ECE 398GG – ELECTRIC VEHICLES

11. *EV* Integration into Today's Grids

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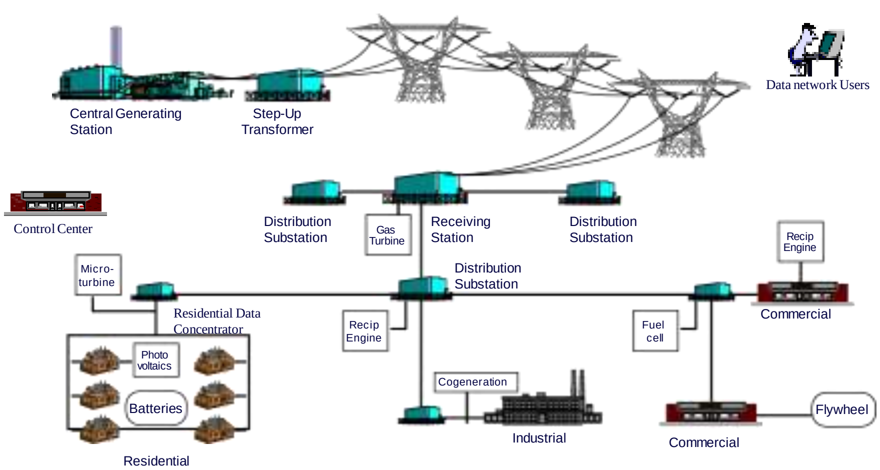
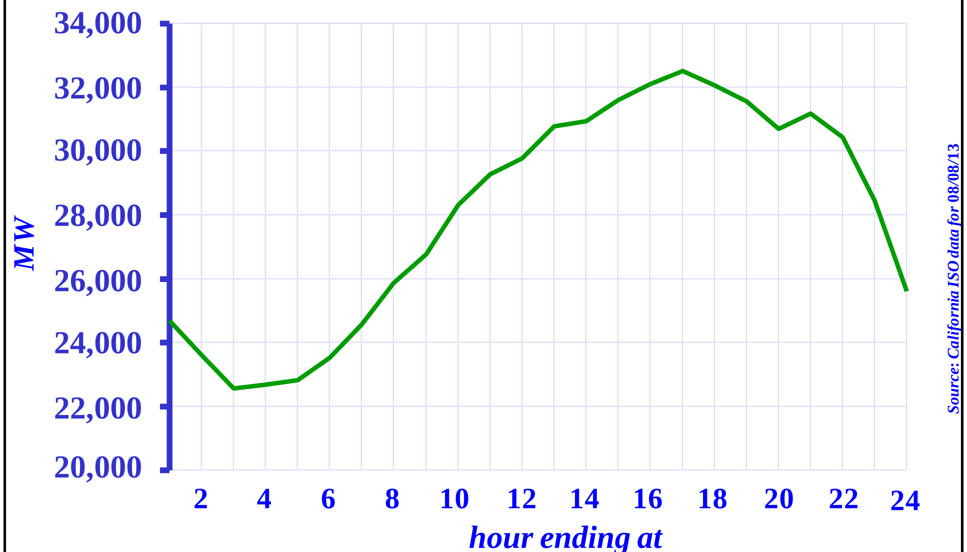
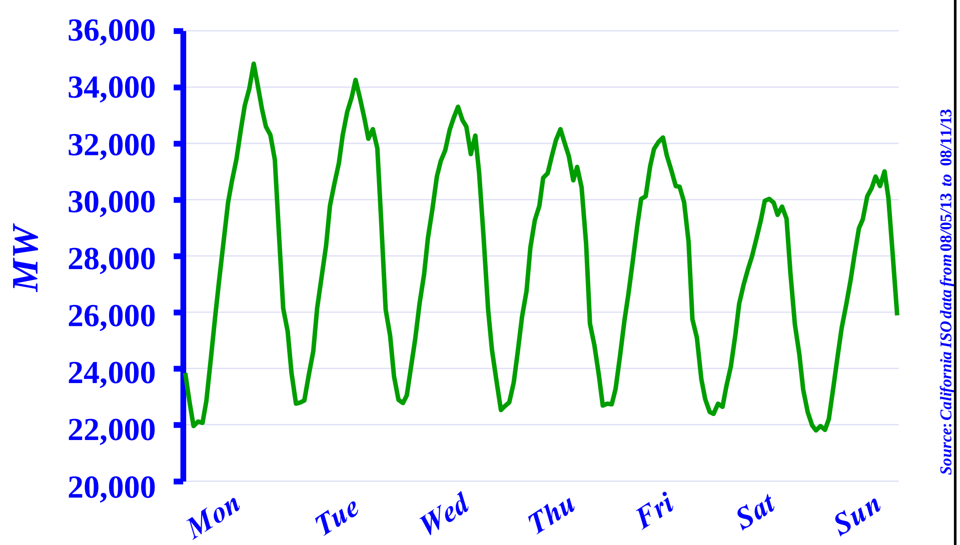
ELECTRIC SYSTEM INFRASTRUCTURE



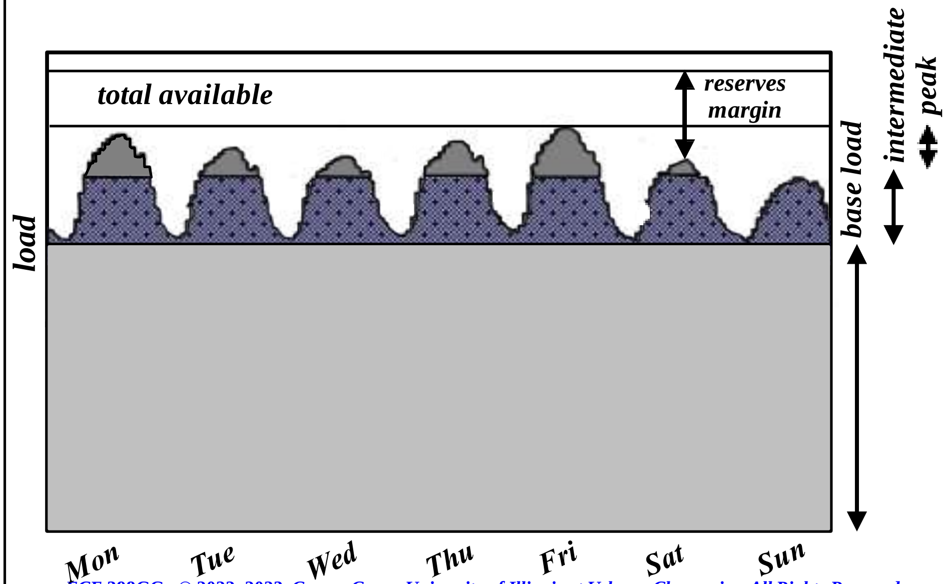
24 – *HOUR* PROFILE



WEEKLY LOAD CYCLE



THE WEEKLY LOAD SHAPE



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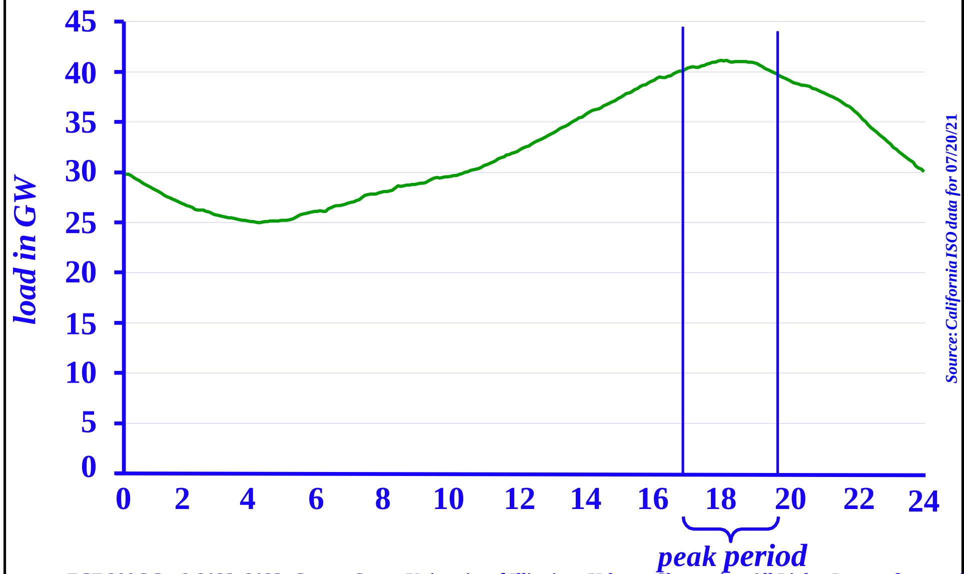
CALIFORNIA SUMMER LOAD: TYPICAL DAILY LOAD SHAPE



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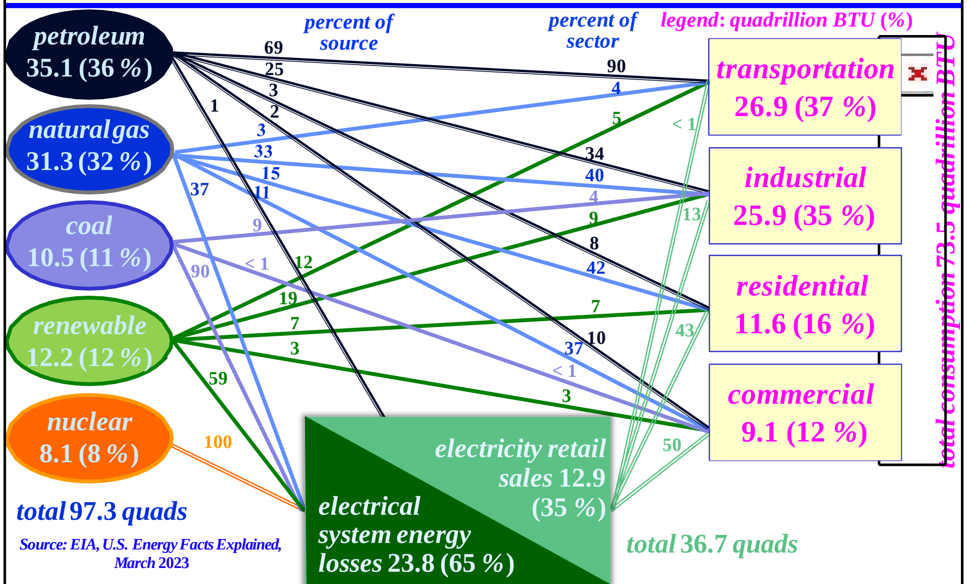
US ENERGY CONSUMPTION IN 2021



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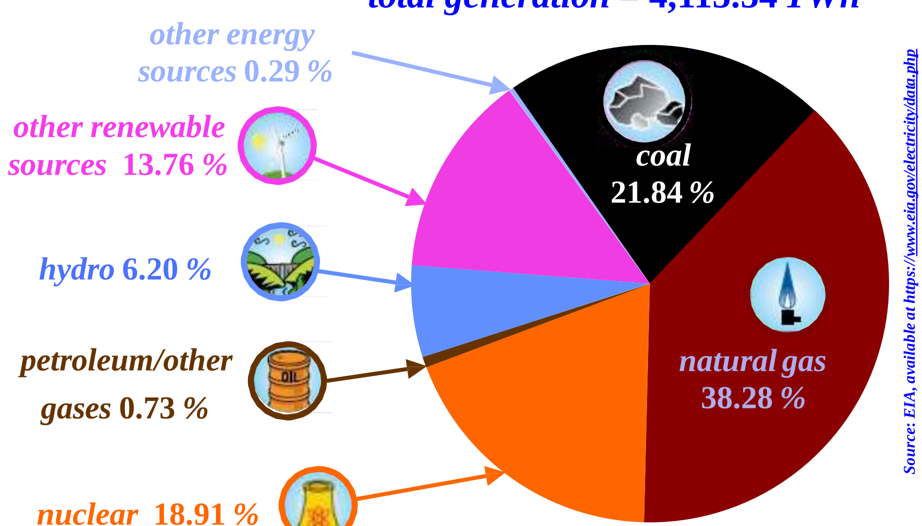
2021 *US* GENERATION BY SOURCE

total generation **= 4,115.54 *TWh***



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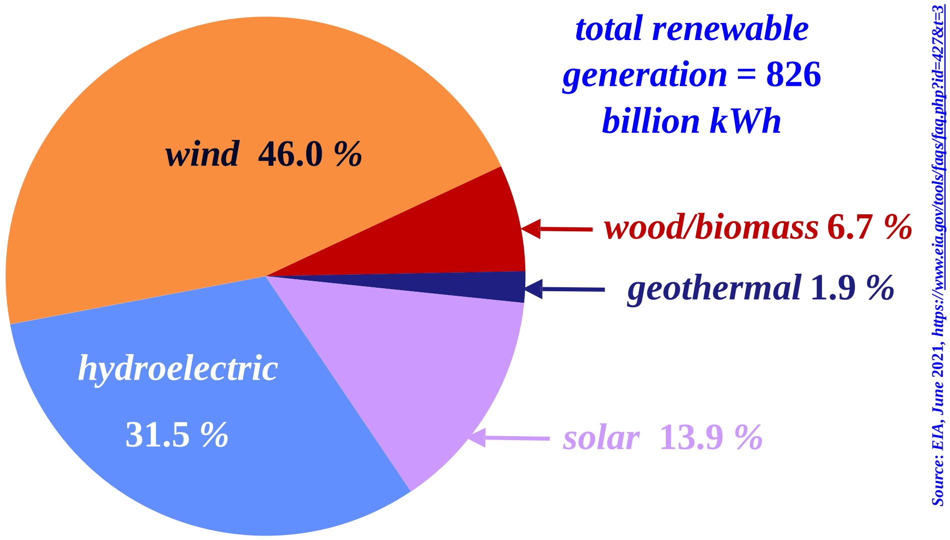
2021 NET GENERATION OF RENEWABLE ENERGY SOURCES



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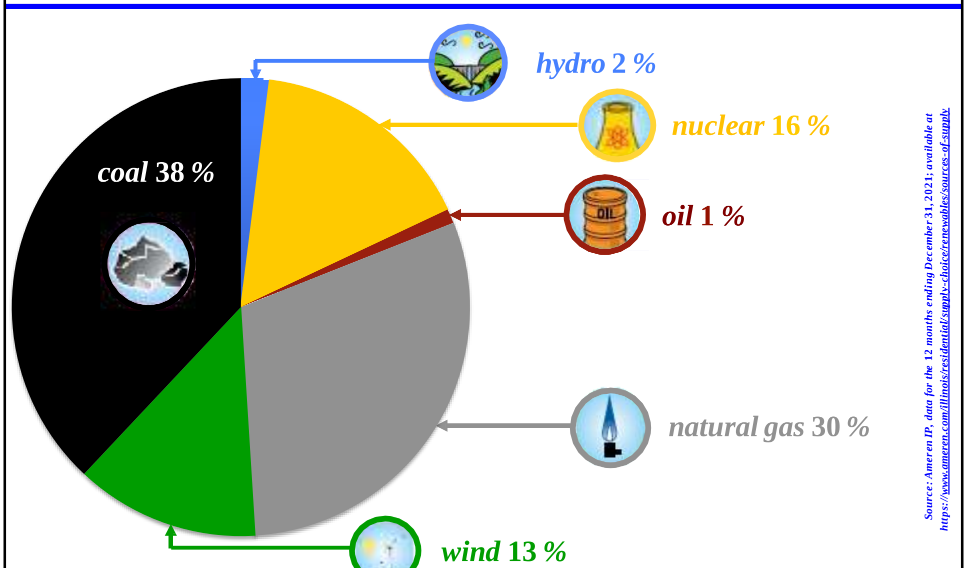
AMEREN ILLINOIS ENERGY SOURCES OF ELECTRICITY SUPPLIED IN 2021



