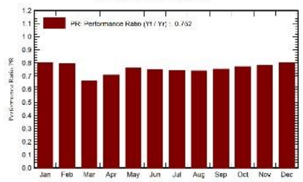
System Production

Produced Energy	4194 kWh/year	Specific production	953 kWh/kWp/year
		Performance Ratio PR	75.19 %

Normalized productions (per installed kWp)



Performance Ratio PR



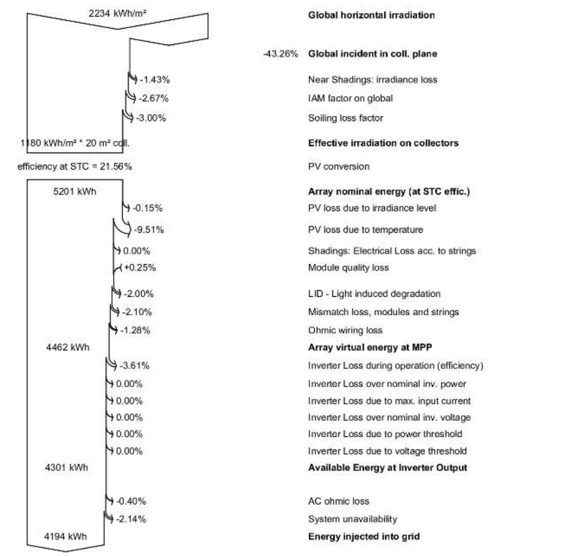
Balances and main results

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray kWh	E_Grid kWh	PR ratio
January	121.3	28.59	15.70	77.7	71.1	286.0	274.2	0.802
February	130.8	38.17	17.88	78.4	71.9	285.9	274.5	0.796
March	186.7	47.42	21.85	107.3	99.3	385.0	312.0	0.661
April	212.9	55.60	25.61	115.3	107.5	408.4	359.9	0.709
May	240.9	62.51	30.29	130.1	121.8	455.0	437.1	0.764
June	251.5	46.59	32.93	133.6	125.0	459.5	441.5	0.751
July	253.6	48.49	34.97	137.9	129.0	469.5	450.9	0.743
August	232.1	51.26	34.75	123.3	115.0	418.0	401.3	0.740
September	195.8	44.42	31.70	113.3	106.2	391.4	375.8	0.754
October	165.9	37.33	28.30	102.1	95.8	362.3	347.8	0.774
November	129.5	24.54	22.39	76.5	70.6	275.1	263.7	0.783
December	113.0	25.70	17.37	72.3	66.4	265.8	255.0	0.801
Year	2234.0	510.62	26.19	1267.7	1179.7	4462.2	4193.7	0.752

Legends

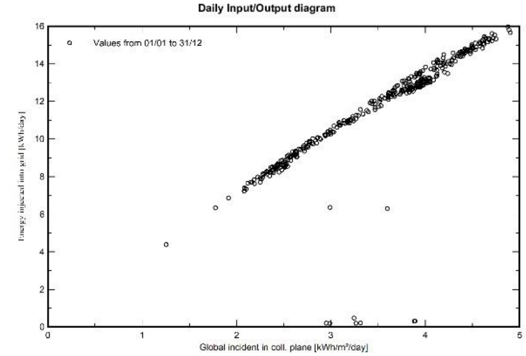
GlobHor	Global horizontal irradiation	EArray	Effective energy at the output of the array
DiffHor	Horizontal diffuse irradiation	E_Grid	Energy injected into grid
T_Amb	Ambient Temperature	PR	Performance Ratio
GlobInc	Global incident in coll. plane		
GlobEff	Effective Global, corr. for IAM and shadings		

