U.S. DEPARTMENT OF ENERGY

unifi consortium

universal interoperability for grid-forming inverters

UNIFI Consortium Overview

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UNIFI Organizational Director

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UNIFI is pronounced the same as unify

unifi consortium

universal interoperability for grid-forming inverters

Future power systems with any mix of machines and IBRs at any scale that are affordable, secure, reliable, clean, and resilient

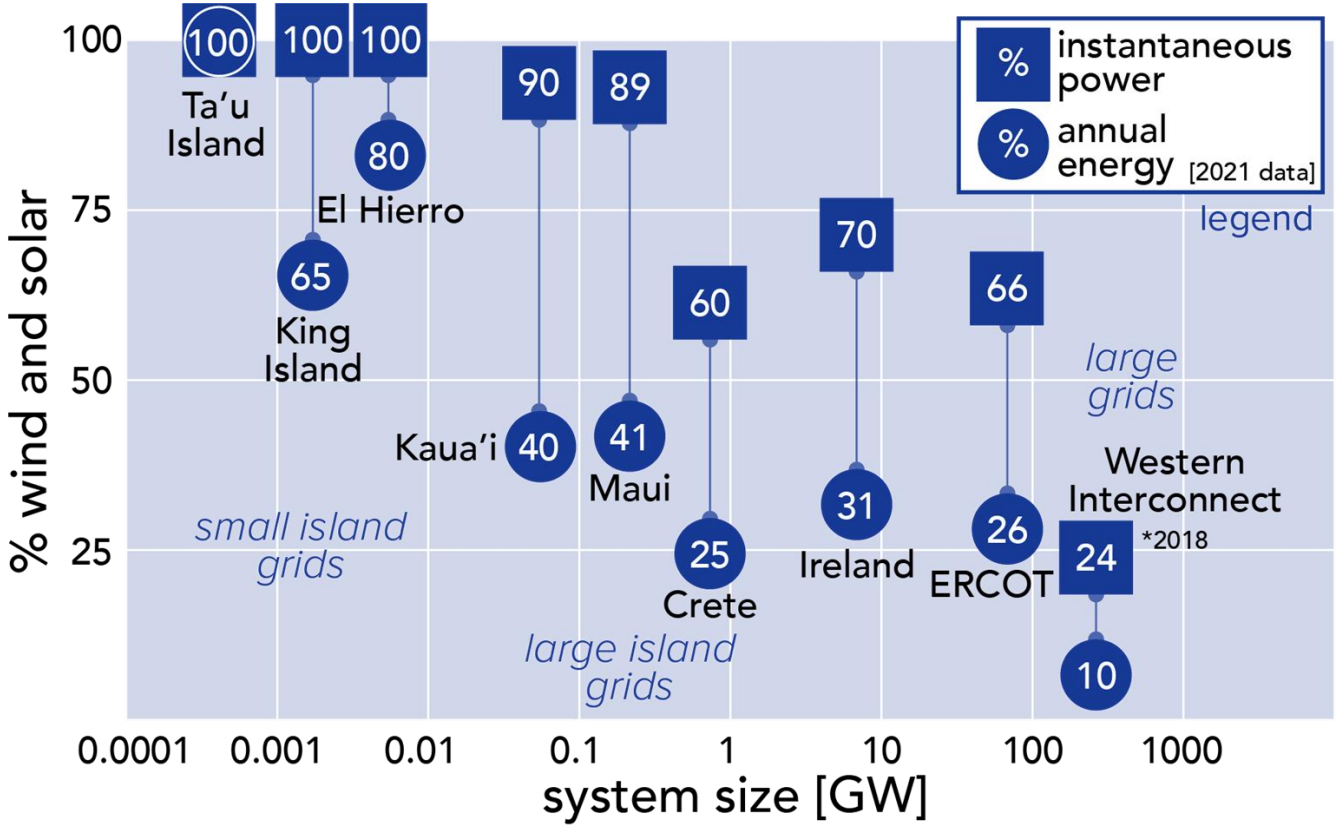
Vision

Forum to address fundamental challenges in seamless integration of grid-forming (GFM) technologies into power systems of the future

Purpose

Conduct research and development, demo concepts at scale, author best practices and standards, train next-generation workforce

Goal



IBRs = inverter-based resources

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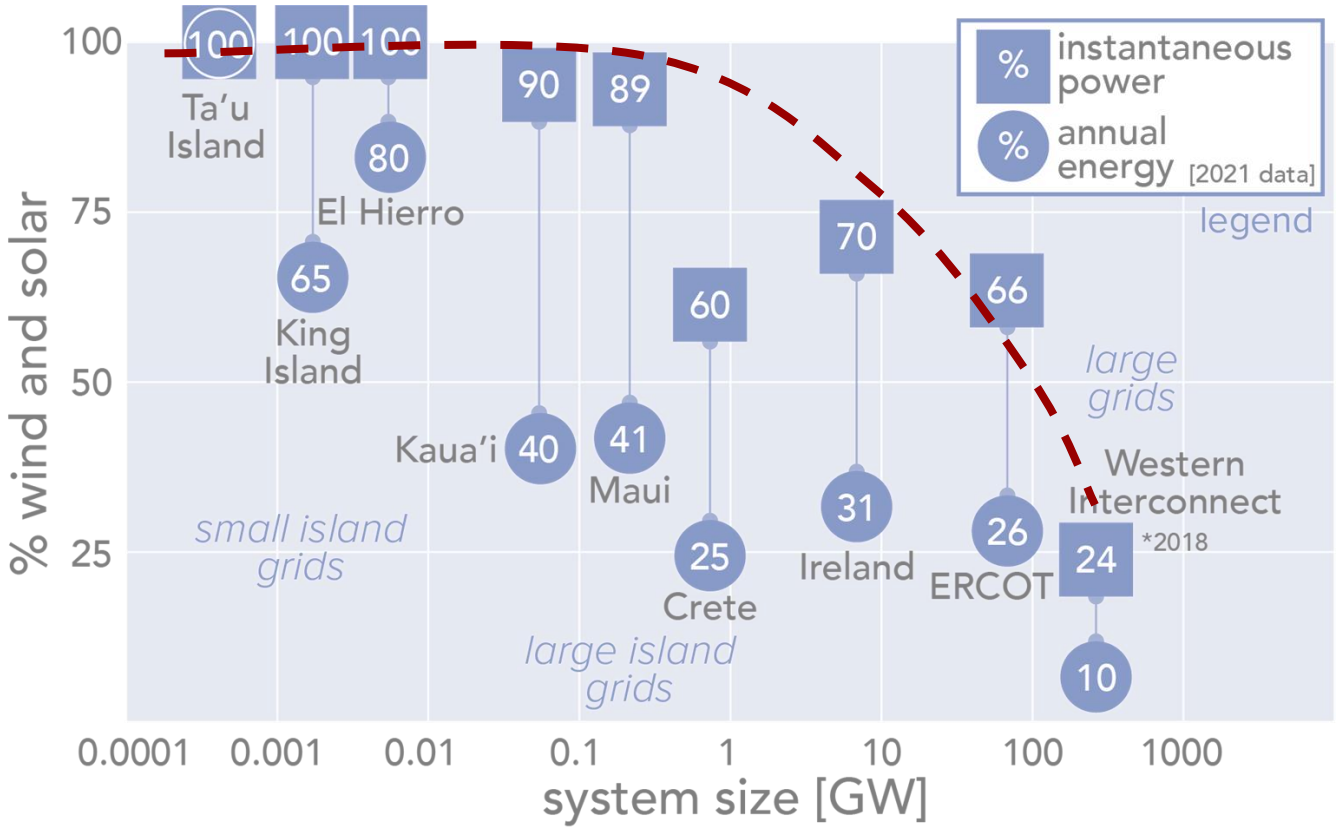

