Energy Sustainability for Smart Transportation and Infrastructures

ENERGY RENOVATION OF TRANSIT FACILITIES:

Aeroporto di Capodichino

Efficiency-First approach

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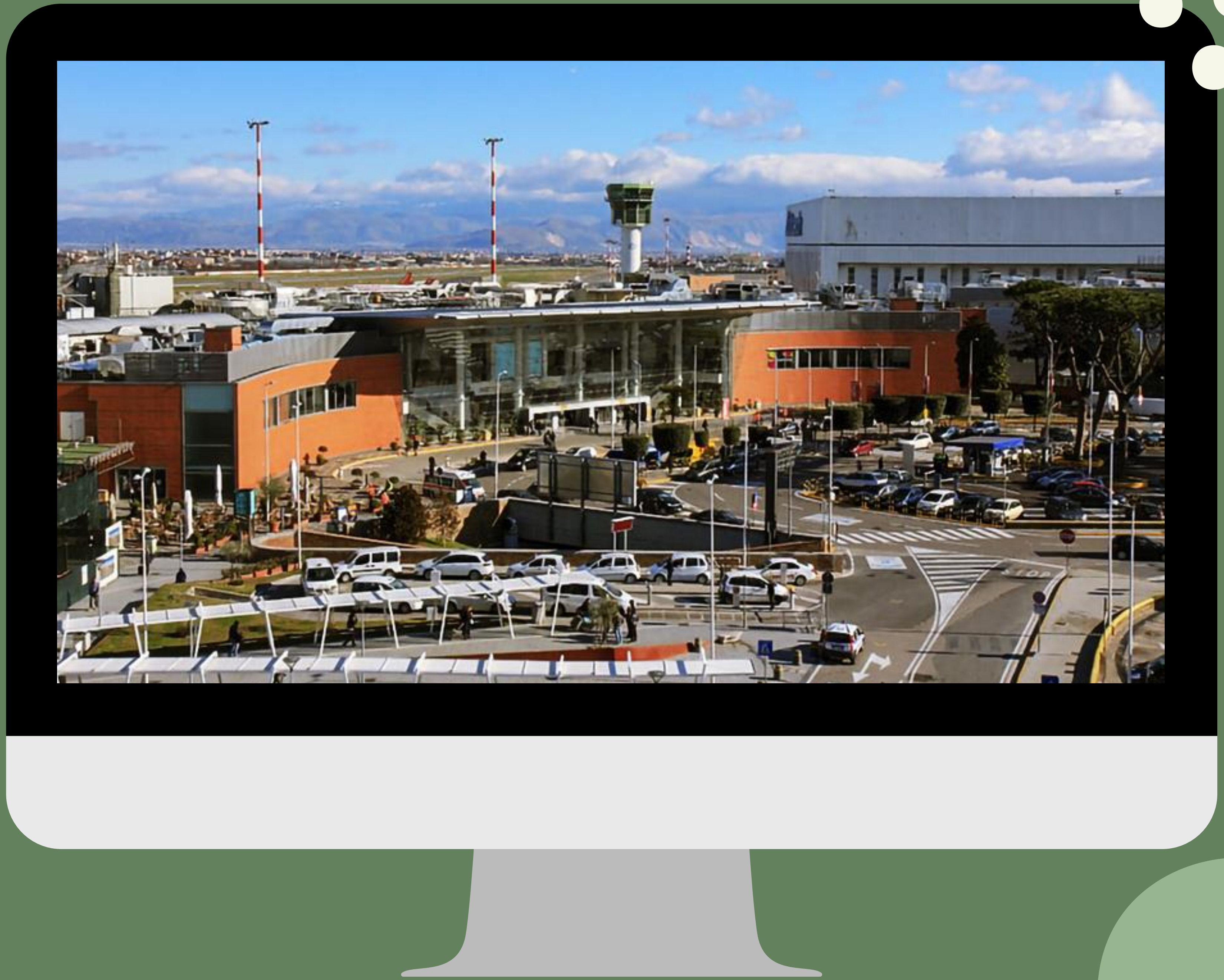
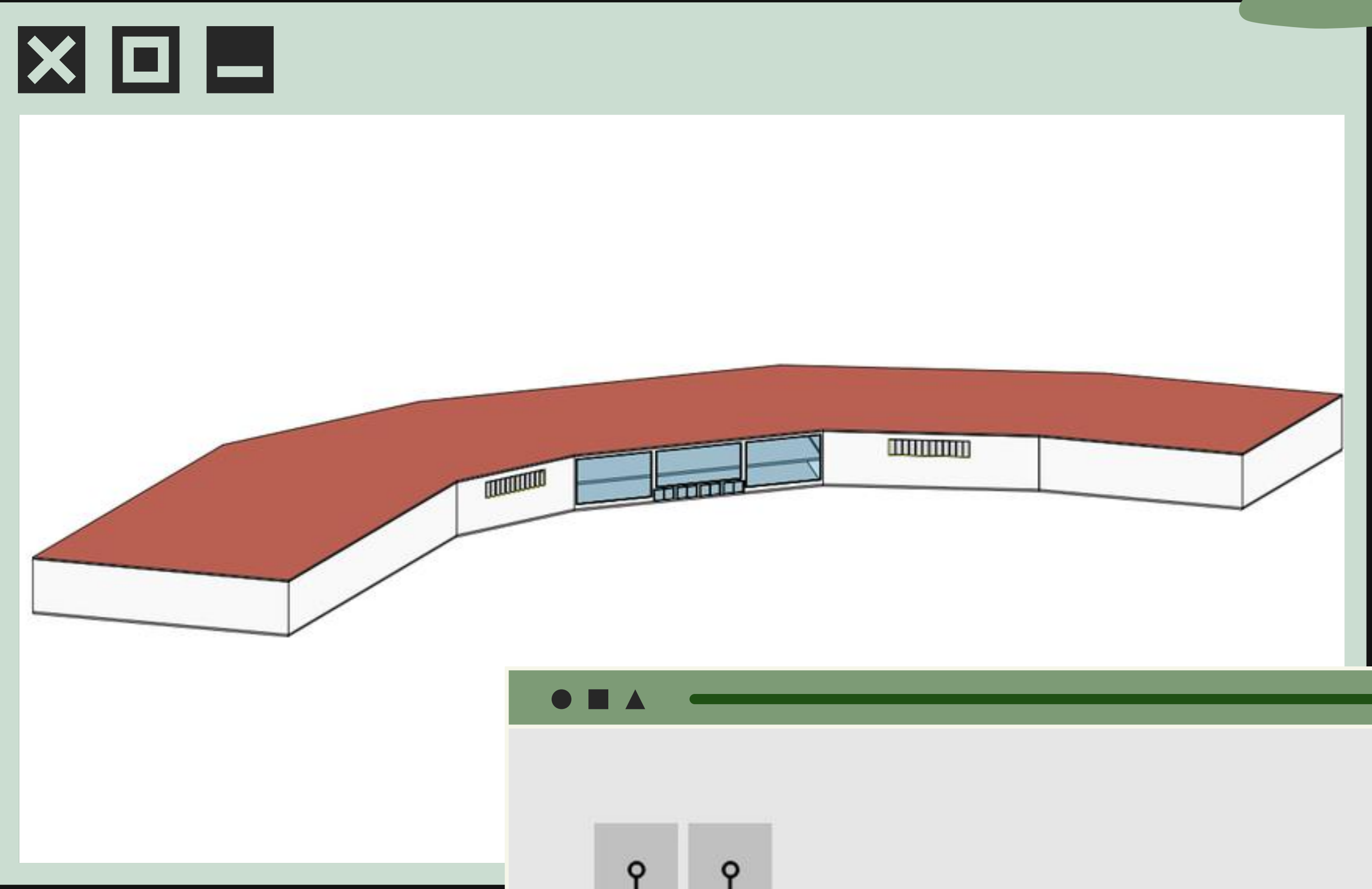
INTRODUCTION

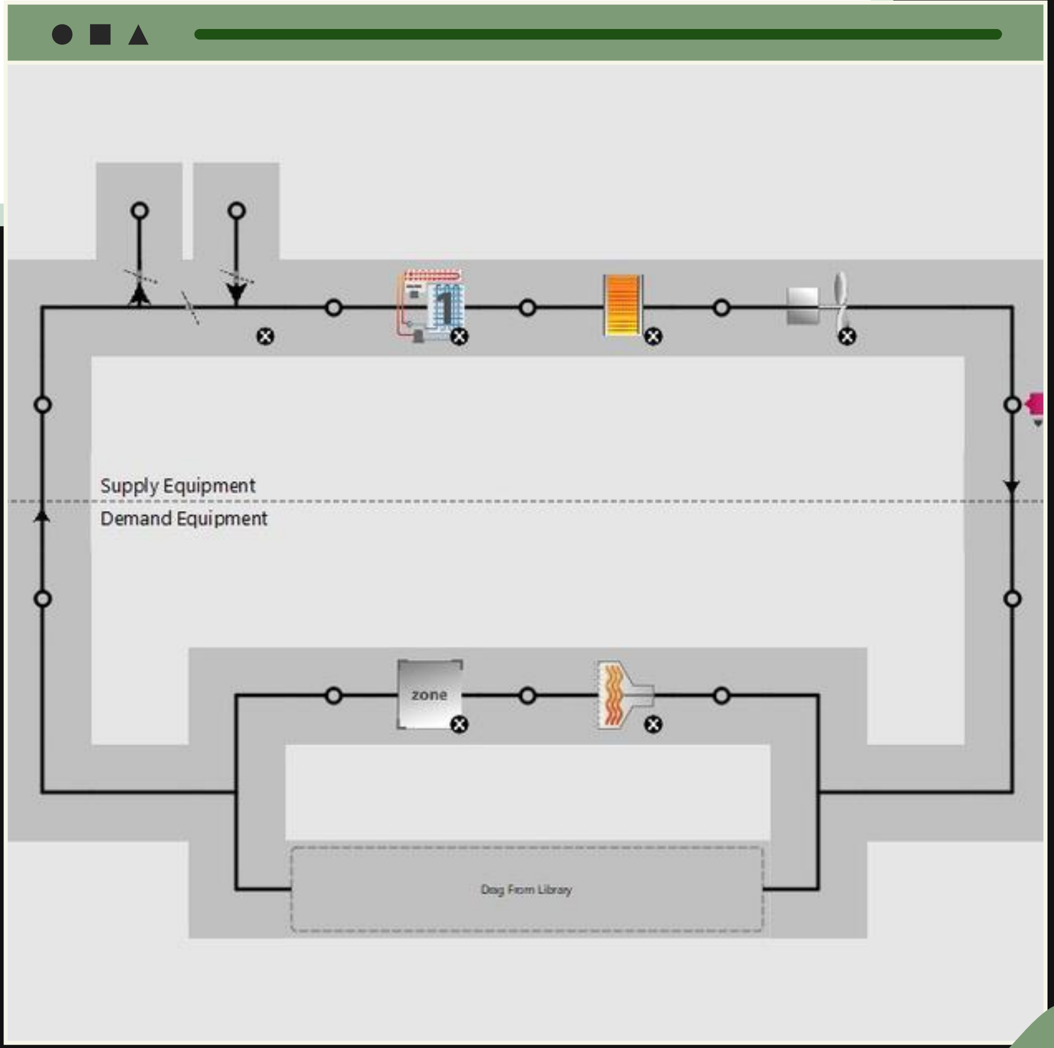
- Two-stories building with occupied area of 26’000 m2 and 81’000 m3
- Naples Airport handled 11’000’000 passengers in 2019
- HVAC operated 19/24h – 7/7d
- Several Air Handling Units (AHU) (Constant airflow volume)
- Several air-source heat pumps/chillers supply heating and cooling demand



CASE 0: State of Fact

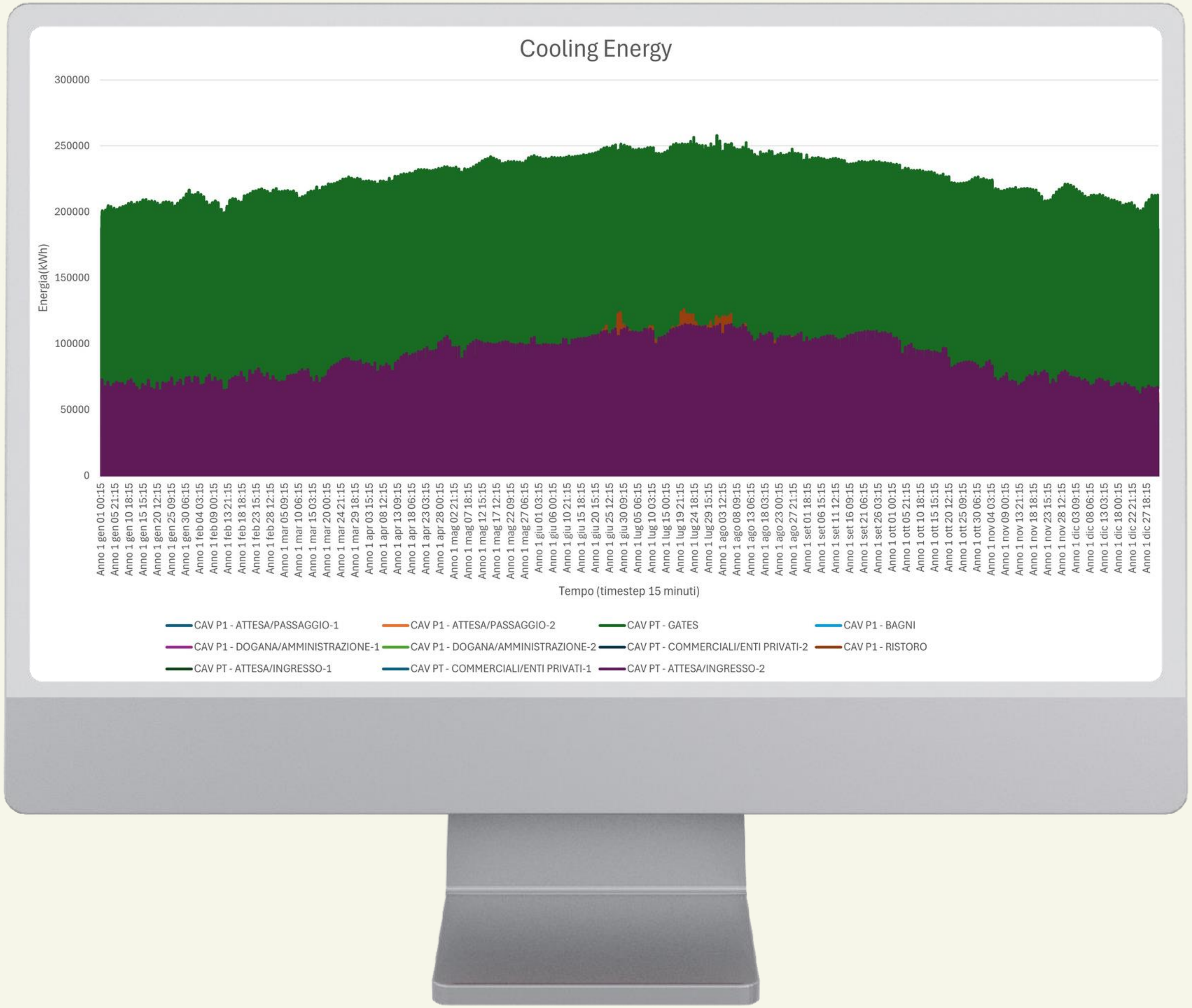
- Simplified BIM model using Autodesk Revit;
- BEM model using OpenStudio;
- Constant air volume HVAC (CAV) modeling;
- 12 different HVAC systems that cover the heating and cooling demand of each area;
- Air flow between 0.009 - 0,011 m3/s per person and per area, following the UNI 10339 standard;





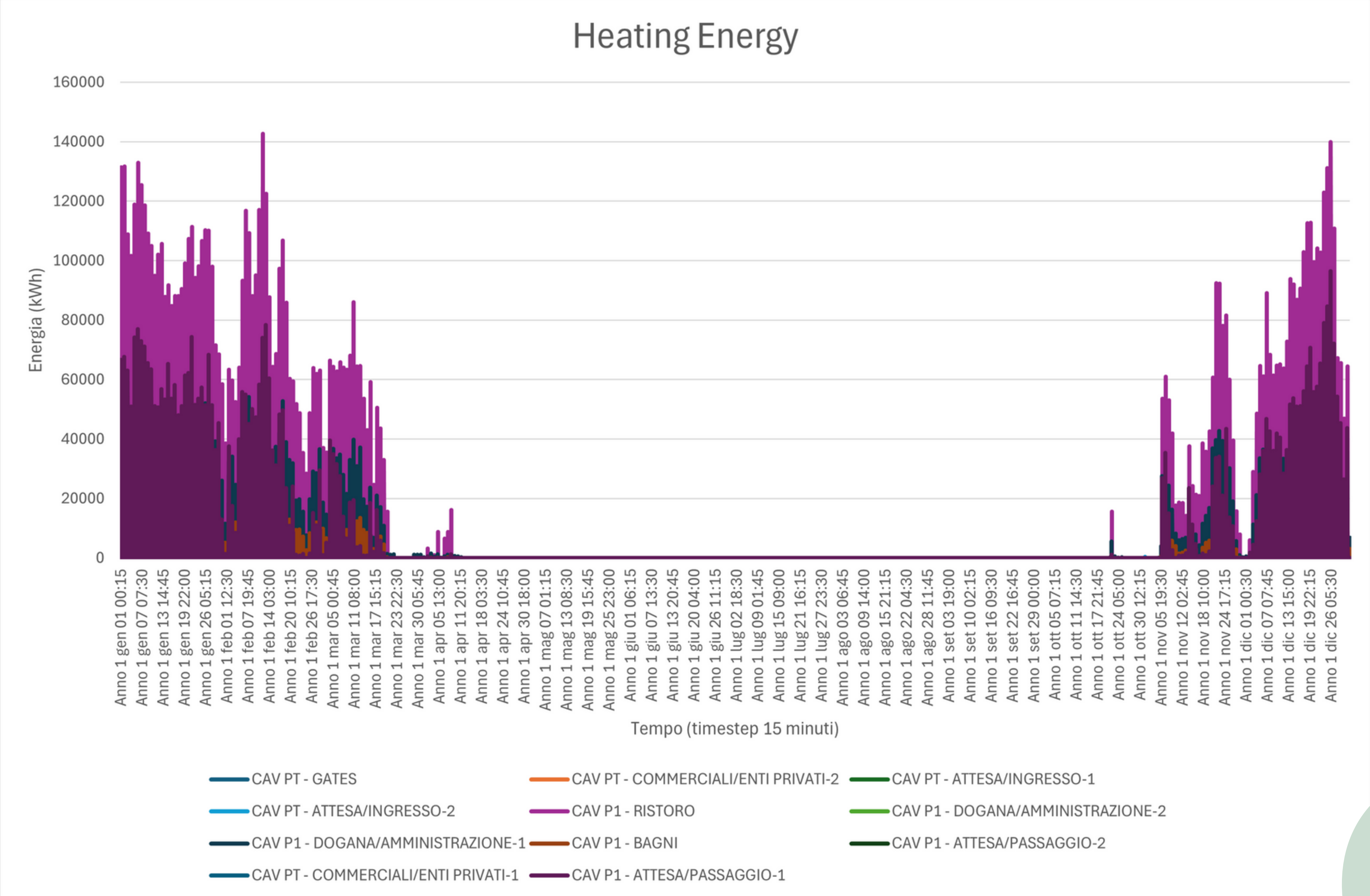
CASE 0: Results - Cooling energy demand

Gates area with the highest cooling energy demand;

