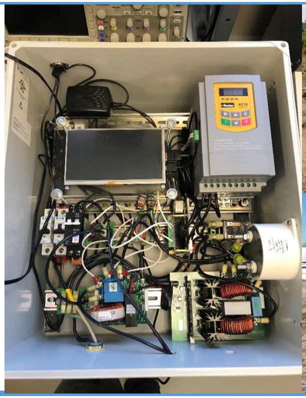
From Energy Access to Grid Resiliency: A Story of Anthropology, Engineering, and Business



September 14, 2018

Dr. Nathan Johnson, Director and Assistant Professor

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Shammya Saha, Graduate Research Assistant

IRA A. FULTON SCHOOLS OF engineering
ARIZONA STATE UNIVERSITY

Laboratory for Energy and Power Solutions (LEAPS)
The Polytechnic School

Laboratory for Energy And Power Solutions

The Laboratory for Energy And Power Solutions (LEAPS) takes energy innovations from concept to construction with a focus on microgrids, off-grid solutions, smart networks, and capacity building.

Dr. Nathan Johnson manages the one-acre microgrid test bed and computational laboratory that combines simulation-based design with hands-on fabrication to create next-generation solutions to current market needs. The entire LEAPS team is active in technical development and service, and regularly participates in capacity building programs inside and outside standard curriculum.

- 25-person research team including students and staff
- Basic and applied research in microgrid simulation and control
- One-acre microgrid test bed, planning expansion
- Development leading to commercialization
- New market opportunities for on-grid and off-grid solutions

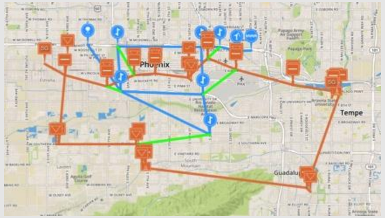
Turning Ideas into Prototypes

Build

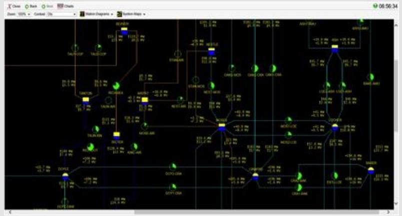
Turning Prototypes into Reality

A plug-and-play environment for advanced energy research, development, testing, and education

Simulation and Design Environments

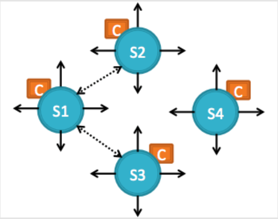


System/network design



Real-time simulations

Power hardware in the loop



Intelligent distributed controls

Grid Modernization & Microgrid Test Bed

Flexible microgrid designs

Campus-scale solutions

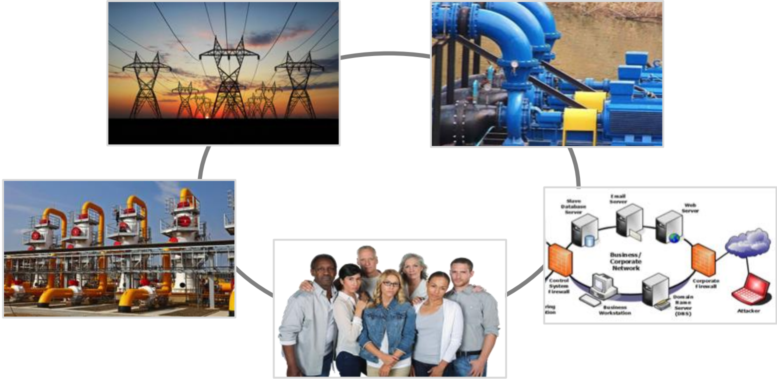
"Test bay" for new equipment

Testing and refinement

Grid Modernization

Off-grid Solutions

Critical Infrastructure



Workforce Development

Engineering Ethnography




23 12 '95



Utila Cays

2.7 Billion

Energy

1.0 Billion

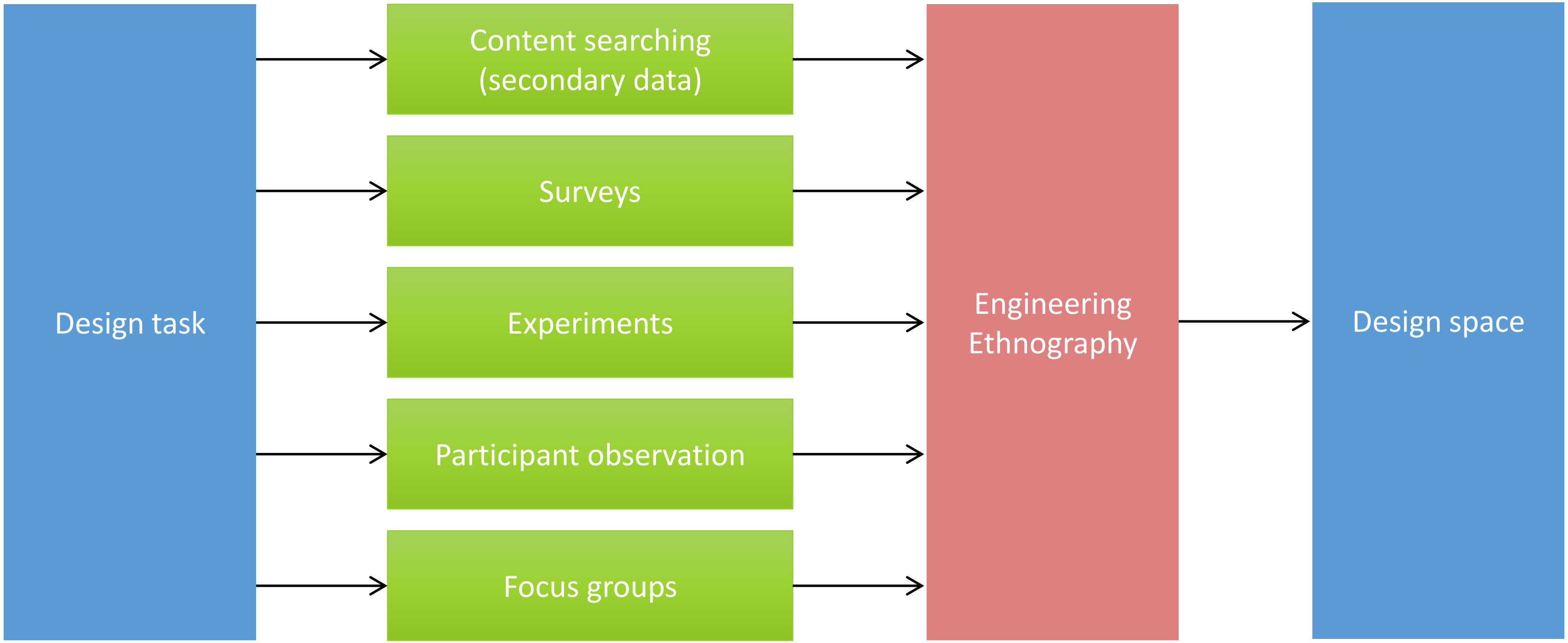
Poverty

1.4 Billion


Collage rapide
et Charge Batterie
BK


?

Improving understanding through qualitative and quantitative methods



Using participatory observation to gain deeper insights

Actions

Choice

Judgment

Viewpoint

Dissatisfaction

and

Aspiration

General needs

and

Specific interests

Let's take an example

Viewpoint

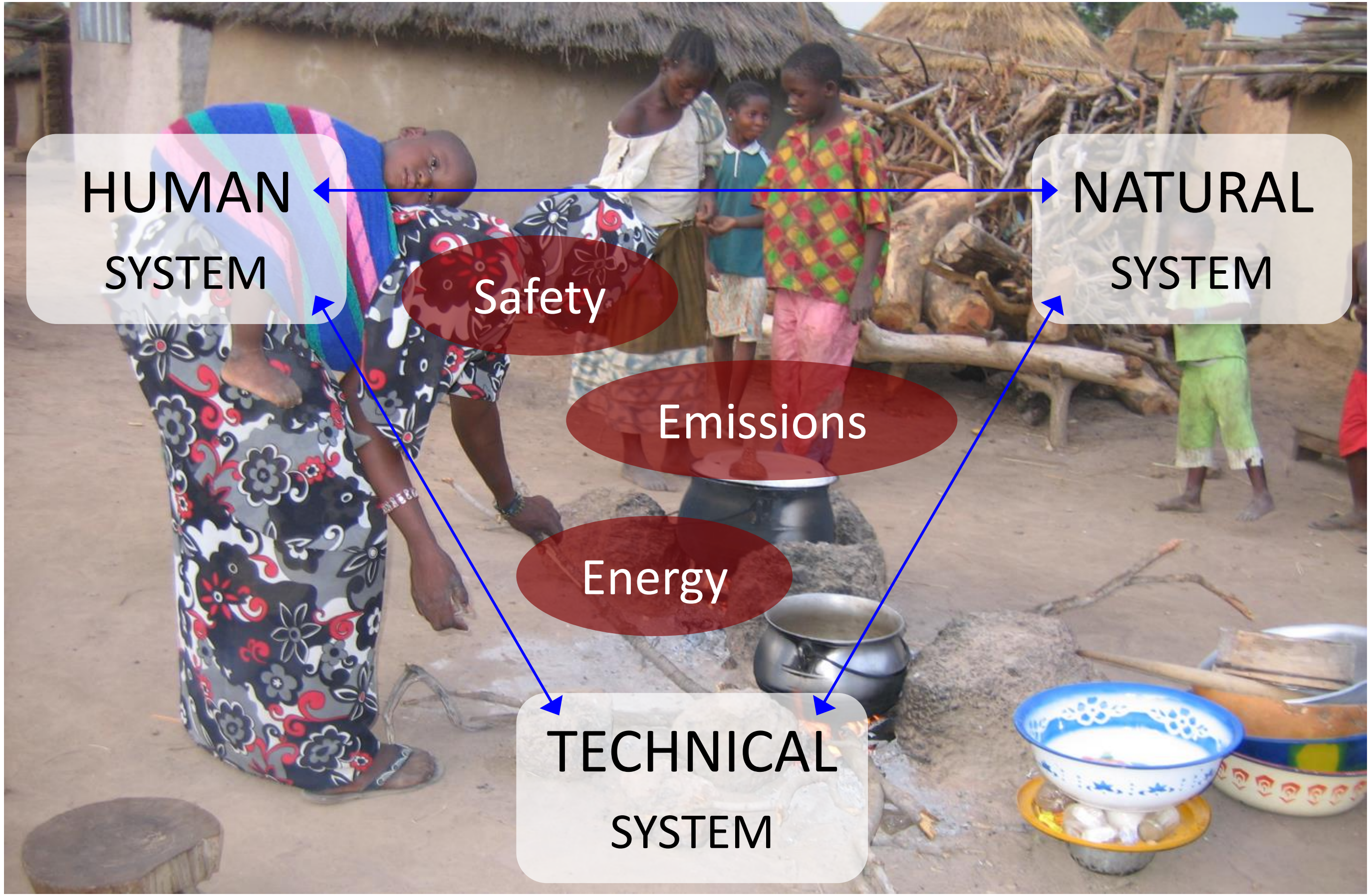
Judgment

Choice

Action

Detailed look into a single home (over 2,000 visited)

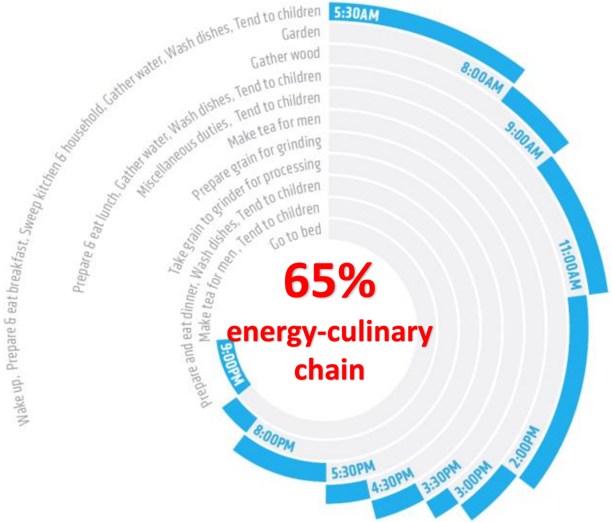
Taking cooking as a example



Engineering a value proposition - consumer

Removes pollution

Saves time

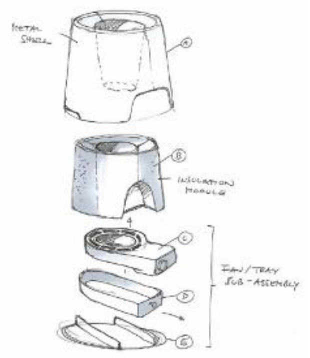


Johnson NG, Bryden KM. 2013. Clearing the air over cookstoves. DEM+ND. 1(1):8–13.

Value for money

Engineering a value proposition - product

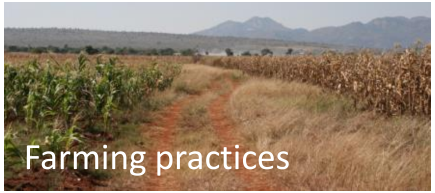
Designing for Modularity

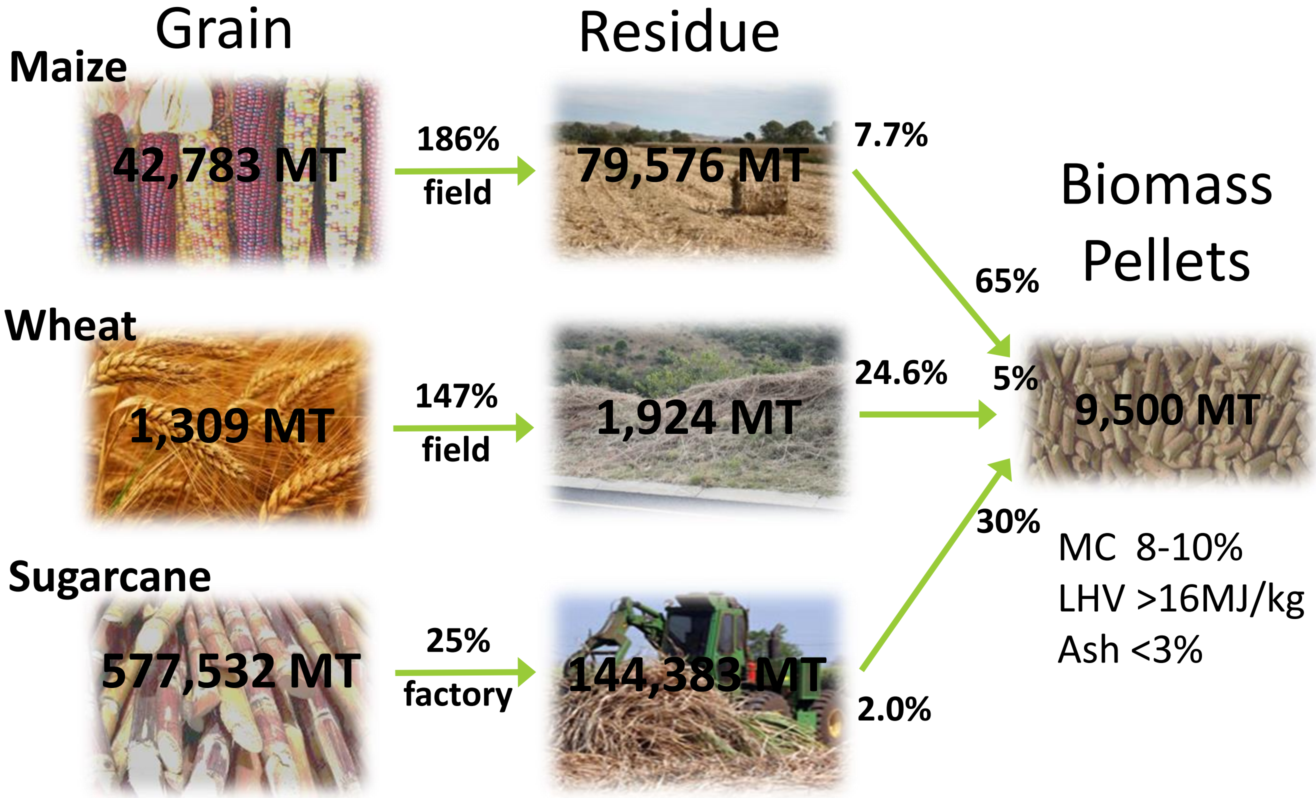


Forced draft stove

Locally sustainable fuel

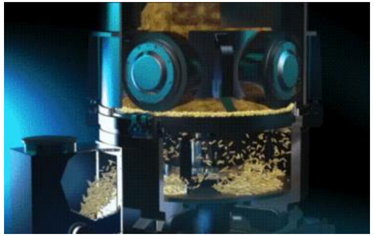
Engineering a value proposition - business





Agyemang M, Johnson NG. 2015. "Development of biomass energy technologies and business models for Southern Africa," Proceedings of the 2015 ASME International Design Engineering and Technical Conferences and Computers and Information in Engineering Conference. Boston, Massachusetts.