Loss diagram

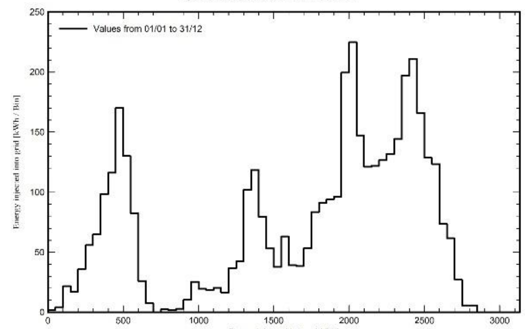


Special graphs

Daily Input/Output diagram



System Output Power Distribution



Version 7.2.6

PVsyst - Simulation report

Grid-Connected System

Project: Green Experiment
Variant: Case 4- South-West
Building system
System power: 4400 Wp
Aqaba - Jordan

Maryam Khlof

Signature

PVsyst V7.2.6
VC3, Simulation date:
10/06/22 18:15
with v7.2.6

Project summary

Geographical Site
Aqaba
Jordan

Situation
Latitude 29.57 °N
Longitude 35.00 °E
Altitude 30 m
Time zone UTC+2

Project settings
Albedo 0.20

Meteo data
Aqaba
Meteonorm 8.0 (2006-2011), Sat=100% - Synthetic

System summary

Grid-Connected System

Building system

PV Field Orientation
Fixed plane
Tilt/Azimuth 90 / 45 °

Near Shadings
According to strings
Electrical effect 100 %

User's needs
Unlimited load (grid)

System information

PV Array
Nb. of modules 8 units
Pnom total 4400 Wp

Inverters
Nb. of units 1 Unit
Pnom total 4000 W
Pnom ratio 1.100

Results summary

Produced Energy 4851 kWh/year — Specific production 1102 kWh/kWp/year — Perf. Ratio PR 74.36 %

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Near shading definition - Iso-shadings diagram ____ 5
Main results ____ 6
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Project: Green Experiment
Variant: Case 4- South-West

PVsyst V7.2.6
VC3, Simulation date:
10/06/22 18:15
with v7.2.6

General parameters

Grid-Connected System

Building system

PV Field Orientation

Orientation
Fixed plane
Tilt/Azimuth 90 / 45 °

Sheds configuration

Models used
Transposition Perez
Diffuse Perez, Meteonorm
Circumsolar separate

Horizon
Free Horizon

Near Shadings
According to strings
Electrical effect 100 %

User's needs
Unlimited load (grid)

PV Array Characteristics

PV module
Manufacturer Longi Solar
Model LR5-72 HPH 550 M
(Original PVsyst database)
Unit Nom. Power 550 Wp
Number of PV modules 8 units
Nominal (STC) 4400 Wp
Modules 2 Strings x 4 In series
At operating cond. (50°C)
Pmpp 4021 Wp
U mpp 150 V
I mpp 27 A

Inverter
Manufacturer ABB
Model UNO-DM-4.0-TL-PLUS
(Original PVsyst database)
Unit Nom. Power 4.00 kWac
Number of inverters 2 * MPPT 50% 1 unit
Total power 4.0 kWac
Operating voltage 90-580 V
Pnom ratio (DC:AC) 1.10

Total PV power
Nominal (STC) 4 kWp
Total 8 modules
Module area 20.4 m²
Cell area 18.5 m²

Total inverter power
Total power 4 kWac
Nb. of inverters 1 Unit
Pnom ratio 1.10

Array losses

Array Soiling Losses
Loss Fraction 3.0 %

Thermal Loss factor
Module temperature according to irradiance
Uc (const) 15.0 W/m²K
Uv (wind) 0.0 W/m²K/m/s

DC wiring losses
Global array res. 93 mΩ
Loss Fraction 1.5 % at STC

Serie Diode Loss
Voltage drop 0.7 V
Loss Fraction 0.4 % at STC

LID - Light Induced Degradation
Loss Fraction 2.0 %

Module Quality Loss
Loss Fraction -0.3 %

Module mismatch losses
Loss Fraction 2.0 % at MPP

Strings Mismatch loss
Loss Fraction 0.1 %

IAM loss factor
Incidence effect (IAM): User defined profile

0°	25°	45°	60°	65°	70°	75°	80°	90°
1.000	1.000	0.995	0.962	0.936	0.903	0.851	0.754	0.000

