Utility Energy Forum

Microgrids for All – for Customer and Utility Benefit

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BERKELEY LAB

Image from Eric Brewer talk
"**Energy in the Developing World**"
January 14, 2010
(LoCal Retreat)

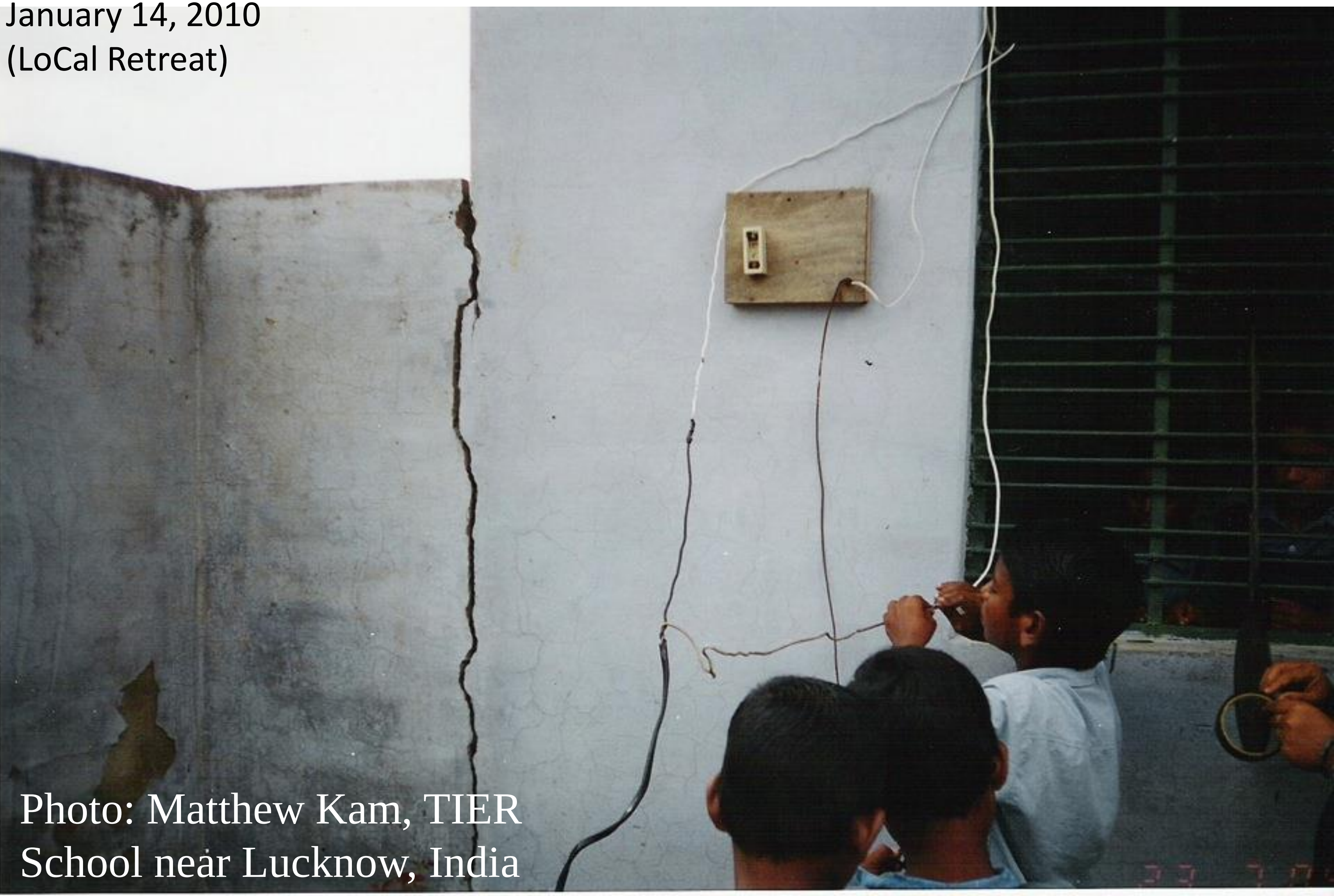


Photo: Matthew Kam, TIER
School near Lucknow, India

Power Distribution features we need

- “Plug-and-play” operation
  - End-use devices
  - Local generation
  - Local storage
- Improved safety
- Arbitrary power topologies – inter-building links
- Fine-grained management of constrained supply
  - Optimal use of distributed storage
- Greater reliability – and lesser
- Universal technologies
- Enabling optimal operation with a local price
- Security / privacy
- Greater efficiency with Direct DC

