An innovative entrepreneurial electrical engineer (*iEEE*): from academia to startups

Mads R. Almassalkhi, Ph.D.

L. Richard Fisher Associate Professor of Electrical Engineering

University of Vermont (UVM)

The UNIVERSITY of VERMONT

Energy Innovation & Entrepreneurship

April 12th, 2023

Carnegie Mellon University

Short Bio

school
tems
systems
ization
l systems
rbor, Michigan)

Startup company
VC-funded energy optimization
SaaS company for industrial energy plants
(Chicago, IL)

University of Vermont (UVM)
Leading a number of DOE projects
Co-founded cleantech startup
NSF CAREER Awardee
Joint appt @ PNNL
Sabbatical @ DTU
Acquisition

2008 2013 2014 2016 2017 2021 2022 2023

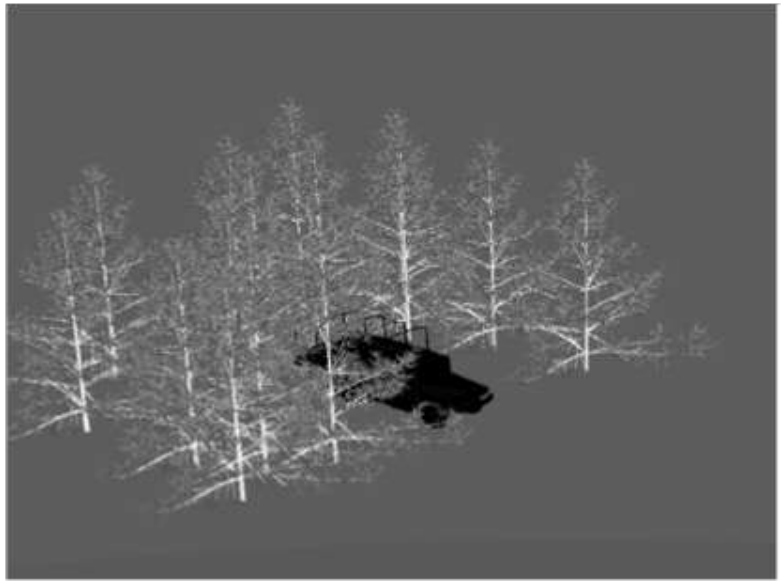
iEEE as an undergraduate

UNIVERSITY OF Cincinnati

- Dual major in EE and applied mathematics
- **UC = First Co-operative (Co-op) Education Program** in the U.S. (1906)
  - Worked for 3 years (50% full time / 50% part-time) in small dynamic, R&D firm: *Etegent Tech*.
  - Focused on algorithm development for signal/image processing (Medical/DoD applications)
  - Picked up image processing, statistical pattern recognition/detection/classification (before it became ML)

Etegent TECHNOLOGIES ltd

Find that which is hidden



iEEE as a grad student

- PhD student in EE: Systems (control theory/pure math focus)
  - 2008-09: focused on semi-autonomous vehicle project, took courses in control theory and math.
  - 2009-13: worked on multi-energy systems, optimal EV charging, model predictive control (MPC)
- Last 18 months of PhD (2011-13): "*We need someone who can do optimization with PWL models*"
  - Deployed algorithms on UChicago energy plant ($40M budget): audit showed **$150,000 savings in 3 months!**

