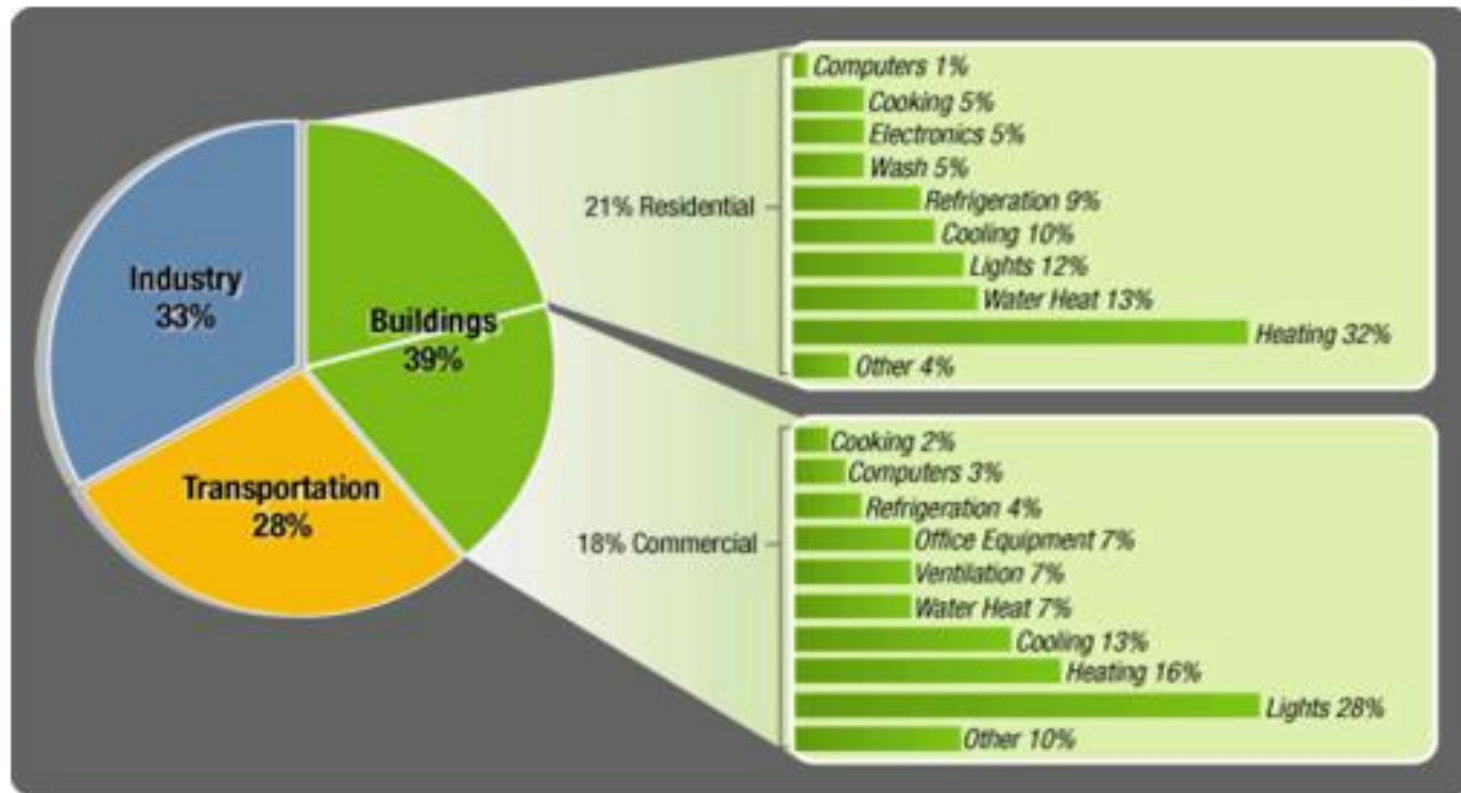# Vision: **Policy-Driven Distributed and Collaborative Demand Response in Multi-Domain Commercial Buildings**