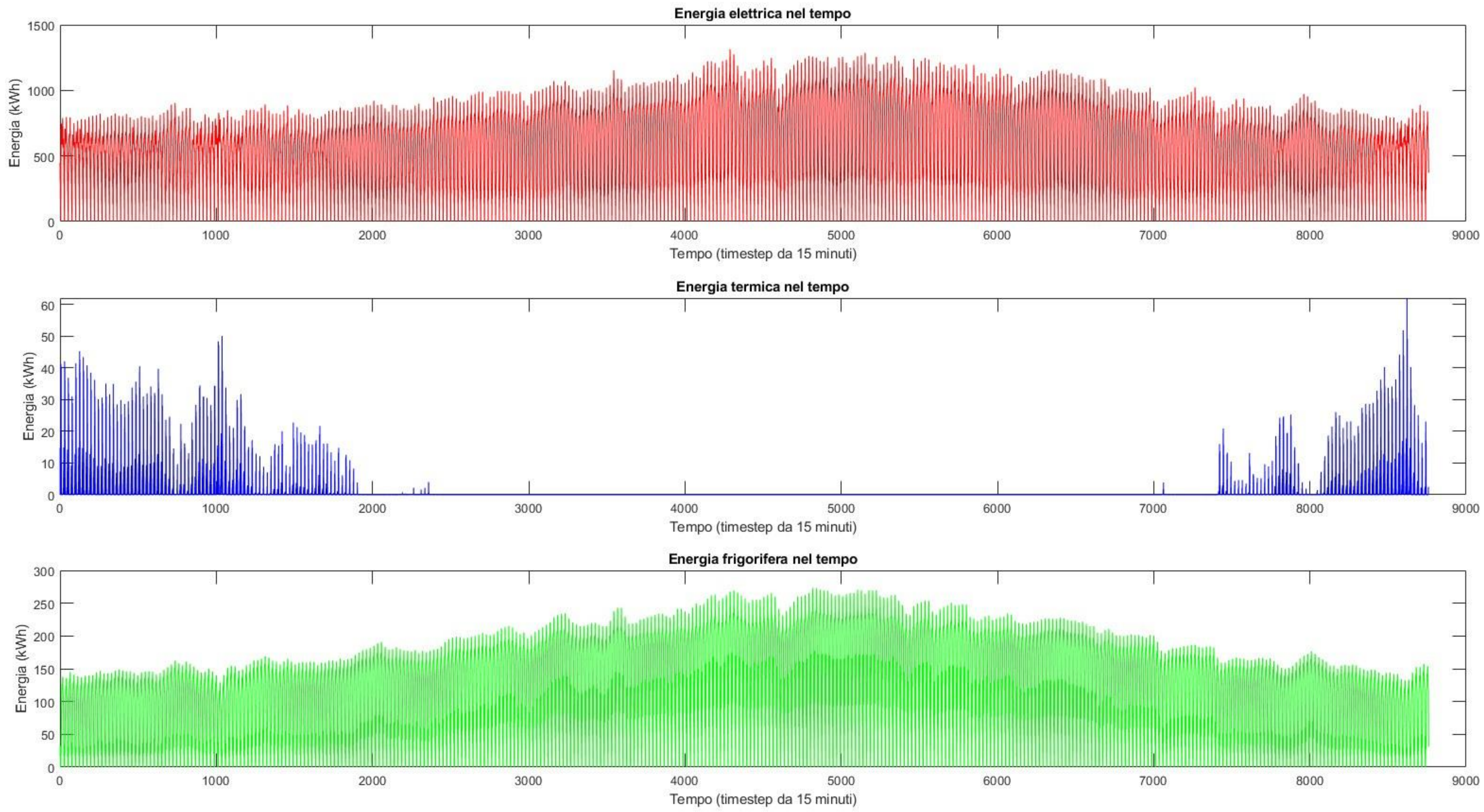


CASE 0: Results - Heating energy demand

Refreshment area with the highest heating energy demand;

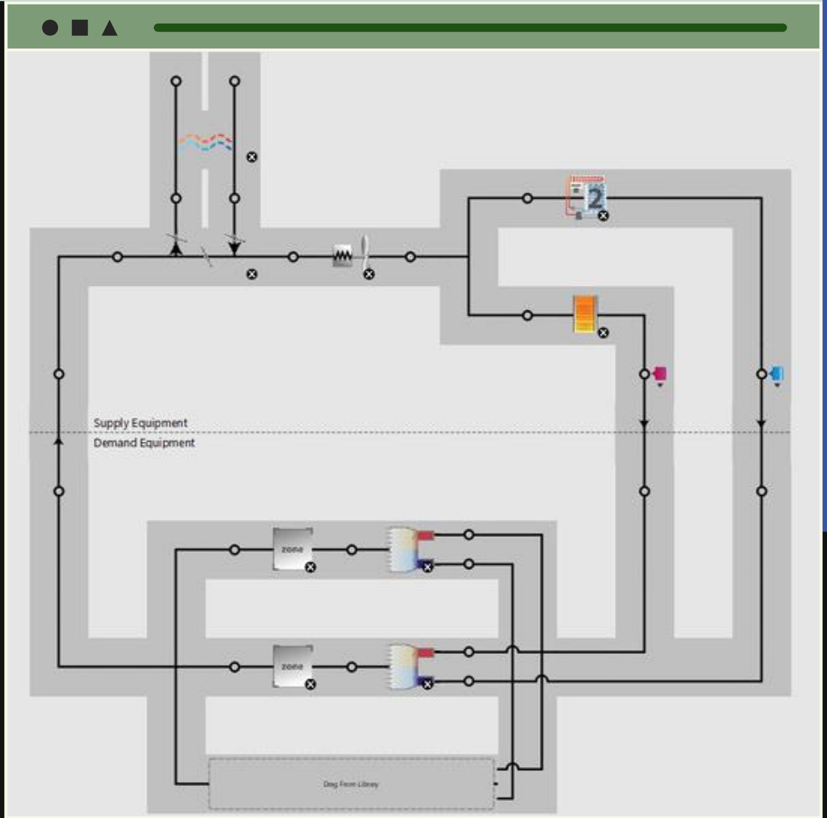


CASE 0: Results - total energy facility demand



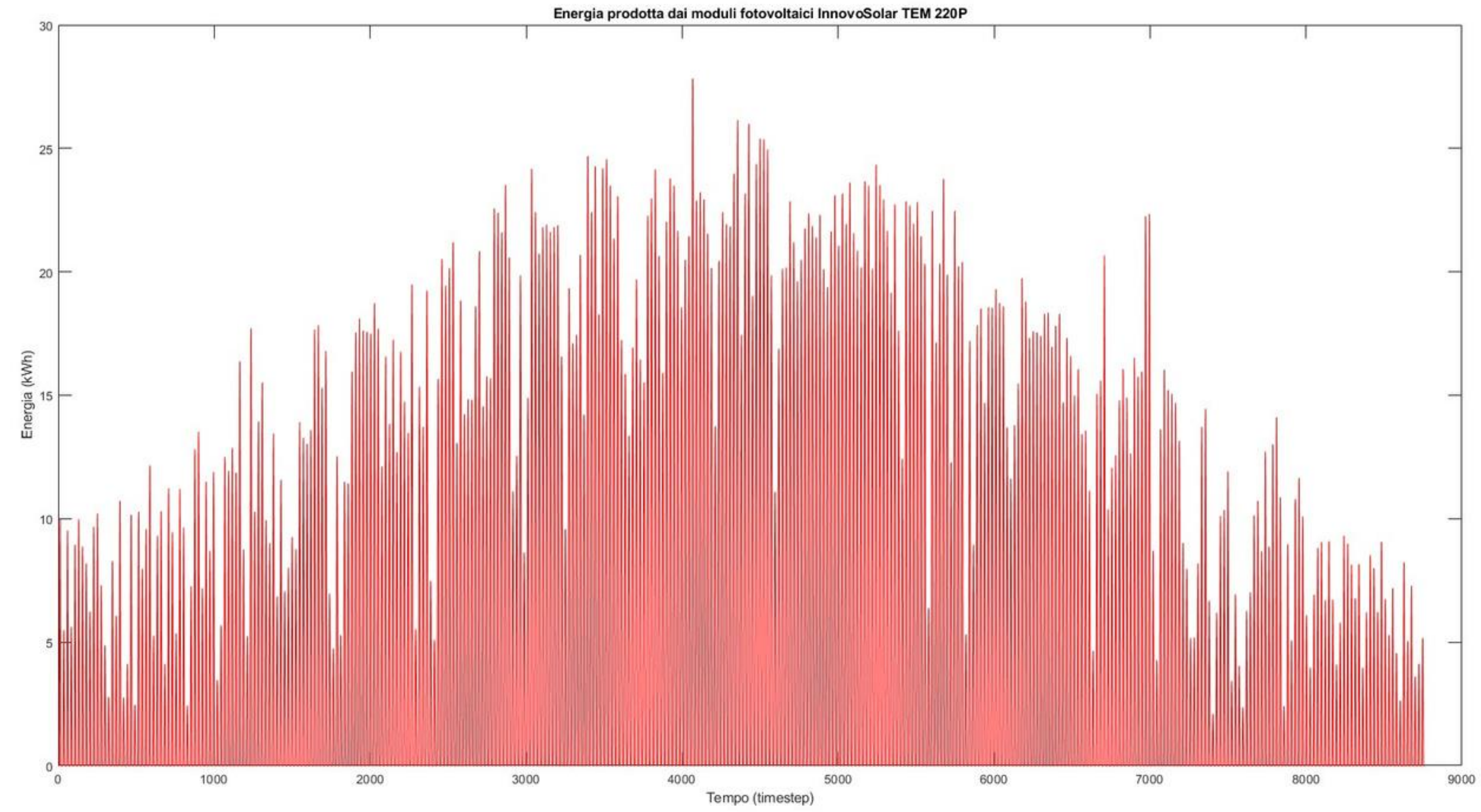
CASE 1:
HVAC VAV + PV

- Improving efficiency with variable air volume HVAC **single and dual duct** systems (**VAV**);
- Modeling of **pre-existing PV system**: 4526 panels with 4 inverters of 900 kW total;

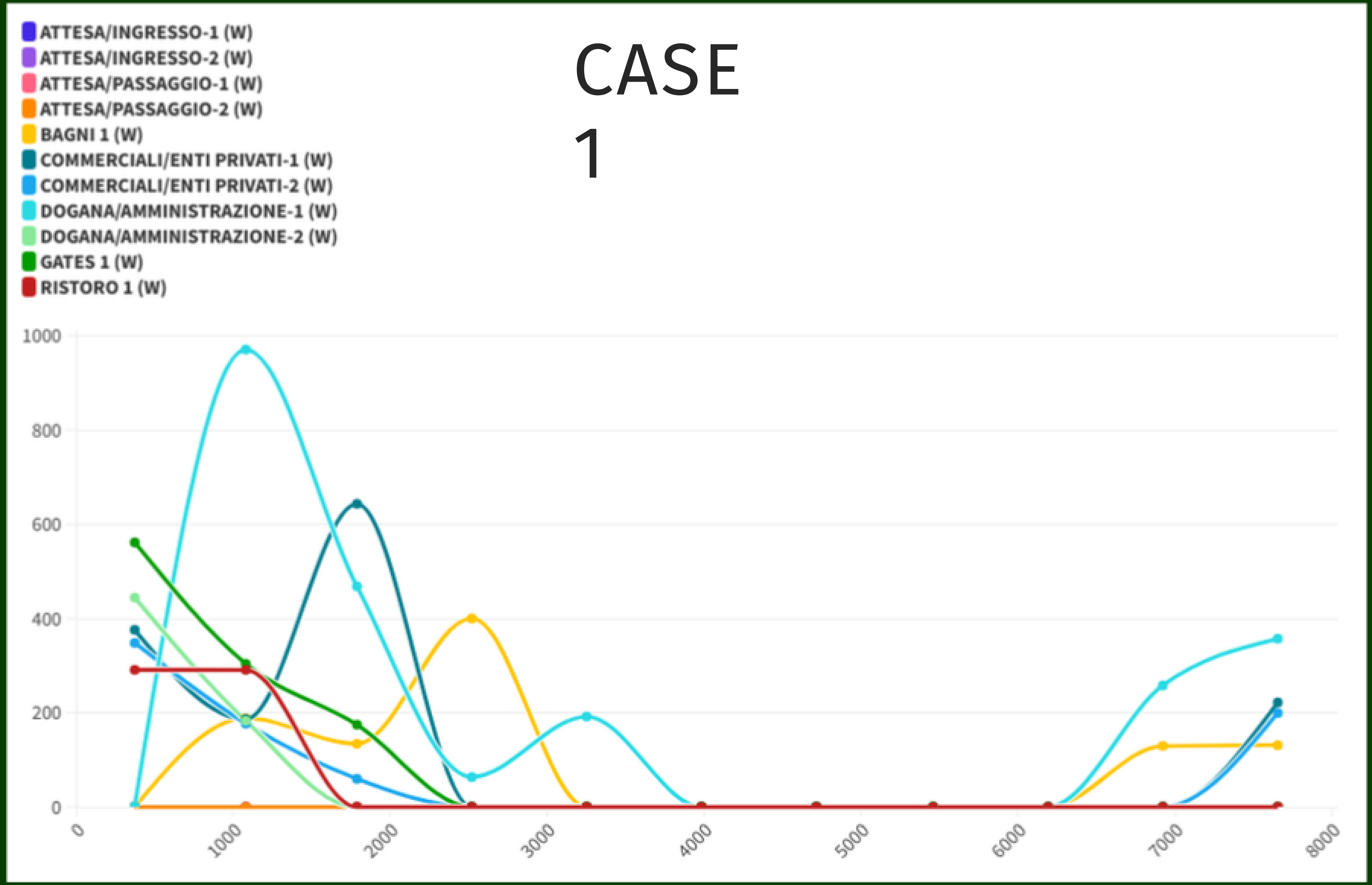


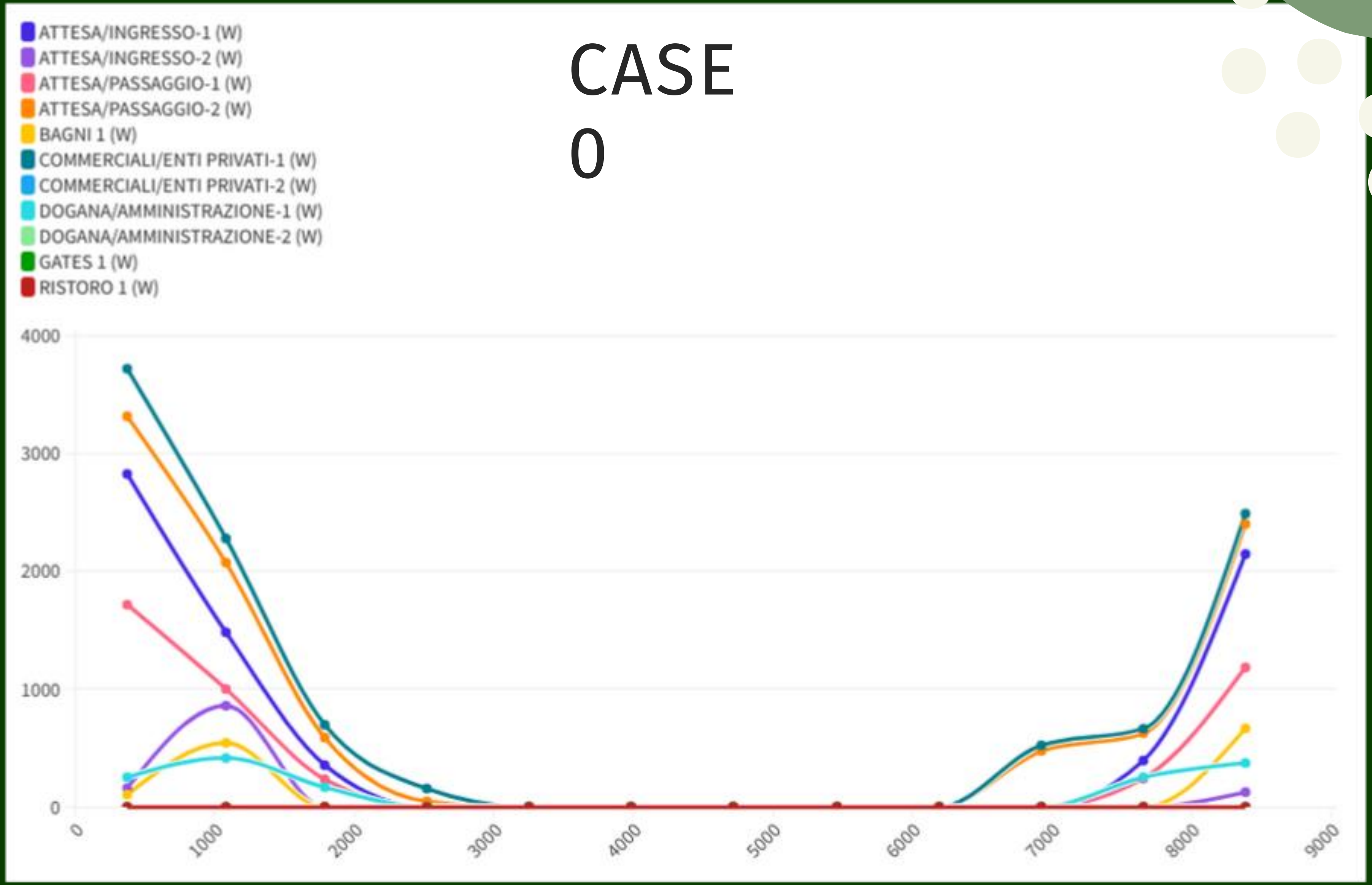
CASE 1: PV system modeling

- 4526 polycrystalline PV modules InnovoSolar TEM 220P installed on the hangar n°1 rooftop;
- Rated power of 220 W each;
- Area of 1.63 m2;
- Total energy produced is 27.82 kWh;
- 4 inverters with 900 kW maximum power;



