DYNAMIC GRID

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Transactive Energy Microgrids

Integrating Load Flexibility into Microgrids for Better Allocation of Resources

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KAY AIKIN, co-founder,
CEO, Introspective Systems
Dynamic Grid

Transactive Energy Microgrids

Microgrids and Networked Microgrids using a one-way Economic Dispatch Value (EDV) to balance and allocate resources efficiently.

Research and Development

5 Department of Energy (DOE) projects

- Fractal electrical grid architectures
- AI powered Transactive Energy controls
- Smart Ledger value transfer
- Enhanced Geothermal evaluation, monitoring and control
- Dynamic Grid Pricing with Edge Load Responsive Device Control

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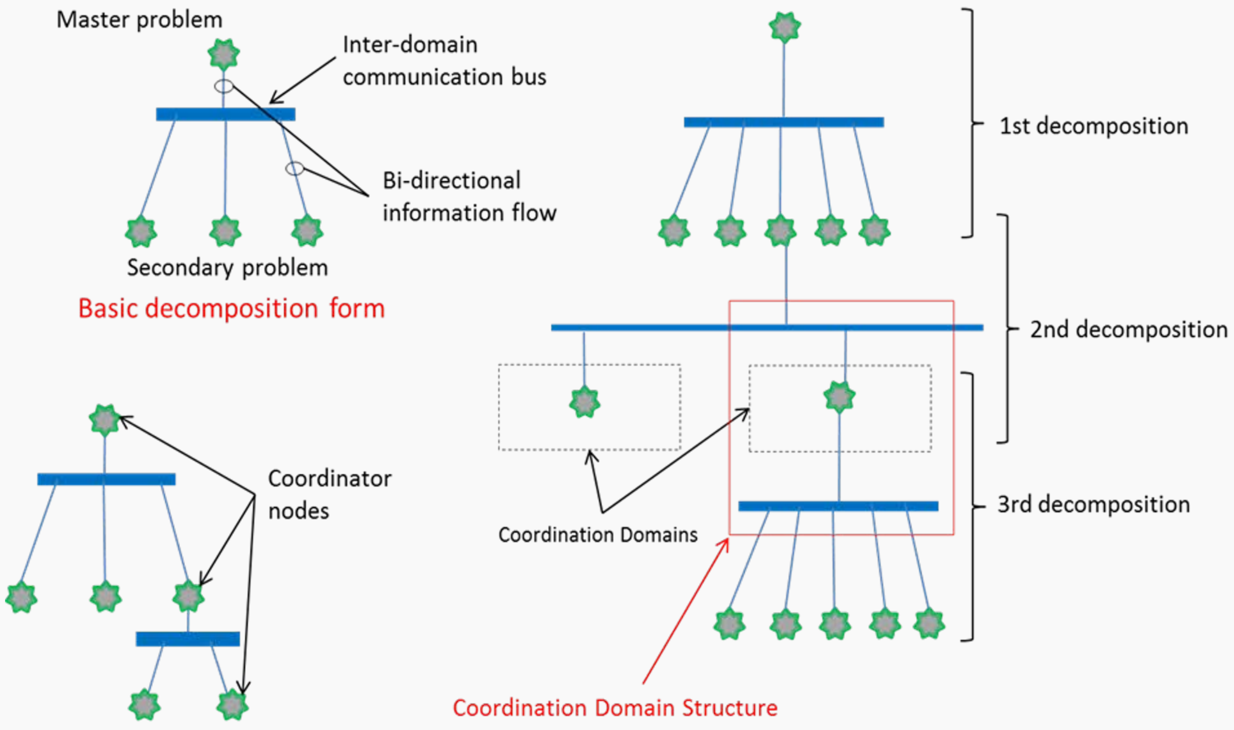
THE ARCHITECTURE

Grid Future State:

Decarbonized, Decentralized and Distributed (D^3)

Path to Full Decarbonization

- High penetration renewable DER
- Beneficial Electrification; electrifying other energy uses
  (EV, space heating, process heat)



GMLC 1.2.1 v0.3 Grid Architecture Specification High DER/DA/STO Reference Architecture, Taft, Etal

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THE CHALLENGES

Grid Future State:
Decarbonized, Decentralized and Distributed (D^3)

Managing;

- Beneficial Electrification
  Broad conversion strategy (EV, Space/process heat)
- Power Quality
  High penetration renewable DER
- Peak Loads
  Storage
  Demand Flexibility

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THE CHALLENGES

Grid Future State:

Decarbonized, Decentralized and Distributed (D^3)

Beneficial Electrification

Broad conversion strategy of fossil fuel energy uses to electricity including, Electrical Vehicles, Space heating/cooling and Industrial process heat.

This is a **policy discussion** with some technology innovation required in the Industrial process heat sector

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THE CHALLENGES

Grid Future State:

Decarbonized, Decentralized and Distributed (D^3)

Power Quality

As we reach high renewable penetrations (>50%), we have a system with dynamic complexity. Currently the system manages this in a centralized fashion. Primary concerns:

- Real-time control and coordination under latency in communications
- Complex computations for system balancing
- System coordination

This is a **technical** discussion with some technology innovation required but most of the technology like smart inverters, SCADA systems, Volt/VAR can handle the power quality problem.

ARE OUR CURRENT POWER QUALITY SYSTEMS BROKEN?

