THESIS

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INVESTIGATION OF FEASIBILITY STUDY OF A SOLAR FARM IN LAOS AND HUNGARY

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I. INTRODUCTION

The need for energy to improve living conditions increases with population growth and technological advancements. However, the use of conventional fossil fuels has resulted in environmental issues such as climate change, air pollution, and acid rain. It is important to develop renewable energy technology to address these challenges. Researchers are interested in determining the economic viability of new sources like photovoltaic panels that utilize solar energy, which is a promising market within the renewable industry (Kim et al., 2014; Sampaio & González, 2017).

Laos and Hungary have energy profiles that are significantly different. Laos is a developing country in Southeast Asia, whereas Hungary is a developed country in Central Europe. Despite these differences, both nations are facing energy issues that require attention. In Lao PDR, most of the electricity generation comes from hydropower plants, which have been heavily harvested to meet the country's energy demand and exported to neighboring countries, aiming to become the "Battery of Southeast Asia" (Runde et al., 2022). However, due to the decrease in precipitation during the previous rainy season and the tremendous climate change, the entire nation is currently facing a long-term electricity crisis, and there is no assurance that the upcoming rainy season will generate adequate precipitation to meet the needs (EDL-Gen, 2007). In addition, despite the growing energy output, the cost of electricity is increasing. In 2022 and 2023, Electricite du Laos (EDL) raised the price of electricity by 2%, making it challenging for ordinary Laotians to pay their bills because of low wages. The country's high electricity rates can be attributed to the significant debt owned by the government to foreign countries for building hydropower dams. Although electrification has been extended throughout the country, rural communities in remote locations still lack electricity due to costly power line installation fees (Phouthonesy, 2021; RFA Lao, 2023). To address the crisis, the government aims to generate a mix of 30% renewable energy, with solar energy as a major component, by 2030 (MEM, 2011). However, the price of solar PV has now steadied and begun to decrease globally, and according to data from the Stimson Center, the Mekong region is also experiencing a decline in the cost of solar modules (Phouthonesy, 2021). Creating a community solar farm could potentially support Laos' targets of electricity exportation and promote long-term sustainability. A community solar farm allows individuals to obtain access to solar energy without installing their own panels. Instead, solar farms generate energy and feed it into the local grid for residents to consume (Perch Energy, 2023). This approach facilitates participation in renewable energy initiatives, reduces electricity costs, and provides social-economic benefits like creating jobs, along with improved sustainable infrastructure accessibility across remote areas (Joshi & Yenneti, 2020).

On the other hand, Hungary has a more diverse energy mix than Lao PDR, where fossil fuels contributed to 68% of Hungary's total energy supply (TES) in 2020. Hungary's reliance on Russia for its domestic energy sources has made it vulnerable to energy security concerns, especially after Russia's invasion of Ukraine. To address the crisis, Hungary plans to enhance domestic gas and coal production, secure extra gas imports, and increase the output of the country's lignite-fired power plant (*Nemzeti Energiastratégia 2030*, 2012). As Hungary is part of the European Union (EU), the EU has energy targets for 2030, including reducing greenhouse gas emissions by 40%, increasing the share of renewable energy by 32%, and improving energy efficiency by at least 32.5% (*NECPs*, 2022). Based on the REpowerEU plan's aim to reduce dependence on Russian fossil fuels by 2027, The country aims to increase the share of renewable energy in gross final consumption by 21%, eliminate coal, and transition to clean energy to achieve 90% clean electricity use in power generation by 2025 (IEA, 2022a). The energy crisis caused by Russia's invasion of Ukraine has given renewable energy a boost, and it is predicted that the renewable industry will account for almost 90% of the growth of worldwide power capacity in the next five years (IEA, 2023). As a result of major capacity growth in 2020 and 2021, the People's Republic of China will have more than half of the world's renewable energy capacity in 2021, while the United States and the European Union have also experienced significant growth (Bojek, 2022). While Laos works on developing its hydropower potential and investigating alternative renewable energy sources, Hungary seeks to diversify its energy supply and lessen its reliance on imports. By solving these concerns, both nations can ensure an energy future that is secure and sustainable. The goal of this research is to investigate the technical, economic, and legal feasibility in terms of the solar potential for a solar farm based on independent data, government policies, and data available online with free access in Laos in comparison to Hungary to determine whether it will be a feasible project or not. Yet there are many criteria that must be met, such as economic and legal aspects as well as the analysis of legal and economic incentives that support solar farm installation.

- If Laos and Hungary have solar potential to install and not conclude land-constraint, then would the installation of solar farm provide cheaper electricity bills to the community.
- implementing a solar farm will result in a profitable investment, as the declining cost of solar technology and the increasing demand for renewable energy sources will allow for competitive electricity prices and a positive return on investment. Countries with favorable policies and legal framework will have higher rates of solar farm deployment.

II. LITERATURE REVIEW

2.1 Solar PV Technology

There are several PV cell methods available now that use a variety of materials, and there will be even more in the future. Depending on the primary material utilized and the level of commercial development, PV cell technologies are typically divided into three generations (HARANGOZO, 2021).

Table 1: Solar PV cell generations

PV	TYPES OF PV CELLS
FIRST GENERATION (SILICON)	- Monocrystalline - Polycrystalline - Amorphous Silicon Cell
SECOND GENERATION (THIN FILM)	- Amorphous silicon - Cadmium Telluride - Copper-Indium-Selenide (CIS) and Copper-Indium-Gallium-Diselenide (CIGS)
THIRD GENERATION	- Dye sensitized (DSSC) - Perovskite - Organic (OPV)

Source: HARANGOZO, 2021; Umair et al., 2021

Many study reviews have been distributed, analyzing the effectiveness of various photovoltaic (PV) modules for deployment in a wide range of applications. See Figure 1. The typically used PV modules are made of wafer-base crystalline silicon cells or thin-film cells built on cadmium telluride or silicon crystalline silicon, which is normally utilized in wafer form for PV modules (Tiwari et al., 2011). Most commercially available solar cells are made of monocrystalline or polycrystalline silicon. With over 95% market share, crystalline polysilicon remains the dominant technology for PV modules (Bojek, 2022). PV modules are very efficient when they have a well-organized crystal structure with atoms in predetermined places. Mono-crystalline cells are made of authentic monocrystalline silicon with no imperfections. The monocrystalline cells are high efficiency and the most costly because of their complicated manufacturing process of a single silicon crystal into thin slice wafers and the process of producing monocrystalline (Arno et al., 2016). In comparison, multi-crystalline cells (also known as polycrystalline cells) are cheaper due to their production techniques but less efficient, with a 23.3% efficiency rate (NREL, 2022; Plante, 2014). which are made of a collection of silicon crystals. Typically, the efficiency of this sort of cell ranges from 21.2% to

27.6%. A thin-film photovoltaic cell is a form of photovoltaic cell that is created by thin layers of light-sensitive material and installed on affordable surfaces such as glass, stainless steel, or plastic. Thin-film technology has increased in recent years because of its flexibility, ease of installation, and approximately 21% efficiency under low light. In addition, these cells have a 25-year lifespan (Mundo-Hernández et al., 2014; NREL, 2022).

Solar PV module has dramatically decreased with crystalline silicon that modules sold in Europe between 88% and 95% during 2009 and 2021 have been a significant contributor to increased competitive with fossil fuels (IRENA, 2021).

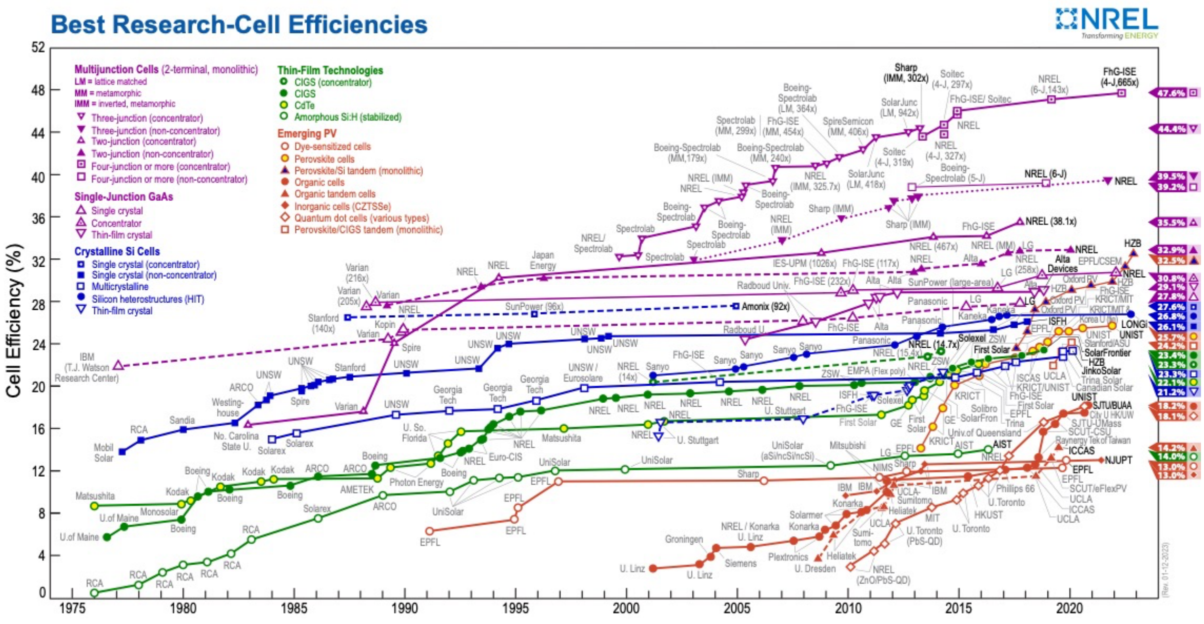

Figure 1: Research on efficiency of solar panels.

