FUTURE OF MICROGRIDS

COMMERCIAL & INDUSTRIAL

ADVANCED ENERGY CENTRE
MaRS Cleantech | Ontario, Canada

FUTURE OF MICROGRIDS SERIES OVERVIEW

Electricity distribution networks globally are undergoing a transformation, driven by the emergence of new distributed energy resources, including microgrids. However, with the majority of microgrids at the pilot and demonstration phase, this series will examine and forecast the commercial viability of microgrids right here in Ontario, and indicate factors that could result in deployment of these systems on fully commercial terms. The analysis, prepared with Navigant Consulting, also takes into account the non-financial factors affecting the overall business case for each microgrid use case, examined within the residential, institutional, utility, and commercial & industrial customer segments.

THE FUTURE OF MICROGRIDS SERIES WAS DEVELOPED WITH SUPPORT FROM OUR SPONSORS:

SIEMENS NRSTOR INC PowerStream TORONTO HYDRO ONTARIO POWER GENERATION

OVERVIEW

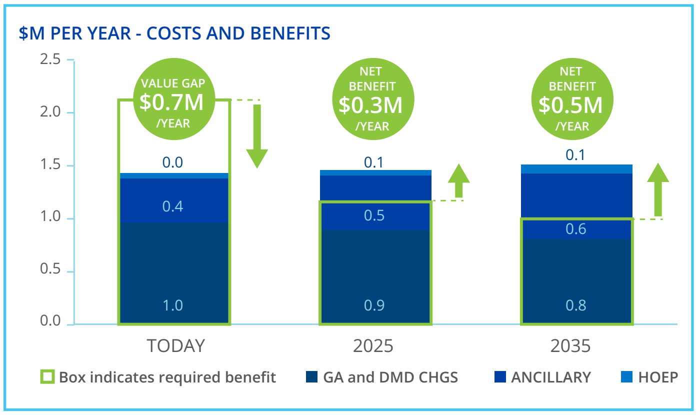
Commercial and industrial (C&I) customers are rethinking their role as traditional electricity consumers. A microgrid enables a C&I customer to become a fast-acting network resource, capable of responding to market signals and providing services to the electricity distribution and transmission network operators. A C&I microgrid consists of an advanced control system (or "controller") that integrates the customer's electrical loads, manages distributed resources such energy storage, and coordinates with the transmission and distribution networks. A C&I microgrid also provides emergency power to critical circuits during power outages, and reduces a customer's dependence on centralized electricity supply.

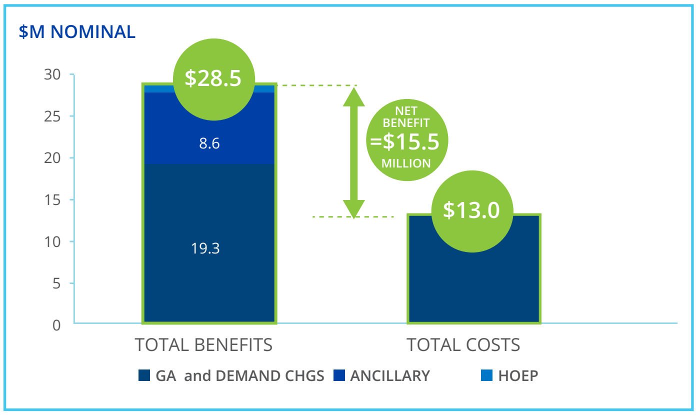
ASSUMPTIONS

This analysis is based on a Class A industrial customer operating a large manufacturing facility. The facility operates on a 24/7 schedule with a relatively flat load that averages 5MW throughout the year, and peaks at 6MW. The microgrid consists of a microgrid controller and a 5MW (10MWh) Li-ion battery. The microgrid controller, the battery, and the microgrid's switchgear enable the industrial facility to sustain power for critical systems during network outages. The battery is also used to reduce demand during Ontario system peaks in order to reduce GA charges, to participate in the operating reserve (OR) market administered by the transmission operator, and to provide demand response (DR) capacity.

RESULTS

The high costs of storage technologies make the deployment of industrial microgrids at scale more difficult today. However, the rapid decline in the cost of Li-ion battery storage is expected to result in a strong and positive business case for industrial microgrids in the near and long term. The value gap (the difference between the direct costs and the direct economic benefits) required to make industrial microgrids cost effective today is estimated to be $700,000 per year. By 2025, the business case becomes positive creating a net-benefit of $300,000 per year, increasing to $500,000 by 2035.





CONTINUED ANALYSIS

This analysis focused on high value opportunities, that is customers with characteristics that are favourable to the economics of an industrial microgrid.

The results presented above are based exclusively on the direct economic benefits of a C&I microgrid, and assuming the desired simple-payback period is seven years.

ASSESSING THE IMPACT OF ECONOMIC FACTORS.

DECLINING TECHNOLOGY COSTS. One of the key drivers of microgrid deployment will be the declining costs of storage technologies. Since 2010, the average cost of a large-scale energy storage system has decreased from $1,300/kWh down to approximately $740/kWh today – a 50% reduction. Storage costs are projected to continue to decrease substantially over the next two decades down to $230/kWh by 2035.

MAGNITUDE OF GA CHARGES. The largest economic benefit stream for a C&I microgrid in Ontario is avoided Global Adjustment (GA) charges. GA costs are the largest component of the electricity bill of most C&I customers. Class A C&I customers pay GA charges in proportion to their contribution to Ontario's top five system peaks. A customer able to decrease demand during those system peak hours can reduce their GA charges. A key implication of the way GA charges are calculated for Class A customers is that charges are determined based on a very small number of hours of the year. As a result, the financial incentive to reduce demand during each of the system peaks is substantial. In 2011, the financial incentive averaged approximately $220,000 per MW of demand reduction. Since then, the financial incentive has increased to close to $500,000 per MW.

GA RESPONSIVE BEHAVIOR. Forecasting the occurrence of system peaks is complex, given the inherent uncertainty of electricity consumption hour to hour and the added intricacy of a number of large customers reducing their consumption on expected peak days in an effort to reduce their GA charges. Most industrial customers hedge the risk of missing the peak by responding on more than five days and for several hours ahead of a potential system peak, and several hours after. Certain industrial customers may respond to +/- three hours around a potential system peak, and others –willing to take on more risk– may limit their response to +/- one or +/- two hours. The duration of a customer's response has direct implications on the amount of battery capacity discharged in each hour. A short response duration will achieve a higher load reduction, while a longer response will achieve a lower reduction. This analysis is based on a battery size of 10 MWh and an average response of +/- two hours –for a total response duration of five hours. In effect, this industrial customer is able to achieve a 2 MW demand reduction during each hour.