THE CHALLENGES

Grid Future State:

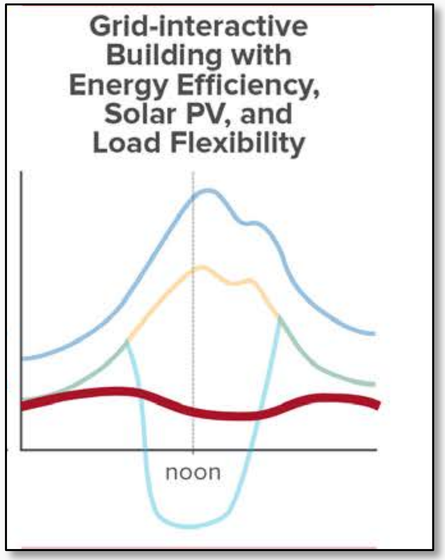
Decarbonized, Decentralized and Distributed (D³)

Peak Loads

As we reach high renewable penetrations (>50%), Temporal interactions between load and variable Distributed Energy Resources (DER) Primary concerns:

- Load Shifting (demand flexibility)
- Storage
- System coordination

This is a **technical** discussion with significant architectural structure decisions and technology innovation required



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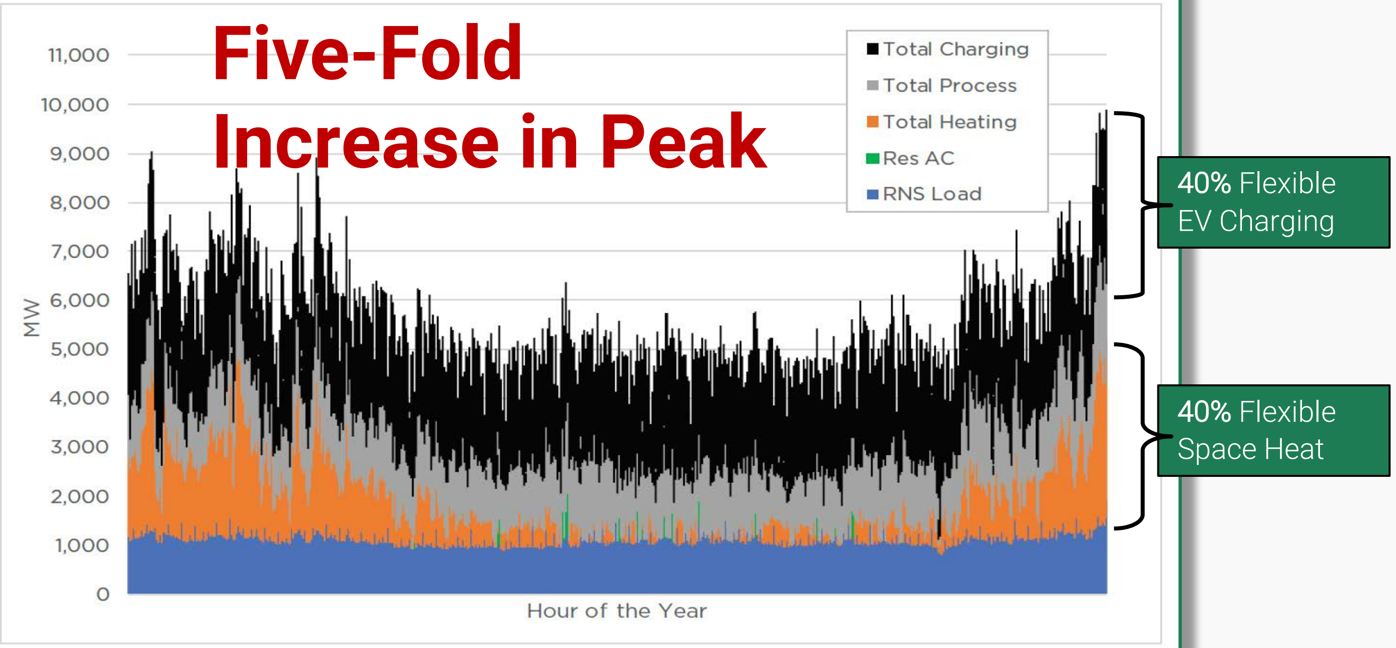
BENEFICIAL ELECTRIFICATION

Challenge: Beneficial Electrification

With the strategic electrification of loads the grid peak will be 3 to 5 times higher

Takeaway:
Major Challenge- but tremendous **Opportunity** to use load flexibility to manage DER variability without massive storage

FIGURE 2-7 | Total Hourly Electricity Use Under Beneficial Electrification



A new Energy Policy Direction For Maine
Rich Silkman, Ph.D. CEO
Competitive Energy Services

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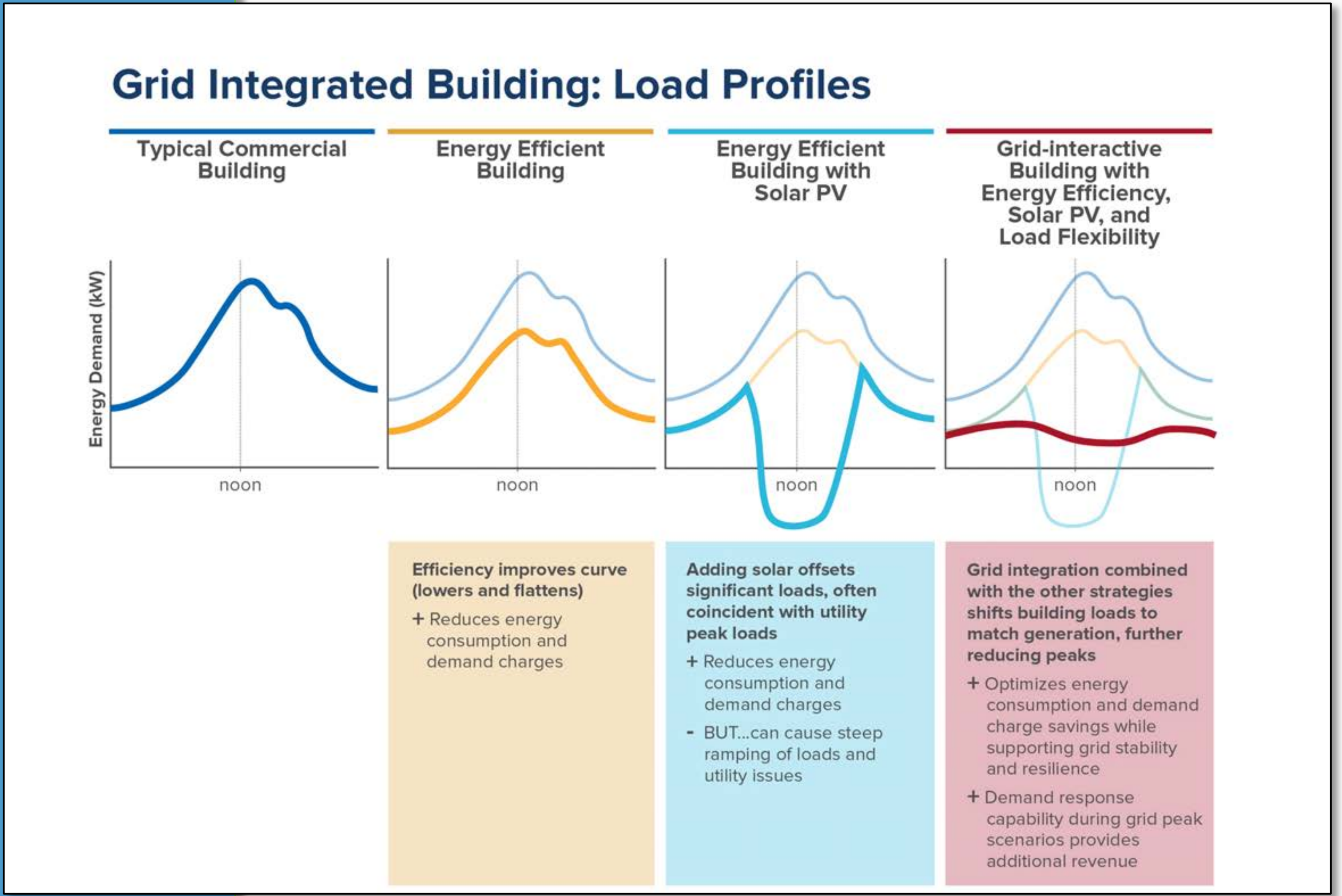
PEAK LOADS

