Expanded Demand Response (DR) Functionality

Action Plan for Rapid Penetration of Home Energy Management (HEM) Technologies

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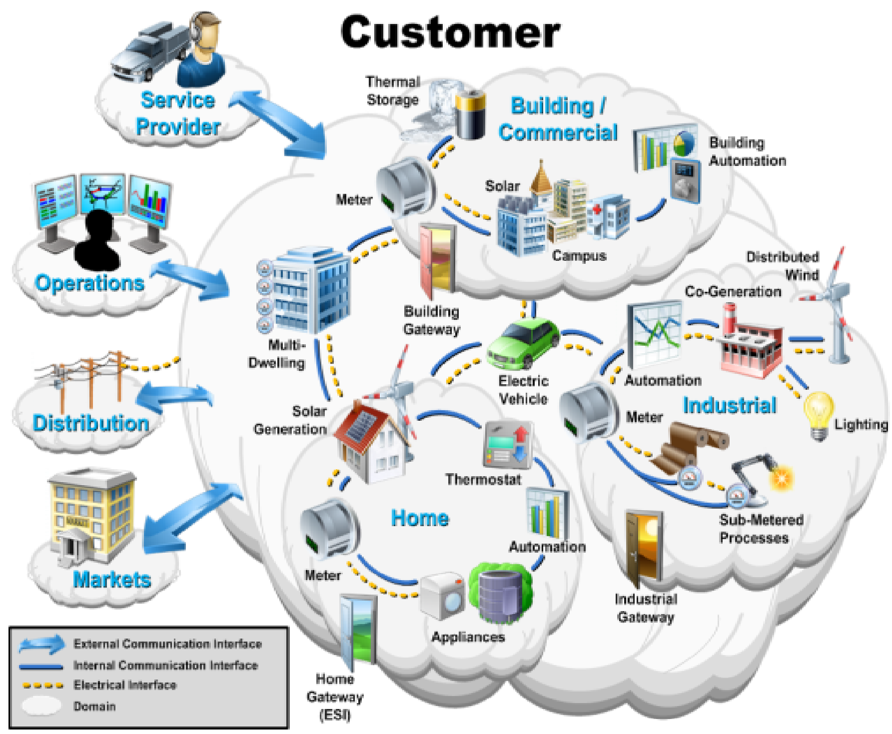
Action Plan for Home Energy Management (HEM)

Objective

- ➢Establish societal & consumer benefits of HEM technologies
- ➢Collaborate with stake holders to address customer & regulator ambivalence towards HEM deployments
- ➢Innovative use of DR resources to realize FERC's assessment of national DR potential & beyond
- ➢Expand HEM market landscape: Develop advanced HEM applications by exploiting the synergy between energy efficiency & DR

Funding Summary ($K)

FY09	FY10	FY11
$282	$730	$730+



Technical Scope

- ➢ Evaluate benefits of smart appliances with AHAM and other stakeholders, facilitate inclusion of 'smart' capability in new appliance efficiency standards
- ➢ CRADA with GE to model & simulate effects of smart appliances & DR control strategies
- ➢ Expand DR to include ancillary-service benefits besides peak-load reduction
- ➢ Use of HEM to integrate renewables including distributed PV
- ➢ Assist national smart grid interoperability, and regulatory efforts for enabling mass consumer participation in smart grid