Engineering a value proposition - business



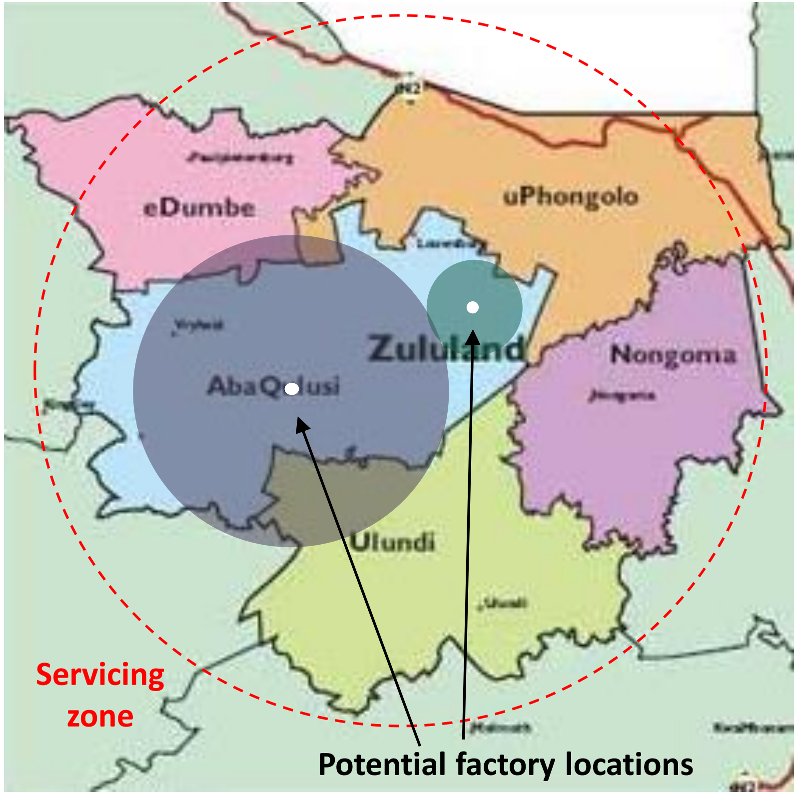
1.12

1.00

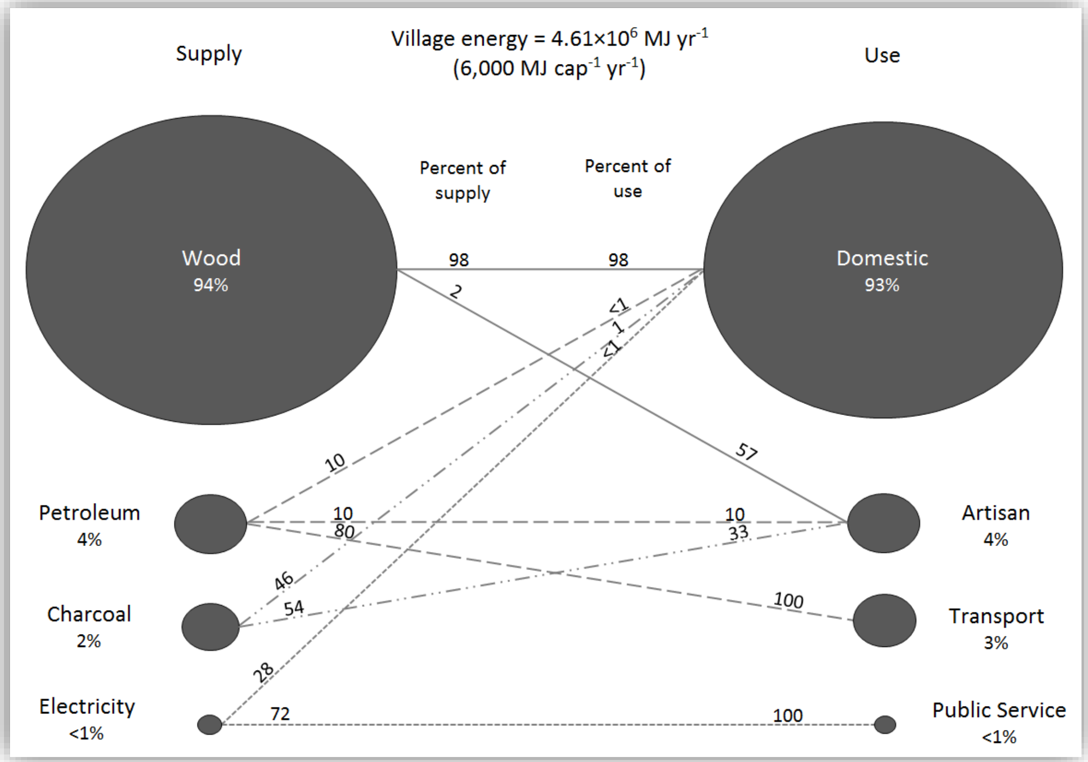
VAT	0.12
Channel mark-up, two layer	0.29
Gross margin	0.08
Secondary transport	0.09
Production and packaging	0.13
Primary transport	0.18
Materials	0.11

0.00

Unit cost per kg (normalized)



Taking a broad look into needs and opportunities



Johnson NG, Bryden KM. 2012. Energy supply and use in a rural West African village. Energy. 43(1):283–92.

75% of all energy on cooking stoves

electricity use is a rounding error yet invaluable

no energy for economic development (value creation)

Off-grid Solutions

Containerized microgrids for disaster response

Challenge: Lack of critical infrastructure after disasters such as Matthew (Haiti), Maria (PR), Sandy (US).

Solution: Turnkey microgrids packed into 20’ and 40’ containers for rapid deployment. Scalable 10-150 kW.

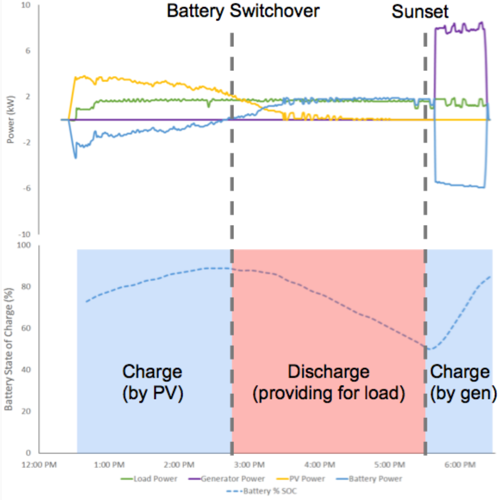
Ease of transport

Rapid deployment

Unpacked microgrid

20 kW solar PV
20 kWh Li-ion battery
20 kW diesel generator
Microgrid controller

Dispatch and AGC



Video: http://tinyurl.com/yan5zlyy

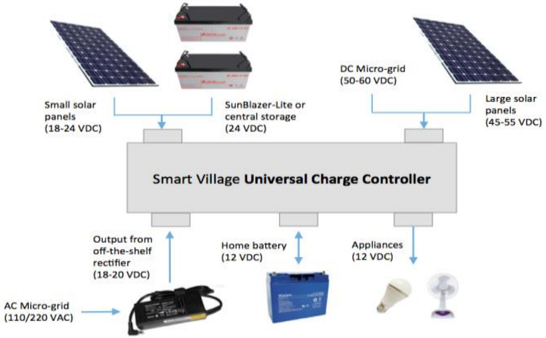
Janko, S., Atkinson, S., & Johnson, N. (2016). Design and fabrication of a containerized micro-grid for disaster relief and off-grid applications. ASME 2016 International Design Engineering Technical Conferences (IDETC) and Computers and Information in Engineering (CIE) Conference. American Society of Mechanical Engineers.

Universal charge controller for off-grid architectures

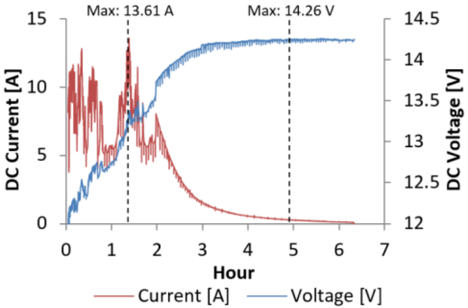
Challenge: 1.4 billion people without power; lots of solutions; high cost and no interoperability.

Solution: Custom 500W inverter for battery charging, solar home, DC microgrid, and AC microgrid.

Applications



Charging battery from solar panels



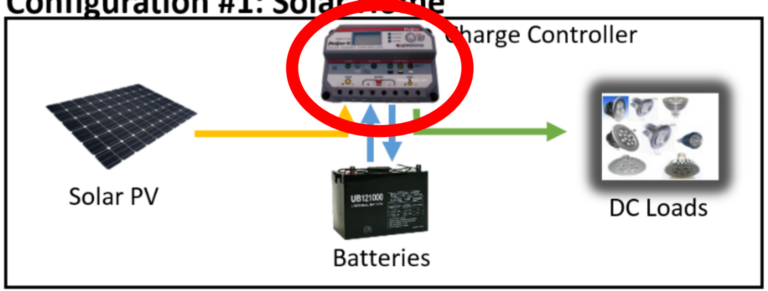
Major features

- Inputs: 12/24/48 VDC, 110/220 VAC
- PWM charging from solar PV
- Current limiting
- Low-voltage disconnect and reconnect
- High-voltage disconnect
- Temperature control
- Lead-acid and Li-ion chemistries
- Pre-pay metering
- WiFi/900 MhZ communication
- Efficiency > 90%, cost < $50

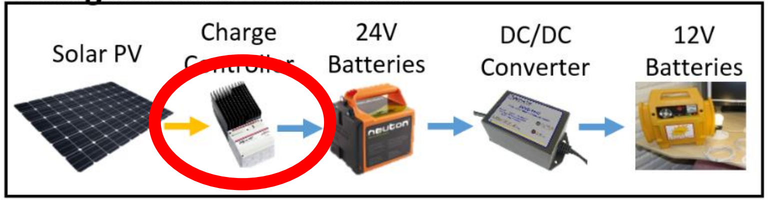
Saha, S., Janko, S., Johnson,N., Podmore, R., Riaud, A., & Larsen, R. (2016). A universal charge controller for integrating distributed energy resources. 2016 IEEE Global Humanitarian Technology Conference, 459-465

Universal charge controller for off-grid architectures

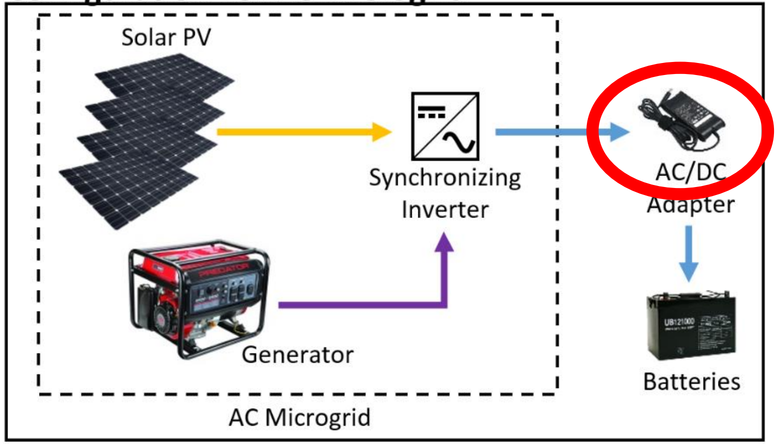
Configuration #1: Solar Home



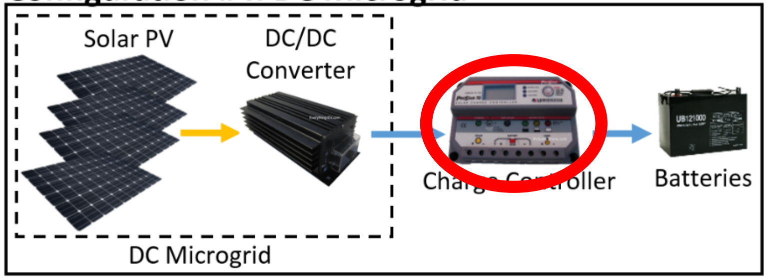
Configuration #2: Sunblazer



Configuration #3: AC Microgrid



Configuration #4: DC Microgrid



Potable water for refugee host communities in scarce water regions

Challenge: Syrian refugees; insufficient potable water; limited access to grid; grid outages.

Solution: Custom 3.5kW inverter, VFD motor drive, and controls for reliable water treatment.

Water System

Reverse osmosis + UV

Power System

Grid + solar PV

Overview:

- Water scarce regions of Lebanon and Jordan
- 18 refugee host communities
- Water kiosks serve 2000 people daily
- 36,000 people total affected

Technical Outcomes:

- Reduce energy costs by 25-50%
- Increase system efficiency by 15-30%
- Provide energy autonomy up to 2 days

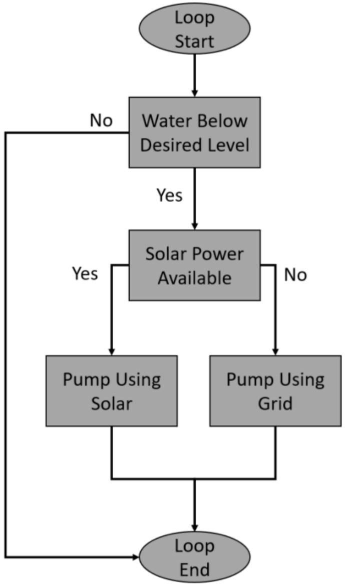
Technical Specifications:

- 2 kW Solar PV and battery storage
- 1,300 Liter/Hour reverse osmosis system
- Grid connection optional

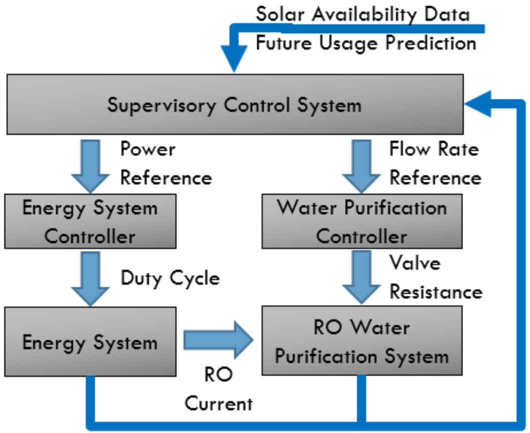
Potable water for refugee host communities in scarce water regions

- Logic vs. model predictive control (MPC)
- MPC enables optimal energy usage

Logic Based



Model Predictive Control



Model Predictive Control Equations

$$J(t) = \sum_{\tau=0}^{N} \overbrace{\left(P_{RO}(\tau) - P_{PS}(\tau)\right)^2}^{\text{Power Balance}} + \sum_{\tau=0}^{N} \overbrace{\left(s(\tau) - s_{opt}\right)^2}^{\text{Tank Level}} + \sum_{\tau=0}^{N} \overbrace{\frac{P_{RO}(\tau)}{F_P(\tau)}}^{\text{Energy/Unit Water}}$$

$$\overbrace{P_{PS}(\tau)}^{\text{Power System}} = \overbrace{P_{Grid}(\tau)}^{\text{Grid Power}} + \overbrace{P_{Solar}(\tau)}^{\text{Solar Power}}$$

$$\overbrace{P_{Sys}(\tau)}^{\text{RO System Pressure}} = \overbrace{\frac{\rho A_p}{A_m k_m}\left(v_f(\tau) - v_r\right)}^{\text{RO System Characteristics}} + \overbrace{\Delta\pi}^{\text{Osmotic Pressure}}$$

