THESIS

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2024

Hungarian University of Agriculture and Life Sciences

Gödöllő Campus

Environmental Engineering

Bachelor’s Degree

How to increase the use of certain renewable energy sources in households

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Place of training (footnote about the training places)

2024

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Acknowledgement

A couple of years back, I was a first-year student, and now I am writing my acknowledgement. It was quite the experience that I emerged from as a changed person, certainly improved. During my journey, I learned more than I expected and the most valuable lesson I gained was the skill to think like an engineer. Nevertheless, I gained more from this place than just one thing.

During this adventure, I met a few beloved individuals who provided me with their support. I want to take the time to show my appreciation and give thanks to my professors and teachers, as their efforts are truly valuable and fulfilling. I would also like to express my gratitude to Mr. Tibor László Csegődi for his support and assistance during my academic and thesis research.

I want to express my deep gratitude to my beloved family and friends for everything I cannot fully repay in multiple lifetimes.

Kind regards.

1. Abstract of contents

This paper is titled “How to increase the use of certain renewable energy sources in households?” and it aims to answer this question. This paper is bachelor’s degree thesis from the Hungarian University of Life Sciences, Environmental Engineering department.

This paper in written by Omar Sherif Anwer Abouelseoud with the supervision of Dr. Tibor László Csegődi.

This study consists of partial literature review to shed light on the topic of solar panels and the benefits and challenges around installing them by households in Europe, especially Hungary. Taking into account the limitations present, two practical methods were implemented to reach optimum results which is to answer the research questions introduced in the next section: a survey and a 3D model. The results are further explained in the paper.

2. Introduction and objectives

Renewable energy is energy harnessed from a source that does not and cannot run out. In the case of this paper, the example is solar energy. Renewable solar energy is trending and adopted by many for low to zero carbon footprints of its applications (United Nations, n.d.). Solar energy is briefly a harnessed energy directly from the sun. There are some ways for us to harness a fair portion of the heat energy provided by the sun and transform it into electrical energy or electricity. There are also ways to store solar energy. If harnessed and stored correctly, solar energy can provide the world usage of yearly energy (Ashok, 2024).

Solar energy application could face some challenges in terms of the public acceptance, upfront costs, installation, area, or maintenance. In the population dense areas, arises a challenge for solar energy applications in terms of installation area. For this problem, providers usually tend to plant solar energy applications in an empty rural area around towns. The energy is then stored to transferred directly to towns. Solar applications can also be greatly harmed in terms of efficiency if not regularly maintained.

Solar energy applications could be used in cooking, pumping, heating, radio, and many other. The type and amount of usage can help determine the most suitable solar energy applications for use.

It is also extremely important to always prove in data and visually as much as possible to the public how solar energy application could be depended on. Every day, more people in Europe are starting to believe in solar energy and have already installed or considered installing solar energy applications in their households.

The objective of this paper is to encourage and prove with data and application examples how solar energy applications can improve the usage of energy and replace the use of fossil fuels or at least decrease it.

This paper also aims to introduce ways European households could benefit along with acknowledging what type of solar application fits better for every form of power usage.

Therefore, through the literature review and the practical work present in this paper, the below research questions will be answered:

1. What are the main deterrents to individuals in EU (especially Hungary), from installing solar panels?
2. How does public awareness and understanding of the long-term economic and environmental benefits of residential solar energy influence the willingness of Hungarian households to overcome the high initial financial investment hurdle and install solar panels?

To be able to answer these questions, scientific data and survey results will be displayed and further explained.

3. General overview

Curiosity is power, and reaching the top is inevitable. In order to lead, challenge, or even start up in the world of today, the world of speed and technology, one's nation should aspire to always invent, improve, or even improvise.

As psychology studies show, we humans tend to hold on the past. There is a general tendency of fearing the new and the unknown. In the fall of any nation, there was always a pattern of rejecting foreign ideas along with refusing to accept that some idea, or invention that is alien or new might conduct or lives in a better way than how it is being conducted.

This fear of the new is not actually tied to a certain group or a society. And since there might be nothing that matters in the world of engineering and programming where a miss spelled colon could cost millions than details.

In society, most of the details are within the streets and within the people. In order to nation to keep up the challenge of today's world with its unprecedentedly fast pace, everybody should cooperate.

Aside from curiosity, the joy, the pleasure of discovery, invention, or improvement, there are also political and geographical challenges or probabilities that will always be there. Today, it is all about energy. Since the discovery of the incorrect or the excess use energy sources like petroleum fuel or gas might have a major impact on the climate and the general health along with how the ownership of these energy sources might cause a conflict of interests within the political world, a new independent and clean source of energy were introduced.

The idea of clean energy is not new. Many great minds have thought about that before in numerous ages. There was the water wheel in Europe around 200 BC where the movement of water along the wheel created mechanical energy. The windmills were trending a lot in Europe around 1590. Windmills were a revolution in the world of power back then a grain miller and a water pump. There even some rumors that great pyramids of Egypt served as what we could understand today as a tesla tower.

Since we mentioned tesla, he imagined a world where we could harness free limitless energy from the atmosphere and convert it into energy of all kinds. Free renewable energy has always been floating in numerous brains along numerous histories.

4. Literature review

4.1.1 Nonrenewable energy and the importance of renewable energy

Since the beginning of time, renewable energy has been the main source of energy; however, this has changed in the last few decades. Wind energy was used to move boats and as technology advanced, it was used for windmills. Hydropower used to grind grains and then developed to generate electricity, and finally solar energy to make fire and power ovens.

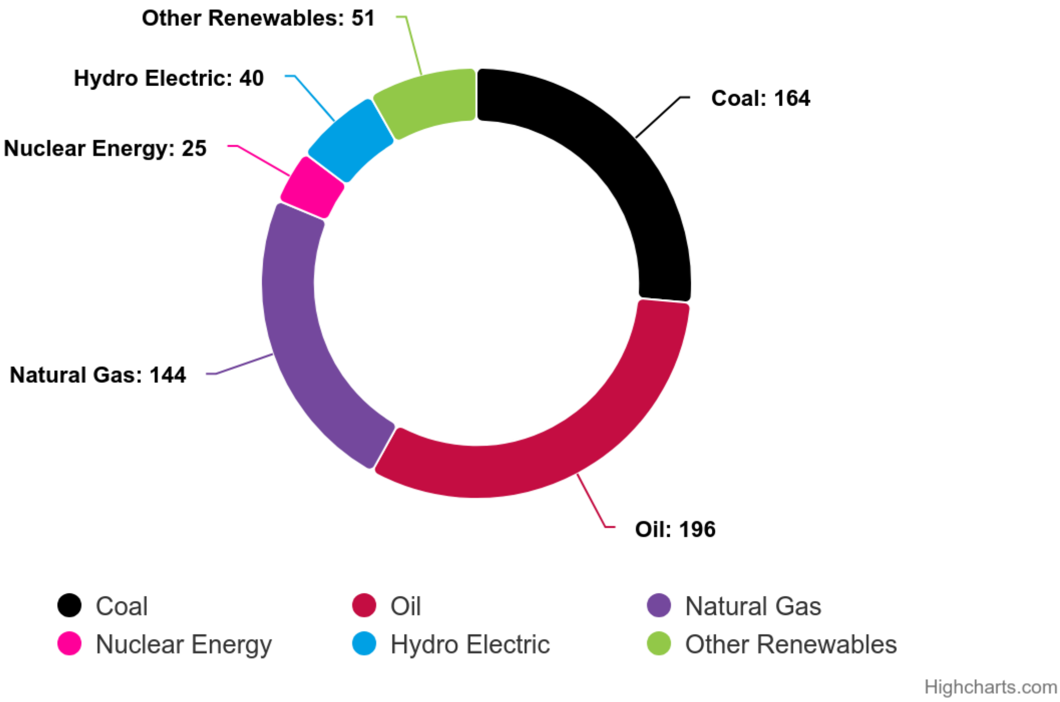
Consumption pattern has changed as the world grew more interconnected and reliant on one another, increasing the usage of nonrenewable resources. The usage of nonrenewable resources could be traced back as early as 600 BC in China, where they used oil from wells that were hand dug, seeps and natural flows. It was not until the industrial revolution where the non-renewable energy took over and transformed the way of living, making it a vital part of life (Sheehan, 2006).

Energy that is obtained from limited or finite resources is called nonrenewable energy. Coal, oil, gas and nuclear energy are the different types of nonrenewable energy, collectively called fossil fuels (Ibid). Fossil fuels are composed of a mixture of animals and plants remains that have been fossilized from millions of years ago (Sullivan, 2022).

Each kind of fossil fuel type has a specific purpose. Coal is a type of fossil fuel that is solid and can be found by digging the ground; it is used to generate heat and power plants. Crude oil is another type of fossil fuel that is in the liquid form and used to product transportation fuels such as Gasoline and Diesel, Petrochemicals such as plastics and cosmetics, lubricants and greases and finally asphalt and road materials. Natural gas is a versatile type of fossil fuel that can be found in wells, similarly to crude oil; it can be used to generate electricity, heating, drying and cooking. Finally, the last type of fossil fuel is nuclear energy which is used for electricity generation, medical and industrial application and could be found when being extracted from mined ores and refined into fuel (Gosh, 2024).

To keep up with the rate of consumption and advancements, the usage of nonrenewable resources increased becoming the main source of energy. According to a report on world energy conducted by the Energy Institute and as shown in Chart 1, a new high record of over 96 million barrels of oil were used each day in 2023, there was also an increase of usage of fossil fuel by 1,5% in 2023 compared to 2022, adding up to a total of 82% of the nonrenewable energy usage. When comparing the overall gas, oil and coal the international trade is currently 53% higher in 2023 than it was in 2000 (Ibid). In the figure below, it shows the consumption of different types of resources used over the world in 2023 (Energy Institute, n.d.).

Figure 1: World's energy usage



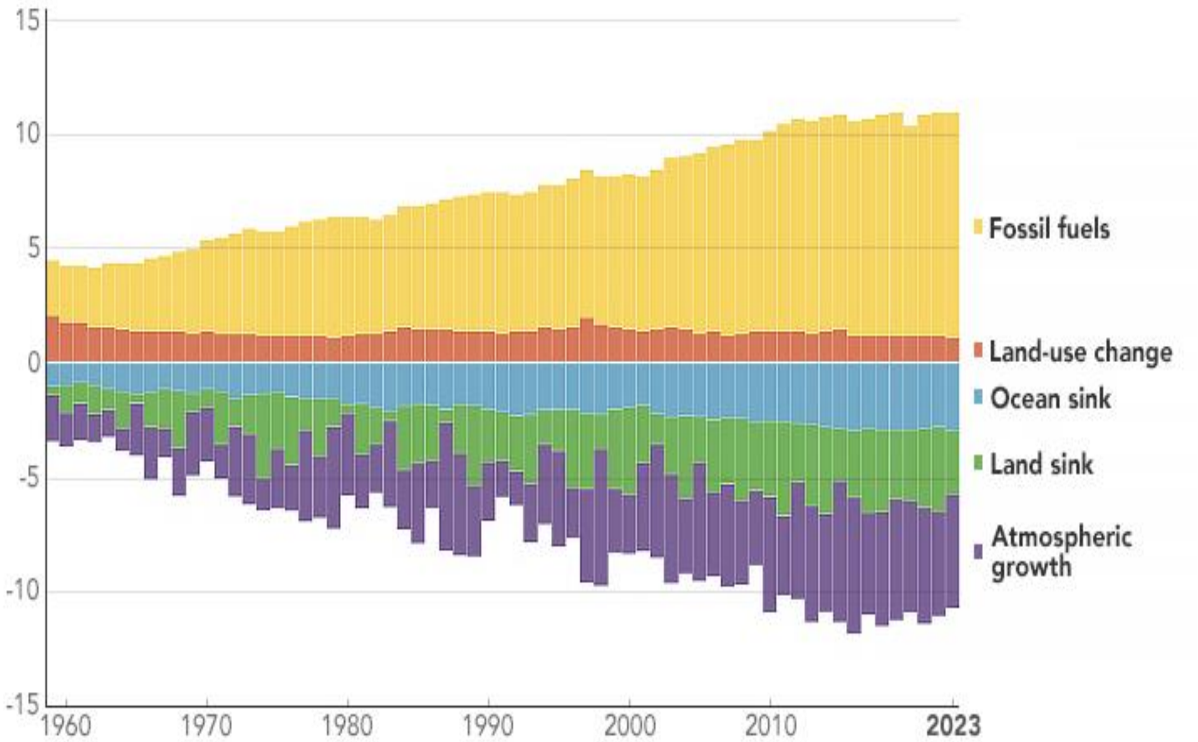
Source: Energy Institute (n.d.)