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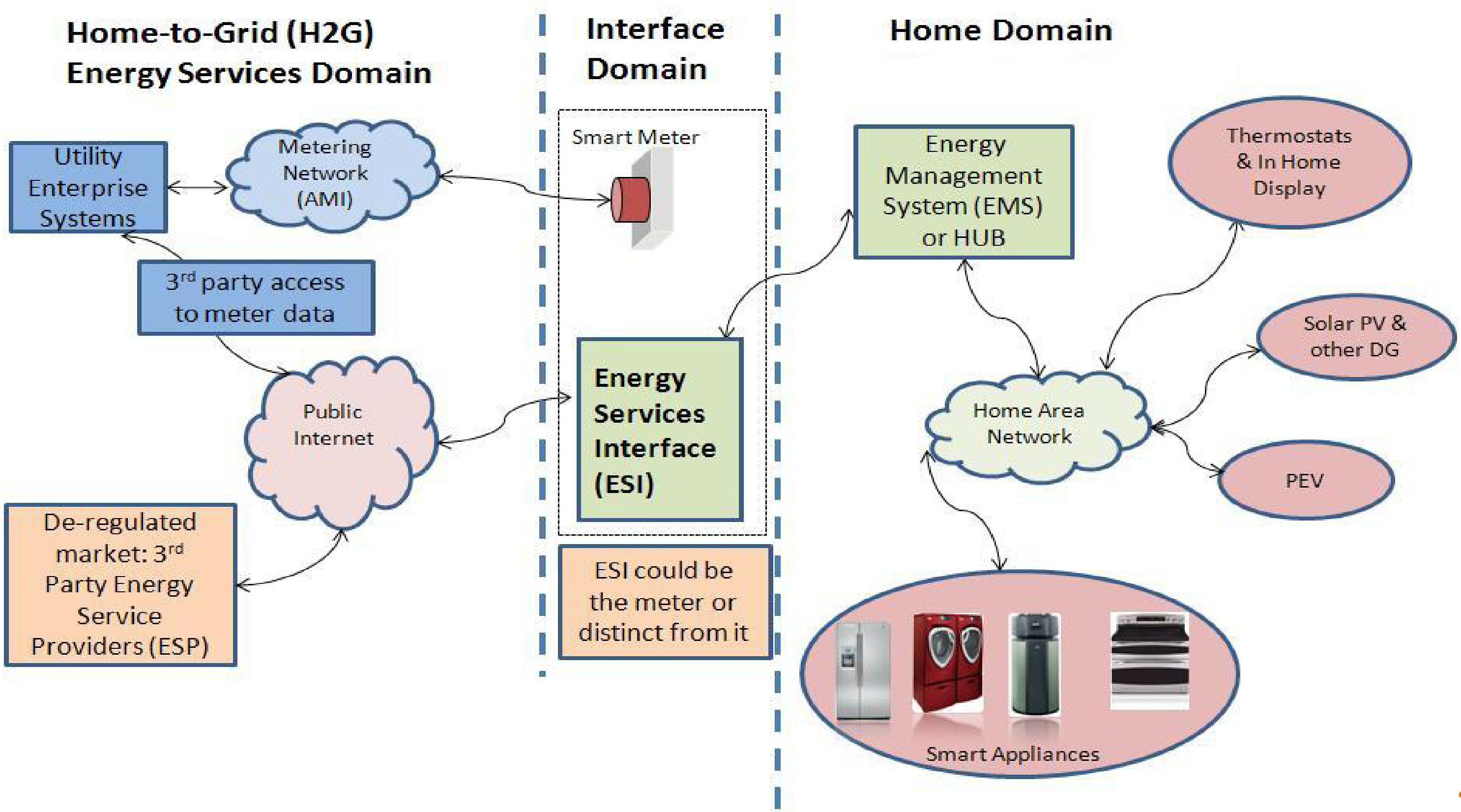
Future HEM Architecture

➤ Future open, interoperable HEM architecture for delivery of smart-grid enabled energy services to customers as envisioned by national smart grid stakeholders

“HEM” ≡ HEM + HAN + H2G



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Why HEM is Critically Important Right Now

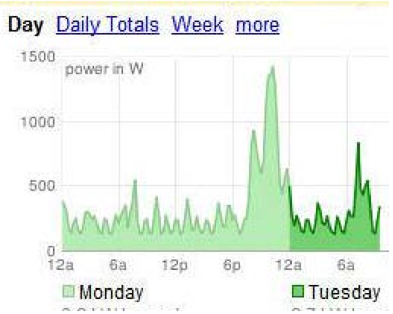
- HEM is needed when DR extends beyond smart thermostats to also manage smart appliances
- HEM is the link between smart grid and energy efficiency in homes – need to leverage the benefits of both
  - Answers expectations from energy advocates
  - Fills demand from consumers for some kind of immediate payoff from AMI deployments
- HEM industry is moving so rapidly, we must insure some degree of quality as rollouts emerge

Challenges, Needs, & Opportunities (1)

