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APPLICATION OF THE NEW TECHNOLOGIES TO IMPROVE THE ENERGY PERFORMANCE OF A CONTEMPORARY BUILDING

Economic Study for the Adaptation of the Photovoltaic-Glass Technology

to the Algerian Market.

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Dedicating this work for my brothers & sisters in Humanity that sacrifices for Peace & Empowerment Youth and Unfortunate Ones, to all that do action not just speeches, to all lovers of humanity together without borders.

This modest work is for all of you.

Abstract

In the frame of sustainable development searching for energy efficiency to reduce the environmental impact wither in cold or hot climate. Conducted us to search for new methods in contemporary construction to moderate our energy consumption with the same if not better performance. Using photovoltaic glass as an alternative for reducing both cost of implementing renewable energy source. Combining glass and solar panels as one product. Studying economic viability and how to master the project cost, to introduce this innovation successfully to the Algerian Market. Results shows that energy subvention is an unappealing for energy transmission at homes but profitable for large buildings.

Photovoltaic Glass, Energetic Efficiency, Renewable Future, Modern Construction Materials, Green Tech, Regenerating Architecture, Sustainable Development.

Résumé

Dans le cadre du développement durable et la recherche de l'efficacité énergétique pour réduire l'impact environnemental et conditions climatiques froides ou chaudes. Nous a conduit à la recherche de nouvelles méthodes de construction contemporaine pour modérer notre consommation d'énergie avec la même, voire une meilleure performance. Utiliser le verre photovoltaïque comme alternative pour réduire les coûts de mise en œuvre des sources d'énergie renouvelables. Combiner le verre et les panneaux solaires comme un seul produit. Étudier la viabilité économique et comment maîtriser le coût du projet, pour introduire cette innovation avec succès sur le marché algérien. Les résultats montrent que la subvention maitre peu attrayantes la transition énergétique dans les maisons, mais rentables pour les grands bâtiments.

Verre Photovoltaïque, Efficacité Energétique, Future Renouvelable, Matériaux de Construction Modern, Architecture Régénérante, Tech Verte, Développement Durable.

ملخص

في إطار التنمية المستدامة، والبحث عن الكفاءة الطاقوية للحد من الأثر البيئي سواء في المناخ البارد أو الحار. دفعنا إلى البحث عن طرق جديدة في البناء المعاصر لتعديل استهلاكنا للطاقة بنفس الوتيرة إن لم يكن بأداءً أفضل. باستخدام الزجاج الكهروضوئي كبديل لخفض تكلفة التغذية من مصادر للطاقة المتجددة. الجمع بين الزجاج والألواح الشمسية في منتج واحد، بالإضافة إلى دراسة الجدوى الاقتصادية وكيفية الحوكمة في تسيير المشروع للتحكم في تكلفته، من أجل تقديم هذا الابتكار بنجاح إلى السوق الجزائرية. في حين دعم الطاقة يشكل عقبة بالنسبة للتحول الطاقوي في المنازل ولكن مربح بالنسبة للبنايات الكبيرة.

الزجاج الكهروضوئي، الكفاءة الطاقوية، المستقبل المتجدد، مواد البناء الحديثة، التكنولوجيا الخضراء، الهندسة المعمارية المتجددة، التنمية المستدامة.

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I-Chapter 01: Introduction

1.1 General Introduction

Using technology to upgrade construction materials, invention where restored to surface and innovation being adapted to the market. Controlling the price which caused the reduction of technology cost, that make it accessible to a large party of population. Simplifying the implementation of these technologies even manually by simple individuals. Regulations and laws to control energy-intensive-consumption equipments and incite people toward more energy efficient life. In the frame of sustainable development the search for efficiency in the energy use and reducing the environmental impact weather in cold or hot weather, conducted us to search for other resources or methods in contemporary construction to moderate our energy consumption with the same if not better performance.

1.2 Problematic

And to achieve that we are going through the discovery of new technologies to improve the energy performance in contemporary building. We chosen one of the latest developed in the last decade and it's the *Photovoltaic Glass*. Since its new let's discover together its capabilities, and study the possibility to implement it in the Algerian market. This leads us to ask the following question in the problematic:

Could the Photovoltaic Glass be suitable for the Algerian market with the exiting energy price?

1.3 Research Objective

Choosing this topic for research didn't come hazardous, but having personal involvement and progressive experiences cumulated during the past four years. Being a professional representative since 2019 of such promising renewable technologies. The challenge where to introduce this innovation in the Algerian market. Both with driven motivation to discover empirically that photovoltaic glass could be one of the best alternatives. To reduce not just consumption, but cost of renewable energy for Algerian families and companies willing to foster a Green Image, showing the support for the United Nations Sustainable Development Goals.

1.4 The Structure of the Thesis

Using "IMRaD" format our research structured by four main section: Introduction, Methods, Results, and Discussion ("The Writing Center | Writing a Scientific Research Report (IMRaD) | Guides,").

Splitting the writing process to four (4) principal chapters:

- ***Introductory Chapter:*** General preamble of the topic, including problematic and research question, objective and why choosing this topic; and before starting theoretical chapter a brief explanation of the thesis structure and methodology of research;
- ***Second chapter:*** includes literature review to simplify to the reader the knowledge building process following by theoretical framework to introduce photovoltaic system components and the potentiality of the Algerian solar power; also, discussing of a new PV Sizing method called '*Schmid's Formula*' for solar systems due to its relevance to our study;
- ***Third chapter:*** is for the implementation to get accurate results and discuss the return on investments, leaving space for future development by mentioning the latest technological advancements and further researches on the field;
- ***Conclusion chapter:*** concluded the research by summarizing what been made and the obtained results.

1.5 Methodology of Research

Why choosing this research: This research of exploratory nature, to introduce more accurate empiric results to foster a realistic view on the subject. To complete the gap introducing the economic aspect, neglected by theatricals researches in architecture field at university. For that reason chosen to calculate the project cost, time for return on investment, and the possibility of marketing photovoltaic glass in the Algerian market. Adding value couldn't be achieved without previous field experience and studying management & entrepreneurship that really helped me throughout this research.

Writing process:

Following the process guideline in my writing approach:

Figure 01: Writing process guideline (Effective Business Writing, Quantic School for Business & Technology, 2022)

Citations & Questions: Using Harvard School brainstorming approach and citation method (Gregersen, 2018) .

Writing method: (“Madman, Architect, Carpenter, Judge: Roles and the Writing Process on JSTOR,”)

Madman: “gathers information and generates ideas, and from *Quantic School* online course: advised to “find what interests you in the topic, the question or emotion that it raises in you” (Effective Business Writing, Quantic School, 2022).

The Architect: “select large chunks of material and to arrange them in a pattern that might form an argument” and “doesn’t worry about sentence structure. “

“The sentence structure is left for the 'carpenter' ”who“nails these ideas together in a logical sequence”.

“The judge comes around to inspect. Punctuation, spelling, grammar, and tone-all the details which result in a polished essay become important only in this last stage. These details are not the concern of the madman, who’s come up with them, or the architect who’s organized them, or the carpenter who’s nailed the ideas together, sentence by sentence. Save details for the judge.” (S. Flowers, 1981).

II-Chapter 02: Theoretical Framework

& Literature Review

2.1 Literature Review

This interesting research started with a motivating TEDx Talks presentation by *Professor Vladimir Bulovic*in. In charge of Emerging Technology at Massachusetts Institute of Technology *(MIT)* University. Who illustrated that collecting one hour from the total sun radiation of 174.000 Tera Watt/second could provide one year of energy to earth, in fact humanity needs just 19 TW. Brief introduction to where solar technology reached today, *Pr. Vladimir Bulvic* illustrated that installation cost for the frame supporting the PV system and labor is two-third (2/3) of the solar system cost, which is higher than the technology itself. With technological advancements the existing tech is more light, thin and easy to install by simple individuals without special training. Technologies like Thin-film solar panels and Perovskite solar modules show that the future is prompting toward switching our energy source to be more renewable, efficient and transparent. Using solar power transparently which can be unnoticed by human eye is actually possible and it's coming in the near future (*The case for a new type of solar technology | Vladimir Bulovic | TEDxBoston*, 2022)**.** Another promising news article from Sky New Arabia, promoting a youth Egyptian researcher *Mahmoud El DAMASSI* who participated in the inauguration of a scientific database (HZB, 2021) at *(Helmholtz-Zentrum Berlin für Materialien und Energie, 2021)* for renewable energies especially solar cells using the recent technology of Perovskite (Stannowski, 2022); even its photovoltaic characteristic where discovered in the middle of the last century, but it's first application was in 2009 to exceed the performance other existing technologies. The unique about this technology is that you can redesign its chemical composition for more performance, print it on glass or plastic. There is still some work to do to upgrade its lifetime, which is 5 years comparing to silicon cells with 20 years. Such data-base and with the use of machine learning and big data analysis could reduce processing time. Connecting dots, and extracting useful information to design new patterns for future technologies development (Sky News Arabia, Ęlmayany, 2021).

Other information will be collected from Scientific Authors, Research facilities, local and International organization, using Books, Researches and white papers…etc. Collecting series of information in a progressive manner, toward more comprehensive and simplified research.

2.2 Viability of PV Glass System Technology

To assess the viability of PV glass systems, the launch of a series of tests by the manufacturing companies in the last decade 2010-2020, where the tests made to show not just that the technology is viable, but also strength and durability.

2.2.1 Impact Tests : We can find the tests for PV Glass for the Spain manufacturer (Onyx Solar, 2017) following their shared video *"The impact resistance test is done by throwing a bag of 46 kg from 1.2 meters and the hard body drop test consists of dropping a 1 kg metallic ball."*[1]

2.2.2 Reliability: Whereas for reliability matter is related to two factors:

i. *"The solar array needs the use of an optimum load to deliver maximum power."* To achieve that you need abundance in the irradiation of the sun, adequate temperature and batteries performance what make it hard to achieve ;

ii. Also the capacity of the photovoltaic system to keep functioning smoothly without interruption for the minimum given life time for the site functioning conditions.(Kaushika et al., 2018, p. 127)

For that when we look for performance we can find it's related to the availability and efficiency of the used equipments during the year and it's expressed by the following formula:

$$A = \frac{\text{MTBF}}{\text{MTTR} + \text{MTBF}}$$

Equation 01: Availability & efficiency

Where:
A = Availability,
MTTR = mean time to repair and,
MTBF = mean time between failure (Kaushika et al., 2018, p. 127).

And for the part of economic viability will be the essence of this research where we will try to evaluate prices for integrating PV glass technology and return on investment. Whereas next we will discover the international actors and initiatives for sustainability and renewable future.

[1] Impact test shared by manufacturer on their official social media page (https://www.facebook.com/watch/?v=397168954428095) Consulted on 17/07/2022

2.3 International Organizations & Initiatives

There was an awaking alert about the human footprint on earth and the negative impact on nature. That moved activist and organizations toward gathering efforts toward a better future delivering earth to future generation preserving its resources and reducing these harmful impacts. Coming next we will introduce some of these organizations and discuss their initiatives.

2.3.1 United Nations Sustainable Development Goals

2.3.1.1 The emergence of UN SDG's

The United Nations sustainable development goals also known in the abbreviation of UN-SDG's. Understanding from where this objectives comes from, we should take a look at the "Brutland report" of the World Commission on Environment and Development titled: "Our Common Future" and defined the concept as following: "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." (World Commission on Environment and Development, 1987) the aim of this commission is to design a plan to reach the end of the 21th century with better sustainability solutions that affects positively our human life (Brundtland, 1987).

2.3.1.2 Definition

A developed definition to illustrate the newly emerged concept of the sustainable development at that time, offered by the Swiss 'Monitoring of Sustainable Development Project' MONET (BFS, BUWAL & ARE 2001):

"*Sustainable development means ensuring dignified living conditions with regard to human rights by creating and maintaining the widest possible range of options for freely defining life plans. The principle of fairness among and between present and future generations should be taken into account in the use of environmental, economic and social resources. Putting these needs into practice entails comprehensive protection of bio-diversity in terms of ecosystem, species and genetic diversity, all of which are the vital foundations of life."* (Marco, 2005).

2.3.1.3 The Millennium Goals

The entrance of the third millennium marked with the first specified sustainable development goals with eight (8) objectives focusing on the eradication of extreme poverty and hunger, achieving universal primary education, empowering women, reducing child mortality, improve maternal health, combat fatal diseases, ensure environmental sustainability and to ensure that these can be achieved successfully it must be a collaborative work for development (Martin, 2015):

Figure 02: The millinium development goals (IISD.org)[2]

[2] Source : (https://www.iisd.org/articles/deep-dive/what-world-learned-setting-development-goals)

2.3.1.4 Envision 2030

Nowadays continue developing objectives dealing with the issues that humanity faces. For that envisaging another fifteen (15) years of collaborative work. Under the new adapted seventeen (17) objectives UNSDG's 2015-2030 ("#Envision2030: 17 goals to transform the world for persons with disabilities | United Nations Enable," 2015).

In the next figure showing the complete seventeen (17) UN SDG's[3] :

Figure 03: Sustainable Development Goals 2015-2030 (Un.org)

A reporting system made it possible to track the progress made toward achieving these goals can be found on the Sustainable Development Report website[4].

Next we will try to demonstrate these objectives relevancy to our research and which of them is influenced by our research.

[3] For more details please visit : (https://sdgs.un.org/goals)
[4] Sustainable development report website : (https://dashboards.sdgindex.org)

3. Good health & Well Being

•Users of PV glass will be protected from intolerable solar radiations, Ultraviolet (UV) or Infrared (IR),

4. Quality Education

•This research mint to explore & demonstrate the latest existing technologies,

7. Affordable & Clean Energy

•PV energy is getting more affordable by time,

8. Decent work & Economic Growth

•The field of renewable energies is under content developement attracting more competencies and experienced persons which allows them to have better condition and more chance for career evolution,

9. Industry, Innovation & Infrastructure

•The field of Renewable energies is knowing a high innovation rate in the recent years and more solution are introduced each year,

11. Sustainable Cities & Communities

•Intelligent cities and the way how we treat our cities will be upgraded progressively,

12. Responsible Consumption & Production

•On-grid system which will make our cities more collaborative, efficient and notorious toward energy consumption,

13. Climate Action

•Our research can be considered a call for action, investments and change toward more responsible community,

15. Life on Land

•Preserving life on land, where the PV glass will reduce the necessity for land for PV panels that will be integrated directly to the building's facade,

16. Peace, Justice and Strong Institutions

•Peace with ourselves by choosing the right options for humanity to live in peace and justice,

17. Partnership's for the Goals

•One hand can't clap, the fruitful collaboration is the right solution for reaching these goals.

Figure 04: UN SDG's influenced by our research - Author

2.3.1.5 Sustainability in Architecture & Environment

After knowing which of the UN goals impacted by our research, a brief resume where we will figure the intersection of the history of sustainability in green architecture and sustainable development goals. Introducing a figure highlighting the important dates which defined our contemporary architecture adopted from (Attia, 2018) by (Mouloudj and FETNI, 2021).

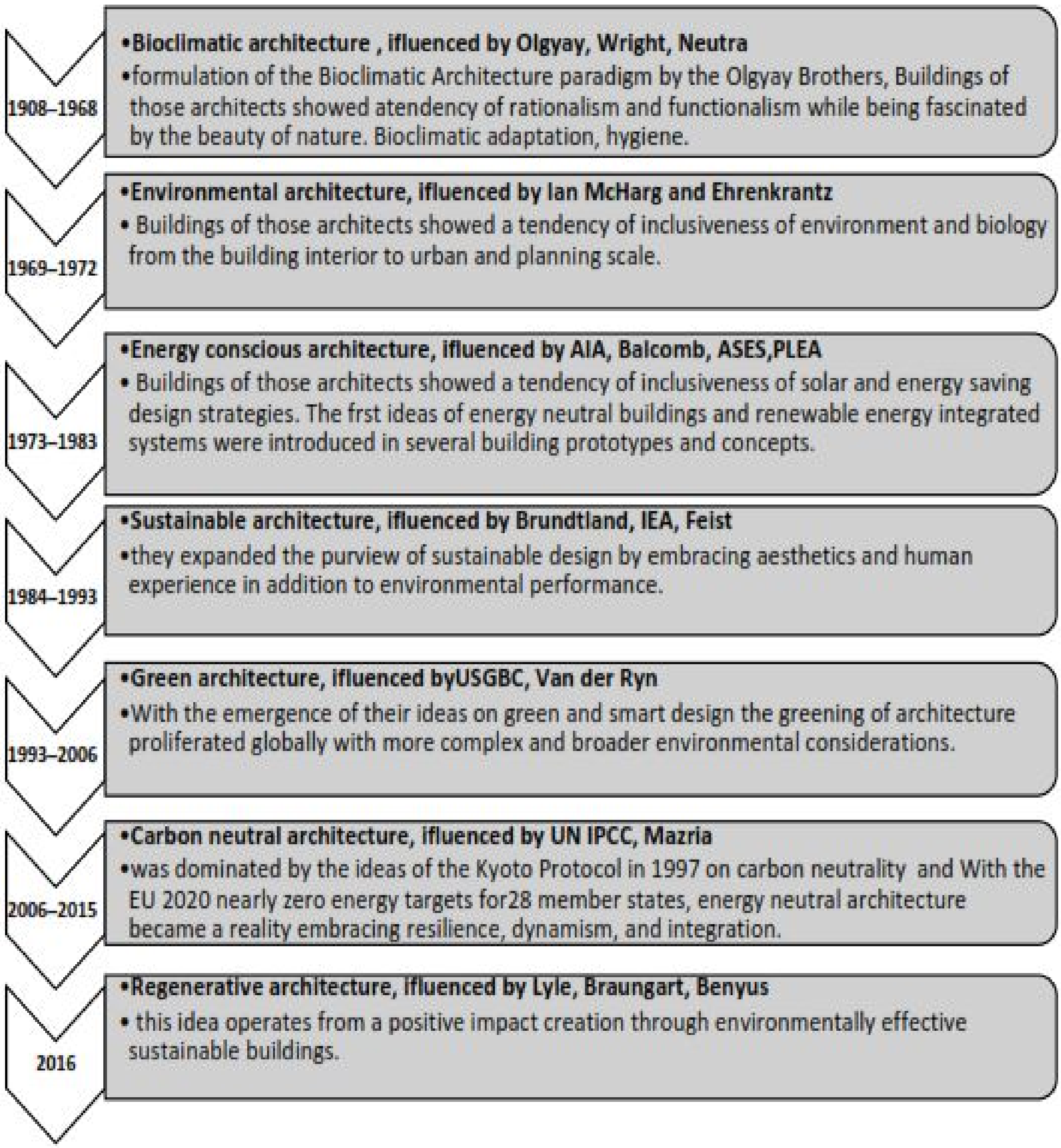

Figure 05: Outline of sustainable architecture history / Source: (Mouloudj & Fetni, 2021) adapted from (Attia, 2018)

2.3.1.6 UNEP/MAP, United Nations Environment Program Mediterranean Action Plan, (Barcelona Convention, Turkey 2021)

With the implication of the twenty-one (21) countries of the Mediterranean Sea, The Mediterranean Action Plan (MAP) following Barcelona Convention System working on with involved collaborators toward a clean environment and sea. Made a footprint for other Sea's actions under United Nations sustainable development program. Their latest meeting where held in COP 22 at Antalya, Turkey ("Home | UNEPMAP," 2022).

Figure 6: Visual Identity of UN Environnent Program & MAP

Barcelona Convention (UNEP.org)

2.3.2 The Worldwide Fund for Nature

As the world's leading conservation organization with sixty -60) years of existence, acting in nearly 100 countries to address the most pressing issues at the intersection of nature, people, and climate. Working with local communities to protect the natural resources to create a future in which both people and nature thrive. Transforming markets and policies toward sustainability, address the threats driving the climate crisis, and protect and restore wildlife and their habitats in collaboration with partners at all levels.

Figure 07: The Worldwid Fund for Nature (worldwildlife.org)

2.3.3 ISO: International Organization for Standardization

Founded in London, in 1947. ISO is an independent, non-governmental international organization based in Geneva, Switzerland. Accounting of 167 members regarded as national standards bodies[5].

Figure 08: Logo ISO (ISO.org)

Working on developing and sharing international standards and knowledge by coordinating with experts to develop voluntary, consensus-based standards to facilitate innovation and embrace solutions to the challenges in the world (“ISO - About us,” 2022).

2.3.3.1 ISO 26000 Social responsibility

Launched in 2010, the social responsibility by ISO, is a non-certified standard, counting on the voluntary engagement of organizations willing to commit to a more ethical and moral standard. Respecting society and environment with best responsible practices. Based on seven (7) core subjects clearly demonstrated below (ISO, 2010):

Figure 09: Social Responsibility 7 core subjects (ISO, 2010)

[5] ISO members by countries and their contribution (https://www.iso.org/members.html)

2.3.3.2 ISO 5001 Energy Management

Nowadays it's Important to preserve resources for every industrial organization, especially with past and current factual situation of the market during conflicts. ISO had developed over the past decade standards for energy efficiency management, besides dealing with the organization impact on different stockholders ("ISO - ISO 50001 — Energy management," 2021), Consistent of three norms as following:

- ***ISO 50001:2018 Energy Management Systems,*** a complementary management system for ISO 9001 and ISO 14001 for quality management and environment;
- ***ISO 50002: 2014 Energy Audits***, for auditors and developed first by ISO;
- ***50003: 2021 Energy Management Systems,*** for certification & audit bodies.

➢ During our research and consulting the ISO website we found that the pre-mentioned standards are withdrawn, and we don't know exactly why!? You can check this from the link below[6].

2.3.4 Human Footprint Initiative

How many earths do we need if we continue to live the way we are doing now!?

It's the basic question behind the initiative of Human footprint on earth. Operating through the *Global Footprint Network,* founded in 2003 an international nonprofit organization. "*Envisions a future where all can thrive within the means of our one planet.*" Their mission consists of making ecological matters being considered in the decision-making process (Global Footprint Network, 2003).

Global Footprint Network
Advancing the Science of Sustainability

Figure 10: Emblem of Global footprint Network (footprintnetwork.org)

[6] ISO withdrawn energy management standards (https://www.iso.org/committee/6077221/x/catalogue/p/0/u/0/w/1/d/0)

The footprint explained by Tim De Chant in 2012 by the following graphic art. And the idea is simply by asking the question: How much area will be needed for seven (7) billion people at that time to live similar to some countries? Starting from more efficient living like Bangladesh where earth could resist more population or more excessive way of living like the United States or Emirates (Wackernagel et al., 2006).

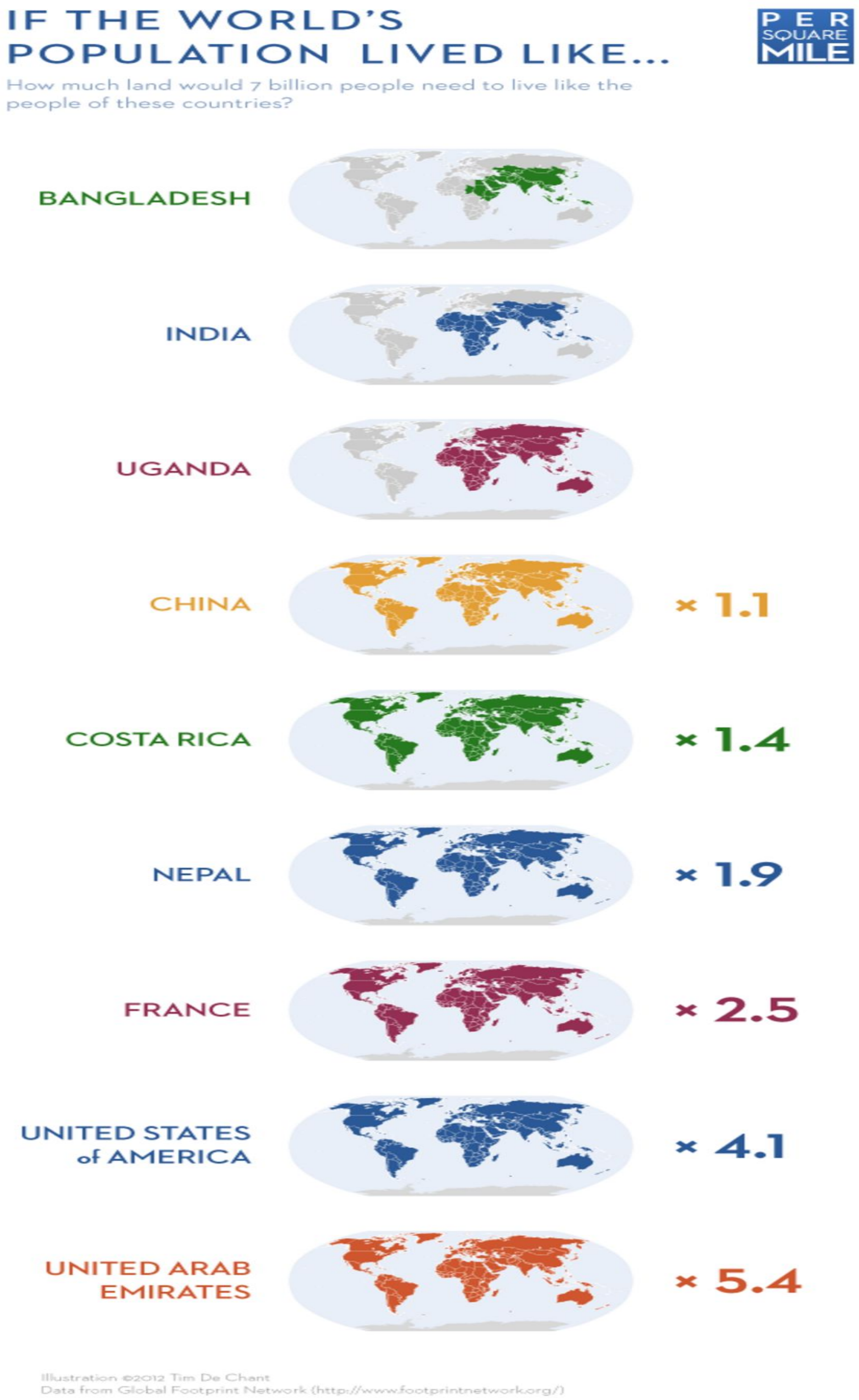

Figure 11: How many Earths do we need! (Tim De Chant, 2012)

In the human footprint Initiative we can find countries consumption of resources exceeding what can be provided. When if all humanity reach the same resources exhaustion, it will be difficult to supply enough without harming nature. For more demonstration the global footprint network website provided tangible data about earth situation for each country[7]. Another innovative tool-metter where you can measure your personal footprint using the "*footprint calculator*[8]" by accessing the link below (GFN, 2022a). Whereas in another map retrieved from *Wildlife Conservation Society* we can see the human influence on nature in red, and in green are inhabited lands or desert with less influence. The map is under the wild project second version 2005 in collaboration with Columbia University, USA in an interactive illustration[9] (Human footprrint, WCS.org, 2021 Accessed in 24/07/2022).