ELECTRICITY SECTOR EVOLUTION. The evolution of the Ontario electricity market and regulatory framework has the potential to create a more favourable market for microgrid deployment. A C&I microgrid, has sufficient scale to deliver value to utilities. A C&I microgrid can be transformed into a flexible and fast-acting resource, capable of decreasing local system constraints and providing ancillary services such as voltage or power quality support to network operators.

THE VALUE OF IMPROVED RELIABILITY. One of the key drivers of microgrid adoption by C&I customers is the prospect of improved reliability. C&I customers can incur significant financial losses – from lost production and sales – as a result of power interruptions, and increasingly due to power quality issues, as a result of the increased use of sensitive power electronic equipment. Interruption costs can vary widely for different C&I customers. Some C&I customers, such as a semiconductor or plastics manufacturer, may be particularly sensitive to power interruptions and may incur interruption costs in excess of $1.0 million per year. These customers will evaluate the adoption of a microgrid not only based on the direct economic benefits but also on the value of improved grid reliability and power quality. Industrial customers incurring annual interruption and power quality costs higher than the current gap in economic benefits – estimated at $700,000 per year– will be able to justify the investment and are likely to lead the adoption of C&I microgrids in Ontario.

THE VALUE OF INTEGRATING DIVERSE RESOURCES AND TECHNOLOGIES. One of the key characteristics of a microgrid is the ability to integrate multiple distributed energy resources and enabling technologies, including demand response, energy management systems, and distributed generation. This functionality has emerged as a major factor that can enhance the economics of C&I microgrids. This diagram shows a qualitative assessment of the impact of several key factors -including distributed resources, technology costs, and market transformation- on the business case of industrial microgrids.

QUALITATIVE IMPACT OF DER AND OTHER FACTORS	
↑ Smart DR & Load Control	↑ Energy Management Systems
↑ Smart EV Charging	↑ Declining Technology Costs
↑ DG Integration	↑ Market Transformation
↓ Anti-Islanding Provisions	↓ Lack of Market Transformation

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FUTURE OF MICROGRIDS SERIES OVERVIEW

Electricity distribution networks globally are undergoing a transformation, driven by the emergence of new distributed energy resources, including microgrids. However, with the majority of microgrids at the pilot and demonstration phase, this series will examine and forecast the commercial viability of microgrids right here in Ontario, and indicate factors that could result in deployment of these systems on fully commercial terms. The analysis, prepared with Navigant Consulting, also takes into account the non-financial factors affecting the overall business case for each microgrid use case, examined within the residential, institutional, utility, and commercial & industrial customer segments.

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FUTURE OF MICROGRIDS COMMUNITY

OVERVIEW

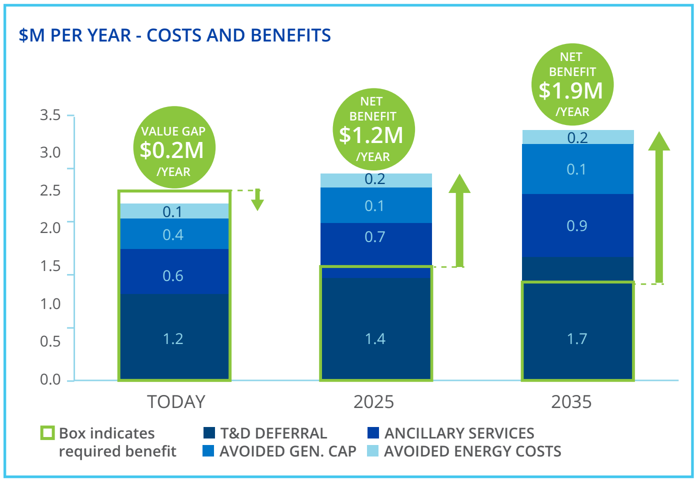
Community microgrids have achieved significant traction in the microgrid market. In response to extreme weather events, states like New York, Massachusetts, and Connecticut have allocated funding to assess the feasibility of community microgrids for emergency resiliency. At the same time, utilities are beginning to look at community microgrids as an alternative to traditional poles-and-wires solutions for heavily loaded distribution feeders and substations. A community microgrid consists of an advanced control system (or "controller") that integrates customer loads and manages distributed resources, and is capable of providing services to the electricity distribution and transmission network operators.

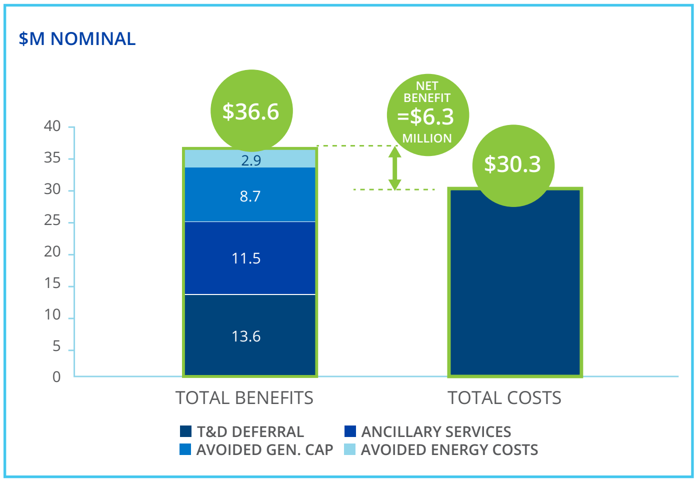
ASSUMPTIONS

This analysis is based on a utility-owned and operated microgrid. The microgrid consists of a distribution feeder serving part of the downtown core of a mid-size Ontario city. This feeder serves a mix of residential apartment buildings and office space with a 12 MW peak. The microgrid consists of a microgrid controller, a 5MW (10MWh) Li-ion battery, a 2MW solar array, and approximately 1MW of remote-controlled demand response (DR) capacity. The battery is primarily used to reduce the local distribution peak and to deliver grid services, and is also used in conjunction with the microgrid controller, and the microgrid's switchgear to sustain power during network outages.

RESULTS

The high costs of solar and storage technologies make the deployment of industrial microgrids at scale more difficult today. However, rapid declines in the cost of solar PV and Li-ion battery storage are expected to result in a strong and positive business case for community microgrids in the near and long term. The value gap required to make community microgrids cost effective today is estimated at $200,000 per year. By 2025, the business case becomes positive creating a net-benefit of $1.2 million per year, increasing to $1.9 million by 2035.





CONTINUED ANALYSIS

This analysis focused on high value opportunities, that is communities and network areas with characteristics that are favorable to the economics of a community microgrid.

The results presented above are based exclusively on the direct economic benefits of a community microgrid, and assessed based on a desired payback period of 10 years.

ASSESSING THE IMPACT OF ECONOMIC FACTORS.