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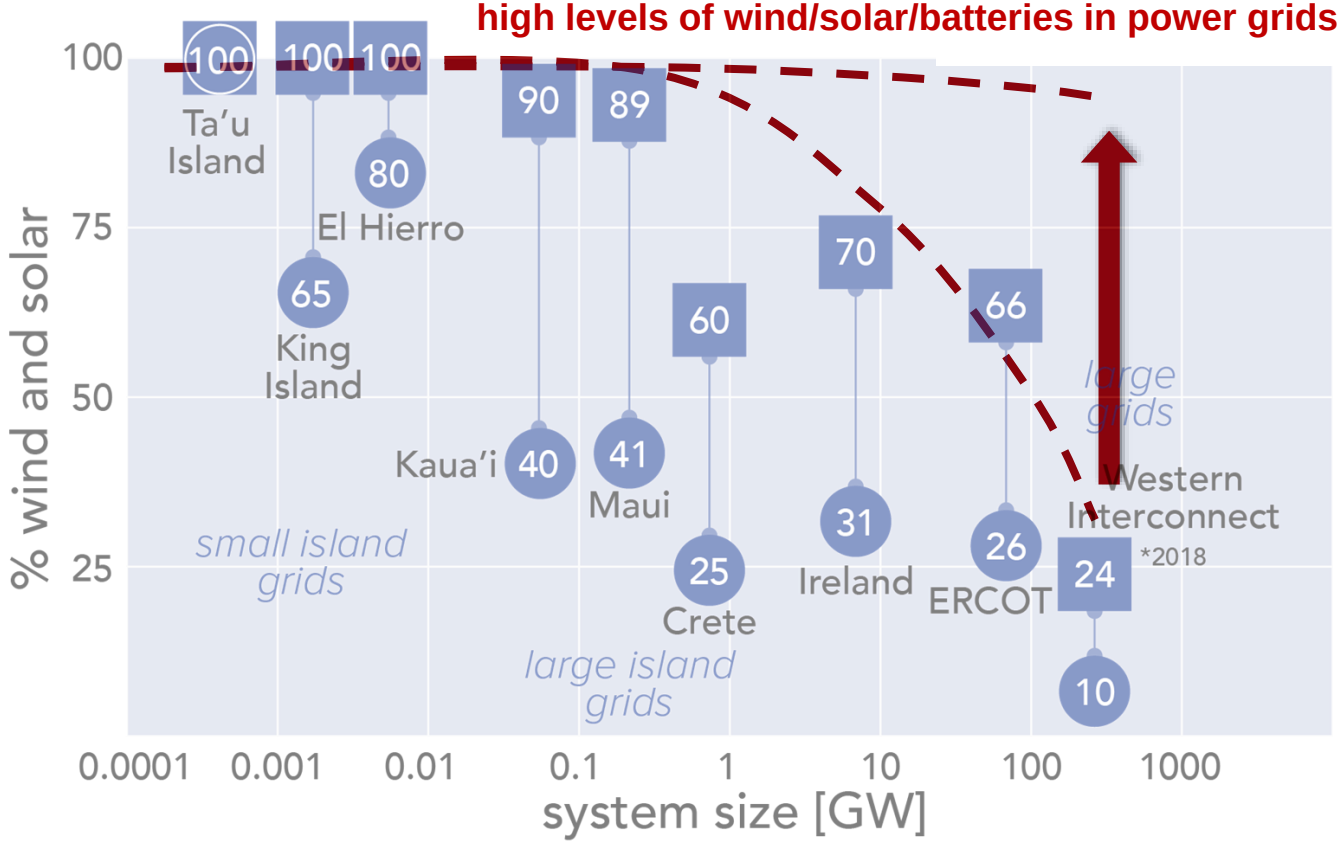
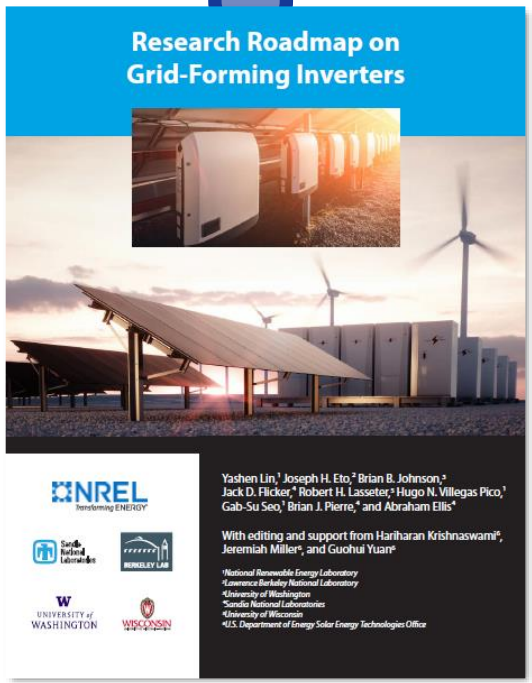
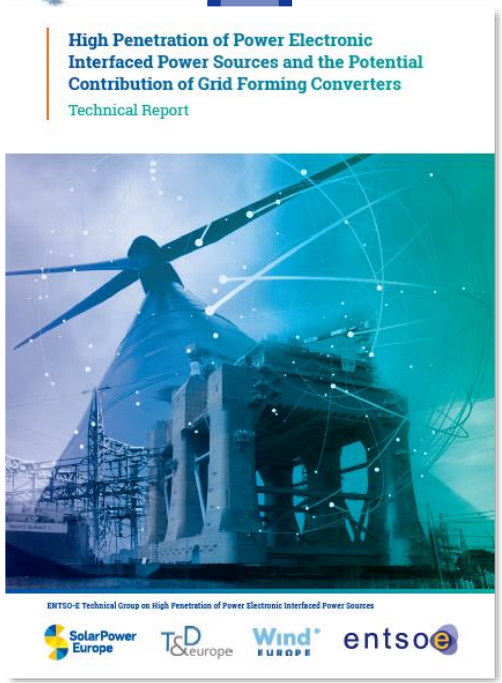
The most critical problem to solve to enable very high levels of wind/solar/batteries in power grids

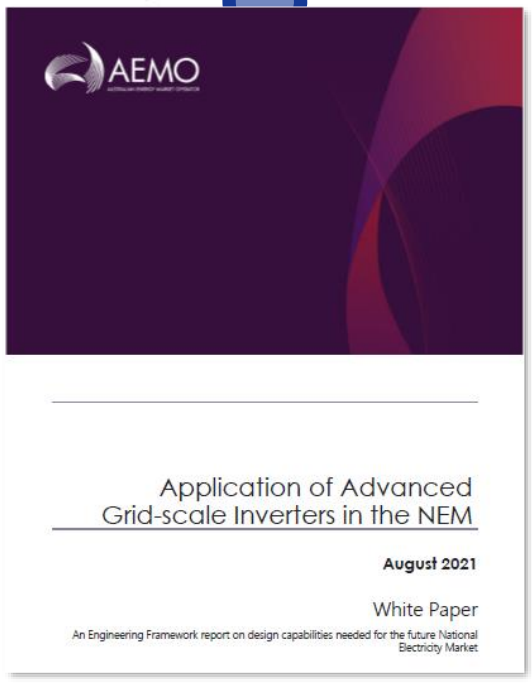


Global Landscape

Grid codes and roadmaps around the world recognize the role of grid-forming (GFM) inverter-based resources (IBRs)







Challenges

- Poor definitions of capability and functionality across technologies; lack of standardization
- Limited-to-no consensus on expected performance from unit and system levels
- Vendors/Manufacturers and Utilities/Operators appear to be locked in circular death spirals

Solutions

- Standardize Requirements
- Validate through models, controls, testing, demonstrations at scale
- Educate the industry

What is UNIFI ?

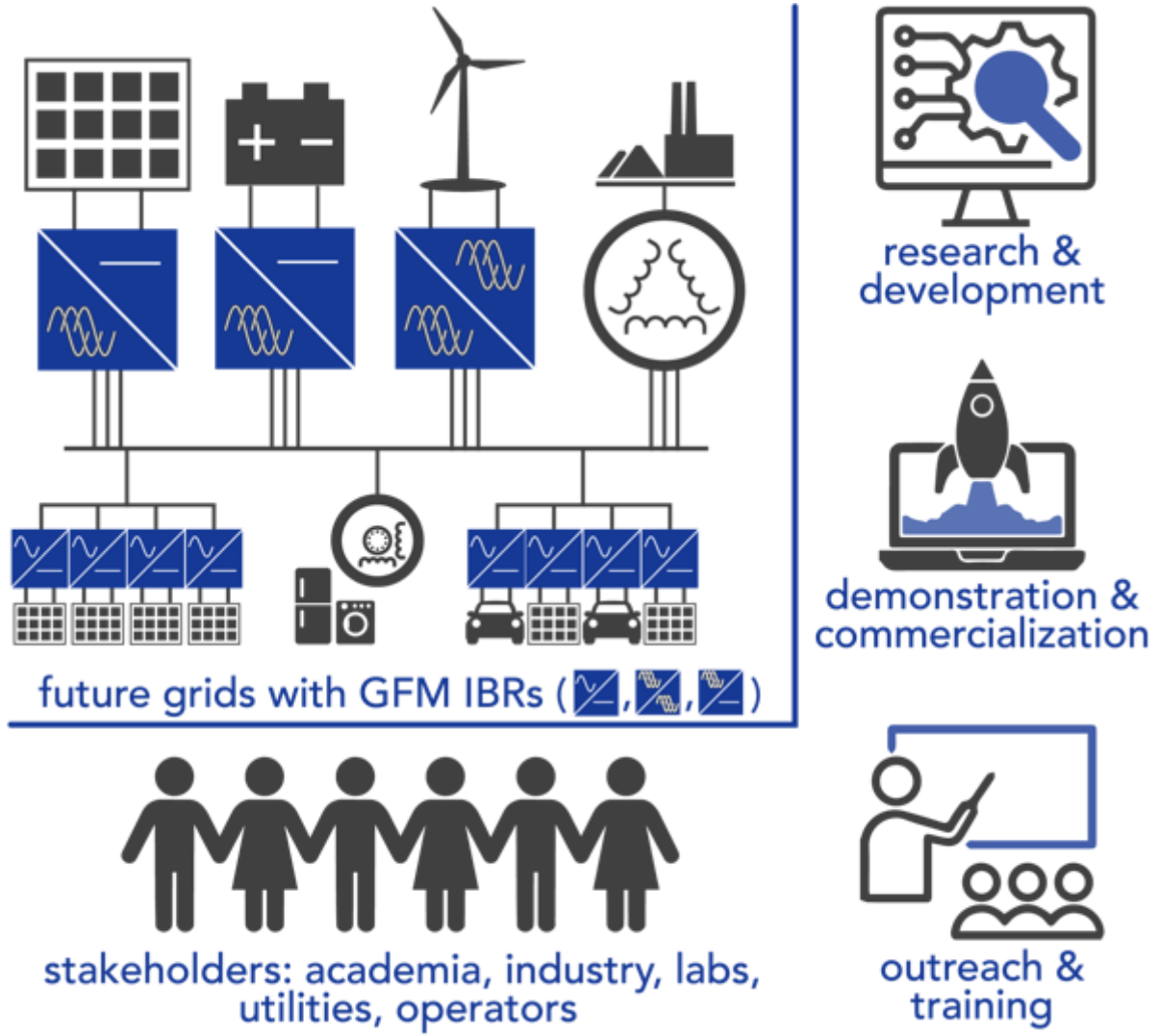
The **UNIFI Consortium** is a forum to address fundamental challenges in the seamless integration of grid-forming (GFM) inverter-based resources (IBR) into power systems of the future.