Source: NREL, 2022

There is no specific technology that is believed to be more ideal for solar farm applications than another, and the PV modules and their configuration will depend on the types of application and the chosen site where the system will be installed (Plante, 2014; Carr & Pryor, 2004).

2.2 Photovoltaic Solar Energy

Photovoltaic (PV) energy, often known as solar electricity, is generated by electrical devices that convert sunlight into electricity through the photovoltaic effect. Typically, the photovoltaic effect refers to the occurrence of a voltage difference at the interface of two dissimilar materials as a result of exposure to visible or other forms of radiation (Zeman, 2010). Photovoltaic materials are capable of absorbing, reflecting, or transmitting photons. As a photon is absorbed, its energy is transmitted to an electron in the material, causing the electron to jump into the conduction band if the photon's energy is greater than the band gap of the semiconductor. This causes the production of electric current. A p-n junction with an applied electric field across its front and rear can be used to remove the free electron from the material. The electron recombines with the atom in the absence of an electric field. Nevertheless, if the photon energy is less than the band gap energy, the electron lacks the energy to migrate into the conduction band, and its extra energy transforms into kinetic energy, which boosts the temperature of the material. Despite the intensity of the photon energy, only one electron can be discharged, which explains why photovoltaic cells have a low efficiency (Kalogirou, 2009).

Solar energy conversion into electricity takes place within a semiconductor device called a solar cell. Individual solar cells only generate about 1 or 2 W of power (Plante, 2014, p. 112). To generate enough electricity, several solar cells are combined to form a solar panel or photovoltaic (PV) module to use solar energy to power operational devices with a certain voltage and current needs. When solar electricity is generated on a utility scale, solar panels are interconnected to produce more power, called a solar array (Zeman, 2010).

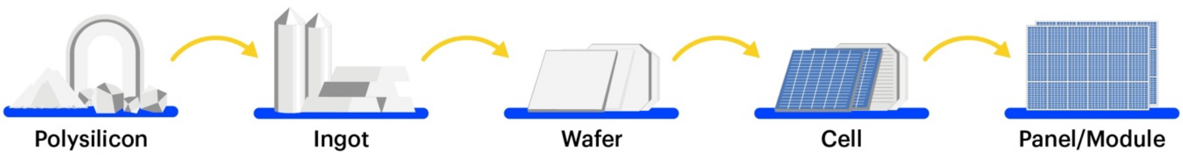

Figure 2: Types of photovoltaic cells

Source: Bojek, 2022

2.2.1 Photovoltaic Solar Energy System

A typical photovoltaic solar system consists of four basic components: a solar photovoltaic module, module mounting systems, a charge regulator, inverters, and, if necessary, a battery.

The PV modules consist of solar cells or surfaces that generate and directly convert sunlight into electricity. These surfaces work without the use of fuel, vibration, noise, or negative environmental impact. In addition, there are no moving parts to wear out or break. Moreover, Module mounting enables PV modules to be safely attached at a set tilt angle to the ground or sun tracking frames. Yet, the charge controller is an essential component for battery preservation, enhancing its life to prevent it from overcharging. In turn, an inverter is responsible for converting the direct current (DC) electricity produced by the solar panels to alternating current (AC) voltage levels and network frequency. In photovoltaic systems, batteries are used to store the extra energy generated by the modules so that it can be used at night or on cloudy days. They are mostly used in stand-alone PV systems (Alasdair Miller & Ben Lumby, 2012; Hosenuzzaman et al., 2015; Kalogirou, 2009; Silveira et al., 2013)

2.2.2 Arrangements

All solar energy systems operate based on same fundamental principles. The process of converting solar energy into useable electrical power involves that conversion of solar energy into DC power. This DC power can then be either stored in a battery or further converted into AC power through the use of solar inverter then can be used to various household appliances.

Depending on the types of solar system, exceed solar energy can be supplied to the grid to generate credits and further reduced in electricity cost. PV applications can be classified into Three main types: stand-alone, grid-connected and Hybrid systems (Newkirk, 2016).

Stand-alone PV systems are installed in locations that are inaccessible or lack access to the main electrical grid. A stand-alone system operates independently of the electricity grid. A general stand-alone system consists of solar photovoltaic modules, batteries, and a charge controller. A system may include an inverter to convert the DC produced by the PV module into AC required by standard appliances. Typically, the energy produced from PV modules are stored in the batteries (HARANGOZO, 2021; Kalogirou, 2009).

Hybrid solar systems integrate solar and battery storage into a unit and are now available in a diverse range of forms and configurations. As a results of the reduction in battery storage expenses, electricity grid-connected systems can now effectively use battery storage. This concept involves the capacity to store the solar energy produced during the day and subsequently using it at nighttime. In situations where the stored energy has been used up, the grid serves as a backup, allowing users to have advantages of both alternatives. Hybrid systems have the capability to recharge their batteries by utilizing cost effective off-peak electricity (HARANGOZO, 2021).

On the other hand, in grid-connected application, the PV system is linked to the local electrical grid. During the daylight, the electricity generated by the PV system can either be utilized directly (typical for systems installed on offices and other commercial buildings) or sold to an electricity supplier (common in domestic systems). In the night, when the solar system is not generating electricity, it can be bought back from the network. The grid functions as an energy storage system, therefore the PV system does not require battery storage (Kalogirou, 2009).

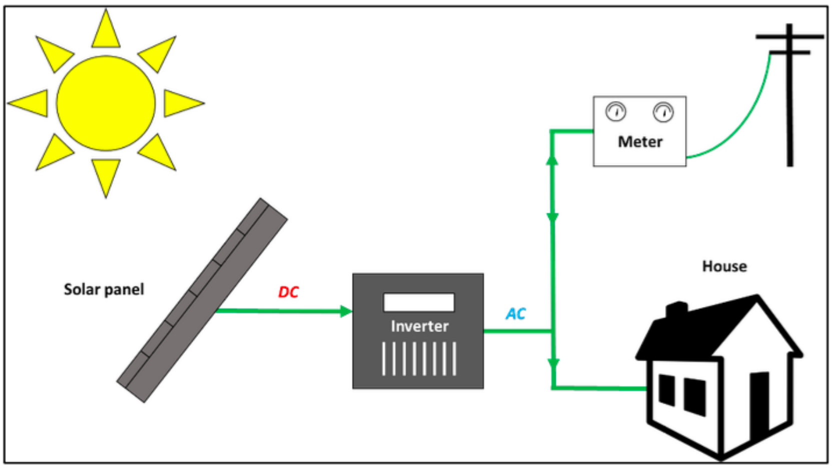

Figure 3: Grid solar energy systems

Source: HARANGOZO, 2021

2.3 Solar Farm

A solar farm, also known as a solar park, is referred to as a large-scale power generating facility aimed at supplying the bulk of the electricity to the community or the electrical grid and producing little noise, no moving parts, and generating no hazardous emissions; some also interpret a solar farm as a large-scale installation on agricultural land that can cover up to 40 hectares of land, where solar panels are interconnected into arrays and mounted into either a fixed tilted array or a tracking array configuration (Jones et al., 2013; Wolfe, 2012). The arrays are mounted on aluminum and steel frames and typically stacked in rows. The panels are ideally oriented and positioned between 1 and 3 meters above the ground to preserve the area's ecosystems and vegetation. The rows are separated to facilitate accessibility and reduce the influence of shading on the system's efficiency and energy output. Generally, solar farms are intended to last between 20 and 25 years and are often viewed as temporary land use. There are no long-term concerns because the entire installation can be removed easily, and the site can be restored to its original purpose if necessary (Jones et al., 2013).

Table 2: Advantages and Disadvantages of solar photovoltaic

Solar Photovoltaic	
Advantages	• Clean energy, renewable resource, noiseless and environmentally friendly • Low expenses for operation and maintenance • Greenhouse emissions reduction • Reliable system

Disadvantages	• Require large amount of land • Low rate of return and long payback period • High initial cost especially with storage Weather dependent (Solar irradiance), no solar power at night	

Source: Sampaio & González, 2017; Soonmin & Taghavi, 2022

2.3.1 Solar Radiation

Evaluation of the solar resource is essential for optimizing the photovoltaic (PV) energy since it determines the viability of a plant in a particular location. Solar radiation refers to the sun's electromagnetic waves, the most plentiful renewable resource. Any surface on earth will receive varying amounts of sunlight based on its location, the time of day, the season, the surrounding topography, and the weather. The primary objective is to determine how much solar potential is accessible and how much electricity can be produced annually by a PV power plant using standard PV technology (Renné et al., 2008).

Radiation is the primary factor in solar energy farms and power systems. In addition, it is measured in W/m^2 and There are three primary components of solar radiation that enter the PV panels: direct, diffuse, and reflected solar radiation (albedo). Direct solar radiation comes straight from the sun without obstructions like clouds along its direct path. Diffuse radiation is spread through atmospheric components like clouds and dust. Reflected solar radiation is reflected from the surface features (Pinde Fu & Paul M. Rich, 1999).

When analyzing the potential solar resource, it is crucial to consider all three components of solar radiation at the earth's surface, as they can have a significant impact on the performance and efficiency of different types of solar energy systems:

***Direct normal irradiance (DNI)*:** The DNI is the amount of sunlight that can be used by concentrating solar power (CSP) systems and high concentration photovoltaic (HCPV) systems, which need direct sunlight to work effectively. Nonetheless, DNI is an essential component of global irradiance, especially in cloudless conditions (Blanc et al., 2014).

***Diffuse horizontal irradiance (DHI)*:** solar radiation from the sky, excluding DNI, that has been scattered by clouds, aerosols, and other atmospheric components present on a horizontal surface, as measured by a shades pyranometer with a 180-degree field of view (Kleissl, 2013).