Challenge: Load Shaping

Increases in peak loads and ramping due to Distributed Energy Resources (DER) can be largely mitigated by load shaping.

Opportunity:

Use load flexibility to manage DER variability without large increases in energy storage



Value Potential for Grid Integrated Buildings in the GSA Portfolio, Rocky Mountain Institute p. 10

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VALUE OF DEMAND FLEXIBILITY

Hourly simulation of Texas power system with a high-penetration demand flexibility.

	WITHOUT FLEXIBILITY	WITH FULL FLEXIBILITY	% CHANGE
AVERAGE ENERGY VALUE OF RENEWABLE GENERATION	$8.70/MWh	$11.82/MWh	36% increase
ANNUAL PEAK NET LOAD	58,441 MW	44,354 MW	24% decrease
AMOUNT OF ANNUAL CURTAILMENT	42,405,742 MWh	25,637,233 MWh	40% decrease
AVERAGE MULTIHOUR NET-LOAD RAMP MAGNITUDE	3,898 MW	1,728 MW	56% decrease
ANNUAL SYSTEM-WIDE CARBON DIOXIDE EMISSIONS	31 million tons	24 million tons	23% decrease

"Reinventing Fire"
Rocky Mountain Institute

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Path forward

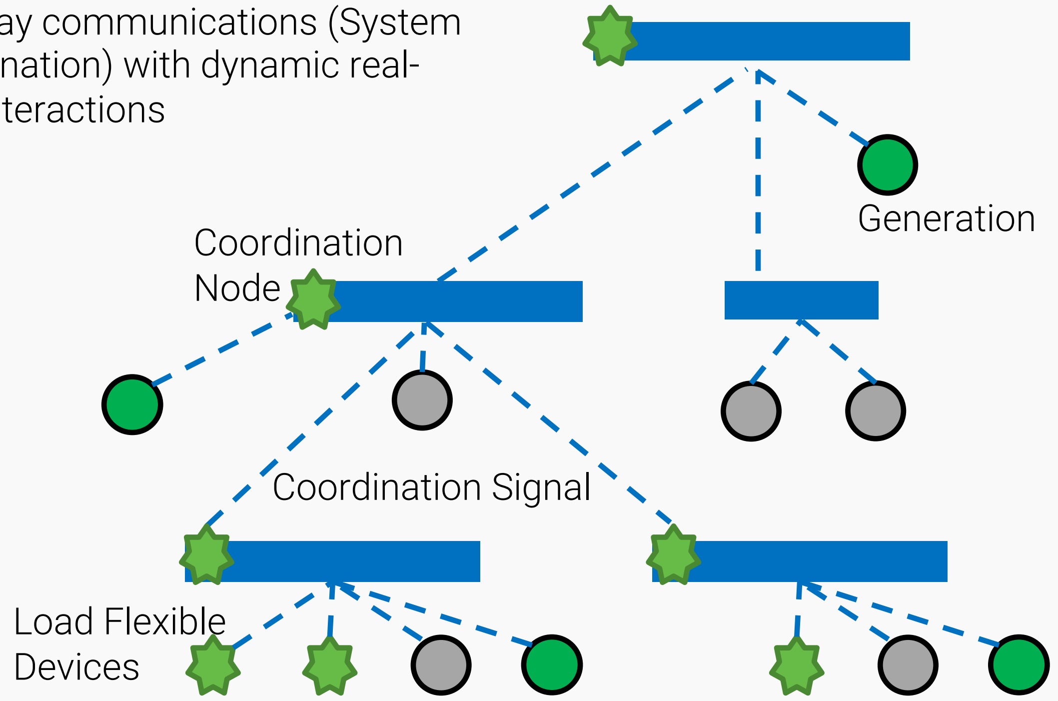
- Layered Decomposition Architecture
- Simplified Coordination Signal (EDV-based on voltage)
- Multi-Agent architecture
- Device Operation based on local data
- Local Agent Optimization (Machine Learning)
- Individual Agents potentially provide multiple services (reliability, capacity, FQ, V/Var, Peak)

Leading to:

Decentralized, Distributed and Collaborative Control Structure

Dynamic Grid Transactive Energy

One-way communications (System Coordination) with dynamic real-time interactions



Opportunity:
Use load flexibility to manage DER variability without large increases in energy storage

