MichaelsEnergy

GOLDEN OPPORTUNITIES WITH EFFICIENCY, DEMAND RESPONSE, & ELECTRIFICATION

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Table of Contents

INTRODUCTION

Decarbonization includes two significant elements: renewable energy generation, mostly from wind and solar, and the electrification of buildings and transportation. Those are the easy parts. The challenges are keeping prices low to make them accessible to all customers and maintaining reliability and grid resilience. Threats and opportunities abound. Planners must consider the entire energy system, from solar panels and wind turbines to the point of use, especially when the energy (wind and solar irradiation) is available versus when the electricity load occurs. There are many mitigation strategies to minimize the frequent and large gaps between available supply and load.

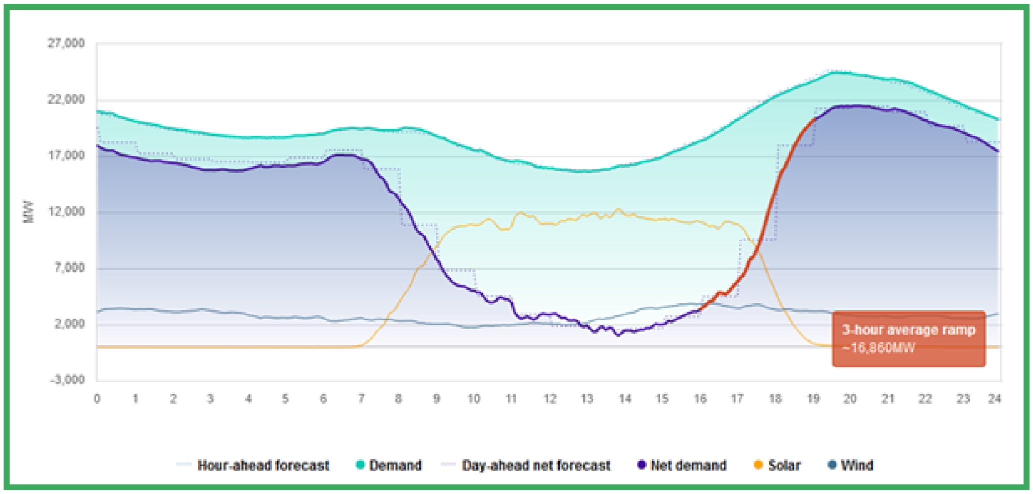
This paper provides a brief background into challenges with maintaining grid reliability followed by traditional demand-side management policies and then moves into many strategies to deploy in building design, technologies, and operation to align with a low-carbon grid. This paper also includes strategies to shrink the gaps between available supply and load, including efficiency, thermal energy storage, building design, waste reduction, and demand response. In most cases, the best strategies include some combination of these elements. A summary of the results and next steps are provided at the end.

Net Grid Loads

As dispatchable thermal power plants are retired and intermittent renewable supplies, especially solar, garner a larger share of electricity supply, the ramp rate of net loads to be met with dispatchable resources increases, and the risk of loss of load and the high-risk period compresses.

As solar generation takes larger shares of the generation mix, utilities will see the formation of duck curves (net load shapes) even in places like the upper Midwest. **Figure 1** shows today's net load curve for California, with a 5,000 MW per hour ramp in the evening, equal to bringing seven combined-cycle natural gas plants[1] online every hour for three hours. This effect is coming to the rest of the country, where the ramp rate is less pronounced for now yet significant in the summer.

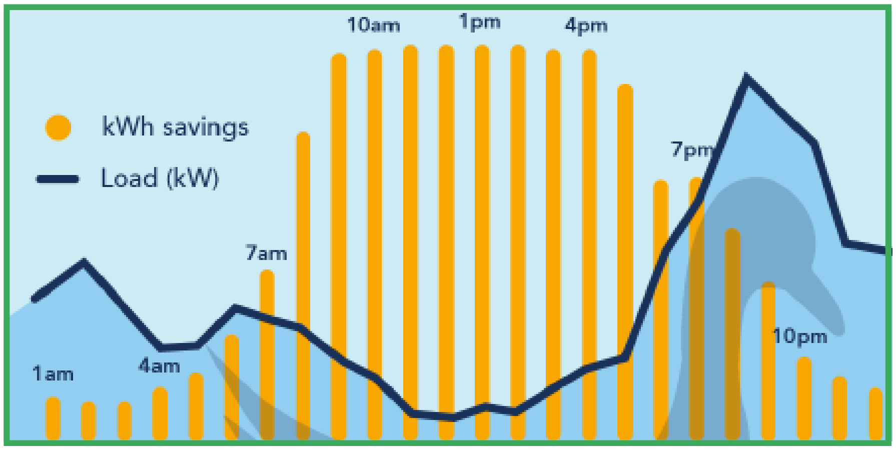
Figure 1: California Net Load Curve [2]



[1] https://www.alliantenergy.com/cleanenergy/ourenergyvision/marshalltowngeneratingstation
[2] https://www.caiso.com/TodaysOutlook/Pages/default.aspx

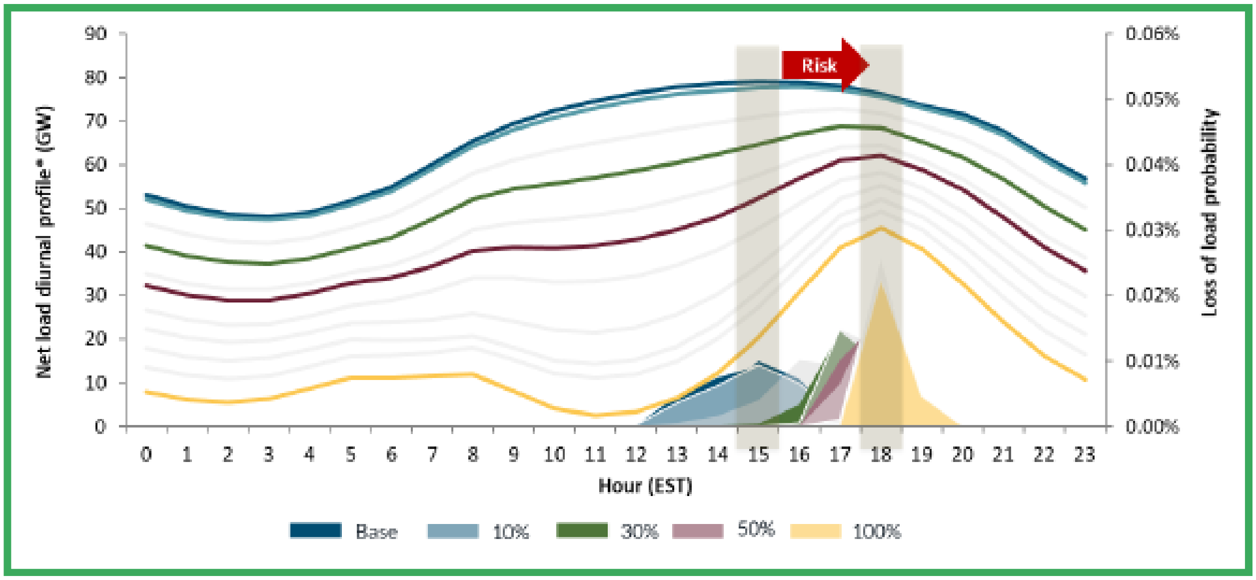
Compounding the ramp rate challenge, typical efficiency portfolios reduce net load and increase the ramp rate further, mainly because lighting is a predominant technology. Load profiles for energy savings are almost non-existent because efficiency has rarely been considered a grid resource. For forty years, efficiency portfolios have focused on saving energy regardless of when the energy is saved. **Figure 2** depicts the net load curve in Arizona Public Service's territory.

