Electrical resilience in residential microgrids powered by biogas micro-Combined Heat and Power (micro-CHP) systems

Iker De Loma-Osorio [1, *], and David Borge-Diez [2]

1 Doctoral School, Universidad de León, Campus of Vegazana S/N, León, Spain;

ideloo00@estudiantes.unileon.es

2 Electrical, Systems and Automation Engineering, Universidad de León, Campus de Vegazana, 28071 León, Spain; david.borge@unileon.es

*Correspondence: ideloo00@estudiantes.unileon.es

1. Introduction

1. Introduction – Objective

- Investigate the economic feasibility of biogas-powered micro-Combined Heat and Power (micro-CHP) microgrids in residential buildings to be resilient during electric blackouts

1. Introduction – Scope

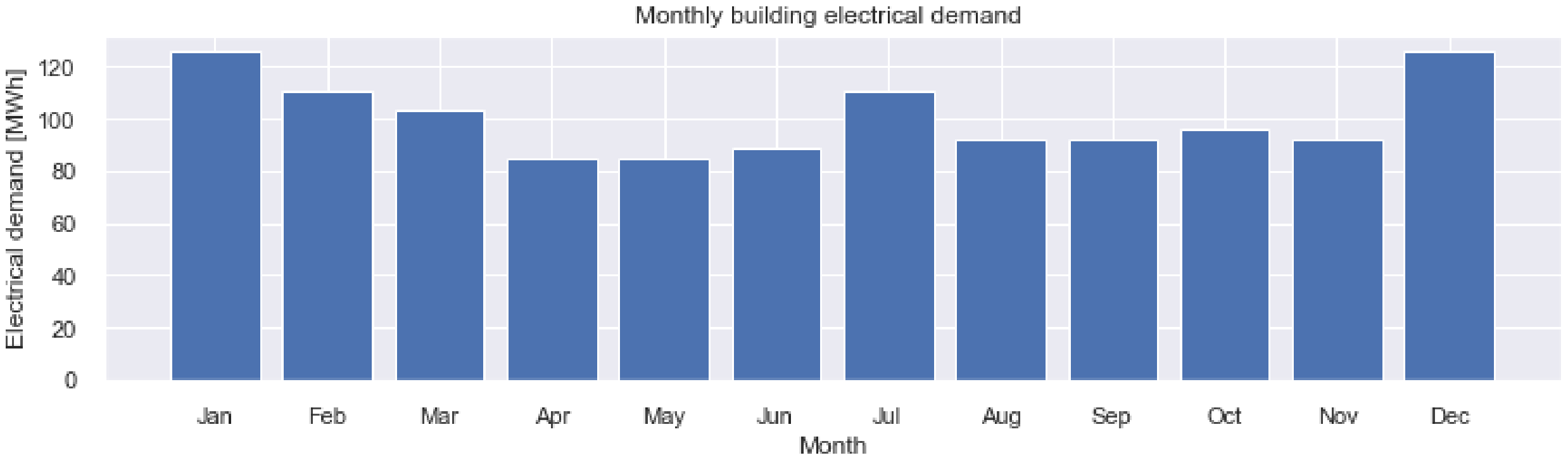
- Microgrids in a residential building
- Demands to cover:
  - Electrical
  - Thermal:
    - Heating
    - Hot water
- Analyze the technical and economic aspects
- Study based on Spain

