CLEAN ENERGY MINISTERIAL

Accelerating the Transition to Clean Energy Technologies

Energy Efficient Cooling and Demand Response

Pre-Read for Public–Private Roundtable

Clean Energy Ministerial

12 May 2014

Seoul, Republic of Korea

OUTLINE

1 **Objectives**

2 Current Landscape

3 Potential Solutions

4 Barriers to Implementing Solutions

5 Opportunities for Progress

Objectives

- To provide an understanding of the technical, economic, and policy issues and opportunities with demand response technologies and efficiency to mitigate peak load demand from space conditioning.
- To identify emerging challenges and promising technologies and policies for addressing these challenges.
- To provide perspective, solutions, and inspiration on how to integrate and accelerate deployment of energy efficient and smart space cooling technologies and policies that can be carried forth through public–private collaboration within the context of the Clean Energy Ministerial.

Discussion Questions

- What are the key trends in cooling demand?
- What are the drivers of these trends?
- Do trends differ in developed/developing / urban/rural settings?
- What are the positive and negative effects of the trends?
- How can the negative effects be managed?
- Can energy supply systems cope with peak cooling loads?
- What can we learn from the experience of CEM countries?
- What are the most promising technical responses?
- What are the most promising policy responses?
- How do building thermal performance, cooling energy efficiency, and demand response interact?
- What are the most effective ways for the appliance industry, government, energy suppliers, and consumers to work together?
- How can CEM countries cooperate to address these issues?

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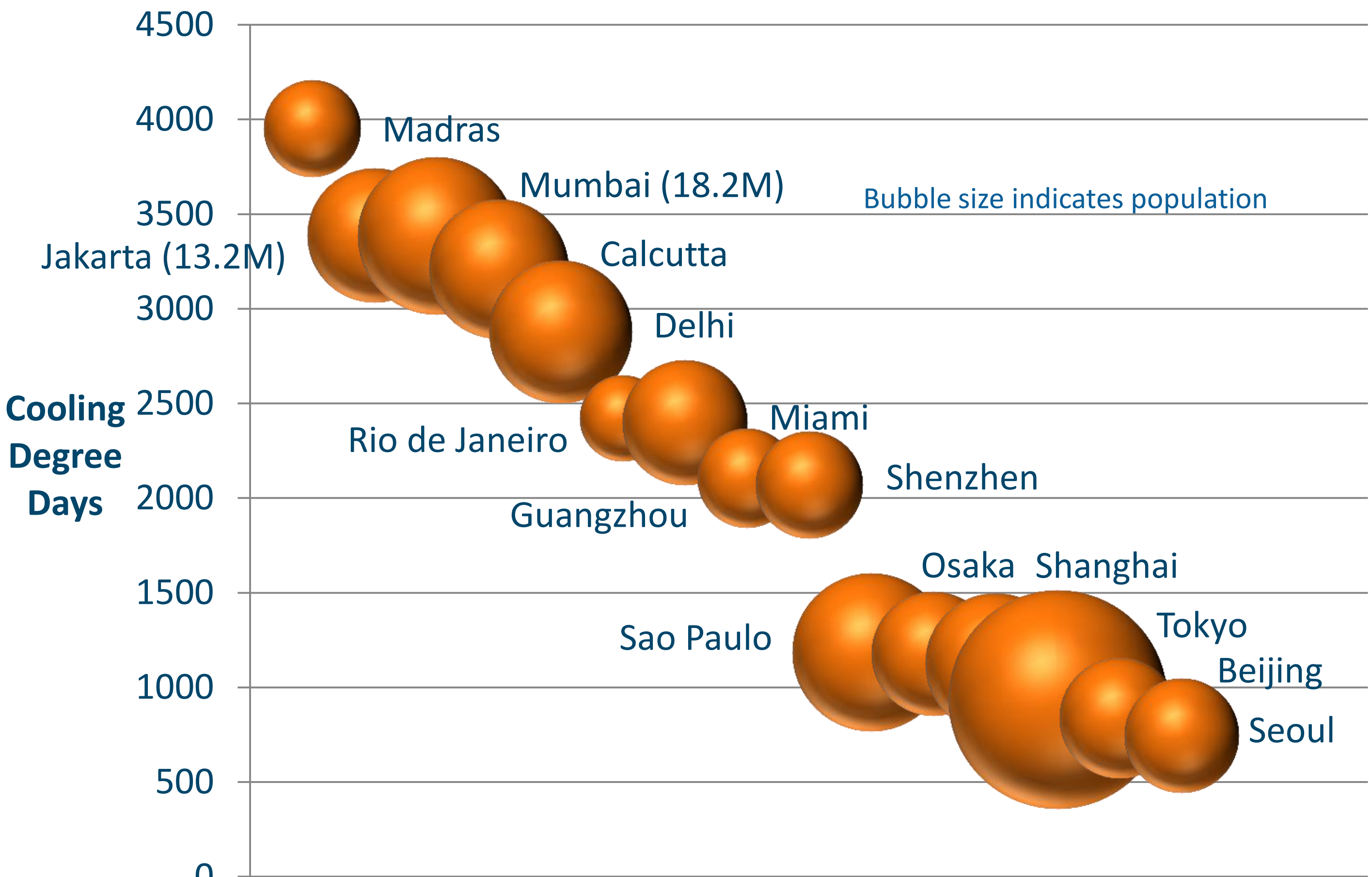
High Cooling Energy Consumption in Largest Metros