"Local Power Distribution"

- "Local" – within a building (or campus)
  - Internal to single customer
- "Power Distribution"
  - "Technology / infrastructure that moves electrons from devices where they are **available** to devices where they are **wanted**"

Local Power Distribution is a
network model of power

Grid terminology

- **Microgrid** Capability

  "… a group of interconnected loads and distributed energy resources …that acts as **a single controllable entity with respect to the grid**. A microgrid can connect and disconnect from the grid to enable it to **operate in both grid-connected or island-mode**." *(DOE Microgrid Exchange Group)*

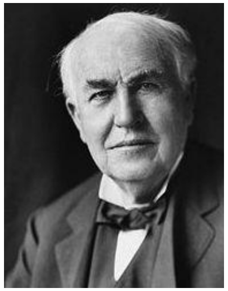
  Implies must connect to utility grid; CIGRE C6-22 defn. similar

- **Nanogrid** Simplicity

  "A **single domain of power**; single voltage, frequency (if AC), reliability, quality, capacity (power), **price**, and administration. Storage is internal to a nanogrid." Generation forms its own nanogrid. *(Nordman, 2010)*

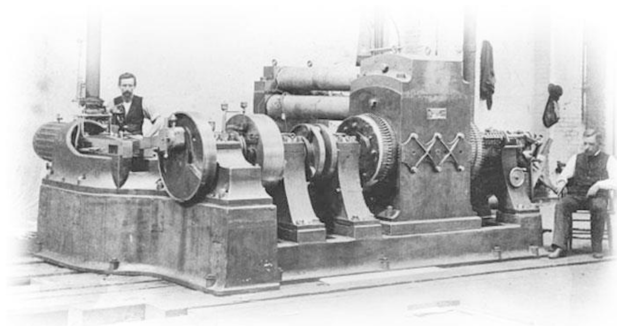
- **Picogrid** Singularity

  An **individual device with its own internal battery** for operation when external sources are not available or not preferred, and managed use of the battery. *(S. Ghai et al. in* e-energy 2013; *paraphrased)*