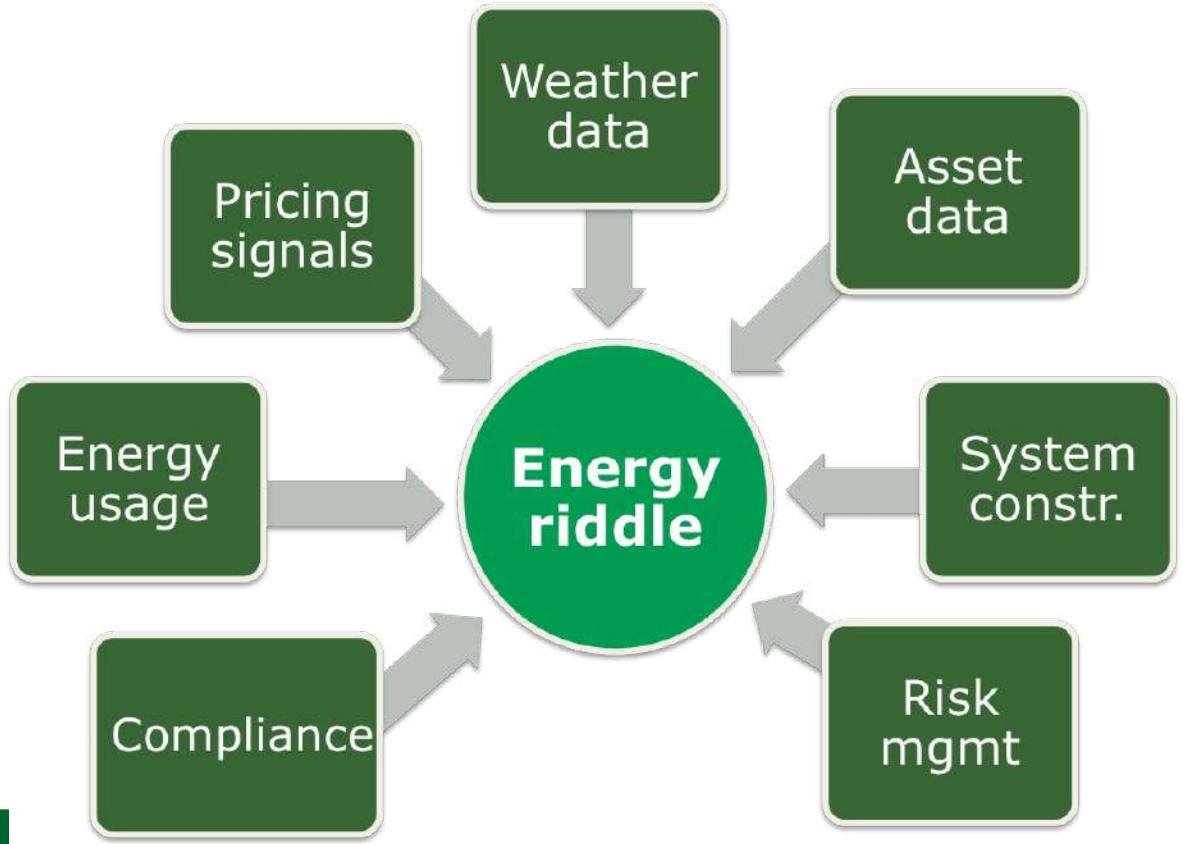
ROOT3

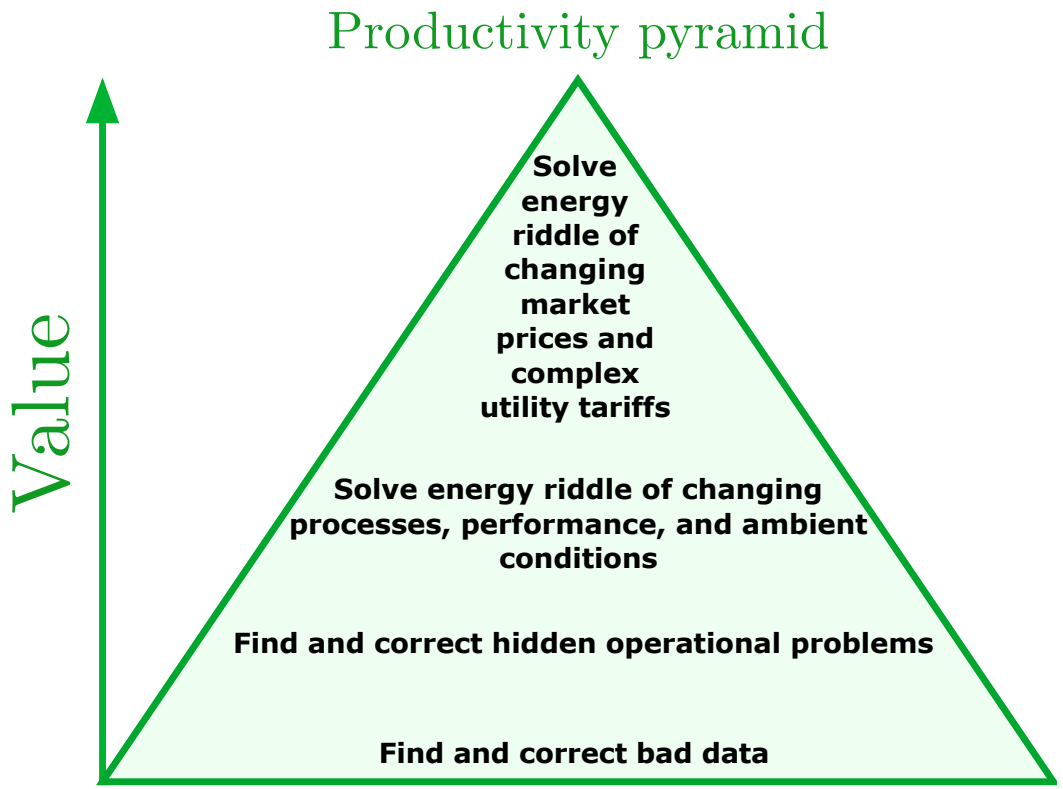
- *Multi-energy modeling*
- *Predictive optimization*
- *Adapt unit commitment*

+ economic dispatch concepts

iEEE as an entrepreneur

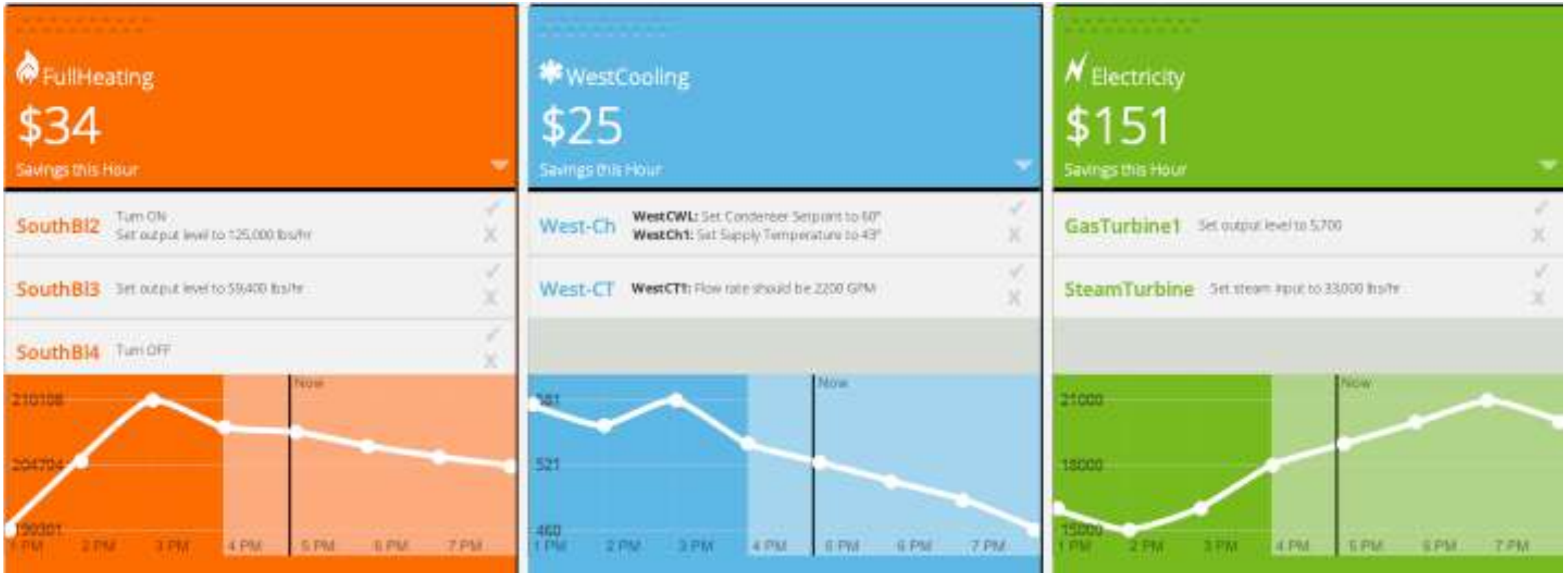
- After successful pilot, Root3 raised $1M seed round from VCs in CA, MI, and IL
  - Joined Root3 after turning down multiple post-doc offers from great people in great places.