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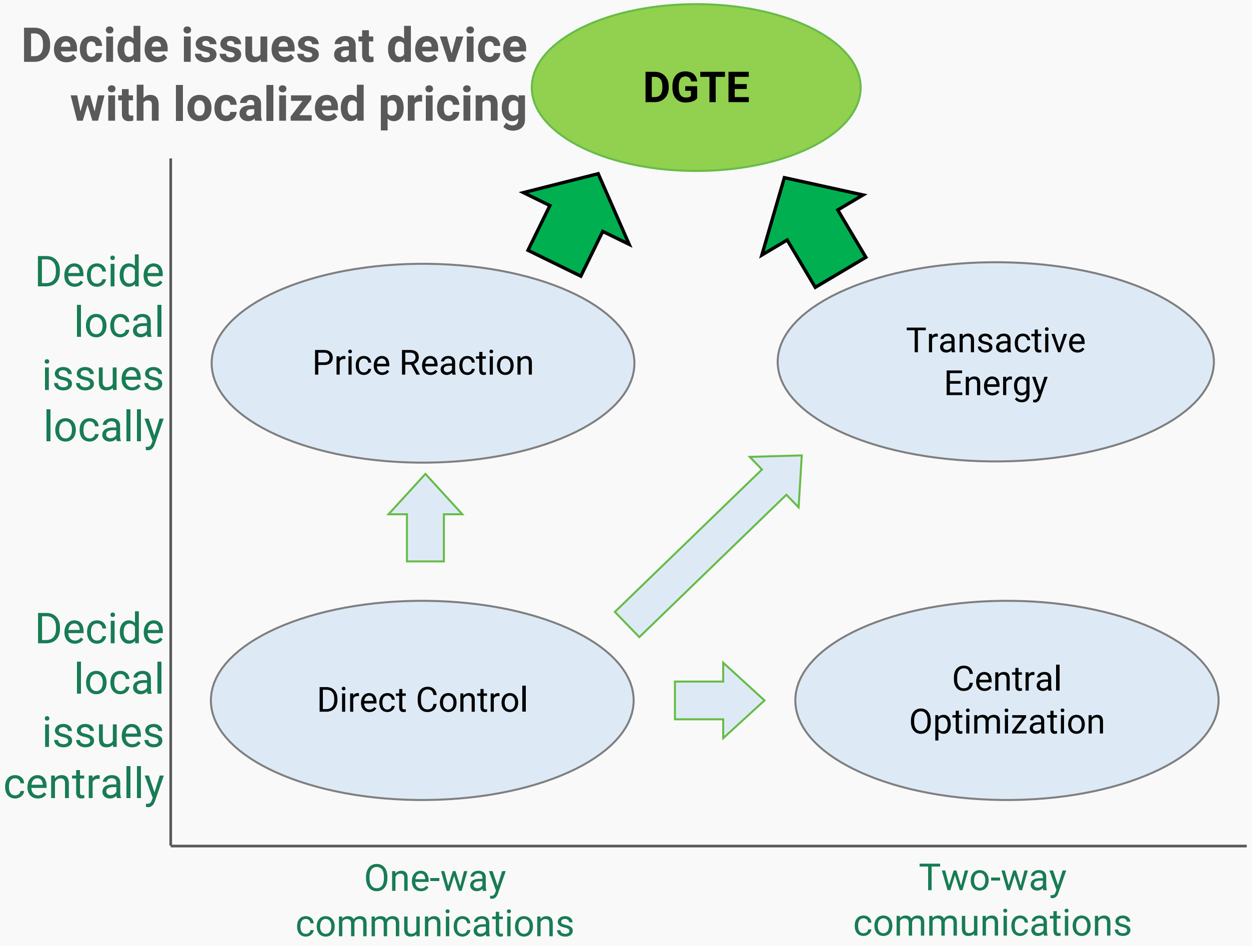
SYSTEM COORDINATION



Adapted From: IEEE Power and Energy Magazine Volume: 14 Issue 3, A Society of Devices: Integrating Intelligent Distributed Resources with Transactive Energy, Koen Kok and Steve Widergren

System Coordination Methods:

- **Direct (Top-Down) Control** (DSM)
- **Central Control/Optimization** (ISO Bulk Power)
- **Price Reaction Control**
- **Transactive Energy (TE)** – Two way (method demonstrated)
- **Dynamic Grid Transactive Energy** – One-way coms with dynamic real-time interactions
  - Autonomous devices (decisions at edge)
  - Layered problem sub-optimization
  - Intelligent gateways develop local dynamic pricing (Economic Dispatch Value-EDV) for reaction by edge devices, EDV is downward only to promote cyber-security and simplicity

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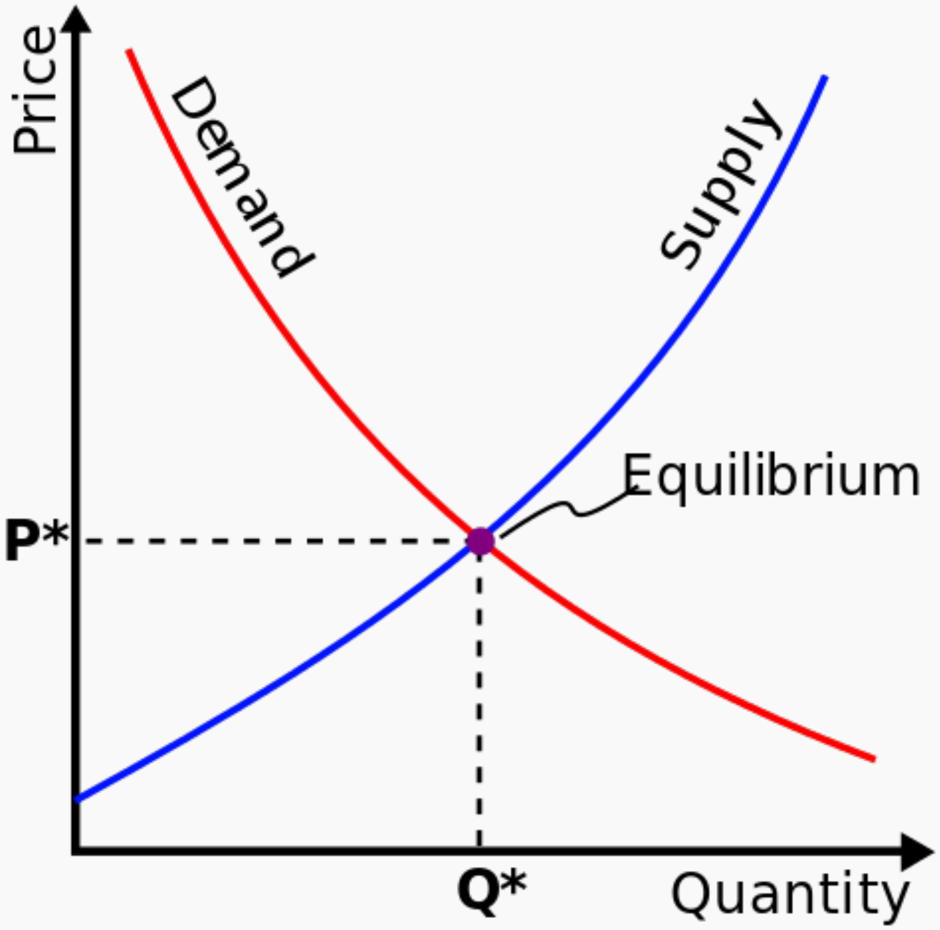
ECONOMICS