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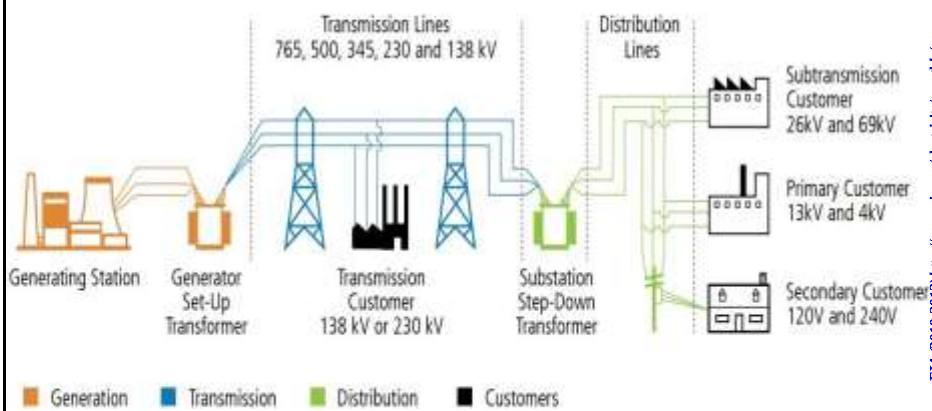
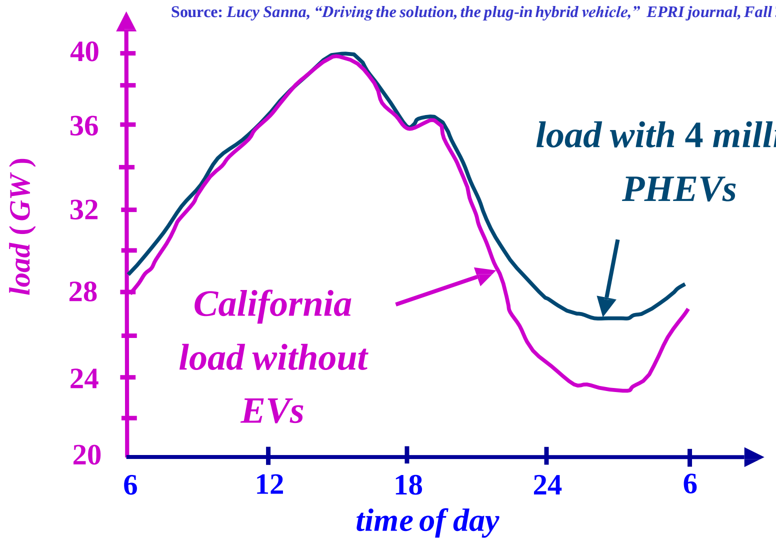
THE ELECTRIC POWER GRID



Source: EIA (2010-2013) http://www.eia.gov/electricity/monthly/current_year/february2014.pdf; pg 134; Issued April 2015

CHARGING THE *EV*s

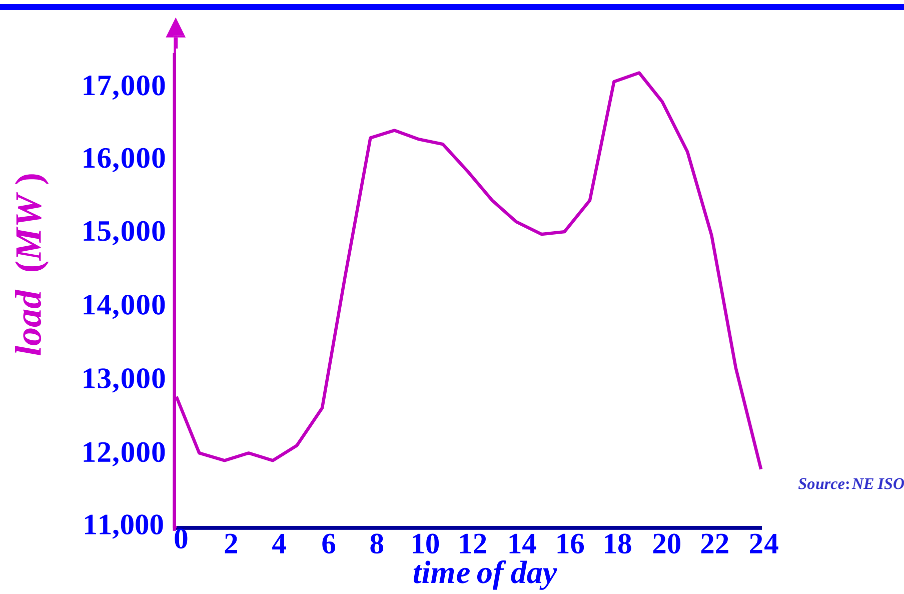
Source: *Lucy Sanna, "Driving the solution, the plug-in hybrid vehicle," EPRI journal, Fall 2005*



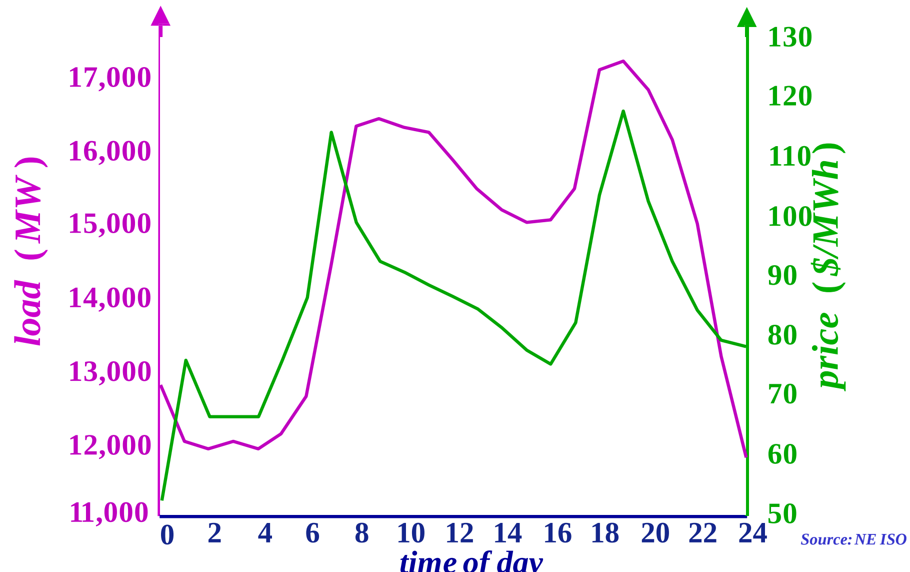
THE ELECTRICITY GRID

- The *MWh* costs and prices are unequal over time
- The value of each *MWh* depends on the time of production/consumption
- The integration of *EV*s into the grid can fully exploit the opportunities to:
  - buy electricity when the prices are *low*
  - sell services when the prices are *high*
  - provide *additional services* needed by the grid

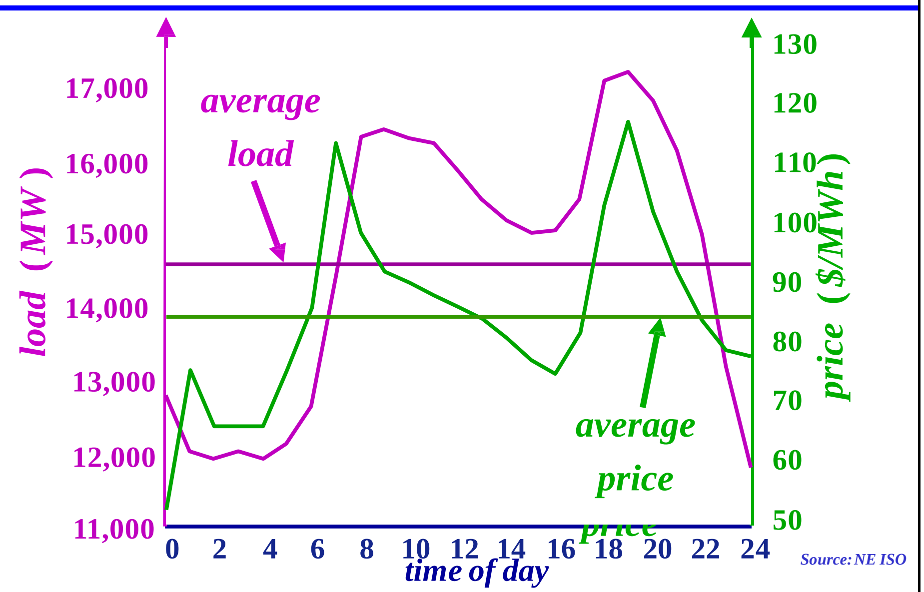
LOAD AND *LMP*



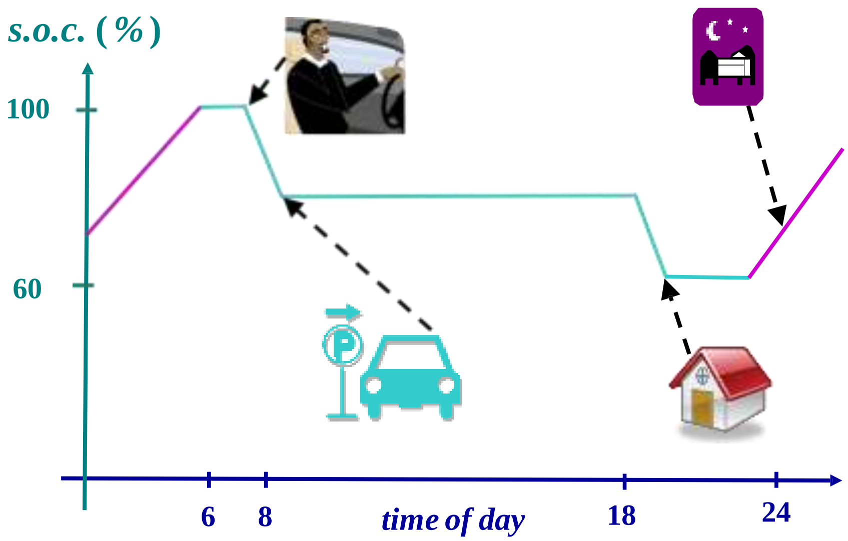
LOAD AND *LMP*



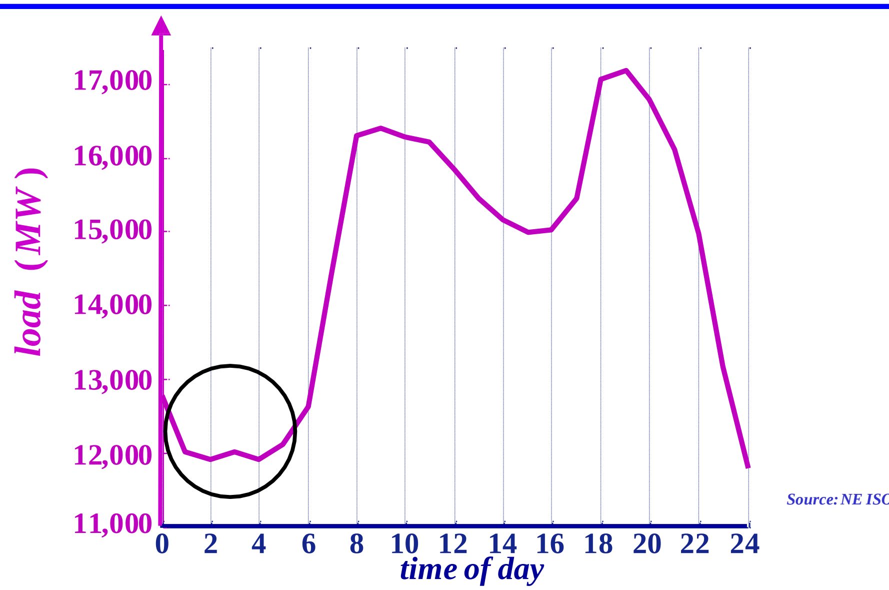
LOAD AND *LMP*



THE *EV* AS A "PURE LOAD"

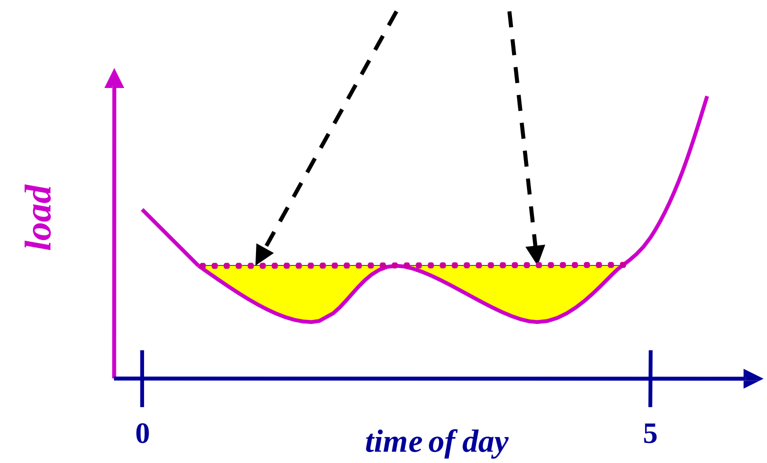


LEVELING THE LOAD

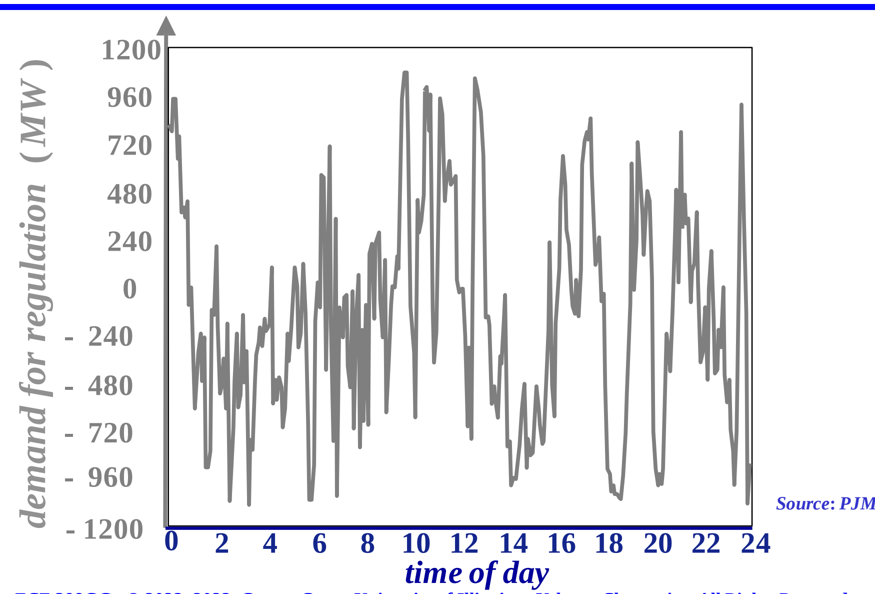


LEVELING THE LOAD

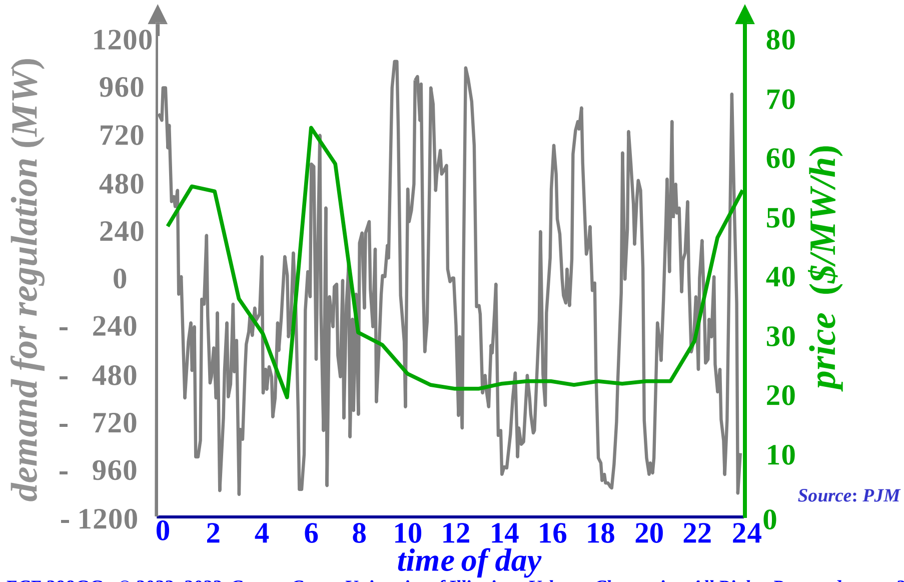
impacts of the controlled charging of the EVs