Figure 2 APS Demand Side Management Savings Curve [3]



The ducks are migrating north per Midcontinent Independent System Operator's report, Renewable Integration Impact Assessment[4]. **Figure 3** shows how the loss of load probability increases, but for a shorter time, as the penetration of renewables increases. This presents great opportunities for dispatchable auto-DR and conventional interruptible resources.

Figure 3 MISO Loss of Load Probability [5]



There are opportunities for demand reduction through energy efficiency without loss of performance. These include technologies that save or store energy and reduce demand during the late afternoon and evening ramp period. Most will be operational savings.

[3] Tom Hines and Jay Delaney, Evolving Residential Energy Management to be a Clean Peak Resource [Conference Presentation]. AESP 32nd 2022 Annual Conference, Nashville, TN. February 7-10, 2022.
[4] https://www.misoenergy.org
[5] Ibid

Demand-Side Resources

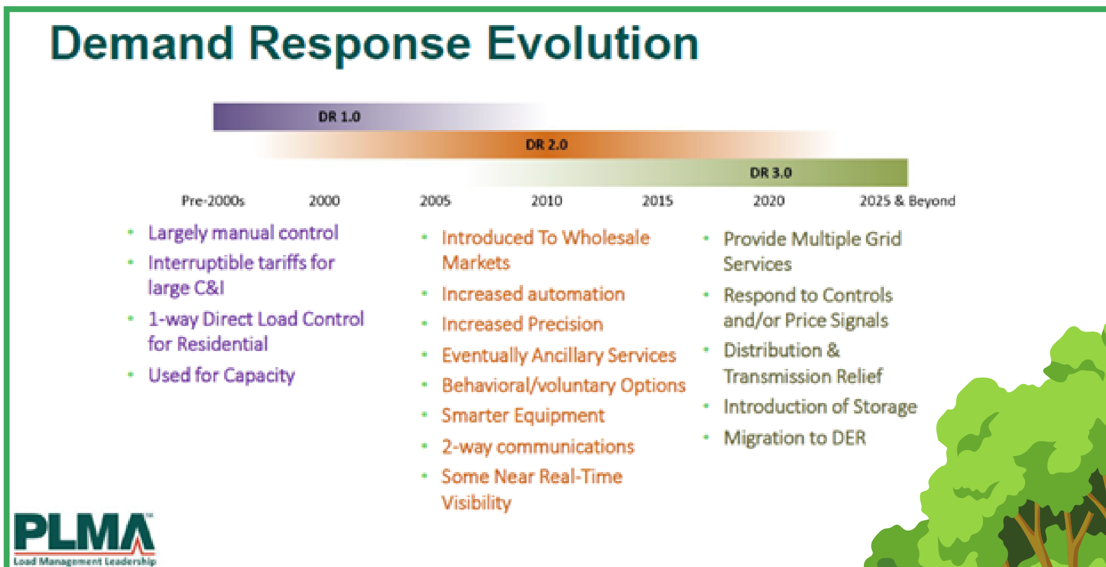
Efficiency programs originated in the late 1970s and early 1980s to reduce demand for energy for scarcity, reliability, and security reasons. Since then, proven fuel reserves have increased while objectives have shifted to decarbonization using intermittent renewable generation, both cyclical and more predictable solar, and powerful but less consistent wind generation. Decarbonization is driving the need for distributed energy resources including load shaping, generation, and storage.

Figure 4 provides a visual representation of demand response evolution. Most utilities have offered DR 1.0 opportunities to customers for many years, and with smart thermostats, they are moving into DR 2.0 as well. Simply put:

- DR 1.0 is on/off, binary, all or nothing, manual for large C&I, more disruptive to customer operation, and has a lower level of service
- DR 2.0 is tunable, customized, flexible, and much less disruptive to customers

This paper examines opportunities to expand DR 1.0 and grow into DR 2.0. Demand response also includes taking excess supply in cases of over-generation by renewable resources, as well as load curtailment in times of shortage. In this way, DR is load-shaping, which we cover later in this introduction.

Figure 4 Demand Response Evolution [6]



[6] Image courtesy of PLMA

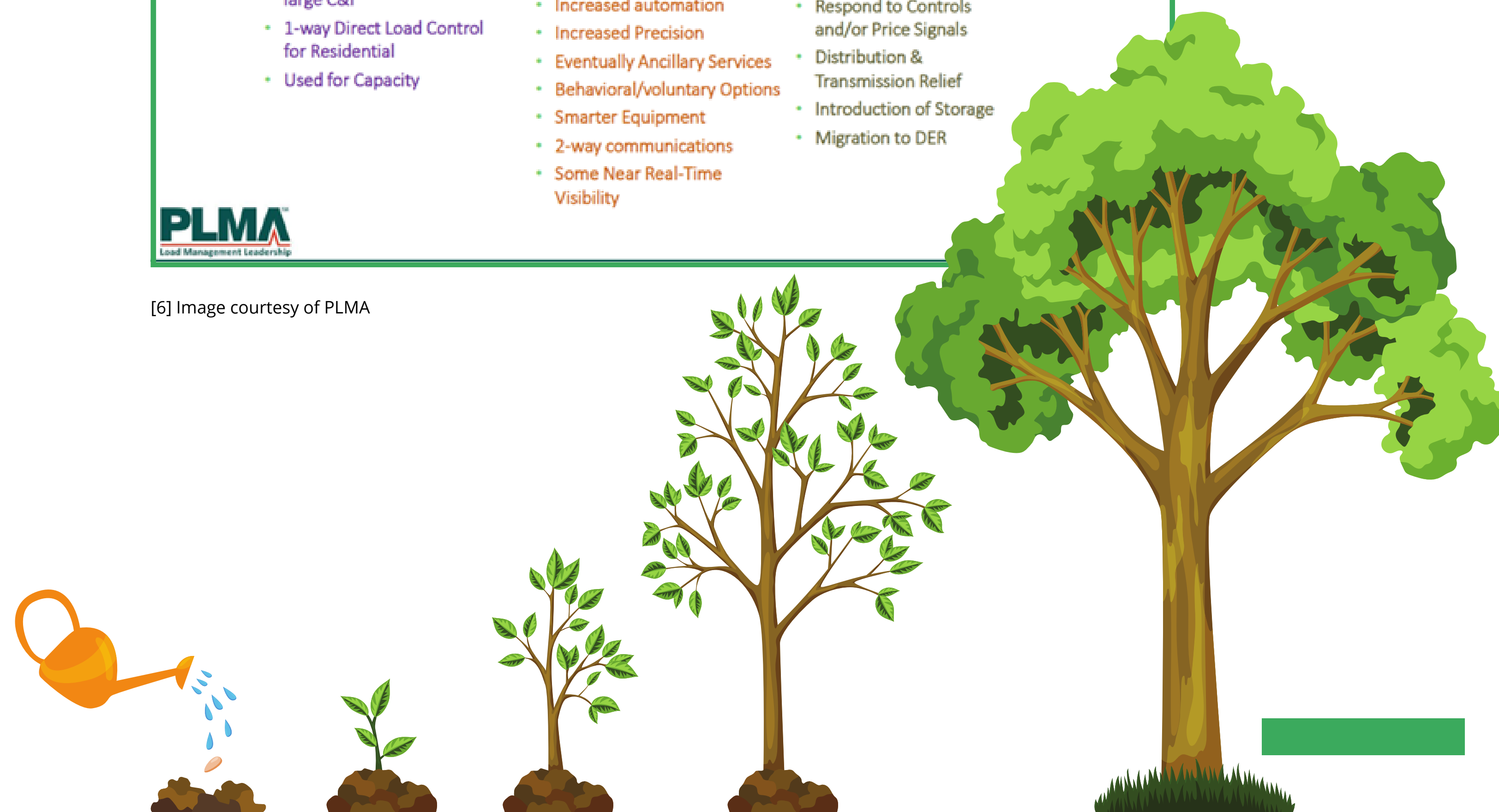
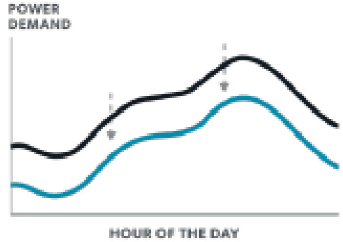
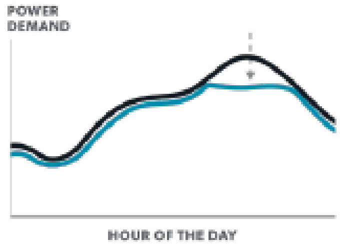
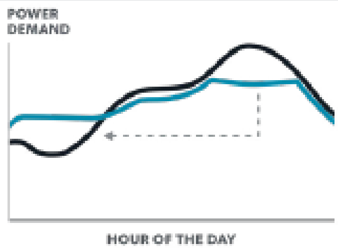
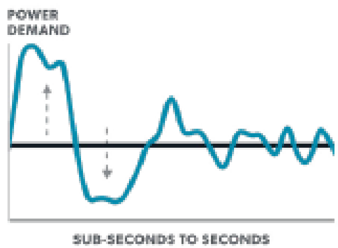
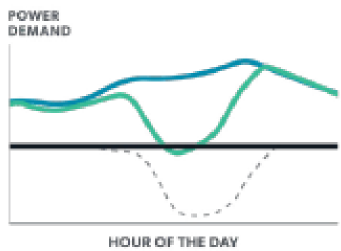