Economic Competitive Market:

- Market clearing (two-way communication) is nearly impossible at scale and cyber-insecure
- Law of many prices rather than law of one price
- Market Localization- Each entity sets their own price based upon past price and local environment and needs
- Neither side considers global equilibrium - resulting in competitive equilibrium.



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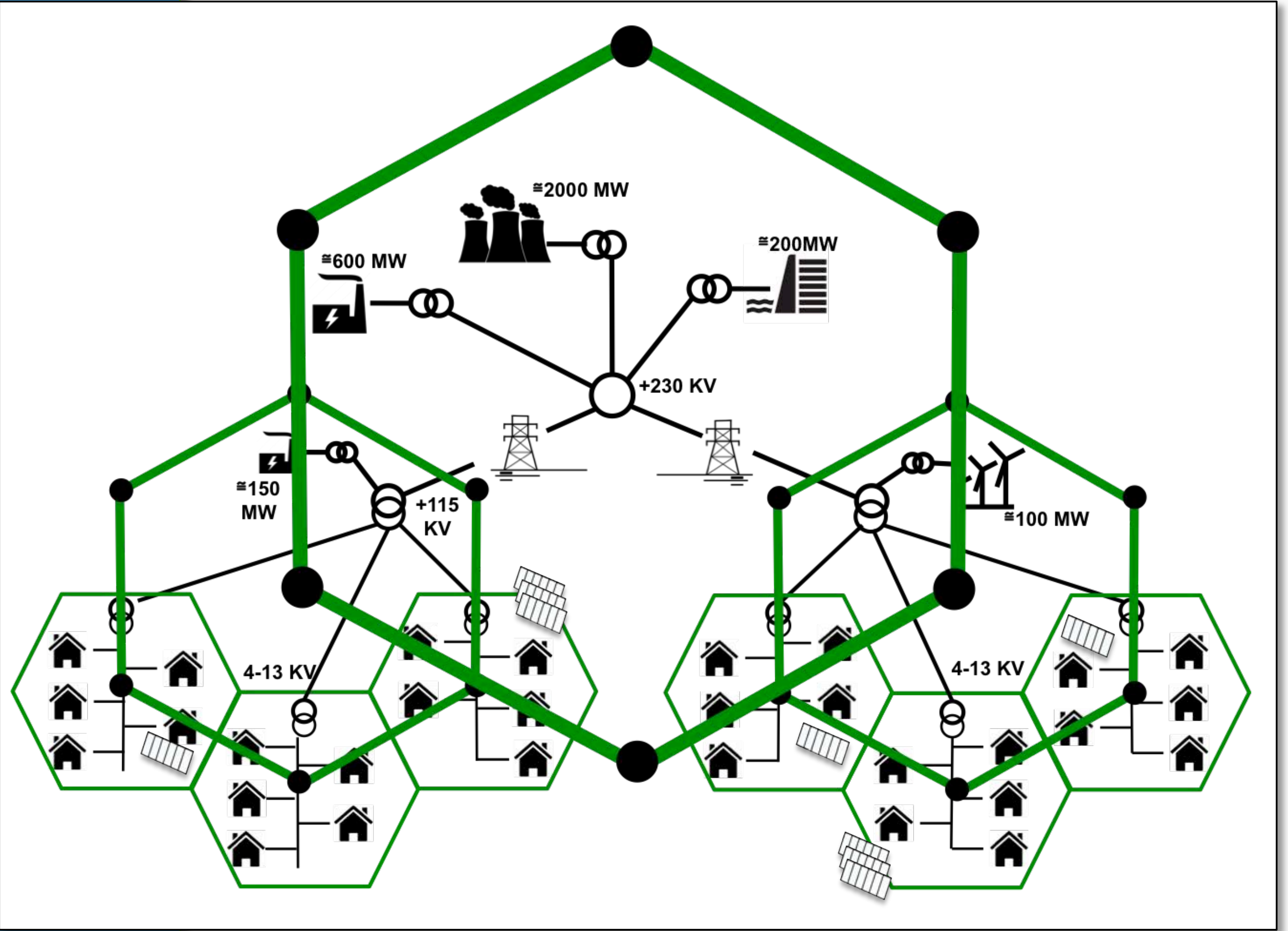
ARCHITECTURE

Layered Networked Microgrids:

Layered microgrids with price coordination

- Fractal (Layered decomposition)
- One-way price responsive (secure)
- Passive feedback (upward response)
- Scales (no complexity bounds)
- Transition path (through microgrids)
- Self-optimizing (Consumer driven)
- No “head nodes” (decisions made by lower entities)