PVsyst V7.2.6
VC3, Simulation date:
10/06/22 18:15
with v7.2.6

System losses

Unavailability of the system

Time fraction	2.0 %
	7.3 days,
	3 periods

AC wiring losses

Inv. output line up to injection point

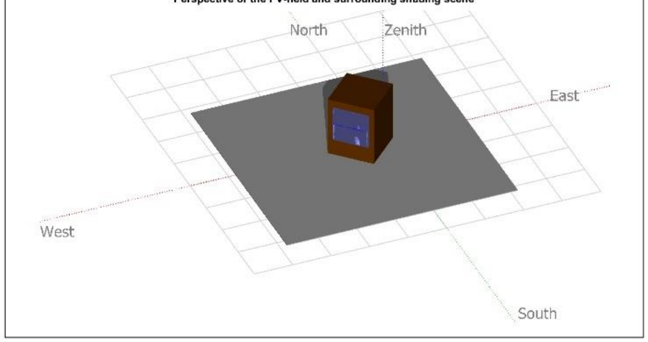
Inverter voltage	230 Vac mono
Loss Fraction	1.00 % at STC
Inverter: UNO-DM-4.0-TL-PLUS	
Wire section (1 Inv.)	Copper 1 x 2 x 3 mm²
Wires length	8 m

Project: Green Experiment
Variant: Case 4- South-West

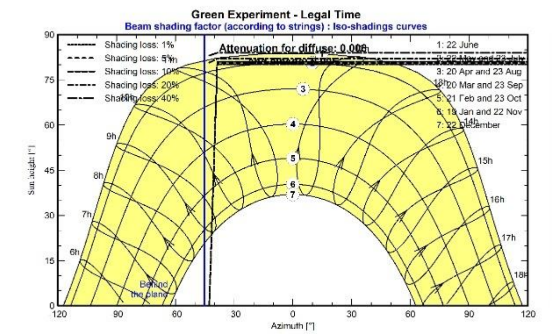
PVsyst V7.2.6
VC3, Simulation date:
10/06/22 18:15
with v7.2.6

Near shadings parameter

Perspective of the PV-field and surrounding shading scene



Iso-shadings diagram



Main results

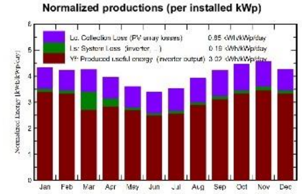
System Production

Produced Energy 4851 kWh/year

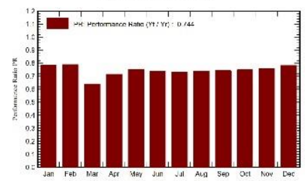
Specific production 1102 kWh/kWp/year

Performance Ratio PR 74.36 %

Normalized productions (per installed kWp)



Performance Ratio PR



Balances and main results

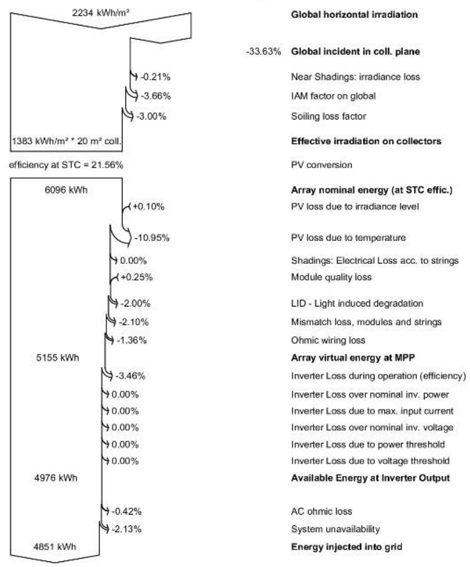
	GlobHor	DiffHor	T_Amb	GlobInc	GlobEff	EArray	E_Grid	PR
	kWh/m²	kWh/m²	°C	kWh/m²	kWh/m²	kWh	kWh	ratio
January	121.3	28.59	15.70	134.3	126.5	482.1	463.5	0.785
February	130.8	38.17	17.88	118.6	111.9	427.2	411.1	0.788
March	186.7	47.42	21.85	131.9	123.5	465.8	371.8	0.641
April	212.9	55.60	25.61	119.0	110.8	418.1	374.0	0.714
May	240.9	62.51	30.29	111.7	102.2	384.6	369.4	0.752
June	251.5	46.59	32.93	101.6	91.9	343.5	329.7	0.737
July	253.6	48.49	34.97	109.4	99.5	367.1	352.3	0.732
August	232.1	51.26	34.75	121.6	112.7	411.6	395.5	0.739
September	195.8	44.42	31.70	126.6	118.5	430.1	413.6	0.743
October	165.9	37.33	28.30	138.3	130.1	474.1	455.8	0.749
November	129.5	24.54	22.39	137.3	129.7	477.2	458.7	0.760
December	113.0	25.70	17.37	132.4	125.2	473.5	455.6	0.782
Year	2234.0	510.62	26.19	1482.6	1382.5	5154.8	4850.9	0.744