***Global horizontal irradiance (GHI)*:** the total hemispheric of solar radiation, including both direct and diffuse radiation, that reaches a horizontal surface (Kleissl, 2013). GHI data, along with DNI, DHI, and reflected ground irradiance (albedo), can be used to estimate the amount of solar radiation on tilted plate collectors. The amount of sunlight that hits solar collectors with horizontal flat plates is described by DHI data. This part of solar radiation is important for all types of PV systems, and it is the most common way to measure the potential of a solar resource (Zell et al., 2015).

Irradiation is measured in kilowatt-hours per square meter (kWh/m2), and typically given daily, monthly, and annual values. A high long-term average yearly GHI is often of the highest relevance to PV project developer (Alasdair Miller & Ben Lumby, 2012).

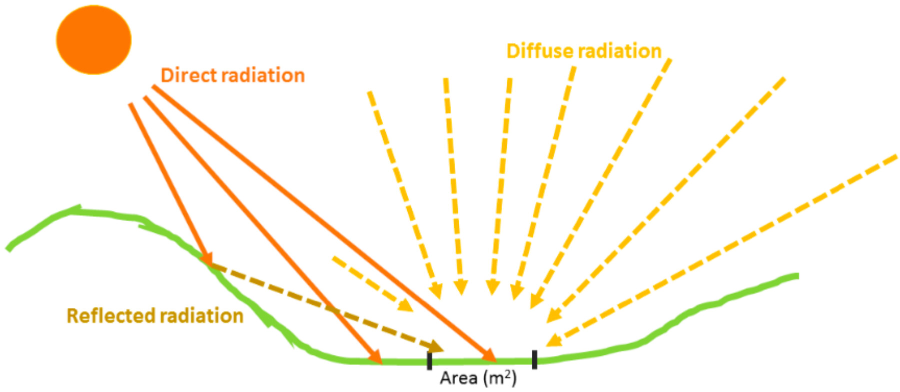

Figure 4: Types of solar radiation

Source: Kauria, 2016

2.4 Current stated of solar energy in Laos and Hungary

Lao PDR is mountainous and forested terrain with tropical climate, solar potential is expected to be 4.4 kWh/m^2/day within a range 3.6 – 5.5 kWh/m^2/day and receives between 1,800 – 2,000 hours and 300 days of sunlight annually (ADB, 2019). With such solar energy potential, photovoltaic technology would produce approximately 146 kWh/m^2/year or $1.5x10^8$ kWh/km^2/year equal to 13 MTOE/ km^2/year (MEM, 2011). Solar power has the potential to play a significant role in providing off-grid electricity to remote areas, given its technical capacity (Hubbard, 2017). According to the National Renewable Energy Laboratory, Laos has suitable locations for solar farms, particularly in the south provinces of Attapeu, Champachack, Saravane, and Savannakhet, in addition to Vientiane and Vientiane Prefecture in the north. See Figure 5. Currently, there are five solar power projects operating in Laos, with a total installed capacity of 32 MW. These projects generate an annual total 59.2 GWh (MEM, 2019). With the target of increasing solar power to 106 MW by 2025 (HELING, 2019).

In recent years, there has been a significant rise in energy consumption in Lao PDR, the residential account for a significant proportion at 51%, correspondingly. The industrial sector comes next in terms of its relative contribution (MEM, 2011). The rise of population and economic activity in Lao PDR is anticipated to result in a surge of energy consumption. Forecasts from the Ministry of Energy and Mines alongside Electricite Du Laos (EDL) suggest that electricity output within Lao PDR will escalate to 5,892 MW by 2030 equal to five times greater than levels observed in 2016. Despite these projections, there are concerns about inadequate energy supply during dry seasons due to its high reliance on hydropower plants as a source of electricity generation (Khamchaleun et al., 2019). The government of Lao PDR targets an energy generation mix beyond hydropower of 30% renewable energy share and 10% energy reduction of total energy consumption by 2025 and 2030 (OECD, 2017).

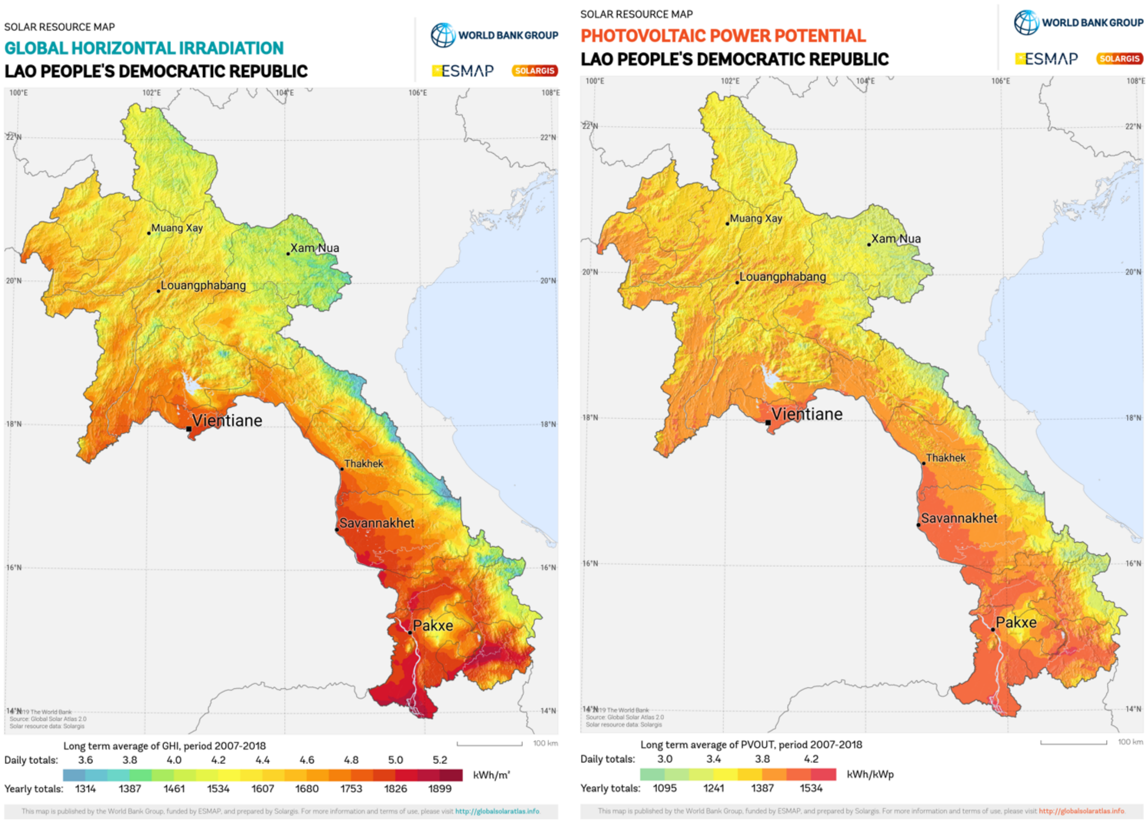

Figure 5: Map of GHI and PV potential in Laos

Source: Solargis, 2018

On the contrary, Hungary has temperate climate with annual global horizontal solar radiation exceeds 1200 kWh/m^2/year and receives up to 1,950 – 2,150 hours of sunlight annually. In particular, the southern part of Hungary has the solar energy potential (Бољевић & Јелача, 2014). See Figure 6. Despite the significant growth the share of renewable energy in the European Union, Hungary has fallen behind this trend. This is mainly due to the country's insufficient experience and skill with renewable energy technologies, as well as the uncertainties around the initiation of the new feed-in tariff scheme called METÁR.

Nevertheless, the total equipped capacity of photovoltaic plants in Hungary has expanded dramatically from 395.63 MW in 2017 to 1,340 MW in 2019, representing an exceptional percentage growth (MAVIR, 2020).

The inadequacy of Hungary's existing grid connection capacity to connect new power plants that weather-dependent, for example solar plants, causing unpleasant solar power entrepreneurs and investor. According to the bidding procedure, no additional connection requests can be accepted, and investors are responsible for grid connection costs. The Hungarian electricity system systems has undergone substantial transformations during the past decade, because of changes in production capacities and customer needs (KERESZTES, 2023; Makszimov, 2022).

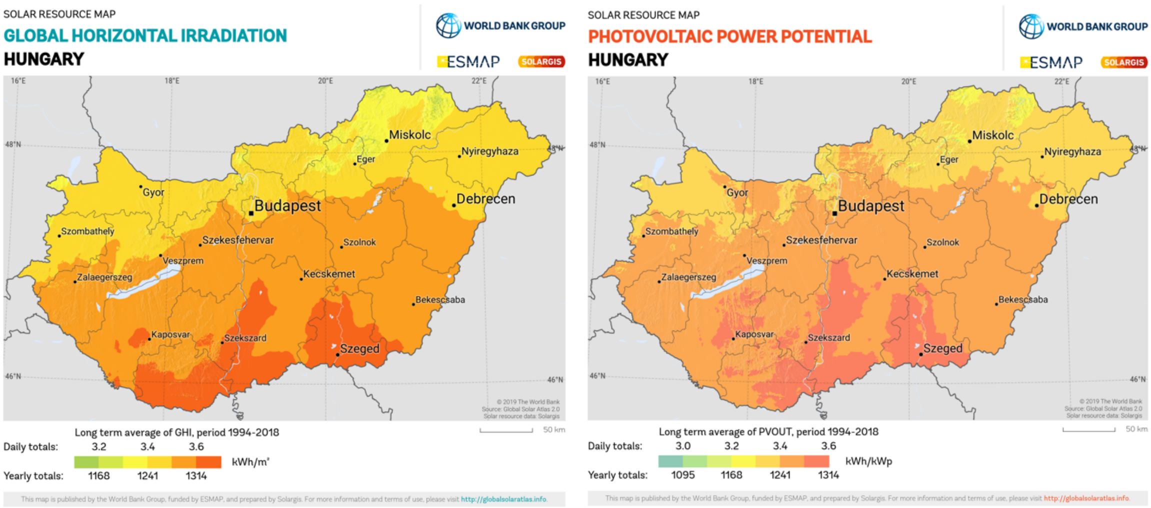

Figure 6: Map of GHI and PV potential in Hungary

Source: Solargis, 2018

2.5 Legal framework in solar farm installation

Over the years, the rules, legislation, regulations, and economic factors associated with the development of PV power plants have continuously been uncertain. These factors influence the feasibility of photovoltaic power plants, financial investments, and preparation procedures. For a foreign investor, the original processes associated with the feasibility and design of PV power plants are complex and ambiguous (Lajos, 2018).

