Local mechanisms to support energy system balancing aligned to the current electricity grid state

VERENA VAN ZYL-BULITTA (Uni Leipzig)
ENRIQUE KREMERS (EIFER, Karlsruhe)
RALF OTTE (HS Ulm)

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Agenda

- Acronyms
- Background
- Goals
- Parallel: congestion pricing (traffic systems)
- Results (data from rural Franconia, Bavaria, Germany)
- Conclusion (note on EU task force on smart appliances)

Acronyms

GFM: grid-friendly mechanisms

GSO: grid-sensitive operation

V2G: vehicle to grid

TOU: time of use pricing

Keywords

decentralised balancing mechanisms

grid-sensitive operation & tariffs

energy system resilience

grid stability

micro-flexibilisation options

Background

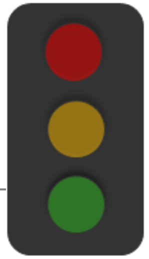
Alignment of physical operation and market aspects

“Solutions”

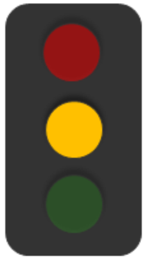
- Redispatch strategy
  - 2014: 200 Mio. Euro
  - 2015: 412 Mio. Euro

- BDEW electricity capacity traffic light is not a practical tool but a legal construct
  - Determines who has control / access / determines the rules

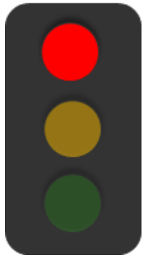
Our strategy works either in a subsystem or an off-grid system, but could be scaled



Ampel Grün:
Alle Strommarktteilnehmer (einschl. Prosumer im Smart Market) können im Verteilnetz Energiegeschäfte frei nach betriebswirtschaftlichen Gesichtspunkten tätigen.



Ampel Gelb:
Die Sicherheit der Versorgung ist angespannt. Durch eine marktliche Steuerung sollen das Smart Grid mit dem Smart Market interagieren.



Ampel Rot:
Die Versorgungssicherheit ist in Gefahr. Die Netzbetreiber greifen automatisiert durch Schaltvorgänge ins Verteilnetz ein.

TYPOLOGY OF CENTRALISED AND DECENTRALISED INFRASTRUCTURE DIMENSIONS

Funcke, S., & Bauknecht, D. (2016). Typology of centralised and decentralised visions for electricity infrastructure. *Utilities Policy*, *40*, 2–9. http://doi.org/10.1016/j.jup.2016.03.005

	Infrastructure dimension	**Decentralised**	**Centralised**
Location of power generation technologies	1. Connectivity: “(De)centralised generation”	Technologies are connected to the distribution grid [Type 1D]	Technologies are connected to the transmission grid [Type 1C]
	2. Proximity: “Geographical distribution”	Technologies are located near load (demand) [Type 2D]	Technologies are located near resources (supply) [Type 2C]
Operational methods for system balancing	**3. Flexibility**	Infrastructure is **balanced** through distributed resources and **demand-side management** [Type 3D]	Infrastructure is balanced through large-scale power generation, storage and transmission grid [Type 3C]
	4. Controllability	Infrastructure is controlled by DSOs and/or **prosumers** and **coordinated** through **regional markets** [Type 4D]	Infrastructure is controlled by TSOs and coordinated through national or international markets [Type 4C]

Goals

Highlight the potential for direct adaptation of loads in response to the current grid state

Separate the socially negotiable with the technologically feasible

??? **Question** ???

How long can the market regulations continue until

- Crash
- Infrastructure degradation
- Structural plans (German grid extension - North / South)

Overview paralleling dynamic tolling with dynamic power pricing from the bottom up

