Microgrids for commercial and industrial companies

delivering increased power reliability, lower energy costs and lower emissions

Picture courtesy of Eaton Corporation

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EXECUTIVE SUMMARY

An increasing number of commercial and industrial (C&I) companies are implementing low-carbon microgrids. A microgrid is a set of energy resources that can operate, if needed, independently from the electricity grid. Traditional microgrids relied on fossil fuels, but now low-carbon microgrids are emerging, which run with predominantly renewable power.

When can C&I companies use microgrids?

Microgrids meet the needs of a wide range of C&I businesses:

- For C&I companies in off-grid areas who require microgrids in order to meet their energy needs.
- For C&I companies with inconsistent energy supply who require microgrids to provide reliable and affordable power.
- For C&I companies in areas with reliable grids who wish to improve the economics for self-production, increase their resiliency and / or lower emissions.

Why should C&I companies install low-carbon microgrids?

Motivation 1: Save on energy bills

For C&I firms who already operate microgrids, switching to low-carbon resources lowers the cost of energy. The falling price of solar photovoltaic (PV) modules and energy storage has led C&I firms to add renewable generation sources to their microgrids. The integration of solar PV into microgrids is particularly attractive for firms using diesel generation, as solar PV is now cheaper than diesel [1].

The rapid fall in prices of lithium-ion batteries also means companies are increasingly adding storage systems. By using storage to optimize production and consumption, C&I firms reduce peak demand charges and lower time of use (ToU) fees. In addition, adding storage allows companies to capture additional value streams, such as participating in demand response and frequency regulation schemes.

Motivation 2: Respond to increasing security and reliability needs

Increasing security concerns, mean more C&I firms are now considering building new greenfield microgrids.

For C&I firms that plan to increase their energy demand (e.g. converting fleets to electric vehicles) or construct new production facilities, the combined effect of falling costs and increased reliability concerns (e.g. more frequent outages due to extreme weather events) are driving them to consider new greenfield low-carbon microgrids. Such microgrids mix the benefits of renewable generation sources, batteries and, where necessary, fossil fuels such as gas, to provide a cost-effective, reliable and low-carbon energy supply.

Motivation 3: Reach renewable energy targets and reduce greenhouse gas emissions

For firms with renewable energy targets, zero-carbon microgrids, relying solely on renewable energy and storage, are emerging as a solution. In recent years, many high-profile companies have set targets of using 100% renewable energy. For these firms, switching to a zero-carbon solar and storage microgrid can be attractive. While cases of zero-carbon microgrids are currently rare, these systems are likely to become more common as storage prices continue to fall.

How can C&I firms finance microgrids?

Innovative finance schemes allow companies to benefit from microgrids without significant upfront investment. Independent Power Producers (IPPs) and investment funds can finance projects with C&I firms acting as an energy off-taker. By signing a Power Purchase Agreement (PPA) and committing to purchase a certain amount of power, C&I firms don't have to raise the upfront capital to pay for the installation. C&I PPAs are a global but recent development, and widely used contract standards are still to emerge. Signing long-term PPAs requires long-term regulatory clarity, which can be challenging where governments are only beginning to develop microgrid policies.

What about wider benefits?

Low-carbon microgrids have positive environmental and social impacts. Not only do low-carbon microgrids help firms reduce their carbon footprint, but they also reduce diesel use in on-site generation, which is beneficial because they lower local emissions of harmful pollutants. In off-grid and unreliable grid areas, C&I microgrids can provide local employment opportunities, both directly at the site and through increased economic activity from additional power supply. Finally, in areas where the project couples C&I use with increased residential access to energy, kerosene use is reduced in households, improving individuals' health and saving household's money.

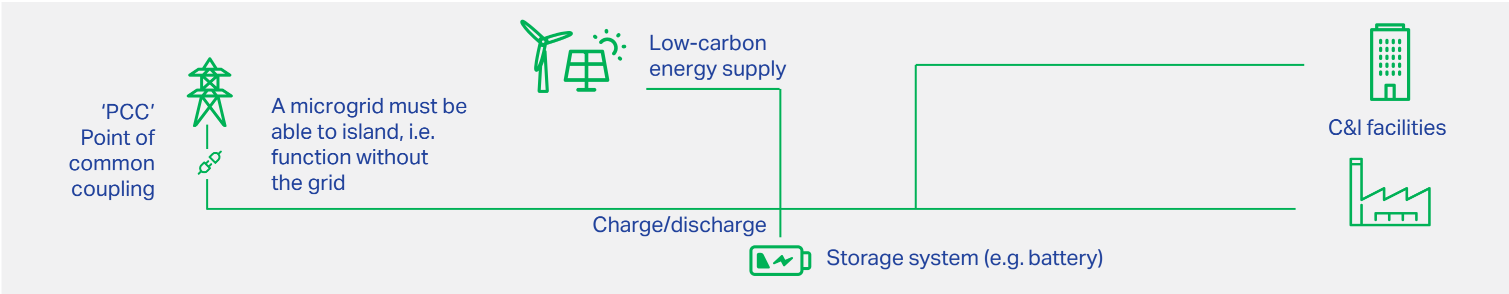
1 What are low-carbon microgrids for C&I companies? Definition and main use cases

1.1 DEFINITION

A microgrid is characterized by its ability to function in island mode. This means the C&I facility can still produce and use energy, even when not connected to the main grid. The ability to island differentiates a microgrid from other similar concepts which do not necessarily need to operate autonomously, such as on-site renewable generation. Box 1 provides a technical definition of a microgrid, while Figure 1 provides a simple diagram of a microgrid.