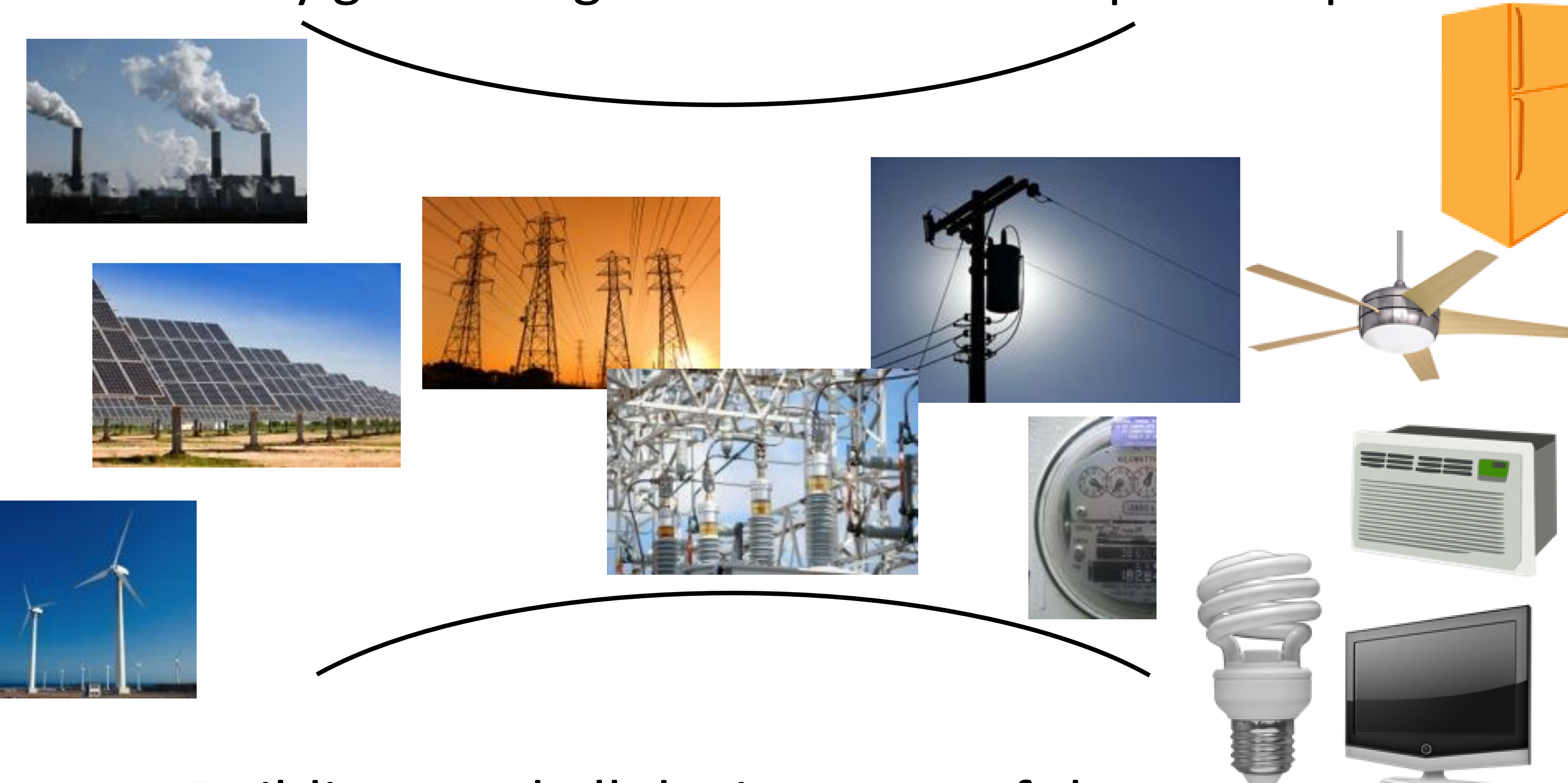
136 … 87 years later

Generation | End use | Distribution

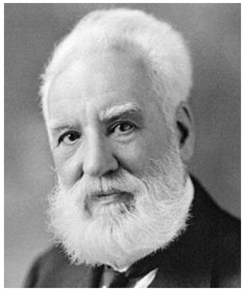


Traditional power distribution

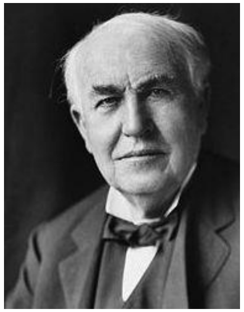
"Unitary grid" - single undifferentiated "pool" of power



- Buildings and all devices part of the pool



Communications and Power



- Phone system and utility grid invented about same time
  - Synchronous – highly coupled
  - Unitary – to end points – centrally managed
  - Organizations conservative - regulated
  - Technology advances slowly
  - Local variations in technology
  - One mode of operation

Paradigms

Unitary	*Networked*
Old phone system	**Internet**
Utility grid	**Network model of power**
19^{th} century	$20^{th}/21^{st}$ century
Centralized	Distributed
Analog	Digital
No storage	Storage widespread
Tightly coupled	Loosely coupled
Entangled technology	Isolated technologies
Custom / Expensive	Commodity / Cheap
…..	…..