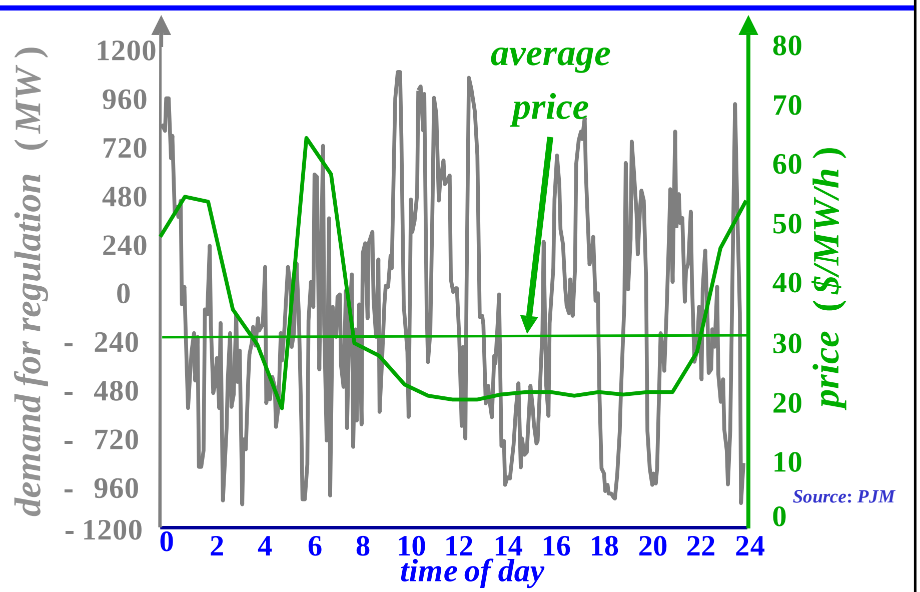
REGULATION SERVICE AND PRICING



REGULATION SERVICE AND PRICING



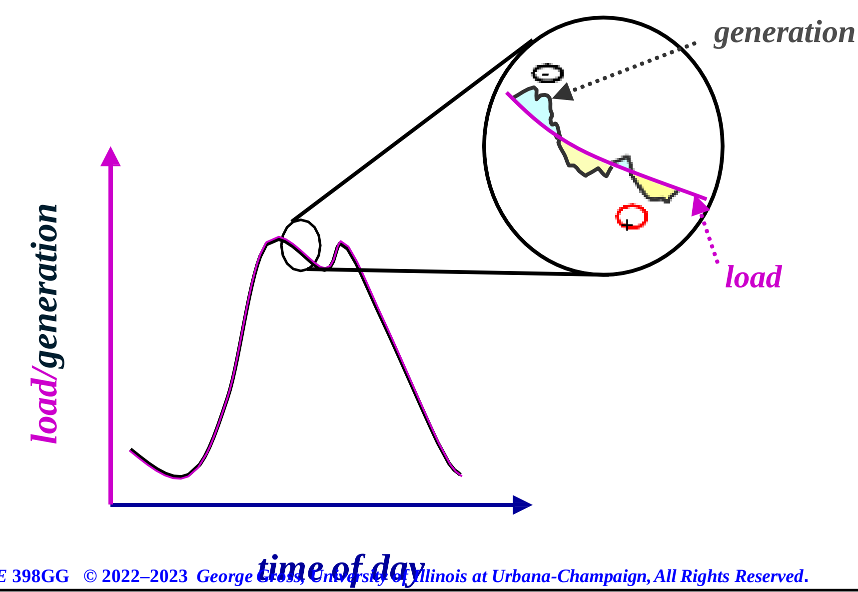
REGULATION SERVICE AND PRICING



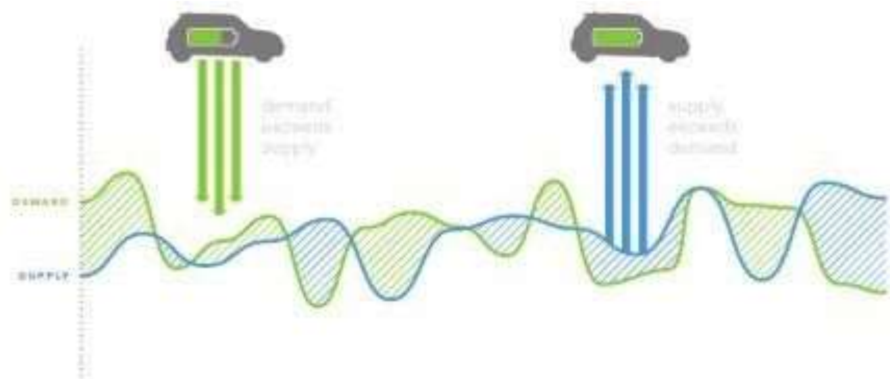
ROLE OF *EV*s IN FREQUENCY REGULATION

- A basic objective of the system operator is to ensure that the supply – demand equilibrium is maintained around the clock
- Imbalances lead to frequency fluctuations that need to be regulated
- In actual systems operations, the supply–demand imbalance is checked every 2 to 4 *s*

ROLE OF *EV*s IN FREQUENCY REGULATION



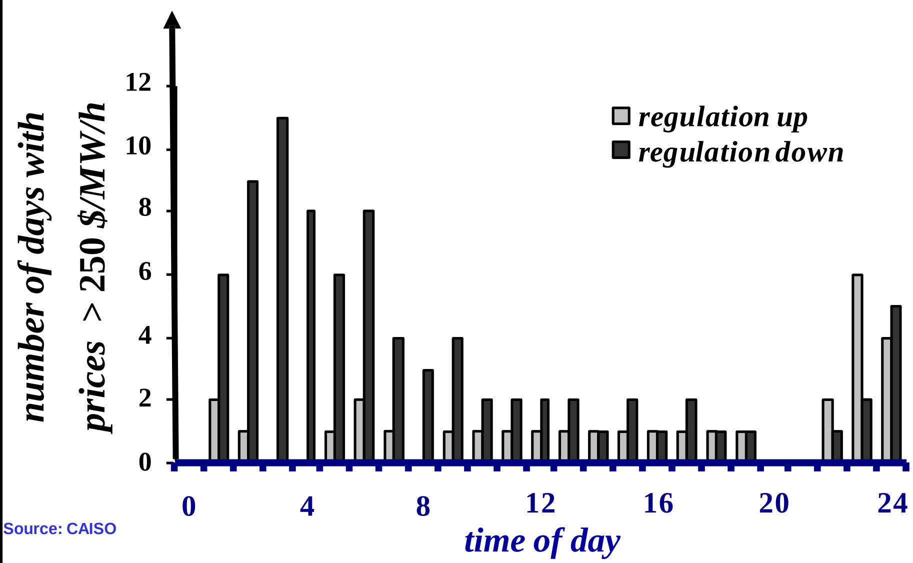
ROLE OF *EV*s IN FREQUENCY REGULATION



OFF – PEAK REGULATION

- **Compliance with the unit commitment schedules becomes a challenge during the *low–load conditions* that characterize the off–peak periods**
- **While the operator may not wish to turn off any units, there may be no choice**
- **Wind integration at deeper penetration further exacerbates the low load conditions**
- **The regulation prices are typically the highest, as many units are required to reduce their outputs**

PEAK AND OFF – PEAK REGULATION

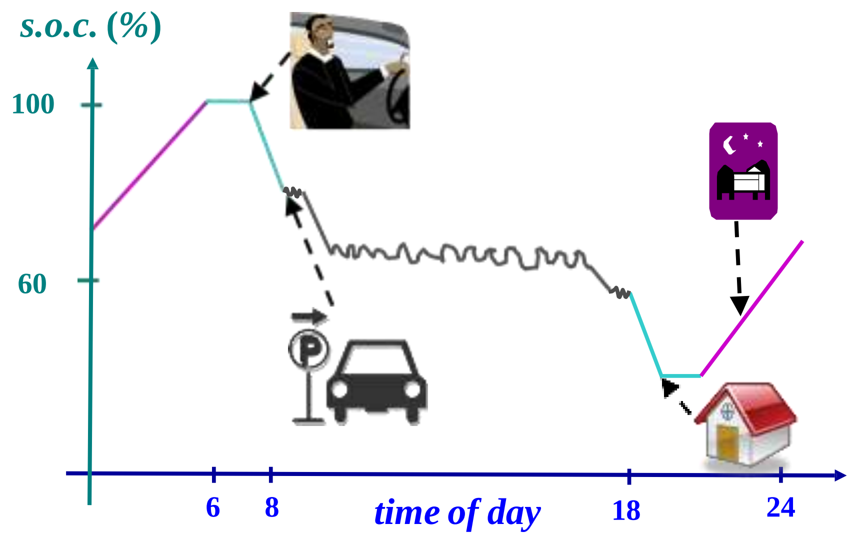


Source: CAISO

*EV*s AND FREQUENCY REGULATION

- Batteries are able to both absorb and discharge energy
- The regulation capacity provided by a battery is relatively small
- Batteries provide very short response times (on the order of *ms*)
- The frequent battery charge–discharge switching may, however, severely reduce battery life

THE *EV* AS A "SUPPLY-SIDE RESOURCE"



BATTERY ISSUES

- The battery capability in terms of *kWh* storage of an *EV* is small
- This capability limitation consequently restricts the "supply–side resource" capacity of each *EV*
- A key requirement for grid integration is the aggregation of *EV*s into a collection with the ability to palpably impact the grid

THE ROLE OF AGGREGATION

- The storage capability C for a typical EV is in the 30 – 60 kWh range
- If we consider the total discharge of the full battery over 5 h, the output is in the 6 – 12 kW range
- The aggregator, who gathers together "many" EVs to create a nontrivial aggregated output and load, can play a critically important role in the effective integration of EVs into the grid so as to *beneficially impact* both supply and demand–side issues

V2G FRAMEWORK

- Load aggregation
- Resource aggregation
- Explicit representation of uncertainty
- Communications/control layer construction
- Development of incentives for aggregation