Legends

GlobHor Global horizontal irradiation
DiffHor Horizontal diffuse irradiation
T_Amb Ambient Temperature
GlobInc Global incident in coll. plane
GlobEff Effective Global, corr. for IAM and shadings
EArray Effective energy at the output of the array
E_Grid Energy injected into grid
PR Performance Ratio

PVsyst V7.2.6
VC3, Simulation date:
10/06/22 18:15
with v7.2.6

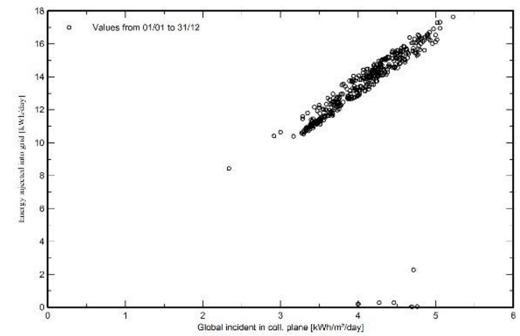
Loss diagram



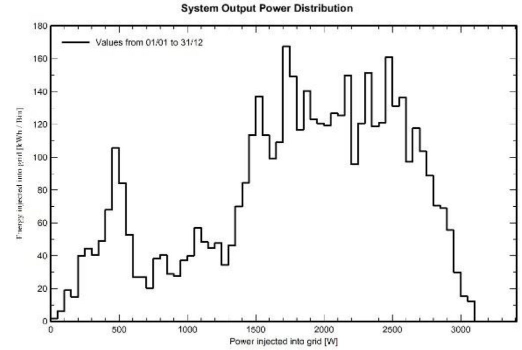
PVsyst V7.2.6
VC3, Simulation date:
10/06/22 18:15
with v7.2.6

Special graphs

Daily Input/Output diagram



System Output Power Distribution



Version 7.2.6

PVsyst - Simulation report

Grid-Connected System

Project: Green Experiment

Variant: Case 5- South-East

Building system

System power: 4400 Wp

Aqaba - Jordan

Maryam Khlof

Signature

Project summary

Geographical Site
Aqaba
Jordan

Situation

Latitude	29.57 °N
Longitude	35.00 °E
Altitude	30 m
Time zone	UTC+2

Project settings
Albedo 0.20

Meteo data
Aqaba
Meteonorm 8.0 (2006-2011), Sat=100% - Synthetic

System summary

Grid-Connected System

Building system

PV Field Orientation
Fixed plane
Tilt/Azimuth 90 / -45 °

Near Shadings
According to strings
Electrical effect 100 %

User's needs
Unlimited load (grid)

System information

PV Array

Nb. of modules	8 units
Pnom total	4400 Wp

Inverters

Nb. of units	1 Unit
Pnom total	4000 W
Pnom ratio	1.100

Results summary

Produced Energy	4907 kWh/year	Specific production	1115 kWh/kWp/year	Perf. Ratio PR	75.33 %

