2015 CEDM Meeting:
A strategy to improve the valuation of reliable electric power

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Why it is important

- Society is becoming **ever more dependent** on electric power so that supply disruptions are becoming more **socially and economically costly**

- Distributed generation, microgrids, distribution automation and similar technologies make it possible to increase the resilience and reliability of electricity supply

- However, all of the things we could do to improve reliability and increase resilience **cost money**

The problems with past studies

- Most past estimates of power disruption have been obtained either by:
  - Estimating the drop in economic activity that occurred during an outage
  - Asking customers about their willingness to pay (WTP) to avoid an outage

- WTP study for residential customers generally looks like this:
  - ***(Scenario of outage)*** "On a winter weekday, a prolonged outage occurs at 6am without any warning. You do not know how long the power outage will last, but after two hours your household's electricity is fully restored"
  - ***(Ask some questions related to given outage or what they normally do when there is no outage during the outage)***
    "What would your household usually do if this outage occurred?"
    "Rate the following inconveniences your household might experience due to this outage from 1 being 'not at all bothersome' to 5 being 'very bothersome'"
  - ***(Ask WTP)*** "What would be the least amount that you would consider a fair payment for each time this outage occurred in your home? (circle or enter number)
    $0 $0.1 $0.25 $0.5 $1 $2 $3 $5 $10 $15 $20 $30 $50 other"

Problems and Issues will be addressed

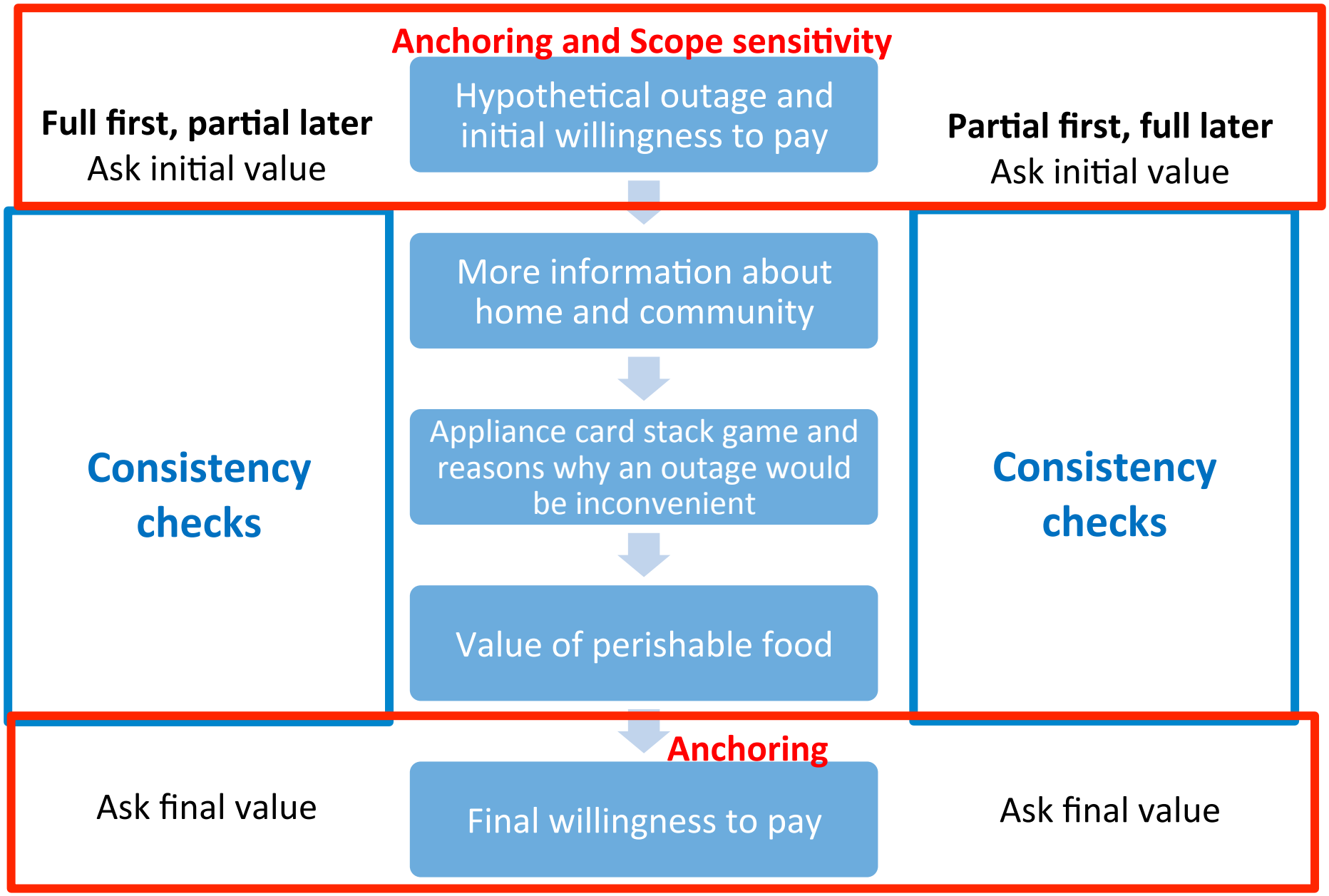
- When we look in detail at the survey questions (Sullivan M.J. et al), we think respondents would need **carefully designed realistic scenario** to understand given hypothetical outage that they never experienced

