ECE 333 – Green Electric Energy

18. Demand – Side Issues in Energy

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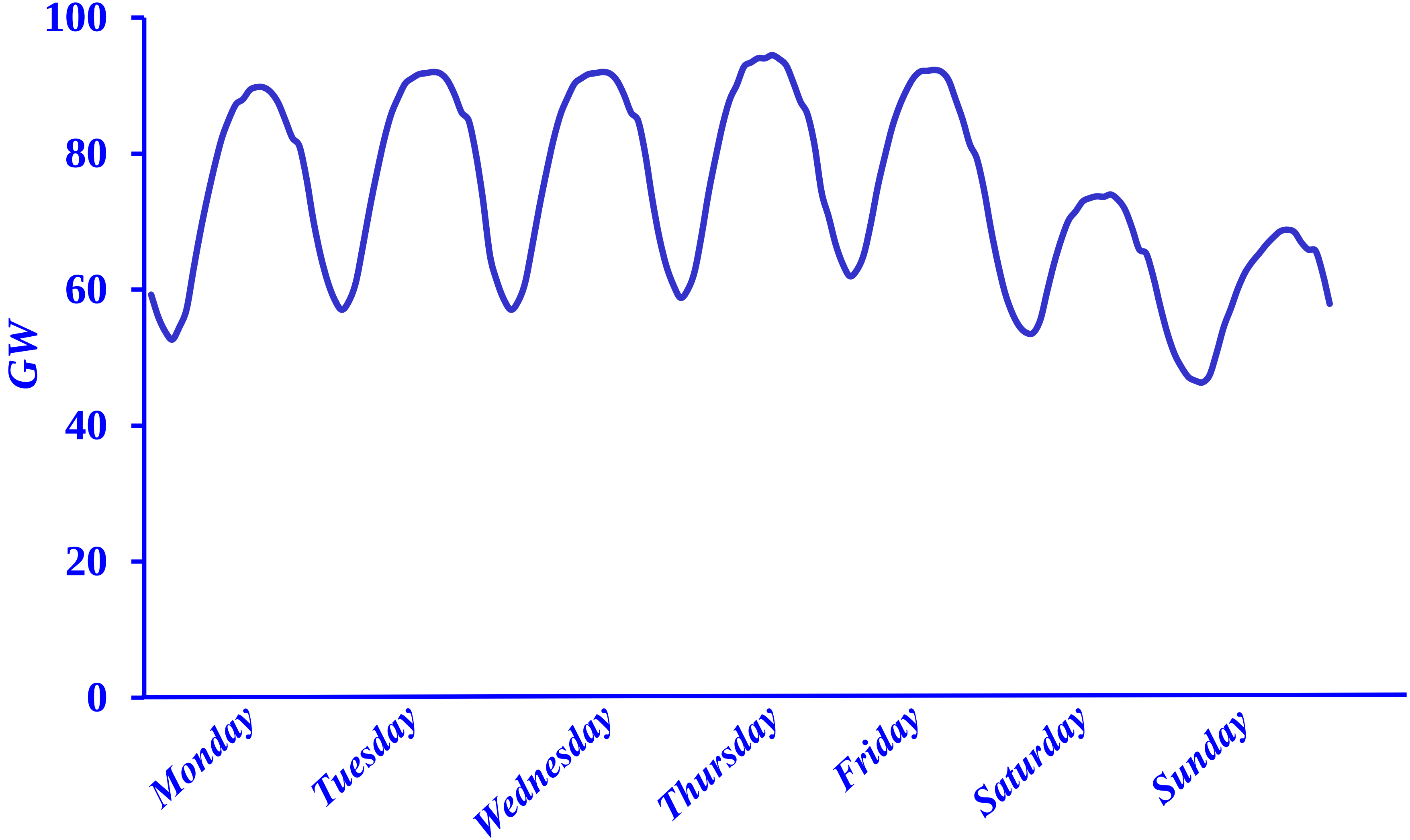
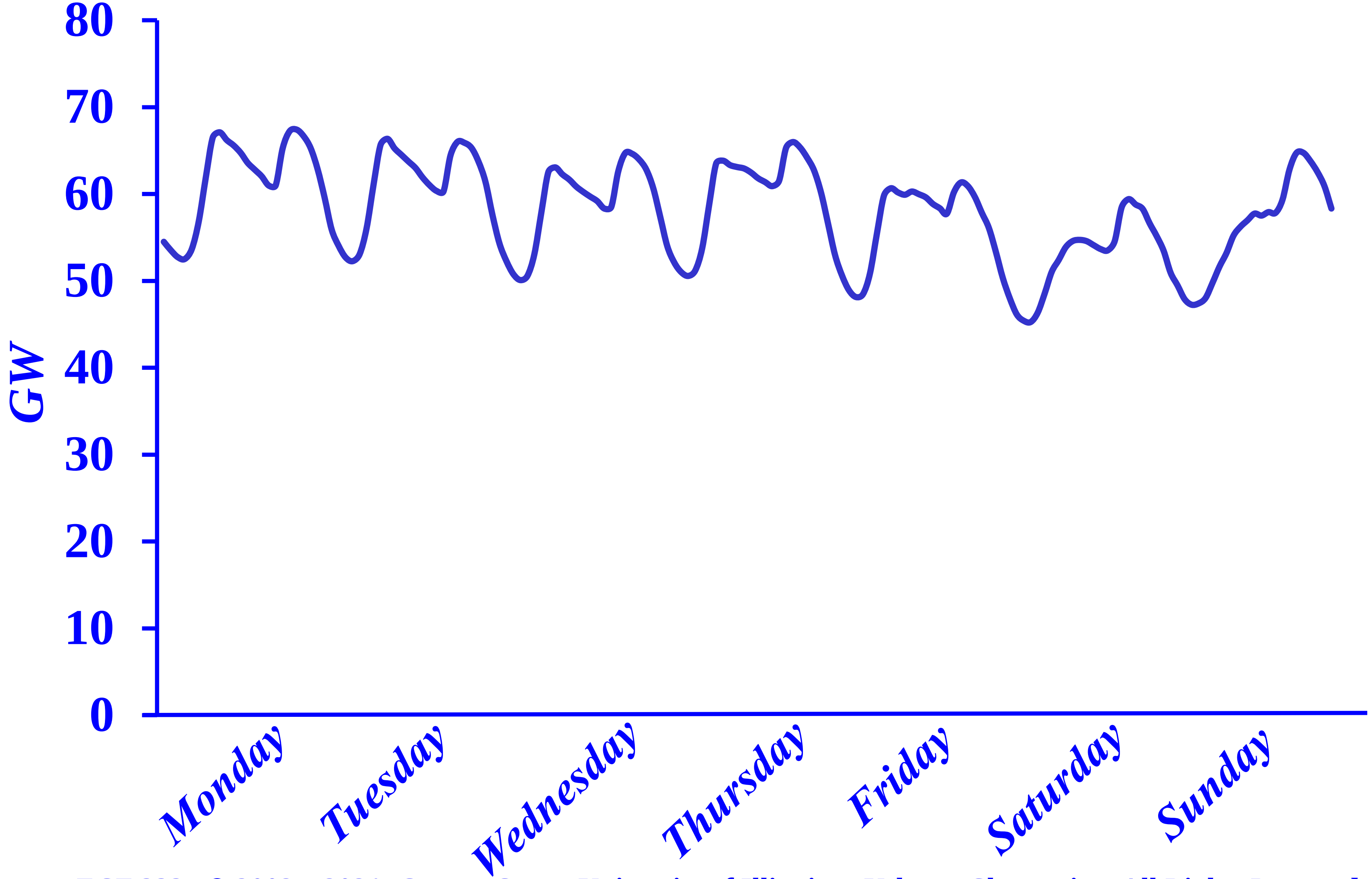
MISO CHRONOLOGICAL LOAD FOR THE JULY 15 – 21, 2013 WEEK



