A demand response mechanism for the minimization of the energy demand and electricity cost of a university building using electric vehicles and a small sized gas turbine generator

Dimitrios Thomas[a,b], Olivier Deblecker[b], Christos S. Ioakimidis[a,]
[a] ERA Chair ‘Net-Zero Energy Efficiency on City Districts, NZED’ Unit, Research Institute for Energy, University of Mons
[b] Electrical Engineering Department, University of Mons
dimitrios.thomas@umons.ac.be, olivier.deblecker@umons.ac.be, christos.ioakeimidis@umons.ac.be,

Abstract

High energy demand in corporate and/or public buildings is nowadays one of the dominant reasons of excessive energy consumption. At the same time, electric vehicles (EVs) are becoming more and more popular worldwide being a considerable alternative power source when parked. In this work we propose demand response mechanism which optimizes the control of the charging-discharging schedule of an altered but finite number of EVs arriving at a university building for a typical load-day in February aiming at the minimization of the energy demand and thus the electricity cost of the building. In the aforementioned framework, a parallel operation of a small sized gas turbine is considered. To this end, a mixed integer linear programing (MILP) model containing binary and continuous variables was developed to optimize the control process and minimize energy cost.

Motivation and Research Question

- Buildings have become the major energy consumers over the world as they consume around 40% of total end-use energy
- Electric vehicles (EVs) are becoming more and more popular worldwide being a considerable alternative power source when parked
- Small sized gas turbines (e.g. CHP generators) are easy to install and are widely suggested in literature as power alternative for the Nearly Zero Energy Buildings Concept (NZEB)
- The idea is to combine the potential power from the EVs in combination with the operation of the gas turbine (GT) to minimize the energy demand and thus the electricity cost of a university building

Problem Formulation

Optimal Charging-Discharging EVs Schedule

$$s_i^n = S_i + \xi_i^n \cdot c^{PHEV} - \sigma_i^n \cdot d^{PHEV} \quad \forall i \in I, n = 1$$

$$s_i^n = s_i^{n-1} + \xi_i^n \cdot c^{PHEV} - \sigma_i^n \cdot d^{PHEV} \quad \forall i \in I, n > 1$$

$$\xi_n^i + \sigma_i^n \leq 1$$

$$s_i^n \leq C^{PHEV}$$

$$s_i^n \geq S_i^{PHEV} = 50\% \cdot C^{PHEV}$$

$$\min \sum_{n \in N} \alpha^n y^n$$

Energy Balance: $y^n + \sum_{i \in I} \sigma_i^n d^{PHEV} + e_{GGT}^n = e_F^n + \frac{1}{\eta^{PHEV}} \sum_{i \in I} \xi_i^n c^{PHEV}$

Optimal GT Operation

$$r_n^{\min} = p_n \cdot gen^{\min} - f^{\min} \cdot fuel^{\cos t}$$

$$r_n^{\max} = p_n \cdot gen^{\max} - f^{\max} \cdot fuel^{\cos t}$$

$$x_n^{\min} + x_n^{\max} \leq 1 \qquad \forall n \in N$$

$$x_n^{\min} - x_{n-1}^{\min} + x_n^{\max} - x_{n-1}^{\max} \leq x_n^{start} \qquad \forall n \in N$$

$$\mathrm{fuel}^{used} \leq 2343$$

$$\max \sum_{n \in N} r_n^{\min} x_n^{\min} + \sum_{n \in N} r_n^{\max} x_n^{\max} - \sum_{n \in N} x_n^{start} S^{\cos t}$$

