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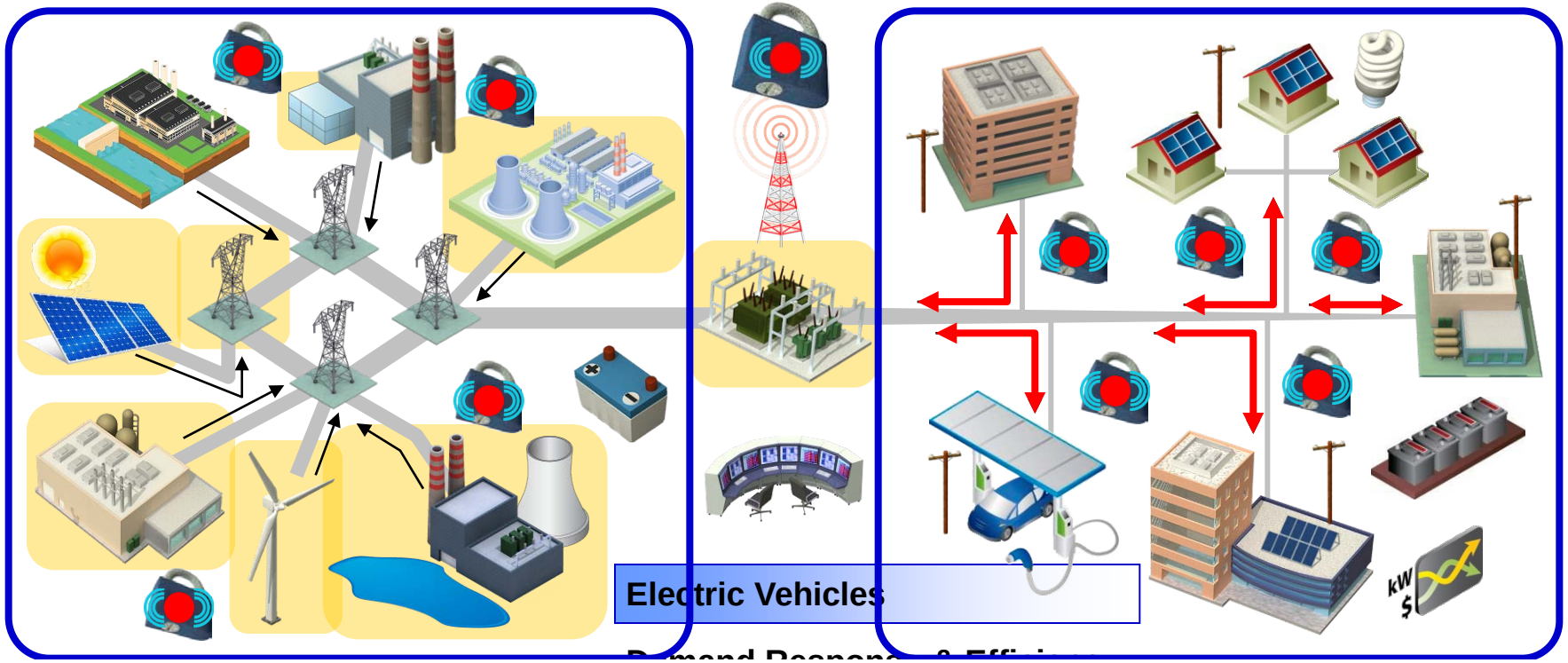
Innovation & Smart Grids

Clark W. Gellings
Fellow

IEEE IAS

January , 201219

Tomorrow's Power System



Requires a full portfolio of innovative technologies.

Long-Term Operations

Renewable Integratio

Water Management

Supply to Demand

Cyber Security

One size does not fit all

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Key Technical Issues

Smart Grid



Energy Efficiency



Long-Term Operations



Renewable Resources and Integration



Near-Zero Emissions



Water Resource Management



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Many Definitions

IntelliGrid

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GRIDPOINT



GALVIN ELECTRICITY INITIATIVE
Sponsored by The Galvin Project, Inc.

Smart Grid

DRSG
Demand Response *and* Smart Grid *Coalition*

GRIDWISE ALLIANCE

SMART GRID CITY™

SMARTGRIDS



EUROPEAN TECHNOLOGY PLATFORM FOR THE ELECTRICITY NETWORKS OF THE FUTURE

Modern Grid
NETL

Illinois SMART GRID Initiative

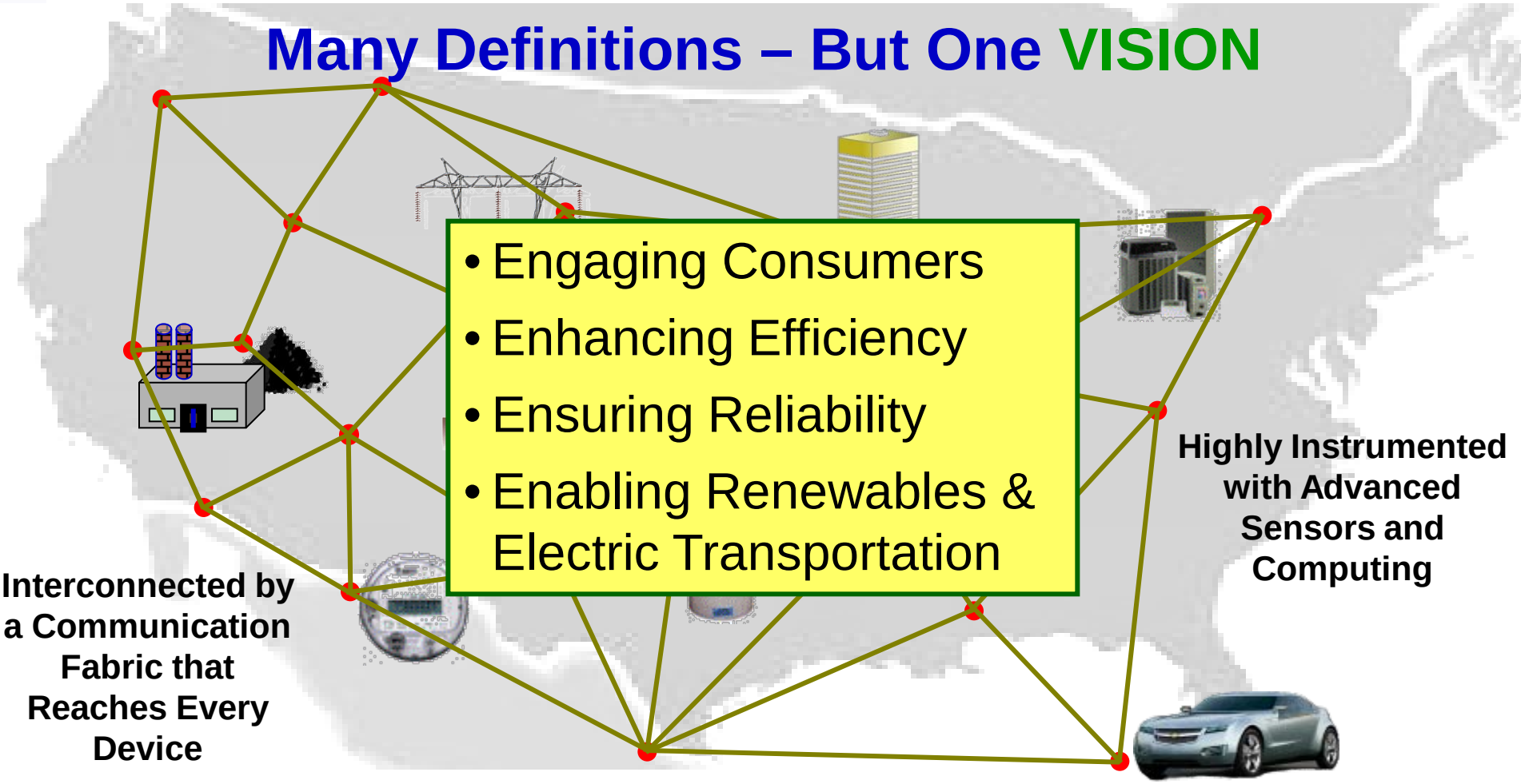
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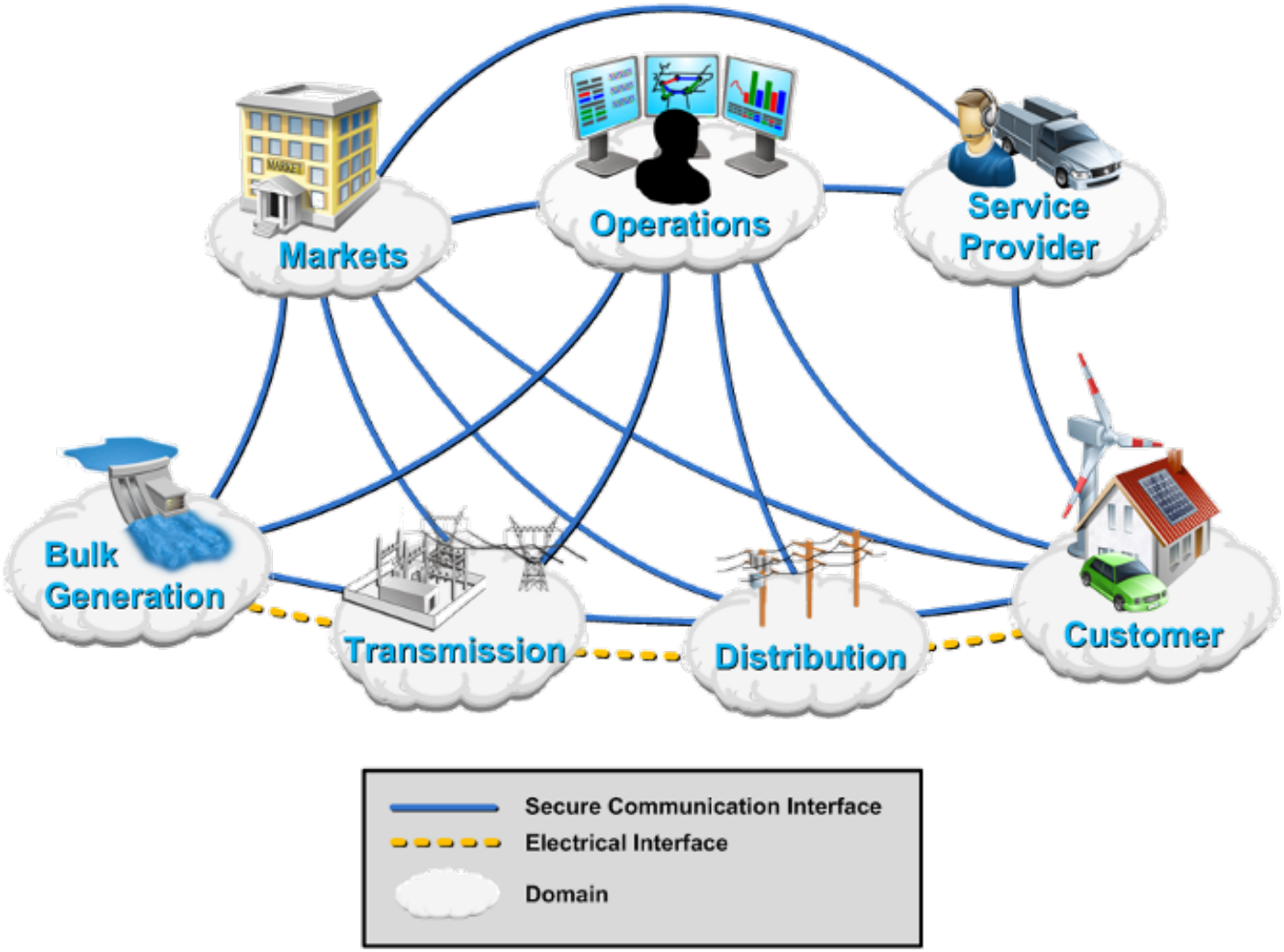
What is The Smarter and Stronger Grid?

Many Definitions – But One VISION



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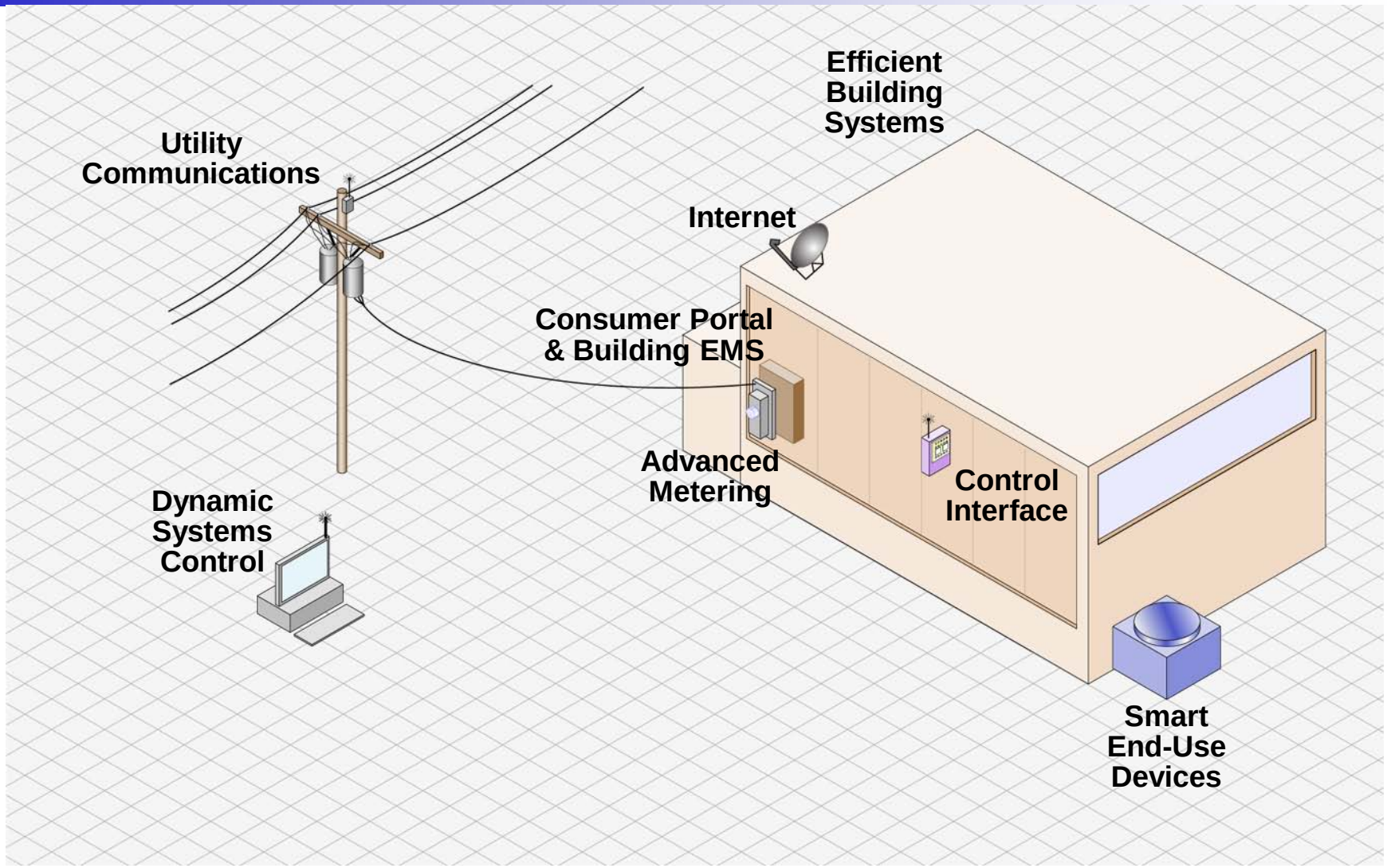
Smart Grid Domains