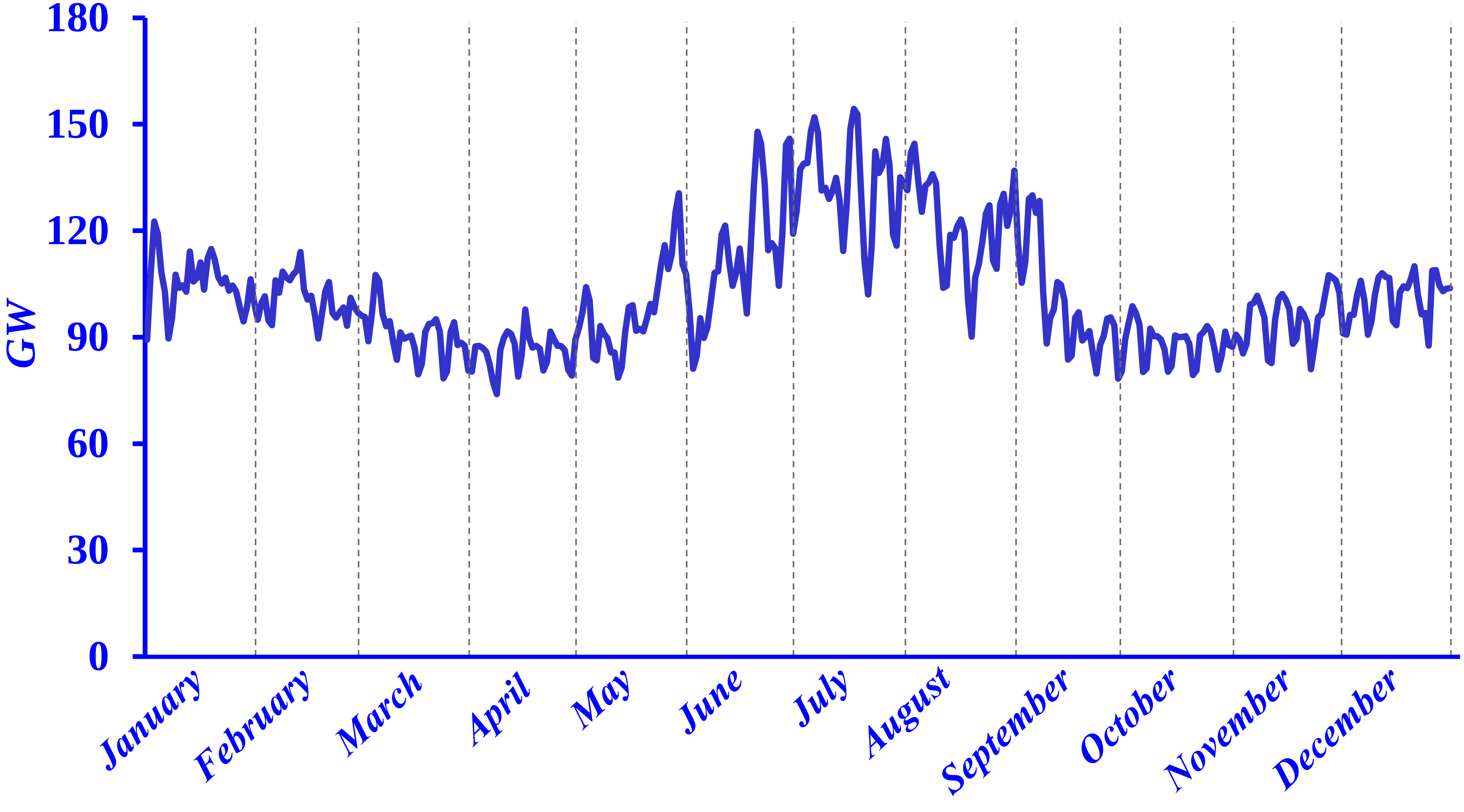
Source: https://www.misoenergy.org/Library/MarketReports/Pages/MarketReports.aspx

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



Source: https://www.misoenergy.org/Library/MarketReports/Pages/MarketReports.aspx

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



Source: http://www.pjm.com/markets-and-operations/ops-analysis/historical-load-data.aspx

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

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**

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

DEMAND – SIDE RESOURCES

- Conceptually, we may view *DSM* as a "source" of energy for meeting the system demand
- Conservation measures save energy by doing away with 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 necessary removal of the load: *e.g., Energy Star* appliances can be used to replace the earlier, conventional appliances to create benefits of reduced energy consumption and associated expenditures and to also *reduce emissions***
- **An efficiency measure reduces the need to add generation, but complications do arise**

ENERGY EFFICIENCY IMPLICATIONS

- **The development of technology that improves the efficiency of a process implies that we can have the same output as with the pre–efficiency improvement process, but the new process requires less energy input; also, leads to *emission reductions***
- **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 HAS IMPLICATIONS

As an example, let us 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 leads people to use their cars to go twice as far as before and thus results in *zero reduction* in the total input fuel consumed

ENERGY EFFICIENCY IMPROVEMENT IN LIGHTING

- **The history of *lighting* has gone through a series of accelerated improvements following the *Industrial Revolution*, including**
  - **"*town gas*" made from coal and deployed for street lighting**
  - ***whale oil*, the favorite indoor lighting fuel for the well-to-do *Americans* until its replacement by the more efficient kerosene**

ENERGY EFFICIENCY IMPROVEMENT IN LIGHTING

- **The *electric lightbulbs* came into use in the years of 1885–1900**
- **As each of these technologies matured, the demand rose and resulted in increased overall energy consumption**
- **As more technology breakthroughs arose, the demand for the newer lighting devices increased and led to lower prices: a study by *Roger Fouquet* of the *London School of Economics* and *Peter Pearson***

ENERGY EFFICIENCY IMPROVEMENT IN LIGHTING

of *Imperial College* **provides evidence that the series of efficiency improvements has brought a 3,000–fold decrease in the real costs of illumination in the *UK* over the past 200 *years***

- **Because cheap illumination fosters economic development, the cheap light technology has found many applications, beyond the illumination**

ENERGY EFFICIENCY IMPROVEMENT IN LIGHTING

of streets, homes and workplaces, such as in *computers*, *TVs*, *minipads* and *cellphones*

- **Studies by the *International Energy Agency* (*IEA*) and the *Intergovernmental Panel on Climate Change* (*IPCC*) show that the price reduction due to the lighting energy efficiency improvements results in usage *rebounds* – increases in energy consumption as high as 50 % in developed nations**

ENERGY EFFICIENCY IMPROVEMENT IN LIGHTING

- **Similar results are expected in developing nations as they make use of cheap lighting technology, as soon as widespread electrification is achieved**
- **The key implication is that overall electricity consumption will likely increase as cheaper lighting is deployed on a geographically wider scale and for a broader range of applications**

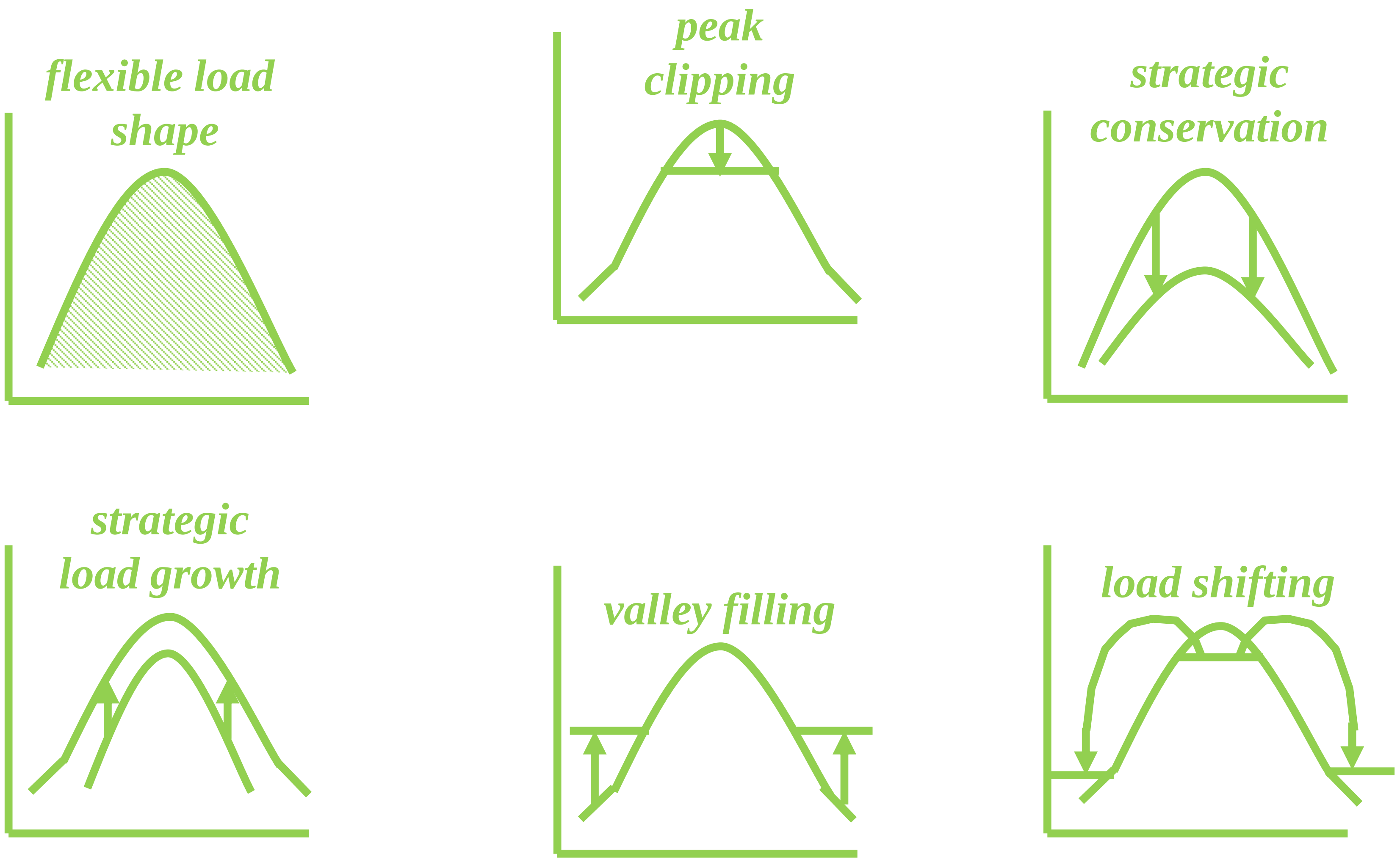
DSRs

- *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 to reduce reliance on peakers

DEMAND-SIDE MANAGEMENT

- The term demand–side management (*DSM*) was used in the 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 influences 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/environmental benefits