Results

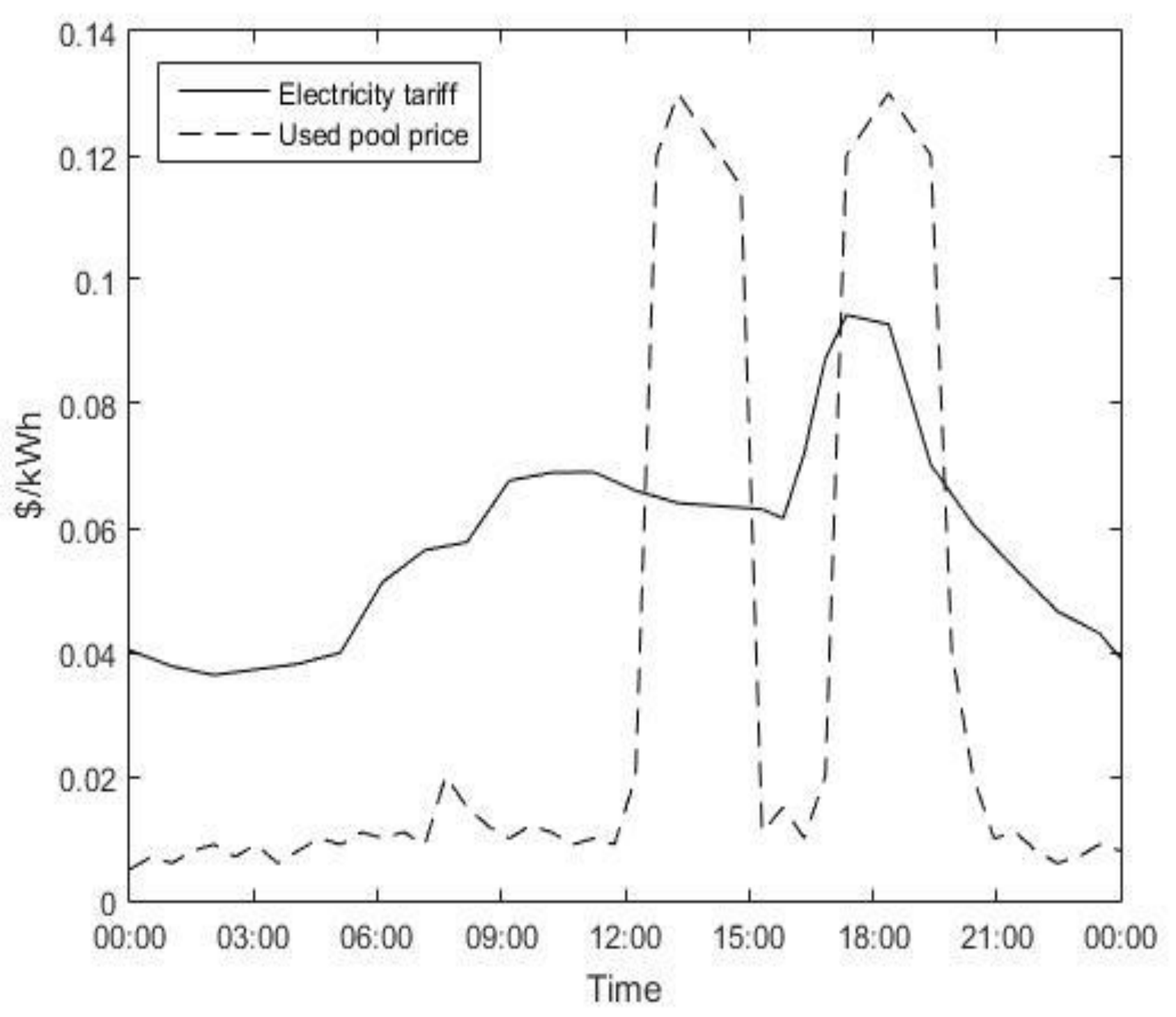

Figure 1 Electricity tariff (spot price) and pool price

