Results and Cost Comparison

Table 1: Total Electricity Costs

Scenario	Total Cost [EUR]
No PV – No Storage	6.0
PV – No Storage	0.9
PV + Storage (SOC 6→6)	−0.2
PV + Storage (SOC 6→1)	−1.2
PV + Storage (SOC 6→10)	0.8

Results Interpretation

- No PV – No Storage: The household relies entirely on grid electricity, resulting in the highest total cost.
- PV – No Storage: PV generation significantly reduces grid purchases, lowering the total cost to 0.9 EUR, but surplus PV energy cannot be shifted in time.
- PV + Storage (SOC 6→6): Battery storage enables temporal shifting of PV energy, leading to a slightly negative total cost (−0.2 EUR) while maintaining equal initial and final SOC.
- PV + Storage (SOC 6→1): Allowing battery discharge at the end of the optimization horizon results in the lowest cost (−1.2 EUR), as stored energy is fully utilized.
- PV + Storage (SOC 6→10): Enforcing a high final SOC requires additional charging, increasing grid purchases and raising the total cost to 0.8 EUR.

Conclusion

PV generation substantially reduces electricity costs, and the addition of battery storage further improves economic performance by enabling energy shifting. The final SOC constraint has a strong impact on total cost, with relaxed final SOC requirements yielding the lowest operating costs.

MATLAB code

```
%% Task 4 – PV Home Storage Problem (48h)
clear all
close all

%% General setup (common for all simulations)
%% Profiles (given)
PV = zeros(1,48);
PV(7:17)  = [1 2 3 4 5 6 5 4 3 2 1]*0.5;
PV(31:41) = [1 2 3 4 5 6 5 4 3 2 1]*0.25;

Load = ones(1,48)*0.5;

%% Prices (constant)
Buy  = ones(1,48)*0.25;     % €/kWh
Sell = ones(1,48)*0.15;     % €/kWh (positive here, handled with minus in objective)
```

```matlab
%% Battery parameters
Ts = 1;         % 1 hour
SOC_min = 1;
SOC_max = 10;
PBat_min = -3;
PBat_max =  3;

N = 48;
idx = @(k,i) 4*(i-1)+k;    % variable indexing


%% Helper function: LP solver (reuse for all cases)
function [x,fval] = solve_PV_storage_LP(PV,Load,Buy,Sell,...
    SOC_0,SOC_end,SOC_min,SOC_max,PBat_min,PBat_max)

N = length(PV);
n = 4*N;
idx = @(k,i) 4*(i-1)+k;

%% Objective
f = zeros(n,1);
for i = 1:N
    f(idx(2,i)) = Buy(i);
    f(idx(3,i)) = -Sell(i);
end

%% Equality constraints
Aeq = zeros(2*N+1,n);
beq = zeros(2*N+1,1);
row = 0;

% Power balance
for i = 1:N
    row = row + 1;
    Aeq(row,idx(1,i)) =  1;
    Aeq(row,idx(3,i)) =  1;
    Aeq(row,idx(2,i)) = -1;
    beq(row) = PV(i) - Load(i);
end

% SOC dynamics
row = row + 1;
Aeq(row,idx(4,1)) = 1;
Aeq(row,idx(1,1)) = -1;
beq(row) = SOC_0;

for i = 2:N
    row = row + 1;
    Aeq(row,idx(4,i))   =  1;
    Aeq(row,idx(4,i-1)) = -1;
    Aeq(row,idx(1,i))   = -1;
end

% Final SOC
row = row + 1;
```

```
Aeq(row,idx(4,N)) = 1;
beq(row) = SOC_end;

%% Bounds
lb = -inf(n,1);
ub =  inf(n,1);

for i = 1:N
    lb(idx(1,i)) = PBat_min;
    ub(idx(1,i)) = PBat_max;
    lb(idx(2,i)) = 0;
    lb(idx(3,i)) = 0;
    lb(idx(4,i)) = SOC_min;
    ub(idx(4,i)) = SOC_max;
end

%% Solve
[x,fval] = linprog(f,[],[],Aeq,beq,lb,ub);
end

%% No PV, no storage (baseline)
Cost_noPV_noBat = sum(Load .* Buy);
[x_npns,f_npns] = solve_PV_storage_LP(zeros(1,48),Load,Buy,Sell,...
    6,6,6,6,PBat_min,PBat_max);
%% PV, no storage
Cost_PV_noBat = sum(max(Load-PV,0).*Buy) ...
               - sum(max(PV-Load,0).*Sell);
[x_ns,f_ns] = solve_PV_storage_LP(PV,Load,Buy,Sell,...
    6,6,6,6,PBat_min,PBat_max);
%% PV + storage (three SOC cases)
%% Case A: SOC₀ = 6 → SOC_end = 6
[x66,f66] = solve_PV_storage_LP(PV,Load,Buy,Sell,...
    6,6,SOC_min,SOC_max,PBat_min,PBat_max);

%% Case B: SOC₀ = 6 → SOC_end = 1
[x61,f61] = solve_PV_storage_LP(PV,Load,Buy,Sell,...
    6,1,SOC_min,SOC_max,PBat_min,PBat_max);

%% Case C: SOC₀ = 6 → SOC_end = 10
[x610,f610] = solve_PV_storage_LP(PV,Load,Buy,Sell,...
    6,10,SOC_min,SOC_max,PBat_min,PBat_max);

%% Cost summary table
CostVector = [ ...
    Cost_noPV_noBat;
    Cost_PV_noBat;
    f66;
    f61;
    f610 ];

Results = table( ...
    CostVector, ...
    'VariableNames', {'TotalCost_EUR'}, ...
    'RowNames', { ...
        'No PV – No Storage', ...
```

