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The Aesthetic Effect of Photovoltaic Cells on the Building Facades

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The Aesthetic Effect of Photovoltaic Cells on the Building Facades

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ABSTRACT

Technological advancement in building incorporated photovoltaic (BIPV) has transformed the façade of the building into a generator powered by renewable energy sources. The BIPV facades are designed to provide energy production alongside traditional design goals such as aesthetics art and environmental control. However, the problem is that architectural design goals sometimes conflict with energy performance such as visibility and daylight versus maximum power output. In this context, the use of renewable energy sources such as solar energy seems to be worthwhile as they are numerous and have enormous environmental and economic prospects. This study aims to provide a new entrance to building design by enhancing a façade with photovoltaic to form aesthetic appeal and construction by studying the current situation of energy consumption. This research will give access to afford sustainable planning decisions that the use of photovoltaic energy in building façades is architecturally feasible to give an elegant design that arises from engineering creativity, satisfies the requirements of efficiency and economy, and is also elegant. in addition to that using a photovoltaic system is the best decision for different building types to become more self-sufficient and, ecofriendly, decrease carbon footprint and reduce monthly electricity bills.

1. INTRODUCTION

Photovoltaics is a widely used technology that generates direct current (DC) power from sunlight. PV systems are made up of PV cells composed of a semiconductor material that are connected together to form a PV module or panel that may be installed on buildings or as a standalone system. PV may be installed on new or existing buildings in two ways: integrated or simply installed [1]. In the latter, we can refer to BIPV (building-applied photovoltaic), whereas BIPV refers to PV modules designed by a designer to replace (not cover) a conventional building element. This can be a roof, cladding on a façade, a shade feature, or a parapet. The main principle hidden beneath the term of BIPV is that solar systems may perform more architectural tasks in buildings than only energy production. Waterproofing and shading are only a couple of examples [16]. That is the most cost-effective and environmentally friendly strategy to maximize profits [13]. When PV systems are put on buildings, no additional land is required, and power is generated directly at the site of use. This will decrease public power network distribution and transmission losses. The potential for designers will be significantly greater if PV systems are appropriately installed and incorporated during the design process [6]. PV may be seen entirely as a construction material, with numerous technological and aesthetic options that contribute to the creation of energy-conscious and comfortable spaces. Because of the diversity now available on the market, the designer may select not only the power and typology of the cell, but also its size, colour, and transparency [8].

2. LITERATURE REVIEW

2.1 Photovoltaic Building Façade Types

The aesthetic aspect of building integration is more important to the architect than the physical integration. The ideal situation is for a system to be physically and aesthetically well-integrated. In actuality, many examples of physical integration show a lack of aesthetic integration. A visual analysis of solar systems in buildings demonstrates that just installing a well-designed system does not improve the look of a poorly built structure [17]. Unfortunately, building-integrated PV is less popular than one might assume. When speaking with architects and homeowners, it is common to hear that BIPV devices are just unsightly and prohibitively costly. On the other hand, to achieve quality in the process, various factors impact and steer PV integration [5]. When integrating these technologies into buildings, there are a number of architectural considerations that must be made. These considerations are critical for achieving high-quality architectural integration. For this, the essential features of construction, such as functional, structural, and formal characteristics, must be met [1].

To achieve quality in the process, various factors impact and steer PV integration. When integrating these technologies into buildings, there are a number of architectural considerations that must be made. These considerations are critical for achieving high-quality architectural integration [11]. For this, the essential features of construction, such as functional, structural, and formal characteristics, must be met. The result of their regulated and cohesive integration simultaneously under functional, constructive, and formal aesthetic points of view can therefore be termed as architectural integration quality of PVs and solar collectors [5].

1. ONYX SOLAR

Photovoltaic glass is increasingly being used in curtain walls in buildings. They enable building owners to produce energy from previously untapped portions of the structure [3]. Buildings take on the role of a genuine power plant, retaining their beauty, efficiency, and utility. For certain applications, both amorphous and crystalline Silicon glass may be utilized, and which one to employ depends on design choices, energy demands, and daylight circumstances. PV Glass for curtain walls is available without a frame and may be installed in any commercial system [14]. The glass contractor will handle the installation from a mechanical standpoint, and the electrical contractor will link the units. There are also several degrees of visible light transmittance to choose from. In a standard curtain wall system, semi-transparent PV Glass for view zones and entirely black glass for the spandrel can be combined. This method helps to maximize the elevation's energy production while keeping clear views. They collaborate with architects and design specialists to create photovoltaic glass designs. Our designs are adaptable to any project requirements, regardless of colour, transparency, form, or accumulation [4].