Although fossil fuel is available, convenient, reliable and affordable, it has impacted the environment and human health negatively. Habitat destruction and land degradation has been one of the environmental impacts that was cause by extracting fossil fuel, which lead to the loss of biodiversity, which also has an indirect impact on farmers and settlements.

Another concern is the water pollution, in the process of extraction and refining, oil spill occurs which contaminated the water, harming life on land, sea and air. Water scarcity is another concern strongly linked to fossil fuel, as contaminated water needs to be treated which leads to high costs and potential health risks.

Global warming and climate change is one of the main pressing issues associated with fossil fuels. To generate energy from fossil fuel, combustion process is needed, which emits CO2 into the atmosphere resulting in the heat being trapped. Not only does this process allow the heat to be trapped, but it also causes air pollution as Volatile organic compounds, sulfur dioxide and other air pollutants contribute to poor air quality which is linked to the degradation of human health such as cardiovascular disease and respiratory problems (Ibid). Chart 2 illustrates the biggest contributor of emissions of carbon being fossil fuels (NASA Earth Observatory, n.d.).

Figure 2: Global carbon budget (gigatons carbon per year)



Source: NASA Earth Observatory, (n.d)

4.1.2 Renewable and solar energy in the EU

It is apparent now that with the depletion and health and environmental concerns linked to fossil fuels, the usage of renewable energy will be necessary again. Renewable energy serves as the foundation for sustainable economic growth, as it is in infinite quantity and naturally replenished.

The oil crisis that occurred in 1970s, and the rising concerns of the environment triggered the environmental movement, leading to government to invest in research and development for solar and wind technologies in the 1980s. Since then, there have been multiple policies and initiatives to combat those issues, however simultaneously, there are many challenges converting to renewable challenges.

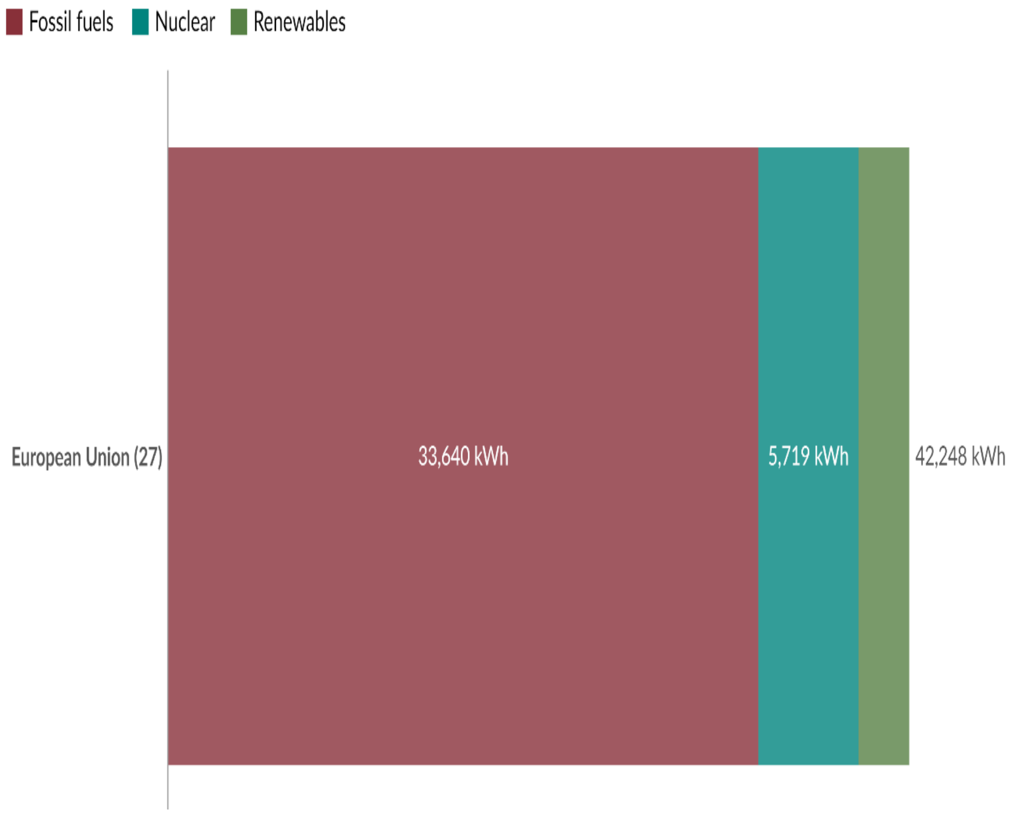
Research shows that the combination of renewable energy and efficiency will become dominant if the energy system is re-designed due to accessibility, applicability, efficiency and affordability. Although there is a continuous increase of production of fossil fuel, some countries are working on transitioning into renewable energy, one of those countries are European union countries. The first efforts for renewable energy in the European Union can be traced back to 1970 following the oil crisis, since then there have been multiple policy measures to serve as an incentive for cleaner energy.

The conversion of energy from the sun into thermal or electric energy is called solar energy (SEIA, 2024). Solar energy is a form of renewable energy that is cleaner, cheaper and more flexible than not renewable energy. According to European Commission, Solar energy is now one of the cheapest forms of renewable energy, making it the dominating and most affordable source of energy in the European Union households, which has estimated to meet 20% of the electricity demand in the EU by 2024 (Eurostat, 2024).

In 2006, the European Commission authorize a financial incentive of 45.5 million Euros which was provided to a company that manufactures solar modules, this has caused over 400 people employees and a capacity of 100-megawatt, which is enough electricity for 60,000 homes for a day, since then the EU has come up with ways to reduce greenhouse emissions.

Europe has set in 2019 the European Green Deal (EDG) to make Europe the first climate neutral continent by 2050, which also aims for increasing the quality of life for the European citizens. There are also multiple different agreements such the 2030 Agenda for Sustainable Development, Paris Agreement and the UN Sustainable Development Goals. Chart 3 shows the comparison of energy per capital from fossil fuels, nuclear and renewable between 2000 and 2023. The significant decrease if fossil fuel energy from 33,640 kWh to 23,779 kWh and increase of renewable energy from 2,889 kWh to 7,669 kWh provides a picture on the momentum of the changes.

Figure 3:Per capita energy from fossil fuels, nuclear and renewables in EU, 2000



Source: Energy Institute - Statistical Review of World Energy (2024); Population based on various sources (2023)

In 2023, the EU member states submitted the National Energy and Climate Plans (NECPs) which plan to increase solar by a weighted average of 87% compared to the 2019 NECPs. Poland has set a plan to increase its target by 3 times the current target, while Portugal, Sweden, Slovenia and Finland have doubled their previous targets.

According to preliminary monthly figures for 2023, coal production and consumption in the European Union hit their lowest levels on record. Production fell to 274 million tons, marking a 22% decline from the previous year, while consumption dropped by 23%, reaching 351 million tons. Compared to the year 2000, the use of fossil fuels in the EU had a substantial decrease of over 100 million tons. Poland and Germany were the largest fossil fuel (specially coal) consumers in 2023. They combined account for 64% of Europe’s fossil fuel consumptions which accounts for nearly two-thirds of EU’s fossil fuel consumption (*Renewable Energy Targets*, n.d.-b).

4.1.3 Barriers of solar energy adaption in the European Union households

Although there is a stronger focus on renewable energy and various incentives are being implemented throughout the European Union (EU), several obstacles still hinder the widespread adoption of solar energy by households.

These obstacles are impeding the shift to solar energy, causing a delay in achieving the EU's ambitious sustainability targets. This part analyses the main challenges to the adoption of solar energy in EU homes, with a specific focus on financial, regulatory, technical, and social hindrances.

The high upfront cost of solar installations is a major obstacle to the widespread adoption of solar energy in households throughout the European Union (EU). Even though solar energy is known for its economic advantages and positive impact on the environment, the initial financial commitment needed to buy and set up solar panels proves to be a significant challenge, especially for households with lower or moderate incomes. This section delves into the different factors contributing to high initial costs and how they hinder the extensive implementation of solar energy in households across the EU (Socinova, 2023).

Technological advancements and economies of scale in manufacturing have led to a significant reduction in the cost of solar panel systems in recent years. Yet, the overall cost of a full solar power system, installation included, still poses a challenge for numerous households. A common home solar system includes not just the price of solar panels, but also extra parts like inverters, mounting hardware, electrical wiring, and metering devices.

The expense of installing a solar panel in most European countries can vary from €5,000 to €15,000, based on factors such as system size, technology, and local market conditions. Even with financial incentives such as grants, subsidies, or tax deductions, the upfront costs are typically too expensive for low-income families. Households lacking savings or credit are discouraged by the expensive upfront costs of solar systems (European Commission, 2024).

The cost constraint to the implementation of solar panels is further worsened by auxiliary

technologies, which include energy storage systems. Whereas solar panels generate electricity during the day that one needs to immediately use or store up for later use, energy storage devices like batteries develop efficiency and financial gains by allowing homes to store excess energy when sunlight is in short supply.
These energy storage systems might therefore range from €4,000 to up to €10,000, depending on the size of their capacity. Solar systems may be more expensive for households, especially in places where energy storage is becoming a necessity to obtain full value from solar. Other optional grid connection costs in terms of size and extension within the grid connection fees, grid improvement costs, might increase the overall investment to be made against some EU countries (Mills & Jacobson, 2011).

This has made the installation of solar panels very expensive upfront and hence unaffordable by low- and middle-income families, who bear a disproportionate share of the burden. Most countries in the European Union have variable financial incentives through grants, subsidies, and tax credits, which in most cases only cover a share of the total cost, with the consumer paying a considerable part of the expenditure. Very often, households also cannot afford the reduced costs (Couture & Gagnon, 2010).

Incentive schemes like tax credits have reduced benefits for low-income households because they do not have sufficient tax liabilities against which to offset the amount. Probably one of the inhibiting factors from having solar energy solution implementations by low-income families is the inability to secure financial aid programs (Schleich & Gruber, 2012).

The costs are generally higher, and it is usually pertinent to a lack of loans or third-party ownership models in developing or economically poor territories. As a result of perceived risks or lack of interest in the renewable energy projects supported, the financial institutions may show a general reluctance in the granting of favorable loan conditions (Bertsch et al., 2019).