- We need **some consistency checks** during the survey to make sure that respondents fully understand the information before they go further

- Respondents' valuations could be affected by **potential biases**, so we need to make additional efforts to minimize the biases

- We will provide two type of backup services to assess the concept of **consumer surplus**
  (previous studies only consider full backup service or nothing)

Overview of this survey



Survey protocol – Hypothetical outage

- A large regional blackout occurs on a hot summer weekend when you and your household members plan to spend the weekend at home.

- Imagine that it is the middle of August. At sunrise you wake up and realize that the power is out.
  Assume that you can find a battery operated radio. It tells you that the power outage is not local, but instead extends across a large region.

Survey protocol – Hypothetical outage

- The radio says that several tornadoes struck big power lines in Indiana, knocking them down. This caused a blackout that spread to the entire Middle-Atlantic and North Eastern parts of the US (see map above). It also tells you that because the tornadoes did not knock down any power lines in the Pittsburgh region, the power company will be able to restore power within a day (in other words, there will be **no power until sunrise tomorrow morning)**.

Survey protocol – Hypothetical outage

- Suppose that during the blackout there is a **private local service** that specializes in disasters and emergencies that can quickly hook up a generator to your house and provide **all the electric power** you would have normally used. Assume your cell phone has enough power to call to get that service and make a one-time payment for one day of immediate service provided by the company.

- Now, let's suppose that there is a different service that uses **smart meter technology** to give you some electricity service during the blackout. This **smart grid company** can quickly connect your house to their smart power system and provide a **limited amount of electricity** for your entire house (about one-fifth of your normal power). With this limited service, you would only be able to **run some of the appliances you might want to use**. Assume your cell phone has enough power to call the smart grid company and make a one-time payment for one day of immediate but limited.

