Grid Modernization Initiative Peer Review

GMLC 1.4.2 – Definitions, Standards and Test Procedures for Grid Services from Devices

ROB PRATT

April 18-20, 2017

GMLC Peer Review Meeting
Sheraton Pentagon City – Arlington, VA

Definitions, Standards and Test Procedures for Grid Services from Devices (GMLC 1.4.2) – High Level Summary

GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

Project Description

Develop characterization test protocol and model-based performance metrics for devices' (DERs') ability to provide a broad range of grid services, i.e., to provide the flexibility required to operate a clean, reliable power grid at reasonable cost.

Value Proposition

- ✓ ***Reward innovation,*** help manufacturers understand opportunities, enlarge the market for devices
- ✓ ***Validated performance & value for grid operator decisions*** on purchases, programs, subsidies, rebates, markets, planning, operations
- ✓ ***Independently validated information for consumers & 3rd parties*** for purchase decisions

Project Objectives

- ✓ **Simple, low-cost testing protocols** manufacturers can use to characterize equipment performance (*Recommended Practice*)
- ✓ **General, standard device model reflecting test results** for each device class
- ✓ **Proven means of estimating performance metrics** for a **standard set of grid services** from the test results
- ✓ **Protocol that can be regionalized** to reflect local markets, new services, weather, loads, etc.

Definitions, Standards and Test Procedures for Grid Services from Devices (GMLC 1.4.2) – Project Team

GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

Project Participants and Roles			Project Funding			
Laboratory	**Device Class**	**Grid Services**	**FY16**	**FY17**	**FY18**	**Total**
Pacific Northwest National Laboratory	1. Thermal storage	A. Peak load management B. Artificial inertia/fast frequency response	$351K	$440K	$401K	$1,191K
National Renewable Energy Laboratory	3. Water heaters 4. Refrigerators 5. PV/inverters	C. Distribution voltage management / PV impact mitigation	$226K	$481K	$409K	$1,116K
Sandia National Laboratory	6. Batteries/ inverters		$106K	$323K	$274K	$703K
Argonne National Laboratory	7. Electric vehicles (DR, V2G)	D. ISO capacity market (e.g., PJM's)	$141K	$288K	$246K	$675K
Oak Ridge National Laboratory	8. Res. & Com. HVAC 9. Com. refrigeration		$146K	$588K	$481K	$1,215K
Lawrence Berkeley National Laboratory	10. Commercial lighting	E. Regulation F. Spinning reserve G. Ramping	$211K	$263K	$226K	$700K
Idaho National Laboratory	11. Fuel cells 12. Electrolyzers		$146K	$313K	$266K	$725K
Lawrence Livermore National Laboratory		H. Wholesale energy market/production cost	$94K	$35K	$48K	$177K
Totals			$1,420K	$2,731K	$2,350K	$6,500K

Definitions, Standards and Test Procedures for Grid Services from Devices (GMLC 1.4.2) – Relationship to Grid Modernization MYPP