DECLINING TECHNOLOGY COSTS. One of the key drivers of microgrid deployment is the cost of solar and energy storage technologies. Since 2010, the average costs of large-scale solar PV systems have decreased from $4.2/watt down to approximately $2.3/watt today. Solar costs are projected to decrease substantially over the next two decades down to $1.2/watt in 2035. The costs of large-scale Li-ion battery storage systems are also projected to decline rapidly, from $740/kWh today down to $230 in 2035.

VALUE OF DEFERRED T&D INVESTMENTS. The largest source of value for community microgrids is from deferred or avoided T&D infrastructure investments. The marginal costs of T&D infrastructure capacity required to serve load growth in capacity-constrained areas can be substantial. These areas will require infrastructure upgrades in the near term and the development of a microgrid may be a more cost effective alternative to T&D upgrades. Highly-loaded distribution feeders and substations operating close to or at their maximum capacity are high-value opportunities for microgrid deployments. This analysis is based on a constrained 12 MW distribution feeder projected to trigger upstream upgrades at an average cost of $450 per kW of additional peak demand. Upgrade costs of this magnitude are not uncommon. Costs in severely constrained areas may be in excess of $600 per kW of demand.

NON-WIRES ALTERNATIVES (NWA) TO TRADITIONAL SOLUTIONS. Non-wires alternatives are an innovative approach to deal with capacity constraints. Instead of traditional, and at times costly, T&D investments, load growth can be met through more innovative solutions such as targeted energy efficiency and demand management, and distributed energy resources (DER). The analysis of this community microgrid is based on the use of a 5MW battery, a 2MW solar array, and 1MW of remote-controlled DR capacity, including direct load control of space cooling and water heating equipment, and smart thermostats. The microgrid controller optimizes the dispatch of these resources enabling a combined peak demand reduction of approximately 4MW. This decrease in peak demand enables the community microgrid to defer planned distribution upgrades by five years and planned transmission upgrades by one year.

One of the most well-known and publicized utility-owned community microgrid projects is San Diego Gas & Electric's Borrego Springs project. Borrego Springs boasts the integration of utility-owned and customer-owned DERs, price-responsive and remote-controlled DR, distributed storage devices, and plug-in hybrid vehicles.

ELECTRICITY SECTOR EVOLUTION. The evolution of the Ontario electricity market and regulatory framework has the potential to create a more favorable market for the development of community microgrids. A community microgrid can deliver significant value to a utility. Community microgrids can be transformed into flexible and fast-acting resource, capable of decreasing local T&D and system peaks and capable of providing ancillary services to network operators.

THE VALUE OF IMPROVED RELIABILITY. One of the key driving factors for the development of community microgrids is the prospect of increased grid resiliency and reliability during severe storms. During natural disasters or extreme weather, community microgrids can island from the macrogrid and provide emergency power to mission-critical facilities. For example, in the wake of Superstorm Sandy, New Jersey established a microgrid fund to assess the feasibility of community resiliency microgrids and hubs across the state. Several other states have since followed suit.

THE VALUE OF INTEGRATING DIVERSE RESOURCES AND TECHNOLOGIES. Community microgrids are characterized by the ability to integrate various DERs, and enabling technologies including utility- and customer-owned solar PV, smart DR loads, energy efficiency, electric vehicles, battery storage, and home energy management systems. The ability to seamlessly integrate various technologies has emerged as a key factor to enhance the economics of community microgrids. This diagram shows a qualitative assessment of the impact of several key factors -including distributed resources, technology costs, and market transformation- on the business case of community microgrids.

QUALITATIVE IMPACT OF DER AND OTHER FACTORS

⬆ High Value T&D Infrastructure	⬆ Declining Technology Costs
⬆ Smart DR & Load Control	⬆ Market Transformation
⬆ Smart EV & DG Integration	
⬇ Anti-Islanding Provisions	⬇ Lack of Market Transformation

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FUTURE OF MICROGRIDS

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FUTURE OF MICROGRIDS SERIES OVERVIEW

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SIEMENS | NRSTOR INC | PowerStream | TORONTO HYDRO | ONTARIO POWER GENERATION

OVERVIEW

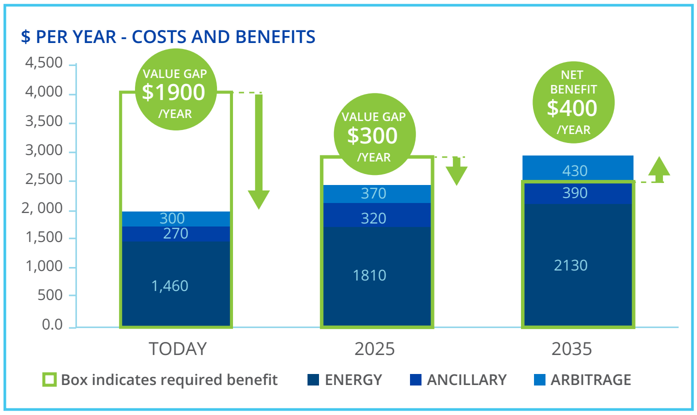
At its core, a residential microgrid consists of an advanced control system (or "controller") that integrates the customer's electrical loads, manages distributed resources such as solar PV and energy storage, and coordinates with the electricity transmission and distribution networks. A residential microgrid provides emergency power to critical circuits during power outages, and reduces a customer's dependence on centralized electricity supply. The microgrid controller transforms a residence into a flexible, dynamic and fast-acting network resource, capable of providing services to the electricity distribution and transmission network operators..