- **Challenge:** A comprehensive action plan, including business drivers required to enable widespread adoption of HEM
  - **Why:** Large residential (and small commercial buildings) customer base and hence expectation among smart grid stakeholders for realizing HEM benefits & opportunities
  - **Why:** Convince PUCs/regulators & consumer advocates to approve smart grid investments
  - **Why:** Need for best practices and benchmarks to spur quality in HEM rollouts
  - **Why:** Test <u>advanced applications</u> in laboratory settings & actual homes
  - **Why:** Large penetration of renewables including distributed generation such as PV will exacerbate the need for balancing services
    - **Opportunity:** Use of HEM beyond managing peak loads to provide ancillary services (e.g., intelligent coordination of appliance, water heater loads, and smart inverters)

Challenges, Needs, & Opportunities (2)

- **Need:** Provide energy efficiency as an immediate smart grid ROI to residential & small commercial building customers
  - ➢ **Opportunity:** Leverage smart grid infrastructure to provide –
    - ✓ Feedback on energy use, costs, and carbon footprint including "peer group" comparisons (~6% savings*)
    - ✓ Diagnostics to detect degradation in efficiency for equipment/appliances (~3% savings*)



* Pratt et. al, Smart Grid: An Estimation of the Energy and CO_2 Benefits

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Technical Approach: Modeling & Analysis

- **AHAM:** Develop **benefits to cost ratio estimates for residential smart appliances**[1] to analyze of AHAM's quest to include smart grid capability within next generation appliance efficiency standards being currently developed
  - Smart appliance benefits include the savings in wholesale power production costs in different markets across USA through
    - Peak load shifting
    - Spinning reserves
  - Cost is defined as performance credit toward meeting the requirements for an Energy Star label

- **GE CRADA**: Modeling and simulation of the **dynamic, aggregate behaviors of smart appliances** in GRIDLAB-D, to evaluate:
  - Impacts on customer in terms of energy/cost savings and convenience
  - Benefits (peak load reduction, ancillary services) & any additional stress (rebound effect) of smart appliances to the power grid
  - Help GE assess & refine their smart appliance designs & DR control strategies

[1]Smart appliances include: clothes washers, dryers, dish washers, refrigerators, freezers, and room air conditioners

Smart Appliance Benefits & Cost (AHAM)

Clothes Dryer On-Peak and Off-Peak Consumption*

ELCAP (1990) Dryer Load Shape					2010 Annual Dryer On-Peak and Off-Peak Consumption		
Load Shape:	Average Day	Annual			Total Annual Consumption (2010)	Annual On-Peak Consumption (2010)	Annual Off-Peak Consumption (2010)
	Daily Total	On-Peak	Avg. No. of On-Peak Days/Yea	Annual On-Peak To Total Ratio			
Start, Hour Ending:	1	13					
Through Hour Ending:	24	18					
	(kWh/day)	(kWh/day)			(kWh/yr)	(kWh/yr)	(kWh/yr)
	2.89	1.06	365	0.37	967	355	612

Wholesale Cost Savings from Using Smart Dryers for Peak Load Shifting

	Annual Hourly Energy Market Clearing Prices			Annual Energy Cost (No Load Shift)		Annual Energy Cost Savings from 50% Peak Load Shift	
	Avg. On-Peak	Avg. Off-Peak	Avg. Shift To Hours	On-Peak	Off-Peak	On-Peak Energy Moved to "Shift To" Hours	Savings
	($/MWh)	($/MWh)	($/MWh)	($/yr)	($/yr)	(kWh/yr)	($/yr)
PJM 2006	$50.64	$39.44	$39.44	$17.98	$24.14	177.49	$1.99
ERCOT 2008	$105.56	$67.09	$67.09	$37.47	$41.06	177.49	$6.83
NYISO 2008	$115.97	$92.25	$92.27	$41.17	$56.46	177.49	$4.21
NYISO 2006	$85.05	$67.44	$67.41	$30.19	$41.28	177.49	$3.13
CAISO 2008	$82.11	$65.01	$65.02	$29.15	$39.79	177.49	$3.03

* Pratt et. al, "End-Use Load and Consumer Assessment Program (ELCAP)"

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Smart Appliance Benefits & Costs (cont)

