2012 Smart Grid R&D Program
Peer Review Meeting

Expanded Demand Response Functionality

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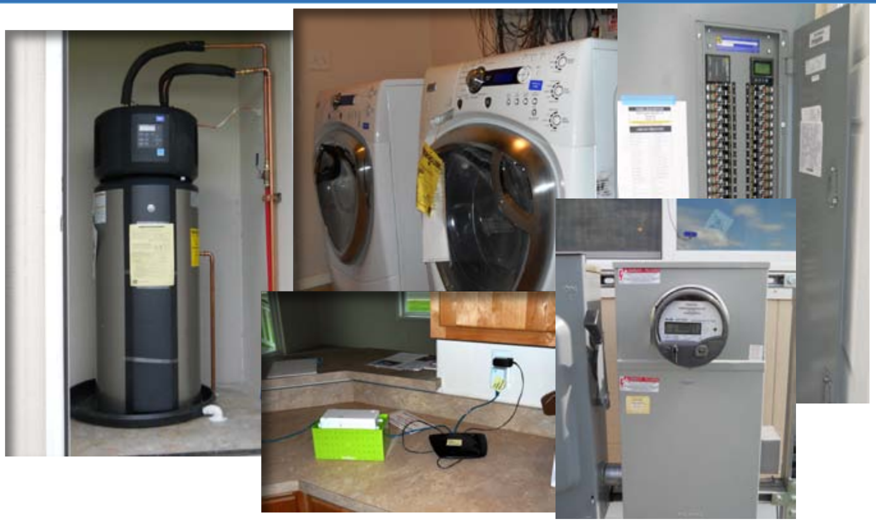
Expanded Demand Response Functionality

Objectives

- Determine capabilities and customer benefits of smart appliances to mitigate impacts of renewables (PV/wind) and provide ancillary services in partnership with industry and stakeholders.
- Advance the business case–from the consumer perspective–for smart appliances and home energy management systems (HEMs).
- Assist developing national standardization and regulatory paradigms to enable mass consumer participation.



Life-cycle Funding Summary ($K)

Prior to FY12	FY12 authorized	FY13 requested	*Out-year
$1,460	$545	$420	
Lab Homes DR Demonstrations		$70	$55
SGiP Business & Policy DEWG		$105	$100
GE CRADA		$165	$150
Smart Industrial Equipment (new)		$80	$135
*Out-year funding does not include new starts beyond FY13.			

Technical Scope

- Model development and GridLAB-D™ modeling and analysis of smart appliances responses to high and critical price signals for peak load reduction and for mitigating rapid voltage fluctuations due to high penetration of renewables.
- Demonstration of a suite of smart appliances/ HEM to understand responses, functionality and interoperability under high and critical price signals.
- Quantify the consumer benefits of DR.

Significance and Impact
DR Value Targets

Appliance	Spinning Reserve								
Appliance	Annual Machine Energy Consump-tion (kWh/yr)	Avg. Market Price, Load-Weighted ($/MW-hr)	Fraction of Load Available	Average Capacity Available (kW)	Wholesale Market Value ($/yr)	Wholesale Market Value ($/15-yr)	Equip-ment & Install-ation Cost ($)	Net Earned Value ($/15-yr)	Average Cost of Resource Provided ($/MWh)
Dryer	967	$9.08	100%	0.110	$8.78	$131.69	$20.00	$111.69	$1.38
Clothes Washer	139	$8.82	100%	0.016	$1.23	$18.42	$20.00	-$1.58	$9.58
Dishwasher	156	$9.53	100%	0.018	$1.48	$22.27	$20.00	$2.27	$8.55
Freezer	423	$7.97	100%	0.048	$3.37	$50.54	$20.00	$30.54	$3.15
Refrigerator	450	$8.08	100%	0.051	$3.64	$54.54	$20.00	$34.54	$2.96
Water Heater	2814	$8.77	100%	0.321	$24.67	$370.04	$100.00	$270.04	$2.37
Air Conditioner	2822	$4.24	100%	0.322	$11.97	$179.54	$100.00	$79.54	$2.36

- Availability for spinning reserve assumed to be 100% of load.
- Marginal smart appliance, thermostat, and HW control costs are estimates.
- Engaging small loads requires very low costs
  - Note clothes washer and dishwasher are not competitive at $20 marginal cost.
- Dryers, refrigerators, freezers, water heaters, AC best targets?

