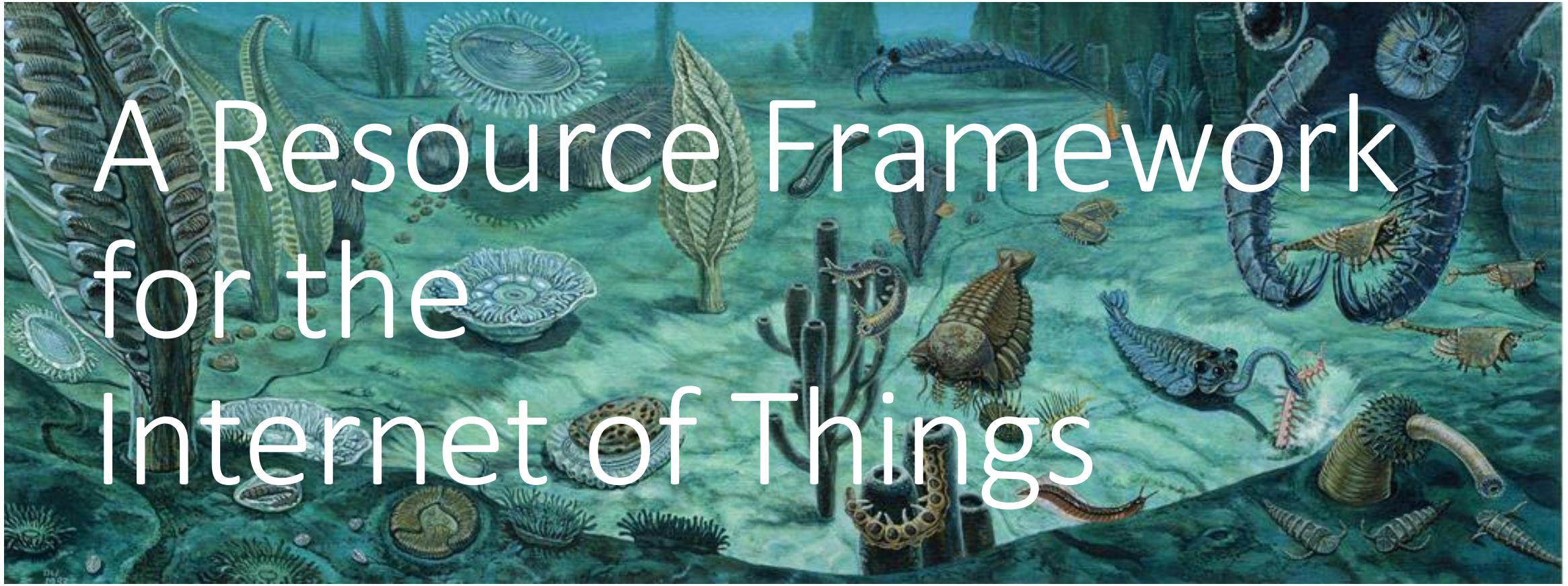
EML The Energy Mashup Lab



A Resource Framework for the Internet of Things

Toby Considine, The Energy Mashup Lab
Bruce Angelis, Enphase Energy

** ediacaria by DW Miller, used by permission*

Resource Framework Session Overview

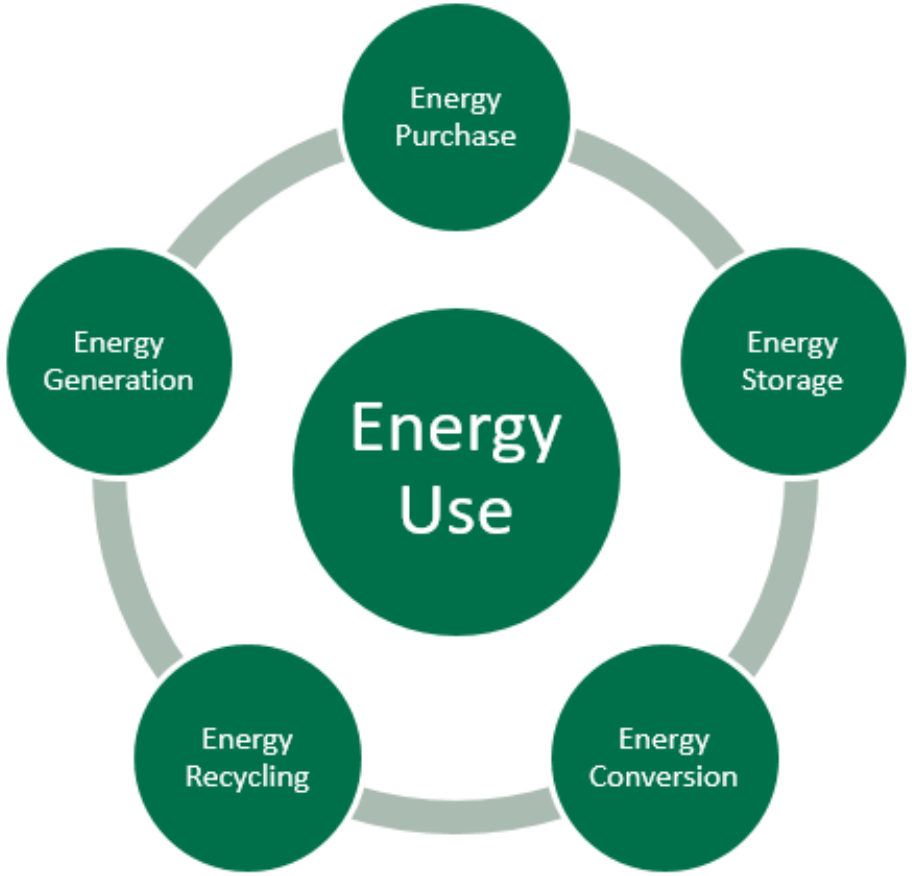
1. Introduction to Transactive Resource Management (Toby Considine, The Energy Mashup Lab)
2. The business case for resource management in microgrids (Bruce Angelis, Enphase Energy)
3. Mashup Lab Approach
4. Call for Participation

The Energy Mashup Lab

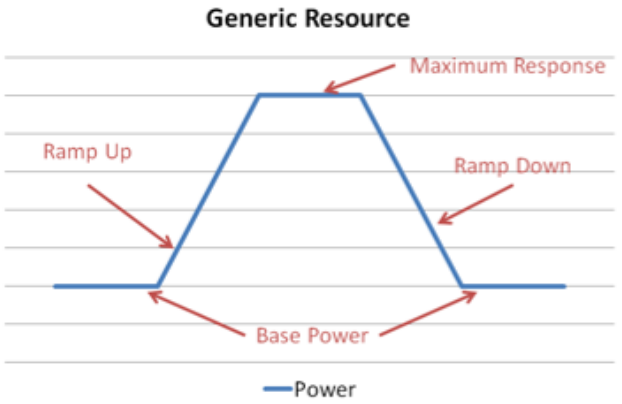
Transactive Resource Management – an Introduction

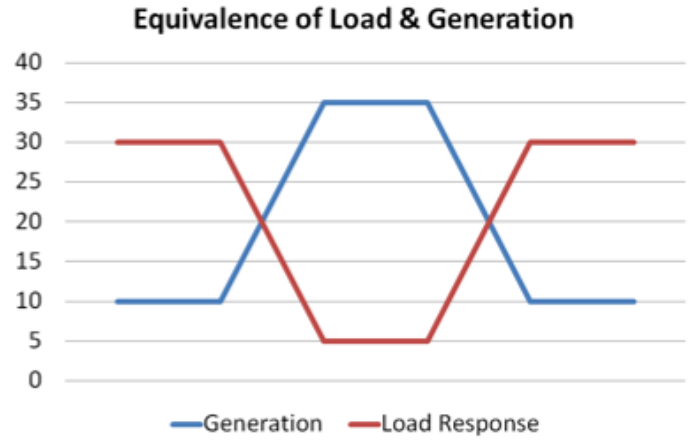
Toby Considine
The Energy Mashup Lab
director@theEnergyMashupLab.org

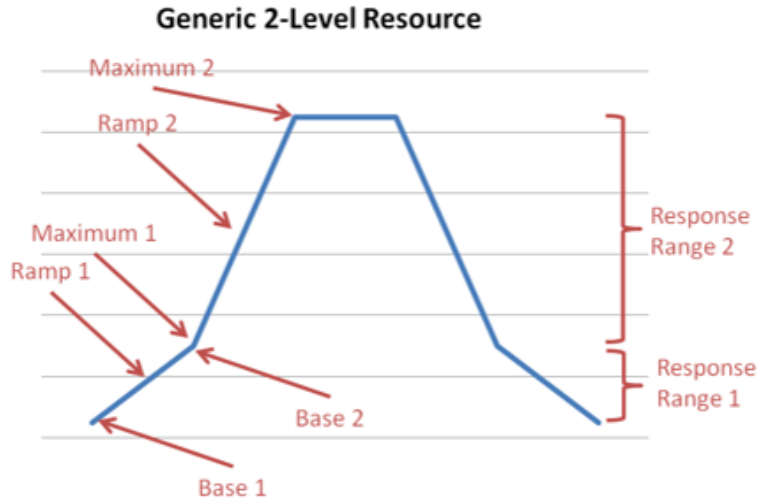
Many Apps and Appliances require access to Resources to deliver service



But Resource Availability varies over time even as demands change on their own schedule







Use Transactive Services to smooth resource use and allocate resources over time without increasing the integration burden.