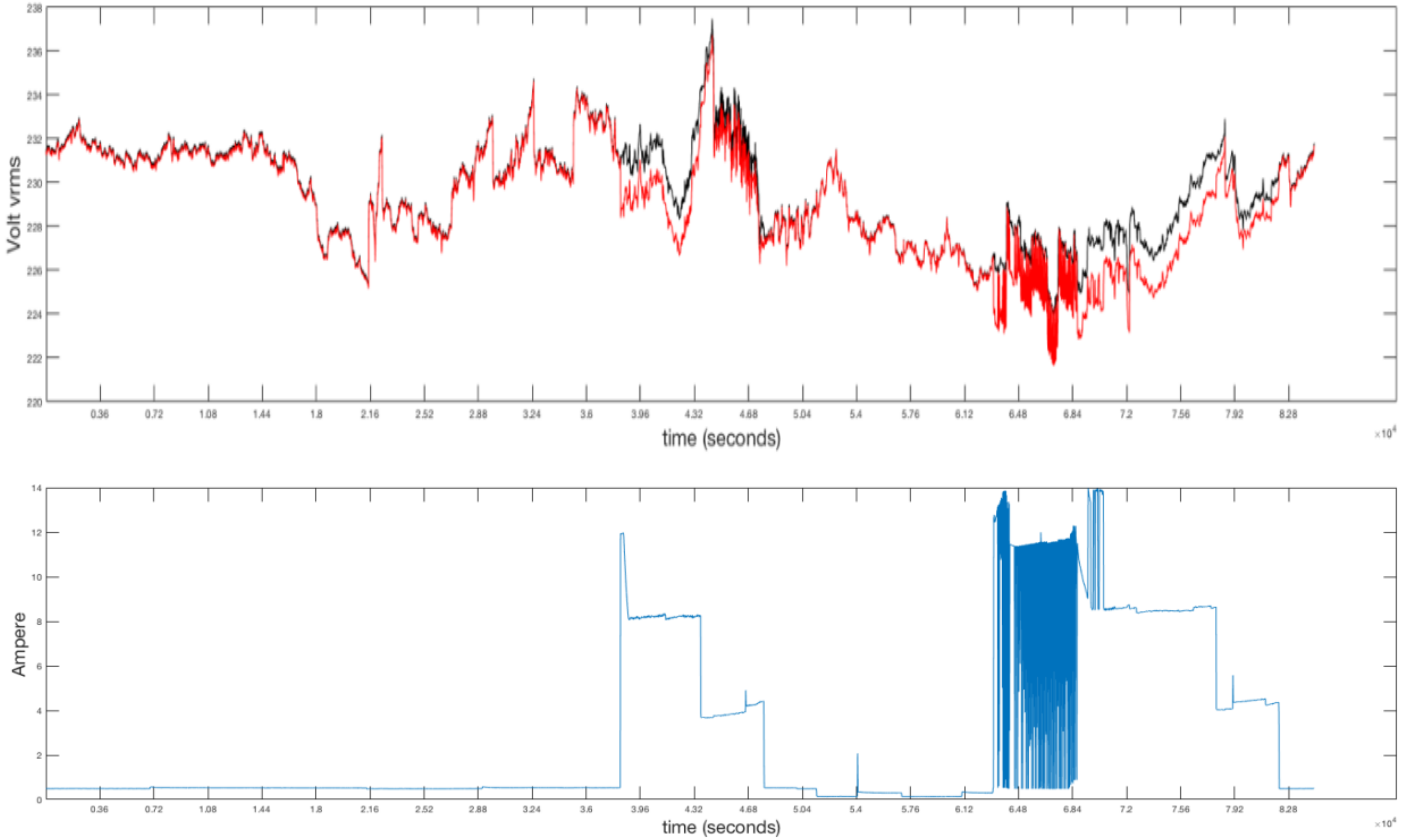
Aspect	Traffic system	Power system
Desired switching behaviour	From peak to off-peak	Same, but possible across time scales
Individual costs incurred	Personal cost (time)	Individual supply security / instant availability
Time-based tariffs	**Static congestion pricing**	**Time of use (TOU) tariffs**
State-based tariffs	**Dynamic pricing**	**Dynamic electricity tariffs**
Traffic parameters to determine toll rate	Travel speed, occupancy and traffic delays	Supply-demand balance (or: residual load), grid congestion, local grid balance
Distance based pricing	Miles driven (irrespective of traffic conditions)	kWh based pricing, without regard to when they were consumed
Constant rates infrastructure service	Static tolling / pricing	Pay per kWh
Shifting scenarios	Demand shift (space, time)	Different options (consumption) over time of day or seasonal differentiation
Utilisation of supply	Roads are usable based on number of vehicles	Electric grid usable based on more complex interplay of various components
Start and stop / versions of a dynamic price	Single or multiple entry / exit points on the road network	Possible: different rates / pricing based on devices’ effects on grid
Balance of flow directions	Flexible adaptation of lane directionality (e.g. USA, Spain)	System always needs to be in balance, less elastic
Location of connections	**Entry / exit ramps on highway**	**Grid connection points of subsystems, indicating health across levels**

