## Assignment 3 – Scheduling Flexibility Resources

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### A diagram of a solar system Description automatically generatedTask 1

Energy balance:  
From\_grid(t) = Base\_load(t) – PV\_prod(t) + Bat\_charge(t) – Bat\_discharge(t)

Battery energy:  
SOC(t) = SOC(t-1) + η\_charge​ \* Bat\_charge(t) – (1/η\_discharge​) \*Bat\_discharge(t)

With boundary conditions 🡪 SOC(t=1)= SOC(t=24)=0

Minimize t=1∑24​ (From\_grid(t)\*price(t))

### Task 2/3

Due to some difficulties with GLPK solver we had to opt for Gurobi solver.

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A screenshot of a computer screen

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Description automatically generated with medium confidence

### Task 4

The battery charges during two key periods over the course of the day, notably around hours 3 and 4, and again around hour 12. This charging behavior likely reflects times when electricity prices are lower or when excess PV production is available. By charging at these times, the system enables the battery to store energy for later use, particularly when grid prices are higher, or PV production is insufficient to meet demand.

The timing of these charging periods suggests that the system is responding efficiently to variations in electricity prices and PV generation. The early morning charging corresponds to lower-demand hours, likely coinciding with cheaper electricity rates. The midday charging aligns well with peak PV production, allowing the battery to store excess solar energy instead of exporting it to the grid.

The battery discharges primarily between hours 9 and 16 and again between hours 18 and 19. These periods likely correspond to times of higher electricity prices or greater household demand, when stored energy is used to reduce reliance on grid imports. By discharging during these hours, the system minimizes the need to purchase energy from the grid at high prices, thus reducing overall energy costs.

This discharging pattern indicates that the battery is being effectively utilized to meet household demand during expensive periods. Rather than relying on grid energy during these peak times, the system strategically uses the battery's stored energy to supply the load, which aligns with the overall goal of minimizing costs.

Grid imports are highest during the early hours of the day (hours 1 to 5) and again in the late afternoon (hours 15 to 18). These are likely times when the battery is either fully depleted or lacks sufficient charge to meet the household's energy needs, necessitating the import of energy from the grid. These periods may also coincide with low PV production or higher household consumption.

Although the battery effectively reduces grid imports during peak hours, the total energy imported from the grid could be further minimized by improving the battery's capacity or charging efficiency. Nevertheless, given the system’s constraints, the current performance strikes a reasonable balance between relying on grid energy and maximizing the use of the battery’s capabilities.

### Task 5

Battery storage systems play a crucial role in managing grid congestion and alleviating pressure during peak demand periods. By charging during off-peak times and discharging during times of high demand, batteries can help smooth out energy consumption patterns, thereby reducing strain on the grid. This ability to shift energy usage is especially valuable in preventing grid overload during peak hours, when demand for electricity is highest. For example, in urban areas where evening energy consumption spikes, a battery system can discharge during these critical periods, reducing the load on the grid and mitigating the need for additional generation from costly and less efficient peaker plants. By doing so, batteries not only reduce grid congestion but also minimize the risks of blackouts and lower overall energy costs.

In addition to managing demand, batteries are also highly effective at supporting grid stability through frequency regulation and other balancing services. The rapid response capability of batteries allows them to absorb or release energy in real-time, helping to maintain grid frequency within safe operating limits. Unlike traditional power plants, which take time to adjust their output, batteries can react instantaneously to fluctuations in demand or supply, providing a critical service in moments of instability. For instance, during sudden dips in renewable energy production or unexpected surges in consumption, batteries can discharge immediately to compensate for the shortfall, ensuring the grid remains stable and reliable.

### Task 6

From\_grid(t) = Base\_load(t) – PV\_prod(t) + Bat\_charge(t) – Bat\_discharge(t)

From\_grid(t) ≤ P\_lim

→P\_lim≥ Base\_load(t) – PV\_prod(t) + Bat\_charge(t) – Bat\_discharge(t)

In order to implement such limit P\_lim must be first defined and then create a constraint function that enforceses such limit

### Task 7

P\_lim could only be as low as 6 kWh

A screen shot of a computer program

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### Task 8

A graph of energy and battery charging

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In terms of battery charging, both plots follow a similar pattern. The battery charges exclusively during the early morning hours, between 2 AM and 5 AM, taking advantage of likely low electricity prices or surplus PV generation. After this period, no further charging occurs for the rest of the day. There is a slight difference in duration and peak value.

In the limited system (on the left) there is a shorter discharge at midday and a second discharge later in the evening while the original system also has two discharges but both at midday.

The SOC also varies with the limited system having a higher charge later in the day that is then used.

The imported energy from the grid although pretty similar offers some differences in timing and peaks, with of course a limit of 6 kWh in the limited system.

In summary, while both plots show identical early morning charging, the second plot demonstrates more aggressive battery usage during the morning and afternoon peak demand periods, resulting in lower grid imports early on but higher reliance on grid energy later in the day. The first plot, on the other hand, shows a more balanced discharge pattern, with the battery being used more consistently throughout the day and avoiding the sharp grid reliance seen in the second plot.