Answer

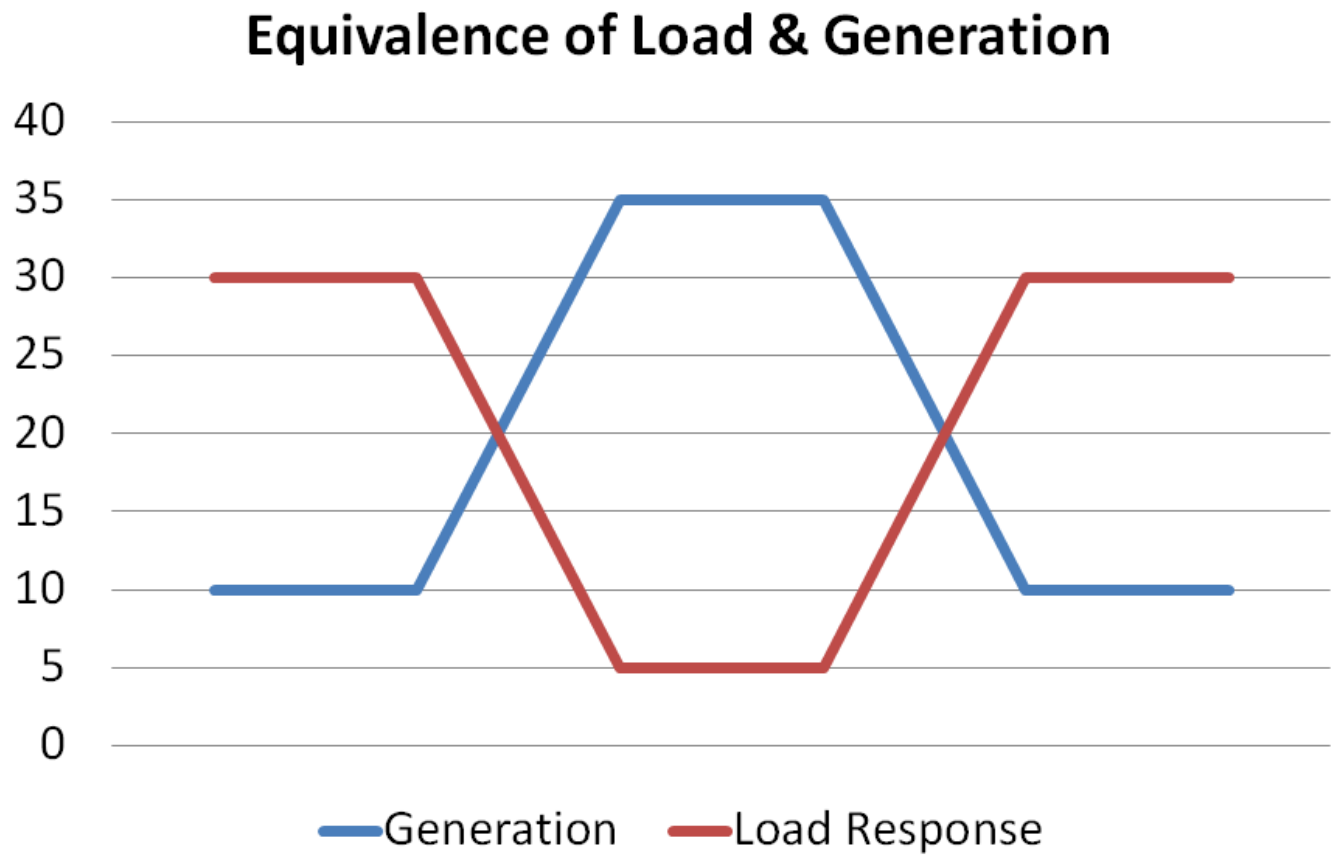
EML
The Energy Mashup Lab

An introduction to Transactive Operation

Light, agile integration style that enables diversity and innovation

Resources

Limited commodities whose value is determined by time of delivery.



Resources can by physical or virtual

- Power / Steam / Wastewater
- Capacity / Congestion
- Transport Fees and Transport Loss
- Reduction of demand has the same market effect as increase in supply

Distributed energy increases local variability in resource supply and demand.

Two Apps contending for a resource can cause damage to themselves and to the systems that support them.