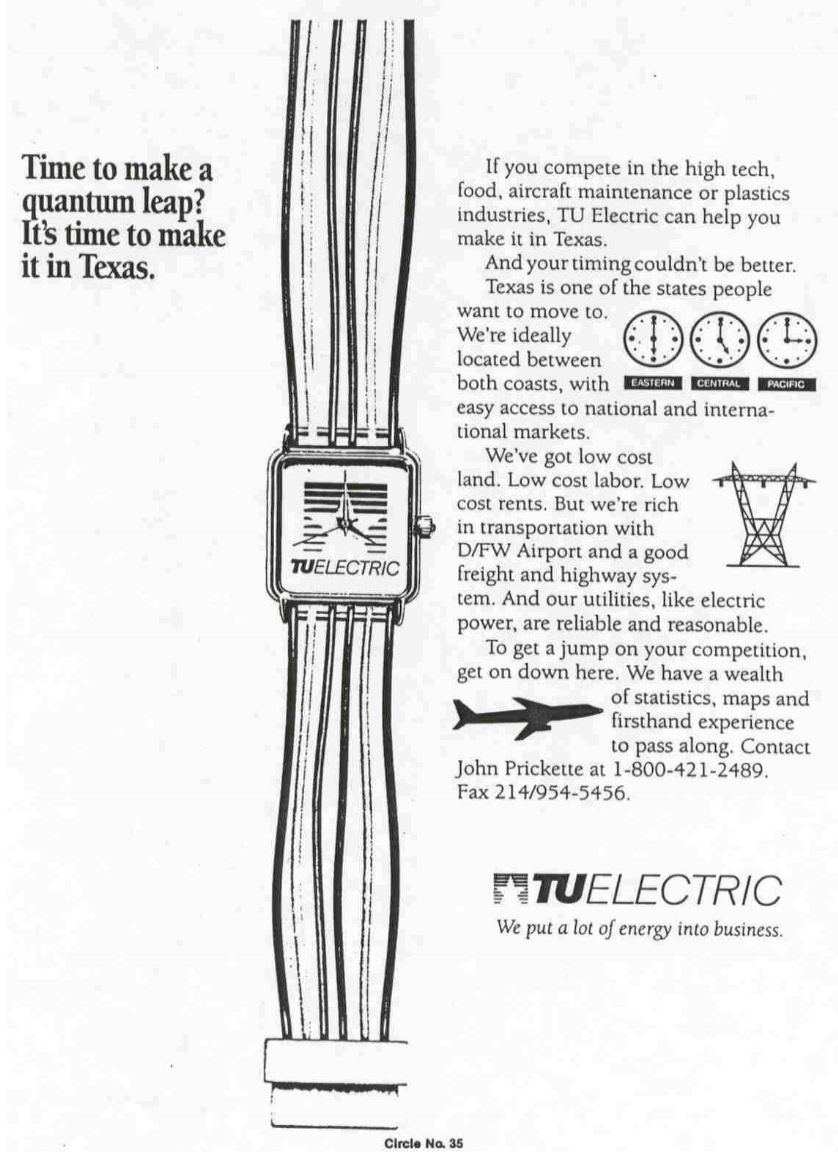
DSM PROGRAMS' LOAD SHAPE OBJECTIVES



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 the 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 – *ISONE*, *NYISO*, *PJM* and *ERCOT* – have encouraged consumer participation and have taken steps to integrate *DSM* into their wholesale markets**

RENEWED INTEREST IN *DSM*

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

RENEWED INTEREST IN *DSM*

- **A number of 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 is about 103 *million* in 2020 and is growing year by year**

APPROPRIATE *DSM* APPLICATIONS FOR DIFFERENT LOAD SEGMENTS

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

LOAD MANAGEMENT PROGRAMS

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

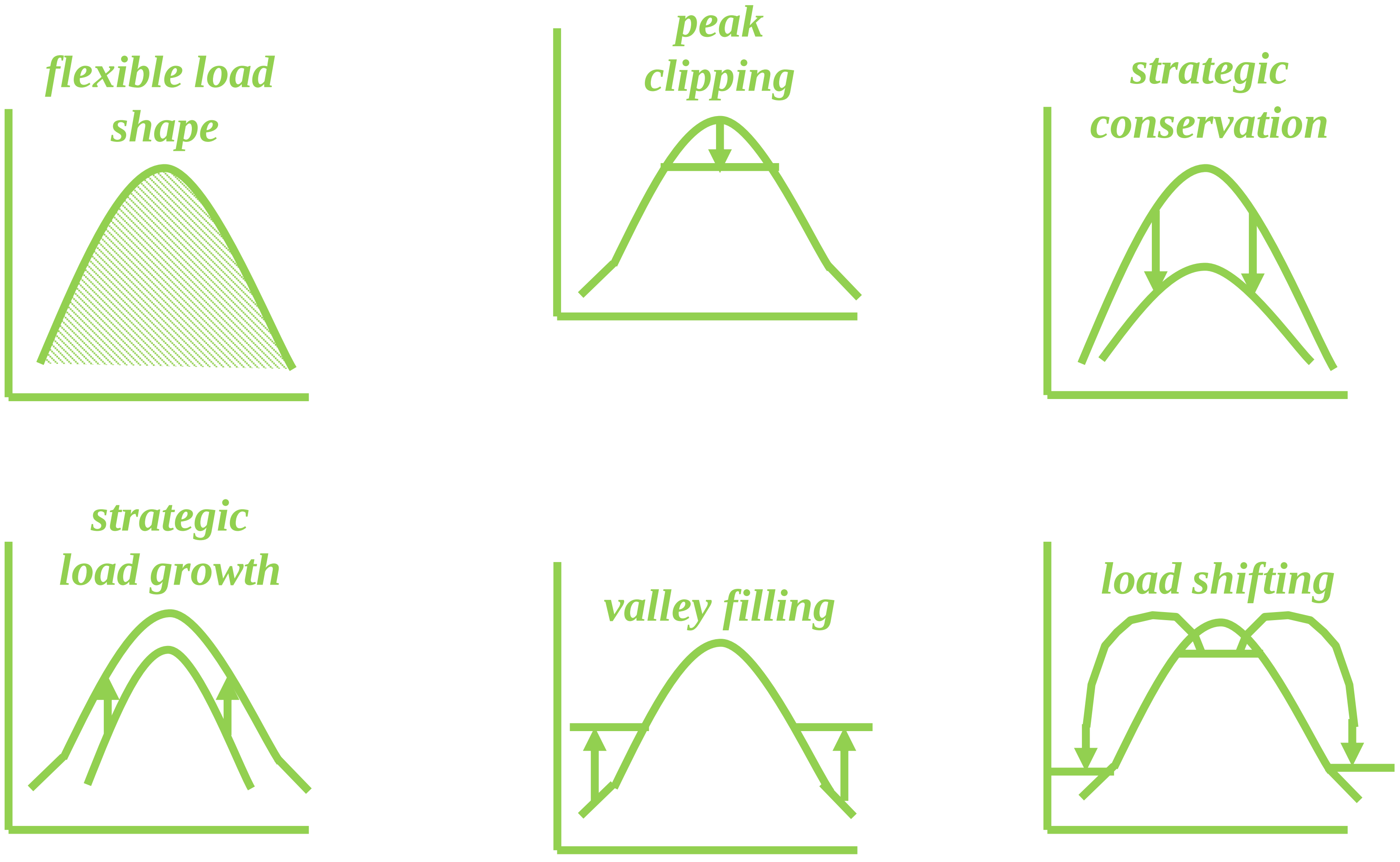
LOAD MANAGEMENT PROGRAMS

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

BASIC ASPECTS OF *DSM*

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

DSM PROGRAMS' LOAD SHAPE OBJECTIVES



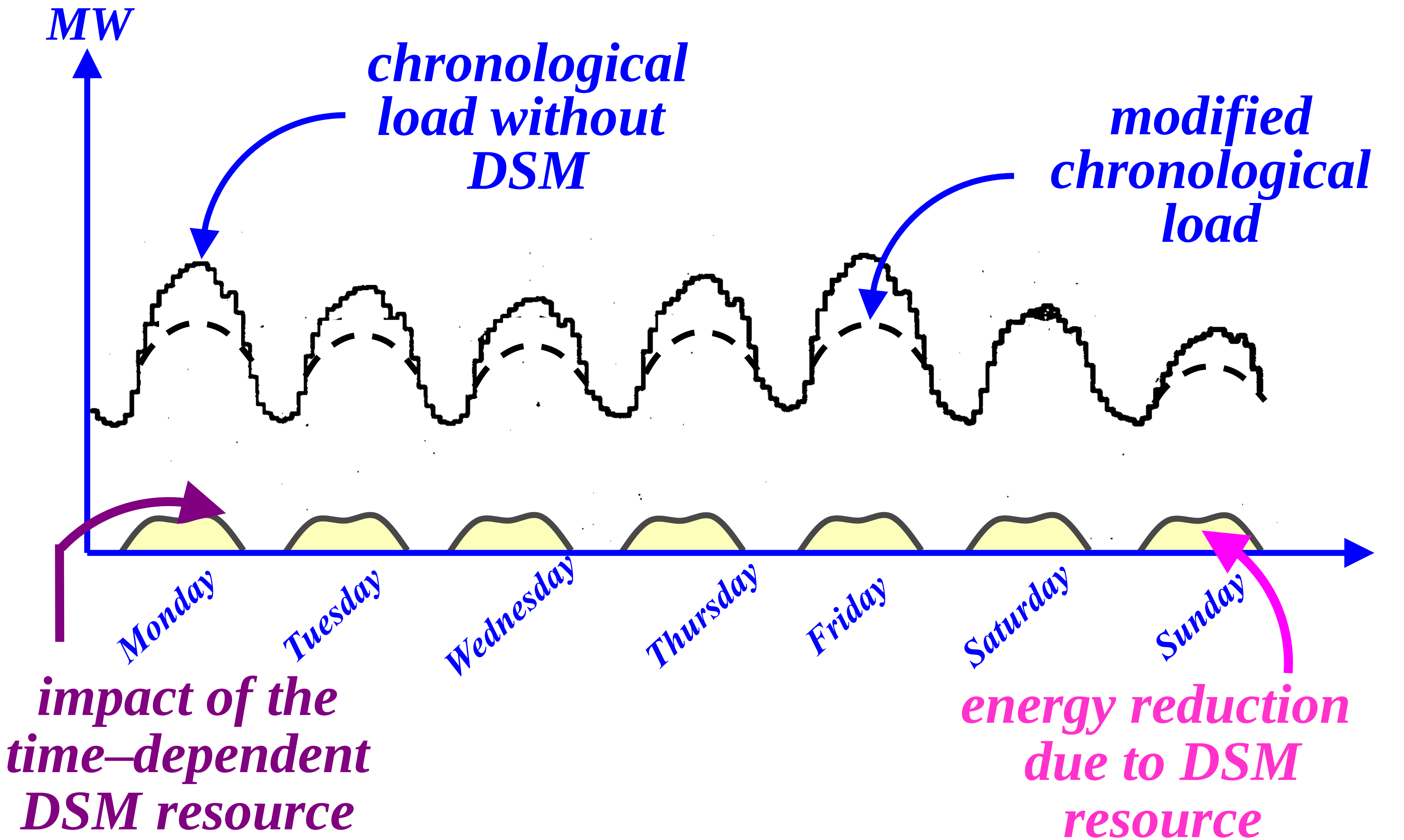
BASIC ASPECTS OF *DSM*

- **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 (*ESPs*) 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**