PRINCIPAL PLAYERS IN THE *V2G* INTEGRATION

- ❑ **Aggregator**

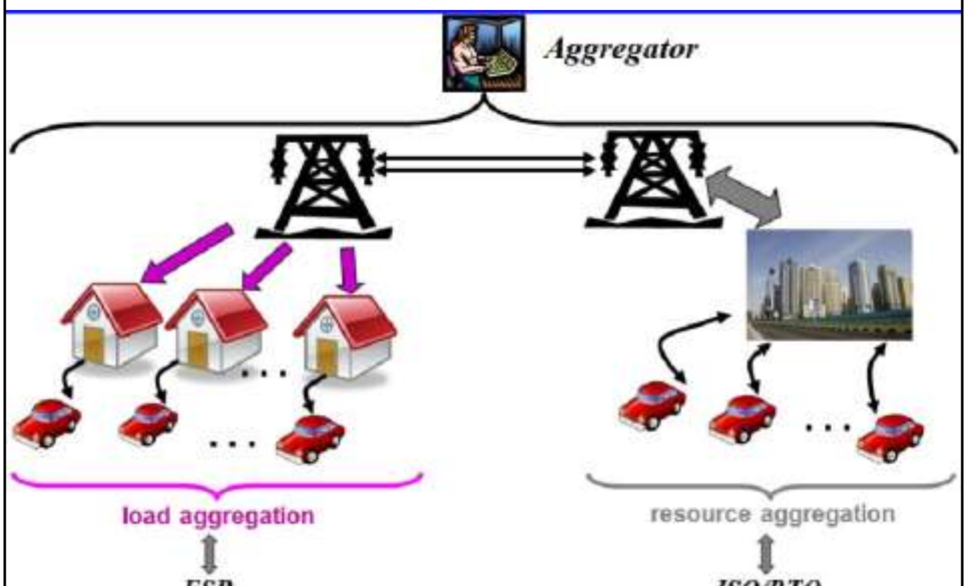
- ❑ **Aggregated *EV*s**

- ❑ ***ISO/RTO***

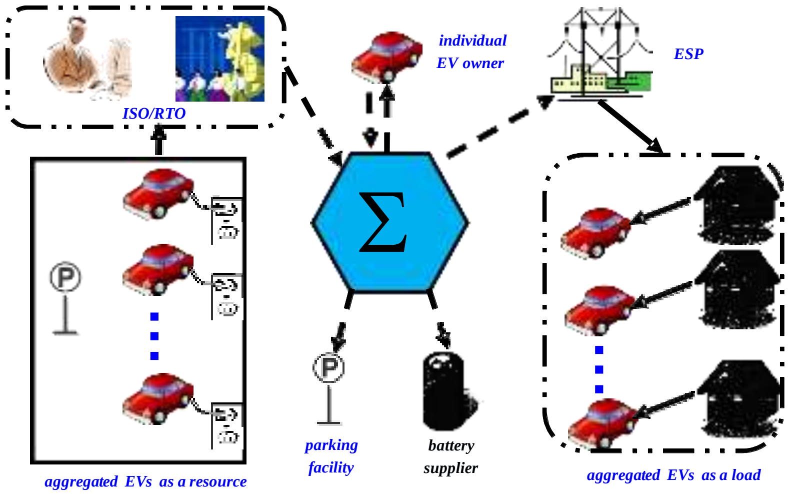
- ❑ ***ESP***

- ❑ **Local distribution company**

THE INTEGRATION FRAMEWORK

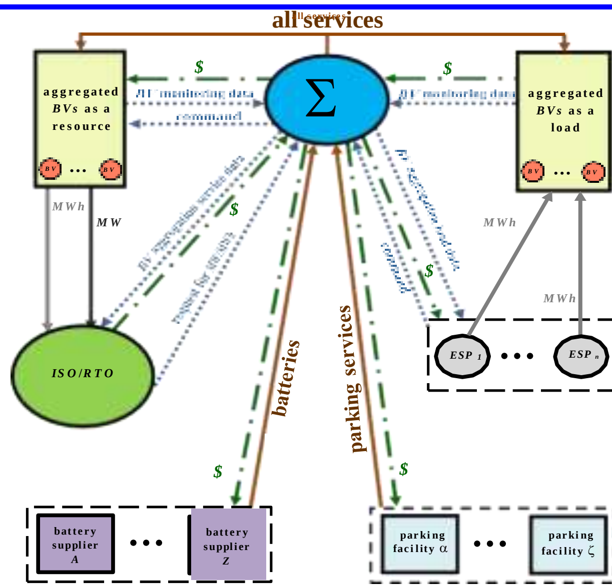


V2G PLAYER INTERACTIONS



dollar flows   capacity/energy flows

FLOWS IN THE *V2G* FRAMEWORK

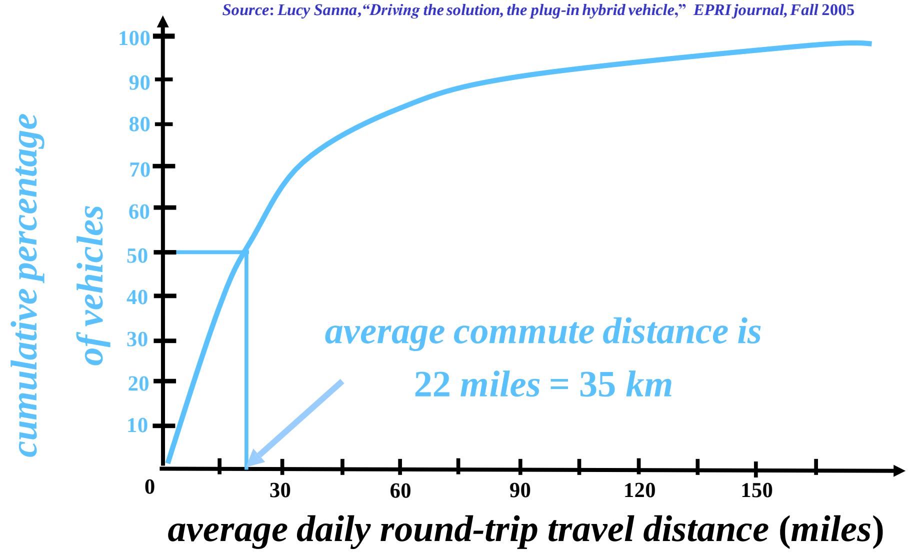


REPRESENTATION OF SOURCES OF UNCERTAINTY

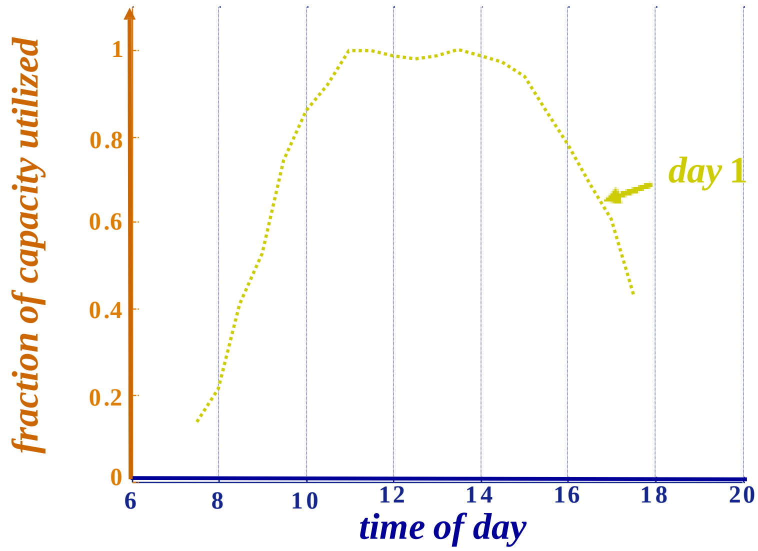
- We take into account various sources of uncertainty, including:
  - time of arrival
  - parking time
  - state of charge (*s.o.c.*)
  - storage capability of the *EV* battery
  - demand
- For the aggregated *EV*s, we make explicit use of the *Central Limit Theorem* ($N > 30$) and represent the uncertainty by using approximations based on *normally distributed random variables*

DAILY COMMUTE DISTANCES

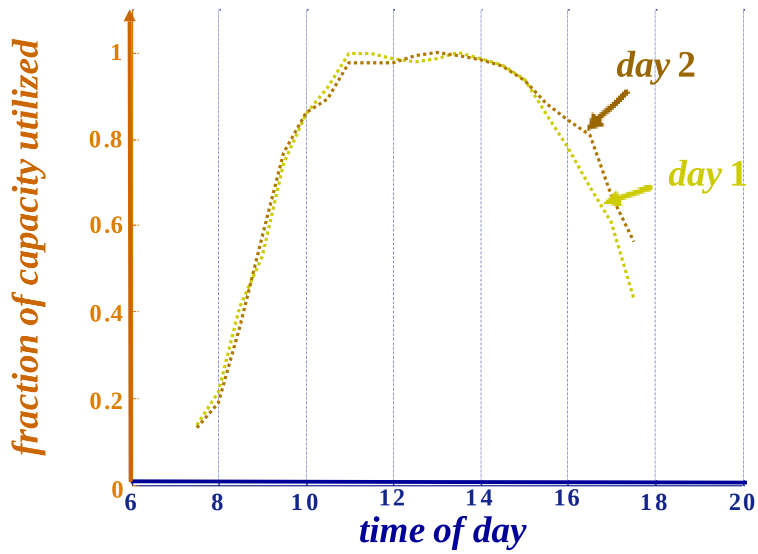
Source: Lucy Sanna, "Driving the solution, the plug-in hybrid vehicle," EPRI journal, Fall 2005



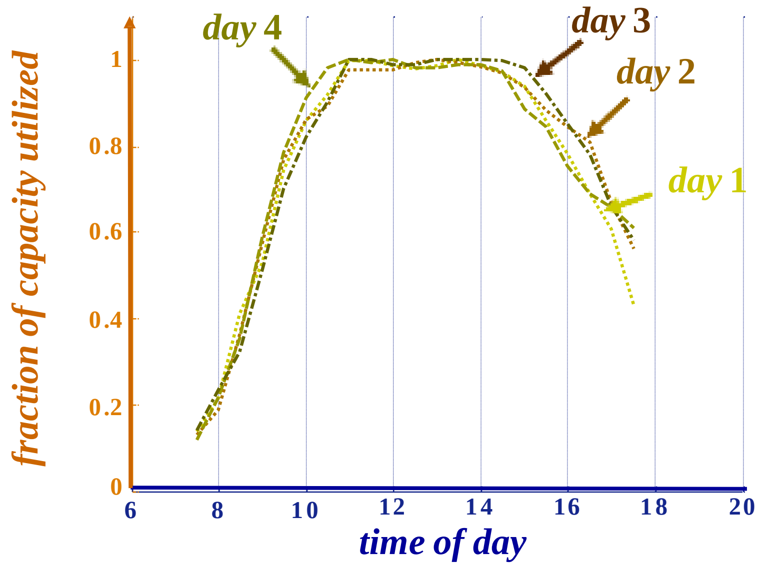
PARKING LOT UTILIZATION AS A FRACTION OF ITS CAPACITY



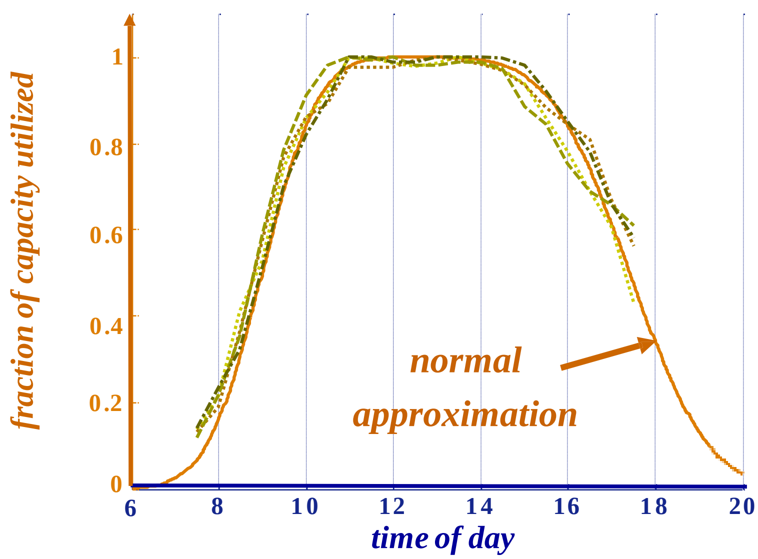
PARKING LOT UTILIZATION AS A FRACTION OF ITS CAPACITY



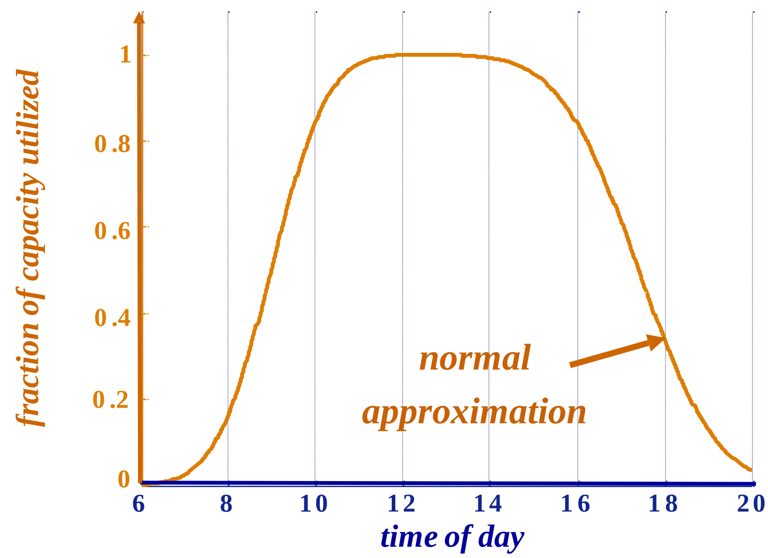
PARKING LOT UTILIZATION AS A FRACTION OF ITS CAPACITY



APPROXIMATION OF PARKING CAPACITY UTILIZATION

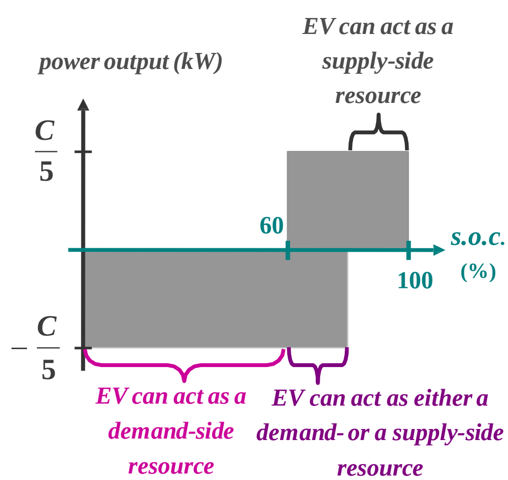


GAUSSIAN MODEL OF PARKING CAPACITY UTILIZATION



s.o.c. OF THE *EV* BATTERY

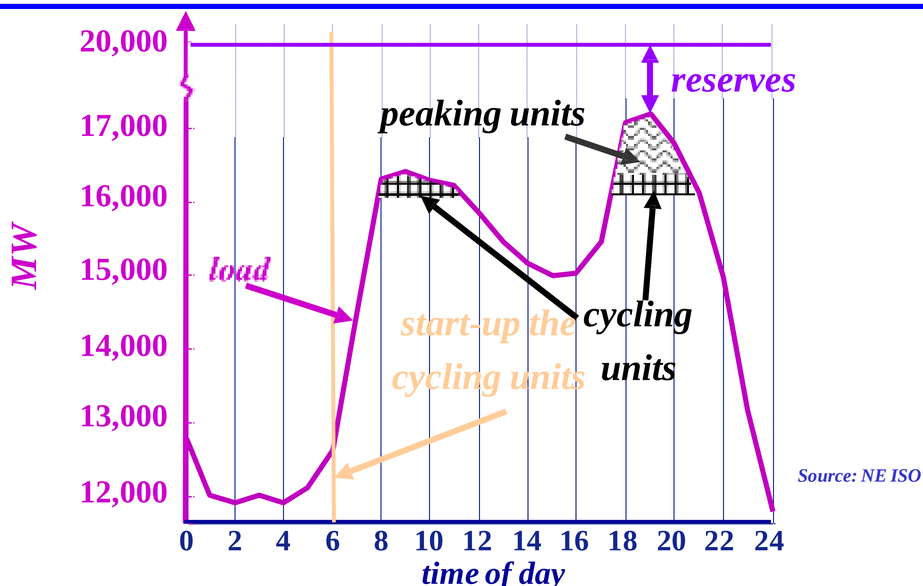
- The role of the *s.o.c.* is critical in the effective management of the aggregated *EV* integration into the grid
- The utilization of a battery depends on its storage capability



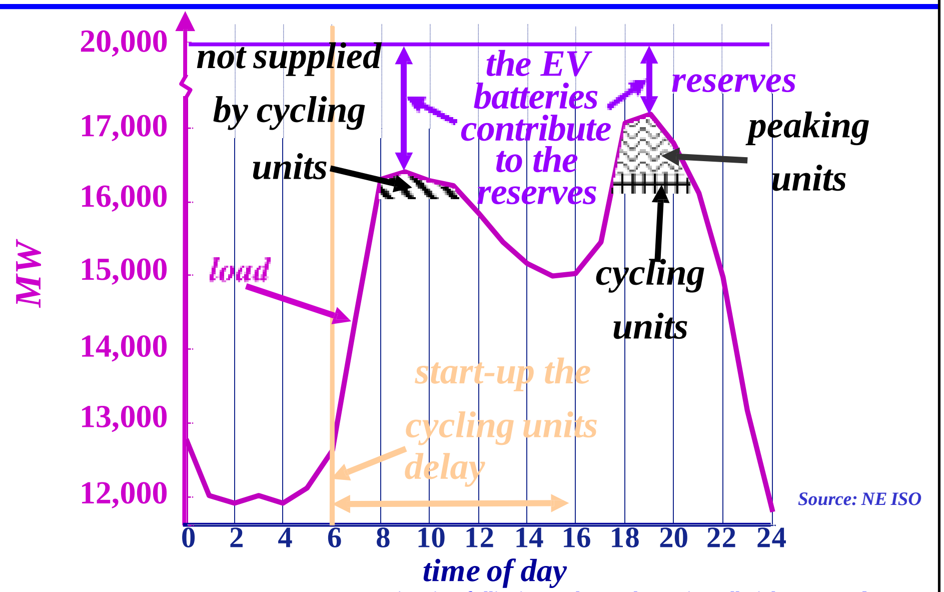
*EV*s' ROLE IN KEY SERVICE PROVISION

- The aggregated *EV*s constitute a very important supply–side resource to the grid
- The *EV*s can provide considerable flexibility to the *ISO/RTO* in the scheduling of units
- As a result, the start–up of cycling & peaking units may be delayed or avoided; the *EV*s strengthen the reserves provision and reduce reserves needed from other resources during off–peak periods