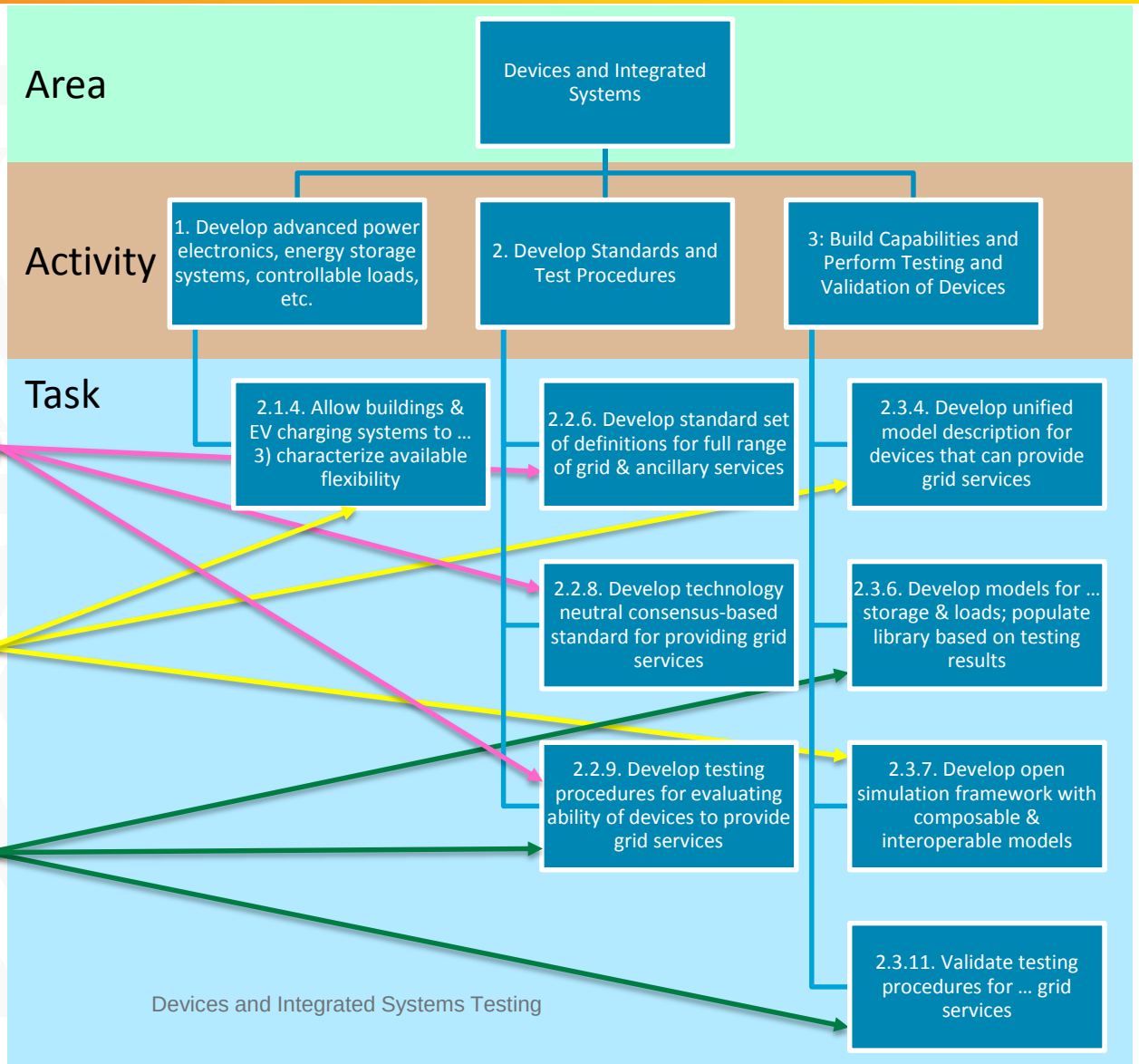
GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

- ✓ *Project is **central to a number of tasks in the Devices and Integrated Systems MYPP: grid services, unified models, testing procedures** and contributes to many more.*

Definition of grid services & representative drive cycles

Battery equivalent model defines flexibility, unifies DR & DER models

Device models & validation test results contribute to testing library



Definitions, Standards and Test Procedures for Grid Services from Devices (GMLC 1.4.2) – Approach

GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

Characterization Protocol

- Measure device fleet parameters describing ability to provide grid services
- Simple, short (<24-hr, inexpensive) procedure, complementing existing test protocols:
  How much, how fast, how long, time lags, etc.

Model Device Fleet

- Time series model of device fleet performance
- Based on measured parameters
- Base case end-use load that must be served
- User and device limitations and requirements
- Express as battery equivalent parameters to grid services model
- Measures of consumer and device impacts

Key Challenges: 1) General battery equivalent model for all devices/services, 2) Modular design & assumptions allow regionalization

Define Grid Service

- Definition and purpose
- Requirements of providing devices
- Representative time-series "drive-cycle" of the service

Grid Service Dispatch Model

- Scale fleet of identical devices to service based on nominal power of devices and peak power required by service
- Simple, direct control of battery-equivalent fleet of identical devices

Performance Metrics

- Grid service performance metrics
- Consumer impacts (energy, comfort, amenity)
- Device impacts (cycles/yr, etc.)