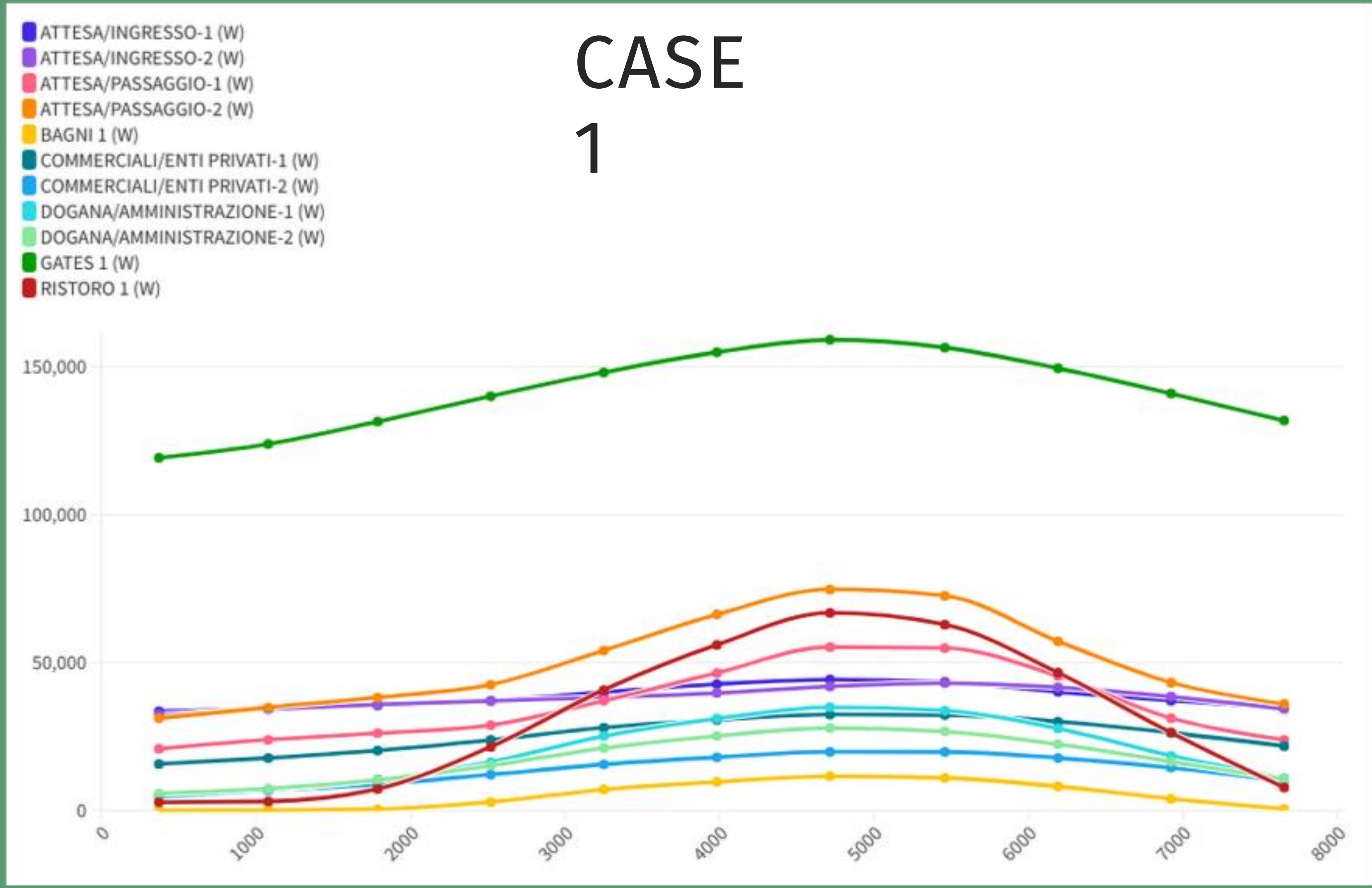
CASE 1: Results - Heating energy demand

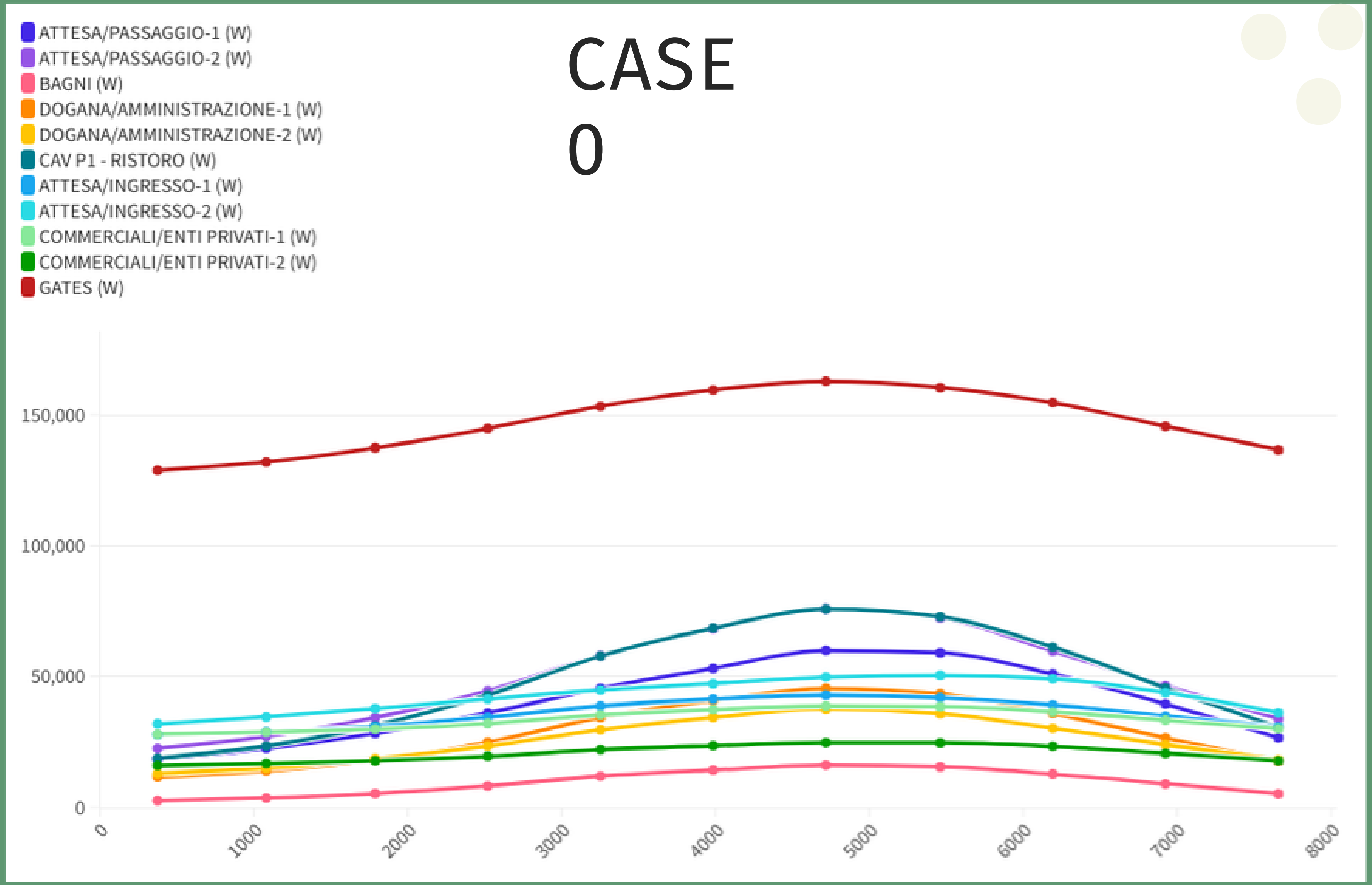




- **Comparison between case 0 and 1:** peak heating monthly demand lowered thanks to VAV system;
- Highest heating demand for customs and administration area;
- Single-speed heating coil with no need to reheat;

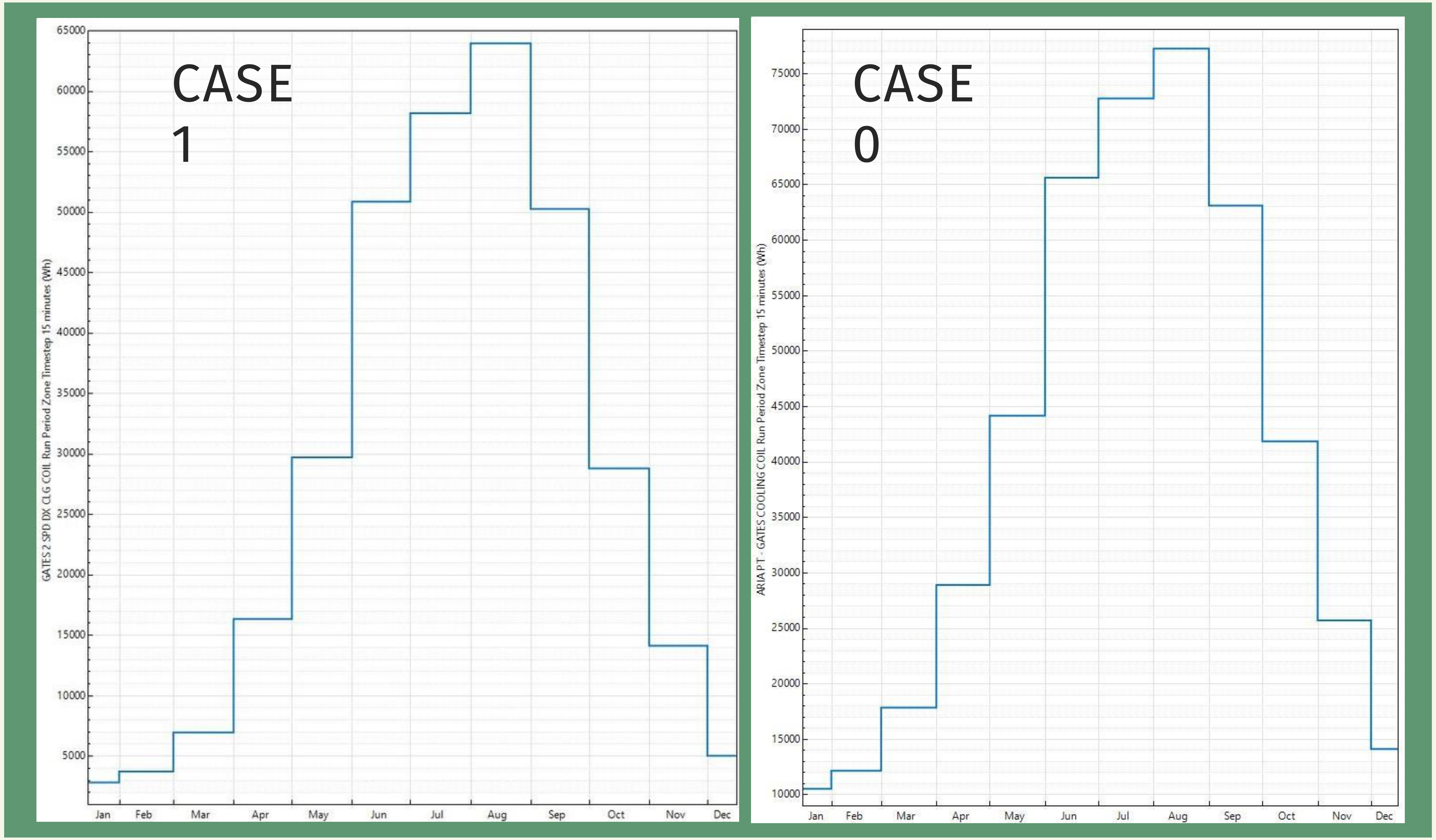
CASE 1: Results - Cooling energy demand





- **Comparison between case 0 and 1:** peak heating monthly demand slightly lowered thanks to VAV system;
- Highest heating demand once again for gates area;

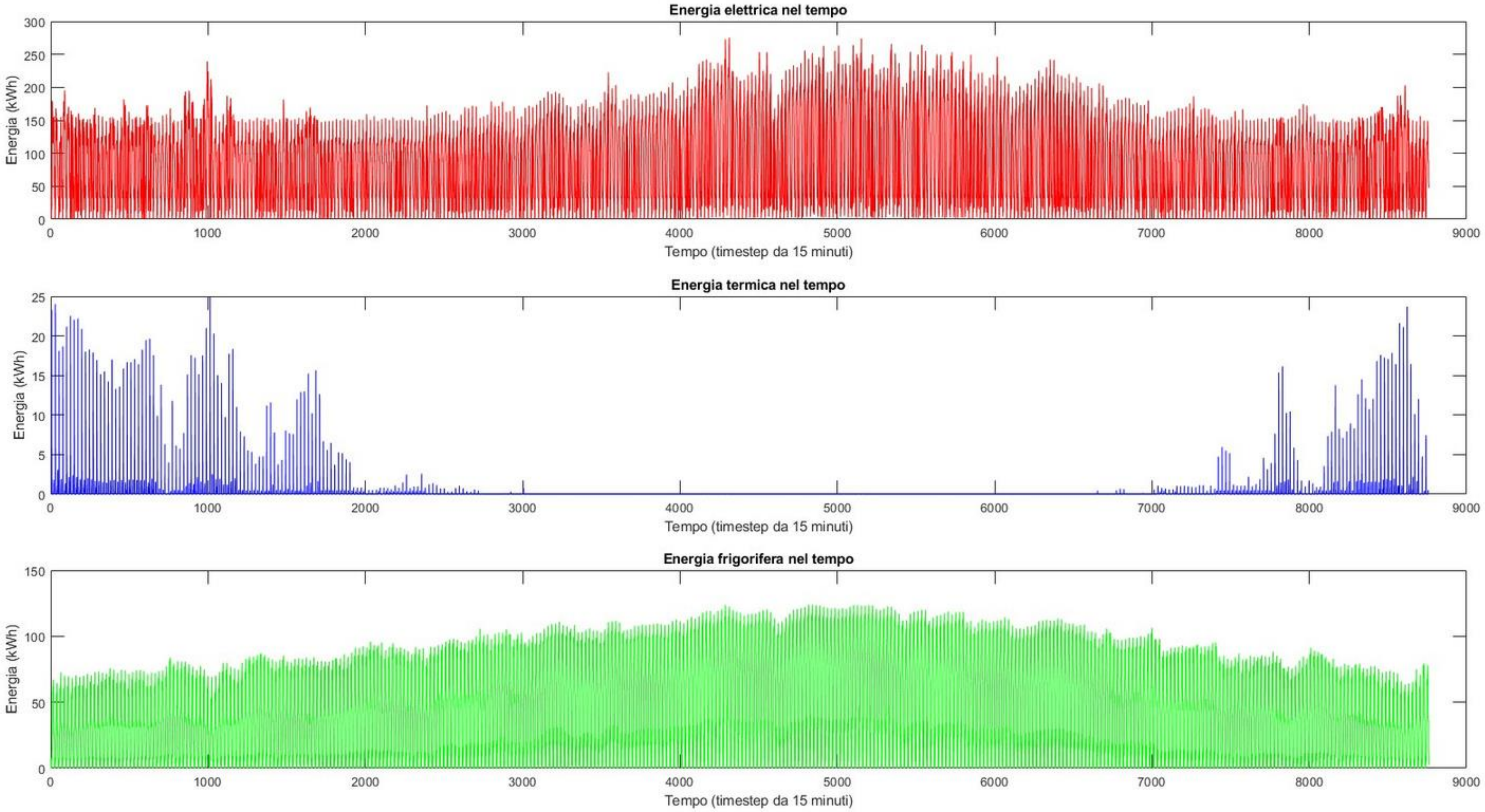
CASE 1: Results - Cooling energy demand
Focus on gates area



- Slight decrease of the peak cooling demand, by 10 kWh;
- Overall shifting of the highest monthly demand;
- VAV Two-speed cooling coil used in the simulation;

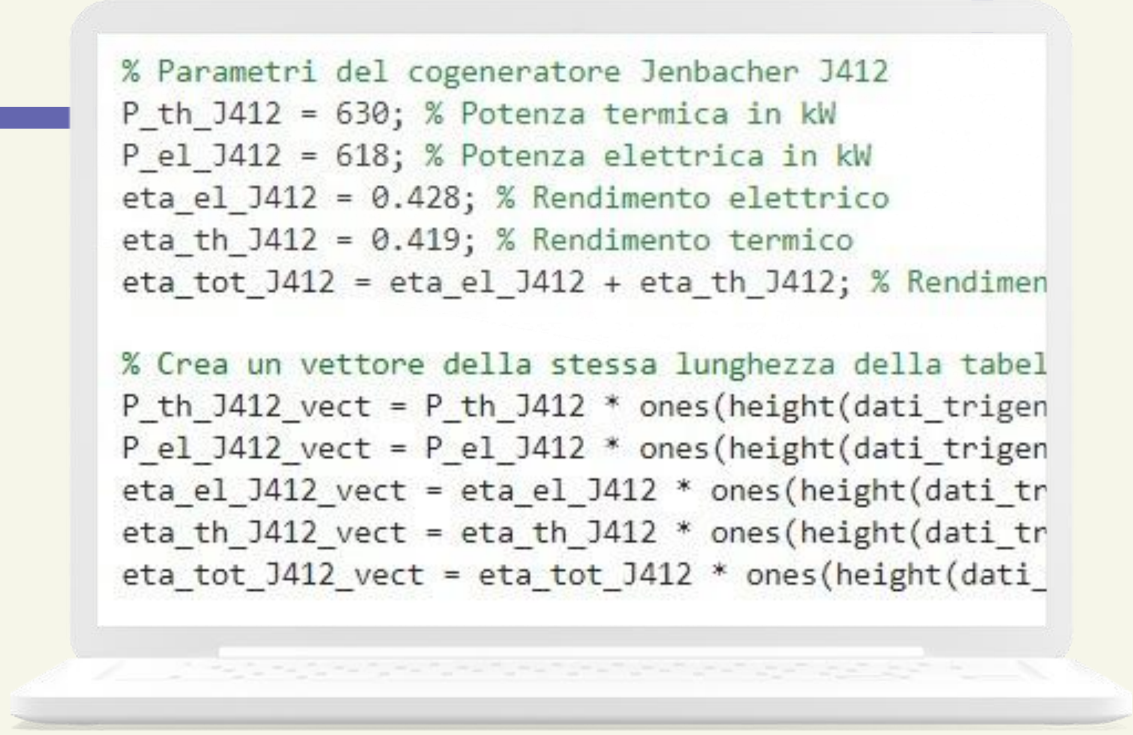
CASE 1: Results – Total energy demand

- Electric demand lowered from 1000 kWh mean to 200;
- Total heating and cooling demand almost halved;



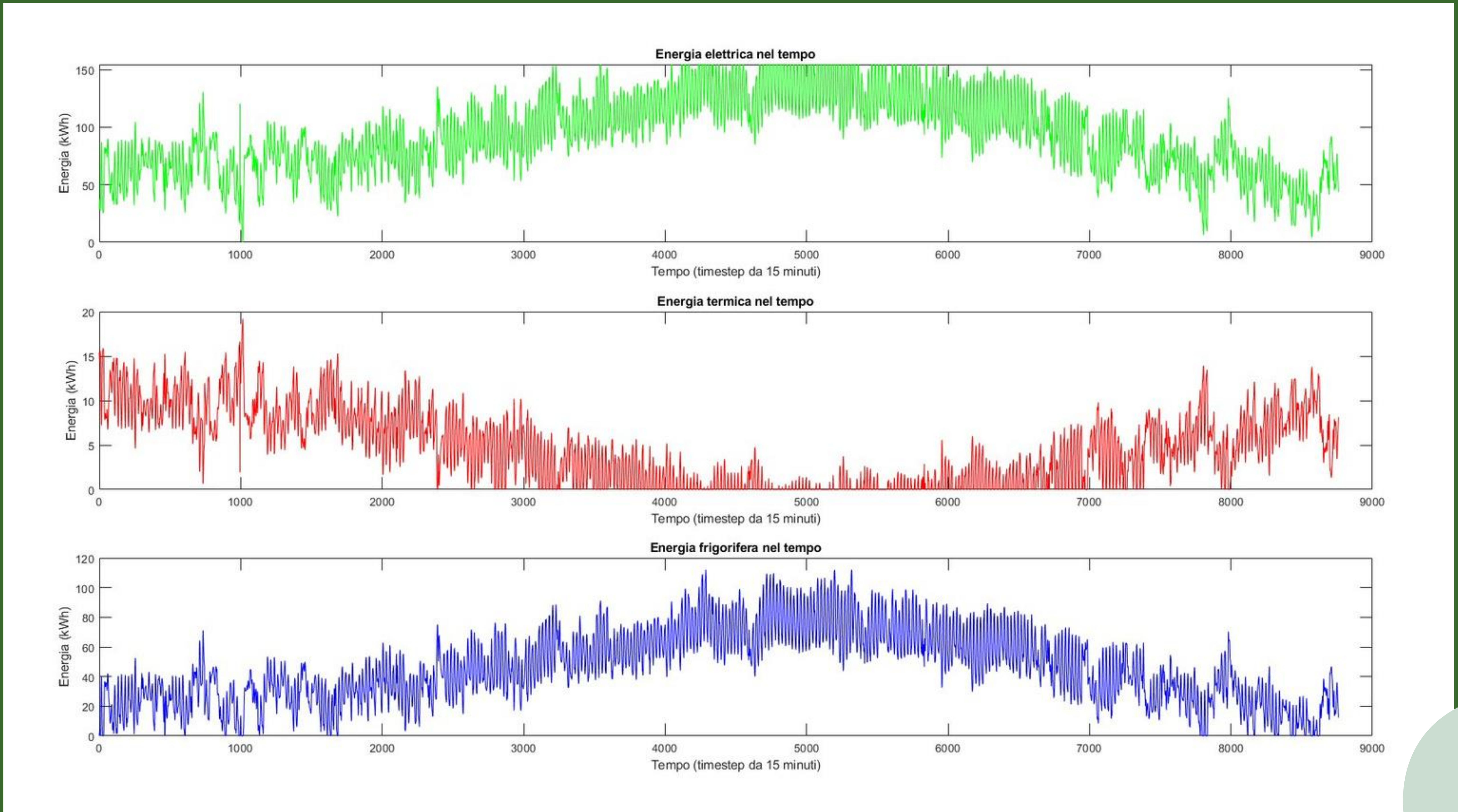
CASE 2: Trigeneration plant

- Modeling of a trigeneration plant using MATLAB and predictive models;
- Jenbacher J412 cogenerator with 630 kW rated thermal power and 618 kW rated electrical power;
- Running with natural gas;
- Thermal efficiency of 41.9% and electrical of 42.8%;