For façades, contemporary architecture is always on the lookout for new and energy-efficient materials [2]. Onyx Solar has built a photovoltaic ventilated façade that provides unquestionable beauty, exceptional thermal performance, and a new source of free, clean power, all inspired by architectural demands. The power generated by the system may either be put into the grid or consumed immediately after it is created

[7]. They can save up to 50% of a building's current energy usage because of the thermal barrier they generate. As a result, I.R.R. and payback time are unrivalled [4].

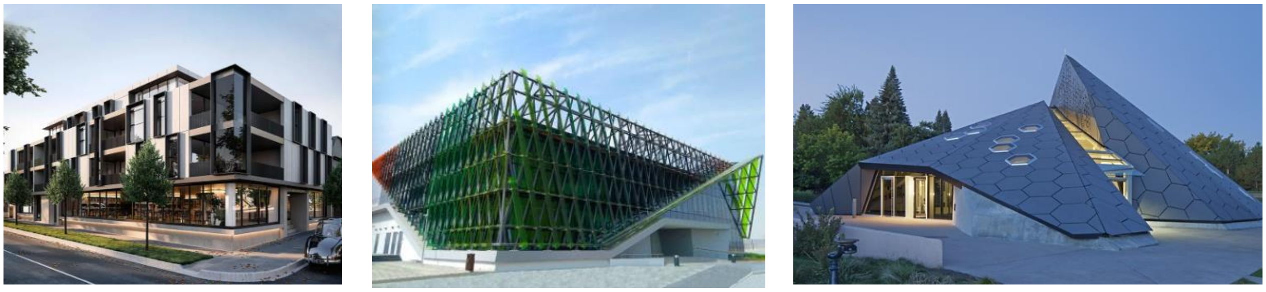


Figure (1) Onyx Solar Photovoltaic Building Facades

2. ERTEX SOLAR

Ertex solar is a versatile group of professionals with a combined 70 years of expertise in the glass industry. Their objective is to incorporate solar technology as seamlessly as possible into building architecture. They manufacture and market solar modules as well as customized, customer-specific solutions for integration into buildings as a full system. This process begins with design planning with architects and concludes with execution planning with top façade construction experts. Ertex solar has extensive expertise in the manufacturing and usage of semi-transparent solar modules as a result of various national and international initiatives in this sector [10]. Ertex solar provides customized solutions that integrate photovoltaic modules with aesthetic concerns. The solar modules may be made to clients' specifications, in various colors and degrees of transparency, and are of exceptional quality. They are one of the few providers that can display certificates in construction, electronics, and photovoltaic technology - two critical building blocks in constructing long-term reliable buildings. These certificates can be used for a variety of services and goods. They can choose from polycrystalline, monocrystalline, high-efficiency, and semi-transparent cells [2].