Figure 5 includes various types of load management taken from the DOE's National Roadmap to Energy Efficient Grid-Interactive Buildings. It provides a good representation of the types of load management and shaping, but this paper presents more than interactive load shaping, which is limited by many factors, including customer inconvenience and a decrease in service level. This paper provides opportunities to shape load using each of these strategies.

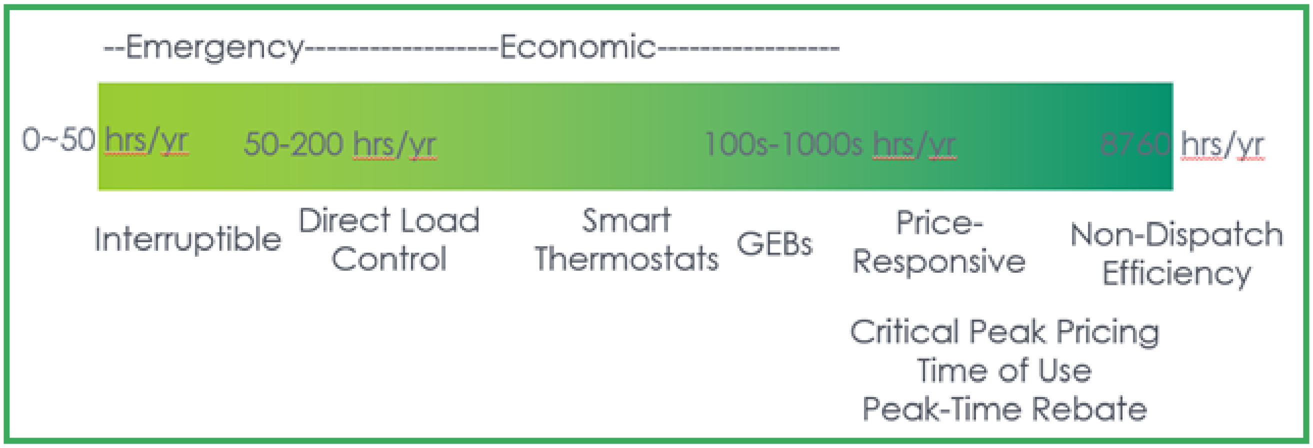
Figure 5 Types of Load Management [7]

	LOAD IMPACT	EXAMPLE MEASURE	EXAMPLE BENEFIT
Efficiency		Building has an insulated, tight envelope and an efficient HVAC system to reduce heating/cooling energy needs	Reduced costs of burning fuel to satisfy energy demand, and reduced emissions associated with lower fuel use
Shed Load		Building dims lighting system by a preset amount in response to grid signals while maintaining occupant visual comfort levels	Reduced investment in generation and transmission capacity due to lower peak demand
Shift Load		Connected water heaters pre-heat water during off-peak periods in response to grid signals	Reduced energy costs due to shifting consumption to cheaper hours of the day; avoided curtailment of renewables during off-peak periods
Modulate		Batteries and inverters autonomously modulate power draw to help maintain grid frequency or control system voltage	Reduced ancillary services costs, improved integration of variable generation resources (e.g., wind, solar)
Generate		Rooftop solar PV exports electricity to the grid	Reduced T&D losses due to on-site consumption; avoided need for grid-scale generation

[7] https://gebroadmap.lbl.gov/

Figure 6 is a graphic of most demand response categories, including energy efficiency, which is a mostly permanent, non-dispatchable load management strategy. Efficiency becomes more useful in demand response when peak savings align with grid or circuit peak load. However, most efficiency programs and strategies exacerbate net load gyrations as this paper will explore.

Figure 6 Demand Response Spectrum



Referring to **Figure 4**, demand response is moving to the middle of the spectrum shown in **Figure 6**, picking up more interactions with building loads and hundreds of hours of load management per year.

The rest of the paper describes decarbonization-enabling strategies for building loads, including efficiency, thermal energy storage, building design, waste reduction, and demand response. In most cases, the best strategies include some combination of these elements. Some strategies can be elements of existing programs, but most would be fit for stand-alone offerings to utility customers.

[7] https://gebroadmap.lbl.gov/

Efficiency and Load Shaping

In this context, efficiency includes non-dispatchable, load-shaping, and cost-saving opportunities through energy and/or demand reduction.

Peak-Demand Focused Retro-Commissioning

A challenge with retro-commissioning (RCx) is that it traditionally has been associated with off-peak savings, including during mild weather and for shutting things down and setting them back overnight. However, with peak ramp time starting at 16:00 through 19:00, RCx can provide a lot of grid support by mitigating the net-load ramp. HVAC loads can be sharply reduced at the close of business, including ventilation and temperature setbacks.

Schools

Schools can be ideal candidates for retro-commissioning and operational adjustments to save energy and demand for customers and for the grid at large. We have found that in the summertime when schools are minimally occupied, they are overcooled in an attempt to keep buildings dry in response to wet cleaning of hard surfaces and carpets. However, this strategy does not work if ventilation supplies, a major source of moisture, are not shut down. There are many potential opportunities in school for efficiency, balancing the grid, and shaving demand when needed.

Summer

- If dehumidification is the driver for mechanical cooling, shut off outside air when the building is not occupied. Drive space temperatures down during off-peak hours to wring the moisture from the air. When the setpoint is reached, shut down the cooling. Repeat this for as many days as required to dry out the building.
- Consolidate summer activities to as few buildings and spaces as possible. This reduces moisture infiltration via ventilation (outside air) and minimizes cooling load.

School Year

- Aggressively set back temperatures once school lets out. When classes are over, most of the cooling load consisting of bodies and ventilation is gone. Spaces should coast comfortably until at least 5:00 PM in the absence of cooling loads.
- Pre-cool until demand response events are called during the school year (refer to Shedding/Capping Load section for mechanisms to achieve this). It is not unlikely that DR events will occur early in the school year in late August and September. As noted above, buildings can coast when the loads are removed. Per MISO's research[8], DR events would not be called before 3:00 when school lets out. On event days, spaces and all their mass (furniture, floors, walls, and partitions) can be precooled to 70F and allowed to coast up to 75F. Results will vary depending on the thermal mass, which correlates to the physical mass, of the building.