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PVsyst V7.2.6
VC4, Simulation date:
10/06/22 18:33
with v7.2.6

Project: Green Experiment
Variant: Case 5- South-East

General parameters

Grid-Connected System

Building system

PV Field Orientation

Orientation
Fixed plane
Tilt/Azimuth 90 / -45 °

Sheds configuration

Models used

Transposition	Perez
Diffuse	Perez, Meteonorm
Circumsolar	separate

Horizon
Free Horizon

Near Shadings
According to strings
Electrical effect 100 %

User's needs
Unlimited load (grid)

PV Array Characteristics

PV module

Manufacturer	Longi Solar
Model	LR5-72 HPH 550 M
(Original PVsyst database)	
Unit Nom. Power	550 Wp
Number of PV modules	8 units
Nominal (STC)	4400 Wp
Modules	2 Strings x 4 In series
At operating cond. (50°C)	
Pmpp	4021 Wp
U mpp	150 V
I mpp	27 A

Inverter

Manufacturer	ABB
Model	UNO-DM-4.0-TL-PLUS
(Original PVsyst database)	
Unit Nom. Power	4.00 kWac
Number of inverters	2 * MPPT 50% 1 unit
Total power	4.0 kWac
Operating voltage	90-580 V
Pnom ratio (DC:AC)	1.10

Total PV power

Nominal (STC)	4 kWp
Total	8 modules
Module area	20.4 m²
Cell area	18.5 m²

Total inverter power

Total power	4 kWac
Nb. of inverters	1 Unit
Pnom ratio	1.10

Array losses

Array Soiling Losses
Loss Fraction 3.0 %

Thermal Loss factor
Module temperature according to irradiance
Uc (const) 15.0 W/m²K
Uv (wind) 0.0 W/m²K/m/s

DC wiring losses
Global array res. 93 mΩ
Loss Fraction 1.5 % at STC

Serie Diode Loss
Voltage drop 0.7 V
Loss Fraction 0.4 % at STC

LID - Light Induced Degradation
Loss Fraction 2.0 %

Module Quality Loss
Loss Fraction -0.3 %

Module mismatch losses
Loss Fraction 2.0 % at MPP

Strings Mismatch loss
Loss Fraction 0.1 %

IAM loss factor
Incidence effect (IAM): User defined profile

0°	25°	45°	60°	65°	70°	75°	80°	90°
1.000	1.000	0.995	0.962	0.936	0.903	0.851	0.754	0.000

System losses

Unavailability of the system

Time fraction	2.0 %
	7.3 days,
	3 periods

AC wiring losses

Inv. output line up to injection point

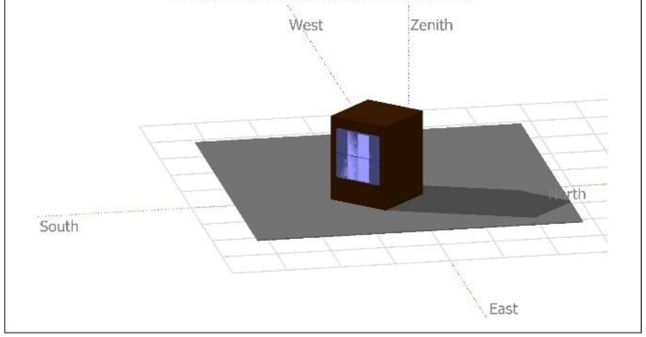
Inverter voltage	230 Vac mono
Loss Fraction	1.00 % at STC

