X SICEL 2021

Transición energética en la 4ta revolución industrial

Universidad Tecnológica de Pereira

UNIVERSIDAD NACIONAL DE COLOMBIA

XSICEL 2021

Transición energética en la 4ta revolución industrial

Optimal Flexible Load Programming Based on Time of Use Pricing for the Colombian Energy Market

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Pontificia Universidad Javeriana

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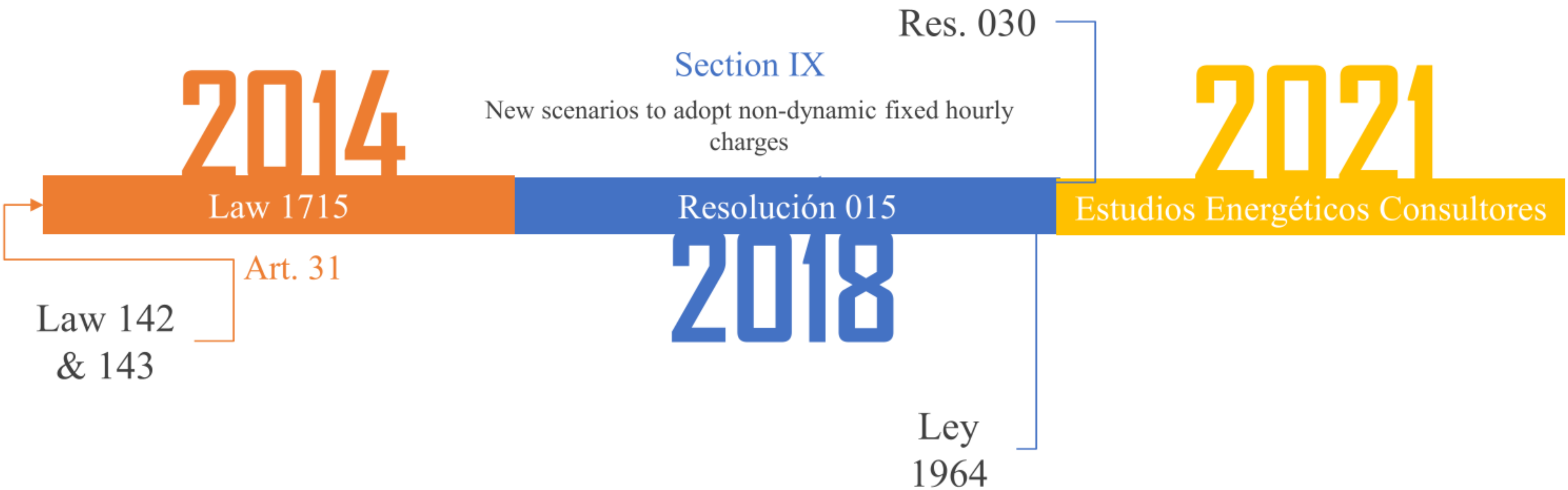
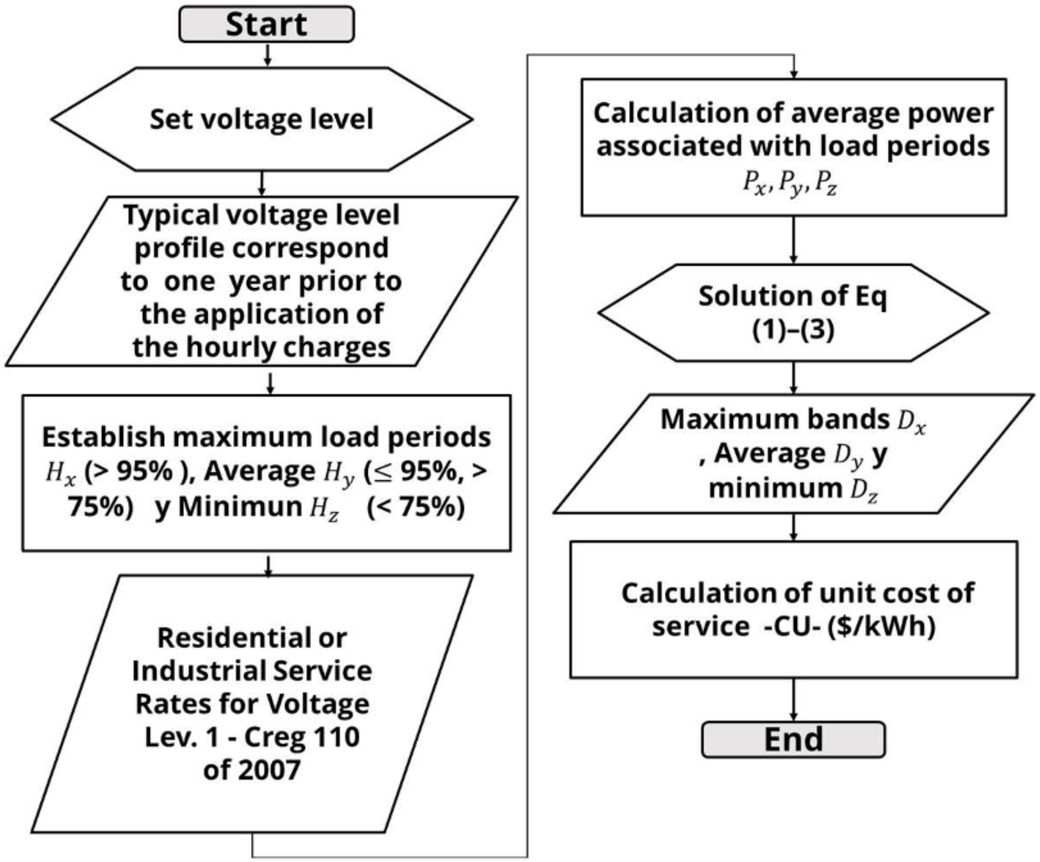
I. Introduction