Schools present popular opportunities for efficiency programs because they are *grounded in the community* and *represent its future*.

[8] https://www.misoenergy.org/planning/policy-studies/Renewable-integration-impact-assessment

Schools have long-term challenges with budgets but have opportunities to participate in demand-management programs through O&M and retro-commissioning-like measures with high rates of return and simple paybacks under one year. A menu of potential school program adders includes:

- Strategic Energy Management (SEM) specific to school districts; either inter-district or intra-district. The scope can include all measures from O&M/RCx and CapEx projects or just the former.
- ENERGY STAR certification, which includes energy benchmarking and a brief inspection to ensure proper ventilation, comfort conditions, and lighting levels. Certification is a source of operational pride and excellence to be shared with the supporting community.
- Wellness certifications that enhance learning environments. There are several wellness platforms that go deeper into the indoor environment to enhance learning. For example, as part of Illinois' "Clean Energy Jobs Act," investor-owned utilities are required to conduct building wellness assessments to estimate certification needs and costs for all schools in their territory, in addition to electrification, solar, and efficiency opportunities.

Commercial

Commercial buildings, like schools, represent a great opportunity for demand management, especially in what will become the shorter, higher-risk period of grid reliability from 17:00 to 19:00. Again, retro-commissioning's challenge has been cost-effectiveness due to most savings occurring off-peak, but that all changes once renewable penetration reaches 20-30% across an entire RTO/ISO region. At that point, the high-risk period moves to what used to be "off-peak."

Ground Source Heat Pumps

Ground source heat pumps were "the thing" back in the aughts and early 2010s in Iowa. Alliant Energy, for example, promoted the technology with great success. Like RCx, ground-source heat pump systems bring benefits of efficiency and smoother load curves in an electrified, low-carbon energy landscape. Unlike air source heat pumps, which are likely to have heating capacity challenges, and will certainly have adverse effects on the grid in very cold northern climates, ground source systems can handle very cold weather because the heat sink is deep underground rather than below-zero air. Furthermore, it is easy to boost the water loop temperature with a little heat from natural gas. Such boosting is not feasible with air source systems.

Figure 7 Climate Zone Map [9]

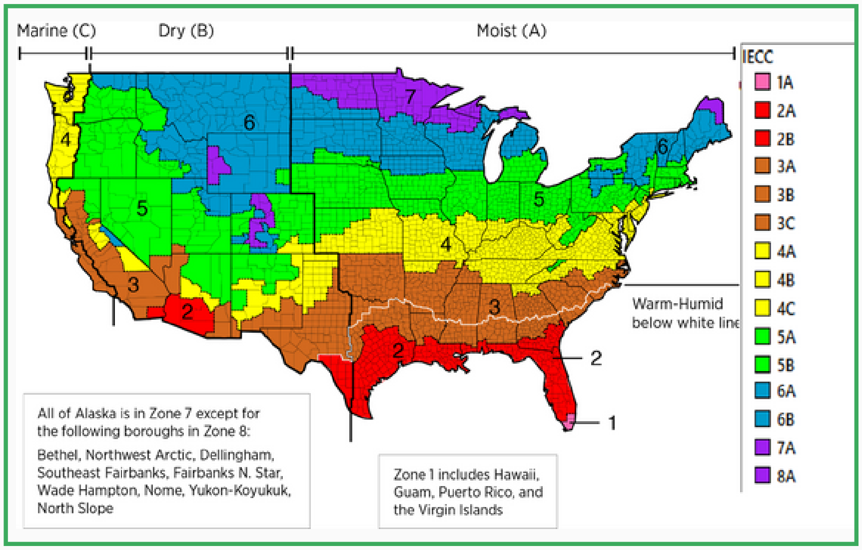


Figure 7 on the left shows design climate zones per the International Energy Conservation Code. Ground source heat pumps are a great choice for the region that is north of a line that cuts through the middle of climate zone 5. South of that line, cold climate heat pumps may handle heating loads in the coldest weather. However, weatherization and load reduction are always advised when electrifying building heating.

[9] Image credit: https://www.pepperconstruction.com/blog/science-building-codes-and-climate-zones

Water source heat pump water heaters can also be connected to the building and ground loop heat exchanger. This technology has an advantage over air source heat pump water heaters because they will not absorb heat from (i.e., cool) the space in which they are located.

Ground loop design is critical for successful heat pump applications. For new construction projects in Minnesota, Michaels Energy partners with a Canadian firm focused solely on ground-source heat exchanger design.

Ground Loop Leasing

Decarbonizing the grid presents risks and opportunities for utilities. Opportunities include investing behind the customer meter and owning and leasing ground loop heat exchangers to building owners. The ground loop heat exchanger for a heat pump system represents about half the cost of a ground source heat pump system. This cost is likely to be $15-$20 per square foot of conditioned floor space.

Why would utilities want to own and lease ground loop heat exchangers to customers?

- It is likely the best way to electrify HVAC systems in cold climates without excessively stressing the grid in the most vulnerable, deadly-cold weather conditions. It's safer than other electric heat, including cold climate air-source heat pump technology, for customers and the grid.
- It will be less costly for the grid as ground source heat pumps will have substantially lower peak demand in peak heating season, especially if coupled with natural gas water-loop boosting.
- In the near term, it is a great way to balance load by adding load in the wintertime. This will increase sales and put downward pressure on utility rates for customers.
- It fits beautifully with renewable energy generation in the upper Midwest. Winds blow the strongest at night and in winter because there is no thermal inversion that occurs during daytime heating in summer, which slows windspeeds at turbine height. However, in summer, solar generation coincides nicely with peak cooling periods.
- Ground source heat exchangers and their geothermal (ground source heat pump systems) are considered renewable energy and therefore eligible for Business Energy Investment Tax Credits through 2023[10]. Based on historical renewal rates, we anticipate they will be renewed.
- The heat exchanger system is very stable with almost no moving parts (pumps), and it should be isolated from customer buildings via a high-effectiveness heat exchanger.

Third-party and utility ownership of ground source heat pumps is not a new concept[11]. Many programs are in place, with electric co-ops leading the way[12]. Eversource is piloting a utility-scale, networked, ground loop for a community in Framingham, MA[13]. Excellent candidates for ground source heat pumps include homes and institutional facilities including K-12 schools, colleges and universities, hospitals, and government. These customers are more accepting of longer-term investments compared to for-profit entities.

[10] https://programs.dsireusa.org/system/program/detail/658
[11] https://www.altenergymag.com/article/2016/01
[12] https://www.renewableenergyworld.com/baseload
[13] https://www.eversource.com/content/ema-c/business

Shedding/Capping Load

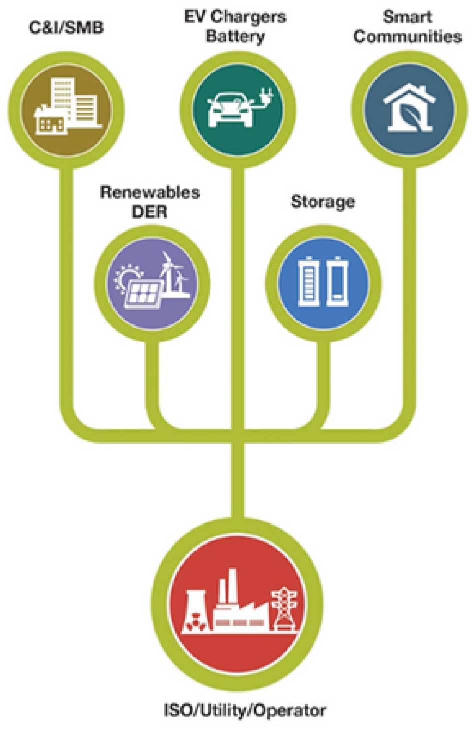
Load shedding includes traditional demand response programs in which there is some decrease in the level of service. Referring to Figure 6, the most disruptive decrease in level of service is caused by interruptible programs that are concentrated among industrial customers. Events are manually executed at customer sites by shutting down systems, equipment, or manufacturing lines, or standby generation may be brought online to reduce net customer demand.