2. Methods

2.1. Analyzed building

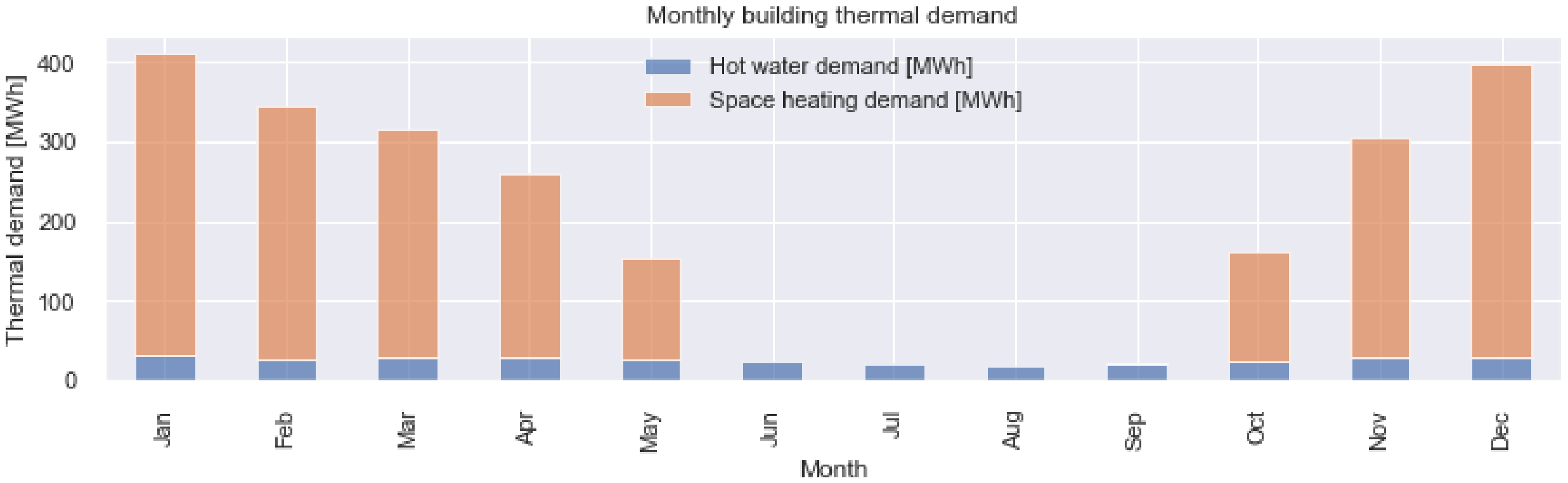
- **Type**: residential
- **Building construction date:** between 1919 and 1921
- **Number of apartments:** 264
- **Location:** Bilbao, Spain
- **Min temperature:** 9.5 °C
- **Max temperature:** 21.6 °C
- **Average temperature:** 15.1 °C
- **How is the electrical demand currently covered?**
  - The building is connected to the grid
- **How is the thermal demand currently covered?**
  - Each apartment has its own system such as individual boilers, or electric heating systems (electric water storage, and electric heaters)

2.1.1. Electrical demand of the building



- The effect of electric heating systems and less hours of light can be appreciated
- In July, there consumption is higher due to cooing devices