Need paradigm shift

Power & information distribution

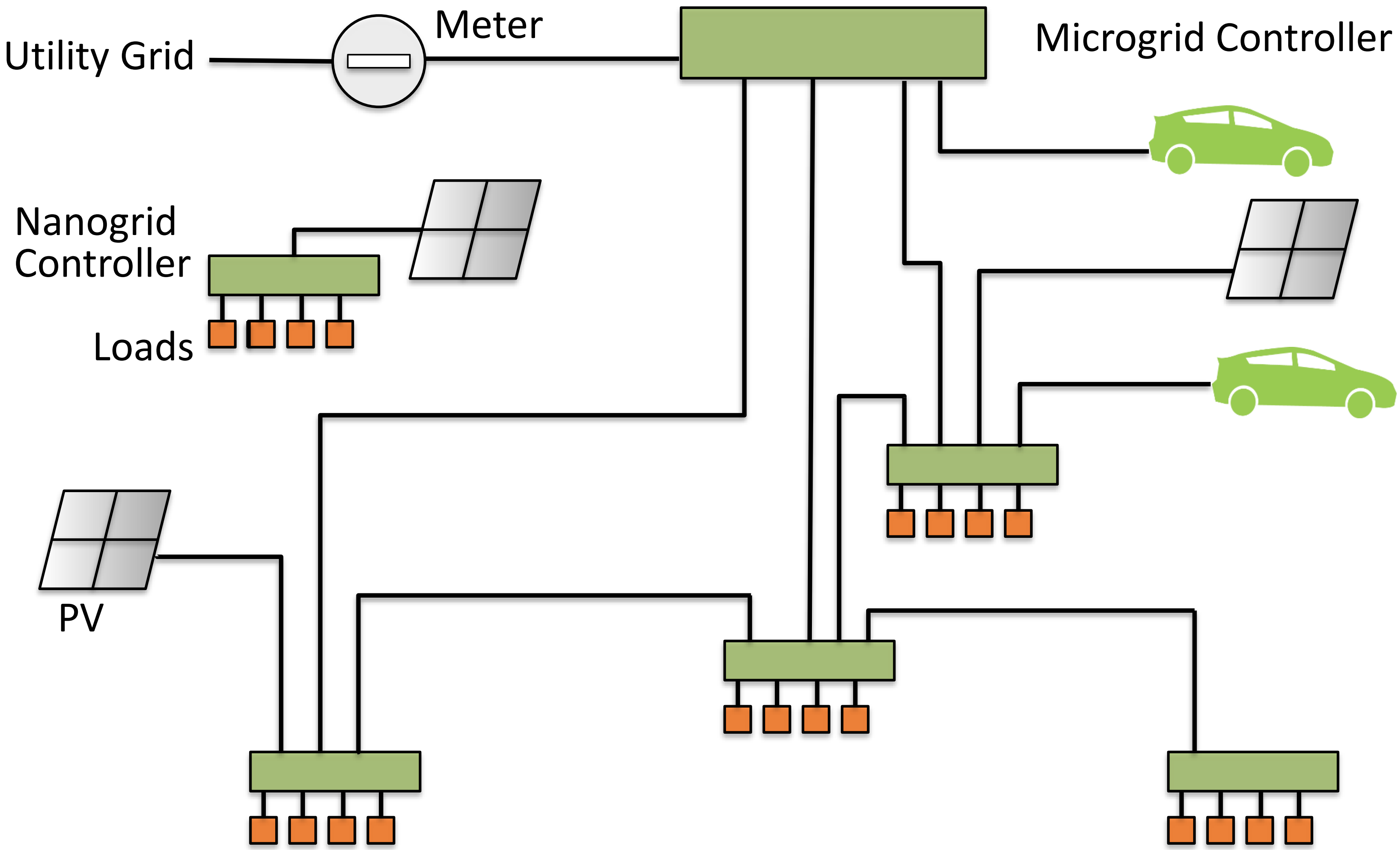
"Technology / infrastructure that moves data / electrons from devices where they are available to devices where they are wanted"

All bits/packets different; all electrons same

- Need a **fundamental mechanism** for a network model
- Communications: understand system topology (addressing) and move data accordingly
  - Data routing is how bits know where to go
- Power: balance supply and demand
  - Price is how electrons know where to go
    - Routing power makes no sense