Wholesale Cost Savings from Using Smart Dryers for Spinning Reserves

	Annual Hourly SR Market Clearing Prices			Annual Dryer SR Market Value		
	Avg. On-Peak	Avg. Off-Peak	Avg. Shift-To Hours	On Peak: 50% Dryer Load Available for SR After 50% Shifted	Off-Peak: Dryer Off-Peak Load + 50% Load shifted from Peak to 'Shift To' Hours	Total Spinning Reserve Cost Savings
	($/MWh)	($/MWh)	($/MWh)	($/yr)	($/yr)	($/yr)
PJM 2006	$7.29	$8.08	$8.08	$1.29	$6.38	$7.67
ERCOT 2008	$36.85	$23.76	$23.76	$6.54	$18.76	$25.30
NYISO 2008	$14.84	$8.56	$8.56	$2.63	$6.76	$9.39
NYISO 2006	$12.40	$5.42	$5.42	$2.20	$4.28	$6.48
CAISO 2008	$13.26	$3.56	$3.57	$2.35	$2.81	$5.17

Smart Clothes Dryer Benefits to Cost Ratio (Peak Load Shift + Spinning Reserves vs. 5% energy credit)

	Grid Operational Cost Savings (Benefits)	Cost of Additional Energy Consumption at 5% Credit	Benefits to Cost Ratio
	($/yr)	($/yr)	(-)
PJM 2006	$9.66	$2.11	459%
ERCOT 2008	$32.13	$3.93	818%
NYISO 2008	$13.60	$4.88	279%
NYISO 2006	$9.61	$3.57	269%
CAISO 2008	$8.20	$3.45	238%

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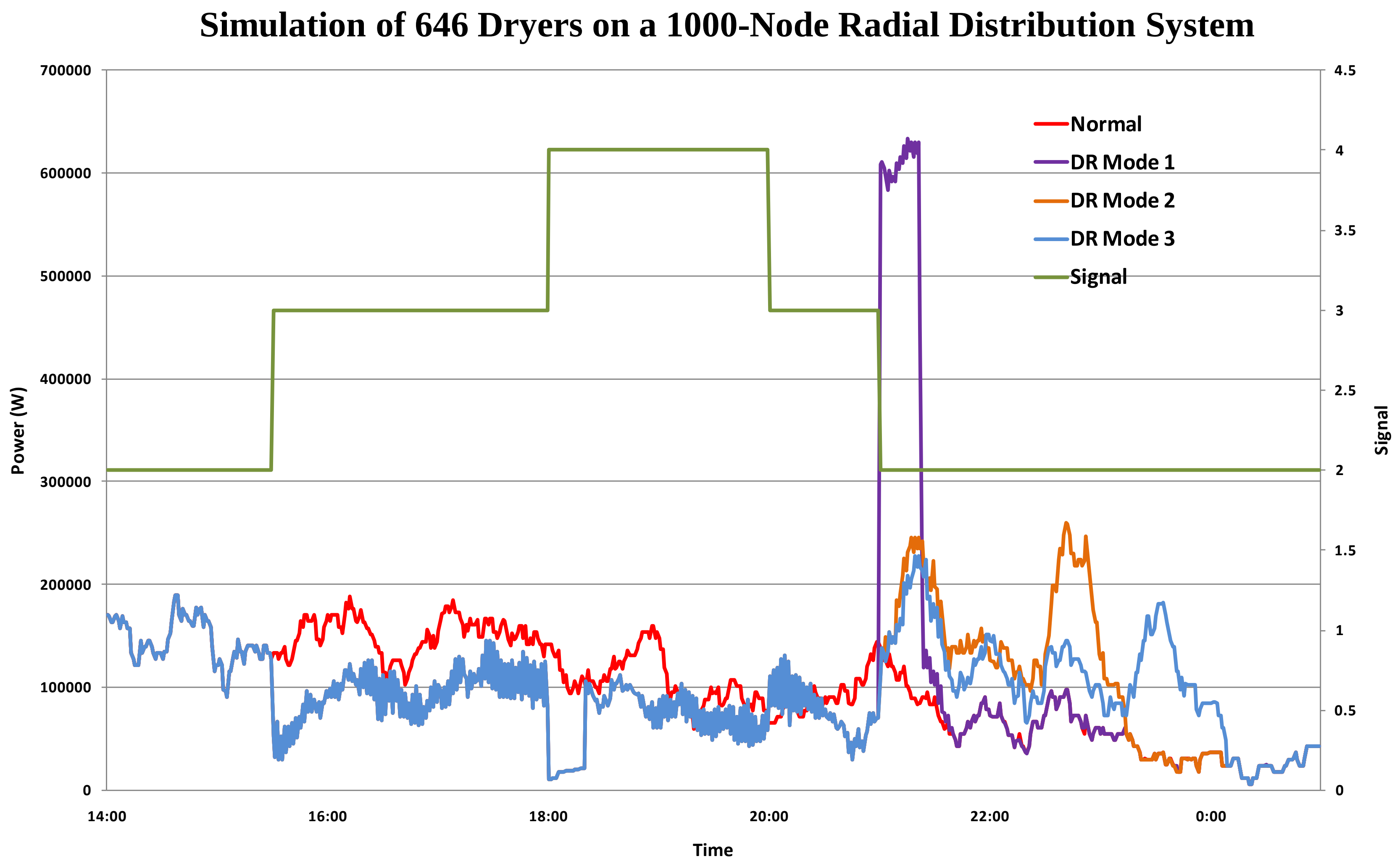
GE CRADA Smart Appliance Simulation