Source: EPRI Report to NIST on Smart Grid Interoperability, June 2009

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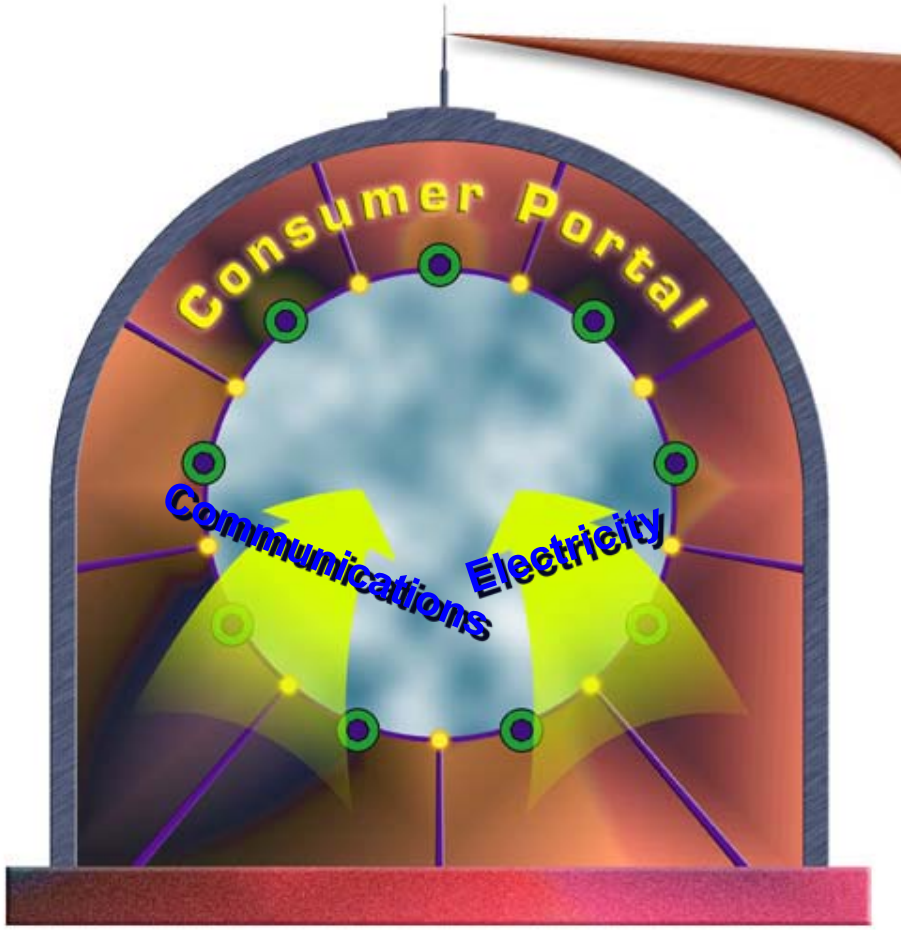
Dynamic Systems Infrastructure: Basics



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The Portal Empowers Consumers



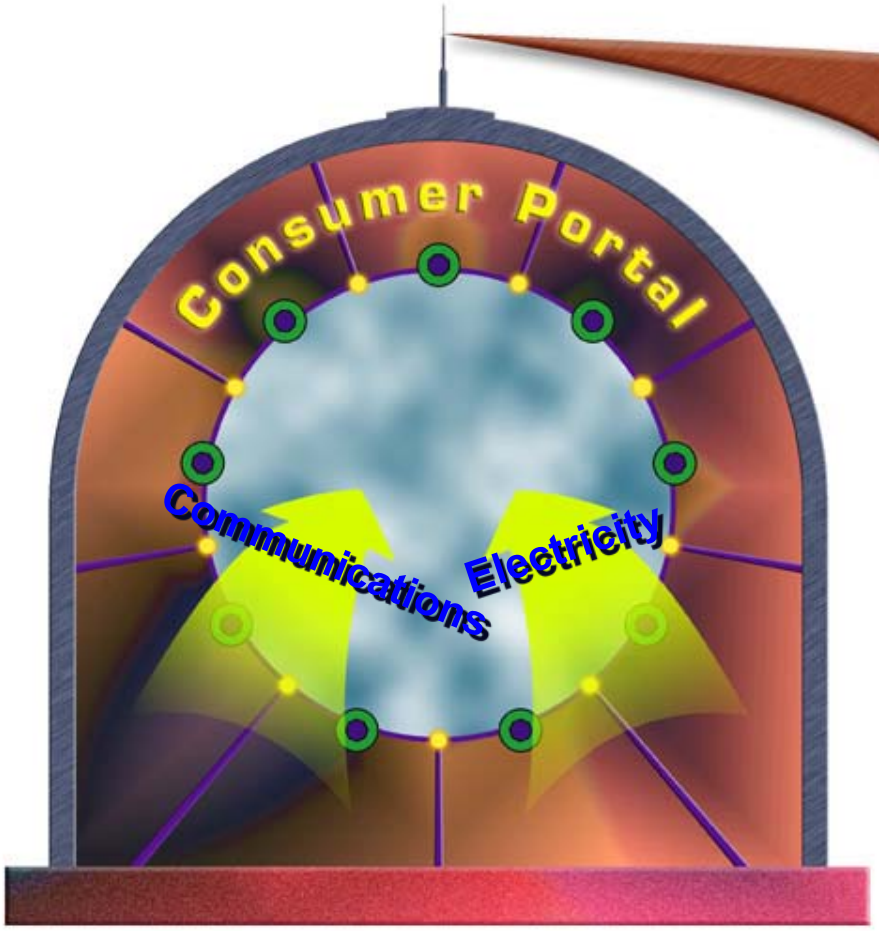
- Connectivity to electricity markets
- Information on consumption
- Access to other services

Choice | **Convenience** | **Value**

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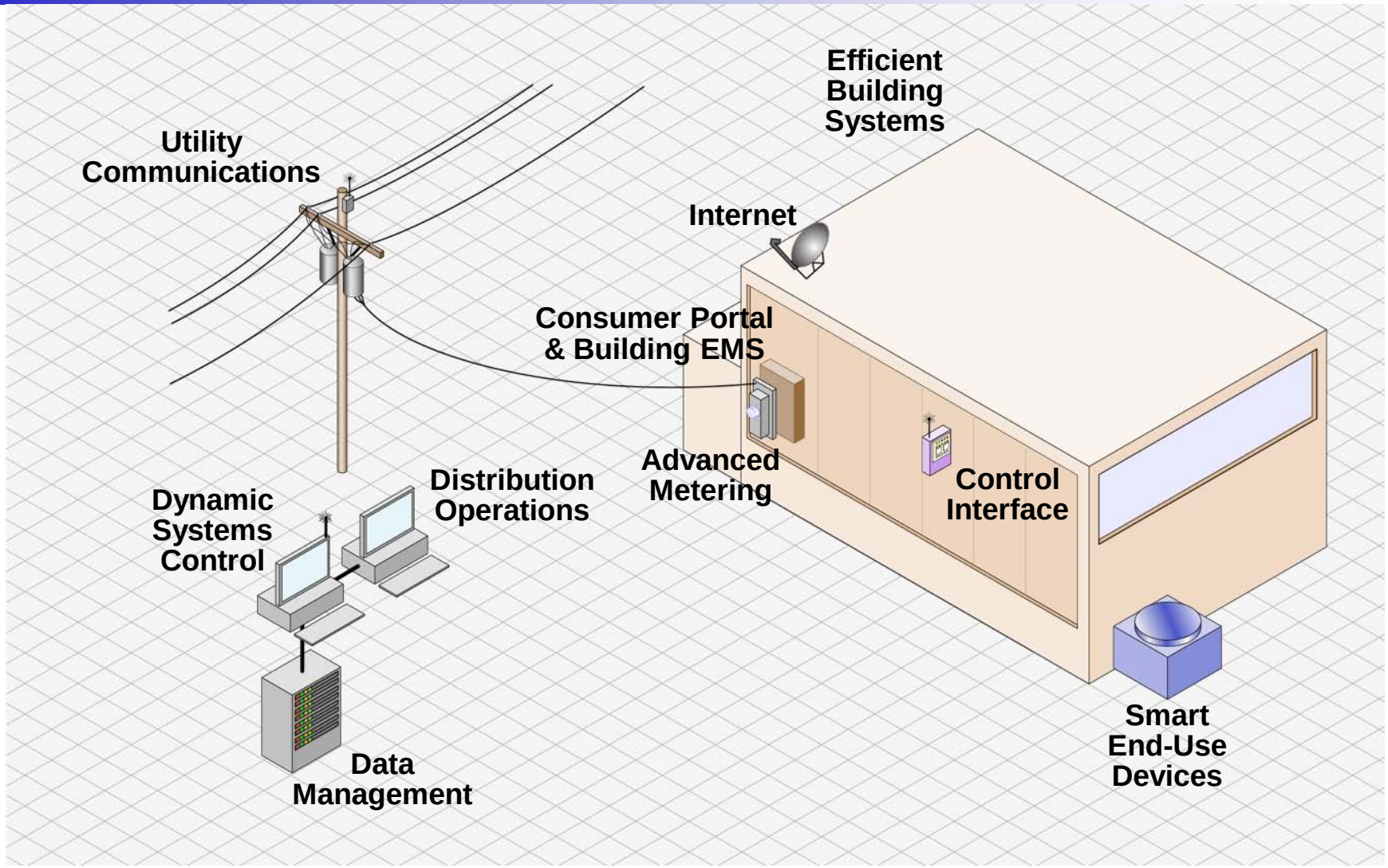
The Portal Empowers Consumers



- Choose suppliers
- Select tariff
- Monitoring usage
- Respond to price signals
- Monitor appliances and devices
- Remotely program operations
- Consolidate bills
- Outage detection
- PQ monitoring
- Security
- Data
- Entertainment

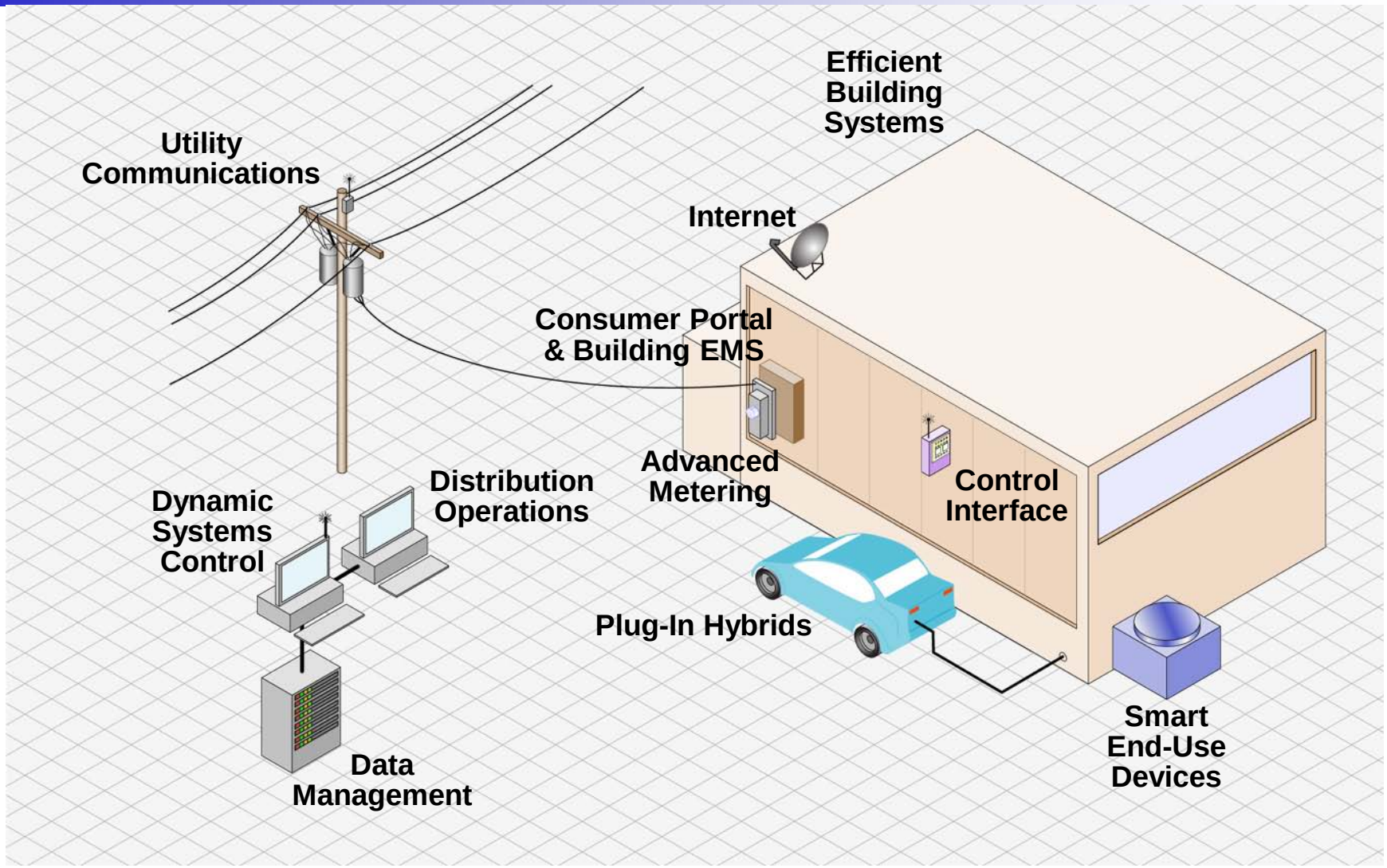
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Dynamic Systems Infrastructure: Utility Operations



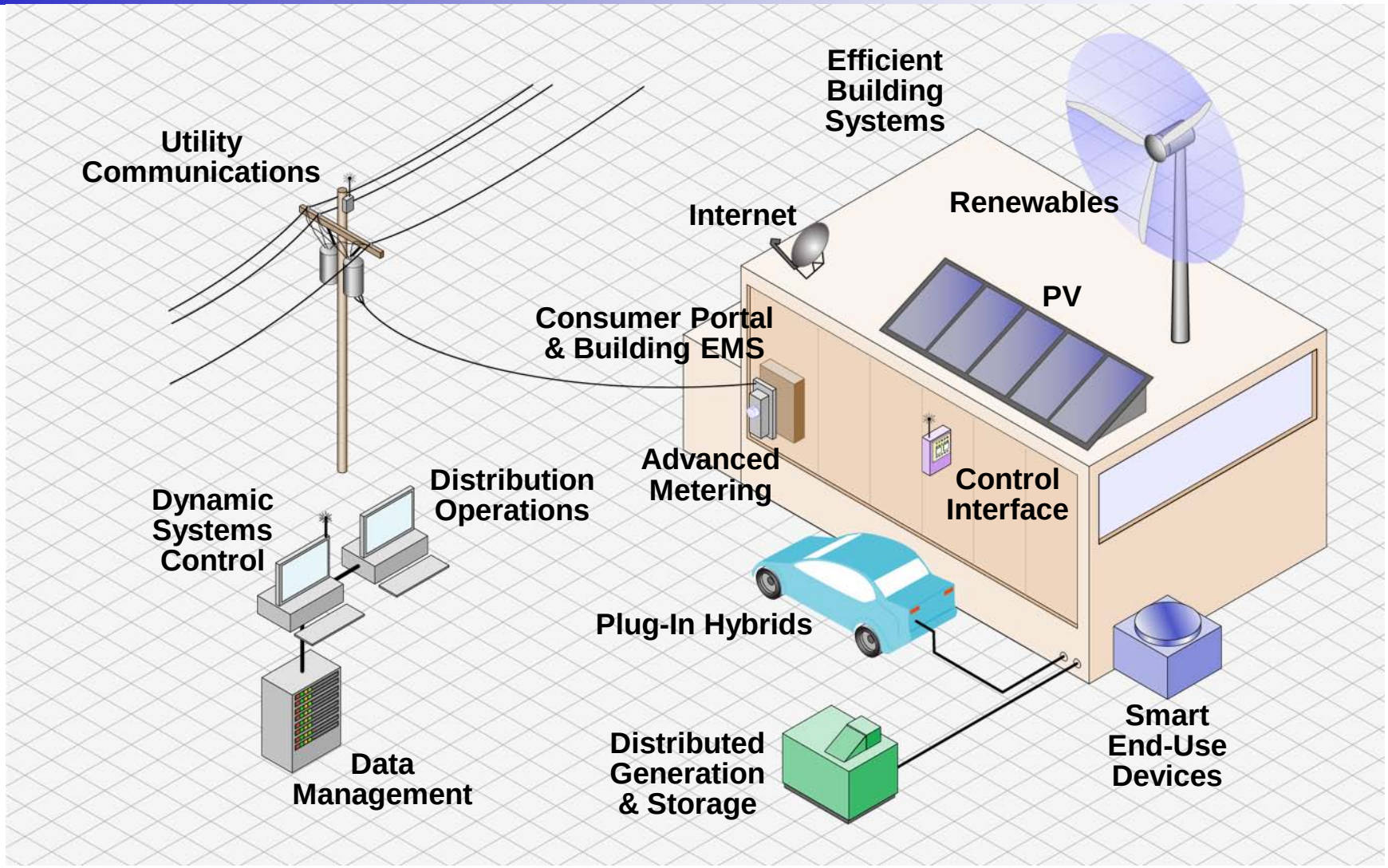
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Dynamic Systems Infrastructure: Consumer Opportunities