Another factor that contributes to the high upfront investments for solar systems relates to the serious financial option for consumers to finance these systems gradually. While the programs in other countries, such as in Germany, offer low-interest loans through programs like the KfW Bank, these choices to be consistently accessible throughout the EU. Homeowners in countries where this financial avenue is not available usually pay all at once-

a fact that deters many people from turning into renewable sources of energy.
As a result, the EU is excluded from a range of innovative financing options, such as pay-as-you-save plans and third-party ownership, which allow for greater diffusion through the fact that households can adopt solar energy without paying the full upfront cost. However, there are only a few such models in Europe, and this acts as a barrier in developing these models to surmount financial barriers (O'Rourke & Feiock, 2016).

Given their lack of money and limited access to affordable loans, low-income families are more adversely impacted by the expensive initial expenses of solar energy. Even with grants and subsidies, households often still must pay a large portion of the total cost themselves as these financial aids only cover a fraction of the expenses. The existing disparities are worsened as low-income families are neglected while wealthier households embrace solar energy (Lozano-Garcia et al., 2016).

In order to tackle this inequality, certain EU nations have launched focused initiatives designed for low-income families. In Hungary, about 31,000 low-income households will receive financial aid for solar panel installations through the EU's Recovery and Resilience Facility. Nevertheless, these programs are not common throughout the EU (EU Funding Possibilities in the Energy Sector, n.d.-b).

Besides the financial barriers, the high cost of solar installations is perceived as an obstacle to the adoption of renewable energy resources. Households consider solar systems too costly, even when financial incentives and financing options are available for them. Mostly, this perception is rooted in the general lack of understanding about the overall cost, the available incentives, and the future savings an individual might gain. Public awareness programs like the "Solar is Now" program in Germany, with sewage-heating programs at a number of schools with solar panels on rooftops, especially attest to this step forward in overcoming myths by pushing the long-term financial benefits and incentives of the solar industry. In all other EU countries, however, such a program does not exist to enlighten households (European Environment Agency, 2023; European Commission, 2024; European Parliament, 2022).

Another cost barrier is the extended payback period of the initial investment in the solar panels. While the solar systems may lead to lower costs of energy and even an opportunity to sell back the excess energy into the grid, the household may take up to 10 to 15 years to refund its initial investment in the same. The long-term payback period of these solar systems may be less lucrative for a household considering short-term relocation. Even though property with solar panels can fetch higher prices in the real estate world, that is again not good enough to take away anxieties about the whole financial gain in the future. Among other major factors, the overall lack of appropriate and affordable financing options for residential properties stands as a barrier for the utilization of solar energy in the EU (Mathew & Pandian, 2023).

Even besides grants and subsidies, many families cannot afford to get money required for expensive initial costs. These define regions with underdeveloped financial markets and low- to middle-income families lacking the initial funds.

In certain EU nations, low-interest loans assist households in handling the expenses associated with solar installations. Germany's KfW Bank provides loans for energy-saving upgrades in homes, such as solar systems (German Federal Ministry for Economic Affairs and Climate Action, 2023). These loans help make solar energy more affordable by lowering initial expenses.

Nevertheless, some EU nations do not provide this funding. In areas lacking these initiatives, individuals encounter increased interest rates, which complicates the ability to pay for solar panel installations. There is a lower willingness to lend in rural financial institutions because of the perceived risks.

New financing schemes, such as third-party ownership and pay-as-you-save programs, have fuelled the acceptance of solar energy in several markets. However, they are not as widely practiced within the EU. Third-party ownership, for instance, sees the installation and ownership of the panels being done by the solar firms while the homeowner pays for the electricity at a lower cost than what their utilities have been charging. This takes care of any need for a capital outlay.
Pay-as-you-save programs "allow households to finance solar installations through the money saved in energy costs". Following these models, the initial expenditure decreases thus making solar power more accessible. The fact that they are not widely spread in the EU, though keeps being a problem for many houses due to their high initial expenses (*Innovative Financing Schemes*, 2023).

The wide range of financing options has resulted in huge variations in the rates at which EU countries adopt solar. Countries with high adoption rates, such as Germany, the Netherlands, and Denmark, have pragmatic government-supported programs with easier access to low-interest loans and innovative financing models (European Environment Agency, 2023; IRENA, 2023).

However, different EU countries, which have weaker financial systems, can hardly provide affordable solar options for individual households. It is hard for the citizens of those areas to seek finance due to limited specification of financing avenues and higher loaning costs, which results in a mismatch in the rate of installation of solar panels across the European Union (International Energy Agency, 2023; European Commission, 2024).

Financial institutions also consider investment in solar energy projects in new renewable energy markets as a far riskier decision. Banks might get suspicious of the capability of repayment because of the long payback periods of solar installations or unpredictable energy markets. The financial institutions might as well opt to cut off or make their lending criteria tighter with wider interest rates, hence making the funds scarce (European Environment Agency, 2023).

This is where the governments can play a very important role in creating better opportunities for financing solar energy systems. Many EU countries have introduced schemes that incentivize banks to provide loans at low costs for renewable energy projects. For example, loan guarantees supported by the government can lower the risks perceived by lenders, prompting them to offer consumers loans at lower interest rates. Government funding directly offered in the form of grants or loans for solar energy projects can help reduce the financial strain on households and decrease the overall expenses of solar systems (European Commission, 2024).

Extending these financial programs supported by the government throughout the EU could guarantee that households in every area can access affordable financing choices. Besides providing funds directly, governments can encourage financial institutions to create new financing models, like pay-as-you-save or third-party ownership arrangements. In this way, households can lower the substantial initial expenses that typically discourage them from adopting solar power (International Energy Agency, 2023).

The complexity and variety of the legal systems regulating solar panel setups hinder the widespread use of solar power across the European Union (EU). While ambitious renewable energy targets have been set by the European Union, in turn setting broad guidelines through plans like the Repower EU plan, its laws are varied as implemented by different member states. This regulatory incoherence thus brings about additional costs, delays, and uncertainty to household solar installations.

One of the significant inconsistencies in permit procedures among different EU countries is one of the big barriers to mainstreaming solar energy resources in Europe. In some countries, approval procedures for installing solar panels make the procedure easy and swift; thus, households easily get all necessary permits. Further, countries such as Denmark and Austria have made alterations to streamline such processes and therefore hasten the integration of solar energy (International Energy Agency, 2023).

In other countries, however, this process is much lengthier and more painful. Homeowners must potentially engage with many different agencies in order to get all the sundry permissions required to do so, which is certainly quite time-consuming and expensive as well. In some countries, the complexity of the procedure for permissions discourages the adoption of this eco-friendly technology installation among households (European Environment Agency, 2023).

One of the major drawbacks is that solar installations are not regularized. While the EU has enacted targets for renewable energy, laws differ from state to state on installation standards, grid connection, and metering. In countries like France with less flexible grid connection standards, homes can hardly connect to the national grid, while in countries where the rules are lax, as in Belgium, the connections to the grid are easily made, thus facilitating net metering and the adoption of solar. The inconsistency in this respect divides the solar market in the EU, bringing both favourable conditions and barriers (European Commission, 2024).

Where the rules are more intricate and involved, the outcome could be high administrative burdens for households that want to install solar panels. Delays and higher costs are experienced by homeowners and providers due to related paperwork, permits, and fees. Long processes for approval sometimes result in a deterring effect on households that wish to pursue a solar project because of the uncertainty and extra costs it entails, while countries that have streamlined such processes enjoy rising adoption rates (IRENA, 2023).

The different financial incentives available to households for switching to solar energy, such as grants, tax credits, and feed-in tariffs, vary significantly among the different EU member countries. Whereas some countries grant considerable incentives to the uptake of solar energy, other countries have either very limited or complex programs that could potentially mislead households over the actual incentives available to them (International Energy Agency, 2023).

Poorly communicated or hard-to-access information about incentives could make households miss some programs that could bring the overall cost of solar installations down considerably. Added to this, uncertainty over the future of incentive programs-for instance, cuts or abolition of feed-in tariffs-complicates decision-making for households considering solar energy. Irregularities in the financial aid systems may restrain the growth of solar energy in the EU (European Environment Agency, 2023).

4.2 Materials and analysis

4.2.1 Solar Panels

Solar panel is a device that absorbs light energy or radiation directly from the sun and turn it electrical energy in simple words. Solar panels, or PV panels are made from a wide variety of materials but one of the most important materials is semiconductor. Semiconductors in the solar panels help produce a limited current of electricity from the sun photons hitting the panel’s surface.
Solar panels can be used for many applications.

Solar panels produce electricity that could power unlimited electrical loads and functions by collecting and absorbing what we would like to refer to as clean renewable solar energy photons from the sun. To get a little deeper into solar panels, it would be important to say that solar panels consist of smaller parts called solar cells. Every solar cell produces electric current individually. Solar cells as well are composed of smaller parts. One part is a layer of silicon, another part is a layer of phosphorus which acts as a negative charge pole in the solar cell. The last layer is boron which acts as a positive charge pole. The current generated by the cells from the absorption of sun photons is by the form of striking electrons out of their orbits to a directional electric current. This whole process of harnessing photons and generating current is known as the photovoltaic effect. The average European household has got enough space for these panels being installed and running (Brown, 2023).

In the presence of a correctly and complete solar power system the current generated by the solar panels can run directly through the usage of electric load in the day hours while the current can run through the electric power grid where it acts as a power storage so that this generated power can be used at night and in the cases of emergencies. This system ensures that no power is lost and that the solar panels along with the electric grid can be completely dependent on. If the house owner agrees to connect his solar power system the common electric grid, they can get paid for the access power generated by their solar panels and inserted into the power grid. While if the house is off grid, the house owners can store the excess power generated by solar panels directly into a solar battery with the addition of few simple electric components like an inverter. The use of the inverter in this case is to invert the direct current provided by the solar panel power generation into alternating current out of the solar battery and into the direct power load. With these technologies and some simple additional parts if needed, an average house, office, or common area can completely meet their power usage needs throughout the year. Additional power that might not be used can be sold to other areas as well if connected to the common power grid (U.S. Department of Energy, 2023; U.S. Department of Energy, 2023).

4.2.2 Benefits of solar panels

As we can conclude a little from the previously stated insights about solar power, we can say that one of the benefits of converting to solar renewable power will be a great decrease in bills along with the ability to even gain money from selling the surplus of unused power generated on your rooftop if connected to the common power grid. Another benefit will be the complete independency of normal non-renewable power grid emergency cases. Since the sun would not explode in our lifetime, energy is limitless and free. Solar power allows one to be completely off grid without the need for applying for endless requests for the government to install a power tower close to your rural area along with a great load a money paid by both sides. With simple and affordable solar power panels installation with a battery and few components, your off-grid house or moving house can be completely independent of unnecessary hustle. More solar power equals always to less coal being burnt and to less carbon emissions. Less carbon emissions and less coal and gas burnt equals directly to less pollution, less money, and less climate problems (Budea & Safta, 2021).

Finally, one of the key advantages of solar panels and solar energy is that after covering the initial installation expenses, the electricity generated for the rest of the system's lifespan, which can last between 15 to 20 years depending on the system's quality, is completely free! For owners of grid-tied solar power systems, the advantages start as soon as the system is operational, potentially eliminating monthly electricity bills or, even better, providing a way to earn extra income from the utility company. How does this work? If your solar electric system generates more energy than you consume, the surplus energy can be sold back to your electricity provider, sometimes at a higher rate.