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and
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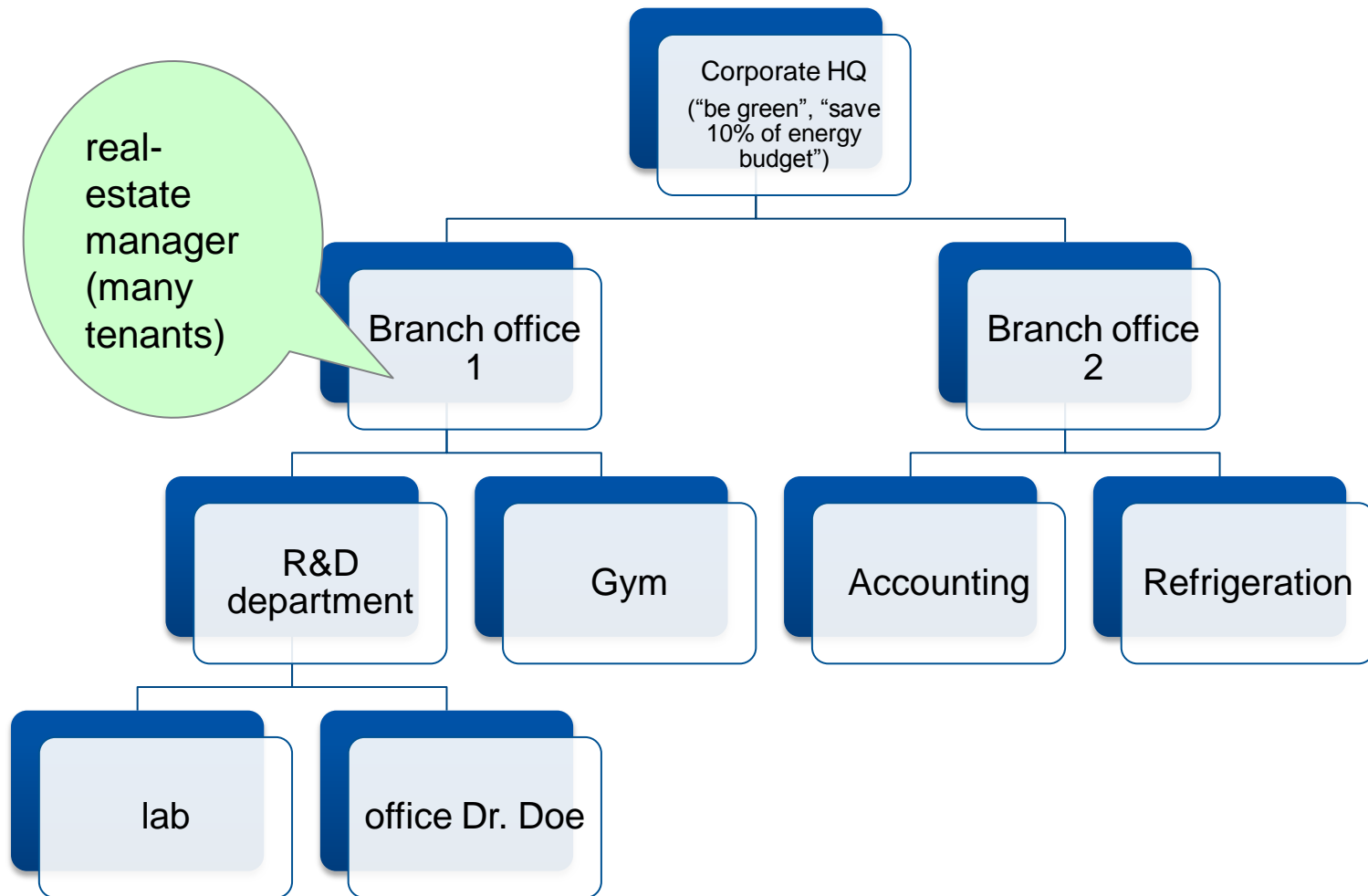
Commercial & residential building energy usage