2.6 Lao PDR

Currently, the renewable energy technology in the Lao PDR's power sector has a small scale. This has led the government to create policies to expand and assist the growth of renewable energy sources. To stabilize the energy supply and contribute to the country's economic and social growth, one of the primary policies is the promotion and development of sustainable and renewable energy sources. A primary objective is to gradually replace non-renewable energy sources with new and underutilized renewable resources in Laos (MEM, 2011).

The policy seeks to promote both domestic and international investment in renewable energy at the village level. This investment is aims at improving access to electricity, generate socioeconomic benefits, and promote environmentally and socially sustainable growth (IEA & IRENA, 2017)

In Lao PDR, the utilization of feed-in-tariff (FIT) methodology to establish generation tariffs for renewable energy sources is absent. Instead, the pricing strategy concerning sales of electricity generated by renewable energy installations is determined through negotiations (EDL-Gen, 2007). However, the investment promotion law of Laos guarantees that investors, including those in sustainable energy, are eligible for a range of fiscal and non-financial advantage. These benefits may include tax holidays as well as fee exemptions on concession agreements.

2.6.1 Financial Incentives

The regulations contains incentives that could potentially be applicable to investments in renewable energy, including (IEA, 2017; MEM, 2011):

- Exemption of production machinery, equipment, and raw materials from import tariffs.
- Exemption from import tariffs for up to seven years for chemical materials used in biofuels.
- Classification of profit tax according to five distinct investment promotions zones, with three categories: 20%, 15% and 10% depending on the size of investment area and activities.
- Exemption from profit tax for the following financial year, if net profits are invested in business growth.
- The investment law, corporate and other taxes may be reimbursed subject to approval by the Foreign Investment Management Committee (FIMC). Additionally, there is a possibility of tax exemption ranging between 2-3% in select scenarios. These circumstances comprise exporting over 70% of products to third-party countries, procuring more than 70% raw materials domestically, and operating from an unfavorable factory location.

2.6.2 Promotion And Development Of Solar Energy

Solar power has the potential to facilitate the government in providing electricity to remote areas and off-grid. The administration is facilitating this objective by advocating for solar photovoltaic (PV) that is connected to the grid and hybrid systems, to supply electricity during dry season. To encourage the use of solar energy, the government will carry out following (MEM, 2011):

- Evaluate the available resources to determine if hybrid systems for off-grid areas and large-scale solar PV systems that are grid-connected can be developed.
- Create a program that specifies how services and training for solar hybrid systems will be provided.
- Develop a strategy to encourage private investment in the construction of large-scale, integrated solar PV installations.
- Conduct initiatives to demonstrate the functionality of hybrid and grid-connected systems and provide relevant information and training and to promote the expansion of solar PV hybrid and grid-connected projects.

2.7 European and Hungary

The European Parliament and Council passed Directive 2009/28/EC (renewable energy directive) in 2009, mandating that the EU must source at least 20% of its energy consumption from renewable sources by the year 2020 (Tutak, 2021). To meet these targets, each member state had to draft plans outlining how they planned on meeting them through their national action plans focused on renewable energy. Progress reports were subsequently submitted biennially for review purposes (European Parliament, 2022).

The directive has revised several times to strengthening the EU's commitment to renewable energy and increase the use of renewables in the EU's energy mix, as seen in Figure 7 , the directive was revised in 2018 (Directive 2018/2001/EU) and 2021 to increase the use of renewable energy and achieve climate goals. The most recent revision propose to rise a renewable energy goal at least 40% by 2030 (EU, 2022).

The European Green Deal now proposes increasing this share further still; aiming instead to achieve a total contribution of up to 45% through sustainable resources by 2030 (European Commission, 2020). In line with the European Green Deal, The REPowerEU, a plan established by the European Commission in May 2022 in response to a temporary emergency regulation energy crisis regulation to accelerate the implementation of renewable energy sources caused by Russian's invasion of Ukraine, The proposal is part of the EU's strategy to diversify supplies, save energy costs in both short and long term by utilizing renewable resources, seeks to reduce reliance on Russian fossil fuels by 2027 and targets particular technologies and projects with high potential for rapid deployment while minimizing environmental impact that contributes towards contributing energy security. The plan seeks to increase the feed-in-tariff (FIT) for 55 renewable energy targets from 40% to 45%, which will demand dramatic increase in renewable capacity across the electricity. The plan seeks to reach 69% renewable energy in electricity by 2030 (European Commission, 2022; IEA, 2022b). As a member of the EU that heavily replies on natural gas imports from Russia, Hungary stands to greatly benefit from this proposed temporary emergency regulation.

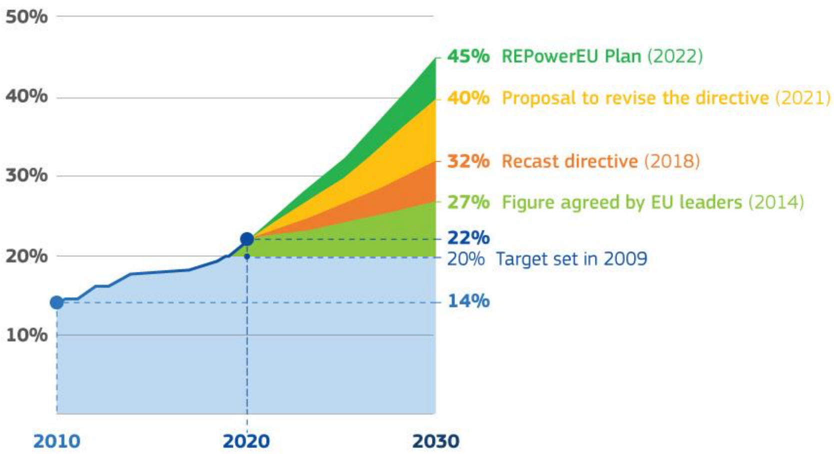

Figure 7: EU directive of renewable energy targets

Source: European Commission

In Hungary, there has been a gradual shift in the operational conditions of system that facilitate renewable electricity generation. At first, the primary objective was to stimulate production and guarantee a stable cash flow through an obligatory off-take system. However, later, there was more emphasis placed on enhancing competitiveness (Baji Gál Imréné Szarvas et al., 2021). Under the KÁT system is where the transmission system operator (MAVIR Zrt) is obligated to buy the electricity that generated from renewable resources from the generators under the FiTplan at a fixed price as specified by the HEA legislation. MAVIR Zrt sells electricity got under the feed-in tariff (FIT) scheme, along with the corresponding balancing energy, and a part of the organized electricity market to traders (Török, 2022). Yet, from 2017 The METÁR renewable support system is in forced replace the KÁT, provides a feed-in tariff for 50 to 500 kW small-scale renewable projects and bidding in auctions for green premiums for small to medium 0.3 to 1 MW and large-scale of renewable power plants 1 to 20 MW (IEA, 2022a). and applies to new renewable electricity projects before construction. Nowadays, solar PV projects can obtain scheme support by participating in the green premium auction. The

METÁR scheme requires tenders to bid the lowest price for electricity generation over a 15 year period. This approach resulted in applicants suggesting prices that were 40-50% lower than those provided under the KÁT system, based on the capacity category of the power plant (Szolnok, 2022). The scheme states that power plant exceeding 1 MW are required to sell their electricity on the market price, if the price of electricity at the Hungarian power exchange falls below the level of subsidy, the producer receives the difference in the form of a green premium, and if the market price is higher than the subsidy price, the producer pays the difference to the electricity TSO MAVIR (Török, 2022).

The scheme promotes competition between investors and producers, hence lowering production costs and making the system more financially self-sufficient. This is advantageous for industrial consumers who subsidize renewable energy providers through premium subsidies by adding market signals into the support scheme, technical improvements, technology costs can be reduced (Baji Gál Imréné Szarvas et al., 2021).

2.7.1 Financial Support in Hungary

The METÁR scheme limits support yearly for new applicants until 2026. This refers to the annual support payment estimation for producers who received support entitlements in the current year. The calculations of photovoltaic power plants includes peak-hour power market prices, and baseload power market prices for other types of plants (MEKH, 2022). There are three types of renewable energy support:

- *Feed-in tariff support (METÁR- KÁT):* account for 1 billion HUF/year 2017 – 2019.
- *Green premium without tender procedure*: half billion HUF/ year between 2017 – 2019.
- *Green premium with tender procedure*: 1 billion HUF/year between 2017 – 2019; 2.5 billion HUF in 2020; 12.26 billion HUF in 2021 and 500 million HUF/year between 2022-2026.

Unused support budget from a given year has the potential to be carried forward to the following year.

2.8 Economics of solar PV

The financial aspect of solar PV plant development plays a crucial role and requires careful consideration. To develop the financial model for the PV plant, it must consider several factors, which include cost and performance parameters. In some cases, incentive-related parameters may also be relevant. the following Table 3. Provides a brief explanation of these parameters (Aghaei et al., 2020).