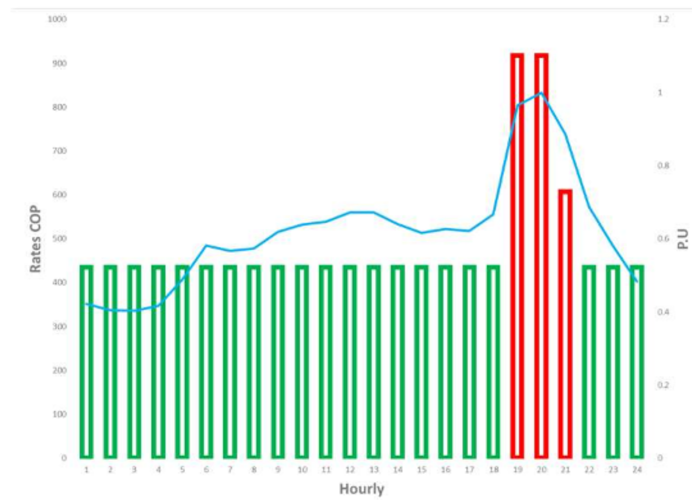
I.CREG 015 – 2018 Methodology



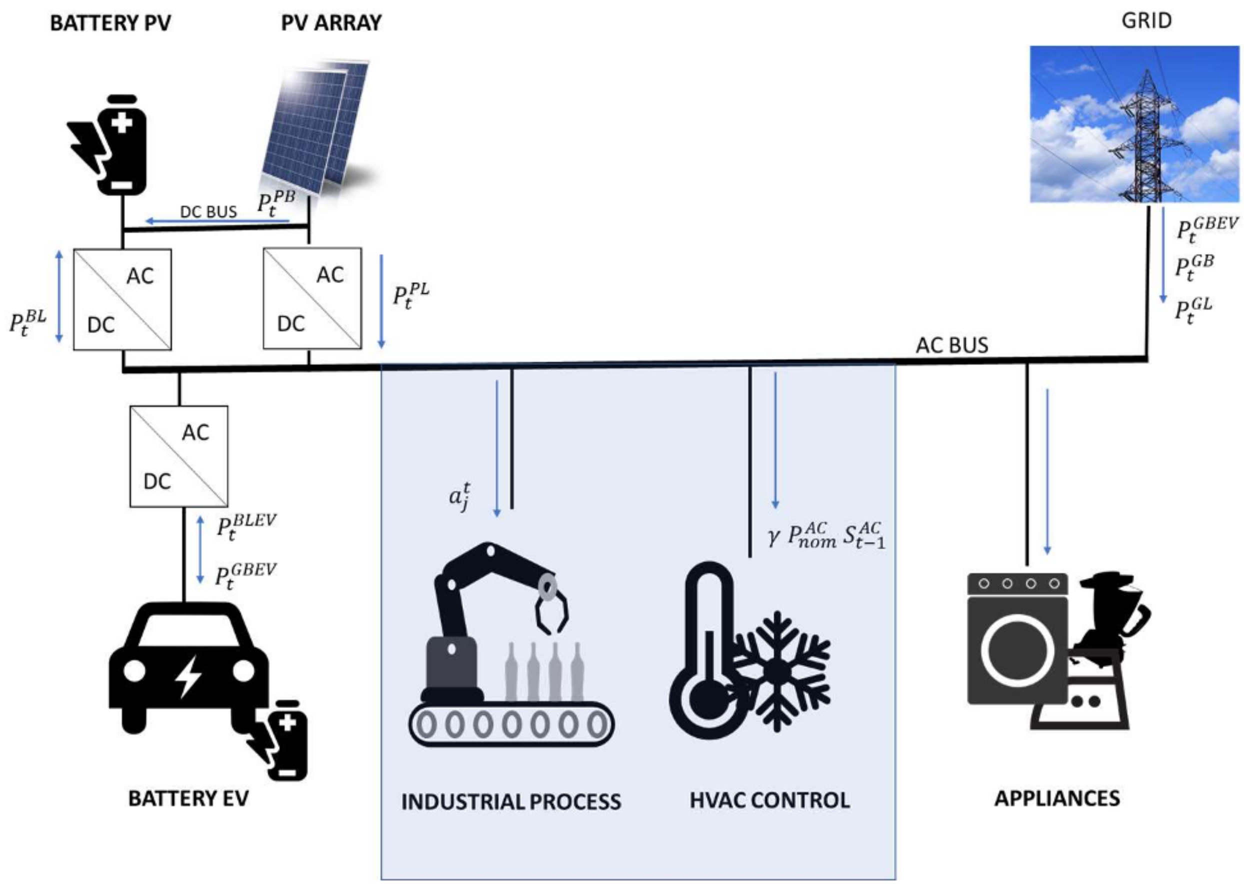
» $$\frac{1}{fch} * H_x * P_x * D_{x,n,j,m,t} + H_z * P_z * D_{z,n,j,m,t} + fch * H_y * P_y * D_{y,n,j,m,t} = Dt_{n,j,m,t} * \sum_{i=1}^{24} P_i$$