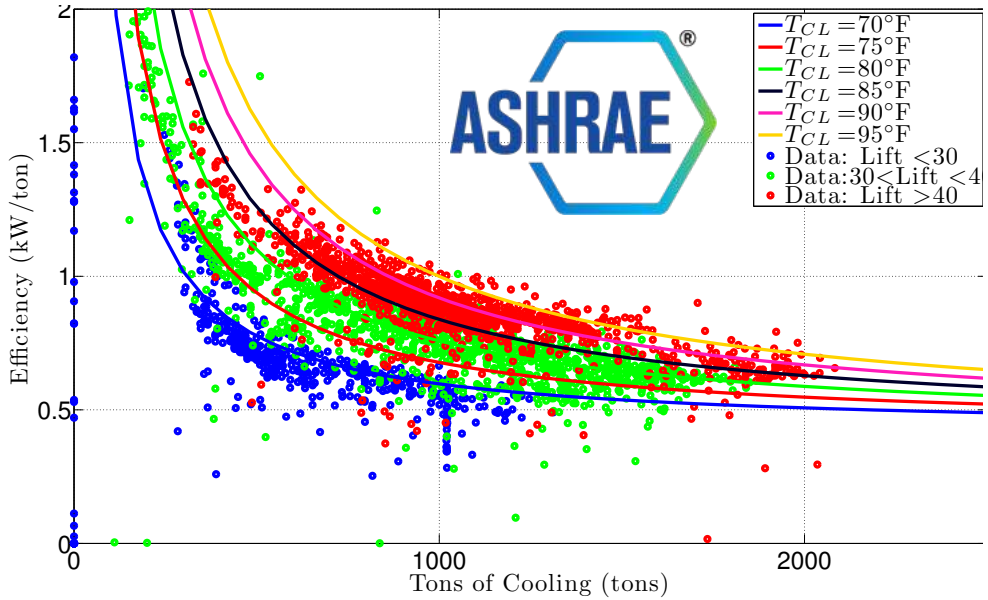
iEEE as an entrepreneur

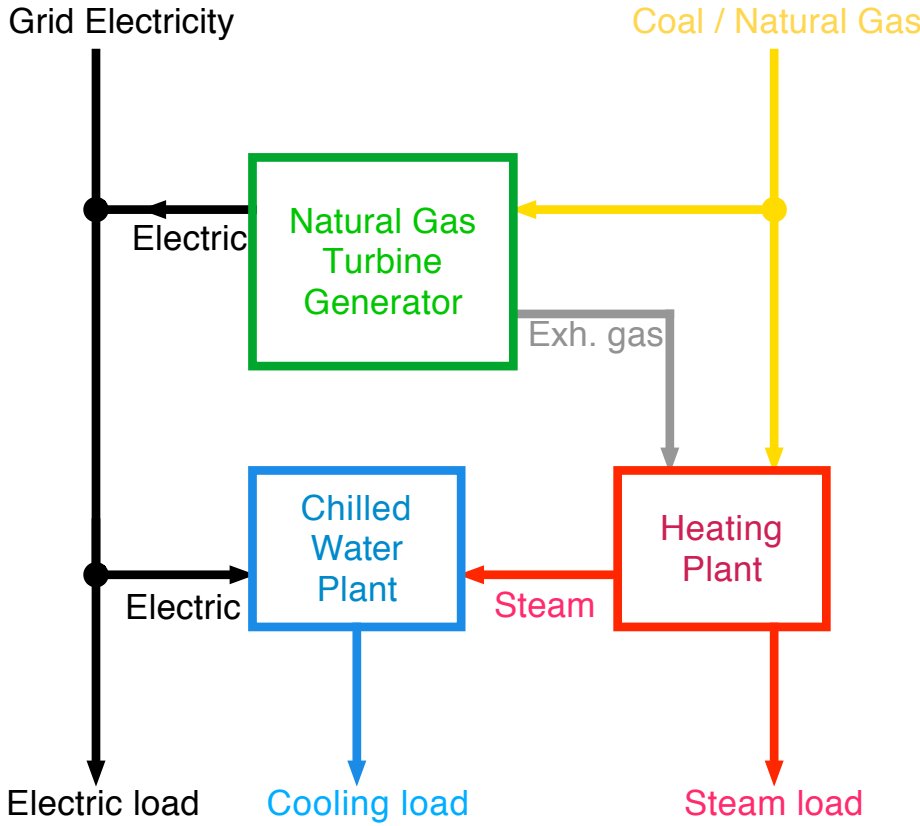
- Focused on optimization, data science, and software UI/UX
- Economic dispatch/unit commitment for C&I energy plants ➔ chillers, boilers, CHPs, TES.



iEEE as an entrepreneur

- Focused on optimization, data analysis (data science!), and software UI/UX work





Each customer became a research project➔ **not** scalable
We needed to stop and re-think approach ➔ **no time.**

2014: Received an offer to join UVM as TT faculty

Interdisciplinary group: energy & autonomy

Objective: sustain and strengthen UVM's research impact in the area of understanding, controlling, and optimizing sustainable, resilient, and autonomous systems and networks by leveraging a group of diverse, interdisciplinary, and research-active faculty.

Mads R. Almassalkhi
(Founding Director)

Jeff Frolik

Amrit Pandey

Bindu Panikkar

Hamid Ossareh

James Bagrow

Luis D. Espinosa

Jeff Marshall

Sam Chevalier
(Starts Aug 2023)

Broad expertise

- Power/energy
- Grid modeling
- Optimization
- Control theory
- Network science
- IoT/Comms
- Data science
- Machine learning
- Energy equity/justice

Impactful R&D with industry & research partners

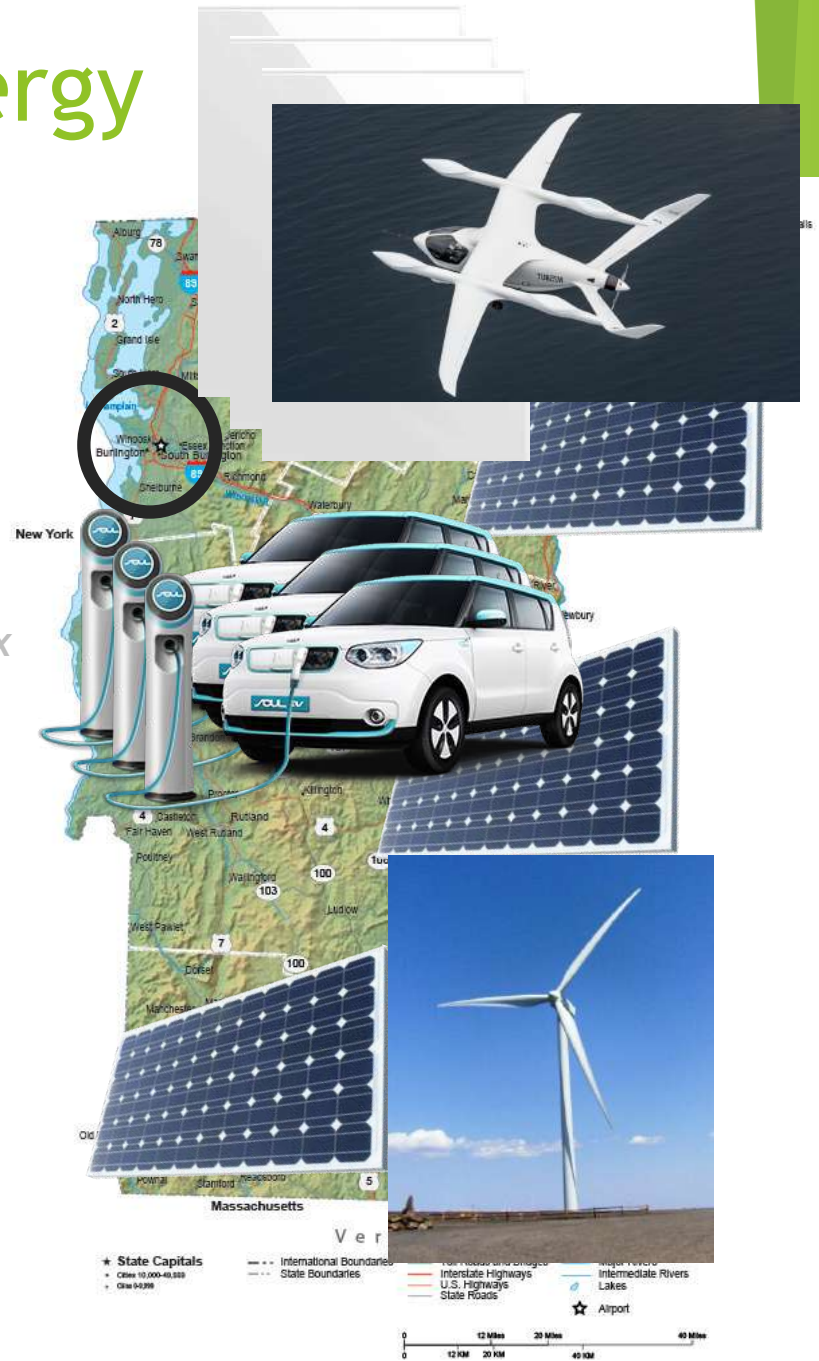
Recent and ongoing industry-supported projects with

