

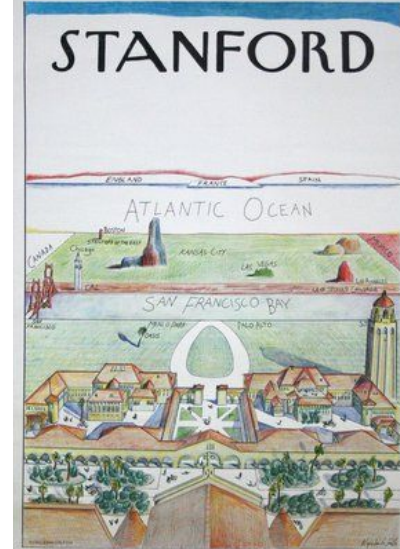
*LF Energy - FAWG*  
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# Grid Architecture from the Customer Perspective

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What you see  
Depends on  
Where you sit



# Questions I have for FAWG

- What building/grid coordination mechanisms does LFE anticipate and/or support?
- How is time-varying pricing supported?

# Background

LBNL - Lawrence Berkeley National Laboratory

- Operated by University of California - for US Dept. of Energy
- Near San Francisco
- Large focus on **energy use/efficiency in buildings** and related topics
- Work on **demand flexibility** began ~20 years ago

Bruce

- Grew up in Silicon Valley
- Focus on energy/**electronics** since mid-90s; energy/**networks** early 2000s
- **Technology standards** a critical way for public sector to influence products
- **Communication**: Device-Device; Device-Grid; Device-Human

# Building / Grid Coordination has 3 dimensions

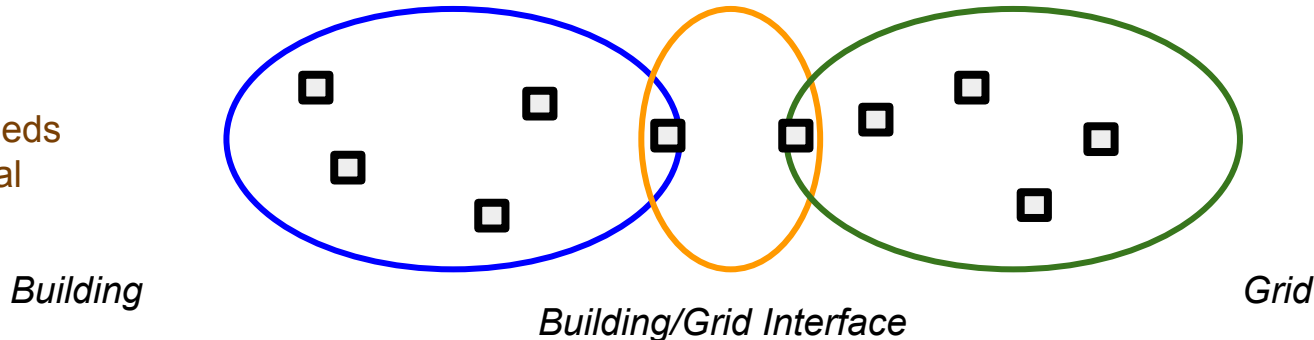
- Energy
  - Shifting/shedding load ('taking')
  - What is assessed at the meter
- Power
  - Mostly what inverters do
  - Reactive power, power quality, ...
  - 4-second regulation signal
- Capacity
  - Most critical hyper-locally
  - Negotiate power limits
  - EVs making this critical

# Buildings (Customers) are their own domain

- For buildings, grid should be a 'black box'
- For grid, buildings should be a 'black box'
- Interface between the two should be as simple as possible
  - And no simpler

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Local tech needs  
to be universal