Location, quantity, timing

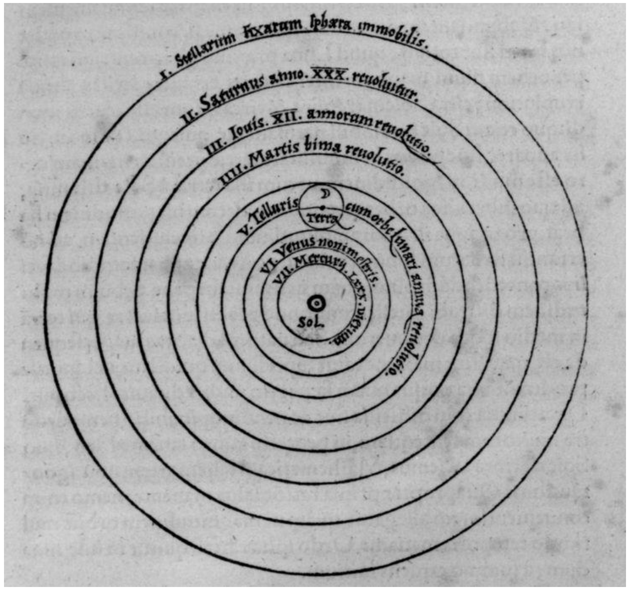
Example local grid network



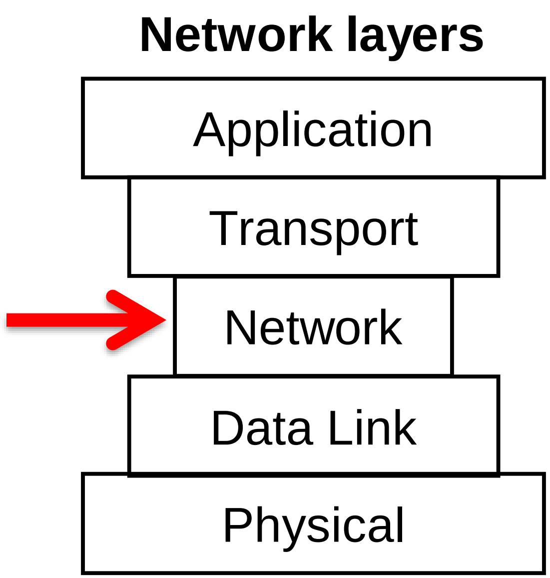
All connections peer-to-peer and can be changed dynamically

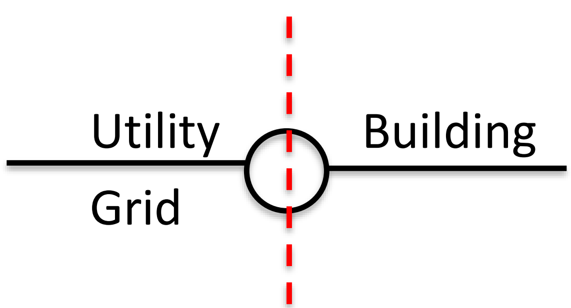
Price is how devices know which way power should flow

Paradigm changes



Buildings need three Layered Models





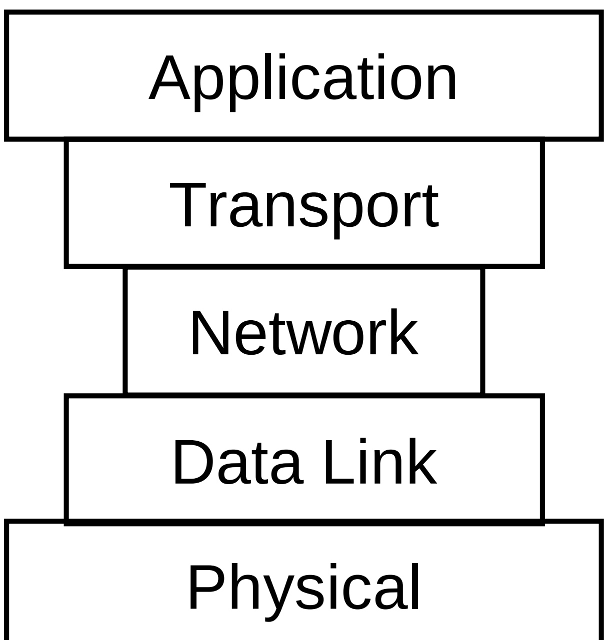
Narrow waist in layering ***isolates complexity*** *– facilitates interoperability*

- Conventional network communication
  - Application and physical layers
- Electricity / utility meter
  - Separate utility grid from building
  - "Highly dynamic pricing"
  - Use only Price, Quantity
  - Only 1-way communication
- Device internal Network Power Integration