Low-carbon microgrids are defined as those microgrids that use renewable energy sources, for a significant part or all of their energy supply. Microgrids are not necessarily low-carbon, and historically relied on fossil fuels - predominantly diesel generation assets.

Figure 1: Basic diagram of a C&I microgrid



Technical definition of a microgrid

The US Department of Energy defines a microgrid as "a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that act as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island mode." This is the definition used throughout this report.

In recent years, hybrid solutions have emerged, integrating a mixture of renewable sources (e.g. solar, wind, hydropower), with fossil fuel-based sources. Falling costs of storage are now allowing for further levels of renewable penetration. Adding renewable energy significantly reduces the carbon footprint of existing microgrids, as diesel generation emits 24 times more greenhouse gases (in CO_2e) than solar PV [2].

1.2 MAJOR USE CASES

This paper studies three major use cases: C&I microgrids are commonly used in off-grid areas (use case 1) and in areas with unsatisfactory and intermittent grids (use case 2). Microgrids in areas with reliable grid supply have historically only been used for facilities with high security needs, such as airports or military bases. However, an increasing number of C&I firms are implementing microgrids to improve economics (use case 3). These three major use cases for microgrids are discussed below, and illustrated with case studies.

USE CASE 1: No grid access - facilities with zero access to the electricity grid, currently relying on fossil fuels

Microgrids can meet energy needs of C&I companies in areas of the world that remain off-grid. In Africa, in Small Island States, and even in sparsely populated developed countries such as Australia, many industries are far from the main grid. For C&I firms operating in these areas, a microgrid is the only way to obtain the energy they require. The falling cost of renewable energy and, more recently, storage technologies, as well as fluctuations in oil prices, have driven more firms to adopt low-carbon solutions.

Especially for extractive industry, low-carbon microgrids offer new opportunities: Mines are often in locations far away from population centers but have substantial power demands. The Degrussa Mine in Australia has historically had a 19 MW microgrid powered by diesel. When the firm chose to expand in 2013, they added 10 MWp of solar capacity and a 6 MW/2 MWh energy storage system.

Case study

ESSAKANE MINE

- Burkina Faso, to be commissioned by the end of 2017
- End-user: IAMGOLD
- PPA agreement with EREN RE - AEMP

USER CASE

- Off-grid
- Extractives (gold mine)

ASSETS

Existing

- 55 MW oil power plant

Upgrade

- 55 MW oil power plant
- 15 MW PV

BUSINESS CASE

Energy security

Allows the mine to be fully autonomous, despite long distance from the nearest grid

Cost savings

Decreases fuel consumption by around six million liters

Sustainability

Decreases CO_2 emissions by 18,500 tons per year

Other

Creates a number of local jobs during both the construction phase and its ongoing operation

USE CASE 2: Unreliable or unsatisfactory grid connections - facilities connected to intermittent or insufficient grid power

Reliable energy is important for C&I businesses in areas of weak grids. Power outages cost African countries an estimated 1-2% of their annual GDP [3]. In Tanzania, their cost amounts to around 15% of annual sales [3]. In India, Latin America and even in rural areas of some developed countries, unreliable grids also negatively affect C&I companies. Microgrids help C&I firms cope with a lack of reliable power. Currently, diesel generators are the most common backup system. In 2015, 25 GW of diesel generators were sold for backup generation worldwide [4], which act as basic microgrids, turning on when the grid is down. A large opportunity exists to replace these generation sets with low-carbon microgrids.

In urban areas, C&I firms are now implementing low-carbon microgrids, particularly in commercial facilities requiring consistent power such as hospitals and malls.

Case study

ABB LONGMEADOW PARK

Johannesburg, South Africa, completed in 2016

Owner, project developer and end-user: ABB

USER CASE

- Unreliable or unsatisfactory grid
- Industrial facility

ASSETS

Existing

- Grid
- 4 x 750 kVA backup diesel generators

Upgrade

- Grid
- 4 x 750 kVA backup diesel generators
- 750 kW solar
- 1 MVA/380 kWh PowerStore

BUSINESS CASE

Energy security

Production keeps running even during grid power outages

Cost savings

Achieves 25% savings in energy costs (from USD $610,000 to $460,000)

Reduction in peak demand charges

Sustainability

Decreases CO_2 emissions by 1,000 tons per year (estimated)

Case study

ESTABLISHMENT LABS

- Costa Rica, commissioned in 2016
- Owner and end-user: Establishment Labs
- Project developer: Demand Energy/ENEL and Rio Grande Renewables

DEMAND energy
An Enel Group Company

USER CASE

Unreliable or unsatisfactory grid

Industrial facility

ASSETS

Existing

- Grid
- 2 x 750 kVA backup Diesel generators

Upgrade

- Grid
- 276 kW solar
- 500 kW/ 1 MWh battery

BUSINESS CASE

Energy security

Prevents the medical manufacturing plant from suffering production losses due to the disruption of the sterilization process during power outages

Cost savings

Significant savings from prevention of production losses

5% reduction in energy bills from peak shaving

Sustainability

Reduces national use of gas peakers

Examples include the Hôpital St-Damien in Haiti, which combines a 0.65 MW of rooftop solar, a 0.65 MW diesel generator and a 500 kW lithium-ion battery, to provide all energy needs for the hospital. However, high cost of land in cities prevents the development of industrial-scale low-carbon microgrids.

Outside urban areas, industrial users are integrating larger quantities of renewable energy, given the lower cost of land. Microgrids are commonly used by large industrial companies situated in areas of weak grid, especially in the case where a grid outage will incur significant costs. For example, the SNIM iron ore mine in Mauritania combines a 4.4 MW of wind with 16 MW of diesel generation, which are integrated into the grid infrastructure. The grid cannot fully satisfy the needs of the iron ore mine, so the firm relies on additional power supplied by the microgrid [5].