» $$\frac{D_{v,n,h,m,t}}{fch \times D_{l,n,hh,m,t}} = \frac{P_v}{P_l}$$

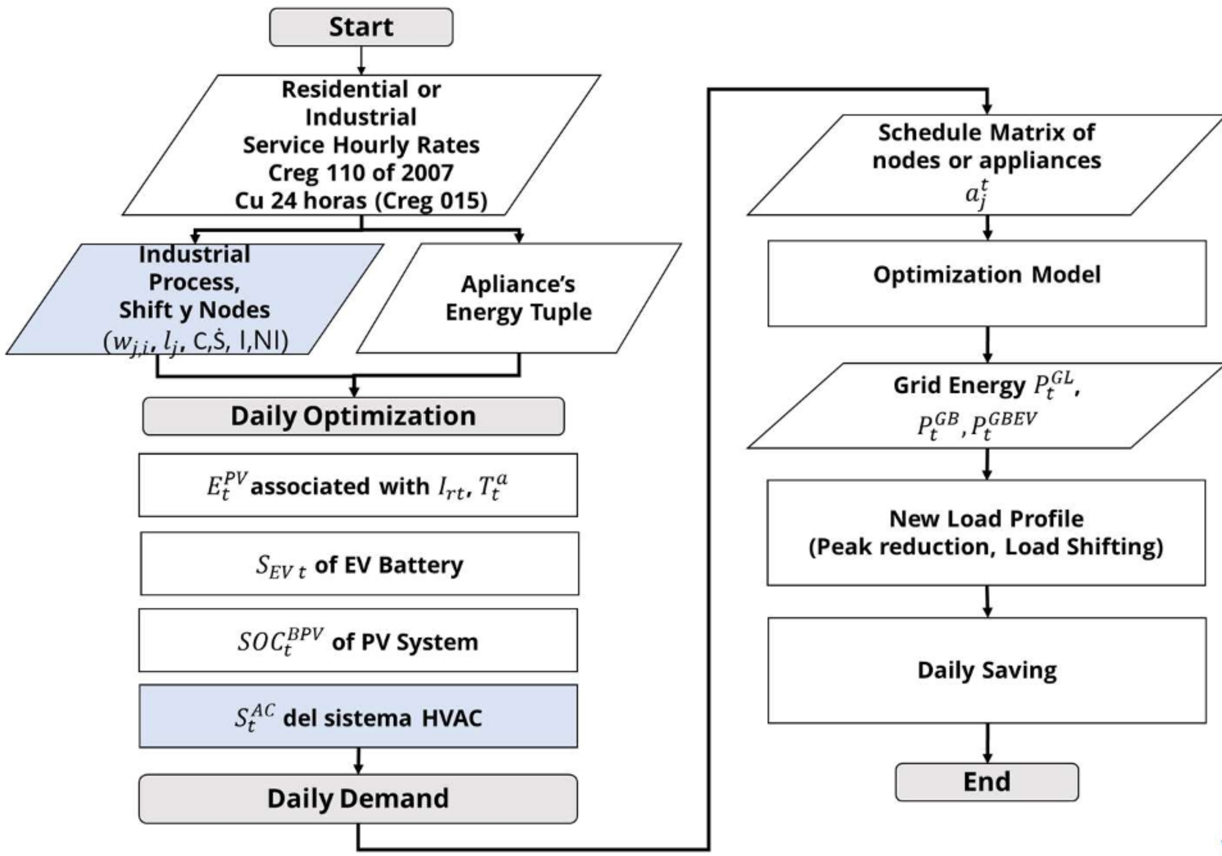
» $$\frac{D_{v,n,h,m,t}}{fch^2 \times D_{p,n,hh,m,t}} = \frac{P_v}{P_p}$$



II. Energy Model (Residential – Industry)



II. Proposed Methodology (Residential – Industry)



II. Objective function

Residential

$$\text{minimize} \sum_{t=1}^{24} C_t (P_t^{GL} + P_t^{GB} + P_t^{GBEV} \beta_t) \boxed{+ \left(S_{EV\, t_{SEV}} * (1-\alpha) \right) CU_{park}}$$

Industrial

$$\text{minimize} \sum_{t=1}^{24} C_t (P_t^{GL} + P_t^{GB} + P_t^{GBEV} \beta_t \quad)$$

II. Constraints / Process

$$\sum_{t=s_j}^{f_j} a_j^t = l_j, \forall j \quad (1)$$

$$\sum_{j=1}^{m} r_j a_j^t \leq P_{max} \quad \forall t \forall j \quad (2)$$

$$\sum_{j=1}^{m} r_j a_j^t = P_t^{GL} + \eta_{eff}^{pINV} E_t^{PL} + P_t^{BL} + P_t^{BLEV} \quad \forall t \quad (3)$$