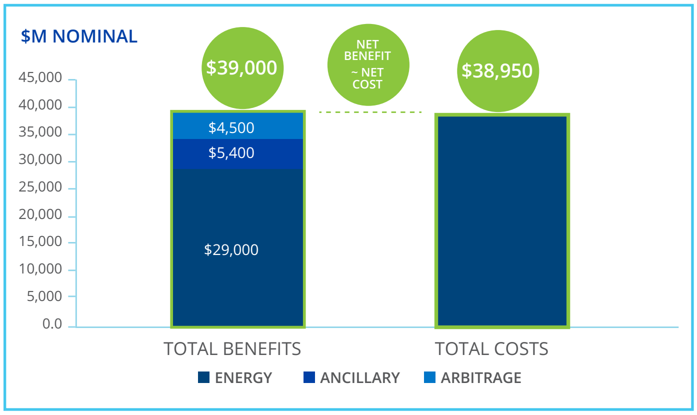
ASSUMPTIONS

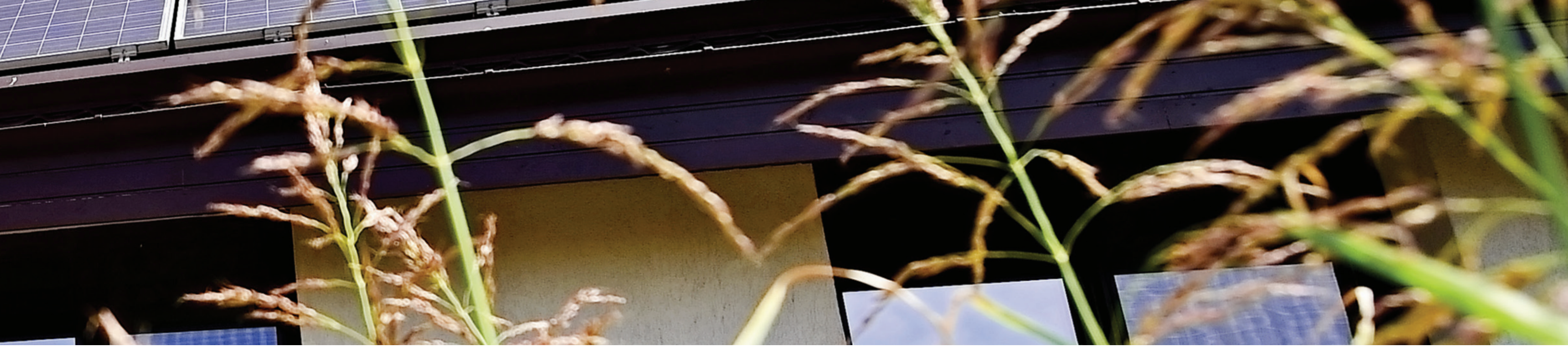
This analysis is based on a large residential customer with an annual consumption of 18,000kWh. The microgrid consists of a 5kW solar PV system coupled with 3kW (6kWh) Li-ion battery. The microgrid controller, the battery, and the microgrid's switchgear enable the residential customer to sustain power for critical systems during network outages. The battery is used to arbitrage energy rates (off-peak charging, and on-peak discharging), to participate in the operating reserve (OR) market administered by the transmission operator, and by a load-aggregator to provide demand response (DR) capacity. The electricity generated from the solar PV array offsets some of the customer's own electricity consumption, and during period of excess generation is sold back to the distribution network operator through a net metering arrangement.

RESULTS

The high costs of solar and storage technologies likely make the deployment of residential microgrids at scale cost-prohibitive today. However, rapid declines in the cost of solar PV and Li-ion battery storage is expected to drastically impact the economics and adoption of residential microgrids over the next two decades. The value gap required to make residential microgrids cost effective today is estimated at $1,900 per year, or $160 per month. By 2025, the value gap decreases to $300 per year (or $25 per month), and by 2035, the business case becomes positive creating a net-benefit of $400 per year (or $35 per month).







CONTINUED ANALYSIS

This analysis focused on high value opportunities, that is customers with characteristics that are favorable to the economics of a residential microgrid.

The results presented above are based exclusively on the direct economic benefits of a residential microgrid, and assessed based on a desired payback period of 8 years.

ASSESSING THE IMPACT OF ECONOMIC FACTORS.

DECLINING TECHNOLOGY COSTS. One of the key drivers of microgrid deployment is the cost of solar and energy storage technologies. Since 2010, the costs of solar PV systems have decreased from $5.0/watt down to approximately $2.7/watt today. Solar costs are projected to decrease substantially over the next two decades down to $1.4/watt in 2035. The costs of Li-ion battery storage systems are also projected to decline rapidly, from $1,200/kWh today down to $400 in 2035.

RISING ELECTRICITY PRICES. Residential electricity rates in Ontario have steadily increased over the last five years. Since 2010, residential TOU rates have increased from ¢5.3/kWh (off-peak) and ¢9.9/kWh (on-peak) to ¢8.7/kWh and ¢18.0/kWh, respectively. As these trends continue, the economics of residential solar systems are becoming increasingly attractive as the costs of generating electricity from a solar PV array approach the retail cost of electricity. Another important characteristic of electricity rates in Ontario is the ratio between on-peak and off-peak rates (the "spread"). In Ontario, this ratio is currently fixed at approximately 2-to-1. Other jurisdictions in North America have more aggressive spreads, which lend themselves to higher economic value for a residential microgrid. Higher on-peak rates are favorable to residential microgrids because generation from a solar PV array generally coincides with on-peak and mid-peak periods, and because higher on-peak rates increase the value of energy arbitrage by the Li-ion storage system.

ELECTRICITY SECTOR EVOLUTION. The evolution of the Ontario electricity market and regulatory framework has the potential to create a more favorable environment for residential microgrids. Transmission and distribution utilities can draw significantly value by leveraging the capabilities and flexibility of microgrids to provide grid services. While a single residential microgrid may provide little value to a utility, the aggregation of strategically-located residential microgrids on a distribution network may provide significant value as an alternative to traditional poles-and-wires solutions. By reducing customer loads that would otherwise be served by the grid, microgrids can decrease local system peak demand and reduce electrical losses. In the long run, residential microgrids may enable utilities to defer or avoid costly reinforcement and system expansion.

Although the direct economic benefits are critical and significantly influence customer adoption, some attractive aspects of a residential microgrid -and perhaps the most important- are non-economic in nature.

THE IMPACT OF NON-ECONOMIC FACTORS. Power reliability, for example, can be a critical issue for some residential customers, particularly during major storms. For some customers, the risk of even a momentarily loss of power is not just a matter of inconvenience. In certain cases, and despite the high reliability of the electricity grid (>99.95% availability), the risk of losing power can drive residential customers to install emergency back-up generators to guarantee steady power supply during power interruptions. This illustrates that certain residential customers are willing to pay for increased grid reliability. Similarly, other residential customers will be attracted to microgrids by the environmental attributes of renewables adoption, by reducing their dependence on electricity grid, or simply by the fascination and wow factor of the technology. These customers will evaluate the adoption of a residential microgrid not only based on the direct economic benefits but also the non-economic benefits. Ultimately, residential customers that place a higher value on these non-economic factors (reliability, sustainability, grid-independence, and appeal) than the current gap in economic benefits -estimated at $170 per month- will be first movers and will lead the adoption of residential microgrids in Ontario.

THE VALUE OF INTEGRATING DIVERSE RESOURCES AND TECHNOLOGIES. One of the key characteristics of a microgrid is the ability to integrate multiple distributed energy resources and enabling technologies. With the increased adoption of electric vehicles and advanced demand-side technologies such as smart thermostats, load control switches, and home energy management systems, this capability is emerging as a major factor that can enhance the economics of residential microgrids. This diagram shows a qualitative assessment of the impact of several key factors -including distributed resources, technology costs, and market transformation- on the business case of residential microgrids.