USE CASE 3: Reliable and sufficient grids – facilities requiring autonomous functioning, and/or looking for low-carbon energy supply for environmental and economic reasons

Historically, energy users with high security concerns have been the main beneficiaries of microgrids in reliable grid areas. In developed countries, power outages are extremely rare - meaning, microgrid investments were typically due to an assessment of long-term security risks rather than cost reduction strategies. Hence, customers with highly critical power requirements - such as military facilities, data centers, hospitals and airports - have implemented microgrids for many years.

C&I firms in areas of high grid reliability and capacity are increasingly considering microgrids with renewable power and advanced batteries, given the improving economics of using storage, the increasing focus on renewable use and increasing needs for energy security. Initial projects were installed in more developed, more liberalized energy markets, such as in the United States and Europe. Indeed, 35% of businesses in the United States who have suffered increased energy outages indicate they have considered implementing or participating in a microgrid [6]. Examples include the Navy Yard project in Philadelphia which combines 6 MW of natural gas engines with 2 MW PV and 1 MW of battery storage to provide power for 120 companies [7].

Case study

BOSTON ONE CAMPUS

- Boston, United States, commissioned in April 2017
- End-user: Schneider Electric
- PPA agreement with Duke Energy (REC Solar)

Schneider Electric

USER CASE

- Reliable grid
- Commercial facility

ASSETS

Existing	Upgrade
Grid	Grid
	448 kW solar
	500 kW/ 1 MWh battery
	Backup natural gas generator

BUSINESS CASE

Energy security

Powers the building in emergency grid outage cases (natural event, etc.)

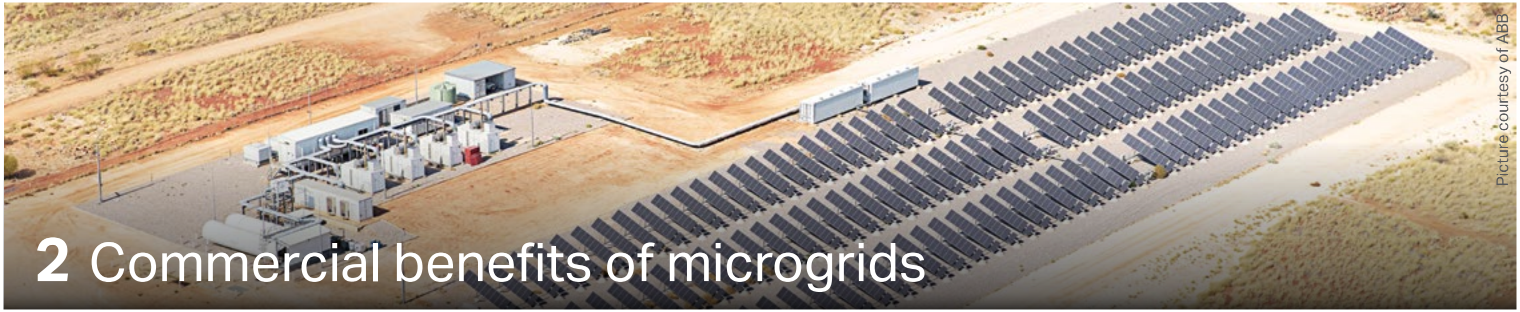
Cost savings

Saves 5% of energy costs (estimated)

Optimized performances based on integration of weather forecast and available storage capacities (e.g. electric vehicles)

Sustainability

Reduces greenhouse gases emissions the equivalent of those produced by more than 2,400 passenger vehicles a year



2 Commercial benefits of microgrids

The commercial benefits of microgrids for C&I companies are multiple: They improve security of supply, lower energy bills, increase long-term electricity cost visibility and reduce environmental tax burden. Indeed, these benefits are expected to lead to strong market growth, with the C&I microgrid market predicted to amount to USD $18 billion globally by 2026 [8].

2.1 SELF-RELIABILITY AND SECURITY OF SUPPLY

The ability to run in island mode is the principal benefit of a microgrid for an off-grid facility. However, grid-connected companies can also desire autonomous energy supply.

Firstly, for businesses in areas of unreliable grid, microgrids make economic sense as they avoid costly production interruptions. In India, 61% of companies surveyed suffered more than 10% loss in production due to power outages, affecting revenue [9]. Moreover, in hotels, malls and other service sector facilities, power cuts may substantially reduce customer satisfaction.

In addition, for those C&I firms with high security concerns, establishing microgrids allows firms to protect critical functions, in case extreme events damage the grid. C&I companies may require certain critical assets to continue functioning 24/7 (e.g. a data server, a research lab, a high-security IT system, prisons). Even a highly reliable grid may occasionally have power outages, for example due to extreme weather events. During Hurricane Sandy in 2012, the only facilities still running were several microgrids, such as the one at Princeton University [10]. More extreme weather events due to climate change are likely to encourage more C&I facilities to implement microgrids.

Finally, low-carbon options can offer more security than diesel (or other fossil fuel) generation sources. Diesel often needs to be imported, meaning companies are vulnerable to national/regional fuel stock-outs.

2.2 CHEAPER ENERGY COST AND PRICE VISIBILITY

Falling solar and storage costs mean C&I microgrid owners are switching to low-carbon energy sources. Globally, solar costs fell by more than 60% between 2009 and 2015 [1], while lithium-ion battery costs reduced by more than 50% from 2013-2016 [11]. The price of solar is expected to fall further, and wind and hydro solutions now also offer more competitive prices than diesel. By contrast, diesel prices are not likely to fall.