Potable water for refugee host communities in scarce water regions

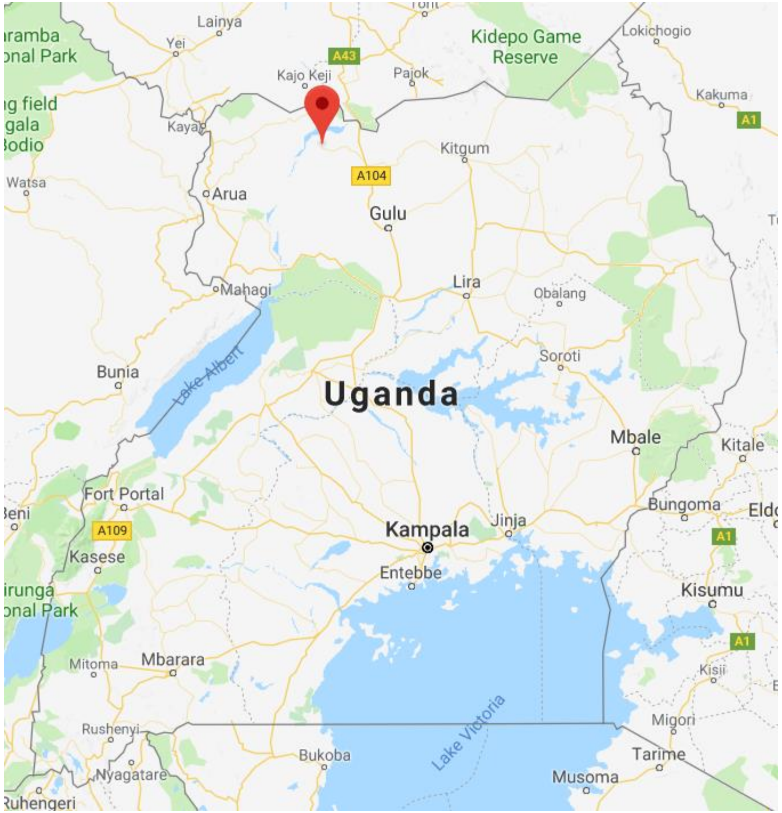
- Commissioned prototype unit in Lebanon
- Decreased operational cost

Goal	Existing Solution	Generation 1	Generation 2
Cost of energy ($/kWh)	.13	.065	.055
Energy per unit water (kWh/L)	.0011	.0011	.00056
Grid independent operation (hours)	0	3	3+

Containerized power-water-healthcare for refugee populations

Challenge: Refugee camps; water access; limited access to grid; medical needs.

Solution: Provide turn-key capabilities to expeditionary naval, disaster response, and humanitarian aid applications.

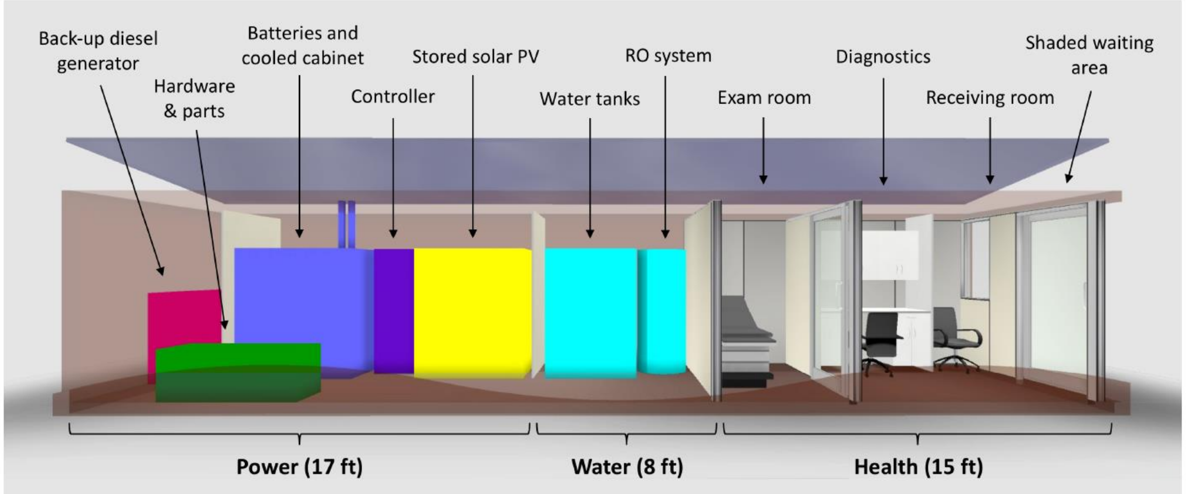


Containerized power-water-healthcare for refugee populations

- Off-grid, rapidly-deployable system with power, water, and healthcare

- Includes solar PV, backup generator, diesel fuel storage, a large capacity battery, UV water purification, and medical equipment

- Designed to be rapidly deployment on site for military bases, humanitarian needs, and disaster response

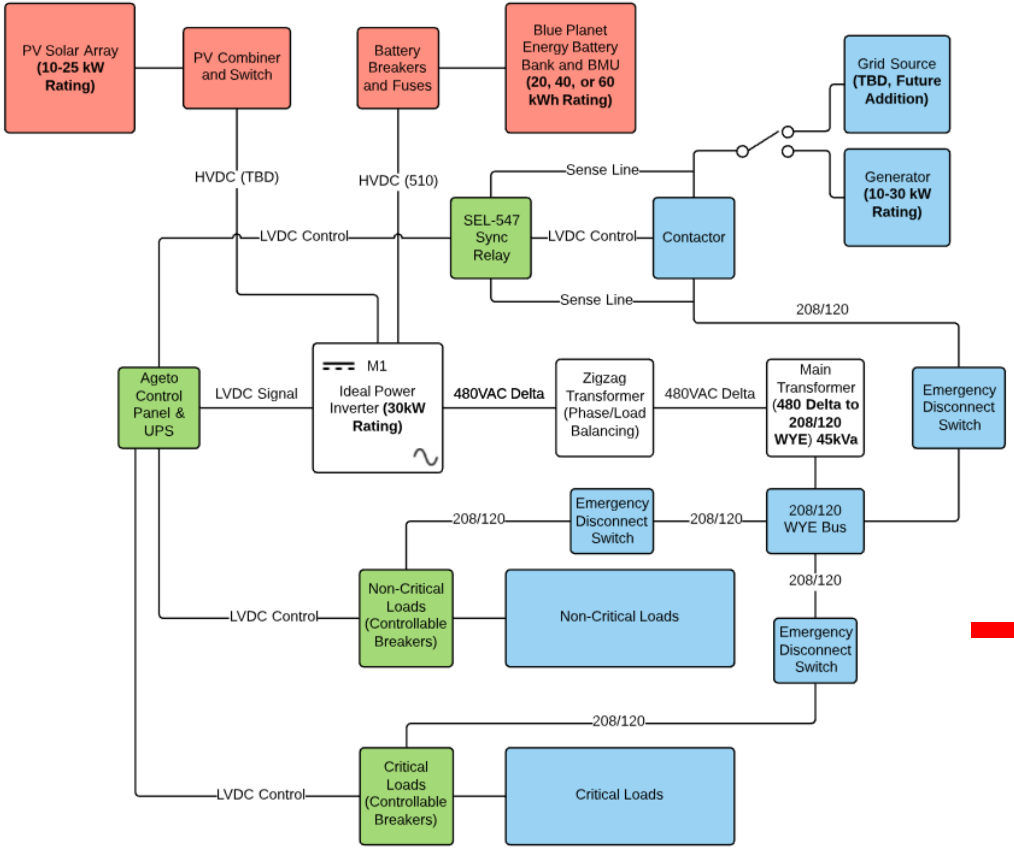


Containerized power-water-healthcare for refugee populations

- Site visits are critical to the “empathize” design phase of engineering

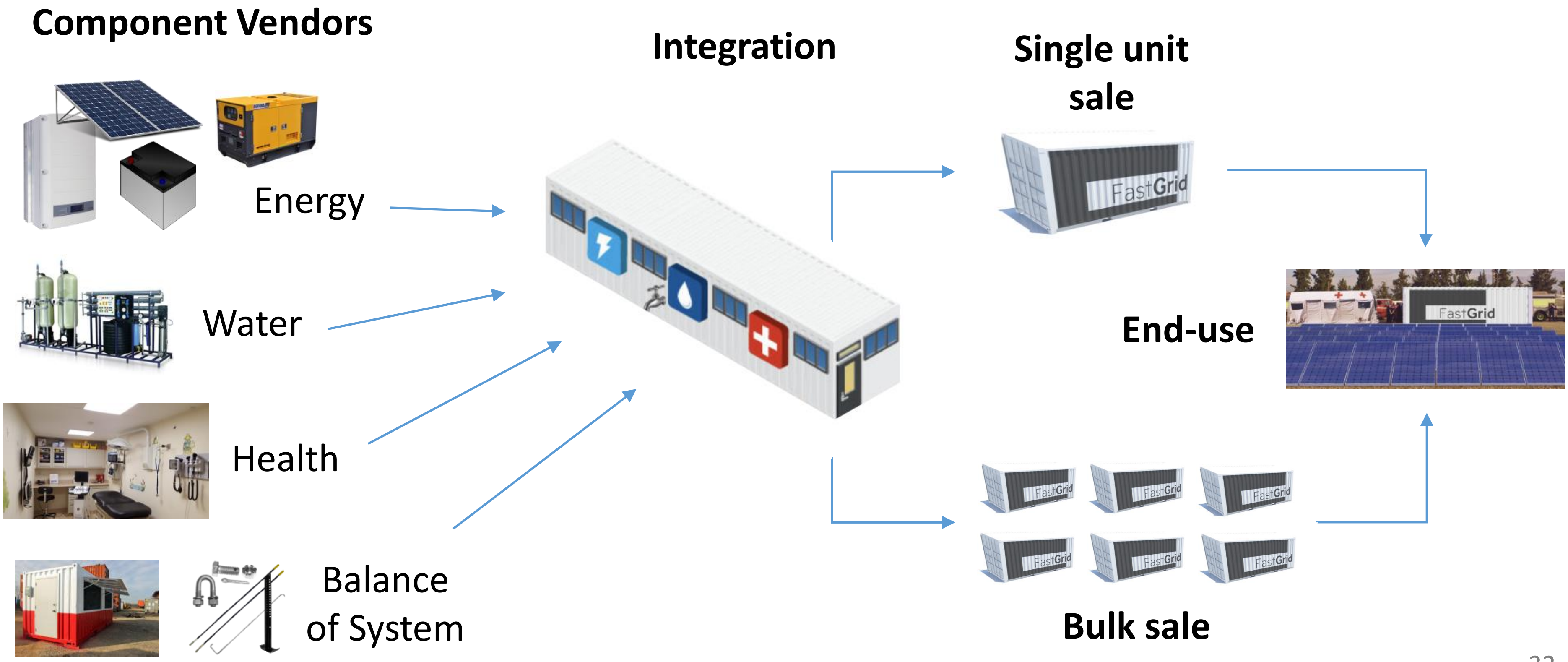
- Understanding your end user’s needs to build a system that addressed the actual problem (rather than the perceived problem)

Containerized power-water-healthcare for refugee populations



- Electrical design layout that is used to implement the electrical infrastructure

Containerized power-water-healthcare for refugee populations



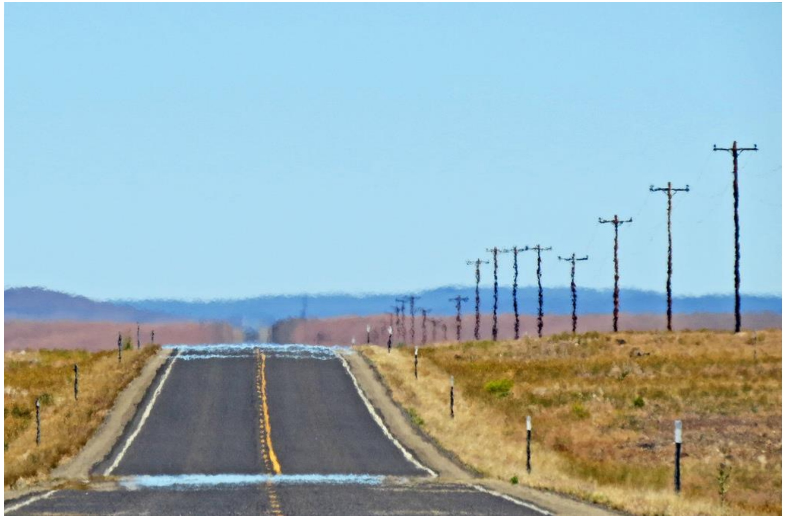
Critical Infrastructure

Increasing stress on infrastructure uncovers more vulnerabilities

Challenge: Extreme weather events causing unforeseen failures in coupled infrastructure systems

Solution: Quantify and simulate the effects of extreme events to improve planning and operations

Climate non-stationarity



The “slow bake” problem

Extreme events

Exacerbated weather incidents

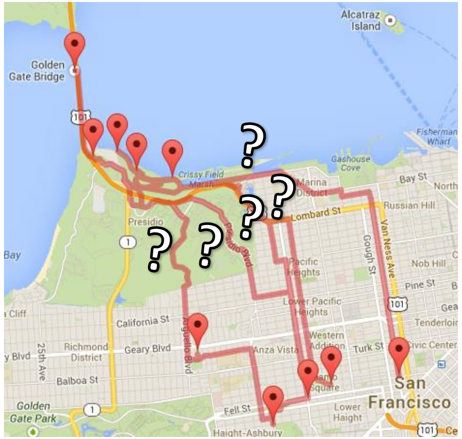
We are trained as problem solvers but not as problem finders.

Problem Solvers

Known problem, scripted approach, one solution

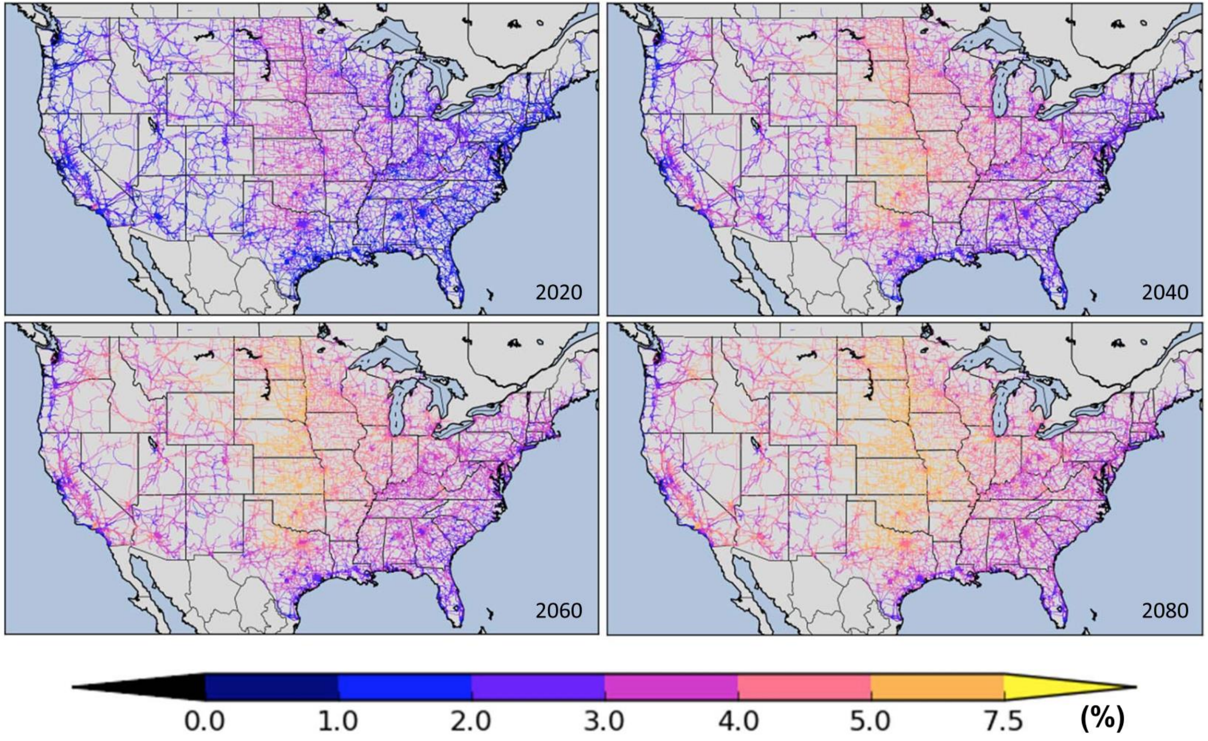
Problem Finders

Unknown problem, exploratory approach, multiple solutions



We need to advance our approach, tools, and training to become problem finders.