Transactive Energy Microgrids

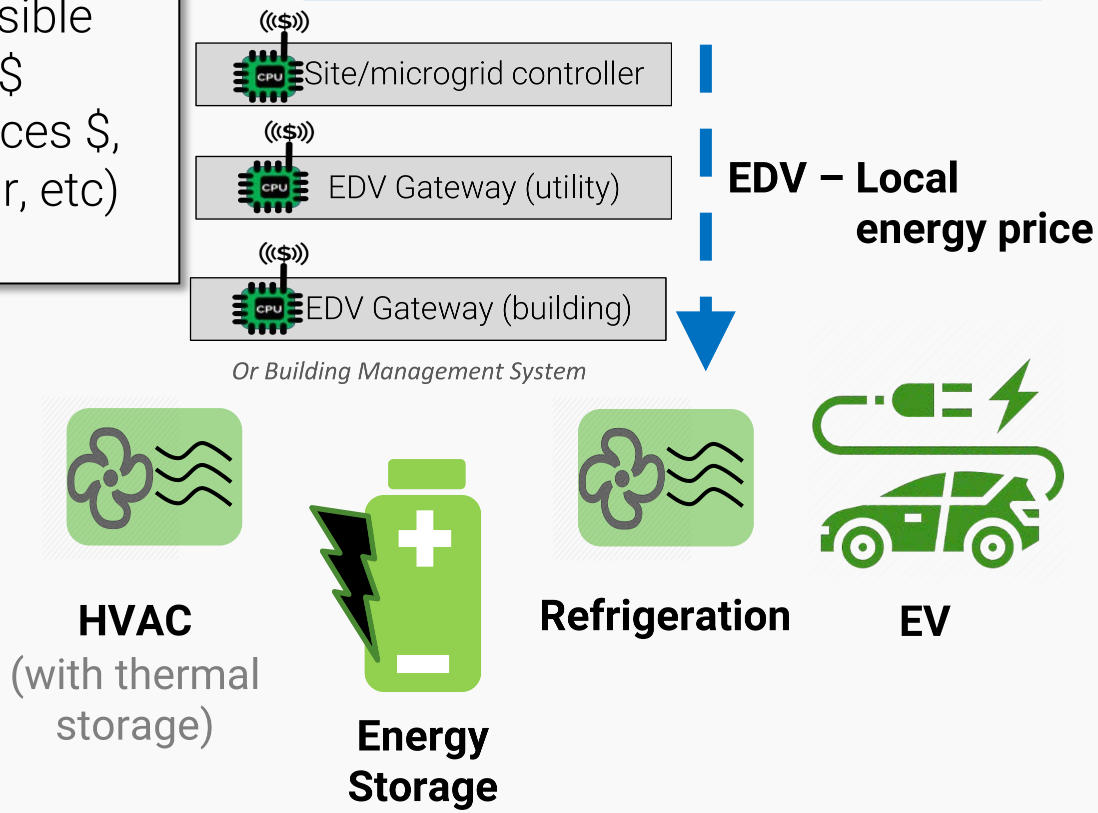
Expand demand response value streams beyond direct load control

- Peak Load (Infrastructure deferral)
- Curtailment (increase RE capacity factors)
- Load Ramp (decrease ramping needs and peaker plants
- Decarbonization (decrease CO^2 across entire energy sector
- Storage (decrease requirements for storage)

EDV= resource $,

Others Possible
+ Capacity $
+ Grid services $,
+ (FQ, V/Var, etc)
+ Carbon

ECONOMIC DISPATCH VALUE



Edge devices operate independently without direct coordination

By responding to EDV, edge devices provide load deferral/load augmentation services to grid for value

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ISLE AU HAUT MAINE

Project Objectives:

The proposed system must meet the following criteria:

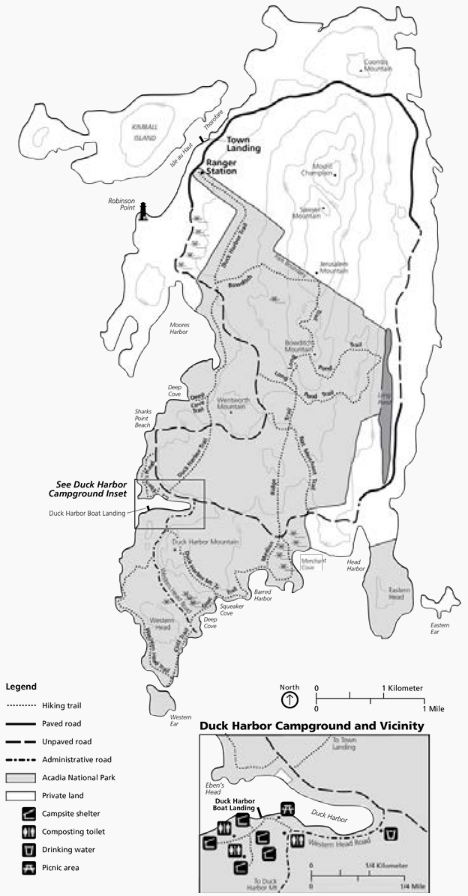
- Maintain power without a grid link (Islandable).
- Keep electricity pricing at or below the current blended price (service charge + energy) including inflation.
- Enable IAHEPCO sufficient monetary funds for operations and maintenance.
- Design a system that is locally maintainable.
- The aim for 100% renewable energy.

95 kW peak load with 37-year-old seven-mile undersea cable ready to fail and 143 households. Large imbalance between summer/winter load. To serve summer load winter supply would be excessive.

300 kWp DC PV and 1 MWh battery.

SOLUTION: Co-optimization financial/systems engineering and controls

- Include up to 20 plus heat pumps with thermal storage to use excess winter generation
- Dynamic Grid's edge-based Intelligent Control System (ICS). It provides an Economic Dispatch Value (EDV) to heat pumps that determine their own optimal dispatch.