Residential

$$\sum^{24} a_j^t = w_{j,i} \quad \forall j \quad (1)$$

$$a_i^t * w_{j,i} \leq \sum^{t-1} a_j^k \quad \forall t \quad (2)$$

$$a_i^t \leq a_j^{t-1} + \sum^{t-1} a_i^k \quad \forall t \in NI \quad (3)$$

$$a_j^t \leq a_j^{t+1} + \frac{1}{w_j} \sum_{k=1}^{t} a_j^k \quad \forall t \quad (4)$$

$$\sum_{j=1}^{m} l_j a_j^t \leq P_{max} \quad \forall t \quad (5)$$

Industrial

II. Constraints / Electronic Vehicle Storage

$$\mathrm{S}_{\mathrm{EV}\ t} = \mathrm{S}_{\mathrm{EV\ t-1}} + \eta_{\mathrm{eff}} \mathrm{P}_{\mathrm{t}}^{\mathrm{GBEV}} - \frac{1}{\eta_{\mathrm{eff}}} \mathrm{P}_{\mathrm{t}}^{\mathrm{BLEV}}, \quad (4)$$

$t \in \{1,2,..,23\}$

$$S_{EV\ 1} = S_{EV\ 24} + \eta_{eff} P_1^{GBEV} - \frac{1}{\eta_{eff}} P_1^{BLEV} \quad (5)$$

$$u_{DC}^t + u_C^t <= 1, \forall t \quad (6)$$

$$0 \le P_t^{GBEV} \le b_{max} u_C^t * \beta_t, \forall t \quad (7)$$

$$0 \le P_t^{BLEV} \le b_{max} u_{DC}^t * \beta_t, \forall t \quad (8)$$

$$0.2E_{max} \le S_t \le 0.8E_{max}, \forall t \quad (9)$$

$$u_{DC}^t, u_C^t \in \{0,1\}, \forall t \quad (10)$$

$$\boxed{\begin{array}{ll} S_{EV\ t_{SEV}} \ge 0.6 * E_{max} & (11) \\ S_{EV\ t_{lEV}} \ge S_{EV\ t_{SEV}} * \alpha & (12) \end{array}}$$

Residential

$$\beta_t = \begin{cases} 0 & t_{lEV} \le t \le t_{sEV} \\ 1 & Another\ Case \end{cases} \quad (13)$$

II. Constraints / PV System

$$E_t^{PV} = P_t^{PL} + P_t^{PB} \; \forall \, t \quad (15)$$

$$E_t^{PV} = \eta_{eff}^{pv} A_{pv} I_{rt} \big(1 - 0.005(T_t^a - 25)\big) \; \forall \, t \quad (14)$$

$$SOC^{LO} \leq SOC_t \leq SOC^{UP} \,, \forall \, t \quad (16)$$

$$SOC_t^{BPV} = (1 - \beta \;)(\eta^{CC}\eta^{C} \, P_t^{PB} + \eta^{Bin}\eta^{CC} \, \eta^{C} P_t^{GB} - \frac{P_t^{BL}}{\eta^{Bin}\eta^{CC} \, \eta^{D}}) \; \forall \, t \quad (17)$$

$$u_{PVDC}^{t} + u_{PVC}^{t} = 1, \forall \, t \quad (18)$$

$$0 \leq P_t^{GBPV} + P_t^{PBPV} \leq b_{maxPV} u_{PVC}^{t} *, \forall \, t \quad (19)$$

$$0 \leq P_t^{BLPV} \leq b_{maxPV} u_{PVDC}^{t}, \forall \, t \quad (20)$$

II. Constraints / HVAC System (Industrial)

$$\theta_{max}\,°C \leq \theta_t^{in} \leq \theta_{min}\,°C \;\; \forall\, t \tag{6}$$

$$\theta_t^{in} = \alpha\theta_{t-1}^{in} + \beta\,\theta_{t-1}^{ext} + \gamma\,P_{nom}^{AC}\,S_{t-1}^{AC} \quad \forall\, t \tag{7}$$