Significance and Impact
DR Value Targets

Appliance	Regulation								
Appliance	Annual Machine Energy Consump-tion (kWh/yr)	Avg. Market Price, Load-Weighted ($/MW-hr)	Fraction of Load Available	Average Capacity Available (kW)	Wholesale Market Value ($/yr)	Wholesale Market Value ($/15-yr)	Equip-ment & Install-ation Cost ($)	Net Earned Value ($/15-yr)	Average Cost of Resource Provided ($/MWh)
Dryer	967	$30.56	25%	0.028	$7.39	$110.88	$20.00	$90.88	$5.51
Clothes Washer	139	$30.18	25%	0.004	$1.05	$15.75	$20.00	-$4.25	$38.33
Dishwasher	156	$31.37	25%	0.004	$1.22	$18.34	$20.00	-$1.66	$34.22
Freezer	423	$31.27	80%	0.039	$10.58	$158.72	$20.00	$138.72	$3.94
Refrigerator	450	$31.25	80%	0.041	$11.25	$168.73	$20.00	$148.73	$3.70
Water Heater	2814	$30.57	50%	0.161	$43.01	$645.19	$100.00	$545.19	$4.74
Air Conditioner	2822	$39.02	50%	0.161	$55.05	$825.77	$100.00	$725.77	$4.72

- Fraction of load availability is variable.
- Marginal smart appliance, thermostat, and HW control costs are estimates.
- Engaging small loads requires very low costs
  - Note clothes washer and dishwasher are not competitive at $20 marginal cost.
- Dryers, refrigerators, freezers, water heaters, AC best targets?

Significance and Impact

R&D/Modeling of Electric Water Heaters (MSU subcontract)

- Model water heating as a DR resource and understand the economic value of this resource for frequency and voltage regulation to mitigate the impacts of wind and PV generation on the power grid.
- Model the impact of large (15%-30%) PV generation in a distribution feeder and on the whole power grid for concentrated and distributed PV *(2014-2020 load factor target).*

GE Smart Appliances GridLAB-D Modeling (CRADA)

- Quantify responses of individual appliances (refrigerator, washer, dryer, dishwasher, range, heat pump water heater) to high and critical price signals for peak load reduction and for mitigating rapid voltage fluctuations due to high penetration (>30%) PV *(2014-2020 load factor target).*
- Goal to quantify DR resource and better understand how the GE Nucleus/HEM will enable smart appliances to improve utility load factor and reliability *(2014-2020 load factor target)*.

Significance and Impact

Hawaii Electric Company (HECO)/Maui Electric Company (MECO) Demonstration

- Evaluate the impacts on distribution of renewable resources and develop mitigation strategies for future high penetrations of PV *(2014-2020 load factor target/2016 demonstration target).*
- Evaluate use of distribution level storage and/or EVs to mitigate transmission level wind variability *(2016 demonstration target).*

PNNL Lab Homes Smart Grid Appliance Demonstration

- Understand interoperability/DR of a suite of GE smart appliances under simulated price signals and occupancy *(2016 demonstration target)*.
- Integrate ‘smart’ EV charging and HEM evaluation with future PV+smart inverter *(2016 demonstration target)*.

SGiP Business & Policy Domain Expert Work Group (Overarching Activity)

- Quantification of peak demand response/ancillary services benefits of appliances/equipment (business case/DR value targets).
- Continued development of interoperability standards for smart grid appliances/HEMs.

Technical Approach & Transformational R&D

R&D/Modeling of Electric Water Heaters (MSU subcontract)

- Adaptive hill climbing (AHC) control and a step-by-step (SBS) controller is used to determine the minimum amount of required load manipulation.
- Linear programming (LP) is applied in a distribution feeder with 5 DR providers using the PJM's DR market to select the best DR price offers.
- Thermostat setpoint control is applied through direct load control (DLC) and time-of-use pricing programs for peak shifting and load following.

GE Smart Appliances GridLAB-D Modeling (CRADA)

- Create highly detailed models in GridLAB-D that incorporates GE's proprietary DR control algorithms for their appliances.
- Currently focused on mitigating rapid voltage fluctuations with appliances due to high penetration of solar (PV).
- Develop business case for DR from suite of appliances utilizing multiple revenue streams (spinning reserves and load shifting).

Technical Approach & Transformational R&D

Hawaii Electric Company (HECO)/Maui Electric Company (MECO) Demonstration

- Collaborate with HECO/MECO to create detailed models in GridLAB-D including building populations that represent customers served by Kehei, Maui substation.
- Solar data from NREL used to develop solar/PV models for substation feeder to examine impacts of current and future PV penetration.
- Evaluate possible mitigation strategies for transients to enable higher PV penetration levels in HECO/MEC service territory.