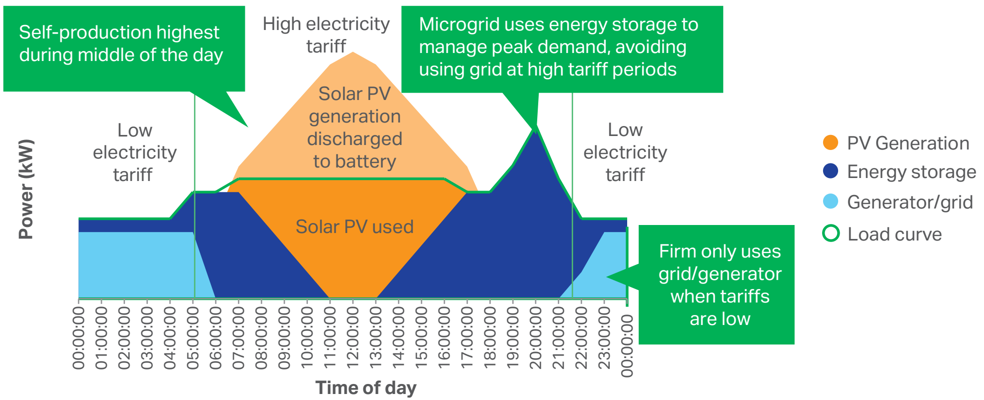
Adding storage can reduce peak demand charges and time of use (ToU) charges, further reducing energy bills. In many geographies, C&I firms pay an amount for the total energy consumed (in MWh), and for the peak demand (in MW) they use. Where these peak demand charges are significant, such as in certain US states, a microgrid with a storage system can provide peak shaving (using self-generated stored energy when consumption is highest), substantially lowering demand charges. In addition, where power is more expensive at different times of the day (i.e. where ToU charges are in place), storage, coupled with an energy management system, can use self-produced energy when power is expensive, and store when power from the grid is cheap. Figure 2 illustrates how microgrids can reduce ToU charges by using stored energy when electricity prices are high.

The long-term pricing of renewable energy solutions is less volatile than diesel generation, particularly if the C&I firm locks in a price with an external provider. C&I firms may sign a Power Purchase Agreement (PPA) with an outside finance party, and thus achieve a low energy price over the long-term (see Section 4). By contrast, diesel prices will depend on fluctuating oil prices. Due to the complexity of microgrids, standardized PPAs are still in development.

2.3 EXTERNAL REVENUE STREAMS

Other than reliability needs and the desire to reduce energy bills, several other revenue streams can further improve the economic case for low-carbon microgrids. In addition, new emerging technologies may advance the business case for microgrids in the future.

Figure 2: Schematic explanation of reducing time of use (ToU) charges through energy storage



For grid-connected microgrids, C&I companies can benefit from providing support services to the electricity grid. Regulators and grid operators are balancing the power grid by using mechanisms such as demand response programs or frequency response markets. They give companies incentive to provide additional power to - or reduce consumption from - the grid at peak periods. This report covers these opportunities in detail in Section 4.2.2.

In off-grid areas, C&I companies can sell excessive power to nearby customers. If the off-grid facility is near a local community, the C&I firm can sell additional power to local households and businesses that also have no access to the grid. While remote, low-income communities might have low ability to pay, recent market experience in the off-grid energy access sector demonstrates households are willing to pay for energy that is more affordable and more reliable than fossil fuels. C&I firms can develop innovative business models that jointly benefit their company and the nearby customers.

Finally, new disruptive technologies, such as electric vehicles may increase the economic case for microgrids. As electric vehicles reach scale, this will result in consumers demanding significant amounts of additional power. Rather than the distribution system operator (DSO) adding more generation units and grid infrastructure, or C&I firms paying more in demand charges, local authorities and C&I firms may instead prefer to develop local microgrids. In addition, electric vehicles can be used for grid balancing, using locally produced energy when it is available, rather than relying on the main grid. However, business models for electric vehicles in microgrids are yet to emerge.

2.4 ENVIRONMENTAL TAX REDUCTION AND ACHIEVEMENT OF RENEWABLE ENERGY TARGETS

Low-carbon microgrids help companies reduce their environmental tax burdens, while advancing their progress towards renewable energy and greenhouse gas emission reduction targets. In jurisdictions with carbon pricing (e.g. EU Emissions Trading System or UK carbon floor price), moving to a low-carbon microgrid reduces a firm's compliance costs. In addition, many companies have set internal carbon prices, or have set targets for reducing emissions under the GHG protocol. Microgrids running primarily on renewable sources can reduce companies' GHG Protocol Scope 1 emissions (for those already self-producing energy from fossil fuels on-site), and Scope 2 emissions (for those historically importing from the grid).

Many multinationals have set ambitious renewable energy goals, and low-carbon microgrids help firms achieve their targets. Almost half of the largest companies in the U.S. have established clean-energy targets for themselves – including many who are aiming for 100% renewable production, such as industrial paint producer AkzoNobel, car manufacturer BMW and the world's largest brewing company, InBev [12]. Establishing low-carbon microgrids allows firms to switch to cleaner energy sources, helping them to reach their targets.

3 Environmental and social benefits

Implementing microgrids also has positive social and environmental impacts. Firstly, shifting existing microgrids from diesel-based to renewable energy sources reduces local pollution. Secondly, the widespread introduction of new low-carbon microgrids will reduce global fossil fuel-based generation. Finally, providing increased amounts of reliable energy in weak grid and off-grid areas can improve local economic growth and provide access to energy.