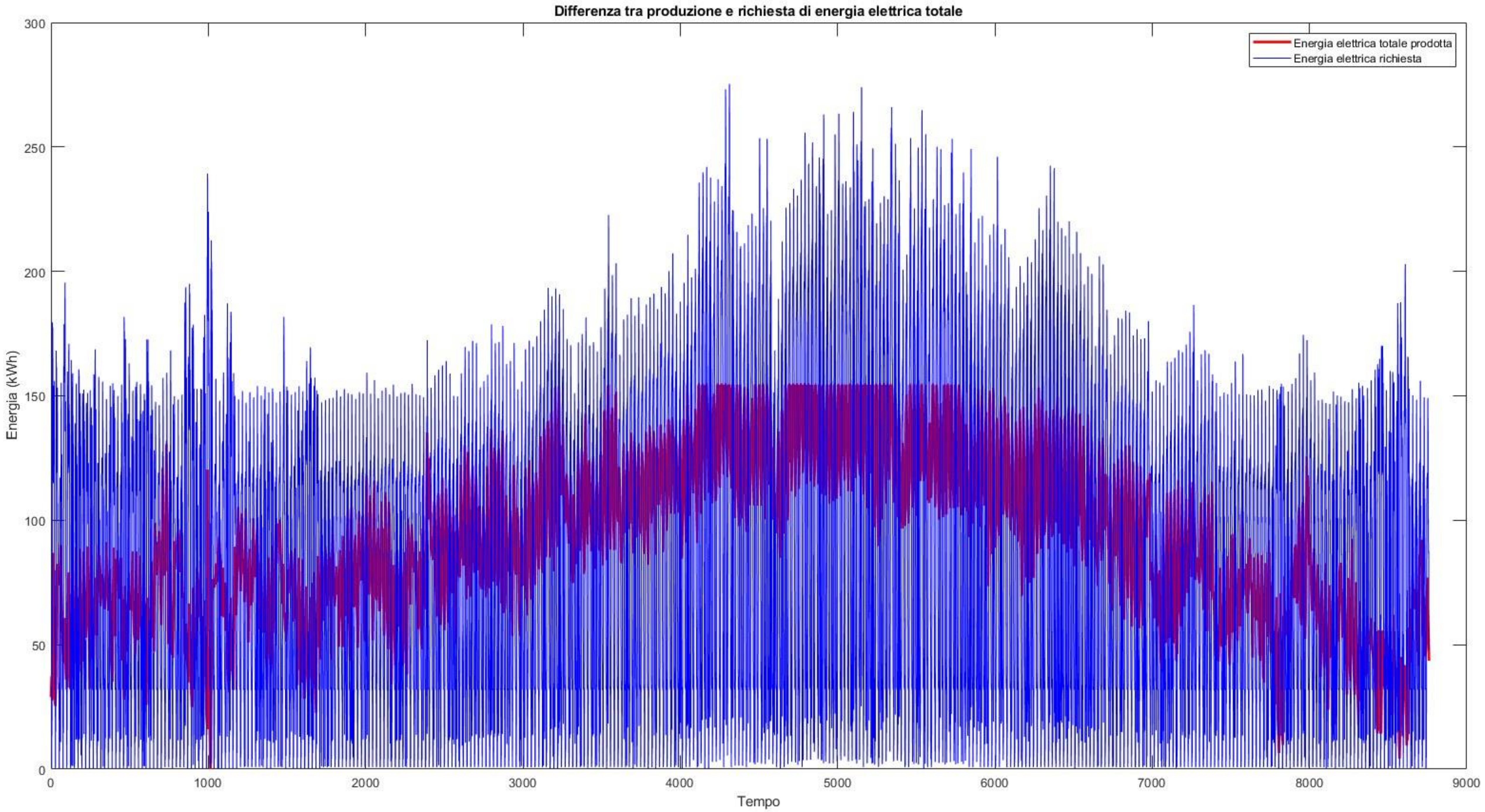


CASE 2: Results – Total energy produced by the cogenerator

- Estimation of the energy produced through the use of a predictive model for each timestep;
- Outdoor temperature used as an independent variable to create a polynomial relationship;
- Limitation of the power produced to the rated power of the cogenerator;



CASE 2: Results – Comparison between energy produced and energy demand



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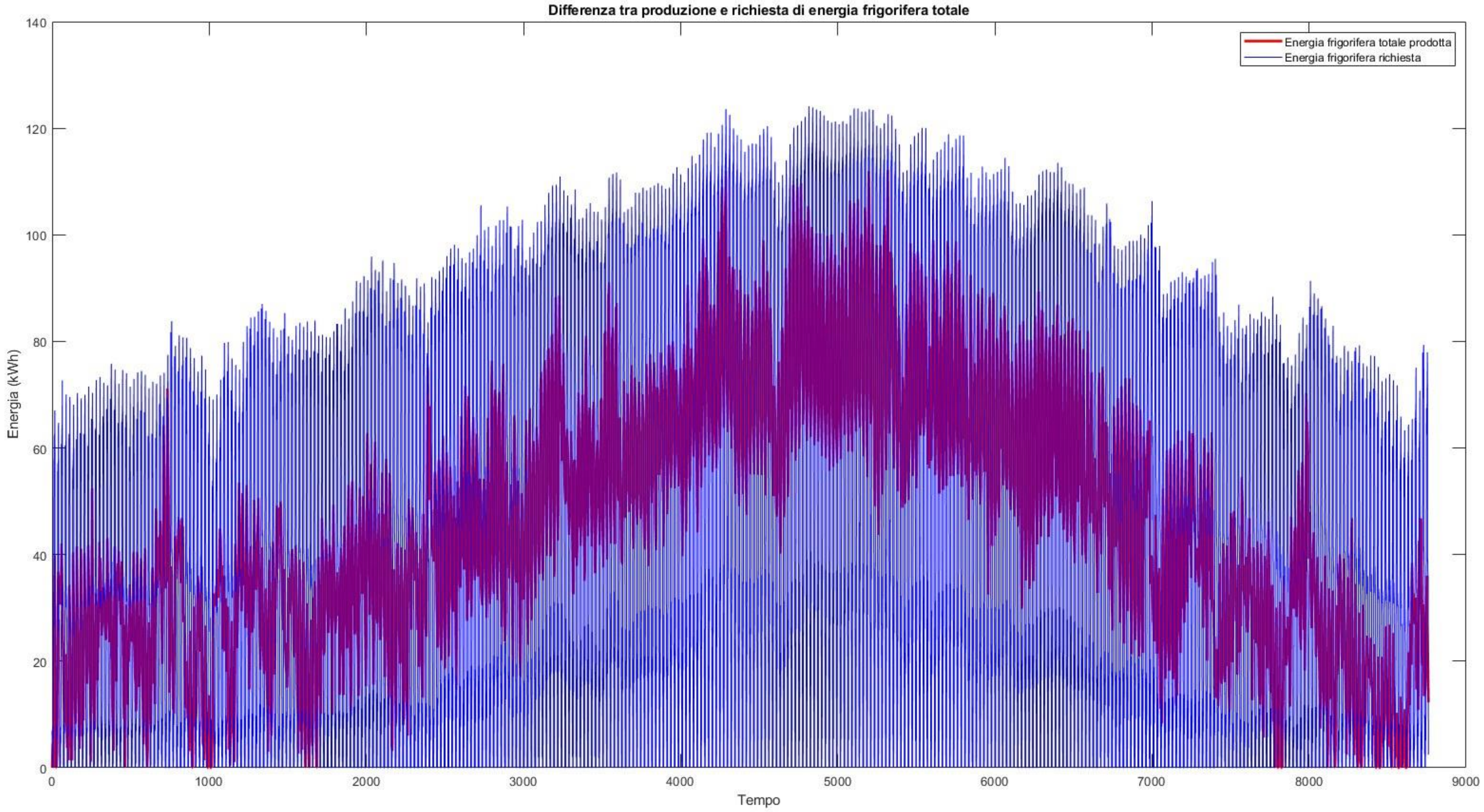

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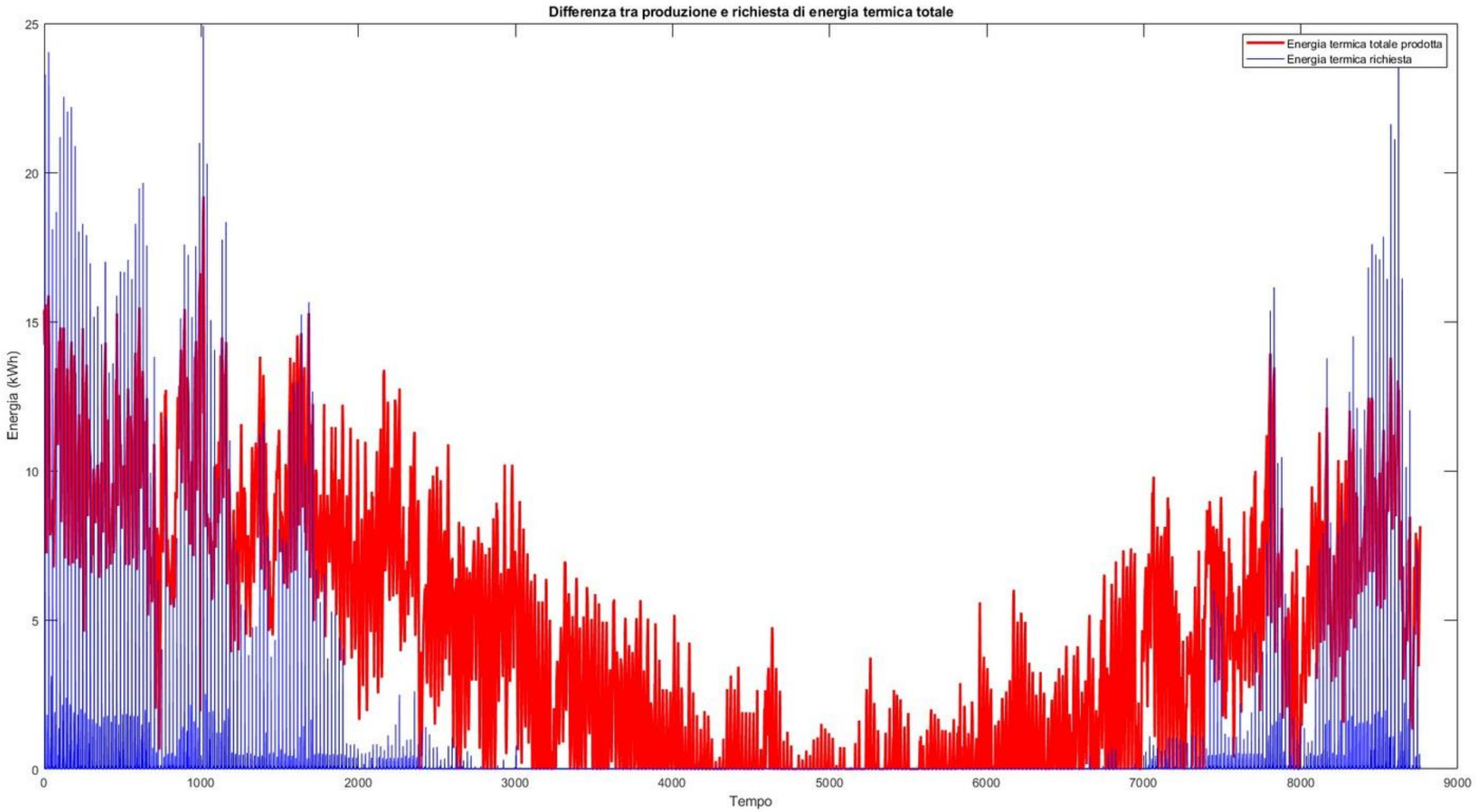


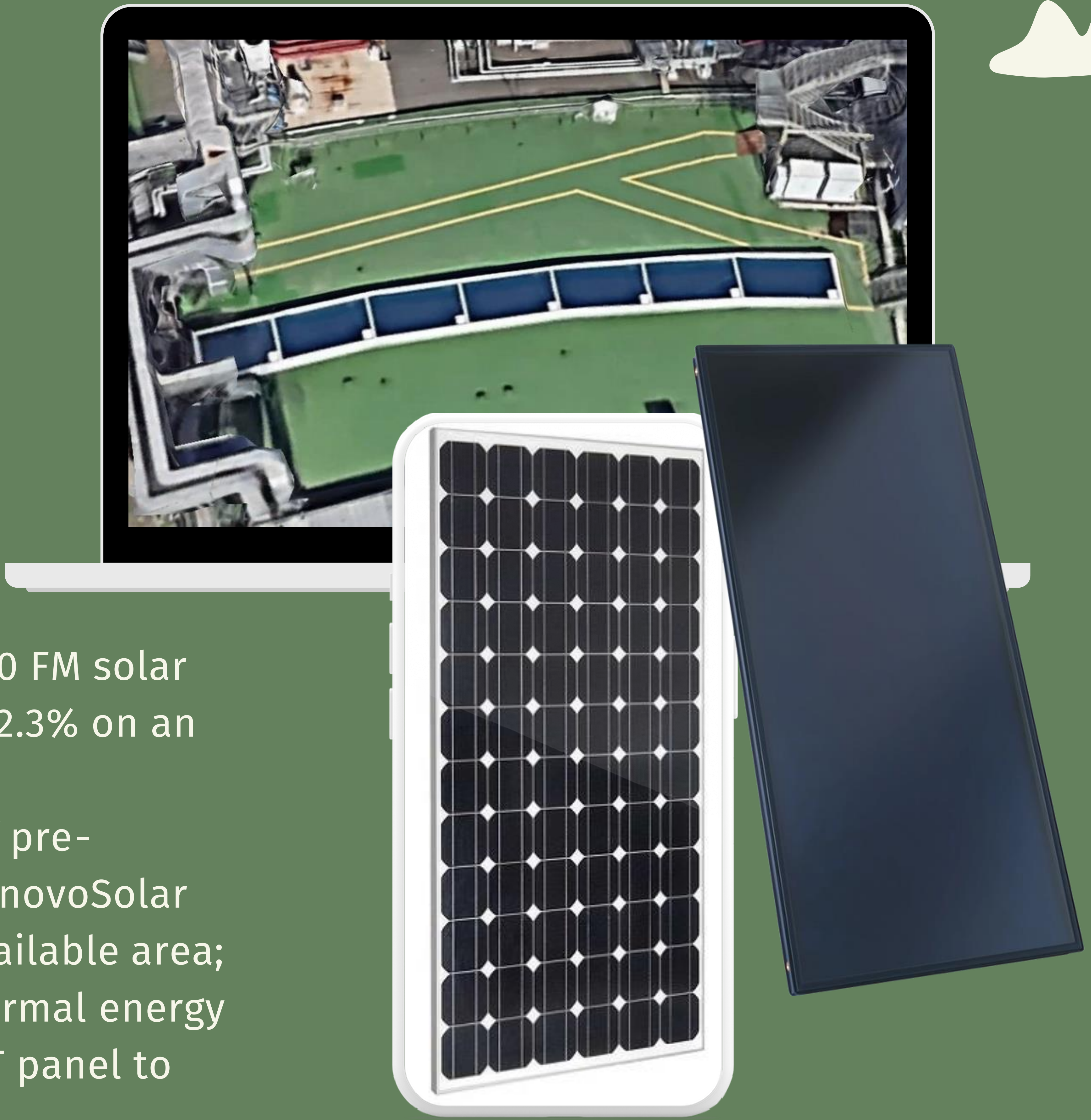
CASE 2: Results – Comparison between energy produced and energy demand

- Despite the high power of the cogenerator, the total energy demand cannot be completely satisfied;
- Increasing the power of the cogenerator is not worthwhile, both from an economic point of view and from that of space availability;
- Need for electrical, heating and cooling energy integration;