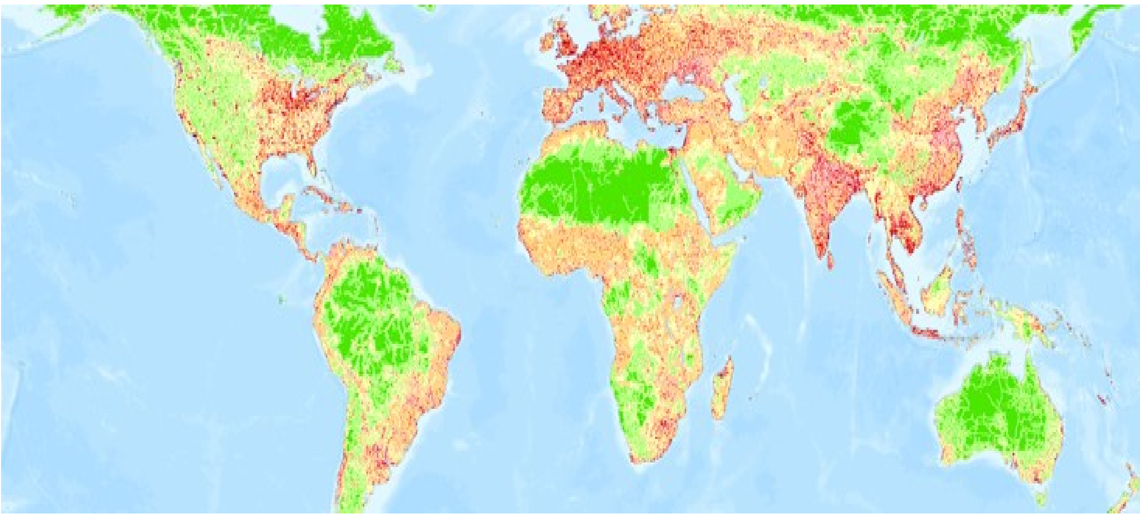

Figure 12: Human footprint map (ci.wcs.org)

Finally, *the earth overshot day*[10] which means the day where humanity consume the amount of biological resource needed to be regenerated for one year from earth, and from that point starts to consume more. This year earth overshot is 28th of July 2022. And we need 1.75 earths if we continue this way (GFN, 2022b).

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[7] Footprint data (https://data.footprintnetwork.org), accessed in 24/07/2022

[8] Personal footprint calculator: (https://www.footprintcalculator.org/home/en), accessed in 24/07/2022

[9] Wild Project, Version 2, 2005 (LWP-2) accessed in 24/07/2022 (https://sedac.ciesin.columbia.edu/data/set/wildareas-v2-human-footprint-geographic),

[10] Earth overshot day (https://www.overshootday.org) accessed in 24/07/2022

2.3.5 GRI: Global Reporting Initiative

GRI[11] is a standardization and reporting entity that help spreading the optimum reporting practices, to incite the organization for more transparency toward environment, economy and people ("GRI - Homepage," 2022).

2.3.6 ILO: International Labor Organization

An agency of the U.N since 1919 with particularity of gathering the three parties including *governments, employers and employees* from 187 member nations, setting standards, upgrade policies to support better working conditions for all collaborators (About ILO.org, Accessed 24/07/2022).

Figure 13: ILO Logo (Ilo.org)

2.3.7 Impaakt

A fresh Rating instrument for investors to chose wisely where to invest their money, within companies with positive rating indicating their positive impact on earth and like the organization would be accountable, and best of them gets more capitals to prosper ("Impaakt," 2022).

Figure 14: Impaakt Digital appearance (Impaakt.com)

Table 01: Companies detailed score (impaakt.com, 2022)

COMPANY	IMPACT SCORE	INDUSTRY	LISTING COUNTRY
Etsy	+1.98	E-Commerce	US - United States
Verisign	+1.85	Software & IT Services	US - United States
Banco Sabadell	+1.84	Commercial Banks	ES - Spain

[11] Global Reporting Initiative (https://www.globalreporting.org) accessed in 24/07/2022

2.3.8 Green Peace

Greenpeace is an independent organization started from a journey to stop a nuclear bomb testing by the US government in the arctic back to 1971. Consists of 26 national and regional organizations in more than fifty-five (55) countries. They made a strong statement: "*Greenpeace uses non-violent creative action to pave the way towards a greener, more peaceful world, and to confront the systems that threaten our environment.*" Seeking for quality living, more social and secure life, organic food, fresh air and clean energy (Greenpeace.org, Accessed in 24/07/2022).

Figure 15: Greenpeace Logo Arabic (Greenpeace.org)

2.3.9 Ummah for Earth

Is an initiative developed by Greenpeace Middle East and Africa, using a chart representing the culture of the region. Resilient for more opportunities to contribute for clean, green and peaceful earth. And you can join the movement by creative way by signing to regional organization for Middle-East, the online pledge and sharing the word (Home page, Ummah for Earth, n.d. Accessed 26/07/2022).

Figure 16: Ummah for embleme (ummah4earth.org)

2.3.10 The International Renewable Energy Agency (IRENA)

IRENA is an intergovernmental organization for international cooperation that promotes the energetic transition, widespread adoption and sustainable use of all forms of renewable energy, including bio-energy, geothermal, hydropower, ocean, solar and wind energy. With a mandate from countries around the world, IRENA encourages governments to adopt enabling policies for renewable energy investments, provides practical tools and policy advice to accelerate renewable energy deployment, and facilitates knowledge sharing and technology transfer. Publishing annual reviews of renewable energy (Home page, IRENA, Accessed 27/07/2022).

Figure 17: IRENA logo (IRENA.org)

2.3.11 The Organisation for Economic Co-operation and Development (OECD)

For cooperation and collaboration we could take the example of *The Organisation for Economic Co-operation and Development (OECD).* As an international organization with expertise's of sixty (60) years, generating policies with the best impact on human lives. Collaborating with governments, policymakers, and individuals to develop evidence-based global standards, tackling social, economical and environmental matters ("About the OECD - OECD," n.d. Accessed 27/07/2022).

Figure 18: OECD Embleme (OECD.org)

2.3.12 Foresight on Humanity Development & Cooperation

Showing all these initiatives was intended to demonstrate that there are accounts-less efforts everyday toward building peace, preserving environment and bringing prosperity to every individual in our societies. Dialogue is one important element to reach humanity goals and the picture titled: "*The future is shaped in the present through dialogue*" explain it well (oecd-opsi.org, 2016). Heading to the Middle East with Ummah for Earth we came closer to Algeria, where our next part starts with the discovery of the solar potentiality, and efforts made to build a resilient sustainable economy independent from fissile-fuel.

Figure 19: Dialogue for the Future (oecd-opsi.org, 2016)

2.4 Solar Energy and Solar Radiation

The earth receives solar energy in the form of solar radiation. This radiation consists of ultraviolet, rays visible and infrared. The amount of solar radiation that reaches a given location depends on a number of factors such as geographic location, time of day, season, terrain extent and local weather conditions (NAIL Raouhi, 2020).

2.4.1 Solar Radiation

Is divided into three components:

- ***Direct radiation*** received from the sun without being diffused through the atmosphere.
- ***Diffuse radiation*** from the sun after its direction has been modified by the diffusion of the atmosphere.
- ***Total solar radiation (global radiation)*** this is the sum of direct and diffuse solar radiation on a surface (Appelbaum, 1986). Explained in the figure below how radiation are distributed on earth (Palmer, 2015).

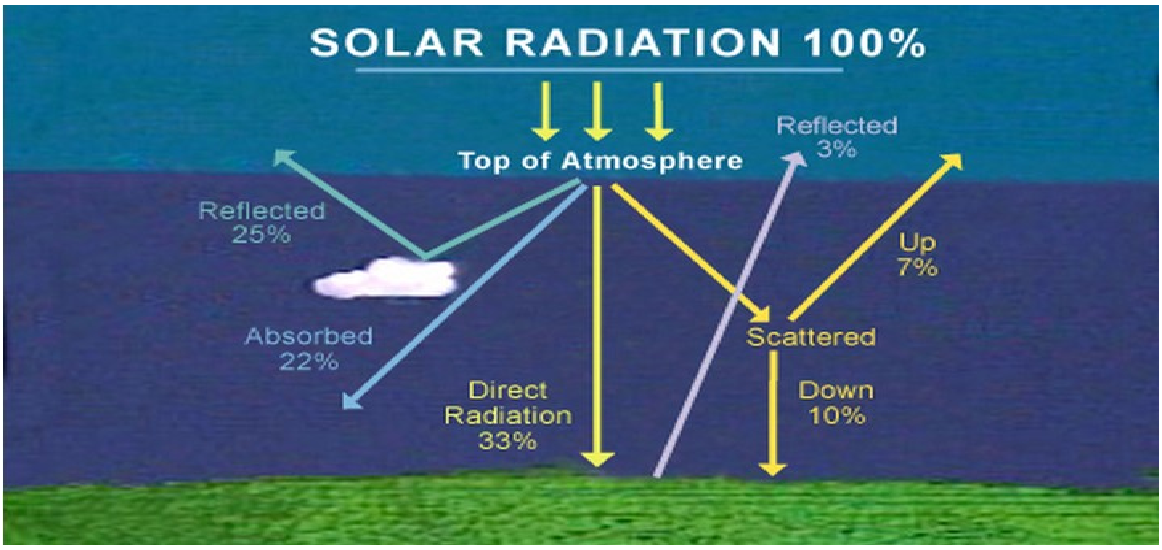


Figure 20: Solar Radiation Distribution (Palmer, 2015)

2.4.2 Distribution of Solar Radiation on the Planet's Surface

It is well known that solar radiation is unevenly dispersed on the Earth's surface, and that its concentration differs from one geographical location to another, depending on latitude, time of year and time of day. For the sake of maximum convenience and simplicity, the diffusion of the total amount of solar radiation in different geographical areas worldwide can be described from the point of view of its concentration in horizontal global solar irradiation (NAIL Raouhi, 2020).

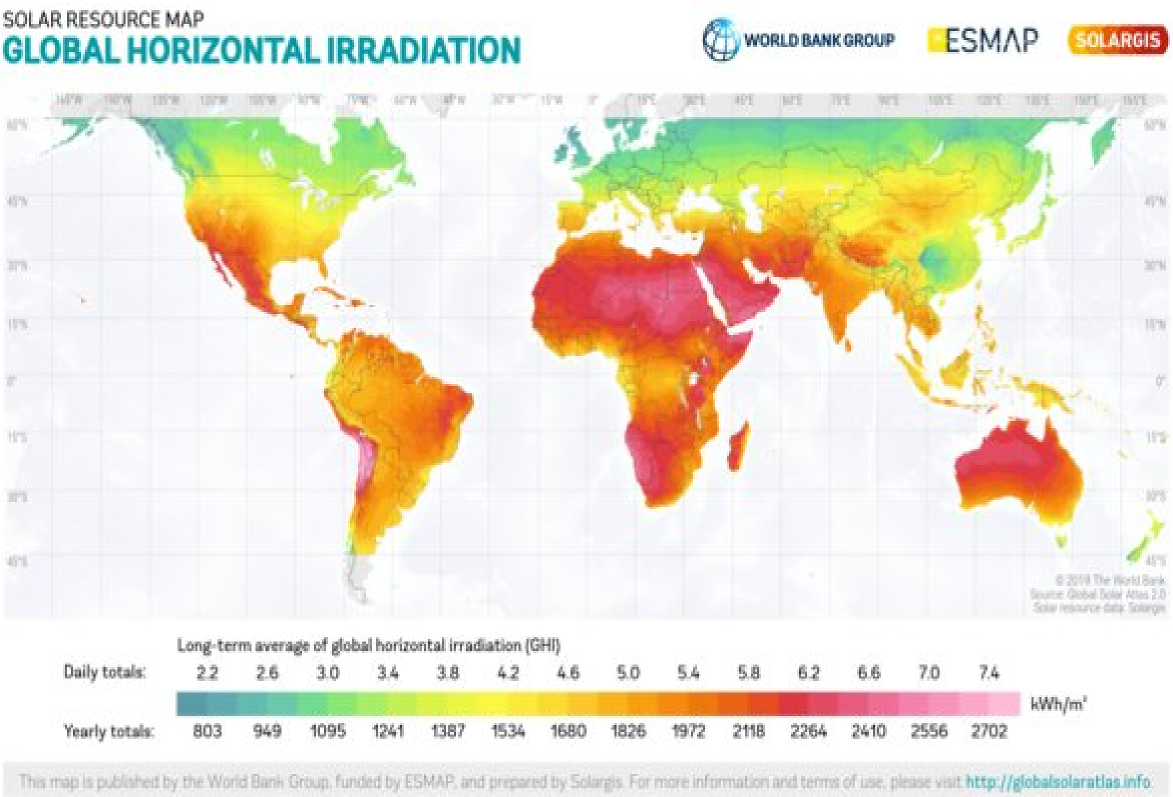


Figure 21: Global Horizontal Radiation © 2020 The World Bank

Source: Global Solar Atlas 2.0, Solar resource data: Solargis)

2.5 Solar Thermal Energy (STE)

Worth mentioning that different form of converting solar radiation into energy, By using the heat in Solar thermal energy (STE) or converting photons into electricity in Solar Photovoltaic (SPV). The process of solar thermal energy (STE) is a technology that uses solar energy to generate thermal energy (heat). Low-, medium-, and high-temperature collectors are the three types of solar thermal collectors. Where high-temperature collectors use mirrors or lenses to focus sunlight and are typically used to generate electricity (Bhatia, 2014). Also according to the author STE differs from *'and in fact outperforms'* photovoltaic's, which will see next how it converts solar energy directly into electricity.

2.6 Photovoltaic Solar Energy

From (Boyle, 2004) definition of the phenomenon of photovoltaic, that occurs when PV cell is exposed to sunlight. The effect produces electric current through converting sun photos to electrical energy. Developed by Edmond Becquerel in 1839, when experimenting with wet cells. He noticed that when the cell's silver plates were exposed to sunlight the voltage rose. (Williams, 2015)

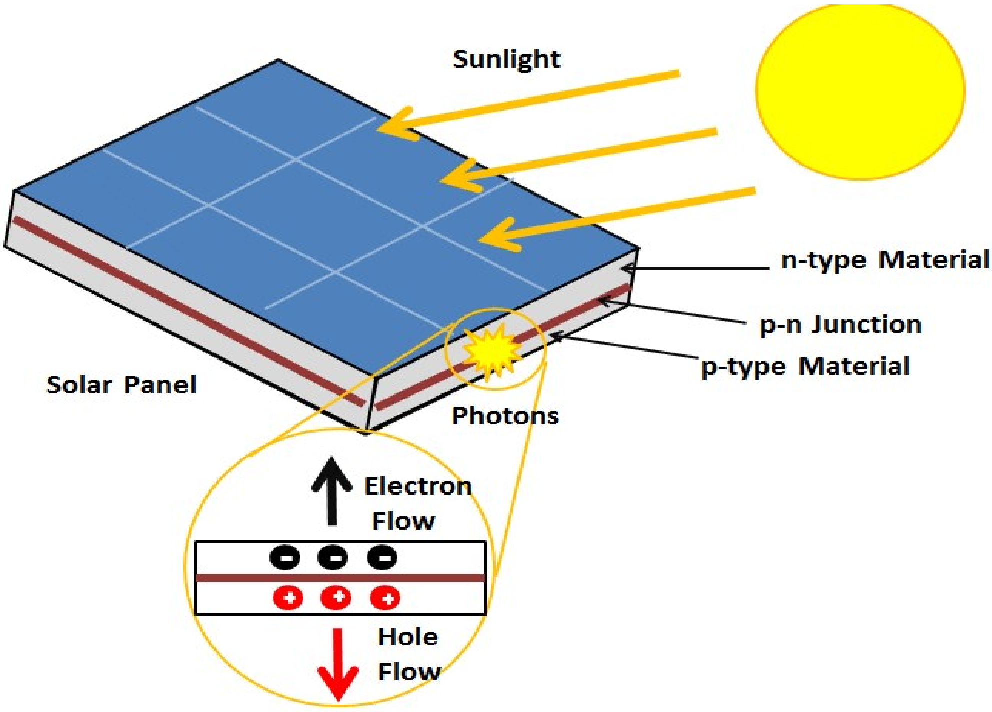


Figure 22: Photovoltaic effect (Created by EnergyEducation.ca, Adapted from: Ecogreen Electrical (August 14, 2015)

2.6.1 Photovoltaic Power Potential

The potentiality of the photovoltaic power differs from countries to another, with most of the concentration in Middle East, Africa and Australia (Solargis.com, 2020).

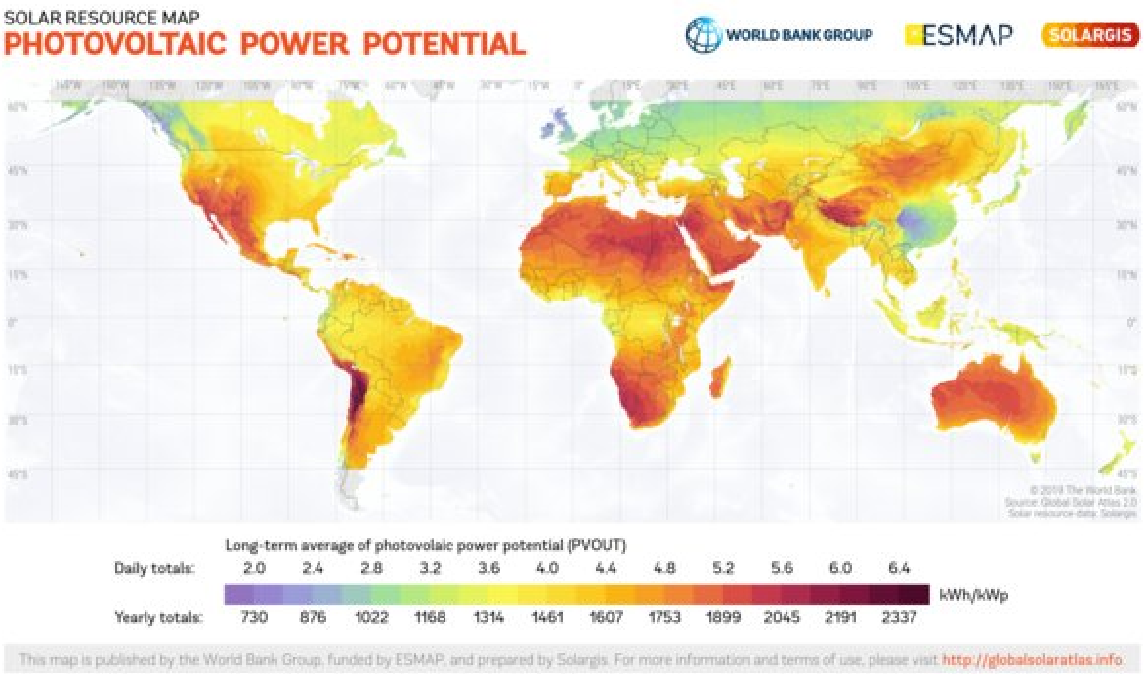


Figure 23: Photovoltaic Power Potential © 2020 The World Bank, Source: Global Solar Atlas 2.0, Solar resource data: Solargis)

Data shows that developed countries uses more renewable sources with less coverage then most of countries with the most potentiality especially solar based 2 out of total 197 TW representing (1%) of worldwide exploited solar energy. (Whiteman et al., 2016)

Table 02: Renewable electricity generation by region (Whiteman et al., 2016)

Generation in 2014 (TWh)	Hydro	Wind	Bioenergy	Solar	Geothermal	Total
Africa	118	5	2	2	3	131
Asia	1 520	198	85	62	23	1 888
Central America + Caribbean	24	3	4	<1	4	35
Eurasia	239	9	1	<1	3	252
Europe	595	258	170	99	11	1 133
Middle East	26	<1	<1	<1	<1	28
North America	683	213	77	27	25	1 024
Oceania	44	13	4	5	8	74
South America	658	16	55	1	<1	730
World total	3 907	714	399	197	77	5 294

2.6.2 Photovoltaic System (SPV)

The power generated by the solar photovoltaic (SPV) system can be stored or utilized directly for a variety of uses. Photovoltaic cells with better energy conversion efficiencies are manufactured using special sorts of semiconductor materials. Silicon is a popular element in the SPV system. Single crystal silicon, multi crystal silicon, and amorphous silicon are all types of silicon-based solar cells. Other materials that can be used to make solar cells include "polycrystalline thin films" such as gallium, arsenide, cadmium telluride, and copper-indium-diselenide (Hanif et al., 2022). The classification of the aforementioned tech well presented in the work of (García Moreno et al., 2020) in the figure below. For some details of these prompting technologies which are tangible innovation. With large scale commercialization ability, covered in our future development part at the end of this research.

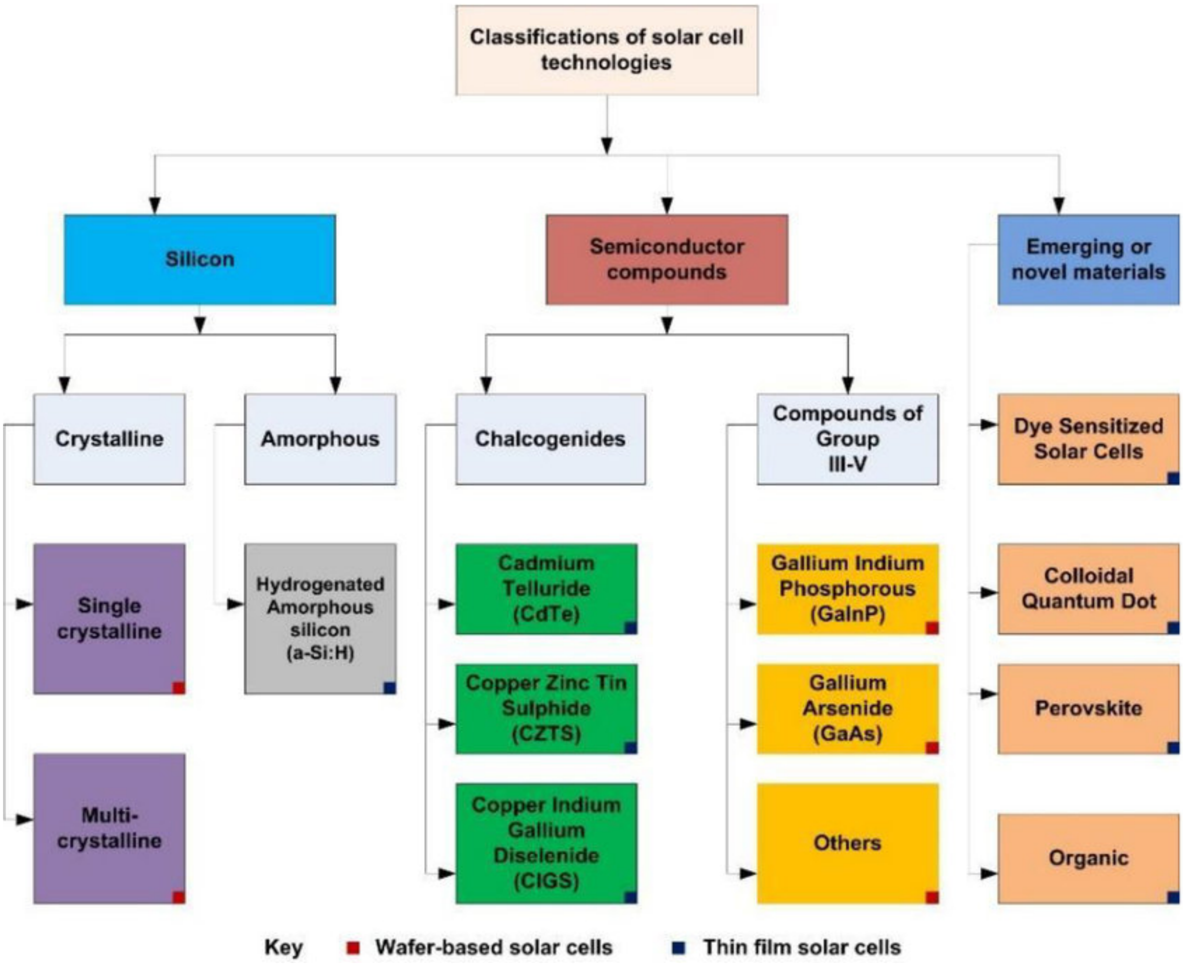


Figure 24: Classification of PV Cells Technologies (García Moreno et al., 2020)

2.6.3 Structure of a Crystalline Silicon-based PV Cell

To cover the basics we represent you with the structure of a simple silicon based crystalline PV cell. A solar cell is nothing more than a PN junction diode under sunlight, made up of silicon which is a good semiconductor chemical element, functions as a both conductors and insulators (Let's Talk Science, 2020). The coming photons containing energy can be reflected absorbed or pass through the cell when light of a specific wavelength strikes a semiconducting material, the photon's energy is transmitted to an atom of the material in the p-n junction. The electrons then go to a higher energy state known as the conduction band, leaving a "hole" in the valence band from which the electron leaps. This generation of photoelectric voltage is known as the photovoltaic effect (Boyle, 2004).