Table 3: Key parameters for financial of Photovoltaic

Parameter	Definition	Notes
Maximum installtion capacity	The power plant's overall capacity for generating energy, which is typically measured in kilowatts (kW) or megawatts (MW)	- The cost of PV capacity will vary depending on the types of PV technology utilized.
		- The capacity would be determined based on the available area and the conditions particular to the location
Lifespan	The projected timeframe for both the entire project and the lifespan of individual components shall be taken into acoount. Typically, a photovoltaic (PV) system is expected to maintain operational effiency over a period spanning 25 - 30 years	- The lifespan of PV modules may vart compared to other components within the PV systems, including power converters and batteries
Degradation rate	The annual decline in energy generation by a percentage, which has a consistent impact on the PV plant's financial performance	- The rate of degradation is specific to PV technology
		It also dependent upon climate conditions
Pricing structure	The pricing model refers to a mutual agreement between electricity generators and the utility company. The tariff rate is considered by many as a highly effective pricing model, and it is adopted by many countries	- The determination of the tariff rate typically relies on various techni-economic parameters. Generally, the size of the photovoltaic (PV) plant is a determining factor in most cases.
		- The tariff rate, and influenced by the configuration of the PV installation in certain circumstances

Source: Alasdair Miller & Ben Lumby, 2012

2.9 Environmental and social impact of solar farm

The impact of the environmental effects of developing solar farms will depend on many factors, such as location, size, and proximity to the populated area (Moore-O'Leary et al., 2017). In the context of photovoltaic (PV) systems, the efficiency of land use in generating electricity is a crucial aspect when considering PV systems. Large-scale PV system require the amount land area compared to other sources of renewable energy like wind, hydropower, and biomass (Fthenakis & Kim, 2009; Hernandez et al., 2014). Land can be significantly and possibly irreversibly impacted at every stage of the energy conversion chain associated with PV systems such as exploration, extraction, manufacturing of raw materials, construction of plants activities, generation of energy, operation, and maintenance as well as disposal (Fthenakis & Kim, 2009). There has been controversy between land usage for agricultural and energy uses, which has always drawn the attention of researchers who believe that large-scale PV systems might negatively impact potential soil production areas; thus, energy production is considered as competitive as food production (Tsoutsos et al., 2005).

The primary impact on wildlife and their environment is caused by the power plant occupying the land by restricting animal movements with fences, altering habitats for hiding places, food availability, and predator-prey dynamics. The construction process involves clearing soil down to bare ground and using herbicide or keeping vegetation below a few feet tall. In either case, a significant alteration to the vegetation occurs (Turney & Fthenakis, 2011). The disturbed habitat is unsuitable for the flora and fauna to survive in. In addition, the high temperatures from solar modules or mirrors have led to numerous bird fatalities in that area (Laine, 2017). The study conducted by (D et al., 1984) on solar energy's effects on wildlife in the desert near Daggett, California. According to the results, six birds each year were killed by the strong light and hundreds of insects per hour were burned.

The construction of solar power plants can lead to adverse effects on geohydrological resources, including the depletion of topsoil and groundwater recharge reduction. Proper measures must be implemented to address stormwater flow and erosion when constructing such plants in sloping areas (Battany & Grismer, 2000). The replacement of natural vegetation with either agriculture or solar panels could change soil infiltration rates as well as runoff ratios; consequently, impacting the services provided by forests for water purification and flood control. It is possible to mitigate this effect, but it is vital to regularly monitor local hydrological and soil resources using scientific projections (Turney & Fthenakis, 2011).

The studies conducted show that solar projects could lead to social impacts for local communities where transportation routes during the planning phase of solar projects may result in construction traffic passing through in local community, which may have negative impact for these areas. The studies suggest the important of including the community in the construction of solar farms through engagement should be considered as an essential aspect of the development process in order to facilitate a productive engagement with the local community (Jones et al., 2013).

III. MATERIAL AND METHODS

The thesis aims to analyze the feasibility study of solar farms in Laos and Hungary by choosing existing solar farms that have been developed as studies using RETScreen to stimulate the results of technical, economic, and legal aspects in both countries. The potential solar resources were gathered from free-access available data and secondary data. The economic assessment was considered according to the methodology found in the international literature. The thesis will emphasize the following:

- Choosing the study area for solar farm project
- Proposed 1 MW Solar potential to generate electricity for the grid
- Financial analysis assumes of the solar potential
- Understand how policies influence the installation of solar farms

3.1 Area of study

The forecast of site-specific irradiance supports the comprehension of projected photovoltaic potential. Theoretically, both countries have solar potential, but selecting a specific site for solar PV is ideal to achieve optimal solar potential. In this case, the chosen area of study for 1 MW as a solar farm in Lao PDR is the Vientiane Capital Area, about 28 km from the capital city, and is located in Chengsavanh Village, Naxaythong District. Latitude 18°09′42" and longitude 102°30′17" On the other hand, the selected solar farm in Hungary is located in the Pest country, in the settlement of Újszilvás, which is located approximately 71 km to the east of Budapest, the capital city of Hungary. The town has a population of around 2,500 residents. Latitude 47°16′23.8"and longitude 19°55′58" (Kulcsar et al., 2014).

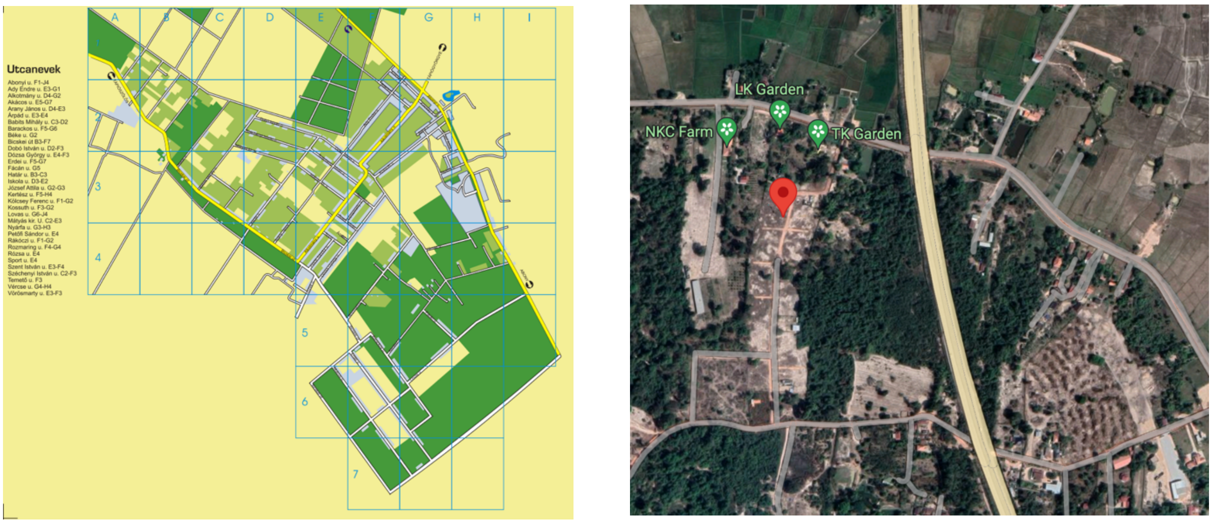

Figure 8: Selected area of study; right-handed is Naxaythong district; left-handed is Újszilvás

Source: Újszilvás Kösség official website, 2009; Google map

3.2 RETScreen software

RETScreen is a free software support tool for clean energy developed by Natural Resources Canada. However, the newest updated version, RETScreen Expert for Professional Mode, is for subscription only and is fully functional, allowing users to have more options and define their own data.

The software holds the ability to assess the feasibility of energy projects, evaluate the performance of projects, and inspect existing projects (Sowe et al., 2014a). This software can be used globally to evaluate the costs, emissions reductions, financial viability, and risk associated with various forms of renewable energy and energy-efficient technology (RETs) (Government of Canada, 2023). Using RETScreen software offers decision-makers a significant benefit by simplifying the project evaluation process. However, RETScreen allows users to input data that comes with a database of PV panels. The users should input information such as the type of panel, PV installed power, miscellaneous losses, inverter efficiency, and size. The financial analysis worksheet includes input factors like operational life, initial cost, discount rate, and debt ratio, along with output factors such as IRR, simple payback, and NPV, which help users easily determine financial viability through calculated results. The software creates various types of tables and graphs, for example, daily solar horizontal irradiation and annual electricity production.

There have been many studies conducted to assess the feasibility of photovoltaic power plants, like solar power plants in Iran (Mirzahosseini & Taheri, 2012). Moreover, the users of RETScreen can access climatic data through two options: either by utilizing ground monitoring stations or by using a data set from the NASA Space Environments and Effects (SEE) satellite. The RETScreen allows the user to select between two methods of calculation, the first of which is less complicated than the second. In this thesis, the second method will be selected to determine the feasibility of the solar farm, which requires the PV module, power capacity, manufacturer, and model types, and generates electricity that is delivered to the grid on a monthly and annual basis.

