

Project Proposal

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1 Question to be Answered and its motivations

1.1 Research question

Our client, a Swiss energy company, asked us to identify the best locations for photovoltaic (PV) panel installations. Using long-term sunshine data from weather stations across Switzerland, we will analyze solar exposure and other parameters to rank potential sites and deliver data-driven recommendations for efficient and sustainable investments.

1.2 Motivations

Renewable energy will play an increasingly central role in reducing dependence on fossil fuels. Solar energy, in particular, is fundamental to the energy transition. We are all concerned by this challenge and aim to better understand how to optimize the development of solar parks in the future.

Selecting optimal locations for solar panels is not straightforward, as multiple factors must be considered. These include sunshine duration (which is central to our project), topography, accessibility, and urbanization, which can act as a constraint.

Meanwhile, numerous studies are currently underway to improve the efficiency and durability of solar panels. These efforts focus on developing new cell technologies, optimizing module angle and orientation, and integrating cooling systems. These advancements underscore the importance of rigorous site selection to maximize the benefits of emerging technologies under real environmental conditions.

2 Current State-of-the-Art

There are many existing maps and datasets on sunshine duration in Switzerland, but no pre-existing code adapted to our specific needs for data-analysis but we have the library PVlib that can help us for complex calculus. We will therefore develop our own code to model and analyze the data. Our results will be compared with those from MeteoSwiss to ensure reliability.

For the impact of certain parameters of a location that affect yield, such as cell temperature, we will mainly rely on an article from Science Direct : ‘The environmental factors affecting solar photovoltaic output’ [2] and on mathematical models that we will cite.

At EPFL, researchers are also investigating similar questions, which supports the scientific relevance of our approach.

According to [3], the instantaneous efficiency of a PV module can be approximated by:

$$\eta(T) = \eta_{\text{ref}} [1 - \beta(T_{\text{cell}} - T_{\text{ref}})]$$

Where:

- η_{ref} is the nominal efficiency at $T_{\text{ref}} = 25^{\circ}\text{C}$,
- T_{cell} is the cell temperature (often estimated from the ambient temperature),

- β is the temperature coefficient (approximately 0.004–0.005 / °C for crystalline silicon).

The reference efficiency, denoted as η_{ref} , represents the ratio between the electrical power output and the incident solar power under standard test conditions. For each type of solar panel we have this efficiency [4] :

Table 1: Typical Efficiency of Photovoltaic Panels under Standard Test Conditions (STC)

Cell Technology	Typical Efficiency (%)
Amorphous silicon (a-Si)	6–9
Polycrystalline silicon	13–18
Mono crystalline silicon (PERC, TOPCon)	18–24
Hetero junction / Tandem (HJT, Perovskite-Si)	25–28

We model the temperature of the photovoltaic cell (T_{cell}) using an empirical equation of the form [6] :

$$T_{\text{cell}} = T_a + \frac{E_{\text{POA}}}{U_0 + U_1 \times WS}$$

where

- T_{cell} is the cell temperature (°C)
- T_a is the ambient air temperature (°C)
- E_{POA} is the irradiance incident on the plane of the module or array (W/m²)
- U_0 is the constant heat transfer component (W/m²K)
- U_1 is the convective heat transfer component (W/m³sK)
- WS is the wind speed (m/s)

In his paper, Faiman measured irradiance, wind speed, and module temperatures on seven different types of modules and fit the data to values of U_0 and U_1 . Note that all modules had front glass covers and Tedlar® backs.

- Values of U_0 varied from 23.5 to 26.5 with a combined fit = 25 W/m²K
- Values of U_1 varied from 6.25 to 7.68 with a combined fit = 6.84 W/m³sK

3 Objective and Scope

Our objective is to compare the amount of sunshine at different sites and the influence of certain local parameters on the yield of solar panels in order to identify the most favorable location for installing a photovoltaic park. The photovoltaic technology selected for this project is monocrystalline silicon, as it is the most widely used type of PV cell, accounting for approximately 80–90% of global installations [8]. Its high efficiency, durability, and low cost make it the most suitable choice. The project requires a minimum PV surface

area of 2 hectares. The photovoltaic park will be installed with a fixed tilt angle of 30° relative to the horizontal plane, facing due south. This configuration is chosen to optimize the angle of incidence of solar radiation throughout the year, thereby maximizing energy yield. The 30° inclination is consistent with best practices for fixed installations at Swiss latitudes and ensures a balanced capture of solar irradiance across seasons [4].