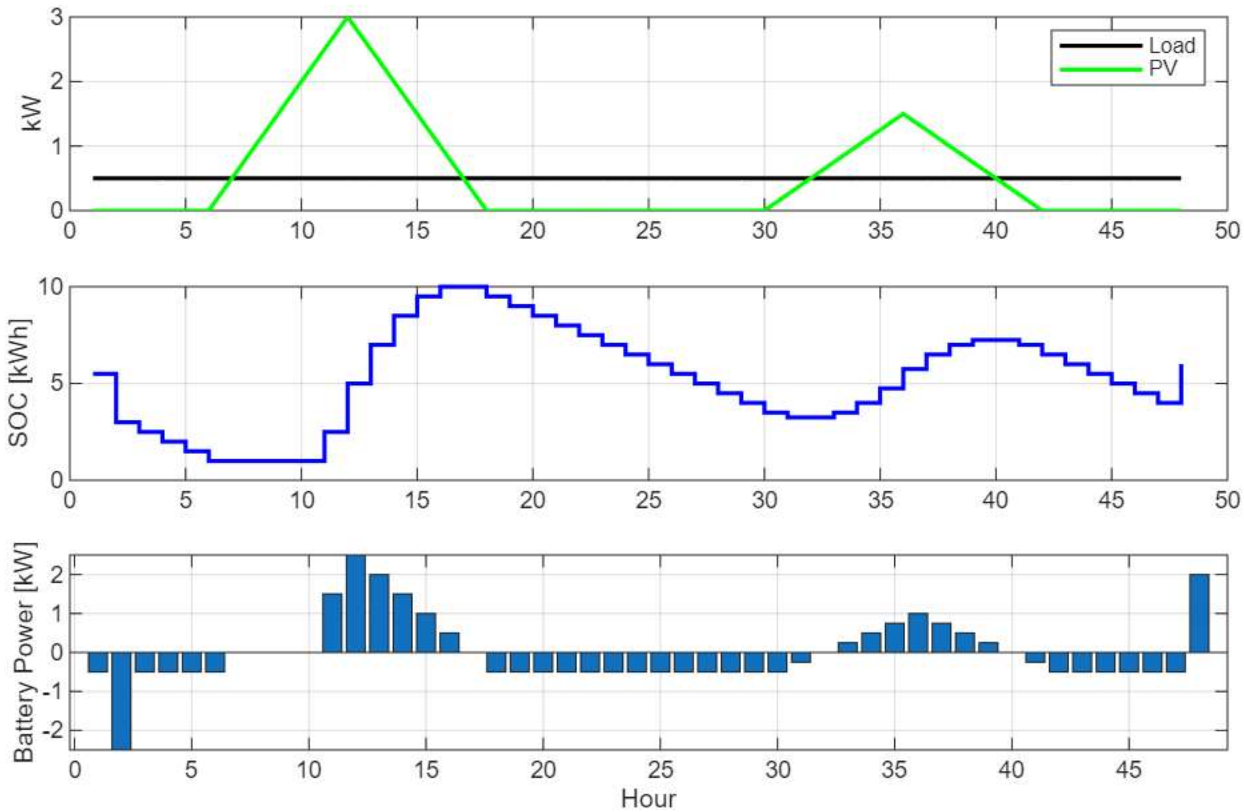
```
        'PV – No Storage', ...
        'PV + Storage (SOC 6→6)', ...
        'PV + Storage (SOC 6→1)', ...
        'PV + Storage (SOC 6→10)'});

disp(Results)

%% Graphical results
SOC = x66(4:4:end);
Pbat = x66(1:4:end);

figure
subplot(3,1,1)
plot(Load,'k','LineWidth',1.5); hold on
plot(PV,'g','LineWidth',1.5)
legend('Load','PV'); grid on
ylabel('kW')

subplot(3,1,2)
stairs(SOC,'b','LineWidth',1.5)
ylabel('SOC [kWh]')
grid on

subplot(3,1,3)
bar(Pbat)
ylabel('Battery Power [kW]')
xlabel('Hour')
grid on

%% Extract purchase & feed-in
% Preallocate
P_buy     = zeros(N,1);
P_feed    = zeros(N,1);
P_buy_nb  = zeros(N,1);
P_feed_nb = zeros(N,1);

for i = 1:N
     % no pv, no storage
    P_buy_npns(i)  = x_npns(idx(2,i));
    P_feed_npns(i) = x_npns(idx(3,i));

     % pv, storage
    P_buy_ns(i)  = x_ns(idx(2,i));
    P_feed_ns(i) = x_ns(idx(3,i));

    % pv, battery 66
    P_buy_66(i)  = x66(idx(2,i));
    P_feed_66(i) = x66(idx(3,i));

   % pv, battery 61
    P_buy_61(i)  = x61(idx(2,i));
    P_feed_61(i) = x61(idx(3,i));

    % pv, battery 610
    P_buy_610(i)  = x610(idx(2,i));
```