Bringing the industry together to unify the integration and operation of inverter-based resources and synchronous machines

Three major focuses:

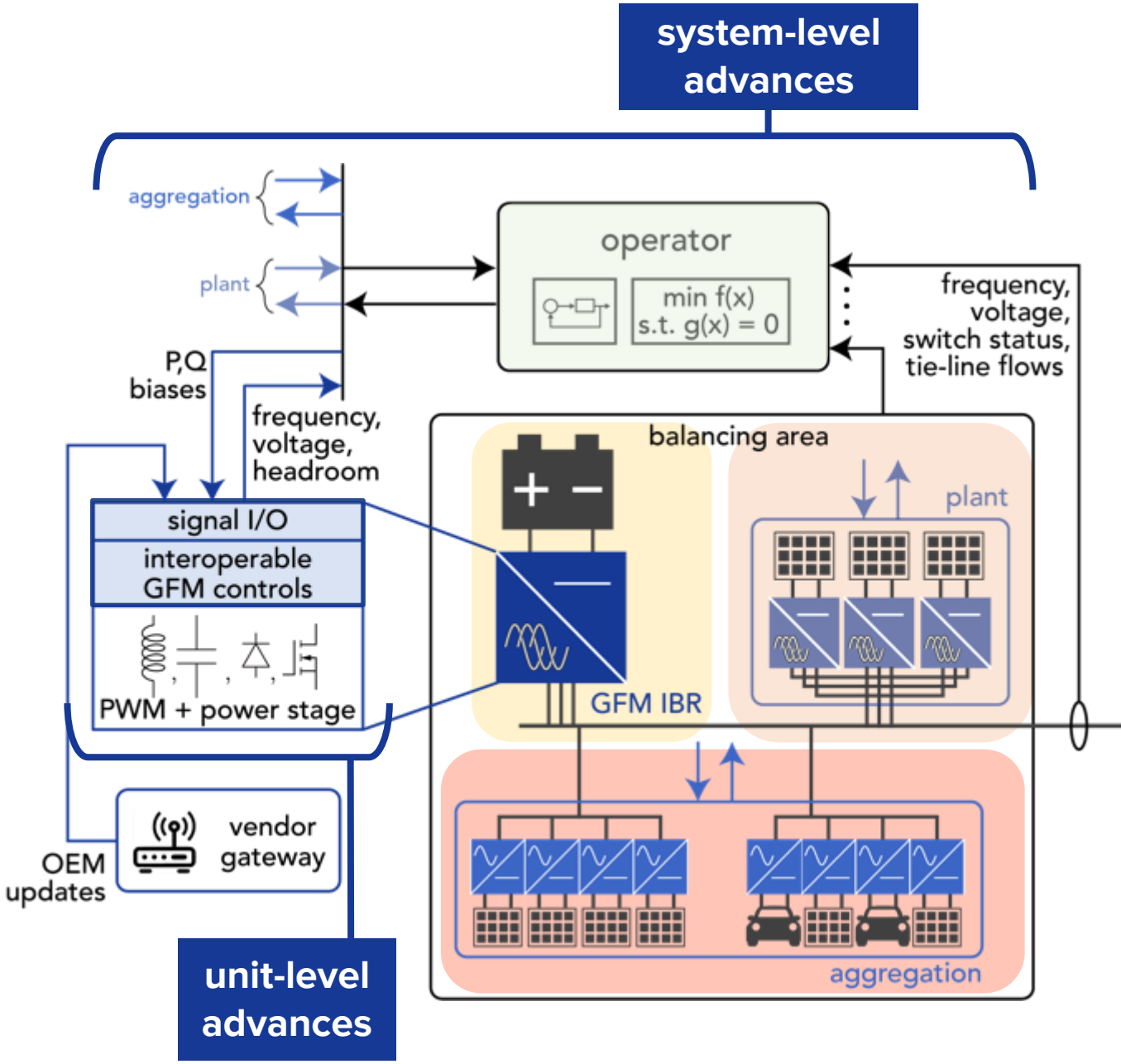
- Research & Development
- Demonstration & Commercialization
- Outreach & Training

DOE is funding a 5-year project – Started in January 2022. Idea is to create a sustainable organization through memberships.



Envisioned System Architecture

- GFM technologies: individual **GFM IBR**s, **plants** or **aggregations**
- GFM unit-level functionality includes vendor-specific proprietary controls aided by a middle-layer (labelled **interoperable GFM controls**) that translates system-level control objectives
- Exchange standardized signals through suitable interface (**signal I/O**) in a cyber-secure manner with the system operator to regulate frequency & voltages via secondary control, and manage operations (e.g., black-start)
- Distributed optimization and control algorithms within and across grid **balancing areas** may be required
- Will require both unit-level and system level advances



GFM = grid-forming inverter IBRs = inverter-based resources

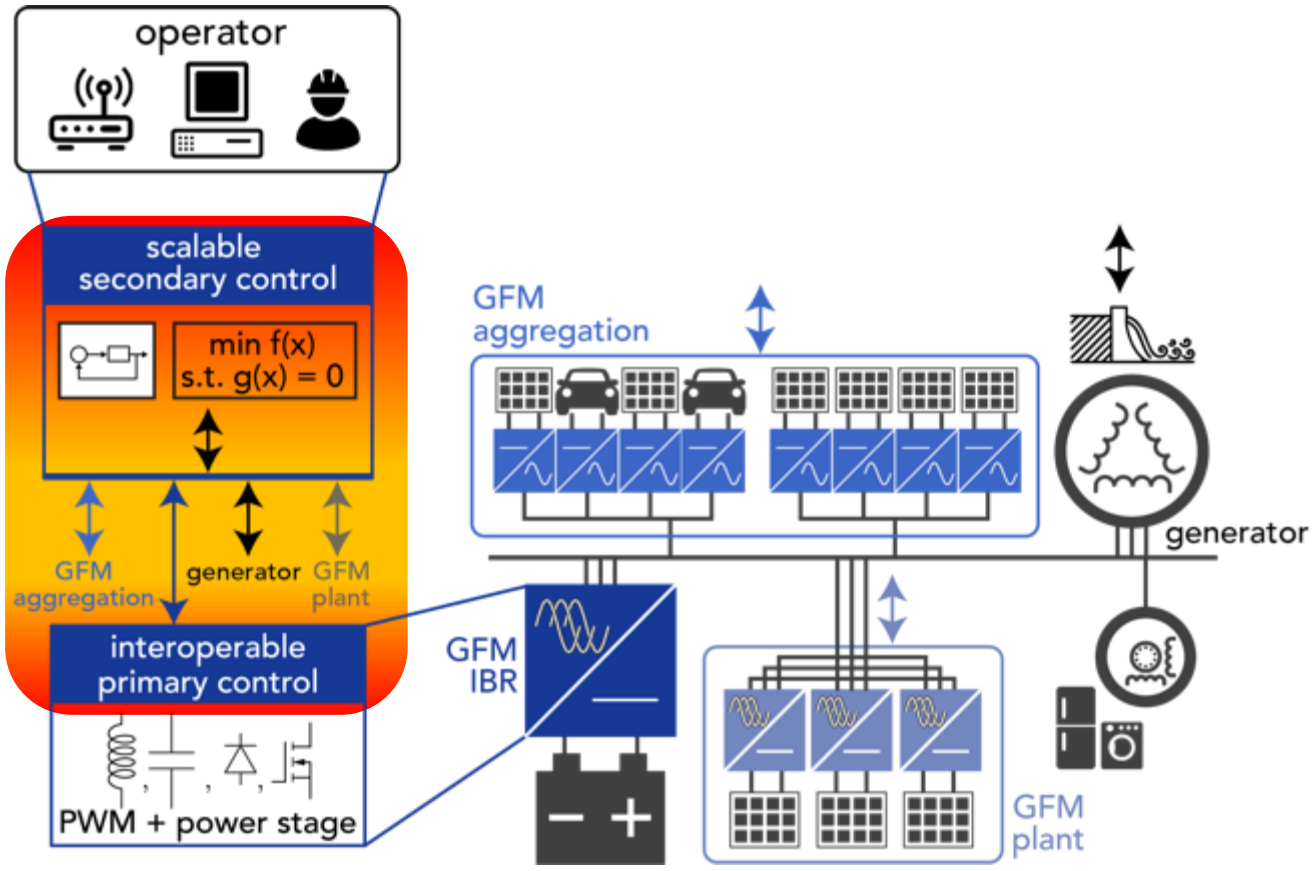
UNIFI Goals

Curate vendor- and technology-agnostic ***"UNIFI Specifications"*** that standardize performance and benchmark capabilities of GFM technologies across scales