3.1 ENVIRONMENTAL BENEFITS

Replacing diesel generation leads to reduced air pollution and health benefits for local residents. Diesel engines release a wide range of harmful substances, including soot, nitrogen oxide and carbon monoxide [13]. In Nigeria, the tripling of asthma rates in recent years has been attributed to diesel use [14]. Switching to a renewable energy solution can reduce these local environmental impacts. A microgrid on the Portuguese island of Graciosa reduces overall environmental impacts by 43% by switching to low-carbon sources [15].

In cases where low-carbon microgrids replace coal-fired generation (typically for combined heat and power), fly ash pollution falls. Where microgrids use wood-fired boilers, microgrids reduce local deforestation.

A low-carbon microgrid can also lower transport emissions, particularly in off-grid areas. Companies using diesel microgrids need to regularly transport substantial amounts of fuel. By using self-generated clean energy, these regular deliveries will be reduced, lowering local environment pollution. This is particularly relevant in off-grid areas, where facilities are located far from the diesel distribution network.

In the long-term, scaling up microgrids will reduce the need for centralized fossil fuel power plants, especially peaking plants. For now, microgrids are not widespread enough to make a significant impact on global fossil fuel use. However, implementation at scale will reduce the overall use of fossil fuels. In particular by using storage, microgrids can reduce impact on the grid at peak times, and can therefore avoid the construction of new fossil fuel based peaking plants.

3.2 SOCIAL BENEFITS

3.2.1 Access to energy for local businesses and households in off-grid areas

Microgrids increase local economic growth when providing access to energy for productive use. In off-grid areas, microgrids with C&I companies as anchor clients can provide energy to smaller local businesses. Giving local communities access to energy offers a host of development opportunities and benefits which extend beyond a company's direct area of influence. Potential customers for productive use of energy range from farmers and food processers to shop owners, restaurants, workshops and service providers. For example, at the Zangamina Power Limited microgrid in Zambia, the microgrid is shared between anchor businesses (a farmer and two telecom towers), small businesses (welders, hammer mills, bakeries, cold rooms, etc.) and around 500 households [16].

Access to energy can also improve health, education and financial inclusion for low-income households. 1.2 billion people worldwide live without access to the electricity grid [17]. Typically, these households rely on kerosene for their lighting needs.

By providing clean and affordable energy to local populations, low-carbon microgrids can lead to better health outcomes (fewer premature deaths from indoor air pollution [18]) and educational benefits (lighting at night allows to study in the evening; less time is spent collecting wood). Advances in health and education are immensely beneficial for economic and community development.

Extending access to energy through inclusive business models benefits microgrid operators too. Productive energy use by local business secures minimum energy demand, reduces the risk of revenue loss and creates additional revenue streams. Extending access to energy to households can also lead to new markets and a broader customer base. An initial focus on business customers and recruitment of households in a second phase can be a useful strategy in this context – this is called the ABC (anchor, business, community) model [19].

Construction and operation of low-carbon microgrids can provide direct local employment. Compared with using small diesel generation units, low-carbon microgrids provide increased local employment. Firstly, at the construction stage, local workers are required to install solar panels, or assist with construction of mini-hydro plants. Secondly, during operations, companies employ local firms to maintain the equipment, for example keeping solar panels free from dust and dirt.

3.2.2 Community resiliency

Increasingly, communities wish to be more resilient, to improve their self-sufficiency and to protect residents from outages in the electricity system. Communities who depend on an unreliable grid, or are vulnerable to extreme weather events, can benefit from microgrids.
The state of Massachusetts has set up a USD $40 million fund to support resilient microgrid projects [20]. Other American states are working on their own schemes, including Rhode Island and New Jersey [21].

For DSOs, microgrids reinforce the grid infrastructure in case of a power outage. On-grid microgrids provide constant power to a limited number of connected customers. These grid-connected customers (not owning a microgrid) may be willing to pay a premium for ensuring they are a part of a "reliability zone," where the grid is always available. The microgrid owner could receive additional revenue from the DSO for providing these reliability zones.

4 Finance: ownership models, project economics and innovative capital sources

Low-carbon microgrids require relatively high levels of upfront investment. Several external finance options exist for C&I firms to reduce the upfront payment. In addition, subsidies and new regulatory schemes are emerging to support distributed energy including microgrids. New innovative finance solutions may also drive down microgrid investment costs.

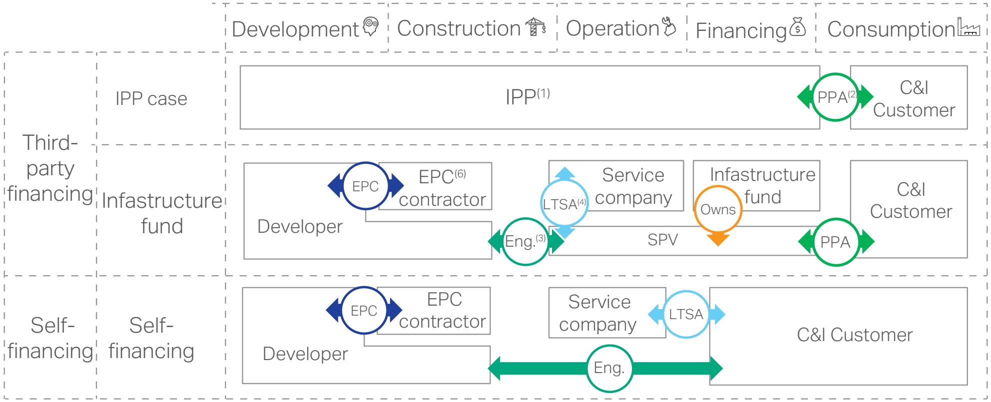
4.1 FINANCING AND OWNERSHIP MODELS

Different finance and ownership solutions have emerged to facilitate development, construction and operation of low-carbon microgrids. Finance can be a barrier for developing low-carbon microgrids, as projects are relatively capital-intensive, with small operations and maintenance costs. When electricity is purchased from the grid, most costs are invoiced in monthly energy bills. For an off-grid diesel generation microgrid, most expenditure will be in regular purchases of fuel. By contrast, a combined solar PV and storage solution requires high initial investment, followed by very low operations and maintenance costs. As such, it is essential to find ways to spread the financial burden for C&I companies over the operation period of the microgrid.