Mechanism to measure & price contributions to the grid state

- Basis: determine local voltage of the external environment
  - without self-induced effects
- Mirror what would have been grid voltage, had I not consumed (or produced / fed in) energy
- Heuristic
  - calculated artificial voltage time series by taking an approximate empirical estimate of the local grid impedance ($z = 0.2$)
  - multiplied with the irms value in each time instant
  - added this to the measured vrms values
  - to yield theoretical 'external' voltage without own contributions

→ Tariffs should be dependent upon the amount of (absolute or %) deviation from the permissible or recommendable bounds of the current voltage (maybe also frequency)

- where the voltage is a reflection of the local stability and the frequency reflects global stability

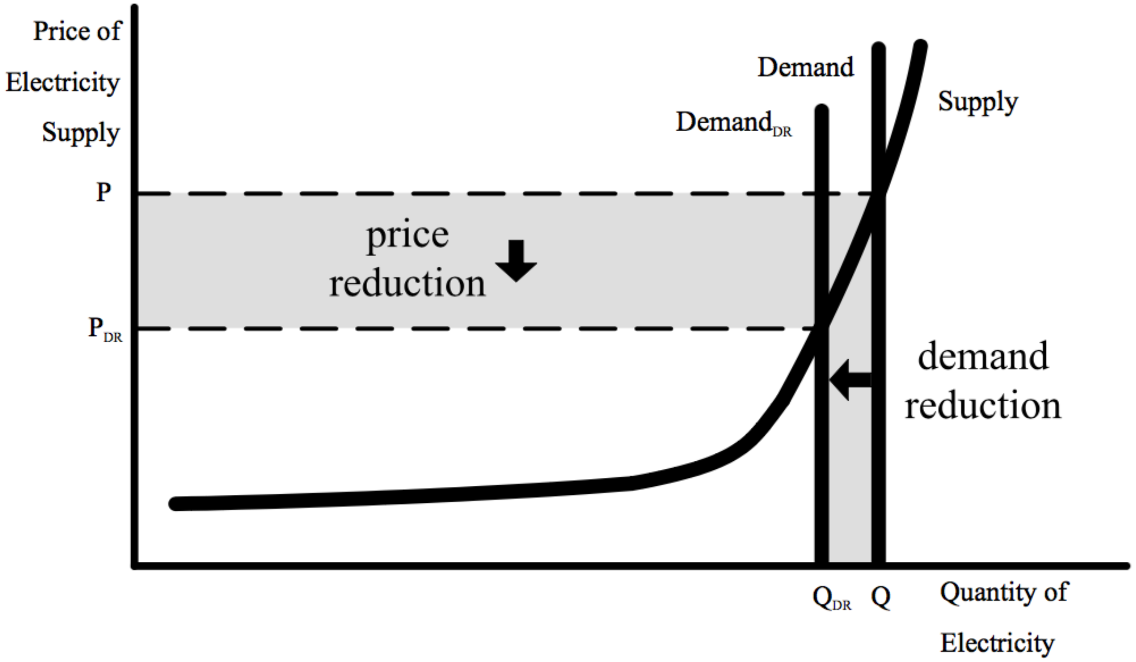


2016/04/19 00:00-23:28, x-axis (s): Empirically measured vrms (red), theoretical voltage (black) when calculating the effect of the irms (blue) electric current values due to the EV charging ‘away’