Automated Demand Response (ADR)

ADR for commercial buildings is an under-utilized strategy for demand response with minimal decrease in service and immense savings opportunities to support DR programs with more frequent events – such as critical peak pricing and peak demand rebates. Programs vary in the number of events called and maximum event duration, but there may be 30 events per year and curtailment periods for any customer may be four hours[14].

ADR can be delivered with an open-source standard like OpenADR depicted in Figure 8. A "virtual top node" (VTN) server controlled by a DR aggregator or utility sends signals to "virtual end nodes" (VEN) located at the resource level – in this case, a building. The VEN interacts with control devices in the building, including common building automation systems like those provided by Automated Logic, Carrier, Johnson Controls, and Siemens.

Figure 8 OpenADR Network [15]



These programs are like ADR for residential programs that use smart thermostats to trim load. Strategies include temperature setpoint increases or decreases, limiting fan and pump speeds, and limiting chiller demand. Buildings can also be slightly preheated or precooled going into the event to maintain a more comfortable temperature band through the event. Strategies are established with an assessment in collaboration with customers. Controls contractors program the system for event strategies that take the signal from the VTN. The VTN confirms curtailment activity and determines impacts.

Demand Limiting

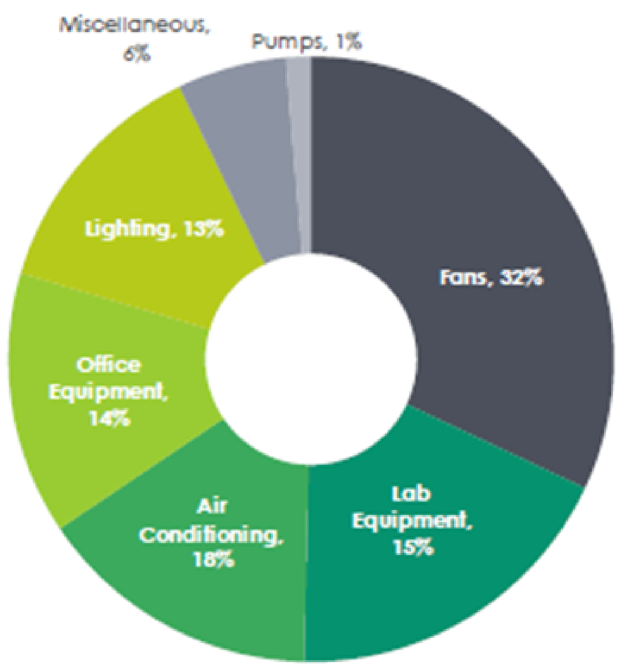
As the share of electricity that comes from renewable energy increases, energy charges are likely to decrease while demand charges are likely to increase. Energy will be inexpensive and at times is so abundant that real-time prices fall below zero. Since electricity cannot be cost-effectively stored in bulk, demand charges will be high and dispatchable resources will be in high demand. Per our audits and discussions with large energy users on general service and large general service rates, customers want to know how to reduce their demand charges and electricity service bills. One way to do this is to provide demand and usage data in near real time (five-minute increments) so they can respond with operational changes before shooting through a self-imposed demand ceiling.

[14] https://www.xcelenergy.com/staticfiles/xe-responsive
[15] Image credit: https://www.openadr.org/openadr-and-der

Demand Assessments

Energy assessments, audits, and feasibility studies traditionally provide end-use of energy breakdowns that customers find to be useful tools for managing energy consumption. Please refer to **Figure 9** for example results of an end-use assessment.

Figure 9 Customer Electrical End Use



More recently with the deployment of AMI, Michaels has added demand heat maps and power distribution charts shown in **Figure 10** and **Figure 11** on the following page. Customers love these data visualizations, but it only goes so far. Why? Because for 30+ years, programs have been focused almost exclusively on saving energy and not on demand, which comes along for the ride. This needs to be flipped to focus on demand while allowing energy savings to come along for the ride.

We see in Figure 11 that this customer has a long "tail" of demand each for very short durations. The last four bars represent 56 kW with almost no duration. If this customer curtailed load for about 90 hours during the year, they could save about $30,000 in demand charges[16].

Our research has shown that demand limiting and demand response save about three to four full-load hours of demand in energy savings[17]. For example, if demand response saves 140 kW, energy savings would be 420-560 kWh.

[16] Assumes one month of full demand savings & 75% ratchet at $20 per kW demand charge.
[17] https://michaelsenergy.com/wp-content/uploads/2021/12/DR-Snapback-Report.pdf

Figure 10 Electric Demand Heat Map

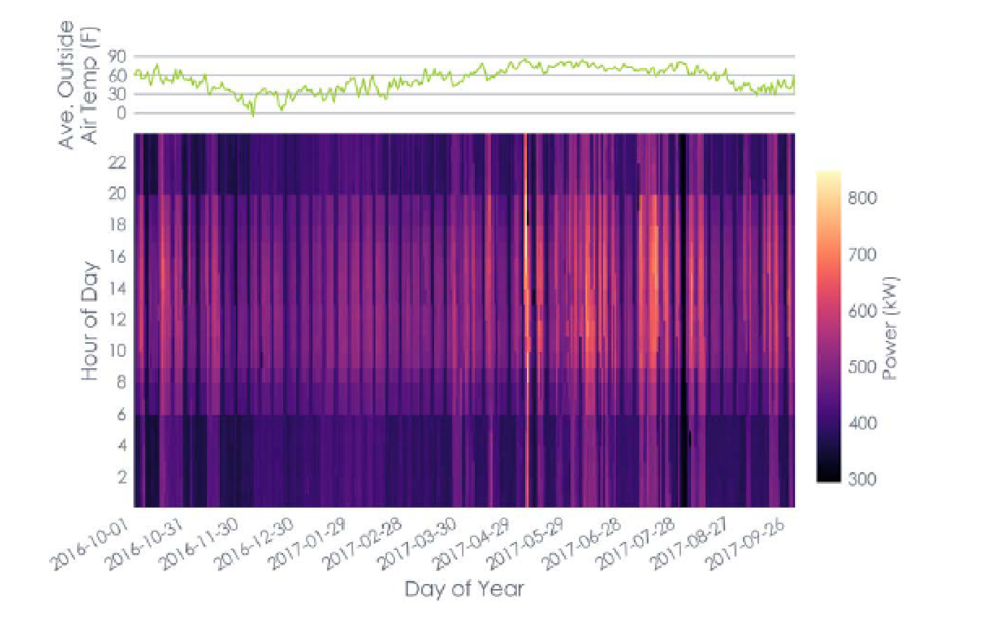
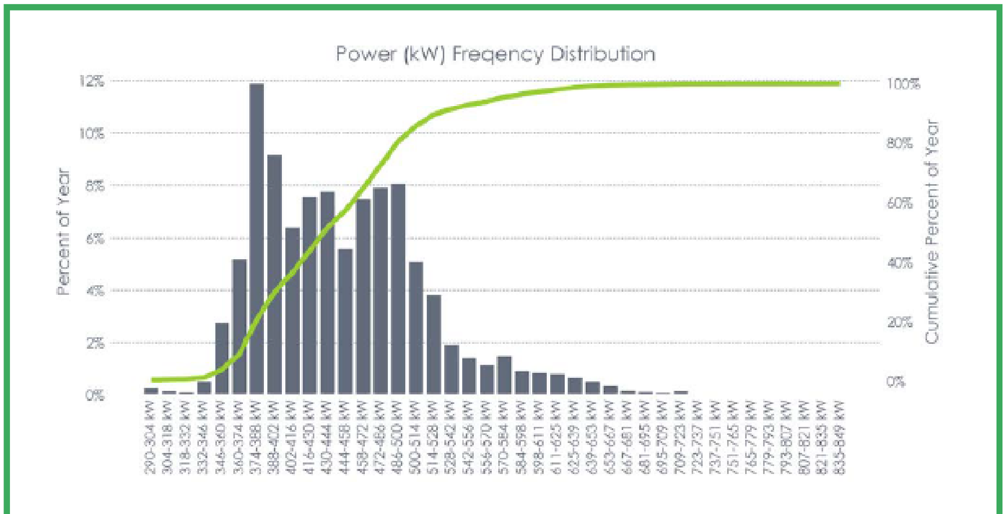