Quantifying the effect of extreme heat on US transmission infrastructure



transmission infrastructure

+

summer peak demand

+

climate models

+

population growth

+

line thermal limits

=

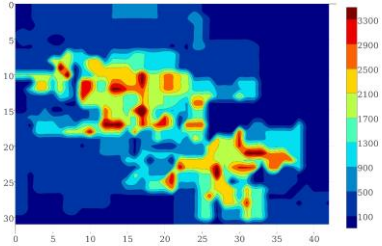
reduction in ampacity

(line carrying capacity)

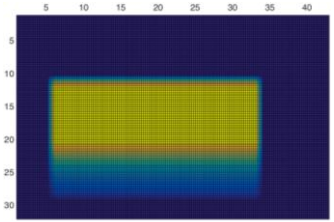
Burillo, D., Chester, M. V., Ruddell, B., & Johnson, N. (2017). Electricity demand planning forecasts should consider climate non-stationarity to maintain reserve margins during heat waves. Applied Energy, 206, 267-277.

Quantifying the effect of dust storm intensity and propagation on solar PV output reduction in Phoenix area

Population density and solar penetration

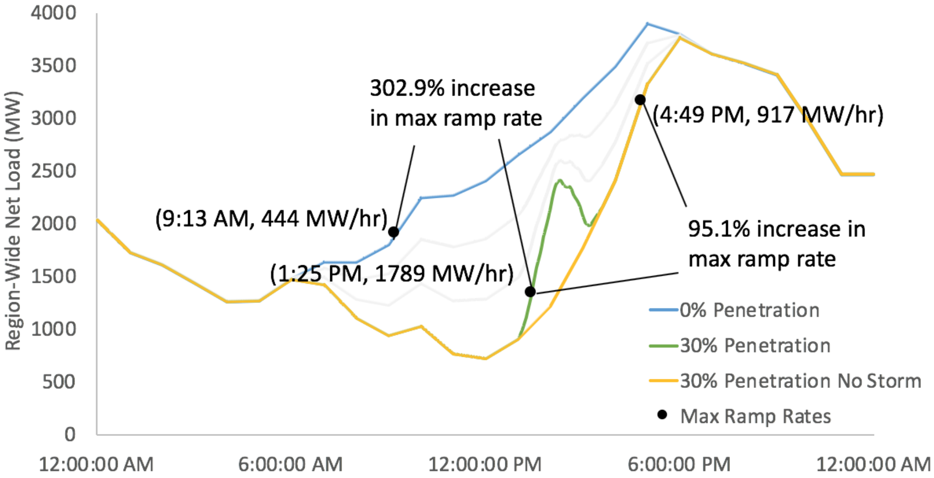


Dust storm intensity



Dust storm propagation

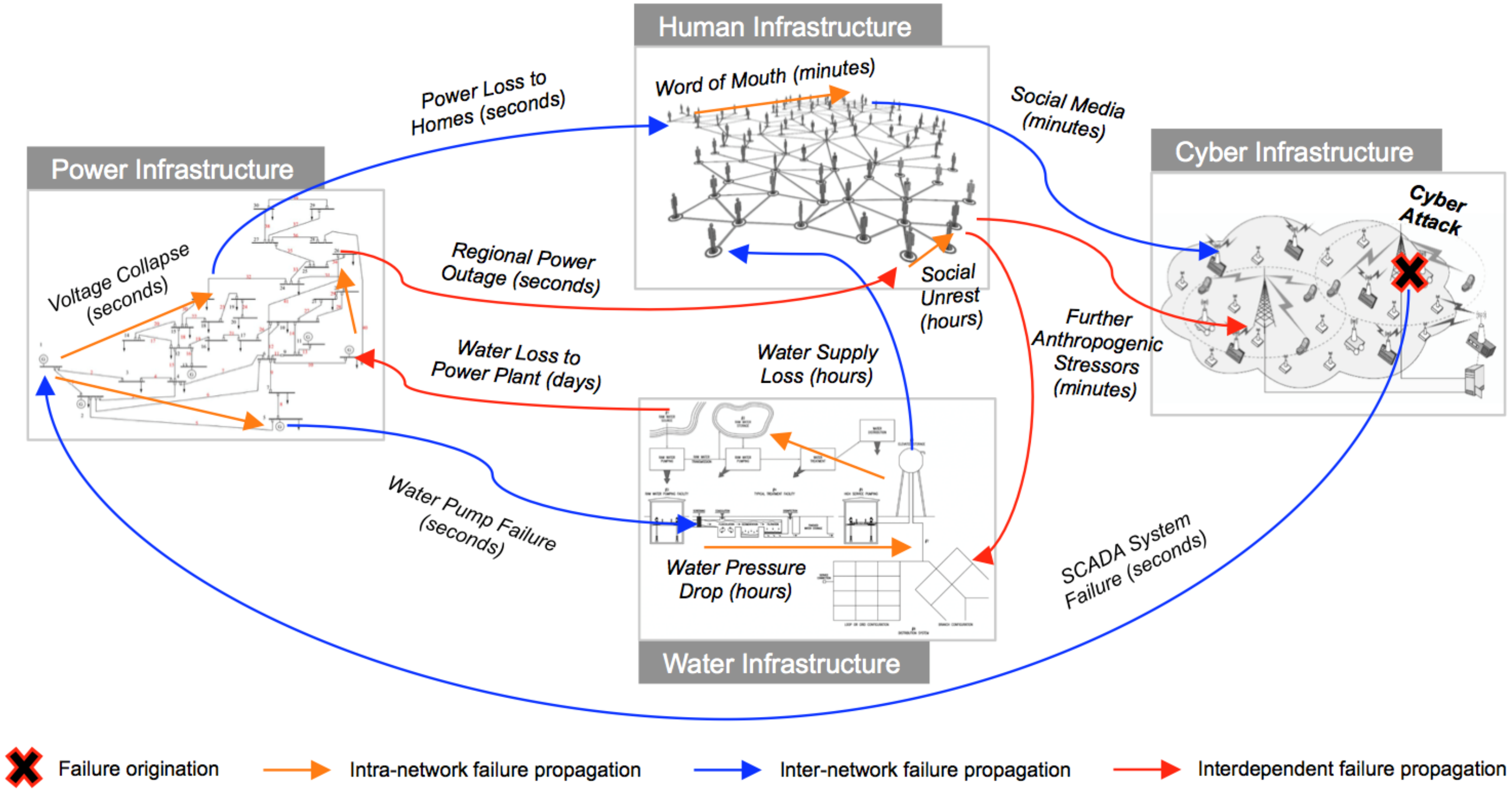
Dust storm effect on system net load



https://www.youtube.com/watch?v=vYnuzoH5oBA

Janko, S. A., Gorman, B. T., Singh, U. P., & Johnson, N. G. (2015). High penetration residential solar photovoltaics and the effects of dust storms on system net load. In ASME 2015 International Design Engineering Technical Conferences (IDETC) and Computers and Information in Engineering (CIE) Conference. American Society of Mechanical Engineers.

But what about connections between infrastructures and interdependencies?



The Resilient Infrastructure Simulation Environment (RISE)

The **Resilient Infrastructure Simulation Environment (RISE)** is a real-time simulation and training environment that enables researchers and operators to test *network design configurations* and *operating strategies* to improve system resilience to environmental (e.g., extreme heat), anthropogenic, and cyber threats. https://tinyurl.com/ybl65vn6

Infrastructure Models

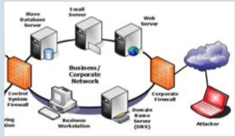

Power


Water

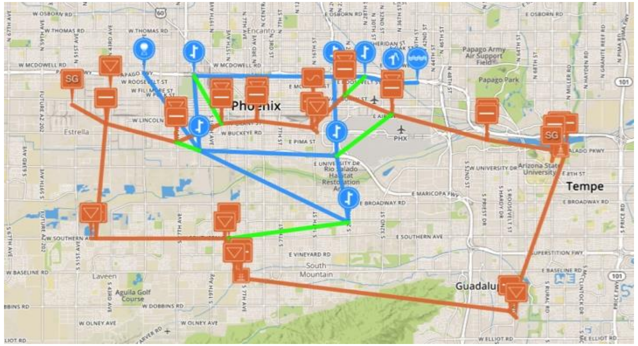

Gas


Transportation


Social



Cyber



Threat and Resiliency Simulation


Interdependency


Threats


Stressors

Human Interaction


GIS Maps


SCADA



Infrastructure Management



Real-time Adaptation & Response

Gorman, B., Hamel, D., Bondank, E., Barela, E., Scott, S., Carmody, C., Lajom, A., Chester, M., Johnson, N. G. (2017). Real-time simulation and control of interdependent power and water networks using Resilient Infrastructure Simulation Environment (RISE). In ISSST.

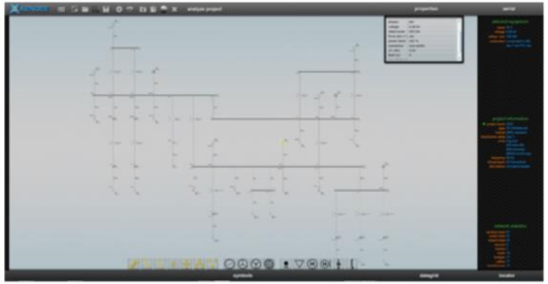
What we model and measure

Temporal Domain	Spatial Domain	
	Local effect	***Regional effect***
Fast-acting	• Grid voltage (power) • Individual movement (social) • Protection mechanisms (power) • Network reconfiguration (power/cyber) • Direct personal communication (social)	• Grid frequency (power) • Electrical resource adequacy (power) • Social media traffic (social) • SCADA denial of service (cyber) • Reported outages (cyber/social)
Slow-acting	• Water pressure (water) • Time allocation of activities (social) • Power/water source selection (social) • Communication format (cyber/social) • "Waiter" malware (cyber)	• Population movement (social) • Loss of water availability (water) • Fuel availability (power) • Market operation (power/water) • Direct personal communication (social)

But the connections and relationships between these are rarely tracked …
… which leads to unknown vulnerabilities

Taking research into practice

Resiliency score & cost



XENDEE microgrid and distribution network design with costing

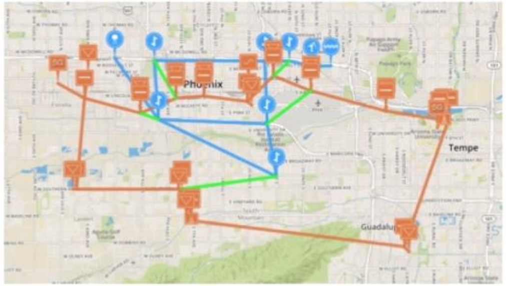
Microgrid developers

Cyber attack / controls

IncSys/PowerData PowerSimulator for real-time operation

Electric utilities and ISOs

Resiliency planning, disaster risk reduction



ASU RISE network design and real-time operation

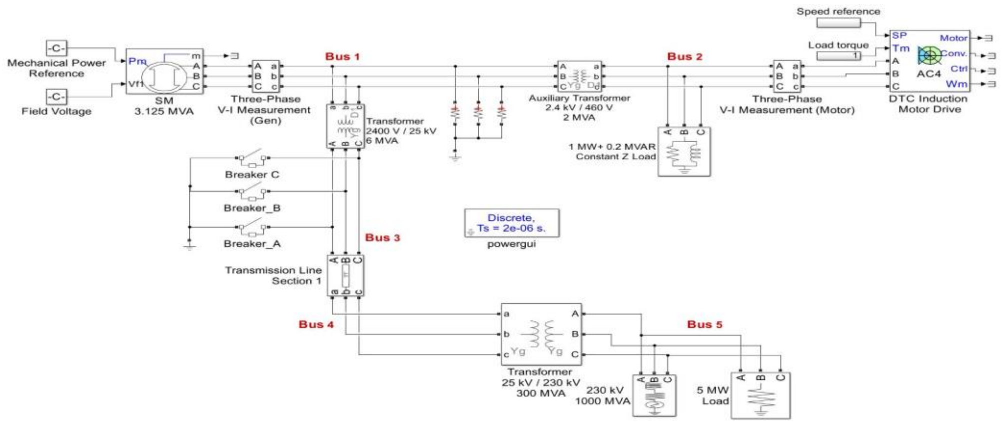
City and community planners, electric utilities

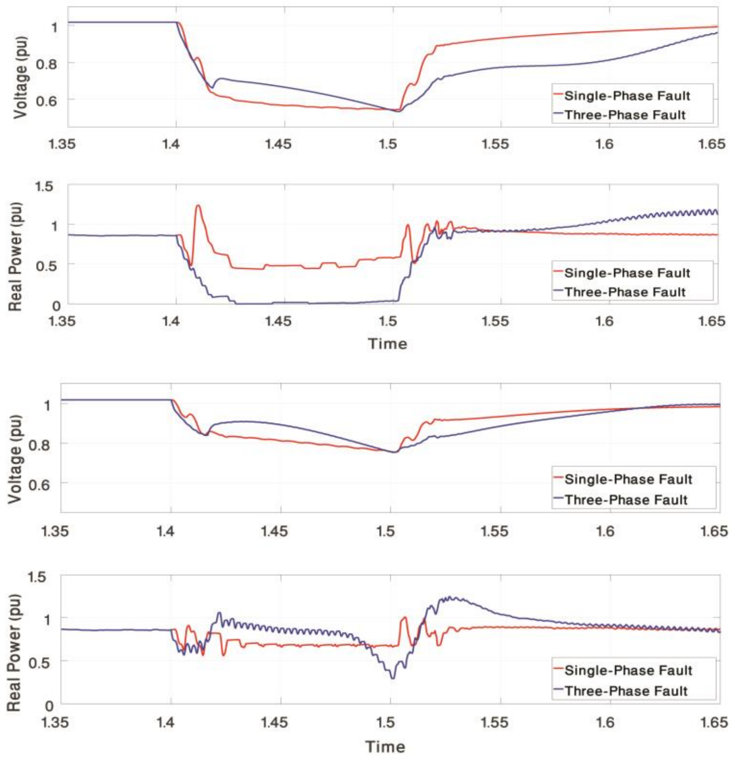
Grid Modernization

Power system equivalent model development for power electronics devices

Challenge: Power system equivalent model development of power electronics components

Solution: Developing equivalent simulation models mimicking the behavior of power electronics components





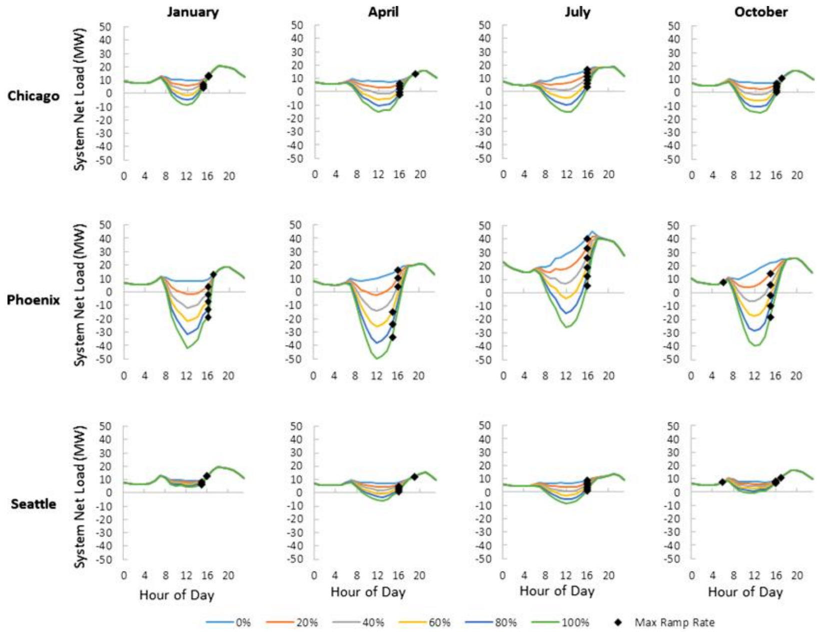
For a three-phase fault, the positive sequence power dropped immediately to zero for the case **with the greatest voltage dip (53%)** and decreased slowly to zero for smaller voltage dips as fault duration increased.