Layered model for device operation for Local Power Distribution

Network Power Integration

Network layers

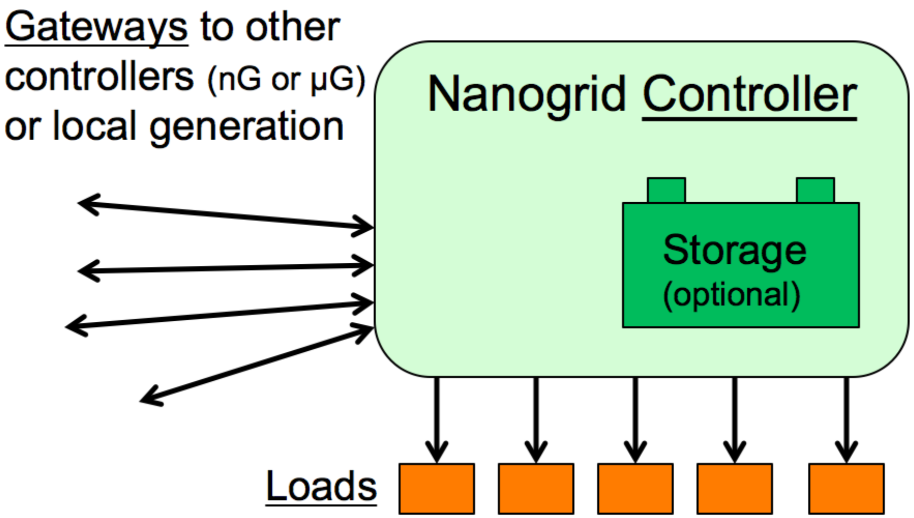


NPI layers

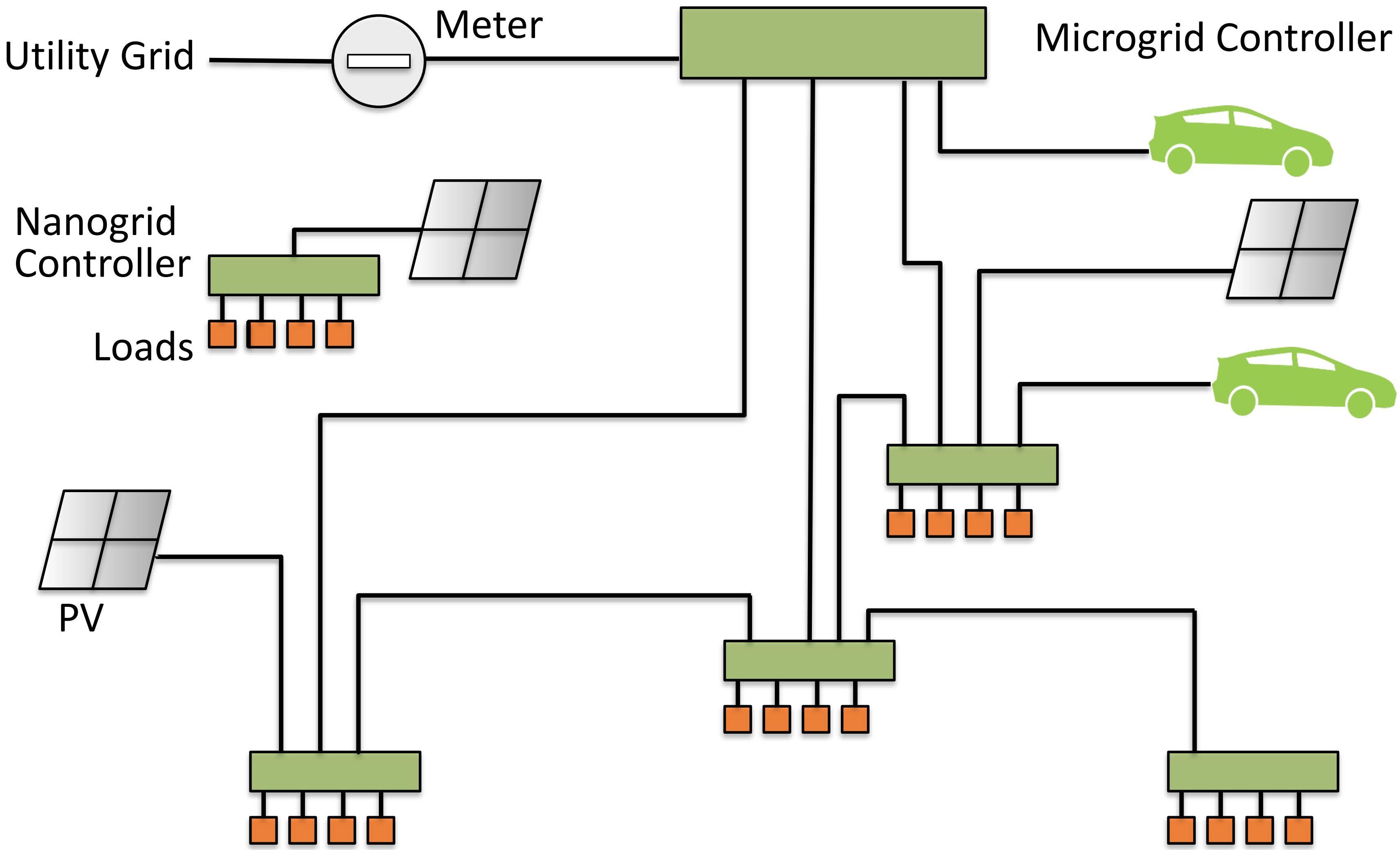
5. Functional coordination
4. Device discovery and events
3. Internal integration — Quantity, Price
2. Exchange within/between grids
1. Transport of electrons