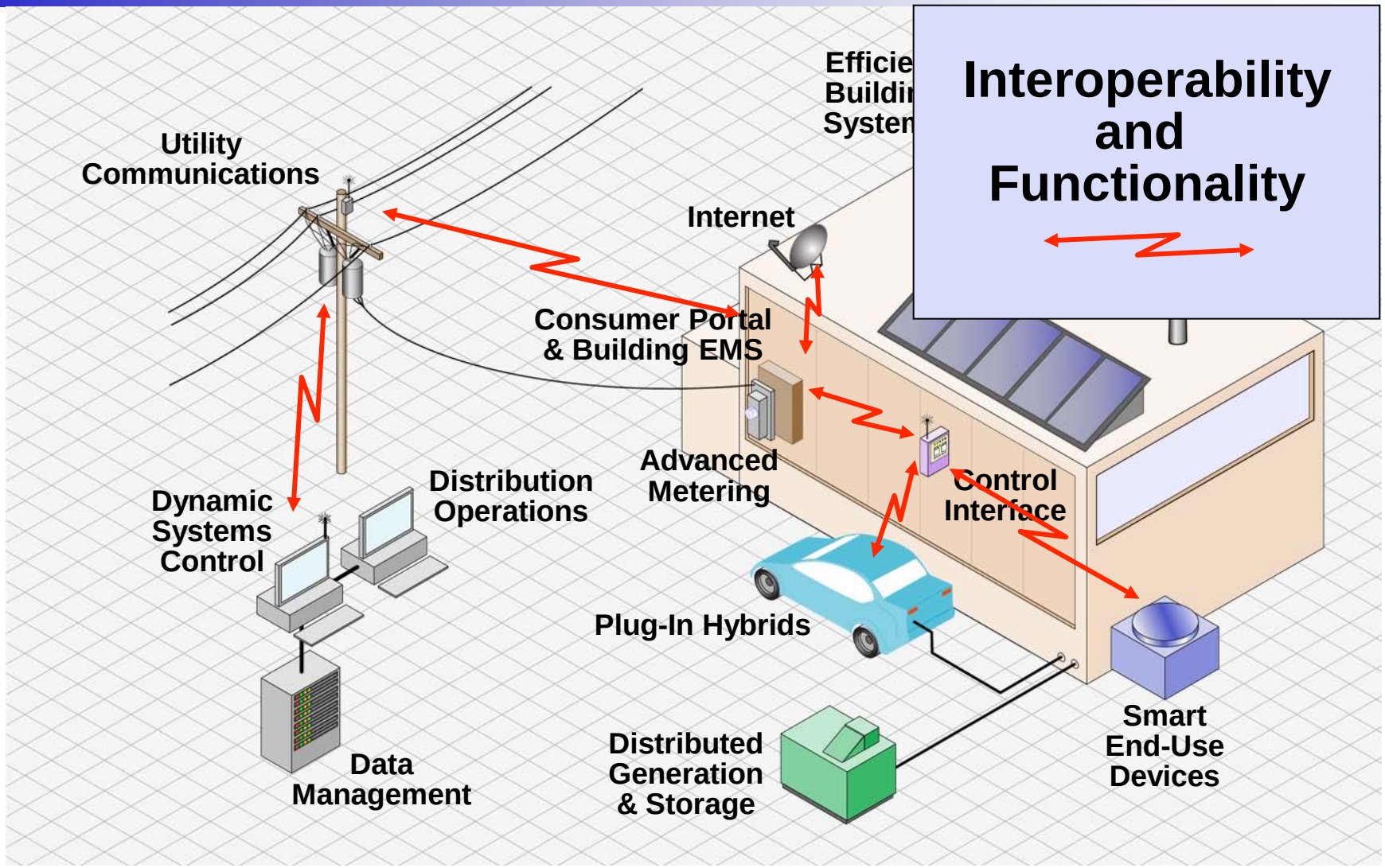
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Dynamic Systems Infrastructure: Consumer Opportunities



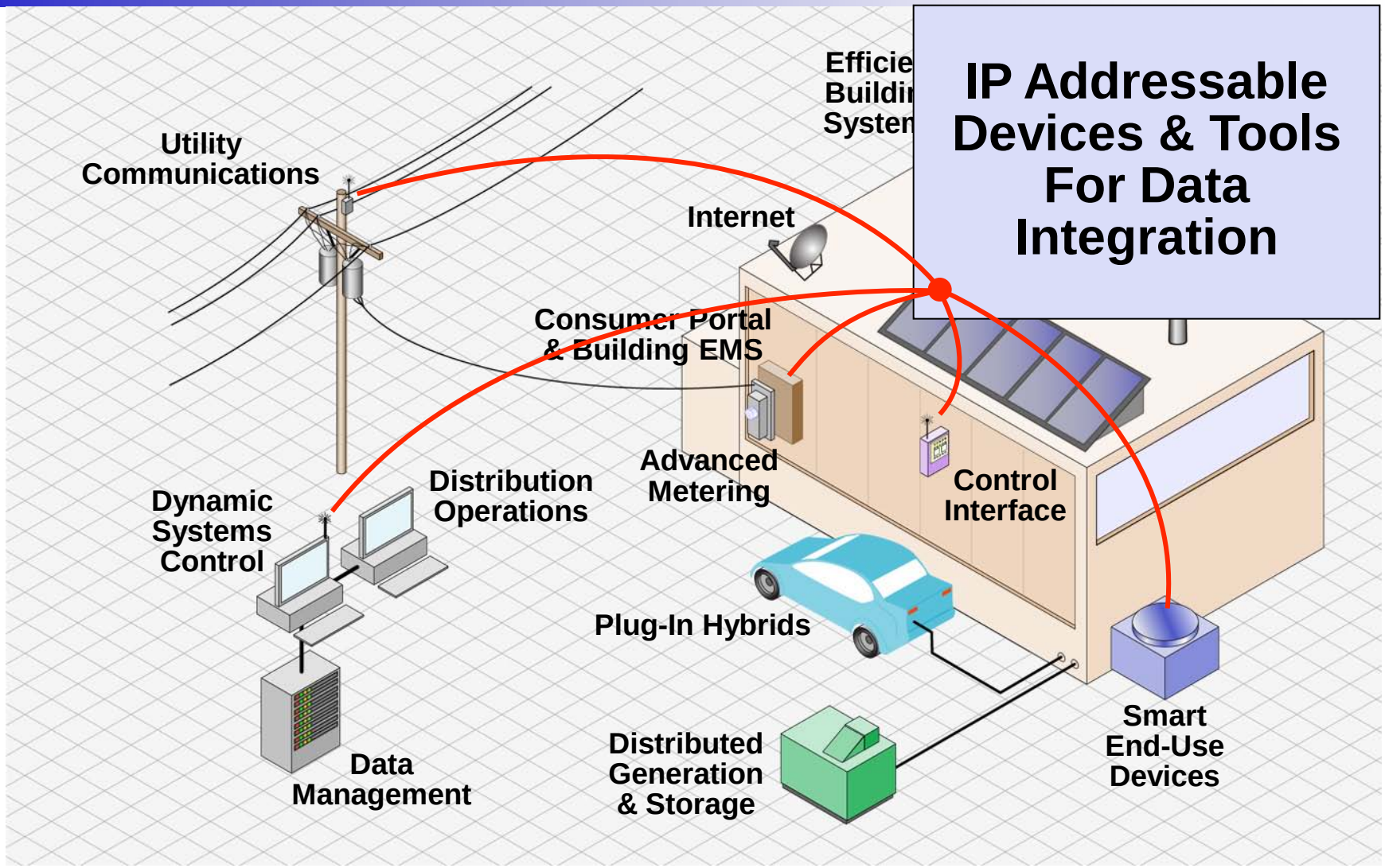
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Dynamic Systems Infrastructure



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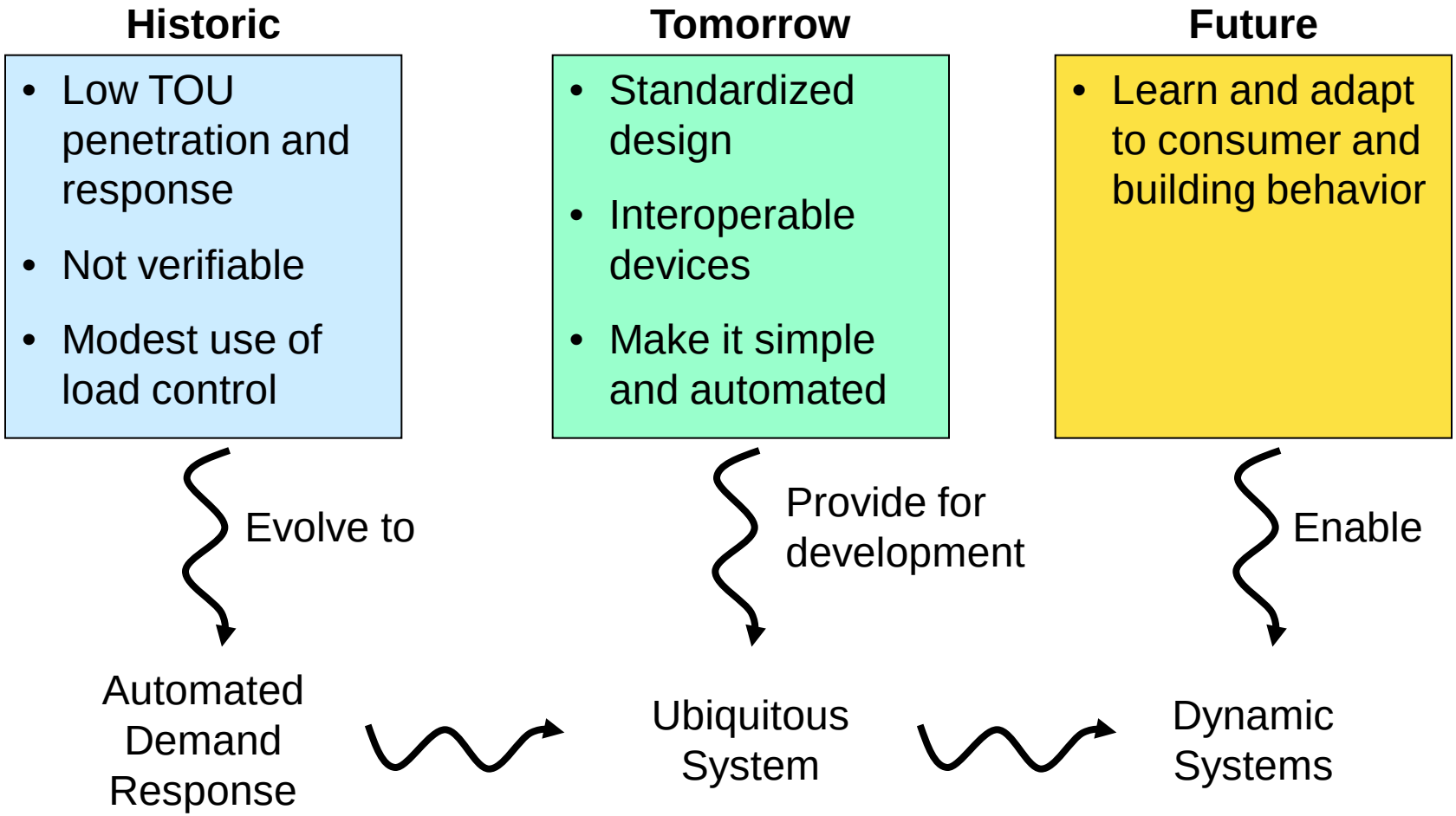
Dynamic Systems Infrastructure



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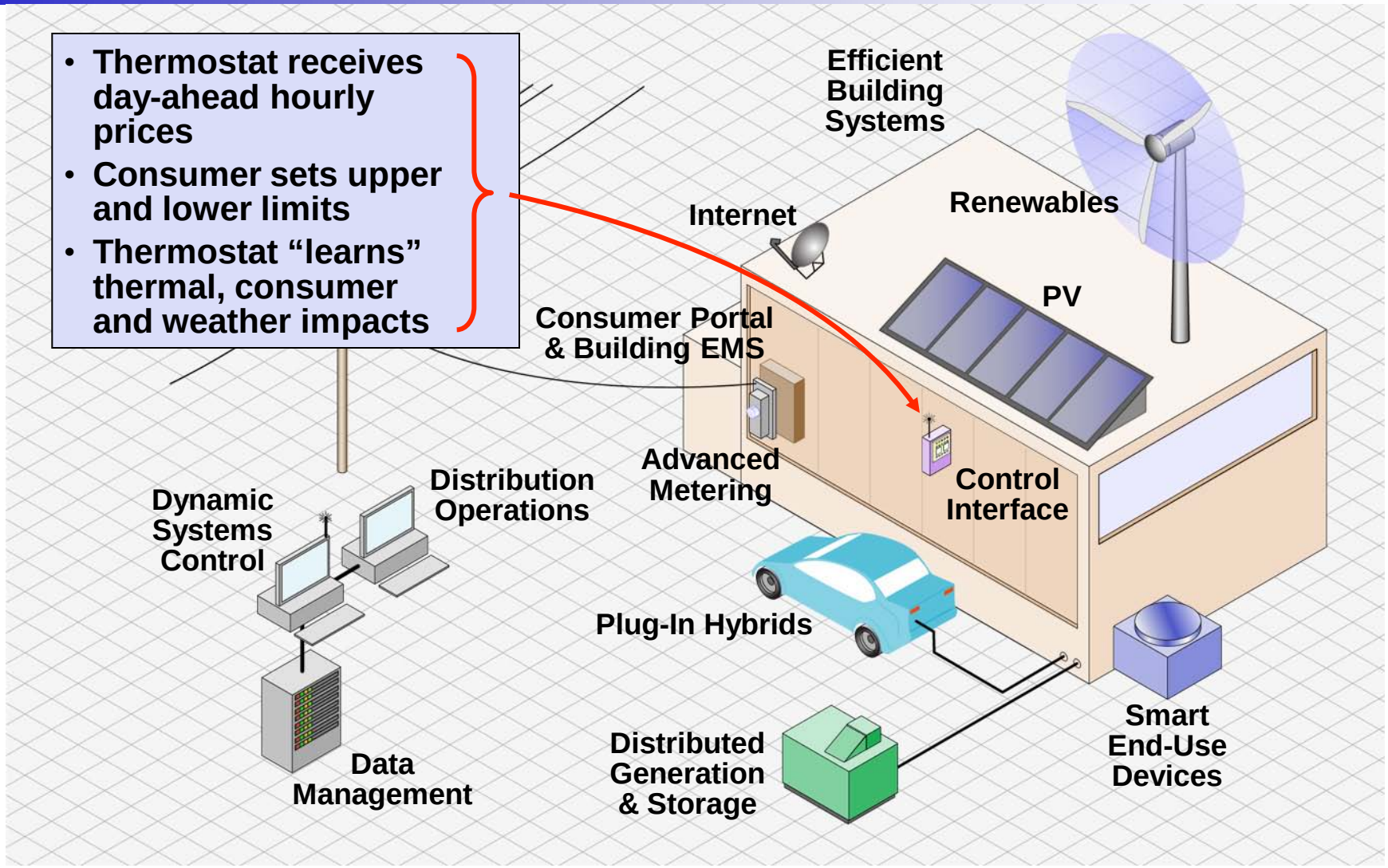
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The Evolution of Dynamic Systems



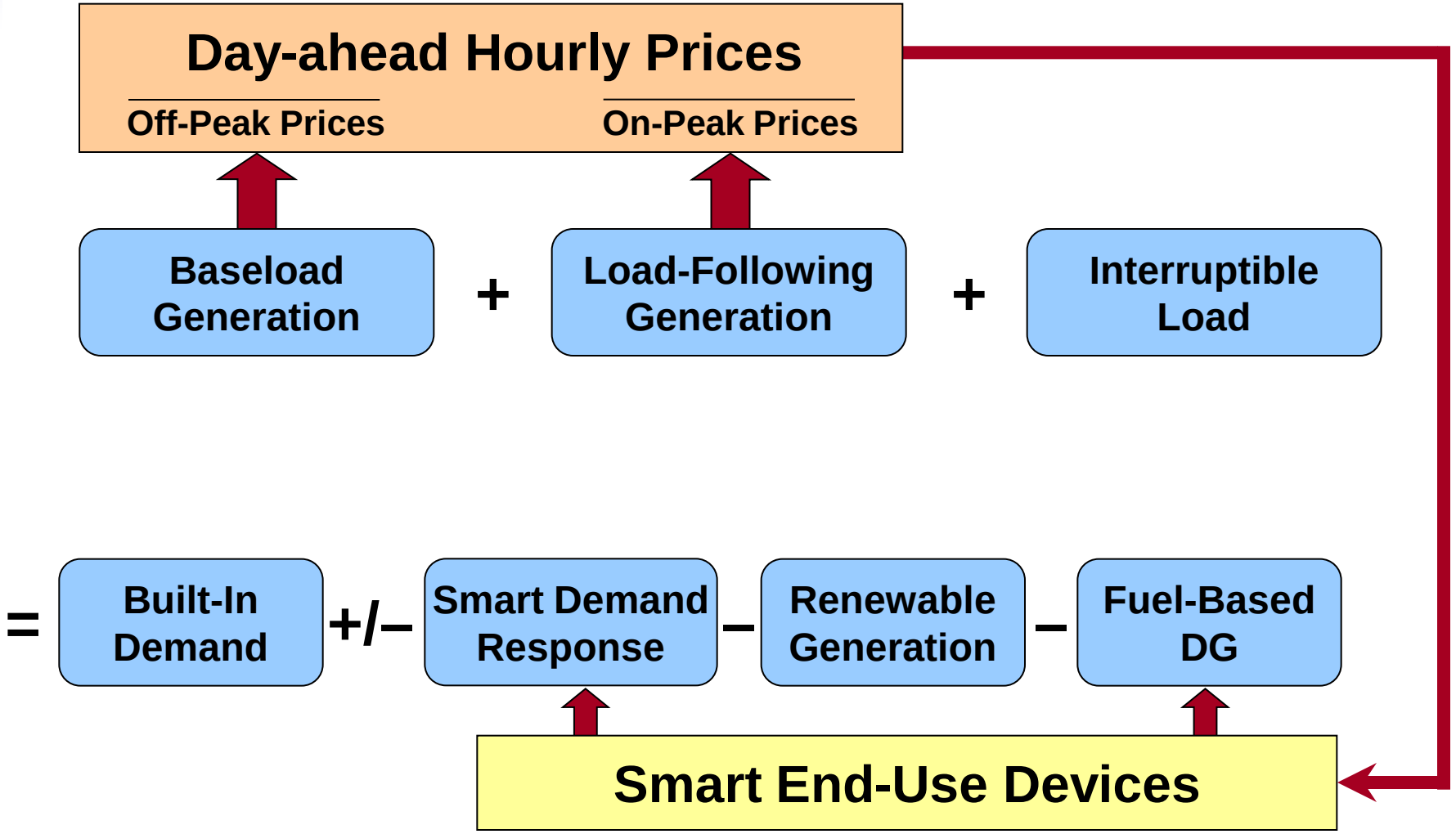
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Dynamic Systems Infrastructure – Example