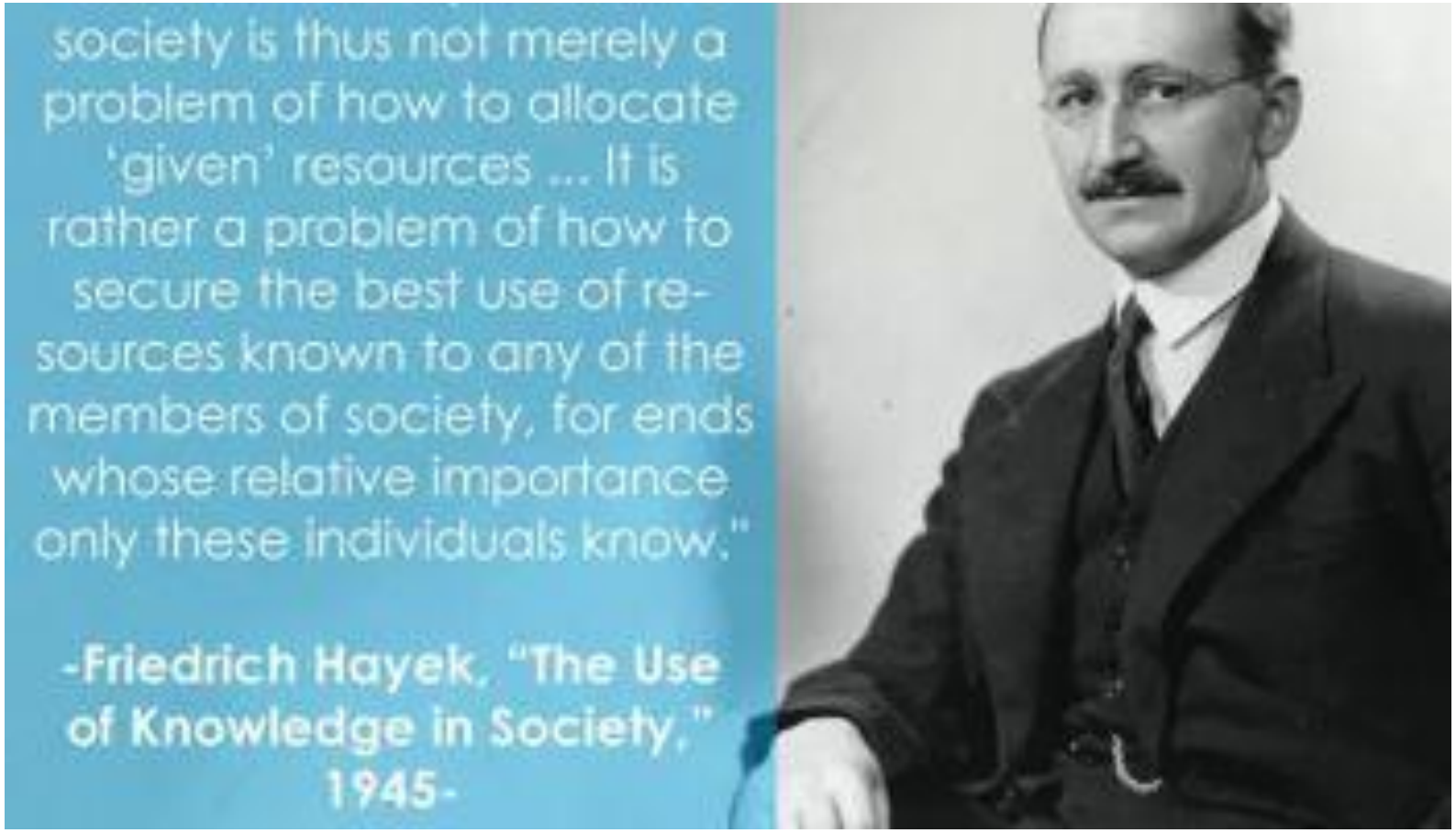
Transactive Operation

reduces the cost of integration

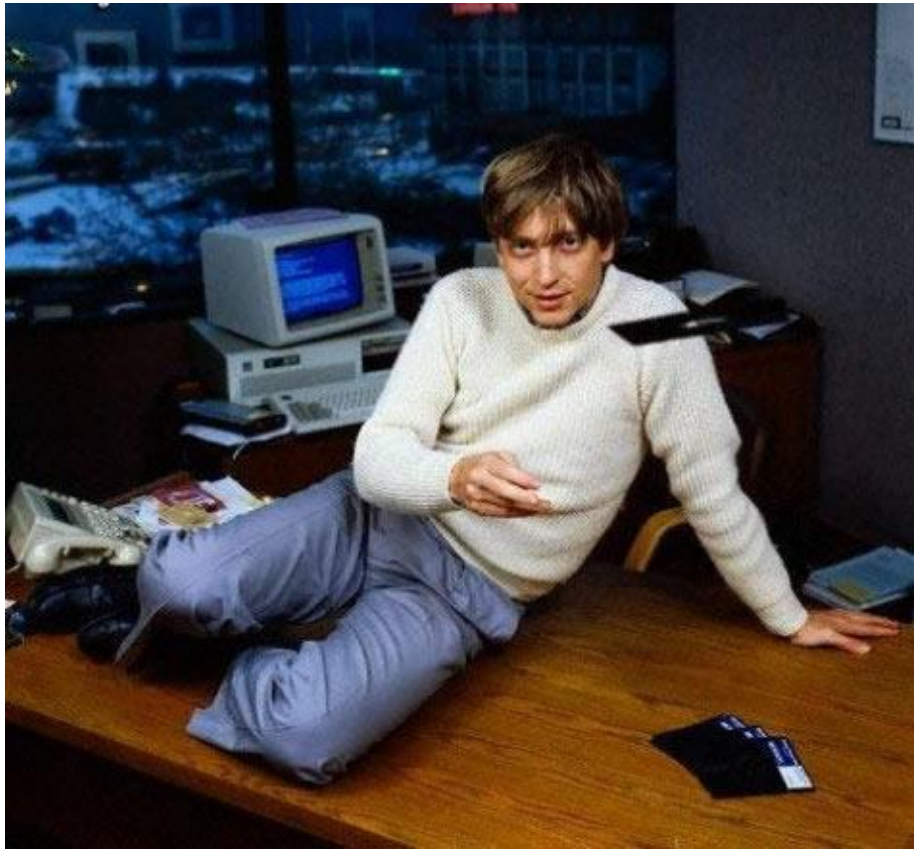
The Knowledge Problem in systems integration

- Knowledge of what technology is in a system
- Knowledge of the purpose of the system
- Knowledge of the motives and values of the system owners

Transactive Operation is a low integration method for allocating resources using market dynamics



Xerox PARC pioneered Transactive Operation in 1993



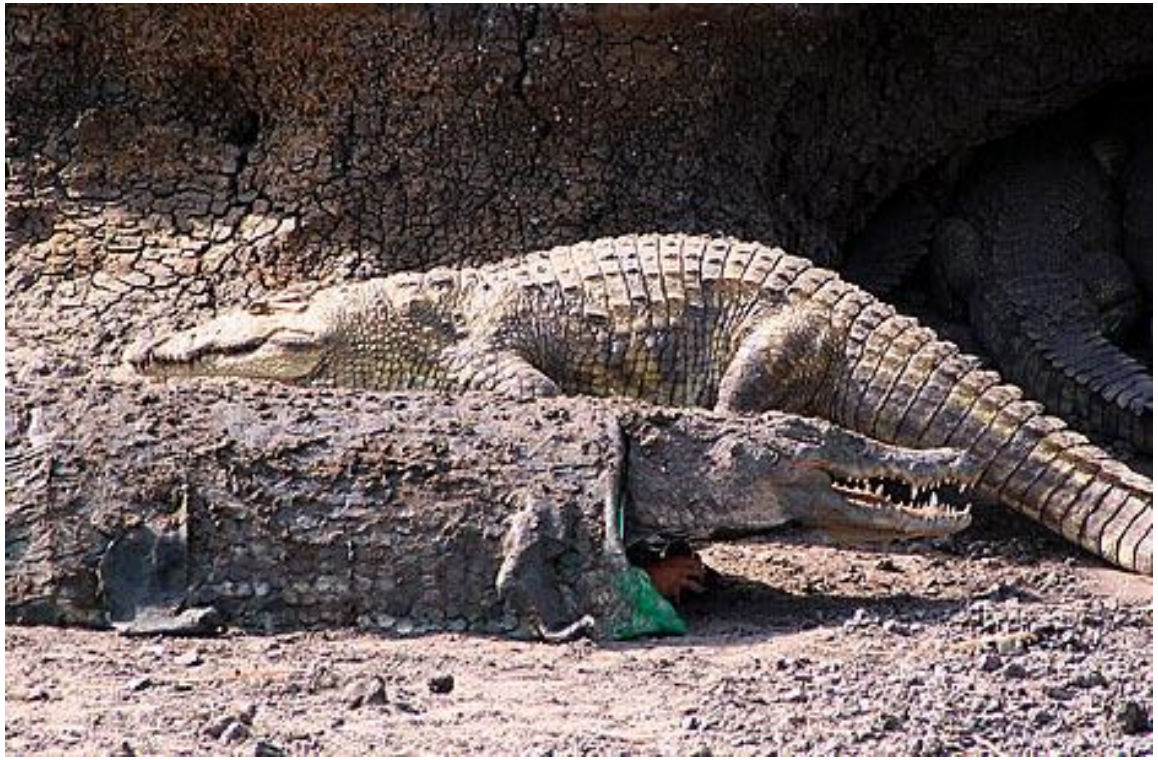
"Well, Steve, I think there's more than one way of looking at it. I think it's more like we both had this rich neighbor named Xerox and I broke into his house to steal the TV set and found out that you had already stolen it."