QUALITATIVE IMPACT OF DER AND OTHER FACTORS	
⬆ Smart DR & Load Control ⬆ Smart EV Charging ⬆ Increase in TOU Spread	⬆ Declining Technology Costs ⬆ Market Transformation
⬇ Anti-Islanding Provisions	⬇ Lack of Market Transformation

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FUTURE OF MICROGRIDS INSTITUTIONAL

OVERVIEW

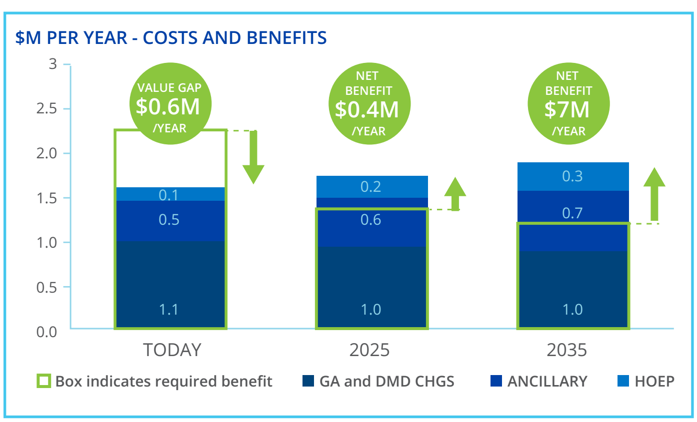
Institutional customers such as universities, colleges, and hospitals are uniquely positioned to pursue microgrids. These customers aggregate multiple buildings and on-site generation resources such as combined heat and power (CHP) and back-up generation systems. A microgrid enables them to take the next step and incorporate an advanced control system (or "controller") to become a dynamic and fast-acting network resource capable of responding to electricity price signals and providing services to the electricity distribution and transmission network operators. A microgrid also enables institutional customers to provide emergency power to critical circuits during power outages, and reduces a customer's dependence on centralized electricity supply.

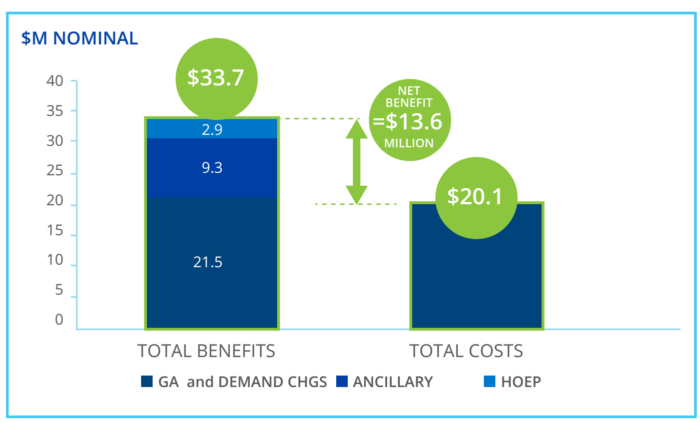
ASSUMPTIONS

This analysis is based on a Class A, medium-size university campus, composed of lecture halls, research and administrative buildings, and student residences. This university campus has an average load of 8 MW, and a 13 MW peak hourly demand. The microgrid consists of a microgrid controller, a 5MW (10MWh) Li-ion battery, and a 1.5 MW solar array. The microgrid controller, the battery, and the microgrid's switchgear enable the campus to sustain power for critical systems during network outages. This analysis assumes an existing CHP facility, allowing the microgrid to optimize its operation and ride-through long power outages. The battery is also used to reduce Global Adjustment (GA) charges, to participate in the operating reserve (OR) market, and to provide demand response (DR) capacity.

RESULTS

The relatively high costs of solar and storage technologies make the deployment of institutional microgrids at scale more difficult today. However, rapid declines in the cost of solar PV and Li-ion battery storage are expected to result in a strong and positive business case for institutional microgrids in the near and long term. The value gap (the difference between the direct costs and the direct economic benefits) required to make institutional microgrids cost effective today is estimated to be $600,000 per year. By 2025, the business case becomes positive creating a net-benefit of $400,000 per year, increasing to $700,000 by 2035.





CONTINUED ANALYSIS

This analysis focused on high value opportunities, that is customers with characteristics that are favourable to the economics of an institutional microgrid.

The results presented above are based exclusively on the direct economic benefits of an institutional microgrid, and assessed assuming that the desired simple-payback period is seven years.

ASSESSING THE IMPACT OF ECONOMIC FACTORS.

DECLINING TECHNOLOGY COSTS. One of the key drivers of microgrid deployment is the cost of solar and energy storage technologies. Since 2010, the average costs of a large-scale solar PV system has decreased from $4.2/watt down to approximately $2.3/watt today. Solar costs are projected to decrease substantially over the next two decades down to $1.2/watt in 2035. Similarly, the average cost of a large-scale Li-ion battery storage system is also projected to decline rapidly, from $740/kWh today down to $230 in 2035.

MAGNITUDE OF GA CHARGES AND RESPONSE. Much like C&I microgrids, the largest economic benefit stream for an institutional microgrid in Ontario is avoided Global Adjustment (GA) charges. Class A institutional customers pay GA charges in proportion to their contribution to Ontario's top five system peaks. A customer able to decrease demand during those system peak hours can reduce their GA charges. A key implication of the way GA charges are calculated for Class A customers is that charges are determined based on a very small number of hours of the year. As a result, the financial incentive to reduce demand during each of the system peaks is substantial. In 2011, the financial incentive averaged approximately $220,000 per MW of demand reduction. Since then, the financial incentive has increased to close to $500,000 per MW. Forecasting the occurrence of system peaks is complex, given the inherent uncertainty of electricity consumption hour to hour and the added intricacy of a number of large customers reducing their consumption on expected peak days in an effort to reduce their GA charges. Most institutional customers hedge the risk of missing the peak by responding on more than five days and for several hours ahead of a potential system peak, and several hours after. This analysis is based on a battery size of 10 MWh and an average response of +/-2 hours –for a total response duration of 5 hours. In effect, the university is able to achieve a 2MW demand reduction during each hour.

DISTRIBUTION SYSTEM OWNERSHIP AND CHP. Microgrids have achieved great traction across university and college campuses. In many cases, universities and colleges own the substations, distribution lines, and equipment supplying the campus buildings with power. Single ownership and management over their distribution system, loads, and resources allows campuses the flexibility to pursue reliability improvements, energy efficiency projects, and major system investments – such as a microgrid. Another key reasons for the early microgrid adoption by universities and colleges is the pre-existence of CHP systems. For example, the cornerstone of the Princeton University microgrid is its 15 MW CHP plant. For over a century, Princeton has been supplying steam across campus with a district heating system. This infrastructure enabled Princeton to pursue a CHP system – which was later transformed into today's microgrids.

ELECTRICITY SECTOR EVOLUTION. The evolution of the Ontario electricity market and regulatory framework has the potential to create a more favourable market for microgrid deployment. An institutional microgrid has sufficient scale to deliver value to utilities. An institutional microgrid can be transformed into flexible and fast-acting resource, capable of decreasing local constraints and providing ancillary services such as voltage or power quality support to network operators.