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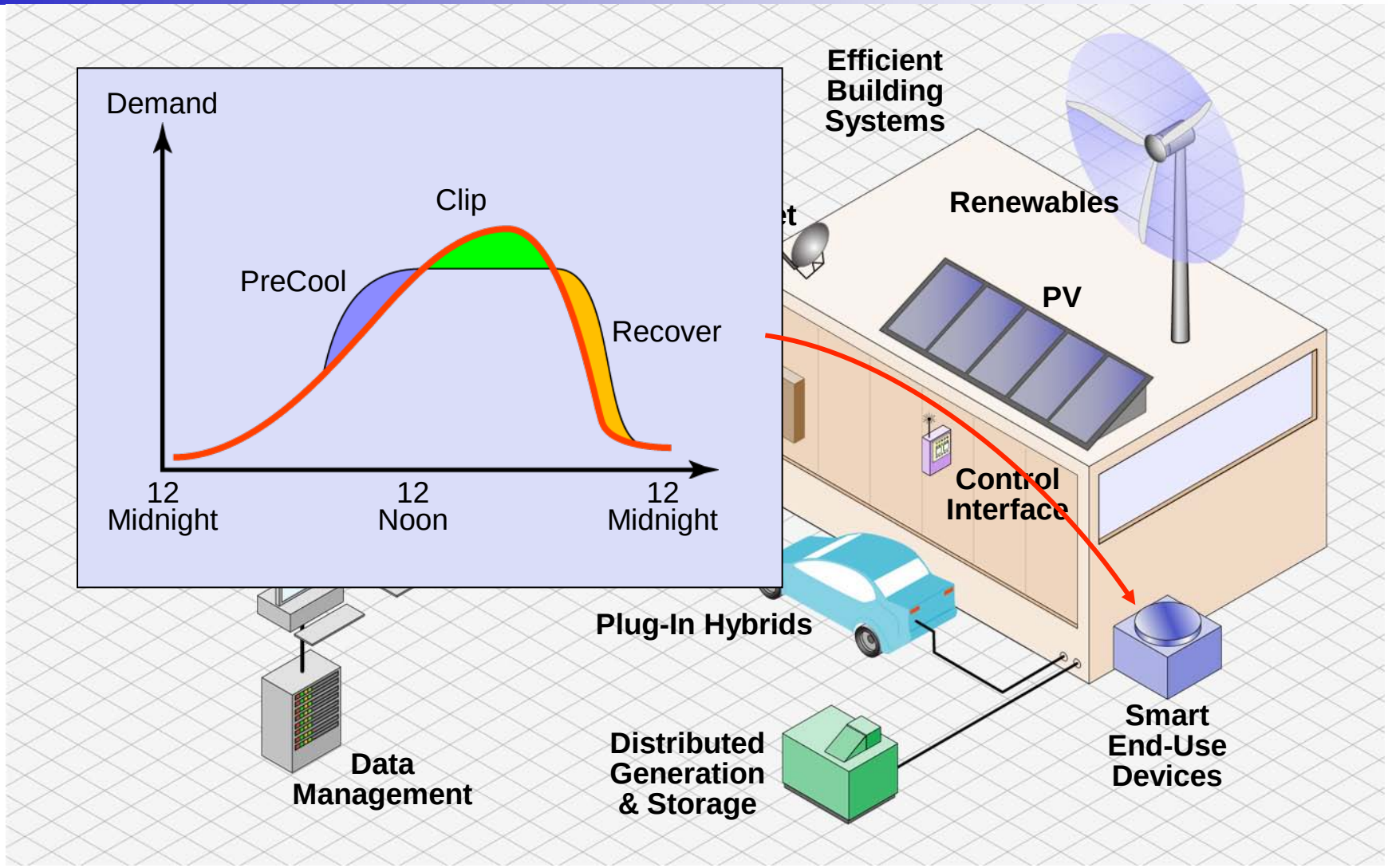
Smart Infrastructure… "Prices to Devices"SM



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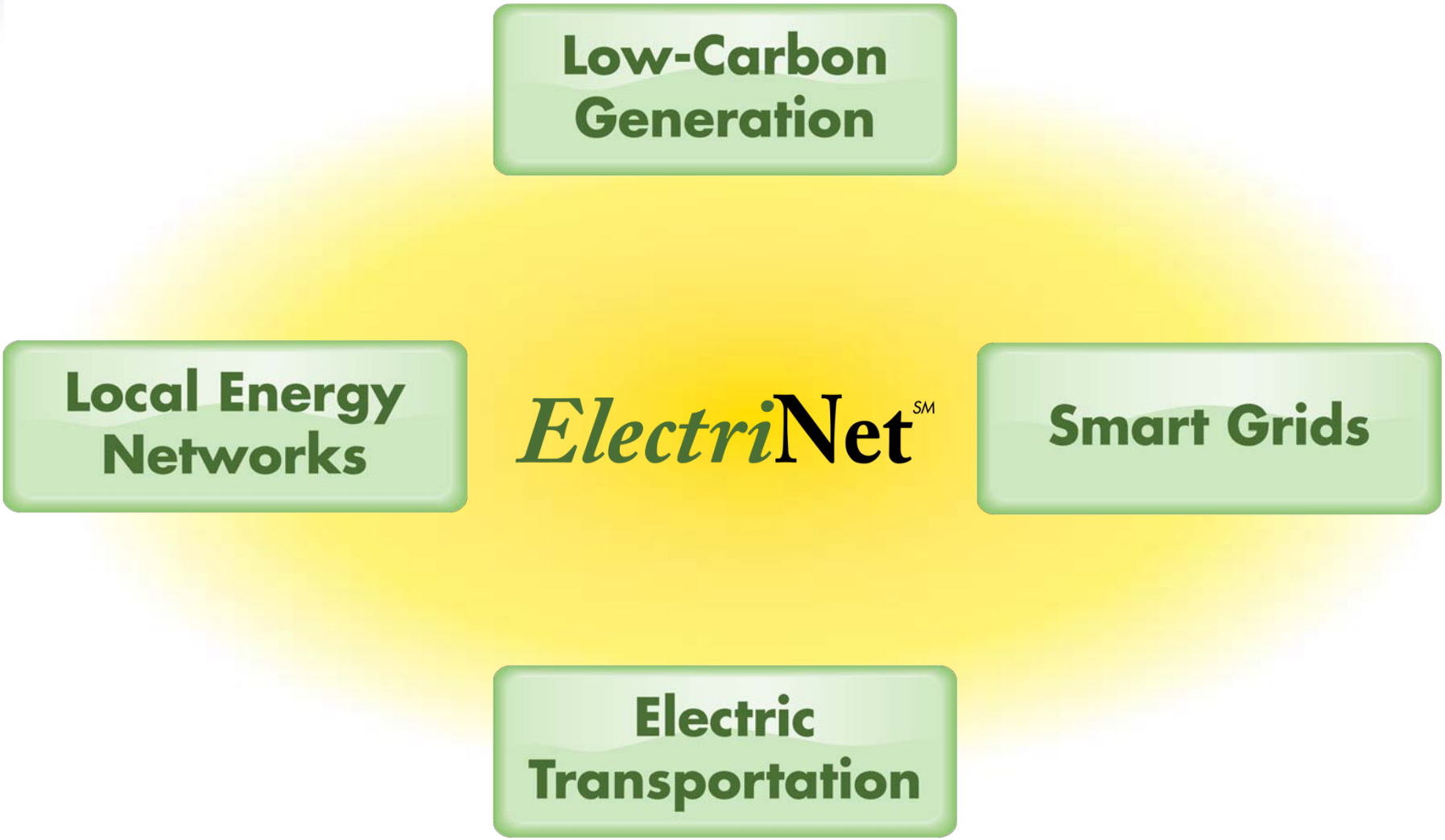
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Dynamic Systems Infrastructure – Example



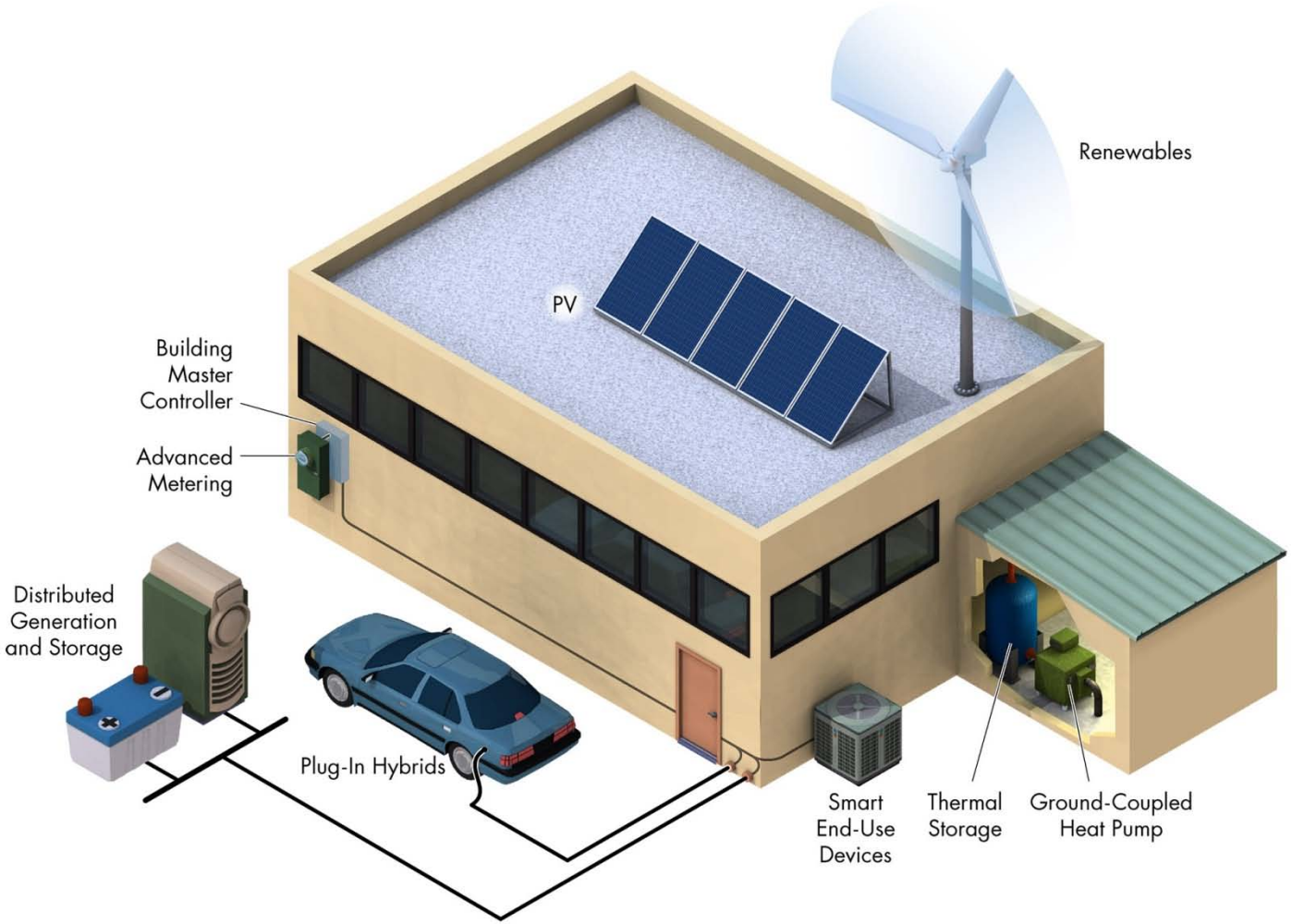
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New Infrastructures Need to be Integrated



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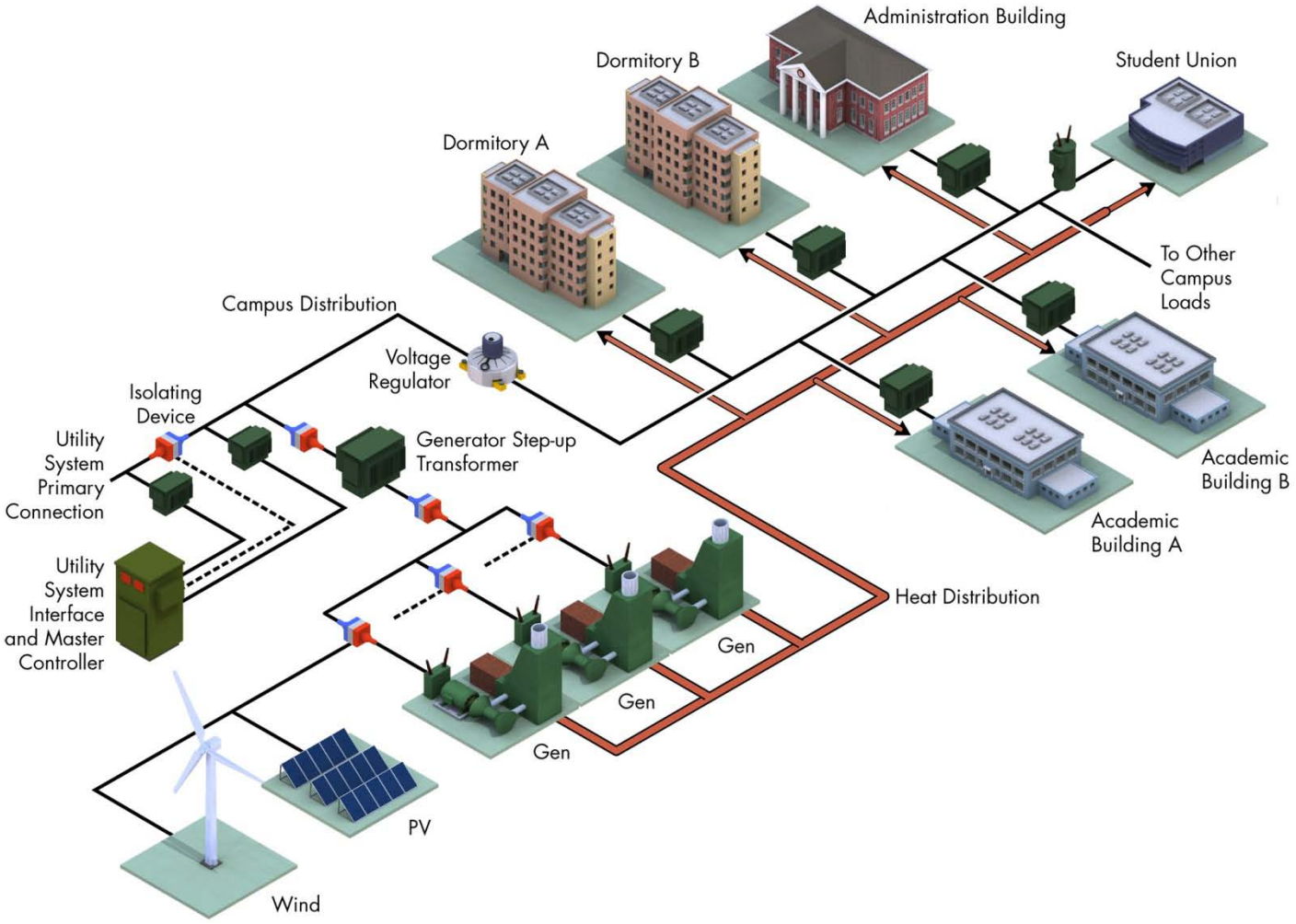
Building-Level Local Energy Network



