The Calculations Behind our Installation and Dismantling Models for PV-Modules:

Introduction:

The PVWDH (Photovoltaic Waste Datahub) is a platform that combines historical data : what was installed in PV capacity (per year / region) and combines it with mathematical models based on regional and governmental forecasts of how much said capacities are expected to reach in order to deliver a realistic forecast for the future installations and dismantling of PV Modules in the target regions which will give an insight and a planning edge for the recycling process that is becoming a necessity and even endorsed by law in the modern day

Installation of PV-Modules:

Our Installation-Model is based on historical installation data from 2000 till 2024. The Installation-Model builds off of the most recent data (installations in 2024) and, then, estimates future installation amounts using a logistical function, which has three main components : the maximum installation capacity (L) , the growth rate (k), and the infliction year (x_0). The maximum installed capacity was researched by looking at the long-term solar power capacity of each country. In other words, how many solar panels does a country need to install to meet its energy needs (excluding needs already met with other sustainable methods such as wind power). The growth rate is determined with the historical installation data. And, the infliction year is calculated with help of the maximum capacity and the growth rate.

Here is the logistical function that serves as the base for our model:

$$f(x) = \frac{L}{1 + e^{-k(x - x_0)}}$$

This function is applied twice to calculate a maximum and minimum approximation. The first approach calculates multiple installation predictions with the above function and a range of possible maximum capacities, growth rates, and infliction years. It then analyzes all of these different curves and fits it to the historical data. The second approach utilizes researched values for the maximum capacity, growth rate and infliction, which are directly inputted in the function to calculate the predictions.

After the installation predictions are calculated in GWp, the data is converted into number of modules and tons. To accurately convert between units, we researched the capacity and weight of singular solar panels historically and, with that data, we can estimate the capacity and weight of solar panels to be installed in the future.

As seen in our premium version, we have also calculated how much raw material is associated with the installations. We are able to estimate how much raw material is installed with solar panels each year by looking at the material composition of different solar panels (both between different manufacturers and over the years) and our own Installation-Model. Due to the range in our Installation-Model and the differences in the material composition (see Table 1), our estimation of the materials installed with solar panels each year also ranges between a maximum and minimum calculation.

Material	Min	Max
Si	1,82%	5%
Ag	0,06%	0,12%
Cu	0,56%	3,89%
Al	8,12%	22,1%
Polymere (EVA)	4,52%	11,25%
Glass	54,7%	80%

Table : Raw Material Percentages in the PV Modules used in the PVWDH Forecast Model

Mulazzani, Andrea & Eleftheriadis, Panagiotis & Leva, S.. (2022). Recycling c-Si PV Modules: A Review, a Proposed Energy Model and a Manufacturing Comparison. Energies. 15. 8419. 10.3390/en15228419.

Dismantling of PV-Modules:

The Dismantling-Model is based primarily on our Installation-Model and data regarding the lifespan of solar panels in different installation sites. We specifically differentiate between distributed installations (private / rooftop) and utility installations (commercial / industrial / utility - excluding off-grid because of their nuances in reported values) to be able to more accurately estimate the lifespan. We also researched how the climate of the different regions affects the life span of solar panels and integrated unique degradation rates for each region in the Dismantling-Model.

In the Dismantling-Model, we took into account four different scenarios that consider the theoretical, technical life span of solar panels but also the fact that commercially installed solar panels are often replaced earlier in favor of newer, more efficient ones (solar park repowering).

The model also considers the main causes for dismantling of solar panels:
Early-Stage Defect: *Failure shortly after installation due to manufacturing or installation issues*

Random: *Unpredictable failure caused by external or accidental factors*

Degradation: *End-of-life dismantling due to performance loss over time*

We calculated the early-stage defects and random dismantling using static coefficients based on historical data. We calculated how many solar panels were dismantled due to performance loss using an adapted Weibull distribution (as seen in the formula below), which is based on the lifespans of the solar panels that vary due to installation site (distributed/utility and the region) and the scenario.

$$F(x) = 1 - e^{-\left(\frac{x}{\alpha}\right)^{\beta}}$$

We took into account the following scenarios:

Base Case Scenario : Baseline assumption where both commercial and private fleets follow the same degradation-driven trajectory, and modules are treated as reaching the relevant threshold once performance drops to a minimal performance rate of 0.80.

Early Loss Scenario : A more conservative case where we assumed earlier effective "loss" by using a stricter threshold (minimal performance rate = 0.85) and applied a stronger acceleration to the commercial degradation than residential to reflect that commercial assets are more often reach their EOL earlier.

Extended Commercial Lifetime Scenario: A more lenient threshold (minimal performance rate = 0.75) is used to represent longer operation before "end-of-use," while the commercial segment is assumed to stay in service longer than in the baseline via a milder adjustment.

Technical EOL Scenario: A "technical end-of-life" definition where modules are assumed to remain deployed until performance drops to minimal performance rate of 0.70, with no difference between commercial and private behavior.

The same method to convert between units was applied here as in the Installation-Model. We researched the material composition of different solar panels and then applied this to our input, installation data and prediction, and then calculated the output, dismantling data, in that unit. This is important because the efficiency and weight of the solar panels is dependent on the year installed, not the year dismantled

Additionally, the Dismantling-Material-Model in the premium version aims to give an overview of how much materials will flow into the recycling process. The data is an optimal calculation that assumes that all dismantled solar panels are either recycled or find a second-life – this is of course not the reality. However, with optimized recycling processes that are accessible to all, this could one day become the reality.

The data is calculated by first looking at how much material was installed and then applying the Weibull distribution to estimate when which solar panels with which material compositions are dismantled. It is important to consider the material composition of the installation year.

Since there is a difference in the material composition depending on the technology used to make the solar panels and even in the same category it tends to alter from one producer to another, an approach of using the minimum and the maximum value that can be found in the modules (see Table 1) was adapted to have a general overview of all the possibilities regarding dismantling amounts.

Conclusion:

The final step was to compare the predictions of the model that used the historical data till the year of 2024 with the current available data from the previous year 2025 and the numbers have a plausible prediction range of between 5% - 20% from the forecasted value depending on the region which reflects the difference in reporting compared to the actual values, it is still a work in progress because it relies solely on mathematical equations and predictions and the results can vary heavily because of the future of politics regarding the renewable energy and the technological advancement in the field , the model offers a safe way to get ahead of the curve but it should be used carefully along with internal information of any international or national development of the solar energy.