THE VALUE OF IMPROVED RELIABILITY. One of the key drivers of microgrid adoption by universities and colleges is the prospect of improved reliability. Institutional customers can incur material losses - due to lost power to essential facilities and laboratory research – from power interruptions, and increasingly due to power quality issues, as a result of the increased use of sensitive research and power electronic equipment. Universities and colleges should evaluate the adoption of a microgrid not only based on the direct economic benefits but also on the value of improved reliability and power quality. Universities and colleges incurring annual interruption and power quality costs higher than the current gap in economic benefits –estimated at $600,000 per year– will be able to justify the investment and are likely to lead the adoption of C&I microgrids in Ontario.

THE VALUE OF INTEGRATING DIVERSE RESOURCES AND TECHNOLOGIES. One of the key characteristics of a microgrid is the ability to integrate multiple distributed energy resources and enabling technologies, including demand response, energy management systems, and distributed generation. This functionality has emerged as a major factor that can enhance the economics of institutional microgrids. This diagram shows a qualitative assessment of the impact of several key factors -including distributed resources, technology costs, and market transformation- on the business case of industrial microgrids.

QUALITATIVE IMPACT OF DER AND OTHER FACTORS

⬆ Smart DR & Load Control	⬆ Energy Management Systems
⬆ Smart EV Charging	⬆ Declining Technology Costs
⬆ CHP & DG Integration	⬆ Market Transformation
⬇ Anti-Islanding Provisions	⬇ Lack of Market Transformation

The Advanced Energy Centre is a independent non-profit catalyst for adoption of innovative energy technologies, hosted at the MaRS Discovery District in Toronto, Canada. We facilitate solutions-based approaches to addressing today's energy challenges, by collaboratively identifying systemic barriers with industry, and providing a linkage to Canadian energy technology entrepreneurs.

We'd like to acknowledge the partners of the Advanced Energy Centre, including the Ontario Ministry of Energy, Siemens Canada, Ontario Power Generation (OPG), London Hydro, the Independent Electricity System Operator (IESO), Hydro Ottawa, NRStor, Greater Sudbury Utilities and Oakville Hydro for their ongoing support of energy innovation in Canada.

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NAVIGANT

ASSUMPTIONS SUMMARY

Table 1. Microgrid Characteristics

Component	Community/Utility Distribution	Commercial & Industrial	Institutional	Residential Nanogrid
Customer Characteristics	• Distribution feeder serving a mix of residential apartments and office space • 12 MW (peak)	• Large C&I customer with (mostly) flat profile • 6 MW (peak), Class A customer	• Medium-size university/college campus • 13 MW (peak), Class A customer	• Large residential customer • Annual consumption of 18,000 kWh
Microgrid Core Components	• 7.5 MW/15 MWh battery • 2.0 MW Solar • 1.0 MW DR loads • Microgrid Controller	• 5 MW/10 MWh battery • Microgrid Controller	• 5 MW/10 MWh battery • 1.5 MW Solar • Microgrid Controller	• 3 kW/6 kWh battery • 5 kW Solar • Microgrid Controller
Desired Payback Period	• 10 years	• 5 years	• 7 years	• 8 years

Table 2. Microgrid Costs for Residential (2016 $ CAD)

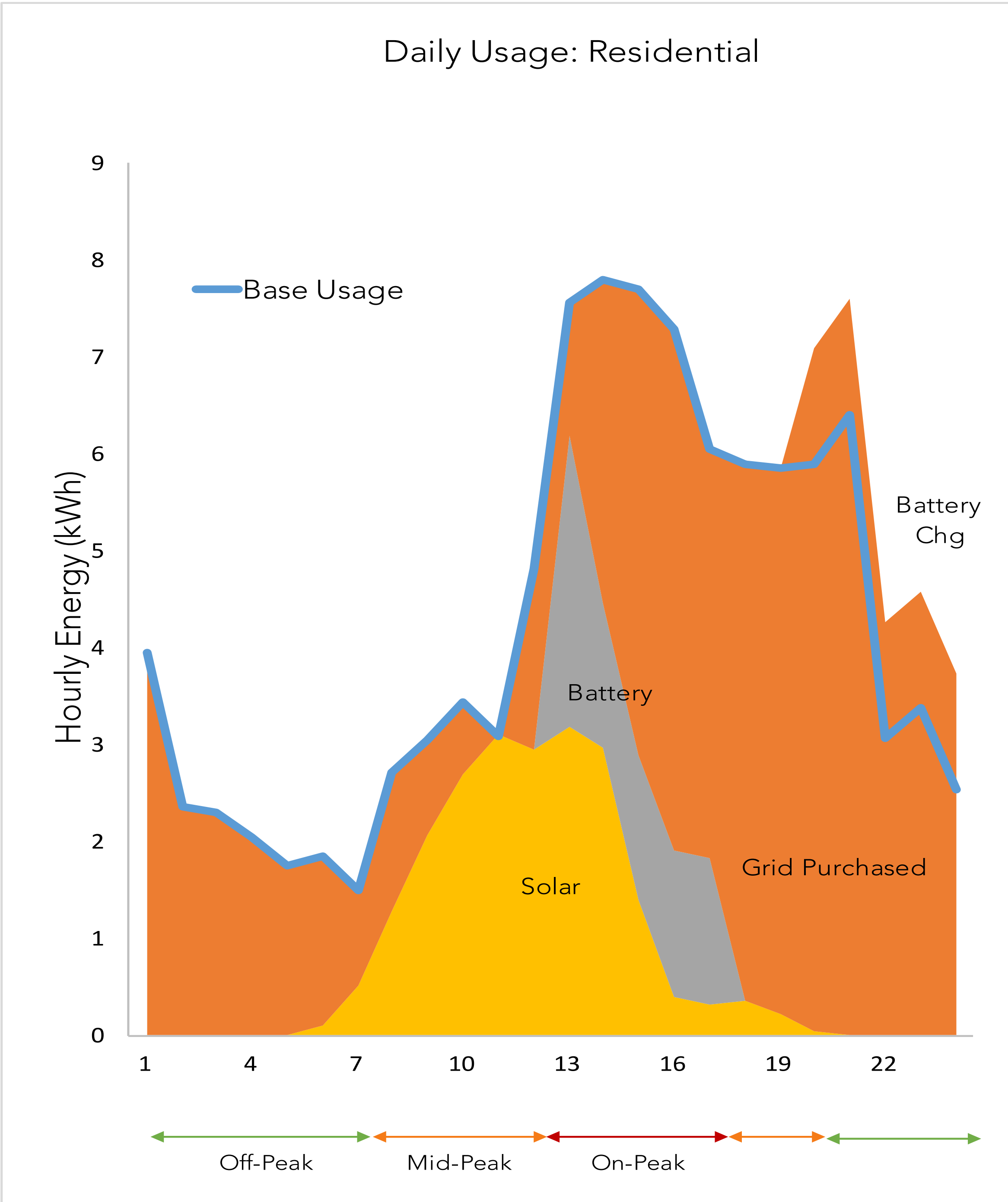
Component	Unit	Today	2025	2035	CAGR
Solar (excl. inverter)	/kW	$2,450	$1,860	$1,370	-3.0%
Storage (excl. inverter)	/kWh	$1,000	$ 480	$ 320	-5.8%
Inverter	/kW	$ 410	$ 180	$ 140	-5.5%
Software, Controls, Other	/sys-kW*	$ 300	$150	$ 120	-4.8%