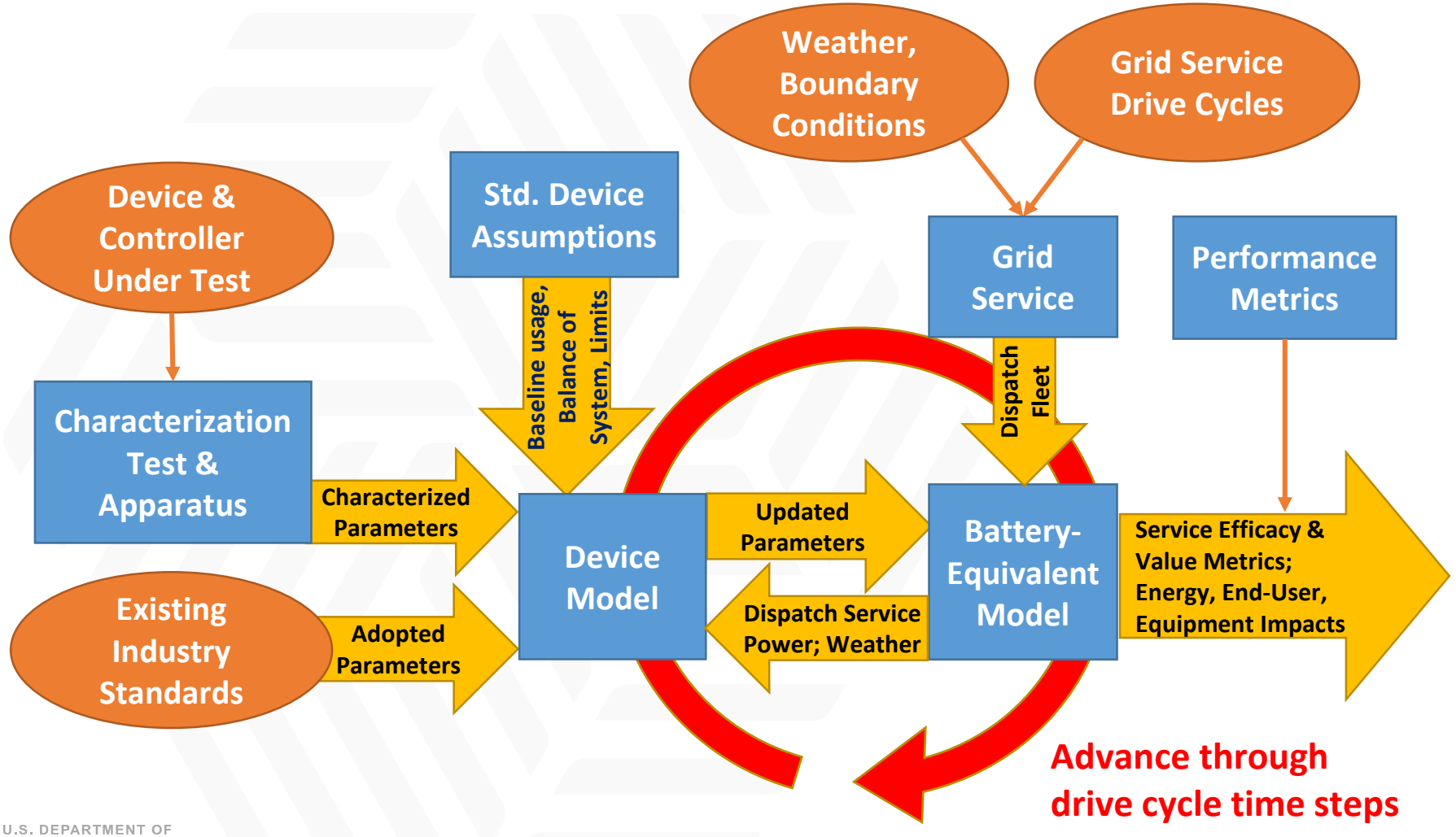
Definitions, Standards and Test Procedures for Grid Services from Devices (GMLC 1.4.2) – Key Project Milestones

GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

Milestones* (FY16-FY18)	Status	Due Date
1. **Standard definitions & drive cycles for grid services** (draft for industry review)	1. **Complete** 	**October 1, 2016**
2. **General device model** (draft for industry review)	2. **Complete** 	
3. **Extrapolation procedure for performance of grid services**	3. **Complete** 	**April 1, 2017**
4. **Draft *Recommended Practice*** (vetted with industry)	4. **Underway** 	**October 1, 2017**
5. **Trials of device characterization protocols** (for each device class) 6. **Manufacturers review of characterization protocol & test results**		April 1, 2018
7. **Proof-of-concept testing validates extrapolation procedure**		October 1, 2018
8. **Stakeholder group consensus that *Recommended Practice* is useful & accurate**		April 1, 2019

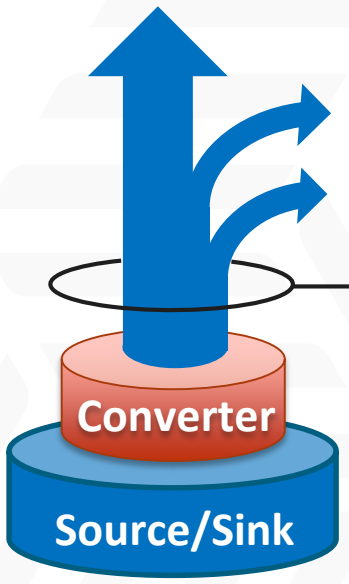
Definitions, Standards and Test Procedures for Grid Services from Devices (GMLC 1.4.2) – Accomplishments

General Framework and Approach



Definitions, Standards and Test Procedures for Grid Services from Devices (GMLC 1.4.2) – Accomplishments

Define Generic Devices: Power Flows & Services



Power injected into grid (P_{Grid})