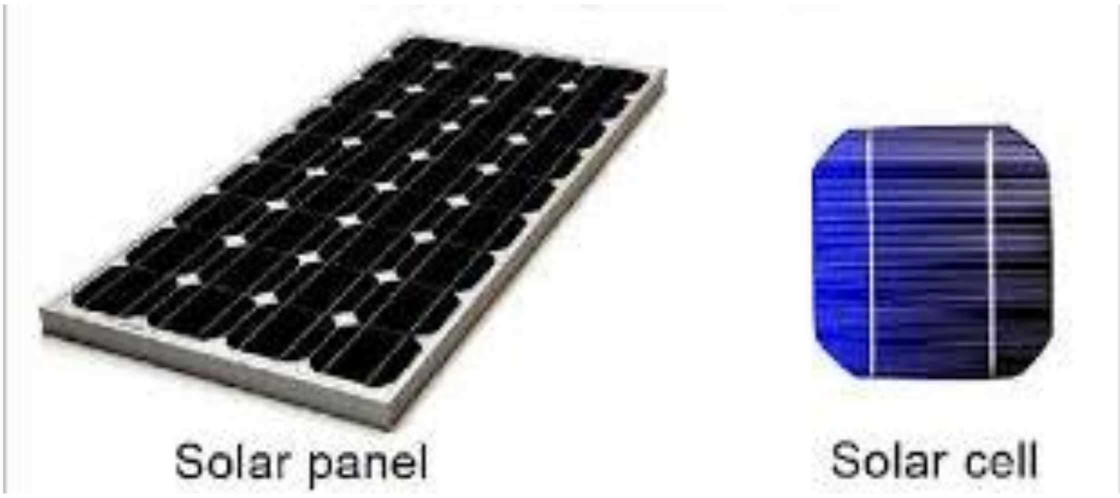
4.3 Types of solar panels

4.3.1 Monocrystalline Solar Panels (Mono-SI)

Considered as one of the first generation of solar panels along with being labelled as the purest form of solar panels is the monocrystalline solar panel. It is made of monocrystalline silicon with gives it the dark colour and the greatly high efficiency. As shown in Figure 1, monocrystalline solar panels have even more efficiency than many of the new enhanced solar panel technologies.

These monocrystalline solar panels generate strong and high output electric energy or power. These panels have a very high life expectancy along with being low on space occupancy. Unfortunately, they are one of the most expensive panels compared to other panels. Monocrystalline panels have a high immunity to very high temperatures as well.

Figure 4: Illustration of monocrystalline solar panel and solar cell

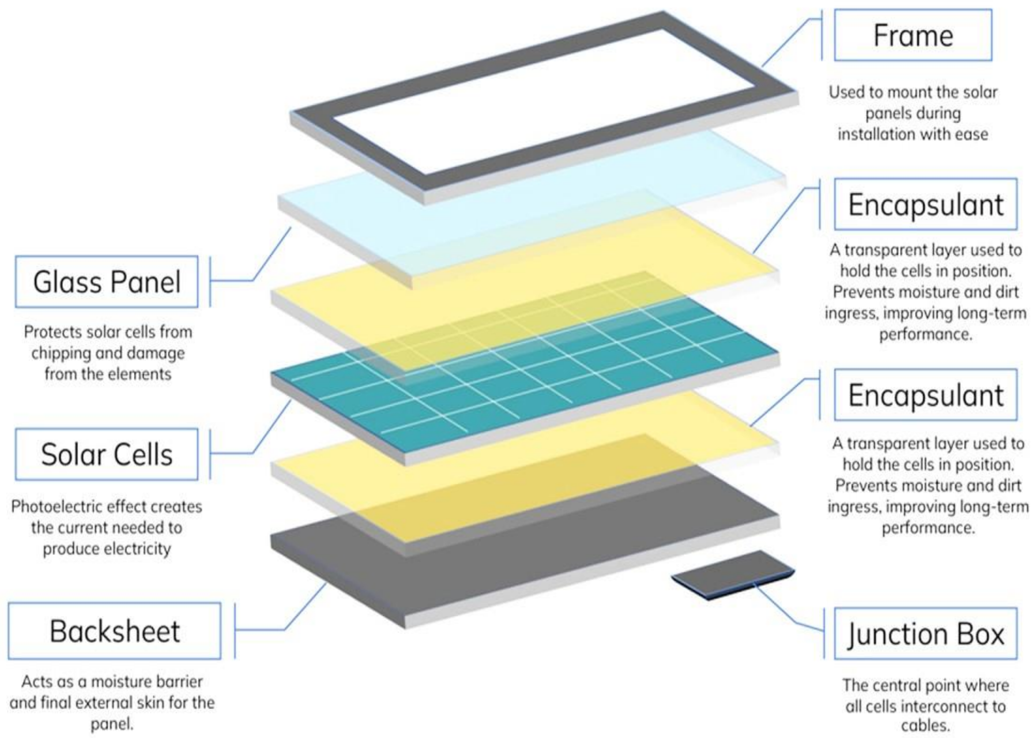


Source : HCPV Solar Parabolic Solar Concentrator - Solartron, 2016

4.3.2 Polycrystalline Solar Panels (p-Si)

Unlike monocrystalline panels which have a dark look and a round edge, this polycrystalline solar panels have bluish colour and square edges as illustrated in Figure 2. These polycrystalline have less immunity to high temperature compared the previous one. Polycrystalline panels are made from melting raw silicon. This process is faster and a lot cheaper than monocrystalline panels along with even having a bit less efficiency and shorter lifespan. Yet, the distinctions between mono- and polycrystalline solar panels are not very noticeable, and your decision will mainly rely on your individual circumstances. The initial choice provides a slightly better space efficiency at a slightly higher cost, but the power outputs remain essentially unchanged.

Figure 5: Polycrystalline solar panel



Source : Arbouch & Karzazi, 2014

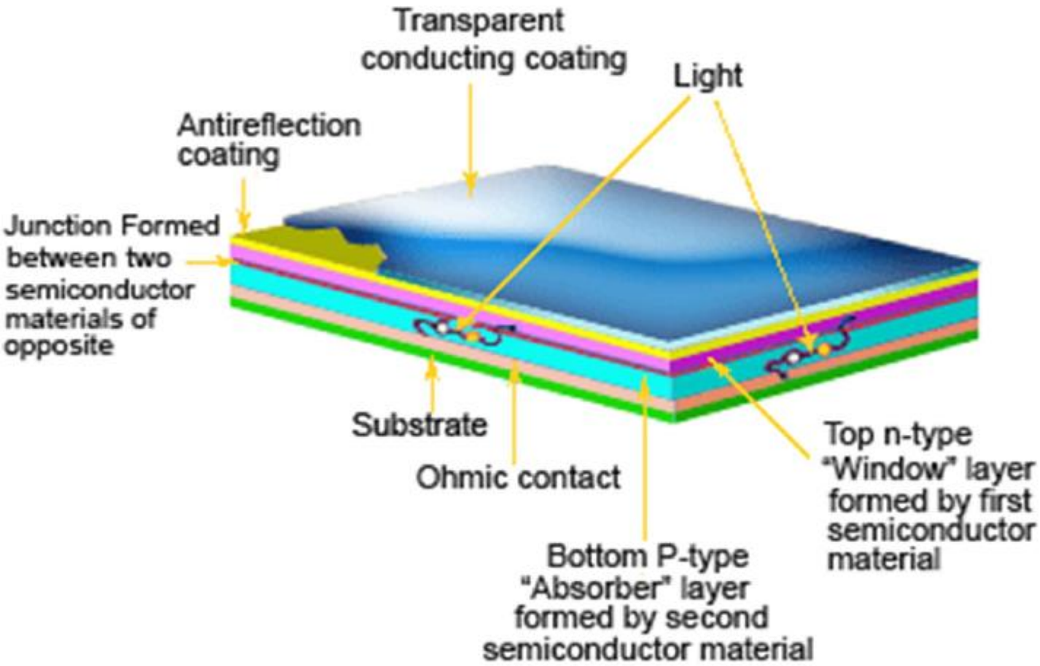
In this figure we can see exactly what the layers and the components of the polycrystalline panel are starting from the back sheet and the junction box up to the glass panel and the frame surrounding the main solar cells generating power to the junction box.

4.3.3 Thin-Film: Amorphous Silicon Solar Panels (A-SI)

Thin-film solar panels are a more affordable option. Thin-film solar panels are created by applying photovoltaic materials like silicon, cadmium, or copper onto a surface. These particular solar panels are the simplest to manufacture and cost less than other options because they require less material to produce, thanks to economies of scale.

They are versatile, offering several applications, and exhibit resilience to elevated temperatures. The main issue is their substantial spatial requirements, which generally make them unsuitable for residential environments. Moreover, their warranties are abbreviated owing to their reduced lifespan in comparison to monocrystalline and polycrystalline solar panels. Nonetheless, choosing them may be a feasible option among the several solar panel alternatives, provided there is sufficient room (Liu et al., 2022).

Figure 6: Thin-film solar panel



Source : Mag, 2022

4.3.4 Amorphous silicon solar panel

The amorphous silicon solar panel, used predominantly in pocket calculators, is one of the various types of solar cells available. This solar panel type utilizes a three-layer technology, which is considered the most superior among thin film options.

To briefly explain the concept of "thin" in this context, we are referring to a measurement of 1 micrometre (one millionth of a metre) in thickness. Although they are less efficient compared to crystalline silicon cells with an efficiency rate of around 18%, A-Si Cells have the advantage of being relatively affordable at only 7% efficiency rate.

Figure 7:Amorphous solar panel

Source : Zsiborács et al., 2017

4.3.5 Concentrated PV Cell (CVP)

The Biohybrid solar cell is a type of solar panel that is currently undergoing research. An expert team at Vanderbilt University made the discovery. The concept of the new technology is to utilize photosystem 1 to imitate the natural process of photosynthesis. If you are interested in understanding the intricacies of the biohybrid solar cell, check out the American Journal of Optics and Photonics for more information. It provides a more in-depth explanation of the functioning of these cells. The materials in this cell are mostly the same as traditional methods, but when multiple layers of photosystem 1 are combined, the conversion of energy from chemical to electrical becomes significantly more effective (up to 1000 times more efficient than first generation solar panels).

In the array of various solar panels, this method utilizes Cadmium Telluride for producing solar cells at a cheap cost, resulting in a quicker payback period of less than one year. Out of all types of solar energy technologies, this one uses the smallest quantity of water during production. With the short energy payback time of CdTe solar cells in mind, they will help minimize your carbon footprint. The sole drawback of Cadmium Telluride is its toxicity when consumed or breathed in. Especially in Europe, this is a major challenge to address, as there is significant apprehension among individuals regarding the technology involved in these solar panels.

Concentrated PV cells produce electricity in the same way as traditional photovoltaic systems. The efficiency rate of multi-junction solar panels can reach up to 41%, making them the most efficient photovoltaic systems available.