Figure 11 Power Distribution



But even knowing what the savings potential is with these data and graphics, customers want to know where they can trim, and what the impact will be on their operation. They need a demand assessment of the components that contribute to their peak demand, a tripwire to notify a peak event is on the way for their specific facility, based on past performance, and a plan to head off a peak event or breaking through a demand ceiling. The impact on their operation may be unnoticeable because they are flying blind and wasting demand and energy, only to get their bill days or weeks into the future and then wonder what happened.

A demand management platform with a real-time display and dashboard is a critical component to inform building operators to enable them to manage energy and demand.

Shifting Load with Higher Efficiency

Thermal Storage with Phase Change Materials

For the context of this paper, phase change includes melting or solidifying (freezing) materials including water, saltwater solutions, and organics, including plant-derived fats. These are three classes of "phase change materials" or PCMs.

Ice Storage for HVAC

Ice storage for chilled water systems has been used for 50 years, first to shift chiller energy demand and consumption off-peak, and second as an offset to reduce necessary chiller capacity purchase cost. Cost-effectiveness was a challenge due to rate design, but this is changing as some utilities charge very little for energy but a lot for demand. Now, customers would be loading their chillers off-peak with nearly-free energy and avoiding major demand charges.

Everything has changed with the modern grid and high penetrations of renewable energy, so what was considered not to be cost-effective deserves fresh looks.

Saltwater PCMs for Commercial and Industrial Freezers

The material in plastic freezer packs for coolers is a solution of water and some type of salt to decrease the freezing temperature below 32F. The higher the concentration of salt, the lower the freezing point.

This is a simple technology that works great for a wide variety of frozen food storage from grocery applications to frozen food warehouses. **Figure 12** shows freezer packs hung from the ceiling in a walk-in freezer. They look familiar!

Figure 12 Saltwater PCM for Frozen Storage[18]

[18] Photo credit: Viking Cold Solutions. https://microgridknowledge.com/thermal-storage/

This old technology, coupled with controls to correctly time the charge (freeze) and discharge melt) of the material provides great benefits to the customer and the grid:

Saltwater PCMs reduce on-peak demand and save energy. Charging and refrigeration load is shifted to nighttime hours when it is cooler outdoors with a lower wet bulb temperature. This allows refrigeration compressors to operate at lower head pressure and higher efficiency.

At wind turbine hub height, the wind blows harder at night year-round. This allows the technology to soak up more plentiful, less expensive, off-peak energy.

Since the PCM absorbs and dissipates heat at a constant temperature, the refrigeration compressors can operate at their sweet spot of efficiency when charging, rather than normal continuously varying shell loads and lower part-load efficiencies.

The PCM offers temperature stability in the space, especially if there is a disruption of power, or a compressor, evaporator, or other equipment malfunction. Customers love this because stable temperatures are paramount for food quality.

The material stores in the space above the racked product requiring no invasive installation. It is very simple compared to ice storage for HVAC, which is quite simple because it has been perfected over decades.

There are no moving parts or maintenance requirements. The expected useful life is decades.

This is a viable tested technology approaching the emerging technology phase of adoption. Pilot studies in California have demonstrated savings of 30-40% on energy[19], but more importantly, the demand from the grid can easily be moved out of a four-hour DR event or spread over a longer event.

Bio PCMs for Telecom

Bio PCM applications for telecom are much like the saltwater PCMs for freezer spaces, except temperature control in conditioned telecom spaces is not as critical as it is for storing food and other perishables. Telecom equipment can operate safely over a wide range of temperatures.

Like saltwater PCMs that passively serve their function in freezer spaces, bio PCMs passively serve telecom spaces. The PCM material is built into panels that are mounted on walls or partitions in telecom facilities, including data centers.

Pilot studies for bio PCMs in telecom facilities like the one shown in **Figure 13** save energy in a range of 15-20%[20]. The load is shifted to night when it is cooler outdoors and systems run more efficiently.

Figure 13 Bio PCM Panels [21]

[19] https://phasechange.com/
[20] https://www.scte.org/
[21] Photo credit: Phase Change Solutions

Bio PCMs for HVAC

Bio PCMs for occupied-space conditioning offer advantages and can be used for different purposes compared to conventional ice storage. Ice storage systems operate with an efficiency penalty that typically reduces dollar savings. The efficiency is lower because it is more energy-intensive to make ice with a 25F solution of water and antifreeze. The refrigeration compressor lift is significantly greater than it is for making the typical 40F chilled water. Antifreeze also adds viscosity to the fluid and that increases pumping energy. Finally, antifreeze has poorer heat transfer properties compared to water, which results in a larger temperature difference required for an equivalent heat transfer rate.

Bio PCMs can change phases (melt and freeze) at many discrete temperatures, including 39F, a typical chilled water temperature. This can avoid the efficiency penalty associated with thermal (cooling) storage with PCMs.

Possibly a better use of bio PCMs for thermal storage is to use them as heat sinks for any temperature, including both heating and cooling. Think of it as being like a ground source heat exchanger for water loop heat pump systems. The ground is the source of heat in the winter and the heat sink to reject heat to in the summer. Bio PCMs can be used in similar ways to get through daily peaks of heating or cooling.

Finally, bio PCMs have been tested for use as economizers to be charged (solidified/frozen) at night and absorb building heat from occupants, lighting, and equipment during the day. There needs to be forced circulation of water or air over the packaged PCM. Passive heating and cooling as part of wall structures don't perform as well, but it has been tested as a means of adding the equivalent of thermal mass to buildings – like thick brick walls, but consisting of framing, insulation, and PCM material rather than massive masonry. This application saves energy by avoiding refrigeration and its associated demand for space cooling, at least for many days. A system could be designed for both economizer, for free cooling, and to shift load from peak to off-peak.

A final note – some program administrators are studying electrification with cold weather air source heat pumps and thermal storage with hot water tanks and electric resistance heating, just to avoid off-peak demand for four hours. That is not nearly as good a system as PCMs, which can store more heat per unit volume/mass and possibly avoid the use of inefficient and wasteful electric resistance altogether.

Bio PCMs for Refrigerated Storage

Bio PCMs have huge potential to carry refrigerated storage, especially for non-perishable items like beer, soda, and certain dairy items like butter and cheese, through peak cooling periods. This application is the same as the proven saltwater storage for frozen food warehouses, except at 32F-plus temperatures.

Bio PCMs can change phases (melt and freeze) at many discrete temperatures, including 39F, a typical chilled water temperature. This can avoid the efficiency penalty associated with thermal (cooling) storage with PCMs.

Smart Efficiency & Electrification

Several technologies are sucking all the oxygen out of the electrification space, but electrification must be done right, appropriately pairing technologies to use cases. Otherwise, systems won't perform for the customer, and they may be a major burden rather than an asset to the grid. One example is the cold climate air source heat pump, which has serious problems meeting load below zero Fahrenheit. The heating capacity drops off very rapidly in colder temperatures and so does the efficiency to the point where they may be even less efficient than electric resistance heat because they require energy to defrost while they deliver no heat to the space. They do, however, have their place in appropriate climates.