Recent and ongoing funding partners

Vermont is an exciting platform for energy

- ✓ Population: 650,000 people with a peak load of ca. 1GW
  - *AMI deployed at >95% of customers in State*
    Vermont Renewable Portfolio Standard (RPS): 75% by 2032
- ✓ Small state ➔ easy to collaborate, create change, have impact
- ✓ Close partnerships with nationally-recognized innovative industry
  - *VELCO, GMP, BED, VEIC, Dynapower, Vermont Gas, Beta Technologies, etc.*

- ✓ Outstanding interdisciplinary collaborations at UVM with *Engineering*, *Complex Systems Center* and *Gund Institute for Environment*
- ✓ **VT is #2 state in U.S. for Clean Energy Momentum** (UofCS, 2017)
  - 5.4% of workforce is clean energy economy (#1 in 2021)
    - *Next largest are at ~3%*
  - 99.9% of VT *generation* is renewable (#1 in US in 2019)
    - 66% of consumed electricity is renewable (2019)
  - 15% of electricity from solar PV (#4 in US in 2020; #6 per capita)
  - 5.4% of new cars sold are EVs in 2021 (VT was #9 in 2018)
  - VT predicted to become net exporter on sunny days in 2032.

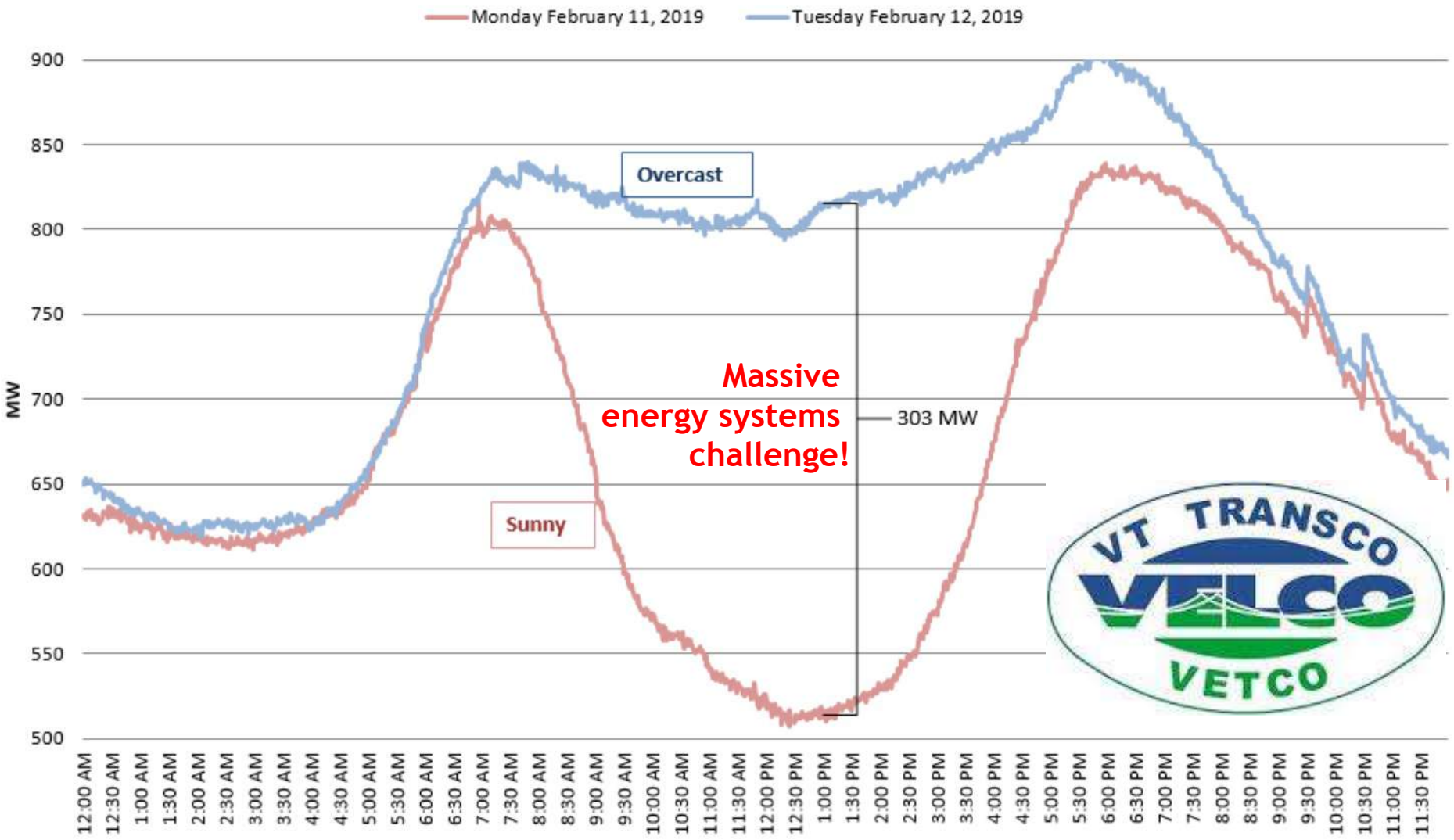


Vermont is *America's living energy laboratory™*

First U.S. efficiency utility (2000)

First U.S. utility to be 100% renewable (2014)

#1 in 2018 (Energy)
#5 in 2019 (Energy)