CYCLING UNITS WITHOUT *V2G*



CYCLING UNITS WITH *V2G*



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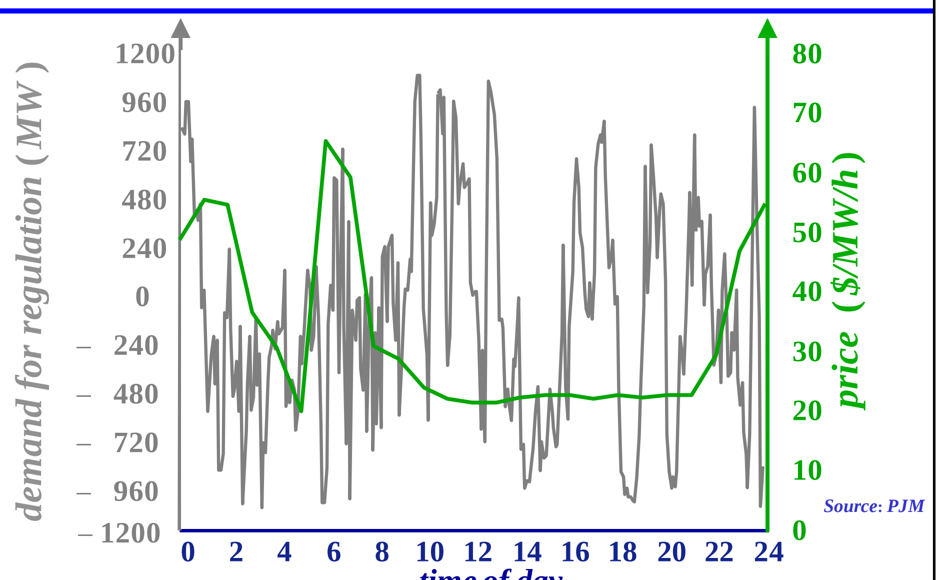
REGULATION SERVICE AND PRICING



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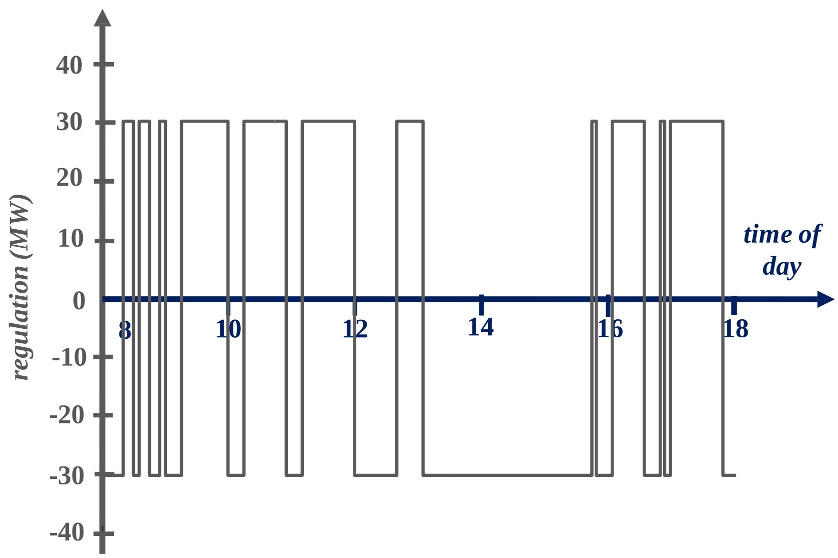
DAY – TIME REGULATION SERVICE PROVISION BY 100,000 *EVs*



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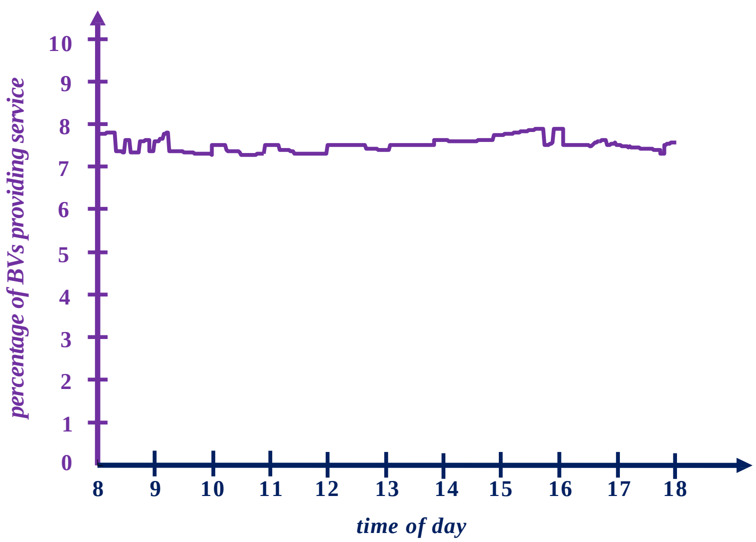
PERCENTAGE OF *EVs* PROVIDING THE REGULATION SERVICE



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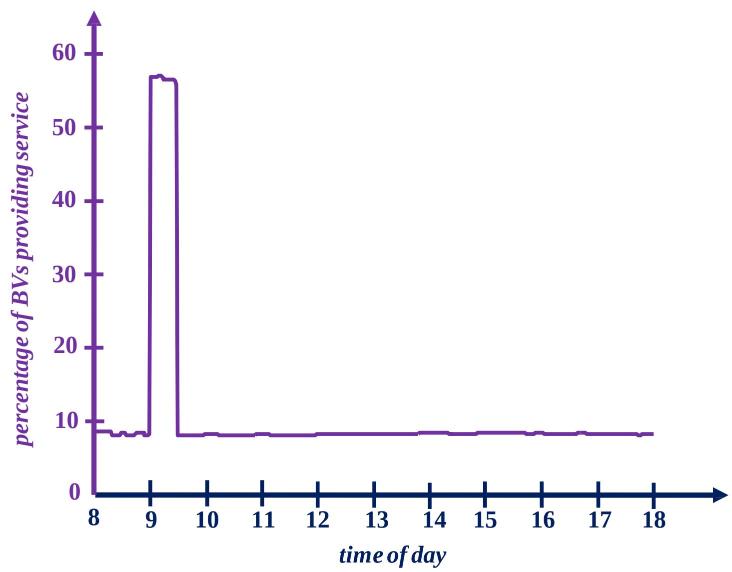
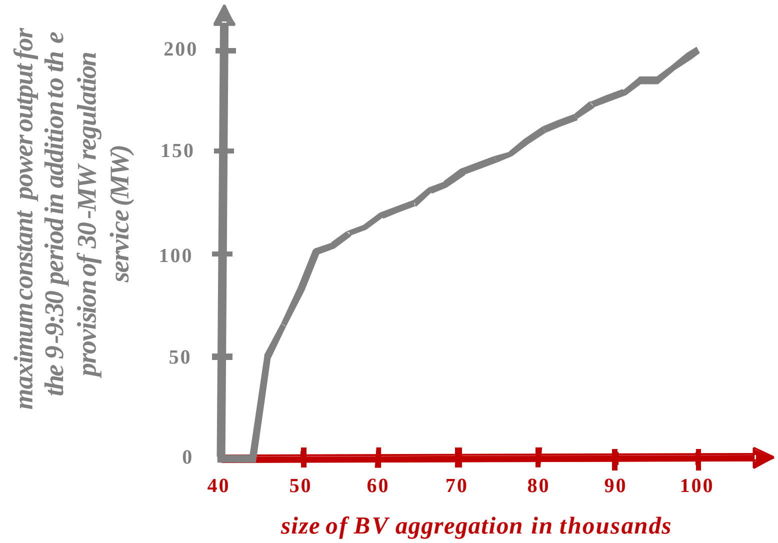
PROVISION OF LOAD SHAVING SERVICE IN ADDITION TO REGULATION

- The number of *EV*s providing regulation service remains rather low, with fewer than 8 % of the *EV*s in the aggregation providing service at any point in time from 8 *a.m.* to 6 *p.m.*
- We consider the provision of load shaving service in addition to the regulation service
- We show that the Aggregator can also provide 100 *MWh* of load shaving service at a constant power output between 9:00 and 9:30 *a.m.* via a collection of 100,000 *EV*s

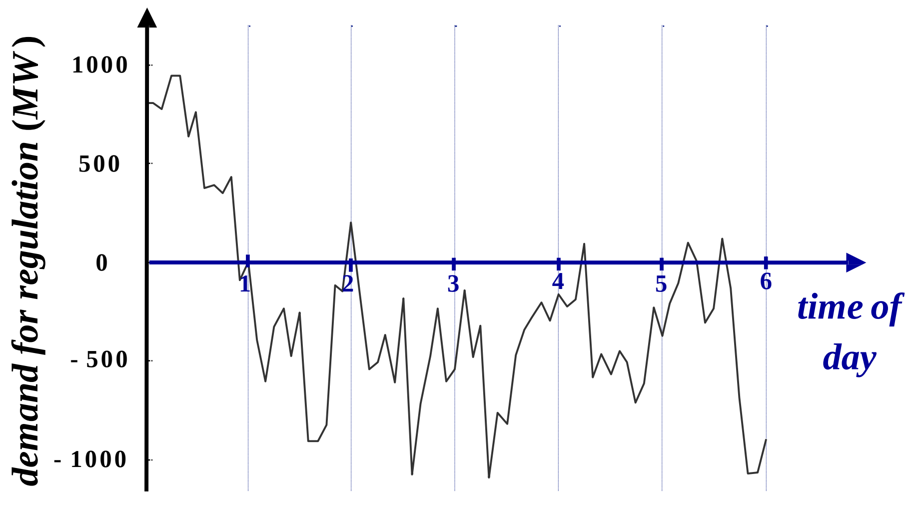
PERCENTAGE OF *EV*s PROVIDING LOAD SHAVING AND REGULATION SERVICE



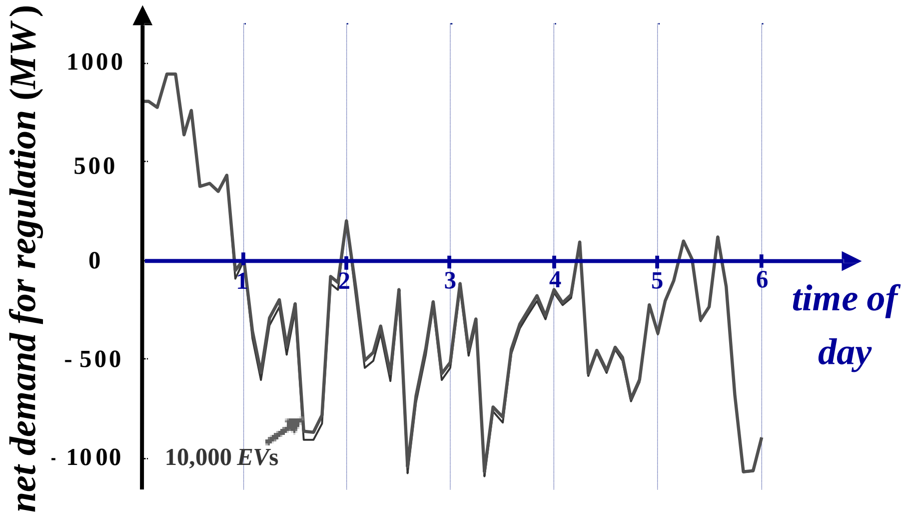
ENERGY PROVIDED IN ADDITION TO THE REGULATION SERVICE



REGULATION DEMAND FOR OFF-PEAK CONDITIONS



REGULATION DEMAND FOR OFF-PEAK CONDITIONS



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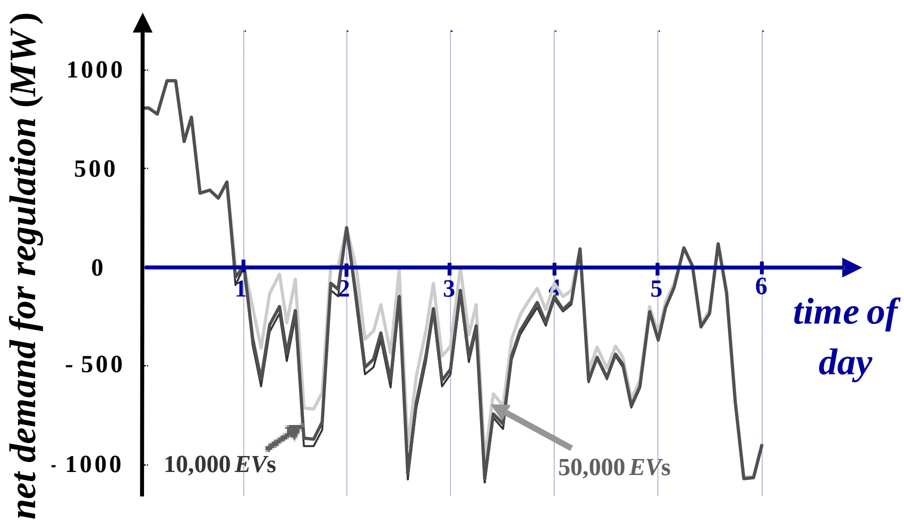
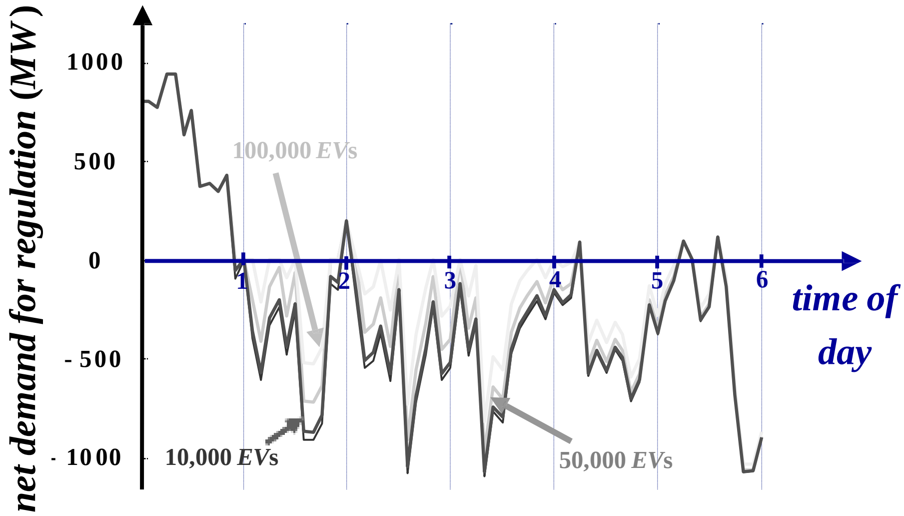