In the new world of decarbonization, electrification, and deep penetration of renewable energy supply, program administrators and utilities must consider supply, storage of any type (including thermal), and customer load profiles in order to align each of these entities at all times. We want loads to increase and sponge electricity as non-dispatchable renewables flood the grid with power, and we want them to decrease with decreasing supply. This was easy in the dwindling days of dispatchable thermal power plant supplies. Periods of supply and demand mismatch will become much more frequent, and therefore, demand flexibility, new building design features, and new and underused technologies must be wisely deployed to match the use case of the customer AND the grid.

In the electrified northern half of the United States, heat is precious at times, and dumping it outdoors, which happens in massive quantities in many facilities year-round, is extremely costly and wasteful for electrified buildings, and it must be avoided or minimized.

Heat Recovery Chillers and Heat Pumps

Many commercial and industrial buildings simultaneously burn energy to generate heat and burn energy to cool spaces and products. Heat recovery chillers and water-loop heat pump systems present an opportunity to burn only one fuel, electricity, to simultaneously meet space or production heating and cooling loads.

Commercial Buildings

Substantial areas of large commercial buildings require cooling all year, even during the coldest weather of the coldest climates in the United States, like Minneapolis. Even a typical large box store may require cooling in the middle of the store on a brutally cold day. Here is an opportunity to use an internal, free, high-temperature source of heat to heat the perimeter of the building where the heating loads exist. The inefficient and standard electrified alternative may be air source heat pumps where the middle of the building or store is cooled with outdoor air while the perimeter must flip into electric resistance heating because it's below zero outside.

A heat recovery chiller is a large heat pump that makes chilled water and hot water at the same time. In the case above, it would use the chilled water to cool the middle of the building, extracting the heat, and rejecting it to the perimeter. In the summertime when all zones need cooling, it operates like a conventional chilled water system with no added load over the status quo.

Water-to-air heat pumps may also be used. They can transfer heat from the middle of the building to the exterior zones using a pumped water loop where heat is extracted from the middle zones, rejected to the water loop, and then extracted and delivered to the perimeter zones. Even if there is insufficient heat in the coldest weather, these systems can still greatly reduce grid demand by transferring some internal heat gain.

Variable refrigerant volume systems can also simultaneously cool some zones of a building while heating other zones with one refrigeration cycle.

The bottom line is electrified buildings in the northern half of the country cannot afford to dump heat from people and internal gains. It must be recovered and used where needed when needed.

Grocery Stores

Few people realize it, but grocery stores have simultaneous heating and cooling loads every operating hour and probably every hour of the year. Refrigerated and frozen food cases absorb heat from the space all the time, which means, it cools the occupied space. Although many stores have installed cases with doors rather than open cases or strip curtains to minimize heat gain to the cases, there is still a refrigeration effect on the space. Furthermore, humidity control in stores is paramount to minimize refrigeration and freezer frost formation and the resultant defrost cycles and energy. Dehumidification may require simultaneous heating and cooling, just like a home dehumidifier operates.

Cases need to be cooled while there is a need for heat in other places. Again, electricity is used to reject heat outdoors, although sometimes small fractions are recovered for interior use. At the same time, natural gas is used for space heating in the winter, service water heating, and space heating in refrigerated case areas all year. Two energy sources are consumed when as we have found, one fuel (electricity) is nearly all that is needed to provide heating with the heat rejected from the refrigeration system.

Industrial Facilities

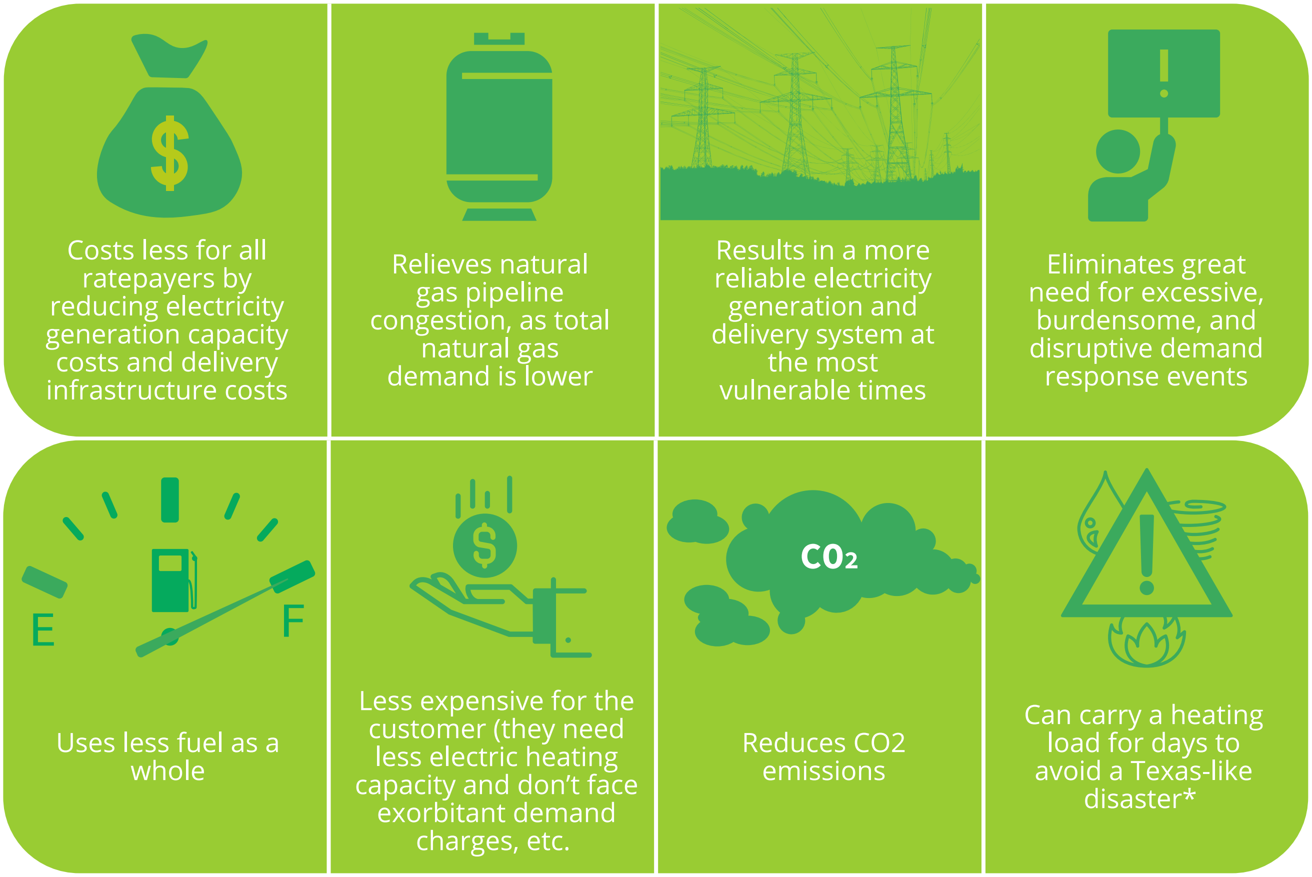
Many industrial facilities, especially food processors, have almost constant simultaneous needs for chilled water and hot water. Chilled water can be used for refrigeration or space conditioning, especially dehumidification, while hot water may be used for process hot water and space conditioning as well. Heat recovery chillers provide hot water and chilled water simultaneously with one fuel – electricity.

Hybrid Systems

Hybrid systems include an option to use natural gas or even delivered fuel in times of peak customer or grid demand. Consider air source heat pumps. When the temperature in the north country falls below zero at night and the wind isn't blowing, power is generated with natural gas, with a delivered efficiency of maybe 50% to a heat pump that is operating with a conversion efficiency of 100% at best. The system including the power plant heats customer spaces at 50% efficiency from the source fuel, natural gas. Furthermore, consider the excessively costly generation, transmission, and distribution required to heat with 50% efficiency.