Source: Sivak, 2009

Many of the world's most populous metropolitan areas have hot climates

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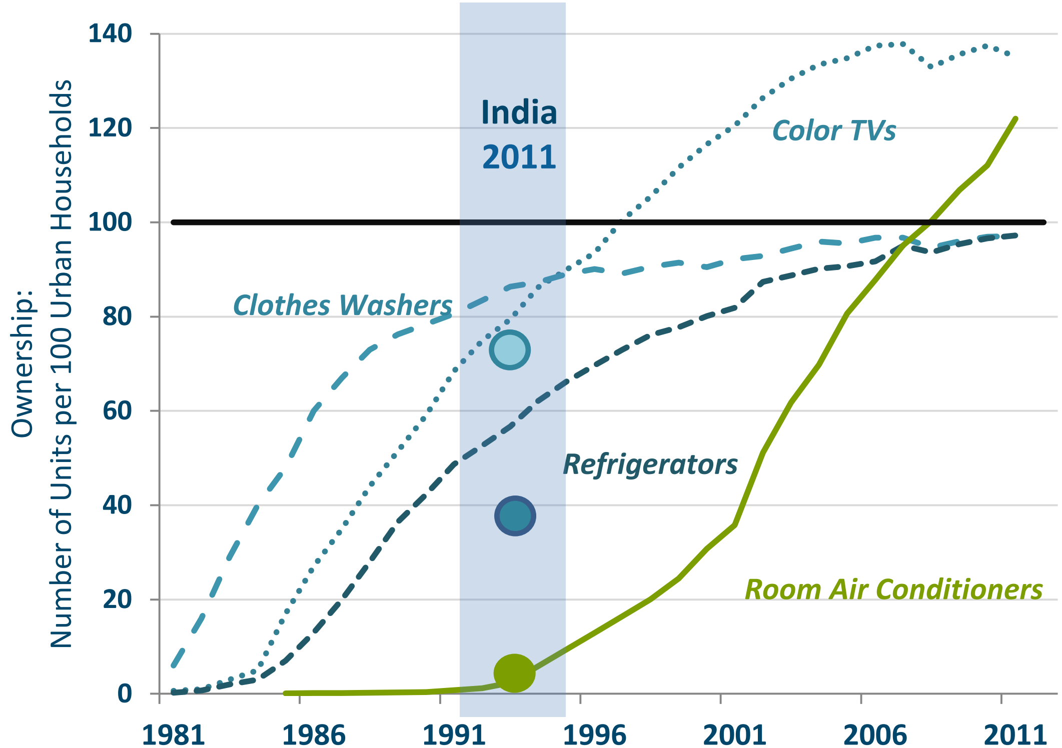
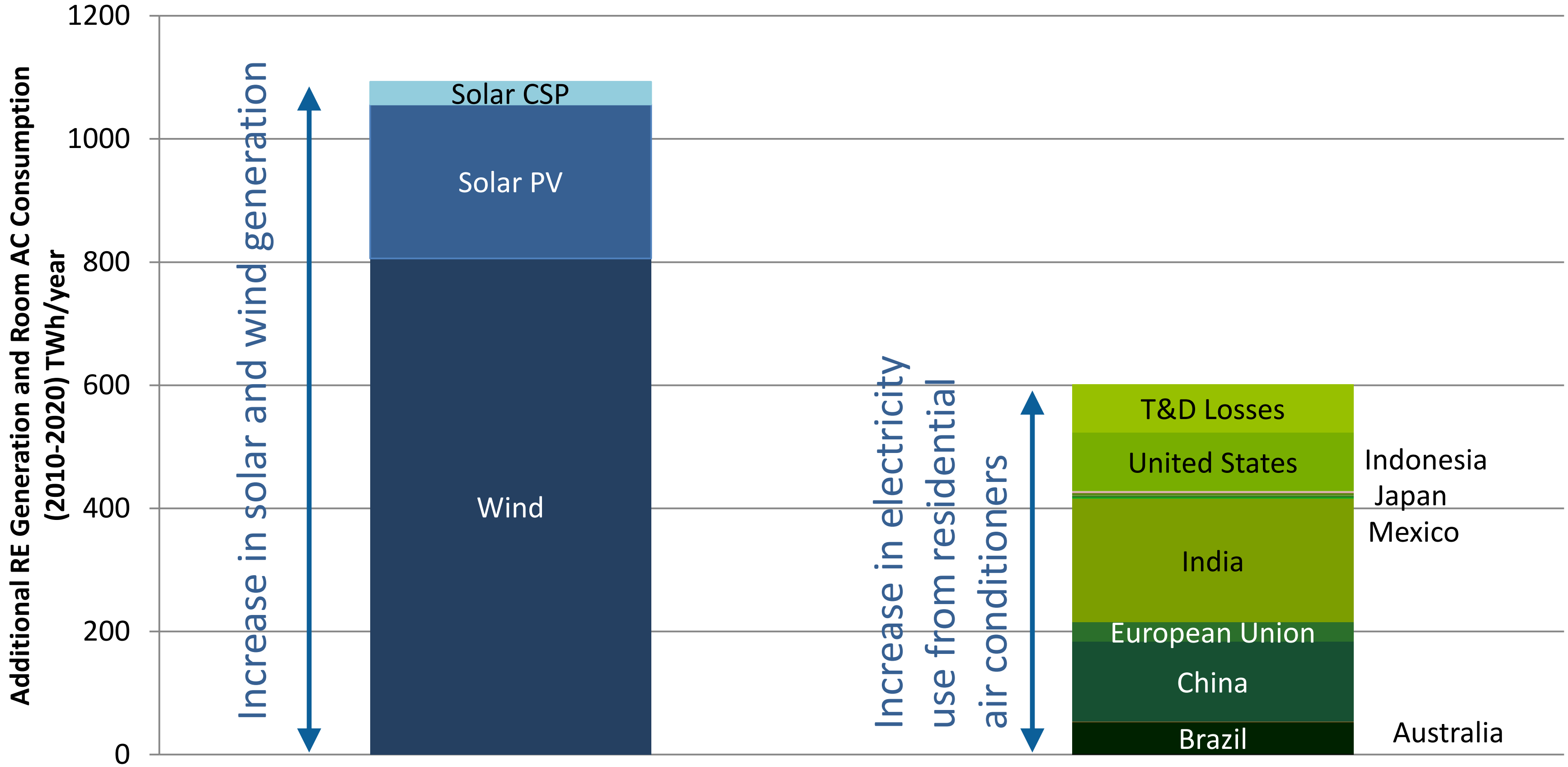
Example of High Growth—China



Source: NSSO, 2012, Fridley et al., 2012

- The AC ownership rate in urban China went from almost 0% in 1990 to over 100% in 25 years.
- AC sales in major emerging economies are growing at rates similar to China circa 1994–1995, e.g., India room AC sales growing at ~30%/year, Brazil at ~20%/year (Shah et al., 2013).

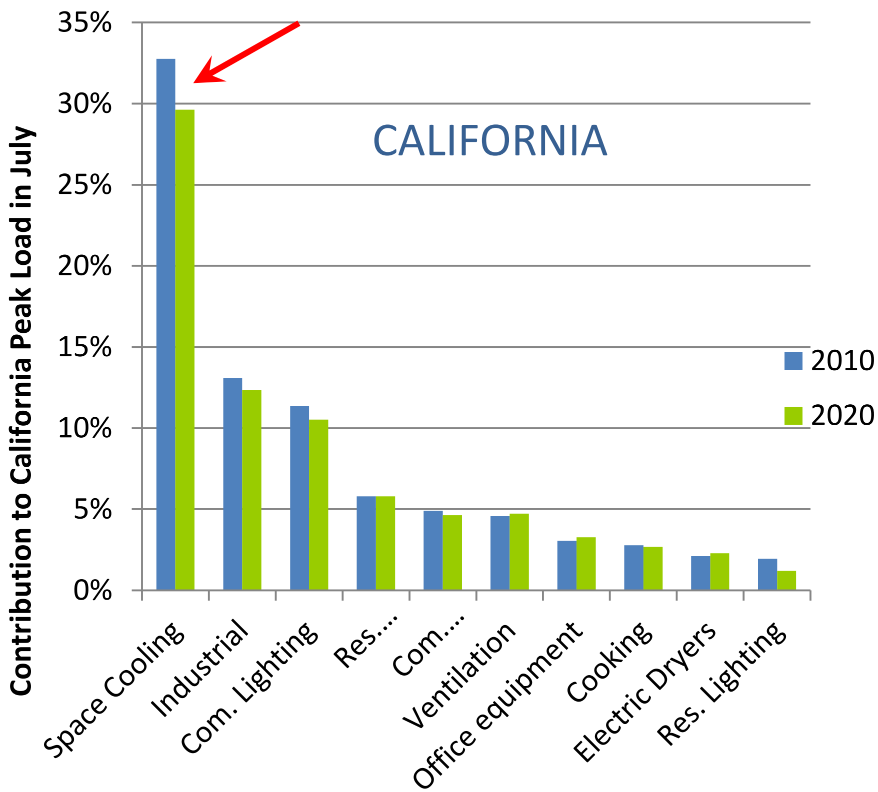
Growth in Renewable Generation and Cooling Energy, 2010–2020



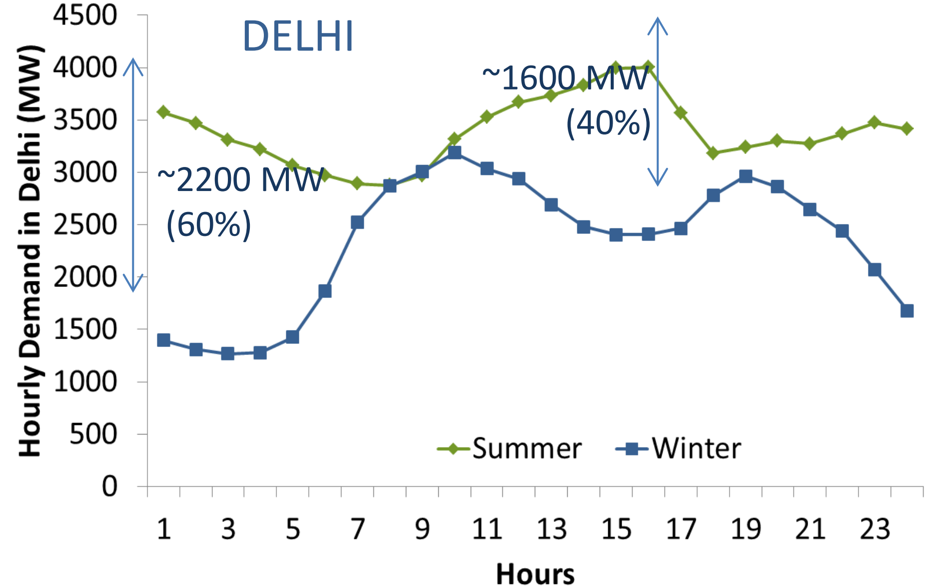
Renewable energy generation: IEA World Energy Outlook 2012 (Current Policies scenario).
Residential air conditioning consumption: Shah et al. (2013); LBNL's Room AC analysis for the SEAD initiative; and V. Letschert et al. (2012), LBNL's BUENAS model.