Wide area tech  
can vary over  
space and time

# Energy Access context indicates need for alternatives

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 – 139 ... 90 years later\*

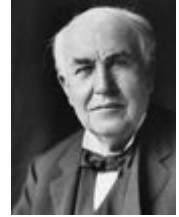
## Generation



## End Use



## Distribution



Thomas Edison

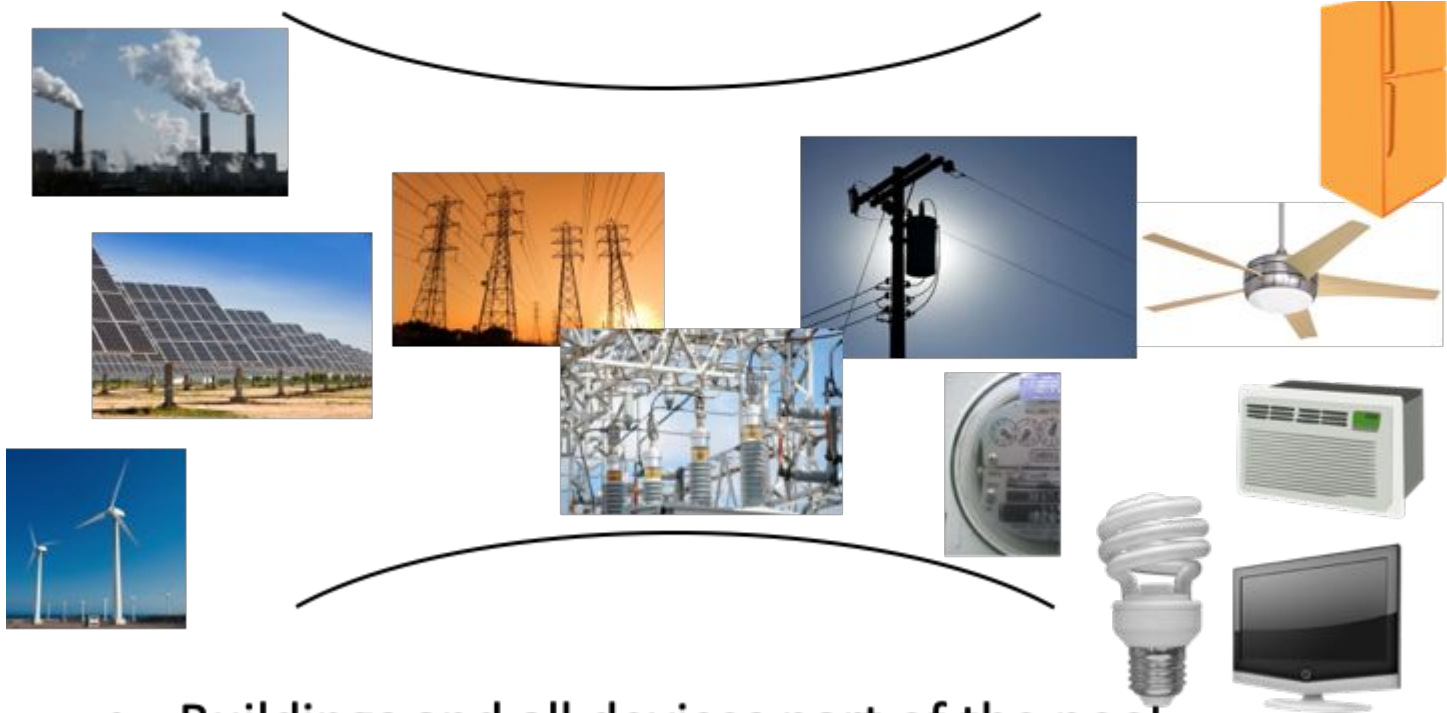
- Wires
- ~~Fuses~~ Circuit Breakers
- Junction boxes
- ...



\*1882: Utility grid  
1931: Edison dies



# “Unitary Grid” - single ‘pool’ of power



- Buildings and all devices part of the pool

# Similar histories - Phone system and Utility grid

- invented about same time (circa 1880)
- Synchronous – highly coupled
- Unitary – to end points – centrally managed
- Organizations conservative - regulated
- Technology advances slowly
- Local variations in technology - minor
- One mode of operation

| <b>Old phone system</b> <i>Unitary</i> | <b>Internet</b> <i>Networked</i>           |
|--|--|
| <b>Utility grid</b>                    | <b>Network model of power</b>              |
| 19 <sup>th</sup> century               | 20 <sup>th</sup> /21 <sup>st</sup> century |
| Centralized                            | Distributed                                |
| Analog                                 | Digital                                    |
| No storage                             | Storage widespread                         |
| Tightly coupled                        | Loosely coupled                            |
| Entangled technology                   | Isolated technologies                      |
| Custom / Expensive                     | Commodity / Cheap                          |
| .....                                  | .....                                      |