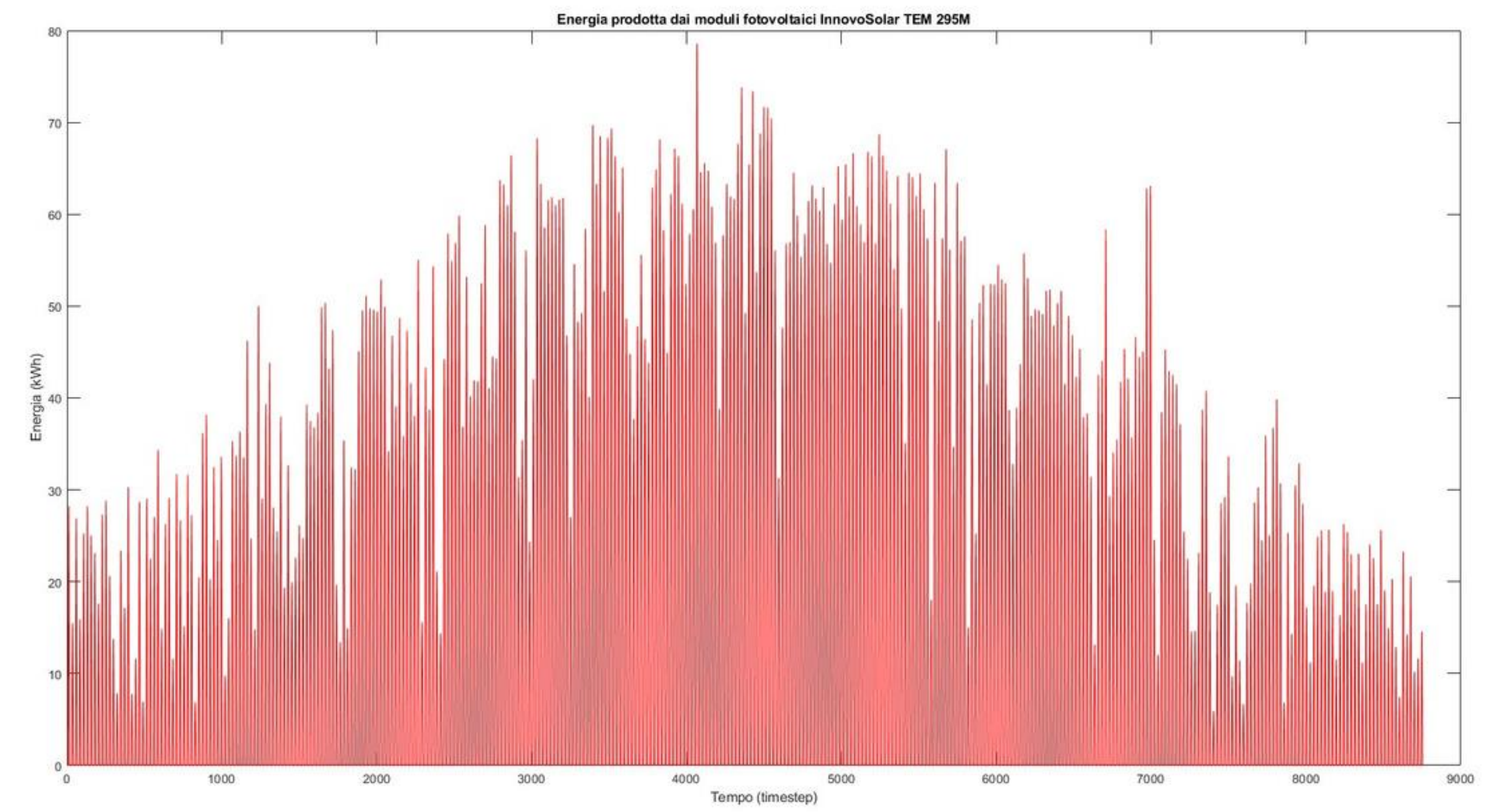
CASE 3:

Trigeneration plant with PV and PT panels integration

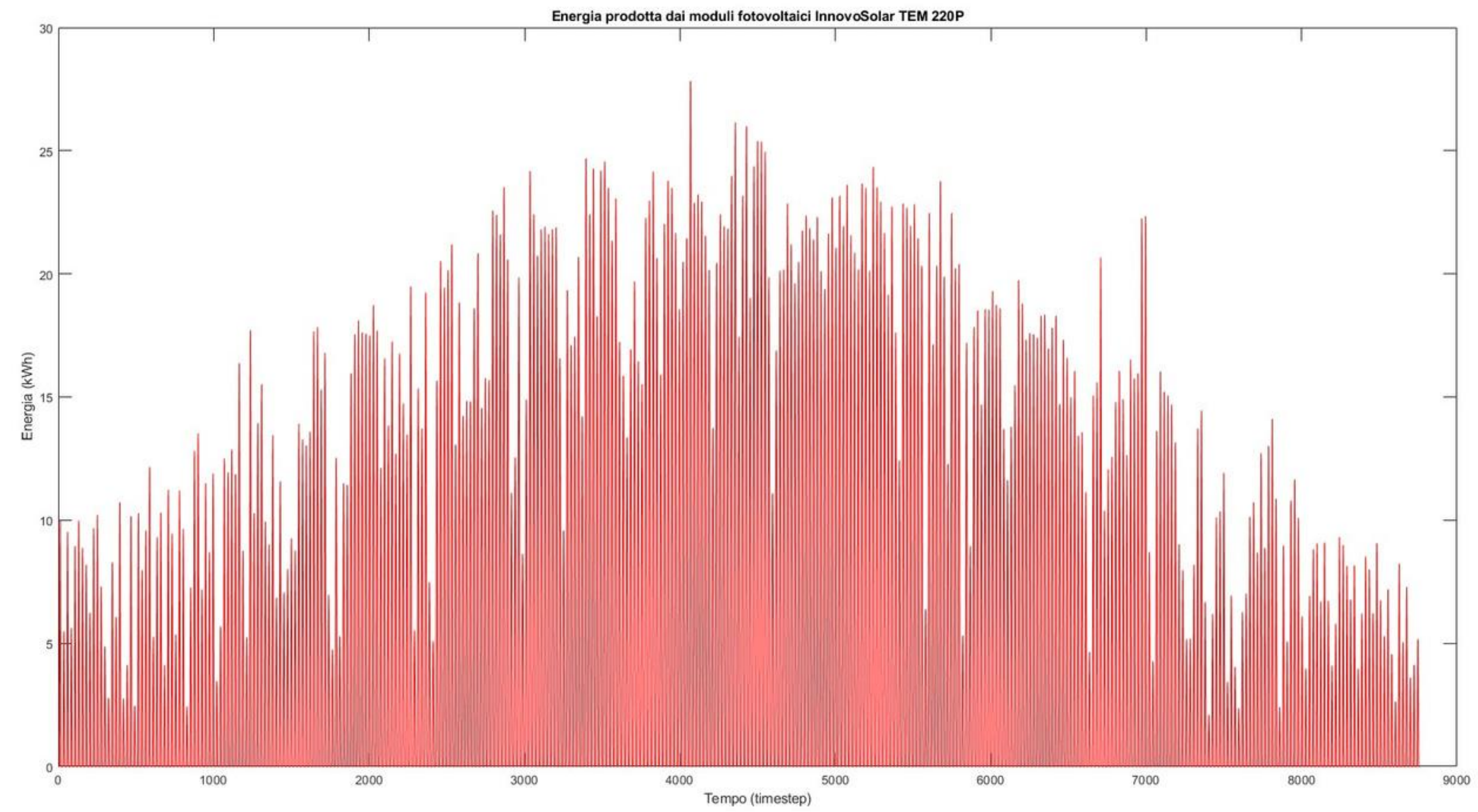
- thermal energy integration with Vitosol 200 FM solar thermal panels with optical efficiency of 82.3% on an available area of approximately 530 m2;
- electricity integration with replacement of pre-existing PV panels with monocrystalline InnovoSolar TEM 295M of 295 W each, with the same available area;
- Cooling energy integration with excess thermal energy produced in the summer months by the PT panel to power the cogenerator absorber;



CASE 3: Trigeneration plant with PV and PT panels integration



InnovoSolar TEM 295M

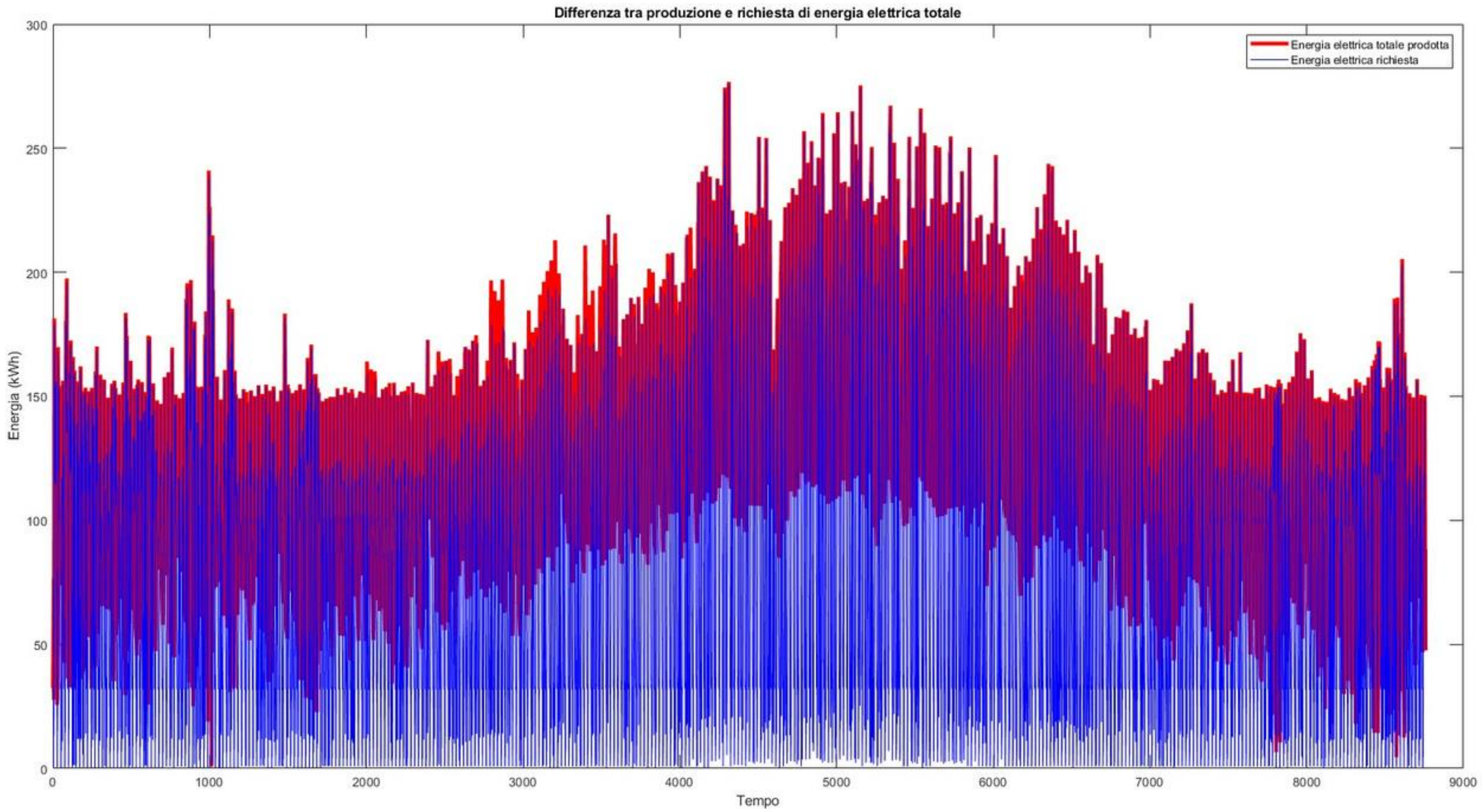


InnovoSolar TEM 220P

Comparison between the thermal energy produced by the old and new PV modules

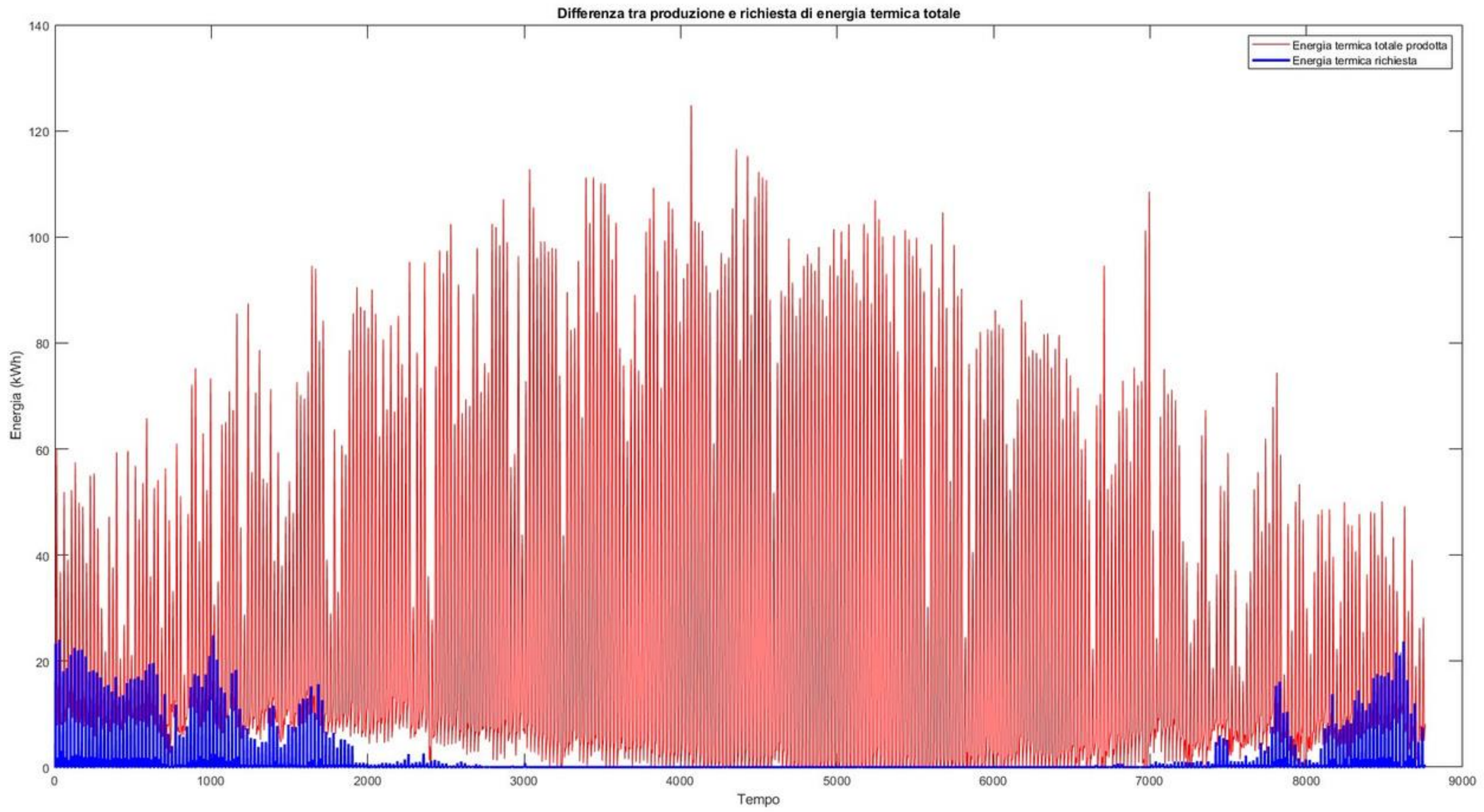
CASE 3: Results - Electric energy production

- Comparison between electric energy produced by the entire system and energy needs;
- Part of the electricity demand is covered by the cogenerator and the PV system;
- The remaining part is integrated by the electricity grid via a grid-tie inverter with 750 kW nominal power;



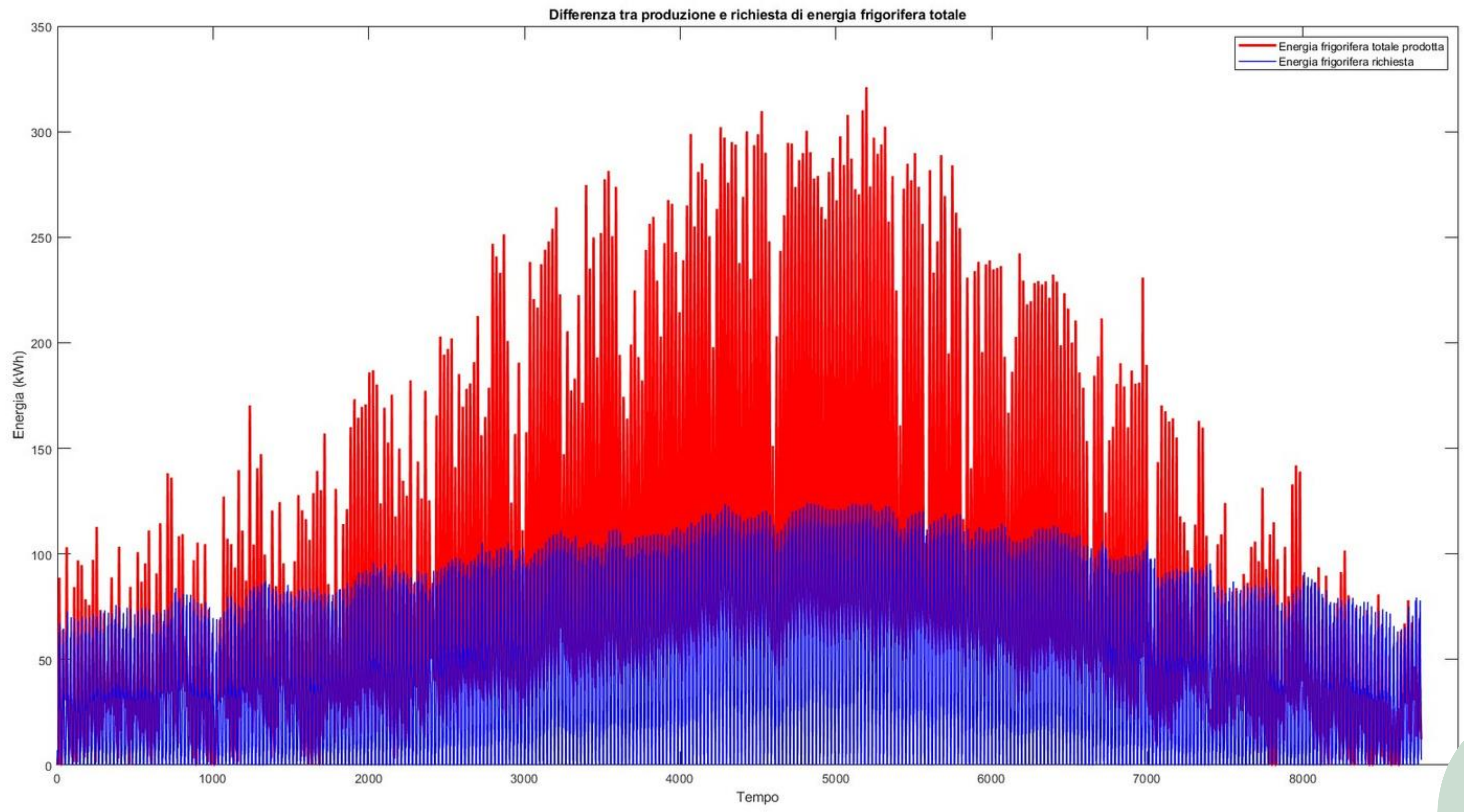
CASE 3: Results - Thermal energy production

- Comparison between thermal energy produced by the entire system and energy needs;
- Thermal solar panels that directly integrate the cogenerator when necessary;
- Total coverage and even excess thermal energy;
- Possibility of using excess thermal energy to power the absorber and produce cooling energy;