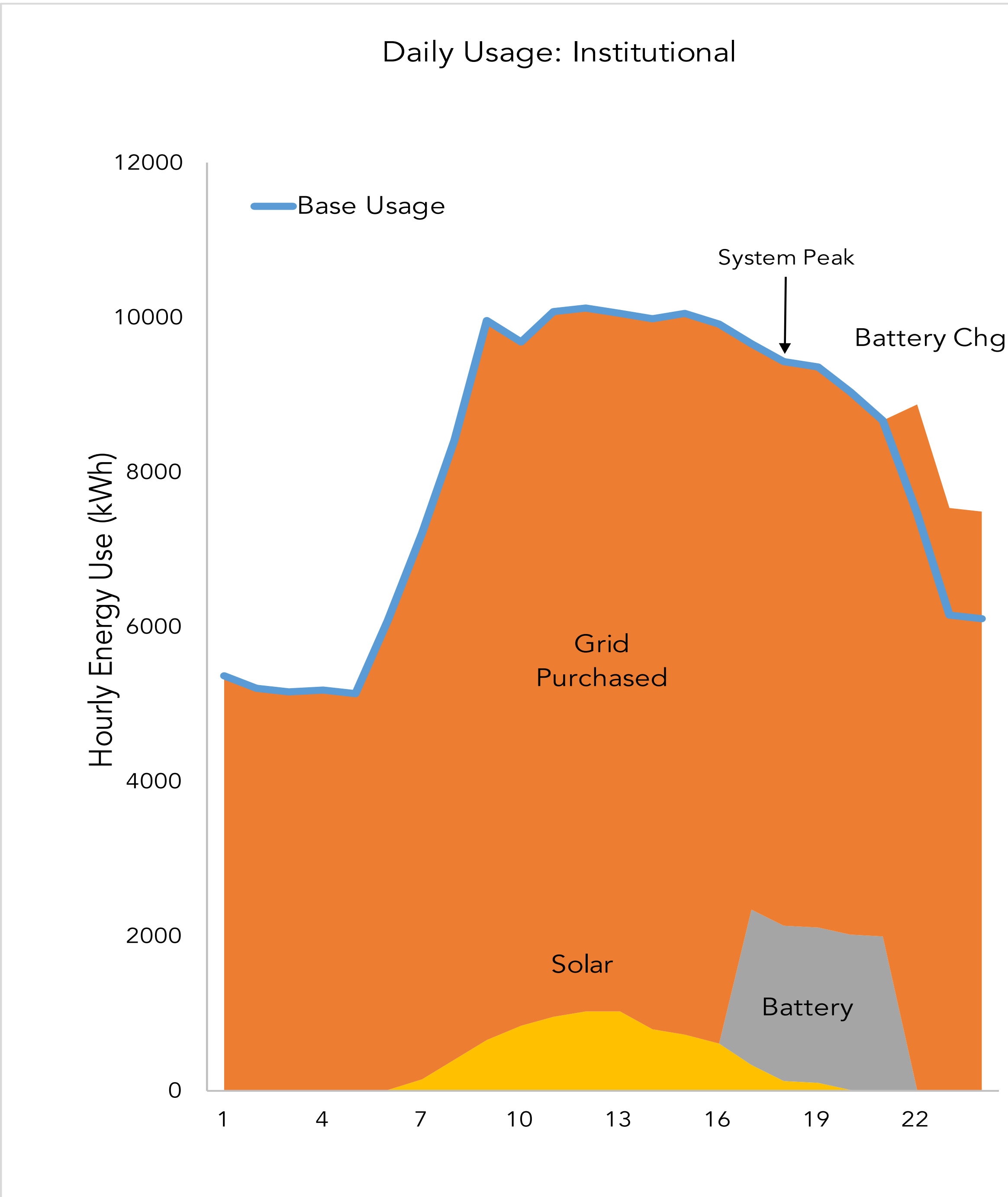
Table 3. Microgrid Costs for Community, C&I, and Institutional (2016 $ CAD)

Component	Unit	Today	2025	2035	CAGR
Solar (excl. inverter)	/kW	$ 1,870	$ 1,420	$ 1,050	-3.0%
Storage (excl. inverter)	/kWh	$ 660	$ 320	$ 240	-5.2%
Inverter	/kW	$ 250	$ 110	$ 80	-5.9%
Software, Controls, Other	/sys-kW*	$ 240	$ 150	$ 130	-3.2%

The 'sys-kW' unit is the based on the kW of the inverter.