DR responses differ due to amount of delay in entering DR operation and other randomization features

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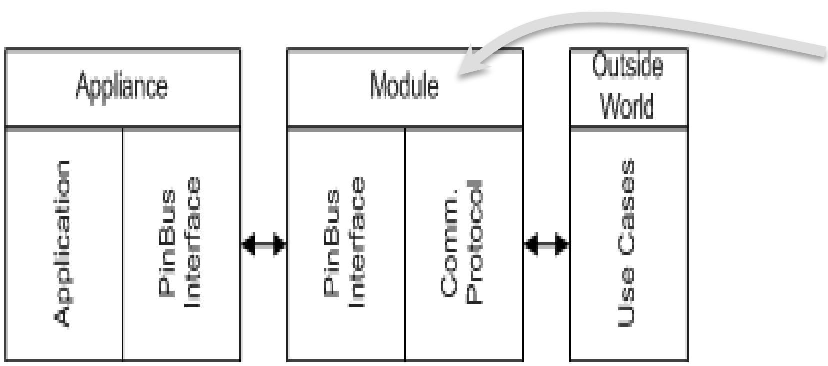
Technical Approach: Stakeholder Engagement

- Influenced development of interoperability standards and information models **white papers, presentations, & comments**
  - ➢ Actively participated and contributed to NIST process
    - ✓ Domain expert working groups B2G & H2G (HAN)
    - ✓ Priority Action Plans #10 (Standard Energy Usage Information), #9 (Standard DR and DER Signals)
  - ➢ Contributed to the EPRI's "**Demand Responsive Appliance Interface**" project specifying a simple, inexpensive interface to smart appliances
    - ✓ PNNL formulated a simple analog pin interoperability interface to minimize cost of smart appliances



Modules can be added by utility programs post-retail purchase

Action Plan for FY11

- Continue FY10 efforts to solidify the business case for HEM to remove barriers and accelerate deployment. In FY11, this will include evaluation of retail incentive structures

- Develop prototypes of advanced HEM applications hitherto unavailable and spur their commercialization

  - ✓ Diagnostics

  - ✓ Ancillary services

- Develop HEM best practices to spur quality in presentation, advice, etc., related to home energy use

  - ✓ Quality of end-use disaggregation: benchmark “ground-truth” disaggregated data sets