REGULATION DEMAND FOR OFF-PEAK CONDITIONS



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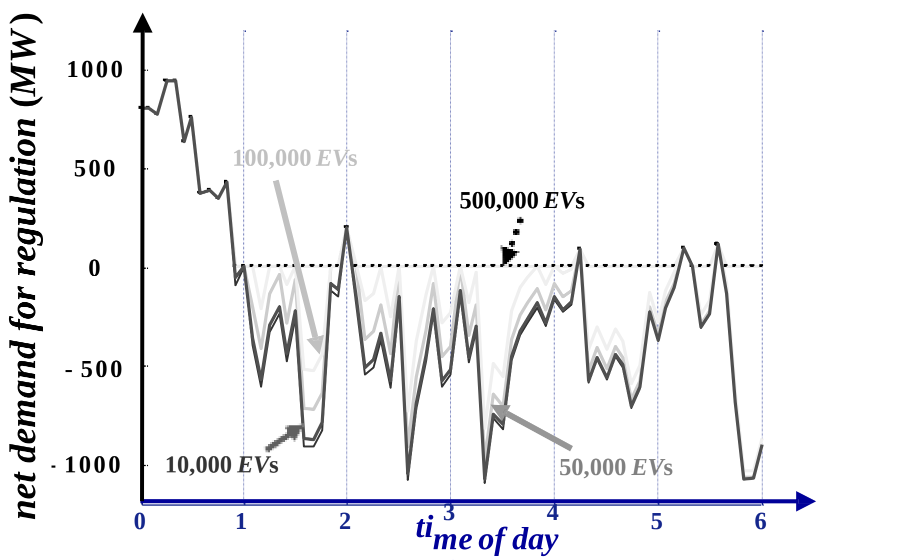
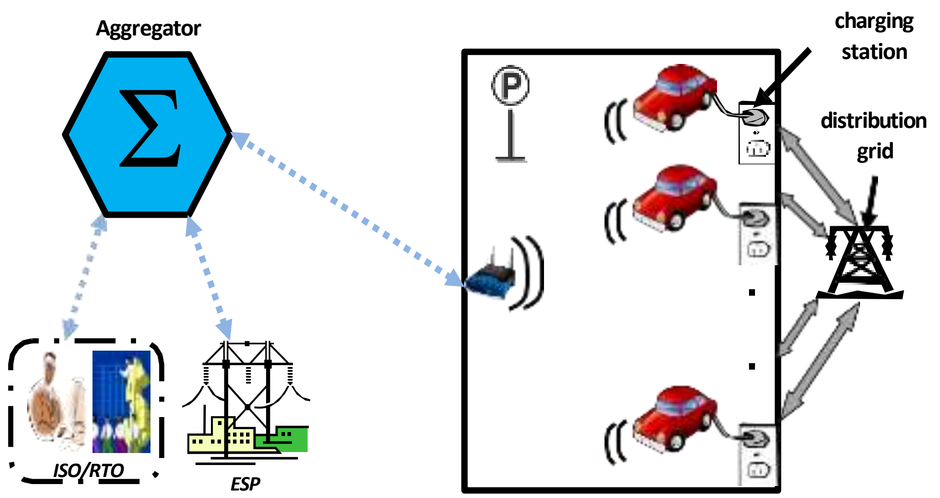


V2G COMMUNICATION AND METERING



ESSENTIAL COMMUNICATION/CONTROL SYSTEM REQUIREMENTS

- **Speed**: signals need to be sent every 1 to 2 *s*
- **Range**: every *BV* in a parking lot must be on the communication network
- **Measurement**: metering must be installed to enable payment for services
- **Reliability**: full utilization of all parked aggregated *BV*s
- **Security**: *BV*s make the network vulnerable to cyber attacks

ESSENTIAL COMMUNICATION/CONTROL SYSTEM REQUIREMENTS

- **Costs: each *BV* has an implanted device and the costs per unit must be low for the large collection of aggregated *BV*s**
- **Extendibility: the communication layer must allow the integration of additional *BV*s**
- **Interoperability: a non-restrictive, flexible standard needs to be introduced and implemented**

INFORMATION LAYER FLOWS

- **ID of each *EV***
- **Preferences/constraints of each *EV***
- **Parking status of each *EV***
- **Storage capability of the *EV* battery**
- **The *EV* battery *s.o.c.***
- **Power flows from *EV* battery to the grid**
- **Measured value of metered quantities**

THE ROLES OF THE AGGREGATOR

- ❑ Development of the parking infrastructure
- ❑ Maintenance of the batteries and the network
- ❑ Creation of relationships with the *EV* and battery manufacturers
- ❑ Interface with *ISO*/*RTO*

VALUE ADDED BY THE AGGREGATOR

- ❑ Provides a "package deal" to the aggregated *BV*s in terms of:
  - ❍ parking facilities
  - ❍ service acquisition and provision
  - ❍ charging of *BV*s
  - ❍ battery service
- ❑ Allows "one-stop shopping" for potential *BV* participants
- ❑ Acts as the "representative" for the provision of environmental benefits from reduced emissions

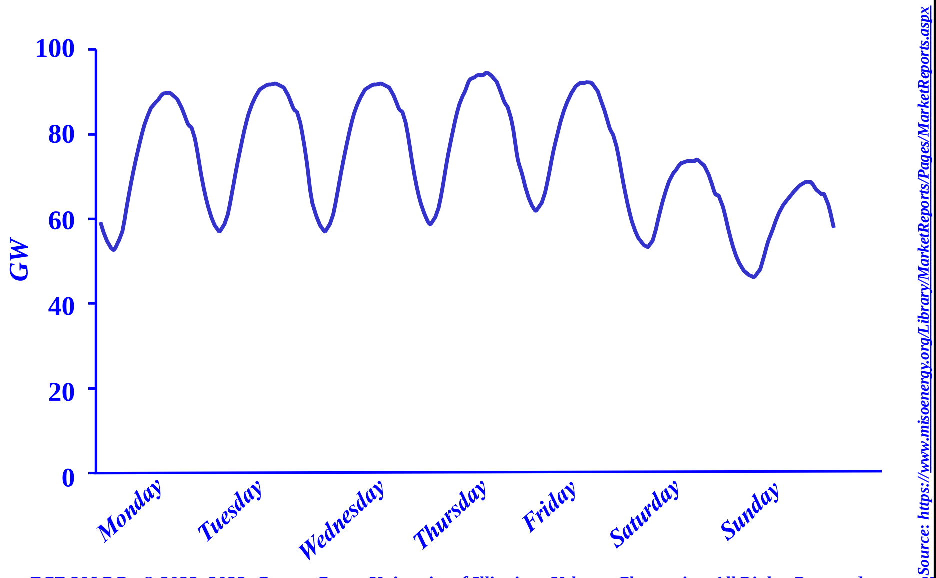
REFERENCES

- C. Guille and G. Gross, "A Conceptual Framework for the Vehicle-to-Grid (*V2G*) Implementation," Energy Policy, November 2009, pp. 4379 - 4390.
- C. Guille, "A Conceptual Framework for the Vehicle-To-Grid (*V2G*) Implementation," MS Thesis, ECE Department, University of Illinois, Urbana, September 2008; available at http://energy.ece.illinois.edu/gross/papers/Dissertations/Guille.pdf

OUTLINE

- Supply – side resources
- Demand – side resources
- Impacts of ***demand – side management*** (***DSM***)
- Challenges in ***DSM*** implementation
- Illustrative example of savings in ***DSM***
- Role of demand response resources (***DRR***s)
- ***DRR*** participation in electricity markets

MISO CHRONOLOGICAL LOAD FOR THE JULY 15 – 21, 2013 WEEK



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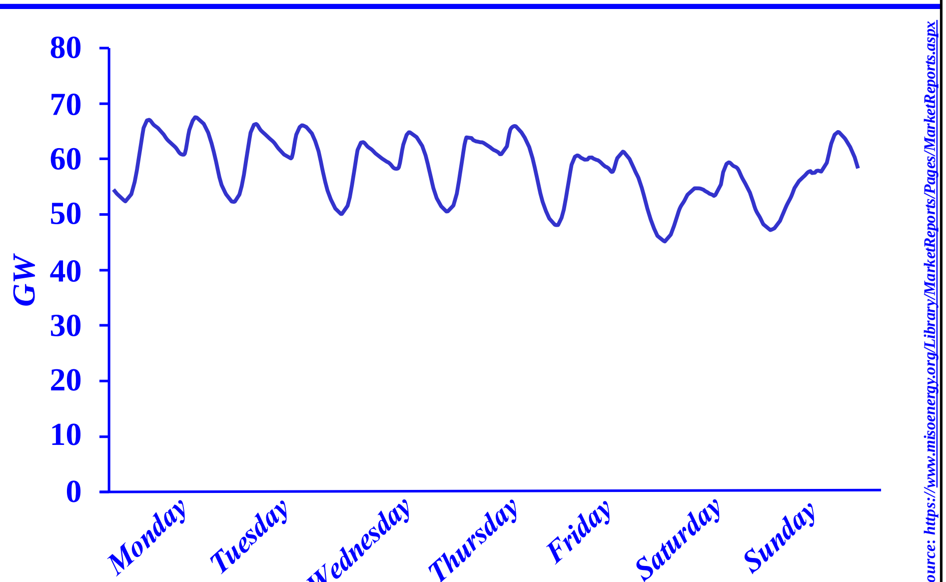
MISO CHRONOLOGICAL LOAD FOR THE JANUARY 7 – 13, 2013 WEEK



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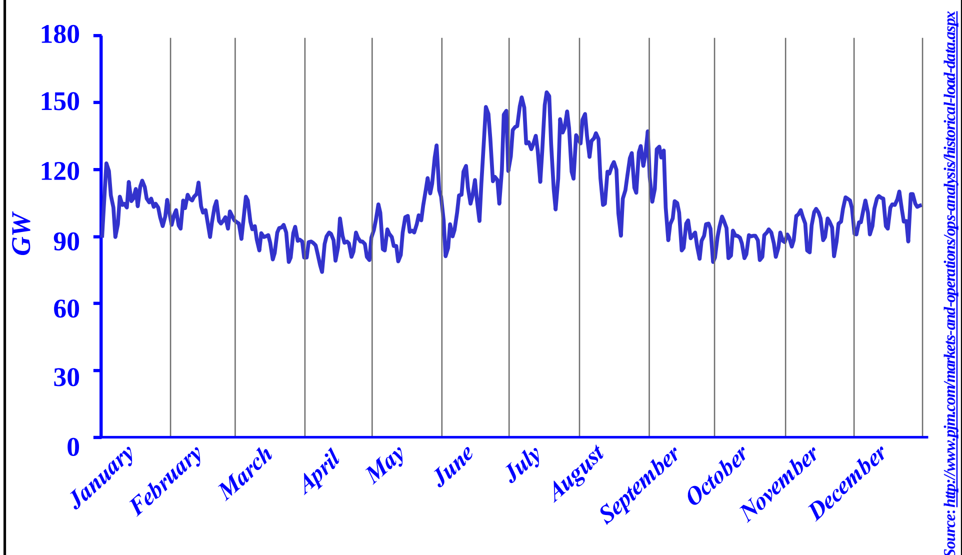
52 – WEEK DAILY *PJM* PEAK LOAD PROFILE FOR 2012



SUPPLY – SIDE RESOURCES

- We consider *generation sources* to be *supply–side resources* as they provide the grid with
  - energy; and
  - capacity
- In addition, supply–side resources provide a variety of services ranging from reactive power support to system stability enhancement
- Unfortunately, many supply–side resources may also have undesirable environmental attributes

CONVENTIONAL SUPPLY – SIDE RESOURCES

resource use	*examples*
base–loaded generation	*combined cycle, co–generation, coal, run–of–river hydro, geothermal*
mid–range generation	*combined cycle*
peaking generation	*gas turbine, peaking hydro*
purchases from other entities	*firm capacity and energy contracts*

ADDITIONAL SUPPLY – SIDE RESOURCES

resource type	*examples*
non–utility source purchases	*co–generation; wind, small hydro, small coal, solar; larger thermal resources*
exchanges	*peaking capacity with off–peak energy return; seasonal capacity exchanges*
renewable	*solar, wind, hydro, PV, biomass*
energy storage	*pumped storage hydro, compressed air energy storage technology, batteries*

DEMAND – SIDE RESOURCES

- Programs designed to modify the demand via
  - efficiency improvement/energy conservation;
  - electricity consumption reduction; and/or
  - shift of loads to periods with lower demand

  help to *effectively* meet customers' demand, but with a reduced negative environmental impact
- We call these programs *demand–side management* (*DSM*) or *demand–side resource*s (*DSR*s)

DEMAND – SIDE RESOURCES

- Conceptually, we may view *DSM* as an energy "source" to meet the system demand
- Conservation measures save energy since they put a stop to certain types of consumption; for example, insulation of a house reduces heating/ air conditioning needs over the life of the house
- Every implemented energy conservation effort reduces overall demand in all subsequent periods

DEMAND – SIDE RESOURCES

- Efficiency improvements serve to reduce demand without necessarily removing the load: *e.g., Energy Star* appliance purchases that replace the earlier, conventional appliances create benefits via the reduced energy consumption and lower expenses and, moreover, the *reductions in emissions*
- An efficiency measure reduces the need to add generation, but complications do arise

ENERGY EFFICIENCY IMPLICATIONS

- The implementation of technology that improves the efficiency of a process implies that we can obtain the same output as with the pre–efficiency improvement process, but the new process uses less energy input and thus *reduced emissions*
- Unfortunately, the *energy efficiency improvement* in a specific application reduces the required energy input but need not significantly reduce the total energy consumption for that application

ENERGY EFFICIENCY IMPLICATIONS

- For example, we consider the case of doubled number of *km* per *l* of input fuel, say from 8 *km/l* to 16 *km/l* ; typically, such an efficiency increase results in the use of the cars to go twice as far as earlier and thus results in *zero reduction* in the total fuel consumed; ditto for the associated emissions

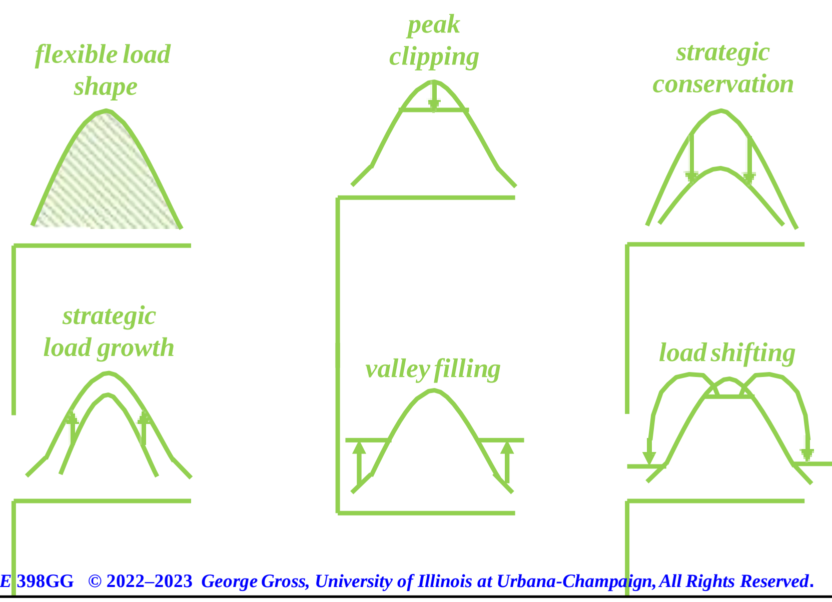
*DSR*s

- *Demand shifting programs* aim to move energy consumption from peak load times to periods of lower system loads, typically, in off–peak hours; such load shifts serve to reduce or defer the need for additional capacity from supply resources
- *Load management programs* are able to switch loads *on and off* to effectuate *lower* system demand at various times, particularly at times of peak load, in order to reduce reliance on peakers

DEMAND-SIDE MANAGEMENT

- The term **demand–side management** (*DSM*) was used in the earlier, regulated environment to refer to the implementation of extensive programs that modify the demand of the system
- In practical terms, a *DSM* program is **any measure that impacts load on the *customer side*** of the meter
- In analogy to supply–side resources, *DSR*s may be targeted for **base**, **intermediate** and **peaking uses** to attain economic benefits with a **reduction of the impacts** on the environment