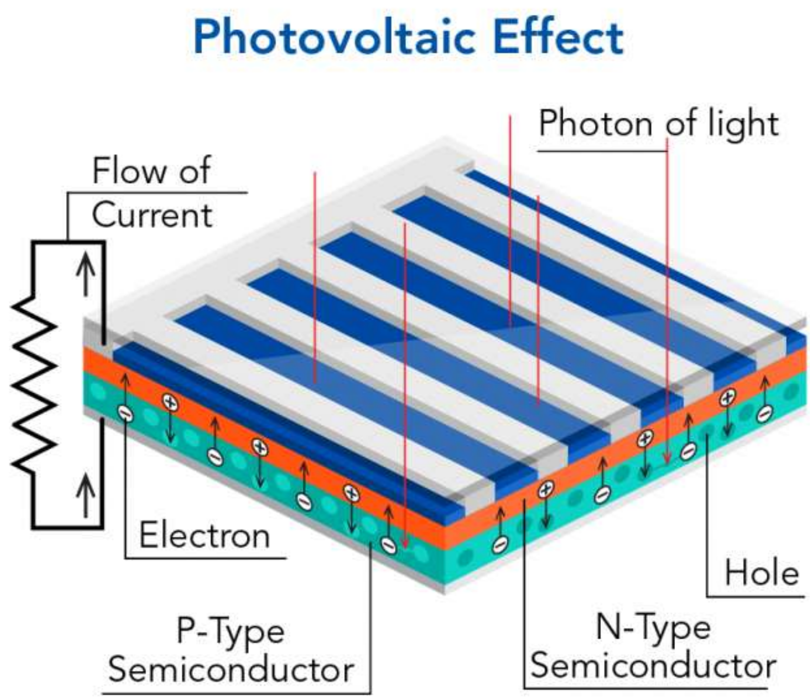


Figure 25: Photovoltaic Effect (Let's Talk Science using an image by ser_igor via iStockphoto).

2.7 Components of a PV System

A photovoltaic wage installation is composed of 4 main elements:

- ***Photovoltaic modules*** : or solar panels which are the only components present in all installations, in our case PV glass;
- ***Batteries*** : if you want to consume electricity at night or during periods of low sunlight;
- ***An Inverter :*** if it is necessary to convert the direct current produced by the photovoltaic modules into alternating current;
- ***A Solar Controller:*** to improve the life and efficiency of the installation (NAIL Raouhi, 2020).

The interconnection between components explained in the figure[12] below.

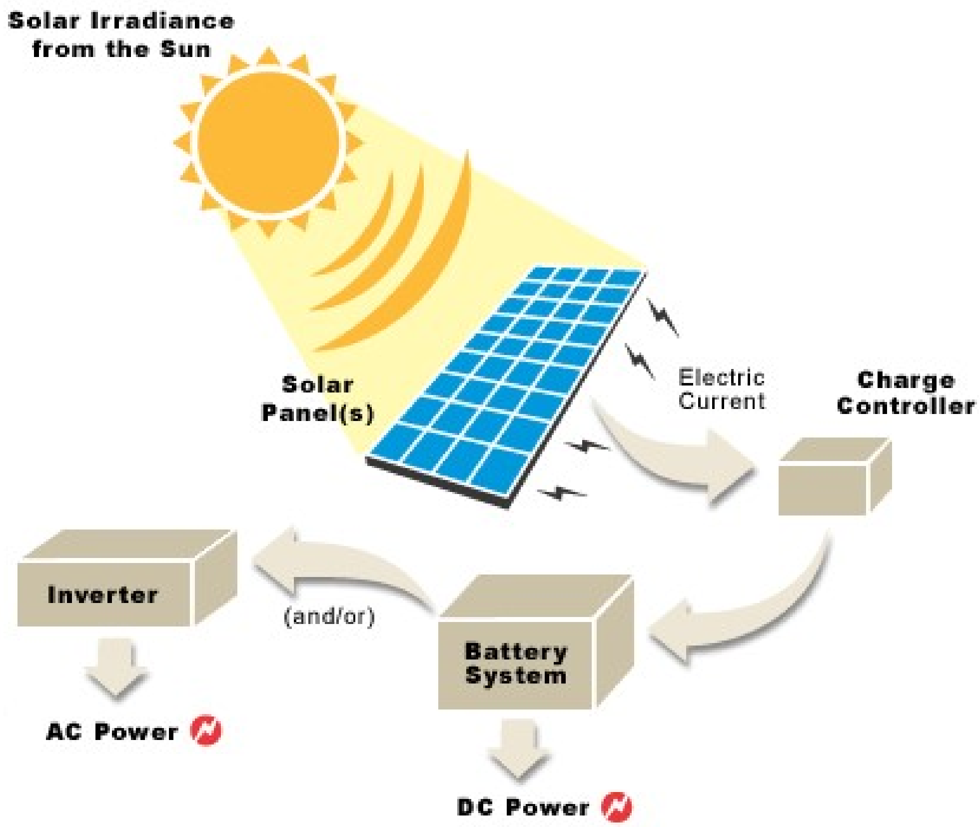


Figure 26: Components of Solar PV System (clipart-library.com)

[12] Retrieved from Clipart Library (http://clipart-library.com/clipart/yckrLnRzi.htm) accessed 10/09/2022

2.7.1 Photovoltaic Module & PV Glass

Photovoltaic cells are encapsulated in waterproof modules that protect them from moisture shocks and nuisances. At the same time, the assembly of photovoltaic cells in a module serves to increase the power and the output voltage (NAIL Raouhi, 2020).

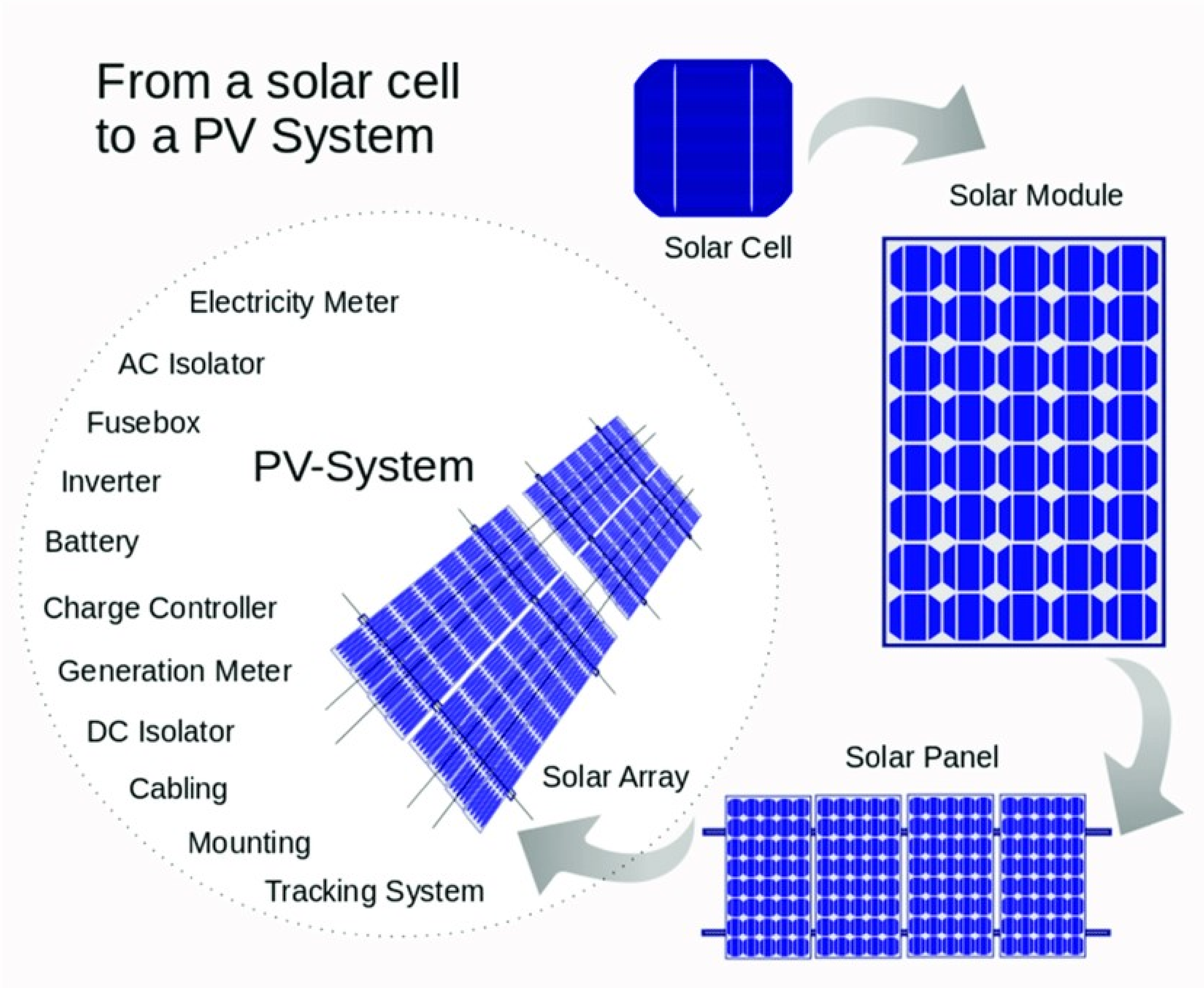


Figure 27: From a solar cell to a PV System (Wang and Tsai, 2018)

In our case we are going to use PV glass and it is a recent innovation developed to be more adapted to contemporary architecture needs. Giving the freedom to designers to use limitless imagination with 16 million of colors that can be incorporated to the glass, with different shapes and forms. Respectively to the designer’s dimensions and needs it fits to all type of modern, organic or post constructivism buildings. We will discuss basically two forms, add-on modules and integrated solar cells.

2.7.1.1 Add-on module

The first generation of solar windows was built around transparent, photosensitive modules that were coated on the glass. These amorphous silicon-based modules often have decreased transparency and a somewhat orange tint. Another cutting-edge method is to spray a photosensitive coating on the glass, which filters out invisible radiation (Innovation-hub, 2017).

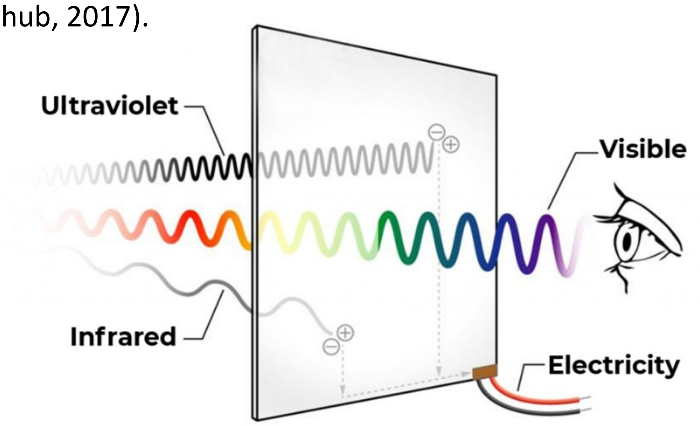


Figure 28: Transparent photovoltaic glass (innovation-hub.com)

2.7.1.2 Integrated Solar Cells

Following that, the incorporation of solar cells in the glass[13] itself was researched, mostly using organic chemicals. Transparent luminescent solar concentrators (TLSCs), for example, divert radiation to the sides of the window where the photovoltaic cells are mounted. To achieve a comparable outcome, so-called "quantum dots" are also employed. Another area of study is the integration of semitransparent perovskite cells. This invention has the potential to increase the efficiency of solar windows. The article mentioned that its development still in an infancy state (Innovation-hub, 2017).

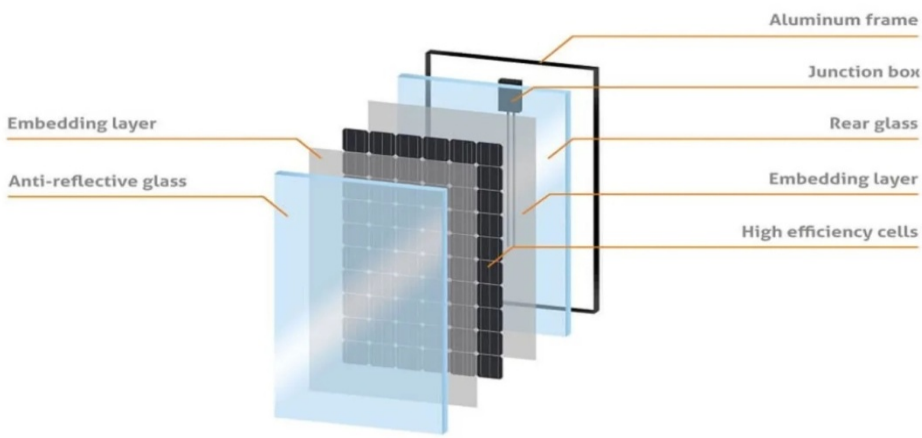


Figure 29: Integrated solar cells (PV manuficturing.org)

[13] (https://pv-manufacturing.org/glass-glass-modules)

We will return to this perovskite cell technology in the future development sections. Where we will mention some developments made since then. Some manufacturers reached manufacturing and commercialization stage with limited production.

2.7.2 Photovoltaic Inverters

An inverter converts direct current from sources such as the battery into alternating current. Electricity can be at any voltage, it can operate AC equipment designed for mains operation, or straightened to produce direct current at any desired voltage. A solar inverter or PV inverter is an essential component of a photovoltaic system. It converts the variable direct current of the solar panel into an alternating current at the frequency of the service that can be injected into the power grid or used by an off-grid local power grid. Solar inverters have special functions suitable for photovoltaic modules or PV glass in our case (NAIL Raouhi, 2020).

2.7.3 Regulator (Load/Discharge)

This device regulates the electricity voltage from the PV network to the battery. This controller keeps the battery charged at full capacity without overloading it. When the controller detects that the battery is fully charged, it reduces or stops the flow of electricity from the photovoltaic generator (NAIL Raouhi, 2020).

2.7.4 Storage of Solar Energy

Solar panels are only energy converters and not tanks (like batteries). They transform energy but don’t store it. If the application requires energy outside the production periods, it will necessarily have to be recovered in storage (battery, accumulator) or other energy source. In all other cases, a storage battery will be used to produce electricity in the dark and also when the voltage demand is greater than the voltage supplied at that time by the PV glass (starting an electrical equipment) (NAIL Raouhi, 2020).

2.8 Different Categories of PV Systems

In the following figure will see the design consideration to fit these equipments in the PV system (Waqas et al., 2018). And will showcase in different categories of PV Systems that depends on the source of energy and weather it's connected or not to the grid or network.

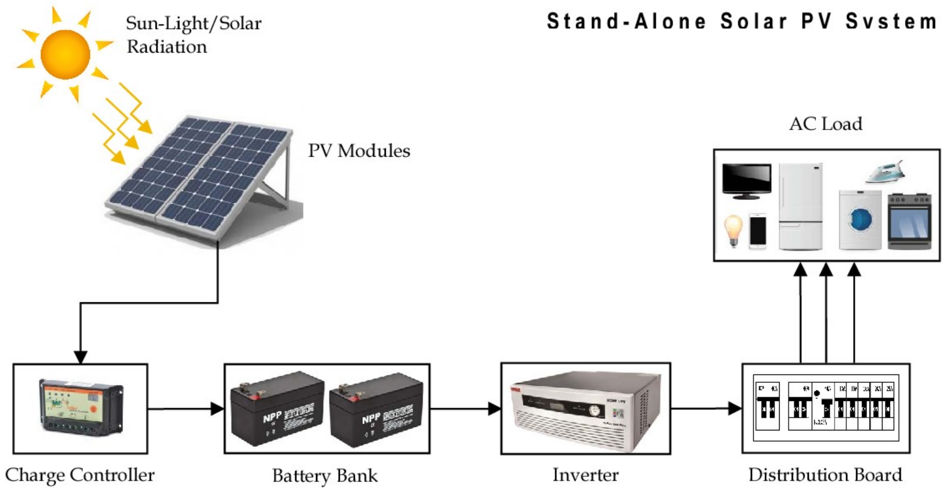


Figure 30: Different equipments of PV System (Semanticscholar.org)

2.8.1 Autonomous PV System (Stand-alone / Off Grid)

The system will work independently using the equipments showed in the following figure below without injecting it with the public network of electricity. The stored energy during the day in battery will be used by night or when the energy needed exceeding what is produced by PV modules[14].

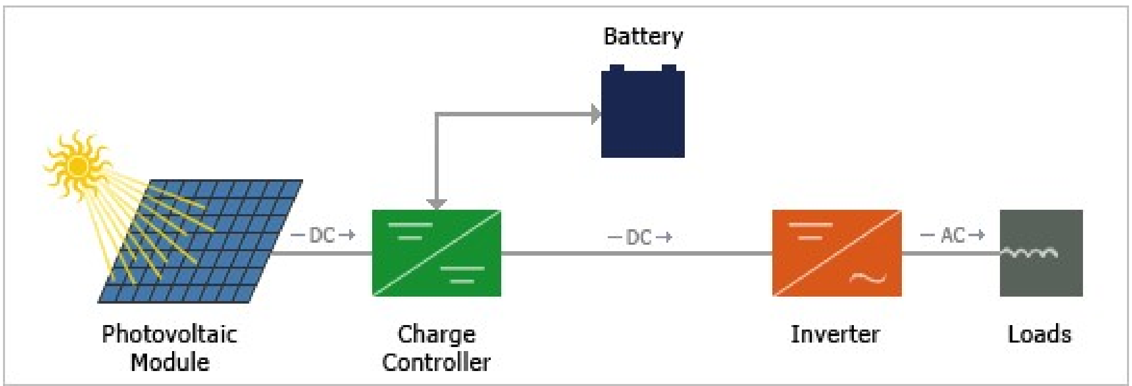


Figure 31: Diagram of Stand-alone PV System (Autonomous / Off Grid) (synergyenviron.com, 2022)

[14] Supplying the Ac load (Alternative current) as shown in the Figure.

2.8.2 Grid connected PV systems (On Gird)

A PV system in interaction with utility grid (public network in Algeria). Energy supplied from both sources and designed with and without batteries. Since in day time we can use PVS and utility by night or switch between them if the other fails. PV generated DC[15] electrical power supplied from panels transferred toward batteries, using charge regulator to prevent overcharging. Then transferred to AC[16] load by inverter, to finally supply electrical equipments (synergyenviron.com, 2022).

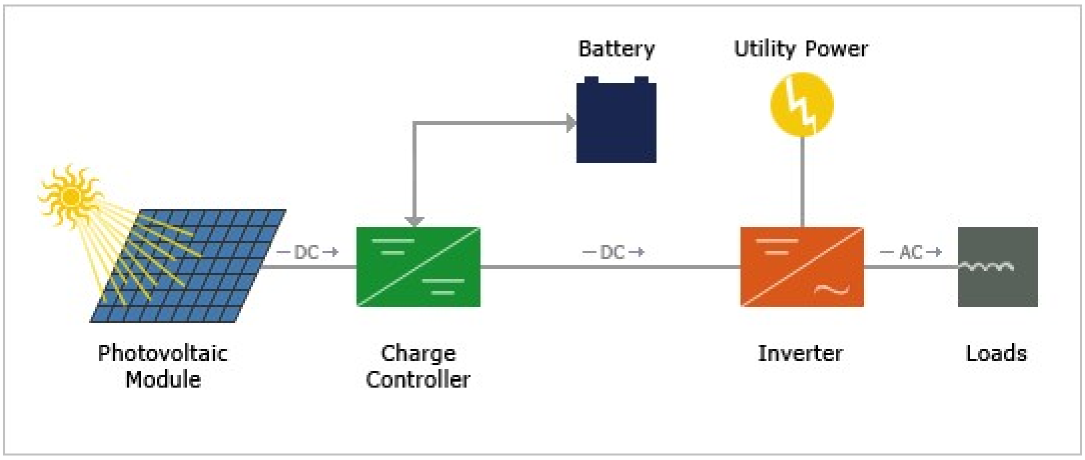


Figure 32: Diagram of Grid Connected PV System (synergyenviron.com, 2022)

2.8.3 Hybrid PV System

In the case of multisource of power we call it Hybrid PV system. Commonly combined with gas or diesel generators, or completely renewable sources PV/wind System. We can find details in the figure below using a diesel generator[17] (synergyenviron.com, 2022).

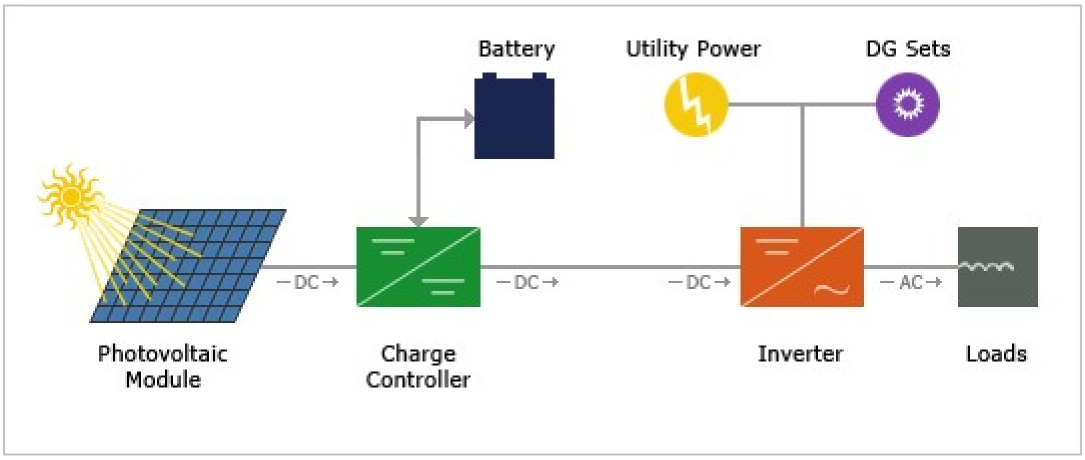


Figure 33: Hybrid PV System (On grid) (synergyenviron.com, 2022)

[15] DC : Direct current
[16] AC: Alternative Current
[17] Diesel generator, referred to in the figure as DG Sets.

2.8.4 Some Precautions Measures in PV Systems

The following diagram is provided with interactive links in the given website[18] (follow the link below for more illustration on the subject). It shows also the importance of using:

- ✓ Isolator and solar generation meter to follow the well function of your system;
- ✓ Fuse box before distribute to the user;
- ✓ Grounding cable to transfer the extra charge;
- ✓ Good electrical cables and adequate electrical outlets.