DAILY LOAD PROFILES




Daily Usage: Institutional
Base Usage
System Peak
Battery Chg
Grid
Purchased
Solar
Battery
Hourly Energy Use (kWh)
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10000
8000
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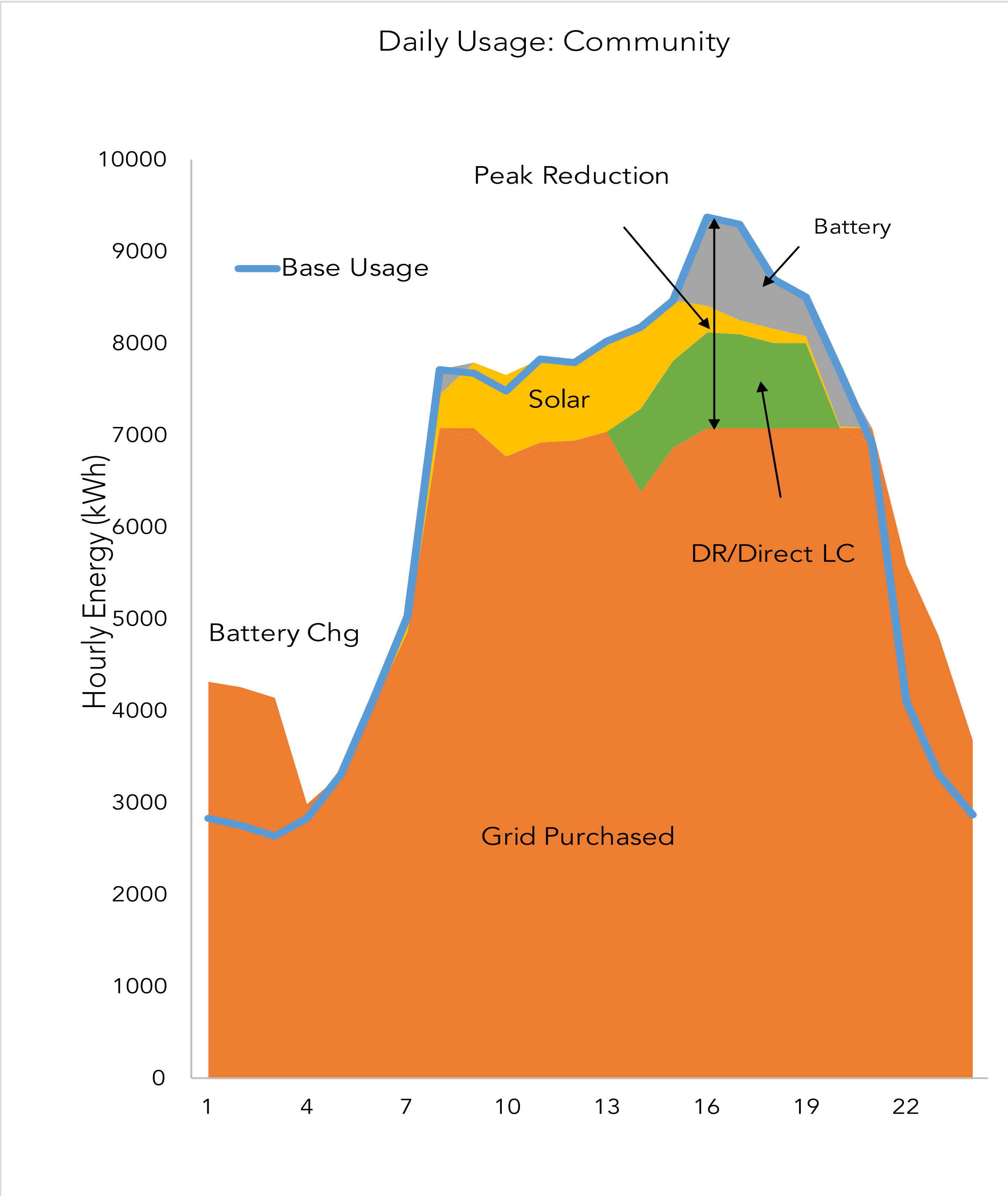
4
7
10
13
16
19
22


Daily Usage: Community
Peak Reduction
Battery
Base Usage
Solar
DR/Direct LC
Battery Chg
Grid Purchased
Hourly Energy (kWh)
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9000
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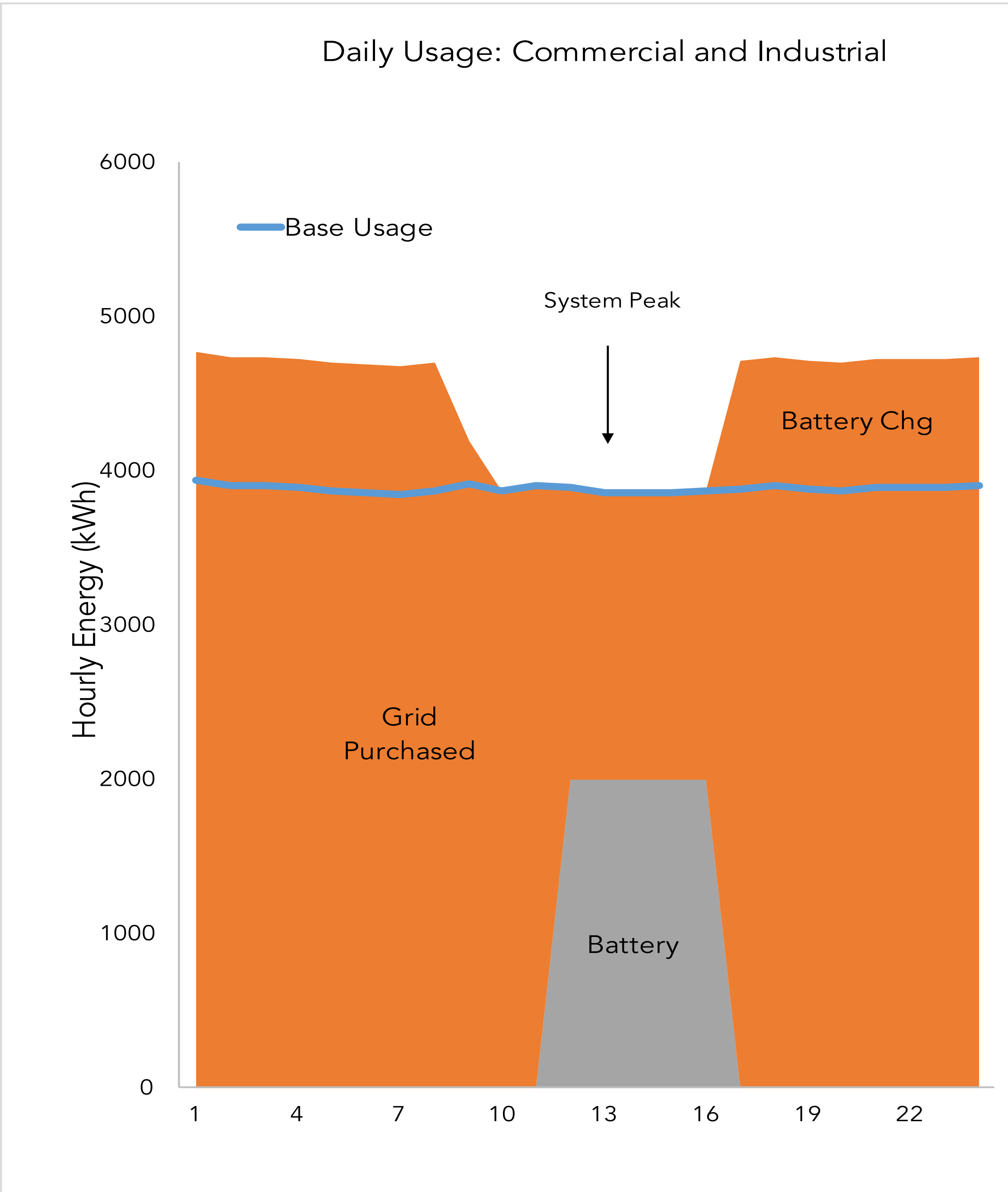
10
13
16
19
22


Daily Usage: Commercial and Industrial
Hourly Energy (kWh)
6000
5000
4000
3000
2000
1000
0
Base Usage
System Peak
Battery Chg
Grid
Purchased
Battery
1
4
7
10
13
16
19
22