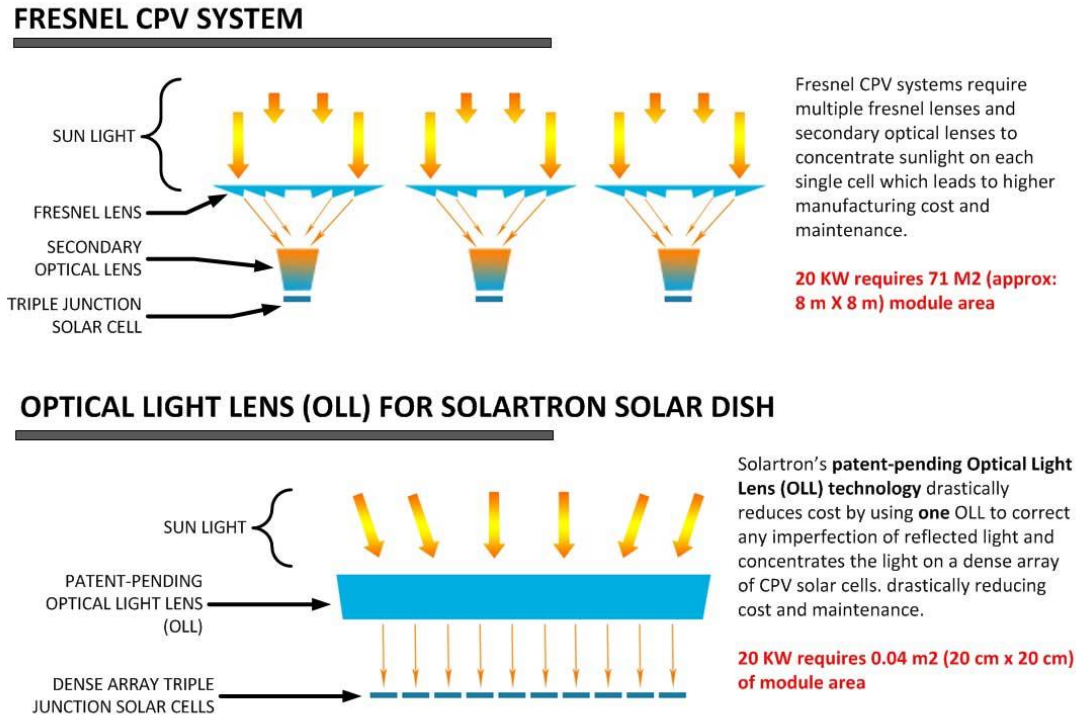
The efficiency of CVP cells is attributed to their use of curved mirror surfaces, lenses, and cooling systems to concentrate sunlight, making them more effective than other solar panels.

Through this method, CVP cells have emerged as one of the most effective solar panels, achieving a performance and efficiency rate as high as 41%. The only way for CVP solar panels to be efficient is if they are positioned at the correct angle facing the sun. To achieve high efficiency levels, a solar tracker within the solar panel oversees tracking the sun.

Figure 8: CVP solar system

Source : Zeina & Almaz, 2023

Figure 9: HCVP solar system



Source: *HCPV Solar Parabolic Solar Concentrator - Solartron*, 2016

4.3.5 Advantages and disadvantages of different types of solar panels

Only a small number of individuals are knowledgeable about the various technologies available in the market for solar energy, including solar thermal and solar water heating.

While these non-traditional solar panel options are primarily utilized for water heating, the upcoming sections provide a deeper overview of various solar panel types designed for producing eco-friendly electricity. Many years of research, effort, and progress have resulted in the diverse array of solar panels currently being offered in the solar panel market.

For example, if there isn't enough room on the roof, another option is to choose solar panels for the garden.

In order to provide a more extensive summary, Green Match has compiled useful details on the typical and unique varieties of solar panels.

Table 1: Solar panels comparison

Solar Cell Type	**Efficiency Rate**	**Advantages**	**Disadvantages**
Monocrystalline Solar Panels (Mono-SI)	~20%	High efficiency rate; optimised for commercial use; high life-time value	Expensive
Polycrystalline Solar Panels (p-Si)	~15%	Lower price	Sensitive to high temperatures; lower lifespan & slightly less space efficiency
Thin-Film: Amorphous Silicon Solar Panels (A-SI)	~7-10%	Relatively low costs; easy to produce & flexible	shorter warranties & lifespan
Concentrated PV Cell (CVP)	~41%	Very high performance & efficiency rate	Solar tracker & cooling system needed (to reach high efficiency rate)

Source : Askari Mohammad Bagher et al., 2015 ; UK Department of Energy & Climate Change, n.d.

4.3.6 How to upgrade European households with solar technology and analysis

Faced with a combination of crises including escalating climate change, political unrest, and energy insecurity. Increasing disparities and soaring living expenses - the need for immediate action is clearer than ever. The field of science1. absolutely makes clear the urgent need to quickly shift from fossil fuels to renewable energy to remain viable.

This means that the reduction of global warming to below 1.5°C requires a very radical transformation of our energy systems if consumption of energy is to be strongly reduced and an increase in sustainable renewable energy sources must reach the goal of 100% renewable energy. The EU strives for such a system, to be at least initiated by 2040. This transition has to be fast and just, centred on citizens and communities. Solar power serves as the catalyst for the transition to a people-centred approach by democratizing energy generation (Types of Solar Panels: November 2024 Guide, 2024).

Individuals and local communities are encouraged to be actively involved in the process of energy transition and to benefit from its fruits. Solar power, especially with its huge potential, scalability, and ease of access, enables households or community-level production of their own electricity to reduce energy bills and reliance on insecure and expensive sources. This will contribute to alleviating energy poverty and enhancing energy independence by not using hazardous fossil fuels.

Besides, rooftop PV systems do not occupy any space and may have negligible environmental impact. Their proximity to the point of use makes integration into the electricity system easy, thus ensuring minimum impacts of use. Rooftop solar PV offers benefits not only in addressing the climate crisis but also in the aspects of economic and social resiliency towards moving to a future where energy is fully renewable, affordable, and accessible to all [20].

Table 2: Engaging citizens and local communities in the solar revolution

Key Development	Date	Description
Adoption of REPowerEU Plan	May 2022	TThe "REPowerEU7" plan, which included a specific EU Solar Energy Strategy, was endorsed by the European Commission. It set goals for solar photovoltaics of 400 GW/dc by 2025 and 750 GW/dc by 2030. A "European Solar Rooftops Initiative" was also introduced by the EU Solar Energy Strategy, offering Member States specific recommendations.
Recommendation on speeding up permitting	May 2022	The Commission also presented the EC Guidance9 to Member States on best practices to expedite permit-granting procedures, including those on small-scale renewables by households and energy communities, and a Recommendation8 on expediting permit-granting procedures for renewable energy projects in conjunction with the

		RepowerEU plan.
Adoption of the revised Renewable Energy Directive (RED III)	Entered into force on November 2023	a significant advancement. According to RED III, Member States must allow no more than three months for the installation of solar energy equipment (and co-located energy storage) on man-made buildings like rooftops. The procedure should take no more than a month for installations under 100 kW, such as those made by self-consumers and renewable energy communities. For these smaller establishments, RED III also institutes 'administrative positive silence', in which the absence of an answer from the authorities is taken as acceptance. (Article 16d).
Emergency Council regulation on accelerating the renewable energy deployment	Since December 2022 until June 2024	By expediting the simplification of permitting procedures, including the installation of solar energy equipment on man-made structures like rooftops and granting positive administrative silence for the installation of solar energy equipment with a capacity below 50 kW, the regulation includes actions aimed at accelerating the deployment of renewable energy sources. The rule fills the gap until the Member States must implement the new permitting provisions from the updated RED.
Electricity Market Design Reform	December 2023	The Council and the Parliament have come to a tentative agreement to revamp the EU's electricity market structure with the goal of reducing the influence of fluctuating fossil fuel prices on electricity costs, protecting consumers from sudden price hikes, speeding up the adoption of renewable energy sources, and enhancing consumer safeguards. This reform defines regulations for energy sharing and responsibilities for system operators.

Source: Cots, F., et al., 2024

5. Methodology

Most people are aware of global warming and its effects on our planet and in result, most people are also familiar with solar panels and their use. Although, only a small fraction of individuals are truly aware of their environmental impact, such as their ability to provide clean, renewable energy and its cost effectiveness in the long term. Consequently, even though it seems like a good idea to install solar panels, many individuals never actually do so, frequently because of the high upfront costs, a lack of knowledge about incentives, or ambiguity regarding the installation procedure.

This paper consists of two separate practical research which will assist in reaching the end goal of the study. The first methodology employed in my thesis was a survey to assess the level of knowledge regarding solar panels and to measure the willingness of installing solar panels among the average European households (mainly in Hungary).

The survey was generated using Google Forms and a URL was distributed to 140 participants, mainly co-workers, friends and family who live in European countries.

The initial part of the questionnaire is comprised of four questions that are designed to collect demographic information from the respondents. These questions include the respondents' ages, levels of education, principal residence types, and whether or not they own or rent their primary property. When it comes to the scope of our research, this data is particularly important since it provides us with significant information such as the varied attitudes towards installing solar panels among those who own their property as opposed to persons who rent their residence. Additionally, it will shed light on the ways in which education directly influences an individual's tendency to gravitate toward a lifestyle that is more sustainable.

The second section of the survey consists of 4 questions to measure the level of awareness and attitude towards solar panels. This section will further assist in measuring the willingness of individuals in installing solar panels in regard to the level of knowledge they have about it.

The third and last section consists of 4 questions about financial considerations. As mentioned earlier, the majority of people shy away from installing solar panels due to financial concerns, even though many European countries offer loans and payment plans. The aim of this section of the survey was to analyse the effects of financial strain on participants' decision-making process in regards of installing solar panels and to gather real life data. The second practical study conducted in this paper is a model of a real standalone house that I 3D modeled in SketchUp. The house is located in a small town near Budapest Airport called Vesces. The exact co-ordinate of the house is Vecsés, (47°24'43"N 19°15'34"E). The house is a standalone one floor with an attic. This place accommodates three people at the moment.

I started by modeling the house on SketchUp by getting the exact location on Google Earth and the co-ordinates of the house. Using the "Add Location" option On SketchUp, I added the location and applied it to my 3D model. I started by laying the map's picture on the floor of the drawing to get the measurements of the house. I only modeled the exterior of the house as that was what is relevant to my practical study. The house is a pitched roof house, like most houses in the area, which is well suited for installing solar panels. I Applied 10 solar panels and placed them accordingly to the direction of the sunlight. Since the most common type of solar panel used in Hungary due to its better performance in low-light conditions is the monocrystalline silicon solar panel, it will be assumed that the 10 digitally installed solar panels are that type. These solar panels are assumed to be 1.65 m2 and to produce 300-watt. Then I modeled the solar panels as of the standards for one residential model. Moreover, I installed an extension to SketchUp called "Curic Sun", which tests the sun patterns through every month of the year. This add-on also grants the possibility to set the exact orientation with the help of the "Add location" option mentioned earlier.

The aim of this portion of the practical study is to illustrate a real-life property and digitally install solar panels on it to be able to compare the sustainable produced electricity bills to its current fossil fuel produced bills.

6. Analysis of the practical study

6.1 Survey analysis

6.1.1 Results of the first section (demographic information)

Table 3: Age demographics of the participants

Age demographics	Number of participants	%
Under 25	34	24.3%
25-34	63	45%
35-44	29	20.7%
44 or above	14	10%
Sum	*140*	

Solar panels have been around as early as the 1880s and the extended research around them started in 1970s. Although, solar panels became a part of the normal citizens' life only in the early 2000s. It was then that concerns around global warming became serious and government tax relief initiatives started to come to play (Smith, 2024).
Therefore, it is fair to say that age demographics play a crucial role in an individual's level knowledge and willingness regarding solar panels. In this study, most participants, 45%, belong to the 25-34 age group.