2.1.2. Thermal demand of the building

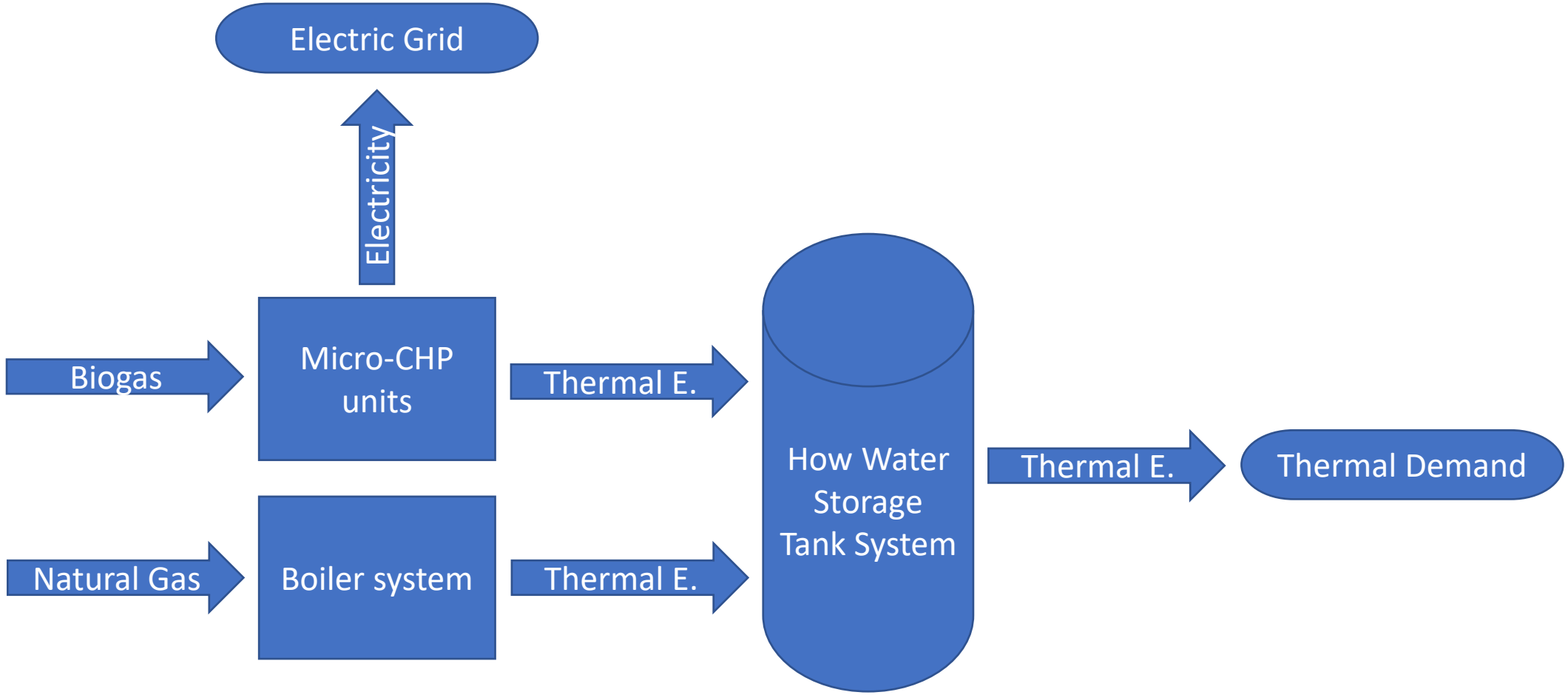


- Great variance in the space heating demand
- Hot water demand more stable

2.1.3. Critical electric loads in residential buildings

- Compared to other type of buildings, residential buildings have a smaller percentage of electrical critical loads
- What is critical in residential buildings?
  - Food loss and its related costs
- The critical electric loads in residential buildings?
  - Refrigerators (7% of the electrical load)
  - Freezers (1.6% of the electrical load)
  - Total: 8.6% of the electrical load

2.2. Micro-grid and energy system configuration



2.1.1. Micro-CHP system

- Requirements:
  - Meet the electrical critical loads: 14.62 kWh (8.6% of the max electrical demand) needs to be covered
- Selection:
  - 2 micro-CHP units: to meet more percentage of the thermal demand and sell more electricity to the grid (0.19087 €/kWh and 0.13337 €/kWh are the export and import prices respectively)
    - Each 25-kW electrical output → 50 kW total
    - Each 38.7-kW thermal output → 77.4 kW total
    - Minimum setpoint of 15-kW thermal
    - Work in parallel
    - Bio-gas powered