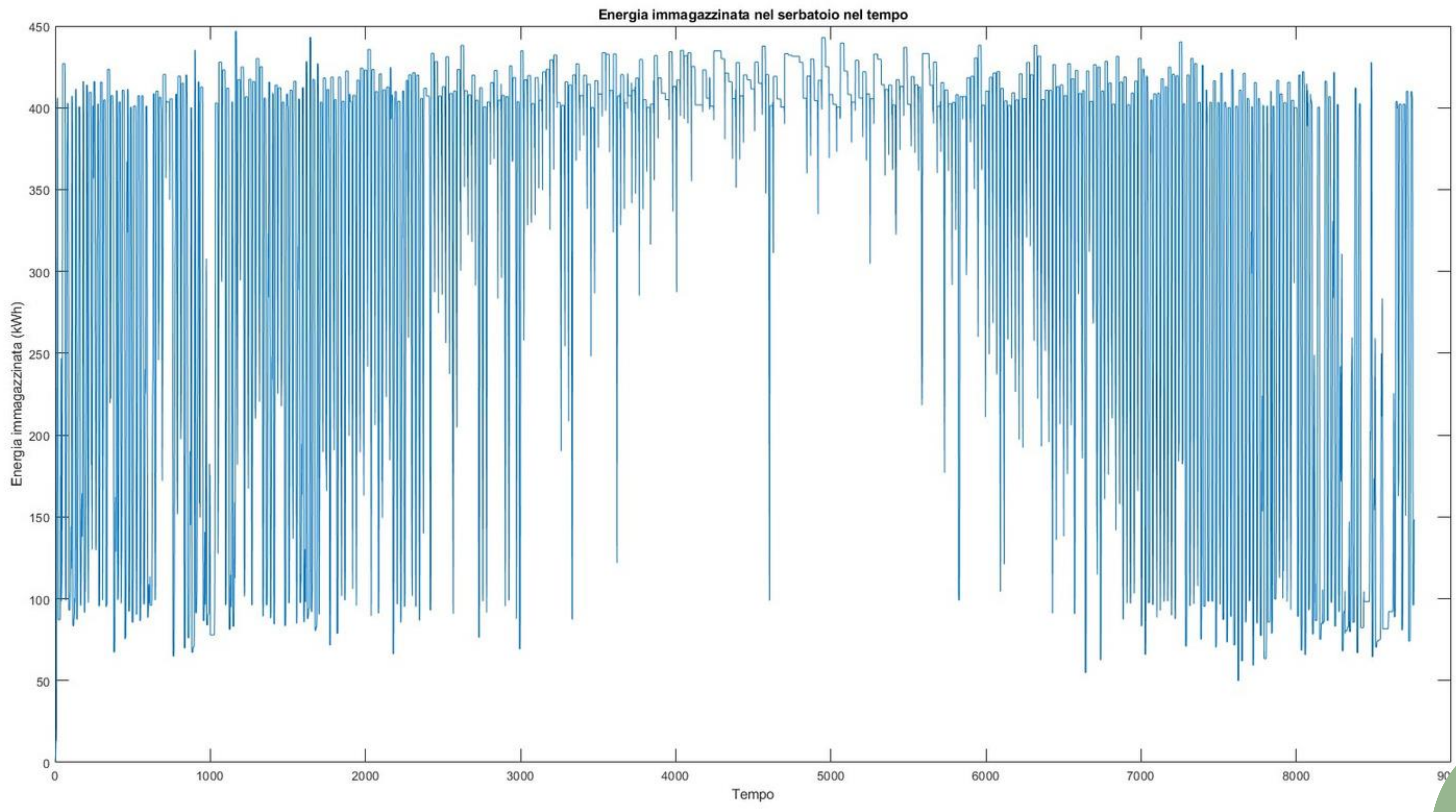
CASE 3: Results - Cooling energy production

- Comparison between cooling energy produced by the entire system and energy needs;
- A large part of the cooling demand is covered by excess heat from solar thermal panels;



CASE 3: Results - Cooling energy production

- Excess cooling energy could be stored for use in case of need;
- this opposite is an **estimate** of the energy stored in the tank over time;
- For example, we may want to fill the tank only when cooling energy production is expected to be less than demand in the near future. Similarly, we may want to empty the tank only when it is expected that cooling energy production will not be sufficient to meet the cooling demand;



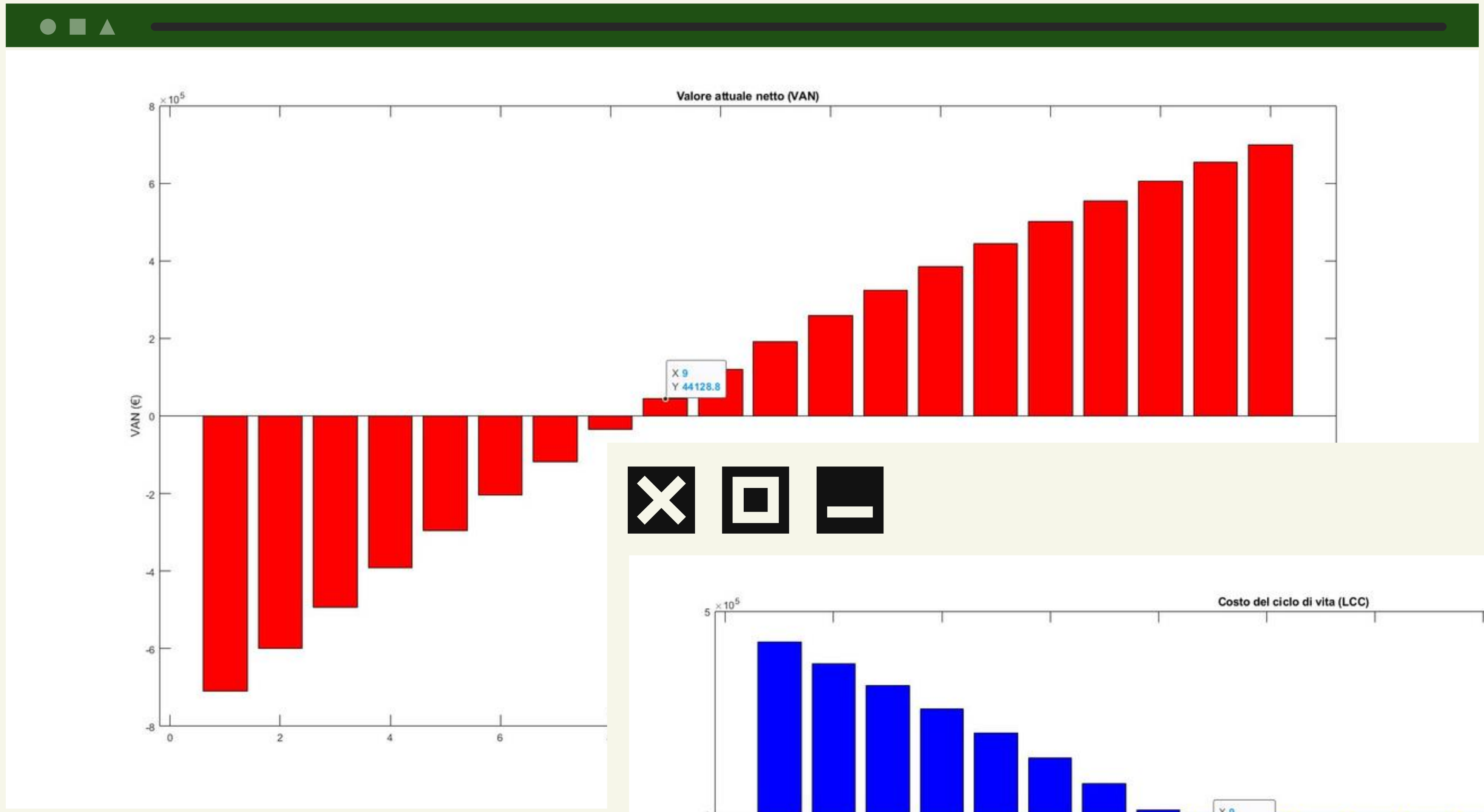
ECONOMIC ANALYSIS:

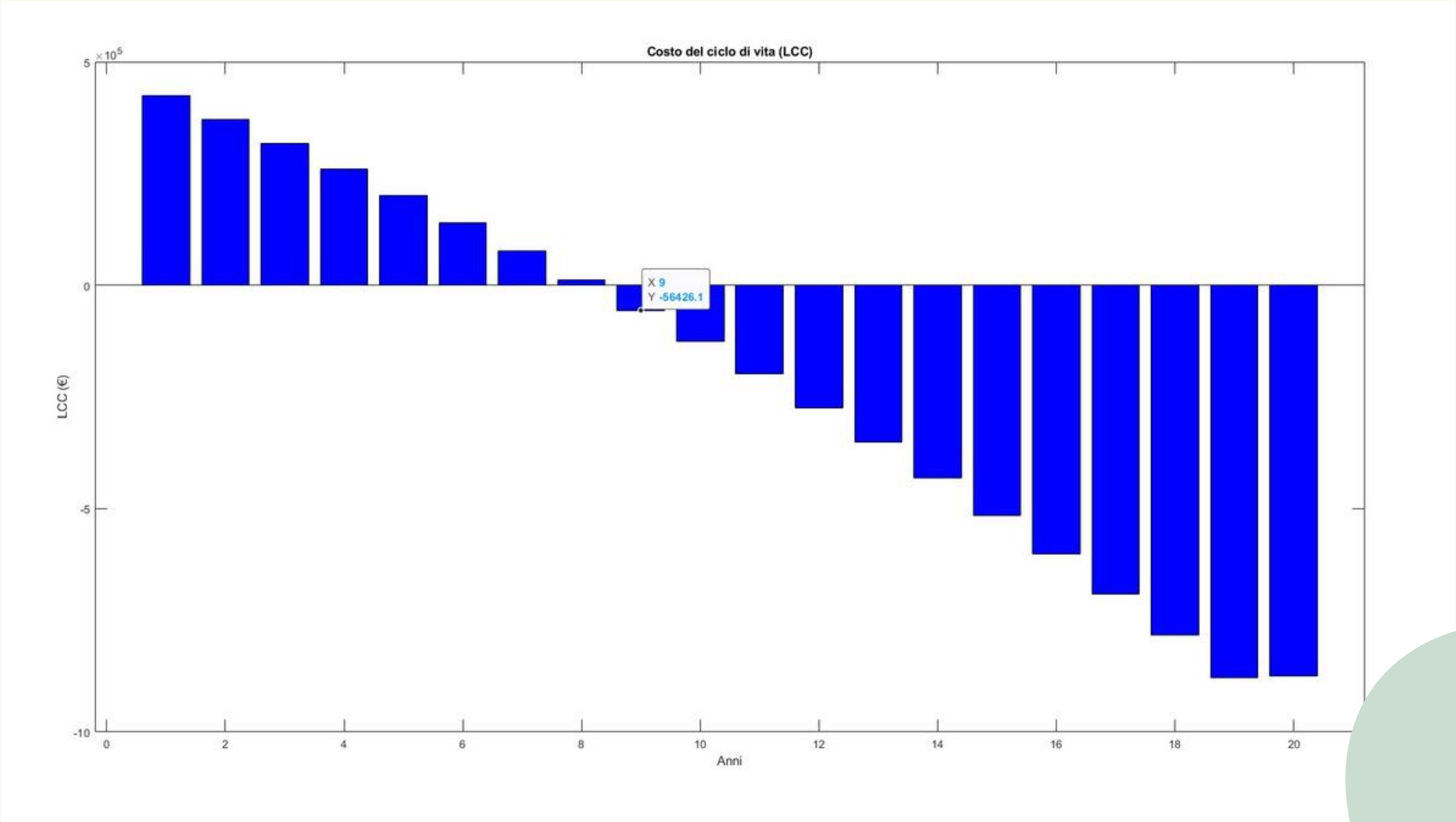
General parameters

- Discount rate of 5%;
- Natural gas cost of 0.0247 €/kWh;
- Cost of electricity of 0.11833 €/kWh;
- Life span of 20 years;
- Annual costs including administration, maintenance, depreciation, insurance and disposal;
- Disposal costs discounted to present value;
- Tax deduction: 65% rate for energy requalification interventions, including trigeneration systems;

CASE 0: RESULTS – ECONOMIC ANALYSIS

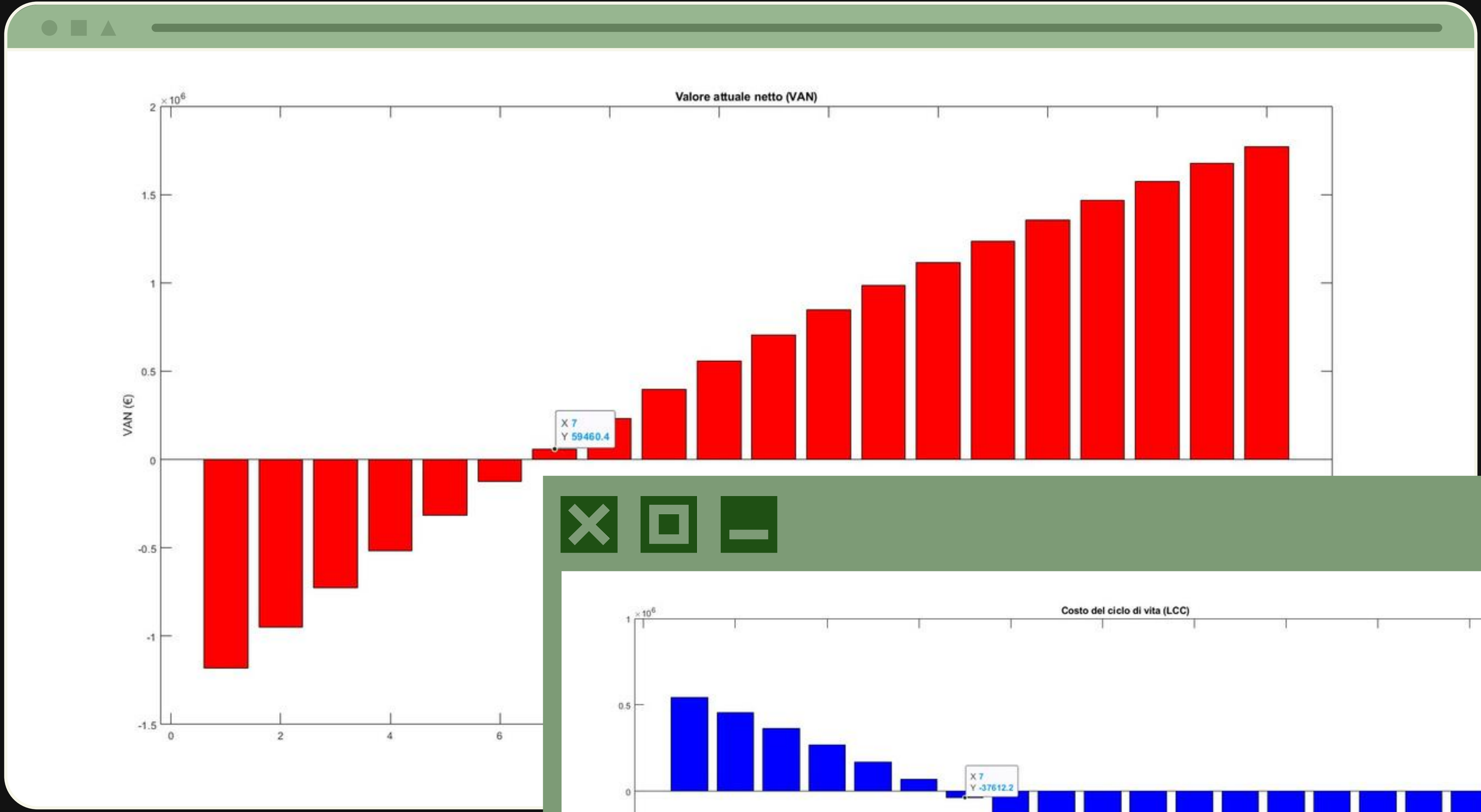
- Initial installation cost of approximately €800'000;
- Positive cash flow obtained after 9 years;
- SPB of 6 years;
- NPV mean of €96736;
- LCC mean of €199050;