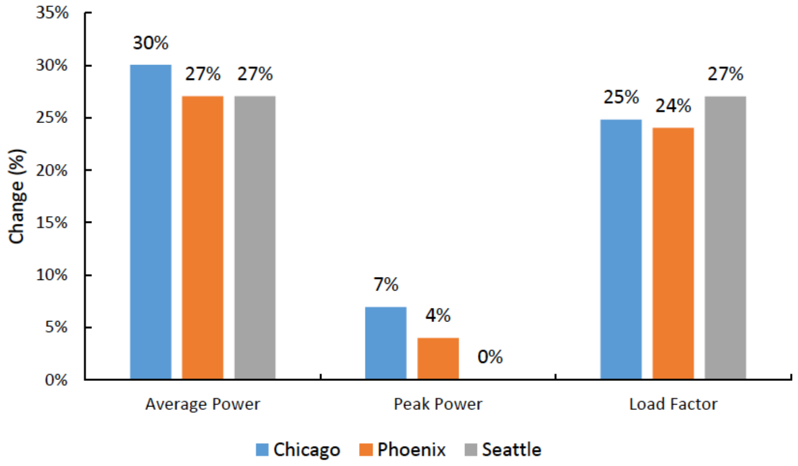
Saha, S. & Johnson, N. (2018). Point-on-wave analysis of three phase induction motor drive under fault external to the power plant. IEEE PES General Meeting.

Assessing the impact of business-as-usual residential solar PV

Challenge: Potential impact of residential solar assuming no technical, financial, or policy change (2015).

Solution: Quantify and contrast potential future scenarios in US cities.





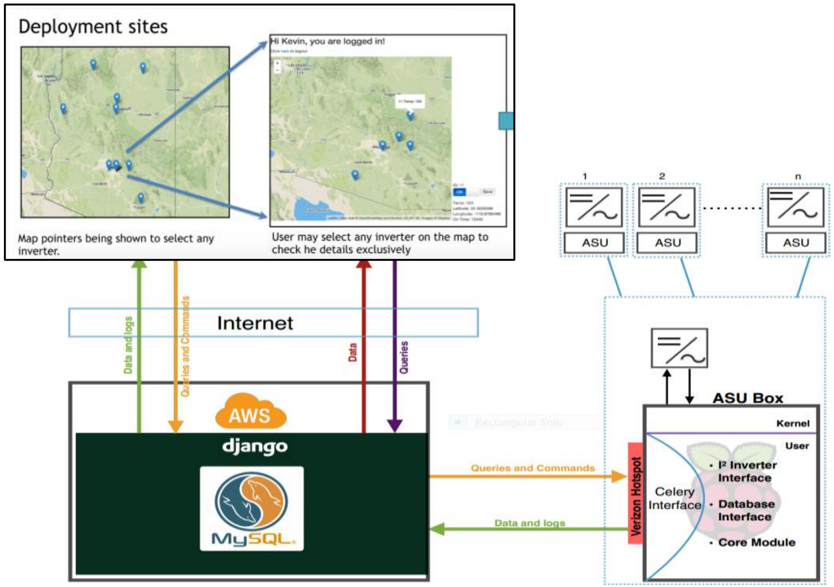
Janko, S., Arnold, M., & Johnson, N. (2016). Implications of high-penetration renewables for ratepayers and utilities in the residential solar photovoltaic (PV) market. Applied Energy, 180, 37-51.

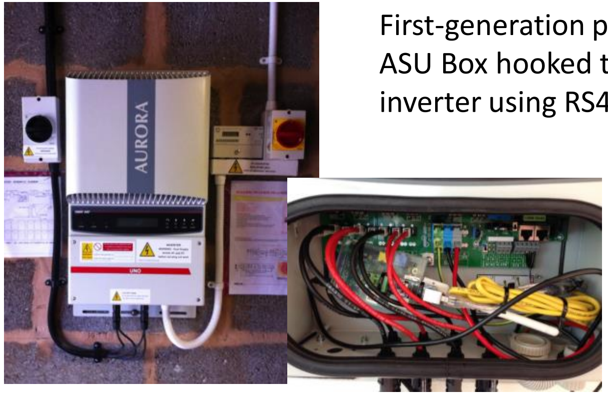
IoT solutions for remote connectivity and control of building EMS

Challenge: Smart inverters lack capability for remote monitoring/control. Utilities forced to take generation.

Solution: Provide seamless remote connectivity and interoperability to solar and other DER assets.

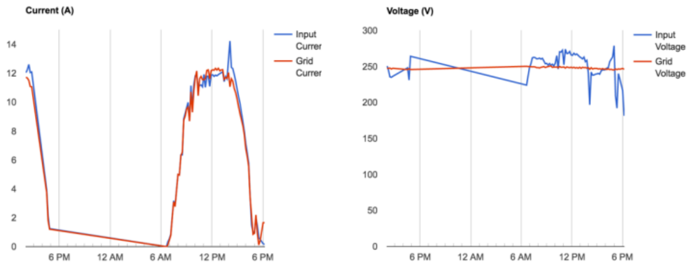
Web-based interface for viewing data and control





First-generation prototype of ASU Box hooked to solar PV inverter using RS485

Real-time data

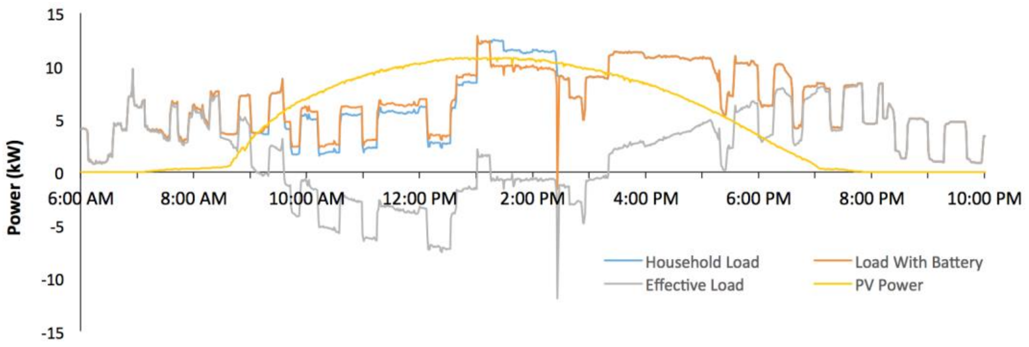


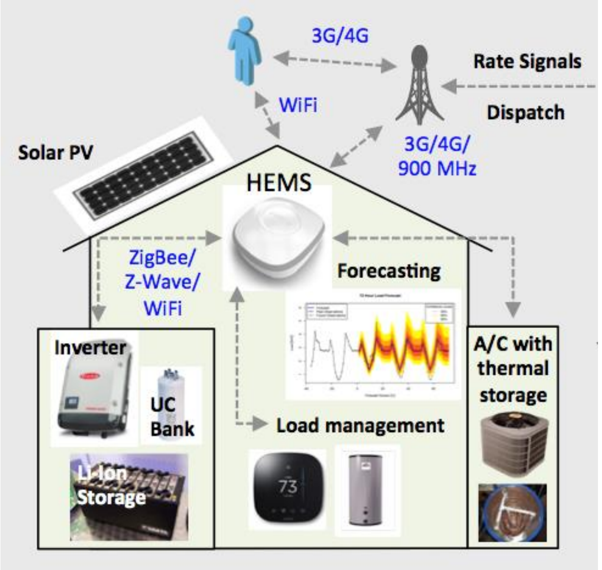
Smart Nodes with building-level EMS controller

Challenge: Greater uncertainty in loads due to increasing amounts of consumer-side technologies.

Solution: Integrate control of all technologies in intelligent home EMS (HEMS); simple external portal.

Each 5-20kW "**Smart Node**" control solution is suitable for buildings, campuses, off-grid sites, and mobile power systems





On-board controls can dispatch assets with simple commands from the utility such as energy cost, net load set point, ancillary services

Model predictive control for scheduling DER assets

Challenge: Poorly coordinated asset scheduling limits cost savings and resiliency

Solution: Optimize near term control to accommodate future variability in resources

Distributed Generation | Energy Storage | Demand Response

$$J := \sum_{t=0}^{T-1} \sum_{i=1}^{N_g} \left[C_i^{DG} P_i(t) + OM_i \delta_i(t) + SU_i(t) + SD_i(t) \right] + \sum_{s=1}^{N_s} OM^s \delta_s(t) + \sum_{h=1}^{N_c} \rho_h(t) \beta_h(t) D_h^c(t) +$$

$$C_E^g(t) E^g(t) + C_D^g \max_{i \in t} P^g(i) - C_{Spin}^g(t) P_{spin}^g(t) - C_{Non-Spin}^g(t) P_{Non-spin}^g(t) - C_{Reg}^g(t) P_{Reg}^g(t) + C_Q^g(t) Q^g(t)$$

Grid Energy Cost | Grid Demand Cost | Ancillary Services | External Thermal Cost

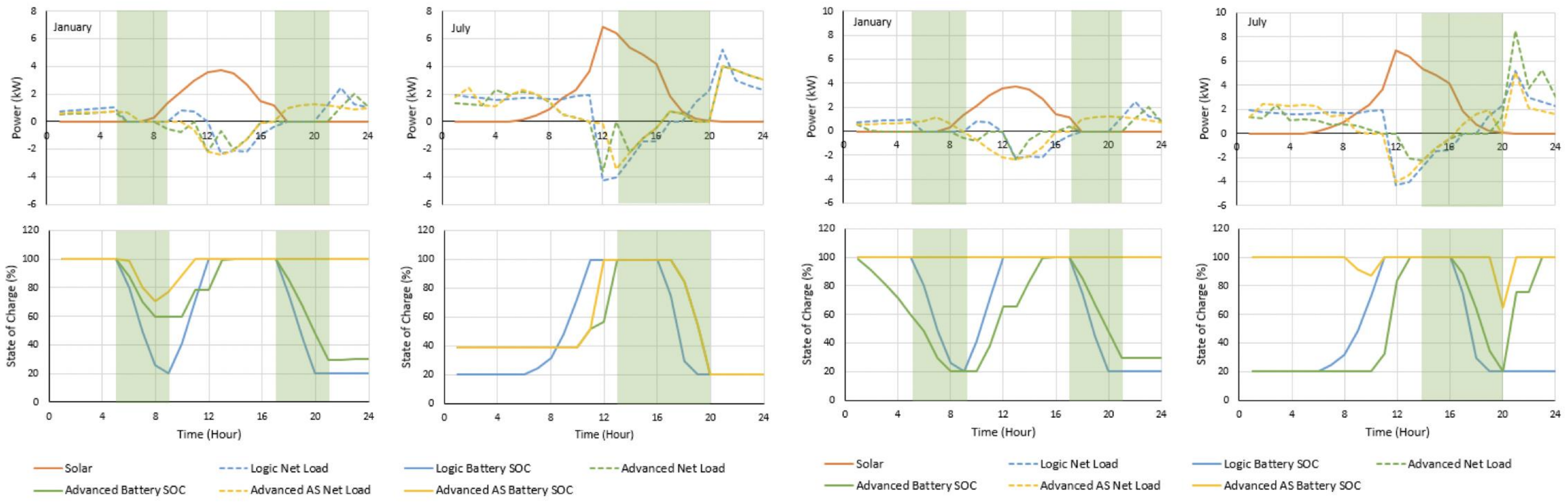
Electrical Generation and Storage | Electrical Loads

$$0 = \sum_{i=1}^{N_g} P_i(k) + P^{res}(k) + P^g(k) - P^b(k) - \sum_{j=1}^{N_j} D_j^{nc}(k) - \sum_{h=1}^{N_c} [1 - \beta_h(k)] D_h^c(k)$$

Thermal Generation and Storage | Thermal Loads

$$0 = Q^g(t) - \sum_{i=1}^{N_{chp}} \frac{P_i(t)}{PHR_i} - P^s(t) - \sum_{j=1}^{N_q} D_j^q(t)$$

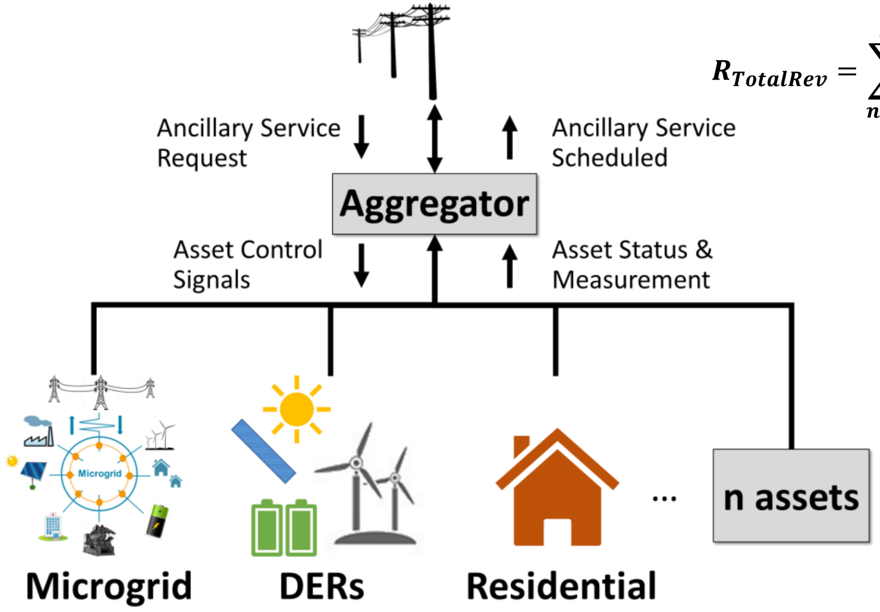
Model predictive control for scheduling DER assets



Rate Structure	TOU				TOU + Demand			
Control Method	Baseline	Logic	Advanced	Advanced AS	Baseline	Logic	Advanced	Advanced AS
Yearly Bill ($)	1764.90 (-)	871.92 (-50.6)	477.16 (-73.0)	525.61 (-70.2)	1534.47 (-)	738.51 (51.9)	567.09 (63.0)	672.76 (56.2)
On Peak Energy (kWh)	5775.33 (-)	181.99 (-96.9)	-912.67 (-115.8)	15.93 (-99.7)	5775.33 (-)	170.83 (-97.0)	-1221.86 (-121.2)	1988.7 (-65.6)

Distributed energy resource aggregation

- **Challenge**: Controlling the increasing number of distributed energy resources (DER).
- **Solution**: Aggregate the resources to enable cost savings and increased grid reliability.