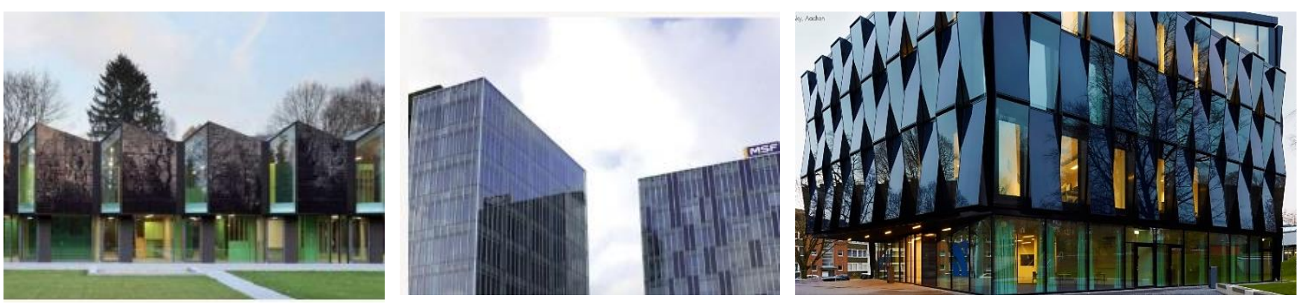


Figure (2) Ertex Solar Photovoltaic Building Facades

Design meets function for architect

Coloured versions can be added with the use of colored cells, colored films, colored glasses, or printed glasses. Semi-transparent solutions are created by varying cell spacing or using semi-transparent cells, resulting in a much more homogenous shadow picture. In projects, they may supply entire services such as laminated safety glass, insulating glass components, varied edge processing, and hole-drilling, depending on the application. Nobody in the world does large-scale projects better than Ertex Solar. In the realm of solar modules, 2440 x 5000 mm is a global record. Architect Hartmut Maurus said, “Ertex solar has further developed semi-transparent photovoltaic cells, making building-integrated photovoltaic cells even more architecturally attractive” [2].

3. SUNPOWER EQUINOX

SunPower Equinox Storage may be stored in a battery throughout the day. can use the solar energy stored in the storage battery to lower the amount of electricity used from the grid during pricey peak hours when utility rates are greatest. The system is supported by the first home solar warranty that covers the whole system rather than just the panels. They have coverage for the next 25 years, including performance, labor, and parts [15]. The SunPower Equinox System with Sun Vault Storage solution works hard to maximize solar utilization by collecting extra energy during the day and distributing it as needed to power key equipment during an outage, minimize dependency on grid electricity, and cut peak-time rates [4].

Figure (3) SunPower Equinox Photovoltaic Building Facades

4. KROMATIX

The application of highly efficient and environmentally friendly nanotechnology surface treatments optimized for solar energy to colour-treated glass for photovoltaic (PV) and thermal panel applications entails the application of highly efficient and environmentally friendly nanotechnology surface treatments optimized for solar energy to colour-treated glass for photovoltaic (PV) and thermal panel applications (photovoltaic and thermal) [9]. This means that our product does not include any paint or tint, instead of relying on atomic deposition to transform solar glass into color. Kromatix technology expands the scope of solar building integration by combining full architectural design flexibility and great panel aesthetics with optimum panel performance. Kromatix glass is utilized in the front glass layer of a solar panel and may be found in a variety of solar-powered items and technologies. Photovoltaic and thermal applications are presently the most popular facade applications. Kromatix glass comes in several sizes and thicknesses and may be bought separately or as part of a complete colored solar (PV or Thermal) panel. Kromatix currently comes in six colours: grey, blue, green, orange, bronze, and brass [4].

Kromatix solar panel performance

IFT Certified Kromatix Solar Glass is available in several colours. Because there are no paints or tints used to color the glass, it remains stable over time and sun exposure, and normal transmittance is between 85 and 90 percent colour dependent due to the unique Kromatix technology [18]. The coloured solar glass comes in a range of sizes and thicknesses and may be processed in the same way as conventional solar glass to meet the demands of the client. the Kromatix glass is made from a combination of two surface treatments: Low-pressure plasma procedures put a stratified coating on the inner glass surface. High solar transmittance, little absorption, and high durability are the only characteristics of its constituent materials, which also maximize high angular color stability. There are no pigments or dyes (paint) used, thus the color will not fade with time or exposure to the sun. Diffuse reflection is achieved by treating the outside glass surface as shown in figure (4). This reduces glare and enhances the masking effect of the solar device's technical components, resulting in improved aesthetics [4].

Figure (4) Kromatix Solar Photovoltaic Building Facades

5. MATRIX SOLAR

Solar panels that are visually beautiful and can be immediately incorporated into building facades have been created by Matrix Solar. Their ground-breaking building-integrated photovoltaic (BIPV) technologies enable architects, engineers, building owners, and investors to embrace and benefit from solar energy while maintaining aesthetics. Solar facades, glass, roofs, siding, greenhouses, railings, and other goods are available. Frameless modules, concealed installation, homogenous surfaces, and the appearance of any material or colour are all features of these systems [12].