Power to end use (P_{EndUse}) +

Parasitic power ($P_{Parasitic}$)

Power from source/sink { Power output from generator (P_{Output}) +

Power discharged from storage ($P_{Discharge}$)

Power Balance:

$$P_{Grid}(t) = P_{Output}(t) + P_{Discharge}(t) - P_{Enduse}(t) - P_{Parastic}(t)$$

Power for Grid Service:

$$P_{Service}(t) = P_{Grid}(t) - P_{GridBase}(t)$$; where *Base* indicates base case

$$P_{Service}(t) = \Delta P_{Discharge}(t) + \Delta P_{Output}(t) - \Delta P_{Enduse}(t) - \Delta P_{Parasitic}$$

; where Δ is the difference between the service case & base case

Definitions, Standards and Test Procedures for Grid Services from Devices (GMLC 1.4.2) – Response to Dec. 2016 Program Review

GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

Recommendation	Response
This project needs a lot more support from industry. The meeting in March 2017 is critical.	**Organized series of webinars & briefings** to raise awareness leading up to 2nd Industry Workshop: • GridWise Alliance pre-workshop webinar (n = 35*) • Commercial lighting webinar (n = 27*) • PV/batteries/inverters webinar (n= 321*) • HVAC & appliances webinar (n=21*) • Thermal energy storage briefings (n = 2*) • Electric vehicle industry meeting presentation (n = 13*) • More webinars to come in April (fuel cells/electrolyzers) **Partnered with the GridWise Alliance to host 2nd Industry workshop** with sponsors GE & Intel @ GE's GridIQ Center in Atlanta GA March 21-22, 2017 (n = 36*) * Count excludes DOE and national laboratory participants

✓ **Project has raised industry awareness of the project dramatically in Q1&2 FY17**

Definitions, Standards and Test Procedures for Grid Services from Devices (GMLC 1.4.2) – Project Integration and Collaboration

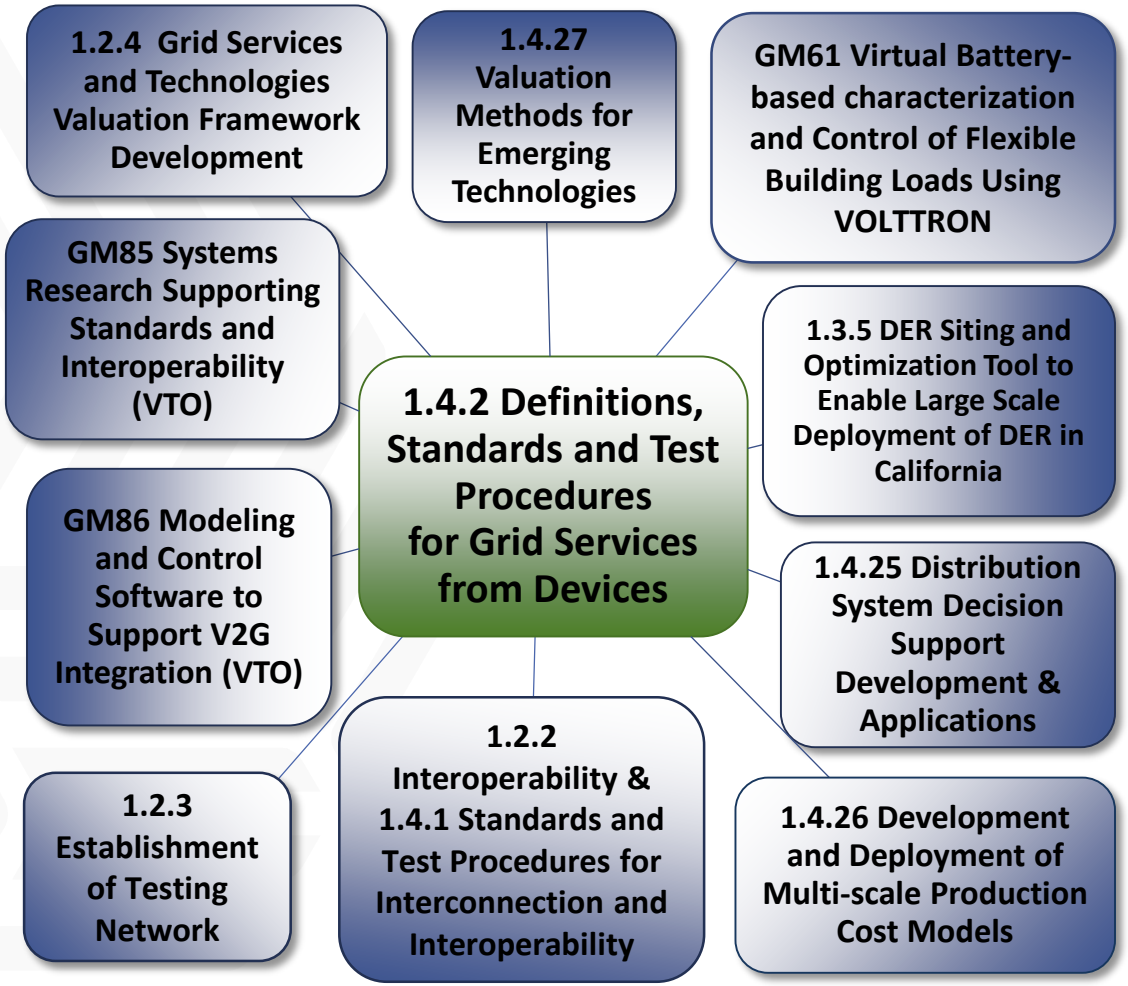
GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