We will use data from MeteoSuisse [1], such as solar radiation, irradiance and temperature, to analyses the duration of sunshine over several years and to estimate the potential output of the park. Where possible, we will also take the terrain into account in order to assess any potential difficulties associated with the installation. The analysis will cover two or three years of data to ensure more reliable results. Our study focuses on data analysis rather than spatial visualization. While mapping can complement the results, our objective is to derive quantitative indicators of solar potential.

4 Approach

4.1 Presentation

Our approach is primarily empirical, based on long-term sunshine records from 132 Swiss weather stations. The dataset, provided as a CSV file, includes monthly sunshine duration, coordinates, and altitude for each station.

The analysis will proceed in several stages. First, the raw data will be pre-processed to ensure consistency, handling missing values and aggregating sunshine duration at annual and seasonal scales. Next, statistical indicators such as mean sunshine duration and standard deviation will be computed to rank sites according to their solar potential.

Modeling will begin by assessing the impact of cell temperature on PV efficiency, a key factor influencing performance. To estimate the cell temperature, we first need to determine the effective plane-of-array irradiance (E_{POA}) from the global horizontal irradiance (GHI). This estimation will rely on functions available in the PVlib library. [5]

The monthly global irradiance is the sum of the direct normal irradiance (DNI) and the diffuse horizontal irradiance (DHI), [7] :

$$GHI = DNI \cdot \cos(\theta_z) + DHI$$

where:

- GHI (Global Horizontal Irradiance): total solar radiation received on a horizontal surface,
- DNI (Direct Normal Irradiance): direct component from the solar disk, measured perpendicular to the sun's rays,
- DHI (Diffuse Horizontal Irradiance): diffuse component from the sky, scattered by the atmosphere,
- θ_z : solar zenith angle (0° when the sun is at zenith).

The plane-of-array irradiance (E_{POA}) is then computed as the sum of three components, [7] :

$$E_{POA} = G_{beam} + G_{sky_diffuse} + G_{ground}$$

- Direct component on the tilted plane, [7] :

$$G_{\text{beam}} = \text{DNI} \cdot \max(0, \cos(\theta_i))$$

where θ_i is the incidence angle, derived from the module tilt β , azimuth γ , and solar angles.

- Diffuse sky component (isotropic model), [7] :

$$G_{\text{sky_diffuse}} = \text{DHI} \cdot \frac{1 + \cos(\beta)}{2}$$

- Ground-reflected component (albedo), [7]:

$$G_{\text{ground}} = \rho \cdot \text{GHI} \cdot \frac{1 - \cos(\beta)}{2}$$

where ρ is the ground albedo.

Once E_{POA} is determined, it can be used in combination with ambient temperature and wind speed to estimate the PV cell temperature using available PVlib functions [5].

If time allows, the analysis will be extended to include additional parameters such as panel orientation, tilt, and terrain slope to refine site-specific evaluations.

The implementation combines MATLAB(2025a) for data processing, visualization, and automated report generation, with C for optimizing computationally intensive tasks (e.g., specific yield or error calculations). This hybrid structure balances clarity and efficiency. While the proposed methodology offers a robust framework for evaluating solar potential, several limitations must be acknowledged. The analysis does not account for shading effects from nearby terrain or vegetation, nor does it incorporate seasonal factors such as snow cover, which may reduce effective irradiance. Additionally, the use of empirical models for estimating cell temperature introduces simplifications that may not capture all site-specific thermal dynamics. These constraints should be considered when interpreting the final site rankings and yield estimates.

4.2 Main Project Steps

- Data Pre-processing: Import MeteoSwiss CSV files and clean data (MATLAB) [1]
- Statistical Analysis: Compute annual means and inter-annual variability to assess site stability (MATLAB, C)
- Solar Panel Efficiency Analysis: Evaluate temperature effects on PV performance, compare models, and estimate errors; potentially integrate other influencing factors (MATLAB, C)

5 Expected Schedule and Feasibility

Data will be collected from the MeteoSwiss open-source platform[1]. Although the data cannot be directly verified, we will validate our results by comparison with existing models

and sunshine maps at a later stage.

Reproducibility is ensured through documented dependencies, automated table and figure generation, and a transparent computational workflow linking results to the underlying dataset.

The expected timeline is as follows:

- Data acquisition and pre-processing: End of September 2025
- Project proposal : October 17, 2025
- Statistical analysis and ranking : October-November 2025
- Validation and comparison of the sites : End of November 2025
- Final report and recommendations : December 17, 2025

References

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