2.1.1. Micro-CHP system

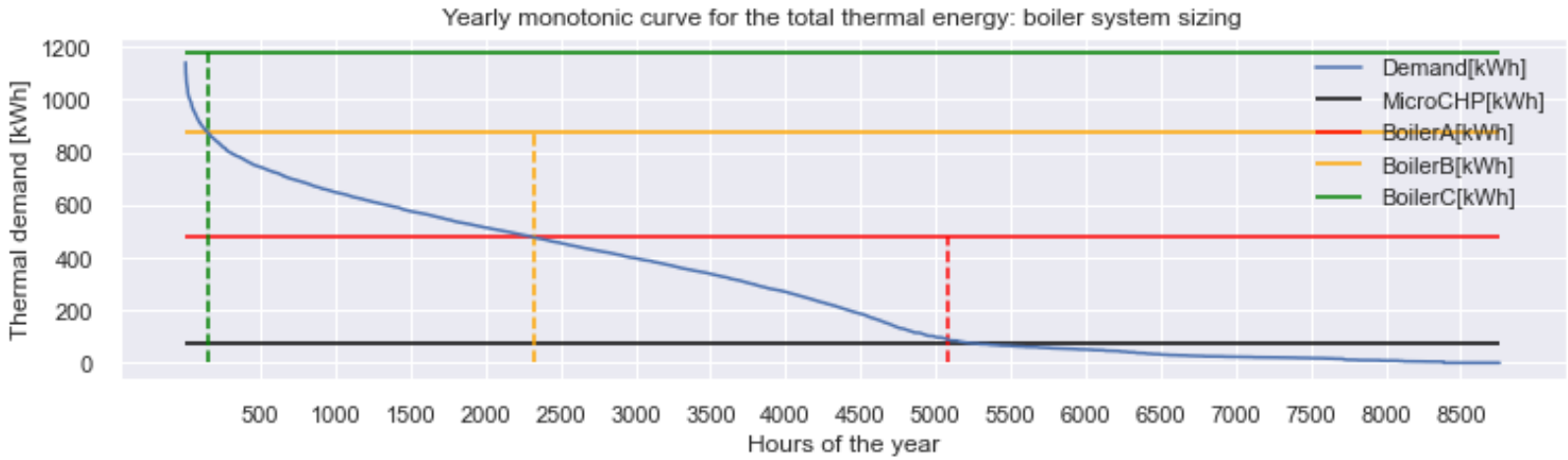
- Max yearly building electric demand: 170 kWh
- Critical loads (8.6%): 15 kWh
- Required micro-CHP rated electrical power: 15 kW
- 2 micro-CHP units have been selected. Reasons:
  - High thermal demand
  - Average electricity export price higher than average import price in Spain (0.19087 €/kWh and 0.13337 €/kWh respectively)
  - Total thermal output: 77.4 kW
  - Total electric output: 50 kW
  - Minimum setpoint of 15 kW to avoid having the units starting and stopping often
  - Both work in parallel: start working when the demand is higher than the setpoint
- Biogas-powered units: promote renewable energies

2.1.2. Water Storage Tank System

- Requirements:
  - 75 kW needed
- Selection:
  - 2 commercial tanks with 49.8 kW and 25.4 kW
  - Considered thermal losses: 3%

2.1.3. Boiler system

- Requirements:
  - Meet the thermal demand that cannot be covered by the micro-CHP system or the water storage tank
- Selection:
  - 3 boilers selected:
    - Boiler A: 400-kW
    - Boiler B: 400-kW
    - Boiler C: 300-kW