Demand Response in Commercial Buildings & Campuses

- Need to move beyond centralized control of limited "high-load" devices to
  - Accommodate different policy domains & administrative hierarchies
    - financial incentives need to be **local**
    - avoid annoying users with inflexible policies
      - e.g., important lab experiments or "need dishes for dinner"
  - Automated incorporation of devices in the DR paradigm
    - load management
    - convenience & comfort (room temperature, boot time) vs. cost
  - Flexible, pricing-based DR (instead of simple peak load control)
  - Delegate down *objectives* and trade-offs (costs), not *commands*
    - and provide feedback to device and user

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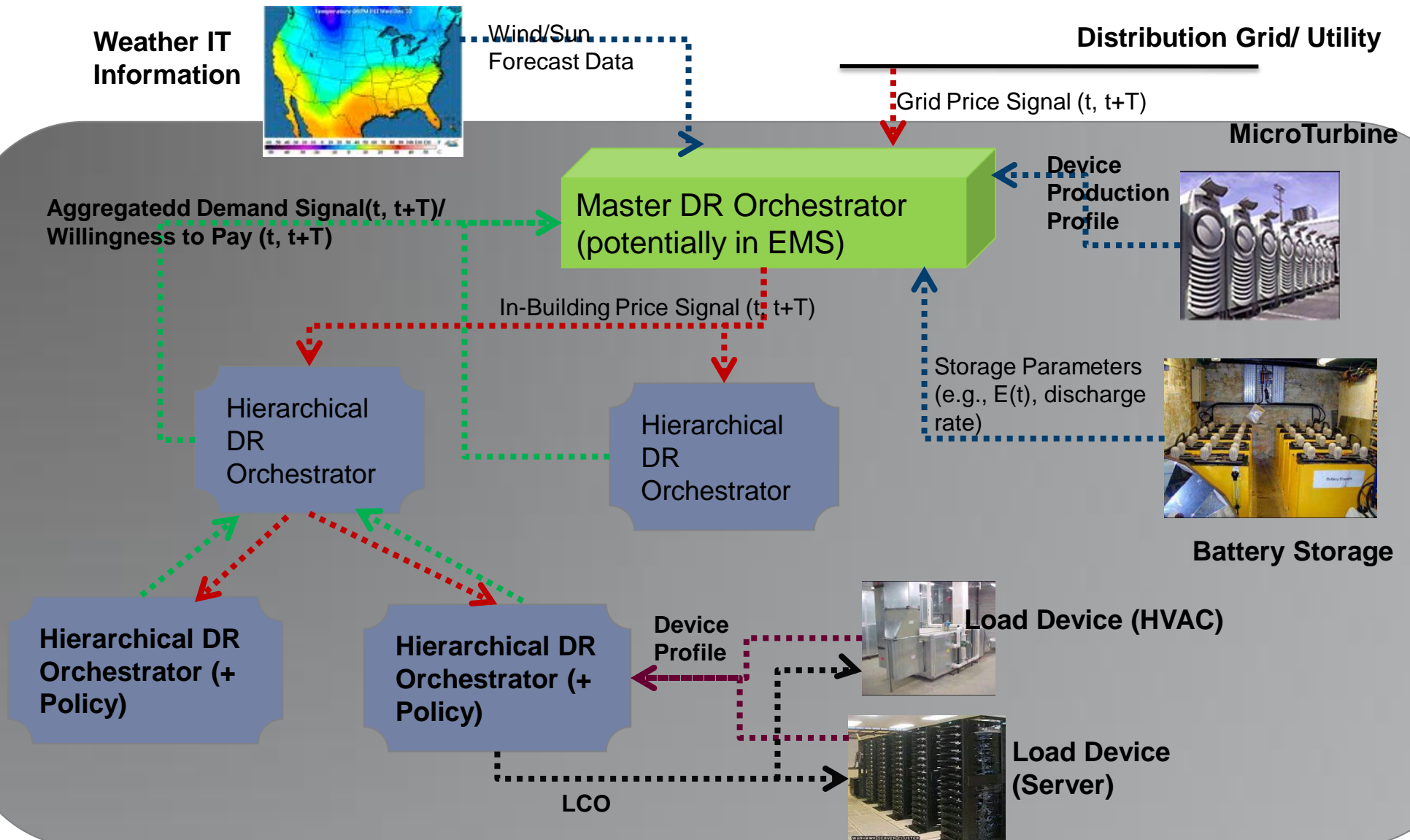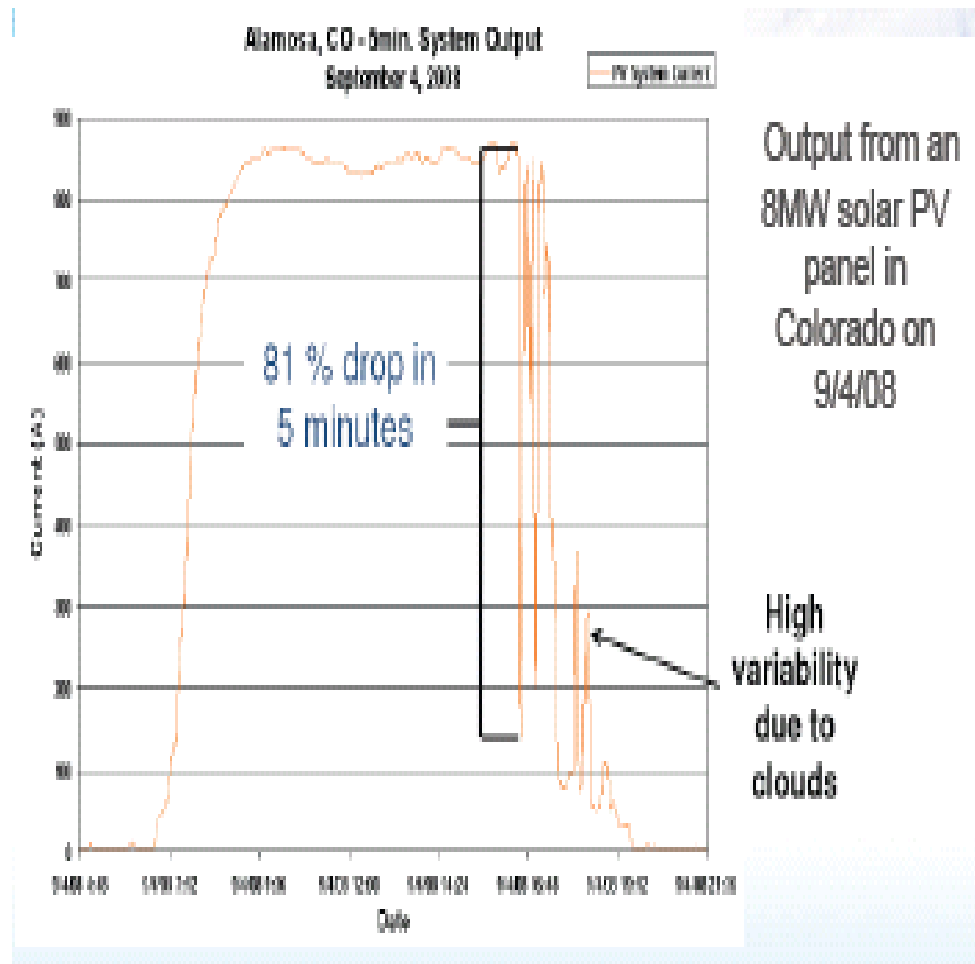
Three Models for Demand Adaptation