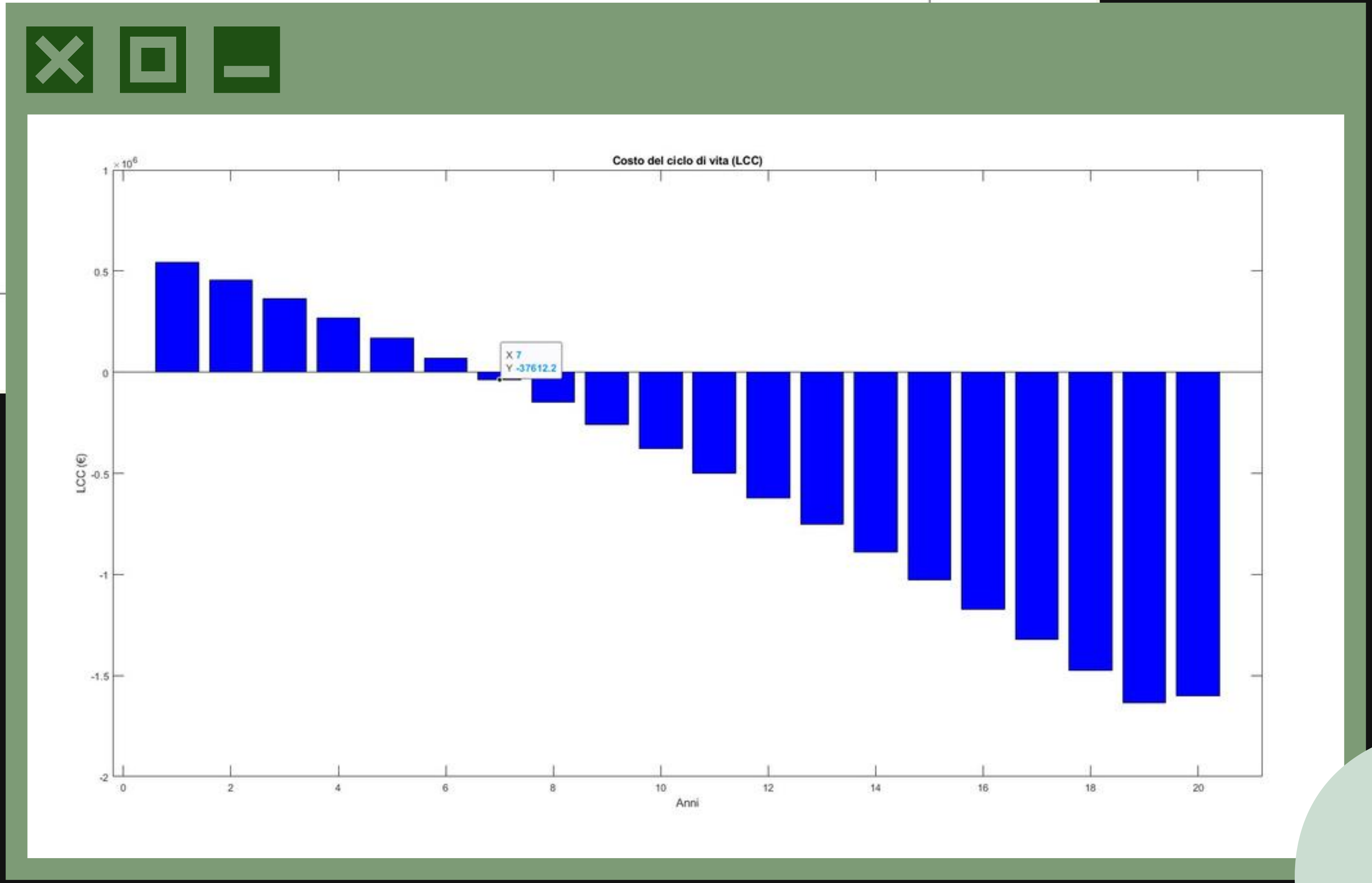




CASE 1: RESULTS – ECONOMIC ANALYSIS

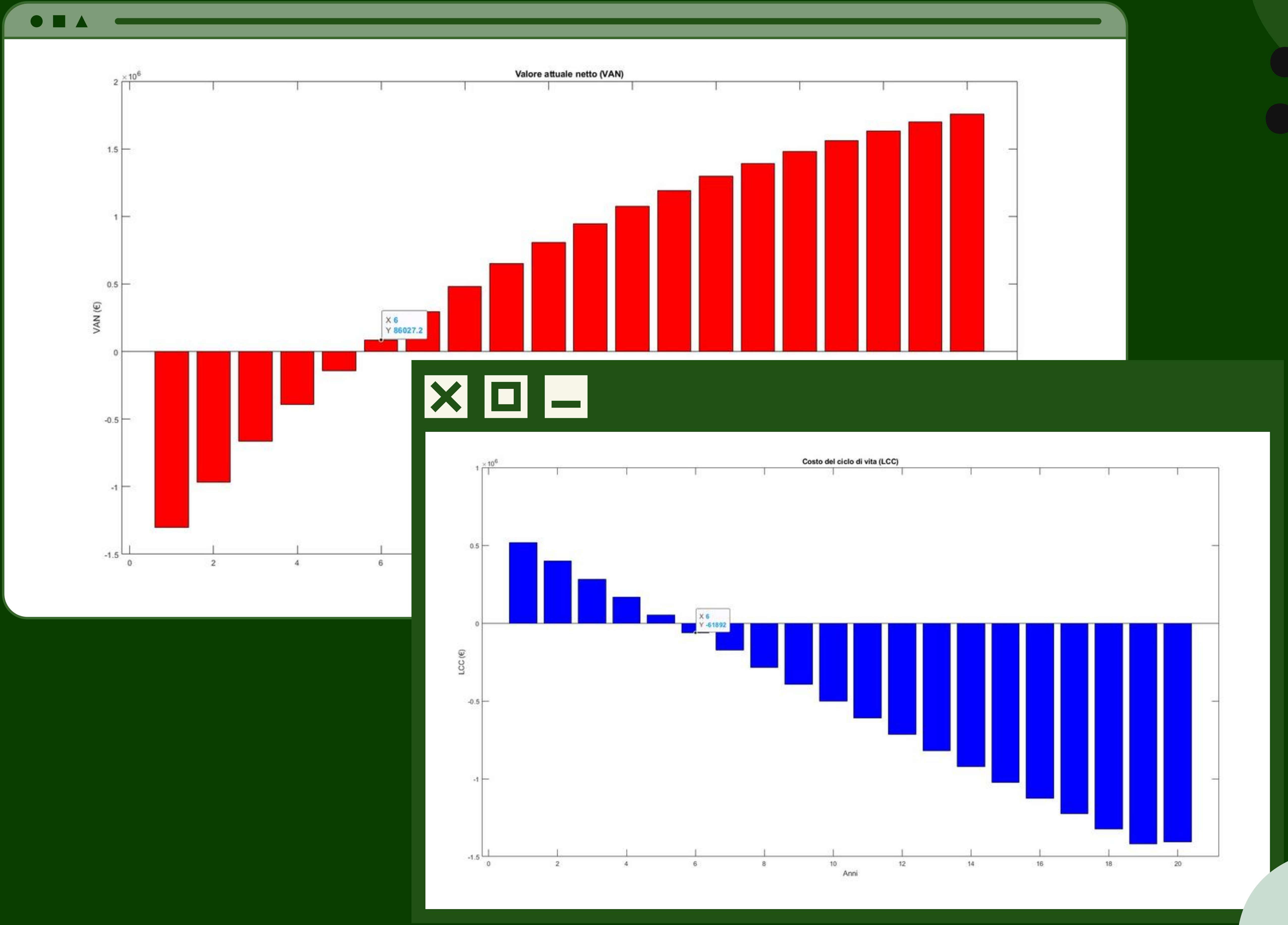
- Initial installation cost of approximately <u>€1'000'000;</u>
- Positive cash flow obtained after <u>7 years;</u>
- SPB of <u>5 years;</u>
- NPV mean of <u>€508'540</u>;
- LCC mean of <u>€497'330</u>;





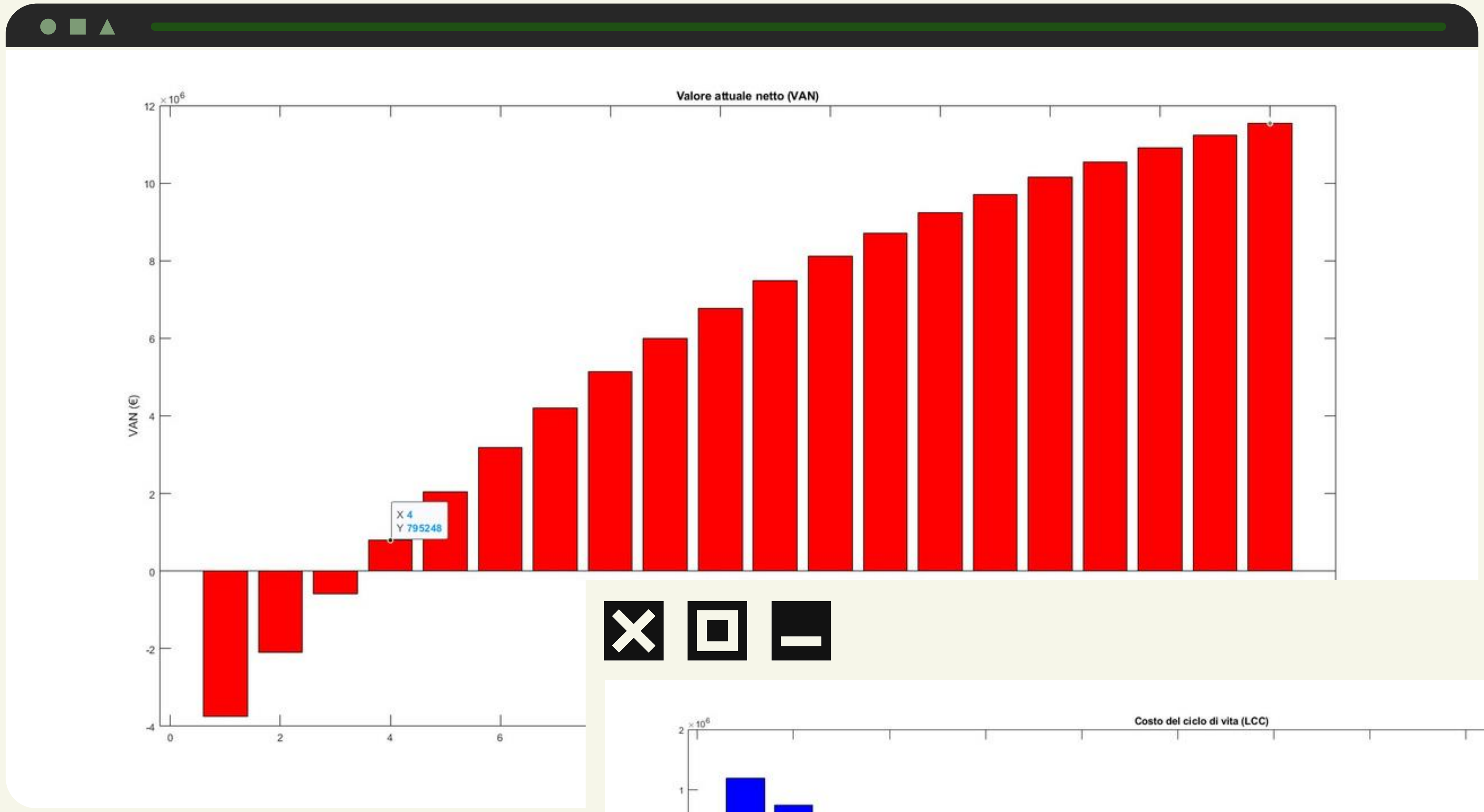
CASE 2: RESULTS – ECONOMIC ANALYSIS

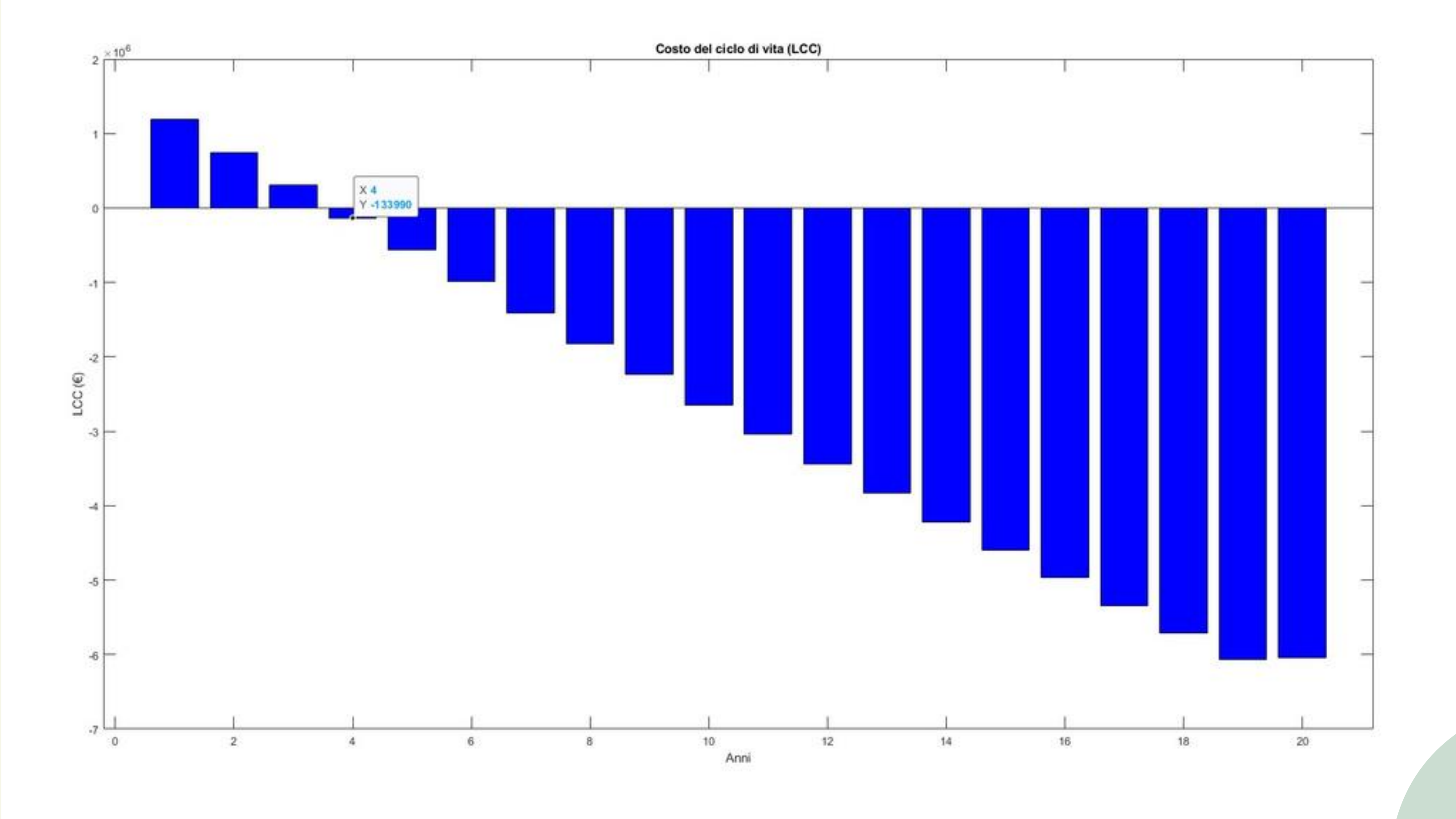
- Initial installation cost of approximately <u>€1'150'000;</u>
- Positive cash flow obtained after <u>6 years;</u>
- SPB of <u>4 years</u>;
- NPV mean of <u>€644'260;</u>
- LCC mean of <u>€529'000;</u>



CASE 3: RESULTS - ECONOMIC ANALYSIS

- Initial installation cost of approximately €4'000'000, the highest of the 4 cases, including PV and PT systems;
- Positive cash flow obtained after 4 years;
- SPB of 2 years;
- NPV mean of €5'968'900;
- LCC mean of €2'740'900;





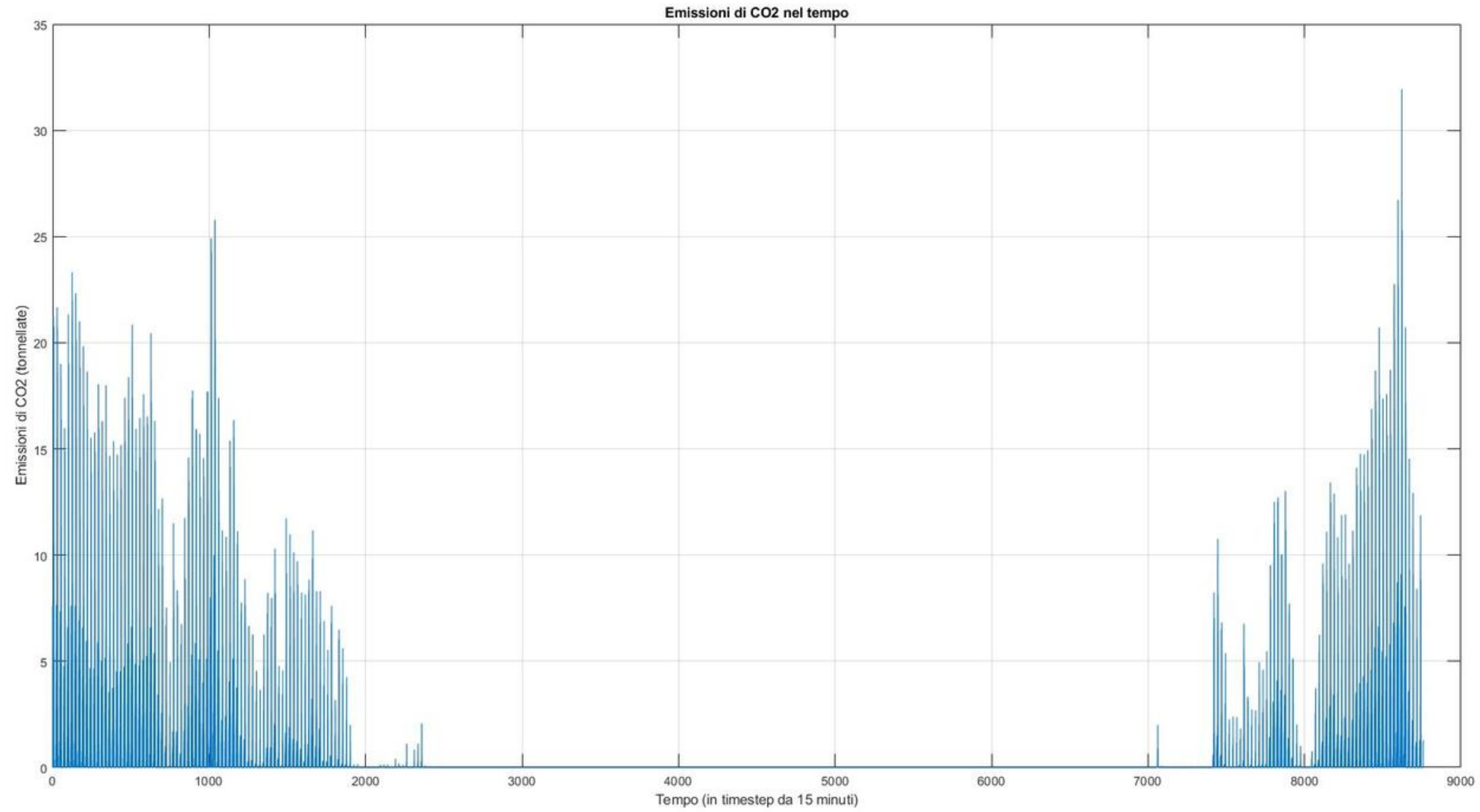
CO2 EMISSIONS ANALYSIS

General parameters

- Natural gas emission factor of 1.984 $tCO_2/Stdm^3$;
- Lower calorific value of 55.5 MJ/kg;
- Density of 0.716 kg/m^3;
- Photovoltaic electricity emission factor of 0.53 $kgCO_2/kWh$;
- Emissions associated with the production and installation of the panels themselves;
- Each kWh produced by the photovoltaic system avoids 0.53 kg of carbon dioxide;

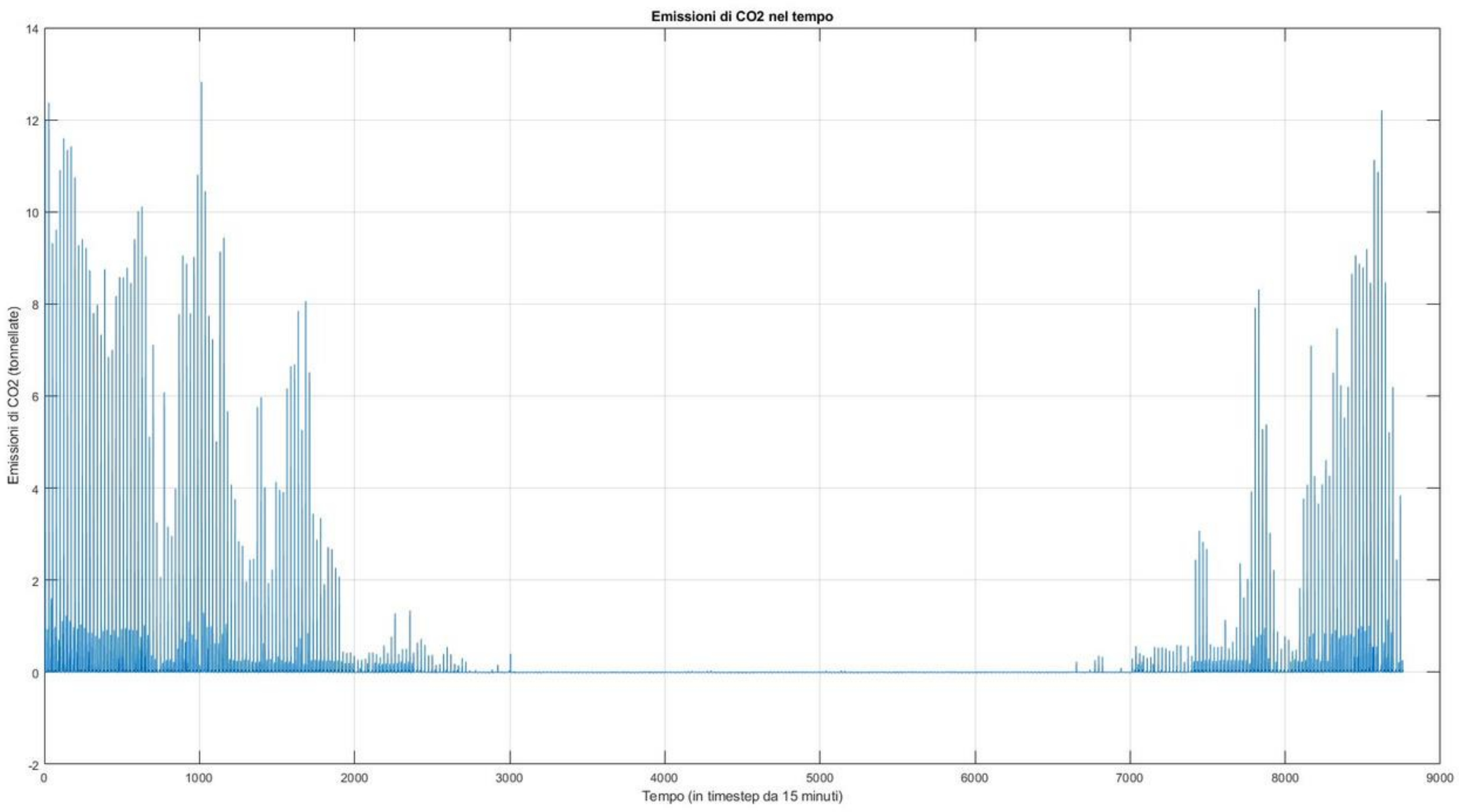
CASE 0: Results – CO2 emissions analysis