# Power & information distribution

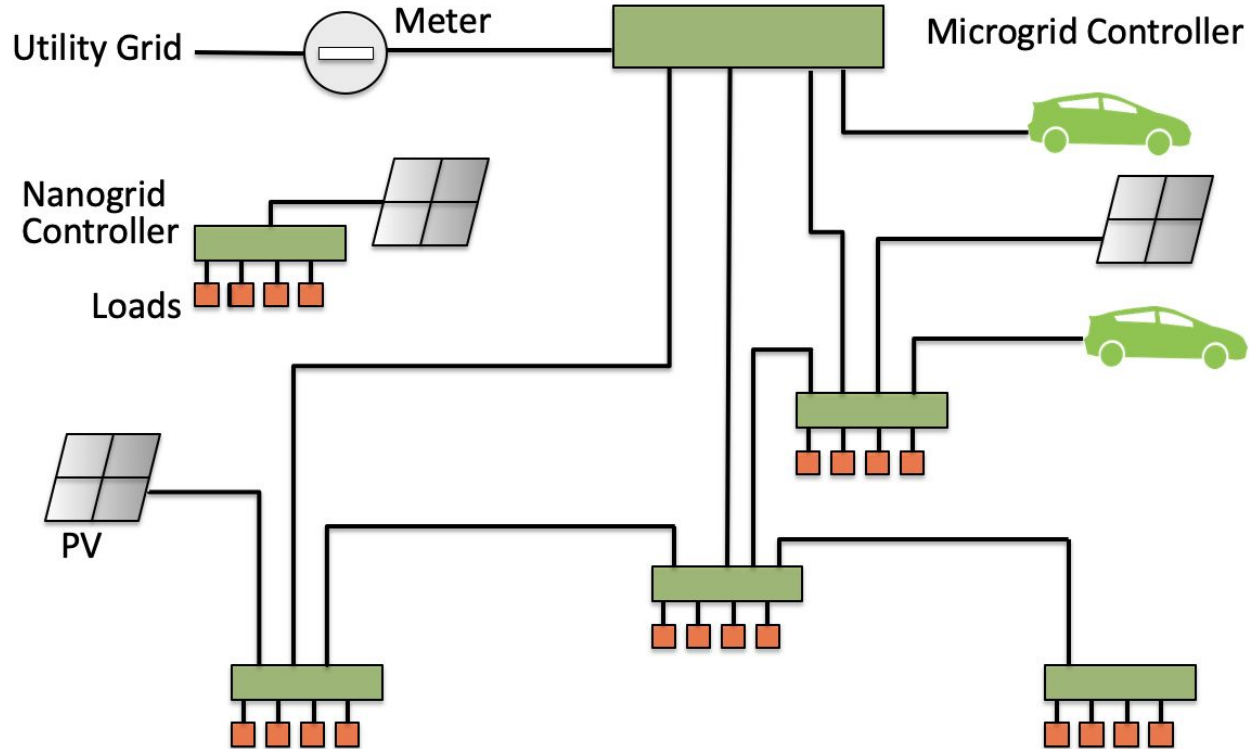
“Technology / infrastructure that moves data / electrons from devices where they are available to devices where they are wanted”

*All bits/packets different; all electrons same*

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

**Location, quantity, timing**

# Networked Electricity - “Local Power Distribution”



- nG controller functions like an Ethernet switch or Wi-Fi access point
- Each nG has elec. storage and its own “**local price**”
- Power only flows toward higher prices
- All communications over single link