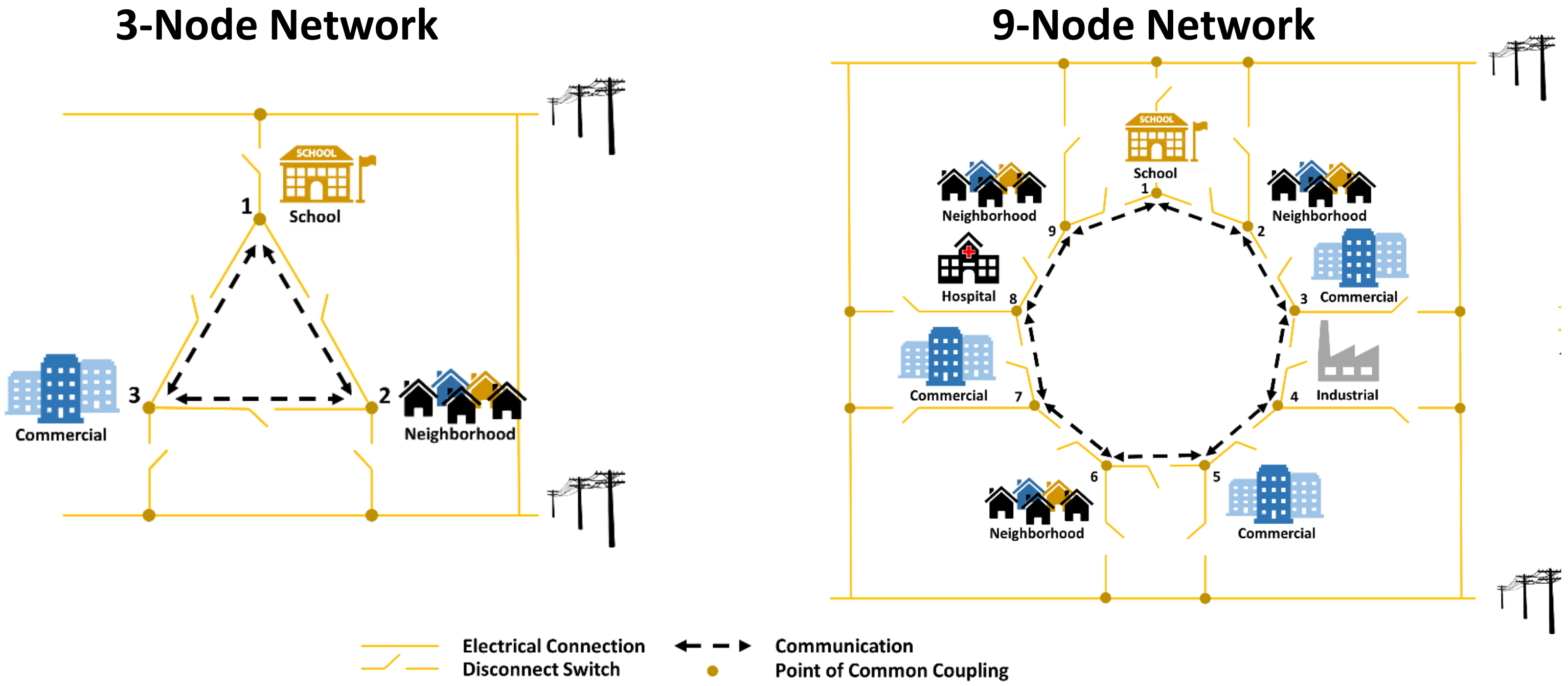
$$R_{TotalRev} = \sum_{n=1}^{N}\sum_{t=1}^{\tau} \overbrace{\gamma_{PowerFlexibilityAS}(n,t) * p_{PowerFlexibilityAS}(n,t) P_{PowerFlexibilityAS}(n,t)}^{Schedule\ Up/Down\ Ancillary\ Service} + \overbrace{\gamma_{SpinningReserveAS}(n,t) * p_{SpinningAS}(n,t) P_{SpinningAS}(n,t)}^{Spinning\ Up/Down\ Reserve\ Ancillary\ Service} + \overbrace{\gamma_{NonSpinningReserveAS}(n,t) * p_{NonSpinningAS}(n,t) P_{NonSpinningAS}(n,t)}^{Non-Spinning\ Reserve\ Ancillary\ Service}$$

- Increase in DER assets requires advanced controls
- On-grid and off-grid applications
- Reduce operational costs
- Increase grid reliability

Multi-agent facilitation of transactive energy networks

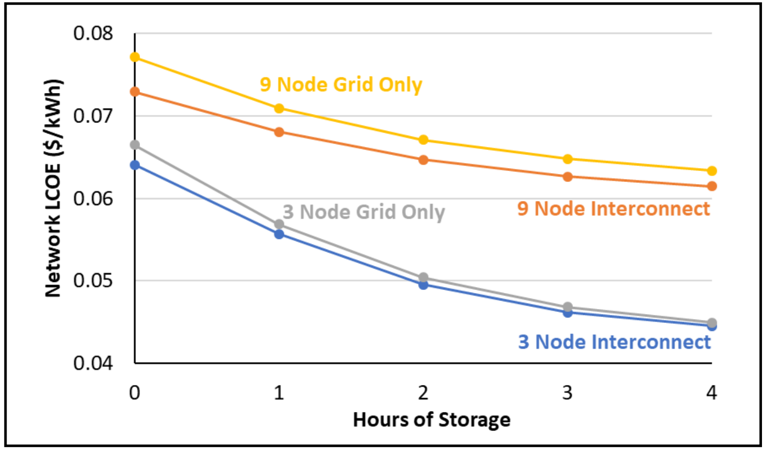
Challenge: Increase in distributed energy resources but no coordinated exchange market.

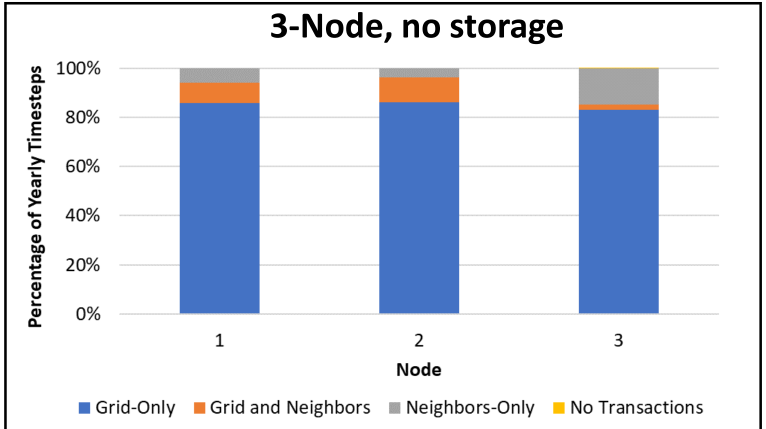
Solution: Transactive energy networks to facilitate trading between microgrid nodes.

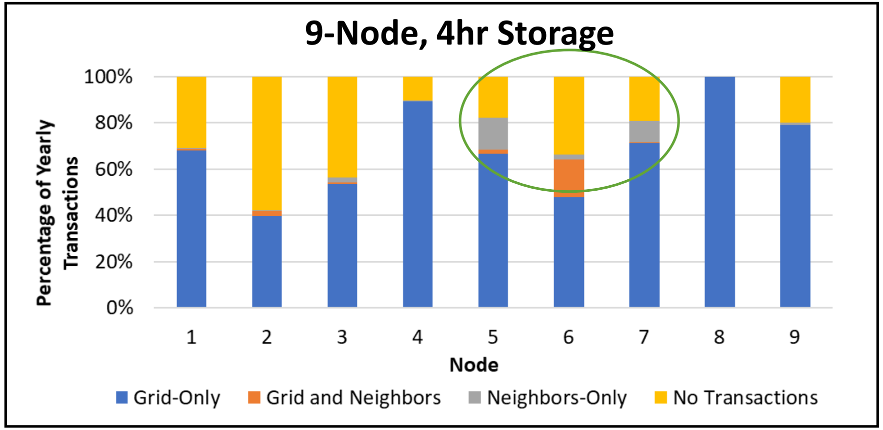


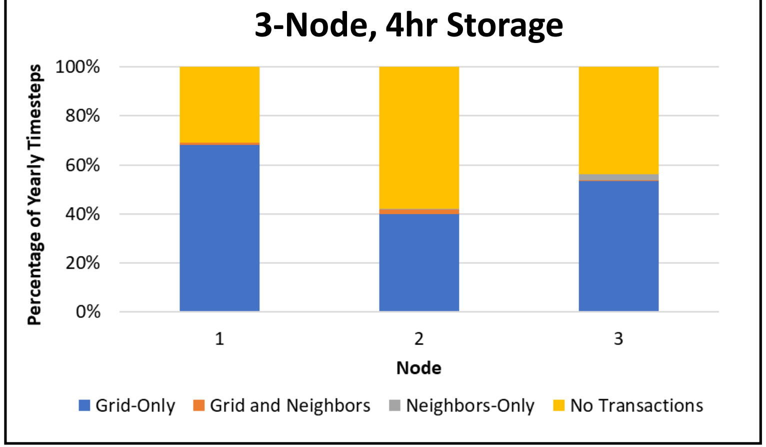
Janko, S. & Johnson, N. (2018). Scalable multi-agent microgrid negotiations for a transactive energy market. Applied Energy, 229, 715-727.

Multi-agent facilitation of transactive energy networks





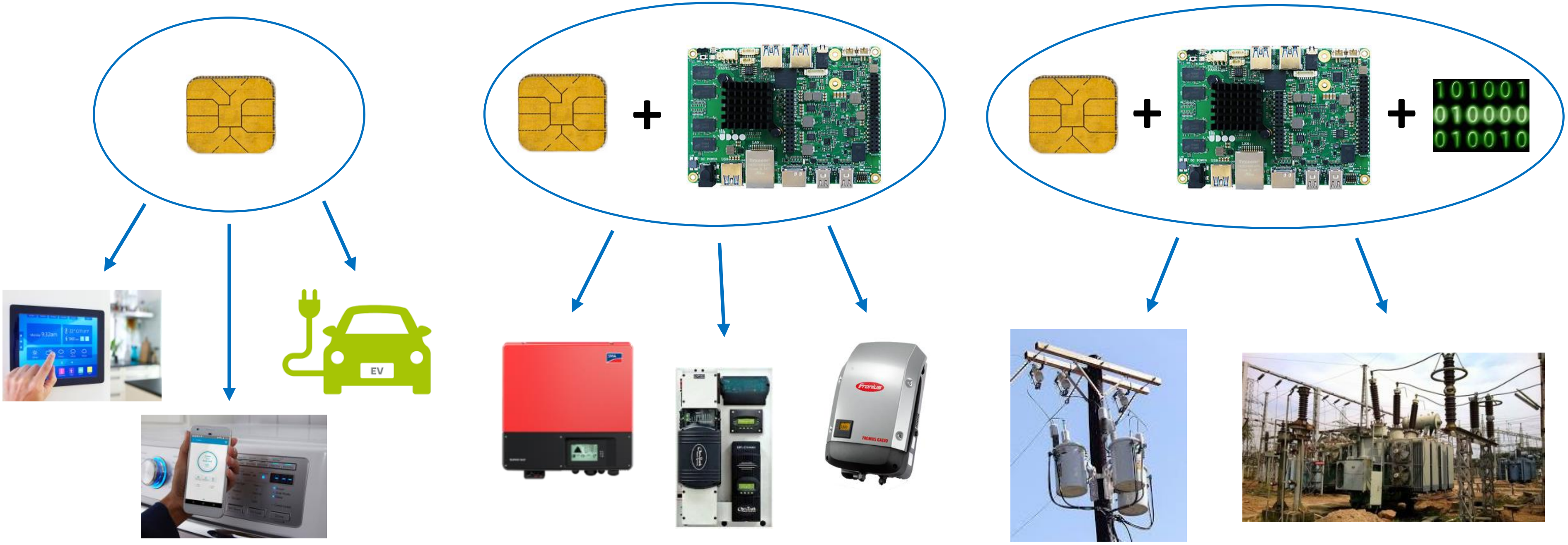




Distributed security of grid-edge devices

Challenge: Security of grid-edge devices threatened by adversaries.

Solution: Advanced intrusion detection techniques coupled with distributed Blockchain ledgers.

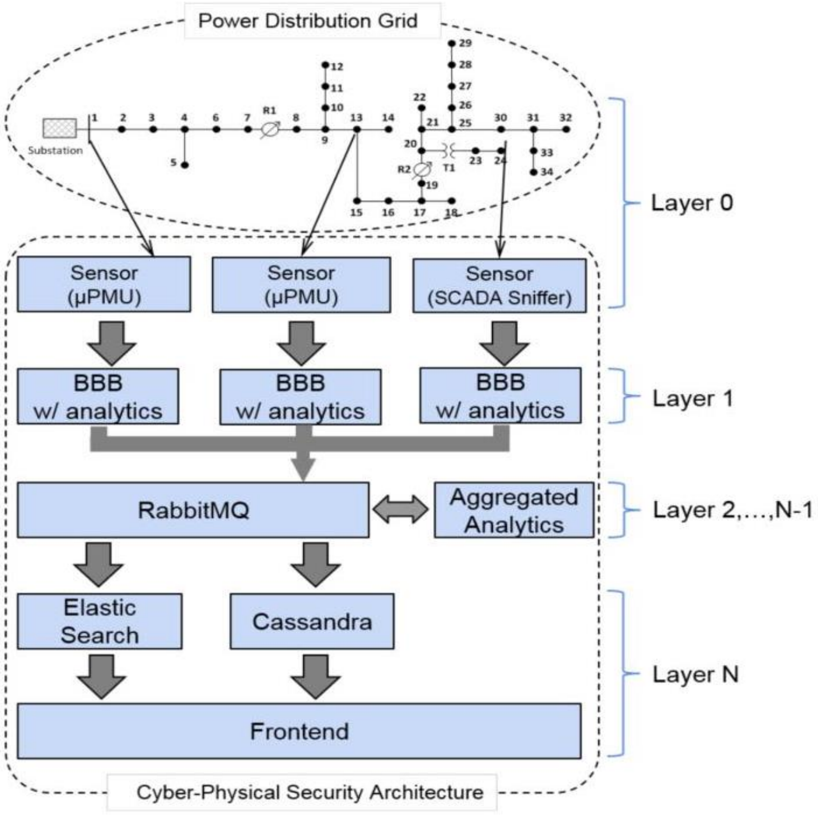


IoT and “smart” vendors

DER product vendors

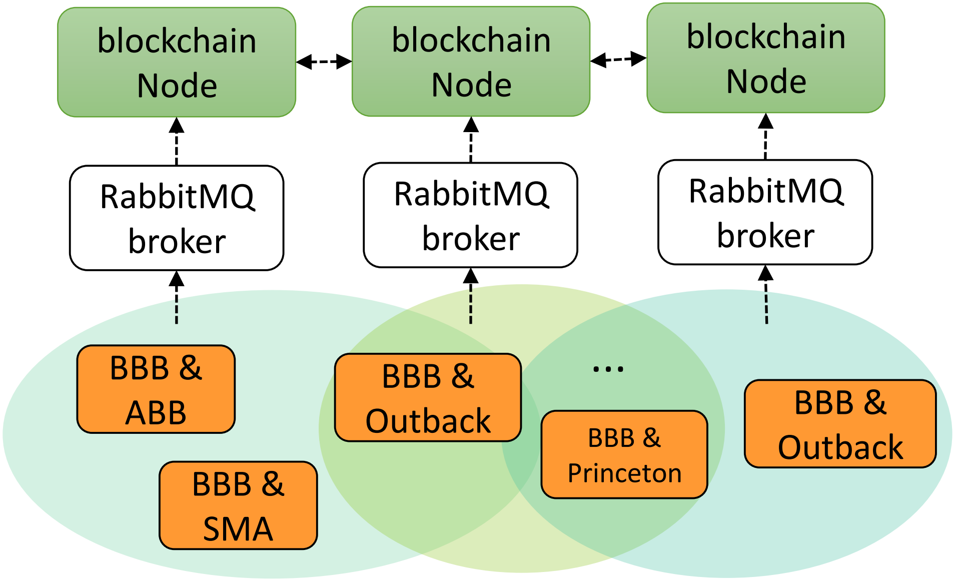
Infrastructure vendors

Distributed security of grid-edge devices



Current Cyber-Physical Security Architecture

**BBB= BeagleBone Black



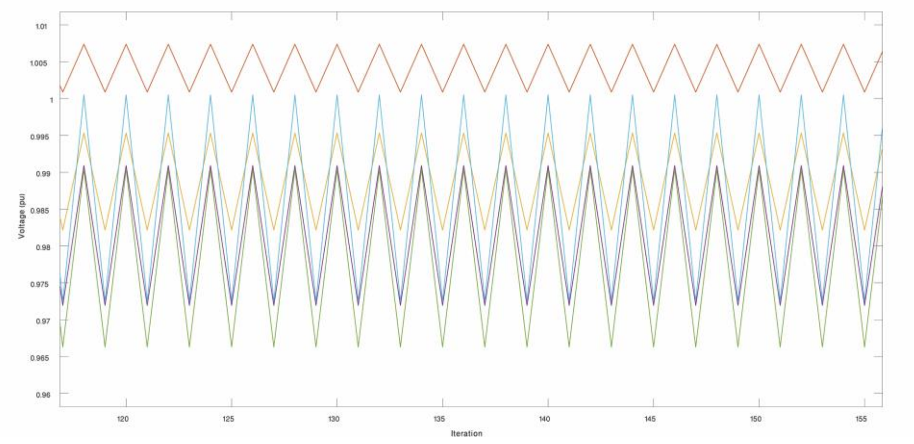
Adding Blockchain to the Existing Architecture

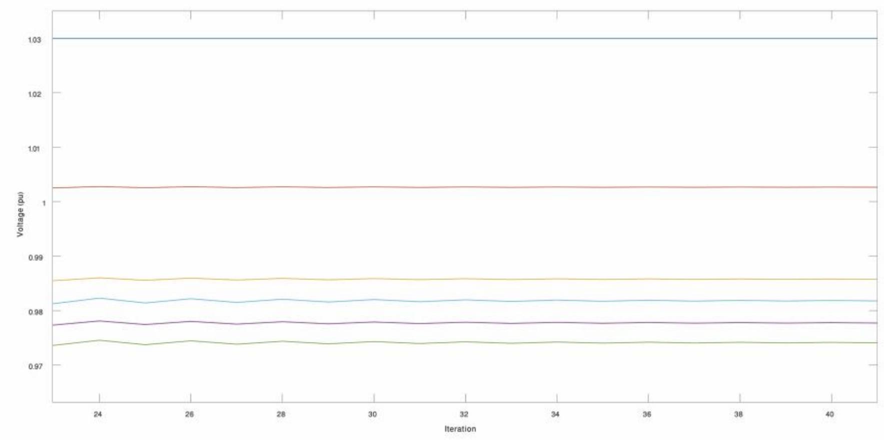
BBB & *** BBB equipped with BF chip

Distributed security of voltage regulating devices

Challenge: Stability of distribution network disrupted by cyberattacks.