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

which correspond to

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

- **The program costs are**

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

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

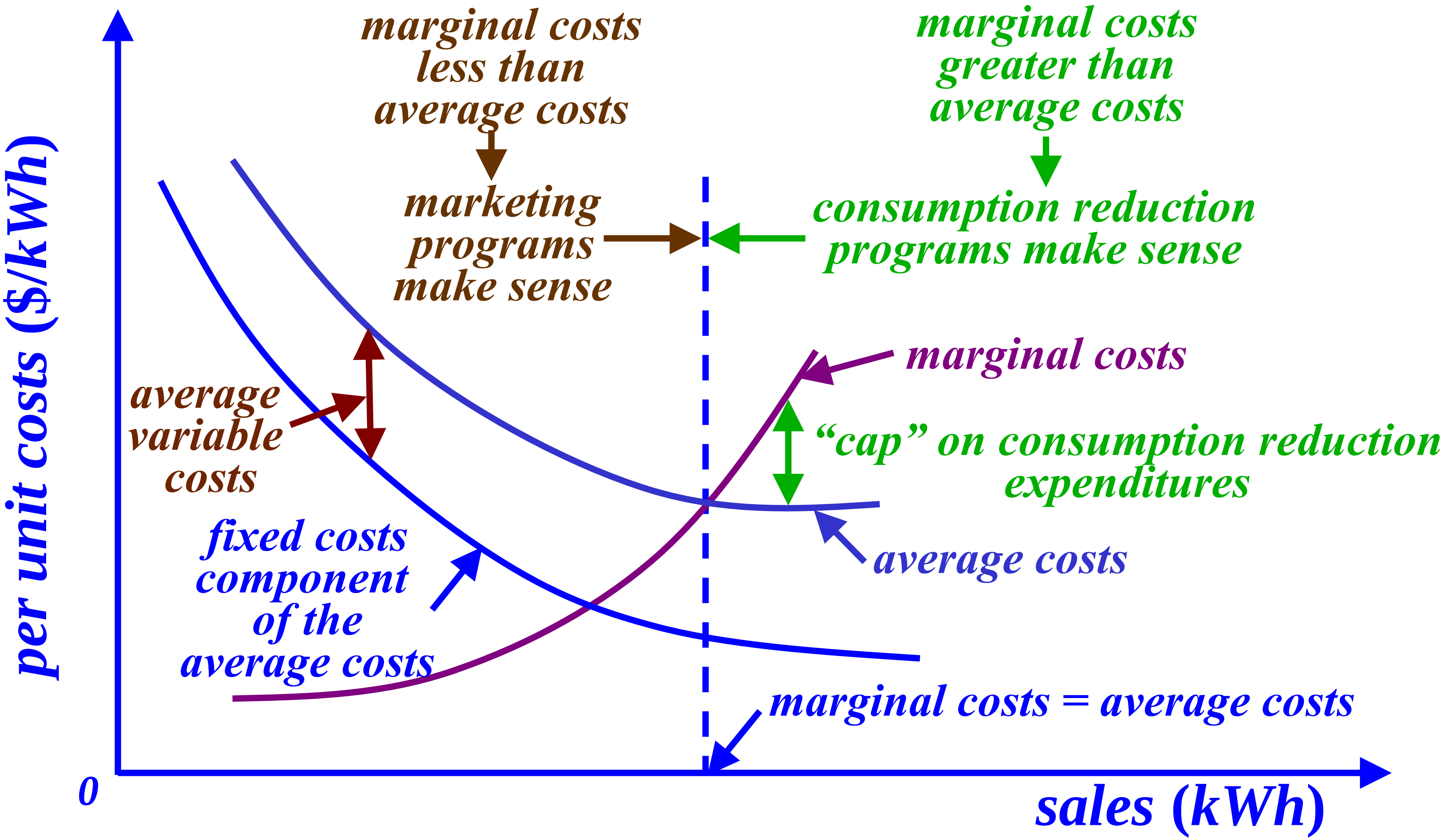
$$DSM\ costs / kWh = \frac{\$\ 3}{570\ kWh} = \frac{¢\ 300}{570\ kWh} = 0.52\ ¢ / kWh$$

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

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

$$< 3\ ¢ / kWh = marginal\ costs$$

A SIMPLE COST – EFFECTIVENESS TEST



COMPLICATIONS IN THE INTEGRATION OF *DSM* PROGRAMS

- **Time–of–day effects: even when the *marginal costs* are below the *average costs* in certain periods, the peak periods *marginal costs* exceed the *average costs*; in such cases, the *ESP* needs to focus on those conservation programs that are particularly effective on–peak (*e.g.*, more efficient air conditio–ners) or undertake *customized load shifting programs***

COMPLICATIONS IN INTEGRATING *DSM* PROGRAMS

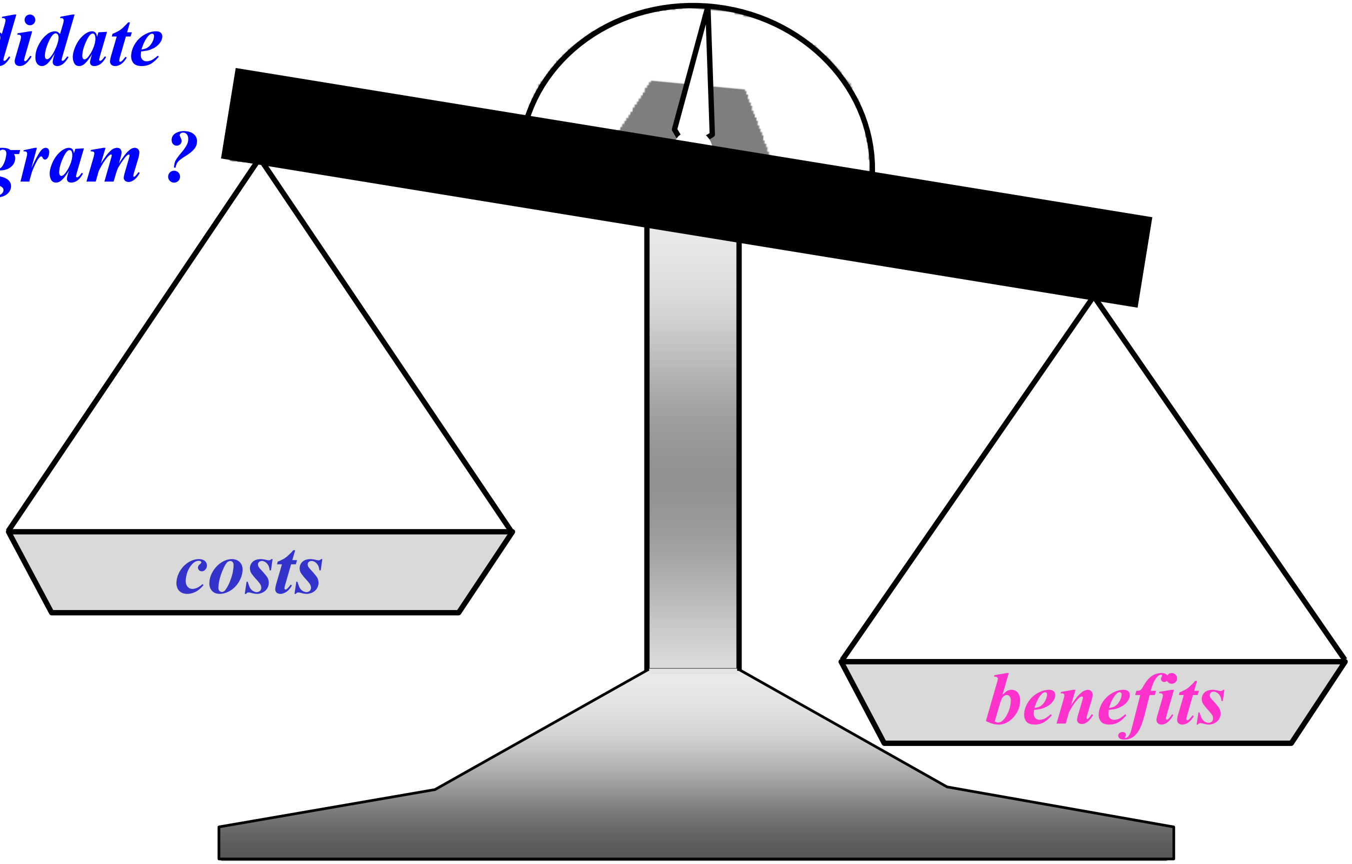
- **Evaluation of *life-cycle benefits*: parties differ over which discount rate is appropriate – the utility's or the customer's**
- **The *economies of scale* in supply–side options fail to carry over to demand–side programs because of saturation effects**