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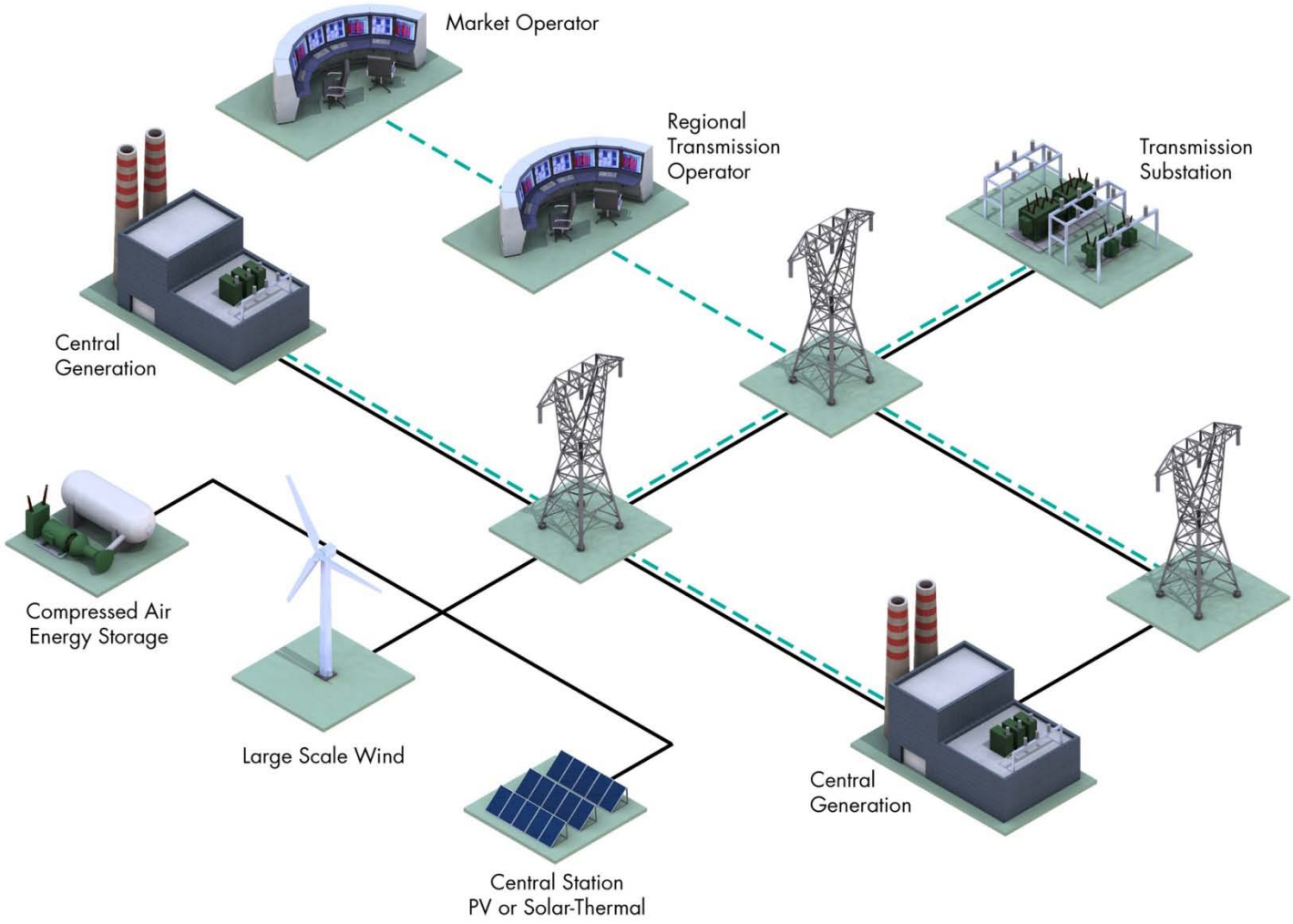
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Campus-Level Local Energy Network



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Bulk Power System

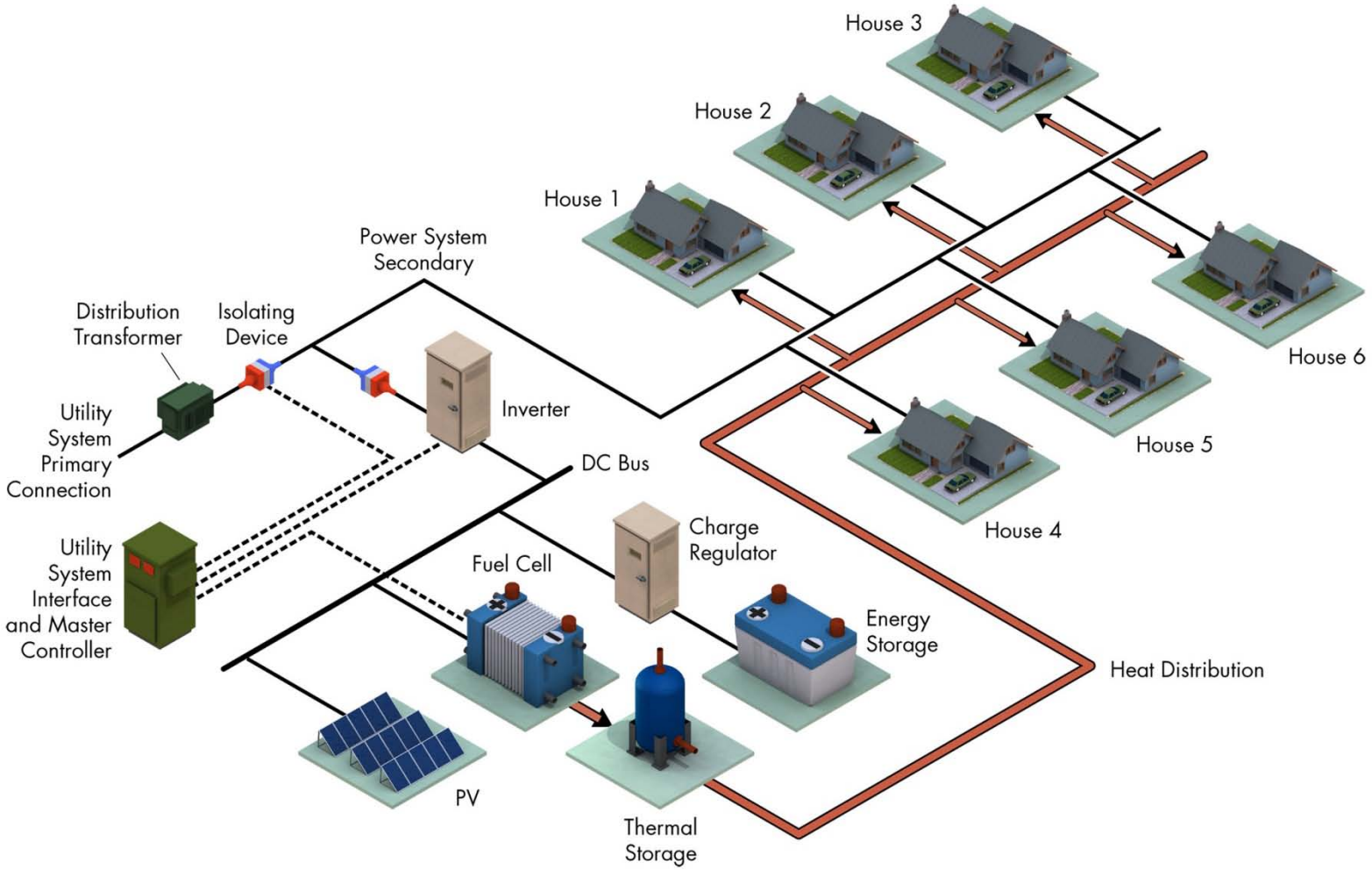


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Community-Level Local Energy Network

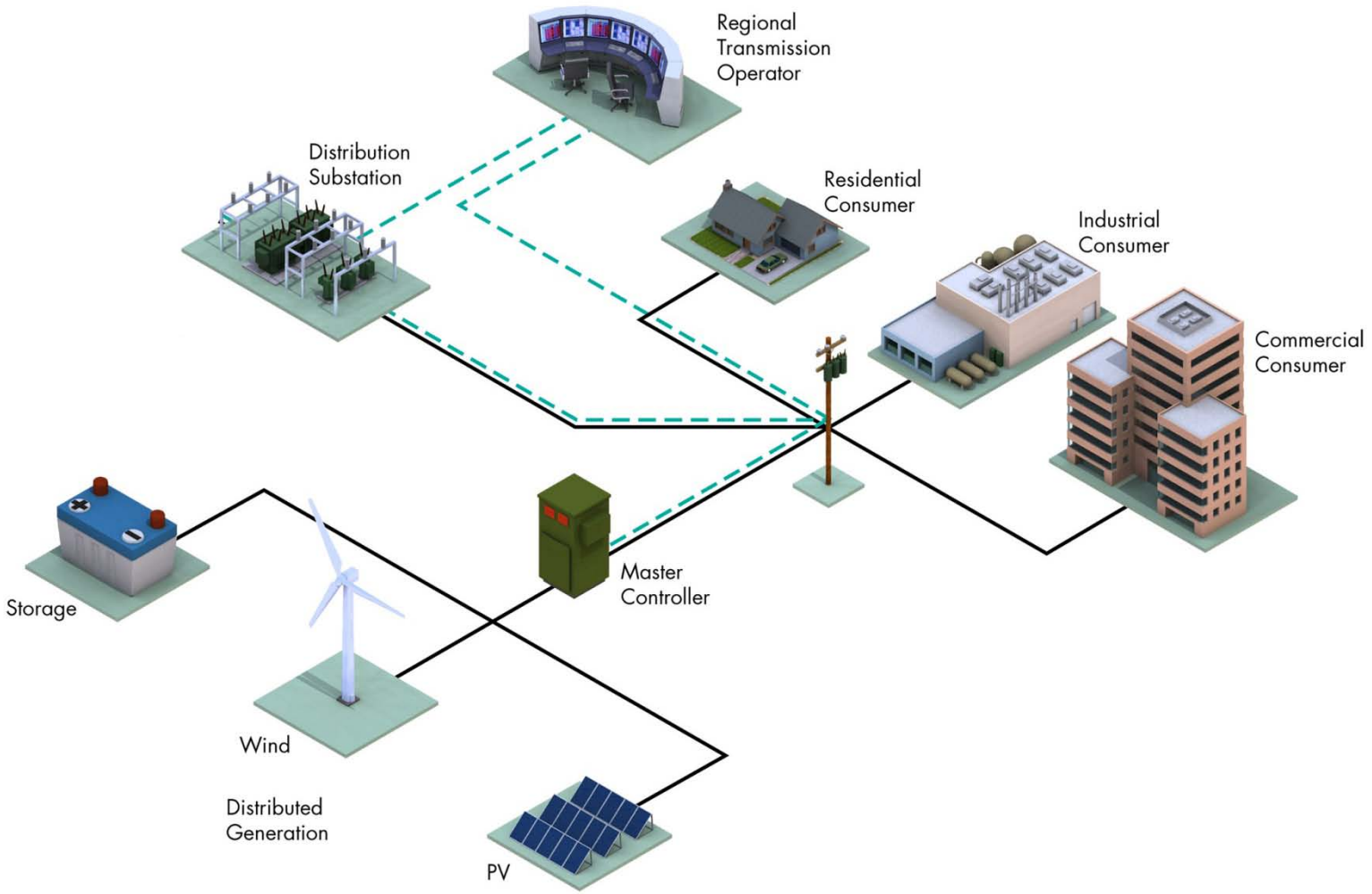


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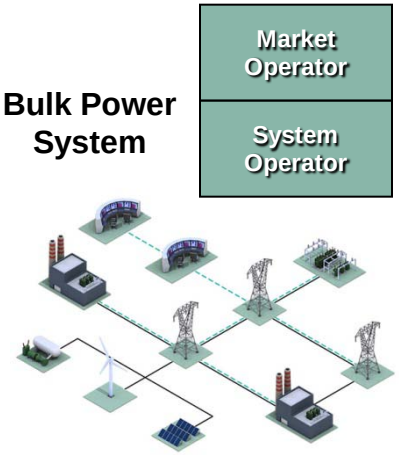
Distribution System



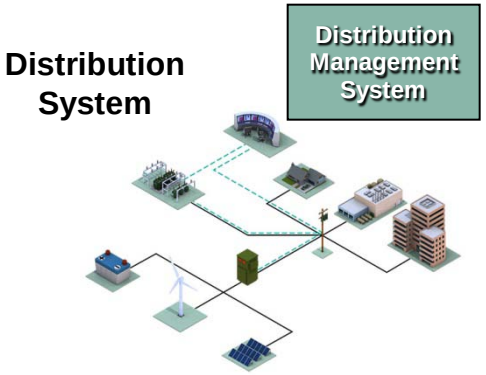
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Creating an Architecture with Multi-Level Controllers

Bulk Power System



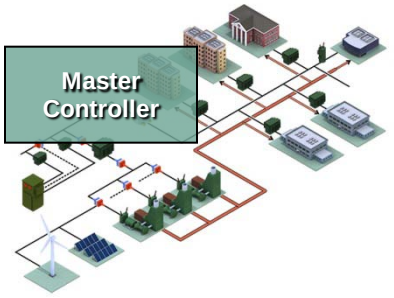
Distribution System



Community LEN



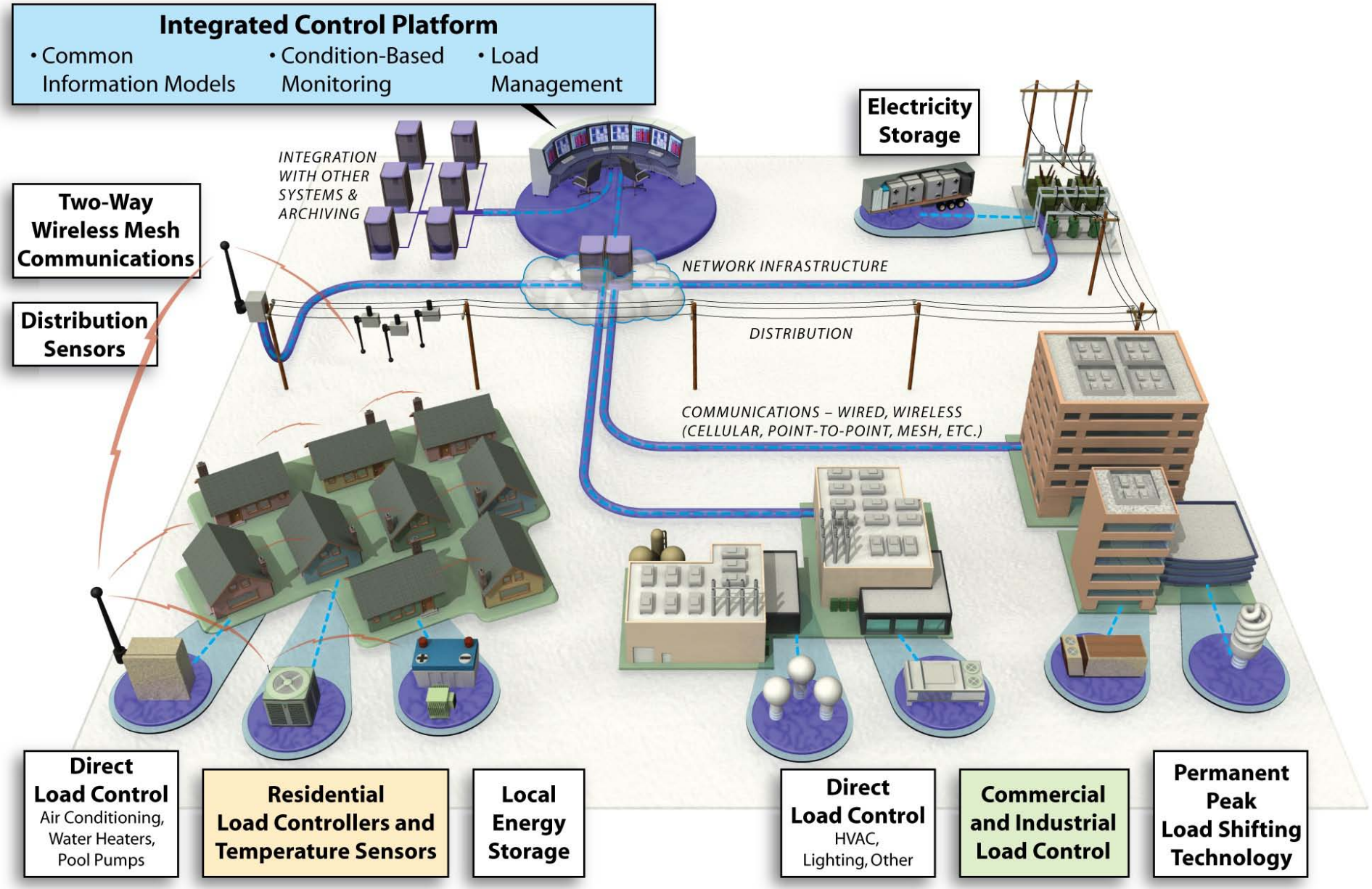
Campus LEN



Building LEN



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FirstEnergy®

Jersey Central Power & Light
A FirstEnergy Company

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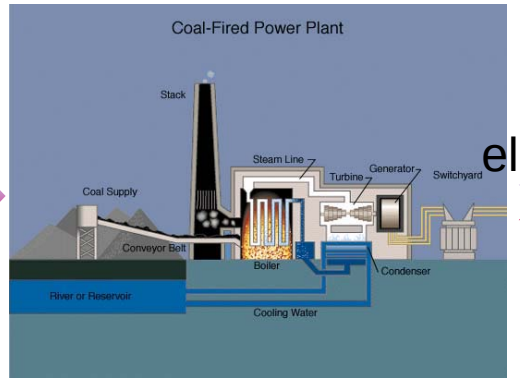
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Example of Losses in the Value Chain

coal

100

~ 65% loss



electricity

~30

~ 7% loss



electricity

~28

~ 88% loss
(incandescent)



Light, heat, motion, etc.)