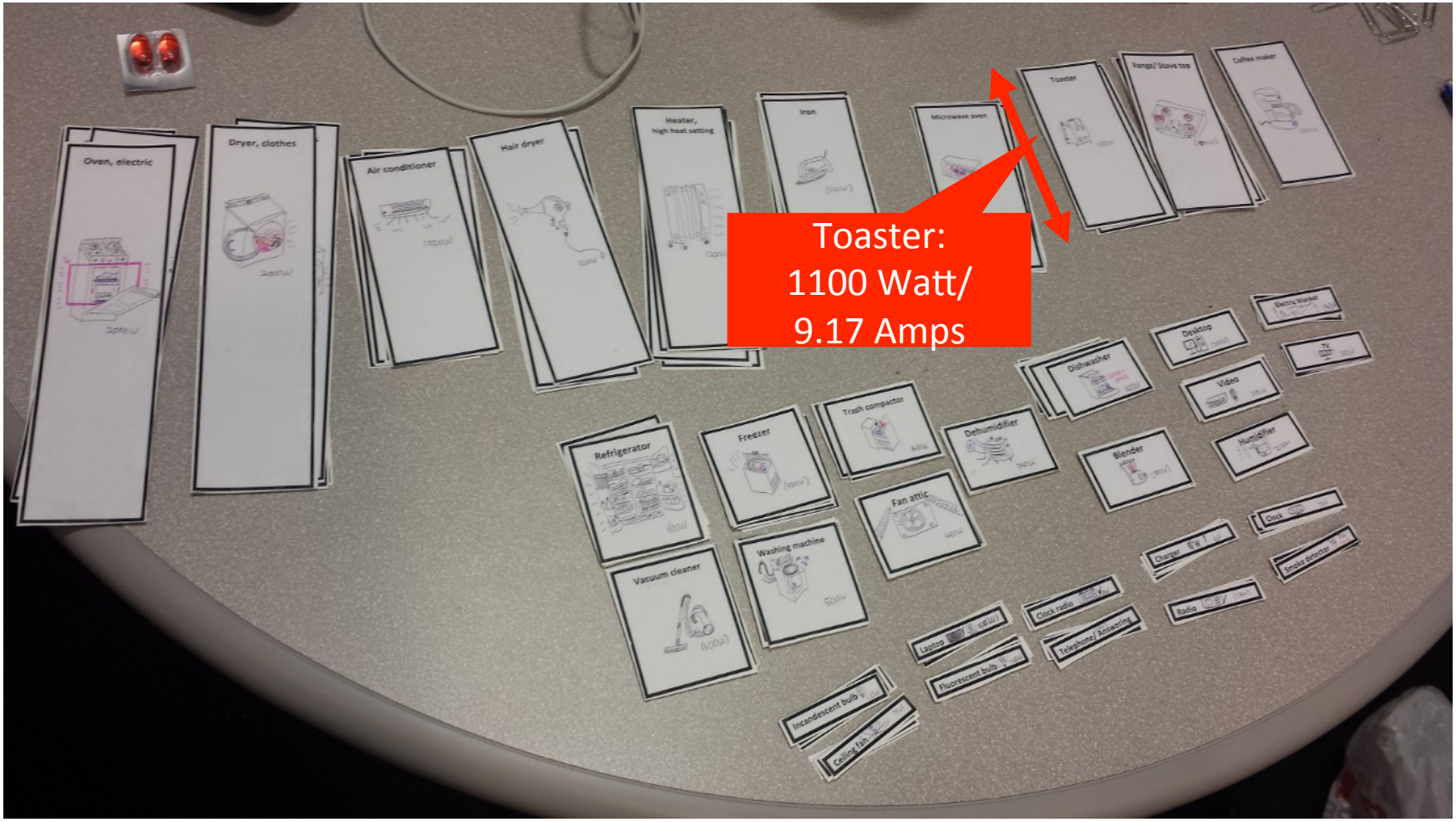
Survey protocol – More detailed information

- With the power out for the entire region, the table below provides a list that will and will not work in their homes and community:

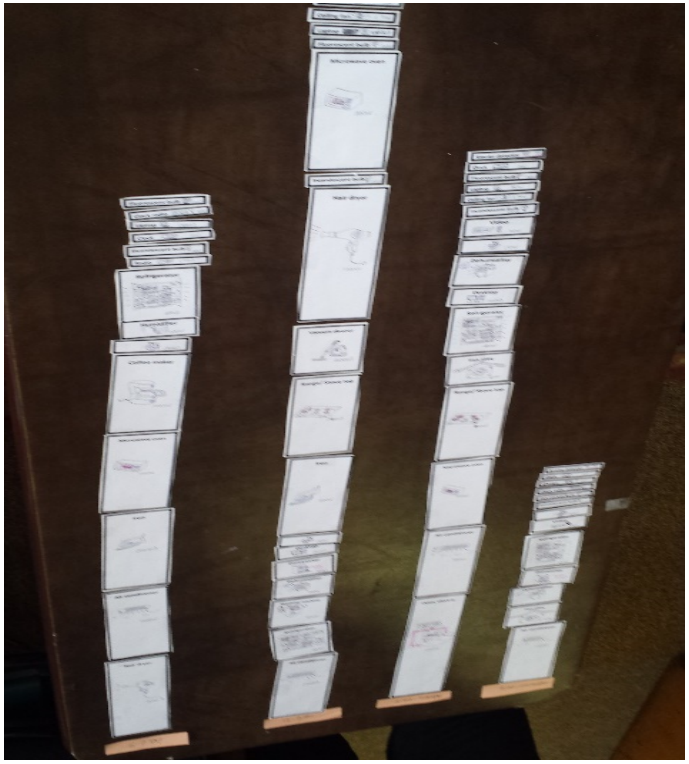
In your home		In your community	
Will work	**Will not work**	**Will work**	**Will not work**
• Old style telephones that have a rotary dial. • Anything that runs on a battery, for as long as the battery lasts. For example, radios, flash lights, laptop computers, and cell phones. • Natural gas and all normal water and sewer services	• New style telephones that include a plug into a power outlet. • All electrical appliances that cannot also run on batteries, including air conditioners and blowers that circulate air. • Cable and internet service	• Emergency service including 911 (via cell phone or rotary dial phone) • Hospitals, police stations and other places that have back-up generators. • TV and radio stations (most have back-up generators) • Natural gas and all normal water and sewer services • Bus service • GPS service	• Traffic signals • Street lights • Banks and ATMs • Most gas stations (pumps need work) • Food stores (lights, refrigeration and cash registers will not work) • Most restaurants (very few have backup generators) • Elevators in buildings without backup • Ventilator fans and lighting in traffic tunnels • Electric trolley service • Airport – major delays