Matrix solar facades layers

A layer of solar cells fastened with a changeable face is mounted on top, replicating any design or color while allowing for energy generation. These panels also provide heat resistance and noise reduction while maintaining durability and safety [3].

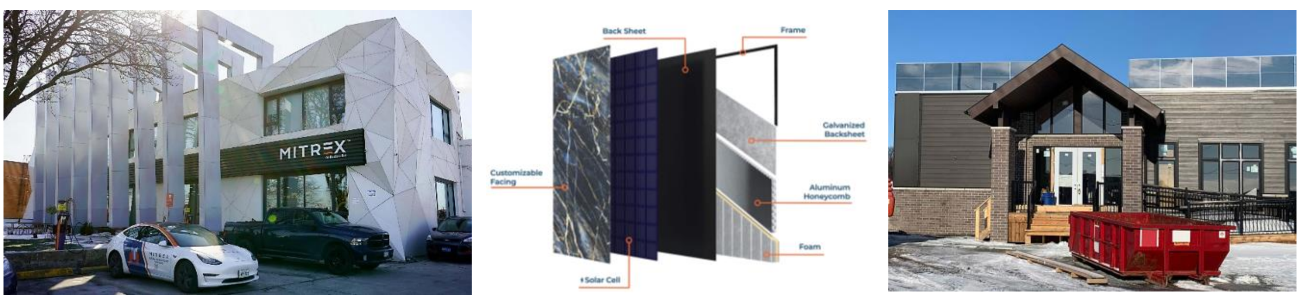


Figure (5) Mitrex Solar Photovoltaic Building Facades

2.2 Building Types

Buildings are classed according to different factors such as size, function, construction, style, design, and so on. The International Building Code (IBC 2018) and the Uniform Building Code (UBC), on the other hand, categorize structures based on use and occupancy. The IBC and UBC requirements are reasonable since they control structural design and construction, and each building reflects a particular amount of risk and neighbouring properties [19].

Building Types
RESIDENTIAL BUILDINGS
A structure with distinct houses where a person can live or stay regularly Each house has its kitchen and bathroom and may also be referred to as an apartment or a condominium [6].

EDUCATIONAL BUILDINGS

The Academic Building was built to hold educational activities such as classrooms, libraries, labs, and computer rooms, as well as administrative and service spaces required for academic and university extension programmers to run well. Preschool, Elementary, Middle, High School, College, University, and Technical are the most common [6].

COMMERCIAL BUILDINGS

Commercial Structures, A comprehensive listing of all notable Commercial Buildings Architecture from across the world. Commercial buildings are those that are utilized for business purposes, such as office buildings, shopping malls, and warehouses. Commercial buildings typically integrate many services, such as an office on floors 2-10 and shops on floors 1. All cities have strong commercial zoning rules. They can rezone any designated land as commercial. As a result, to operate a company, it must be located inside an area designated at least partially for commerce [6].

MIXED-USE BUILDINGS

A mixed-use building combines three or more functions into a single structure, such as residential, hotel, retail, parking, transit, cultural, and entertainment. Whatever the mix, it brings numerous uses together within a single structure or a limited space [6].

RELIGIOUS BUILDINGS

Temples, churches, mosques, and synagogues are used as places of worship as well as storage for the cult's images, relics, and sacred regions. The temple was not necessarily constructed for common usage in earlier faiths [6].

HEALTHCARE BUILDINGS

The term "health facility" refers to a location that provides medical services. Hospitals, clinics, outpatient care centres, and specialty care facilities like birthing centres and mental care centres are among them [6].

OFFICE BUILDINGS

Meeting spaces integrated into the office environment, reception, and office support spaces such as work rooms, storage rooms, file rooms, mail rooms, copier areas, service units/coffee bars, and coat storage integrated into the office environment are all examples of office space types [6].

3. METHOD

Due to the broader framework that depicts inductive approaches; an inductive and integrated approach was determined. This inductive approach appears relevant because theory arises from the exploration of data, of which most is quantitative. The main empirical study objective was a combination of exploratory research, as it intended to gain familiarity with the specific phenomenon of the feasibility of photovoltaic cells, and descriptive, in part, to portray the characteristics of the phenomenon. The data were analysed in qualitative analysis through a questionnaire. The questionnaire will be divided into two sections, the aim of each section is stated according to the literature review information. The answers were presented in graphical illustrations that present the answers rates. The questionnaire aims to find out the Various types of photovoltaics which can be integrated into aesthetic appeal in different types of buildings' facades. Response rate: The questionnaire was integrated among 45 participants. Chosen samples: Experts of professionals, architects, and urban designers as they are the most affected category by this conflict.