$$\theta_t^{in} \geq \theta_{max} - My_t \;\; \forall\, t \tag{8}$$

$$\theta_t^{in} \geq \theta_{min} - Mw_t \;\; \forall\, t \tag{11}$$

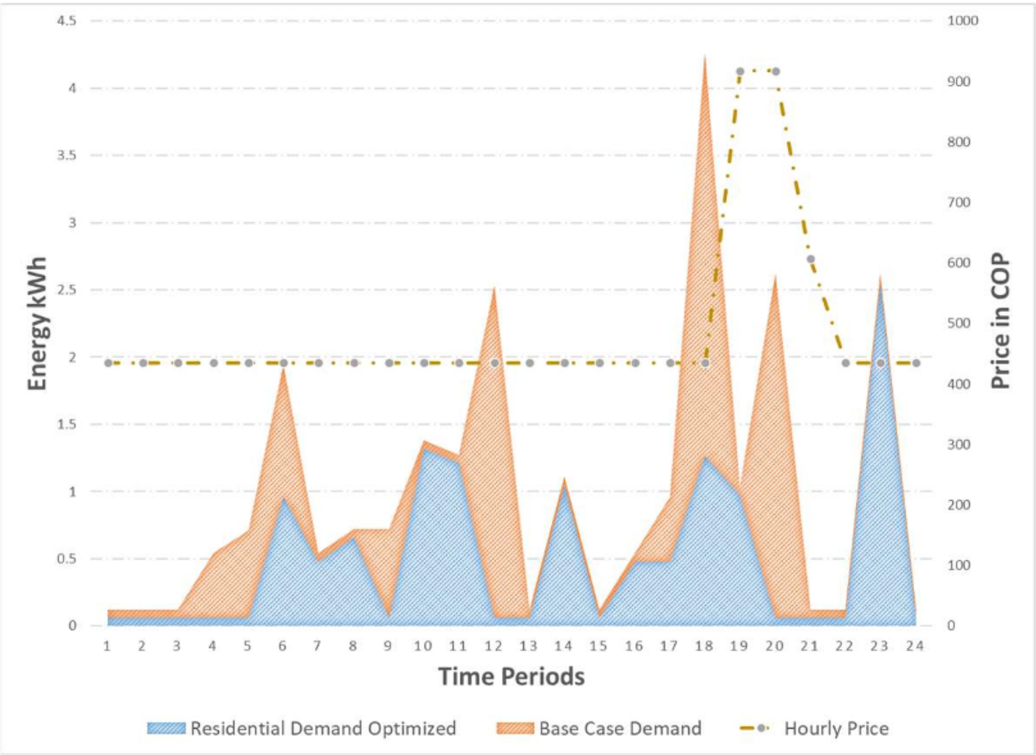
$$S_{t-1}^{AC} \leq w_t \;\; \forall\, t \tag{12}$$

$$y_t + w_t + S_t^{AC} \leq 1 \;\forall\, t \tag{13}$$

$$y_t = \begin{cases} 1 & \text{si } \theta_t^{in} < \theta_{max} \\ 0 & \textit{Another Case} \end{cases} \tag{14}$$

$$w_t = \begin{cases} 1 & si\ \theta_t^{in} < \theta_{min}\ \ o\ \ S_{t-1}^{AC} = 1 \\ 0 & \text{Another Case} \end{cases} \tag{15}$$