Going back in time… 2015

FUNDING OPPORTUNITY ANNOUNCEMENT

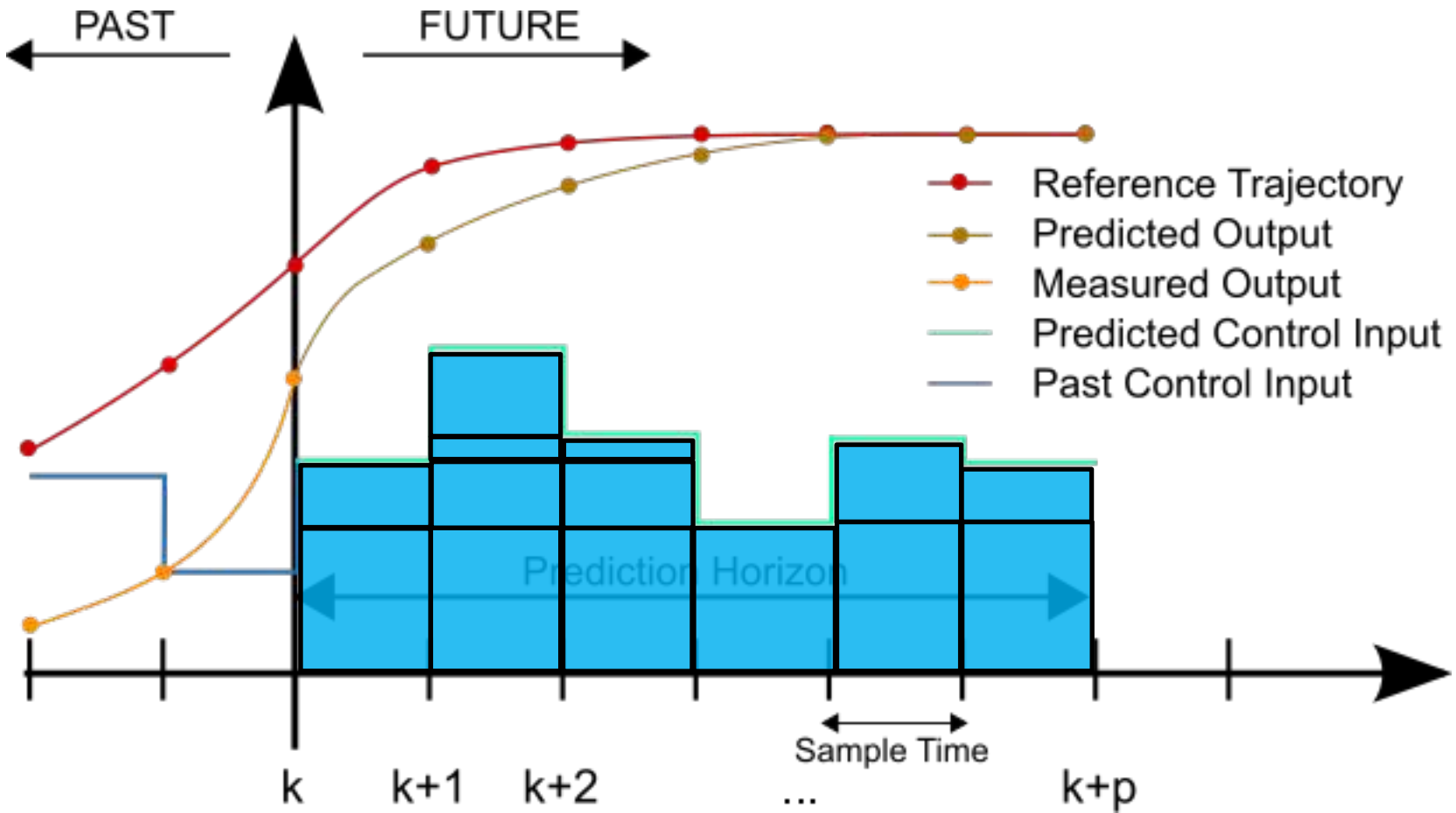
ADVANCED RESEARCH PROJECTS AGENCY – ENERGY (ARPA-E)
U.S. DEPARTMENT OF ENERGY

NETWORK OPTIMIZED DISTRIBUTED ENERGY SYSTEMS (NODES)

Inspiration: predictive control is discrete

Finding the optimal trajectory can be easy (e.g., convex optimization)

Optimally allocating distributed assets to match trajectory in realtime is NP-hard!



arpa·e
CHANGING WHAT'S POSSIBLE

Network Optimized Distributed Energy Systems (NODES)

PROJECT DESCRIPTIONS

University of Vermont – Burlington, VT

Packetized Energy Management: Coordinating Transmission and Distribution - $1,537,904

The University of Vermont (UVM) will develop and test a new approach for demand-side management called packetized energy management (PEM) that builds on approaches used to manage data in communication networks without centralized control and requires a high level of privacy. The PEM system will allow millions of small end-use devices to cooperatively balance energy supply and demand in real time without jeopardizing the reliability of the grid or the quality of service to consumers. The project will develop the PEM method to manage large, rapid fluctuations associated with renewable power generation, while simultaneously ensuring grid reliability. To ensure UVM's PEM method, the integrated system will undergo extensive simulation testing with large-scale hardware implementation for the bulk power grid and in industry-scale, micro-grid environments.

University of California: San Diego – La Jolla, CA

Distributed Grid Control of Flexible Loads and DERs for Optimized Provision of Synthetic Regulating Reserves - $2,338,485

The University of California, San Diego (UCSD) will develop coordination algorithms and software using intelligent control and optimization for flexible load and DERs to provide reliable frequency regulation services for the bulk power grid. The project will develop a multi-layer framework for larger-scale energy aggregators to act on behalf of their smaller-sized customers to help respond to incoming requests from regional transmission operators. The team will develop approaches that aggregators can use to quantify reserves, system objectives and constraints, customer usage patterns, and generation forecasts. Aggregators will use distributed coordination algorithms to rapidly respond
services for customers. The UCSD's techr
operational advantages for utilities, operat

Arizona State University – Tempe, AZ

Stochastic Optimal Power Flow for Real-Demand Response - $3,000,000

Arizona State University (ASU) will develop
framework, which would integrate uncertaint
response technologies into bulk power syst
SOPF software tool to provide system opera

These projects have been selected for negotiation of

arpa·e

demand response. ASU's project features
solar generation and an advisory tool that ge
algorithm outputs.

Stanford University – Stanford, CA

gtm.
A Wood Mackenzie Business

SOLAR
GRID EDGE
ETC.
Videos
The Energy Gang
Webinars
White Papers
About

UVM Receives $1.5 Million Grant from Department of Energy to Help Grid Accommodate Renewables

12-16-2015
By University Communications

The Stafford Solar Hill Farm, a green mountain power facility in Rutland, Vermont. (Photo: Eric Hudiburg)

An innovative project developed at t
Vermont has received a $1.5 million
U.S. Department of Energy's Advanc
Projects Agency-Energy (ARPA-E) for
at making the electric grid better ab
accommodate power generated fro
energy sources. The grant, one of or
nationally, is part of ARPA-E's newes
Network Optimized Distributed Ene
NODES. The title of the project is "Pa
management: coordinating transmis

distribution."

- The University of Vermont won $1.54 million to develop and test a new approach for demand-side management, called Packetized Energy Management, based on approaches used to manage data in communication networks that lack centralized control, but also need high levels of privacy. (That's similar to the architecture being developed by Duke Energy and other partners in support of a new standard for distributed grid communications known as Open Field Message Bus, or OpenFMB, by the way.)
- The University of California, San Diego won $2.34 million to develop coordination algorithms and software meant to allow DERs and end loads to serve frequency regulation s
plants and l
similar appr
flexible ene
- Arizona Sta
manage sto
flow models
unpredictab

Utility DIVE TOPICS FEATURES

Packets of innovation

One interesting DER project funded as part of NODES is a $1.54 million grant to the University of Vermont (UVM) that will test Packetized Energy Management (PEM).

The project "builds on approaches used to manage data in communication networks without centralized control," ARPA-E explained, and aims to aggregate "millions of sma
fluctuations from the incre

In Vermont, Green Mounta
its distribution grid, said M

Weather Sports Wildlife Watch VT Realty Livestream

BURLINGTON, Vt. (WCAX) Water heaters may not be something people often think about, but the team at a local company wants to be on the one to revolutionize how they work.

"A conventional water heater basically heats up in big, bulky 20-minute chunks," said Mads Almassalkhi, the co-founder of Packetized Energy.

Almassalkhi says that happens even when someone isn't home or and when it's not being used. And when a water heater decides it's time to heat up may not be the best time for the electric grid we all use.

"The notion of peaks happening in the afternoon is really becoming and old story and that's not really true anymore," said Almassalkhi. "Peaks are happening whenever the sun doesn't shine or the wind doesn't blow."

Green Mountain Power representatives say when people are using a lot of energy during those peak times, the electric utility must turn to generators that are more costly to operate and use the dirtiest fuels.

Almassalkhi says he wants to stop that.

His product is called the Mello. It sits right on top of a water heater and is smart enough to know when it's a bad time on the grid to ask for a big chunk of electricity.

