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
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 (DRRs)
- DRR participation in electricity markets
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

<table>
<thead>
<tr>
<th>resource use</th>
<th>examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>base–loaded generation</td>
<td>combined cycle, co–generation, coal,</td>
</tr>
<tr>
<td></td>
<td>run–of–river hydro, geothermal</td>
</tr>
<tr>
<td>mid–range generation</td>
<td>combined cycle</td>
</tr>
<tr>
<td>peaking generation</td>
<td>gas turbine, peaking hydro</td>
</tr>
<tr>
<td>purchases from other entities</td>
<td>firm capacity and energy contracts</td>
</tr>
</tbody>
</table>
## ADDITIONAL SUPPLY – SIDE RESOURCES

<table>
<thead>
<tr>
<th>resource type</th>
<th>examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>non–utility source purchases</td>
<td>co–generation; wind, small hydro, small coal, solar; larger thermal resources</td>
</tr>
<tr>
<td>exchanges</td>
<td>peaking capacity with off–peak energy return; seasonal capacity exchanges</td>
</tr>
<tr>
<td>renewable</td>
<td>solar, wind, hydro, PV, biomass</td>
</tr>
<tr>
<td>energy storage</td>
<td>pumped storage hydro, compressed air energy storage technology, batteries</td>
</tr>
</tbody>
</table>
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).
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.
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.
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.

Un fortunately, 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 $\ell$ of input fuel, say from $8 \ km/\ell$ to $16 \ km/\ell$; 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
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.
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, DSRs may be targeted for base, intermediate and peaking uses to attain economic/environmental benefits.
DSM PROGRAMS’ LOAD SHAPE OBJECTIVES

- flexible load shape
- peak clipping
- strategic conservation
- strategic load growth
- valley filling
- load shifting
<table>
<thead>
<tr>
<th>Program Type</th>
<th>Example</th>
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<tbody>
<tr>
<td>Load Reduction</td>
<td>Conservation</td>
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<tr>
<td>Load Buildup</td>
<td>Marketing</td>
</tr>
<tr>
<td>Load Shifting</td>
<td>Load Management</td>
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</tbody>
</table>
WE'LL PAY YOU IF WE CAN DO THIS TO YOUR SPARE REFRIGERATOR.

You'd flatten your spare refrigerator yourself, if you realized how wasteful it is. An average one devours a whopping $150 a year in energy costs. If you let us recycle it, not only will you get rid of an old energy guzzler; you'll get a $50 savings bond from Edison or DWP. To qualify, it must be in working order and used as a second refrigerator for the last six months. So for your $50 savings bond, call Edison or DWP at 1-800-234-9722. Or use our TDD accessible number 1-800-234-9710. It pays to recycle your spare refrigerator.
RENEWED INTEREST IN \textit{DSM}

- After the assessment of \textit{DSR}-provided services, the \textit{Federal Energy Regulatory Commission (FERC)} has repeatedly encouraged the incorporation and wider expansion of \textit{DSM} within today’s organized electricity markets.

- Several grid operators — \textit{ISONE, NYISO, PJM} and \textit{ERCOT} — have encouraged consumer participation and have taken steps to integrate \textit{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

<table>
<thead>
<tr>
<th>Intended Load Segment</th>
<th>Base</th>
<th>Intermediate</th>
<th>Peaking</th>
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<tbody>
<tr>
<td>Typical Programs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>motors</td>
<td></td>
<td>building weatherization</td>
<td>air-conditioner control</td>
</tr>
<tr>
<td>water heater,</td>
<td></td>
<td>air-conditioner or heat pump efficiency improvements</td>
<td>thermal storage HVAC</td>
</tr>
<tr>
<td>refrigerator and</td>
<td></td>
<td>stricter appliance efficiency standards</td>
<td></td>
</tr>
<tr>
<td>freezer efficiency</td>
<td></td>
<td>time-of-use rates</td>
<td></td>
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<tr>
<td>improvements</td>
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<td></td>
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<tr>
<td>lighting</td>
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</table>

*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 management and conservation; programs aim to reduce the need for more electrical energy generation resources and additional installed capacity.
**DSM PROGRAMS’ LOAD SHAPE OBJECTIVES**

- **flexible load shape**
- **peak clipping**
- **strategic conservation**
- **strategic load growth**
- **valley filling**
- **load shifting**
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

MW

chronological load without DSM

modified chronological load

impact of the time–dependent DSM resource

energy reduction due to DSM resource
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.
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:

<table>
<thead>
<tr>
<th>parameter</th>
<th>unit</th>
<th>value</th>
</tr>
</thead>
<tbody>
<tr>
<td>marginal costs</td>
<td>¢/kWh</td>
<td>3</td>
</tr>
<tr>
<td>average costs</td>
<td>¢/kWh</td>
<td>2</td>
</tr>
<tr>
<td>number of CFLs installed</td>
<td>–</td>
<td>$10^6</td>
</tr>
<tr>
<td>administrative/overhead costs</td>
<td>$/CFL</td>
<td>1</td>
</tr>
</tbody>
</table>
EXAMPLE: SHARED SAVINGS PROGRAM