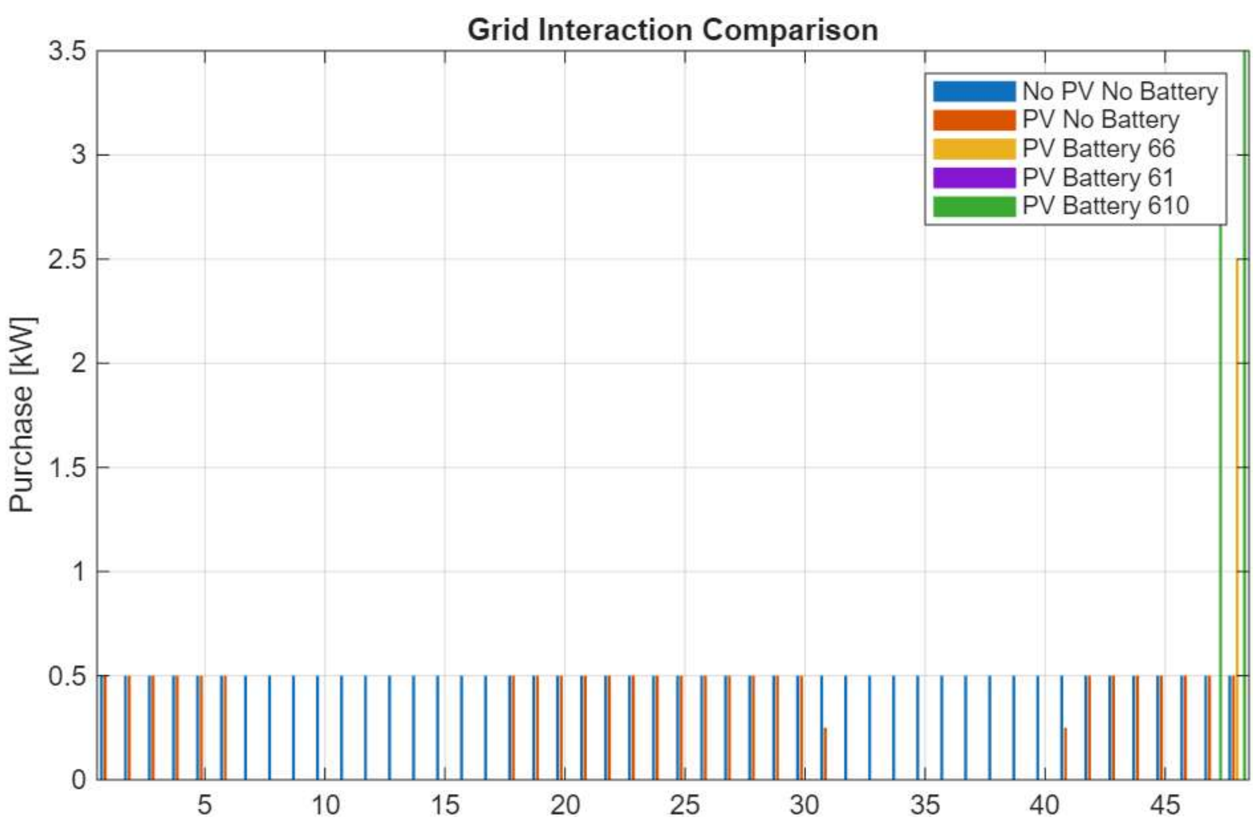
```
    P_feed_610(i) = x610(idx(3,i));
end

%% figure
figure
bar(1:N, [P_buy_npns; P_buy_ns; P_buy_66; P_buy_61; P_buy_610;])
ylabel('Purchase [kW]')
title('Grid Interaction Comparison')
legend('No PV No Battery','PV No Battery','PV Battery 66', ...
    'PV Battery 61', 'PV Battery 610')
grid on


figure
bar(1:N, [P_feed_npns; P_feed_ns; P_feed_66; P_feed_61; P_feed_610;])
xlabel('Hour')
ylabel('Feed-in [kW]')
legend('No PV No Battery','PV No Battery','PV Battery 66', ...
    'PV Battery 61', 'PV Battery 610')
grid on
```