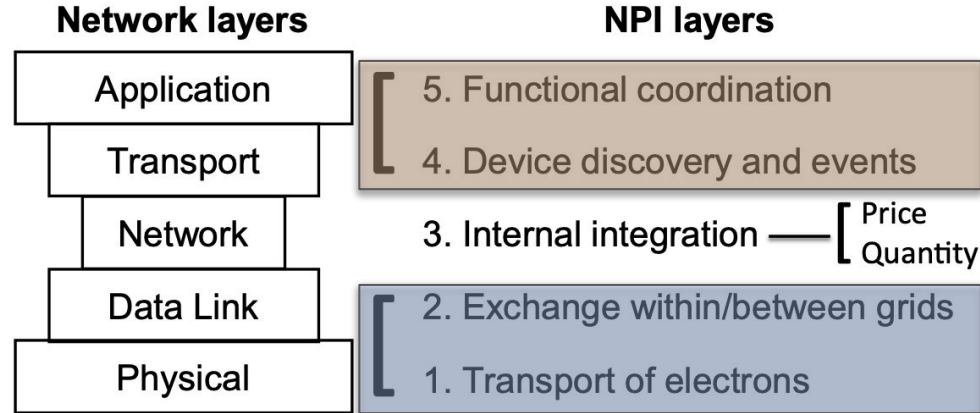
All power distribution digitally managed

# Grid vs. Building

- Grid devices provide no direct benefit to people
- Building devices all\* provide benefit to people
- Two tech domains in buildings
  - Power Distribution
  - Functional Control

*What system architecture innovations are needed for pervasively networked buildings?*

## Network Power Integration



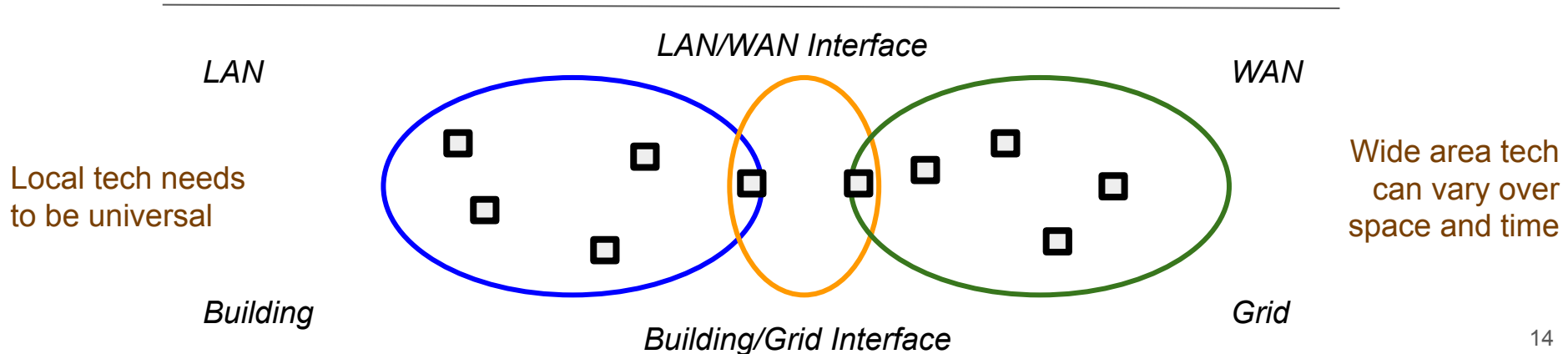
## Infrastructure Devices

- Addition adds some complexity ...
- ... but avoids much more

# Buildings (Customers) are their own domain

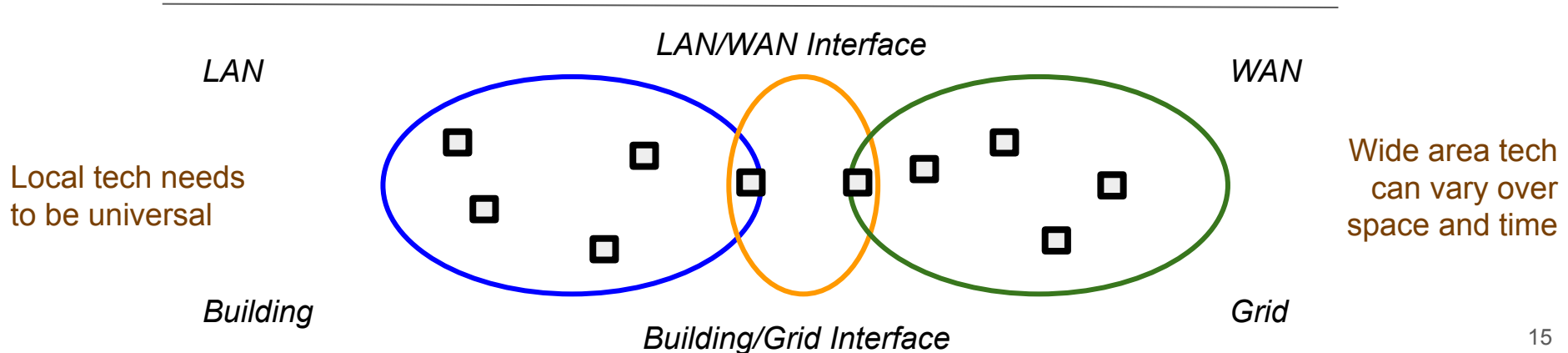
- For buildings, grid should be a 'black box'
- For grid, buildings should be a 'black box'
- Interface between the two should be as simple as possible
  - And no simpler
  - For energy, just price and quantity