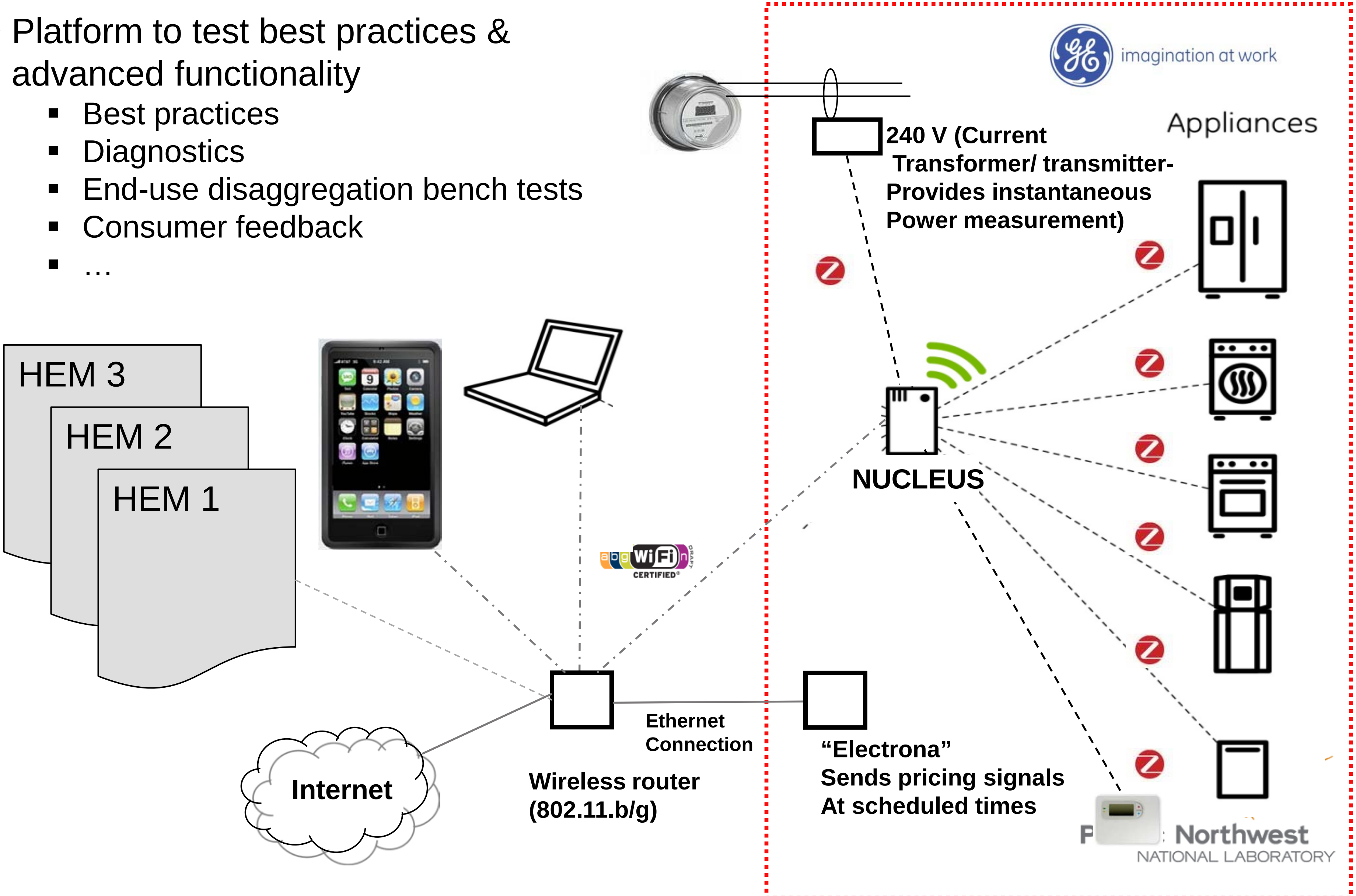
  - ✓ Best practices in user interfaces, displays, advice

Action Plan for FY11 (cont)

- Continue participation in national efforts towards achieving interoperability in the B2G/H2G/HAN part of smart grid
- Initial engagement with the Hawaii-Okinawa Smart Grid Demonstration team *(additional funding requested)*
- Continue collaboration with universities and industry to advance state-of-the-art HEM technologies

HEM R&D Testing Platform

- Platform to test best practices & advanced functionality
  - Best practices
  - Diagnostics
  - End-use disaggregation bench tests
  - Consumer feedback
  - …



Technology Transfer, Collaboration, and Partnerships

- *GE Appliances*: Help develop models of smart appliances and their dynamic behavior. Also, provide insight into requirements for customer participation in smart grid
- *AHAM, American Council for an Energy-Efficient Economy,* and *Northwest Power and Conservation Council*: Help with various underlying assumptions involved in the development of analytic model for studying benefits of smart appliances
- *Montana State University*: Devise intelligent load control algorithms to provide ancillary services
- *Montana Tech University*: Help with simulating dynamic behavior of smart appliances in GRIDLAB-D
- *Intelligent Energy Systems (IES), Alaska*: PNNL will support IES in the design of their rural Alaska microgrids. IES will provide field data for GRIDLAB-D simulations of the microgrids, including the Grid Friendly™ Appliance controller
- *Collaboration with Carnegie Mellon University*: Potential FY11 collaboration with CMU to study advanced disaggregation techniques on end-use metered data from homes with smart appliances
- *Whirlpool/Honeywell*: Help develop & pilot test an advanced HEM system engaging for energy savings (leverage ARR A award from EERE BT)

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