Incremental electricity consumption from residential ACs alone is >50% of solar and wind generation projected to be added between 2010 and 2020.

Large Grid Impact of Cooling Peak Load



Source: End-use peak load forecast for Western Electricity Coordinating Council, Itron and LBNL, 2012

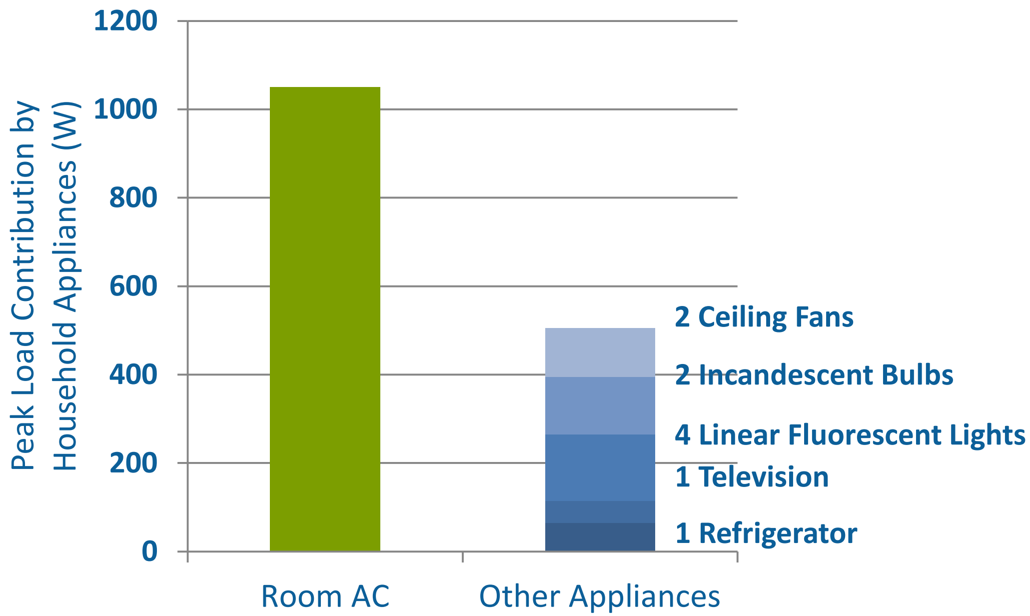


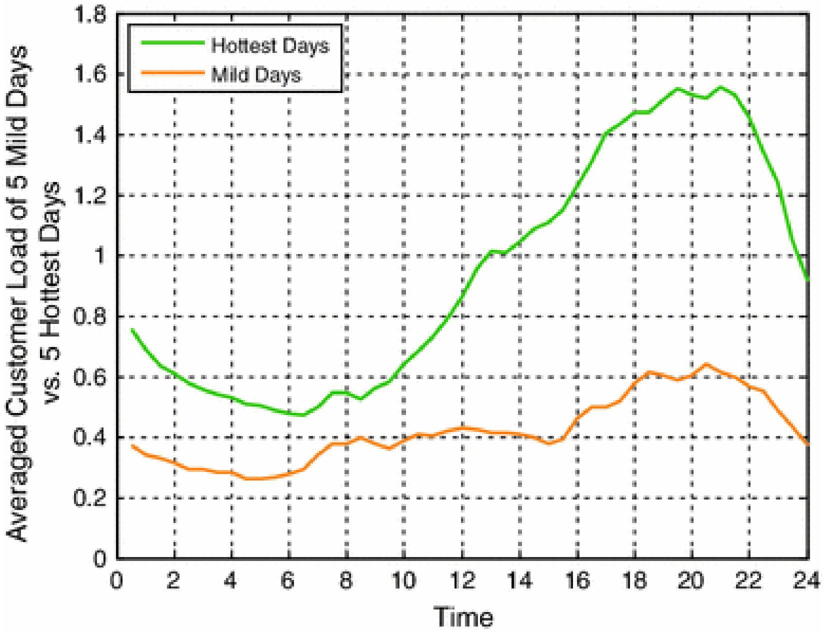
Source: DSLDC, 2012

Cooling comprises ~30% of current and forecasted peak load in California…

…and 40%–60% of summer peak load in large metropolitan cities with hot climates, such as Delhi, India.

COOLING CONTRIBUTION TO PEAK LOAD – PER APPLIANCE





Ausgrid, Australia

Source: Smith et al., 2013

Cooling is the largest contributor to peak load on an appliance basis…

…and can triple load on the hottest days in some areas, e.g., New South Wales, Australia.

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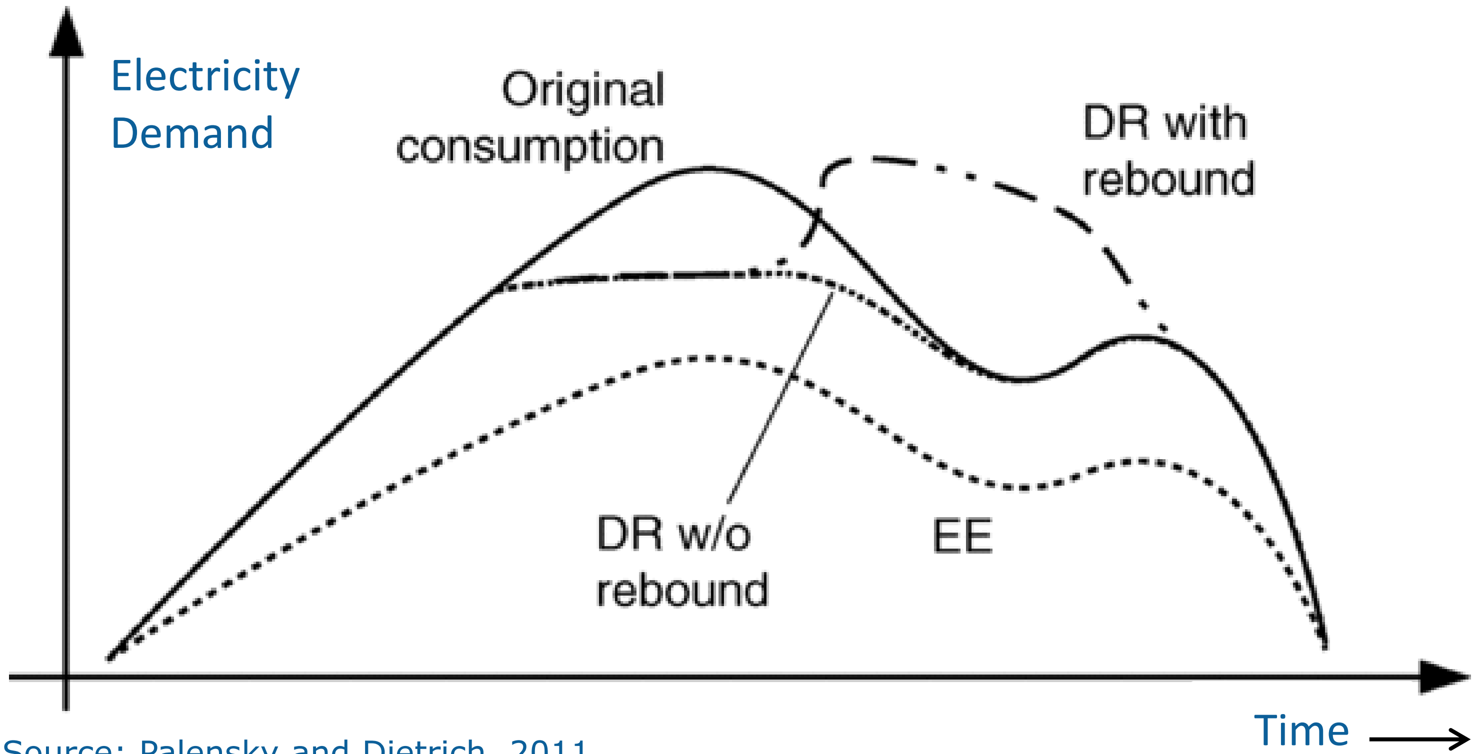
Current Landscape