III. Results - Residential



Load Shifting

56 % Daily Load Shifted

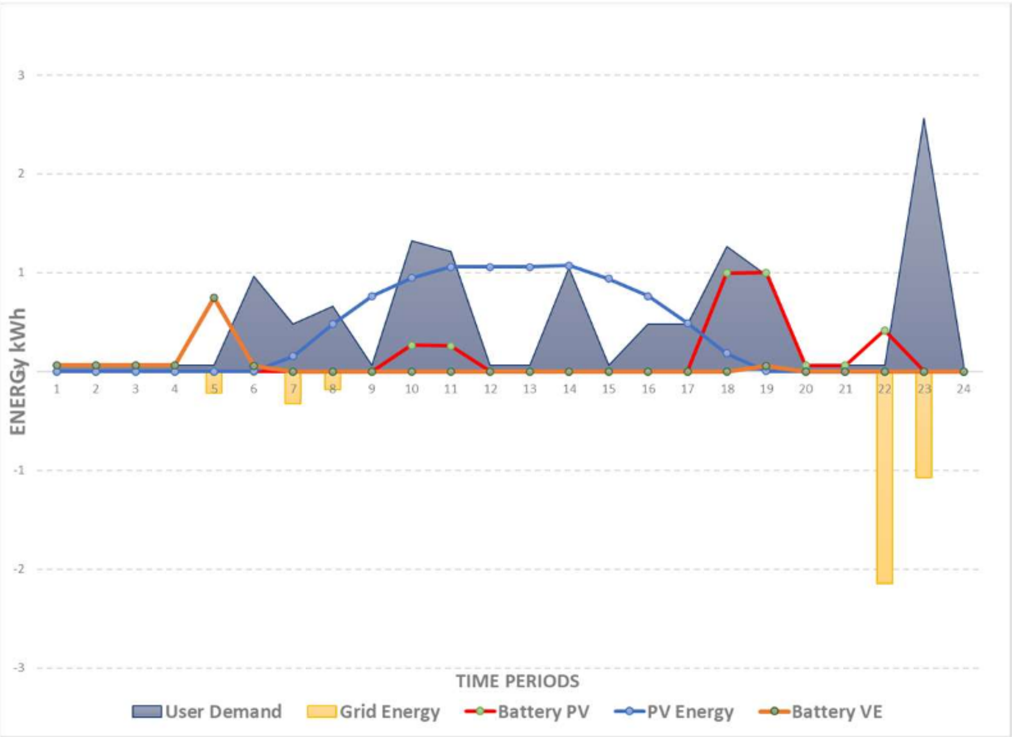
Peak Hours

23 % de Load shifted between critical hours 18 – 21

Daily Price

18.1% of Daily Savings

III. Results – Residential – 2d



Storage Systems

13 % of the Daily Demand

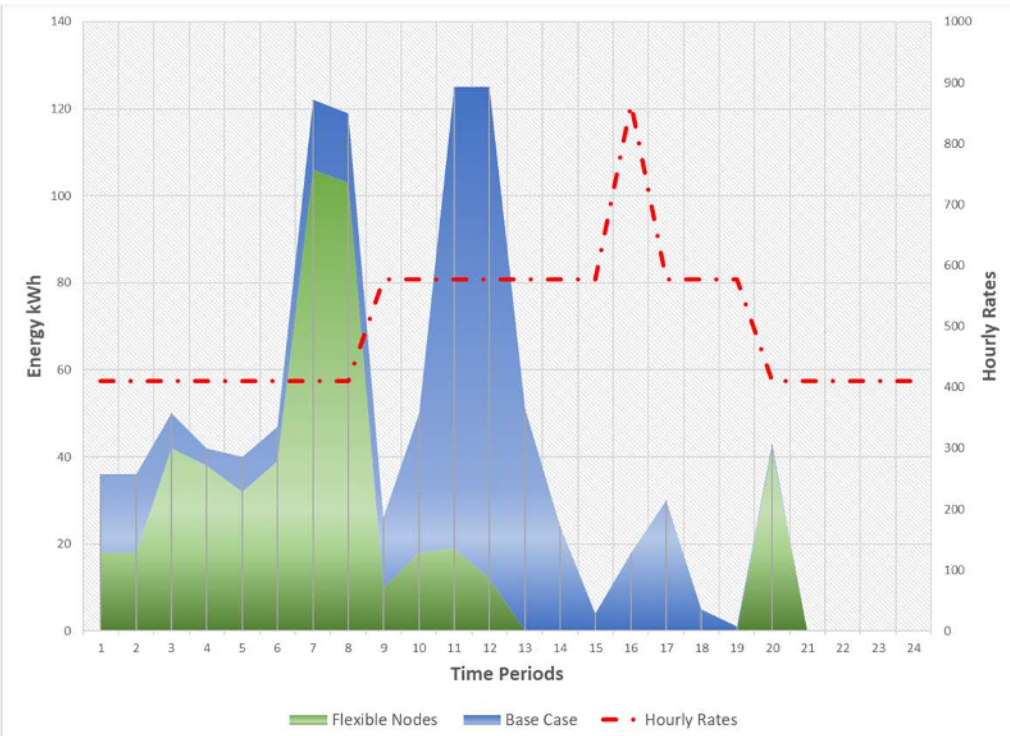
PV System

41 % of Daily Demand

Daily Price

73 % of Daily Savings

III. Results - Industrial



Load Shifting

68 % Daily Load Shifted

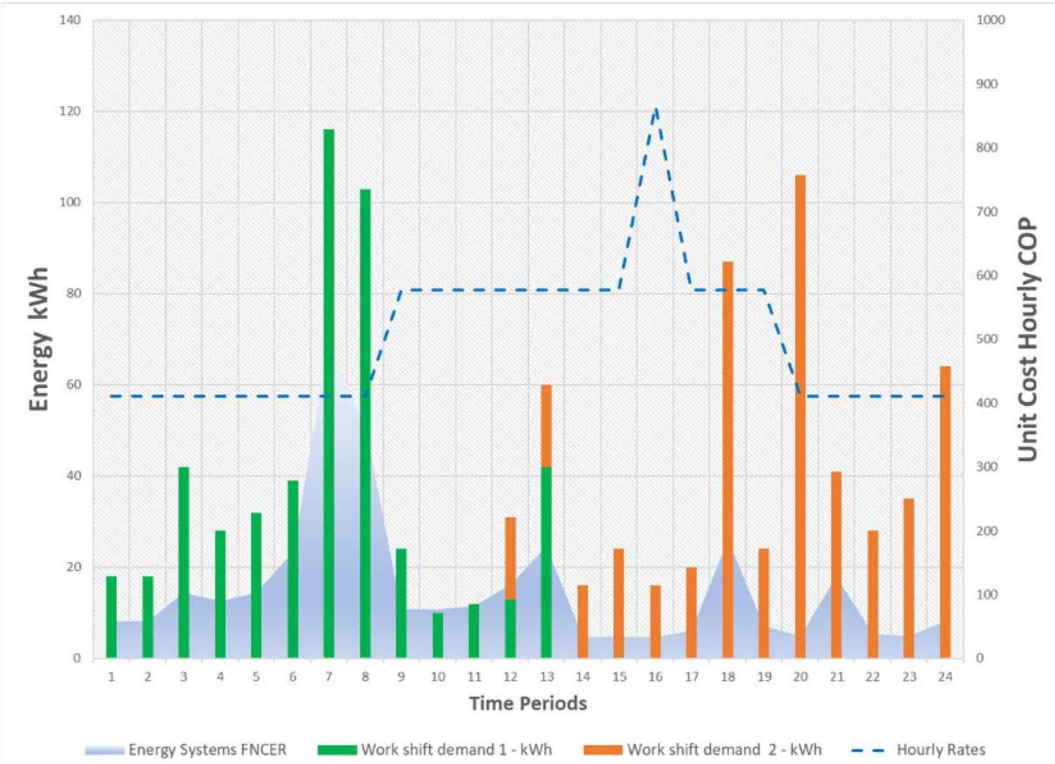
Peak Hours

68 % de Load shifted between critical hours 9-19

Daily Price

22% of Daily Savings

III. Results – Residential – 2d



54% Energy Reduction in HVAC

Storage Systems

28 % of the Daily Demand

PV System

8.9 % of Daily Demand

Daily Price

47 % of Daily Savings

IV. Conclusion

01 Daily energy consumption provides optimal behavior during peak hours for both sectors, with provision for transferring loads at lower cost hours and savings of up to 22%.

02 The possibility of using hourly electricity rates to displace pollution at different times of the day was demonstrated, in some scenarios with a 54% decrease in the daily carbon footprint

03 The inclusion of storage systems with injection of photovoltaic systems, positively impacts the benefit of saving the total daily cost in the residential sector at a rate of 43% with installation area sensitivities.

V. Contributions

The objective of modifying consumption patterns of the residential and industrial users of the CREG 015 resolution as a DSM program, is analyzed for the first time with the perception of a decrease in the payment.

V. Questions