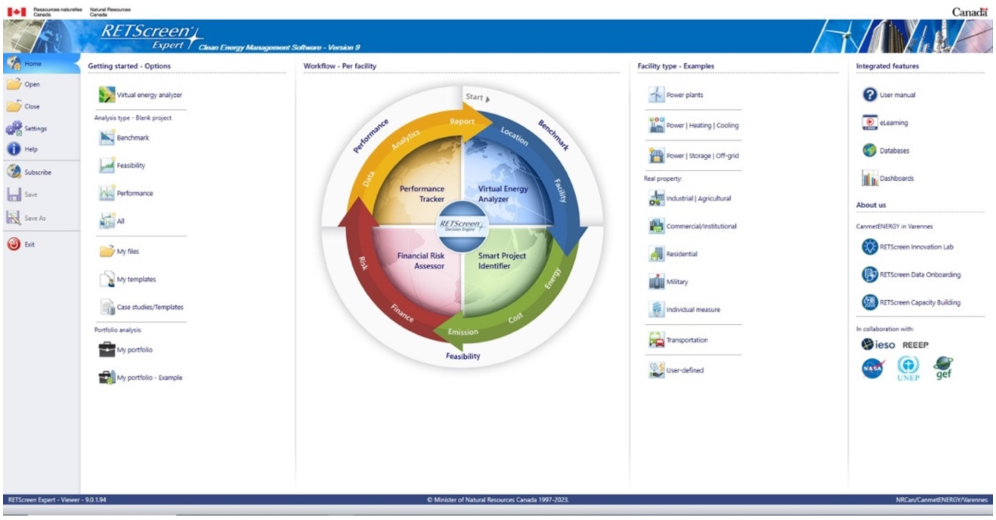

Figure 9: RETScreen software

Source: RETScreen

3.2.1 Orientation and Inclination

When establishing a photovoltaic (PV) system, it is crucial to consider two significant factors to optimize sunlight exposure. The first consideration is the orientation of the object, which should align with the trajectory of the sun. The second factor to consider is the angle at which it is tilted, as it is crucial to optimize it for maximum sunlight exposure (Tarcesoftware, 2022). Fixed tilt planes mounted at optimum angles will be used for this thesis. Fixed tilt planes are characterized by their simplicity, being less expensive, and having fewer maintenance requirements. Countries that are new to the solar sector and have limited production of tracking systems typically prefer utilizing tilt mounting systems (Alasdair Miller & Ben Lumby, 2012). Figures 10 and 11 show the optimal angle of a solar PV panel in a selected location: a fixed tilt mounted at the optimum angle in Laos and Hungary at 22° and 39° degrees with an azimuth of 0°.

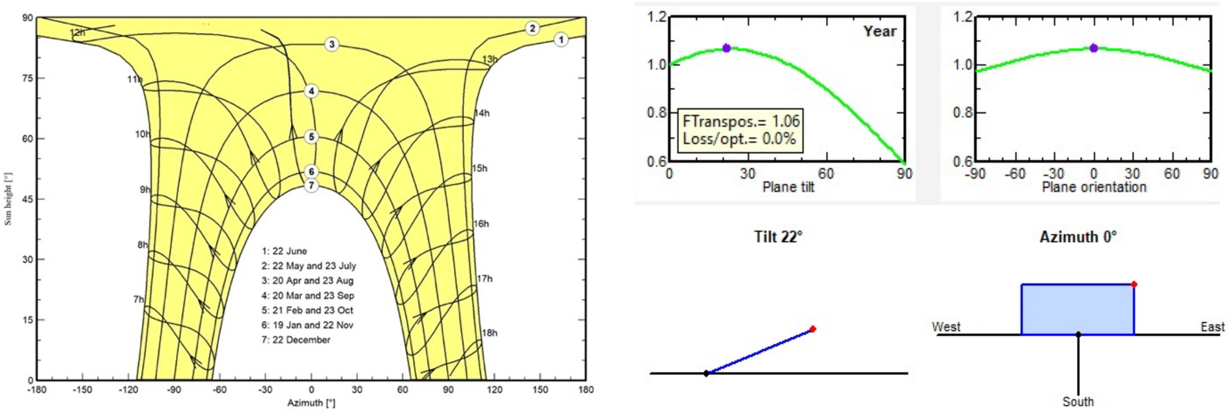

Figure 10: Lao PDR solar paths and inclination

Source: PVsyst software

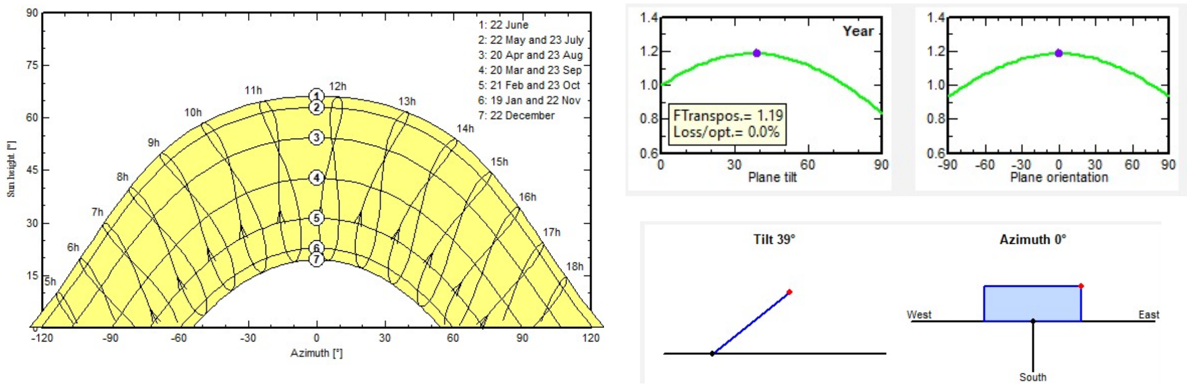

Figure 11: Hungary solar paths and inclination

Source: PVsyst software

3.3 Technical calculations

The technical calculations also take into consideration the implementation of a 1 MW solar power plant in Lao PDR, Talesun Mono-Si-Feather TP660M-270M is used for calculations, which include 3,704 units of mono-crystalline solar cells with a solar efficiency of 16.63% and miscellaneous losses of 12.5% and an inverter with an efficiency of 98% and miscellaneous losses of 2%, which will last for 25 years. Likewise, in Hungary, the solar PV system includes 4,550 units of Canadian Solar Mono-Si, CS5P, and 220M mono-crystalline with a solar efficiency of 17.2%, solar cell losses of 12.5%, and an inverter with an efficiency of 98% and miscellaneous losses of 2%. The term "system losses" refers to all energy losses that occur within the inverter. Energy production will decrease by 0.5% per year (Németh, 2022). DC-AC There are no converters capable of achieving 100% efficiency, and typically the efficiency of an inverter ranges from 95% to 98% (Park et al., 2020). For the technical calculation of a grid-connected PV system, the RETScreen software proved to be an effective tool by giving data that includes climatic data from the ground and NASA satellites. This helped us make estimates for the electricity generated by conventional grid-connected systems, both on a monthly and annual basis.

Table 4: Technical parameters input

Technical data inputs	Naxaythong, Lao PDR	Újszilvás , Hungary
Location	Latitude 18°09′42" Longitude 102°30′17"	Latitude 47°16′23.8" longitude 19°55′58"
Climate zone	Very hot-humid	Mixed-humid
Tracking system	Fixes tilt plane 22°	Fixes tilt plane 39°
Azimuth	0	0
Model type	Mono-Si	Mono-Si
Power capacity	1MW	1MW
Manufacturer	Talesun	Canadian Solar
Model type	Mono-Si – FEATHER TP660M – 270M	Mono-Si – CS5P – 220M
Number of units	3,704	4,550
Efficiency	16.63 %	17.2 %
Nominal operating cell temperature	45	45
Temperature coefficient	0.4 %	0.4 %/℃
Solar collect area	6,014 m^2	5,820 m^2
Miscellaneous losses	12.5 %	12.5 %
INVERTER		
efficiency	98%	98 %
Capacity	1,000 kW	1,000 kW
Miscellaneous losses	2%	2 %

** NASA satellite*

Source: Own work

3.4 Financial analysis assumptions

The financial analysis was evaluated based on assumptions available in the literature. A value of the inflation rate was applied for calculating the dynamic economic outlook in 2021. The cost of PV systems depends on size and other factors, for example, mounting structure and types of PV models. The purpose of this analysis of the project is to last for 25 years. Even though the systems are likely to keep running after these points, the energy production will decrease by 0.5% per year, and the operation and maintenance costs will be around $10/kW per year, according to (Németh, 2022), the cost of land use is not considered as land is already available and all the information is available. The currency in all the economic calculations is the USD, as seen in Table 5.

Table 5: Financial parameters

Financial data inputs	Naxaythong, Lao PDR	Újszilvás , Hungary
Inflation rate	3.8% (2021)	5.11% (2021)
Discount rate	9%	9%
Reinvestment rate	9%	9%
Project life	25 years	25 years
Initial cost	1,200,000 $	1,200,000 $
O&M	10 $/kW	10 $/kW
Capacity factor	13.4 %	13.4 %
Electricity export escalation rate	2 %	2 %

Source: IRENA, 2021; Németh, 2022; The world bank, 2021

The following economic parameters have been taken into account to evaluate simple economics:

Net Present Value (NPV) – the concept of NPV applies to the current value of all future cash flows of an investment project, discounted at the discount rate, and the present value of all cash flows out of the project in the future. If the NPV is negative, it suggests that the project may not be feasible (Mondal & Islam, 2011).

$$\sum_{n=0}^{N} \frac{B_n}{(1+i)^n} - \sum_{n=0}^{N} \frac{C_n}{(1+i)^n} = PVB - PVC$$

Where B_n : expected benefit at the end of the project n

C_n : expected cost at the end of the project n

i : discount rate

n : project duration

N : project period

PVB : present value benefit

PVC : present value cost

The Internal Rate of Return (IRR) – the interest rate that the project makes over its lifetime. It is also called ROI, the rate of return, or the time-adjusted rate of return. The process of calculating the IRR involves finding the discount rate that results in the NPV of the project being equal to zero. A solar project is considered financially feasible for development if its IRR is equal to or exceeds the required rate of return and is greater than the discount rate (Mondal & Islam, 2011).

$$\sum_{n=0}^{N} \frac{B_n}{(1+i)^n} - \sum_{n=0}^{N} \frac{C_n}{(1+i)^n} = 0$$

Payback period (PBP) – the payback period holds significant economic importance from the perspective of investors. If the PBP is high with a long payback period, the project would be considered unprofitable. On the contrary, if the PBP is shorter, it presents a good investment (Sowe et al., 2014a). The calculation of a project's payback period can be achieved through the utilization of a mathematical formula (Mehmood et al., 2014) :

$$\sum_{n=1}^{N} (B_n - C_n) = 0$$

IV. RESULTS AND DISCUSSIONS

Based on the result calculated by RETScreen software of implementing 1 MW grid-connected solar PV system in selected area in Laos and Hungary to supply electricity to the community and identifying of building solar farm leading for electricity bill is cheaper within the community and we came to conclude:

- Technical feasibility
- Economic feasibility
- Legal feasibility

4.1 Technical feasibility

4.1.1 Electricity Generation

The utilization of solar energy, despite being a highly desirable form of renewable technology, encounters numerous challenges. In addition to conducting technical and economic evaluations of solar energy sources, a crucial factor to take into account is their accessibility. The primary determinant for the generation of electricity through solar means is the amount of solar radiation that is available at ground level (Šúri et al., 2007).