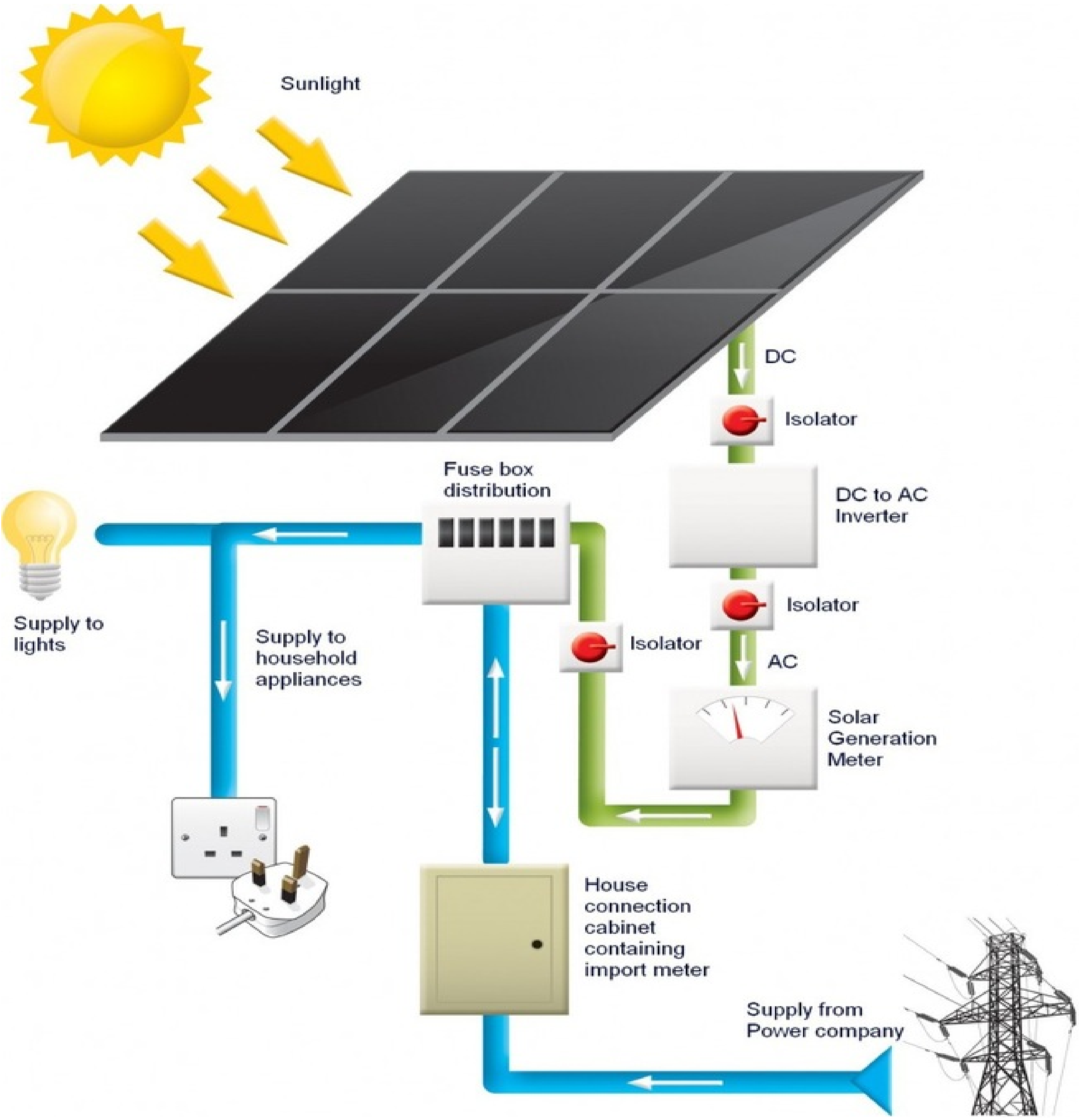


Figure 34: Diagram of Hybrid PV System (On grid) (thingklink.com)

[18] (https://www.thinglink.com/scene/497534423554588674)

2.9 Solar Energy in Algeria

Algeria engagement in the renewable energies dated to its 80s, with the launching of the national program for the implementation of photovoltaic systems. Launched and funded by the government, the first program called the "Far South Solar Energy Program**"** started in 1985 and completed in 1989 ("Bilan sur les actions entreprises dans le domaine de l'énergie solaire," 1993)**.** The second, launched in 1995, is the "southern rural electrification program" ("Stratégies énergétiques au Maghreb," 1995).

2.9.1 Algeria's Solar Field

Because of its geographical location, Algeria has one of the highest solar fields in the world. Almost the entire national territory benefits from more than 2,000 hours of sunshine per year, and can reach 3,900 hours (high plateau and Sahara desert). In most national territories, the energy received per day at the level of 1 m^2 is about 5 kW/h, or about 1700 (kW/h/m2) /year in the north and 2263 (kWh/m2) /year in the south ("Algeria Ministry of Energy," Accessed in 09/09/2022).

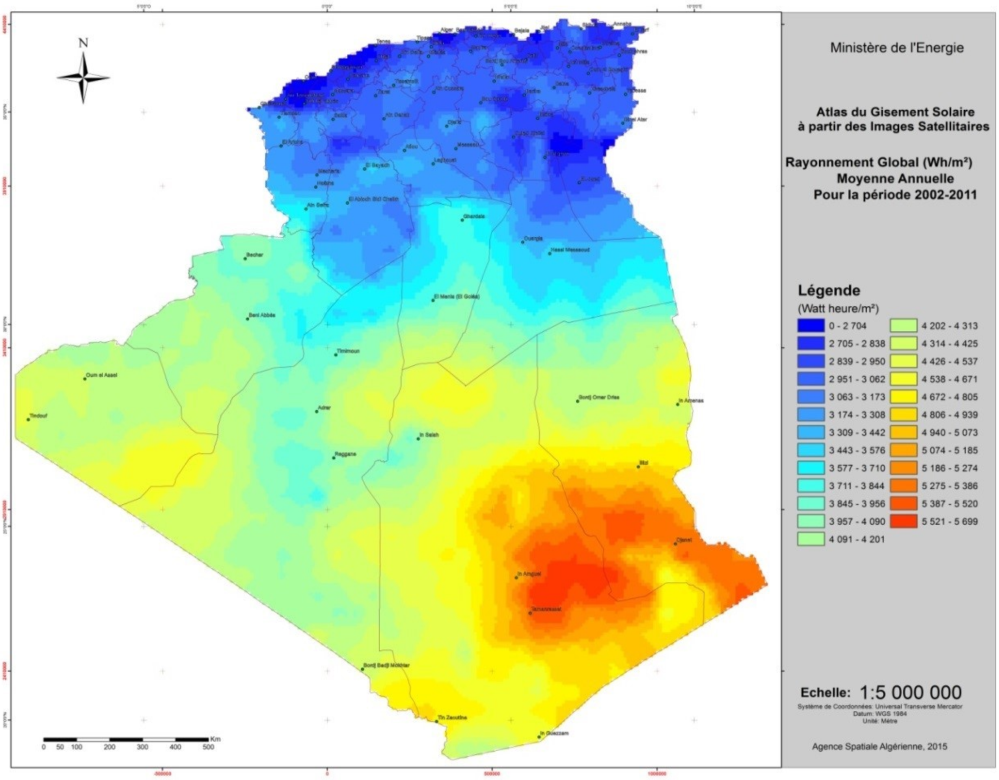


Figure 35: Average Annual Direct Irradiation Map [2002-2011 period] (Algerian Spatial Agency, 2015)

2.9.2 The Far South Solar Energy Program

This program was implemented over a five-year period (1985/89). Its purpose was to install autonomous photovoltaic systems for various applications. This program was carried out by the Centre for the Development of Renewable Energies (CDER).

The realization of this program allowed:

- ✓ Electrification of small isolated villages located in the Sahara. The total power output for the installation was 94 kW. But only 67 kW were actually installed, which represents 70% of the total program;
- ✓ Photovoltaic systems for pumping water, with a total power of 85 kW, have been installed. - 30 kW was used for the lighting of rural houses;
- ✓ Telecommunications systems have also been powered by photovoltaic modules at remote sites. The total power involved is 80 kW;
- ✓ Thirty refrigeration plants have been equipped with PV modules (Maafi. and Delorme, 1996).

2.9.3 The Energy Efficiency Program 2035

Nowadays, continue developing of the regulation adapted in 2011. Algeria government continues its efforts to implement new programs of partnership in the renewable energy sector (EnR) toward a "*green energy*". The program revised in 2015, and placed in the range of national priority by 2016. Nowadays, Benefiting from solar energy as an abundant source of power and developing green hydrogen for the near future. The actualized national program for energy efficiency consisted of setting-up of 22 000 MW of renewable energies by 2030. With exportation ambitions kept in mind, this time the funding is open to private/government partnership to accelerate the implementation of the program. By introducing efficient lighting, thermal insulation and solar water heaters, clean fuels (GPLc and GNc), and high-performance industrial equipment. They aspire to achieve efficient energy use and savings of the order of 63 million TOE[19] by 2030 for all sectors (building and lighting, transportation, and industry). The energy efficiency scheme will save 193 million tons of CO2 as indicated in the ministry website ("Ministère de l'Énergie | Algérie," Accessed in 08/09/2022).

[19] TOE : Tons of Oil Equivalent

The realization of the first part till 2020 knew a heavy pace. Due to the policy of austerity and the delays in launching the pilot projects, the program rescheduled and extended to 2035 (MTEER, 2021). This period also had the creation of the new ministry upgrading regularizations and emergences of new actors in the renewable energies.

2.9.4 Actors of the Energy Sector in Algeria

After been held by Ministry of Energies and due the importance given from the Algerian government, a new tutelage created to organize the sector called the Ministry of Energetic Transition (MTEER[20]). The ministry takes actions through collaboration with:

- ***National organizations***: CEREFE[21], APRUE[22],
- ***Public Companies:*** SKTM[23], SHAEMS[24],
- ***Public Funding:*** FNMEERC[25], FNEL[26],
- ***Laboratories:*** EPST CDER[27], UDES[28] Bousmail,
- ***Education :*** The Higher National School for Renewable Energies[29] (Batna),
- ***National Associations:*** ASPEWIT[30] Tlemcen is the first Algerian association in the environment created in 1979, AGIR Bouira …etc,
- ***International Cooperation's***: for international presence we shall mention (UNDP) The United Nations Development Program and German cooperation GIZ,
- ***Private sector:*** Algerian Cluster for Renewable Energies …etc,
- ***Manufactures:*** Aures Solar, Electromel, Soprec (BSI), Condor, NGT Meziani …etc.

[20] MTEER: Algerian Ministry of Energetic Transition and Renewable Energies (https://mteer.gov.dz),
[21] CEREFE: The Commissioner for Renewable Energies and Energetic Efficiency,
[22] APRUE: National Agency for the Promotion and Rationalization of Using Energy (https://aprue.org.dz),
[23] SKTM:Company of Electricity and Renewable Energies,
[24] SHAEMS: Algerian Renewable Energy Company,
[25] FNMEERC: National Fund for Energy Management and Renewable Energy and Cogeneration,
[26] FNEL : Fonds National de l'Environnement et du Littoral,
[27] EPST CDER: Renewable Energy Development Center, is a research facility in Algiers,
[28] UDES: Development Unit of Solar Equipments, located in Bousmail,
[29] Renewable energy school official website: (http://www.hns-re2sd.dz),
[30] Association for the preservation and promotion of the environment in the state of Tlemcen.

2.10 Practical Method for PV Sizing

Research paper shared in *Science Direct* showing a practical method for PV Sizing, under the name of Schmid's formula. (Skunpong and Plangklang, 2011) Despite of our intention to use computer assisted software's like *PVGis* and *Design Builder,* we will include this formula for reference, its validation and implementation is open for future researches.

To have the most effective sizing to our system we can look after these indicators:

Energy balance: **Edemand ≤ Esupply** (Schmid, 2002)

Equation 02: Energy Balance

2.10.1 Pre-Sizing

- ✓ Annual global radiation: $\mathbf{E_{glob}}$ (kWh/m^2/d);
- ✓ Area consumption based on neighboring facilities;
- ✓ listed in the table bellow consumption of a household;

Table 03: Energy consumption of household, (Skunpong and Plangklang, 2011)

Appliance	Power rating [W]	Daily consumption [kWh/d]	Annual consumption [kWh/a]
1 Incandescent bulb	60	0.25	90
1 Typical fluorescent lamp	40	0.15	60
1 Compact fluorescent lamp (CFL)	15	0.07	25
1 Fan	375	0.75	270
1 Radio	55	0.10	35
1 Television, colour 19″	80	0.14	50
1 Drill, 318″ variable	240	-	10
1 Blender/Mixer	350	0.07	25
1 Refrigerator (12cu. ft./340 litre)	330	2.75	1000
1 Vacuum cleaner	900	-	45
1 Iron	1000	-	50
1 Clothes washer	1150	-	120
1 Toaster	1200	0.12	45
1 Coffee maker	1200	0.30	110
1 Hair dryer	1500	0.33	120
1 Microwave oven	2100	0.35	130

- ✓ Weather the system is autonomous (off-grid) or connected to the public-network (On-grid);
- ✓ Try to avoid including high-energy consumption equipments such as: Air conditioning, electrical heating…etc. and include eco-energy version if existed so, the PV electrical system can support them, rather supported by thermal energy systems like solar water heater;
- ✓ Planning of the operation.

2.10.2 Planning of the Operation

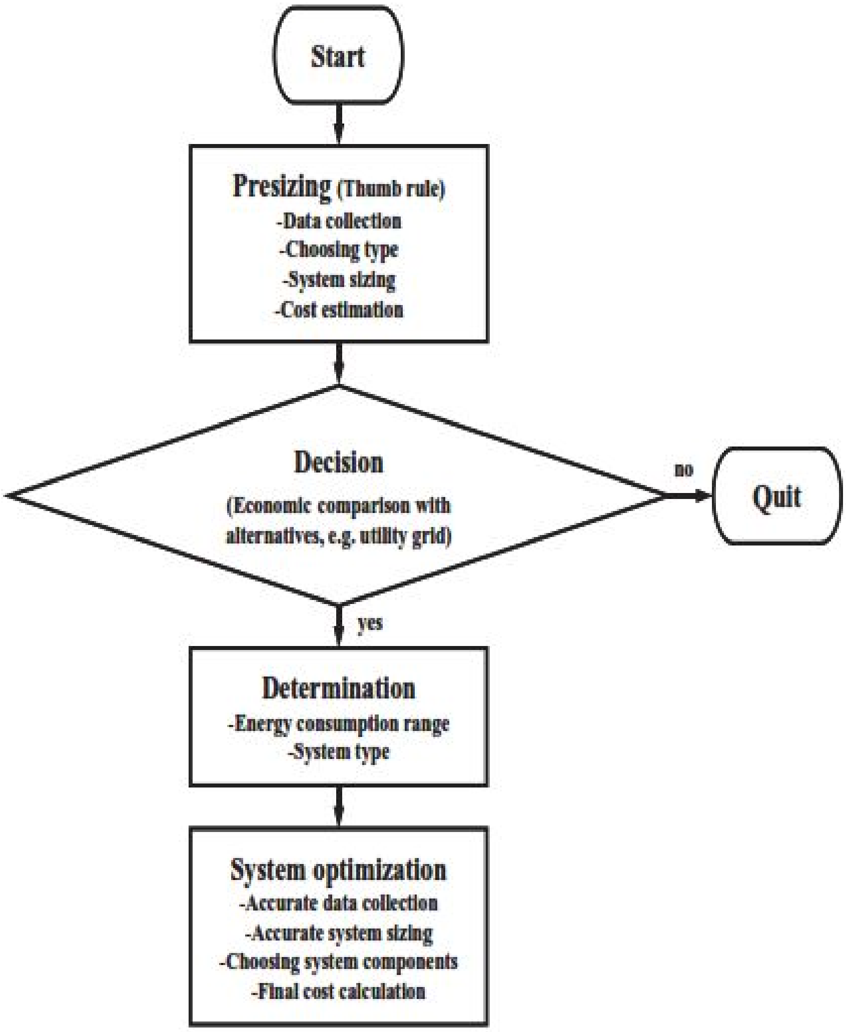


Figure 36: Planning of the PV Sizing Operation (Skunpong and Plangklang, 2011)

2.10.3 Schmid's Formula

Quality factor (Q): Is the quotient representing the real load of the electric energy at system output (**E_{load}**), (**$E_{demande}$**) comparing to the theoretical calculated output (**E_{th}**) under ideal conditions Standard Test Conditions (**STC** : I_{STC} = 1000 W/m^2 **T_{STC}** = 25°C, **AM** = 1.5).

$$\mathbf{Q} = \frac{E(load)}{\mathrm{E(th)}}$$

Equation 03: Quality Factor (Q)

The unit of E (load) & E (TH) is [KWh]

If: E (load) = E(th), means Q = 1, in this case we have the best performance.

Since we can have the E_{load} then we need to identify E_{Th} to test if our system sizing fulfills the quality requirement to achieve better performance, using the equation below:

$$E(th) = \eta \,.\, EGlob \,.\, Aarray$$ Equation 04: Theoretical Load $E_{(Th)}$

η : The efficiency of the PV array [decimal]

E_{glob} : Global Irradiation [KWh/m^2]

E_{Th} **:** Quantity of energy output in the ideal conditions (STC)[31]

A_{array} **:** Area of PV array [m^2]

If the area of the array is frequently unknown and it is difficult to obtain real efficiency values from manufacturers. The following equation are given to simplify the calculation of the missed information and for more details please consult the paper published by (Skunpong and Plangklang, 2011) under the tiltle : A Practical Method for Quickly PV Sizing.

$$P_{peak} = \frac{E_{Load}}{E_{glob}} \frac{I_{STC}}{Q}$$ Equation 05: Peak power of PV array

According to the last two equation (4) and (5) and with substitution of η array :

$$E_{th} = P_{peak} \cdot \frac{E_{glob}}{I_{STC}}$$ Equation 06: Theoretical load E(th)

(Equation with no array)

From the equation (3) and (6) we can calculate the Quality factor out of:

$$Q = \frac{E_{th}}{E_{glob} \cdot P_{peak}} \cdot I_{STC}$$ Equation 07: Quality factor second equation

2.10.4 Battery Sizing

$$CB = 10 \,.\, PPeak$$ Equation 08: Battery Sizing

C_B = Battery capacity

P_{Peak} = Peak power of the PV array [kWp]

[31] STC: Standard Test Conditions (**STC** I_{STC} = 1000 W/m^2 T_{STC} = 25°C, **AM** = 1.5).

2.11 Conclusion of the Theoretical Framework

In this chapter, we have mentioned the basics knowledge for understanding the subject. Highlighted the International organization and initiatives. We presented a general overview of the solar radiation, and solar capacity in Algeria with the mention of the ambitious development programs to switch toward an efficient energetic transition by the year of 2030. Continue to familiarize ourselves with the PV system we explained the different elements of the PV system, namely the PV devices and the modules units. To proceed later in the verification process if the photovoltaic system is economically viable for buildings in Algeria.

III-Chapter 03: Analysis & Discussion

3.1 Case Study

We intended to study two projects, an existing one is: Algeria Venture Headquarter to present an adaptation of PV glass technology which was not possible due lack of documentation and the limited time of this study.

Figure 37: Algeria Venture Headquarter (aventure.dz, 2022)

So, we oriented toward one of our designed proposition for Masjid El-Ihsane. Where we introduced fully panoramic glass facades as for both esthetic and functionality. To participate in energetic performance by producing electricity and isolating the envelope of the building.

3.1.1 Objectives

We hope in this research to emphasize the different architectural aspects by introducing three challenges:

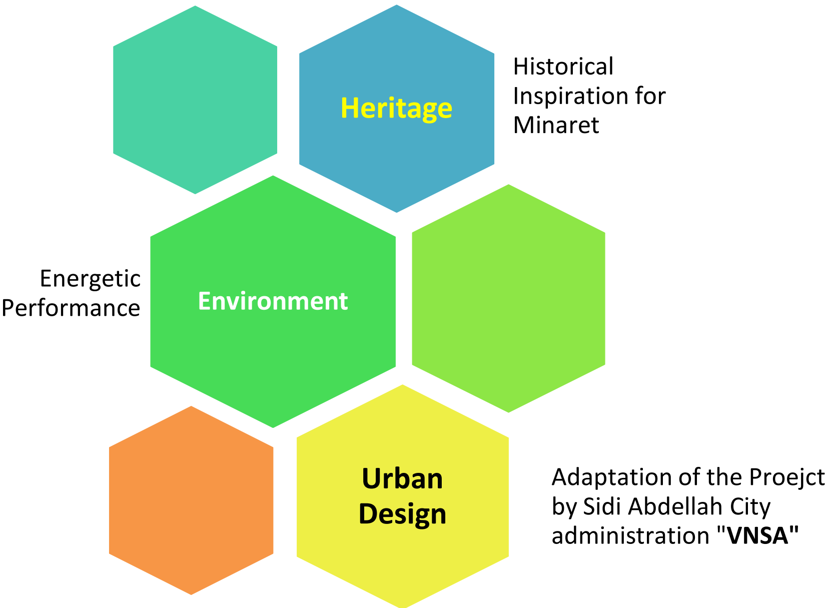


Figure 38: Research Objectives Chart

3.1.2 The Project

The Project is a design by *E3+ Design* Studio of Architecture & Environment solicited by Masjid El- Ihsane association committee for the up-scaling of the Masjid located in neighborhood 2173 apartments, The Smart City of Sidi Abdellah, Algiers, Algeria.

Masjid association requested an extension to receive Ramadan Taraweeh Prayers in the best conditions.

Situation of the Masjid:

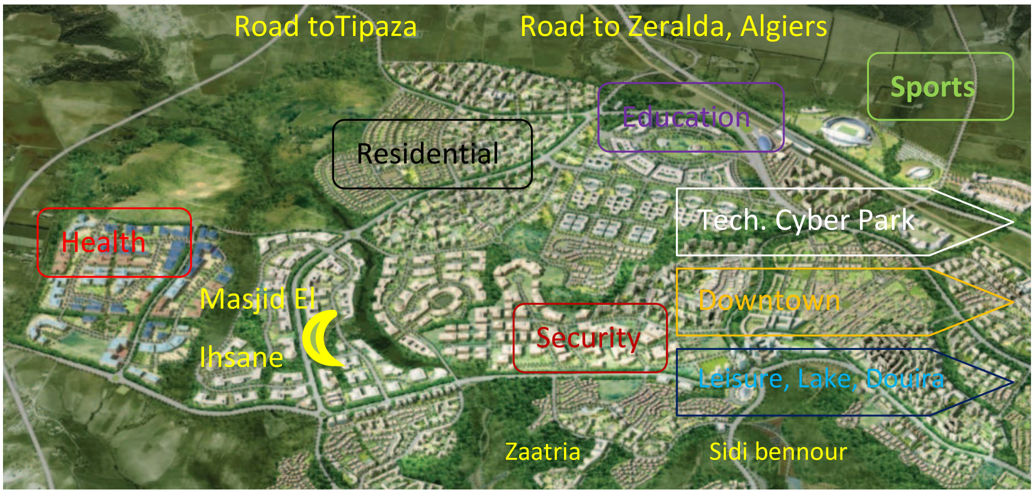


Figure 39: Situation of the Project (“SPACE DESIGN GROUP illo | Sidi Abdellah Masterplan,” 2009)[32]

Surrounding Areas:

[33]

Figure 40: Area of the Project (Google maps, 2021)

[32] Sidi Abdellah Masterplan (http://illo.co.kr/?portfolio_page=sidi-abdellah-masterplan)
[33] Masjid Photos taken by author and Sid Ali.

3.1.3 The Idea Development Process

The starting thoughts were to use the concept of Ihsane (The limits of excellence) in the design process and rethink the use of land in innovative manner. Combining the two neighbor projects by a meaningful philosophy. We found that the Masjid represent the submission manifested in starting to incline from top down; and the school representing science, which lift you from the ground to unlimited horizon. Splitting the area in four parts, figure below shows details of the idea development, surfaces and zoning of the Masjid.

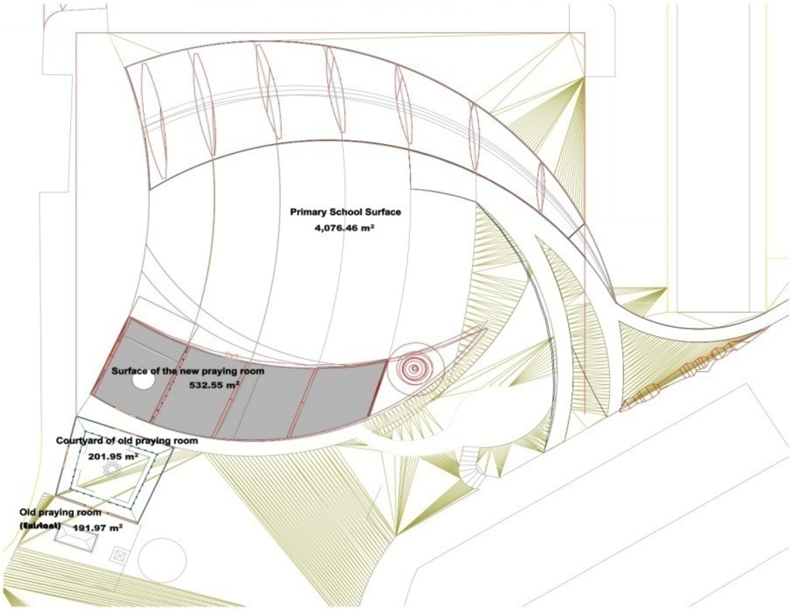


Figure 41: Idea development, Surfaces and zoning of Ihsane Masjid (E3+ Design, 2021)

Part 01: rehabilitation of the old praying room: to be used as a Quran teaching School, with upgrading the outside area including arches inspired from Andalusia Moorish style and water fountain as ottomans Turkish style.

Figure 42: Rehabilitation of old praying room and Courtyard (E3+ Design, 2021)

Part 02: A new praying hall: separated from the old building, combined they will mixing between tradition and modernization in a fascinating contemporary artistic touches.

Figure 43: The Extention of Masjid El Ihsane (E3+ Design, 2021)

Part 03: Combining design of the two buildings: the reserved land of primary school or in more accurate expression the designated land, referring to the possibility of change the occupation of the pre-mentioned land by the authority of the ***(VNSA)*** Enterprise of the New City of Sidi ABDELLAH, with the land left for the Masjid which is not sufficient to produce a complementary design for both projects surrounding of a middle open area.

Figure 44: Community Center and primary school in Red roof (E3+ Design, 2021)

Part 04: Structure & landscape design: Preserving the natural grading which give us the possibility to include flowing water, and using slumps instead of stairs, making it much practical for persons with disabilities to enjoy the edifice with ease.

Figure 45: Landscape design of exterior spaces of Masjid El Ihsane (E3+ Design, 2021

Structure: The idea of raising the structure of the primary school above pillar's in the shape of two hands praying to symbolize the bridge to heaven so the meaning was science and learning bridge.

The last element of that learning structure is the library where infinite knowledge and to continue reading and rising for students that keep learning, hard working and struggling for excellence.

