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# ULISSE


### Executive summary

The future is electric and photovoltaic (PV) technology is a key to this green revolution. The solar modules installation is increasing and occasionally they are combined with storage systems in order to accumulate only the excess of production.

The project suggests a solution for energy management, merging photovoltaics and storage systems together with the use of Artificial Intelligence (AI), considering as case study focused on a building with high density of households.

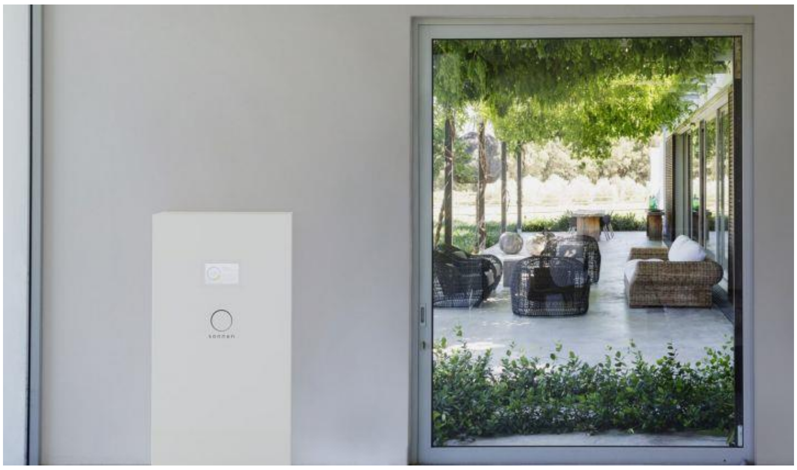
Using the AI, Ulisse can predict the next day building's behavior and the energy produced by the PV installed on the rooftop. If the needs outweigh the production, Ulisse will accumulate the difference into the storage when it costs less (typically at nighttime).

- Buying energy at the minimum price in order to reduce the users bill cost, according to the energy management predictions.
- consumption and avoiding buying energy at pick.



### Key Words

Smart community; Energy storage; TCN for energy prediction; Energy price fluctuation.

Residential Energy Storage System

**Project description written by the Principal Academic Tutor**

The Ulisse project aimed to explore, design and study innovative and integrated software and monitoring systems applied to energy systems, with particular reference to PV installations combined with storage systems.

The main objective of this project is to develop and implement an integrated tool for optimization and control on the basis of specific stakeholders' requirements, integrating physical and numerical models, acquired data from real-time monitoring systems, inspection data from unmanned technologies and multi-source forecasting performance based on AI techniques. All parts of the system have been validated on a real test case and with industrial partner cooperation, creating an ad hoc tool for integrated multi-energy sources on a residential scale, designing an optimization process for energy management considering both overall costs and performance. The final step of the project was targeted to finalize a computational tool able to process the system architecture data and perform predictive capabilities based on Deep Learning Neural Networks.

In a multidisciplinary context, this project has covered topics related to multiple energy sources management and residential infrastructure performance monitoring, combining data processing applied to different energy models, artificial intelligence and optimization algorithms, providing an energy asset management tool to be extended to other engineering and architecture fields.

**Team description by skill**

The team that carried out the project is perfectly balanced. It is composed of three industrial engineers, a data scientist and an architect.
The first three, thanks to their hard skills, were able to produce the physical models of the PV (to forecast their production) and the storage.
The data scientist was a key figure because he had to design both the Neural Network, able to predict the consumptions, and the whole algorithm that merges the physical models and the forecasted load profile in order to take the best decision to reduce the user bill cost.
Finally, the architect had the fundamental role of understanding the context in which the solution fits itself: cities and buildings, energy communities and the integration of PV in the urban environment.
Furthermore, what made possible the development of ULISSE was the passion of the team members towards project management, economics and technology, key aspects to transform a good idea into a real solution.

## Goal

The software saves money for energy consumers, predicting their energy needs and buying it when it costs less. It works in buildings where both photovoltaic and storage systems are present. The software manages the energy fluxes, just controlling the energy accumulator and buying, through it, energy during the night. An AI tool is needed, because the storage has losses and the self-produced energy cost less than the one bought even at the minimum price: it has no sense to buy as much energy as possible, but the difference between the one you will consume and the one you will produce. The software, with this purpose, makes predictions about the energy that will be produced, using as input real-time weather forecasts.

With respect to the actually installed most advanced solution for energy management, this solution is able to save 75€ per family per year, at zero additional cost! Over the savings in the electrical bill of 55%, this solution brings a smarter use of the storage, because it passes from being empty for 72% of the time to only the 4%.

The software introduces energy management concepts to residential districts, which could be achieved by combining the use of AI, storage devices, local energy production and smart sensors as remote data sources. The output is a software, able to interact with users, to update them about consumptions and average statistics and as any other solution actually proposed in the energy management market is currently doing, it takes decisions independently according to the energy management predictions.