We compute the energy savings to be

\[ kWh \text{ saved} = (75 - 18)(10,000) 10^6 = (570)10^6 kWh \]

which correspond to

\[ energy \text{ cost savings} = (57)10^7(.03) = $17.1M \]

The program costs are

\[ implementation \text{ costs} = (2+1)10^6 = $3M \]
The net savings for the *ESCO* are

\[ \text{net savings} = 17.1 - 3 = $14.1M \]

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.

\[
DSM \text{ costs} / kWh = \frac{\$3}{570 \text{ kWh}} = \frac{\$300}{570 \text{ kWh}} = 0.52 \, \text{¢} / \text{kWh}
\]

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

\[
\text{average costs} + DSM \text{ costs} = 2 + 0.52 = 2.52 \, \text{¢} / \text{kWh}
\]

\[
< 3 \, \text{¢} / \text{kWh} = \text{marginal costs}
\]
A SIMPLE COST–EFFECTIVENESS TEST

- **Marginal costs less than average costs**
  - Marketing programs make sense

- **Marginal costs greater than average costs**
  - Consumption reduction programs make sense

- **Marginal costs = average costs**
  - "Cap" on consumption reduction expenditures

**Graph Details:**
- **Y-axis:** Per unit costs ($/kWh)
- **X-axis:** Sales (kWh)
- **Key Points:**
  - Average costs
  - Fixed costs component of the average costs
  - Marginal costs
  - "Cap" on consumption reduction expenditures

**Equations:**
- Sales ($/kWh) = Fixed costs + Variable costs
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 conditioners) 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.
add candidate DSM program?

a candidate program may be implemented if \( \text{benefits} > \text{costs} \)
DEMAND RESPONSE RESOURCES (DRRs)

- price-sensitive passive loads
- DRRs
- generation resources
- market clearing
- transmission scheduling
The objective of DRRs 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. DRRs curtail their loads in response to incentive payments to reduce electricity consumption at specified times. DRRs are attractive alternatives to supply-side resources to meet the supply-demand balance.
**DRR ACTIVITIES**

- **flexible load shape**
- **peak clipping**
- **valley filling**
- **load shifting**

**DRRs** help to balance the supply and demand around the clock and in ancillary service provision.

- **transmission scheduling**
- **market clearing**
- **ancillary services**
ELECTRICITY MARKET CLEARING

$/MWh

$ MWh

high willingness-to-pay of fixed loads

market equilibrium

$ MWh
HOUR $h$ DRR CURTAILMENT MARKET IMPACTS

$\lambda^*$

$\lambda'$

$\lambda'$

$\Delta \ell$

impact of hour $h$ DRR curtailment

reduction in market clearing price

$/\text{MWh}$

$\text{MWh}/\text{h}$

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**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**

- **Environmental concerns**
- **Advent of aggregators**
- **Reliability**
- **Smart grid technologies**
- **Policy initiatives**
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.

- DRRs 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

MWh/h

DRR curtailments

system load

DRR energy recovery
DRR WITH ENERGY RECOVERY ACTS

$\text{MWh/h}$

- Reduced system peak load
- Increased system base load
- DRR–modified system load

$h$
FERC ORDER NO. 745

- **FERC** Order No. 745 specifies the incentives to the *DRRs* for load curtailments in the *DAMs*.

- 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.
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 (DERs)

- 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 DERs.

- The participation of DERs in electricity markets presents various technical and implementation challenges to RTOs/ISOs, including:
DISTRIBUTED ENERGY RESOURCES (DERs)

- DERs are integrated into a grid, over which the RTOs/ISOs 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 DERs may lead to computational & communication challenges.
DER OPPORTUNITIES

- Distribution-side **DRRs** are also **DERs** and a large portion of the demand is on the distribution side.

- Residential **DRR** examples are “smart” appliances, water-heating and **HVAC** systems.

- **DERs** also include rooftop **PV** and **EV** batteries.

- **DERs** 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

- Aggregator
- Electricity
- Curtailment and provision
- Capacity
- Ancillary services

Information flows

Electricity consumers

ISO/RTO

$$$

flows
The coordinated operation of multiple DERs enables RTOs/ISOs to represent DERs 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 DERs 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 DERs 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
Order No. 2222 requires ISOs/RTOs to allow all DERs whose capacity is 100 kW or higher to participate in bulk electricity markets.

DERs with capacity below 100 kW may still provide services to electricity markets through an aggregator, defined as “the entity that aggregates one or more DERs for purposes of participation in the capacity, energy and/or ancillary service markets of the RTOs and/or ISOs”.
 ROLE OF AGGREGATION

- An aggregator is officially defined in Order No. 2222 as “the entity that aggregates one or more DERs for purposes of participation in the capacity, energy and/or ancillary service markets of the RTOs and/or ISOs”

- Aggregators act as an intermediary between the ISO/RTO and electricity consumers to deliver services from DERs to markets
ROLE OF AGGREGATION

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

- The aggregator is responsible for managing, dispatching, metering and settling its individual DERs.
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

CONCLUDING REMARKS

- DRRs 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 DRRs to provide grid services, such as regulation and load following, and to play a role in the reliable and effective integration of renewable resources.