- Mean CO2 emissions of 0.3327 tons;
- Thermal power produced by pre-existing systems considered in the calculation;



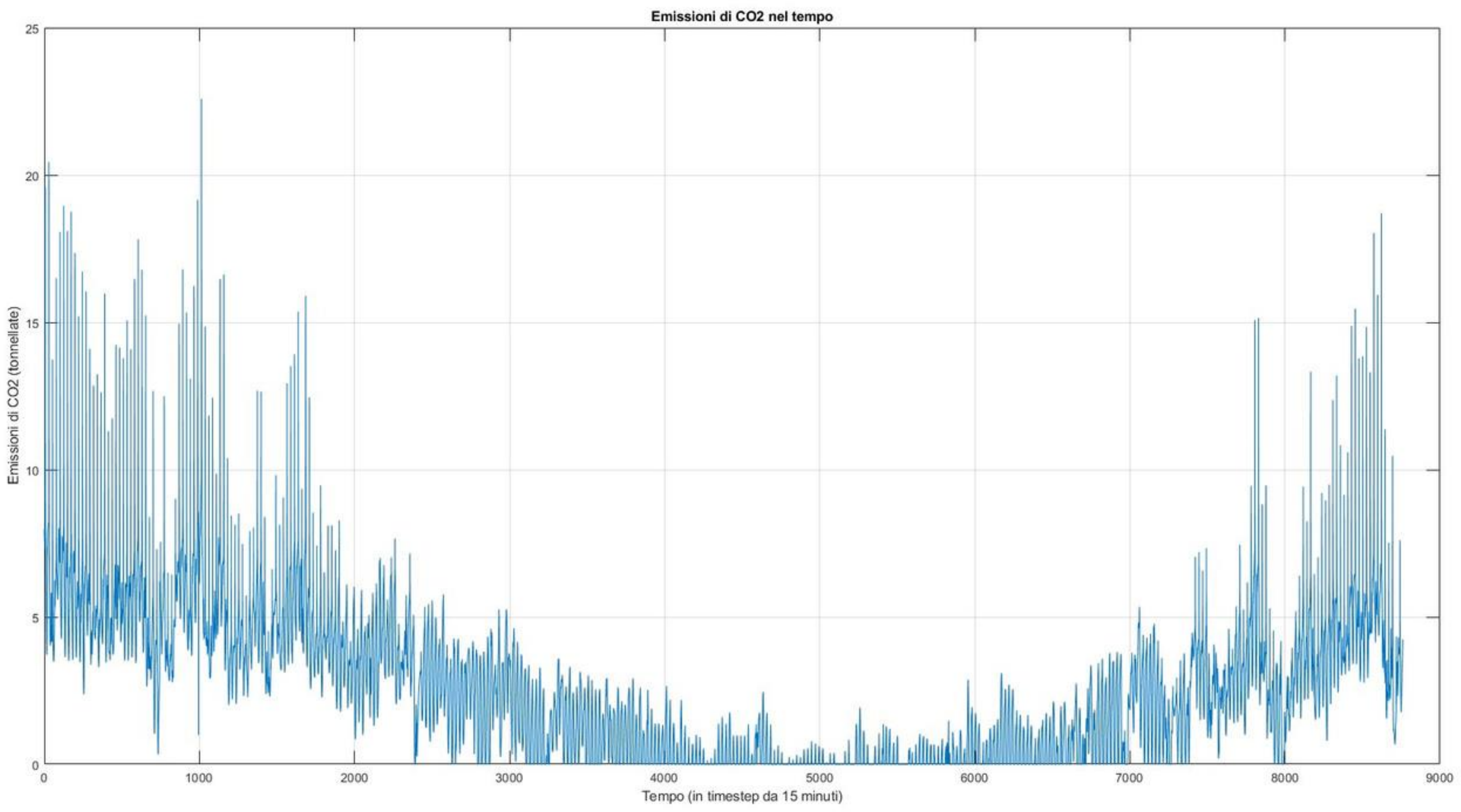
CASE 1: Results – CO2 emissions analysis

Mean CO2 emissions of <u>0.0759 tons;</u>



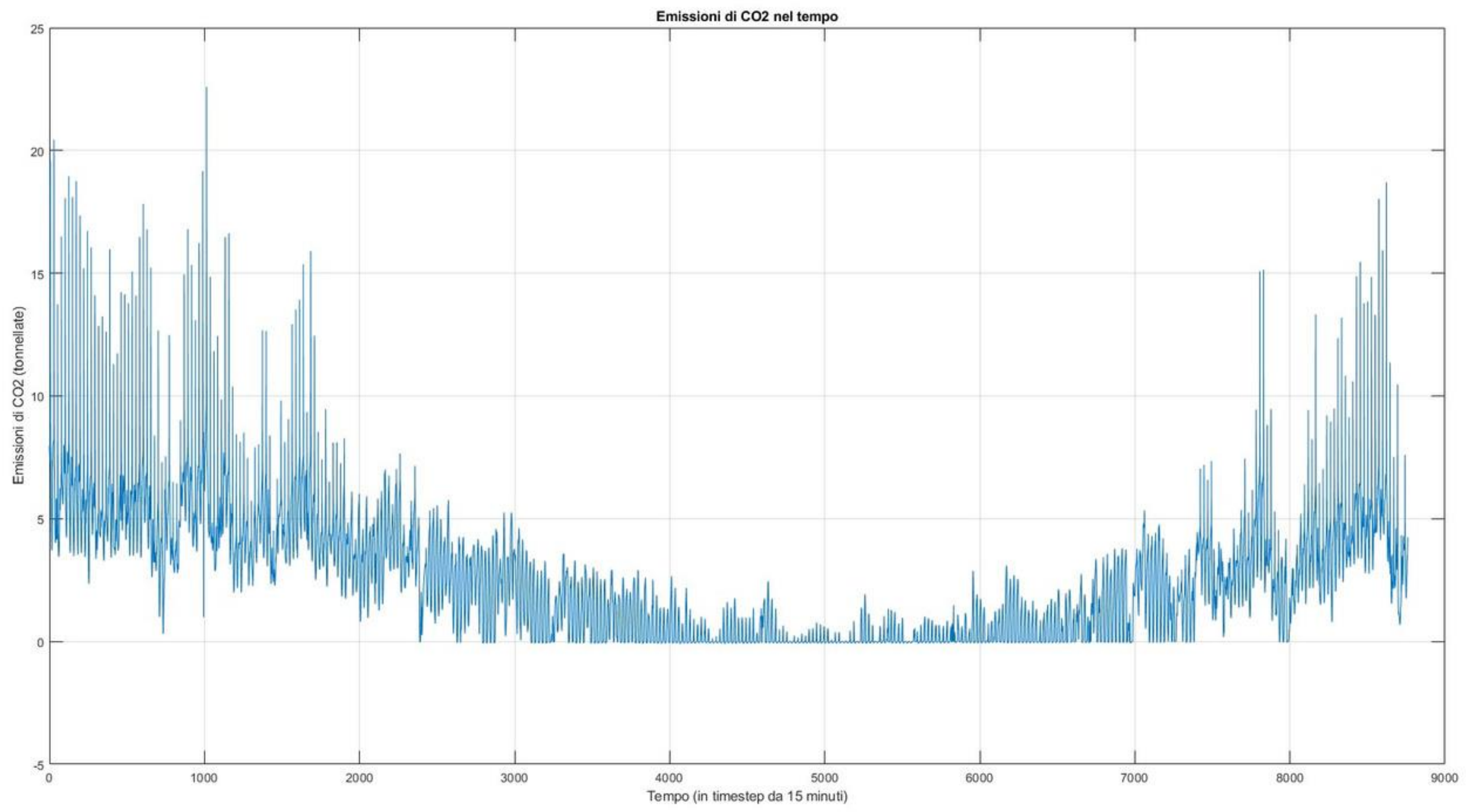
CASE 2: Results – CO2 emissions analysis

- Mean CO2 emissions of <u>2.4254 tons</u>;
- Thermal power produced by the cogenerator considered in the calculation;



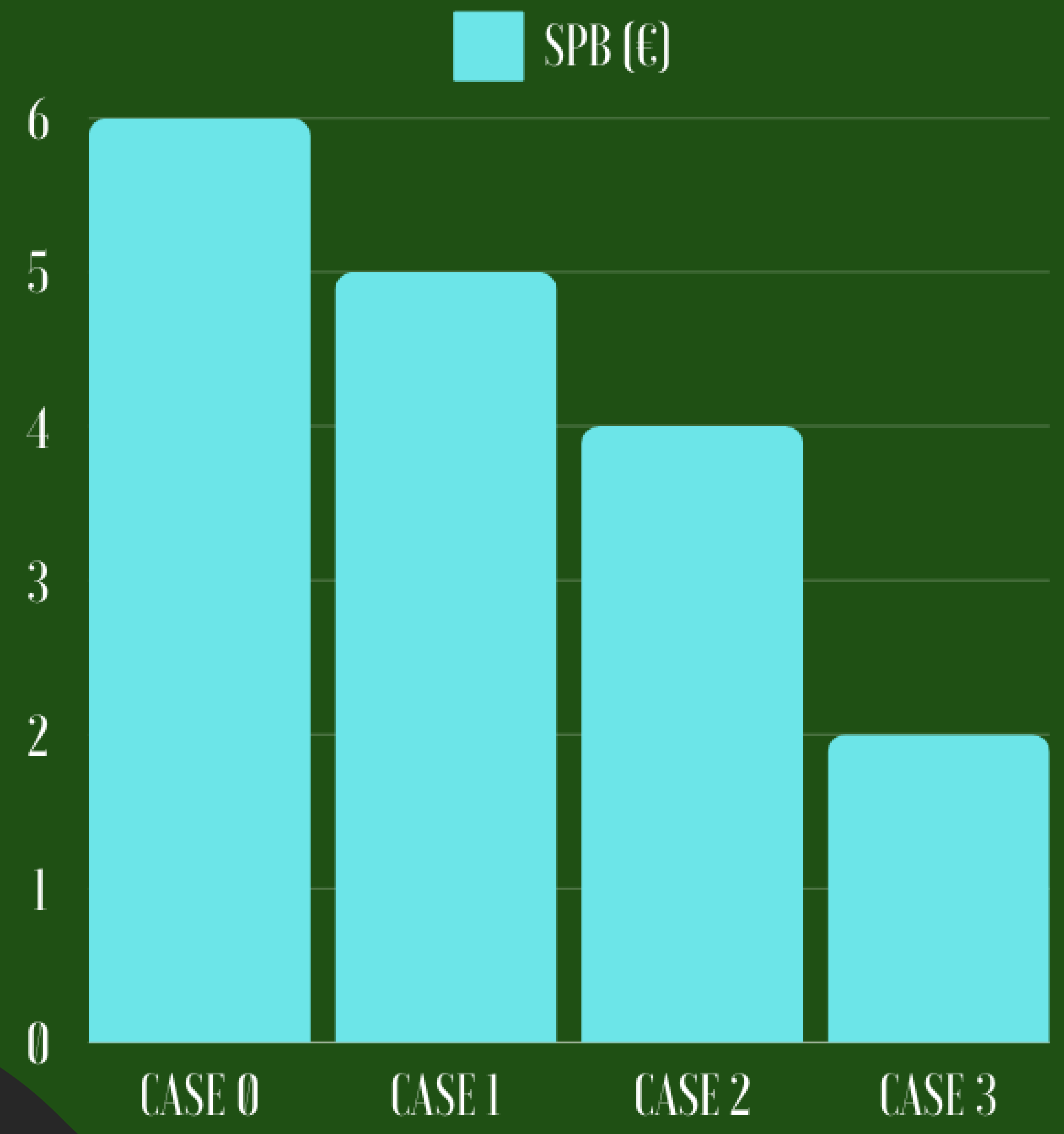
CASE 3: Results – CO2 emissions analysis

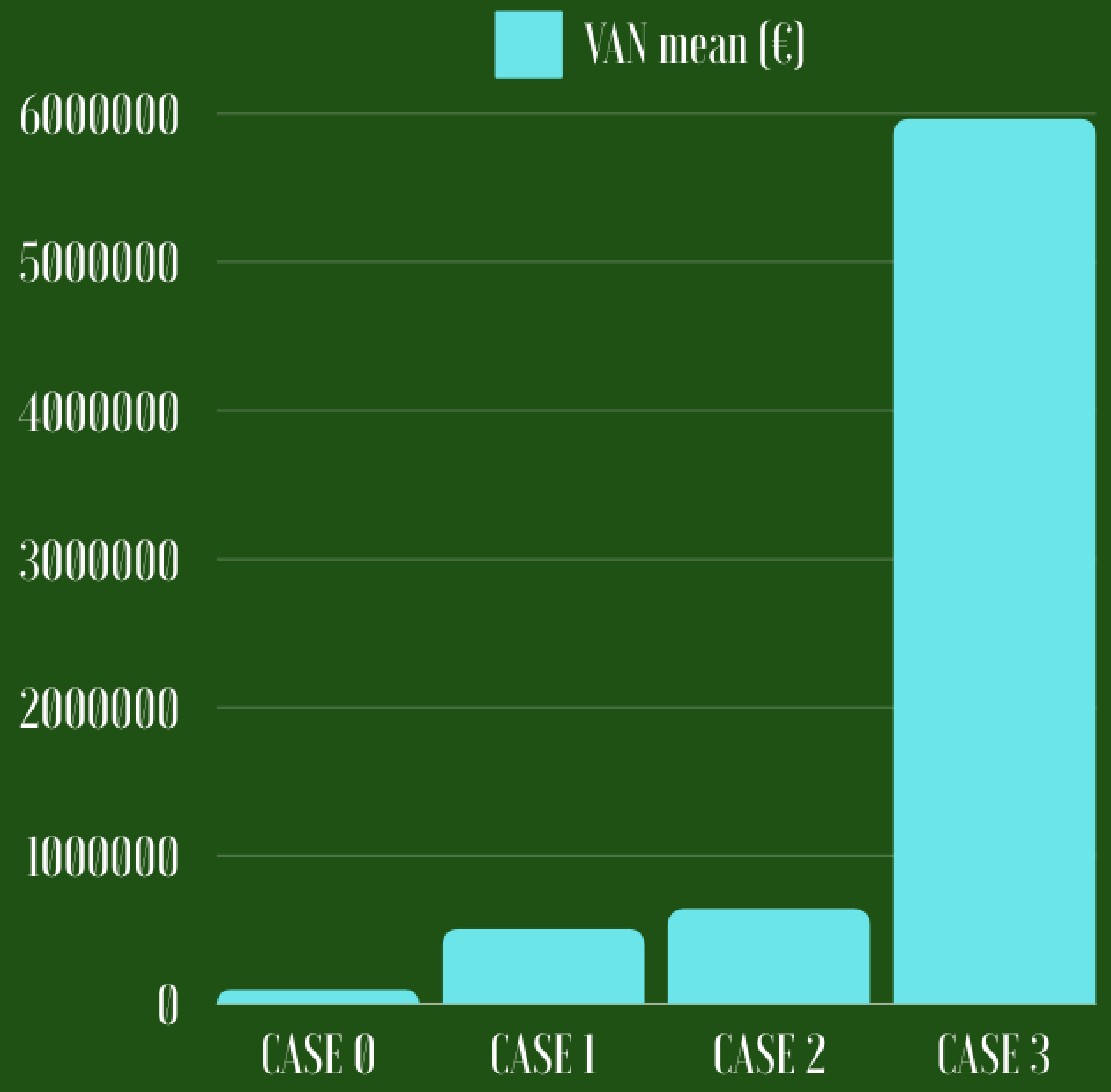
- Mean CO2 emissions of <u>2.4196 tons</u>;
- Thermal power produced by the cogenerator and PT system considered in the calculation;



CONCLUSION

Final review among the case studies analyzed





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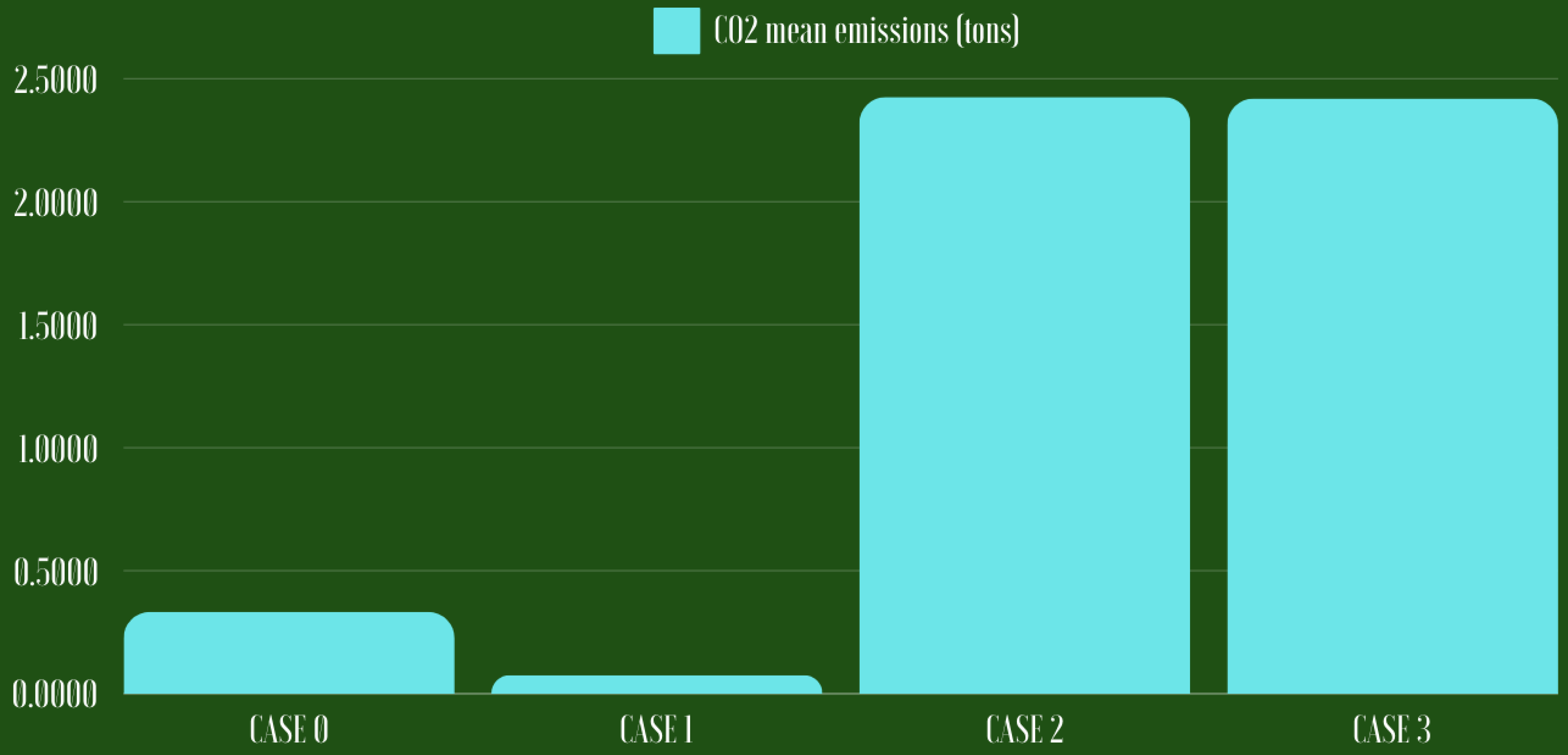

Thank you!

THANK YOU FOR YOUR TIME!

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