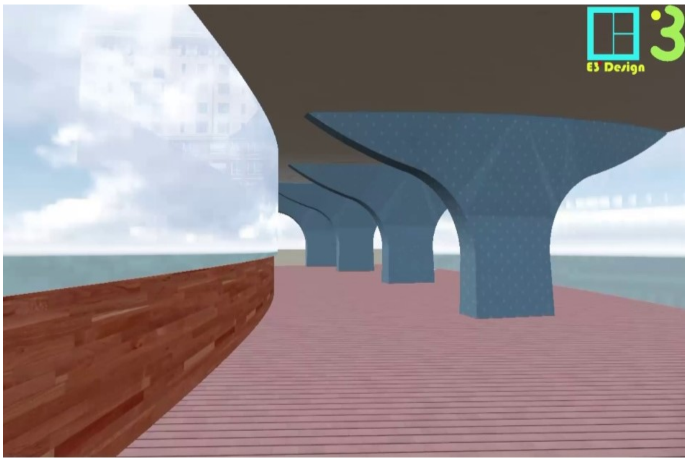


Figure 46: The Structure of Community Center & Primary School (E3+ Design, 2021)

Inspired from the Arabic proverb: "*Spare me to win glory's forbidden prize. Glory in hardship, sloth in comfort lies*." (Al-Mutanabbi, 915 - 965). Mentioning hardship takes us to the next point of the challenges facing the realization of this project.

3.2 Challenges

Acquiring land to realize the building needs transferring primary reason of exploitation it to a more general and inclusive idea to benefit the neighborhood. Where the intended primary school area will include also a community center; the up floor-for studying and down to activities relevant to the needs of the surrounding residents. We can find a public library and kinder-garden, activities rooms for associations and other public needs. By using those rooms along with the open spaces and arena (esplanade) to diverse manifestation and recreation. Divided into four major challenges for preserving heritage, urban design, Environment and economic viability.

3.2.1 Heritage

First challenge, consisted of preservation of the historical touch, melted with modern architecture. This will manifest in the minaret, which will be covered with traditional rocks to be crafted locally. Designed with supplementary challenge for the law of physics can be achieved only by valuable collaboration with distinguish civil engineers.

This will manifest the minaret using local materials, and rehabilitation of the old praying room, and rehabilitation of the old praying room using arches inspired from Andalusia Moorish style combined with a water fountain following the ottomans Turkish style.

Figure 47: The Design of the Minaret of Masjid El Ihsane (E3+ Design, 2021)

3.2.2 Urban Design

The second challenge is urban design laws. Due that the smart city of Sidi ABDELLAH had a unique management, through the economic state-owned enterprise ***EPIC VNSA*** (Ville Nouvelle de Sidi ABDELLAH). The Government granted VNSA the authority of exploitation and valorization the property and real estates of the city. We can compare this initiative to Emirates leading experience in this field. Where Dubai Government owned properties and real estate's with some recommendations, where we can refer to a personal visit there and observed the following:

- ✓ The importance showed by Dubai Government to the surrounding environment of the land field even for those non-purchased lands in suburb areas;
- ✓ Landscape planned before even selling the land and construction works begin;
- ✓ Preservation the beauty of the urban facade, where we can see the implementing of different techniques like taking care of project fences to be considered as an element of urban integrated and respectful image;
- ✓ Reducing the visual pollution, like covering the entire building with the photo of the completed version;
- ✓ Using visual fences to cover unsold lands which located in the middle of urban areas, with huge publicity panels;
- ✓ Transportation to every corner of the city both urban and suburb areas.
- ✓ The uniqueness of the smart city of Sidi ABDELLAH over the rest of Algeria cities reside in the possibility given to its authority (VNSA) to manipulate the exploitation of the urban land reserve, which was under regional states or public administration for each type of building respectfully.

Implementing theses recommendation adapting the characteristics of the city of Sidi Abdellah respectfully, leading to a progressive experience for new cities in Algeria.

3.2.3 Economic Viability

The challenge here consists of guarantying to the user of the PV glass technology the efficiency with a convenient price and less maintenance fees. Comparing to Algeria market low electricity and energy cost in general. We will see details in the implementation process later.

3.2.4 Environment

The fourth and last challenge which is our topic of research. Answering the question on how we provide a renewable energy source using new technologies, to emphasize the energetic efficiency in the buildings of the project.

As a General Idea:

- ✓ Using solar panels in the roof needs a considerable flat surface, whereas the project design is curved shapes both vertical and horizontal;
- ✓ Using panels and maintenance against natural impact is hard; So instead,
- ✓ We suggested the use of ascended technologies that is photovoltaic glass to transfer sun's light photons into electricity power;
- ✓ Implemented replacing the glass of curtain walls;
- ✓ Why not using that facade surface to produce energy, with that we earn twice, High-end glass that reduces intolerant sunlight and radiation;
- ✓ Knowing our space is wide open which gives us an important surface to use with great panoramic view.

Sustainability Matters:

- ✓ Product manufacturing process should be eco-friendly;
- ✓ Near-Zero stock policy to reduce waste;
- ✓ Convenient supply chain if possible to control environmental impact.

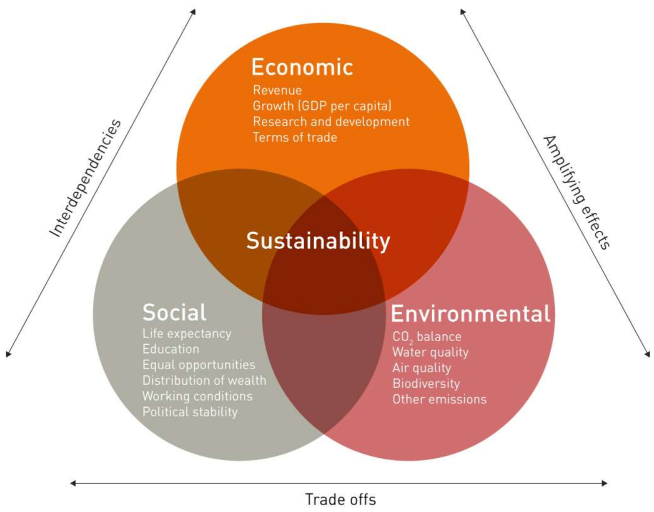


Figure 48: The three dimensions of Sustainibility (Economiesuiss.ch, Passet, 1979)

3.3 Implementation & Recommendation

3.3.1 Comparison between a Conventional Glass & PV Glass

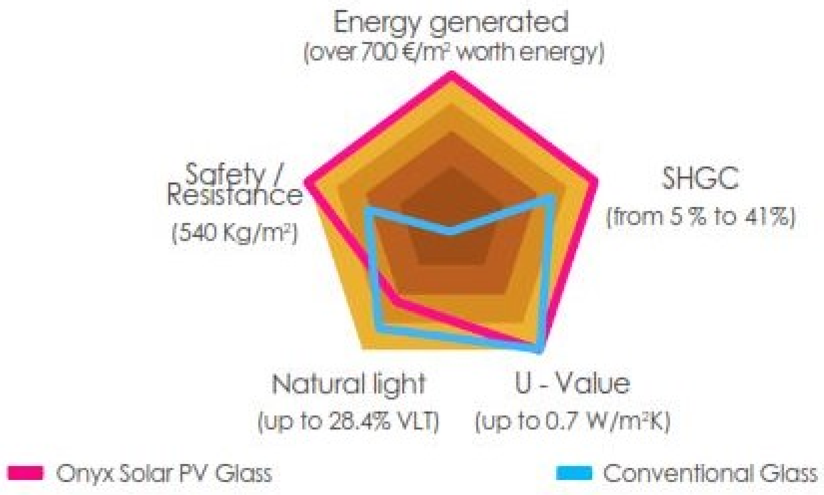


Figure 49: Comparison Between a Conventional Glass & PV Glass (Professional Experience, OnyxSolar, 2019, p. 13)

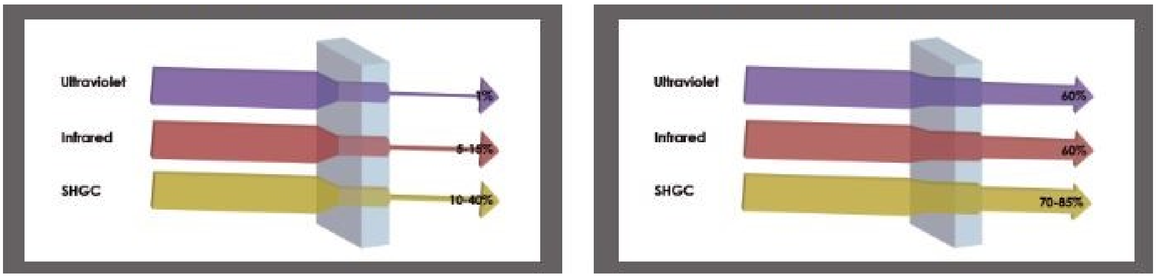


Figure 50: Infiltration of the Natural Light (Professional Experience, OnyxSolar, 2019, p. 15)

Table 04 : Comparaison between PV glasses & PV modules (Professional Experience Book OnyxSolar, 2019, p. 15)

	ONYX SOLAR®	LOW-E GLASS	CONVENTIONAL GLASS	CONVENTIONAL PV MODULE
Selective IR Filter	✓	✓	✗	✗
Selective UV Filter	✓	✓	✗ *	✗
Solar factor / SHGC	✓	✓	✗	✗
Natural lighting	✓	✓	✓	✗
Thermal performance U < 2 W/m²K U< 0,35 BTU/hft²F°	✓	✓	✗	✗
Acoustic performance	✓	✓	✓	✗
Electricity generation	✓	✗	✗	✓
Aesthetic integration in buildings	✓	✓	✓	✗

* The UV filter can only be achieved by laminated glass.

3.3.2 Characteristics & Efficiency of Amorphous PV Glass

Choosing amorphous glass instead of silicon glass, since we need maximum visibility and natural lighting in the building and serve as a PV Generator[34].

Figure 51: Advantages of using PV Glass (Professional Experience Book, OnyxSolar, 2019, p. 13)

3.3.2.1 Transparency Level

The company offers 3 types of transparency grades or a dark, of course dark is more efficient but in our case we choose low Transparency. Since higher transparency means losses in PV glass performance, we get by that 40wp/m^2.

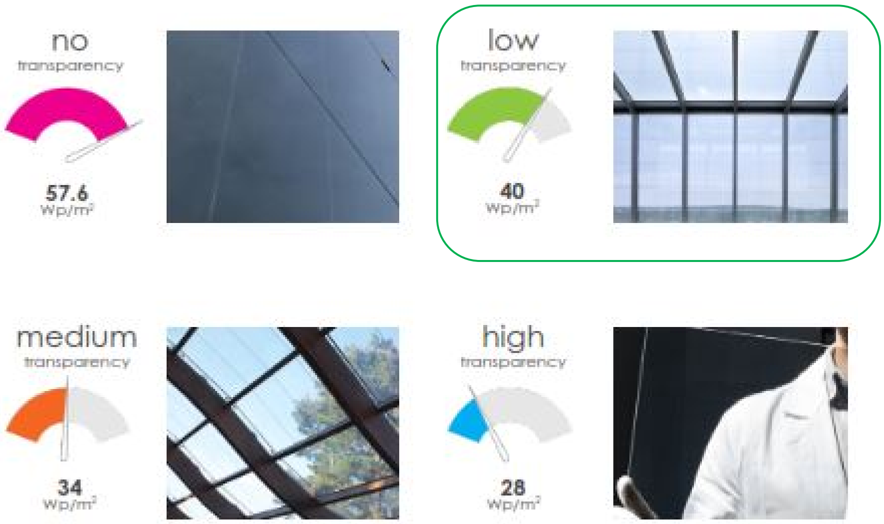


Figure 52: The Efficiency of Amorphous PV Glass (Professional Experience Book, OnyxSolar, 2019, p. 17)

[34] To learn more on how to return your entire building as a PV Generators please refer to Appendices 01

3.3.2.2 Size and Shape

Offering a sufficient size for buildings in standard dimensions reaching 4m high (x) 2m wide. Since the commercialization made on demand, manufacturing offers customized dimensions and shapes related to the customer's needs and orientation.

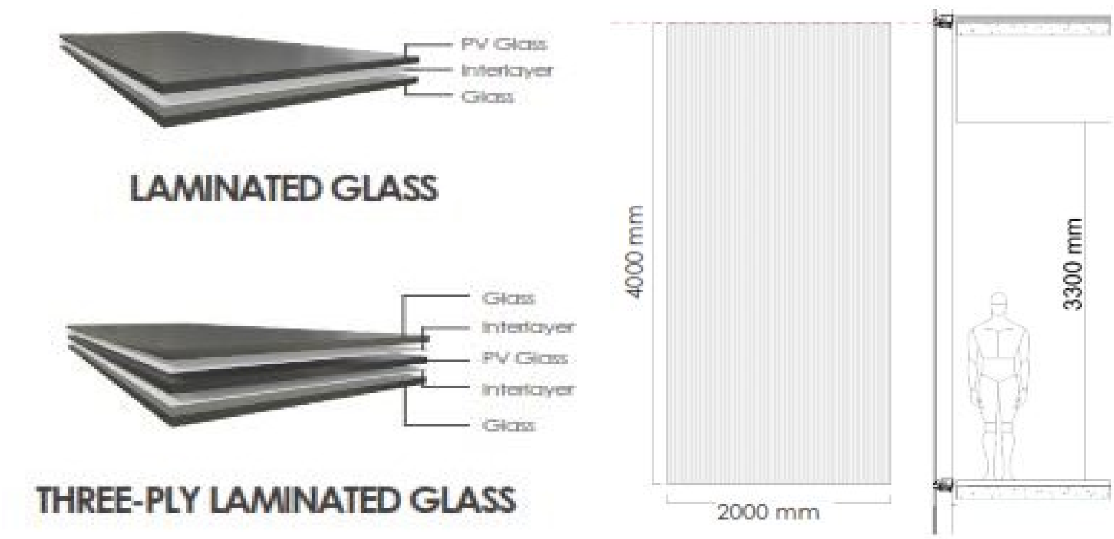


Figure 53: Shape and form of PV Glass (Professional Experience, OnyxSolar, 2019, p. 21)

Chosen thickness for testing is **4T+3.2+4T** [35]. The following table for illustration:

Table 05: Thickness Configuration (OnyxSolar.com, 2022a)

THICKNESS CONFIGURATION (mm)**	**SHGC**	**U value m^2**	**U value ft^2**	**External Light Reflection**	**Transparency**	**Peak Power**
	%	W/m^2K	Btu/h ft^2 F	%	%	(Wp/m^2
3.2+4	34%	5,7	1.00	7,6%	20,0%	34
6T+3.2+6T*	**32%**	**5,2**	**0.92**	**7,3%**	**20,0%**	**34**
6T+3.2+6T/12Air/6T	14%	2,7	0.48	7,3%	20,0%	34
6T+3.2+6T/12Air/6T low-e	12%	1,6	0.28	7,3%	20,0%	34
6T+3.2+6T/12Argon/6T low-e	12%	1,2	0.21	7,3%	20,0%	34
6T+3.2+6T/12Argon/4/12Argon/6T low-e	12%	1,0	0.18	7,3%	20,0%	34

From this table we conclude that the material and gas used in-between external glass layers matter for less thermal losses and more envelope efficiency.

[35] T= Tempered glass
* These values are valid with minimum changes in thickness settings, such as 4T + 3.2 + 4T instead of 6T + 3.2 + 6T and 4T + 4T, 8T + 8T instead of 6T + 6T,
** The thickness of the inner glass layer does not change the U value, so both 6T and 4 + 4 are valid
Retrieved from (https://www.onyxsolar.com/product-services/technical-specifications).

3.3.2.3 Customizable Colors

Customizing the building based on the designer choice, made possible using advanced technology they brought 16 million gradients mixing of all the spectrum colors.

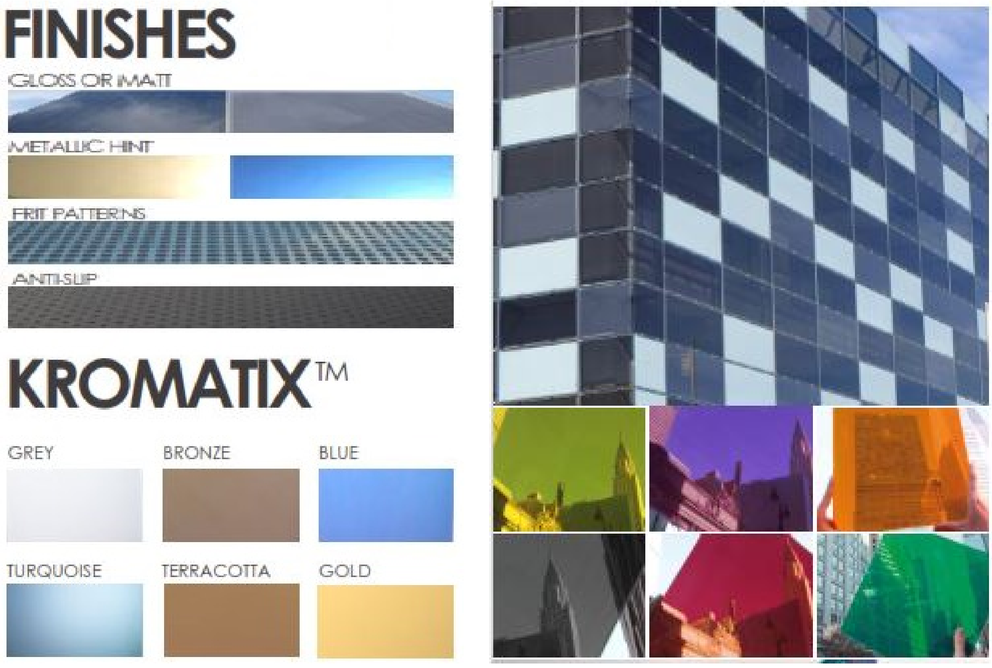


Figure 54: PV Glass Colors (Professional Experience, OnyxSolar, 2019, pp. 20–21)

3.3.2.4 Junction Type of PV Glass

Each PV glass modules comes with a Junction box connecting the PV glass to the system.

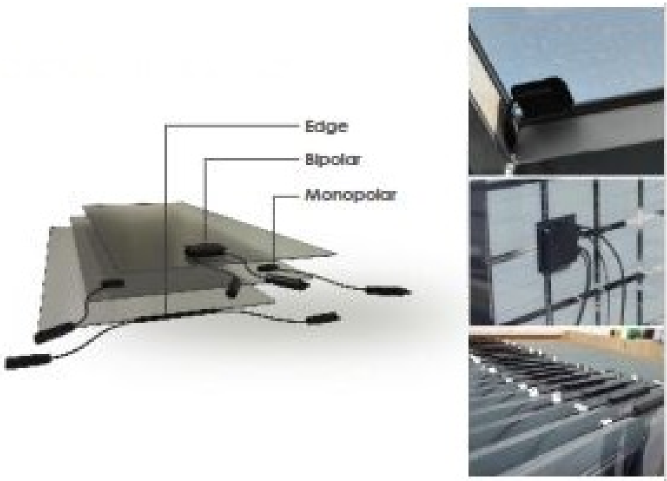


Figure 55: Junction of PV Glass (Professional Experience, OnyxSolar, 2019, p. 21)

3.3.2.5 Optical and Thermal Properties

PV glass surpasses conventional glass properties while it can be enhanced for better performance. "*The solar factor, also known as "g-value" or SHGC, is the key to achieve thermal comfort in any building. The company Thin-Film glass displays a solar factor that ranges from 10% to 40%, and makes it an ideal candidate to achieve control over the interior temperature.*" U-Values rages according to the architectural specifications, following designer orientation. Offering single laminated, double and triple glazing, Air and Argon chambers, and other configurations (OnyxSolar.com, 2022b).

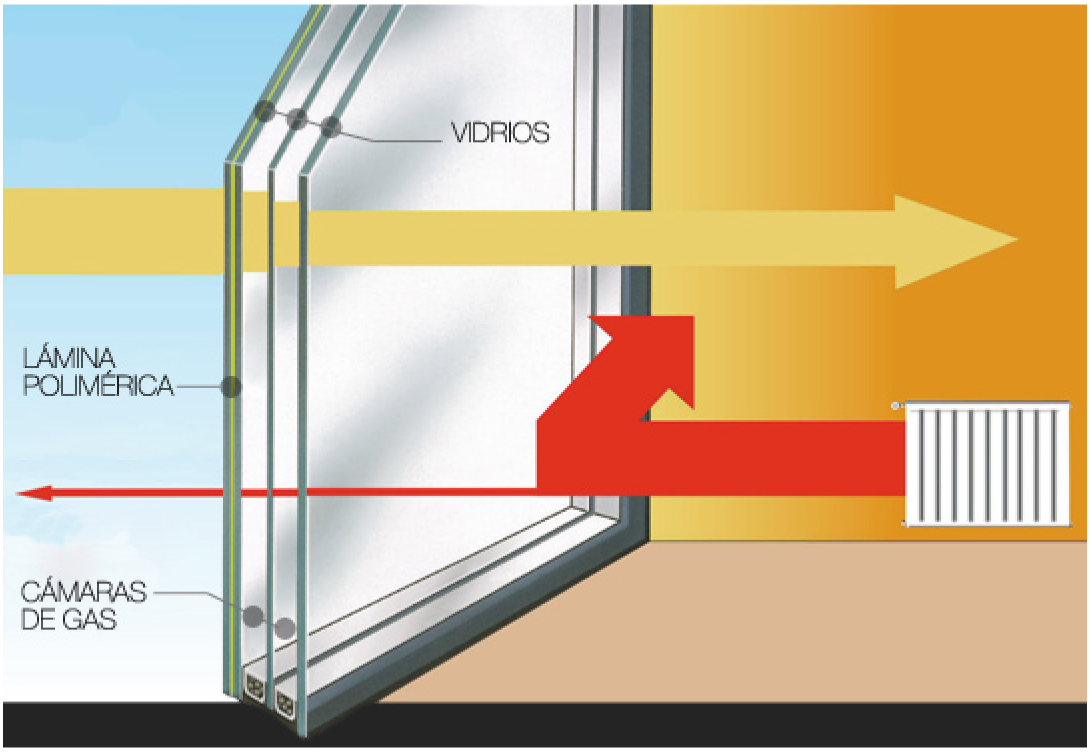


Figure 56: Optical & Thermal Properties of PV Glass (OnyxSolar.com,12/09/2022)

Calculating the U value[36] (or thermal transmittance) of our PV glass system. This indicates « the quantity of heat that can be lost through a glazed structure. Relating to energy efficiency, the lower the U value is, the greater the thermal insulation is and therefore the greater efficiency level. » (OnyxSolar.com, 2022b). In the next part will be calculating the different energetic efficiency performance indicators.

[36] Using this link for online calculation: (https://www.onyxsolar.com/u-termical)

3.4 Energetic Performance

To simplify the calculation and comparison task, we chose to concentrate only on one part of the building. That is the entrance of the new praying hall. Then we can generalize the results.

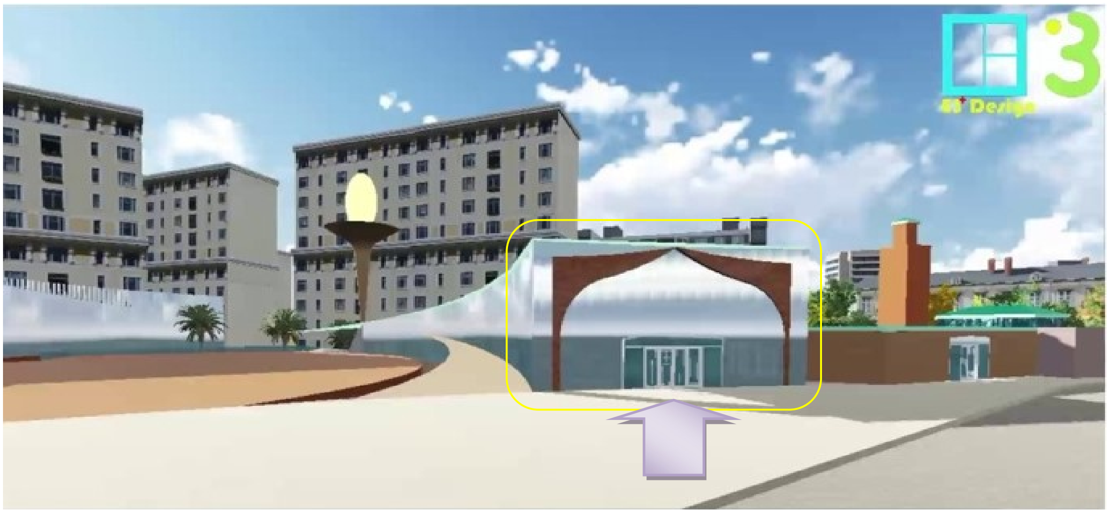


Figure 57: The Entrance of the New Praying Hall (E3+ Design, 2021)

Covering the façade of ($99.4m^2$), (7m x14.20m). Elevated with one meter above the roof as per ventilated façade requirement, we get ($112m^2$), (8m x 14m). Using the highest dimension of PV Glass: 4m (x) 2m, to reduce the cost of shipping and handling. We get fourteen (14) panels as shown in the figure below.