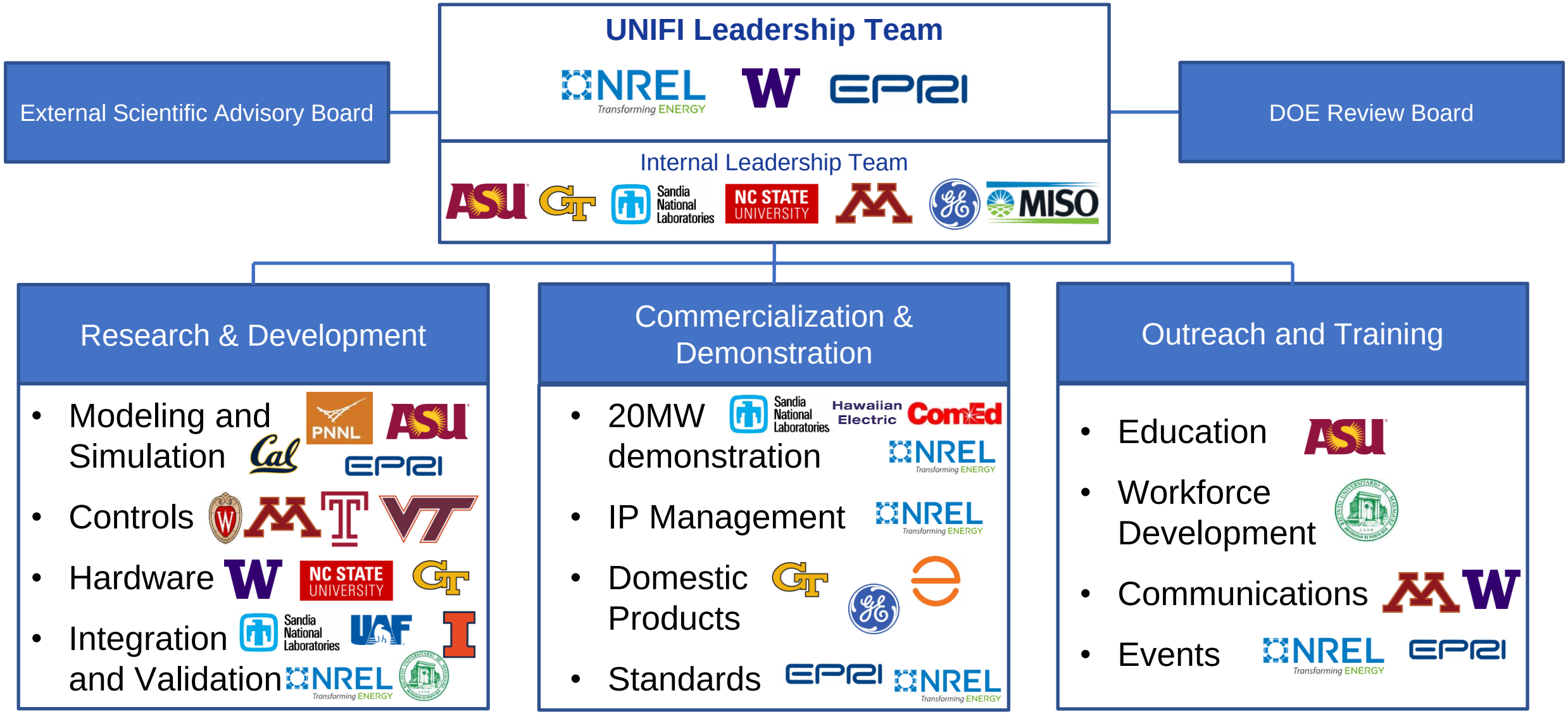
- ***System Level - Interoperability Guidelines*** *- that promote the coordinated and seamless operation of GFM technologies from multiple vendors while ensuring stable and reliable power grids*
- ***Inverter Level - Functional Requirements*** *– that define GFM-IBR capabilities which are specified in a vendor-agnostic fashion to satisfy all system-level interoperability guidelines*

Convene continuous collaboration between inverter manufacturers (on one end) and system operators and utilities (on the other) to bridge gaps between power-systems and power-electronics industries

Cultivate inclusive culture and leverage member cooperation for sustained innovation



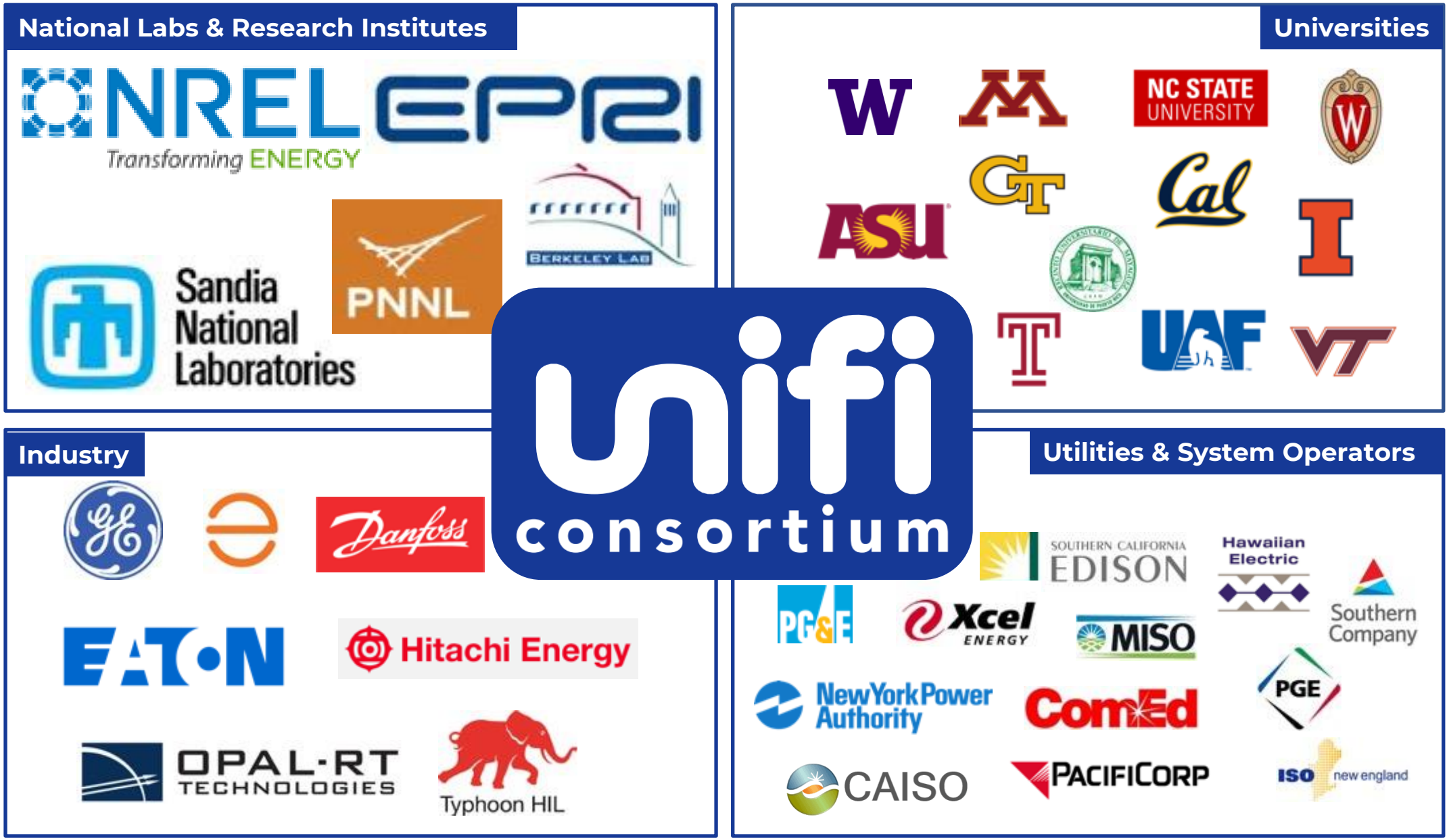
UNIFI Organizational Structure



UNIFI Working Groups (WG)