~3

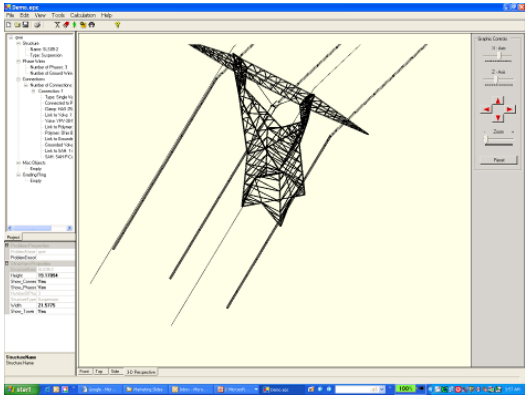
U.S.: More than 210 billion kWh per year is lost in the delivery of electricity from power plant to end-use devices

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Reduced Losses: Opportunities for Improving Efficiency

Transmission



Shield Wire Segmentation

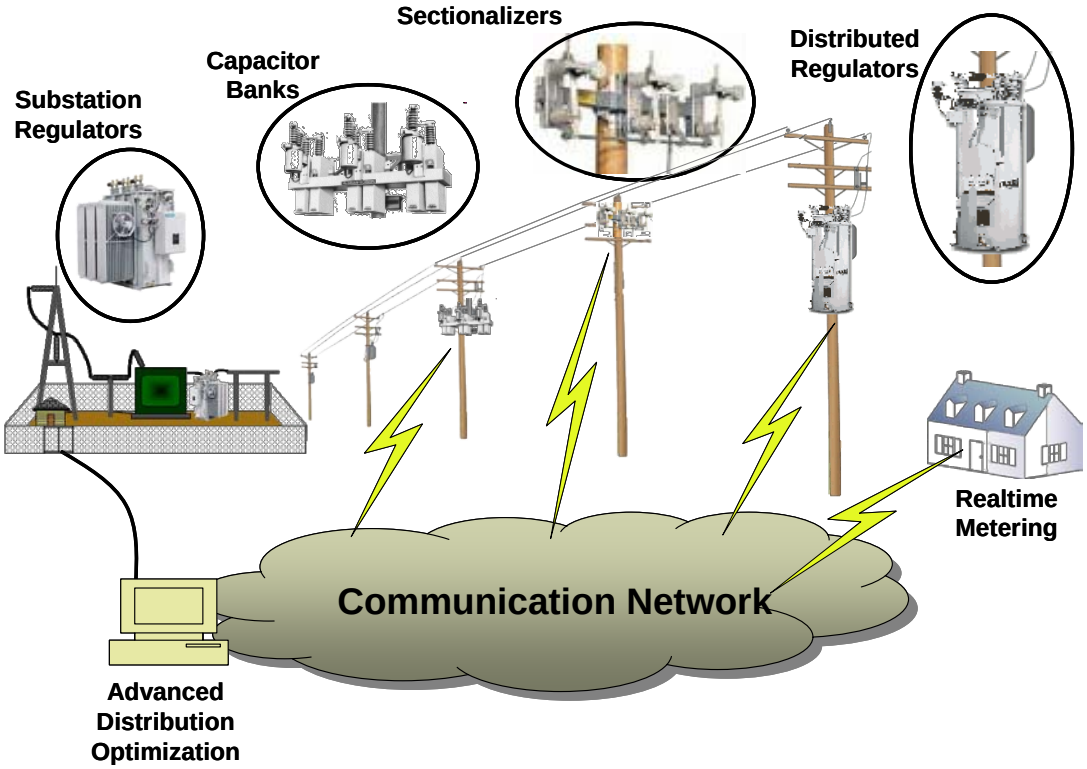
Advanced Conductors

Bundle Optimization

Corona/Insulation Losses

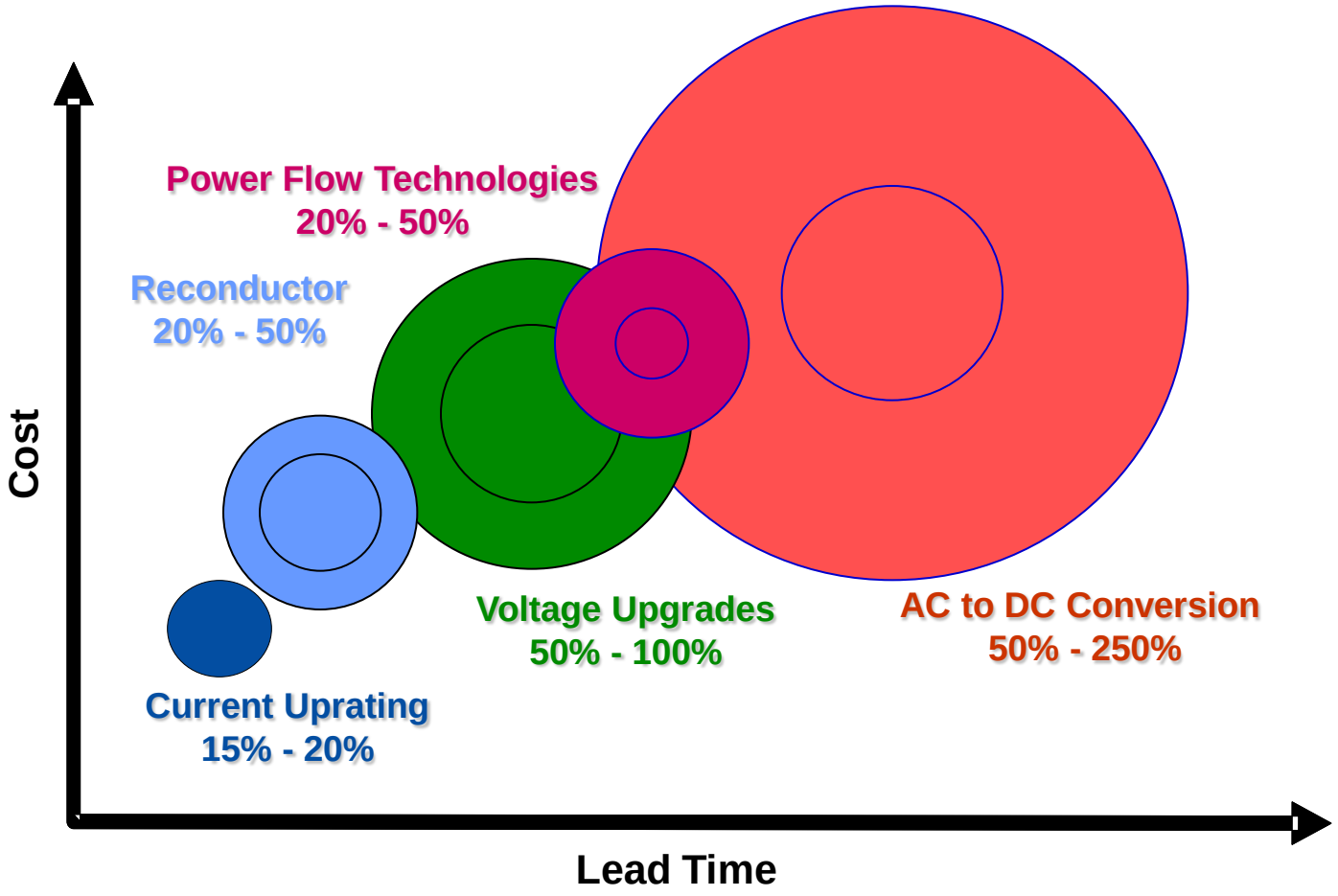
Voltage Optimization

Distribution



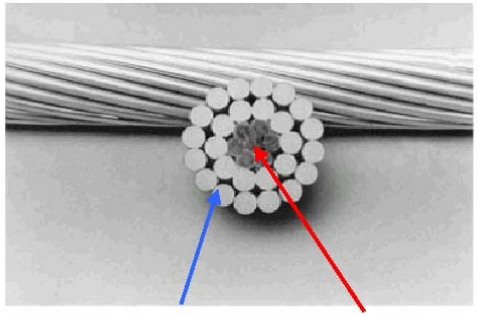
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Increased Power Flow



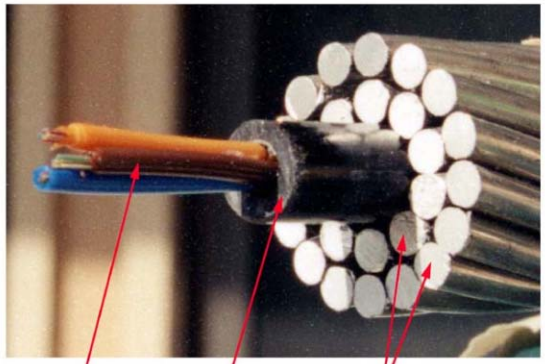
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High-Temperature, Low-Sag Conductors



Aluminum-Zirconium Alloy
(240^{0}C peak)

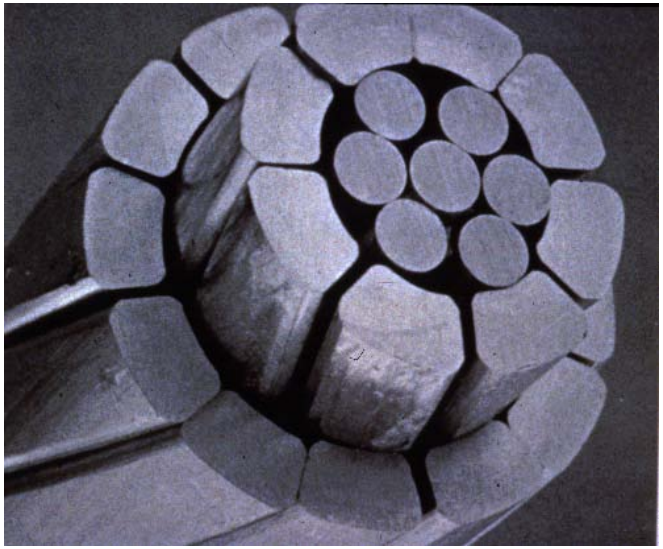
3M Composite
Core

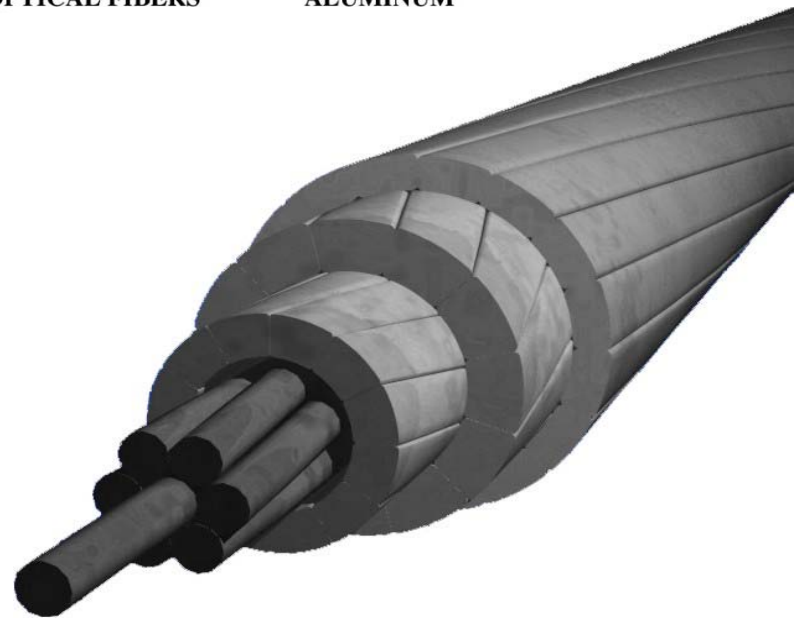


COMPOSITE

OPTICAL FIBERS

ALUMINUM





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Solid State Current Limiter (SSCL)

Value

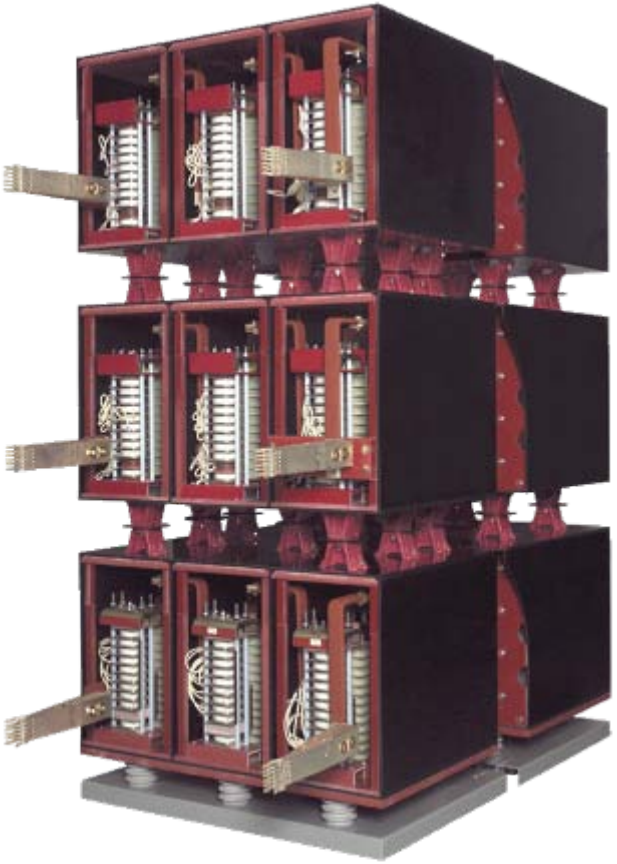
- Enhanced ability to utilize existing equipment to manage increasing fault current

R&D Highlight

- First ever 15kV class SSCL design, manufacture and testing at full power

Next Steps

- Design refinement for field testing, 69kV design

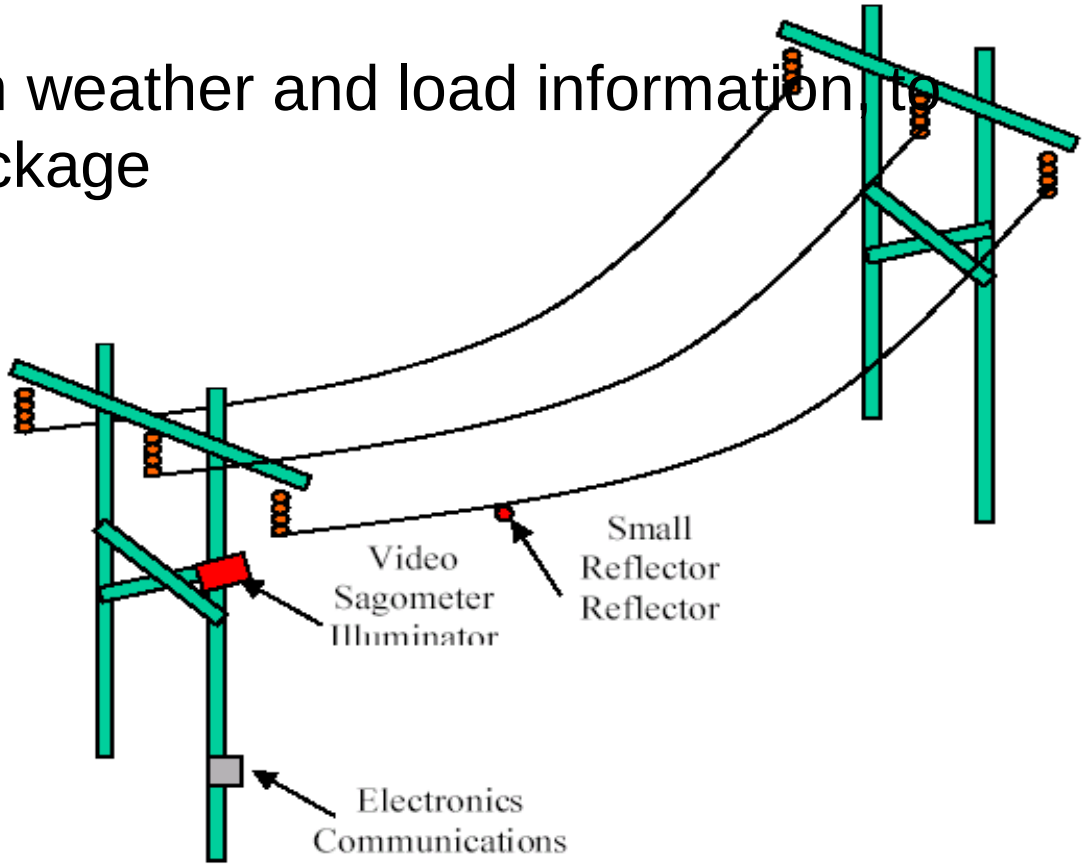


SSCL: 15kV, 1200 A continuous
80 kA rms Symmetric fault current

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How It Works – The Sagometer