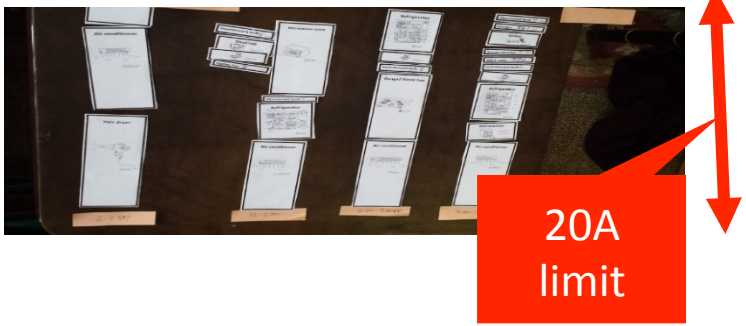
Survey protocol – Appliance card stack game

Electric appliance cards where *height* of each card represents the amount of electricity that each appliance consumes



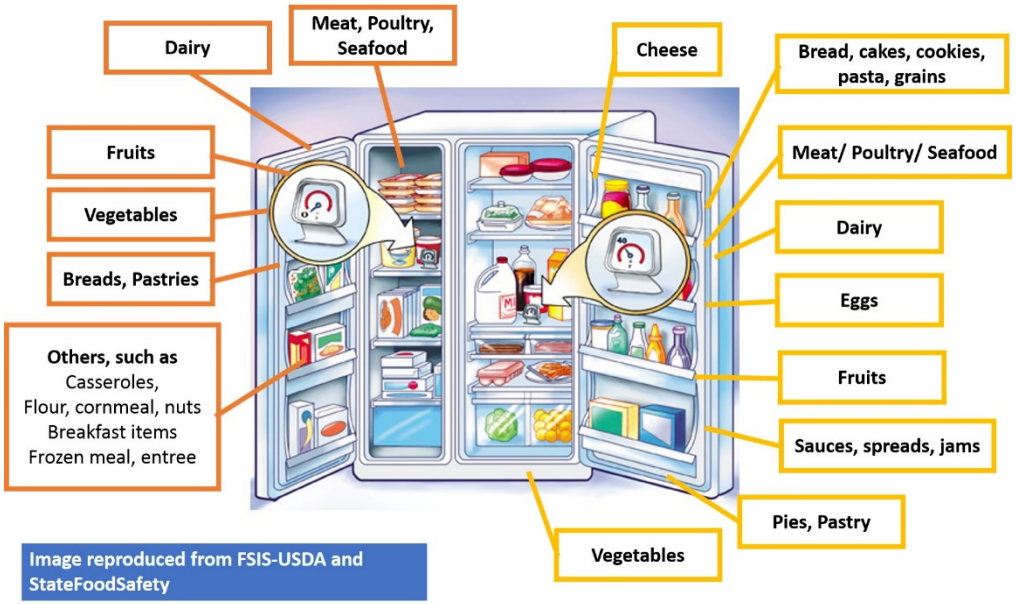
Survey protocol – Appliance card stack game





- "Electric-appliance-stack-game" to build up electricity demand profile
- Both group **build electricity profile** for normal circumstances first (Full), and then build profile with limits (=20A, Partial)
- After they construct their electricity appliance card stacks, they will think about why an outage **without any backup service** or **with partial backup service** might be inconvenient

Survey protocol – Value of perishable food



- The US Department of Agriculture (USDA) says that 'perishable food stored in a refrigerator longer than 4 hours without power' should be discarded. Four hours may be too conservative, but if the power is out for a day you will definitely lose some perishable food in your refrigerator. Please describe how you feel about the power outage and food safety information from USDA, and how you would actually respond to the recommendation.