VPR Vermont's NPR News Source
Listen Live · VPR
Vermont Edition

Home Listen VPR News Vermont Edition VPR Classical Programs Support Inside VPR Search

Software Teaches Your Basement Water Heater To 'Store' Renewable Energy

By KATHLEEN MASTERSON • AUG 30, 2016

Most large energy appliances can be packetized

Water Heaters

The Mello smart thermostat

EV Chargers

Packetized Webasto Level 2 EV charging system

HVAC Thermostats

Heat Pumps (mini splits)

Refrigeration

Grid Edge Batteries

Pool Pumps

Irrigation Pumps

PV Inverters

Advantages inherent to PEM

Set it and forget it

Smart design makes our software easy to use for both end users and utilities

Scalability

Built on ideas that run the Internet, our solutions increase in value as they scale

Consumer comfort

Device-driven solutions enable flexibility without impacting customer comfort

Privacy & security

Bottom-up design minimizes data collection and reduces security threats

Initial momentum

2013-2015

IP DEVELOPMENT

Initial R&D, first patent disclosure applied to EVs

2016

TECH ADVANCEMENT

$2M ARPA-E project, company founded, second patent disclosure, awarded first pilot

2017

CUSTOMER ADOPTION

Launched 2 new projects, UL listed smart device for water heaters, new DOE and NSF grants awarded

2018

COMMERCIAL VALIDATION & PARTNERSHIPS

Launching new projects in CA, new OEM partnerships, system deployment

2019

SCALING

Proving value, sales, moving from demonstration projects to full-scale deployment

CB INSIGHTS "Game changing startups of 2019"