What is a Nanogrid?

- Smallest unit of power distribution
- Single physical layer (voltage; usually DC)
- Single domain: administration, reliability, capacity, and **price**
- Can interoperate with other local grids through gateways
  - Generation forms own nanogrid
  - Only two device types: grid controller and load
- In fully-functioning nanogrid, all links include communications
- Wide range in technology, capability, capacity



Example local grid network



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Price is how devices know which way power should flow

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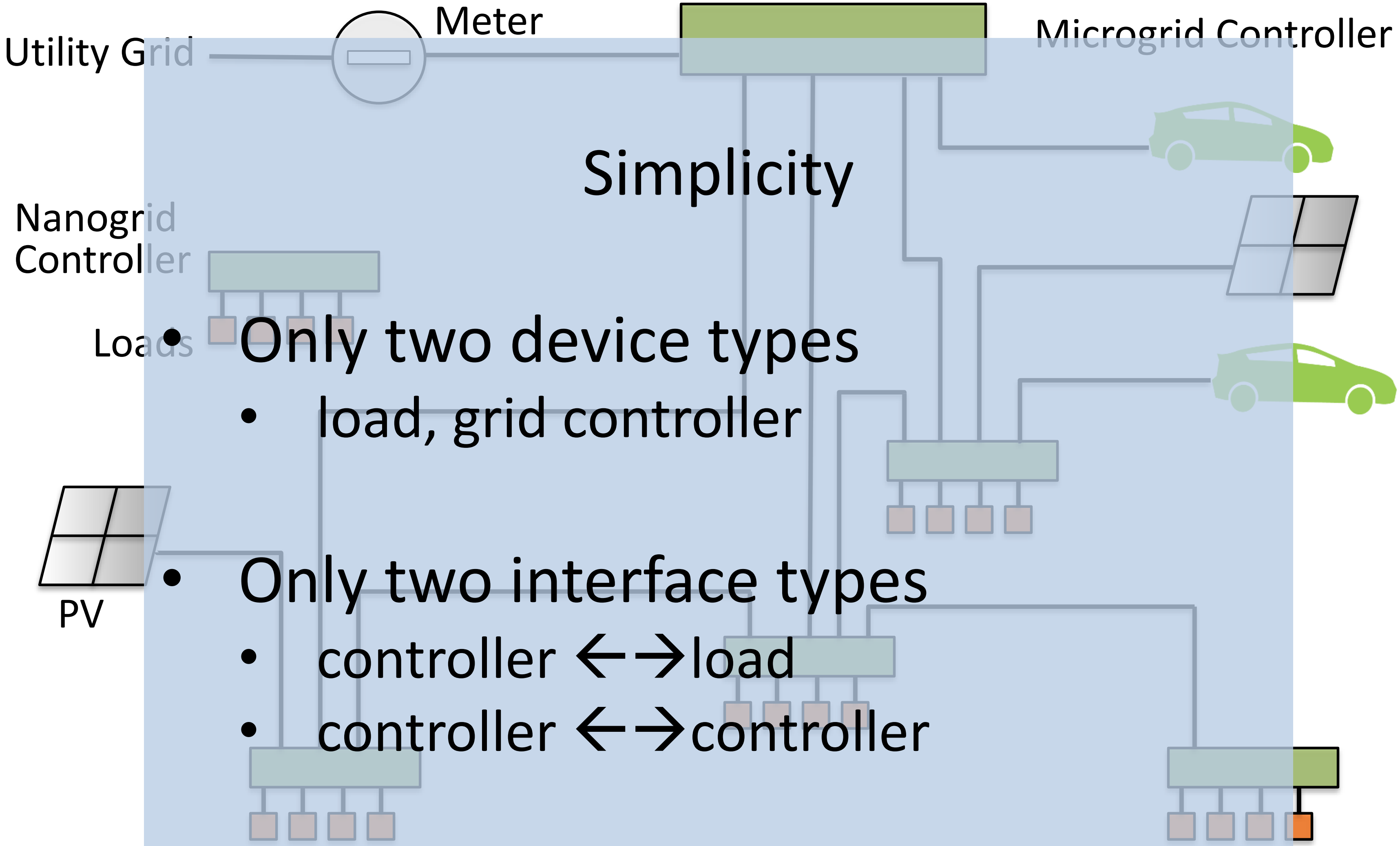