COMPLICATIONS IN INTEGRATING *DSM* PROGRAMS

- **The savings due to a demand–side program are difficult to determine accurately; for example, an owner whose home has been insulated may set his thermostat to a higher temperature, which eliminates some of the benefits that are attainable with the implemented insulation**

PROGRAM BENEFIT/COST ANALYSIS

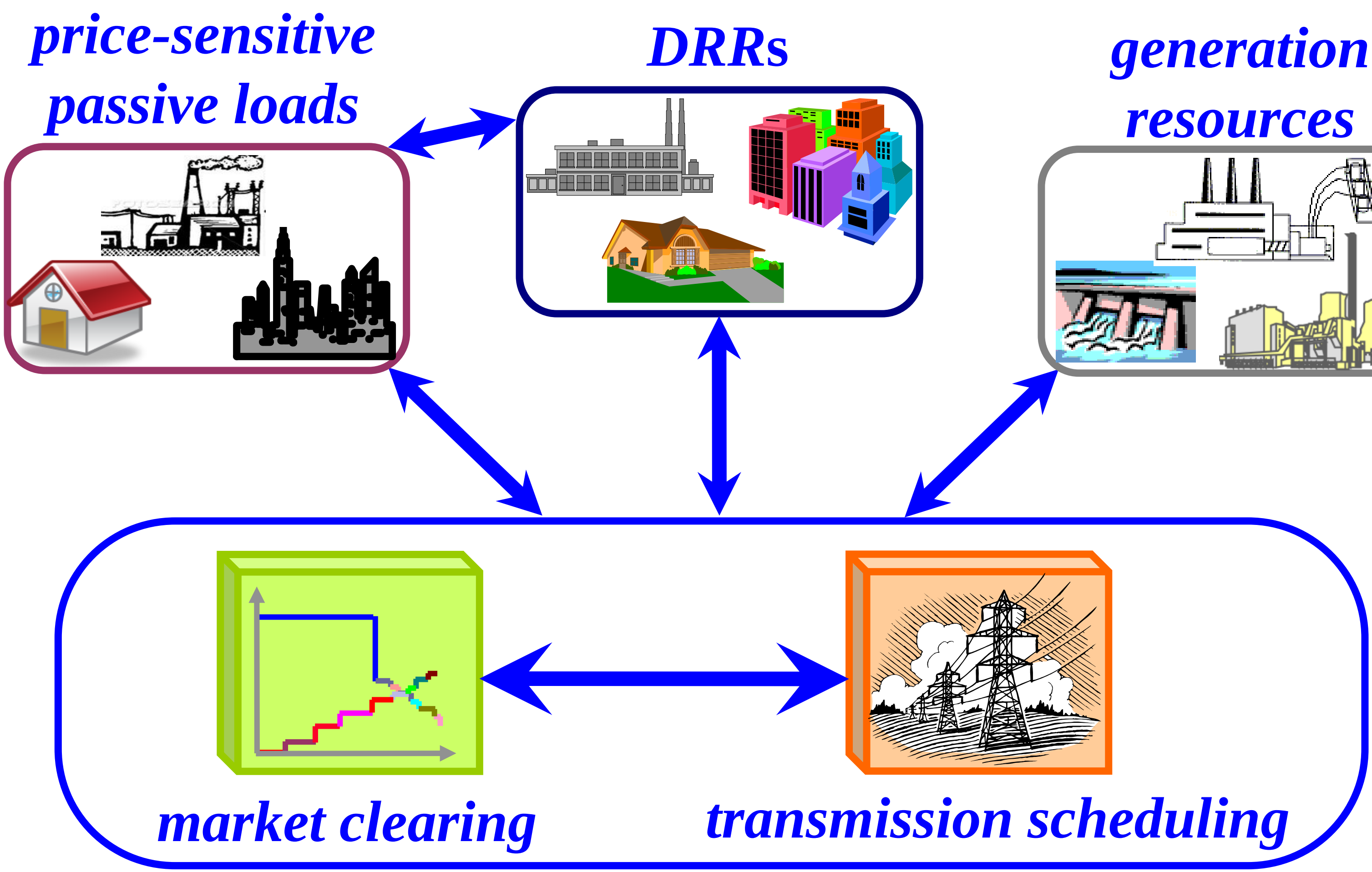
add candidate DSM program ?



a candidate program may be implemented if

benefits > *costs*

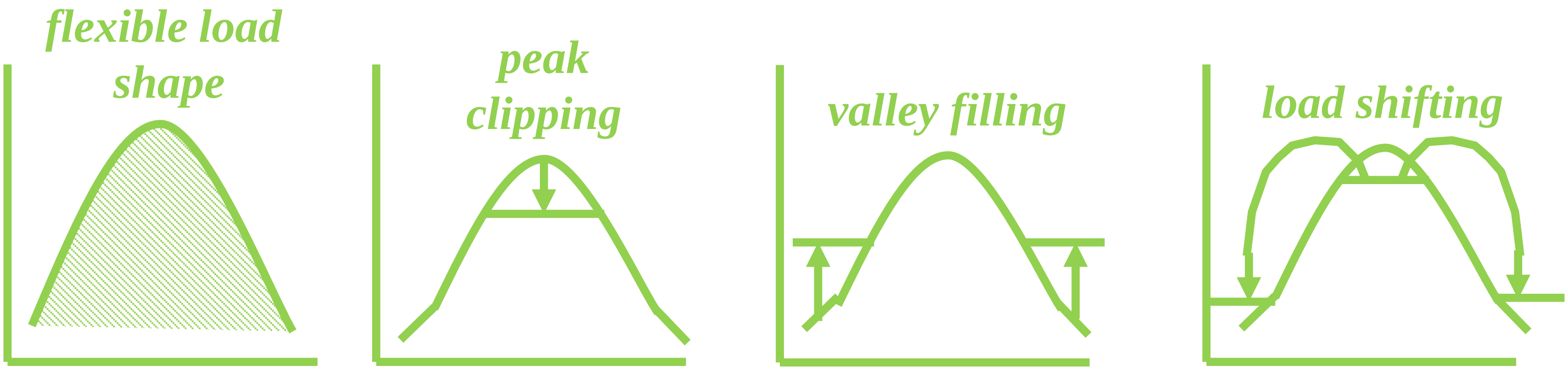
DEMAND RESPONSE RESOURCES (*DRRs*)



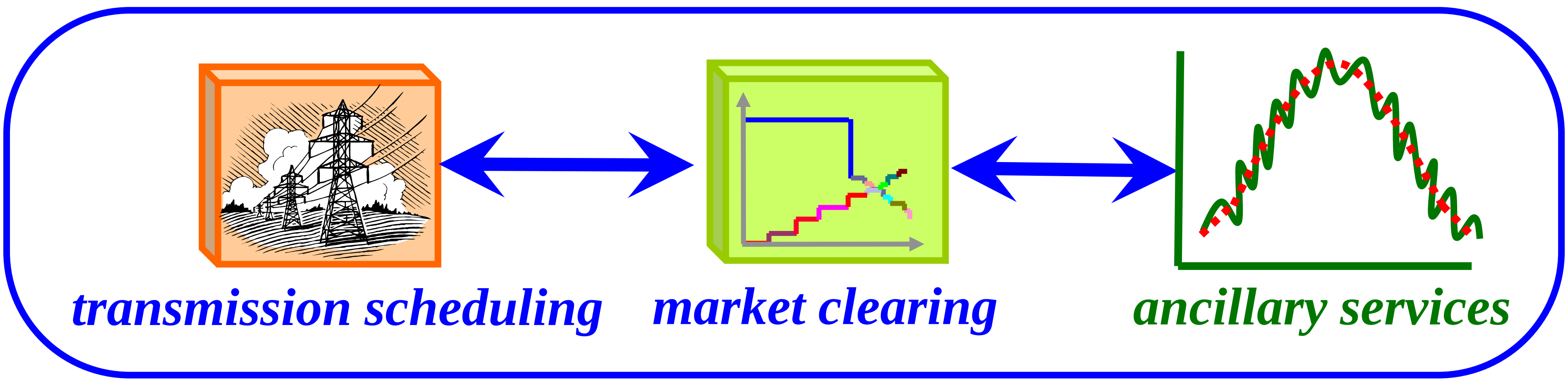
NATURE OF *DRR*

- The objective of *DRR*s 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 are attractive alternatives to supply–side resources to meet the supply–demand balance