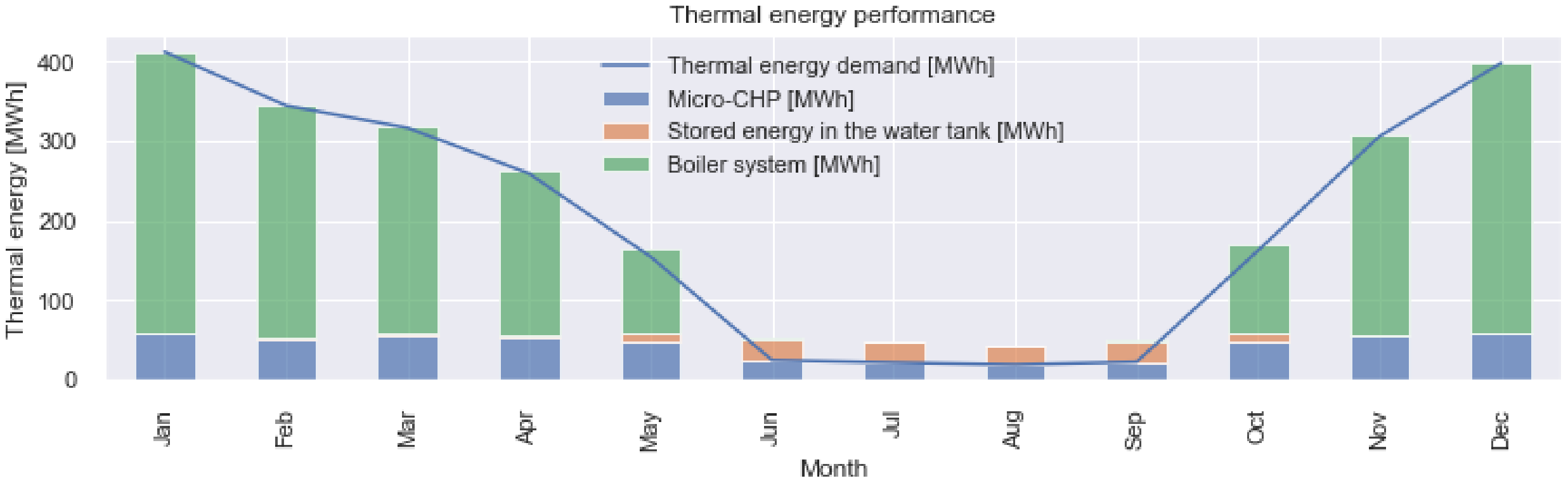


3. Results

3.1. Electrical energy

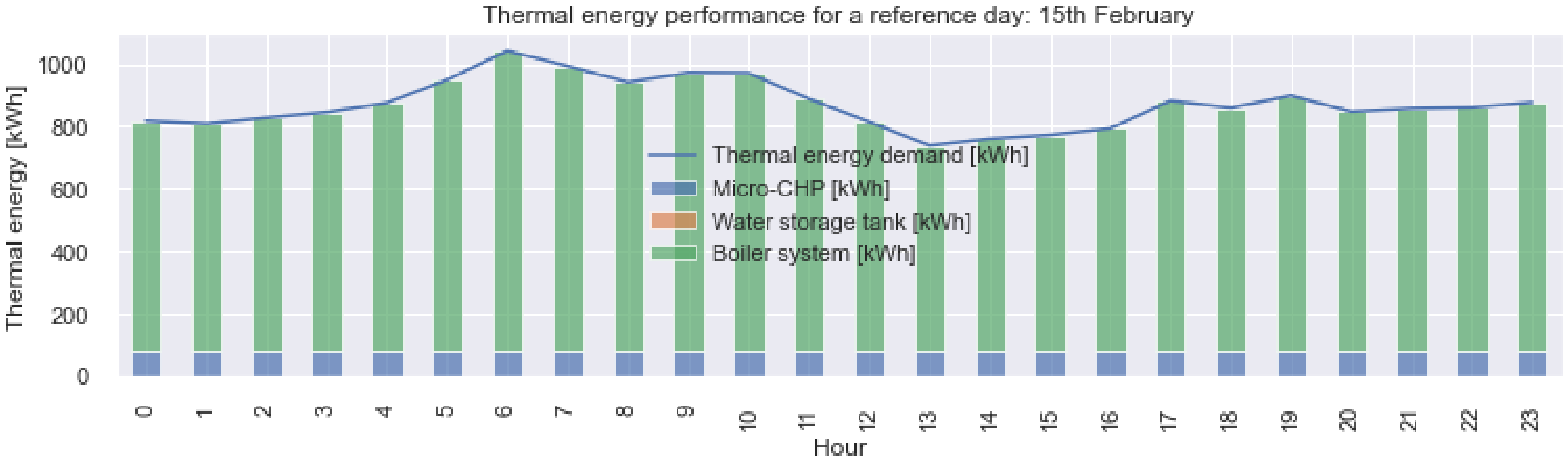
- The system is resilient to provide electricity to the critical loads:
  - Max electrical load: 170 kWh
  - Critical load (8.6% of the electrical demand): 14.62 kWh
  - Micro-CHP units electrical power output: 50 kW (30% of the max electrical load)
  - Use the remaining for other noncritical demands

