Opportunities for Mass Market Demand Response to Provide Ancillary Services

Rob Pratt
Pacific Northwest National Laboratory
robert.pratt@pnl.gov

with contributions from
Dave Najewicz, GE Appliances

DOE OE/EERE Workshop
Washington, DC
October 2011

Pacific Northwest
NATIONAL LABORATORY

What do We Mean by “Mass Market” DR?

- “Mass market” suggests mass distribution of demand response (DR) devices with a “one-size fits all” character
- Mass distribution could be
  - Consumer-driven purchases, with or without utility/grid subsidy
  - Wide-scale deployment with utility purchase and installation
  - Something in between
  - Suggests opportunities for market transformation activities
- “One-size fits all” implies residential & small/medium commercial loads such as
  - Thermostats (residential, unitary commercial)
  - Elec. water heaters (or load controllers)
  - Pool/spa pumps & elec. heaters (or load controllers)
  - Smart appliances (clothes washers, dryers, dishwashers, refrigerators, freezers)
  - Smart electronics? (computers, entertainment, printers, etc.)
  - Other?

Mass Market DR-based Ancillary Services – Current Baseline

- Many utility programs, pilots, demos of DR focused on peak loads/prices, not ancillary services
- A few notable demos of ancillary services
  - RLTech freq.-responsive refrigerators in UK (n=300/3000?)
  - PG&E/LBNL – spinning reserves, Res. AC (n=250)
  - SCE/LBNL/ORNL – spinning reserves, Res. AC (n=2000)
  - Ecofys (BPA/NW utilities) – regulation for wind integration
    - Water heaters (n=90), thermal storage furnaces (n=7), refrig. warehouses (n=5), commercial thermostats (n=?)
  - PJM/Steffes – regulation, Res. water heater (n=1)
  - GridWise Olympic Peninsula (BPA/NW utilities) – autonomous, under-freq. load shedding dryers & water heaters (n=50 ea.)
  - NW Smart Grid Demo (ARRA) – numerous technologies
  - PJM – regulation, PHEVs (3)
  - Analysis/PNNL: PHEVs could supply all additional ancillary services for integration of 30% wind in Pacific NW

Technical Issues

Spinning reserve & up regulation (decreasing loads)

- Similar to traditional demand response (relatively well understood)
  - Curtailing all or part of load
  - Slowing appliance processes
  - Requires short-cycle protection for refrigerant cycles (AC, refrigerators, freezers, heat pumps)

Down regulation (increasing loads)

- Difficulty is designing control strategies to increase loads
- Returning curtailed loads or slowed processes
- Shifting cycles coincident with reg. signal can be accomplished by shifting thermostat setpoints
  - Only works on avg. in populations, not individual loads
- Desire to mimic droop characteristic of generator governor controls
  - More/faster frequency deviation = more response

Value of Spinning Reserve from Residential DR

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 for illustration
- Engaging small loads requires very low costs
  - Note clothes washer & dishwasher are not competitive at $20 cost
- Dryers, refrigerators, freezers, HW, AC better targets (?)

Pacific Northwest NATIONAL LABORATORY

Five Characteristic Load Types re. Regulation

Load Type	Control Strategy	Resource Availability
Periodic, low duty-cycle: refrigerator*, freezer*	shift cycles coincident with reg. signal	80% (?)
Periodic, high duty-cycle: AC*, heat*, HVAC*	shift cycles + some curtailment	50% (?)
Continuous service: CW, dryer, DW	slow rate of service, modulate	25% (?)
Thermal storage: HW - no mixing valve	slow rate of service, modulate	50% (?)
Thermal storage: HW - with mixing valve	also allows overheating	100% (?)