- UNIFI Specifications
  - Defining specifications and requirements for GFM
- Modeling and Simulation Area
  - GFM Model Development and Theoretical Innovations WG
  - Use Case, Software Testbed, and Interoperability
- Controls Area
  - Real-time Control and Dynamic Stability WG
  - Communication-coordinated Control and Cybersecurity WG
- Hardware Area
  - Open-source Code Development and Experiment Planning & Design WG
- Integration and Validation Area
  - Validation of UNIFI Specifications WG
  - 1MW Multi-vendor Experiment WG
- 20MW Demonstration Area
  - 20MW Demo Specifications WG
- Standards Area
  - Standards Coordination WG
- Education Area
  - Education WG
- Workforce Development Area
  - Seminar Series WG
  - Tutorials WG

UNIFI Members - Project Team



Additional Partners

UNIFI is working with a broader spectrum of partners to ensure industry-wide acceptance

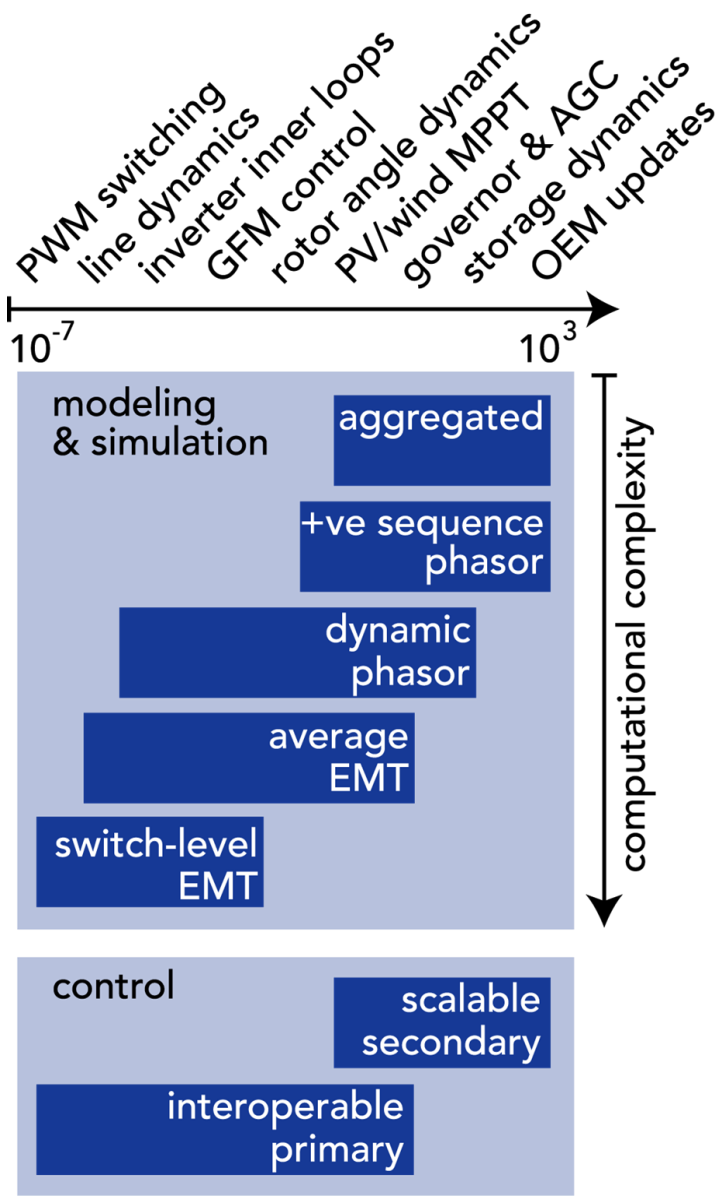
Research & Development (R&D) Thrust

- **Modeling & Simulation:** Develop and Publish GFM-specific models for use in power system simulations. Bridge gaps to HIL.
- **Controls:** Unit- and system-level to ensure grid stability and cybersecurity
- **Hardware:** Anticipate industry needs and develop open-source prototyping
- **Integration & Validation:** Conduit to demonstrations, 1MW experiment at NREL

Modeling & Simulation Area

Snapshot of Innovations:

- Interoperability standards and application programming interfaces (APIs) to allow GFM models to be directly used by different software vendors
- Develop HIL-compatible software models:
  - Hybrid between virtual power stage model & controller in the loop
  - Integrated into commercial and open-source simulation tools
- Model interoperability tests on a virtual platform that provides a secure workspace for tool vendors and a means for utilities to participate and evaluate solutions
- UNIFI has partnerships and collaborations with **all** commercial power-system simulation-software vendors that cover timescales ranging from real-time through micro-/milli-second simulations:
  - EMT simulation (PSCAD, EMTP, HYPERSIM, PLECS)
  - Positive-sequence simulation (PSLF, PSS/E, TSAT, PowerWorld)
  - Real-time simulation (Opal-RT and Typhoon HIL)

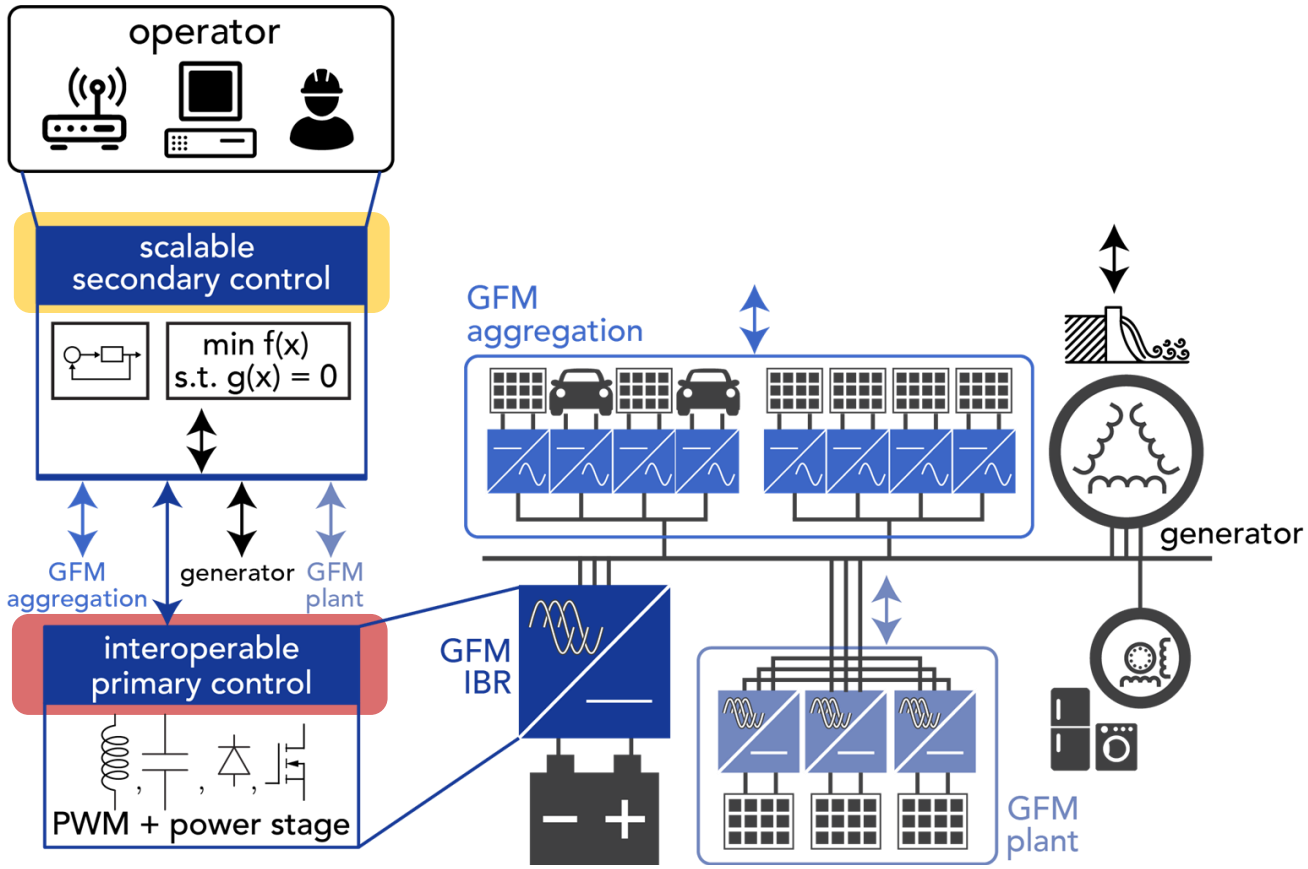


Controls Area

Snapshot of Innovations:

- **Interoperable GFM primary-control architecture:**
  - Compatible with generation and storage technologies via vendor-agnostic middle-layer that translates system-level control signals
  - Coordinates energy transfer within hybrid IBR-plants, large-scale PV, and wind energy conversion systems while managing IBR-level source-side and inverter limits

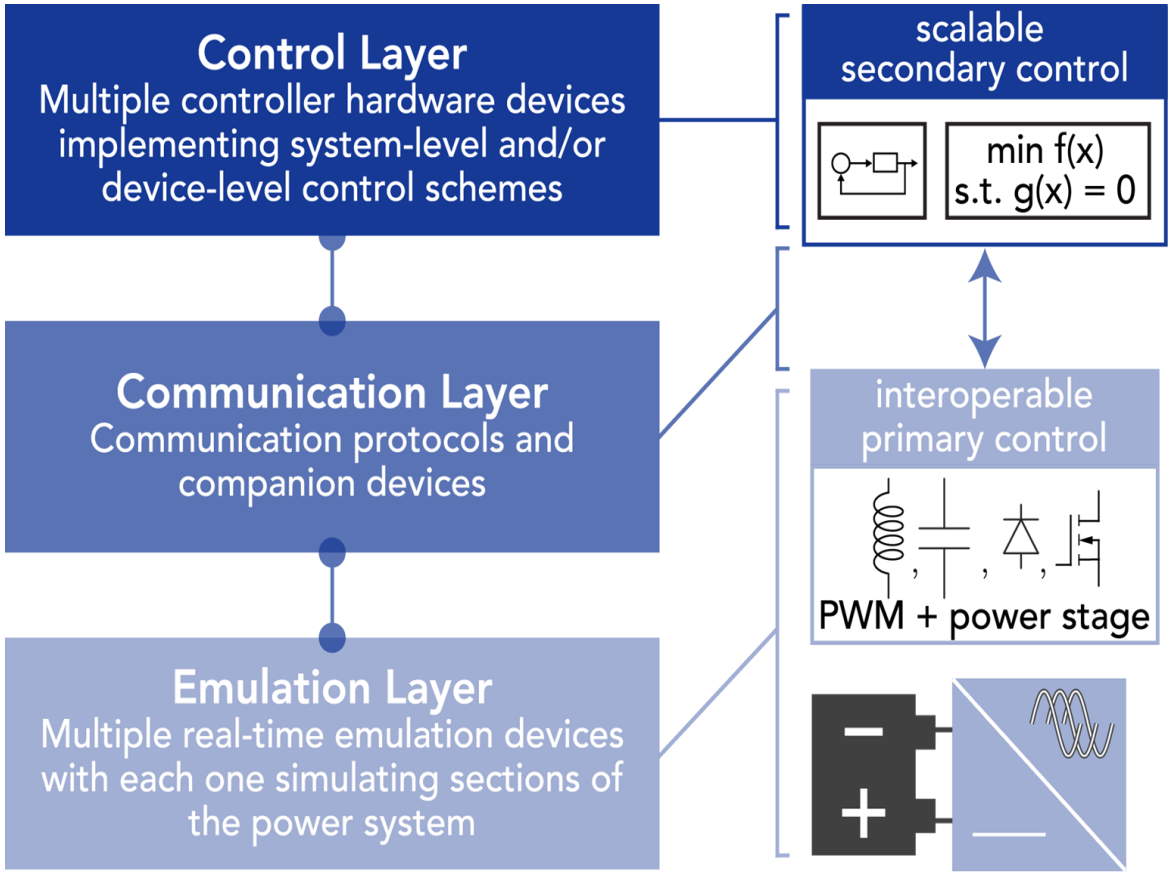
- **Scalable secondary-control architecture:**
  - Generalize area control error (ACE) beyond frequency (to include, e.g., voltage magnitude, phase imbalance)
  - Coordinate and prioritize between different balancing areas while accounting for IBR limits

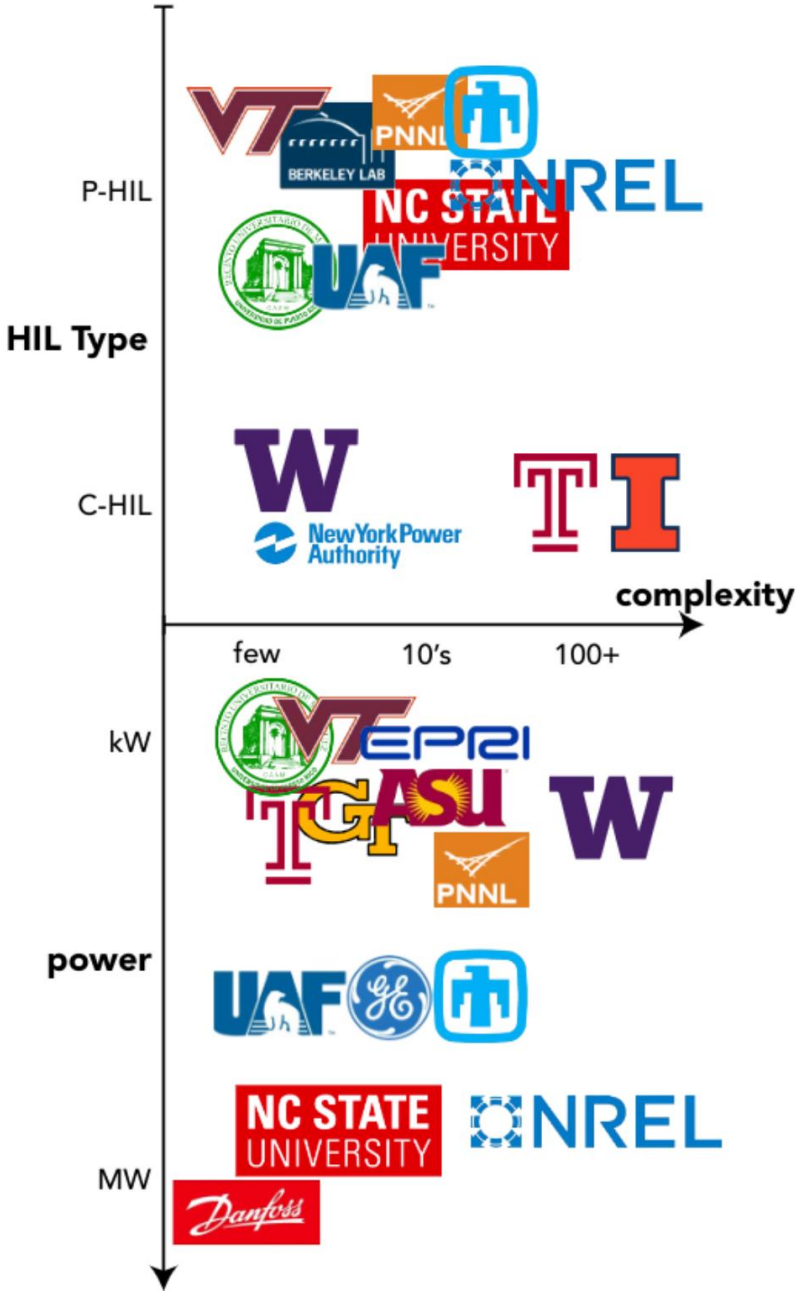


Integration & Validation Area

Snapshot of Innovations:

- Federate and standardize testing and characterization facilities across partnering institutions
- Use cases → testing, evaluation, communication protocols → certification-type testing environment → user facilities for fee





Integration & Validation Area

1 MW Experiment – at NREL in Year 3

- Create a hardware testbed that all vendors that follow the UNIFI Specifications for interoperability should be able to plug and play with other vendors
- Includes various physical sizes (250W-1MW)
- Three-phase, single-phase generation & loads
- Multiple source-side resources (PV, energy storage, wind (if possible))
- 50%, 75%, 90%, and 100% power contribution from GFM IBRs
- Connections to multiple laboratories: integrated testing and validation approach to realize multiple 1MW demos