Relationship to Other GMLC Projects

- ✓ Defining grid services, & metrics for grid services are value based (1.2.4 & 1.4.27)
- ✓ Use virtual battery concept as common device model interface to each grid service (GM61)
- ✓ Device models & grid service performance models useful for long-term planning (1.3.5, 1.4.25 & 1.4.26)
- ✓ Interoperability & Interconnection (1.2.2 & 1.4.1)
- ✓ Test procedures, data, & device models delivered to GMLC Testing Network's test procedure repository library (1.2.3)
- ✓ Leverage testing & interoperability for electric vehicles (GM85 & GM86)

Engagements

- ► 1st Industry Workshop – 9-12-17, NREL
- ► 2nd Industry Workshop – 3-21/22-17, Atlanta
- ► 4 device-class & services webinars – Mar '17



Definitions, Standards and Test Procedures for Grid Services from Devices (GMLC 1.4.2) – Next Steps and Future Plans

GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

This project is about

- **Enhancing**
- **Empowering**
- **Unlocking**
- **Unleashing**

the value of grid modernization devices everywhere!

Oct-'17: **Draft *Recommended Practice*, vetted by utility & device industries**

Apr-'18: **Test rigs & trials of characterization protocol, each device class**

Apr-'19: **Proof-of-concept testing of measured device performance against actual grid services**

Impact:

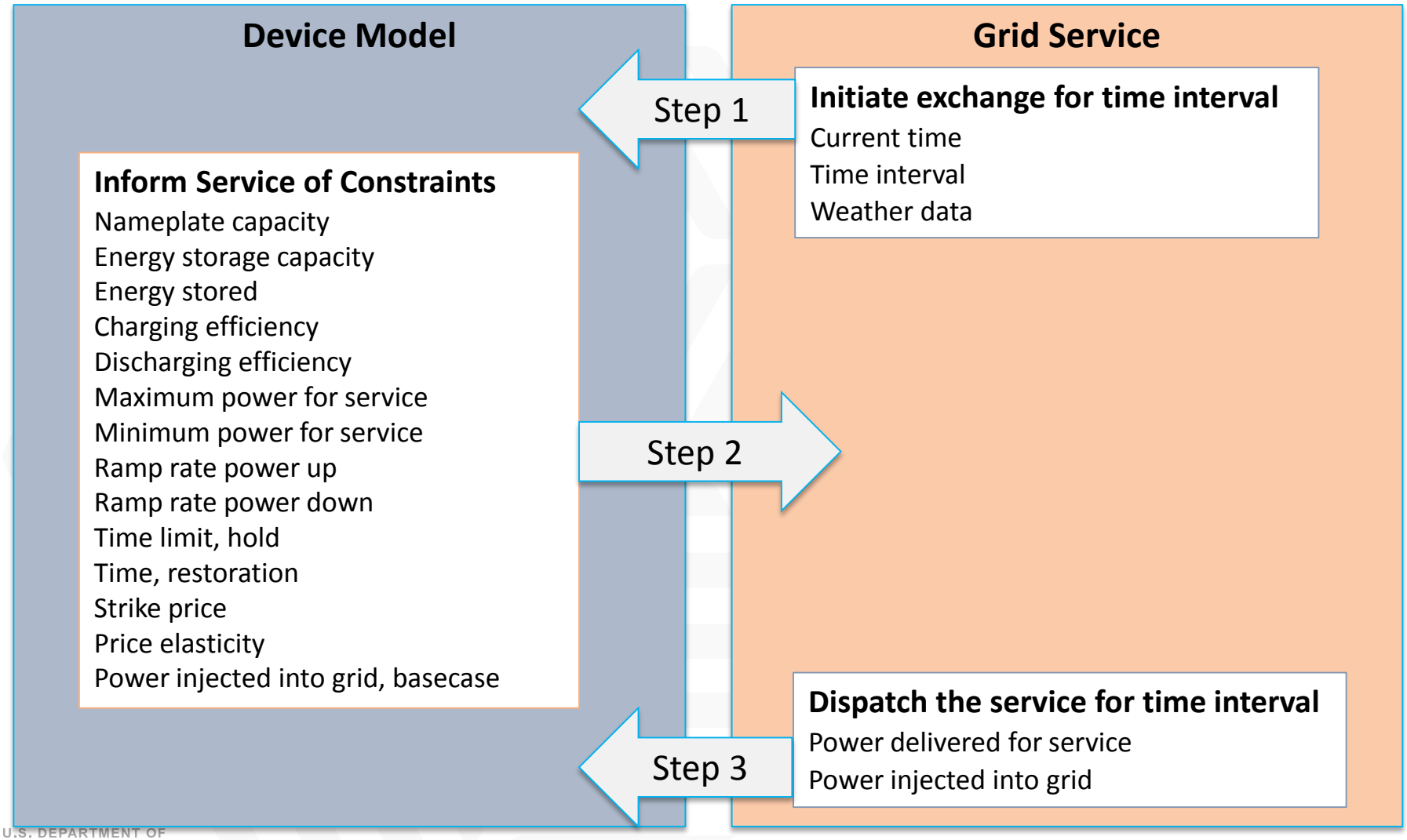
- ✓ Std. performance, value & impact metrics for devices providing grid services
- ✓ Reward innovation, sell more devices
- ✓ Better decision-making by consumers, utilities, 3rd parties
- ✓ Lower cost, more reliable, cleaner grid