Transactive Operation creates more resilient systems of systems

Break up the span of control

Isolate diversity

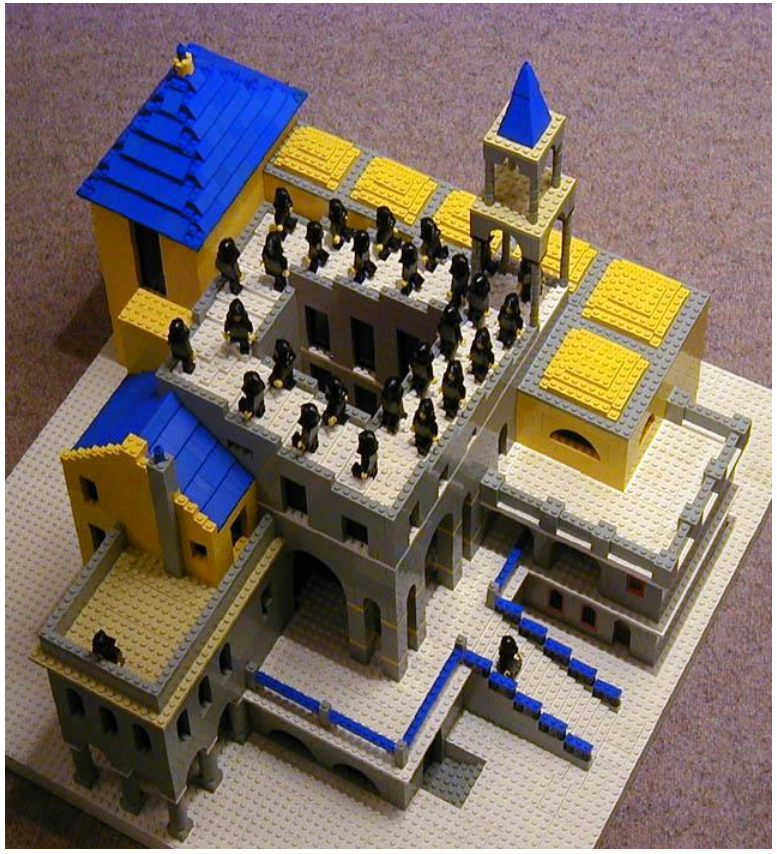
Empower consumers



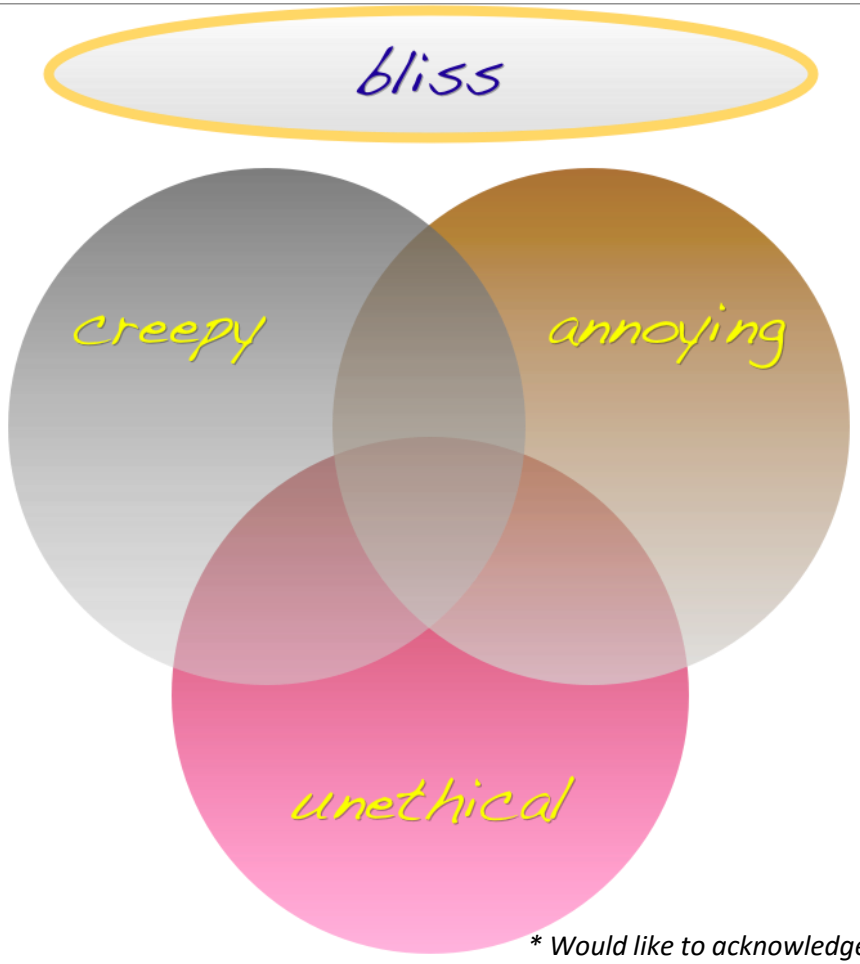
Why a Resource Framework

EML

Many processes can be delayed or accelerated without reducing the service they provide

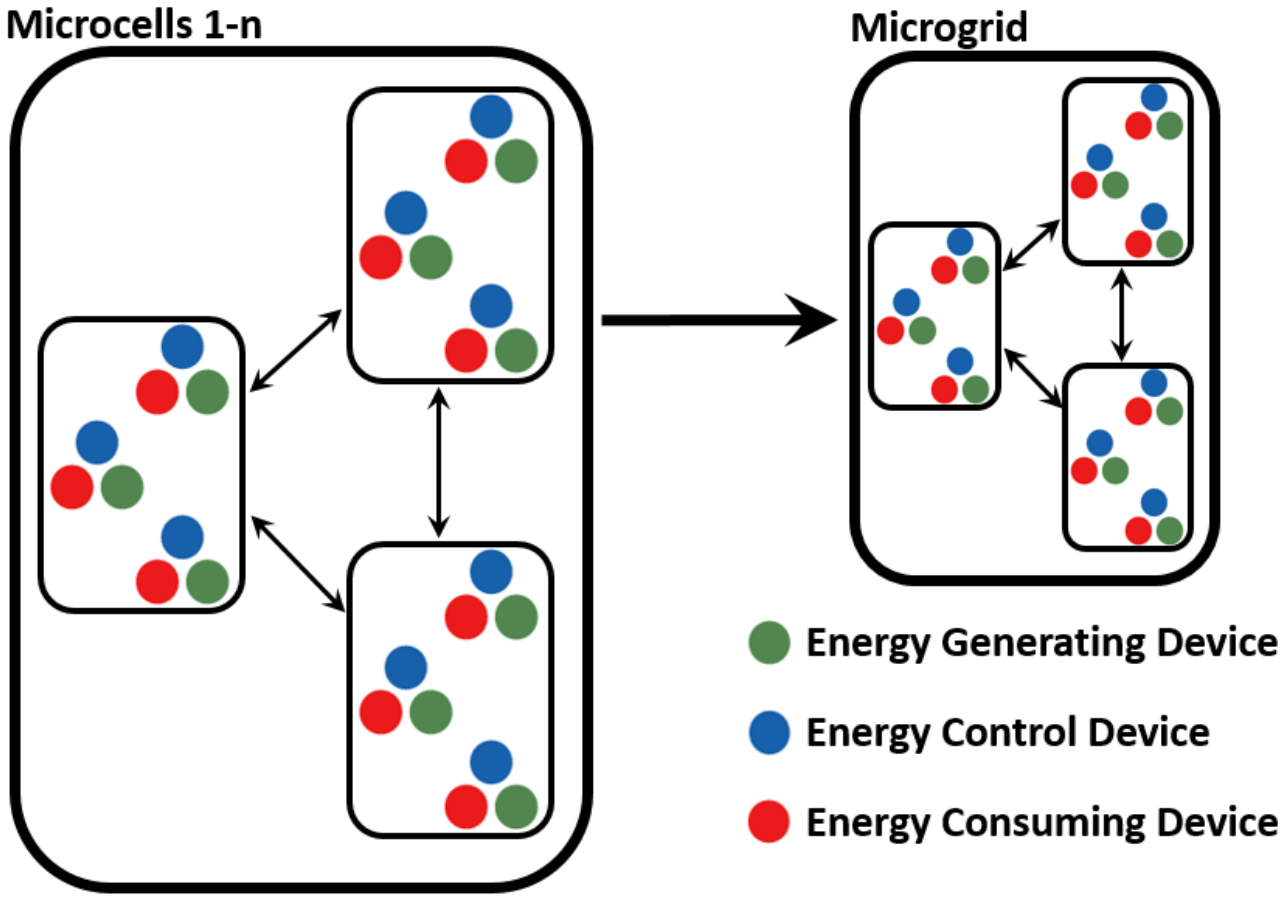


A Resource pool managed by a transactive market need only share aggregate market position with a containing pool



** Would like to acknowledge the unknown internet genius who conceived this Venn diagram*

Fractal integration



Open Specifications

WS-Calendar,
EMIX,
OASIS Energy Interoperation

Existing specifications define the information payloads necessary for Resource micromarket.

Core Transactive Services *en route* from NIST Transactive Energy Challenge

OASIS WS-Calendar

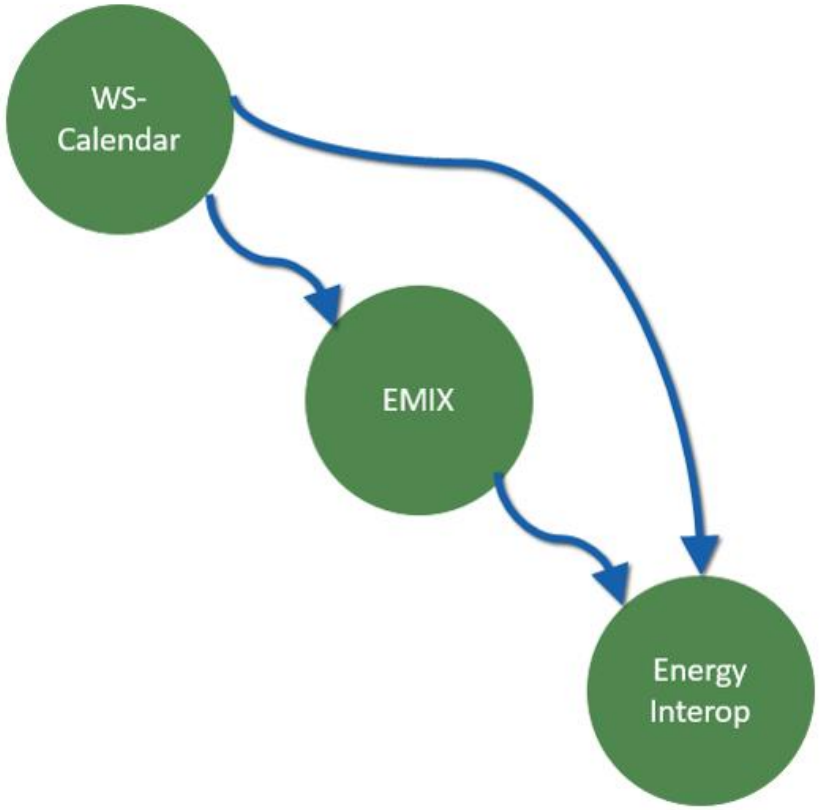
- Machine to Machine negotiation of human-centric schedules
- Semantically compatible with RFC 5556 (iCalendar)
- Availability defines limits of market participation
- Template-friendly messages support complex schedule communications

OASIS Energy Market Information Exchange (EMIX)

- Product description
- Incorporates WS-Calendar
- Options

OASIS Energy Interoperation

- Seven services with a half-dozen methods each that define market interactions
- Includes Market Oriented Services
  - Market Enrollment
  - Market Description, including Market Rules
- Incorporates WS-Calendar and EMIX
- Can support either peer-to-peer or market maker based settlement
- Moving toward vote as IEC 62939



Questions?