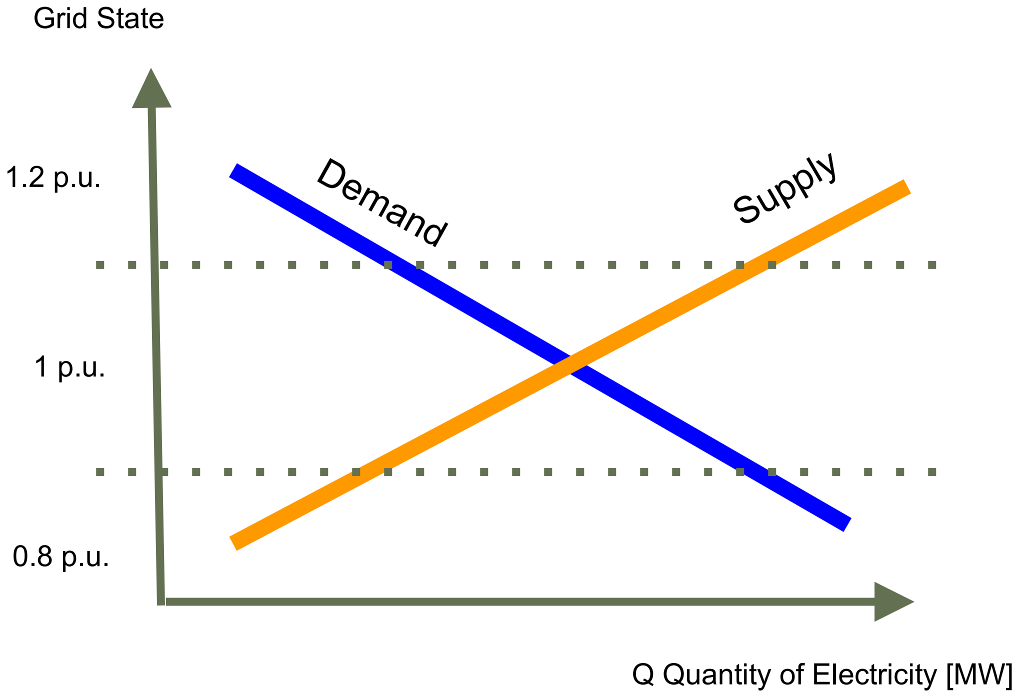
Comparison (different seasons): local voltage effect with(out) EV charging as basis for tariffs

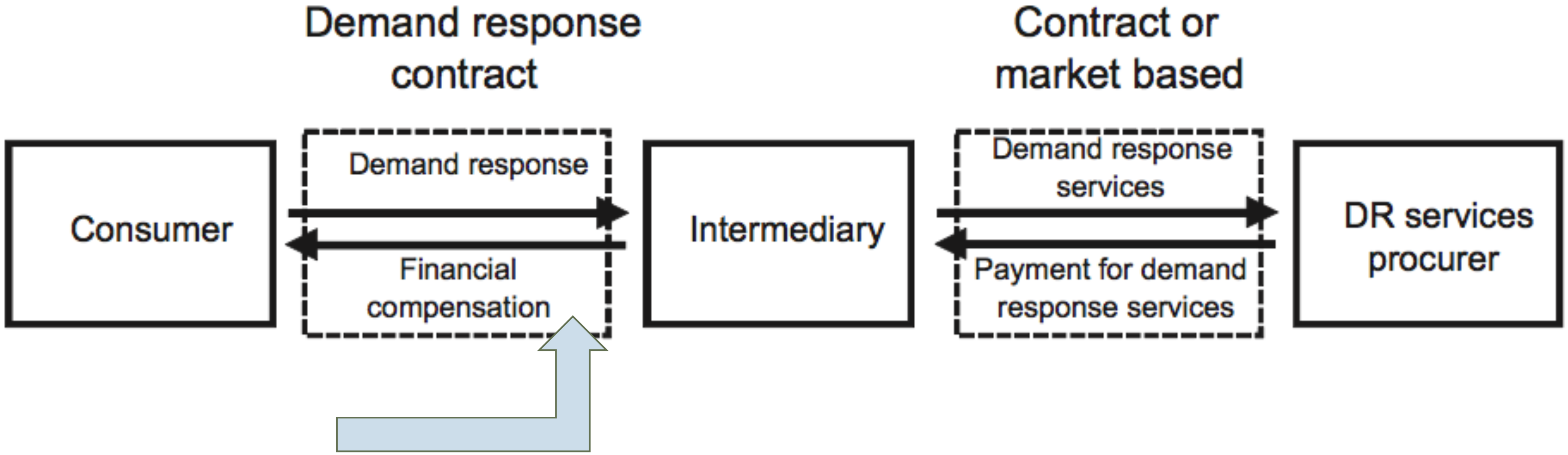
Grid parameter	Range (spring)	Average (spring)	Average (summer)	Average (autumn)	Average (winter)
Irms (Phase 1, mainly EV charging)	13.85 A	2.83 A	1.37 A	2.40 A	1.88 A
Vrms (empirical)	9.45 V	**229.04 V**	226,41 V	225,62 V	226,45 V
Vrms charging (current > 3A)		**227.75 V**	225,67 V	225,39 V	225,64 V
Vrms no charging (current <= 3A)		**230.25 V**	226,52 V	225,71 V	226,66 V
Vrms theoretical	9.46 V	**229.61 V**	226.68 V	226.10 V	226.83 V
Vrms theoretical charging		229.25 V	227,13 V	226,87 V	227,12 V
Vrms theoretical no charging		230.35 V	226,62 V	225,81 V	226,75 V