Table 4: Education level of the participants

Education level	Number of participants	%
Highschool diploma	15	10.7%
Bachelor's degree	75	53.6%
Master's degree	42	30%
PhD	8	5.7%
Sum	*140*	

More than 85% of the participants hold a university degree, which plays a crucial role in their level of knowledge and interest about solar energy.

Table 5: Primary residence type

Residence type	Number of participants	%

Single-family home	44	31.4%
Apartment/ condo	63	45%
Townhouse	32	22.9%
Other	1	0.7%
Sum	*140*	

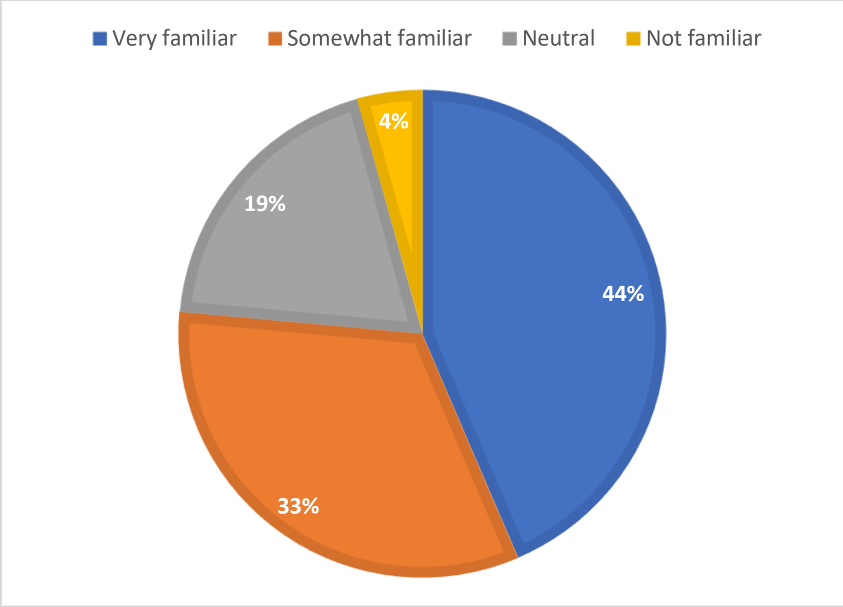
Table 6: Do you own or rent your residence?

	Number of participants	%
Own	44	37.9%
Rent	63	48.6%
Living with parents	32	13.6%
Sum	*140*	

Due to increasing prices of homes and the current world-wide economic challenges, most younger people live in rentals. This directly influences the reason people shy away from installing solar panels (even if the funds are available to them).

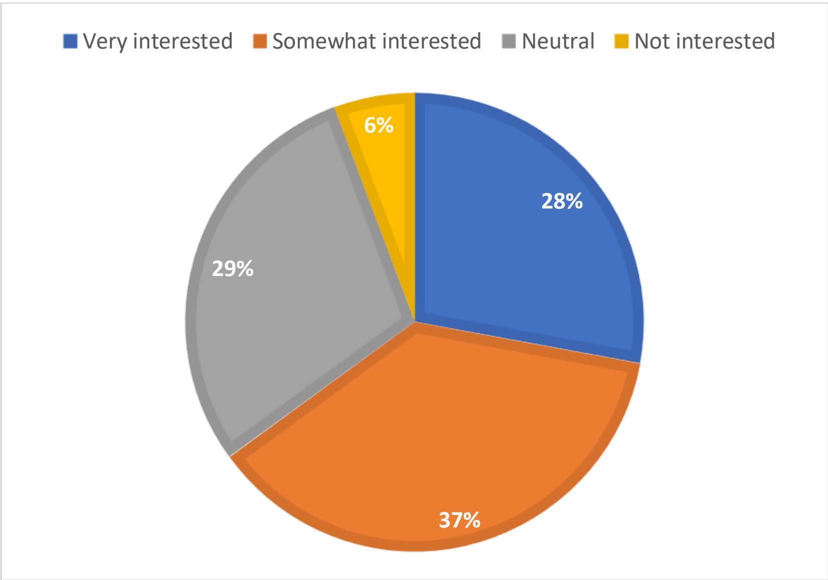
6.1.2 Results of the second section (awareness and attitude toward solar panels)

Figure 10: How familiar are you with solar panels?



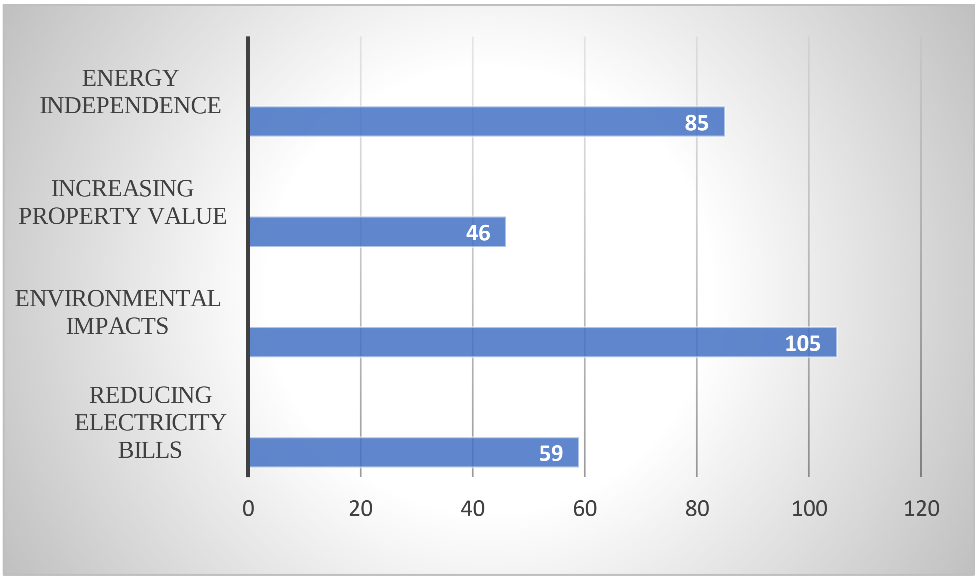
More than 70% of the participants were familiar with solar panels which could be directly related to the high level of education shown in the previous chart.

Figure 11: Current level of interest in installing solar panels



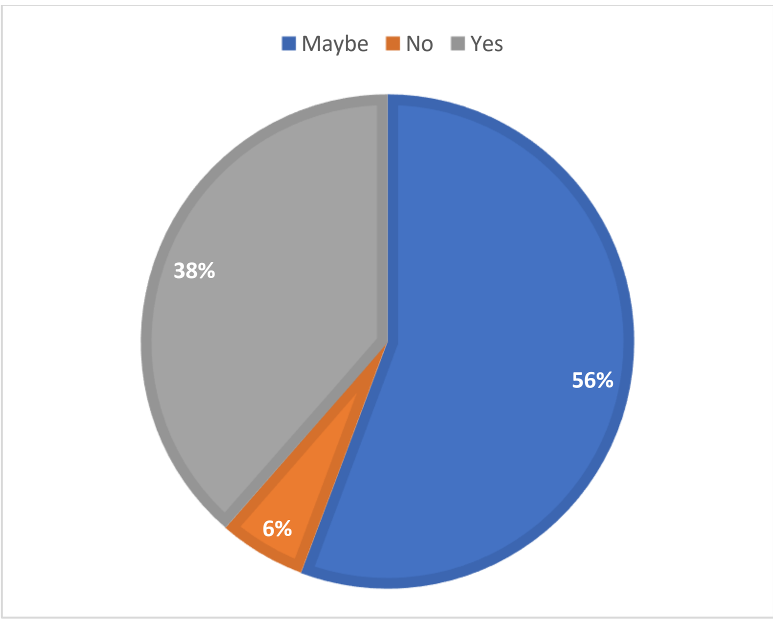
More than 60% of the participants showcased some level of interest in installing solar panels. Although, the majority responded that they are “somewhat interested”. This illustrates the hesitation present in people regarding this topic.

Figure 12: What do you believe are the main benefits of installing solar panels?



In this question, the participants where free to choose as many options as they desire. It can be observed that most of them believe the main benefit of solar panels is the positive environmental impact. Although, considering the current harsh economic environment and the increasing economical struggles, this is not convincing enough for the average citizen to invest in solar panels.

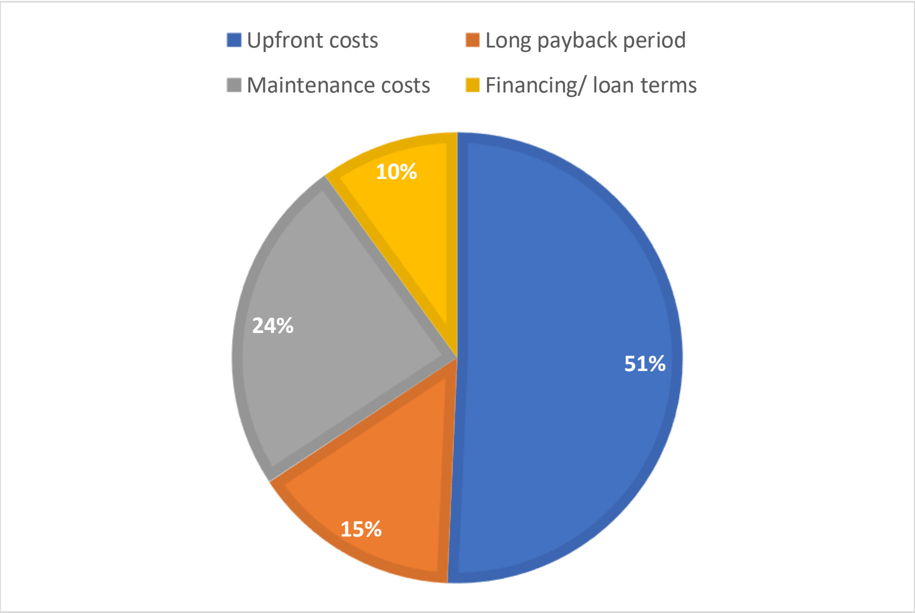
Figure 13: With your current level of knowledge about solar panels, do you believe that installing it is worth it?



The aim of this question was to get an understanding of the participants' current willingness of installing solar panels. Over half of the respondents selected "Maybe," reflecting a notable hesitation. This response aligns with previous findings on participants' interest levels in solar panels, further highlighting their cautious outlook. The next section of the survey about financial considerations sheds more light on the main reason of this hesitation.

6.1.3 Results of the third section (financial considerations)

Figure 14: Primary financial concern about solar panels



On average, the cost of installing solar panels in Hungary can be between HUF 1.2 million and HUF 5 million. Recent events such as COVID-19 and the war between Russia and Ukraine, has led to serious price increases across Europe, especially Hungary resulting in a significant decline in citizens' purchasing power. Therefore, this price for solar panels is considered high for them (Bene, 2022).

The results of this questions reflect the same concept. More than half of the respondents are concerned about the upfront costs.