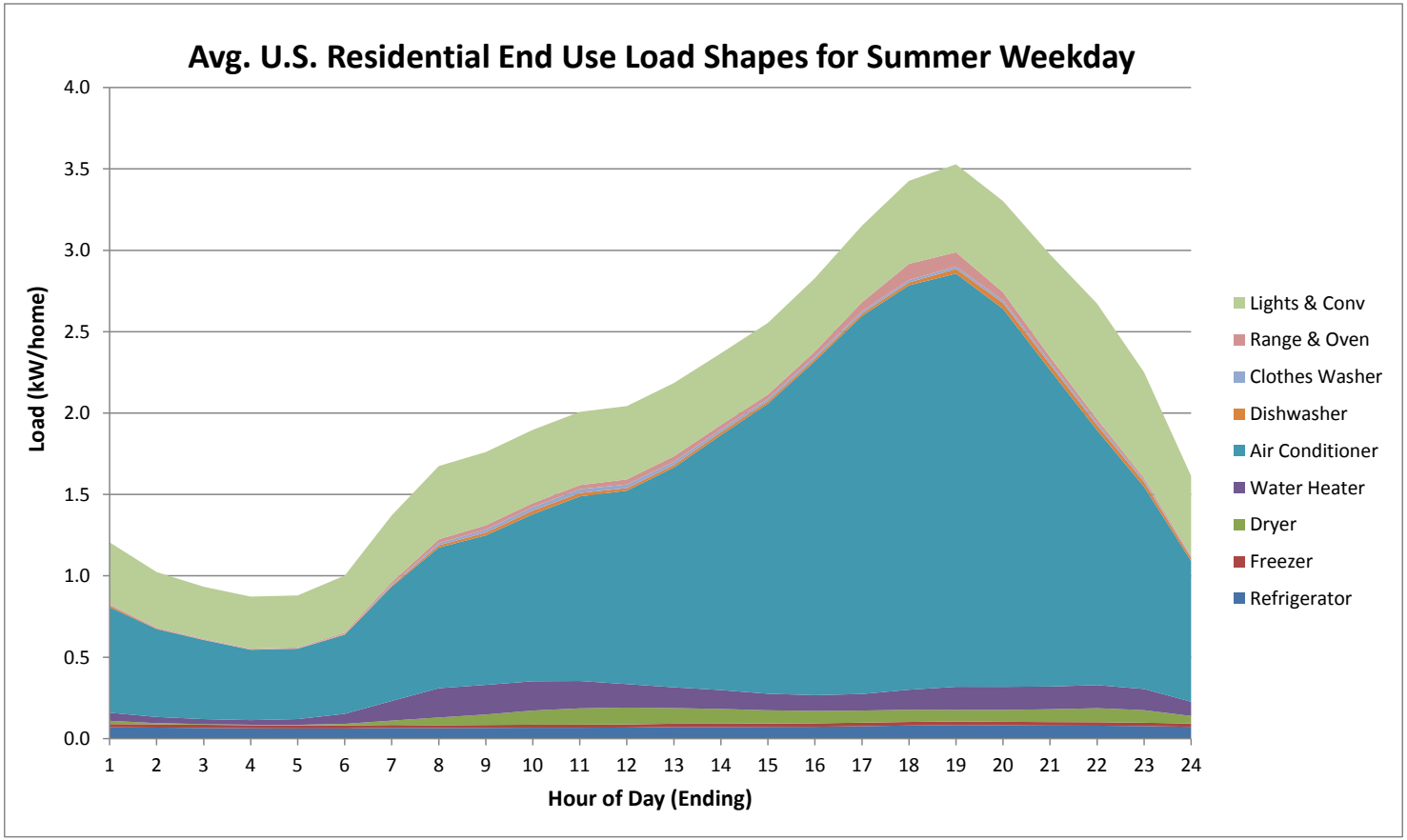
* Includes small medium commercial: offices, retail, grocery, warehouses

Value of Regulation from Residential DR

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

- Availability for regulation assumed (see previous page)
- Marginal smart appliance, thermostat, and HW control costs are for illustration
- Engaging small loads requires very low costs
  - Note clothes washer & dishwasher are not competitive at $20 cost
- Dryers, refrigerators, freezers, HW, AC better targets (?)

