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Dynamic Incentive Design for DEMAND RESPONSE in Energy System MicroGrids

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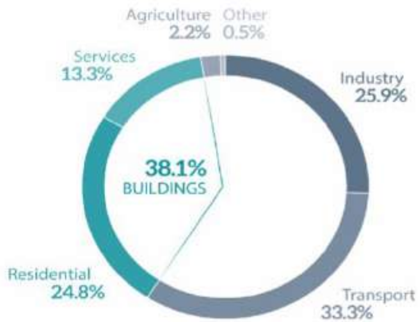
Motivation: Supply of Security Problem

Therefore, $Demand_t > Supply_t$



Data source: Eurostat, 2014.

Demand Response Programs (DRP)

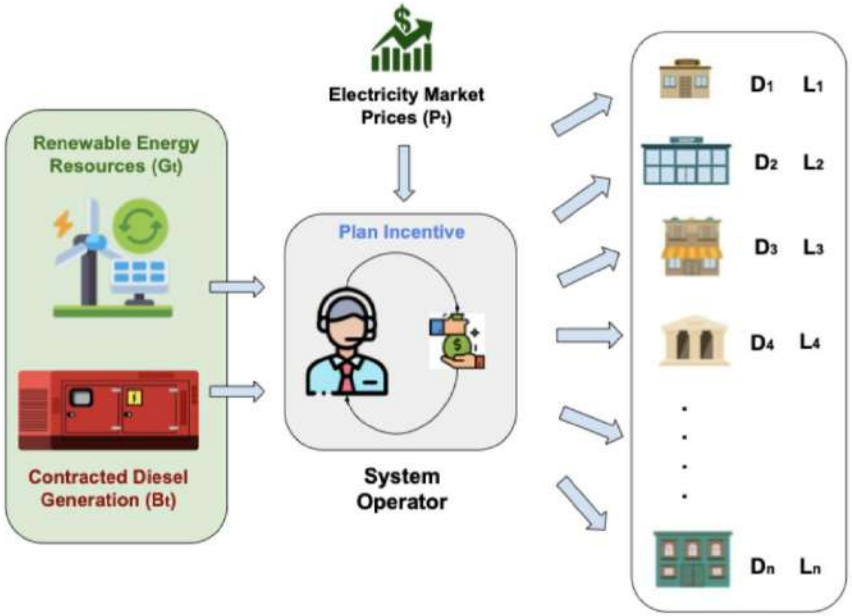
But, traditional **DRP**:

- Offer **static incentives** broadcast uniformly to all consumers.
- Fail to account **consumer heterogeneity**.

- Ineffective load shifting,
- Reduced consumer participation,
- Inefficient grid balancing during critical shortages.

Personalized, adaptive Strategies

Problem Settings - A MicroGrid



MILP Baseline :

$$\text{Maximize} \quad \sum_{i=1}^{n}[P_t(D_{it} - \mathbf{E}[\Delta D_{it}]) - I_{it}\mathbf{E}[\Delta D_{it}]] - C.B_t \qquad (1)$$

$$\text{Subject to} \quad \Delta D_{it} = L_i D_{it}, \qquad (2)$$

$$\mathbf{E}[\Delta D_{it}] = p_{it}\Delta D_{it} \geq 0, \qquad (3)$$

$$p_{it} = f(I_{it}), \qquad (4)$$

$$\sum_{i=1}^{n}(D_{it} - \mathbf{E}[\Delta D_{it}]) = G_t + B_t, \qquad (5)$$

$$0 \leq B_t \leq ((\sum_{i=1}^{n} D_{it}) - G_t) \qquad (6)$$

$$0 \leq I_{it} \leq I_t^{max} \qquad (7)$$

Our Approach : Physics Informed GLM UCB Bandit Framework

A Multi-Bandit Multi-Arm setting: For every bandit (or building), there are K arms (incentives)

$$I_{it} = \{0, \frac{1}{K-1} I_t^{max}, \frac{2}{K-1} I_t^{max}, \cdots, I_t^{max}\}$$

Each arm has a reward distribution:

$$R_{it}^k | I_{it}^k = P_t(D_{it} - \mathbf{E}[\Delta D_{it}]) - I_{it}^k \mathbf{E}[\Delta D_{it}]$$
$$= P_t(D_{it} - f_{it}^k \Delta D_{it}) - f_{it}^k I_{it}^k \Delta D_{it}$$

f_{it}^k is a realization of F_{it}^k and $F_{it}^k \sim Bernoulli(\theta_{it}^k)$, $\tilde{\theta}_{it}^k = \frac{\exp(\beta_{0t} + \beta_{1t} I_{it}^k)}{1 + \exp(\beta_{0t} + \beta_{1t} I_{it}^k)}$

$$UCB_k = Q_k + \mathcal{U}_k \quad \begin{cases} Q_k = \mathbf{E}[R_{it}^k | I_{it}^k] \\ \mathcal{U}_k = stddev(R_{it}^k | I_{it}^k) \end{cases}$$

$$argmax_k \quad UCB_k - \lambda \left| B_t - (\sum_{i=1}^{n}(D_{it} - \mathbf{E}[\Delta D_{it}]) - G_t) \right|$$