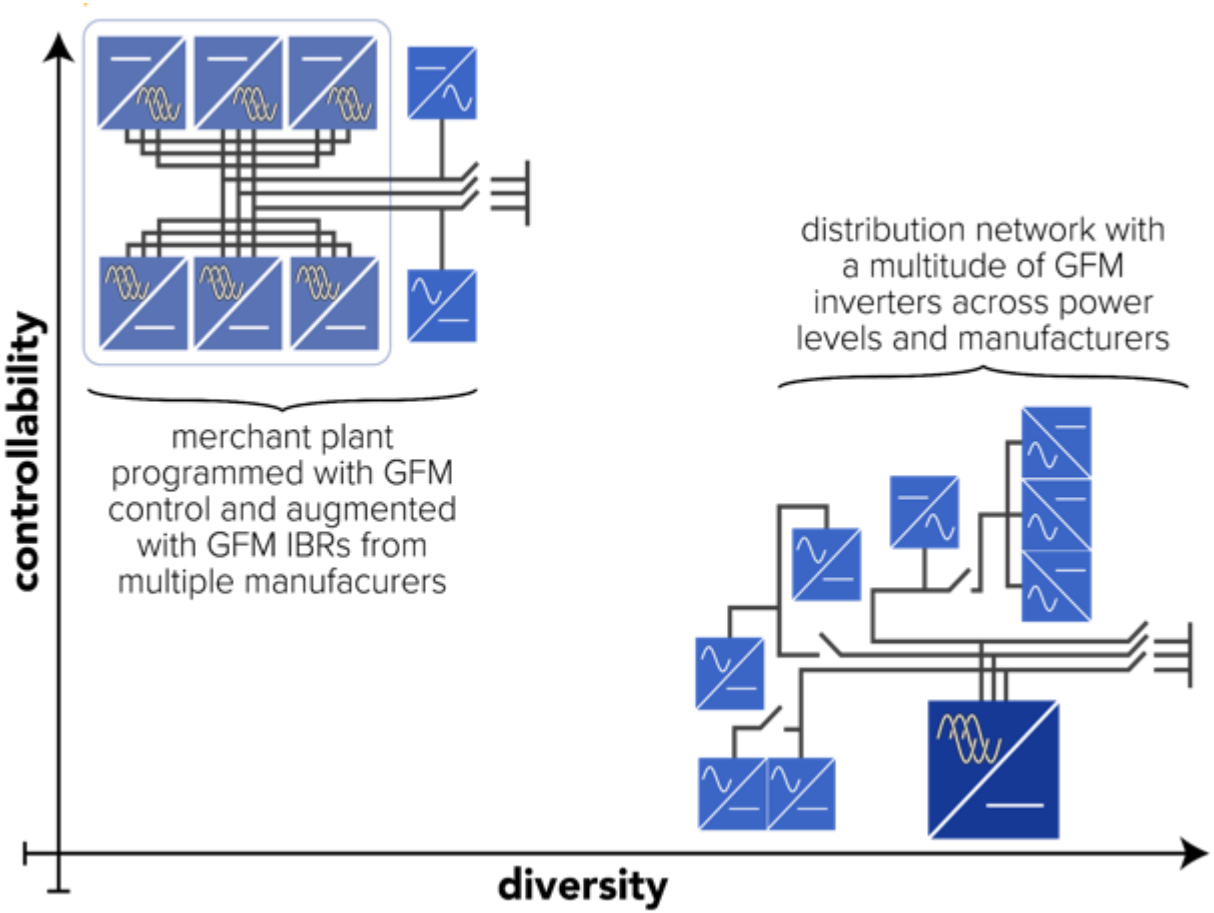
Demonstration & Commercialization (D&C) Thrust

- **20+MW Demo:** Demonstrate UNIFI specifications at utility scale demo
- **IP Management:** Identify “Core” IP needed to meet UNIFI Specifications
- **Domestic Products:** position US as world leader in PV, wind, and storage
- **Standards:** Align with standards cycles to address gaps coving GFM

20+MW Demonstration

Large-scale Plant Integration

[Barilla Solar, TX]



Distribution Networks with high PV integration

[Chicago, IL]

[Oahu, HI]

- Examining a range of possible sites that trade off controllability and diversity of resources and IBR size
- Also looking for demonstrating much larger than 20MW sizes and at possibly at multiple sites
- Demonstrate a full range of GFM services and validate *Interoperability Guidelines & Functional Requirements*
- Would like to examine unique objectives if possible such as energy justice (collocate with underserved communities)

20+MW Demonstration

We are looking for sites that include some or all of the following:

- a mix of three-phase/single-phase resources
- a mix of GFM IBRs, GFL IBRs, and machines
- devices that have a wide range of power ratings (from 250W to MW)
- solutions from multiple vendors a plurality of source-side energy sources (PV, energy storage, wind)
- plant-level controls and SCADA as required
- range of load types and sizes (resistive/inductive, single-/three-phase)

Would like to validate the UNIFI system interoperability guidelines and functional requirements

- interoperable and scalable primary and secondary control
- frequency and voltage control
- power sharing among units
- black-start
- transient operation during balanced and unbalanced faults
- operations to achieve up to 100% power contribution from IBRs during medium- and high-demand periods

Let us know if you have potential demonstration sites

Prior Work

Demonstration of Essential Reliability Services by a 300-MW Solar Photovoltaic Power Plant

Clyde Loutan, Peter Klauer, Sirajul Chowdhury, and Stephen Hall
California Independent System Operator

Mahesh Morjaria, Vladimir Chadliev, Nick Milam, and Christopher Milan
First Solar

Vahan Gevorgian
National Renewable Energy Laboratory

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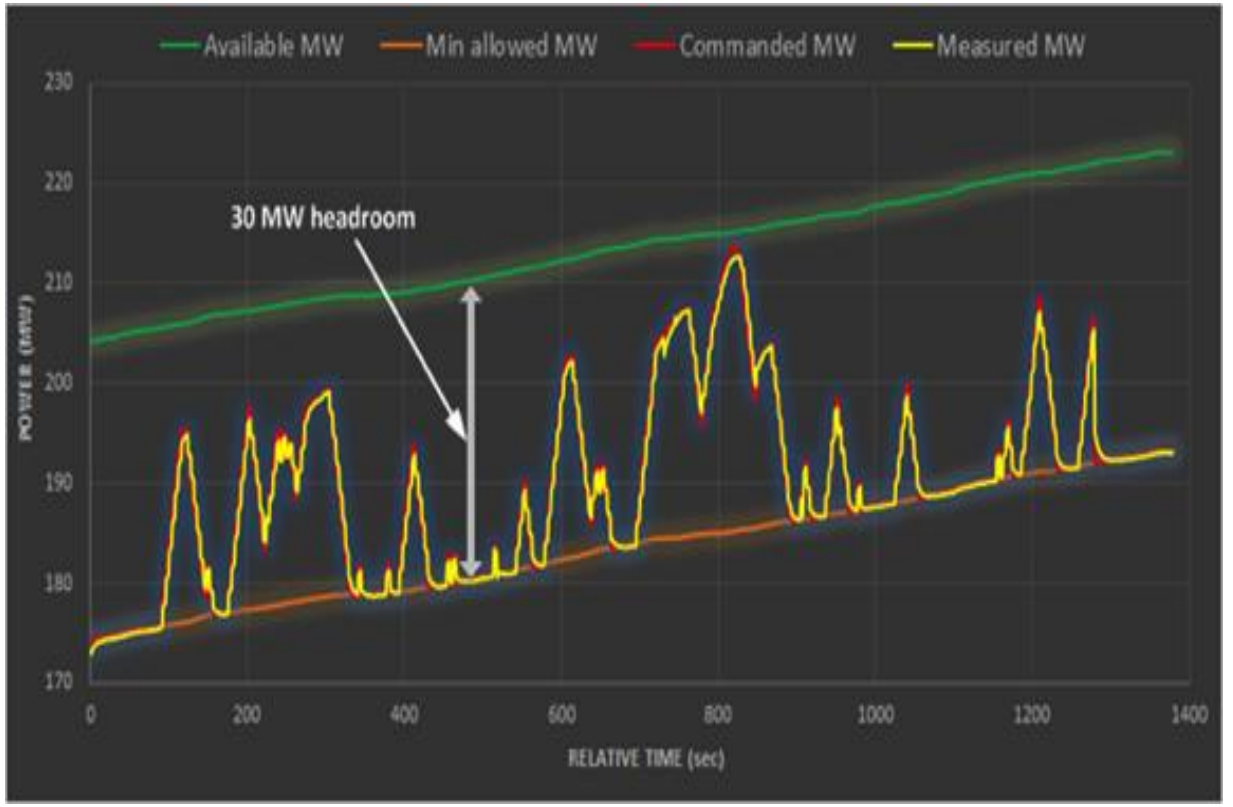