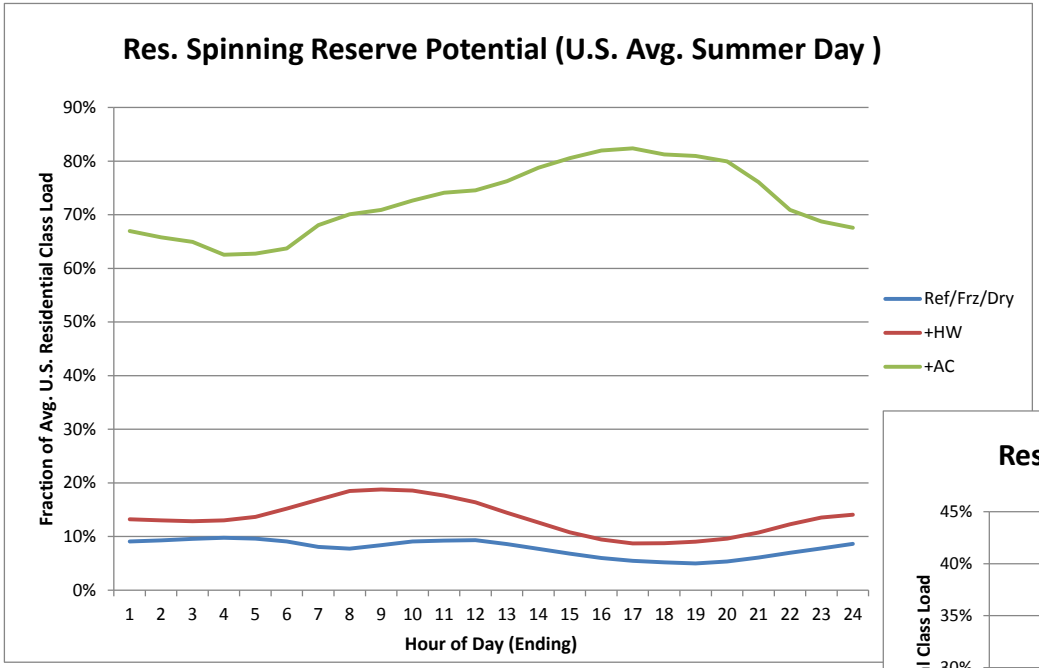
End-Use Load Shapes (Summer Weekdays)



- Metered end-use loads shapes (ELCAP)
- Scaled to current appliance standards & U.S. avg. AC, elec. heat & HW loads
- Appliances as a group are always available (unlike AC, heating)