Renewable energy development and financing are not a core competency of C&I firms, leading them to often choose to externalize finance. C&I companies tend to be focused on their main product or service, rather than on energy production. Energy is a means to meet their business goals and most companies look to outsource the energy component of their business, while being mindful that the chosen solutions fit their energy and sustainability strategies.

Figure 3 describes the major financial and ownership structures available for firms looking to develop a microgrid.

Figure 3: Major ownership structures for a microgrid



(1) IPP: Independent Power Producer (2) PPA: Power Purchase Agreement (3) Eng.: Engineering Services
(4) LTSA: Long-Term Services Agreement (5) SPV: Special Purpose Vehicle (6) EPC : Engineering, Procurement, and Construction

4.1.1 Third-party financing

Third-party financing removes the need to raise upfront investment for a microgrid. If C&I firms do choose a third-party to finance a microgrid construction, they will typically sign a PPA (Power Purchase Agreement) with the owner/developer. This type of financial agreement commits the C&I customer to pay a pre-set rate (in currency per MWh consumed) for a fixed period (typically ranging from 10 to 20 years) for the generated power. This rate will be typically lower than the rate offered by the local energy supplier.

In many cases, the C&I company will choose to entrust the entire development, financing, construction and operation of a microgrid to a single entity, typically the IPP (Independent Power Producer). This is the simplest solution for C&I customers, who contractually commit themselves to one trusted partner who takes charge of all

Case study: Upfront financing

For its new Boston Campus One headquarters in Massachusetts, Schneider Electric has developed a solar-gas hybrid microgrid, which required no upfront payment. Schneider signed a PPA with Duke Energy and REC Solar. Duke and REC will own and operate the microgrid under a 20-year agreement, with Schneider paying an agreed price for its energy. The business model has been described as 'microgrid-as-a-service'. More details can be found in the Section 1.2.

stages of microgrid implementation and operation. According to a recent study, an IPP providing a solar-hybrid diesel solution can reduce MWh energy cost by 20-50% compared to diesel-only microgrids [22]. This option, however, leads to the least control over the power plant's operations, and the firm is highly dependent on the quality of the service provided by the IPP. In addition, the IPP will take the majority of the economic returns from the microgrid.

Alternatively, the C&I firm can divide the IPP's role between several entities while remaining within a third-party financing scheme. For example, a firm may rely on an infrastructure fund for project financing, and contract other entities to manage the development, implementation and operation of the microgrid asset. The infrastructure fund and C&I firm would likely collectively set up a Special Purpose Vehicle (SPV), through which the fund jointly owns the project with the C&I firm. Although more complex from a contractual standpoint, these hybrid solutions are more adaptable over the lifetime of the project (e.g. the C&I firm can buy back the project afterwards, or the customer can decide to internalize operations).

The many additional benefits of microgrids outlined in Section 2 of this paper (e.g. reliability of supply), make financial structures for microgrids more complex than standard projects without island mode. Typically, in standard C&I renewable energy projects, the main objective for a project is reducing the energy price. However, given the many benefits of microgrids beyond cost saving, financial structures for microgrids are more complex, as contractors will have to commit to performance levels in multiple areas (e.g. reliability and/or autonomy).

Currently, standardized PPAs for C&I microgrid PPAs do not exist. In the case of utility-scale projects, most countries now have standardized PPAs. Similar efforts are underway for C&I projects to provide for quicker negotiations and increased clarity for investors, but no standards have been set yet.

4.1.2 Self-financing

C&I companies with sufficient financial capacity and the desire of ownership, may decide to finance their microgrid with their own funds. This applies particularly to C&I firms with very low costs of capital or in cases where a local authority is involved in the project, and able to raise cheap finance (e.g. through a municipal bond).

In case of self-financing, C&I firms can choose to rely on external contractors, such as EPC (Engineering, Procurement, Construction) contractors who have the expertise to assist companies in the development and construction the microgrid. Typically, the firm's contracted project manager is responsible for design and development, while the EPC contractor carries out construction. Partnering with external contractors through two different contracts leads to a different risk distribution between the parties.

During the operation phase, the C&I firm can sign an LTSA (Long-Term Service Agreement) with a service enterprise to operate and maintain the site. The service enterprise would guarantee a certain level of performance, which will be subject to penalties if not met. This company may often be the same as the contractor that carried out construction.

4.2 PROJECT ECONOMICS

The economic case for microgrids can be improved by subsidies, revenues from selling power to the grid and payments from providing stabilization services to the grid.

4.2.1 Access to subsidies

Given the multiple public benefits of microgrids, local and national governments have implemented a wide range of subsidy programs to support them.

Firstly, several government schemes provide direct grants to fund C&I firms' microgrid development costs to increase community resiliency, or to meet local environmental objectives. In New York State, the USD $50 million New York Prize offers up to USD $1 million per firm to pay for feasibility studies [20].

Secondly, governments support C&I companies through tax credits. Tax credits have been one of the support mechanisms for renewable energy, and schemes are emerging to support microgrids. For example, in the US, the Commercial Property Assessed Clean Energy (PACE) program enables C&I property owners to pay for energy upgrades, including the implementation of microgrids, through a reduction in their future property tax.