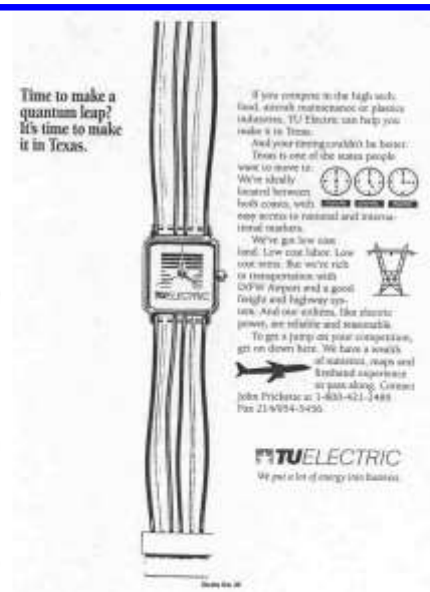
DSM PROGRAMS' LOAD SHAPE OBJECTIVES



TYPICAL EXAMPLES OF *DSM* PROGRAMS

program type	*example*
load reduction	*conservation*
load buildup	*marketing*
load shifting	*load management*

ENERGY EFFICIENCY AND ECONOMIC DEVELOPMENT



RENEWED INTEREST IN *DSM*

- After its assessment of *DSR*-provided services, the *Federal Energy Regulatory Commission* (*FERC*) has repeatedly encouraged the incorporation and wider expansion of *DSM* within today's organized electricity markets
- Several grid operators – *ISO-NE*, *NYISO*, *PJM* and *ERCOT* – have encouraged consumer participation and took steps to integrate *DSM* – the *DSR*s – into their wholesale electricity markets

RENEWED INTEREST IN *DSM*

- Some states – *MD, NJ, NY* and *PA* – have adopted *real–time pricing* as a default service for *large loads,* or have implemented *critical peak pricing* programs, as in *CA* and *FL*
- Several major utilities – *Georgia Power, Duke Power* and *TVA* – have attracted significant customer participation in *real–time pricing programs* as an optional service for large customers

RENEWED INTEREST IN *DSM*

- Many utilities have already deployed or are considering the deployment of advanced metering infrastructure (*AMI*) on a system–wide basis to implement price–sensitive demand response
- The number of *US AMI* units deployed in 2020 was about 103 *million* and is growing year by year

APPROPRIATE *DSM* APPLICATIONS FOR DIFFERENT LOAD SEGMENTS

intended load segment	*base*	*intermediate*	*peaking*
typical programs	*motors* *water heater, refrigerator and freezer efficiency improvements* *lighting*	*building weatherization* *air-conditioner or heat pump efficiency improvements* *stricter appliance efficiency standards* *time-of-use rates*	*air-conditioner control* *thermal storage HVAC* *high peak rates*

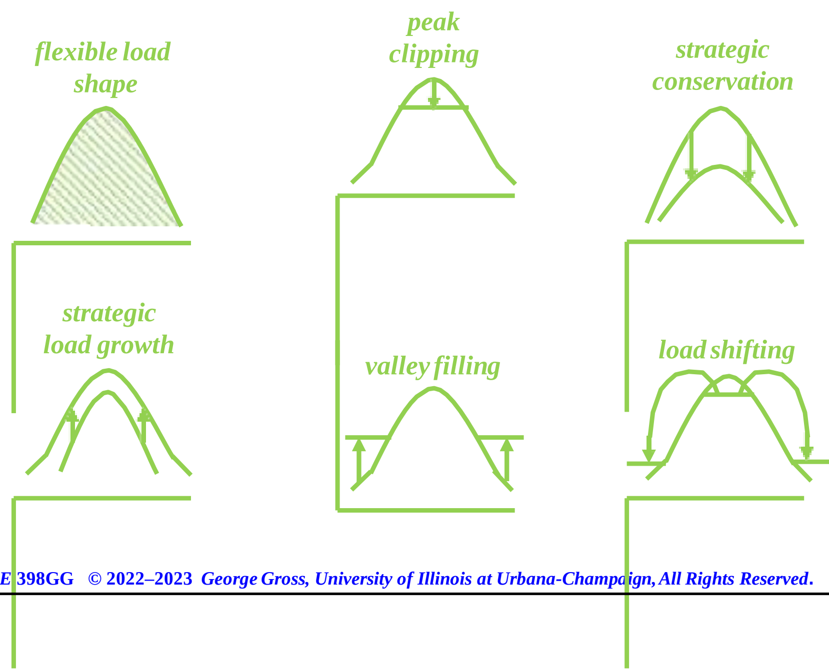
LOAD MANAGEMENT PROGRAMS

- **The key objective is to *strategically* reduce *end-user* consumption at peak load times**
- **The deployment of these programs avoids the need to construct more peaking units**
- **Such programs, typically, have *minor impacts* on the *total energy consumption***

LOAD MANAGEMENT PROGRAMS

- **These programs constitute the *mature parts of DSM***
- **The two major classes of programs**
  - ***direct load control*; and**
  - **indirect control via *pricing–based options* – interruptible, curtailable, time–of–use rates – or the deployment of *customized design of the incentives for load management***

DSM PROGRAMS' LOAD SHAPE OBJECTIVES



BASIC ASPECTS OF *DSM*

- The *DSM* activities focus on the *customer–side of the meter* and aim to influence end use of electricity to attain the desired *changes in the load shape*
- *DSM,* in practice, has become a collection of programs for increased efficiency, conservation and load management; programs aim to reduce the need for more electrical energy generation resources and additional installed capacity

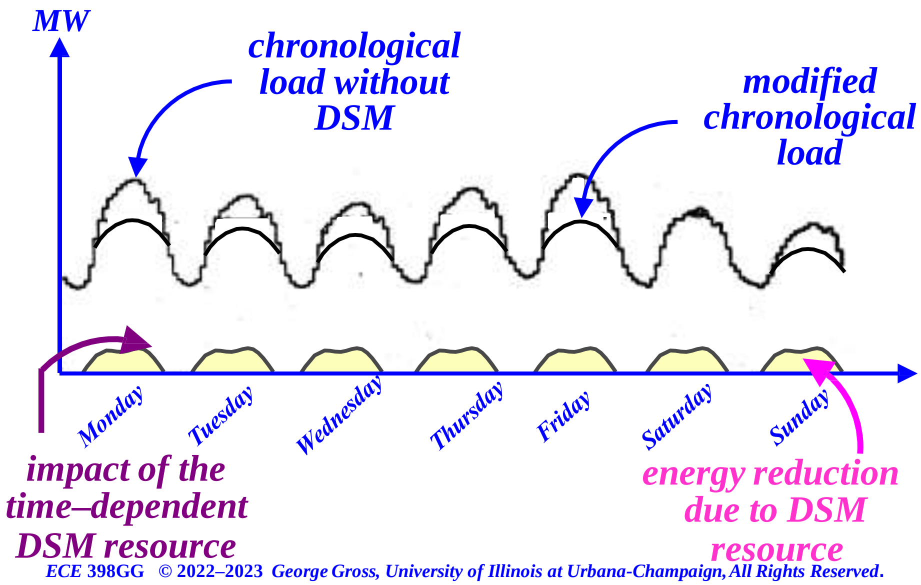
BASIC ASPECTS OF *DSM*

- **Load demand is not considered to be fixed: the changes in demand are planned concurrently with supply–side modifications, and the *DSM* program execution and energy dispatch are carried out in an *integrated* manner**
- **The dispatch of implemented *DSM* programs becomes an inherent part of system operations**

KEY *DSM* IMPACTS

- **Modification of the chronological load shape**
- **Reduction of the peak load**
- **Delivery of the electricity at a lower consumption level**
- **Reduction in the overall emissions**
- **Deferral and possible avoidance of the need to add new supply–side resources**

DSM INTEGRATION



KEY CHALLENGES IN *DSM* IMPLEMENTATION

- **Electricity service providers (*ESP*s) need to overcome the disincentives caused by *conventional* rate–making realities: the more electricity is sold, the higher the contributions to profits**
- **The development of *rate structures* that not only permit the recovery of *DSM* program costs but also provide *additional incentives* to encourage *DSM* implementation over investments in *grid–integrated* supply–side resources is critically important**

KEY CHALLENGES IN *DSM* IMPLEMENTATION

- The *education/training of customers* through the timely provision of information on topics, such as:
  - effective energy utilization;
  - the important role of demand in attainment of supply–demand balance; and
  - cost–effective approaches to manage the customer energy needs

  is a fundamentally important requirement

KEY CHALLENGES IN *DSM* IMPLEMENTATION

- Design and implementation of *appropriate tariffs and incentives* for customers to
  - improve *efficiency* and adopt new *conservation measures*;
  - shift loads to periods with lower demand;
  - obtain regulatory approval for their timely launch and marketing
- Solution to the *free rider problem*

EXAMPLE: SHARED SAVINGS PROGRAM

- An energy services company (*ESCO*) undertakes a lighting program to improve energy efficiency through the replacement of 75–*W* incandescent bulbs by 18–*W*, 10,000–*h* compact fluorescent lamps (*CFL*) that produce an equivalent amount of illumination
- As an incentive to customers, the *ESCO* offers a $ 2 rebate on each installed *CFL*

EXAMPLE: SHARED SAVINGS PROGRAM

- We have the following data for the *ESCO* program:

parameter	*unit*	*value*
marginal costs	¢/*kWh*	3
average costs	¢/*kWh*	2
number of CFLs installed	–	10^6
administrative/overhead costs	$/*CFL*	1

EXAMPLE: SHARED SAVINGS PROGRAM

- We compute the energy savings to be

$$kWh\ saved = \underbrace{(75-18)}_{W}\underbrace{(10{,}000)}_{h}\underbrace{10^6}_{\text{CFL units installed}} = \underbrace{(570)}_{\text{energy savings per CFL unit}}10^6\ kWh$$

which correspond to

$$energy\ cost\ savings = (57)10^7(.03) = \$17.1\,M$$

- The program costs are

$$implementation\ costs = (2+1)\ 10^6 = \$3\,M$$

EXAMPLE: SHARED SAVINGS PROGRAM

- The net savings for the *ESCO* are

$$net\ savings = 17.1 - 3 = \$14.1\,M$$

- A shared savings program is typically carried out with the allocation of the net savings to the customers and the *ESCO* along some specified basis: consider an allocation of 15 % to the *ESCO* and 85 % to the customers:

$$ESCO\ net\ benefits = \$2.12\,M$$

$$customers\ net\ benefits = \$11.99\,M$$

EXAMPLE: SHARED SAVINGS PROGRAM

- The ability of the *ESCO* to directly receive a share of the *net savings* provides incentives to undertake additional lighting programs

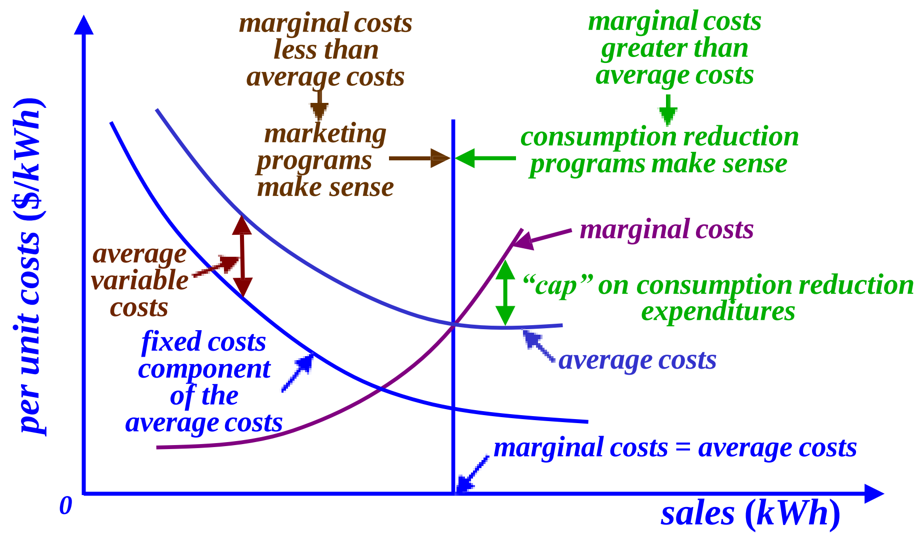
$$DSM\ costs / kWh = \frac{\$\ 3}{570\ kWh} = \frac{¢\ 300}{570\ kWh} = 0.52\ ¢ / kWh$$

- The *CFL* program is judged to be *cost effective* since

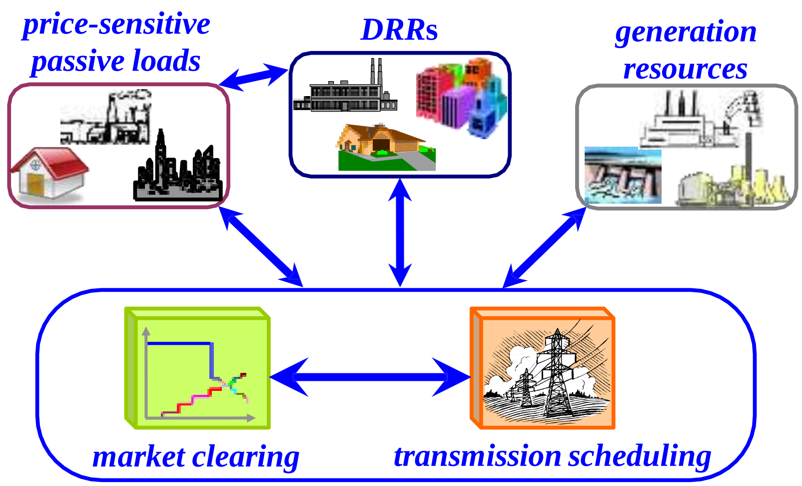
$$\begin{array}{c} average \\ costs \end{array} + \begin{array}{c} DSM \\ costs \end{array} = 2 + 0.52 = 2.52\ ¢ / kWh$$

$$< 3\ ¢ / kWh = marginal\ costs$$

A SIMPLE COST – EFFECTIVENESS TEST



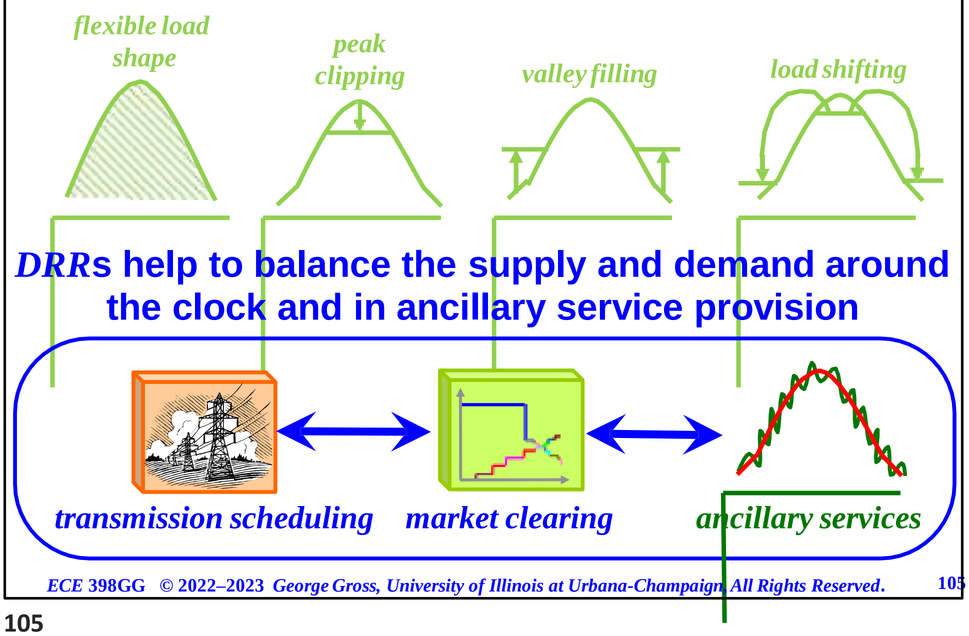
DEMAND RESPONSE RESOURCES (*DRR*s)