3.2. Thermal energy



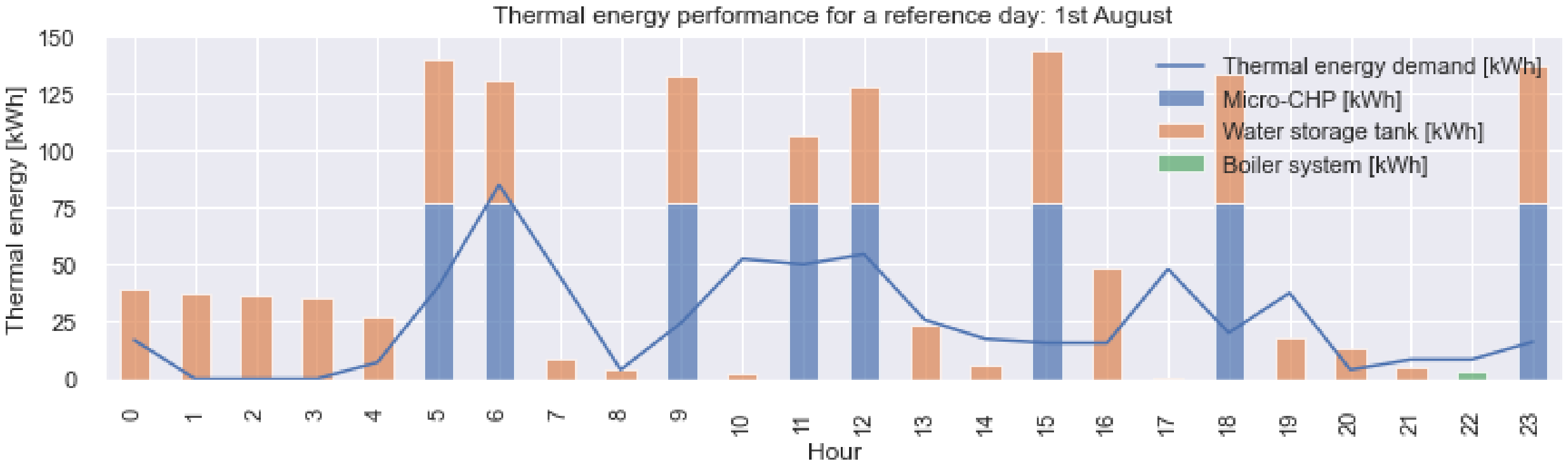
- The micro-CHP working constant
- The boilers adapt to the thermal demand changes
- The water storage tank is well sized to the system

3.2. Thermal energy



- Boilers provide most of the thermal demand during colder months when space heating is needed

3.2. Thermal energy



- The micro-CHP system and the water storage tank supply the load
- The boilers only used when there is no stored energy, and the load is smaller than the set point

3.2. Thermal energy

Generator	Working hours per year
Micro-CHP system	6,653
Boiler A (400 kW)	6,400
Boiler B (400 kW)	2,174
Boiler C (300 kW)	146

3.3. Economic results

Concept	Amount
Micro-CHP system working time [h/year]	6,653
Electricity generated by micro-CHP [MWh/year]	332.65
Electricity export price [€/kWh]	0.19087
Revenue from electricity sale [€/year]	**63,493**
Consumed electricity [MWh/year]	1,209
Electricity import price [€/kWh]	0.13337
Electricity cost without electricity sale [€/year]	**161,244**
Electricity cost with electricity sale [€/year]	**97,751**
Savings [%/year]	**40**
Savings per apartment [€/year]	**240**

4. Conclusions

4. Conclusions

- It is feasible to have a resilient microgrid based on biogas-powered micro-CHP generation
- Savings of 40% in the electrical bill (sale of electricity)
- Thermal economic results not considered in this study
- The methodology can be used in similar buildings and scenarios