LFE should address  
all three domains



# Retail and Wholesale are different

- Intra-grid are wholesale
  - Grid/customer are retail
  - Intra-customer are local
- 
- That efforts are made to put retail into wholesale indicates that retail is broken



# “Coordination Architectures”

- Unstated assumptions about how grid could and should work
- “**Who** talks to **Whom** about **What**”
- Direct Load Control
- Event-based Demand Response
- Price-based Demand Response (One-way Transactive)
- Two-way Transactive Energy (bidding, auctions, ...)
- ...

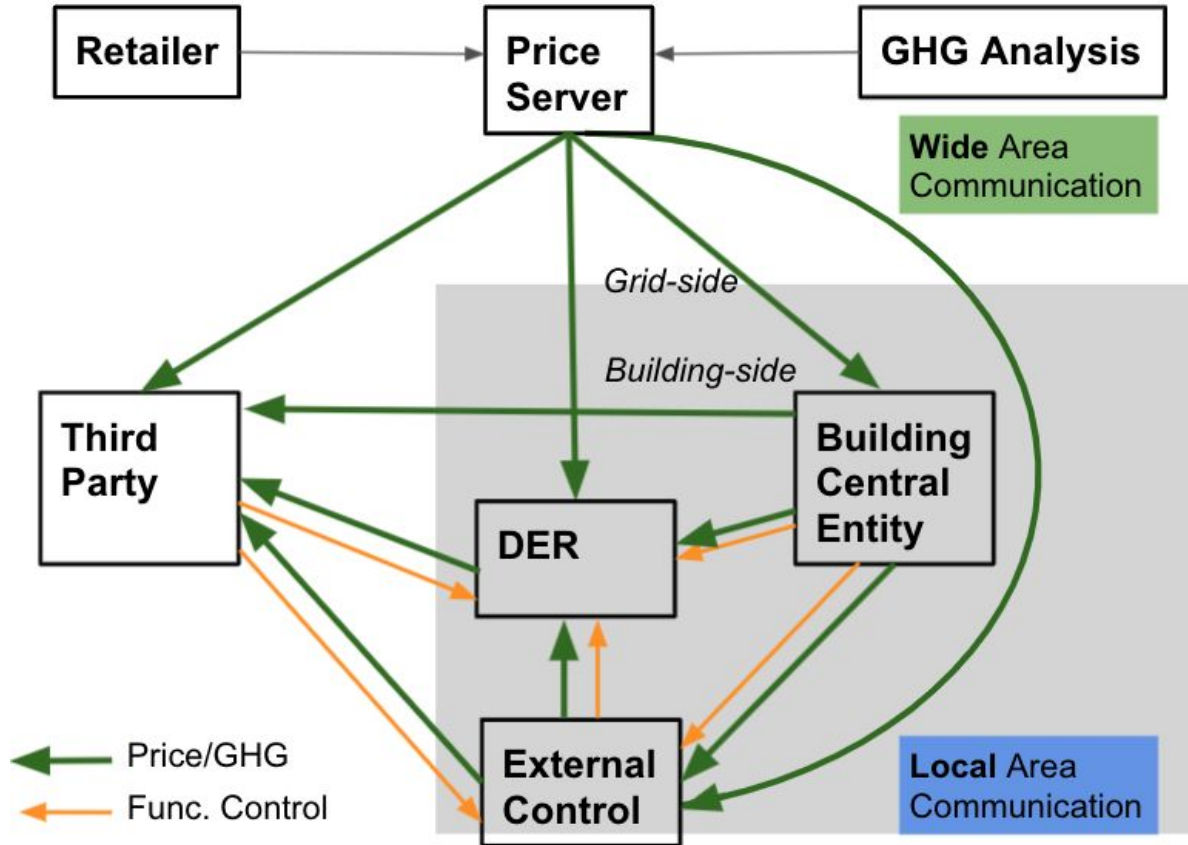
*Global optimum number of Coordination Architectures is One*