The analysis is performed for an optimum tilt angle, which was determined through various evaluations of power generation to maximize power production at the selected locations. The selected tilt angle without shading was based on its ability to generate the greatest solar irradiance and export the highest amount of electricity to the grid at a fixed tilt mounted at an optimum angle in Laos and Hungary at 22° and 39° degrees, respectively. The azimuth studied was 0°. According to Table 6, as expected, the daily solar radiation shows that Laos has solar irradiance of 4.67 kWh/m^2/day throughout the year. The installation of a 1 MW solar PV power plant generates 1,401.371 MWh of annual electricity for the grid.

In comparison, Hungary has a high annual solar irradiance of 3.41 kWh/m^2/day during the summertime and a low annual solar irradiance during the wintertime of roughly 1 kWh/m^2/day. It was observed that the annual electricity export to the grid is 1,173.283 MWh, which could fill the demand for electricity in the public community areas such as geothermal heating, public institutions, and public lighting in order to minimize the costs of the community. Based on the interview with Dr. Petrányi Csaba, Mayor of Újszilvás on 27th April 2023, currently the municipal operating 400 kW photovoltaic power plants covered 2 hectares.

The reason for selecting the site is that both the site is located relatively near the community and close to the main road, making it easy to access during the construction as well as making the transmission line suitable (Yahyaoui, 2018).

Table 6: Average monthly solar PV electricity exported to the grid Lao PDR and Hungary

Months	Naxaythong, Lao PDR			Újszilvás , Hungary		
	Daily solar radiation in Horizontal (kWh/m²/day)	Daily solar radiation in tilted (kWh/m²/day)	Electricity exported to grid (MWh)	Daily solar radiation in Horizontal kWh/m²/day	Daily solar radiation in tilted kWh/m²/day	Electricity exported to grid MWh
January	4.55	5.46	132.507	1.25	2.30	62.039
February	5.17	5.82	125.339	2.12	3.34	80.417
March	5.55	5.78	136.273	3.17	4.03	104.781
April	5.78	5.60	126.944	4.37	4.73	115.974
May	5.11	4.72	112.534	5.35	5.20	128.730
June	4.40	4.02	93.668	5.67	5.25	124.448
July	4.13	3.82	92.524	5.66	5.35	129.632
August	4.18	3.99	96.491	5.05	5.23	126.616
September	4.53	4.55	105.712	3.96	4.40	105.572
October	4.67	5.06	121.237	2.35	3.41	86.930
November	4.63	5.45	127.125	1.33	2.30	58.697
December	4.45	5.38	131.018	0.98	1.83	49.445
Annual	**4.67**	**4.96**	**1,401.371**	**3.42**	**3.95**	**1,173.283**

Source: Own work

4.2 Financial feasibility of solar PV project

Financial has played an important role in the installation of solar PV. The results show the financial viability of Lao PDR and Hungary based on the various financial measures, including pre-tax IRR and MIRR for assets and equity, equity and simple payback, net present value (NPV), and annual life cycle savings. Laos has an internal rate of return for equity investments, which indicates the profitability of the project from an investor perspective before taxes, of 13.7%, and Hungary has less than Laos at 10%, a bit higher than the discount rate of 9%. It was observed that simple payback period is calculating the amount of time required for a project to recover its initial cost. It makes a project more favorable if it has a shorter payback period. Laos has a shorter payback period of 9.2 years and equity payback of 8.1 years, and Hungary has a shorter payback period of 11.2 years and equity payback of 10.9 years. The net present value for Laos is 366,791 dollars and that for Hungary is 75,843 dollars. It is anticipated that investments made in Laos will yield higher profits compared to those made in Hungary.

The NPV is the expected cash flows of the investment project, including costs and benefits, and a greater NPV value indicates a more attractive investment opportunity. See Table 7.

The results show that both projects are profitable with no incentive grants, and the project life has been 25 years so far. However, both countries are distinctive from each other in environmental, climate, economic, and legal aspects.

Table 7: Financial feasibility of Lao PDR and Hungary

Finance Viability	Naxaythong, Lao PDR	Újszilvás, Hungary
Pre-tax IRR - equity	13.7 %	10 %
Pre-tax MIRR - equity	10.8 %	9.4 %
Pre-tax IRR - assests	8 %	5.3 %
Pre-tax MIRR - assests	8.6 %	7.2 %
Simple payback	9.2 yr	11.2 yr
Equity payback	8.1 yr	10.9 yr
Net Present Value (NPV)	366,791 $	75,843 $
Annual life cycle saving	37,342 $/yr	7,721 $/yr
Energy production cost	0.07 $/kWh	0.075 $/kWh

Source: Own work

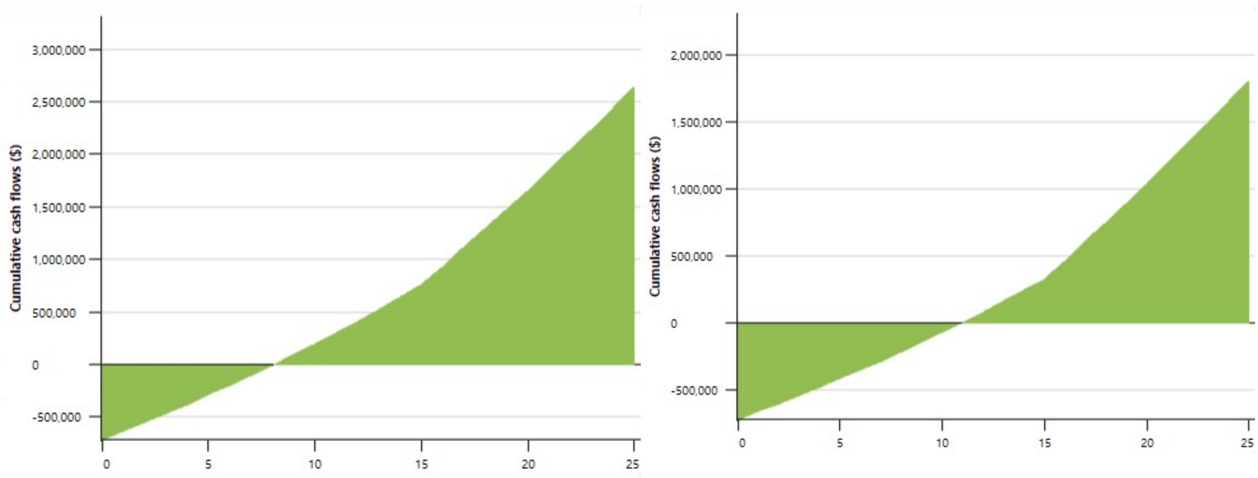

Figure 12: Cumulative Cash flow Naxaythong, Lao PDR and Újszilvás , Hungary ($)

Source: Own work

According to (eurostat, 2022), the electricity price in Hungary is relatively low compared to the EU average of 62.5%, where the electricity price for households accounts for 9.34 USD per 100 kWh. The price has been converted to USD in order to compare electricity prices with Laos. On the other hand, the latest information on the electricity price for households in Lao PDR is 8 USD per 100 kWh, including the tax and maintenance of the meter, in 2019 (Nanthavong, 2015; Vongphachanh, 2023).

In accordance with the installation of 1 MW of grid-connected solar PV, electricity production costs range from 0.07 to 0.075 $/kWh, so both countries could pay a cheaper bill according to the stimulation. The electricity production cost of a PV system is slightly lower than the current energy price in Lao PDR. Nonetheless, the price is adjusting in accordance with the inflation rate; EDL announced it would raise the price of electricity by 2% in 2023 and anticipates an increase in the future (Phouthonesy, 2021; RFA Lao, 2023).

4.3 Legal feasibility

Solar energy, particularly solar power, has become a significant contributor within the field of renewable energy solutions. The significance of renewable energy contributions within the framework of a country's sustainable growth plan is important. The significance of government administration is necessary in the carrying out of policies that promote sustainability.

Based on the legal framework for renewable energy in Lao PDR, it appears that Laos has policies and regulations in place to promote the development of renewable energy, especially solar energy, to increase the 30% renewable energy share of total consumption by 2025. As well, the objective of the Lao PDR government is to ensure that 90% of households in the country have access to electricity by 2020, with 75% of households being connected to the national grid (World Bank Group, 2010). which Laos has accomplished the targets by 94.29% (LAOSIS, 2021). and planning to achieve an electrification rate of 98% by 2025 (Erdiwansyah et al., 2019). In accordance with these policies, the country is currently undertaking efforts to expand its electricity coverage.