Energy Efficiency and Demand Response

- ***Energy Efficiency*** refers to increasing the output of energy services from a given level of energy use (or providing the same outputs with less energy) through changing building or product technology. This is more durable than changing the behaviour of users.

- ***Demand Response*** refers to changes in the operating mode of appliances or equipment in response to changes in electricity prices, the state of the electricity network, or external requests for load modification. The user may respond manually, or may willingly permit automated changes in return for lower energy costs or cash incentives.

Energy Efficiency and Demand Response



Source: Palensky and Dietrich, 2011

- Energy efficiency reduces the original cooling demand uniformly and permanently.
- Demand response reduces the original cooling demand at the peak.
- Demand response with "rebound" shifts some of the original demand to a non-peak time as some, but not all, of the curtailed demand comes back online.

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ENERGY EFFICIENCY: POTENTIAL AND EXAMPLES

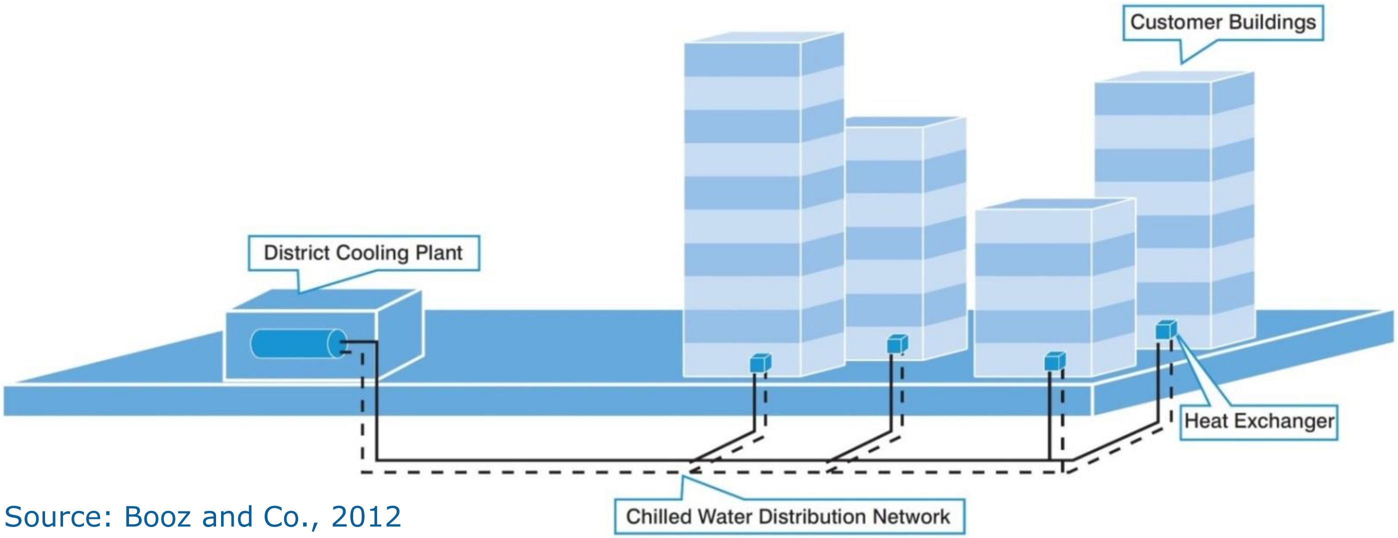
Cooling Efficiency Has Large Potential

- Air Conditioner Energy Efficiency:
  - With currently available technology, efficient air conditioning can save 60%–70% of energy consumed currently.
  - Efficient split air conditioners alone can save energy equivalent to 180–300 medium-sized (~500 MW) power plants by 2030. (Shah et al., 2013)
- Building Energy Efficiency:
  - With recent advances in materials and passive design elements, final energy use for cooling can be decreased by 60%–90% for new buildings and 50%–90% for retrofits, with cost savings typically exceeding investments. (GEA, 2012)

Energy Efficiency Programs and Policies

Efficiency policies could include appliance and building codes and minimum energy performance standards, labels, incentive programs, and awards programs, depending on the level of efficiency targeted.