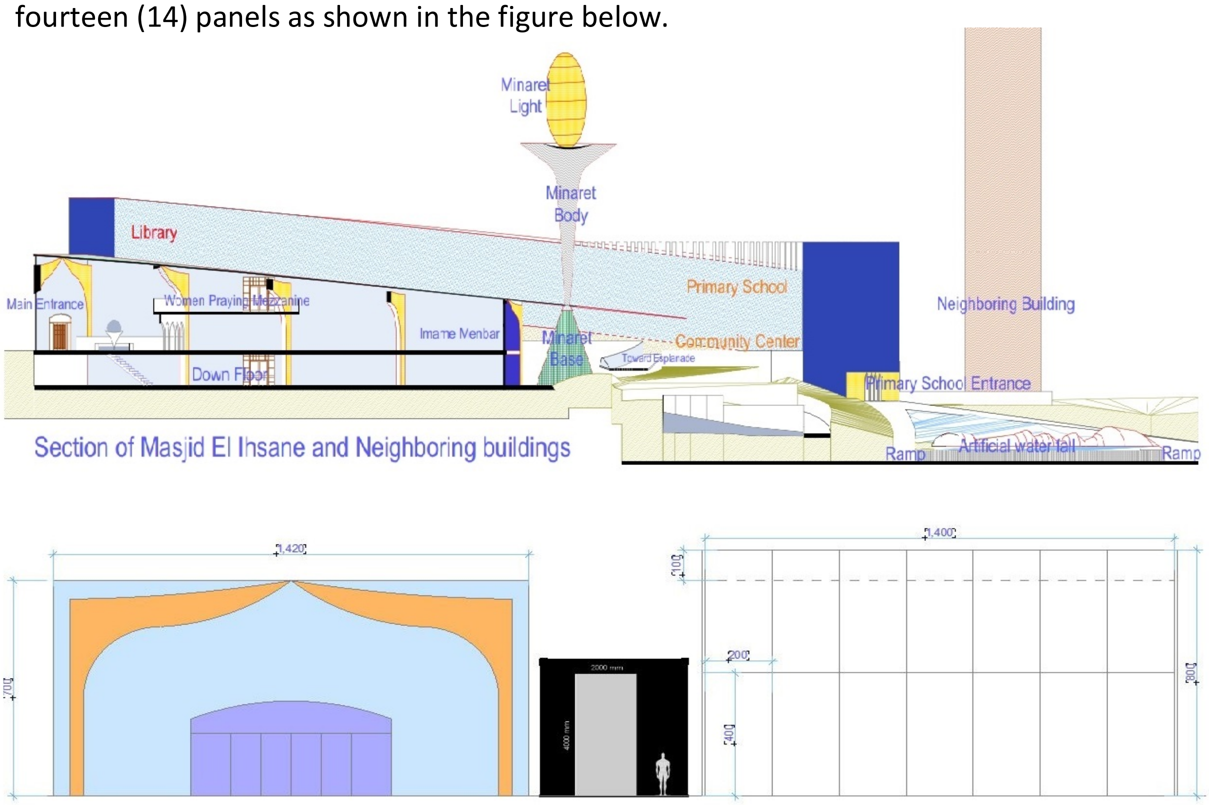


Figure 58: Details and Section of the Praying Hall and Entrance (E3+ Design, 2021)

3.4.1 Calculate the Glazing Thermal Transmission (U)[37]

In Algeria U ≤ 1.8 $w/m^2 k$ is tolerated and recommended by APRUE and must be validated from CNERIB[38] research and tests center. So we intend to have less than 1.8 w/m^2k. Details will be provided in the following table and for details a screen capture of results from the company website is provided, please refer to Appendices 02.

Table 06: Characteristics of PV Glass Panel (Author, 2022)

Characteristics	Quantity	Details
Tilt	90°	Vertical
Chambers	1	Air
Encapsulant Sheets Thickness	1	0.38 mm
Glass Panes	3	4T+3.2+4T (mm)

Results

Figure 59: The Results of the Thermal Transmission (U) (OnyxSolar.com, 2022)

The results shows with the indicated characteristics we get a 1.6 W/m^2K and it's acceptable according to Algerian government recommendation from APRUE. Continue next to estimate photovoltaic capacity of the amorphous silicon system.

[37] Using this link for online calculation: (https://www.onyxsolar.com/u-termical)
[38] CNERIB : National Center of Studies and Research Integrated to Building (http://cnerib.edu.dz)

3.4.2 Photovoltaic Estimation

Photovoltaic estimation is an integrated online tool to recapitulate gained advantages from installing PV glass technology and measure the environmental impact. We indicate the information related to our project as shown in the figure below:

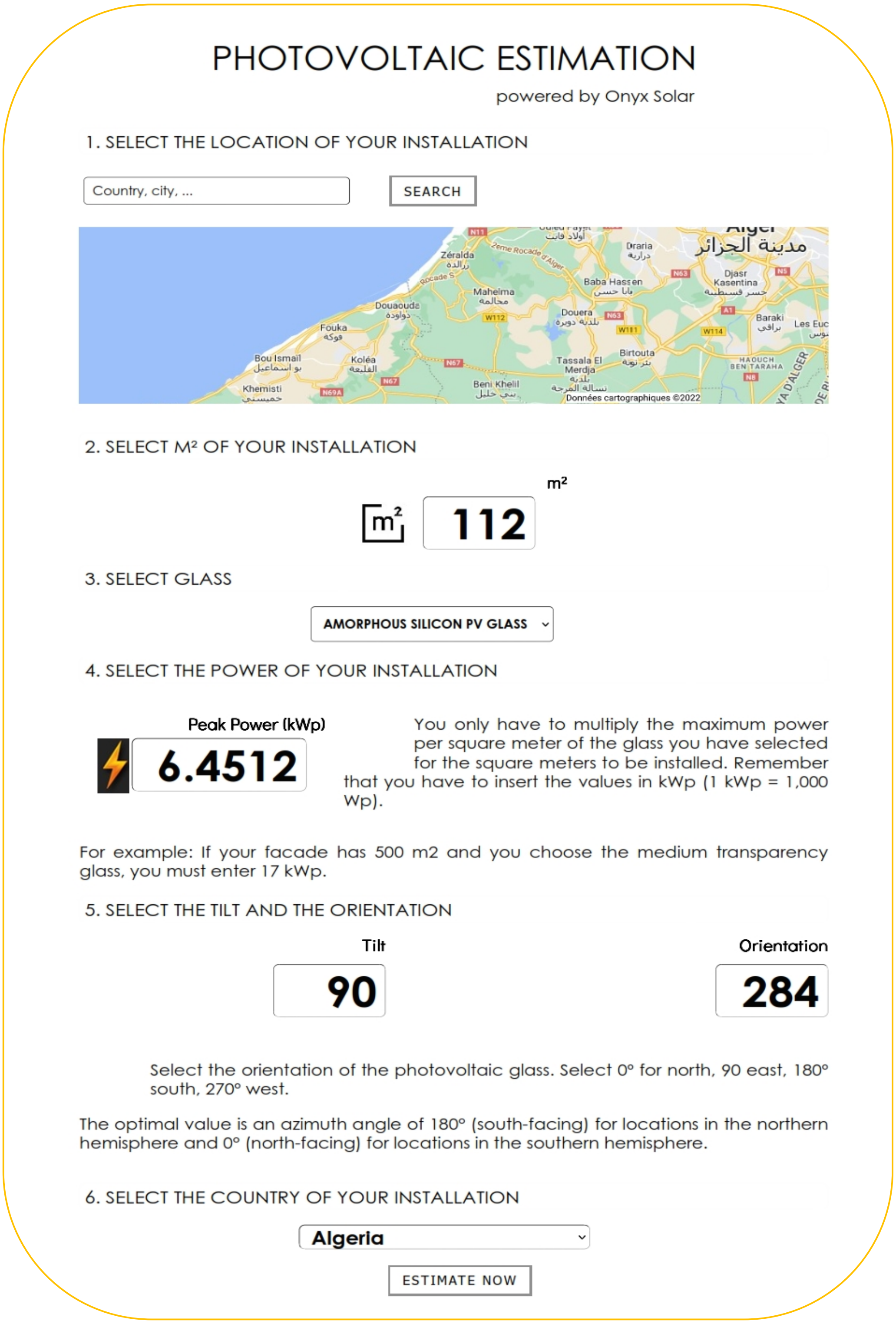


Figure 60: Photovoltaic Estimation Information Input (OnyxSolar.com, 2022)

Benefiting from the calculation tool in the company website[39]. Results showing how much are encouraging and appreciated even small steps toward sustainable living.[40]

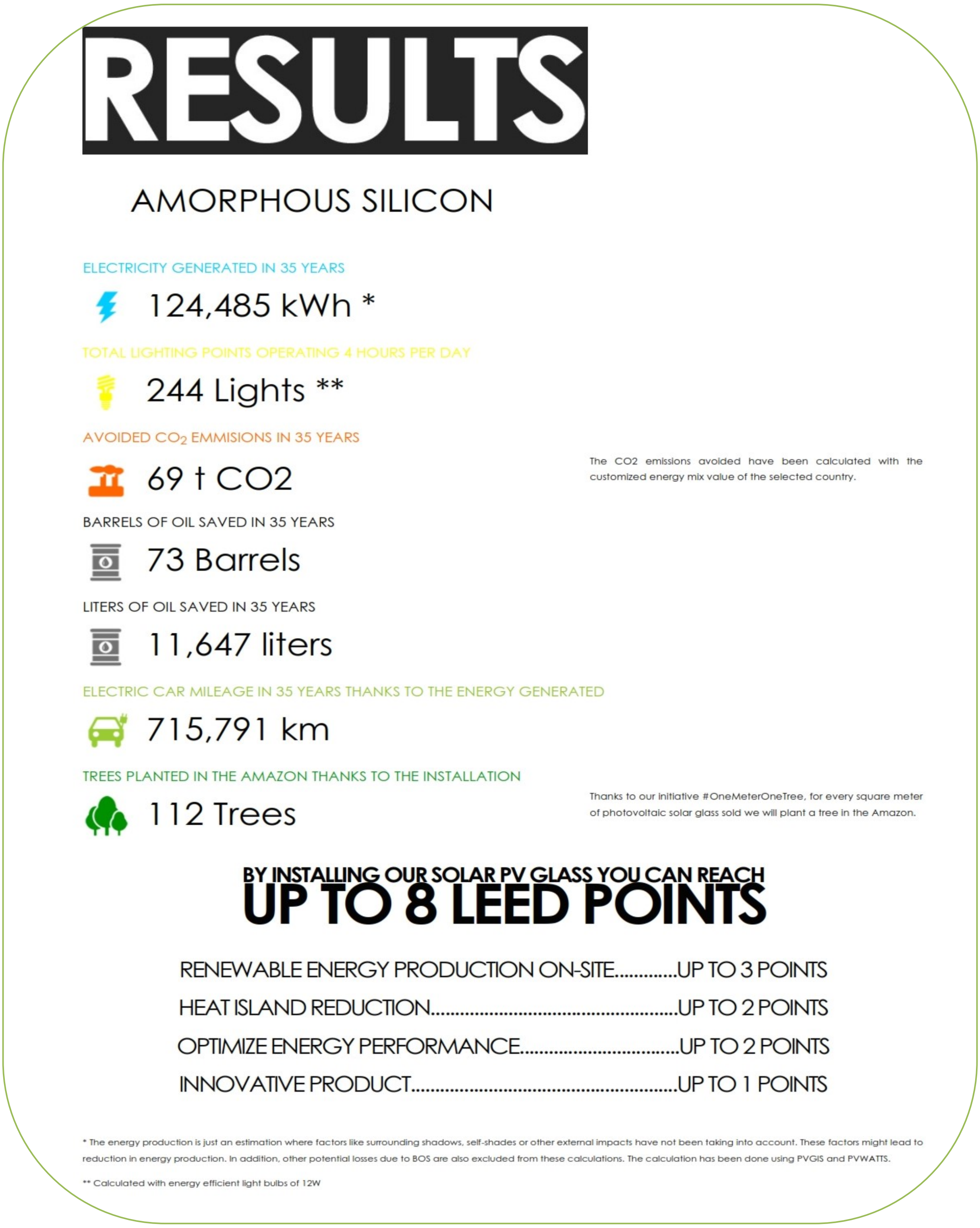


Figure 61: The Results of Simulation for the Photovoltaic Estimation (OnyxSolar.com, 2022)

[39] Photovoltaic Estimation Tool Online (https://www.onyxsolar.com/photovoltaic-estimation-tool)
[40] For the detailed monthly results please refer to Appendices 03.

3.5 Project Cost Breakdown

The costs of the project will be based on the basic dark PV Glass Product with no transparency. Whereas in the previous section we indicated more suitable specification for environmental requirements and the prices could be higher.

3.5.1 Product Purchase

Since prototype made based on principal façade (112m^2). And since both the Masjid Project and Community Center with Primary School proposed to be covered with PV Glass. Then it will surely exceed the **(4000 m^2)** required to benefit from this reduced price of **(109.13€).** Actually, this is the price of dark PV glass and its rising gradually for more transparency levels, but calculation will be on the minimum to facilitate implementation. Otherwise, in reality we recommend using mixture of Amorphous and Silicon PV Glass. Where the Amorphous will be just covering the windows areas.

Table 07: Price of Basic PV Glass (OnyxSolar, 2019)

PHOTOVOLTAIC GLASS FOR FAÇADE, CANOPY, BACKYARD WALL									> 4.000 m^2 > 180 boxes	
Colour	Finish	Size	Thickness	Pieces/box	Box size	Box weight	Peak Power	Reference	€/m^2	€/Piece
Black	Solid	1245x635 mm	3+4 mm	34	1380x680x860 mm	600 kg	46 Wp	034-CN-1245x635001	109,13	86,21

We summarized the whole procedure including customs taxes in the following table:

Table 08: The Purchase Price of PV Glass (Author, 2022)

Designation	Unity	Price	Quantity	Total (€)	Total (Dzd)[41]
PV Glass	M^2	109	112	12 208	1.786.152,48
Shipping	Kg	1	3360	3 360	491.601,60
				18 928	**2.277.754,08**
				Taxes (5%)	89.307,62
				Total	**2.367.061,70**

- ✓ The manufacturing is made after the purchase, which means zero stock,
- ✓ Customized following collaborator requirements,
- ✓ Guarantying that the product reaches the customer with manufacturer price,
- ✓ Taxes are reduced based on the government intention to support investments in some sectors for small and medium companies.

[41] Exchange rate for 16/09/2022 from Algeria National Bank (BNA) 1€ = 146.31 Dzd (https://www.bna.dz)

3.5.2 Shipping and Handling

We did go with the largest size of (4m x 2m) to reduce shipping and handling costs, especially for sensible products like glass. Looking first at the security measures in the shipping box.

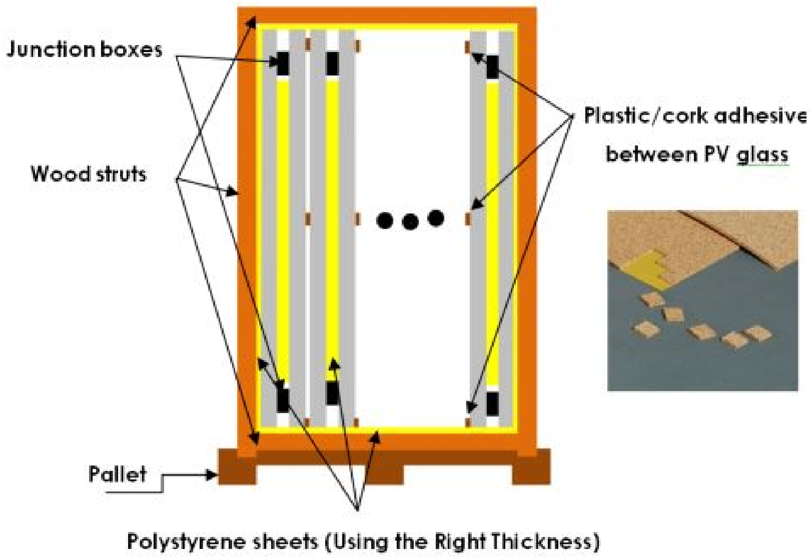
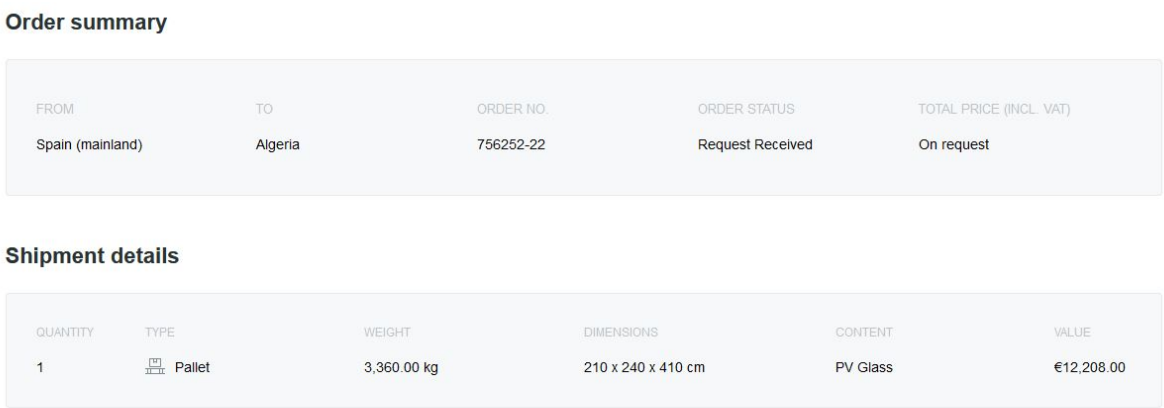


Figure 62: Shipping Box Security Measures (Product Manual, OnyxSolar, 2020, p. 28)

Next Step is to find the best valuable shipping company, with extra precautions for sensible products like glass, reflected on higher fees been charged. Not choosing a close date of pickup makes it look like an urgent situation causing rise of fees. We prepared the order based on detail in the product manual (OnyxSolar, 2020).



Order summary

FROM	TO	ORDER NO.	ORDER STATUS	TOTAL PRICE (INCL. VAT)
Spain (mainland)	Algeria	756252-22	Request Received	On request

Shipment details

QUANTITY	TYPE	WEIGHT	DIMENSIONS	CONTENT	VALUE
1	Pallet	3,360.00 kg	210 x 240 x 410 cm	PV Glass	€12,208.00

Figure 63: Shipping Order Summary (Eurosender.com, 2022)

After contacting a shipping company, they appologies for not serving the route of Spain to Algeria. For that we would estimate the cost arround 1000€ to standard shipping, and higher around 3000€ for more security measures. To simplify estimated at 1€/kg which means 3360€.

3.5.3 Installation: Construction Method of Ventilated Facade

Chosen the Ventilated façade since its more efficient and auto aeration as shown in the following figure (Ramseystone.com, 2022).

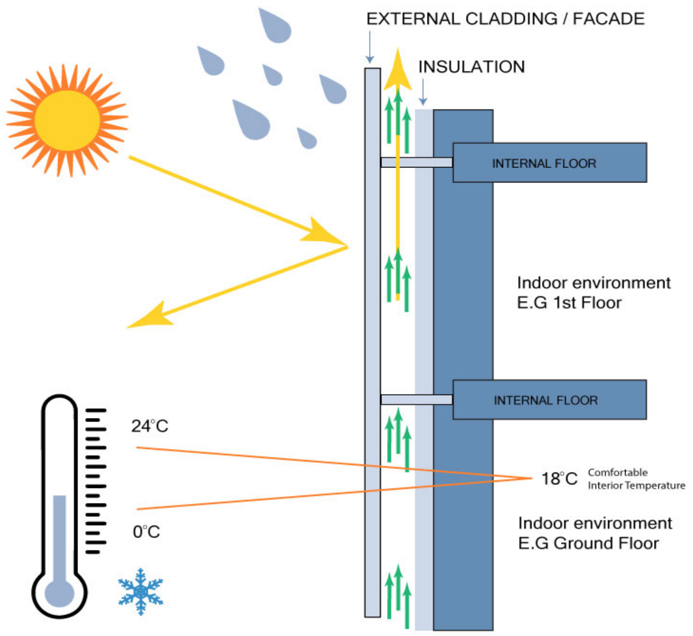


Figure 64: Ventilated Facade (Ramseystone.com, 2022)

The PV Ventilated facade needs a careful look on structural details for primary and mounting structure. The panel needs to fit while reserving an invisible spot for electrical cables.

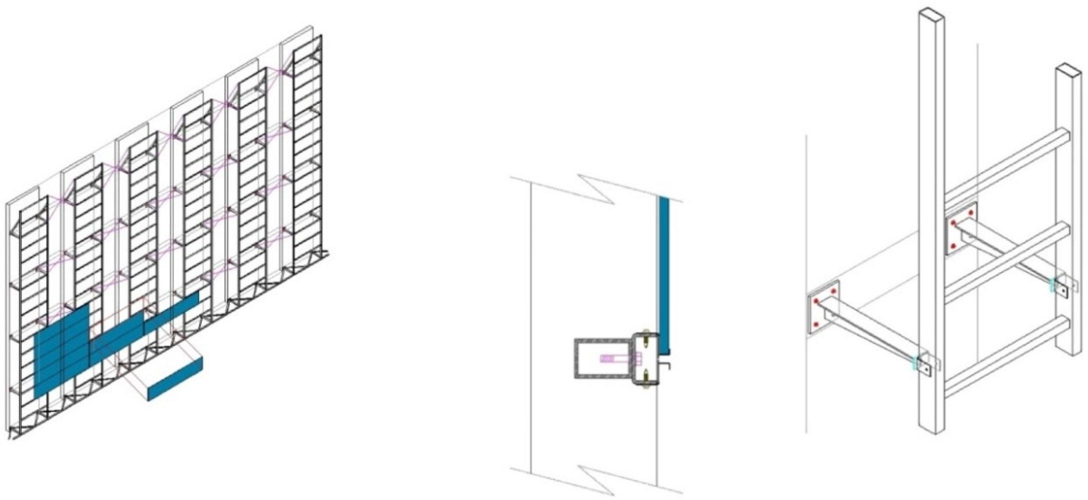


Figure 65: Construction method of the Ventilated Façade (Product Manual, OnyxSolar, 2011)

3.6 Return on Investments

Based on the company calculation the client will be on profit after one year of exploitation of the system. Making reference of Madrid (Spain) electricity price[42] basically it costs 1.25€ to cover the implementation of the photovoltaic glass project. Starting right away to economies in energy to be self efficient building (OnyxSolar, 2019).

In Algeria right now the price of subvention offers competitive price for regular energy public supplying channel. This policy doesn't encourage people to switch toward using renewable technology at home. But, with continue rising of the bills and maintenance fees, we can talk about sooner energetic transition in our country. Meanwhile the multinational with intention of transferring a green image and showing supports for the United Nations sustainable development goals. They will lead the way in acquiring more green techs.

Our idea will be covering many aspects:

1. **First:** Comparing the price of normal facade with standard silicon PV system to a PV glass facade,
2. **Second :** The energetic efficiency between the two previous solar systems,
3. **Third:** The thermal isolation of the two systems that we saw previously.

3.6.1 Comparison with Conventional glass Project Cost

- Standard curtain wall for double glass with gas costs between:

2 240 000,00 Dzd to **3 360 000,00 Dzd,** with good structure; ……………… (1)

- To compare and since the traditional do need a separated PV system that cost around: **280 000,00 Dzd** to **420 000,00 Dzd,** for each 1kw; ……………………………… (2)
- Calculating based on the production capacity we found in the PV system glass of (112m^2) every (m^2) produce (40w) per hour, and Algeria benefits from more than 2000 hours yearly which means 5.5hours a day.