Solution: Develop methodology and tools allowing automatic reconfiguration of distribution grids .





Inverters fail to converge to a stable point due to steep droop curve

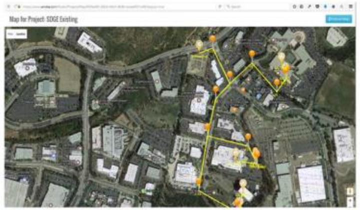
Inverters converge to a stable operating point with updated droop curve

Rapid design and evaluation of microgrids and DER distribution

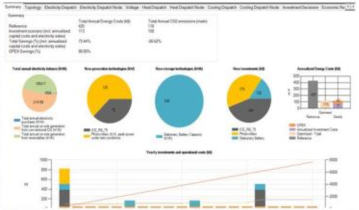
Challenge: Long time to design and quote. Each project is unique; start from scratch. Project management.

Solution: Single tool combines analysis of generation, distribution, loads, economics. 90% time reduction.

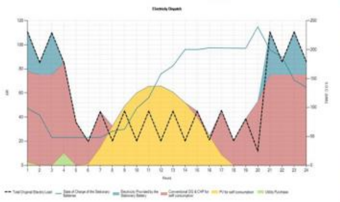
GIS layout



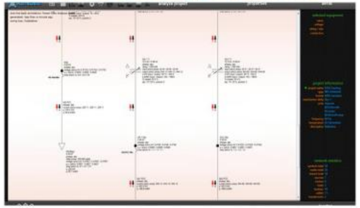
Cash flow



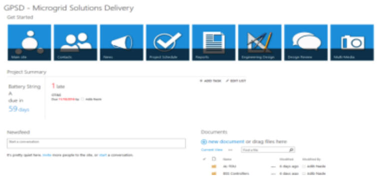
Time series



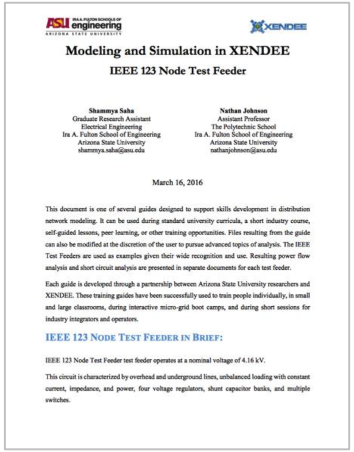
Power flow



Project management



Training guides



Modeling and Simulation in XENDEE

IEEE 123 Node Test Feeder

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March 16, 2016

This document is one of several guides designed to support skills development in distribution network modeling. It can be used during standard university curricula, a short industry course, self-guided lessons, peer learning, or other training opportunities. Files resulting from the guide can also be modified at the discretion of the user to pursue advanced topics of analysis. The IEEE Test Feeders are used as examples given their wide recognition and use. Resulting power flow analysis and short circuit analysis are presented in separate documents for each test feeder.

Each guide is developed through a partnership between Arizona State University researchers and XENDEE. These training guides have been successfully used to train people individually, in small and large classrooms, during interactive micro-grid boot camps, and during short sessions for industry integrators and operators.

IEEE 123 NODE TEST FEEDER IN BRIEF:

IEEE 123 Node Test Feeder test feeder operates at a nominal voltage of 4.16 kV.

This circuit is characterized by overhead and underground lines, unbalanced loading with constant current, impedance, and power, four voltage regulators, shunt capacitor banks, and multiple switches.

Modeling Overview: https://youtu.be/-C0E5j9prxo
SnapShot Power Flow: https://youtu.be/3F1ay5CazCQ
Google Maps Integration: https://youtu.be/QwA2lMMU-Nk

Workforce Development

LEAPS workforce development

*Our eight training programs support the advancement of **microgrid project funders/managers**, **engineers**, **technicians**, **operators**, and **installers** through in-person workshops and online content delivery.*

Entity	Training	Delivery	Capacity	Trained so Far	Comments
ASU	Microgrid Boot Camp	In-person	20/session	80	Five days, offered twice per year at ASU
ASU	Microgrid Master Class	In-person	Varies	100	One or two days, offered anywhere
ASU/HNEI	Grid Resiliency	In-person	20/session	Upcoming	Two days, offered once per year at ASU
ASU	Microgrid Design and Control	In-person	25/session	25	Three-credit special topics course at ASU
IncSys	Grid Cybersecurity	In-person	25/session	20	Two days, offered once per year at ASU
IncSys	Power4Vets	Online	10/session	20	90-hours online, available anytime
ASU/XENDEE	Microgrid Design	Online	N/A	Upcoming	20-hours online, available anytime
BlockFrame	New Cyber Frontier	Online	N/A	No data	Online cybersecurity show, monthly

ASU collaborate with **HNEI** , **IncSys** , **XENDEE**, and **BlockFrame** to create and deliver training materials and programs to benefit civilians, Navy Veterans, and active military.

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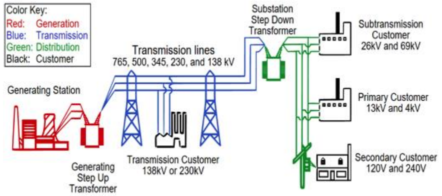
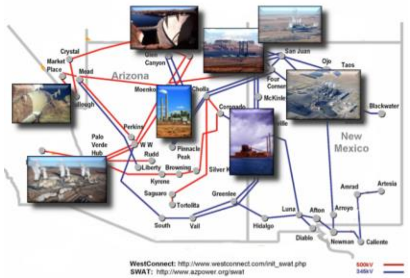
Microgrid boot camp for civilian and military applications

Challenge: Rapidly growing market needs require short courses and continuing education credits.

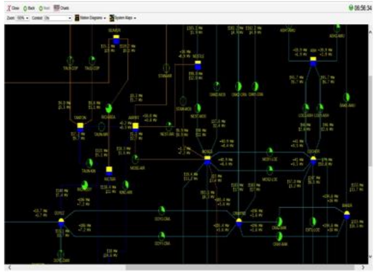
Solution: One-week introductory course for design, installation, operation, maintenance, and safety.

Infrastructure basics





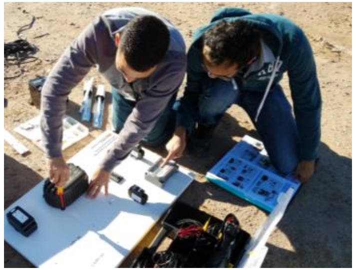
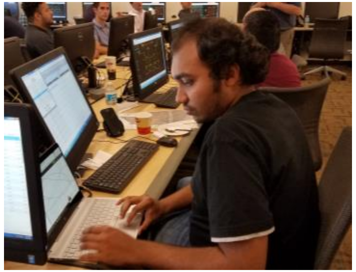
Simulation-based design



Hands-on integration

Interactive tours

Microgrid boot camp for civilian and military applications

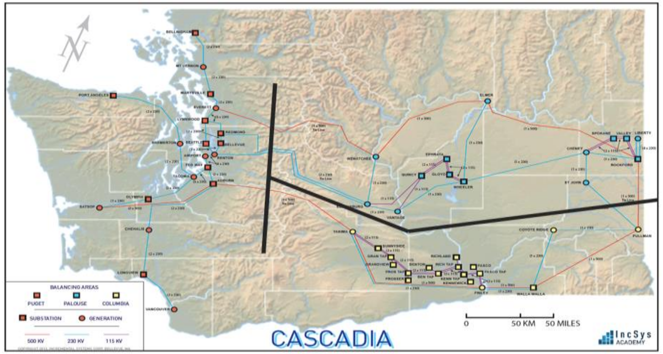
Monday	Tuesday	Wednesday	Thursday	Friday
Introduction • Basics of microgrids and energy infrastructure • Small-scale hands-on activity	**On-grid and Off-grid Systems in HOMER** • System sizing and component selection • Applying HOMER to personal case study • Mobile microgrids	**Hands-on Integration Microgrid Test Bed** • Safety training • System deployment and testing • Primary controls • Controller configuration	**Distribution Network Simulation & Analysis** • Power flow analysis • QSTS analysis • Short circuit analysis • Voltage stability and asset sizing/placement	**Walking Tours of Local Facilities** • Power plant tour (SRP Santan Generating Station – 1.2 GW) • Grid-operator control center tour
				

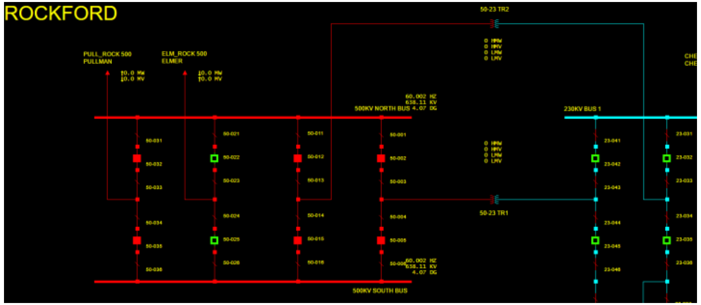
Video: https://vimeo.com/285148179/69793233bd

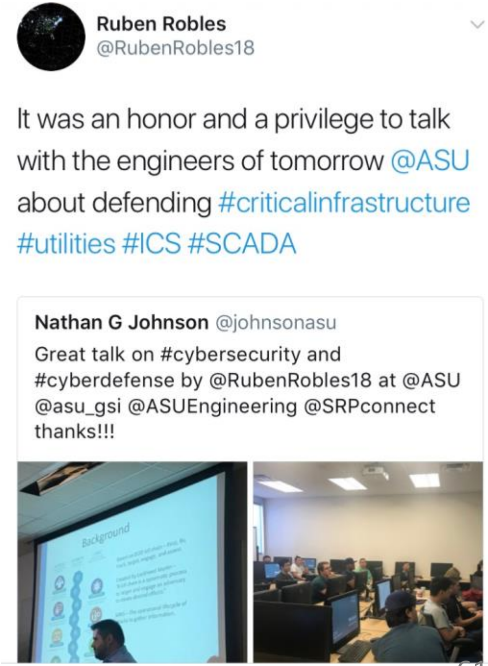
Cyber and kinetic vulnerabilities in electrical infrastructure

Challenge: Cybersecurity threats rapidly evolving with uncertain entry points and impacts.

Solution: Real-time simulations with regional assets and transmission lines; competitive attack-defend.





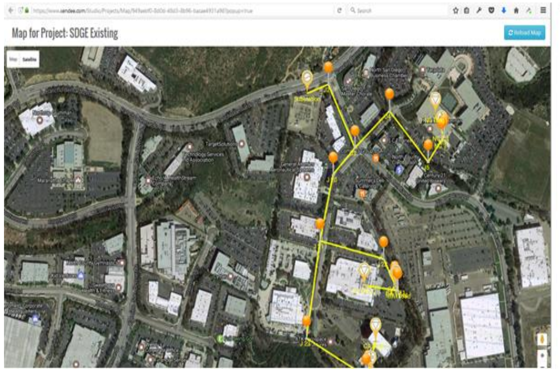


Scaling to meet a growing global workforce

Challenge: A $40B market without sufficient trained personnel to realize market potential.

Solution: 200+ hours of classroom, simulation, and hands-on curriculum.

Online Microgrid and DER Design Tool and Program Management



Grid Modernization and Microgrid Test Bed

Mobile Microgrid Training Platform

Video: https://vimeo.com/252371023/80fe83fc61

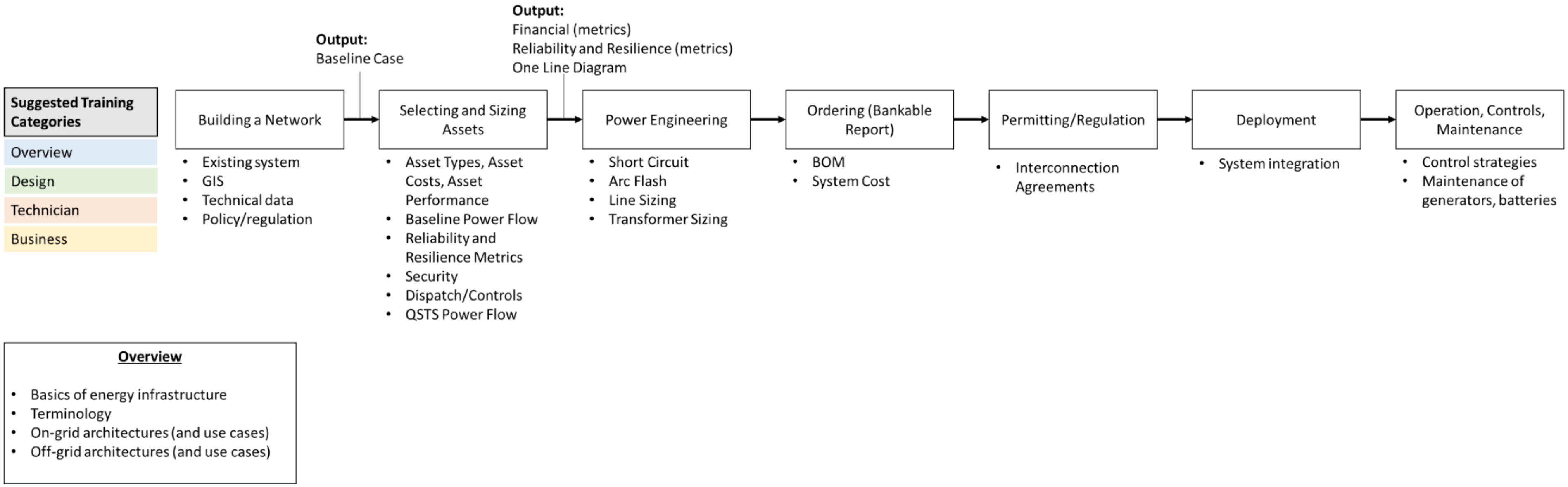
Microgrid master classes

Event Agenda *(example)*

8:00am	**Introductions and Overview** *Dr. Nate Johnson, Assistant Professor, **ASU***
8:15am	**Introduction to XENDEE** *Shammya Saha, Graduate Research Assistant, **ASU***
12:00pm	Lunch Break
1:00pm	Split into three groups and switch every hour: **Group 1: Mobile Microgrid Training Platform** *Alexander Mobley, Microgrid Testbed Manager, **ASU*** **Group 2: Primary Control Demonstration** *James Nelson, Graduate Research Assistant, **ASU*** **Group 3: Mobile Training Toolkits** *Shammya Saha*
4:30pm	**Closing Discussion** *Nate Johnson*