- A small camera “looks at” a target on the line
- Artificial intelligence in the camera determines sag (clearance)
- Data is sent, along with weather and load information, to the DTCR software package

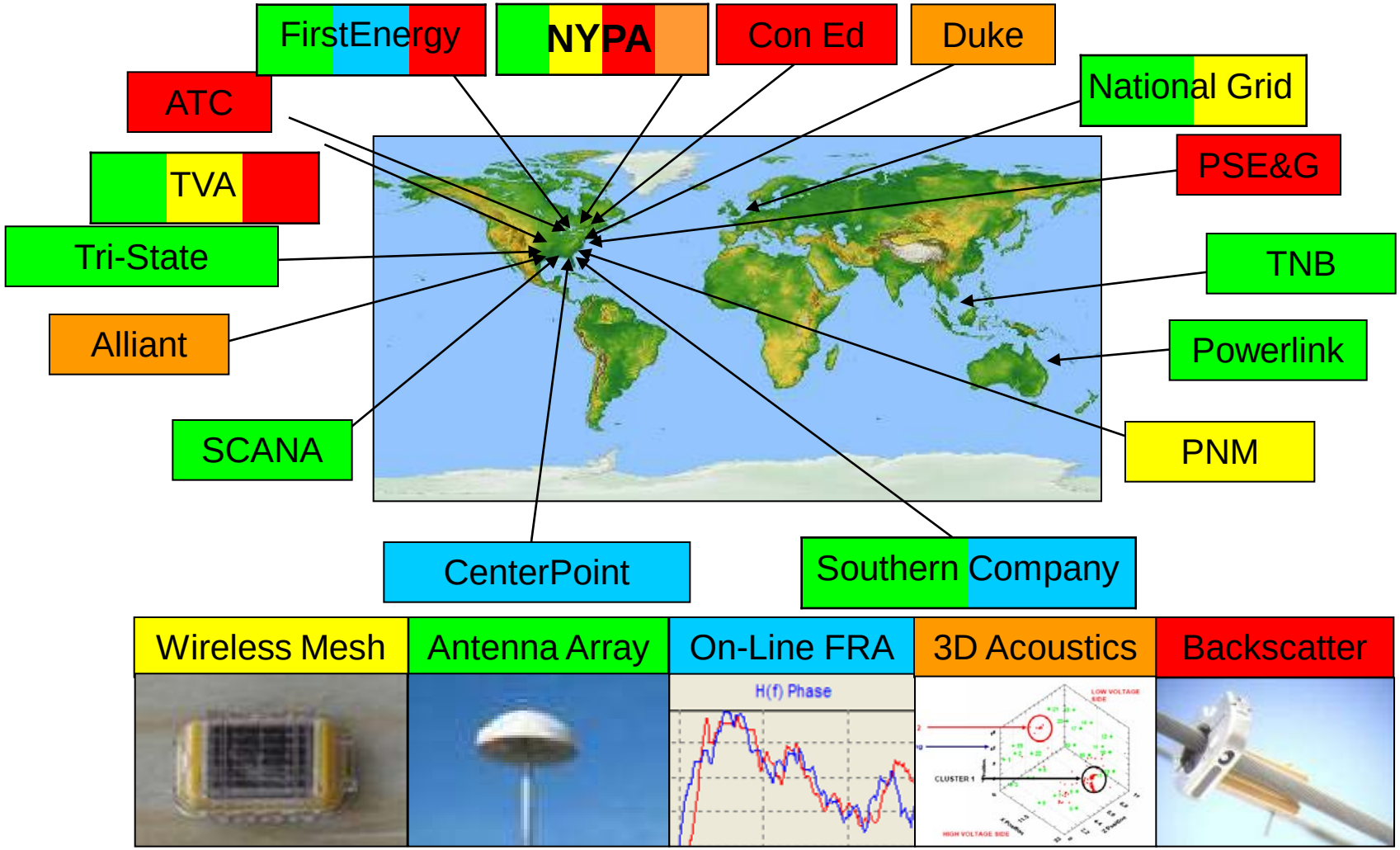


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Sensor Applications

Automate Inspection & Condition Assessment



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Smart Grid:
Enabling PHEV Through Smart Charging





AMI Path

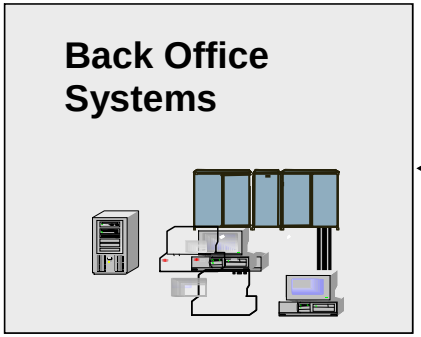


Standard
Interface



Non-AMI Path

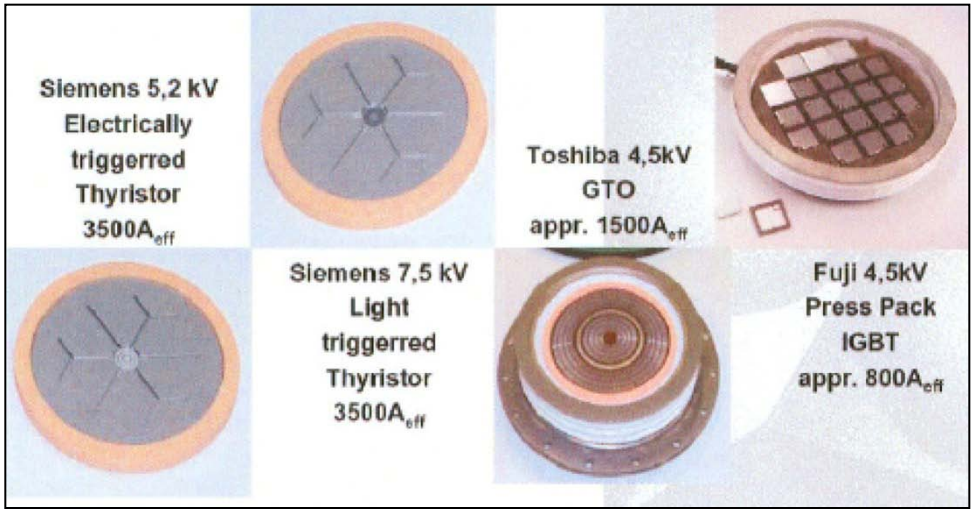
- Utility – Auto industry collaboration
- Standardize interface vehicle-to-grid
- Open systems



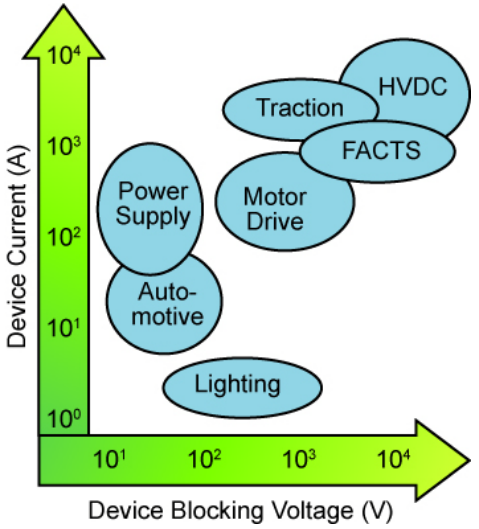
Smart Charging Back End
Energy Management, Cust ID, Billing

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Power Semiconductor Devices & Applications



(a)



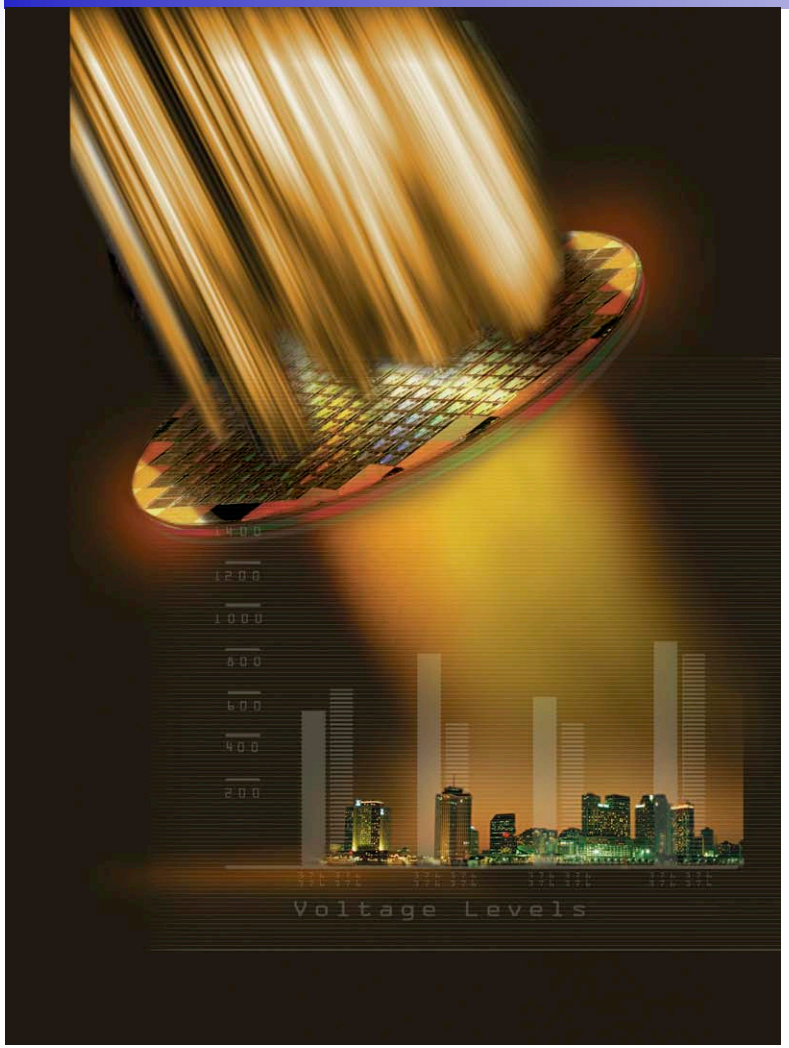
(b)

(a) Ratings (Source: Siemens)

(b) Various applications (Source: ABB)

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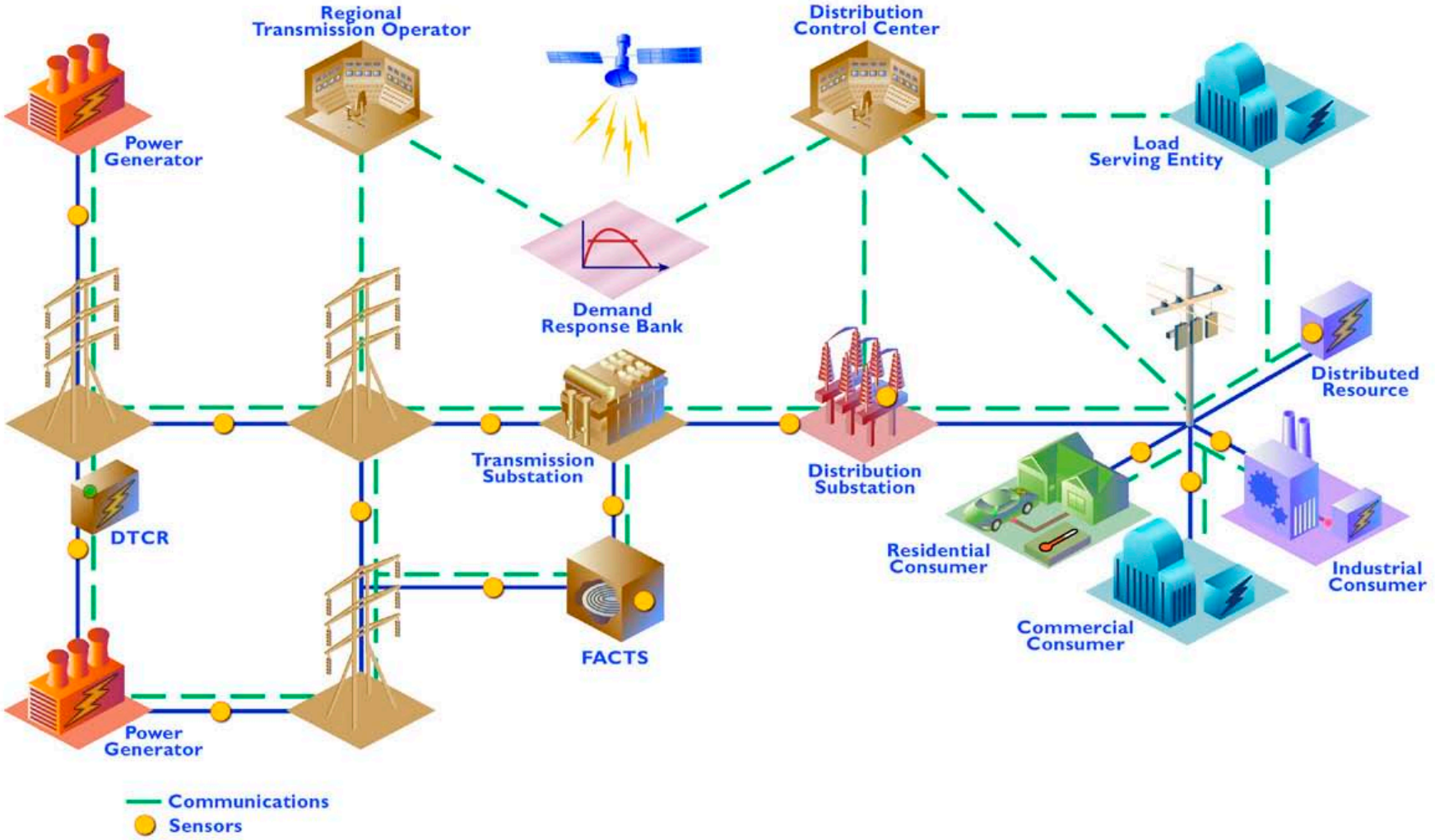
Flexible AC Transmission Systems (FACTS)



- FACTS: A “World Class” set of electric transmission VAR and flow path control devices that have extremely fast time response capabilities to match changing load and flow conditions
- FACTS devices utilize solid state electronic switches, which evolved from the “Second” Silicon Revolution
  - High speed
  - High power (voltage and current)

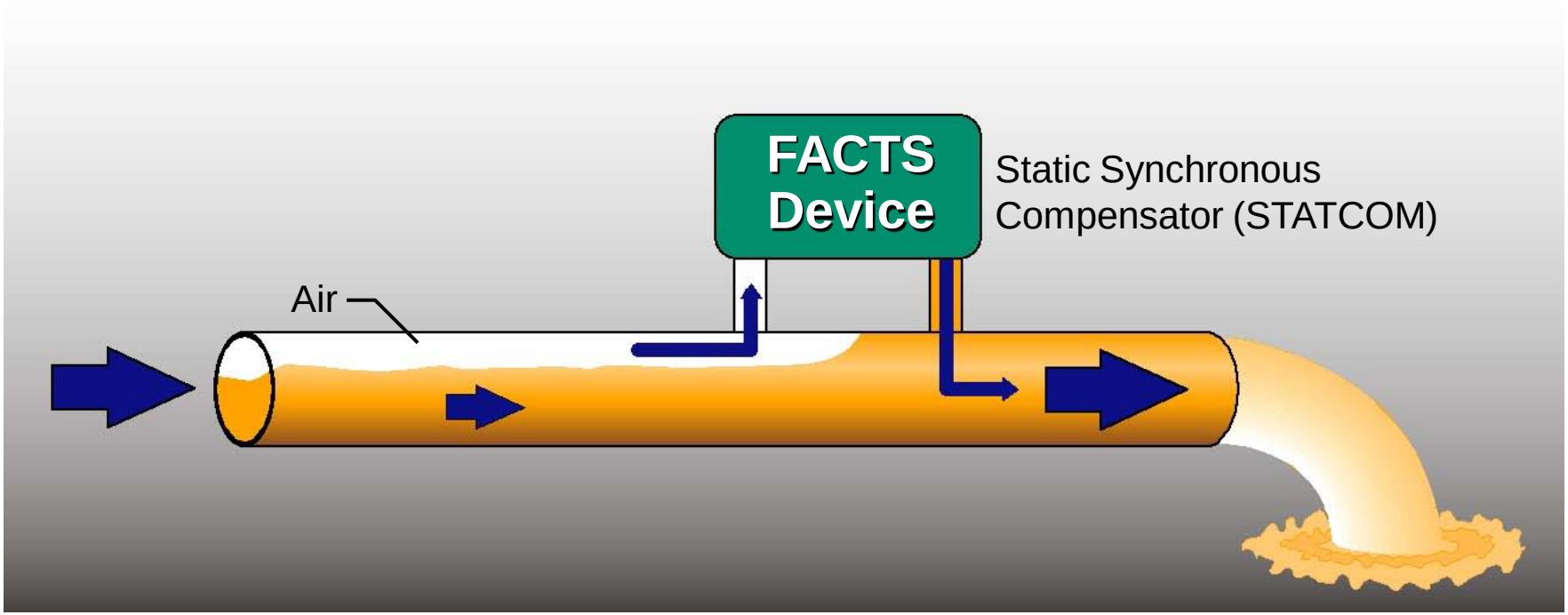
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Apply Dynamic Thermal Circuit Rating (DTCR)