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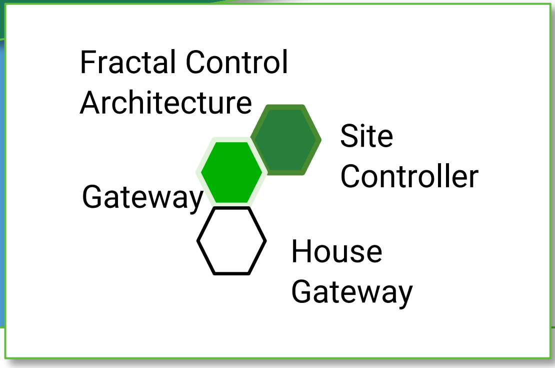
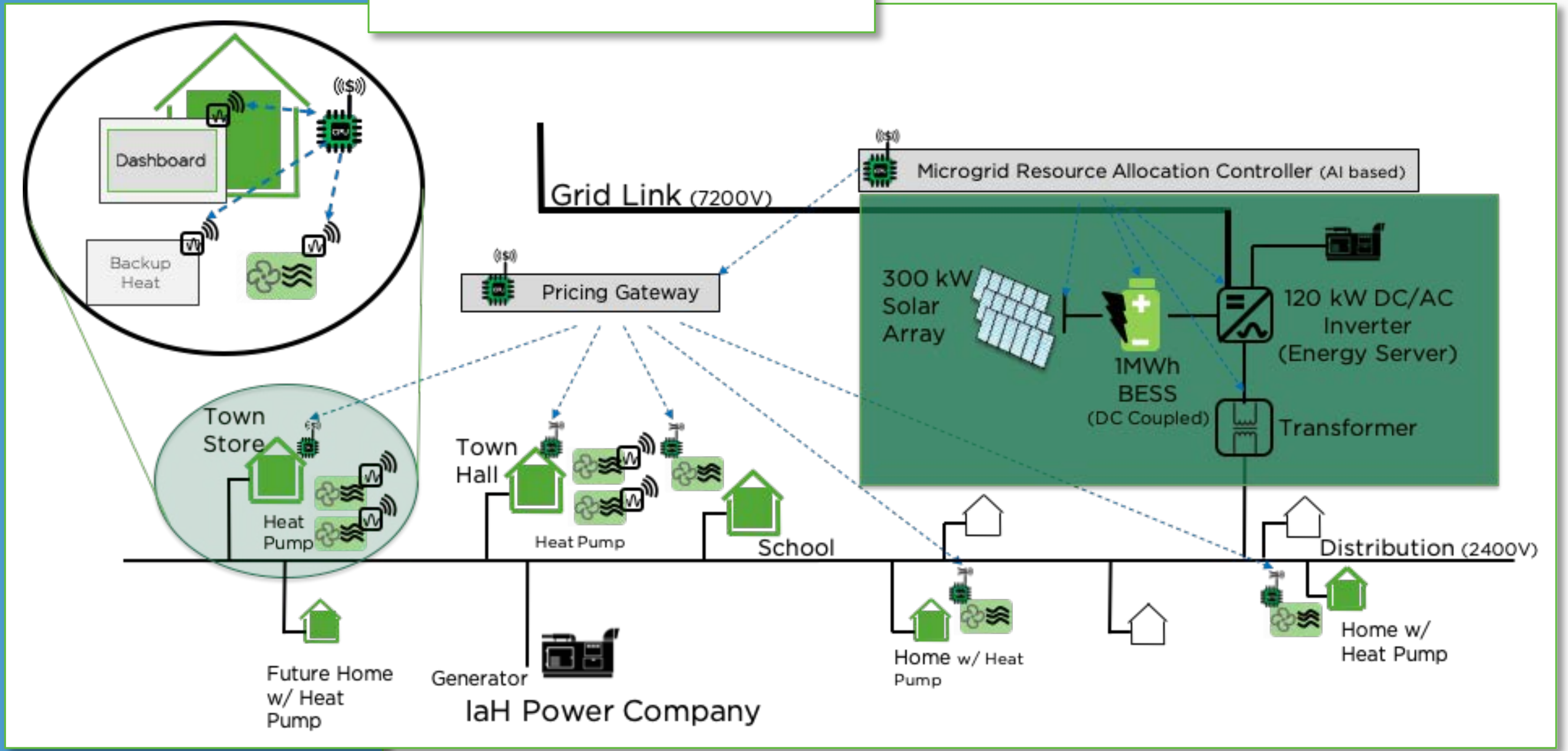


ISLE AU HAUT MAINE

Transactive Energy Microgrids

Take advantage of **Load Flexibility** for dynamic system management and renewable energy balancing improving microgrid revenues

- One-way, Economic Dispatch Value (EDV) signal sent by Gateways (coordination nodes)
- Three layers of coordination
- Heat pumps and other building loads develop optimal local policy (edge devices)



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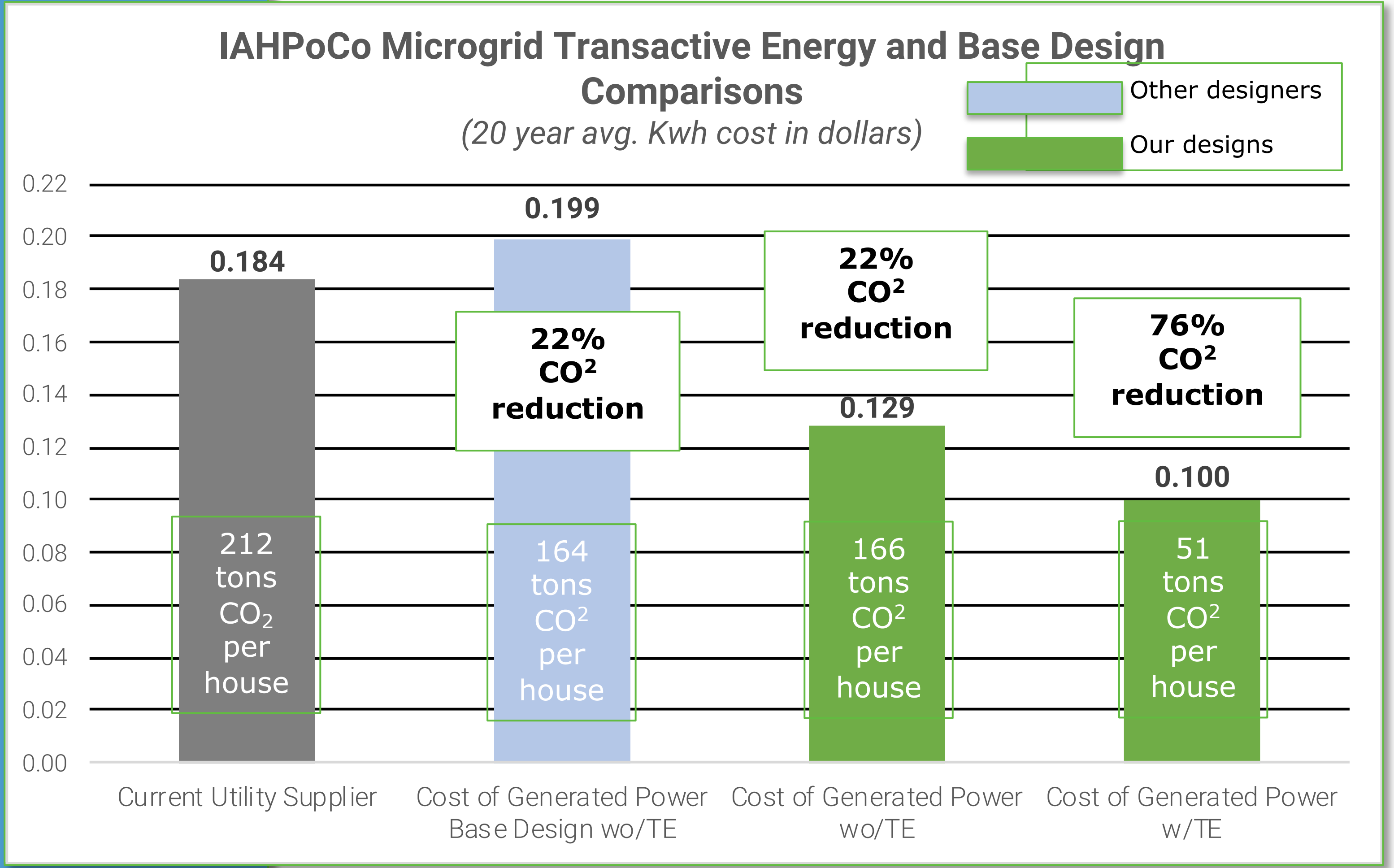
RESULTS