Online microgrid design courses

- Partnership with GOEE and EdPlus for online content development
- Partnership with XENDEE for design software
- Microgrid Design Process curriculum



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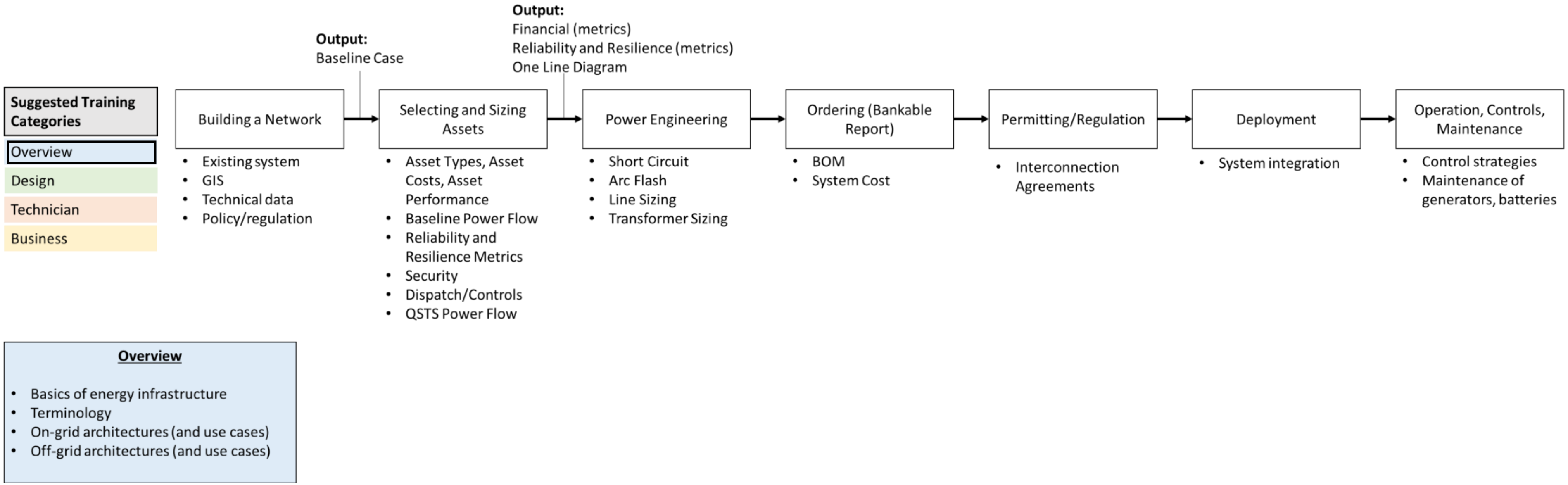

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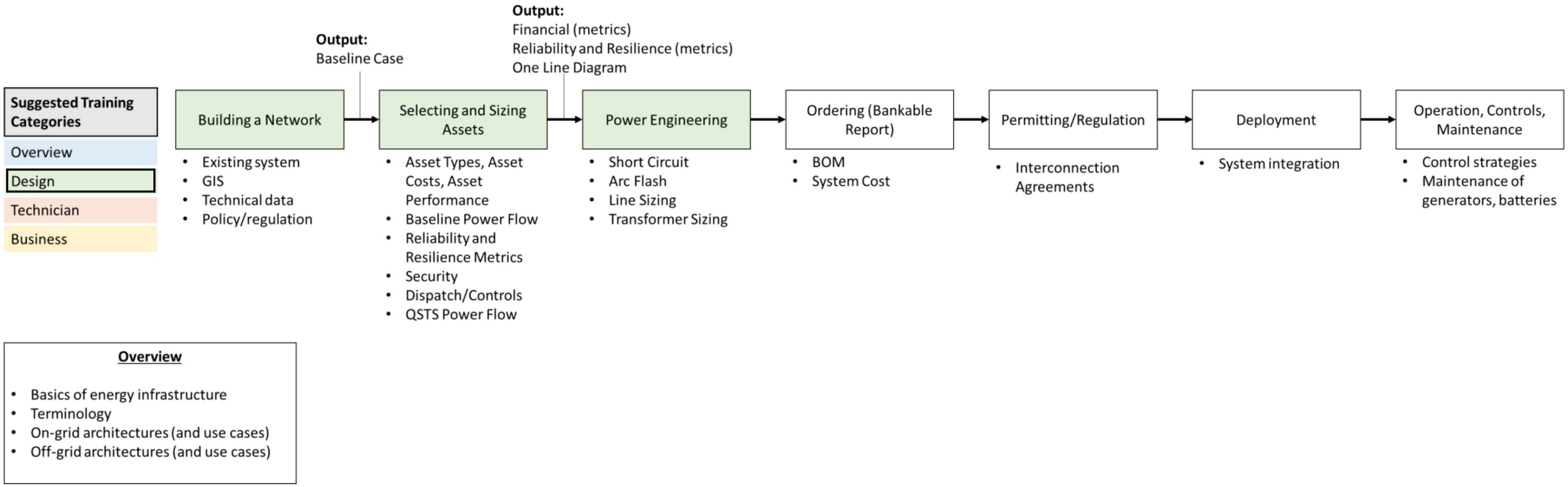

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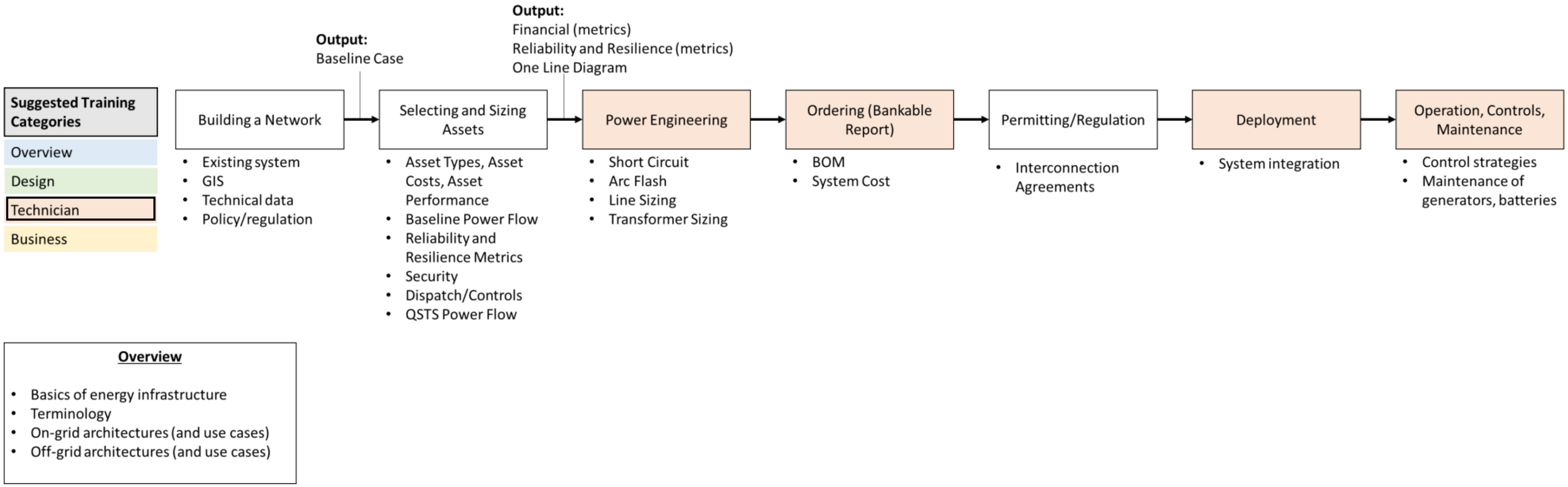

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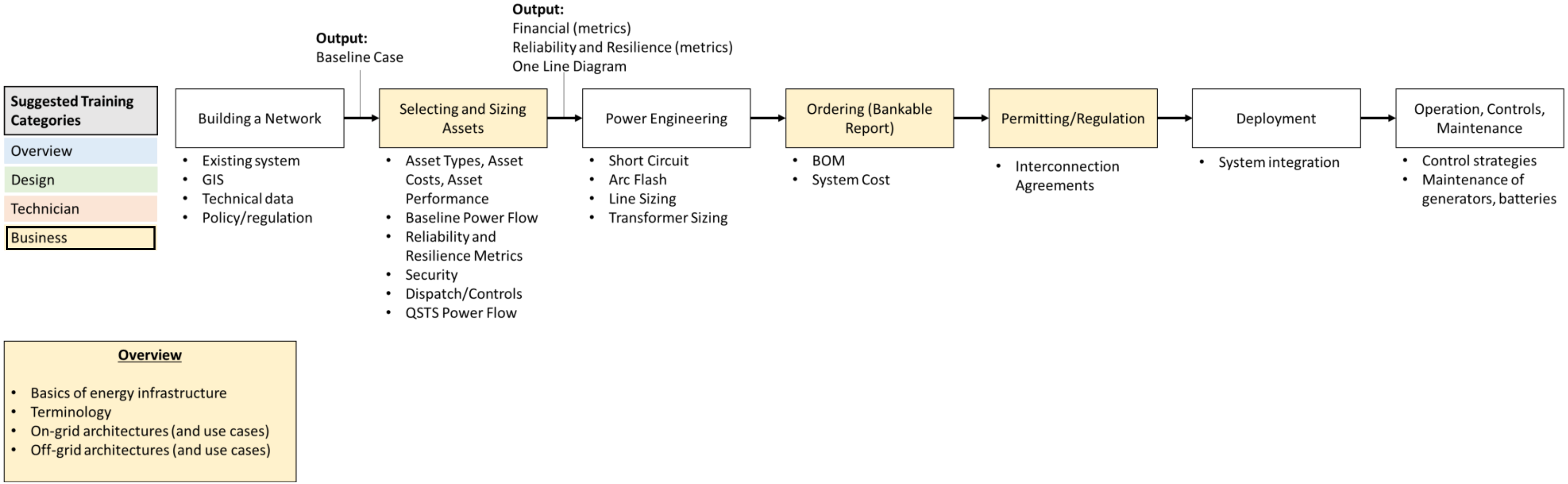


Online microgrid design courses

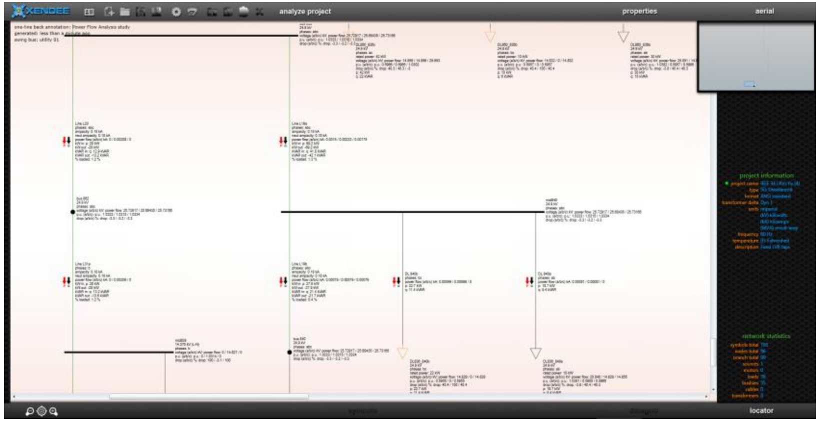
Starting with 18 hours of content (Fall 2018). Includes videos and activities on the following topics:

Basics of Microgrids (6 hours)
- Basics of Energy Infrastructure (1 hour)
- Terminology (1 hour)
- On-grid Architectures (2 hours)
- Off-grid Architectures (2 hours)

Selecting & Sizing Assets in XENDEE (4 hours)
- Economic and Technical Feasibility (2 hours)
- Financial Analysis of On-grid and Off-grid Systems (2 hours)

Power Flow in XENDEE (5 hours)
- Power Flow Analysis (5 hours)

Commissioning/Deployment (3 hours)
- Inverter Setup (1.5 hours)
- Microgrid Integration (1.5 hours)



Supporting Entities and Partners

Sponsors

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USAID From the American People
IDB Inter-American Development Bank
IRENA International Renewable Energy Agency
SRP
nrg Renew
verizon
IncSys
AORA Green Energy. Local Power.

Partners

HNEI Hawai'i Natural Energy Institute University of Hawai'i at Mānoa
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BLOCKFRAME

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SPAWAR
UP GRID
NTUA Navajo Tribal Utility Authority
NPS Praestantia per Scientiam 1909
SRP
SIEMENS
SIGORA
WorleyParsons resources & energy
MIT Lincoln Laboratory

Thank you!

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Shammya Saha
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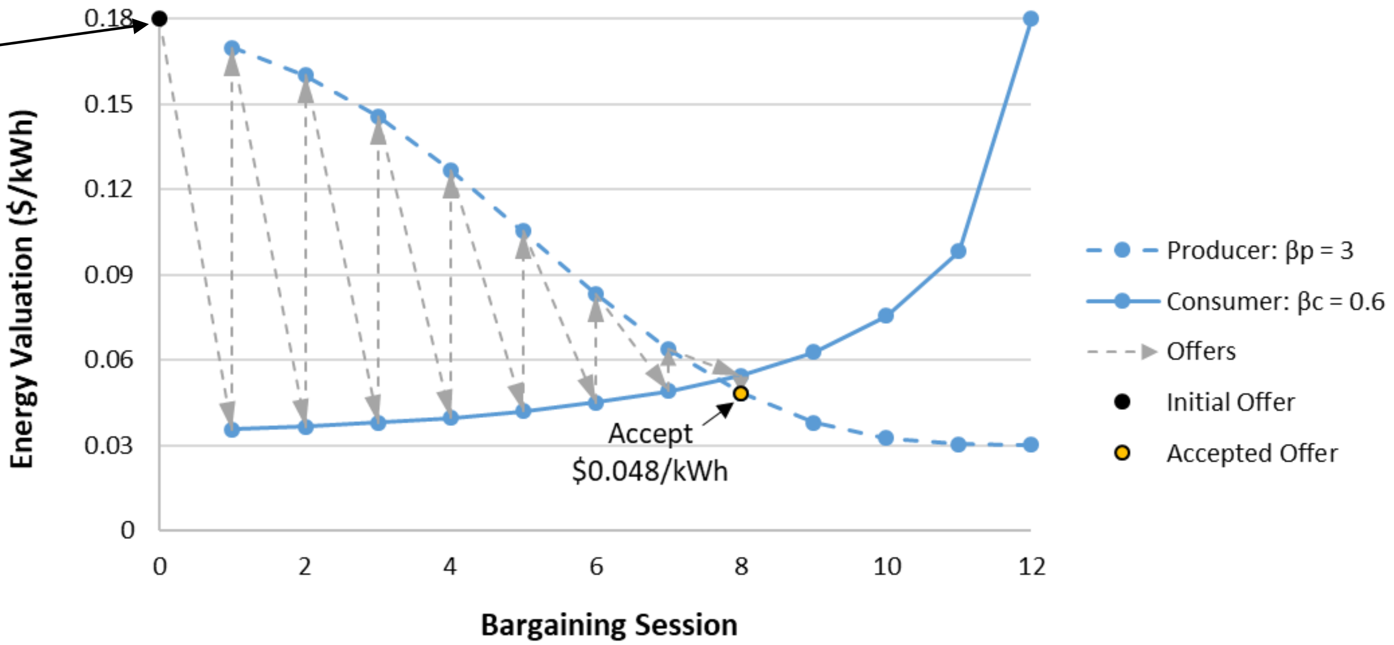
IRA A. FULTON SCHOOLS OF engineering
ARIZONA STATE UNIVERSITY

Multi-agent Facilitation of Transactive Energy Networks

Initial Rate Offer: Very close to grid price

Initial Power Offer: Total available from the producer **or** load requested by consumer



$$\beta_c = \frac{Consumer\ net\ load}{Consumer\ electrical\ load}$$

$$\beta_p = \frac{Initial\ offer\ to\ consumer}{Producer\ electrical\ load}$$