SYSTEM-WIDE EFFICIENCY: DISTRICT COOLING



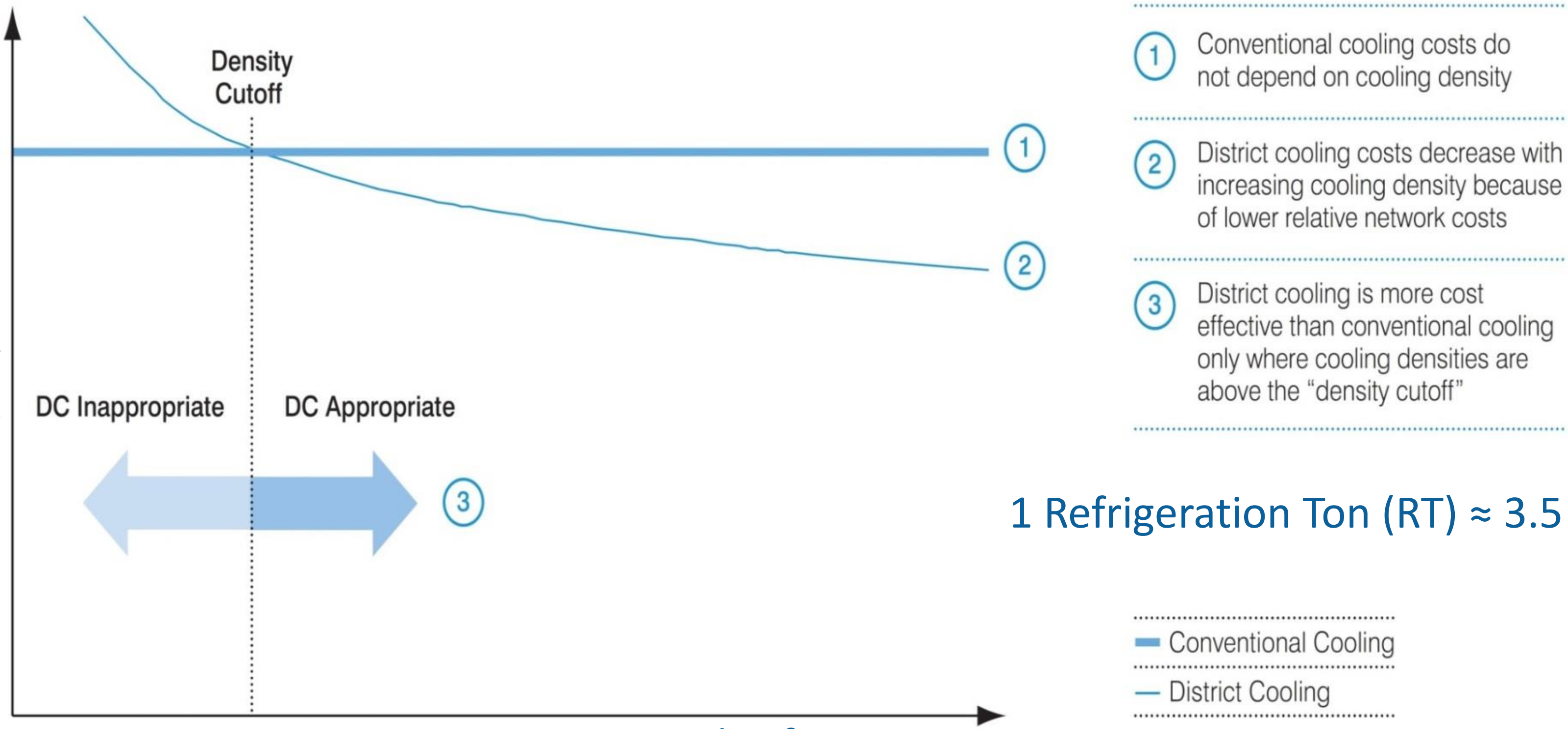
Source: Booz and Co., 2012

Efficient cooling technologies could include district cooling:

- Has 30%–50% lower energy requirements per "refrigeration ton" or RT (~3.5 kW) compared to single-building or single-user cooling.
- Efficiently aggregates peak demand from multiple disparate cooling loads (e.g., residential, commercial, office), reducing required peaking cooling capacity compared to aggregate capacity of individual loads.
- Can be integrated with thermal energy storage as a demand response strategy, e.g., storing chilled water.

DISTRICT COOLING REQUIRES HIGH COOLING DENSITY

Cost of cooling ($/RT)



1 Refrigeration Ton (RT) ≈ 3.5 kW

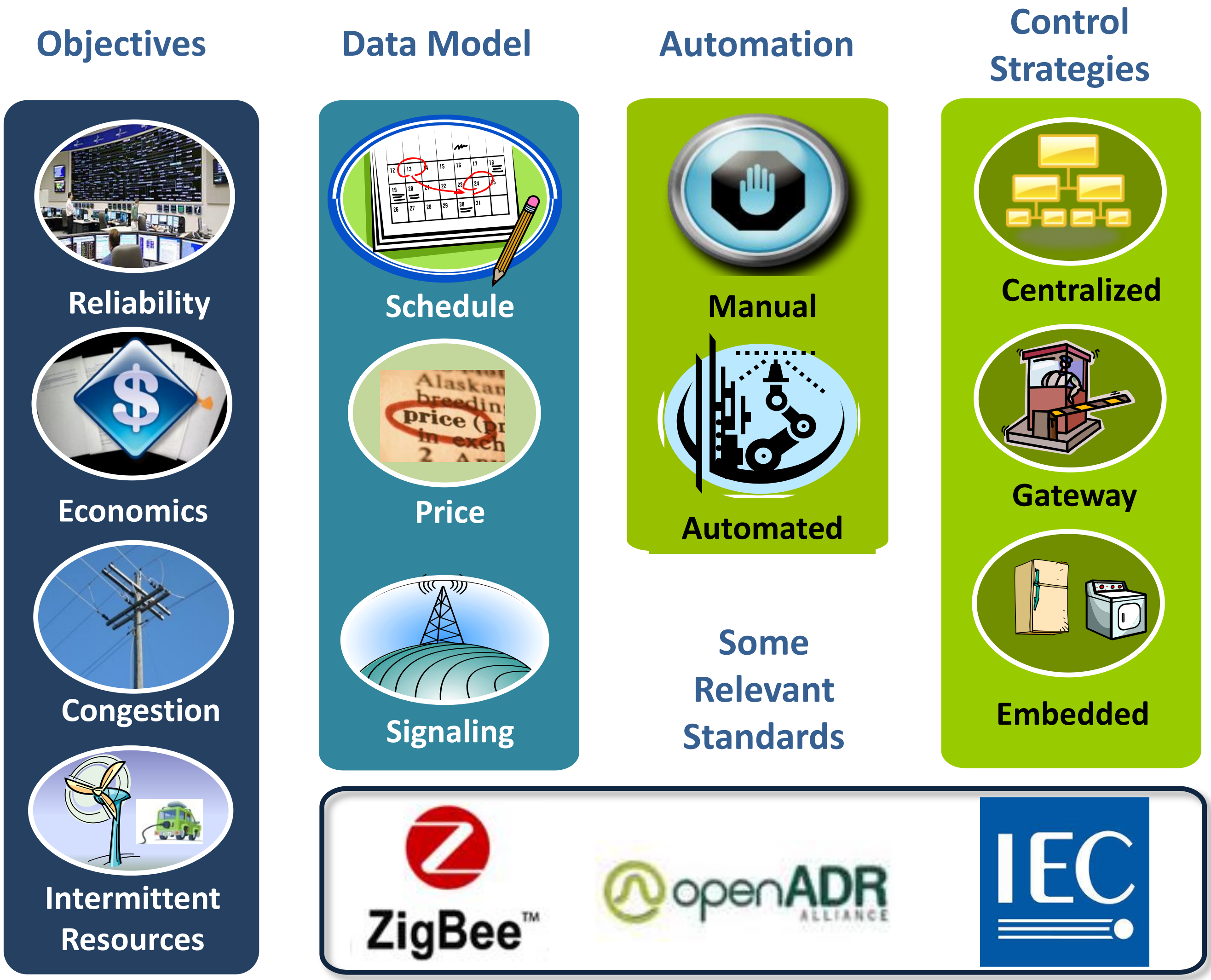
Cooling density (RT/km^2)

Source: Booz and Co., 2012

Cooling density is a measure of how much cooling is required per geographic area. In areas where required cooling density is high and space cooling is affordable, efficient cooling could include approaches such as district cooling.

DEMAND RESPONSE: POTENTIAL AND EXAMPLES

DEMAND RESPONSE SIMPLIFIED



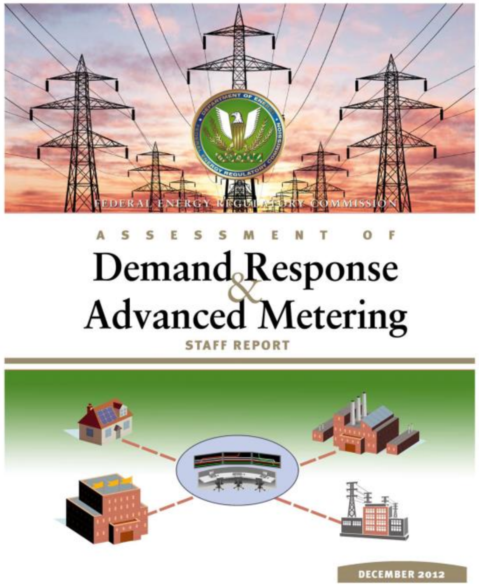
Adapted from *Demand Response NARUC Webinar*, R. Levy and S. Kiliccotte, Levy Associates and LBNL webinar presentation, May 4, 2011

U.S. Demand Response Program Typology

2012 FERC Survey Program Classifications	Description
Direct Load Control (DLC)	Sponsor remotely shuts down or cycles equipment
Interruptible Load	Load subject to curtailment under tariff or contract
Load as Capacity Resource	Pre-specified load reductions during system contingency
Time-of-Use Pricing (TOU)	Average unit prices that vary by time period
Emergency Demand Response	Load reductions during an emergency event Combines direct load control with specified high price
Spinning Reserves	Load reductions synchronized and responsive within the first few minutes of an emergency event
Non-Spinning Reserves	Demand-side resources available within 10 minutes
Regulation Service	Increase or decrease load in response to real-time signal
Demand Bidding and Buyback	Customer offers load reductions at a price
Critical Peak Pricing (CPP)	Rate/price to encourage reduced usage during high wholesale prices or system contingencies
Critical Peak Pricing w/Control	Combines direct load control with specified high price
Real-Time Pricing (RTP)	Retail price fluctuates hourly or more often to reflect changes in wholesale prices on day or hour ahead
Peak-Time Rebate (PTR)	Rebates paid on critical peak hours for reductions against a baseline
System Peak Response Transmission Tariff	Rates/prices to reduce peaks and transmission charges