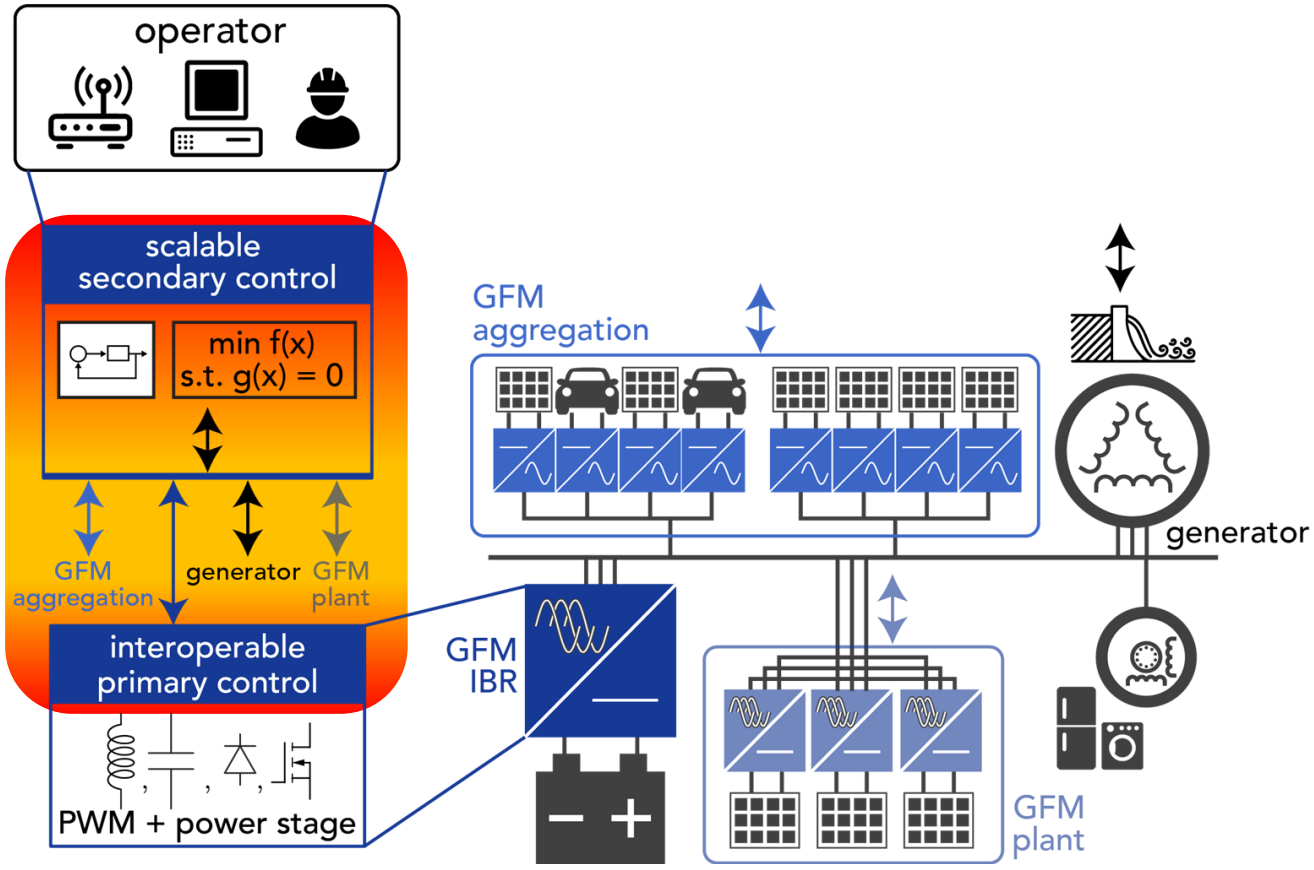
NREL/FirstSolar/CAISO experiment: 300-MW plant following Automatic Generator Control (AGC) signal

Source: C. Loutan, P. Klauer, S. Chowdhury, S. Hall, M. Morjaria, V. Chadliev, N. Milam, C. Milan, V. Gevorgian, *Demonstration of Essential Reliability Services by a 300-MW Solar Photovoltaic Power Plant*, http://www.nrel.gov/docs/fy17osti/67799.pdf

IP Management and Product Development

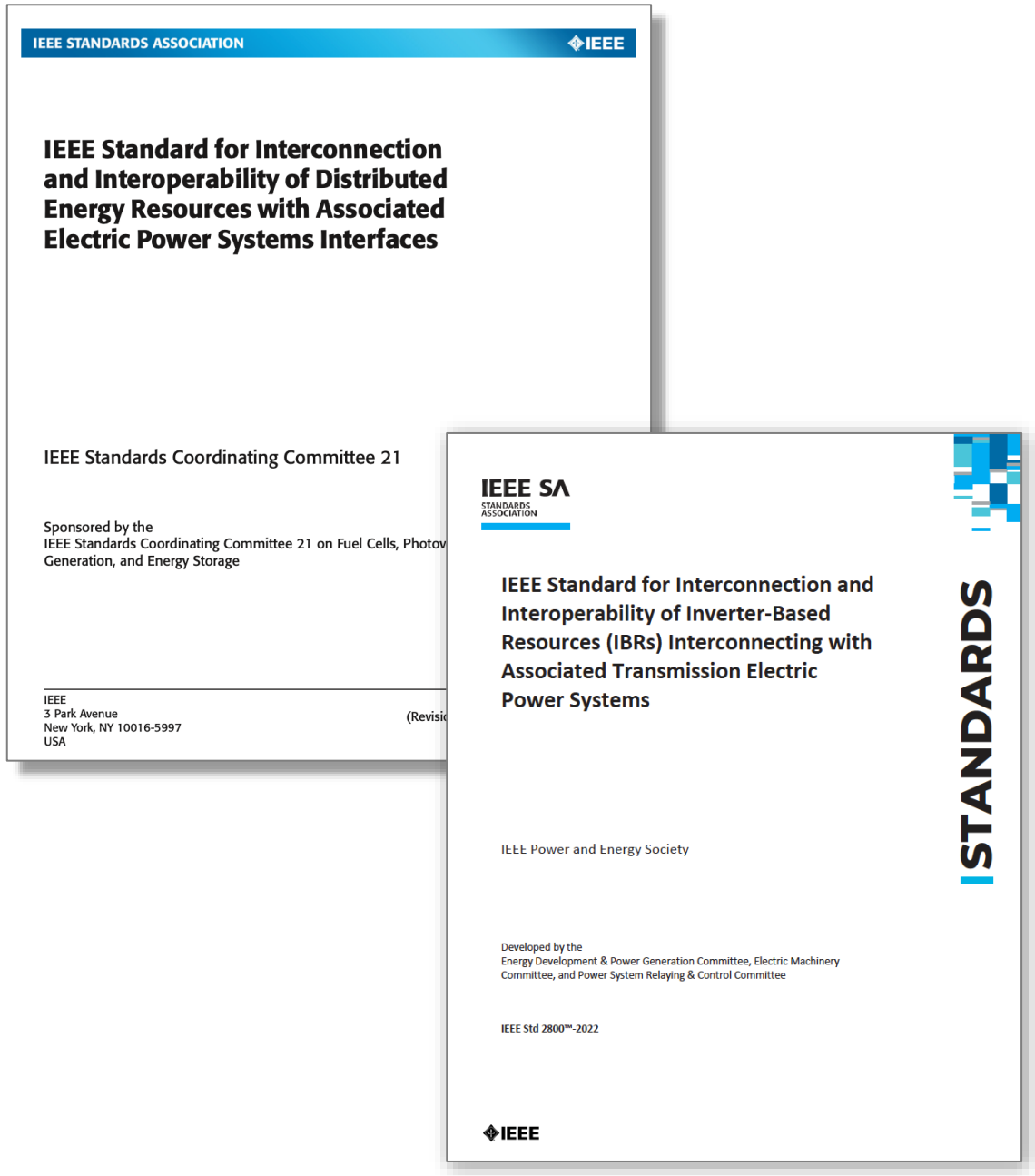
- UNIFI plans to work with members to determine and develop *"Core Stack"* IP that will enable GFM technologies to meet the Interoperability Guidelines and Functional Requirements

- Ensure that members have ability to meet UNIFI Specifications



Standards

- Current standards for interconnecting IBR to power systems do not specifically address GFM technologies
  - IEEE 1547 - Distribution
  - IEEE 2800 - Transmission
- Conducting a gap analysis on existing IEEE 1547 and 2800 standards along with development of technical minimum capabilities for GFM devices
- UNIFI will focus on developing specification for GFM technologies
- Working closely with Standard Development Organizations, UNFI will bring expertise on GFM to future updates of these standards



Outreach & Training (O&T) Thrust

- **Education:** develop educational material, certificate programs, and certification for teachers
- **Workforce development:** develop short courses & tutorials, safety-certification courses
- **Communication:** website and e-newsletter(s)
- **Events:** annual meetings, webinars

https://pes-gm.org

Outreach & Training (O&T) Thrust

Industry-led training events

Interoperability Events

Workshops (in person!)

Leverage Institutional partnerships

UNIFI Seminar Series

15 seminars every Spring and Fall for the next 5 years – Mondays at 4-5pmET/1-2pmPT

Free and Publicly Available

How to get involved with UNIFI?

- UNIFI has a paid membership structure to allow organization that were not part of the original project to join.

Check for the the "**UNIFI Consortium"** Group on LinkedIn

Benefits of Membership

- Seat at the table alongside other vendors, utilities, system operators
- Participate in (and drive) cutting-edge R&D through UNIFI working groups
- Access UNIFI specifications that will leapfrog traditional standardization process
- Access to core stack IP that is key to interoperability of GFM technologies across scales
- Participate in 1MW and 20MW demos
- Network with wide student pool across universities that will enter workforce
- UNIFI events (training, job fairs, workshops) will be key to educate on novel technology area
- Access to educational and training material in up-and-coming technology space

For more information on Memberships Contact: Ben Kroposki (benjamin.kroposki@nrel.gov) or Iqbal Hussain (ihusain2@ncsu.edu)

Thank you