Inverter: UNO-DM-4.0-TL-PLUS

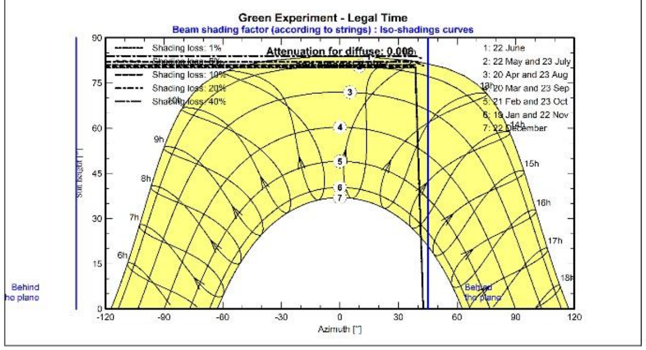
Wire section (1 Inv.)	Copper 1 x 2 x 3 mm²
Wires length	8 m

Near shadings parameter

Perspective of the PV-field and surrounding shading scene



Iso-shadings diagram



Project: Green Experiment
Variant: Case 5- South-East

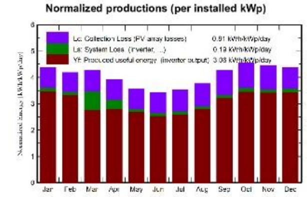
PVsyst V7.2.6
VC4, Simulation date:
10/06/22 18:33
with v7.2.6

Main results

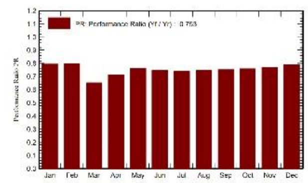
System Production

Produced Energy	4907 kWh/year	Specific production	1115 kWh/kWp/year
		Performance Ratio PR	75.33 %

Normalized productions (per installed kWp)



Performance Ratio PR



Balances and main results

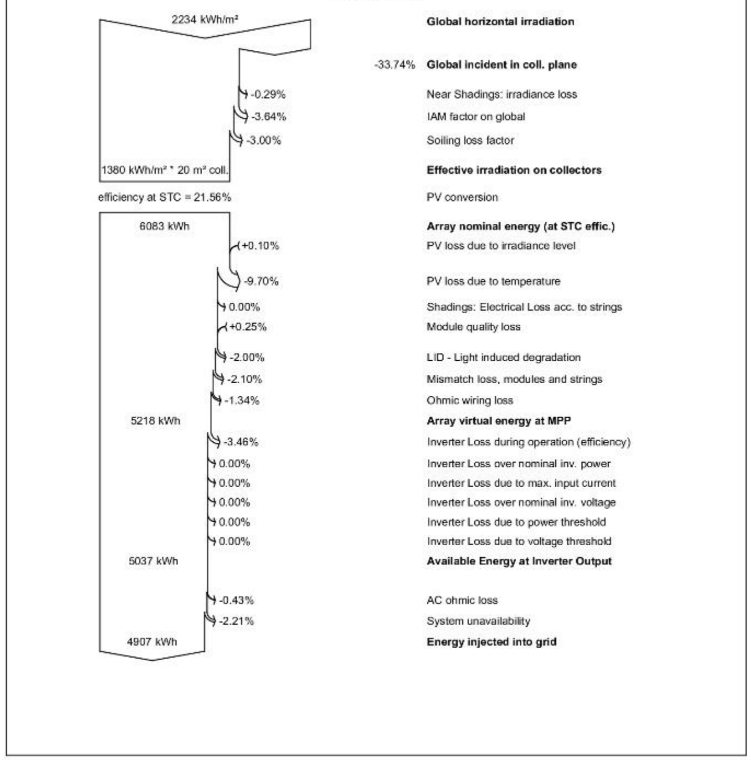
	GlobHor	DiffHor	T_Amb	GlobInc	GlobEff	EArray	E_Grid	PR
	kWh/m²	kWh/m²	°C	kWh/m²	kWh/m²	kWh	kWh	ratio
January	121.3	28.59	15.70	135.7	128.0	494.7	475.5	0.796
February	130.8	38.17	17.88	117.1	110.4	426.7	410.5	0.797
March	186.7	47.42	21.85	132.2	124.0	474.8	379.4	0.652
April	212.9	55.60	25.61	117.7	109.4	418.3	370.2	0.715
May	240.9	62.51	30.29	110.1	101.0	385.4	370.2	0.764
June	251.5	46.59	32.93	102.6	92.4	350.3	336.3	0.745
July	253.6	48.49	34.97	109.1	99.3	372.2	357.3	0.744
August	232.1	51.26	34.75	116.8	107.9	398.9	383.2	0.746
September	195.8	44.42	31.70	128.2	120.1	442.4	425.4	0.754
October	165.9	37.33	28.30	141.5	133.3	492.5	473.6	0.761
November	129.5	24.54	22.39	133.7	126.1	471.2	453.0	0.770
December	113.0	25.70	17.37	135.6	128.1	490.5	472.0	0.791
Year	2234.0	510.62	26.19	1480.3	1379.7	5218.1	4906.5	0.753