Business Case for Lab Participation

Enphase Energy

ENPHASE®

- **Our mission is to build the world's finest networked energy system and revolutionize power generation on a global scale – one solar panel, one kilowatt hour at a time.**

End-to-end Energy Production and Management

Worlds first Microinverter

Enphase Microinverter

- Advanced semiconductor design Converts DC to AC at the solar panel

AC Battery

Scalable Energy Storage

- Integrated microinverter for simple installation

In-home Gateway Networking Technology

Envoy Smart Gateway

- Local intelligence with WAN and LAN connectivity

SaaS Energy Management Platform

Enlighten Platform

- Analytics ensures maximum production

 |

ENPHASE.

Enphase from Start-Up to #1

2006

Founded by Raghu Belur and Martin Fornage in California

2007

First microinverter system introduced

2008 ~ 2011

1 million units shipped, Enphase expands globally

2012

Enphase listed on **NASDAQ** under symbol ENPH

2013

Fourth-generation technology introduced

2014

Home Energy Solution AC Battery storage system announced

2015

Approximately 10 million units shipped, representing over 2GW

Fifth-generation technology introduced

ENPHASE.

Global Impact The Environment

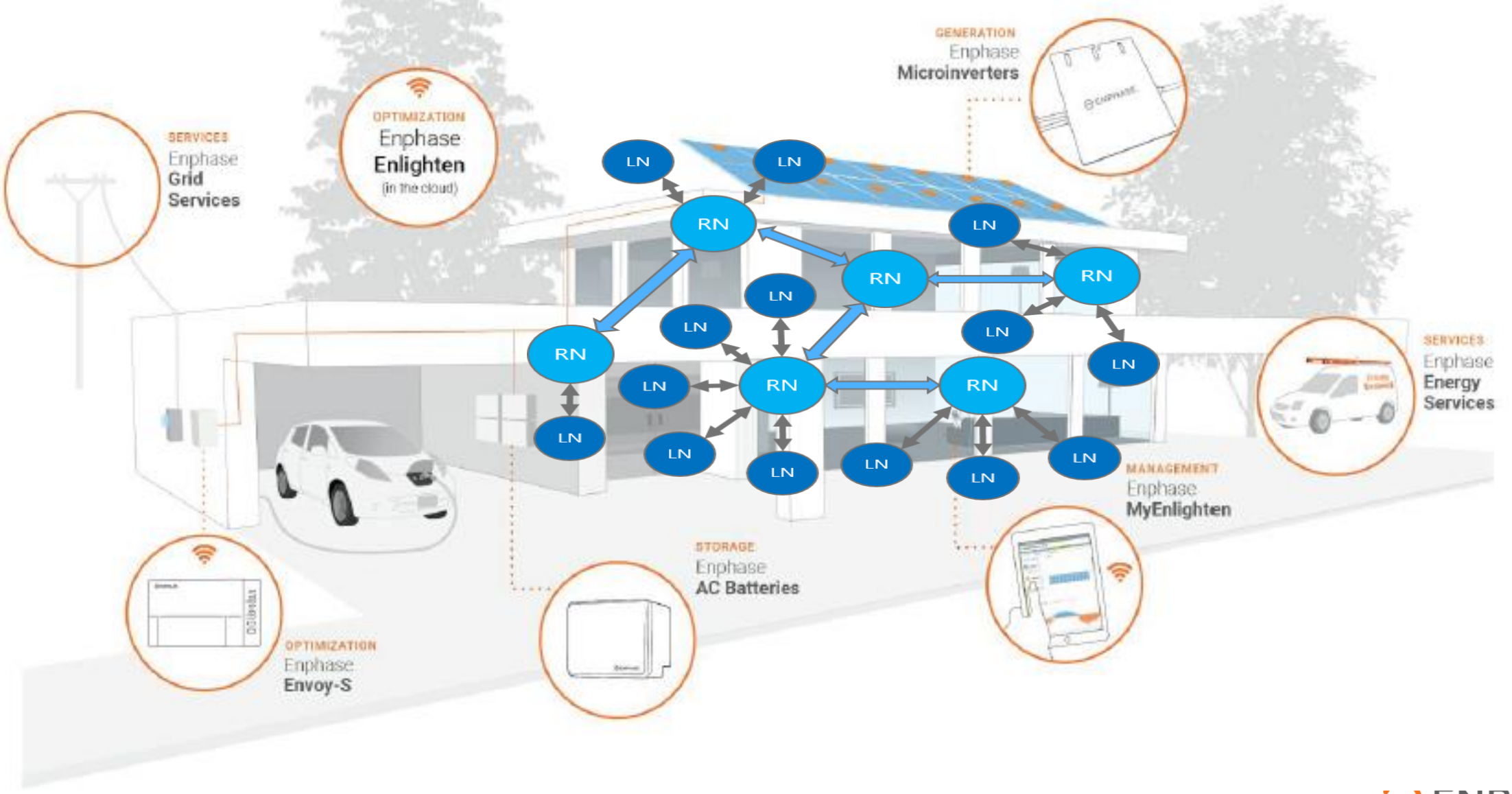
Carbon Offset

- **3,086,471 tons**
- **Enphase systems have offset the equivalent of:**

 |

ENPHASE.

Enphase Energy's Residential Solutions



 |

ENPHASE.

A Resource Marketplace Framework

- **Bring market place dynamics to communities and homes**
  - Resource prosumers can offer, bid and trade
  - Reflecting the “Transactive Energy” movement
  - Applicable to other resources

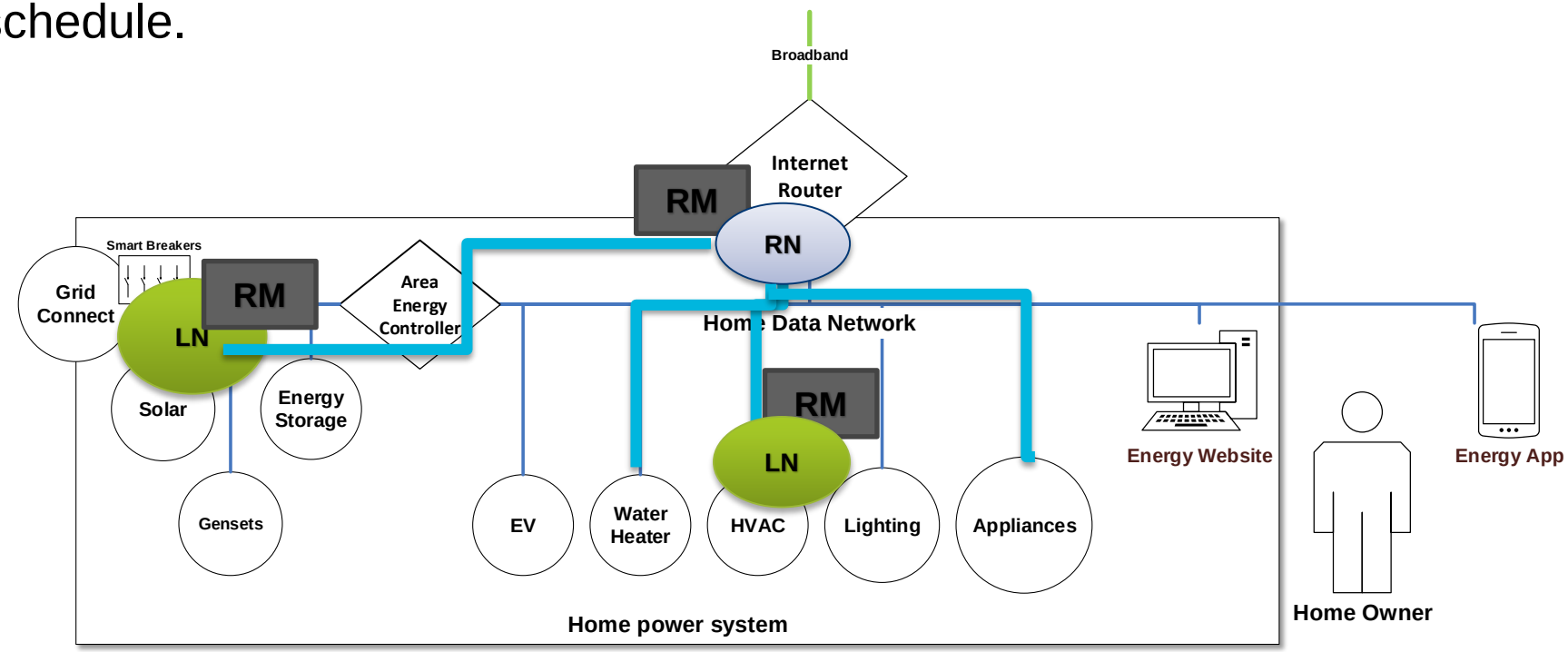
- **Establish a large ecosystem of smart energy producers, traders (eg. storage) and consumers who participate in the in-home resource market**
  - Application framework that makes market participation open and easy
  - Enable Applications to innovate around user continence and optimal decision making

- **Autonomous areas of control**
  - Each area responsible for it’s resources that can be inter-connected to other areas via a contract-like interties.
  - Nested areas of control

ENPHASE.