Centralized
- administrator-driven adaptation

DRACHMA
- hierarchical
- owner/user policy-driven adaptation

Decentralized
- device-centric adaptation

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Hierarchies of control

DR For Commercial Buildings: The Problem Space

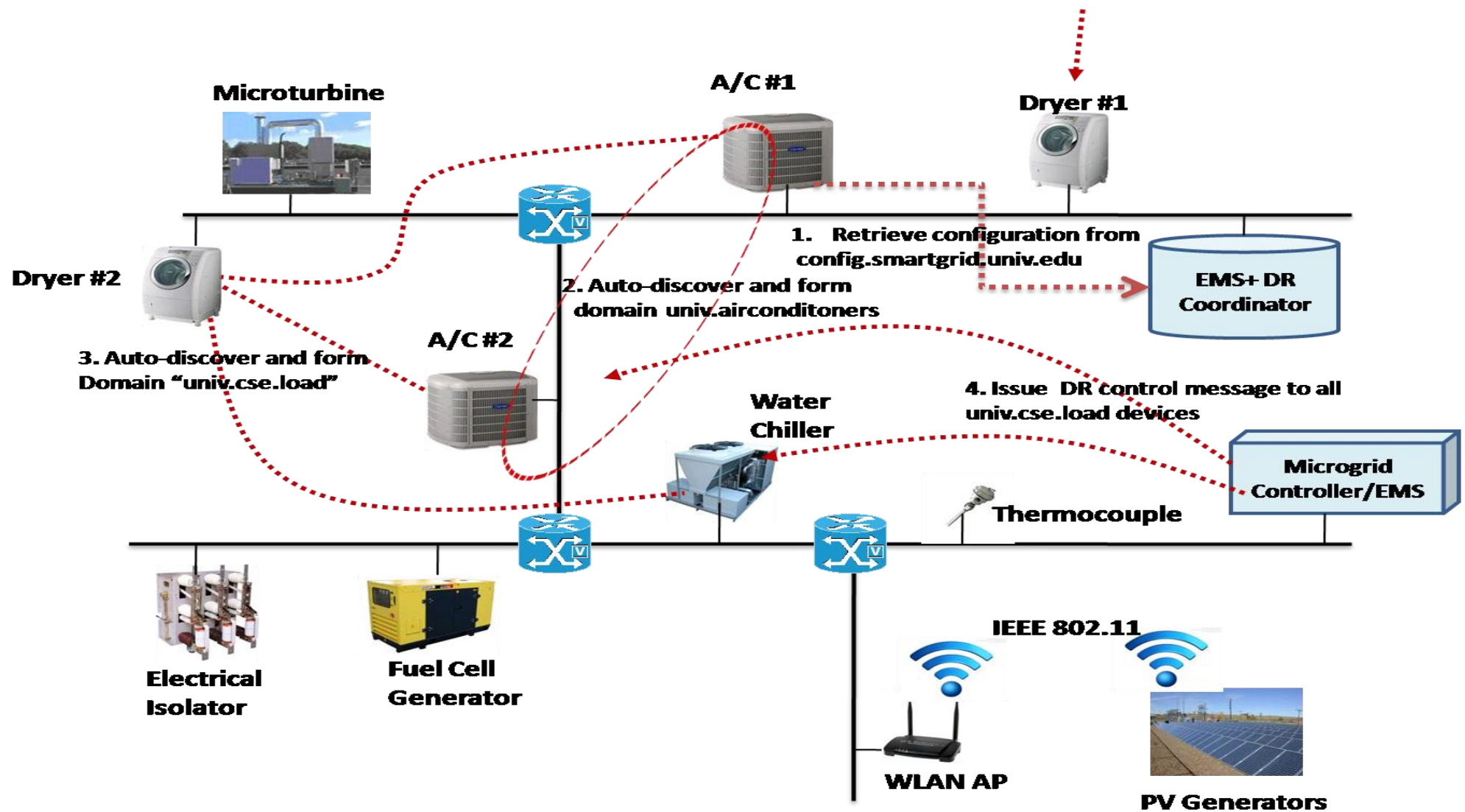| Feature	Residential	Commercial	Campus
Typical DER Resources	PVs, CHP	PVs, CHP, micro-turbine	PVs, micro-turbine, capacitor banks
Major loads	HVAC, lighting, fridge, pool, washing machine, dishwasher	HVAC, lighting, office equipment, IT servers, refrigeration	HVAC, lighting, elevators, lab equipment, IT servers
# of DR Loads	O(10)	O(100)	O(1000)
Major Distinguishing Issues		Multiple operational domains (different organizations/companies)→ distributed DR; High device heterogeneity	Potentially multiple operational domains (univ. departments); differentiated priority among domains to DER resources