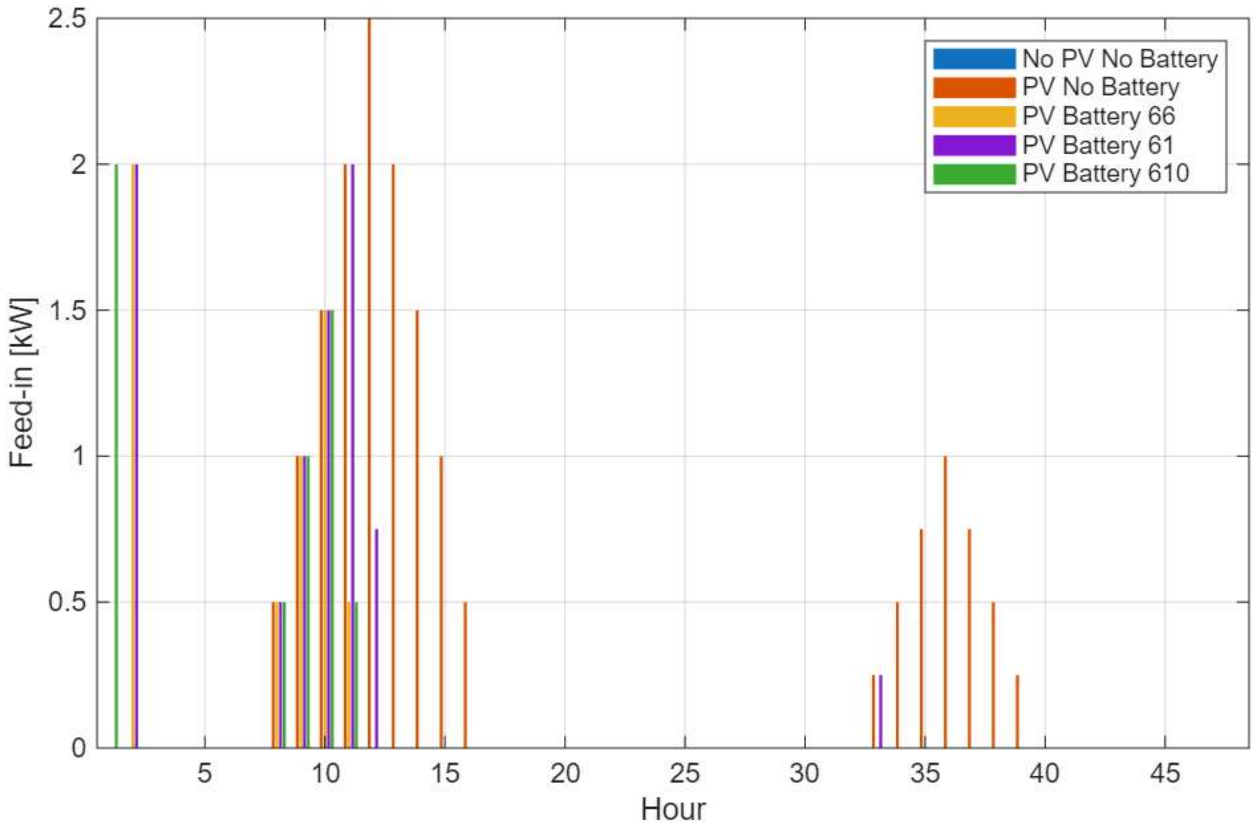
>> Task4

```
Optimal solution found.


Optimal solution found.


Optimal solution found.


Optimal solution found.


Optimal solution found.
```

	TotalCost_EUR
No PV - No Storage	6
PV - No Storage	0.9
PV + Storage (SOC 6→6)	-0.2
PV + Storage (SOC 6→1)	-1.2
PV + Storage (SOC 6→10)	0.8


Load
PV
kW
SOC [kWh]
Battery Power [kW]
Hour


Grid Interaction Comparison
No PV No Battery
PV No Battery
PV Battery 66
PV Battery 61
PV Battery 610
Purchase [kW]


No PV No Battery
PV No Battery
PV Battery 66
PV Battery 61
PV Battery 610
Feed-in [kW]
Hour
2.5
2
1.5
1
0.5
0
5
10
15
20
25
30
35
40
45