Instead, simply use natural gas with at least 90% source fuel efficiency at the point of use, avoid excessive power generation infrastructure and delivery systems, and total fuel consumption.

A hybrid system:



**Any type of storage, other than a ground loop heat exchanger, will never be cost-effective compared to a supply of natural gas.*

New Buildings

Electrification is likely to render useless the standard practice and rules of thumb for building design. The balance between envelope cost, HVAC system cost, and energy cost is likely to shift toward envelope enhancement to minimize heating loads. Phase change materials need to be considered for many types of loads, including the condensed net load peak in the early evening. Thermal energy is much less expensive than electricity storage.

Designers must always consider preservation of Btus (heat) and scenarios of renewable generation on a seasonal and daily basis. For example, unfortunately, the month with the least wind resources by far is August, when cooling loads are near peak. How can buildings be designed to decrease cooling load and absorb abundant solar-generated electricity to keep the head of the duck as low as possible?

Summary and Next Steps

The table below summarizes and characterizes the technologies, programs, and system design strategies in this paper.

	Strategy	Passive, Active, Persistence?	Demand Savings	Energy Savings	New Const.	Retrofit/ Replacement	Next Step
1	School and Commercial Demand-Reduction RCx	Persistence	Primary	Secondary	No	No	Pilots
2	School SEM	Active	Secondary	Primary	No	No	Pilots
3	School ENERGY STAR	Persistence	Secondary	Primary	No	Maybe	Pilots
4	School Wellness	All	Secondary	Secondary	No	Yes	Research
5	Ground Source Heat Pumps	Passive	Primary	Secondary	Yes	Yes	Research
6	Ground Loop Leasing	Passive	Primary	Secondary	Yes	Yes	Research
7	Auto-DR	Passive	Primary	Secondary	No	Yes	Pilots
8	Demand Limiting	Active	Primary	Secondary	No	Yes	Pilots
9	Demand Assessments	All	Primary	Secondary	No	Yes	Pilots
10	Ice Storage HVAC	Passive	Primary	Secondary	Yes	Yes	Research
11	Saltwater PCM in Freezers	Passive	Primary	Secondary	Yes	Yes	Pilots
12	Bio PCM for Telecom	Passive	Primary	Secondary	Yes	Yes	Pilots
13	Bio PCM for HVAC	Passive	Primary	Secondary	Yes	Yes	Research
14	Bio PCM for Refrigeration	Passive	Primary	Secondary	Yes	Yes	Research
15	Heat Recovery Chillers Commercial	Passive	Secondary	Primary	Yes	Yes	Pilots
16	Grocery Store Heat Recovery	Passive	Secondary	Primary	Yes	No	Research
17	Heat Recovery Chillers Industrial	Passive	Secondary	Primary	Yes	Yes	Pilots
18	Hybrid Systems	Passive	Primary	Secondary	Yes	Yes	Pilots
19	Comprehensive New Bldg Design	Passive	Primary	Secondary	Yes	No	Research

The first characterization is whether the strategy is passive, active, or requires persistence from the perspective of the customer. Most of the strategies are passive because that's what customers tend to prefer. Persistence is used for strategies that are passive but require some action as well, and continuous monitoring for performance. For example, RCx measures might be undone as a result of building managers not understanding the measure or trying to fix another issue with anything that might work. Once the measures are in place, it's passive, but the customer needs to be aware of the measures to make sure they are not reversed.

The next characterization is whether the strategy is driven by demand savings versus the status quo, or energy savings. Many strategies, such as ground source heat pumps and some thermal energy storage strategies are almost equally demand and energy savings. However, with increasing penetration of renewable supply, the nod goes to demand savings. The next characterization is whether the strategy mostly applies to new construction or if it is a retrofit/replacement measure. Some strategies may apply to either, such as ADR, a technology/program that is ready for existing buildings today.

Finally, the next step column indicates whether the strategy is ready for a pilot or whether the next step should include more research. Some research is always warranted, even to start a pilot. But the ones labeled research in this table require more extensive research to answer questions such as, what is the cost/benefit analysis for a ground source heat pump program to help customers electrify their loads? That is more of a load building and load management program for utilities than it is a traditional DSM program. However, this is changing with recent policy adoption in some states such as Minnesota. Combinations of strategies are often very beneficial. For example, Schools that engage with demand-centric RCx can make good use of the demand limiting strategy that is accompanied by graphical displays and dashboards to monitor energy and demand in real time.

Next Steps

Michaels' product development cycle is shown in **Figure 14**.

1. We are constantly assessing the market for trends, needs, and opportunities to help our clients minimize waste and maximize the value of assets to shareholders and customers.

2. We identified many next-generation programs, services, and technologies that will enable high penetrations of renewable energy while minimizing cost and maximizing reliability for customers.

3. This paper presents those identified services, programs, and technologies, and explains the why, how, and what without digging into the details to save your time and ours.

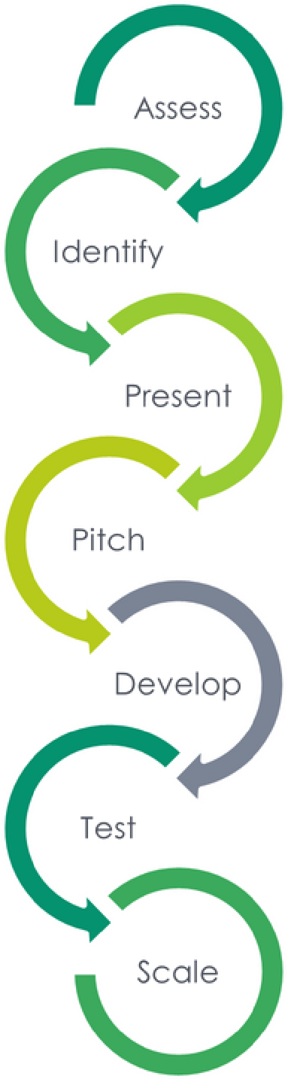
4. At this point, we hope your interest is piqued and you want us to tell you more as it applies to your scenario. We'll add customization to the ideas and pitch them to your team in a dialogue setting.

5. From the pitch session, we will take one to three opportunities that emerge and develop those further to quantify and help you better visualize the product or service.

6. We then test the product or service against the market. Does it deliver what customers want or need with the desired experience? Is it cost-effective for all involved?

7. With the information gathered from testing and research, we are ready to scale the product to your customer base with annual budgets, impacts, processes, marketing, and outreach plans, and deliver it to the market.

Figure 14



Take Action

Decarbonization and electrification are more radical and difficult than stakeholders realize because no one entity is in charge to accommodate the entire system from supply through the point of end use – most importantly, the temporal variability of supply versus a very different temporal pattern of demand from the grid. Therefore, a combination of radical ideas for decreasing and shifting load and storing energy combined with pragmatic approaches to cost-effectively handle extreme and rare conditions and events is best.

This paper has provided a menu of innovative ideas for programs, pre-emergent technologies, and building design. Every strategy described in this paper is either proven or will work with additional product development, testing, and optimization.

Customers want to decarbonize, but they need expertise to do it right. Without it, those that do decarbonize will face extreme bills, and some costs will be socialized to other customers because no tariff is 100% equitable. Utilities can guide customers to the best solutions using the strategies in this paper while minimizing cost for their entire customer base. There is no simple, LED-lightbulb-style solution, and utilities do not have the time or luxury to wait and hope for one to come along. The future is in highly integrated solutions, and it will be led by those with both the daring and the know-how to bring it about.

So, get ***curious*** and ***call us***.

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