Expansion Potential:

- ✓ Battery equivalent interface as a modeling standard
- ✓ Allows detailed, state-of-the-art device models to plug & play into planning and operation tools

Backup Slides

Definitions, Standards and Test Procedures for Grid Services from Devices (GMLC 1.4.2) – Data Flow between Device Model and Grid Service: the Battery Equivalent Model



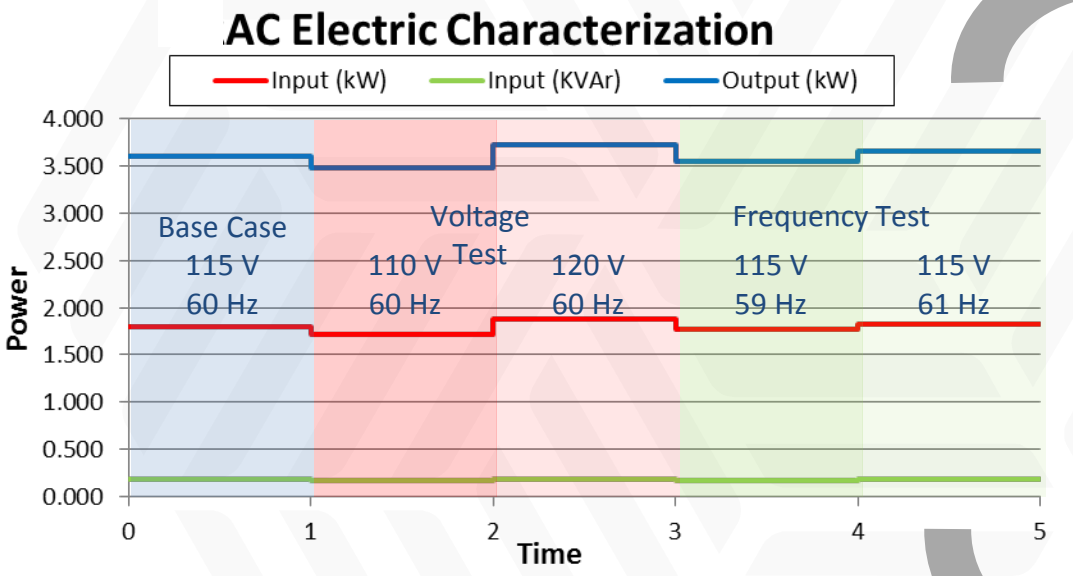
Definitions, Standards and Test Procedures for Grid Services from Devices (GMLC 1.4.2) – Design Principles & Functional Objectives

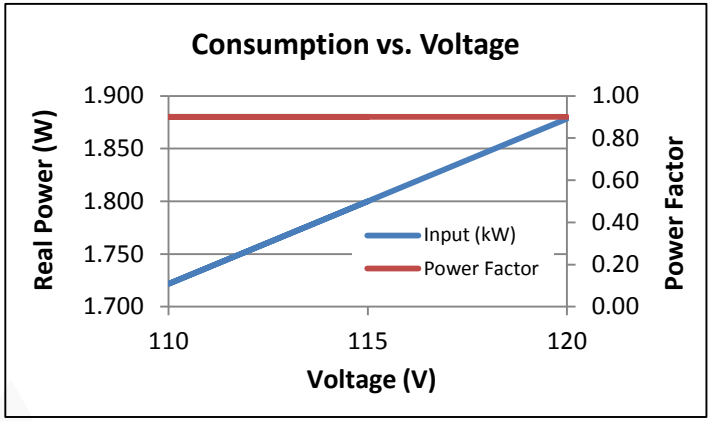
GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