Scenario: Surplus Solar, so lets pre-cool the house

1. It's a sunny afternoon and production is up, consumption is down
2. The energy production system announces that PV power is cheap
3. Apps within the home decide if the price is right
4. The thermostat determines that it's a good price and timing to pre-cool the home ahead of the preset schedule.



 |

ENPHASE.

Mashup Software Project in Formation

Multiple inputs and Outputs

Multiple Inputs

Infotility GridAgents

NIST Transactive Energy Challenge

- Core Transactive Services
- Camp Pendleton live testbed

Enphase Energy

Other codebases in negotiation

- Contribution License to donation-specific Github
- Code Laundering
- Apache 2 Contribution License into contribution library when “scrubbing” complete

EML

Multiple Outputs

- - AllSeen Alliance
  - AllJoyn Resource Project
- Open Connectivity Foundation
- Industrial Internet

Defined Contributions of suites of code

- Interoperability sets

Alternate “market” constructions,

- including Blockchain

Desired Alignment with other open source projects

PowerMatcher

- http://flexiblepower.github.io/

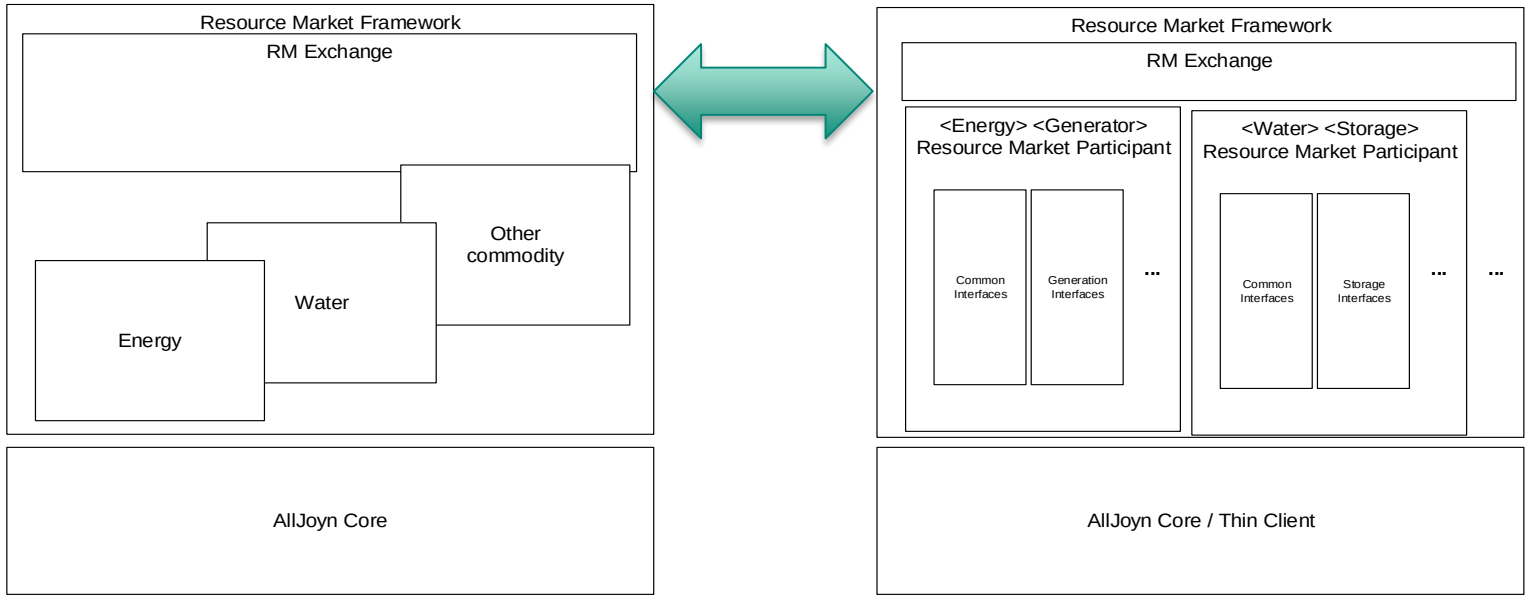
TransActive Grid (TAG)

- Brooklyn blockchain PEV project
- Ethereum open source blockchain platform

Open Ledger Project

- IBM

Questions and Discussion?
Resource Market Framework (RMF)



- RMF supports multiple resource types (eg. Energy, water) side-by-side
- The RMF exchange state is replicated and distributed
- Common RMF interfaces enable all contracts on any RMF exchange
- Devices & Apps can participate in zero or more market types simultaneously
- Devices can assume one or more roles (eg. Supplier, Consumer) simultaneously

Active Project Proposal

Energy Mashup Lab within AllSeen Alliance

AllJoyn Resource Market Framework Project Proposal

Toby Considine
The Energy Mashup Lab

Bruce Angelis

Enphase Energy
April 5, 2016

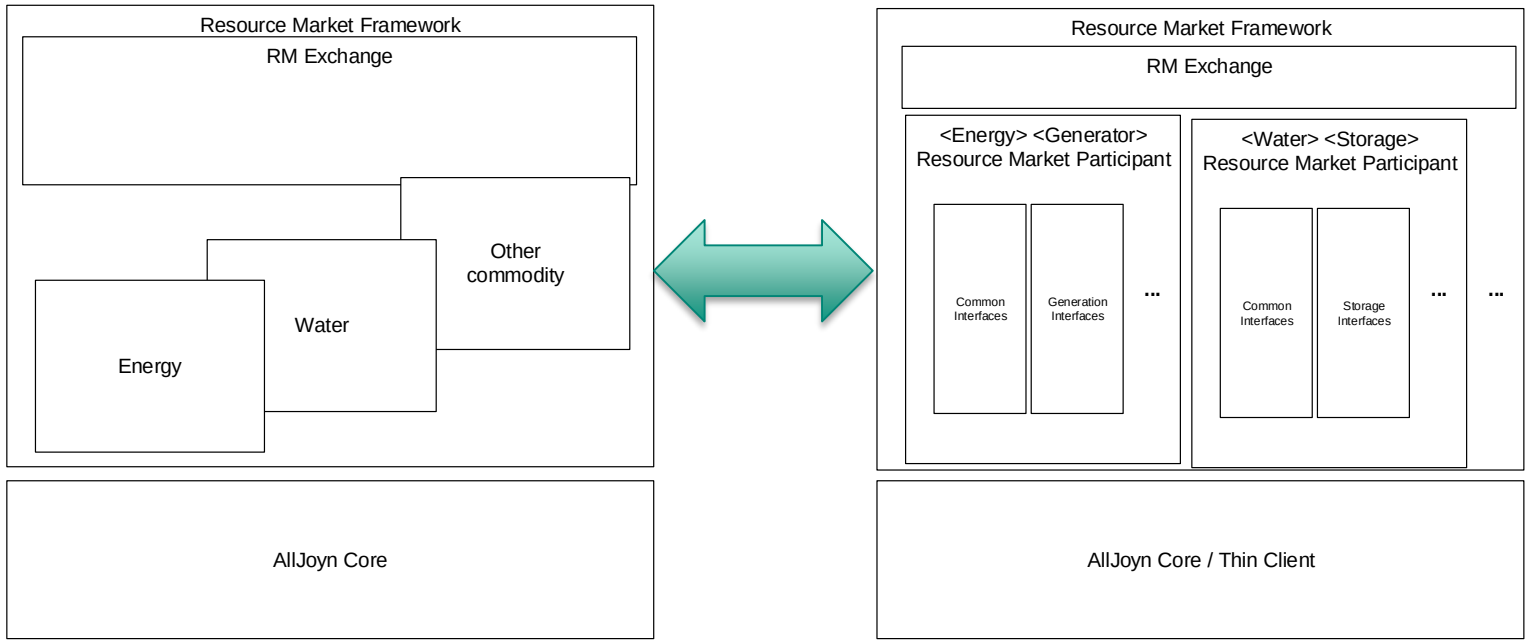
AllJoyn Resource Market Framework Project Overview

- Different Apps may provide, consume, and compete for a limited supply of a specific resource over time.
- A resource is a commodity whose value is determined by time of delivery.
- Markets are a means to optimize both resource allocation and resource utilization.
- The Resource Market Framework enables a collection of Apps to coordinate their use of a Resource, to adjust to changes in supply and demand, and to work within specific and aggregate resource budgets.
- A specific App environment may incorporate more than one Resource.
- Apps must be able to advertise, tender, and transact each Resource they supply or demand. These market offers include descriptions of each Resource, called *Product Descriptions* or *Products*.
- For each Product there may be a Resource Market.