Simplicity

- Only two device types
  - load, grid controller
- Only two interface types
  - controller ←→load
  - controller ←→controller

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Power Distribution features we need

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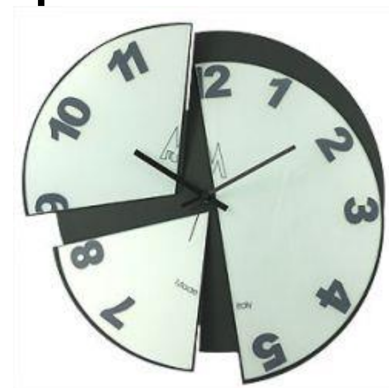
LPD provides these features

Myth of uniform power availability

- Electricity is <u>not</u> equally available across space and time
  - Has long been true within utility grid
    - "Locational Marginal Price"
  - Increasingly true within buildings
    - Local storage and/or generation, islanded grids, capacity constraints, combined heat-and-power, vehicles/mobile



- Technology we have today presumes uniform availability – **hence constant price**
- Dynamic pricing at meter a needed starting point
  - Grid can express preferences to customer

Reasons for differing local prices

- Differential buy/sell prices from utility
- Local valuation of carbon
- Losses from AC/DC or voltage conversion, battery losses, wiring losses
- Capacity constraints
- Off-grid operation – incl. mobile
- Battery management goals
- Local generation conditions (dispatch; co-gen)

- Price always **current** price and non-binding **forecast** of future prices

Everyone's 2nd Microgrid

Issue

- Communications (VOIP, Internet) no longer reliable during grid outages
- AC UPS are expensive, inefficient, non-optimized

Solution

- All communication devices be USB-powered
- Consumers have USB hub with integral battery
- Battery provides reliable power for many hours
- Hub can signal when on battery
  - Devices can reduce services to save power
- Battery can provide demand response services
- Could connect PV panel for multi-day reliability
  - Buy solar one panel at a time
  - No permits, no prof. labor – plug-and-play
- Can take camping

How is this good for customers?

- Inexpensive local reliability (microgrids)
- Buy PV one panel at a time
- Easy storage integration
- Flexibility - mobility
- Price-responsiveness – for TOU and beyond
- Efficiency (Direct DC)

- Isolates complexity of grid from building
  - Don’t need aggregators
- Great for privacy / security (1-way comm.)

How is this good for utilities?

- All devices can participate in price-based demand response
  - Maximize use of customer flexibility
  - Minimize costs for customer flexibility
  - Align utility and customer interests
- Turning off feeders in emergencies easier
  - Can relax reliability (quality) goals

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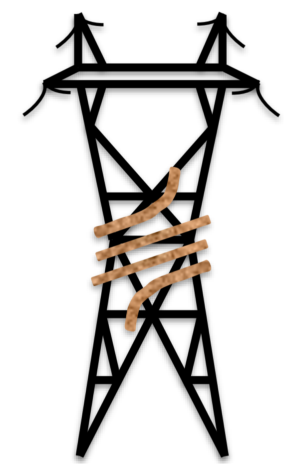

Summary

- Networked electricity key to ‘microgrids for all’
  - Local Power Distribution highly practical
  - You Can Help

- Highly Dynamic Pricing is a critical need
    - Best for customers
    - Best for utilities
    - Best for environment
  - Synergistic with networked electricity

Thank you