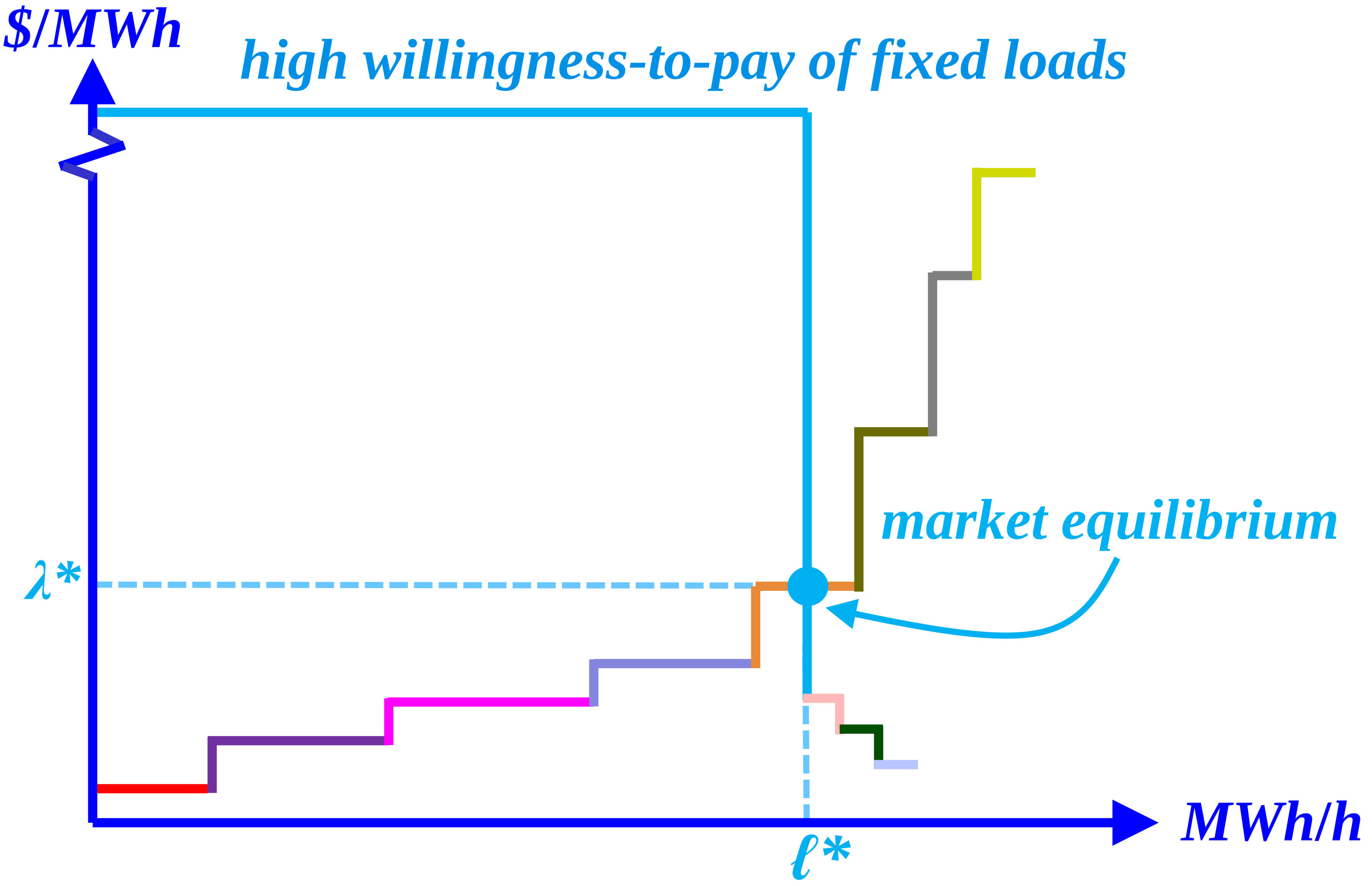
DRR ACTIVITIES



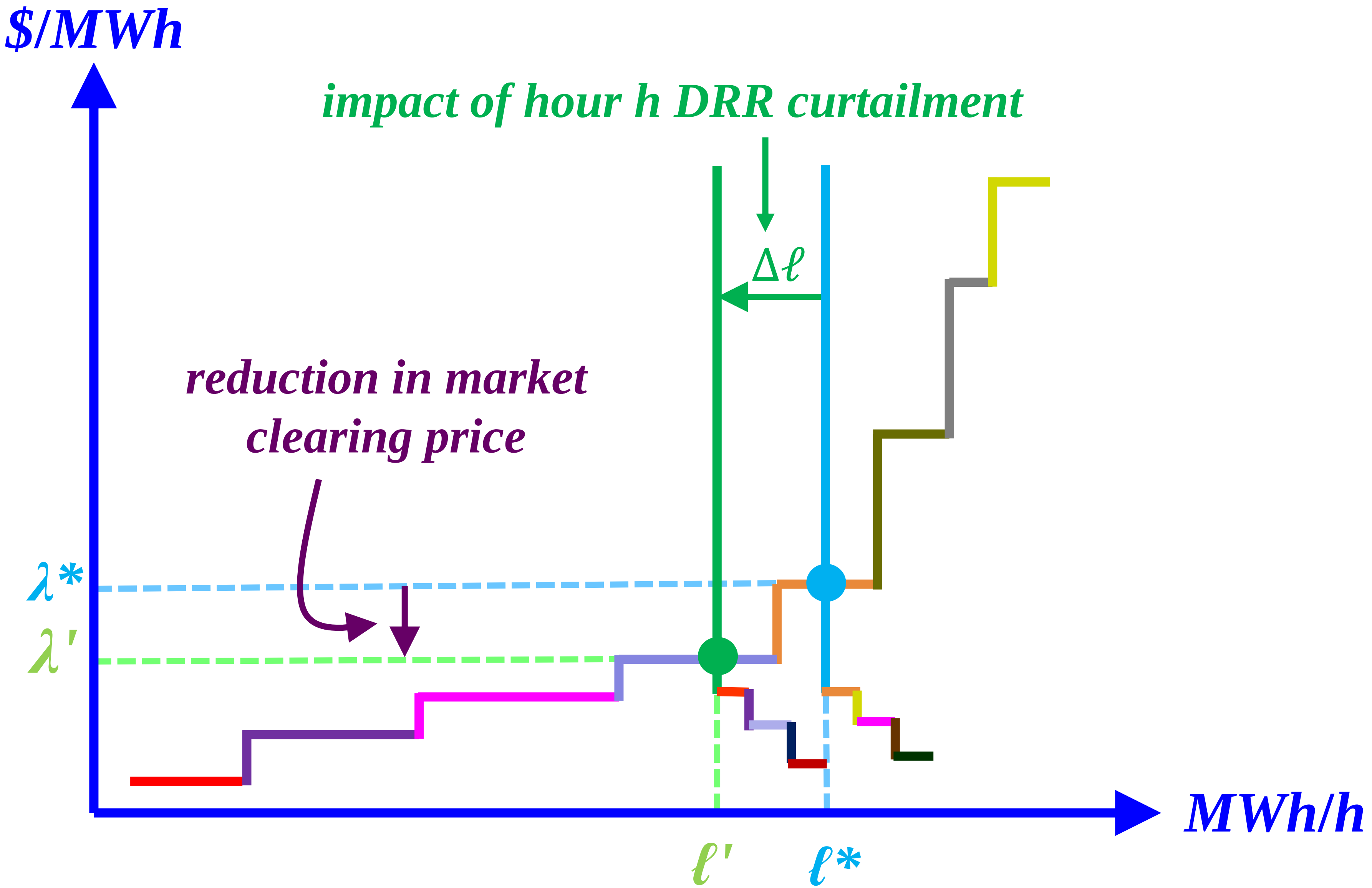
***DRR*s help to balance the supply and demand around the clock and in ancillary service provision**