Project Scope

- The Project will deliver a common implementation of the Resources Market Framework (RMF).
- The First Resource Market built on the RMF will be for home energy
  - Consistent with resource markets such as the NIST Transactive energy challenge.
  - Multiple product types/ resource types (electricity, gas, water, waste water, etc.)
  - The RMF will be common across resource types
  - Market to market trading is supported.
- Scope of devices under this project
  - Energy Loads (Refrigeration, HVAC, Water heater, etc)
  - Energy Controllers
  - Energy Meters
  - Energy Generators
  - Energy Storage
  - Energy System (an aggregated set of the above Devices)
- Standard AllJoyn transactions for each device
  - Energy supply (sell)
  - Energy consume (buy)
  - Energy Store (trade)
- Additional Services for telemetry, fault detection, O&M support, etc.
- Define standards encodings for the Energy interop objects and others as needed.

Resource Market Framework (RMF)

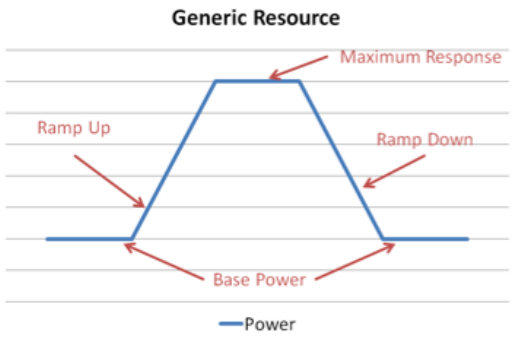


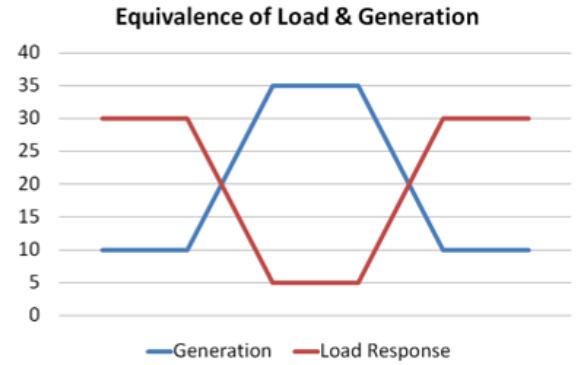
- RMF supports multiple resource types (eg. Energy, water) side-by-side
- The RMF exchange state is replicated and distributed
- Common RMF interfaces enable all contracts on any RMF exchange
- Devices & Apps can participate in zero or more market types simultaneously
- Devices can assume one or more roles (eg. Supplier, Consumer) simultaneously

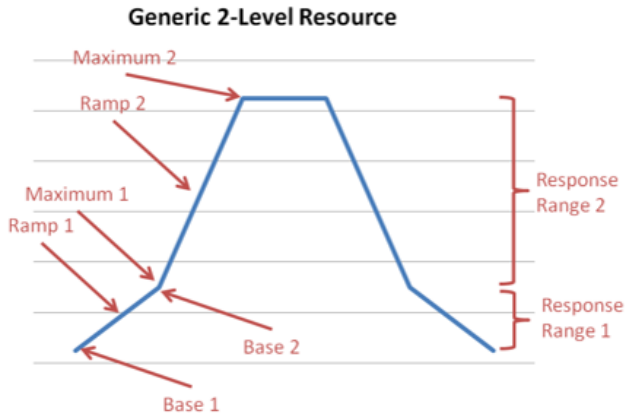
Apps can cooperate to smooth resource use and optimize multi-system efficiency

Examples of Products that can be managed by resource markets include, but are not limited to:

- Power
- Capacity
- Heat
- Cooling
- Water
- Bandwidth



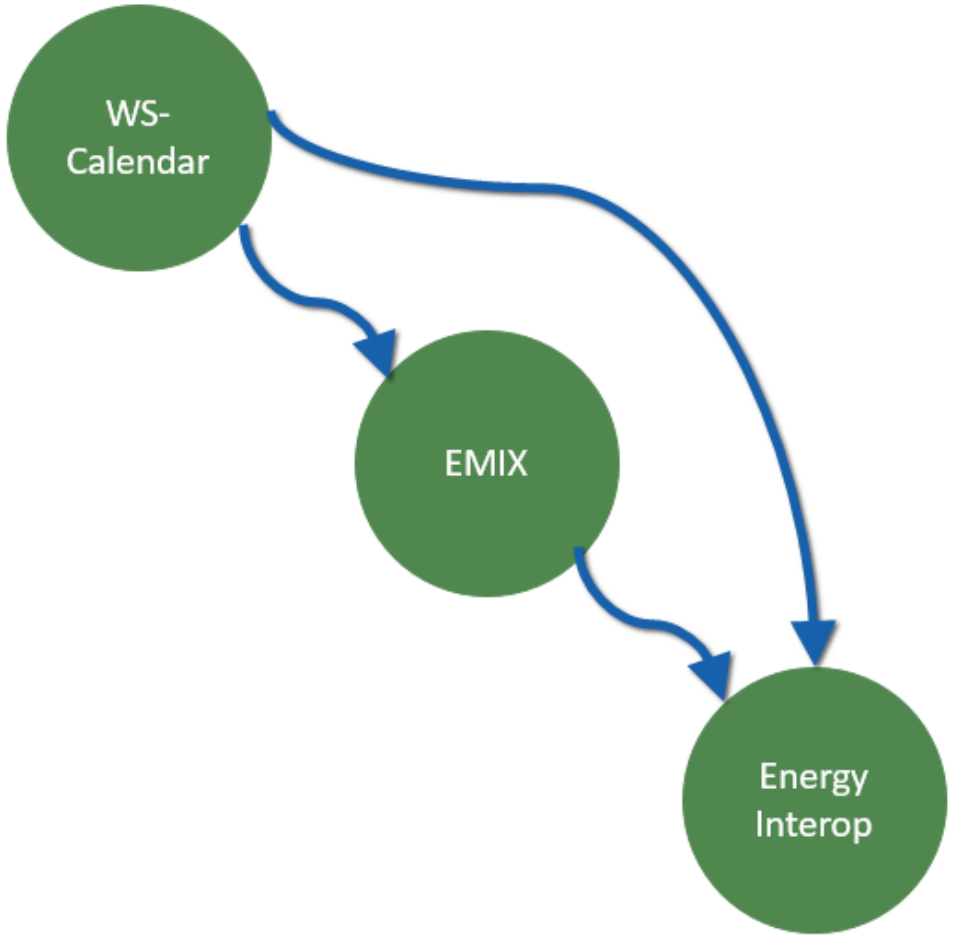




Managing Resources using Micromarkets

Based on the OASIS market-oriented smart energy specifications

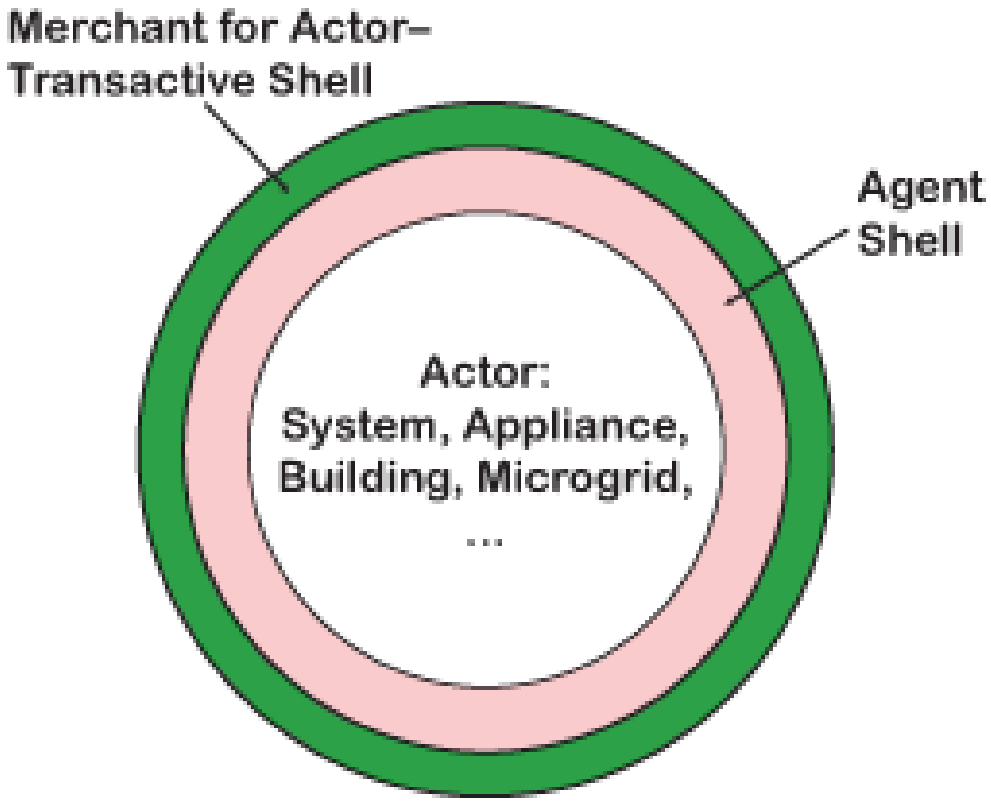
- WS-Calendar
  - Negotiating Time
  - Advertising Availability
- EMIX
  - an information model for conveying product descriptions incorporating schedules
- Energy Interoperation
  - Negotiating service oriented energy, now in process in the IEC
- Additional support
  - To accommodate issues such as fault detection and recovery



Resource Architecture for AllJoyn Apps and larger systems

A developer using the framework creates the actor in the middle of this figure.

The pink agent shell is part of the EML planned software but is not in the initial release of the Resource Market Framework



Actor–Details of Transactive Participant

Features and Benefits

Features

- *Markets and framework enables* smoothing, balancing, and improved resource use within an AllJoyn ecosystem.
- All Resources managed in a common way
- The framework can be used by any device with sufficient computing resources
- Provides a basis for Acquiring Resources from or Selling to systems external to the AllJoyn ecosystem
- Market size and Market details and location agnostic; local & remote Products are treated alike

Benefits

Because all resources are transacted based on a consistent abstract product, optimum use of any resource can be realized with a single code base, limited only by the Product Descriptions known to the Apps.

AllSeen Alliance Project Proposal

- Working Group: Resource Markets
- Staff – affiliated with The Energy Mashup Lab
  - Maintainer: TBD
  - Committers: TBD
- Dependencies:
  - Stable releases from Energy Mashup Lab repositories
  - AllJoyn Core most recent stable version
- Supported platforms:
  - Embedded Linux / others to be determined
- GIT repository: Pending
- Mail list: Allseen-resource@lists.allseenalliance.org
- Development Plan
  - TBD
- We ask support from the TSC for approval of this project.

External Library Dependencies

Dependency	Description	License	URL
Energy Mashup Lab	Transactive services, examples	Apache 2.0 license	http://theenergymashuplab.org
Scheduling Service	The schedule information is semantically compatible with existing human schedules (RFC5545)		The project will review existing open-source calendar servers (CALDAV et al.) to find the lightest weight codebase.

Thank you

Follow us on

Toby Considine, director@theenergymashuplab.org

The Energy Mashup Lab is a 501C3 corporation whose purpose is to create open source software to enable self-assembling microgrids. The proposed AllJoyn project is closely aligned with the purposes of The Lab.

Bruce Angelis, bangelis@enphaseenergy.com

is busy at Enphase Energy, a global energy technology company, building smart, connected solar energy and storage systems. Bruce sees AllJoyn and the Resource Market project as a key technology to enable reliable energy management solutions for smart solar homes.

Notes and References

Using Markets for Control

B. Huberman and S. H. Clearwater, "Thermal markets for controlling building environments," Energy Engineering, vol. 91, no. 3, pp. 26-56, January 1994.

B. Huberman and S. H. Clearwater, "A multi-agent system for controlling building environments," in First International Conference on Multiagent Systems, 1995.

Knowledge Problems and Spontaneous Order

- F. A. Hayek, "The Use of Knowledge in Society," The American Economic Review, vol. 35, no. 4, pp. 519-530, 1945.
- L. Kiesling, "The Knowledge Problem, Learning, and Regulation: How Regulation Affects Technological Change in the Electric Power Industry," Studies in Emergent Order, vol. 3, pp. 149-171, 2010.
- Hayek and the Knowledge Problem, Lynne Kiesling https://vimeo.com/76456397
- *A Prosperous and Cleaner Future: Markets, Innovation, and Electricity Distribution for the 21st Century*. Conservation Leadership Council Policy Paper, June 2015.

Energy-Related OASIS Specifications

OASIS Energy Interoperation 1.0. 2012.

- Designed to work to, from, inside, and outside microgrids
- http://www.oasis-open.org/committees/energyinterop
- Proposed IEC 62939

OASIS Energy Market Information Exchange Version 1.0. 2012.

- Price and product definition/description
- Transactional EMIX Notes
- http://www.oasis-open.org/committees/emix
- http://docs.oasis-open.org/emix/emix/v1.0/emix-v1.0.html

OASIS WS-Calendar 1.0. 2011.

- http://www.oasis-open.org/committees/ws-calendar
- http://docs.oasis-open.org/ws-calendar/ws-calendar/v1.0/ws-calendar-1.0-spec.html

OASIS Reference Model for Service Oriented Architecture 1.0.

- *OASIS Standard.*
- http://www.oasis-open.org/committees/soa-rm

Microgrid Architecture

Grid Fault Recovery and Resilience: Applying Structured Energy and Microgrids. **Cox, William T and Considine, Toby. 2014.** Washington, DC : IEEE Conference Publications, 2014. 2014 IEEE PES Conference on Innovative Smart Grid Technologies.

Structured Energy: Microgrids and Autonomous Transactive Operation. **Cox, William T. and Considine, Toby. 2013.** Washington, DC : IEEE Conference Publications, 2013. 2013 IEEE PES Conference on Innovative Smart Grid Technologies.

Understanding Microgrids as the Essential Smart Energy Architecture. **Considine, Toby, Cox, William and Cazalet, Edward. 2012.** Irving, TX : GridWise Architecture Council, 2012. Grid-Interop Proceedings.

Energy, Micromarkets, and Microgrids. **Cox, William and Considine, Toby. 2011.** Phoenix, AZ : GridWise Architecture Council, 2011. Grid-Interop 2011.

Architecturally Significant Interfaces of the Smart Grid. **Cox, William T and Considine, Toby. 2009.** Denver, CO : Gridwise Architectural Council, 2009. Grid-Interop Proceedings.

Price Communication, Product Definition, and Service Oriented Energy. **Cox, William T and Considine, Toby. 2009.** Denver, CO : GridWise Architectural Council, 2009. Grid-Interop Proceedings.

New Applications of Electronic Commerce Technology to Energy, Buildings, and Capital Management. **Cox, William T and Considine, Toby. 2008.** Atlanta, GA : GridWise Architectural Council, 2008. Grid Interop Proceedings. pp. C5-C11.

Other Microgrid Papers

Mobile Agents in Networking and Distributed Computing. Cao, Jiannong and Das, Sajal K. 2012. Wiley, 2012.

A Pricing Strategy for a Lean and Agile Electric Power Industry. Electricity Policy. [Online] Centolella, Paul A. 2012

http://ElectricityPolicy.com.

Community-Based Electric Micro-Grids Can Contribute to Rural Development: Evidence from Kenya. Kirubi, Charles, et al. 2009. 7, July 2009, World Development, Vol. 37, pp. 1208-1221.

Galvin Electricity Initiative. [Online] http://www.galvinpower.org/.

Modified microgrid concept for rural electrification in Africa. Blyden, Bai K and Lee, Wei-Jen. 2006. s.l. : IEEE, 2006. Power Engineering Society General Meeting.

Microgrids are already all around.

Industrial Microgrids
- Includes District Energy

Isolated Microgrids

Development Microgrids

Military Microgrids

Motivational Microgrids

Hidden Microgrids
- Post-Sandy Experience

Consumer Electronics