THE NATURE OF *DRR* DEPLOYMENT

- The objective of *DRR* usage is to make the load an *active participant* in the around-the-clock balance of electricity supply and demand via side–by–side competition with supply–side resources
- *DRR*s curtail their loads in response to incentive payments to reduce electricity consumption at specified times
- *DRR*s provide *attractive alternatives* to supply–side resources to attain the supply–demand balance

DRR ACTIVITIES



_DRR_s help to balance the supply and demand around the clock and in ancillary service provision

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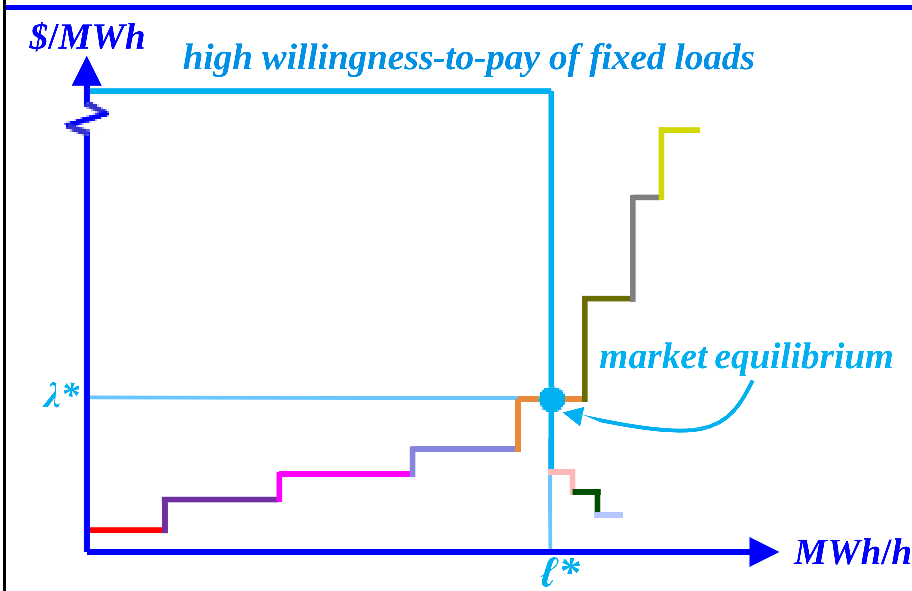
ELECTRICITY MARKET CLEARING



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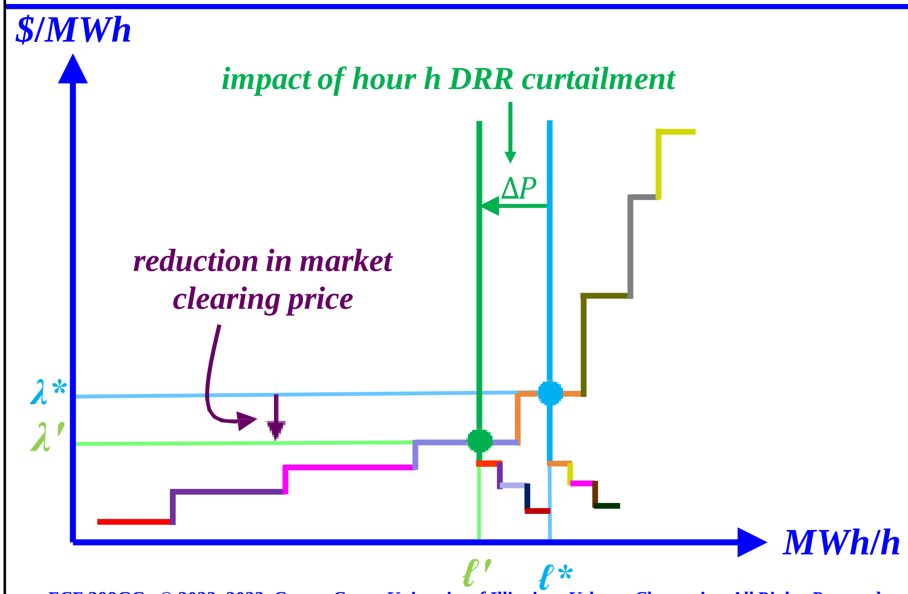
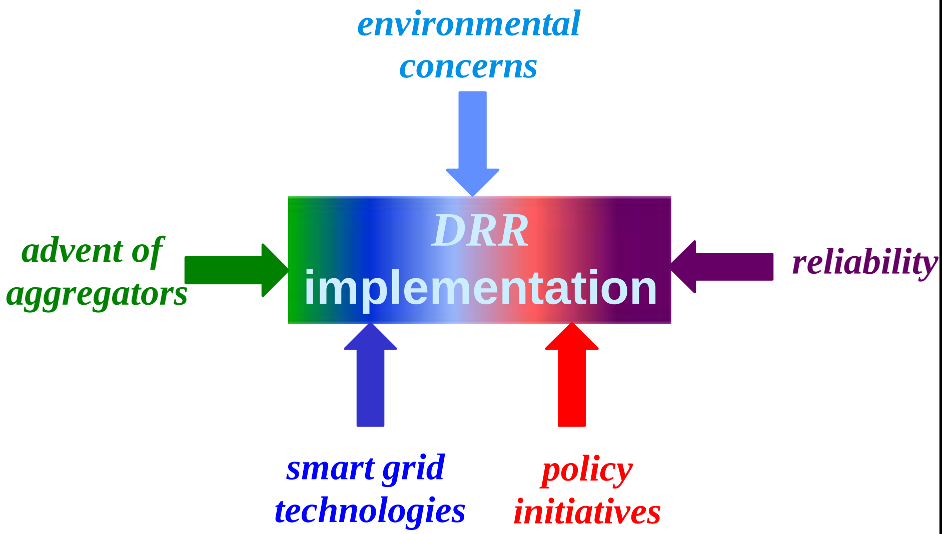
HOUR *h* *DRR* CURTAILMENT MARKET IMPACTS



DRRs ARE ATTRACTIVE

- ***Jon Wellinghoff, past Chairman, FERC*: "There are tremendous benefits from demand response at very low costs, costs much lower than we can put any supply in place. This is the first fuel."**
- ***Jim Rogers, CEO, Duke Energy*: "The most environmentally responsible plant you build is the one that you don't build."**

DRR IMPLEMENTATION DRIVERS



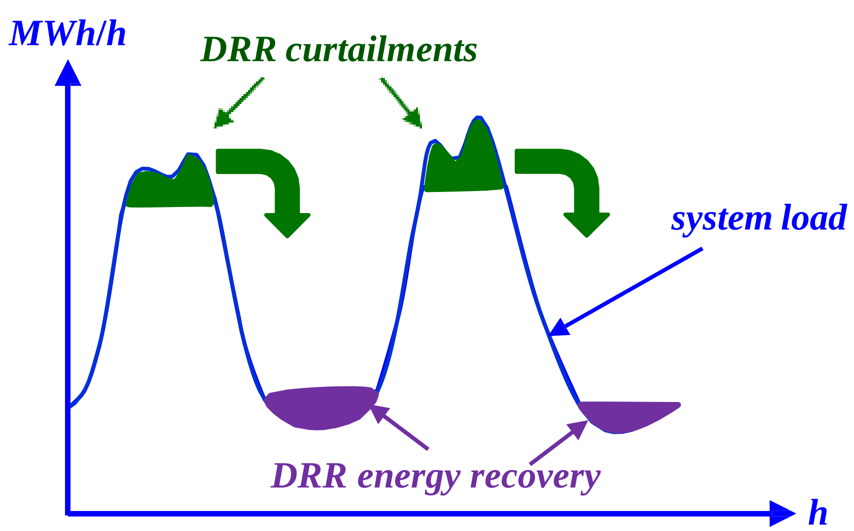
DRR LIMITATIONS AND CHALLENGES

- The potential for *DRR* implementation is *limited* and challenges arise as *DRR* penetrations deepen
- Policies to incentivize *DRR* participation must be formulated in such a way as to effectively balance the benefits among all the market players – the sellers – *suppliers* – and the buyers – *consumers*

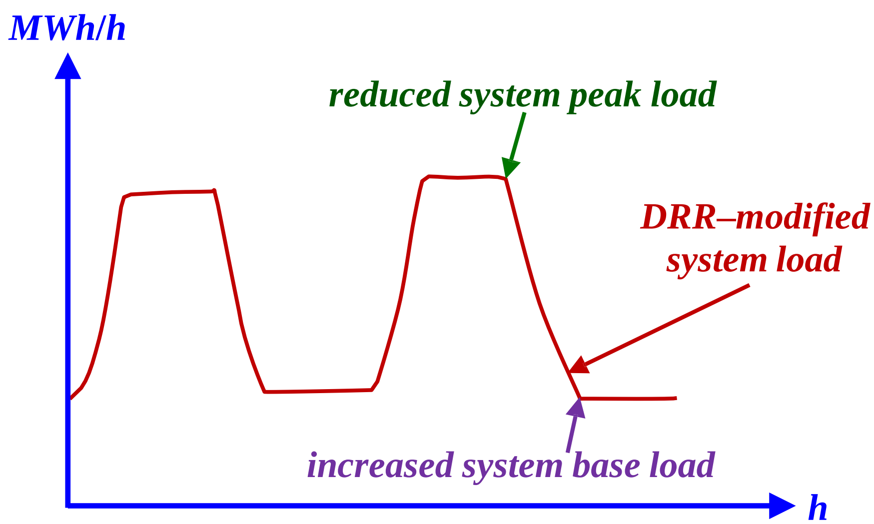
DRR LIMITATIONS AND CHALLENGES

- ***DRR*** **curtailments in high–load hours are likely to be followed by energy recovery in lower–load hours, the so–called *payback effects*, with the associated price impacts**
- ***DRR*s cannot provide the system dynamic effects that generators do; thus, their *physical limitations* restrict the depths of effective *DRR* penetration**

DRR WITH ENERGY RECOVERY



DRR WITH ENERGY RECOVERY



FERC ORDER NO. 745

- *FERC* Order No. 745 specifies the incentives to the *DRR*s for load curtailments in the *DAM*s
- The Order represents a significant increase in *DRR* incentives over past practices
- These incentives provide a major stimulus for *DRR* participation in electricity markets

DISTRIBUTED ENERGY RESOURCES (*DER*s)

- We use the term *resources* to refer to *both supply– and demand–side resources*
- We refer to energy resources integrated into the distribution grid as *DER*s
- The participation of *DER*s in electricity markets presents various technical and implementation challenges to *RTO*s/*ISO*s, including:

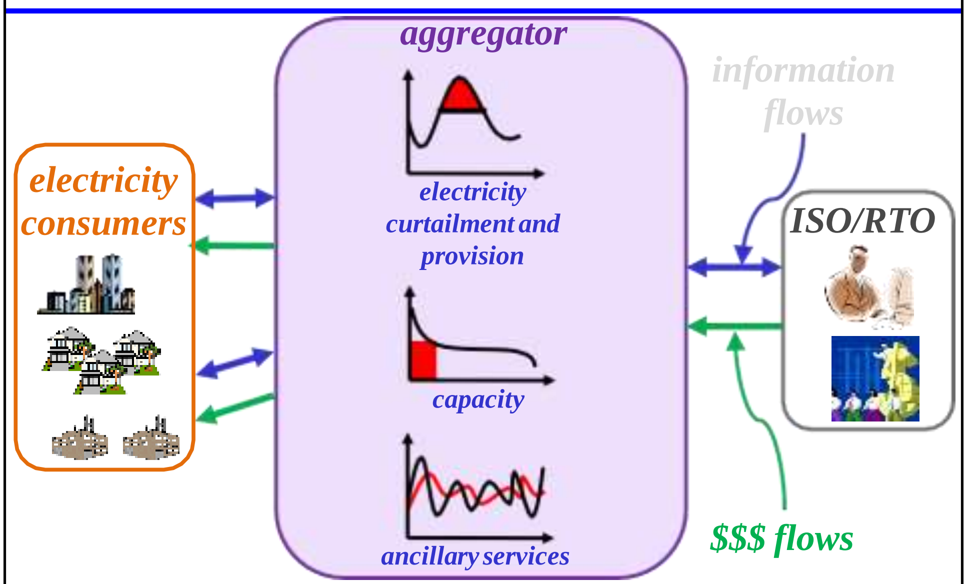
DISTRIBUTED ENERGY RESOURCES (*DER*s)

- *DER*s are integrated into a grid, over which the *RTO*s/*ISO*s have no monitoring/control capabilities
- there is a limit of the size of a resource that is palpable to the bulk grid
- *DER* operational constraints arise from both the distribution and the transmission grids
- the presence of numerous *DER*s may lead to computational & communication challenges

DER OPPORTUNITIES

- Distribution-side *DRR*s are also *DER*s and a large portion of the demand is on the distribution side
- Residential *DRR* examples are "smart" appliances, water-heating and *HVAC* systems
- *DER*s also include rooftop *PV* and *EV* batteries
- *DER*s can provide capacity at times of peak demand to avoid costly infrastructure upgrades
- *DER* integration enables retail customers to purchase electricity when demand/prices are low and to provide various services to the grid

AGGREGATOR SERVICES



FERC ORDER NO. 2222

- The coordinated operation of multiple *DER*s enables *RTO*s/*ISO*s to represent *DER*s as a *single aggregated resource* to simplify *DER* representation
- The aggregator is the entity that performs such coordination and acts as the liaison between the *ISO*/*RTO* and electricity consumers to enable *DER*s to participate in bulk electricity markets
- In September 17, 2020, *FERC* issued *Order No.* 2222 to specify the rules of participation by *DER* aggregations in bulk electricity markets

OFFICIAL *DER* DEFINITION

- Order No. 2222 officially defines *DER*s as "any resource located on the distribution system, any subsystem thereof or behind a customer meter"
- This broad and technology-independent definition enables, virtually, any device connected to the distribution grid to be considered to be a *DER*

FERC ORDER NO. 2222

- Order No. 2222 requires *ISO*s/*RTO*s to allow all *DER*s whose capacity is 100 *kW* or higher to participate in bulk electricity markets
- *DER*s with capacity below 100 *kW* may still provide services to electricity markets through an aggregator, defined as "the entity that aggregates one or more *DER*s for purposes of participation in the capacity, energy and/or ancillary service markets of the *RTO*s and/or *ISO*s"

ROLE OF AGGREGATION

- An aggregator is officially defined in Order No. 2222 as "the entity that aggregates one or more *DER*s for purposes of participation in the capacity, energy and/or ancillary service markets of the *RTO*s and/or *ISO*s"
- Aggregators act as the intermediary between the *ISO*/*RTO* and electricity consumers to deliver services from *DER*s to markets