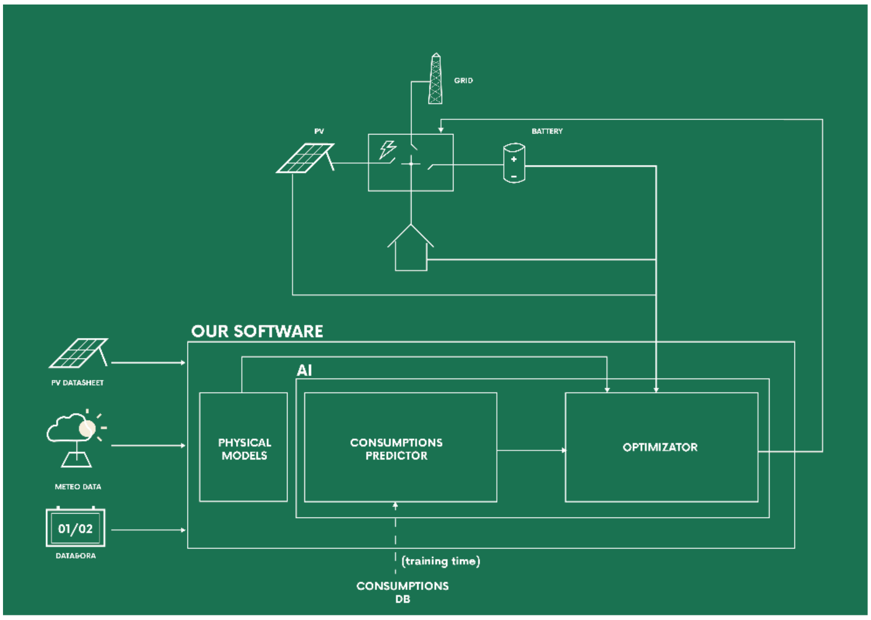
## Understanding the problem

Different energy markets exist and, for each of them, the energy price can assume different values:

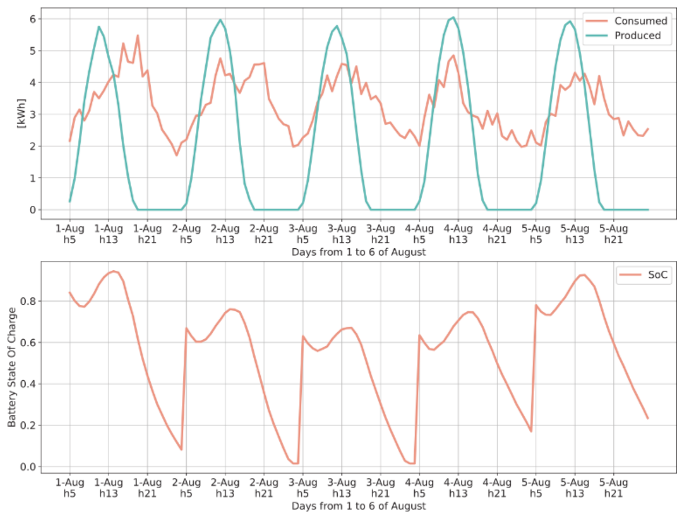
- Where there is not a national single price (PUN) for the energy, the price for the final user varies hour by hour, with a difference that can reach 50%. Australia is an example.
- In nations where PUN exists, the final user can stipulate agreements with the energy seller, for which the energy price changes along the day, assuming pre-settled values. Typically, small variations in the price occurs, yet from it results that in some fixed moment of the day, buying energy costs less.
- Independently by the presence of a PUN or not, another opportunity consists in selling energy to the TSO for electrical net compensations. In this sense, TSO could pay "prosumers" for energy when the electric net goes into instability for excessive demand. This energy is typically paid more because it is demand driven, and it is typically beaten at auction in the 'capacity market'. In particular, in this case, users can take advantage not on the purchase, but by selling at the higher price the energy produced or, if necessary, also accumulated.

Independently by where a residential building is, it can take advantage just from a smart and sensible re-arrangement of its energy flux, which can be planned in order to speculate on the price variations. Note that a solution cannot be just in buying energy when it costs less, up to filling the accumulator: in this case there could not be availability for accumulating energy produced by PV and, in that case, energy should be sold at a price lower than the minimum one at which energy can be bought. At the same time, as the nowadays most updated solutions do, the storage could be used only for accumulating self-produced energy: in this case, there would be the potential economic loss that this software would want to exploit, predicting the "available space" into the storage.

Prediction passes through the user habits and the cyclical changing of the external temperature, along the seasons. This problem is highly specific for each considered case, and it needs the use of advanced methods for getting a solution. Furthermore, in dependence on the nation where we are, dealing with the three points from which this paragraph has started, the way through which speculations on the prices variations changes.




Architectural block diagram of the proposed solution. Our AI module monitors the building to generate predictions about energy demand; the optimizer combines this information with the forecasted PV production using our physical models, and as an output it acts on the system scheduling purchases of energy at the minimum price.




Results applying the ULISSE sofware : behavior of the SoC of the storage in a ULISSE system in response to consumption/production curves

## Exploring the opportunities

Opportunities for making this solution always more convenient comes from many fields:

- the price of accumulator is actually one of the main limits, but price trends shows it will drop down by the 30% in the next 15 year;
- Electric Vehicles are increasing more and more in our cities, and new charging stations are installed in our cities every day. This green trend has a main drawback: any charging stations produce sudden peaks in the energy demand of the district, bringing consistent problems to the energy net.
- Energy prices are increasing and, even if the world is trying to come back to pre-covid situations, smart working is keeping many of us to work more at home than what we did before, increasing our consumption.

All these three points are three independent reasons for which this solution could be, in the future, one of the key drivers for the transition to self-consumption.

## Generating a solution

ULISSE plugs itself in a scenario that essentially comprehends a building equipped with a PV and a storage system. The system has two main sources of inputs: one of course coming from the building, monitoring the state of the storage, the demand and the PV output; and another input comes from the weather forecast, that is going to be applied to the physical model of the PV to extrapolate the forecasted power output. Internally, the forecasted power output of the PV is combined with the prediction of the demand, and it is then fed to the optimizer module that provides the strategy to follow. The strategy in detail consists in deciding at what time and what amount of energy has to be purchased from the grid, in order to fully exploit the storage asset and maximize final energy self-consumption.

This new solution can have a huge impact on both the economic and energetic point of view. In particular, the main benefit of the solution proposed is not only reducing the electricity bill price, but also stabilizing the electric system and opening up future distributed energy community exchange models.

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