Survey protocol – Value of perishable food

- Please use the table below to understand and estimate the value of perishable food you have and will lose if the power goes out for a period of 24 hours.

	Your rough estimate of the value of perishable food that is in your refrigerator:	Your rough estimate of the value of perishable food that will go bad and need to be replaced:
Meat, Poultry, Seafood Raw or leftover cooked, Thawing meat or poultry, Salads: Meat, tuna, shrimp, Chicken, or egg salad, Gravy, stuffing, broth, Lunchmeats, hot dogs, bacon, sausage, dried beef, Pizza – with any topping, Canned hams labeled 'Keep refrigerated', Opened canned meats and fish, Casseroles, soups, stews	$	$
Dairy Milk, cream, sour cream, buttermilk, evaporated milk, yogurt, eggnog, soy milk, Open baby formula	$	$
Eggs Fresh eggs, hard-cooked in shell, Custards and puddings, quiche	$	$
Fruits Opened canned fruits and juices	$	$
Bread, Cakes, Cookies, Pasta, etc. Refrigerator biscuits, rolls, cookie dough, Cooked pasta, rice, potatoes, Pasta salads with mayonnaise or vinaigrette, Fresh pasta, Cheesecake	$	$
Some Pies and Pastry	$	$
Some Vegetables (except raw vegetables)	$	$
Some (soft) Cheese	$	$
Rough sum:	$	$

Survey protocol – Wrap up

- After have gone through four steps and provided all the information, respondents might think their value of electric supply differently

- At first, respondents will rank three information in order of importance and most critical in deciding their value of reliable electric supply

	Most important	Moderately important	Slightly important
More information about your home and your community	q	q	q
Appliance card stack game and reasons why the outage would be inconvenient	q	q	q
Value of perishable food	q	q	q

- And then, I will ask their final willingness to pay for two services (both full backup service and partial backup service)

Conclusion/ Policy implications

- In this study, we enhance past studies by adding carefully specified scenario, more detailed information from various aspects, consistency checks, and a method to check anchoring and scope sensitivity

- We could figure out which information people need for the valuation and how much given information affects their value of reliable electric services

- This study will be extended into areas with different outage experiences and geographical/climate characteristics either by automated computer tool or by paper-and-pencil version

- With derived results, utilities and local/regional communities could set up informed investment and management plans

Thank You!

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Appendix 1: Previous studies

- There is a large and rather mixed literature on how utility customer value electric service reliability and cost of outages.

- Woo et al (1992) observe that, in general customer valuation of supply disruptions "**Cannot** be determined or observed directly from market behavior… because there is **no market for reliability**"