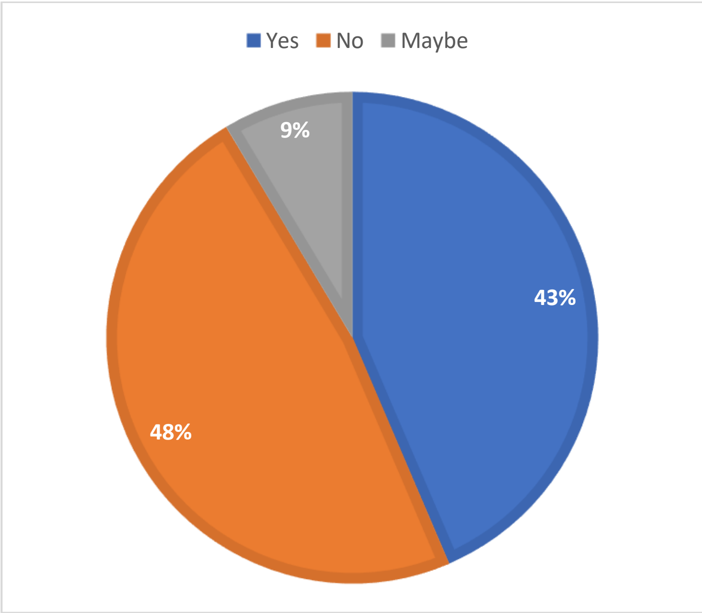
Table 7: Willingness of installing solar panels if financing options are available

Willingness	Number of participants	%
Very willing	68	49%

Somewhat willing	42	30%
Neutral	27	19%
Not willing	3	2%

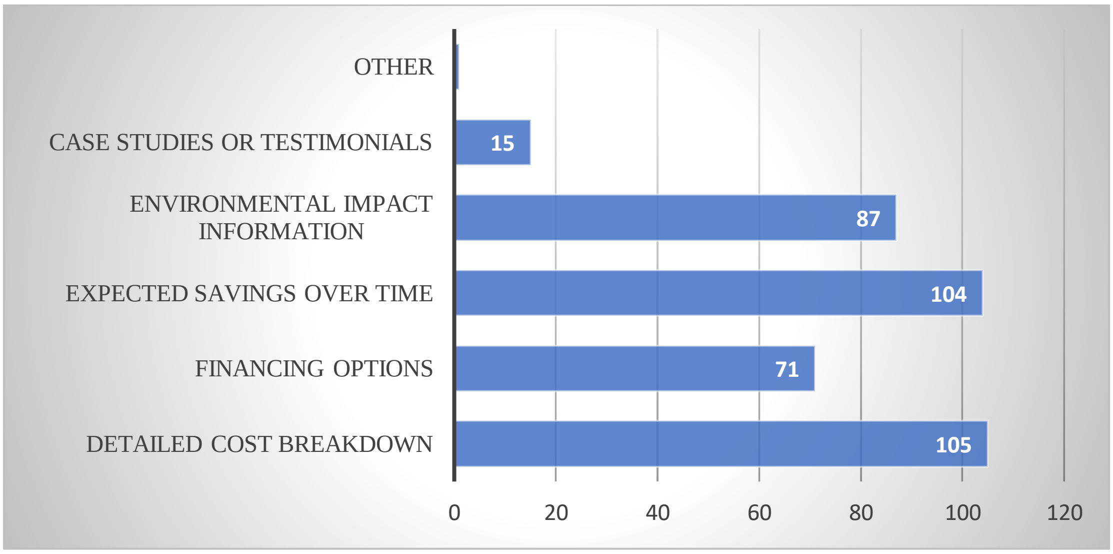
Although the participants showcased hesitation about installing solar panels due to high costs, it can be derived from the results of this question that if financing options are available, most of them are willing to take the initiative and install solar panels on their properties.

Figure 15: Would you consider a leasing option or a monthly payment plan for solar panel installation?



91% of the participants answered “Yes” or “Maybe” when given the leasing or a monthly payment plan option. This demonstrates that governmental financial support for the adoption of renewable energy, via reasonable lease or monthly payment choices, is a key step. Government financing options could increase the accessibility of solar panel installations for the general public. Such programs alleviate the financial strain on families facing substantial initial expenses, enabling more homes to transition to renewable energy and contribute to national and international sustainability objectives.

Figure 16: What additional information would help you decide to install solar panels?



In the last question, the participants could choose as many options as they wanted. It is important to understand what information the general public want to acquire to better have the possibility of making a decision towards installing solar panels. Most individuals think that having more knowledge about expected savings over time and detailed cost breakdown would be beneficial for them.

The overall result of this survey indicates that the majority of participants are interested in this topic and if financing options are available, may consider installing solar panels. It can also be derived that providing more information about solar energy and its long-term benefits would be valuable could encourage people to adopt it in their lifestyle.

6.2 3D Model

Figure 17: Sun light orientation comparison on January 1st and June 1st at 09:00

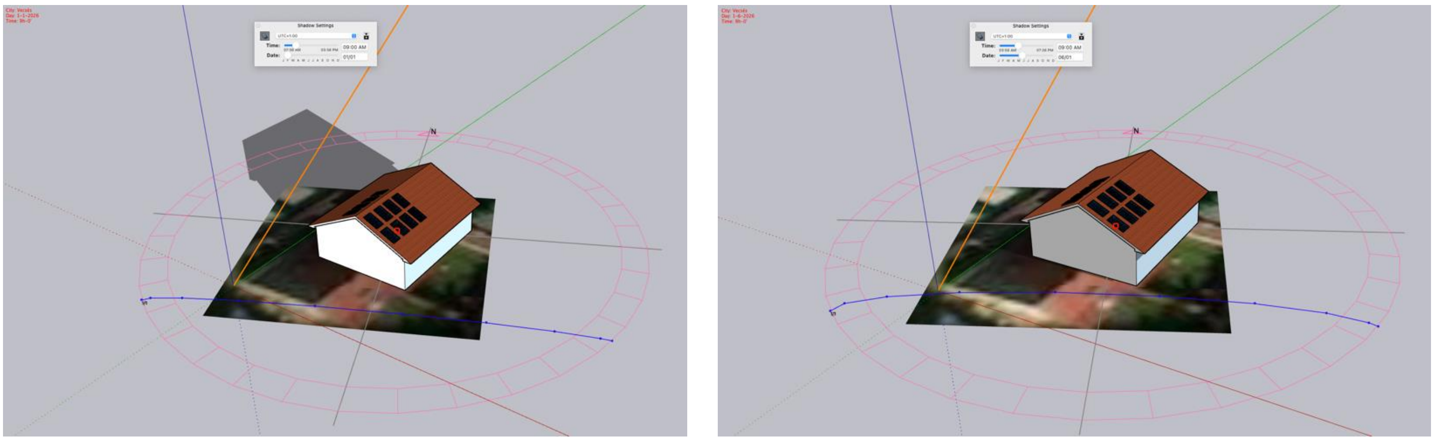


Figure 18: Sun light orientation comparison on January 1st and June 1st at 12:00

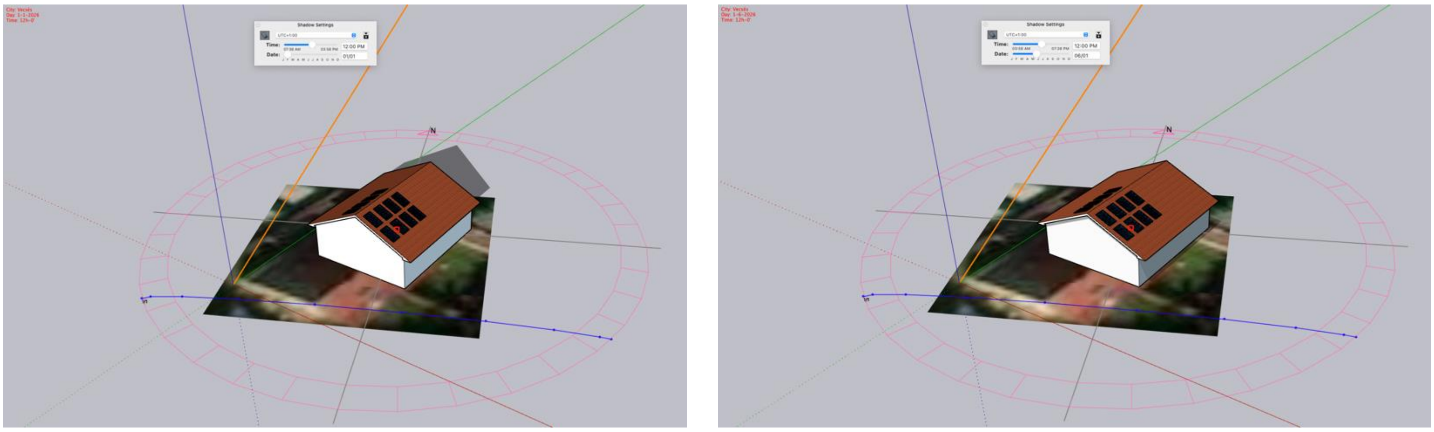
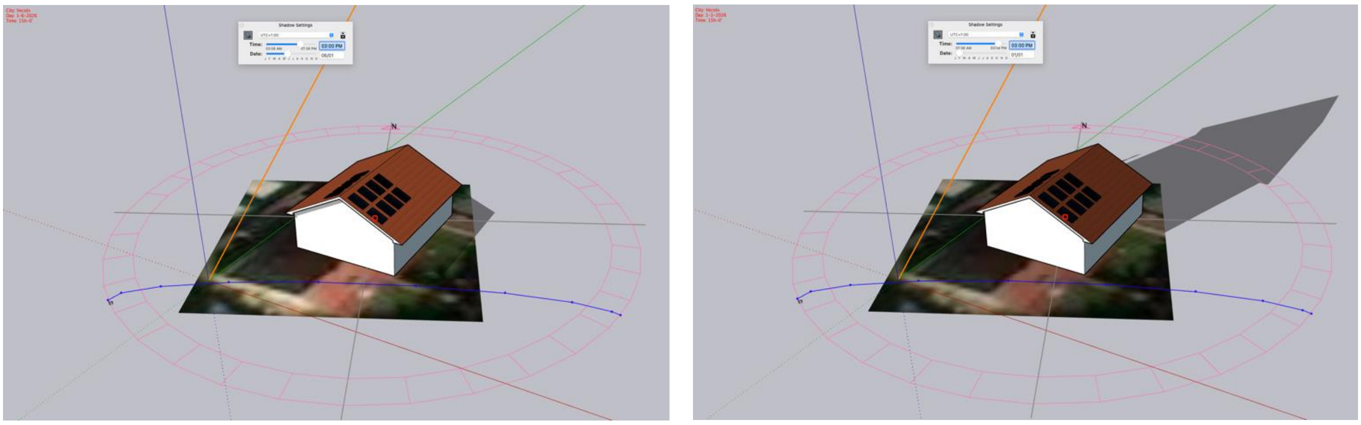


Table 8: The property's monthly electricity bill (Vecses, Hungary)

Figure 19: Sun light orientation comparison on January 1st and June 1st at 15:00



Above are the pictures of the model created from the property with solar panels installed. In each picture, three different times of the day in the months January and June is portrayed; 9:00 in the morning, 12:00 at noon and 15:00 in the afternoon. These three hours were picked to showcase the intensity of sun light in various times during the day. Although in June the sun sets at around 20:30, the hour 15:00 was picked since in January, the sun sets around 16:30. These two months were picked since they showcase the highest and lowest amount of sunshine Hungary generally receives, therefore it accounts for better comparison.

Table 9: The property's monthly electricity bills (Vecsés, Hungary)

Month	Total power usage (kWh)	Cost (HUF)
January	1153	61 115
February	1080	57 258
March	995	52 760
April	1064	56 408
May	932	49 375
June	691	36 612
July	587	31 107
August	1002	53 089
September	1224	64 870
October	219	11 618
November	512	27 115
December	896	47 512

The information of the above table was acquired from the owner of the property, and it illustrates the amount of electricity usage and its cost by that household.