Legends

GlobHor	Global horizontal irradiation	EArray	Effective energy at the output of the array
DiffHor	Horizontal diffuse irradiation	E_Grid	Energy injected into grid
T_Amb	Ambient Temperature	PR	Performance Ratio
GlobInc	Global incident in coll. plane		
GlobEff	Effective Global, corr. for IAM and shadings		

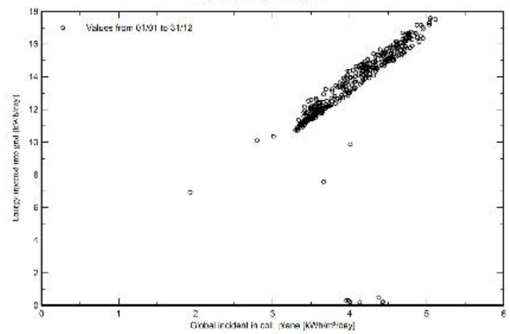
PVsyst V7.2.6
VC4, Simulation date:
10/06/22 18:33
with v7.2.6

Loss diagram

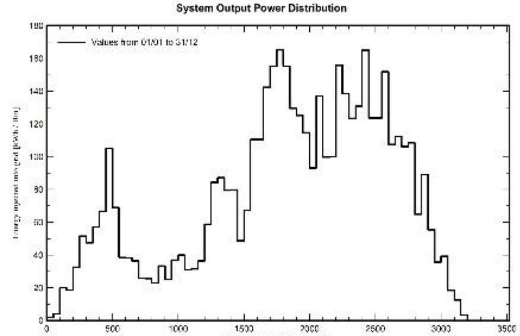


Special graphs

Daily Input/Output diagram



System Output Power Distribution



Appendix III

The Tried Plants Characteristics

The Tried Plants Characteristics (Picturethisai website, 2022)

Plant picture				
Common name	Allublab, English ivy	Common passion flower	Passion fruit	Railroad Vine Beach Morning Glory Goat's Foot Convolvulus
Botanical name	*Hedera Helix*	*Passiflora caerulea*	*Passiflora edulis*	*Ipomoea pes-caprae*
Plant family	Araliaceae	passifloraceae	passifloraceae	convolvulaceae
Description	Evergreen climbing, temperature-resistant, poisonous to humans and dense foliage plant.	Perennial lifespan, evergreen climbing and temperature-resistant plant.	Perennial life span, all year around bloom, 60-90 cm height, produce sweet edible fruit and temperature-resistant plant.	Perennial lifespan, all year around bloom 10 cm height, high temperature-resistant, high salt-resistant, high dense foliage, very fast growth and less maintenance plant.
Current status	Died	Died	Exists	Strongly exists

Appendix IV

Plant Growth Progress

Plant Growth Progress

The progress of plant growth is estimated as coverage ratio as shown below.

15.7.2021 28.7.2021 6.9.2021 22.9.2021 23.9.2021 10.10.202
18.11.2021

5% 2% 20% 35% 50% 77% 70%

4.12.2021 8.3.2022 12.4.2022 27.4.2022 8.6.2022 26.6.2022

84 % 75% 86% 90% 93% 100 %

المعلومات الشخصية

الاسم: مريم محمد الخلوف

التخصص: ماجستير الإدارة الهندسية

الكلية: الهندسة

سنة التخرج: 2022