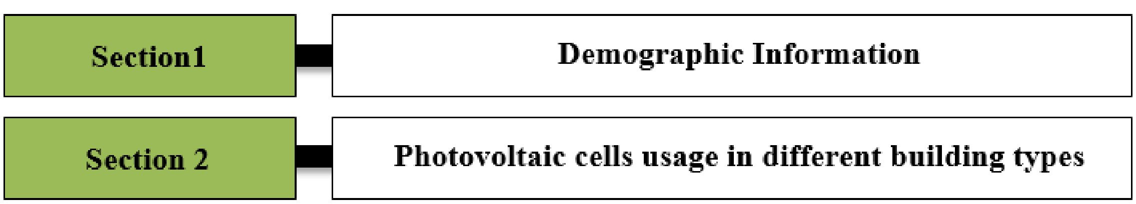


Figure (6) Research Methodology

Section (1): Demographic Information

The first section (Demographic Information) will be general information about the user that aims to guarantee the strength and reliability of the answers and responses. included participants' age (21-30, 31-50, above 50) and job specifications (Architect, urban designer, expert, and professional in the field)

Section (2): Photovoltaic cells usage in different building types
The second section (Photovoltaic cells usage in different building types) included questions asking about each photovoltaic type (Onyx solar, Ertex solar, SunPower equinox, kromatix, Matrix solar) and its relation to different building types (residential, educational, commercial, mixed-use, religious, healthcare, office).

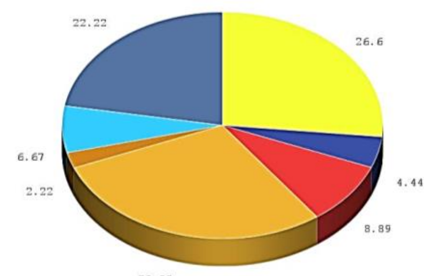
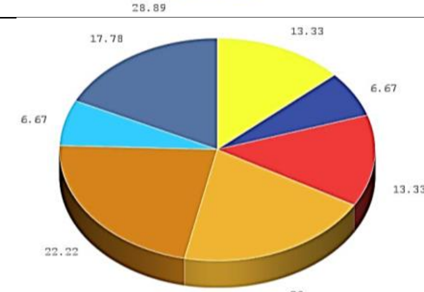
Table 1 – Photovoltaic cell façade types [7]

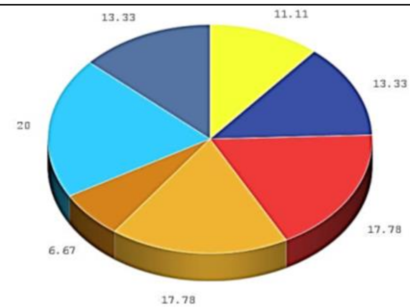
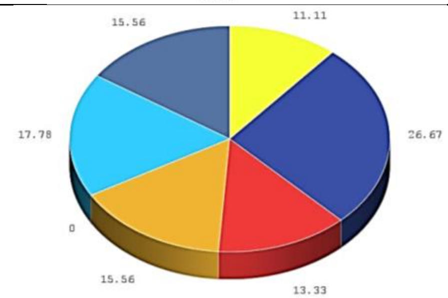
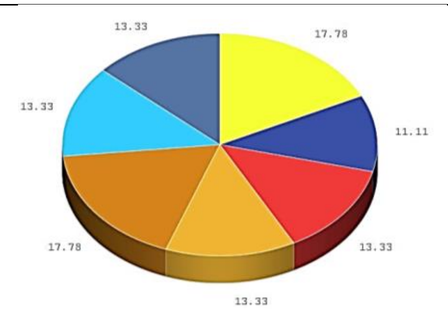
Photovoltaic cell façade types	Onyx solar
	Ertex solar
	Sunpower equinox
	Kromatix
	Matrix solar