From market to grid-state driven logic



Source: US DOE (2006). Benefits of Demand Response in Electricity Markets and Recommendations for Achieving Them. *U.S. Department of Energy* http://doi.org/citeulike-article-id:10043893





→ Market is broken down to enable grid-friendly behaviour, which is also remunerated
→ Driven by grid dynamics and health

EU task force on smart appliances

- Special case of DR: smart appliances measure local grid parameter & autonomously respond …
- This type of DR differentiates itself
  - as no communication is required from the smart appliance to the outside world
  - costs are avoided
  - no privacy issues emerge
  - Uptake is not hindered for people who lack affinity with networked technology
- Adding **grid friendly demand response (GF-DR)** will hopefully raise the awareness on its benefits
  - reduced cost
  - dramatically improved **security characteristics**
- Sadly, many “mainstream” articles tend to misunderstand intention of
  - “**grid code aware DR**” & put it into “**big brother**” category, albeit technically it is the total opposite!
- Respecting the voltage and frequency is more comparable to the electrical “**grid code of honour**” and not “**1984**” (http://www.gridco.de/en/2015/07/01/Ecodesign-studies-the-grid-code/)

Thank you

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verena@bulitta.com
kremers@eifer.org

Demand Response Options	
Price-Based Options	**Incentive-Based Programs**
• *Time-of-use (TOU):* a rate with different unit prices for usage during different blocks of time, usually defined for a 24 hour day. TOU rates reflect the average cost of generating and delivering power during those time periods. • *Real-time pricing (RTP):* a rate in which the price for electricity typically fluctuates hourly reflecting changes in the wholesale price of electricity. Customers are typically notified of RTP prices on a day-ahead or hour-ahead basis. • *Critical Peak Pricing (CPP):* CPP rates are a hybrid of the TOU and RTP design. The basic rate structure is TOU. However, provision is made for replacing the normal peak price with a much higher CPP event price under specified trigger conditions (e.g., when system reliability is compromised or supply prices are very high).	• *Direct load control:* a program by which the program operator remotely shuts down or cycles a customer's electrical equipment (e.g. air conditioner, water heater) on short notice. Direct load control programs are primarily offered to residential or small commercial customers. • *Interruptible/curtailable (I/C) service:* curtailment options integrated into retail tariffs that provide a rate discount or bill credit for agreeing to reduce load during system contingencies. Penalties maybe assessed for failure to curtail. Interruptible programs have traditionally been offered only to the largest industrial (or commercial) customers. • *Demand Bidding/Buyback Programs:* customers offer bids to curtail based on wholesale electricity market prices or an equivalent. Mainly offered to large customers (e.g., one megawatt [MW] and over). • *Emergency Demand Response Programs:* programs that provide incentive payments to customers for load reductions during periods when reserve shortfalls arise. • *Capacity Market Programs:* customers offer load curtailments as system capacity to replace conventional generation or delivery resources. Customers typically receive day-of notice of events. Incentives usually consist of up-front reservation payments, and face penalties for failure to curtail when called upon to do so. • *Ancillary Services Market Programs:* customers bid load curtailments in ISO/RTO markets as operating reserves. If their bids are accepted, they are paid the market price for committing to be on standby. If their load curtailments are needed, they are called by the ISO/RTO, and may be paid the spot market energy price.