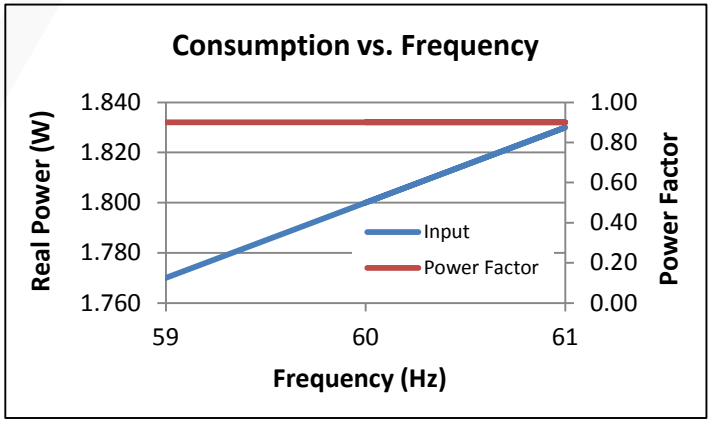
- Test protocol simplicity
  - Short duration, low cost
  - Leverage/complement existing standards
- Test once, rate many
  - Extrapolate test results to grid service via device model
  - Allow new services to be defined, rated
- Device performance as member of a fleet
  - Individual devices may not have fidelity required for a service
- Uniformity across device classes & grid services
  - Common dispatch & performance metrics agnostic to device type
  - Normalize performance to device nameplate capacity
- Support customized assumptions to reflect a region
  - Weather, balance of plant, baseline usage assumptions
  - Grid service “drive-cycle” patterns & values & value streams

Definitions, Standards and Test Procedures for Grid Services from Devices (GMLC 1.4.2) – 1. Electrical Characterization Test for an Air Conditioner (Example)

Purpose: Determine fundamental electrical properties of device & any autonomous responses