Table 10: Estimated monthly solar energy production and saving (Vecsés, Hungary)

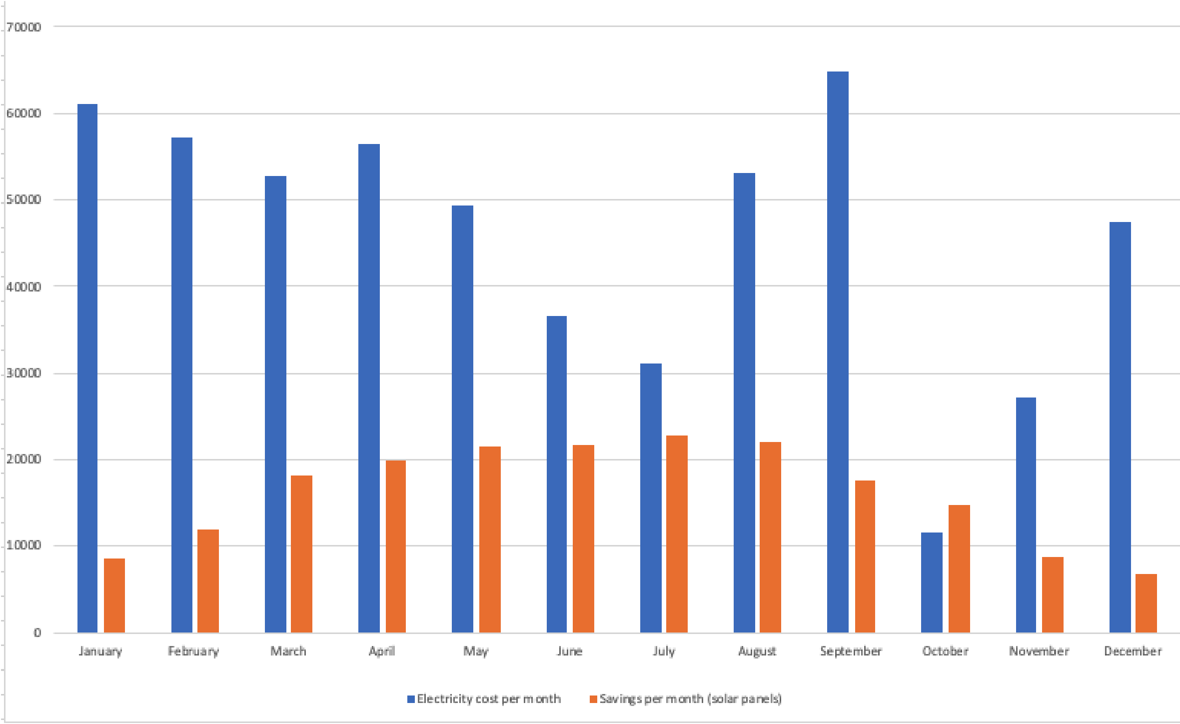
Month	Total power production (kWh)	Savings (HUF)
January	162.7	8 621
February	223.2	11 826
March	340.6	18 092
April	377	19 971
May	406.4	21 540
June	407.7	21 611
July	428.9	22 702
August	416.6	22 096
September	332.3	17 601
October	278.1	14 741
November	164.8	8 738

December	129.1	6 850

Source: Data retrieved from Global Solar Atlas, n.d.

The total power production was retrieved from Global Solar Atlas, considering there is 10*300-watt installed solar panels on the house. The price per kWh for this household was estimated 53 HUF (considering the kWh and the amount paid by the owner) and that is how the estimated savings are calculated.

Figure 20: Costs and savings comparison



The above chart illustrates how much of the total monthly electricity consumption of this property can be saved with solar panels. As expected, in months when the city receives lower amounts of sun, the contribution of the solar panels is minimal. However, in summertime, solar panels contribute greatly. In June and July, the solar panels could generate 60% and 73% of the electricity used. In this case, the bills for these two months would be 15001 HUF and 8405 HUF, which is a significant decrease.

Since Hungary is heavily reliant on fossil fuels, especially natural gas, household energy consumption has a significant negative environmental impact. On average, a typical household emits around 7.3 metric tons of CO2 annually due to electricity consumption (Wang et al., 2024). In addition to the financial gain, these solar panels help reduce the carbon footprint of households by offsetting a great portion of energy that would typically be sourced by fossil fuels.

7. Conclusion and proposals

This thesis will present various possibilities and difficulties found in the domestic utilization of renewable solar energy within the European Union, especially Hungary. A qualitative approach was used to demonstrate possible locations for solar panels, together with a cost-benefit analysis for the 3D-modeled home. Quantitative data came from a survey of 140 participants. The results suggest decisions by householders to adopt solar are complex and multifaceted, involving a wide set of influences with far-reaching consequences for the industry participants and policymakers alike. Based on the results of the survey, it was concluded that the main deterrent for individuals to install solar panels are their upfront costs. In 2022, Hungary suffered from a dreadful inflation rate of 14.61%, exacerbating the financial strain on households and rendering the initial investment in solar energy increasingly unsustainable for numerous individuals. This economic hardship, combined with escalating energy bills, has rendered the environment unfavorable for the widespread adoption of solar technology.

The data in this survey testifies to rather good awareness of solar energy and its environmental benefits. This, however, does not translate directly into wide usage. There is a major disconnection between knowledge and action, orchestrated mainly by high starting costs and a lack of easily accessible financial mechanisms. While the questionnaire revealed that the high proportion of the respondents held university degrees, which points to a higher level of environmental awareness, knowledge alone cannot surmount such a sizeable enough financial barrier. This therefore points to one crucial need for policy intervention in terms of affordability matters rather than merely information dissemination.

Regardless of that, the results obtained from the survey showed that Hungarian residents are indeed very interested in renewable energy solutions because of environmental concerns and financial savings that can be attained in the long run with solar panels after initial costs are surmounted. Promotion by subsidies or incentives to encourage setting up solar installations with public education about long-term savings could thus be quite instrumental in the development of this type of energy not only in Hungary but also in the European Union in general.

Further evidence of the economic challenges facing those who would adopt solar energy comes from the analysis of the 3D-modeled household. The simulation revealed a huge saving in both June and July peak sunlight periods of the electricity bills in this particular household. On the other hand, it also shed light on the considerable initial investment required. The upfront costs involve not just the panels but also their installation, ancillary equipment such as inverters and batteries, and possible grid-connection charges. This rather sizeable upfront expense can be a very important entry barrier for most households, especially for those of modest means.

These results also show the lack of harmonization among states regarding their legal frameworks in the EU. Different procedures for obtaining permits, various rules to connect to the grid, and metering requirements have raised uncertainty, potentially discouraging or delaying implementation. The lack of harmonization suggests a requirement for directing implementation regulations at a European level that would ease installations and reduce associated costs.

Solar energy offers many benefits, opening up the possibility for a wide range of studies and research to be done. Longitudinal study on adoption rates and economic-cum-environmental impacts of the solar panel across various EU member states is required to appraise the effectiveness of various policy interventions. Comparative case studies that analyze successful solar energy adoption strategies across different contexts would offer real value for drawing insights into best practices. The added value of deeper investigation into social and psychological factors that influence household decisions to adopt solar energy-risk-aversion, trust in technology, perceived benefits-may add significant value to understanding and communication strategy. This would be further followed by a detailed cost-benefit analysis at the full life cycle of solar panel systems-manufacture, installation, operation and maintenance, and eventual disposal-to have a better understanding of the long-term economic viability of solar energy and also to inform better policy design.

9. Summary

As the environmental impacts of using fossil fuels for energy productions continue to introduce a significant risk, implementing renewable energy, especially solar energy is becoming more important every day. The aim of this thesis is to identify variables that drive or hamper the adoption of solar energy at the household level in European Union countries, more precisely in Hungarian settings. It employs a mixed-methods approach-e.g., the combination of a survey with 140 participants and a 3D-modeled house simulation. The result indicates a high level of awareness regarding the benefits derived from solar energy; at the same time, great hesitation does exist because of the high upfront costs-a situation that has been exacerbated by the current economic situation in Hungary. The 3D model has huge potential cost savings but points toward a considerable initial investment. Some of the main barriers that have been identified include high upfront costs, complex permitting, and lack of readily available financing options. Thus, the study conclude that such increased solar adoption sets a call for government-supported financial incentives in the way of subsidized loans or leasing, streamlining of EU-wide regulations, and targeted public awareness campaigns. Moreover, further research must be done in order to get clearer views on the long-term economic and environmental impacts that could guide effective policy development.
The study indicates a strong correlation of education level with awareness of solar energy; however, financial concerns far outweigh environmental considerations in driving the decisions to adopt the technology. Such findings suggest a need for supportive policies that address financial and regulatory barriers for wide diffusion of solar energy.

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11. List of tables and figures

12. Annex

Survey questions

1. Age

   a) Under 25

   b) 25-34

   c) 35-44

   d) 44 or above

2. What is your level of education?

   a) Highschool Diploma

   b) Bachelor's Degree

   c) Master's Degree

   d) PhD

3. What is your primary residence type?

   a) Single-family home

   b) Apartment/condo

   c) Townhouse

   d) Other

4. Do you own or rent your residence?

   a) Own

   b) Rent

   c) Living with Parents

   d) Other

5. How familiar are you with solar energy and solar panels?

   a) Very familiar

   b) Somewhat familiar

   c) Neutral

   d) Not familiar

6. What is your current level of interest in installing solar panels on your property?
    a) Very interested
    b) Somewhat interested
    c) Neutral
    d) Not interested

7. What do you believe are the main benefits of installing solar panels? (Select all that apply)
    a) Reducing electricity bills
    b) Environmental impacts
    c) Increasing property value
    d) Energy independence
    e) Other

8. With what you currently know about solar panels, do you feel that installing them would be worth it?
    a) Yes
    b) No
    c) Maybe

9. How willing are you to invest in solar panels if financing options are available?
    a) Very willing
    b) Somewhat willing
    c) Neutral
    d) Not willing

10. What would be your primary concern about the cost of solar panels?
    a) Upfront costs
    b) Long payback period
    c) Maintenance costs
    d) Financing/ loan terms

11. Would you consider a leasing option or a monthly payment plan for solar panel installation?
    a) Yes
    b) No
    c) Maybe

12. What additional information would help you decide to install solar panels? (Please select all that apply)
    a) Detailed cost breakdown
    b) Financing options
    c) Expected savings over time
    d) Environmental impact information
    e) Case studies or testimonials
    f) Other

DECLARATION

the public access and authenticity of the thesis/dissertation/portfolio 1

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Student's Neptun code: FIM6NT

Title of thesis: How to increase the use of certain renewable energy sources in households?

Year of publication: 2024

Name of the consultant's institute: Hungarian University of Agriculture and Life Sciences

Name of consultant's deparment: Department of International Regulation and Economic Law

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Student’s signature

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Omar Sherif Anwer Abouelseoud (NEPTUN code: FIM6NT) as a consultant, I declare that I have reviewed the final thesis and that I have informed the student of the requirements, legal and ethical rules for the correct handling of literary sources.

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The thesis contains a state or official secret: yes **no**

Date: Gödöllő, 11. November 2024

Dr. Csegődi Tibor László

Insider consultant