112x 40= **4.48 Kw** x5.5h = **(24.64 Kw)** generated per day and **(8 960.00 Kw)** yearly…… (3)

[42] Electricity price in Spain: 0.29€ (https://electricityinspain.com/electricity-prices-in-spain)
Comparing to Algeria: 5 Dzd = 0.035€

- The PV glass system generates (4.48kw). To compare we need to calculate the same power generation capacity for silicon panels. Of course quality matters so, we chose the best PV system of 420 000 Dzd x 4.48 = **1 881 600,00 Dzd** ………………………….…… (4)
- From the addition of (1) and (4) the price of Silicon PV System with double glass facade: 3 360 000 + 1 881 600 = **5 241 600,00 Dzd** ……………….………………… (5)
- For more reliable work and less accident Scaffolding costs: **1 332 431,67 Dzd** ………. (6)

To simplify the comparison, we summarized the information in one place:

Table 09: Comparison of Energy Cost in Algeria (Author, 2022)

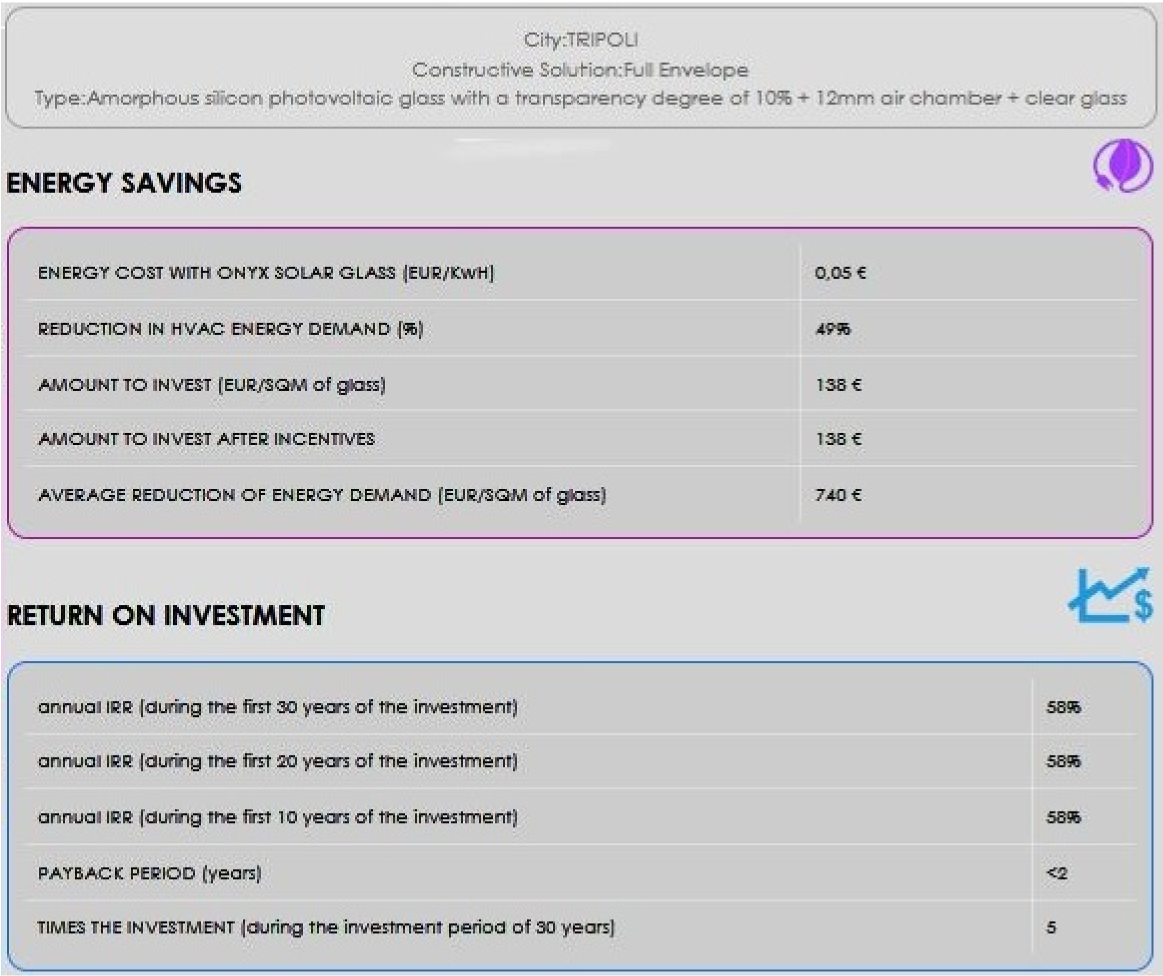
Designation	**Glass PVS**	**Silicon PVS**	**Public Network Household**	**P.N Masjid ($112m^2$)* 3Ph***	**P.N Building ($1000m^2$)* 3Ph***
Panels	2 367 061,70	5 241 600,00	0,00	0,00	0,00
Scaffolding	1 332 431,67	0,00	0,00	0,00	0,00
Installation	2 380 000,00	3 630 000,00	**12 000,00	**18 000,00	**18 000,00
Sub Total (1)	**6 079 493,37**	**8 871 600,00**	**12 000,00**	**18 000,00**	**18 000,00**
Price of energy and maintenance fees[43]			** Estimated (Source: Belghith Abderrehmane, Tarek Ben Abid Sonelgaz ,2022)		
Monthly	0,00	0,00	5 000,00	10 000,00[(44)]	50 000,00
Yearly	0,00	0,00	60 000,00	120 000,00	600 000,00
10 Years	240 000,00	260 000,00	600 000,00	600 000,00	6 000 000,00
35 Years	**570 000,00**	**670 000,00**	**2 100 000,00**	**4 200 000,00**	**21 000 000,00**
* Comparing to PV glass facade of 112m, 1000m respectively.[45]				***Three-phases electricity meter	
Total	**6 649 493,37**	**9 541 600,00**	**2 112 000,00**	**4 218 000,00**	**21 018 000,00**

The similar daily consumption to PV glass of **4.48 kw** would cost you from the network **22.4 Dzd**, or **0,157€**. This negligible amount shows an efficiency that is unreachable from the considerable amount invested in PV system. The choice between **6.65m dzd** or **10k dzd** monthly is incomparable at first sight. But after 35 years of billing you would pay two thirds (2/3) of the cost for the same consumption, or surpass that to triple (x3) in the building of $1000m^2$. In that case the return on investments of PV System can be tangible and is actually obvious to consider its implementation. Knowing traditional energy prices are going continuously higher and renewable getting more affordable by time.

[43] Maintenance fees of PV system are generally used for replacing batteries average life cycle of (5) years.
[44] The bill price estimated on the building consumption, for furthermore details take in consideration the rising prices of electricity, also includes gas since a sufficient PV system could replace the use of natural gas by efficient electrical equipments, central cooling and heating system or solar thermal Energy (STE).
[45] For suburb areas to connect to public network we can add an average of 220 000,00 Dzd cost of connection to the network that can exceed 5million Dzd in case of substation electrical transformer.

3.6.2 Energy Savings

The company doesn’t provide a return on investment study for Algiers[46]. For that we retrieved data from Tripoli[47]. That is separated from Spain by Mediterranean Sea like us, same shipping rote and has many other similarities to Algerian Market.



City:TRIPOLI
Constructive Solution:Full Envelope
Type:Amorphous silicon photovoltaic glass with a transparency degree of 10% + 12mm air chamber + clear glass

ENERGY SAVINGS

ENERGY COST WITH ONYX SOLAR GLASS (EUR/KWH)	0,05 €
REDUCTION IN HVAC ENERGY DEMAND (%)	49%
AMOUNT TO INVEST (EUR/SQM of glass)	138 €
AMOUNT TO INVEST AFTER INCENTIVES	138 €
AVERAGE REDUCTION OF ENERGY DEMAND (EUR/SQM of glass)	740 €

RETURN ON INVESTMENT

annual IRR (during the first 30 years of the investment)	58%
annual IRR (during the first 20 years of the investment)	58%
annual IRR (during the first 10 years of the investment)	58%
PAYBACK PERIOD (years)	<2
TIMES THE INVESTMENT (during the investment period of 30 years)	5

Figure 66: Simulation for Return on Investment for Tripoli (OnyxSolar.com, 2022)

- Comparing to our findings, producing electricity is better with PV systems (0,05€) then grid electricity in Europe; but, to Algerian market, the public network electricity still considerably cheaper with (5 Dzd equivalent of 0,035€);
- Based on the given data installation costs in Algiers[46] are higher comparing to Tripoli.

Table 10: Amount to Invest per Square Meter (SQM)

PV Glass System	Silicon PV System	Tripoli (138€)
54 281,19	**79 210,71**	**20 190,78**

[46] Instead a separated feasibility study for Algiers is provided by the company (Valverde, 2022),
[47] For other cities please refer to the following link (https://www.onyxsolar.com/return-of-investment).

3.6.3 RECOMMENDATIONS

For a successful project we recommend:

- ✓ ***Creating a company*** following the incitation of investments laws and regulations;
- ✓ ***Mastering the Project,*** *by parenting with reliable collaborators and partners;*
- ✓ ***Planning of the operation,*** go through details and organize before starting;
- ✓ ***In the design,*** we use mixture of Amorphous and Silicon PV Glass, where the Amorphous will be just covering the windows areas;
- ✓ ***Purchasing in bulk***, multi companies similar purchase in big quantities;
- ✓ ***Choosing Shipping company*** Carefully to handle the best this sensible product;
- ✓ ***Good scaffolding*** is an important security measure, for both facilitating the work and protecting the employees, even thou in our calculation we estimate that it is provided and included by the installation company. Attached in the Appendices 04 and 05 included an example of scaffolding specification and (BOQ)[48];
- ✓ ***Accredited professional Installers;*** new technology needs specific expertise, so don't hesitate to select top companies to handle the realization of the project;
- ✓ ***Ventilated Facade,*** using a chamber of 12mm, for both having the ventilated facade effect of refreshment and protection from direct explosion to exterior layer. either to use the last layer of simple glass will be sufficient from inside replacing the interior wall or outside as a protection for the Pv glass;
- ✓ ***Buying eco-friendly***, avoid energy-intensive equipments and choose those with A++ energy efficiency tag by APRUE, Led light bulb and other efficient equipments;
- ✓ ***Building envelop,*** plays a determinable role. Because whatever you put as measures to reduce the consumption will be vain, if your envelop had high thermal lose. The solution is to use thermal efficient materials in construction like PVC, wood, double wall of 30cm for exterior walls with 5cm of isolating material or best enclosure of air which is a great isolator;
- ✓ ***Intelligent Control System,*** Last but not least it's like intelligent home systems, where control systems can have an impact reducing the power consumption especially for equipments in standby mode. This point takes us to our next part of future development where we will discover the latest advancement in this field.

[48] (BOQ) : Bill of Quotation

3.7 Future Development

Promising future is waiting the field of energy with the intensive innovation of real efficient tech with affordable price, made us looking forward to its development.

3.7.1 Photovoltaic Glazing & Safety Glass

The picture demonstrates the technology used for PV modules with two options, back sheet layer which is the classical known technology or second glass. The development in this technology allowed introducing a second glass layer for protection. Where the difference between them is perceptible from the lifetime of the modules, which extended with second glass layer from twenty (20) years to thirty (30). Also there is possibility for third glass layer in curtain walls and ventilated facades (Naps Factory, 2019).

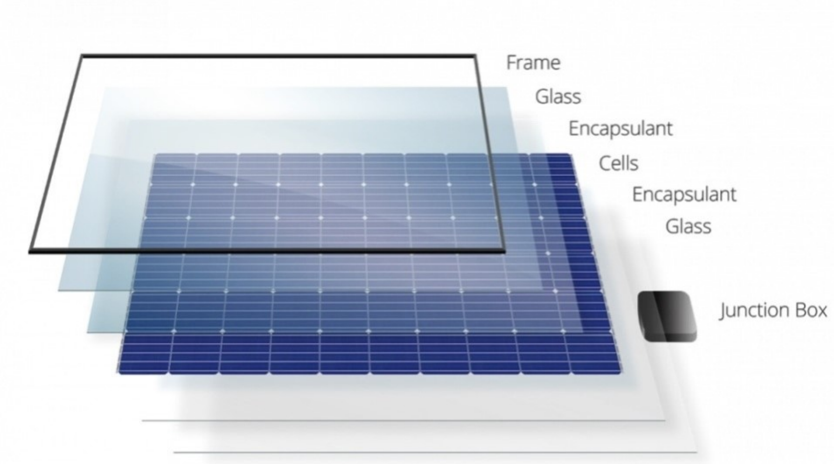


Figure 67: Photovoltaic glazing with encapsulated glass (napsfactory.com)[49]

Another breakthrough is the possibility to acquire multicolor crystalline layers with 17% to 18.3% of efficiency, with glass options from anti-reflective, mate to transparent also possibility of digital printing on the glass. All these innovation incites the architects and designers to the easy integration of these glass modules into all buildings (Naps Factory, 2019).

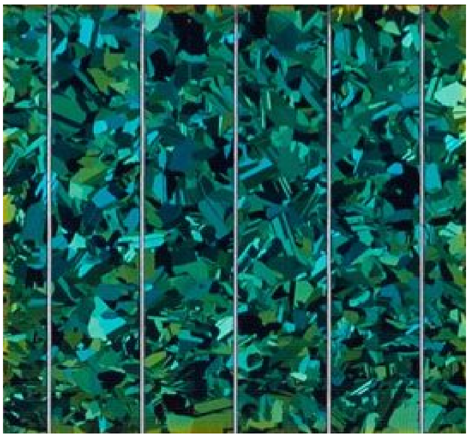


Figure 68: Colored solar cells (napsfactory.com)

[49] Source: (https://napsfactory.com/solar-modules/design-options), accessed on in /06/2022

3.7.2 Transparent Solar Panels

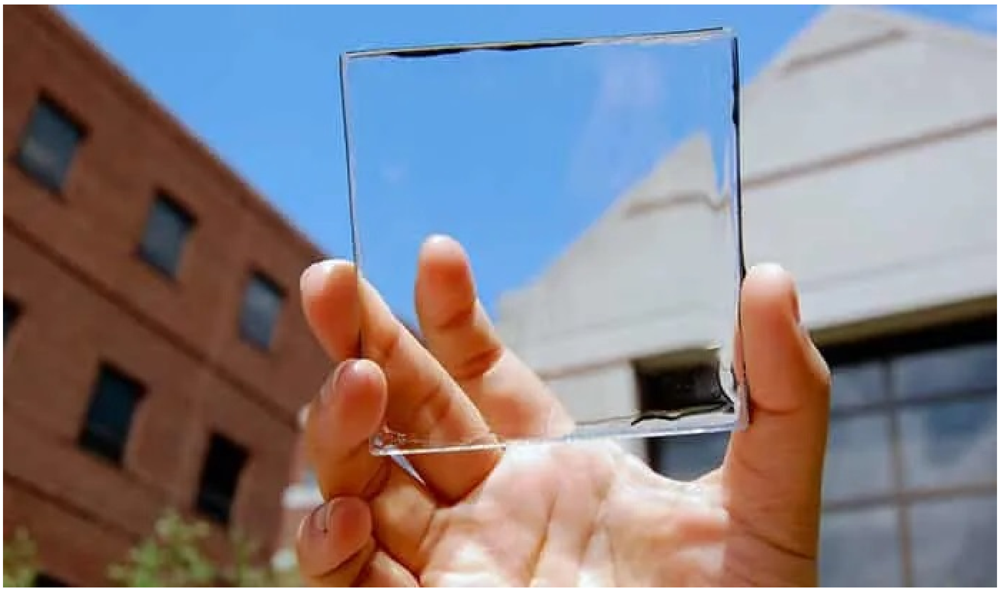


Figure 69: Transparent solar panels (solarmagazine.com)[50]

It is a transparent solar glass that could be a game changer in the world of photovoltaic technology. It could theoretically transform every surface to PV cell like windows, curtain walls and ventilated facades; even more it could be used with our Smartphone's, glass of cars replacing the traditional glass, preserving roof spaces or ground areas. This technology first developed by Michigan State University (MSU) in 2014 when they "*created the first fully transparent solar concentrator*", achieving full transparency by 2020 with a ten 10% efficiency.

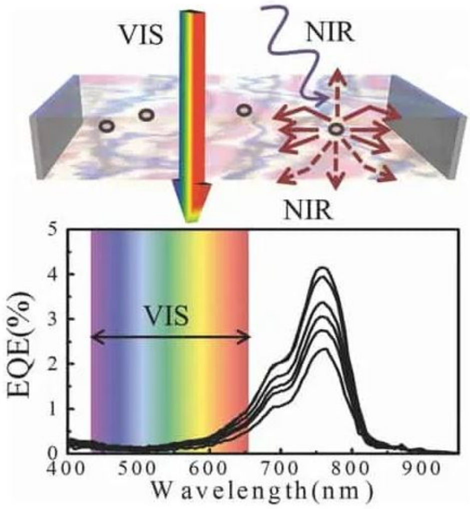


Figure 70: How do transparent Solar glass works? (Solar Magazine,2020),

Diagram by Extreme Tech

How does it work!? *The organic salts absorb UV and infrared, and emit infrared—processes that occur outside of the visible spectrum, so that it appears transparent* (SolarMagazine.com, 2020).

[50] Source : (https://solarmagazine.com/solar-panels/transparent-solar-panels)

3.7.3 Thin-film Photovoltaic Panel

Toshiba announced a power conversion efficiency of 15.1% for a 703 cm^2 polymer film-based Perovskite solar panel. The flexible and lightweight panel recommended for situations where traditional crystalline silicon modules are difficult to install.

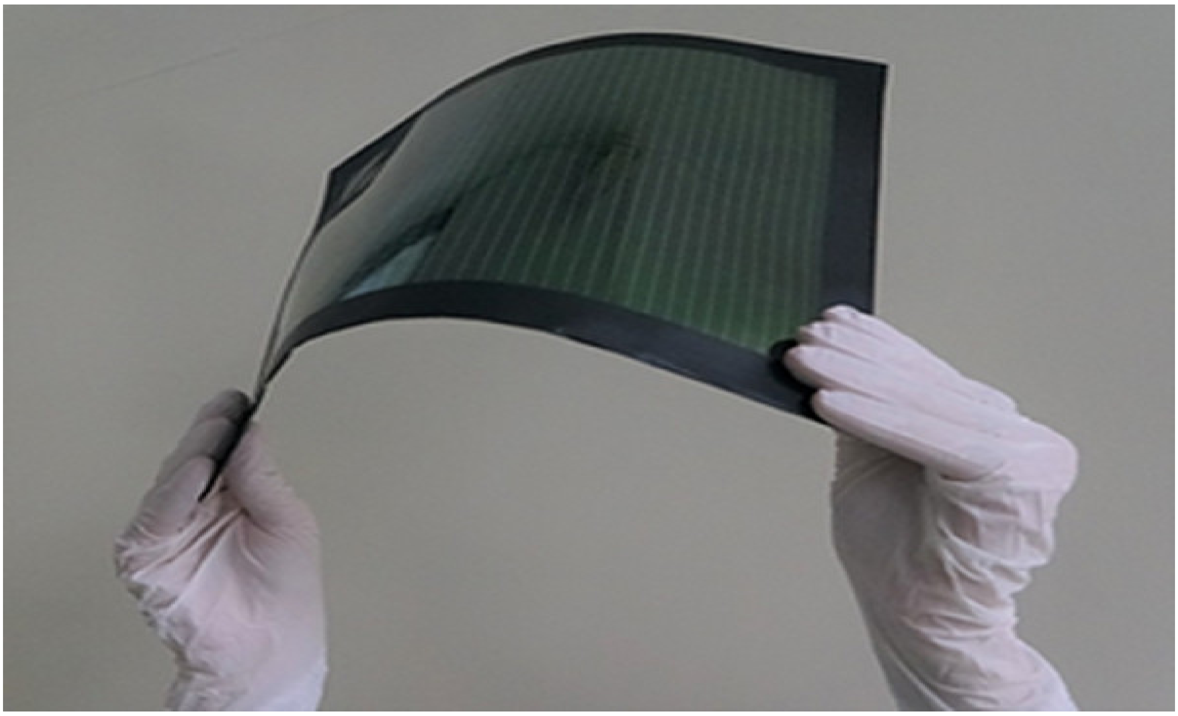


Figure 71: Thin-film photovoltaic panel (pv-magazine.com)[51]

The business stated that it intends to increase the module area to 900 cm^2 and reach efficiency close to 20%. If they made it Toshiba concluded they will reduce the production cost of perovskite photovoltaic modules to around $0.14/W," the study said (Emiliano Bellini, 2021).

In our next point we will explore more to understand this new technology of Perovskite, and its benefits that could revolutionize the way we use solar solutions in our daily life.

[51] Link source : (https://www.pv-magazine.com/2021/09/09/toshiba-achieves-efficiency)

3.7.3.1 Perovskite solar cells Technology

Perovskite materials are derived from a calcium titanium oxide mineral and were first discovered in 1839 by Russian mineralogist Lev Perovski. 10 years ago, a team of researchers in Japan debuted the first-ever application of perovskite for the production of solar cells (Gautam, 2021).

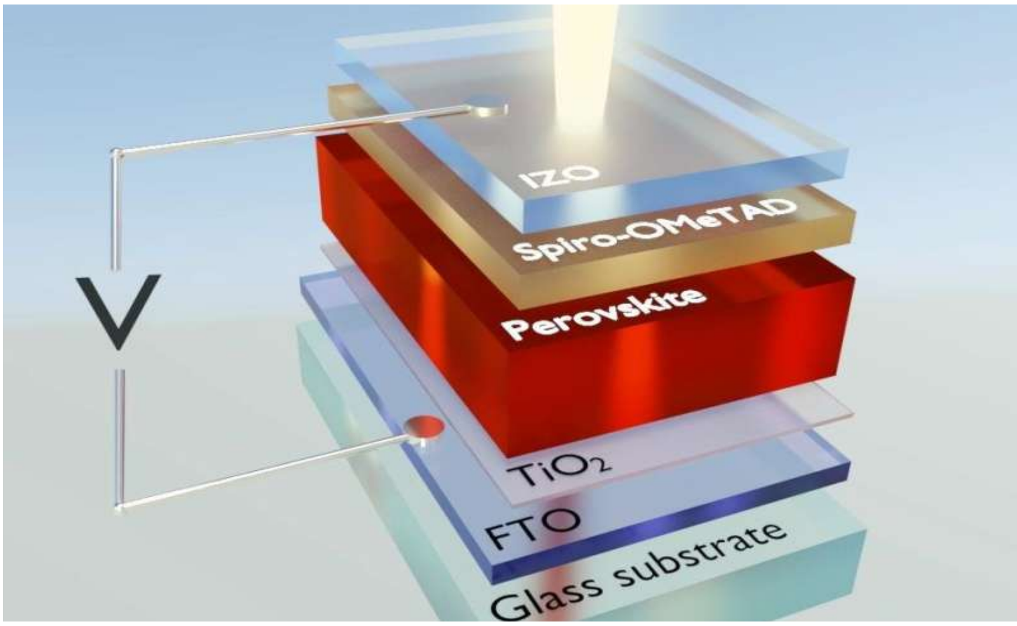


Figure 72: Perovskite solar cells technology components

The function of Perovskite solar cells as shown in the figure[52] above has been fundamentally understood by researchers at the Karlsruhe Institute of Technology. They discovered that "*bound states of electron-hole pairs can form during the absorption of light*". Perovskites are hybrid semiconductors that comprise both organic and inorganic components. When used, they combine excellent efficiency with low-cost production. The related research about these findings have been published in the journal *Applied Physics Letters* (Karlsruhe Institute of Technology, 2018).

[52] Source : (https://phys.org/news/2018-04-perovskite-solar-cells-efficient.html)

Cassey Crownhart from *MIT Technology Review*[53] showed that more recent series of laboratory tests have been conducted by US National Renewable Energy Laboratory[54] to develop materials stability (Crownhart, 2021).

Ninty five percent (95%) of today existing solar cells are silicon based. And to compete in the market Perovskites solutions are:

- Light, cheap and flexible;
- Could be used in many surfaces, printed or even painted;
- Where efficiency record reached over 25%, but in the production line it's now 10% produced by Saul Technologies Warsaw (Crownhart, 2021).

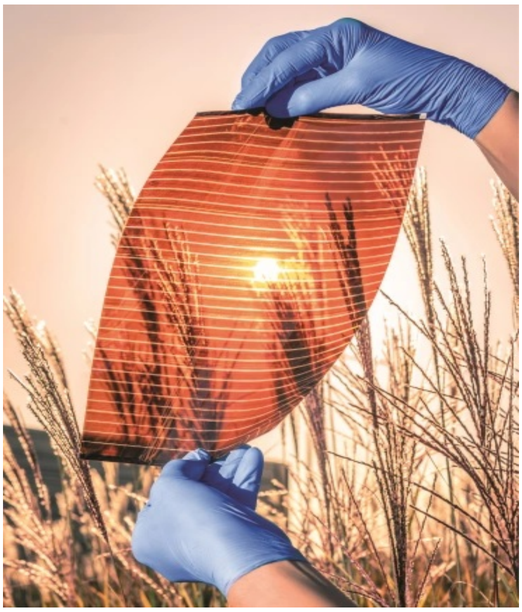


Figure 73: Perovskite solar cells (Saul Technologies)

Whereas *Oxford PV*[55] combines perovskite and silicon to create high-efficiency solar cells with 29.5% of efficiency (Bellini, 2021). That's because silicon absorbs light near the red end of the visible spectrum whereas, perovskites can be adjusted to absorb different wavelengths. Putting a layer of perovskite on top of silicon cells permits combination cells to outperform silicon alone (Crownhart, 2021).

Microquanta Semiconductor[56] Another manufacturer from China is trying to reach 100 megawatts of production. To increase product lifetime manufacturer trying to develop the product stability, which finds to struggle from oxygen and moisture. To prove viability and increase the lifetime to 25 years, they are following a series of tests called the ***IEC 61215*** for outdoor silicon cells (Crownhart, 2021).

[53] Source : (https://www.technologyreview.com/2021/06/29/1027451/perovskite-solar-panels-hype-commercial-debut)
[54] US National Renewable Energy Laboratory : (https://www.nrel.gov/index.html)
[55] Oxford PV : (https://www.oxfordpv.com)
[56] Microquanta Semiconductor : (http://www.microquanta.com/en)

3.7.4 Solar Coating

3.7.4.1 *Solar Cell by Spray Painting*

Researches in 2013 by Sheffield University Department of Physics and Astronomy[57] and the University of Cambridge shown the possibility of the application of active solar cells by spray-coating air based on a smooth surface. To reduce the manufacturing expenses and made this technology more accessible to users. This research open doors for more advancement to come in PV painting (University of Sheffield, 2013).