ELECTRICITY MARKET CLEARING



HOUR *h* *DRR* CURTAILMENT MARKET IMPACTS

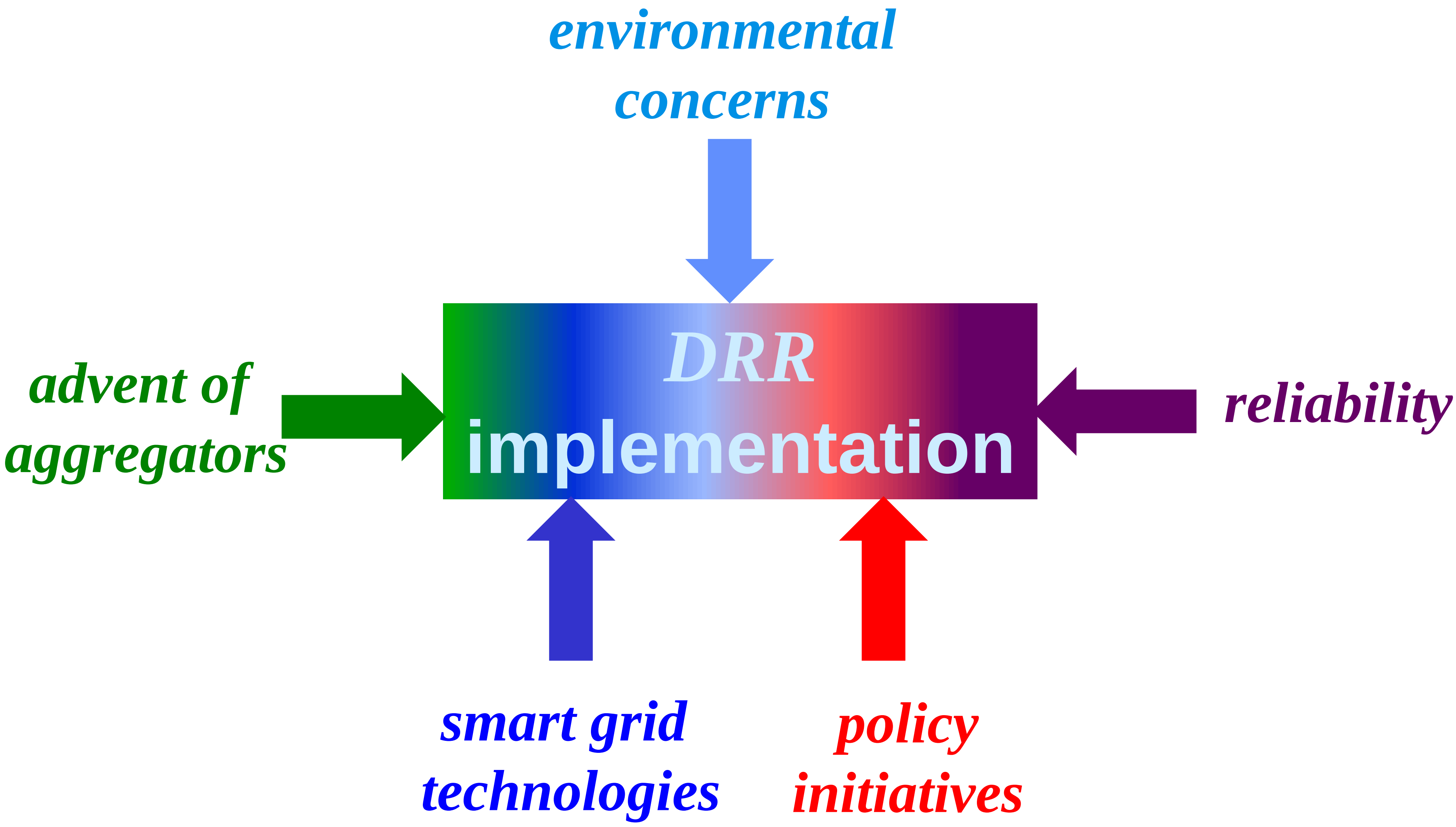


DRRs ARE ATTRACTIVE

- ***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



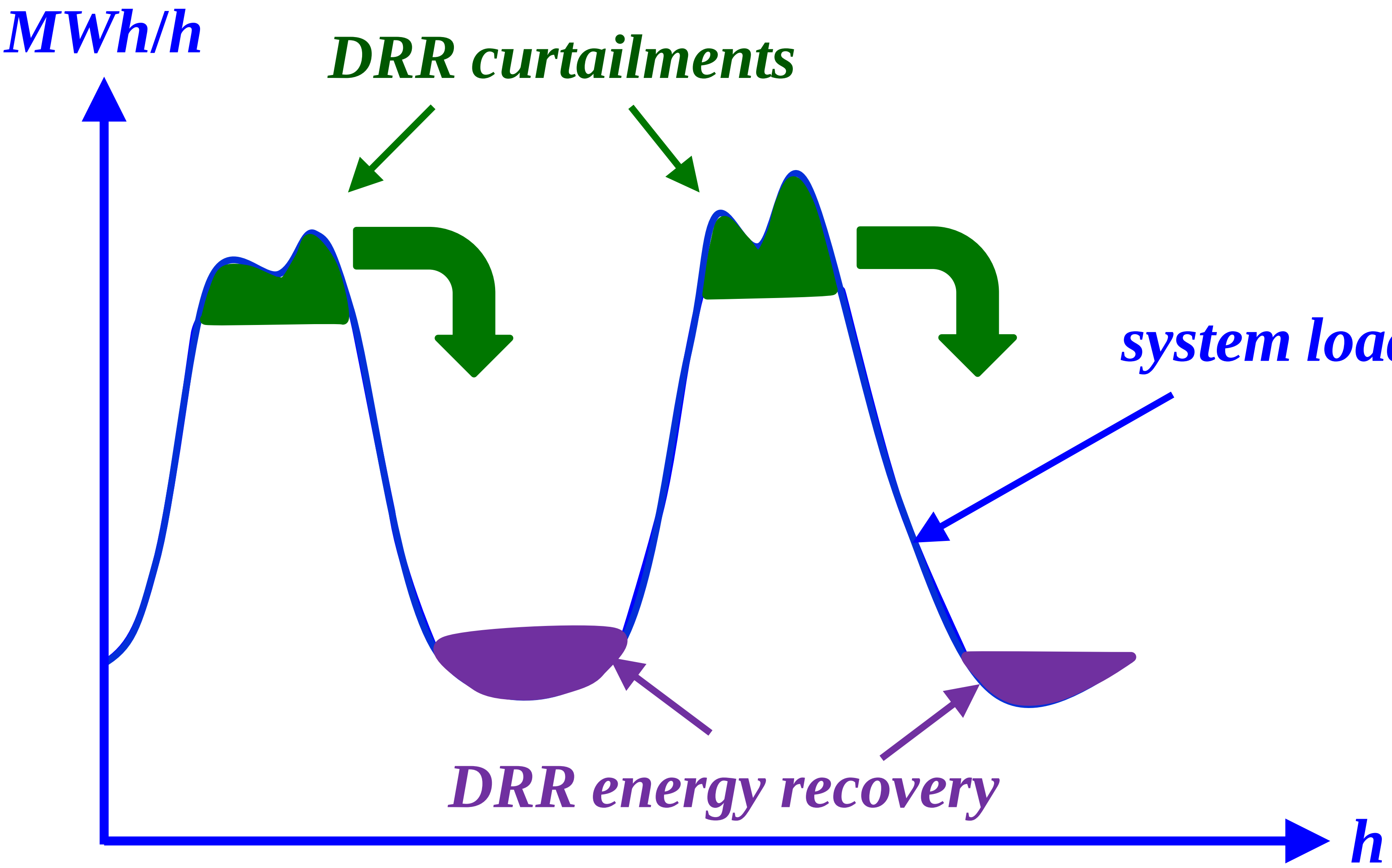
DRR LIMITATIONS AND CHALLENGES

- **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***

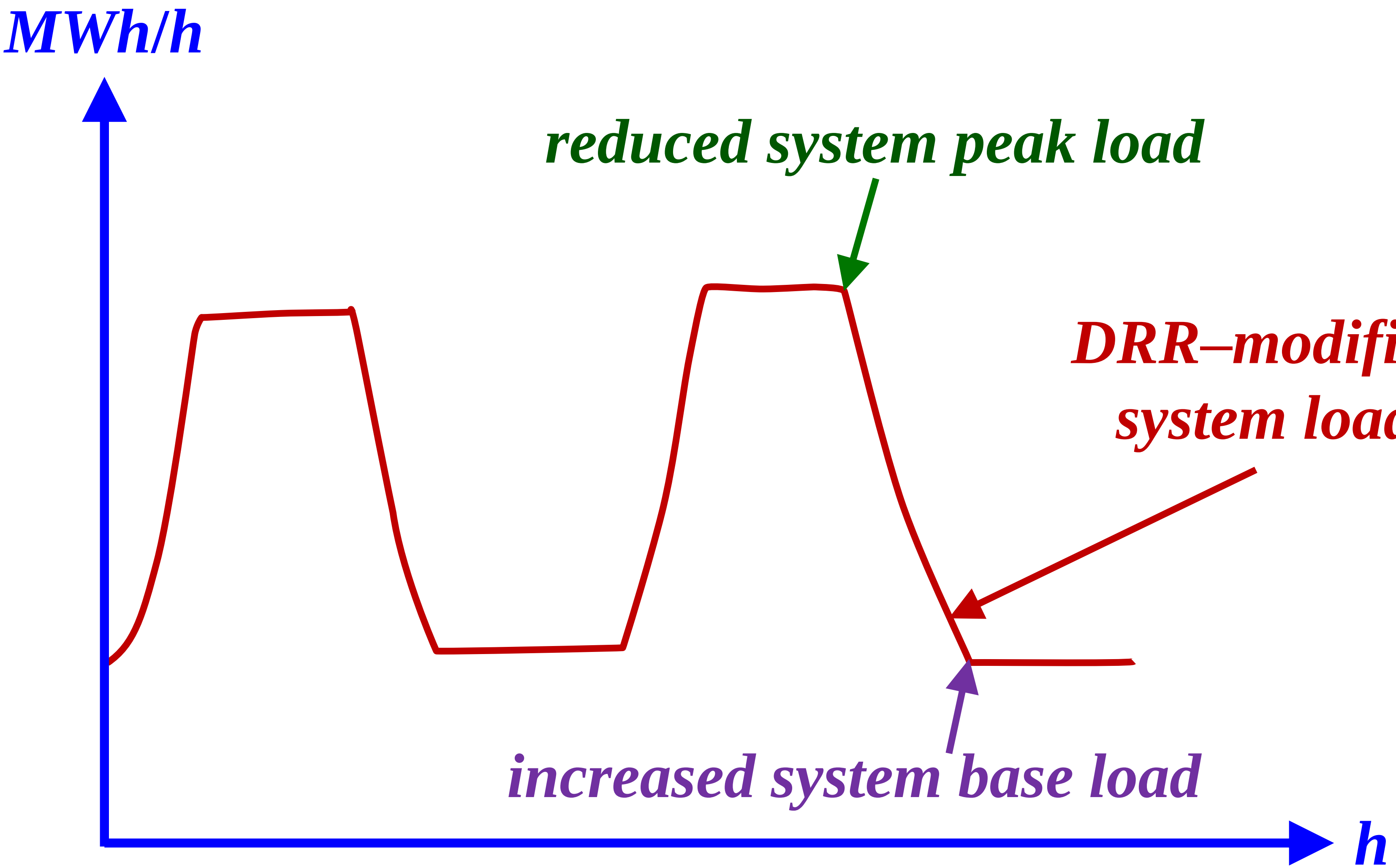
DRR LIMITATIONS AND CHALLENGES

- **_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 and so there are _physical limitations_ to the depths of effective _DRR_ penetration**

DRR WITH ENERGY RECOVERY



DRR WITH ENERGY RECOVERY ACTS



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**

RECENT JUDICIAL DEVELOPMENTS

- A number of generator and utility groups sued *FERC* to appeal Order No. 745
- The *US Court of Appeals* decided to vacate the controversial *FERC* Order No. 745 on demand response compensation
  - the court found Order No. 745 exceeded *FERC's* jurisdiction
  - *FERC* used an extended time period to submit its petition to the Supreme Court