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DRACHMA: The Hierarchical DR Model

Weather IT Information

Wind/Sun Forecast Data

Distribution Grid/ Utility

Grid Price Signal (t, t+T)

MicroTurbine

Master DR Orchestrator (potentially in EMS)

Device Production Profile

Aggregatedd Demand Signal(t, t+T)/ Willingness to Pay (t, t+T)

In-Building Price Signal (t, t+T)

Storage Parameters (e.g., E(t), discharge rate)

Hierarchical DR Orchestrator

Hierarchical DR Orchestrator

Battery Storage

Hierarchical DR Orchestrator (+ Policy)

Hierarchical DR Orchestrator (+ Policy)

Device Profile

Load Device (HVAC)

Load Device (Server)

LCO

Generation variation

Challenge 1: Device and Domain Autoconfiguration

Challenge 2: Distributed DR Adaptation

Three key technical components
- **Stochastic Optimization**: Express the uncertainty in renewable production & demand as stochastic variables.

- **Optimal Control: D**erive key price-inflexion points for the next few minutes to hours.

- **Distributed Utility Maximization:** Set prices to maximize utility & make the algorithms implementable in a practical building environment

Modified Time-Horizon Optimization

$$\text{maximize} \int_{t_0}^{T} f(s(t), c(t), t)\,dt$$

$$\text{subject to } \frac{ds}{dt} = g(s(t), c(t), t), \text{ with } s(t_0) = s_0; \ s(T) = s_T$$

Key Challenges in Building This Distributed Adaptation Framework

- Make Framework work *without explicitly knowing demand functions* (distributed operation)
- Incorporate Consumption Constraints (**6 Different Load Types**)
- Factor in **underflow/overflow constraints** on storage
-

Conventional Instantaneous Optimization

$$\max \sum_{n \in X} U_n(A_{n1}, C_{n1}(t)) - \sum_{i} P_i(A_i, C_i(t)) * \lambda_i \qquad (1)$$

$$\text{such that } \mu = true' \ \mu \in \Gamma,$$

Maximize user comfort—utility functions

Minimize Energy Price

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Challenge 3: Expressing Composite Load/Adaptation Models