The government targets exploring new renewable energy sources to supply electricity to meet the needs and export it to neighboring countries by encouraging both domestic and international investment in renewable energy at the village level, especially in remote areas with on-grid and off-grid connections. The renewable energy strategy development 2011–2025 regulations include financial incentives, promotion, and development of solar energy for investors, including exemption of taxes, etc. (Saignasane, 2021). Although there are policies and regulations in place, they are considered less effective. According to ADB, 2019 forecast of the renewable energy contribution to domestic electricity by 2025 showed that the total renewable energy contribution covered only 23%, which is less than expected when compared to the target of 30% renewable energy share in the development strategies. See Table 8. This difference is caused by a lack of clear regulations and laws on renewable energy and uncertainty over the approval of renewable energy projects (Anbumozhi & Tuan, 2017; MEM, 2011). However, there are domestic challenges to the development of renewable energy in Lao PDR, as there is an absence of specific policies and strategies promoting renewable energy as the drafting of policies is still ongoing. For example, the feed-in tariff is currently determined through negotiations between EDL and investors, which puts investors at risk. The country's power development plans do not include an integrated national policy, strategy, or plan for using renewable energy. Significant challenges include the lack of coordinators across departments and agencies as well as the lack of a competent workforce with expertise and experience in strategy planning and implementation (Anbumozhi & Tuan, 2017).

Table 8: Renewable energy domestic electricity forecast

Year	Demand (MW)	Renewable energy contribution (%)						
		Small Hydro	Solar	Wind	Biomass	Biogas	Solid Waste	Total
2011	820	3.41	0.02					3.44
2013	1,200	2.50	0.08					2.58
2015	1,950	4.10	1.13	0.31	0.67	0.51	0.46	7.18
2020	2,670	5.02	1.35	0.45	0.90	0.71	0.64	9.06
2025	2,863	13.97	1.15	2.55	2.03	1.78	1.26	22.74

Source: ADB, 2019

On the contrary, Hungary has taken steps to increase its climate goals by enacting a target of carbon neutrality for 2050. Furthermore, the country adopted a significant outlook with the National Clean Development Strategy, which acts as a guiding framework for energy policy decision-making. The government aims to achieve 90% renewable energy in electricity by 2030 (IEA, 2022a). Hungary holds strong potential in terms of low-carbon generation due to the significant expansion of solar photovoltaic (PV) technology in the past decade (Patricolo, 2022). Furthermore, Hungary has been among the lowest-ranked renewable energy sources, with solar energy accounting for 10.6% and solar photovoltaic accounting for 2% in 2020 and 3% in 2021 (eurostat, 2023). which these are explained the slow progress of solar energy implementation in Hungary because of the government's policies delayed the development of niche energy sources such as wind and solar energy. Legal barriers were put in place to decrease the development of wind energy, while regulations, subsidies, and taxes were subject to uncertainty, causing delays in the development of solar energy (Antal, 2019) For example, the transition of the renewable energy support scheme from KT to METR is as follows:

The KÁT system applies to the generation of renewable electricity by the producers, which is later bought by the system operator MAVIR for 20–25 years at a pre-determined fixed tariff. The tariff cost is quite high and fixed, which provides producers with a consistent and anticipated cash flow. The KÁT system is simple and does not require specialized expertise to evaluate commercial frameworks, and the costs are not covered by the government's budget; rather, they are included in the electricity tariffs for industrial end-users (Patricolo, 2022).

In comparison, the METÁR scheme complies more closely with market-based energy production, resulting in a higher degree of unpredictability and increased business uncertainties. The implementation of the METÁR scheme promotes competition between investors and producers, leading to a decrease in the overall life-cycle production costs of electricity. This scheme enhances the financial self-sustainability of the system and reduces its reliance on central budget support. Under the METÁR scheme, renewable energy producers receive a subsidy that is funded by industrial consumers. The incorporation of markets is also advantageous, as it may result in decreased technology costs through technological advancements that can influence the domestic market (Patricolo, 2022).

The research employed the MLP framework (Antal, 2019), The rise of illiberalism has increased the challenges faced by the renewable energy industry as it has raised government control over other stakeholders. This has resulted in a shift in the balance of power in favor of the regime's preferred technology while simultaneously preventing the growth of alternative niches. The decision of the regime and government to prevent the progress of wind and solar energy was driven by factors such as financial gain and sustained control.

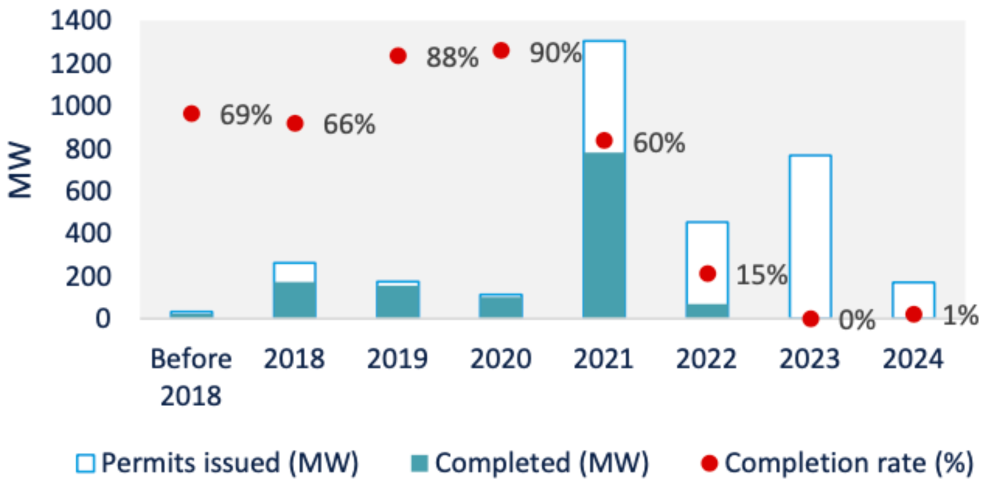

Figure 13: Solar photovoltaic installation by the support scheme

Source: Patricolo, 2022

The Figure 13 shows that the KÁT scheme that were issued in 2017, with a 69% implementation rate, have not been implemented yet. Currently, the ongoing construction projects remain focused on project by the year 2021, with 60 % have been constructed. However, the initiation of the implementation schedule for 2022 and beyond is pending, indicating that there is still a considerable amount of effort required to fulfill the deadline for those projects. Which could explain the slow progress in the renewable energy in Hungary.

V. CONCLUSION

The results revealed the importance of aspects related to the planning and establishment of photovoltaic power plants in Laos and Hungary, including technical, economic, and legal aspects. Theoretically, Laos and Hungary have a high potential for solar energy resources that have not been explored due to technical, economic, and legal barriers.

Technical and economic feasibility using RETScreen to evaluate the solar photovoltaic potential of selected areas in Laos and Hungary is proposed for 1 MW of solar PV with no support grants. Based on the results, there is feasibility for the solar photovoltaic plants fixed tilt in both Laos and Hungary on the selected site. As expected, Laos has higher annual electricity exported to the grid at 1,401.371 MWh and has constant solar irradiance of 4.67 kWh/m^2/day throughout the year, more than Hungary, which has 1,173.283 MWh of electricity exported to the grid and a viable solar irradiance during summertime and wintertime of 3.41 kWh/m^2/day. According to an interview with the mayor of Újszilvás, the current 400 kW solar PV plant could supply electricity to public settlements such as geothermal heating, public institutions, and lighting on the road, which helps minimize the costs of the community.

According to findings of economic evaluation based on assumptions and information found in literature and evaluation, Laos and Hungary's 1 MW solar farm is considered profitable, taking economic evaluation factors such as net present value (NPV), the internal rate of return (IRR), and the payback period (PBP). However, there are still challenges to address before developing a solar farm. One of the challenges is the lack of specific policies and regulations in Lao PDR to develop a solar farm in the country, the unclear approval of renewable energy projects, and a feed-in tariff that currently depends on negotiations with EDL. The policy of renewable energy is in the process of being drafted, and the current policies are not up-to-date, and Laos has no incentive grants to support renewable energy except exemptions of taxes related to the implementation of renewable energy.

On the other hand, Hungary is experiencing a lack of grid capacity to connect new power plants such as solar farms, and investors have to bear grid connection costs, making it less favorable for investment. However, Hungary has implemented the necessary policies required by the European Union, but policy, regulations, subsidies, and taxes supporting renewable energy remain ambiguous; the country does not allow large-scale wind farms in the country; Hungary has delayed the development of renewable energy; and no additional connection requests can be accepted. Therefore, solar energy implementation is the lowest in the EU.

VI. ABSTRACT

Thesis title: **Investigation of feasibility study of a solar farm in Laos and Hungary**
Author name: **Khemnaly Souvanlasy**

Course, level of education: BSc. Environmental Engineering
Host Department/Institute: Environmental Science

Primary thesis advisor: Dr. Csegődi Tibor László, Assistant lecturer
Institute/Department: Institute of Agricultural and Food Economics, Department of International Regulation and Business Law.

As population growth, technological advancements, and economic improvements continue, the need for energy to improve living conditions also increases. Renewable energy is a promising solution to meet these demands and mitigate the adverse effects of conventional energy sources on the environment, especially solar photovoltaic, which has been increasing globally. The deployment of solar photovoltaics is influenced by a range of factors, including technical and economic considerations. However, policies and legal frameworks also play an important role in determining the feasibility and success of solar projects within a country.

The aims of this thesis will focus on solar photovoltaic as an alternative source, considering technical and economic feasibility, with the utilization of RETScreen software. The technical potential of electricity generation will be analyzed by selecting site-specific technologies to comprehend the projected photovoltaic potential. The economic feasibility will be assessed based on assumptions available from the literature, considering economic parameters such as the net present value (NPV), internal rate of return (IRR), and payback period (PBP) of the project. Additionally, the thesis will analyze the legal challenges influencing the implementation of solar PV in Lao PDR and Hungary. The thesis aims to offer a comprehensive overview of the sustainable energy development potential in these countries and contribute to the world's efforts towards achieving a sustainable energy future.

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DECLARATION

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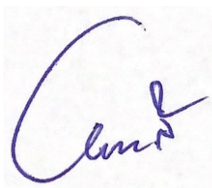

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