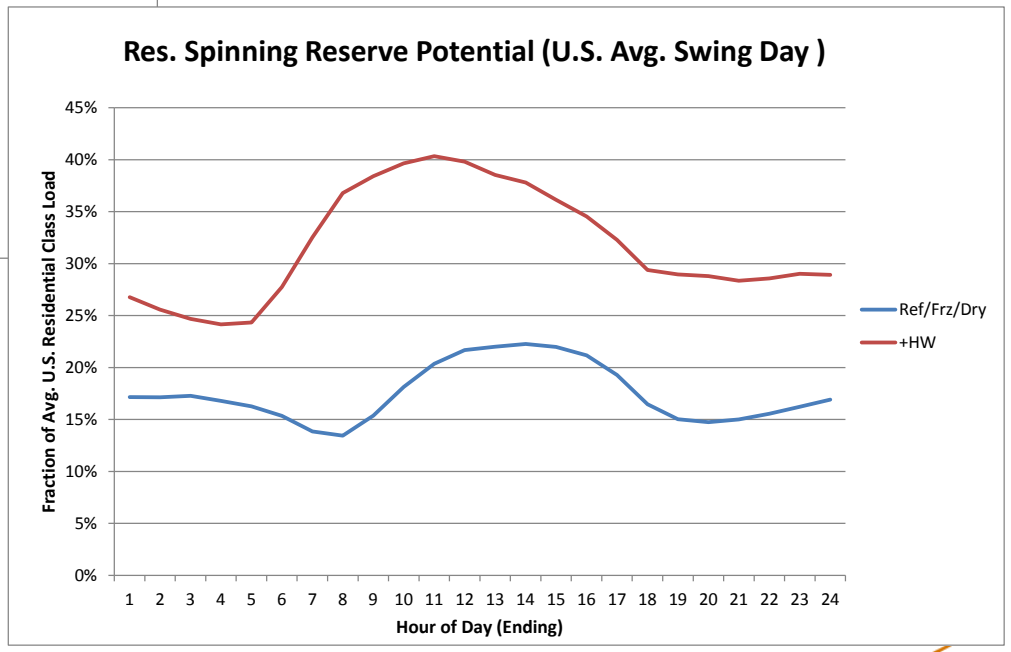
Pacific Northwest
NATIONAL LABORATORY

Potential for Spinning Reserve from Res. DR



Summer

- Ref + Frz + Dry: 5% - 10%
- with HW: 9% - 19%
- with AC: 63% - 82%

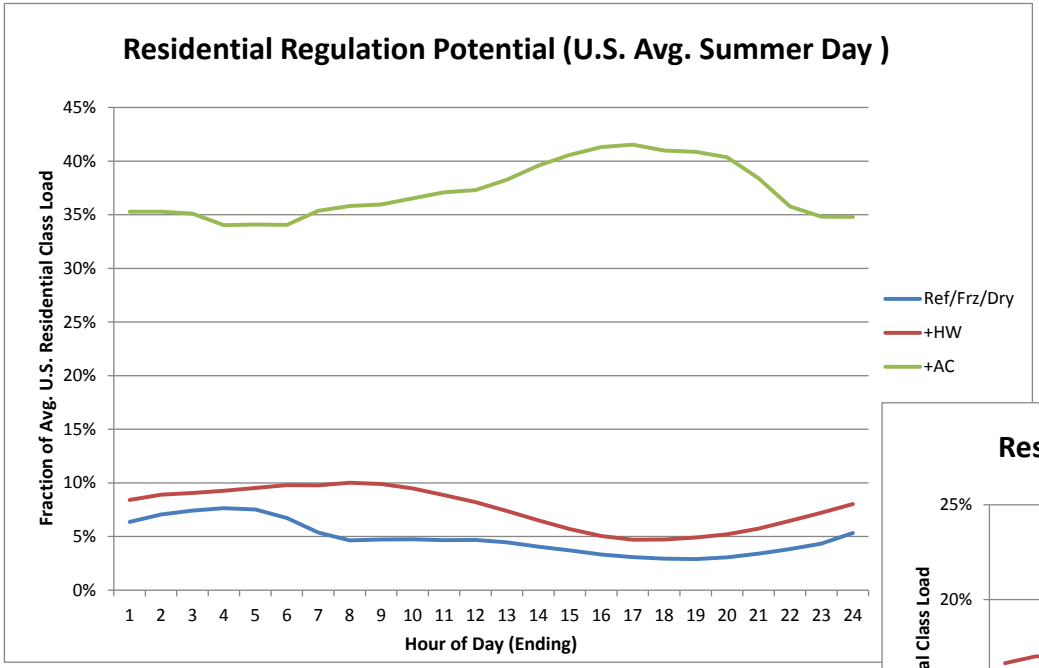


Swing Season

- Ref + Frz + Dry: 13% - 22%
- with HW: 24% - 40%

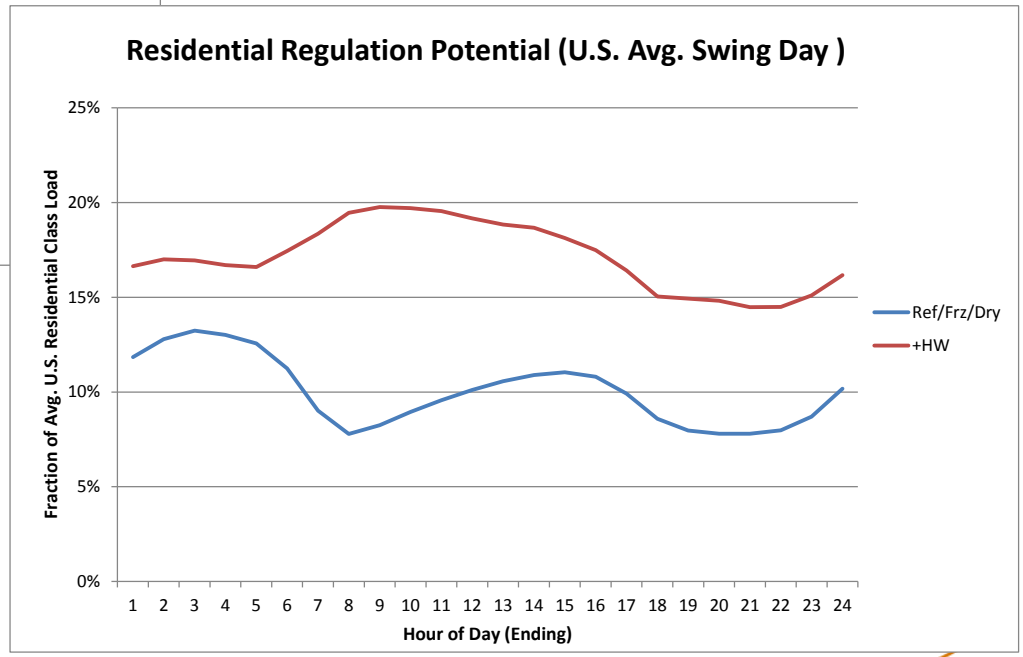
Pacific Northwest
NATIONAL LABORATORY

Potential for Regulation from Res. DR (Fraction Of Res. Class Load)



Summer

- Ref + Frz + Dry: 3% - 8%
- with HW: 5% - 10%
- with AC: 34% - 42%



Swing Season

- Ref + Frz + Dry: 8% - 13%
- with HW: 14% - 20%

Pacific Northwest
NATIONAL LABORATORY

Regulatory Barriers

- Requirement for 4-sec SCADA connection could be (is?) show-stopper for mass market
- Possible from RTO to aggregator, not to loads
- Market rules may have to be adapted
- Balancing area consolidation could enable autonomous approaches: frequency deviation = ACE
- Low total need for regulation (~1%)
  - Will increase with renewables
  - Suggests limited market, potential for price collapse if DR offers plentiful resource into a buyer's market

Barriers – Infrastructure Requirements

- Communications
  - High speed 1-way (broadcast) – NIST BnP DEWG proposing FM radio
  - 2-way (supports M&V)
  - Autonomous: low cost, low latency
- AMI – required (except for one-time payment approaches)
  - Rate of availability of AMI may limit rate of deployment, delay ramp-up by manufacturers
  - Advanced 2G meters being announced
    - M&V could be accomplished with high-speed meter reads
    - Could integrate signal & load coincidence in meter to compute incentive (to deal with bandwidth issues)

Operational and Market-Rule Barriers

Spinning Reserve

- Duration matters (opposite of power plants)
- Loads acts fast, but hard to sustain
  - Does this mean power plant reserve capacity is not displaced, just hours of operation?
- Some RTOs require load switches: no thermostat/population approaches

Regulation

- Some concern about operator knowledge of resource limits
  - Forecasting the resource availability
  - How long until response declines?
  - What rate is the rate of decline?
- Possibility of unstable control strategies

Barriers – Incentives to Customers/Manufacturers

- How is a customer rewarded?
  - 1-time payment (e.g., on purchasing/enabling smart appliance
  - Incentives for response (requires ratemaking + AMI)
    - Regulation: requires real-time prices or response rebates/credits
    - Spinning reserve: could also involve CPP*-like approaches
- How is manufacturer incentivized?
  - Low marginal costs for smart appliances
  - AHAM petition for Energy Start credit
    - Important near term signal to jump start market
    - May not insufficient in long term

** CPP: critical peak pricing*