Today - BACnet
- Load Control Object (LCO): generic mechanism for
  - Transmission of load shed signals (scheduled, current)
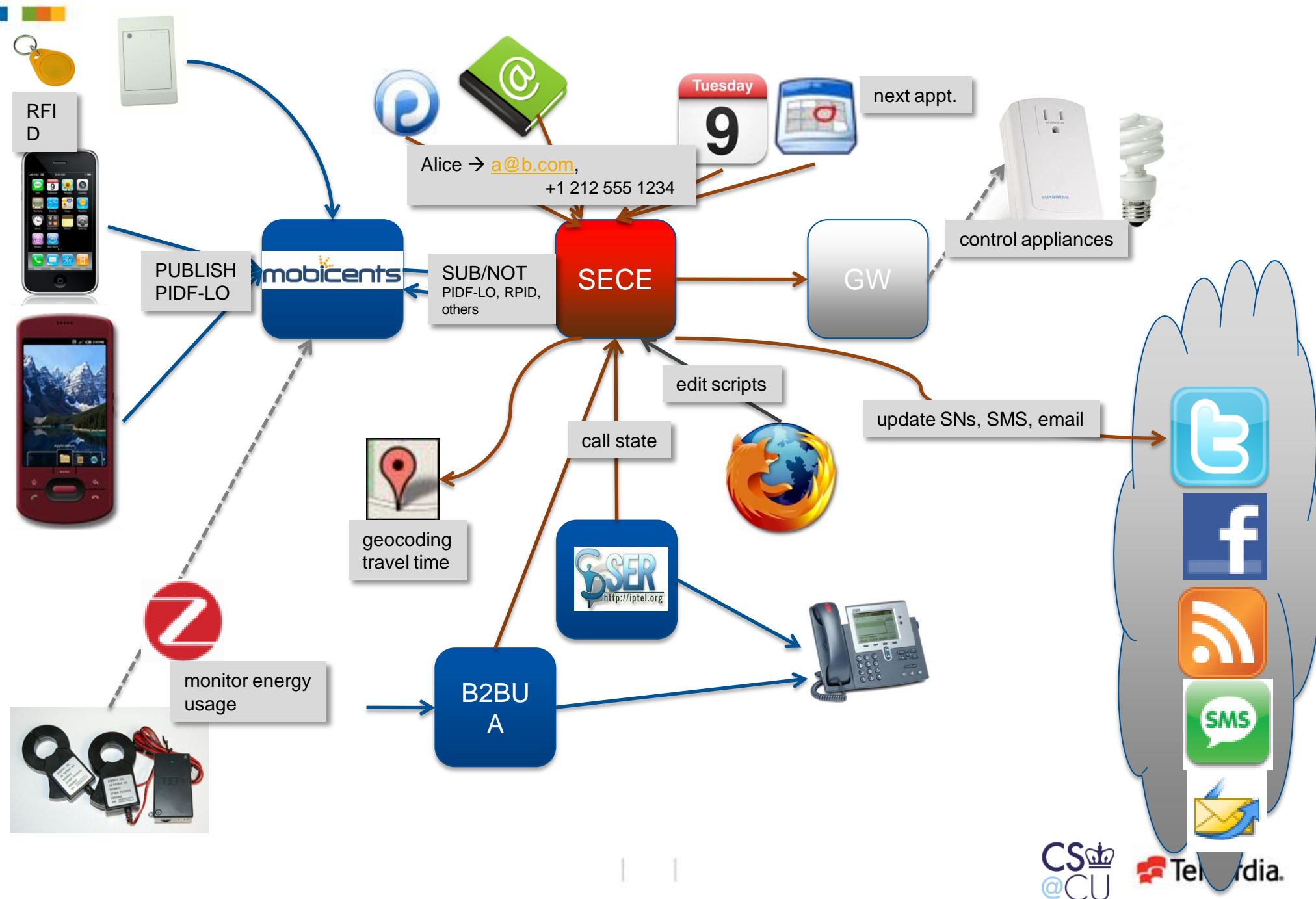 - Notification of compliance to load shed signals

DRACHMA
- hierarchical DR controllers to signal the **aggregate** demand and DR capabilities of sub-trees of heterogeneous devices

Future
- capture the price vs. consumption characteristics and constraints of a collection of heterogeneous devices

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Challenge 4: Automate actions

RFID

PUBLISH PIDF-LO

Alice → a@b.com,
                        +1 212 555 1234

next appt.

SUB/NOT
PIDF-LO, RPID,
others

SECE

GW

control appliances

update SNs, SMS, email

edit scripts

call state

geocoding
travel time

monitor energy
usage

B2BUA

Conclusion

- Need to decentralize control → reflect local organization
- Automate:
    - local and global objectives → local behavior
    - avoid manual actions → input from external data sources