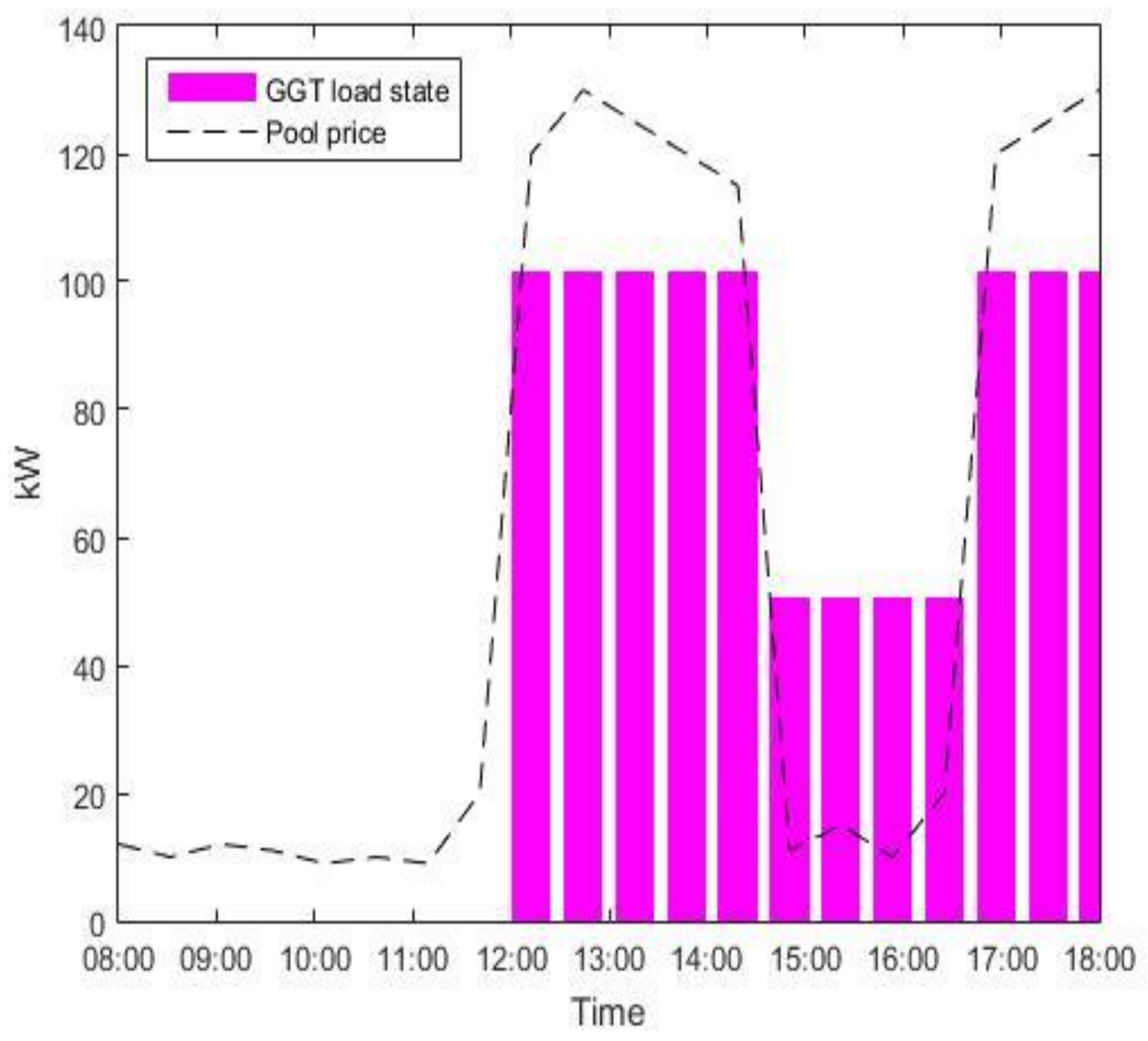

Figure 2 Optimal schedule of the GGT operation

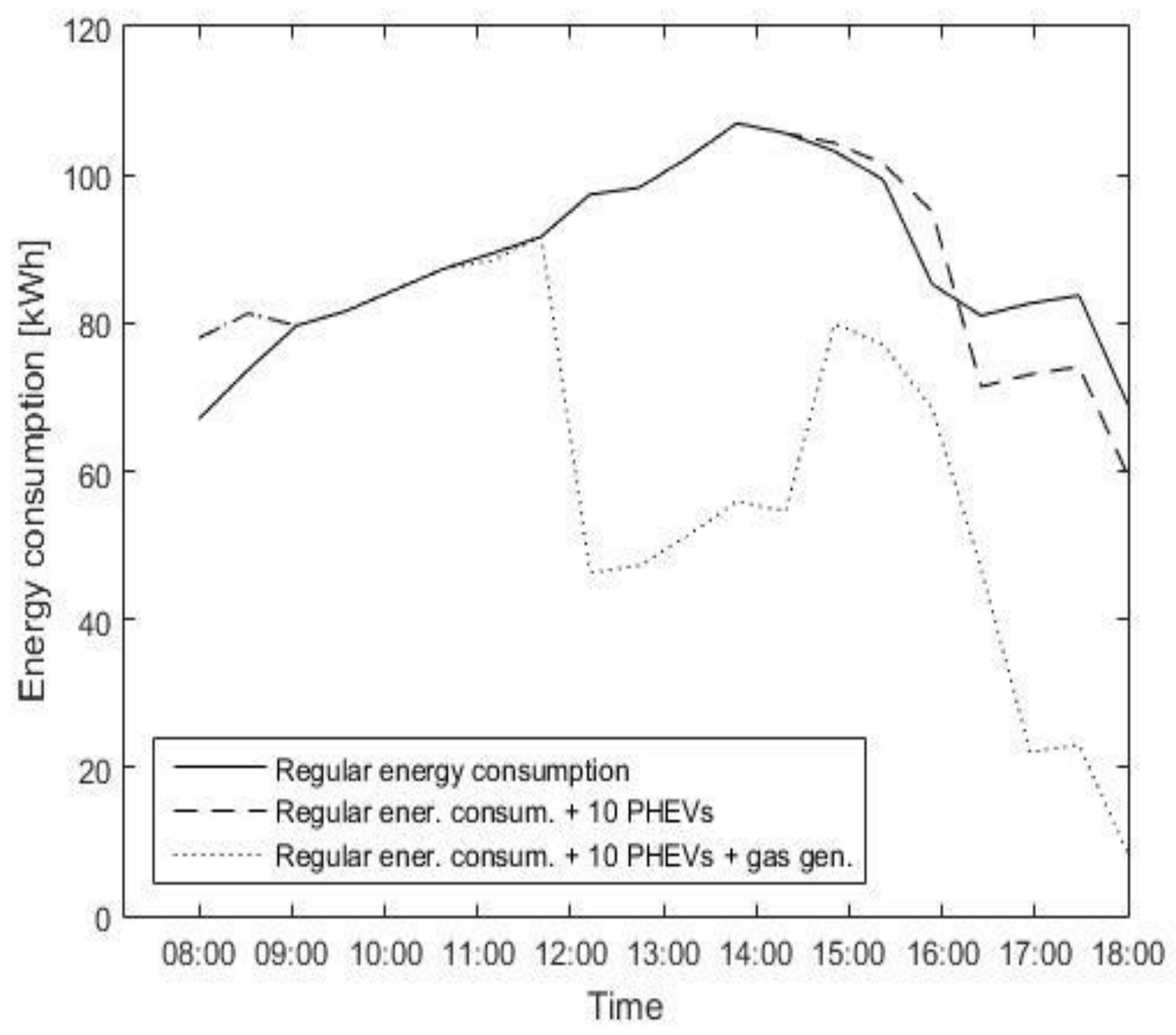

Figure 3 Combined impact of 10 PHEVs and GGT operation on the building’s energy consumption