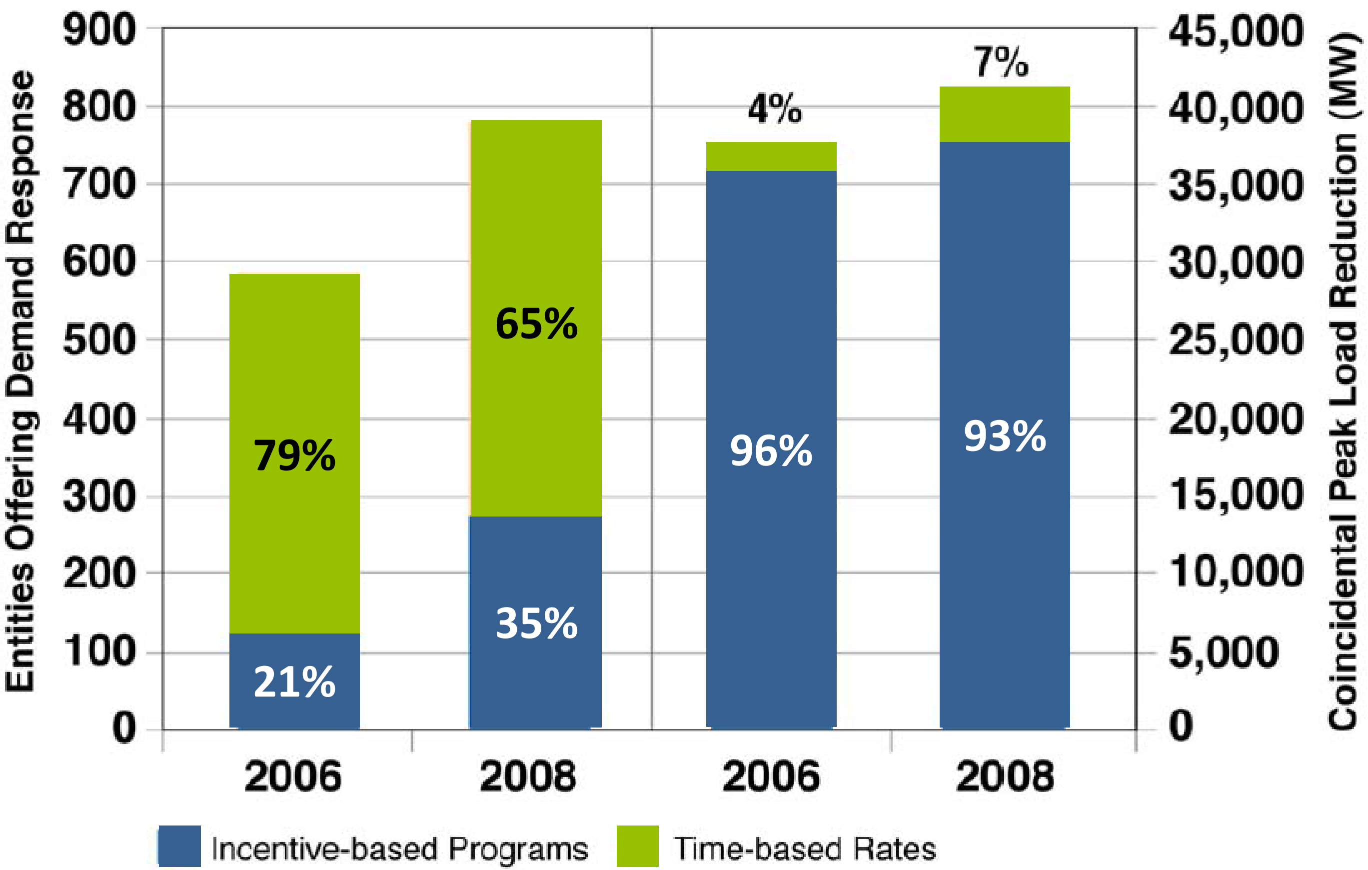
Blue = Incentive-Based Program **Green = Time-Based Program**

80% of ISO participation occurs in these programs. (FERC, 2012)



http://www.ferc.gov/legal/staff-reports/12-20-12-demand-response.pdf

Demand Response Potential in the United States



Source: Cappers, Goldman, and Kathan, 2009

Demand response is a resource that is fast growing and has high potential, particularly for incentive-based programs.

Cooling Equipment Use in Demand Response Programs

Customer Type	Equipment/ Building Component	Control Strategy	DR programs		
			Emergency or Energy Resource	Capacity Resource	Regulation Service or Reserves
Residential	Air conditioners	Cycling/forced demand shedding	✓	✓	✓
Commercial	Chillers	Demand limiting during on-peak period	✓	✓	
		Pre-cool building over night-storage		✓	
		Forced demand scheduling	✓	✓	
Industrial	Chillers	Demand limiting on time schedule		✓	

Source: Adapted from Walawalkar et al., 2010

Cooling equipment can be flexibly used in many DR programs, e.g.:

- as an "emergency" or "energy" resource during a time of high demand
- as pre-scheduled "capacity" that can reduce load according to a pre-planned schedule
- as a means of providing regulation services and reserves in real time or on short notice

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Role of Enabling Technology in Demand Response

- Switches—remotely controlled switches for appliances (e.g., A/C); can be achieved through appliance standards (each new A/C unit could come pre-installed with a switch)

- Advanced meters—a metering system that records customer consumption hourly or more frequently and that provides for daily or more frequent transmittal of measurements over a communications network to a central collection point