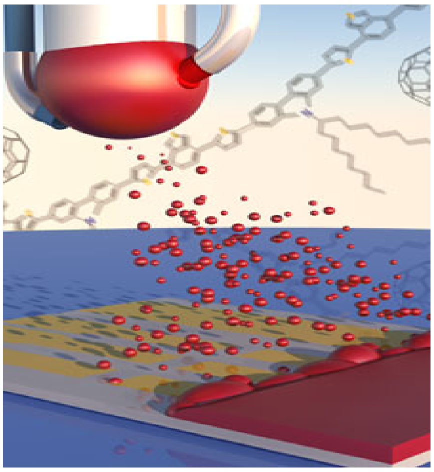


Figure 74: Solar cell by spray painting (University of Sheffield, 2013)

3.7.4.2 Quantum Dot Solar Cells (Photovoltaic Paint)

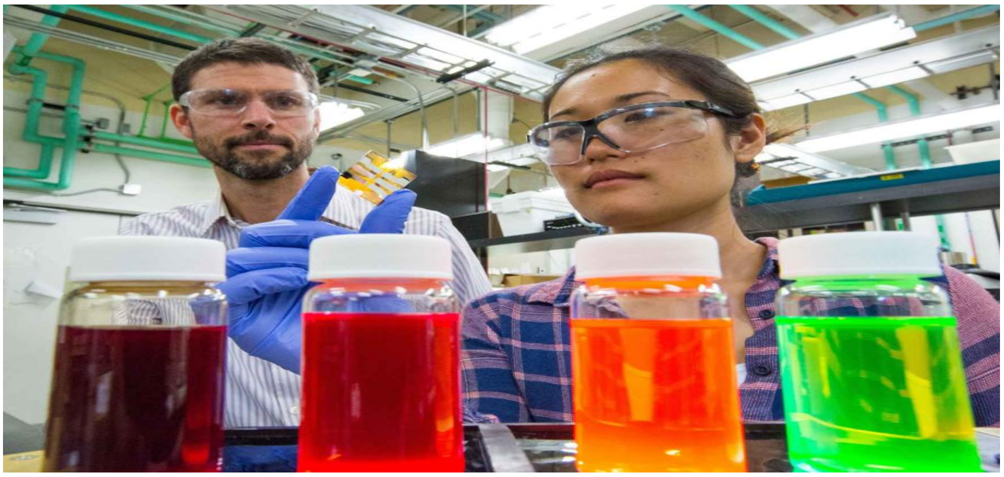


Figure 75: Scientists that have helped NREL set a new efficiency record of 13.4% for a quantum dot solar cell (nrel.gov)[58]

Photovoltaic paint is developed in Toronto University (Lavender, 2013). "*They are nanoscale semiconductors that can capture light and turn it into an electric current.*"(Gautam, 2021). University of Washington Scientists Elevate Quantum Dot Solar Cell World Record to (13.4%) (NREL, 2017)[59].

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[57] Source : (https://www.sheffield.ac.uk/news/nr/solar-photovoltaic-pv-spray-painting-lidzey-1.251912)

[58] Source : (https://www.nrel.gov/news/press/2017/scientists-elevate-quantum-dot-solar-cell-world-record.html)

[59] NREL: The National Renewable Energy Laboratory is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy LLC.

3.7.4.3 Solar Paint Hydrogen

The following year experts at RMIT[60] (Beresin, 2017). A partially supported study from ARC[61] started developing a solar paint that can capture water vapor and divide it to produce hydrogen, the cleanest form of energy as they stated. Even it might be utilized as a substitute to fossil fuels in fuel cells as well as traditional combustion engines. Discovery Project given to Professor Kourosh Kalantar-zadeh in 2014 (Connery, 2017). The research published at the journal of American Chemical Society (Daeneke et al., 2017).

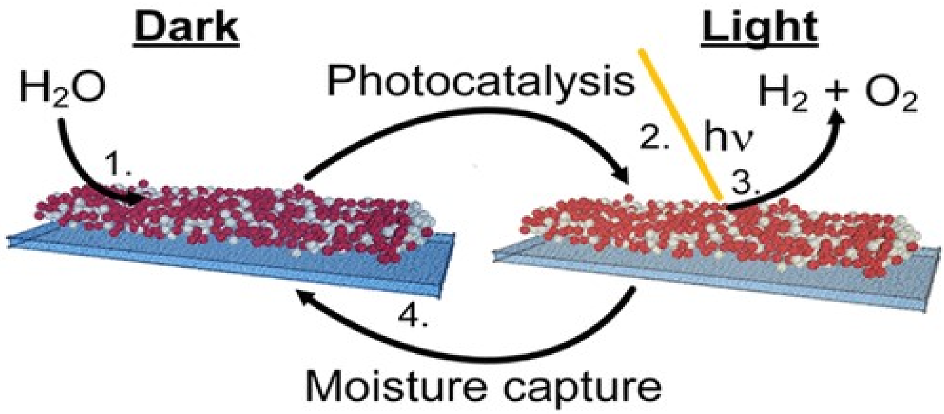

Figure 76: Demonstration of electrolyte less gas phase water splitting (ACS Nano , 2017)[62]

Since we had mentioned Hydrogen based technology let's try to discover more about it.

3.7.5 Green Hydrogen

There are different types in hydrogen production whereas Green hydrogen is produced using a clean source of energies such as wind and solar (World Energy Council, 2019).

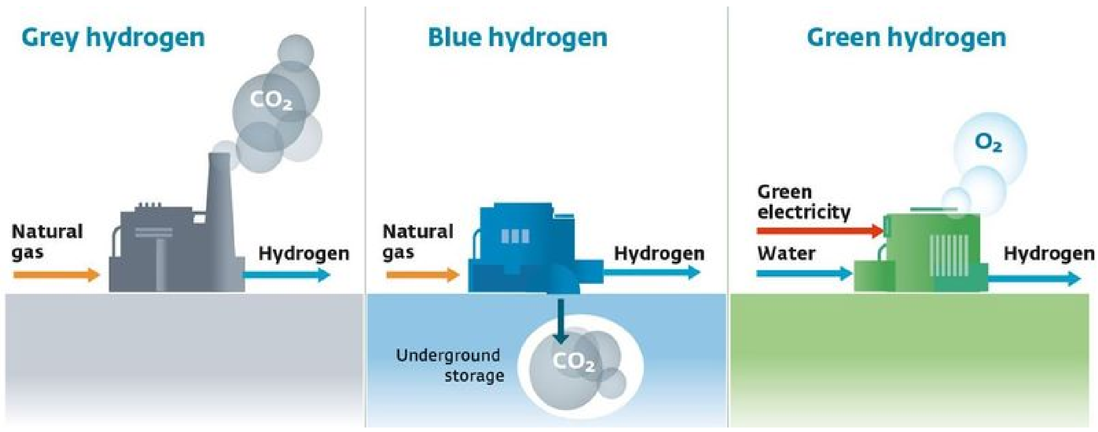

Figure 77: Different types of hydrogen fuel (energyeducation.ca)[63]

[60] RMIT : The Royal Melbourne Institute of Technology, a public research university in Melbourne Australia
[61] ARC : Australian Research Council
[62] ACS : American Chemical Society

3.7.5.1 Green Hydrogen Production Process

Green Hydrogen regarded-to as a low or zero-emission hydrogen since it employs energy sources such as wind and solar that does not emit greenhouse gases when generating electrical power. Green hydrogen is created by splitting water (H2O) into hydrogen (H2) and oxygen (O2) (O2) (Donev and Wiebe, 2021).

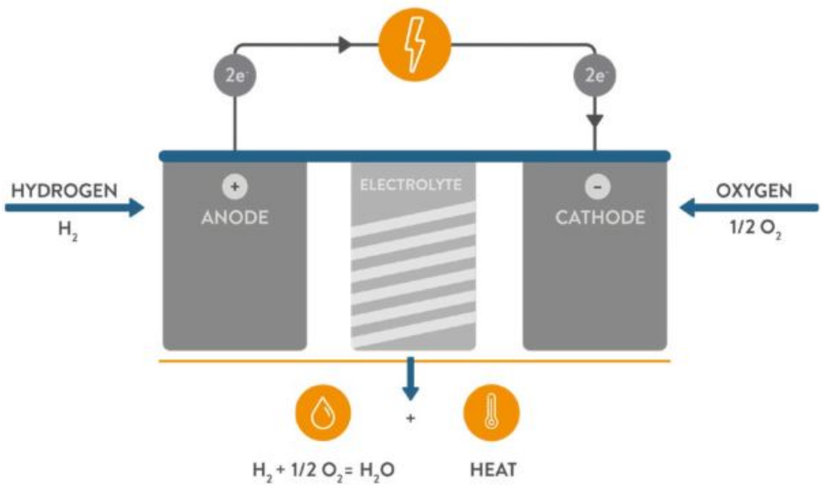

Figure 78: The process of generating green hydrogen (World Energy Council, 2019)

Water splitting, commonly known as electrolysis, necessitates the use of energy. The method of delivering energy to split water is a costly operation, but it is far more eco-friendly than grey hydrogen manufacturing (Donev and Wiebe, 2021).

3.7.5.2 Green Hydrogen in Algeria

Green Hydrogen project in Algeria lead by MTEER. Under scoping study by Tractebel with the involvement of the German agency for cooperation GIZ[64], (BMWi), Sonatrach and CDER (GIZ, 2021). Recent news shows its implementation as a car fuel in Germany. Algeria exporting ambition to neighboring countries and Europe, due to low cost production and using existing gas cannels (APS, 2022). Another strategic technology partnership with Italy where a new agreement signed in the May, 26th 2022 in Rome. Aiming to accelerate the development of Hydrogen gas project (Hydrogen-Central.com, 2022). Showing a real intention to lead the vision of more efficient and sustainable Algeria by 2050.

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[63] Source : (https://energyeducation.ca/encyclopedia/Types_of_hydrogen_fuel)
[64] GIZ : German International Development and Cooperation Agency,
For more information about the organization involved in the initiative please visit the following link: (https://www.energypartnership-algeria.org/home/ptx-green-hydrogen/)

3.7.6 Liquid Solar Power

Figure 79: Liquid solar power (shahbapress.net)[65]

Imagine you can store power up-to 18 years in a small liquid and reuse in thermal shape or energy with simple subtitles. Starting 2017 and after a published paper on *Science alert* (Shahbapress.net, 2022). Swedish group of scientists are developing now this futuristic tech called '*norbornadiene*' that could be a flip point toward a sustainable living. With more efficiency than its solar panel rival. A density of energy reaching 250 watt-hours per kilogram, "twice the strength of Tesla's popular Powerall battery" (Brown, 2019). shows his precautions toward direct implementation and looks at the development of this tech as "a progressive step rather than a revolutionary one". That's actually, because it needs the mastering of the reactivating procedure, reducing any toxic materials included in the process. Lead scientist Moth-Poulsen hopes in the coming years, "*this solar technology conversation heats up*", could increase our thermal comfort and reduce consumption of power especially for heating and cooling (Brown, 2019).

[65] Source : (https://shahbapress.net/archives/23547)

IV-Chapter 04: General Conclusion

General Conclusion

This research of explanatory nature followed by a well structured scientific method. Incited by the latest prompting updates on the advancement in PV technologies. Followed by theoretical framework to introduce photovoltaic system components and the potentiality of the Algerian solar power; exploring 'Schmid's Formula' for PV sizing. Discussing the PV glass integration into the building of Masjid El Ihsane. The implementation given accurate results, calculating the project costs, return on investment, and the possibility of introducing PV glass to the Algerian market.

The uniqueness of the smart city of Sidi ABDELLAH over the rest of Algeria cities, resides in the possibility given to (*VNSA*) to manipulate the exploitation of the urban properties. Therefore acquiring land to realize the Masjid extension needs transferring primary reason of exploitation it to a more general and inclusive idea to benefit the neighborhood. Preservation of the historical touch, melted with modern architecture. If accorded it will be a leading experience for new cities in Algeria.

This research on renewable energy sources implicated some UN SDG's as follow:

- ✓ ***Attracting more competencies***, offers better conditions, good education and more chances for career evolution which reflect positively on economic growth;
- ✓ ***Upgrading human wellbeing,*** by preserving life on land, offering affordable & clean energy, with responsible consumption to build resilient cities;
- ✓ ***Inner Peace,*** by choosing the right options for humanity to live in justice & harmony;
- ✓ ***Gathering efforts,*** to reduce human impact on earth and building peace.

Answering the question on how to provide a renewable energy source, to emphasize the energetic efficiency in the buildings:

- ✓ ***Using of PV glass***, to transfer the facade into a power generator, preserving surface and costs from separated project of PV panels;
- ✓ ***Choosing amorphous PV glass,*** to maximize visibility and natural lighting while reducing intolerant sunlight radiation and gain a great panoramic view;
- ✓ ***Sustainability matters***, we preferred an eco-friendly manufacturing, with zero-stock and convenient supply chain, reducing waste and controlling environmental impact;

For a reliable project make sure of planning the operation ahead taking in consideration:

- ✓ ***Find reliable collaborators***, to follow the incitation of investment regulations by government and managing the operation professionally;
- ✓ ***Intelligent Control System,*** and choosing weather PV System is autonomous (off grid) or Hybrid (on-grid);
- ✓ ***Including eco-energy,*** equipments and thermal energy systems (STE);
- ✓ ***Accredited professional,*** Installers and good scaffolding;
- ✓ ***Isolate the building envelop,*** using Ventilated Façade, thermal efficient materials like PVC, wood, multi layers double glazing and 30cm exterior walls;
- ✓ ***Heating,*** PV system could replace the use of natural gas by using efficient electrical equipments, central cooling and heating system or solar thermal energy (STE);
- ✓ ***Finding renewable alternatives,*** in the Important national program of 15000 MW accounting just for 15 MW in geothermal (Foudad, 2018). Needs a reconsideration to emphasize on geothermal as a sustainable and abundant source of energy neglected in our country where it provides San Francisco with 60% of its energy.

The acquired findings using (40wp/m^2) Amorphous PV glass with law transparency shows:

- ✓ ***PV glass surpasses conventional glass,*** properties while it can be enhanced for better performance, start economies in energy to be self efficient building;
- ✓ ***Reliability,*** PV glass had high Impact resistance and reliable under suitable conditions, taking some precautions measures while shipping and installing the PV system;
- ✓ ***Energetic Performance,*** expressed in the generation 8960 kw of electricity yearly and the thermal losses of 1.6 w/m^2 k, better then what is recommended by APRUE;
- ✓ ***Alternative source of energy,*** PV glass could be one of the best alternatives to reduce not just consumption, but cost of renewable energy for the Algerian market;
- ✓ ***The Energy subvention policy,*** unappealing for change to a renewable source in housing, whereas is advised for higher consumption buildings. Finding that the return on investments of PV System can be tangible and is actually obvious to consider its implementation. Knowing the continuous rise of energy prices and renewable getting more affordable by time, we can talk about sooner energetic transition in our country;

- ✓ ***Customers benefits,*** from manufacturer price, with customized dimensions, shapes and colors relevant to the their orientations;
- ✓ ***In reality we recommend,*** using mixture of mainly Silicon and amorphous PV glass, where the last limited to covering the windows areas to gain more performance and reduce project cost;
- ✓ ***Companies leadings the way,*** mostly multinationals acquiring more renewable techs, with the intention of fostering a green image, showing their support for the UN SDG's;

Promising future is waiting the field of energy with the intensive innovation of real efficient techs with affordable price, made us looking forward to its development. Where Pervoskite will be able to reach 30 years of lifetime along with 30% of efficiency. Transparent PV glass will replace the glass of our windows, smart phones and cars. While painted or printed cells could be placed everywhere, transforming every surface to PV Cell, preserving surfaces and reducing the production cost to few cents per watt. Storing power up to 18 years in small liquid of a density reaching 250Wh/kg, which will lower the maintenance fees of batteries in the PV systems. The future is prompting toward switching our energy source to be more renewable, efficient and transparent.

APPENDICES

Appendices 01: Turn Entire Building into Power Generators (OnyxSolar, 2022)

Appendices 01: Turn Entire Building into Power Generators (Onyxsolar.com, 2022)

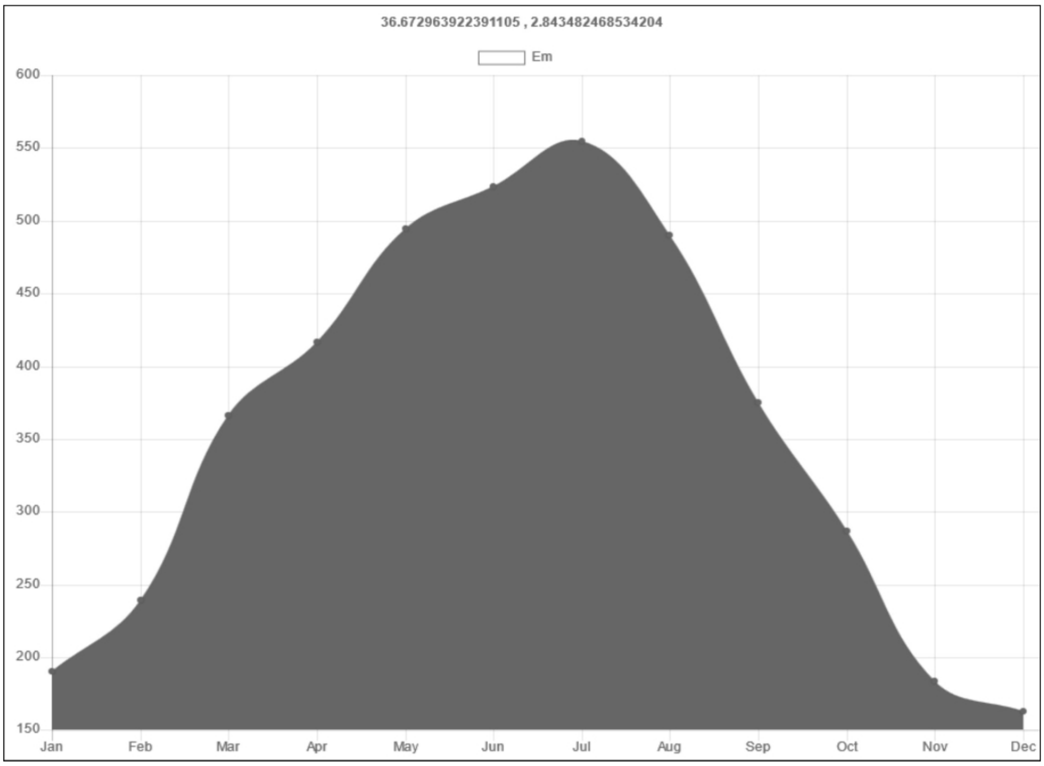
Appendices 02: The Results of Thermal Transmission (OnyxSolar.com, 2022)

Appendices 02: The Results of Thermal Transmission (U) (OnyxSolar.com, 2022)

Appendices 03: Photovoltaic Estimation, Monthly Results (OnyxSolar.com, 2022)

Month	E_d	E_m	H_d	H_m
January	6.14	190.36	1.16	35.98
February	8.56	239.64	1.60	44.66
March	11.82	366.47	2.19	67.84
April	13.88	416.52	2.57	77.15
May	15.95	494.55	2.98	92.26
June	17.44	523.32	3.28	98.53
July	17.90	554.93	3.41	105.78
August	15.82	490.53	3.03	93.94
September	12.50	374.89	2.38	71.43
October	9.26	286.97	1.76	54.41
November	6.13	183.91	1.16	34.83
December	5.26	163.12	1.00	30.94
Yearly average	11.72	357.10	2.21	67.31
Total for year		**4,285.21**		**807.74**

Ed: Average daily electricity production from the given system (kWh)
Em: Average monthly electricity production from the given system (kWh)
Hd: Average daily sum of global irradiation per square meter received by the modules of the given system (kWh/m2)
Hm: Average sum of global irradiation per square meter received by the modules of the given system (kWh/m2)



Appendices 03: Photovoltaic Estimation, Monthly Results (OnyxSolar.com, 2022)

Appendices 04: Scaffolding Specifications (Fr)(Bativert, 2022)

4 ECHAFAUDAGE

BATIVERT EQUIPEMENT

ECHAFAUDAGE FAÇADIER SECURIFRAN

RESISTANCE, LEGERETE, LONGEVITE

Fabriqué en tube de diamètre 45 mm, le **SECURIFRAN** offre un excellent compromis entre résistance et légèreté. Ceci lui permet d'être sans doute l'échafaudage dont le montage est le plus rapide à ce jour. Réalisé en tube d'acier de haute résistance mécanique, il est proposé en finition galvanisée à chaud. Le **SECURIFRAN** est fabriqué en largeur 800 mm et en travées de 3 m et en travées réglables.

SECURITE TOTALE

Le **SECURIFRAN** procure, de par sa conception, une sécurité totale pendant le montage, l'utilisation et le démontage. Les garde-corps de montage et d'exploitation, latéraux et longitudinaux fixes et réglables, mis en place avant l'accès à l'étage supérieur, assurent la sécurité à l'utilisation, comme au montage et au démontage.

SIMPLICITE

La simplicité de cet échafaudage est telle que vous n'hésiterez jamais à le monter, même pour un chantier de courte durée. Aucun outil n'est utilisé.

Nouveau Siége de Cosider - Alger

Appendices 04: Scaffolding Specifications (Fr) (Bativert, 2022)

Appendices 05: Scaffolding Bill of Quotation (Fr)(Bativert, 2022)

BATIVERT EQUIPEMENT

ECHAFAUDAGE - COFFRAGE - ETAIEMENT

Rue des Frères Oudahmane local 02 Lot 08
Axe Nouveau Lycée Tizi-Ouzou
Tél. : 026 19 85 85
Fax : 026 19 94 94
Capital social : 50 000 000,00 DZD
N°Article : 15 012902101
RC N° : 99B 0043525
NIF : 099915004352510
NIS : 0999 1501 12316 32
RIB : SOCIETE GENERALE
021 00 851 113 000 0392 59

Affaire suivie par : **Djamel HAMDI**
Mobile : **0770 254 355**

N° Proforma	Date	Client
DV2201568	13/09/22	C10406

R. Sociale : **International Business Developer**
Adresse :
Ville :
Tél. : (+213) 797 74 78 05
Fax :
Id. Fsc. :
RC :
Art. Imp. :

Echafaudage façadier de type SECURIFRAN, en acier galvanisé conforme aux normes EN12810 et EN12811
Charge admissible : 300kg/m²

Code	Désignation	Quantité	P.U.HT	% Rem	Montant HT	TVA
	ECHAFAUDAGE SECURIFRAN 12 X 8 SOIT 112 m²					
E_4507	VERIN DE NIVEAU 600 mm	10	2 940,00	0	29 400,00	19
1955	CADRE H 2 M SECURIFRAN	20	11 559,10	0	231 182,00	19
1972	GARDE CORPS 3000 SECU GALVA	16	14 195,00	0	227 120,00	19
1961	LISSE ARRIERE RENFORCEE	16	5 831,00	0	93 296,00	19
1960	GARDE CORPS LATERAL SECU	8	4 184,60	0	33 476,80	19
4876	PLANCHER ALTRACIER 365x3000	26	11 270,98	0	293 045,48	19
8116	PLANCHER ALU BOIS A TRAPPE+ECHELLE 300 x 75	3	60 435,90	0	181 307,70	19
1900B	ANCRAGE COMPLET Composé de :	6	5 143,75	0	30 862,50	19
45454	- Cheville d'échafaudage GD 14/70	6				
56418	- Piton d'échafaudage GRS	6				
925	- Barre d'amarrage à crochet 1.5	6				
AE02	COLLIER ORIENTABLE	6				
	GARDE CORPS 3000 NON DISPONIBLE					
	REGLEMENT PAR CHEQUE A L'ENLEVEMENT					

- Validité de l'offre : 15 jours

Poids total kg : **1 152,74**

* **Documents exigés à la commande :** Copie du registre de commerce, Copie de la carte NIF ou NIS, N°Article

- La personne chargée de l'enlèvement du matériel doit être munie du cachet de l'entreprise ou à défaut d'une procuration dûment signée et cachetée.

Arrêtée la présente proforma à la somme Toutes Taxes Comprises de :
Un million trois cent trente deux mille quatre cent trente et un Dinar, soixante sept Centime

TOTAL HT	1 119 690,48
REMISE	0,00
NET HT	1 119 690,48
TVA	212 741,19
TOTAL TTC	**1 332 431,67**
NET A PAYER	**1 332 431,67**

Appendices 05: Scaffolding Bill of Quotation (Fr)(Bativert, 2022)

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Abbreviation, Initials and Acronyms

ACS	American Chemical Society
APRUE	National Agency for the promotion and rationalization of using energy (Agence National Pour la Promotion et la Rationalisation de l'Utilisation de l'énergie)
ARC	Australian Research Council
ASPEWIT Tlemcen	Association for the preservation and promotion of the environment in the state of Tlemcen (Association pour la Sauvegarde et la promotion de l'Environnement de Wilaya de Tlemcen)
BIO-	Bioclimatic
CEREFE	المحافظة للطاقات المتجددة والفعالية الطاقوية The Commissioner for Renewable Energies and Energetic Efficiency Le Commissariat aux Energies Renouvelables et à l'Efficacité Energétique
CNERIB	National Center Of Studies And Research Integrated to Building
ECO-	Ecologically
EnR	Energies Renouvelable, Renewable Energies
EPST CDER	Renewable Energy Development Center, is a research facility (Centre de Development des Energies Renouvelables)
FNEL	Fonds National de l'Environnement et du Littoral
FNMEERC	National Fund for Energy Management and Renewable Energy and Cogeneration
GFN	GFN : Global Footprint Network
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit GmBH / German International Development and Cooperation Agency
GRI	GRI: Global Reporting Initiative
HZB	University of Helmholtz-Zentrum Berlin für Materialien und Energie
ILO	ILO: International Labor Organization
IRENA	The International Renewable Energy Agency
ISO	International Organization for Standardization

MIT	Massachusetts Institute of Technology
MTEER	Algerian Ministry of Energetic Transition and Renewable Energies
NREL	The National Renewable Energy Laboratory – United States
OECD	The Organisation for Economic Co-operation and Development
RMIT	The Royal Melbourne Institute of Technology, Australia
SHAEMS	Algerian Renewable Energy Company
SKTM	Company of Electricity and Renewable Energies, spelled from arabic (Shariket Kahraba Wa Taket Moutadjadida)
SPV / PV	Solar Photovoltaic, or PV: Photovoltaic
STE	Solar Thermal Energy
Tech	Technology
TOE-TEP	Tons of Oil Equivalents - Tonnes Equivalents Pétrole
TW	TW: Tera Watt
UDES	Development Unit of Solar Equipments (Unité de Développement des Equipements Solaire, Bousmail, Tipaza)
UN SDG's	United Nations Sustainable Development Goals
UNDP	The United Nations Development Program
UNEP/MAP	United Nations Environment Program Mediterranean Action Plan
WCED	World Commission on Environment and Development