DECISION OF THE SUPREME COURT

- **The Supreme Court made its decision to uphold Order No. 745 on January 25, 2016**
- **The Court recognized that *FERC* has the authority to regulate electricity rates in retail markets through the wholesale markets; hence, it did not overstep its jurisdiction through Order No. 745**
- **The Court maintains that Order No. 745 was neither arbitrary nor capricious and suggests that the need for *LMP* compensation was justified**

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:

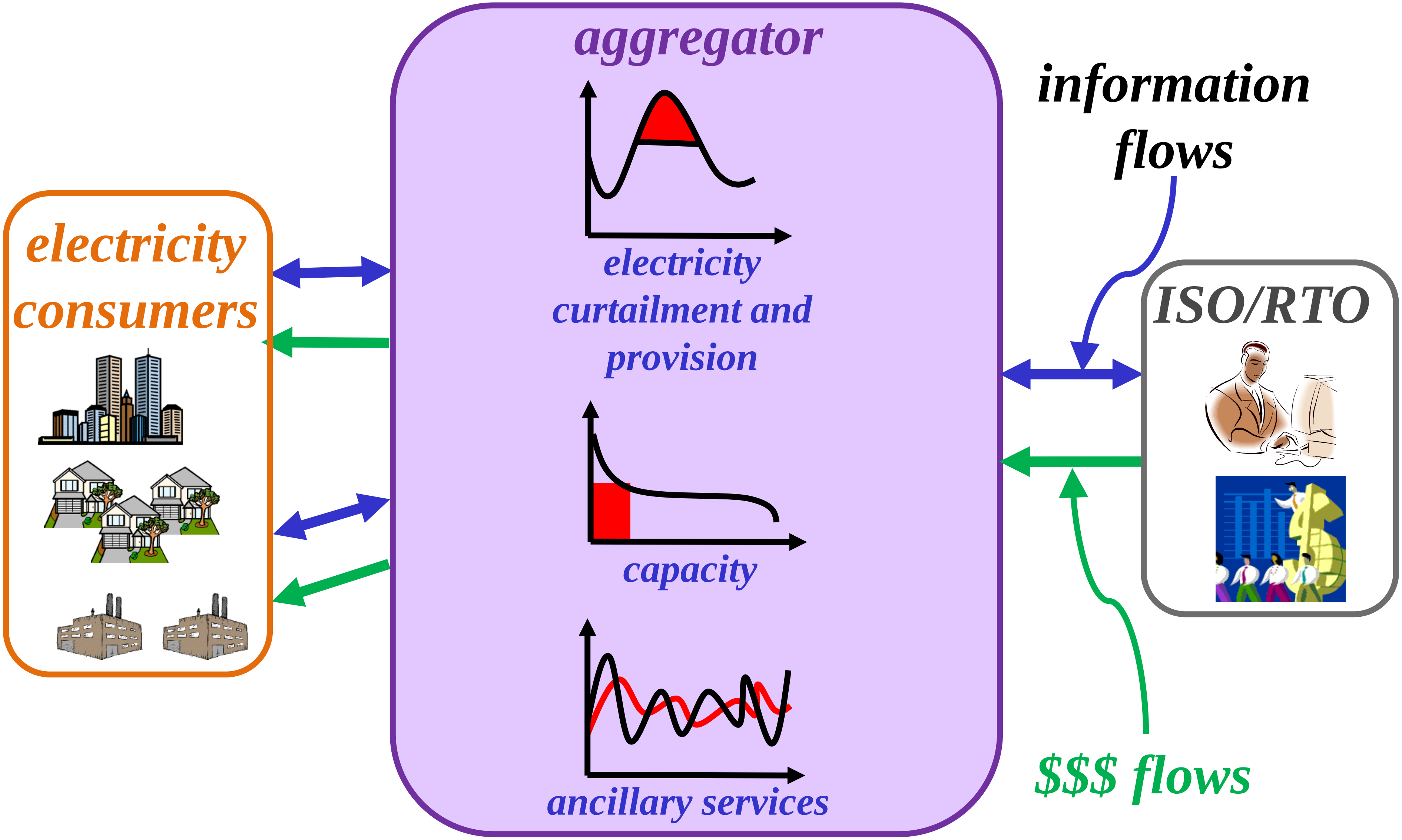
DISTRIBUTED ENERGY RESOURCES (*DER*s)

- ***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
- An 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 as 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 an intermediary between the *ISO*/*RTO* and electricity consumers to deliver services from *DER*s to markets

ROLE OF AGGREGATION

- **Order No. 2222 determines that the *DER* aggregator is the single point of contact between the *DER*s and the *RTO/ISO***

- **The aggregator is responsible for managing, dispatching, metering and settling its individual *DER*s**

THE SMART GRID

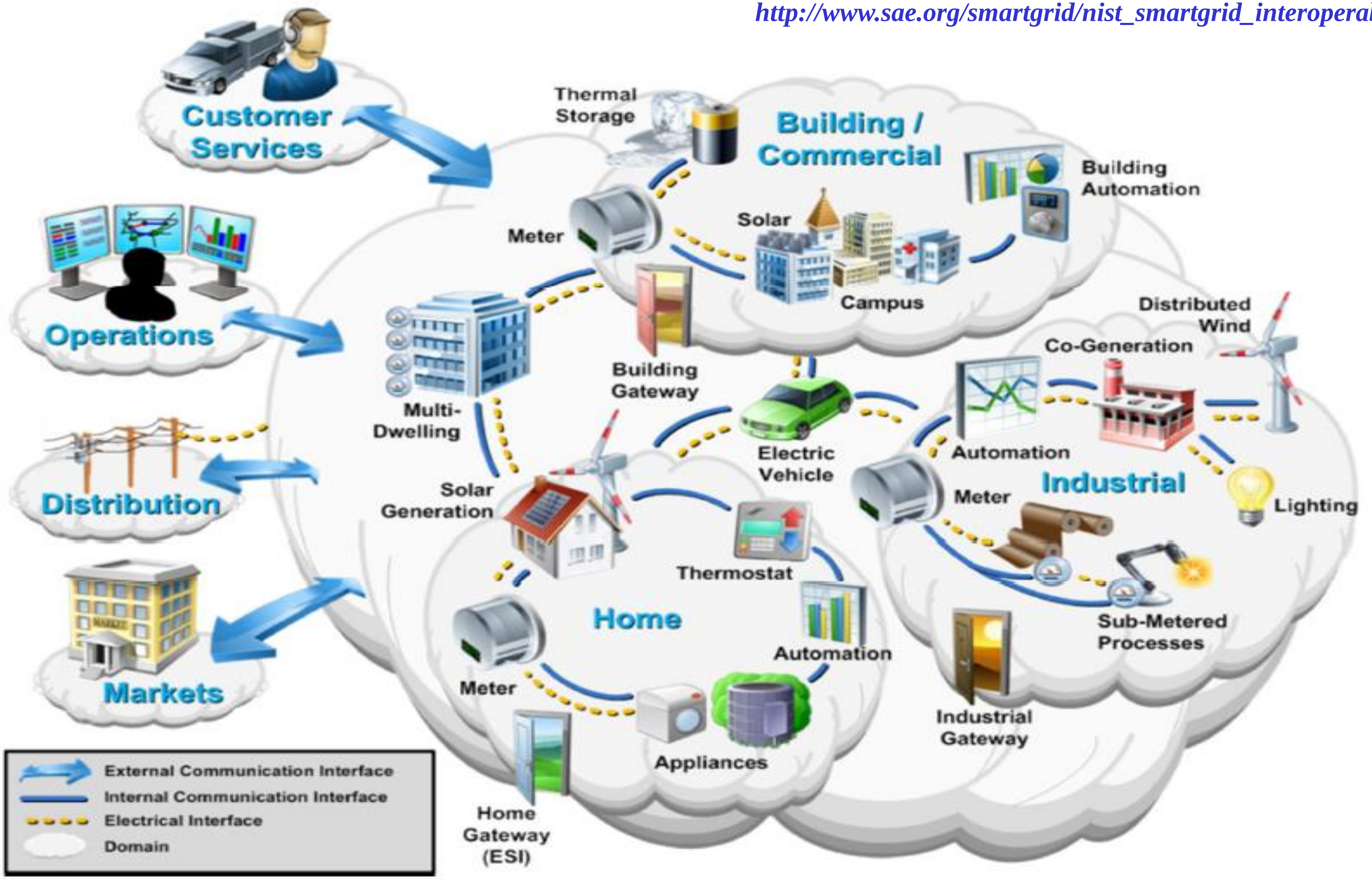
The smart grid represents a modernized electricity delivery system that monitors, protects and automatically optimizes the operation of all its interconnected elements – from the central and distributed generator, through the high–voltage transmission grid and the distribution network to industrial users and building automation systems, to energy storage devices and to end–use consumers and their thermostats, electric vehicles, appliances and other devices

THREE SALIENT ASPECTS

- **Combined digital intelligence and real–time communications:** to improve the operations/control of the transmission and distribution grids
- **Advanced metering solutions:** to replace the legacy metering infrastructure
- **Deployment of appropriate technologies, devices, and services:** to access and leverage energy usage information in smart appliances and in the integration of renewable energy

CUSTOMERS AND THE SMART GRID

Source: NIST Framework and Roadmap for Smart Grid Interoperability, http://www.sae.org/smartgrid/nist_smartgrid_interoperability.pdf



customers

CONCLUDING REMARKS

- ***DRR*s play a larger role today than at any time before in the maintenance of the supply–demand balance and the provision of capacity–based *AS***
- **Smart grid technology, aggregators and policies are key drivers of deeper *DRR* penetrations**
- **Huge potential exists for *DRR*s to provide grid services, such as regulation and load following, and to play a role in the reliable and effective integration of renewable resources**