# Design Principles / Assumptions (subset)

- **Simpler** is better
- **Universal** solutions are ideal
- Learn *appropriate* lessons from the success of **Internet technology**
- **Storage** changes everything
- Pricing covers **all DER**, all of the **time**, for all **customers**
- **Retail and wholesale** entities never overlap
- **5-minute** pricing, with a 24 hour forecast, a likely endpoint
- Price **forecasts** are not guaranteed
- **Third parties** can offer flat rates or guarantees - utilities don't need to
- Coordination with utility grid should enable **microgrid** operation
- The time for “incremental additionality” is over

# “Price-Based Grid Coordination” (PBGC)



- Data flow to DER / customers is one-way
  - Return is measurements from feeders, substations, ...
- Allows innovation in how to determine prices and how DER use them
- Enables multiple locations of translating prices to functional controls
- Building ‘gateway’ not required

# Price Streaming Data Model

## Static Elements

- **Retailer**Long, RetailerShort
- **RateName**Long, RateNameShort
- Country
- State
- Currency\*
- DateAnnounced
- DateEffective
- URL
- BindingPrices
- LocalPrice

*\*GHG Emissions a “Currency”*

## Dynamic Elements

- CurrentTime
- OffsetToFirstPrice
- IntervalCount

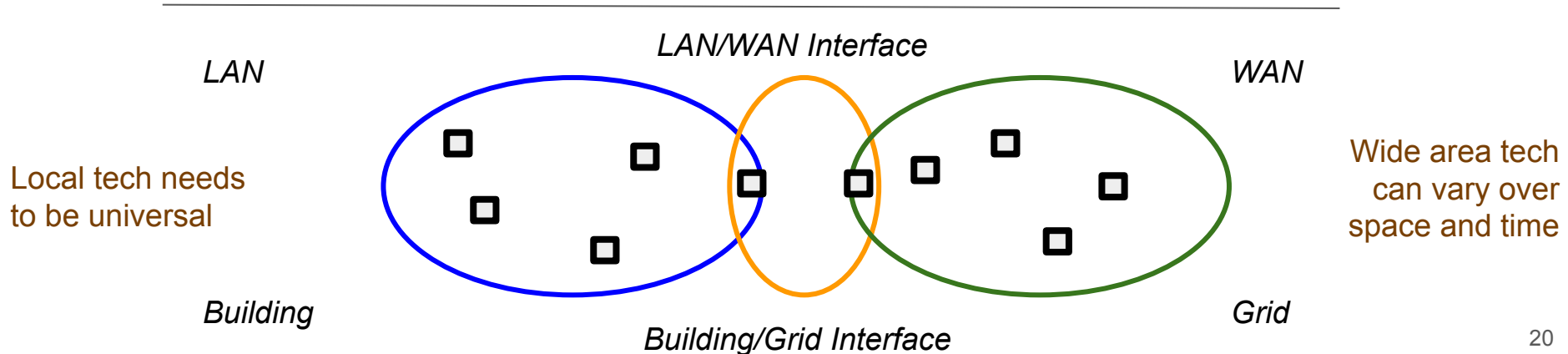
### *For each Interval*

- **TimeStamp**
- **Price**
- ExportPrice

*Each element has definition and standard encoding*

# Recommendations for LFE Architecture

- **Adopt diagram below**
  - Describe “Energy Services Interface”
  - Adopt “Local Price” concept
- **Fully implement dynamic pricing before considering alternatives**



*Thank you*