GREEN MOUNTAIN POWER

PG&E

VERMONT ELECTRIC CO-OP

ENPHASE

RHA delivering solutions

Webasto Feel the Drive

arpa·e CHANGING WHAT'S POSSIBLE

BURLINGTON Electric DEPARTMENT

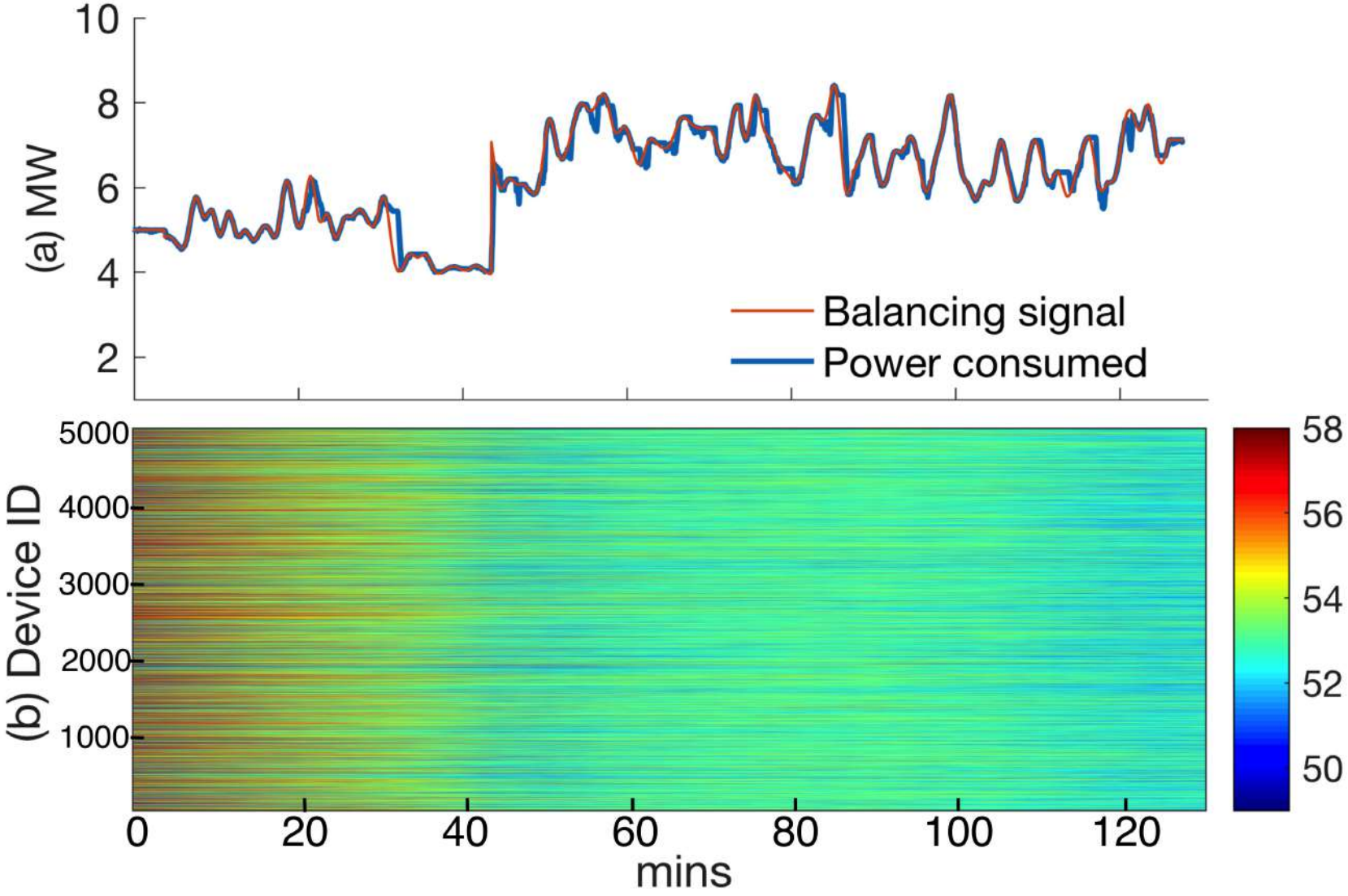
SLAC

U.S. DEPARTMENT OF ENERGY

NSF America's SEED FUND SBIR.STTR

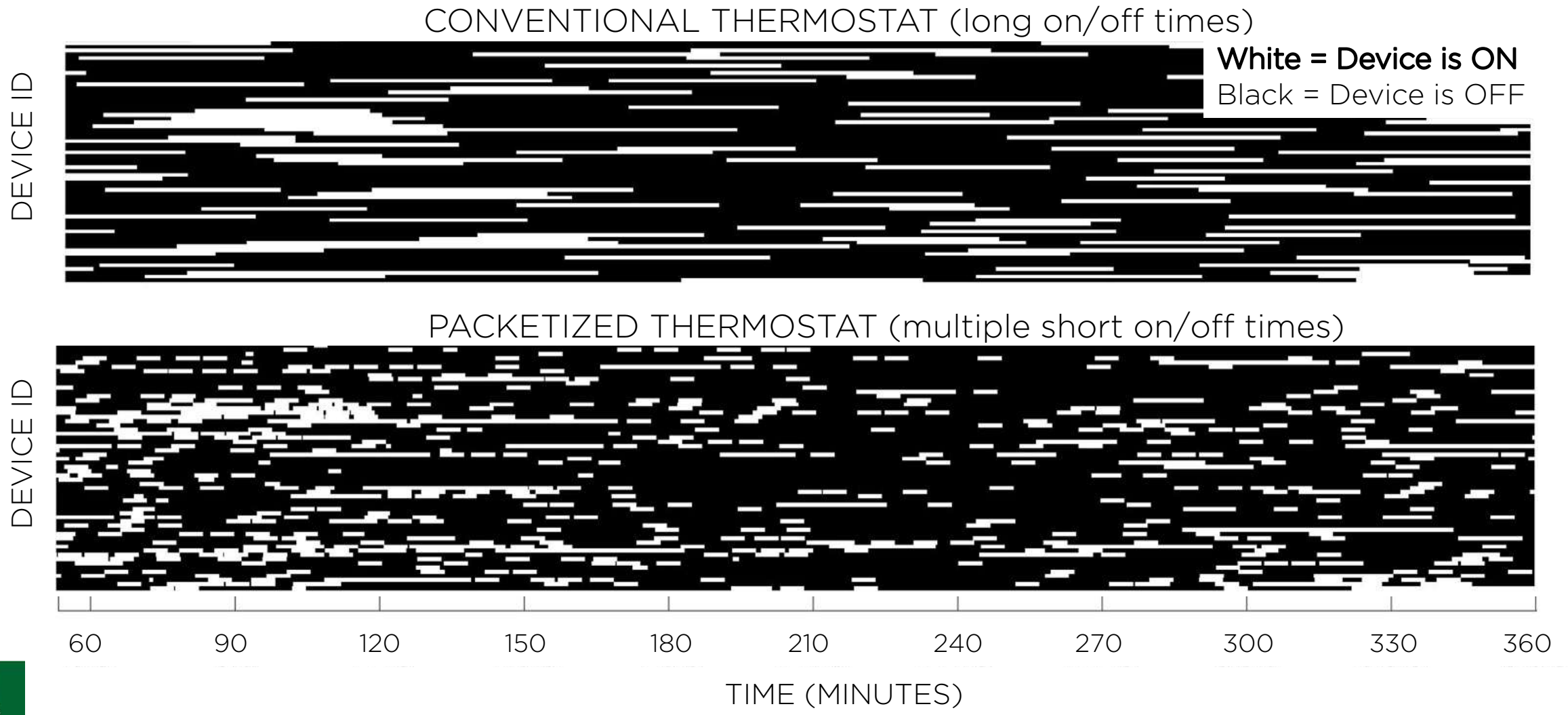
npr

Tracking a time-varying signal (real-time comms)

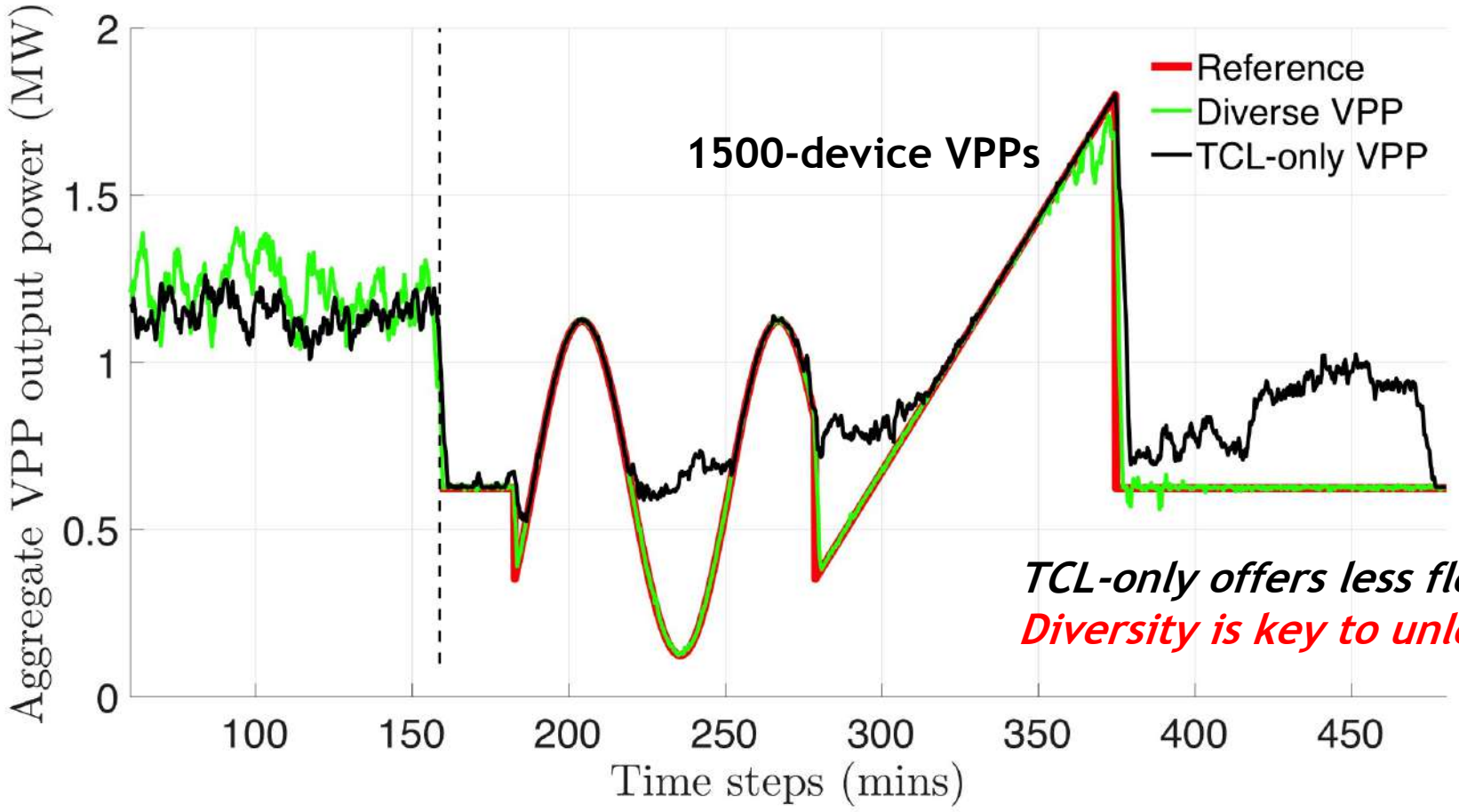


Desrochers, Khurram, et al., *Real-world, Full-scale Validation of Power Balancing Services from Packetized Virtual Batteries*, IEEE ISGT, 2019