Finally, public institutions are establishing debt facilities to help microgrid developers receive cheaper financing. In particular, C&I firms looking to build microgrids in developing countries may be able to access debt from development finance institutions. Indeed, several funds exist to support the finance of off-grid microgrids in Africa and other emerging markets. For example, the Microgrid Investment Accelerator aims to provide USD $50 million to finance debt and equity for microgrids in Africa.

4.2.2 External revenue streams for grid-connected microgrids

Microgrids can often sell surplus power to the grid, assuming they are connected to a national grid and the appropriate regulatory frameworks are in place. Indeed, project developers frequently scope microgrid stations larger than necessary to sell power back to the grid. The regulator manages this injection of power to the grid through two mechanisms: feed-in tariffs and net metering, which are described below.

With a set feed-in tariff, the microgrid operator will receive a payment for all power transferred into the grid. The national regulatory body usually determines this rate. For example, in Kenya, a country that has had a transmission rate policy since 2008, this rate depends on the installed capacity as well as on the renewable energy production technology. A C&I microgrid, which has a photovoltaic power station between 0.5 and 10 MW, receives a feed-in tariff of USD $0.2026 per kWh [23].

Net metering is a common method to optimize revenues from self-production. Net metering happens when the microgrid only pays for the net difference between the power drawn from the main grid and the power transmitted into it. In Pennsylvania, net metering is available to "customer-generator" microgrids up to 5 MW that generate with renewable resources. Certain developing countries have developed net metering regulation, such as Thailand [24], though implementation is relatively limited.

In addition, microgrids can offer ancillary services to the main grid operator through frequency and voltage regulation. Frequency regulation markets are emerging across developed countries to support grid operators manage short-term electricity fluctuations. Similarly, demand response programs offer additional revenue opportunities for microgrids which can store power or are able to reduce consumption at times of grid stress. Microgrids can also offer spinning and non-spinning reserves through the microgrids' battery capacity or backup generators in instances when the main grid's power generators fail. Finally, microgrids can also be valuable for helping the national grid to black-start after a power outage - as large generators need outside electricity supply to restore operations after shutting down. For all those services, microgrids can obtain additional revenue. These advantages will typically only be available in more liberalized, developed markets.

4.3 INNOVATIVE CAPITAL SOURCES

Although in their infancy, crowdfunding mechanisms for energy projects are expanding. Crowdfunding, a mechanism where multiple individuals provide micro-loans (or micro-donations) to projects, can reduce the interest rate of those projects. The World Bank estimates that the crowdfunding market in developing countries could exceed USD $96 billion per year within ten years [25]. Interest rates in developing countries tend to be high, lowering financial attractiveness of C&I projects. Crowdfunding allows IPPs to lower the finance cost of microgrid projects, thereby increasing profitability.

For example, Bettervest GmbH, a crowdfunding firm in Germany, recently provided €200,000 in low-interest loans to build microgrids in India. These Indian companies benefited from an interest rate of 6%, far lower than the average 15%+ loans usually found in India [26].

Community ownership can also provide finance to microgrids. Where a microgrid provides a supply of energy to both C&I companies and local households, community groups may be interested in financing the project. By having participation from local groups, these projects are likely to receive greater public support.

Picture courtesy of ABB

5 Policy and regulatory considerations

As C&I low-carbon microgrids are a recent evolution, regulatory frameworks are still being developed. Few countries have established specific national regulations to govern microgrids. This section explains the major regulatory topics surrounding microgrids.

5.1 LICENSES AND PPA REGULATIONS

Private investors need to obtain the necessary permits for developing microgrids. Though sometimes onerous, several governments are streamlining these approval processes. Microgrids are often subject to the same complex regulatory frameworks as large power projects (e.g. a full environmental impact assessment, multiple layers of approval). For small microgrids, some governments have specific, simplified processes. In Tanzania, for example, minigrids with a capacity of under 1 MW do not need to apply for a generation licence, while the government has developed a minigrid information portal to make the necessary licensing requirements public [27].

In grid-connected areas, microgrids can be exempt from unbundling regulations. In many geographies, sections of the energy value chain have been unbundled - usually the generation and supply from the operation of transmission and distribution networks. However, in a microgrid, one actor - usually the microgrid owner - carries out all of these functions. To solve this unbundling challenge, regulators are putting in place measures. For example, the European Union states that member states do not have to apply the usual unbundling rules to “integrated electricity undertakings serving less than 100,000 connected customers.” European governments are responding, and France has already introduced legislation allowing closed distribution networks. Finland, Austria, Czech Republic and Flanders have also introduced similar policies [28].

Power Purchase Agreements (PPA) for C&I use are often subject to different regulations depending on geography. In the United States, individual states are involved in setting PPA regulation, even though the Federal Energy Regulatory

Commission defines a regulatory framework for PPAs. Fifteen states have passed laws to authorize and regulate C&I microgrid agreements. For example, Arkansas authorizes PPAs to go beyond five years only if the commission believes that the costs involved are reasonable and if, among other aspects, it allows the customer to save money [29].

5.2 GRID CODES FOR INDEPENDENT NETWORKS

Microgrid developers need to seek clarification on grid codes, the rules that govern the interaction between the C&I microgrid and the distribution system operator (DSO) who owns the grid. Below are two example topics on which regulators are working to clarify DSO's obligations:

1. Under most regulatory frameworks, there is currently no obligation for DSOs to grant microgrids the right to reconnect after they have gone off-grid. In case of an industrial microgrid, this could lead to significant repercussions for an enterprise that could be potentially forced to cease production due to not being reconnected to the grid instantly after islanding.
2. The safety of maintenance engineers is a major challenge for electricity distribution networks. Grid codes require DSOs to know in real time if a microgrids' cables are functioning or not to avoid accidents. DSOs and microgrids must develop communication channels, and a protocol to ensure notifications are made in a timely manner.