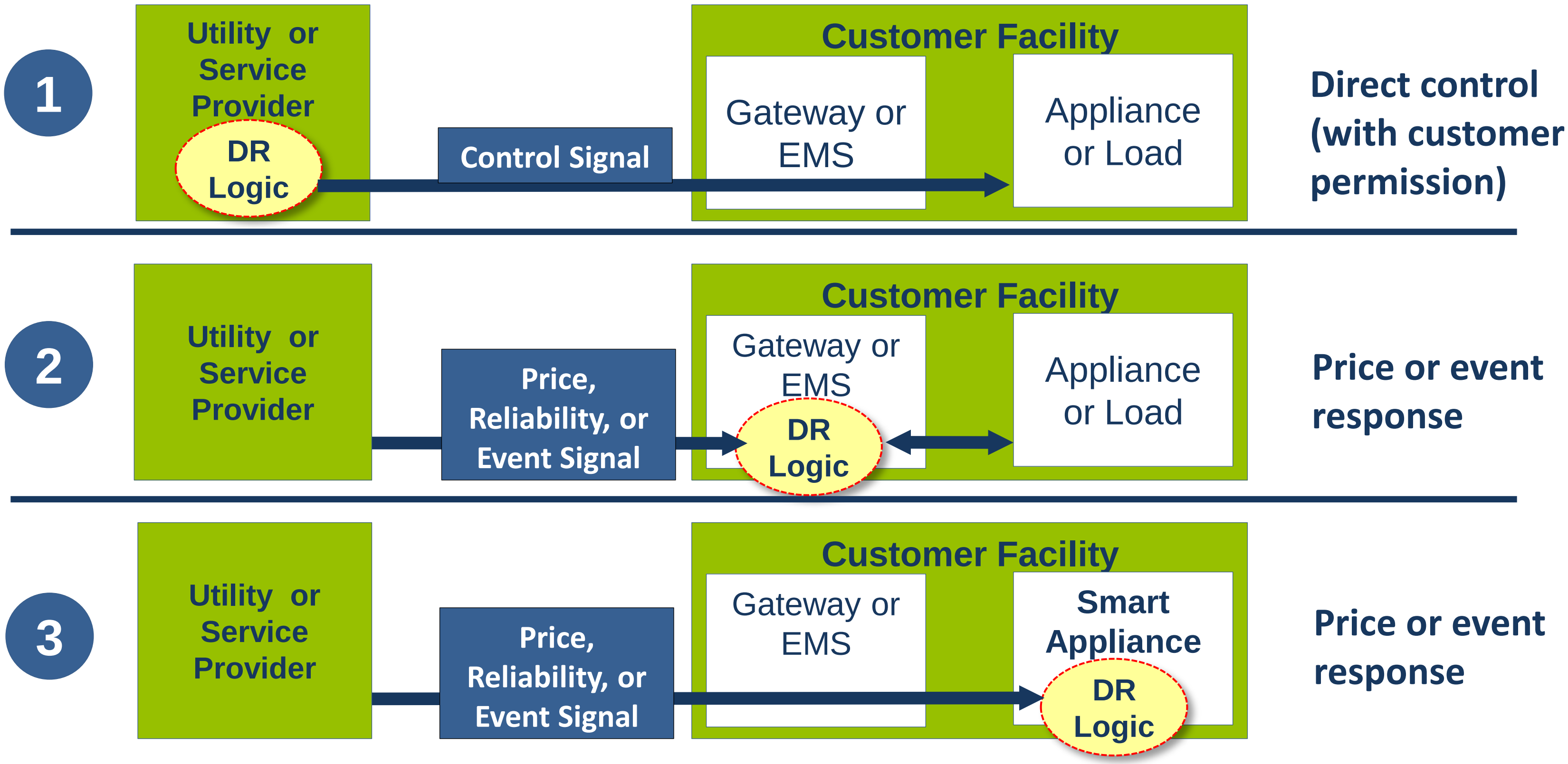
- Energy management systems—collect/compile consumption data by end-use and also deploy strategies for reducing energy use; enhance capability of customers to manage their energy and peak demand effectively

- Communications network—conveys signals from utility to customer (e.g., via phone, pager, internet, etc.)

- Automated DR (e.g., smart programmable thermostats)—eliminates the need for customers to monitor utility signals and to take action to reduce load

Not all of these are necessary for demand response.

UTILITY VS. CUSTOMER CONTROL IN DEMAND RESPONSE



Adapted from: *Direct versus Facility Centric Load Control for Automated Demand Response, Grid Interop 2008*, E. Koch and M. Piette

- DR logic can be utility-centric, built into the building energy management system (EMS), or built into a "smart" appliance, depending on the type of DR.
- A clear and flexible definition of "smartness" is needed along with the type of DR.

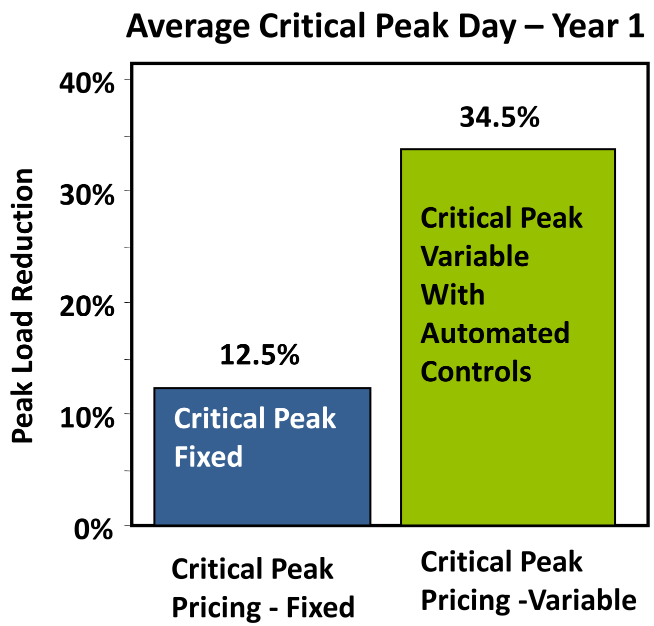
Some Suggested Definitions of "Smart Appliance" (or smart air conditioner)

- "a product that uses electricity for its main power source which has the capability to receive, interpret and act on a signal received from a utility, third party energy service provider or home energy management device, and automatically adjust its operation depending on both the signal's contents and settings from the consumer" (AHAM/ACEEE, 2011)

- "the automated alteration of an electrical product's normal mode of operation in response to an initiating signal originating from or defined by a remote agent" (AS/NZS 4755 Demand Response standard)

AUTOMATION: NECESSARY OR NOT?

- Automation increases load response as shown below (e.g., with smart thermostats or automated controls).
- Provides customers with "set and forget" it capability.
- Improves persistence of response over time.
- Provides faster and more reliable response; demand response can be integrated in electricity system planning.



Source: California SPP, 2003

Rate Group	No Smart Thermostat	With Smart Thermostat
Residential – Critical Peak Pricing	29%	49%
Residential – Peak-Time Rebate	11%	17%
All Electric – Critical Peak Pricing	22%	51%
All Electric – Peak-Time Rebate	6%	24%

Source: PowerCents DC, 2010

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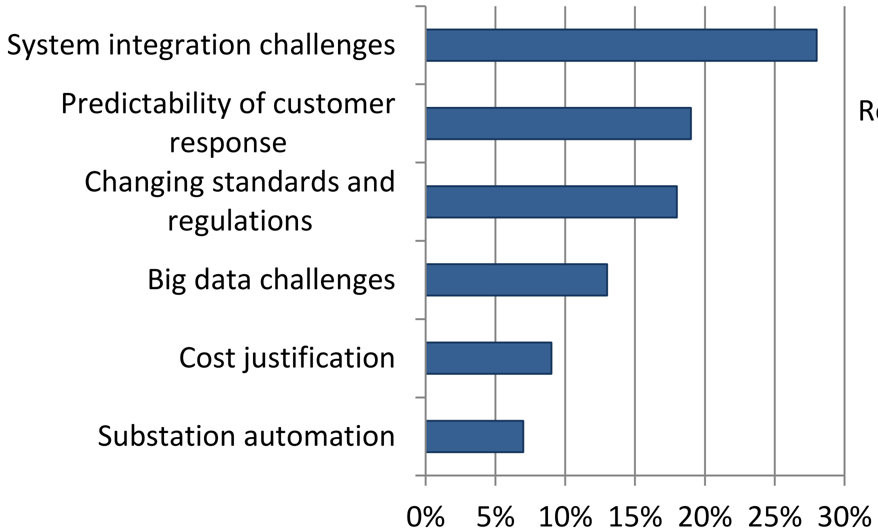
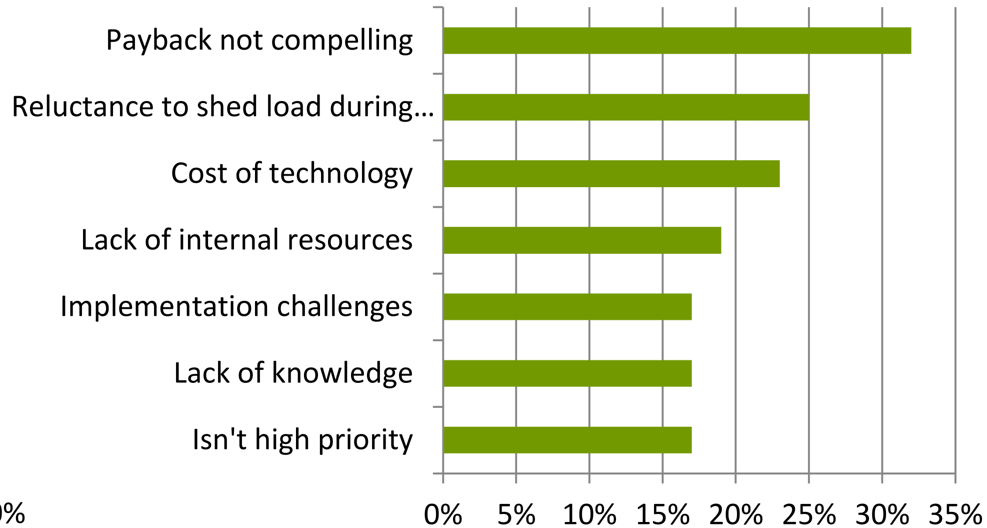
Barriers to Demand Response

Challenges for Utilities



Challenges for C&I Customers



Source: *PLMA Demand Response Market Research Survey Results*, April 2013,
80 participants including utilities, DR providers and technology providers

- Top barriers faced by utilities include system integration challenges, e.g., with many different kinds of products and technologies, cost of technology, predictability and reliability of customer response, and a changing regulatory landscape.
- Commercial and industrial (C&I) DR implementers also face the barriers of high costs, optimal scheduling, and lack of knowledge and internal resources to support DR.