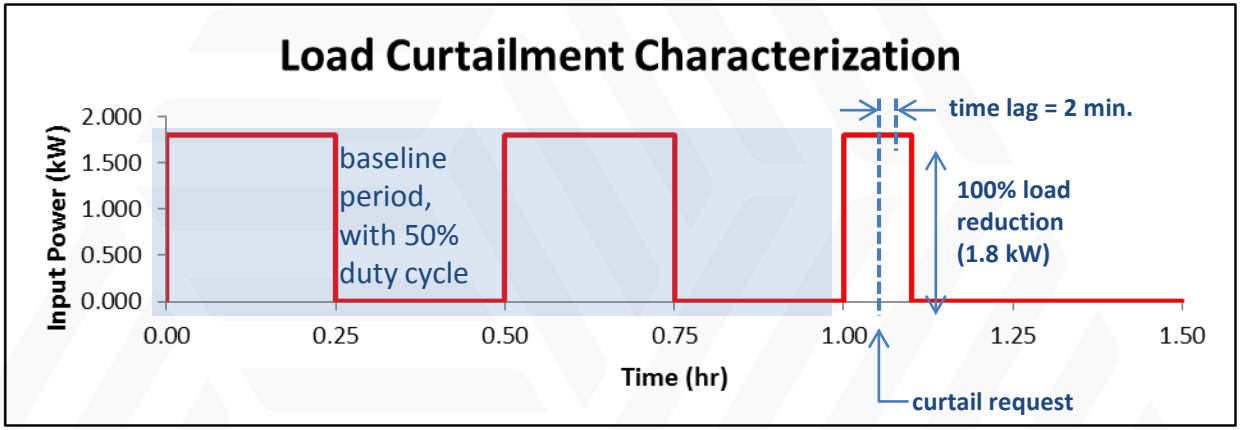






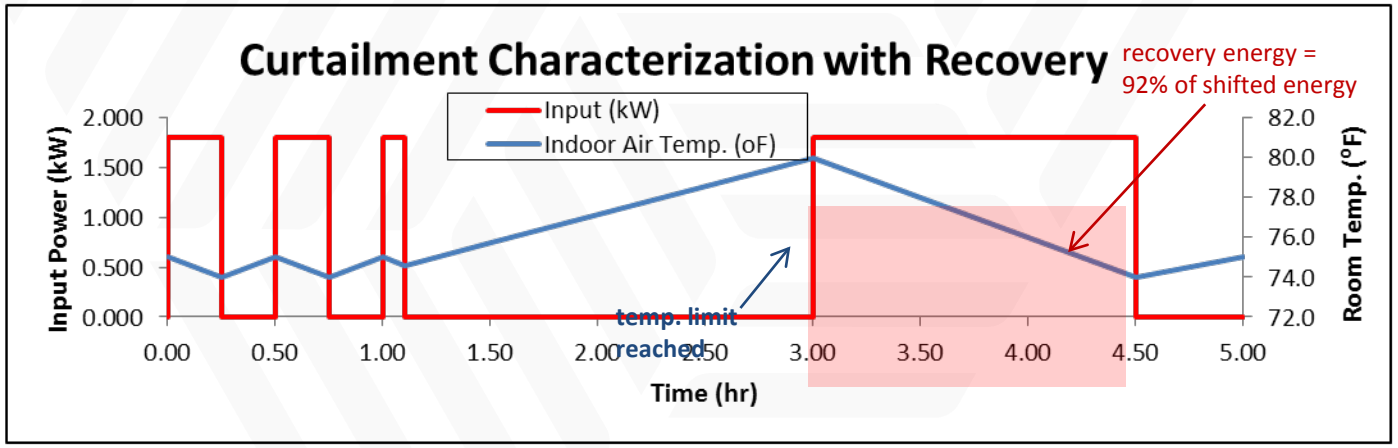
Definitions, Standards and Test Procedures for Grid Services from Devices (GMLC 1.4.2) – 2. Load-Curtailment Characterization Test for an Air Conditioner (Example)

Purpose of test: Characterize curtailment capabilities: e.g., amount of power curtailed, time lag, effect on energy consumption, etc.



Metrics

- **Absolute load reduction**
- **% load reduction**
- **Time lag from request to curtailment**

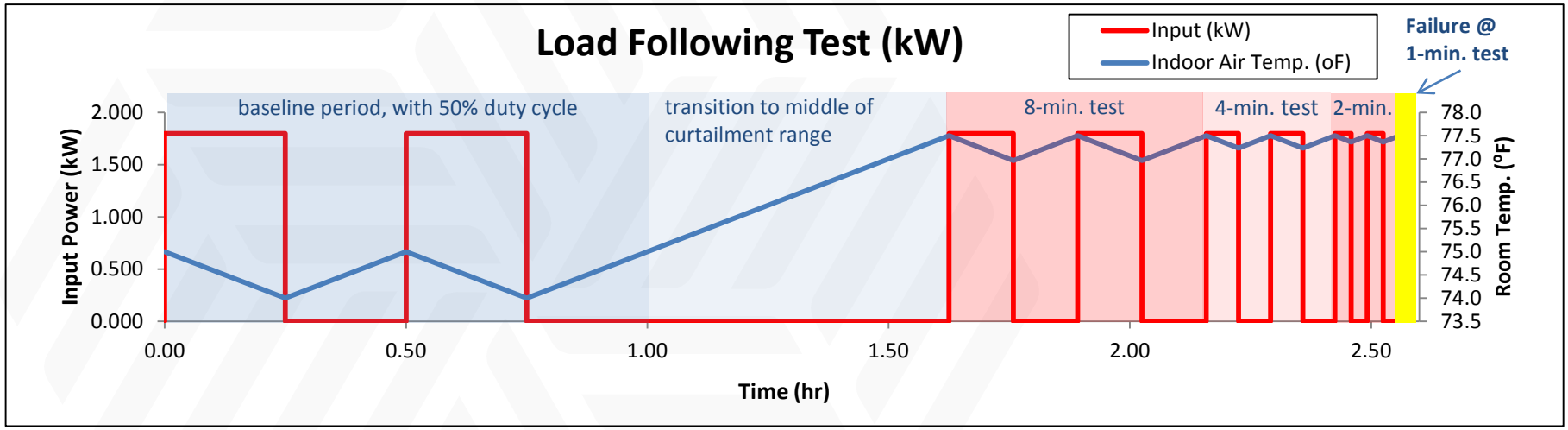


Metrics

- **92% recovery energy**
- **5°F temp. rise limit**
- **5-hr mode time limit (not shown)**

Definitions, Standards and Test Procedures for Grid Services from Devices (GMLC 1.4.2) – 3. Load-Following Characterization Test for an Air Conditioner (Example)

Purpose of test: Characterize load following capabilities, i.e., ability to follow load-up/load-down signals at increasingly short intervals (for ancillary services, renewables integration, etc.)



Example Metrics

- **104% recovery energy (not shown)**
- **100% load following, down 2-minute intervals**
- **Time lag (2-min)**