PNNL Lab Homes Smart Grid Appliance Demonstration

- GE smart appliance interoperability (with HEM) under occupancy-simulated controlled experimental conditions to verify/calibrate GridLAB-D modeling and field-quantify DR response potential.
- Add smart EV charging station and PV/smart inverter to this demonstration.

Context-Aware Adaptive Home Energy Manager (***EERE Funded/Honeywell Partner***)

- Analyze home equipment consumption/load profiles and occupancy characteristics to understand optimal DR targets and context-aware HEM technology for development of a business case. HEM technology to be demonstrated.

Technical Accomplishments FY10-11

Published report: *Demand Response in the Smart Grid*	June 2011
Established interim R&D test environment in PNNL EIOC with GE smart appliances in advance of testing in Lab Home	April 2011
Estimated value of water heaters for providing frequency regulation; A.O. Smith licenses PNNL controller technology.	Mar 2011
Formed appliances integration subgroup as co-chair under SGIP BnP workgroup.	Jan 2011
Published report: *Use of Residential Smart Appliances for Peak-Load Shifting and Spinning Reserves: Cost/Benefit Analysis*	Dec 2010
CRADA in place with GE Appliances	April 2010
White paper to SGIP Home-to-Grid (H2G) workgroup “Free Market Choice for Appliance Physical Layer Communications”	June 2010

Technical Accomplishments FY12 to Date

MSU - Significance: *2014 -2020 load factor target* April 2012

- Modeling indicates large percentage of utility peak EWH demand shifted to off-peak hours by controlling thermostat setpoints. The proposed algorithm successfully regulates the frequency faster than speed governor control.
- A simplified grid model was constructed, which successfully captures the effects of frequency and voltage variations caused by up to 30% PV at the distribution level.

GE CRADA - *Significance: 2014-2020 load factor target* April 2012

- Technical report: *Modeling of GE Appliances in GridLAB-D: Peak Demand Reduction*

HECO/MECO Demonstration Feb 2012

Significance: 2014-2020 load factor target/2016 demonstration target

- Created detailed models in GridLAB-D of building characteristics that conform to Kehei, Maui substation feeder; collecting PV data for integration (NREL).

Lab Homes Demonstration – *Significance: 2016 demonstration target* June 2012

- Instrumented/GE appliances installed, connected to Nucleus and commissioned.

Planned Technical Accomplishments FY12-14

- Complete MSU testing of EWH model for mitigation of PV transients and wind integration (ramp-up speed and mitigation quantification), **September 2012.**
- Complete GE CRADA Task 3 report on evaluation of DR appliances/EV charging on distribution feeder voltage regulation with up to 35% PV penetration, **August 2012**.
- GE CRADA (amended) to develop transactive algorithms for closed-loop control system for appliances to bid into real-time markets represented at feeder substation, **March 2013.**
- GE CRADA (amended) to evaluate DR characteristics of GE smart room A/C (GRIDLab-D and 2nd generation HPWH in Lab Homes (update Task 2 modeling report), **January 2014**.
- GE CRADA (amended) to monetize value of DR and EV charging; update/enhance ancillary services resource spreadsheet, **June 2013**.
- Complete HECO/MECO substation modeling with high % PV penetration and support demonstration as requested by HECO/MECO, **February 2013.**
- Complete analysis for Honeywell to understand appliance/equipment DR potential and HEM adaptive requirements. **March 2013.**
- Develop collaborative and/or CRADA with industrial partners and initiate industrial machinery DR demonstration. **April 2014.**

Project Team Capabilities & Funding Leverage

Project Collaborators & Leveraging

- MSU ($155K DOE/SC): cost-sharing model development of DR response of EHW for PV and wind integration.
- GE Appliances (CRADA $530K): Appliances, hardware/Nucleus, DR response algorithms for GridLAB-D modeling/Lab Home demonstration and general technical support.
- HECO/MECO/NREL/Hitachi/New Energy and Industrial Technology Development Organization (NEDO): characteristic/customer data for creating GridLAB-D models of feeder; assistance in evaluation of Hitachi micro DMS for future Smart Grid demonstration on Maui.
- BPA/DOE/EERE/PNNL ($935K): Funding for Lab Homes siting, construction, modifications and support for instrumentation; funding for EV charging station.
- Honeywell/DOE/EERE ($200K): Understanding residential equipment and occupancy characteristics for developing high value DR targets for developing business case for unique HEM. DR/HEM evaluation in a 5-home demonstration led by Honeywell.

In these collaborations, the DOE value added includes: cost-sharing (EERE/BPA/SC); providing primary data (RECS); independent analysis and modeling (GridLAB-D); and/or a platform for field data collection (Lab Homes).

Contact Information

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