Barriers to Energy Efficiency

	Barrier	Effect
Institutional	Lack of a transparent and open public process that involves all stakeholders	Experiences from many countries have shown that effective policies are difficult to establish without stakeholder involvement.
	Uncertainty	There is uncertainty about future technologies, policies, regulations, codes, and standards.
	Lack of analysis	Policies are not optimized for energy savings and consumer financial benefits.
Financial	Energy consumption subsidies	Cost-effective potential is underestimated, and efficiency is not rewarded.
	High up-front cost of energy efficient products	Even though cost-effectiveness is known, the added first cost of purchasing energy efficient products may be a barrier to buyers.
Capacity	Lack of information	Information about energy efficient technology may not be widely available or widely understood.
	Limited resources	Energy efficiency implementers may have limited human and financial resources.

Sources: Letschert, 2013; IEA, 2010; ORNL, 2008

Transparent and open stakeholder input processes, optimized efficiency policies, and wide dissemination of information about energy efficient technologies and cost-effective energy efficiency potential are needed to address barriers to energy efficiency.

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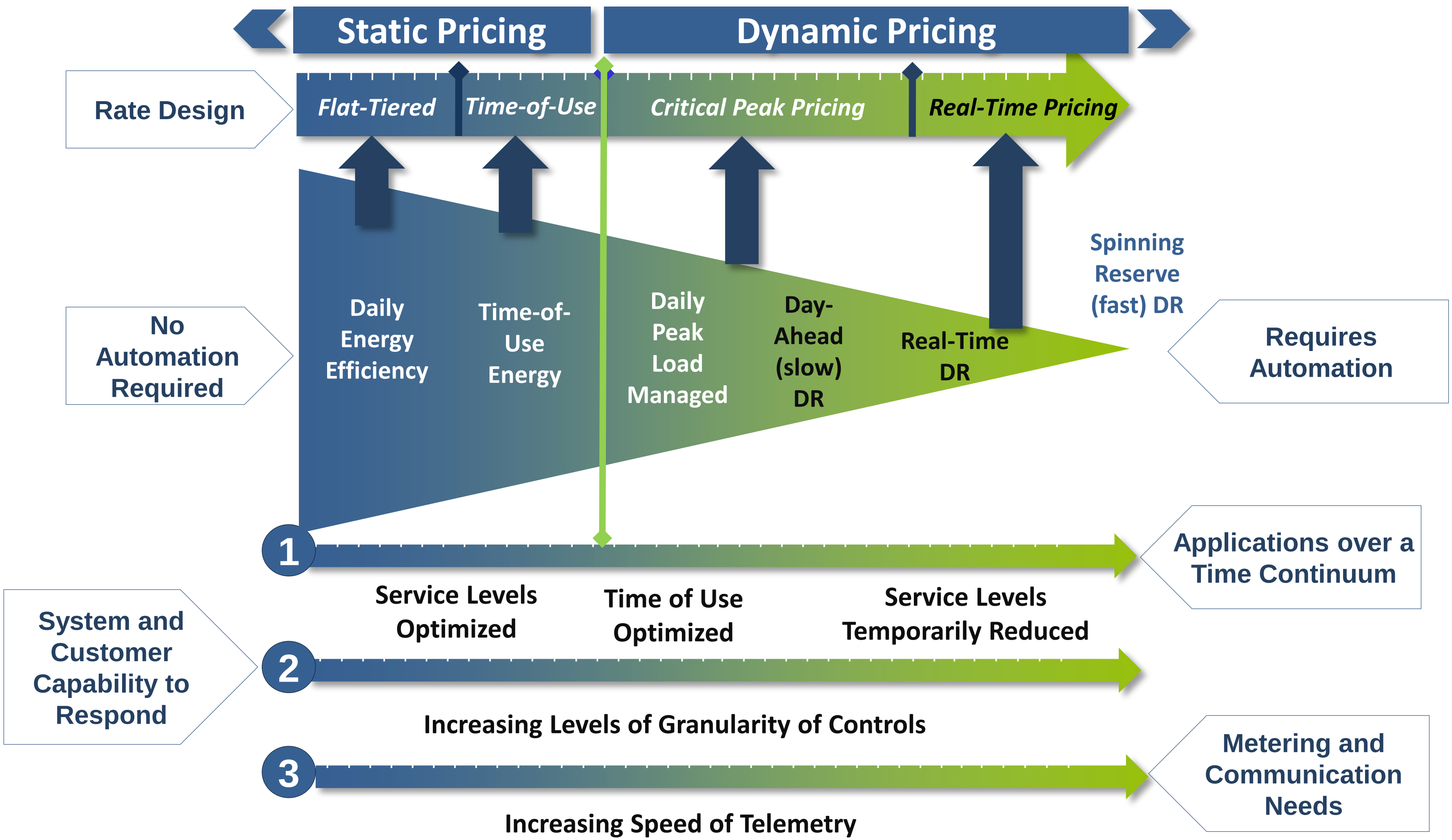
Energy Efficiency & Demand Response Continuum



Adapted from *Experience and Evolution of Demand Response in the U.S.*, LBNL, Andrew Satchwell presentation, November 19, 2013

Opportunities in Energy Efficient and Demand Responsive Cooling

- Developing energy efficient cooling policies, e.g., air conditioner efficiency standards and building codes (developed with private stakeholder input).
- Accelerating deployment of energy efficient technologies, e.g., district cooling, in areas with high cooling density requirements.
- Encouraging the development of open standards.
- Addressing financial and first-cost barriers to energy efficient and demand responsive cooling technologies through incentive programs for energy efficient space cooling.
- Commercial and regulatory arrangements that capture and aggregate financial savings that would otherwise be lost or unrealized.
- Education, outreach, capacity-building and transfer of energy efficient cooling technology to customers and end-users.

OPPORTUNITIES IN DEMAND RESPONSE

Country/ Body	Standard/Committee	Technology/Appliances	Effective Dates
Japan	Echonet	Meters, appliances, home area networks (HANs)	various 1997-2014
USA	Energy Star criteria for connected appliances	Refrigerators	2014
Australia	AS/NZS 4755	Air conditioners, pool pump controllers, water heaters, EV charge controllers	Various - 2008-2014
Korea	Korean labeling criteria for air conditioners and heat pumps	Air conditioners and heat pumps	October 2014
IEC	PC 118 Smart Grid User Interface	User interfaces	Began 2012
	TC 57 power systems management and associated information exchange	Power systems management	
	TC 59 WG15	Connection of household appliances to smart grids and appliances interaction	Began October 2012

Source: Wilkenfeld, 2013 and LBNL

- Many regions and economies are working on "smart" appliance standards.
- A single approach may not be feasible in the short term, but a unifying framework may be possible.
- Public–private partnerships and collaboration can drive architecture and provide clear direction of needs of the electricity grid and of end-users.

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