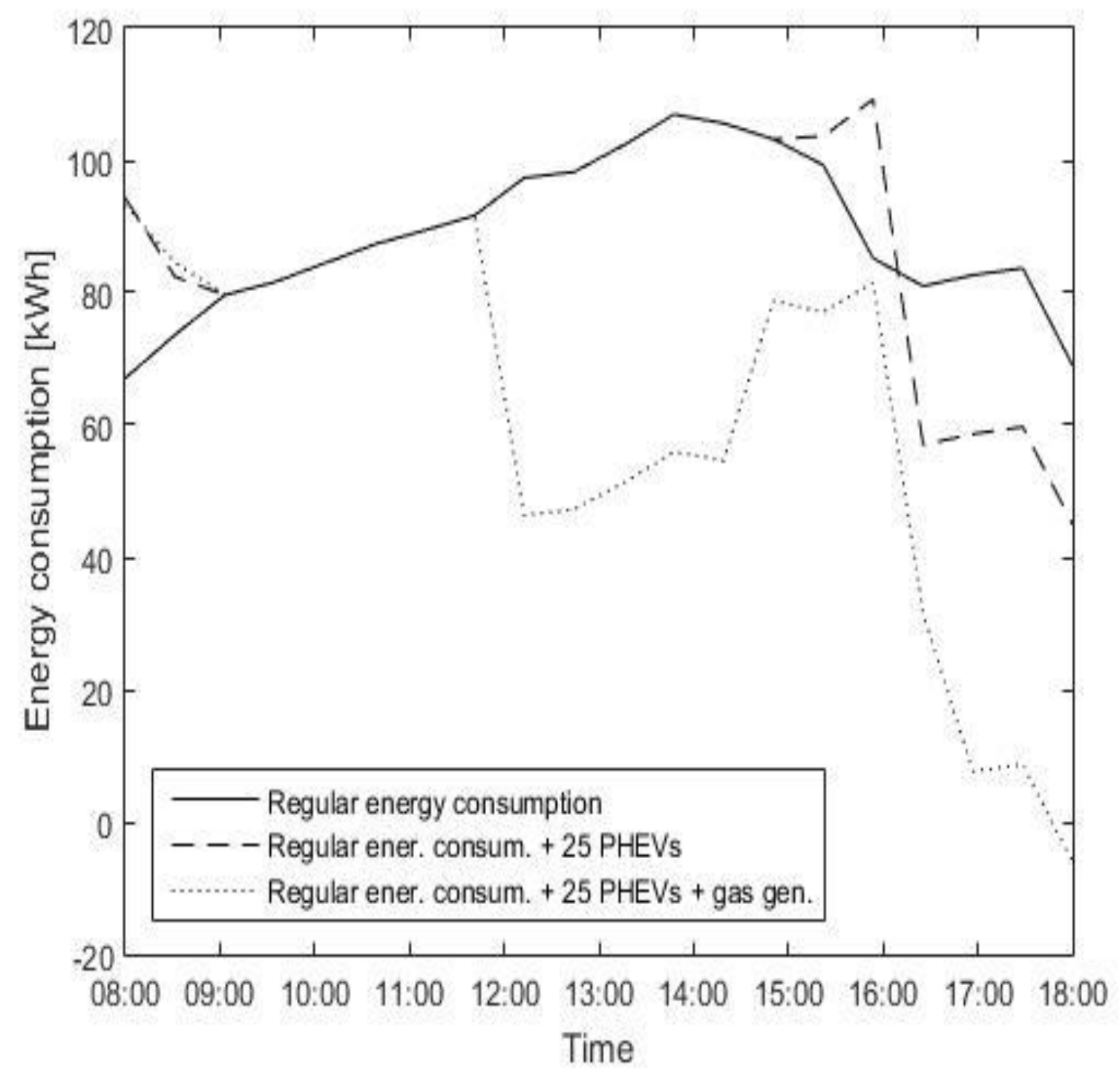

Figure 4 Combined impact of 25 PHEVs and GGT operation on the building’s energy consumption

With support of the FP7 E.U. RE-SIZED (Research Excellence for Solutions and Implementation of NZED) Grant Agreement no 621408