Traditional vs. Packetized



Comparing : diversity increases flexibility

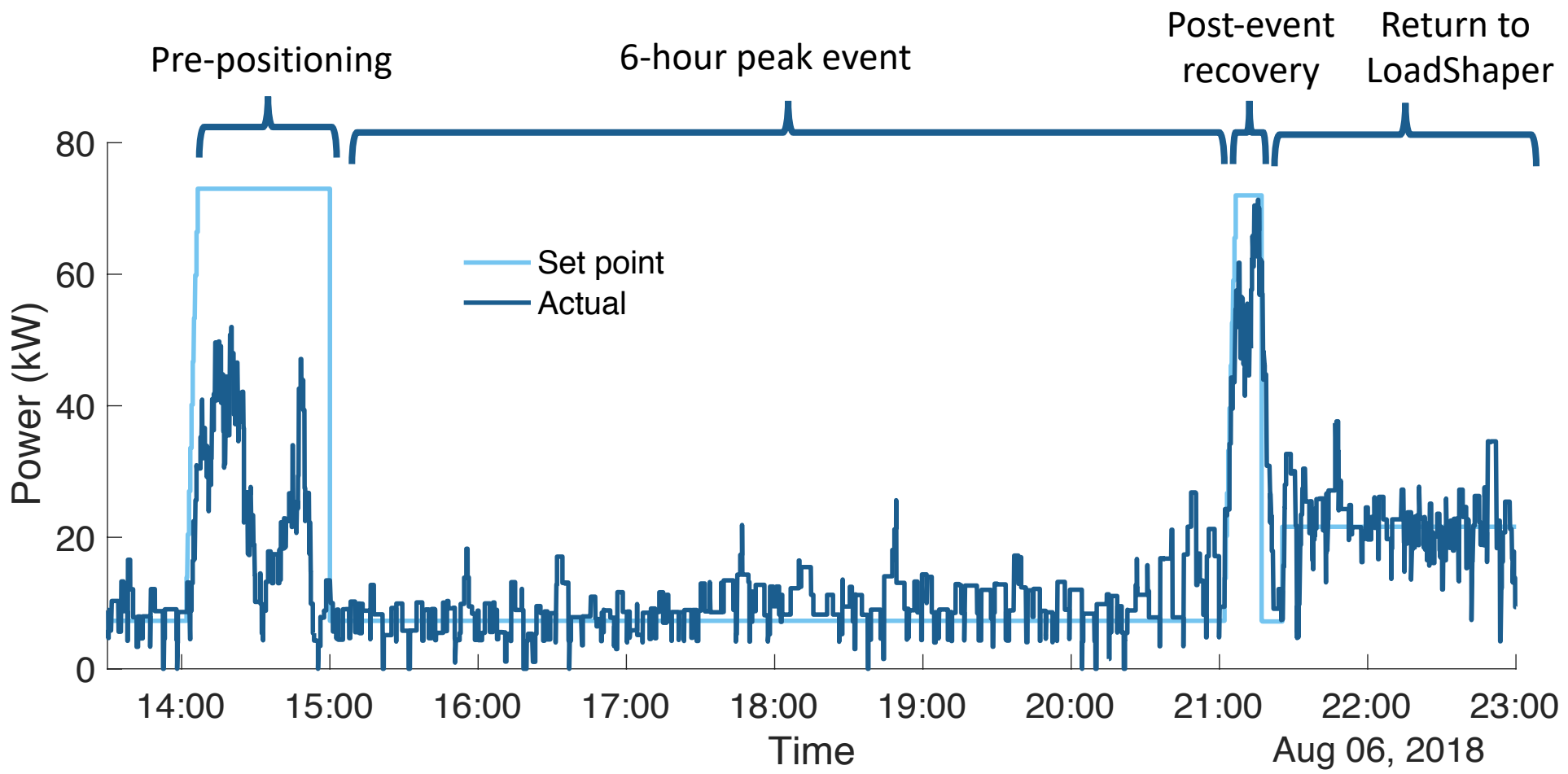


TCL-only offers less flexibility!

Diversity is key to unlock VPP flexibility!

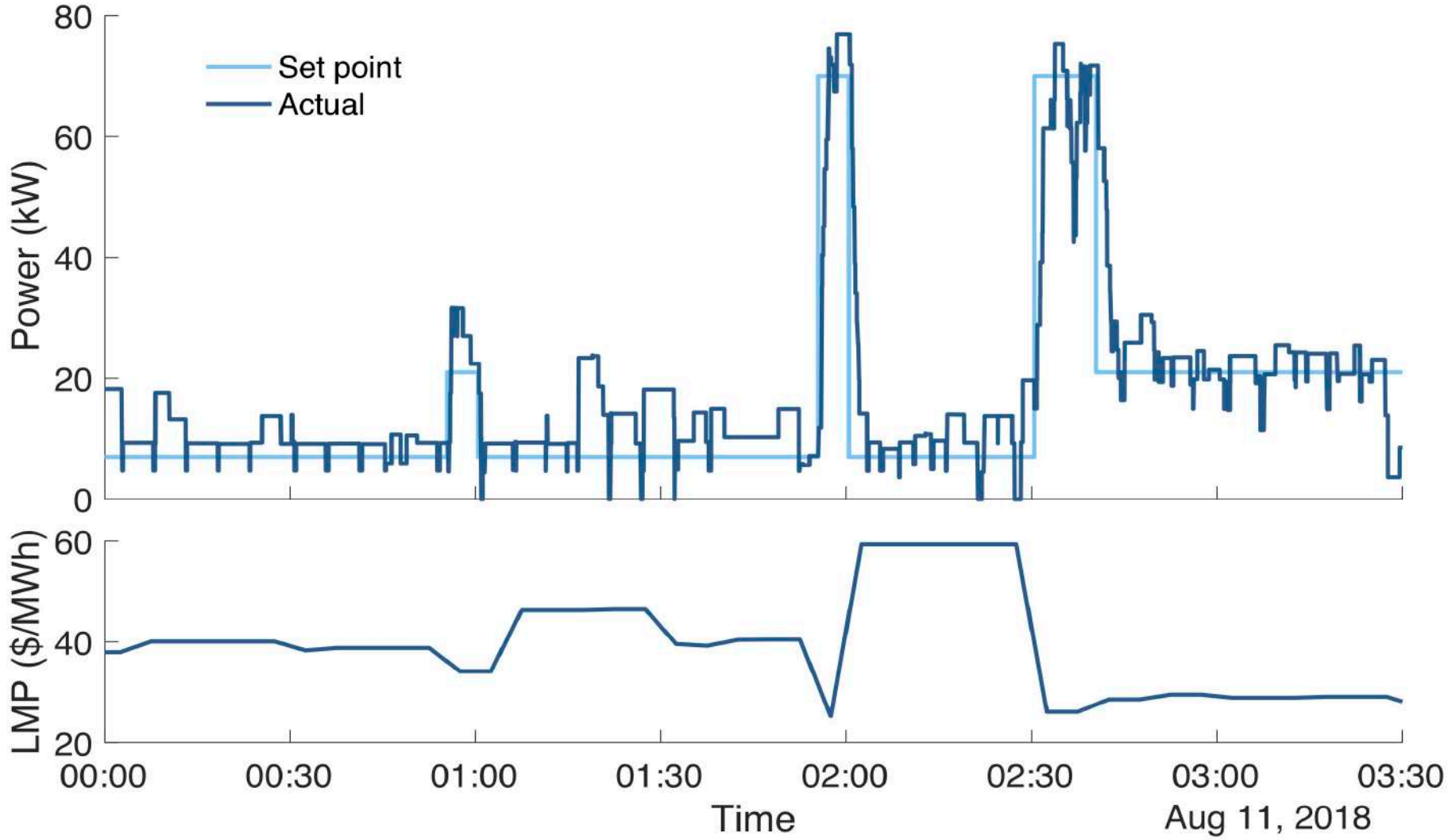
Almassalkhi M., Espinosa L.D., et al. (2018) *Asynchronous Coordination of Distributed Energy Resources with Packetized Energy Management*. In: Meyn S., Samad T., Hiskens I., Stoustrup J. (eds) Energy Markets and Responsive Grids. The IMA Volumes in Mathematics and its Applications, vol 162. Springer, New York, NY

Also in the real world (crushing peaks)



ABOUT 60 WATER HEATERS, VERMONT ELETRIC CO-OP (raw kW data)

Also in the real world (arbitraging)



ABOUT 60 WATER HEATERS, VERMONT ELETRIC CO-OP (raw kW data)

”I cannot imagine that I find this ‘smart grid’ interesting at all.”

Mads Almassalkhi
April, 2009