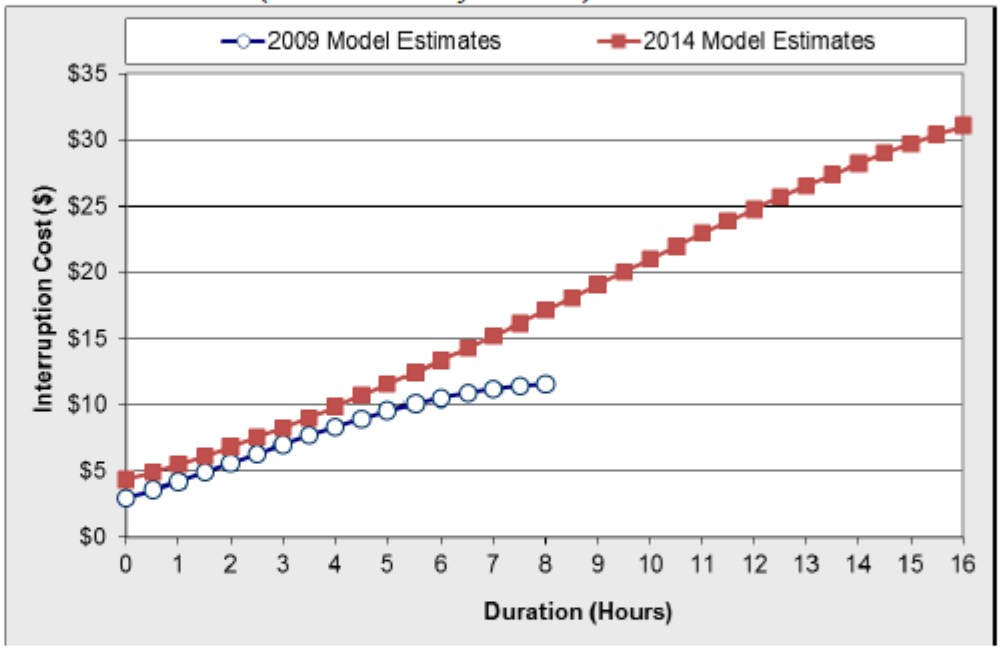
- Most past estimates of power disruption have been obtained either by:
  - Estimating the drop in economic activity that occurred during an outage
  - Asking customers about their willingness to pay (preferences) to avoid an outage

Appendix 2: VOLL from Sullivan (Meta analysis)

- In a series of studies from Lawrence Berkeley National Lab, Sullivan et al (2009 and 2015) performed a synthesis of past individual studies conducted in the US and a regression analysis on results obtained from "34 different datasets from surveys fielded by 10 different utilities between 1989 and 2012".

- In this way, they estimated "**customer interruption costs** per event **by** season, time of day, day of week, and geographical regions within the US for **industrial**, **commercial**, and **residential** customers"

Figure 5-1: Estimated Customer Interruption Costs (U.S.2013$) by Duration and Model (Summer Weekday Afternoon) – Residential



Estimate of VOLL produced by Sullivan et al. (2015), in $\$_{2013}$/kWh for residential customers for summer weekday afternoon as a function of duration.
Figure reproduced from Sullivan et al. (2015).

Appendix 3: Overview of this survey

- In this study, we offer four consistency checks, whether:
  - ❑ one-day payment for backup services should be higher than normal electricity bills (i.e., 11 ¢/kWh multiplied by rough electricity consumptions)
  - ❑ payment for full service should be greater than or equal to partial service
  - ❑ WTP from later step should be greater than or equal to WTP from previous step
  - ❑ WTP from later step should be less variable (respondents have more confidence)

- Also, we divide respondents into two groups to check:
  - ❑ One group goes with full service first and then partial service (group 1) whereas the other group goes with partial service first and then full service (group 2)
  - ❑ Between two groups, we could compare very first WTPs –initial WTP for full service from group 1 and initial WTP for partial service from group 2- to see whether there is **scope sensitivity** (whether they value 20 Amps and 100 Amps service differently)
  - ❑ Between two groups, we could compare WTPs from full/partial services from group 1 with WTPs from full/partial services from group 2 to see whether there is **anchoring bias**

Appendix 4: How to ask respondents' WTP

- I will ask respondents' initial willingness to pays for these services with **Multiple Bounded Discrete Choice (MBDC)**, which provides cues indirectly and improve statistical inefficiency from dichotomous choice

	Would you be willing to pay this amount to get full service on a hot summer weekend day?		
	Yes	Not sure	No
Less than $5	q	q	q
Greater than or equal to $5 but less than $10	q	q	q
Greater than or equal to $10 but less than $15	q	q	q
Greater than or equal to $15 but less than $20	q	q	q
Greater than or equal to $20 but less than $25	q	q	q
Greater than or equal to $25 but less than $30	q	q	q
Greater than or equal to $30 but less than $35	q	q	q
Greater than or equal to $35 but less than $40	q	q	q
Greater than or equal to $40 but less than $45	q	q	q
Greater than or equal to $45 but less than $50	q	q	q
Greater than or equal to $50 but less than $55	q	q	q
Greater than or equal to $55 but less than $60	q	q	q
Greater than or equal to $60 but less than $65	q	q	q
Greater than or equal to $65 but less than $70	q	q	q
Greater than or equal to $70 but less than $75	q	q	q