Table 2 – Photovoltaic cells usage in different building types [7]

Photovoltaic cells usage in different building types	Residential Buildings
	Educational Buildings
	Commercial Buildings
	Mixed-use Buildings
	Religious Buildings
	Healthcare Buildings
	Office Buildings

4. RESULTS AND FINDINGS

Photovoltaic cell façade types	**Photovoltaic cells usage in different building types**							
	Residential Buildings	Educational Buildings	Commercial Buildings	Mixed-Use Buildings	Religious Buildings	Healthcare Buildings	Office Buildings	
Onyx solar	27 %	4.4 %	8.8 %	28.8 %	2.2 %	6.6 %	22.2 %	
Ertex solar	13..3 %	6.7 %	13.3 %	20 %	22.2 %	6.7 %	17.8 %	

	Sunpower equinox	11.11%	13.3%	17.8%	17.9%	6.6%	20%	13.3%	
	Kromatix	11.1%	26.7%	13.3%	15.6%	0%	17.7%	15.5%	
	Matrix solar	17.8%	11.1%	13.3%	13.3%	17..8%	13.3%	13.3%	

4.1 Onyx Solar Photovoltaic façade type

According to the photovoltaic cell façade types piechart analysis, 27% of the people that are part of the onyx solar chose Residential buildings, 4.4% Educational buildings,8.8% chose commercial buildings, 28.8% chose mixed-use buildings,2.2% chose religious buildings,6.6% chose use health care building and 22.2% chose office buildings.

4.2 Ertex Solar Photovoltaic façade type

According to the photovoltaic cell façade types piechart analysis, 13.3% of the people that are part of the Ertex solar chose Residential buildings, 6.7% Educational buildings,13.3% chose commercial buildings, 20% chose mixed-use buildings,22.2% chose religious buildings,6.7% chose use health care building and 17.8% chose office buildings.

4.3 Sunpower Equinox Photovoltaic façade type

According to the photovoltaic cell façade types piechart analysis, 11.1% of the people that are part of the onyx solar chose Residential buildings, 13.3% Educational buildings,17.8% chose commercial buildings, 17.9% chose mixed-use buildings,6.6% chose religious buildings,20% chose use health care building and 13.3% chose office buildings.

4.4 Kromatix Solar Photovoltaic façade type

According to the photovoltaic cell façade types piechart analysis, 11.1% of the people that are part of the kromatix solar chose Residential buildings, 26.7% chose educational buildings,13.3% chose commercial buildings, 15.6% chose mixed-use buildings,0% chose religious buildings,17.7% chose use health care building and 15.5% chose office buildings.

4.5 Matrix Solar Photovoltaic façade type

According to the photovoltaic cell façade types piechart analysis, 17.8% of the people that are part of the Matrix solar chose Residential buildings, 11.1% chose educational buildings,13.3% chose commercial buildings, 13.3% chose mixed-use buildings,17.8% chose religious buildings,13.3% chose use health care building and 13.3% chose office buildings.

5. DISCUSSION

As per the survey results, people have given their views on the recommended photovoltaic cell façade types (Onyx solar, Ertex solar, Sunpower equinox, Kromatix and Matrix solar) that will suit on different building types (Residential Buildings, Educational Buildings, Commercial Buildings, Mixed-Use Buildings, Religious Buildings, Healthcare Buildings, Office Buildings). Most of the people voted that Onyx solar are preferred to be used in Mixed-used building with only 2.2% votes on Religious buildings. Most of the people voted that Ertex solar are preferred to be used in Mixed-used building with only 6.6% votes on Healthcare & Educational buildings. Most of the people voted that SunPower equinox are preferred to be used in Healthcare building with only 11.11% votes on Residential buildings. Most of the people voted that Kromatix are preferred to be used in Educational building with only 0% votes on Religious buildings. Most of the people voted that Matrix solar are preferred to be used in Residential & Religious building with only 11.1% votes on Educational buildings. In summary, the most recommended photovoltaic cell façade as per the survey results in the residential buildings, mixed-used and office buildings is the Onyx solar, in the educational buildings is the Kromatix, in the commercial and healthcare buildings is the SunPower equinox, in the religious buildings is Ertex solar, residential buildings is Onyx solar.

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