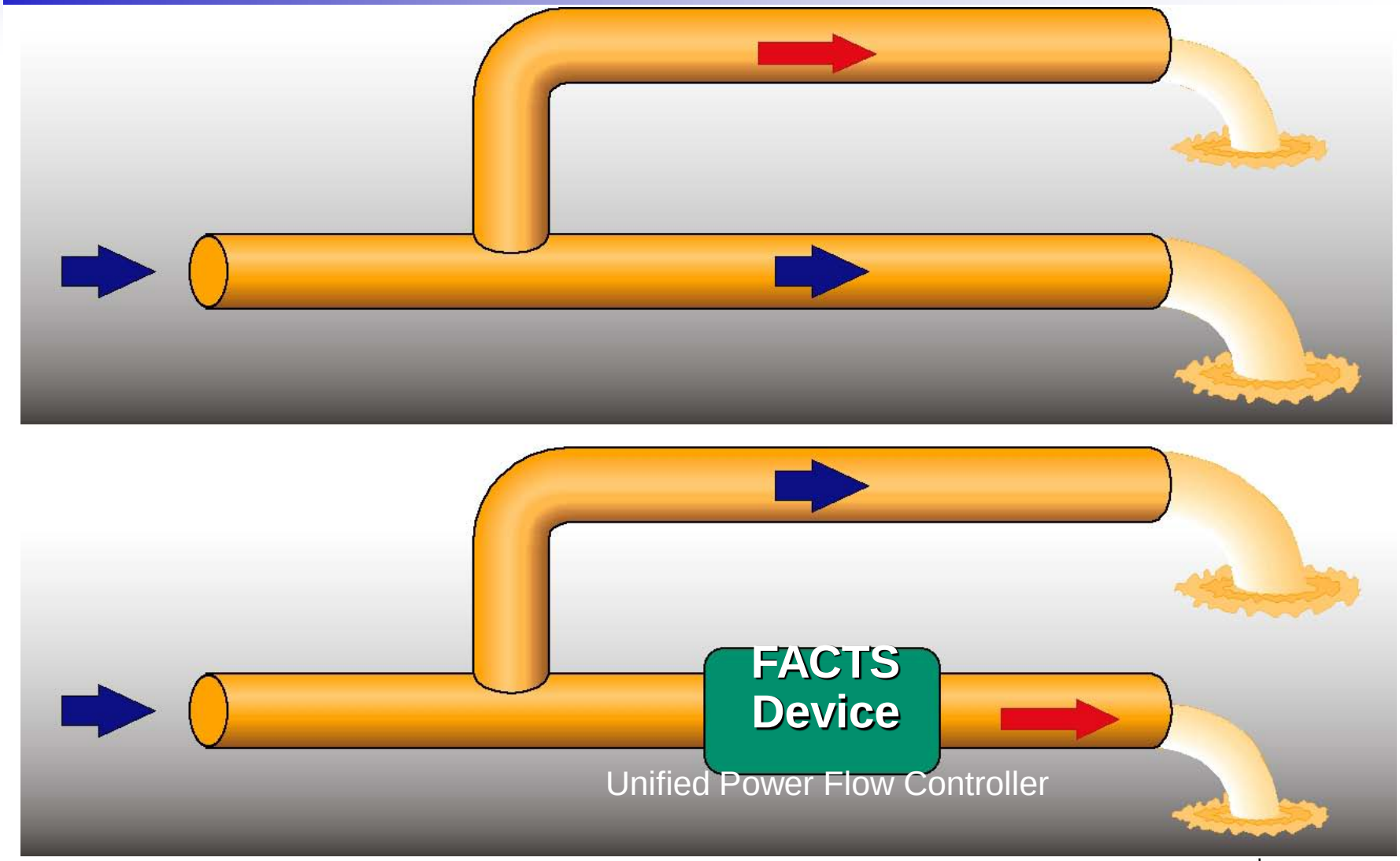
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FACTS Enhances Transmission Capacity



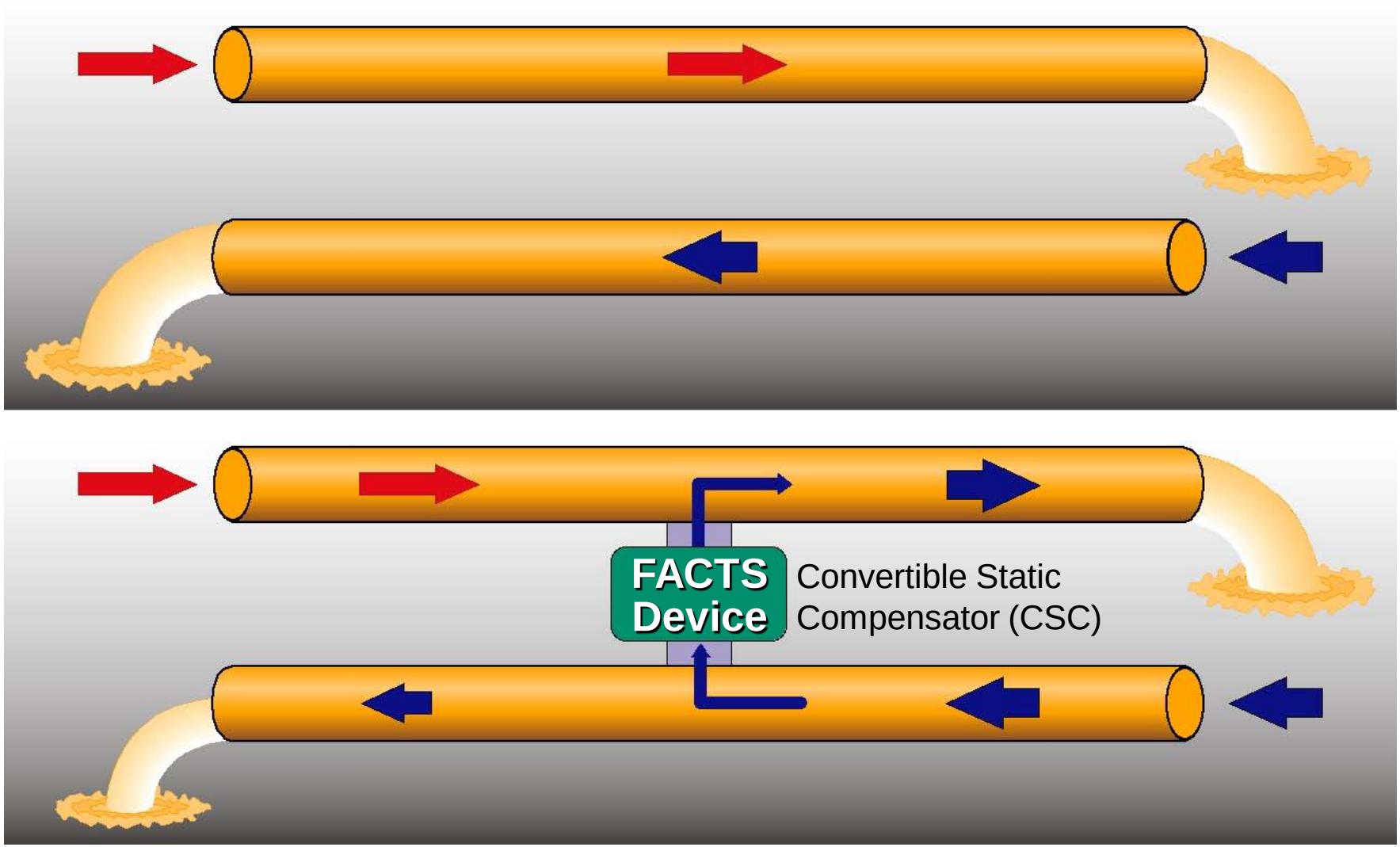
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FACTS Redirects Flow



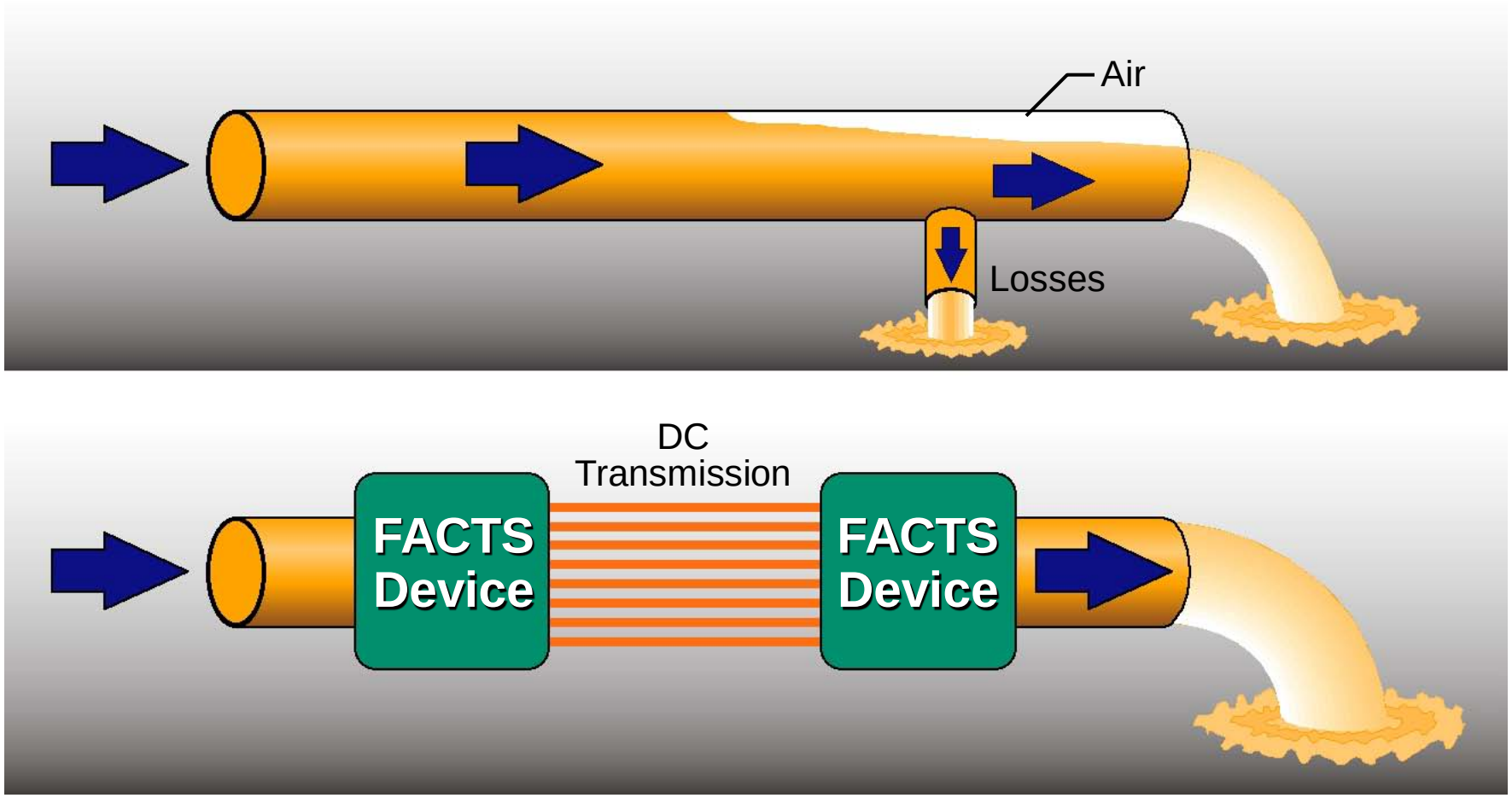
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FACTS Redirects Flow



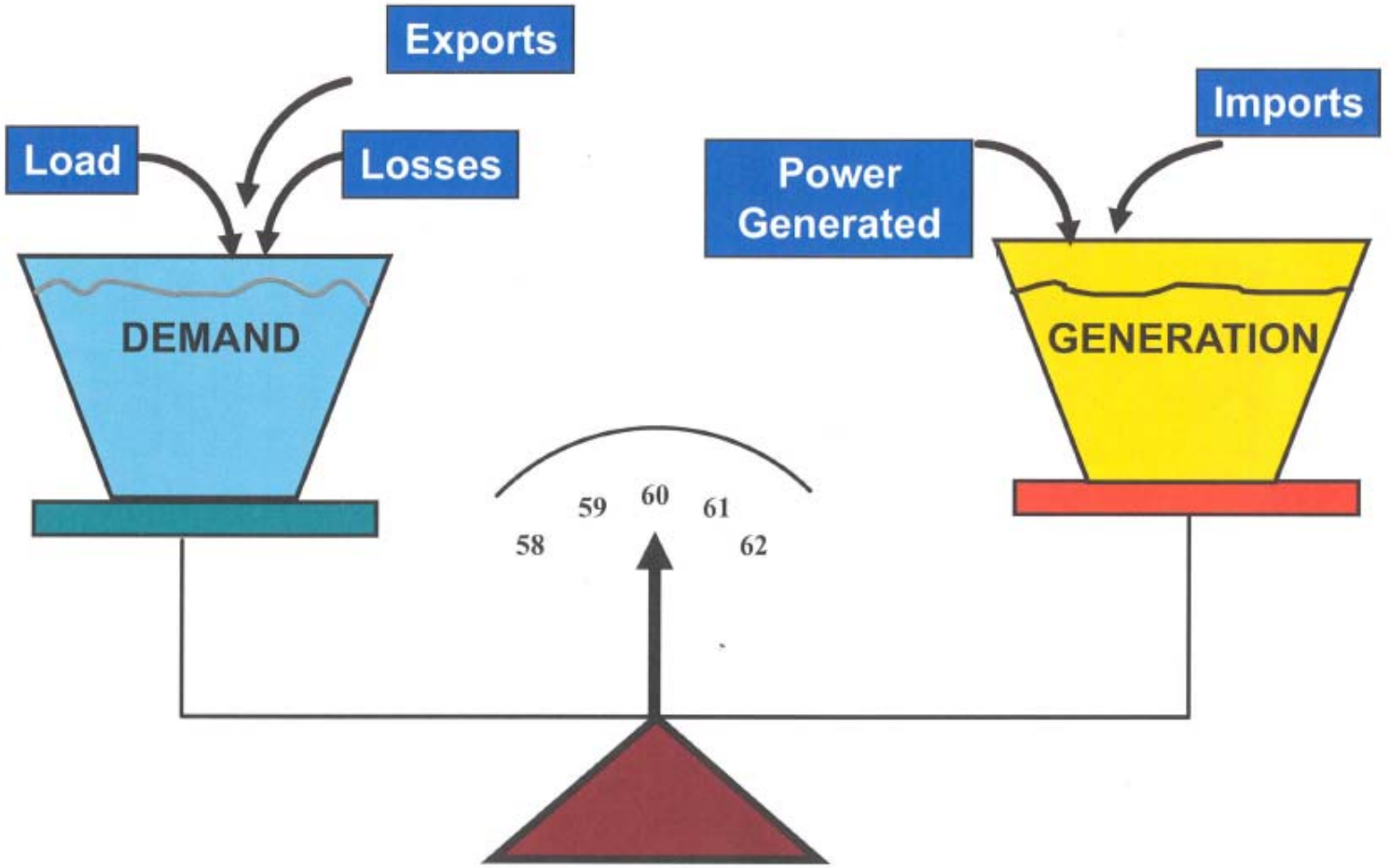
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FACTS in DC Transmission



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Energy Balance



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Imbalance Conditions

- Over-generation
  - Total Generation > Total Load
  - Frequency > 60 Hz
  - Generators momentarily speed up
- Under-generation
  - Total Generation < Total Load
  - Frequency < 60 Hz
  - Generators momentarily slow down



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