Isle au Haut

- 45% lowered kWh cost
- 76% CO^2 reduction



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CONCLUSIONS

Grid Future State:

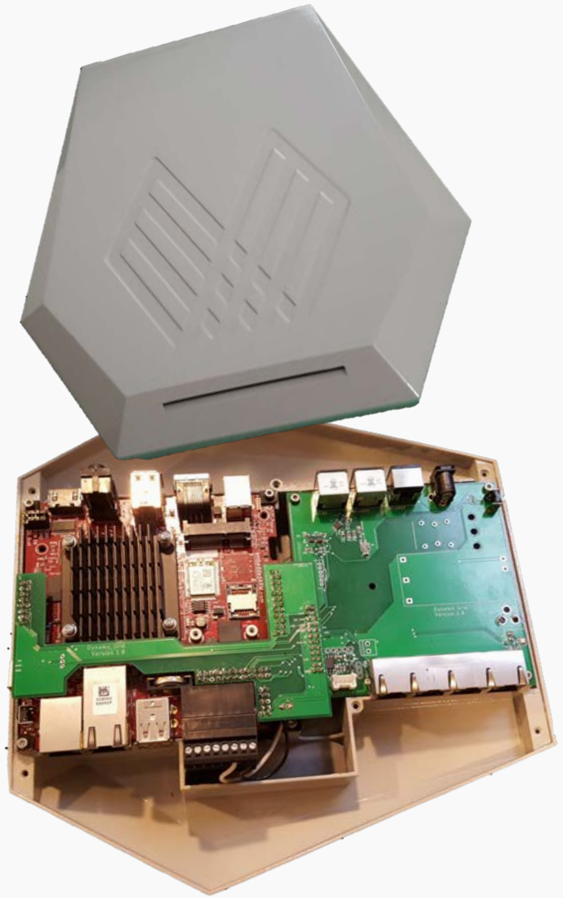
Decarbonized, Decentralized and Distributed (D^3)

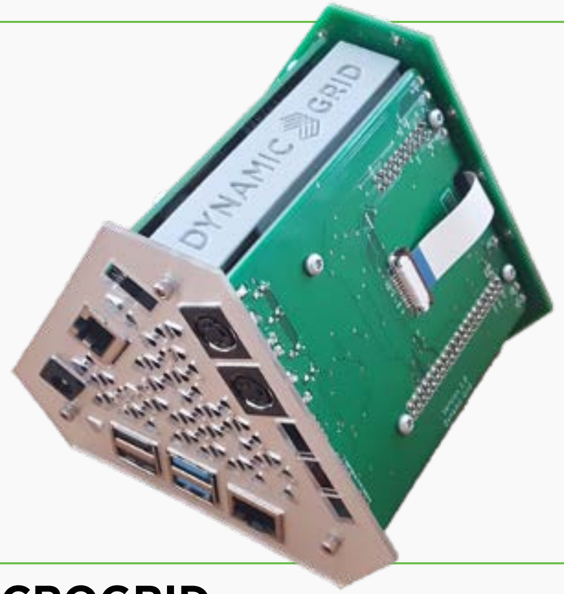
- Decarbonization
- Decentralized and Distributed
- Energy and cost savings
- Increased infrastructure utilization (capacity factor)
- Increased opportunities for Distributed Energy

Need Utility and Regulator focus on **DYNAMIC PRICING**

DISTRIBUTION
ICS GATEWAY–

Intelligent AI powered device that calculates an Economic Dispatch Value (EDV) based upon current conditions, including the EDV received from above and predicted demand.





MICROGRID
ICS CONTROLLER–

Dynamic controller using AI to continuously optimize the management of resources (resource allocation) within the confines of a microgrid. Dynamic control system distributes the EDV to other devices in the ecosystem to communicate the state of the available electricity supply.

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Thank-you

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FURTHER READING

A Practical Approach to the Management of Dynamic Complex Systems
https://www.introspectivesystems.com/wp-content/uploads/2018/11/A-Practical-Approach-to-the-Management-of-Dynamic-Complex-Systems-Introspective-Systems.pdf

Transactive Energy: Real World Applications for an Evolving Grid https://sepapower.org/knowledge/new-smart-electric-power-alliance-report-demystifies-transactive-energy/

The Role of Microgrids in Helping to Advance the Nation's Energy System
https://www.energy.gov/oe/activities/technology-development/grid-modernization-and-smart-grid/role-microgrids-helping