In both cases, the regulator needs to adapt the grid codes to ensure they are suitable for microgrid development.

5.3 POWER INJECTION INTO THE GRID

For on-grid sites, C&I microgrids can benefit from selling surplus power to the grid, if the government has implemented net metering or feed-in tariff regulations. Section 4.2.2 discusses these points in more detail.

For off-grid sites, the arrival of the main grid represents a threat to a microgrid's established business model, and companies need to be aware of regulations governing this process to give clarity to investors. If the national grid arrives in the microgrid area, local customers may choose to switch their electricity purchasing from the microgrid to the national grid. In addition, if regulation is not in place, the utility may not accept to purchase electricity from the microgrid. Both these impacts would significantly reduce the revenues for the microgrid owner. In many countries, regulation related to grid extension is still unclear, which is holding back microgrid investment [19]. Nigeria, for example, has implemented a microgrid policy to deal with this situation [30].

5.4 IMPORT TARIFFS

Microgrid construction is likely to require imported goods, making import tariffs an important part of the project costs. Chinese firms manufacture more than 60% of the world's solar PV modules [31]. In addition, power control systems and energy management systems tend to be produced in industrialized markets. Therefore, particularly in low-income countries, much of the required technology will need to be imported. Several countries (e.g. Kenya and Rwanda) have developed a zero-import tariff and zero VAT policy for solar products, given the high development importance of renewable energy projects. C&I companies are able to benefit from this reduction in import tariffs.

6 Technology options and on-site requirements

Low-carbon microgrids can use a variety of low-carbon energy sources, such as wind and hydropower, though solar PV is the most common given its modularity. The rapid fall in the price of storage means companies with reliability needs and ambitious environmental targets can now install solutions which only use storage and renewable power – avoiding the need for any fossil fuels. This section explains these different technology dynamics.

6.1 GENERAL ARCHITECTURE

Constructing a microgrid with renewable energy sources is technically complex for several reasons: Firstly, any existing system has to adapt to intermittent power generation. Secondly, maintaining the power load regardless of weather conditions or other adverse events requires backup supply, for instance, in the form of battery storage or a thermal generation set.

Thirdly, the microgrid requires computer software capable of intelligently managing a site with multiple production technologies, i.e. the EMS (Energy Management System) controller. Finally, islanding requires the ability to disconnect and reconnect a site to the main grid on demand, and in a timely fashion.

Figure 4 depicts the general architecture of a low-carbon microgrid.

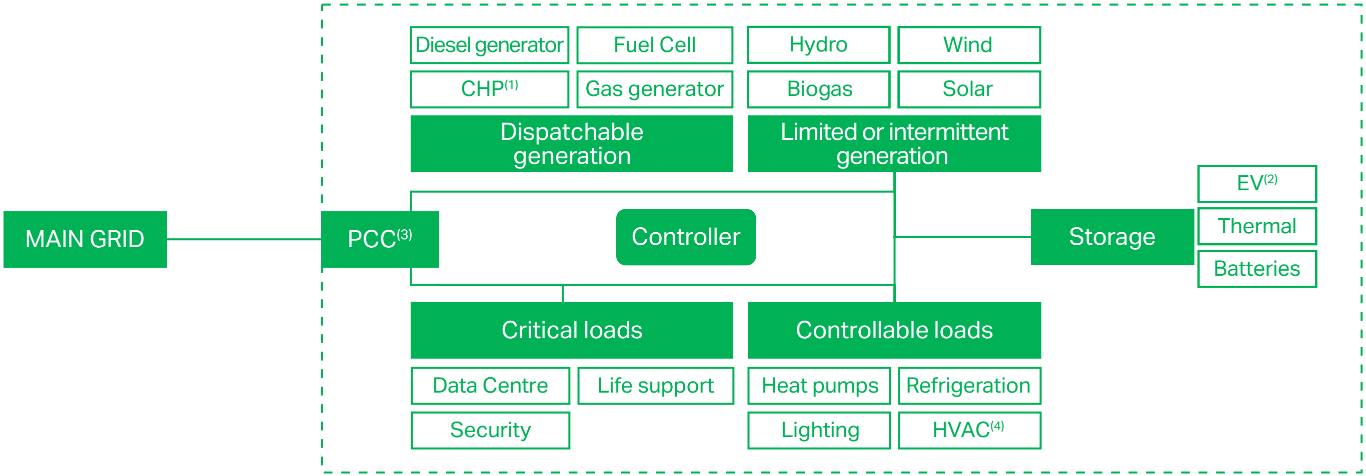
6.2 ENERGY SOURCES

C&I microgrids can use both renewable and non-renewable sources. This section explores these technologies and looks at how C&I firms are increasingly integrating renewable sources into their microgrids.

6.2.1 Renewable energy sources: Solar PV, wind, mini-hydro

The rapid decrease in the price of renewable energy production, particularly for solar PV and wind, has been a game-changer for the development of C&I microgrids. PV module prices decreased from USD $4/Wp in the first half of the 2000s to USD $2/Wp in 2010 and to below USD $0.5/Wp today. This decrease led to

Figure 4: General architecture of a microgrid



(1) CHP: Combined Heat and Power plant
(2) EV: Electric Vehicles
(3) PCC: Point of Common Coupling
(4) HVAC: Heating, Ventilation and Air Conditioning

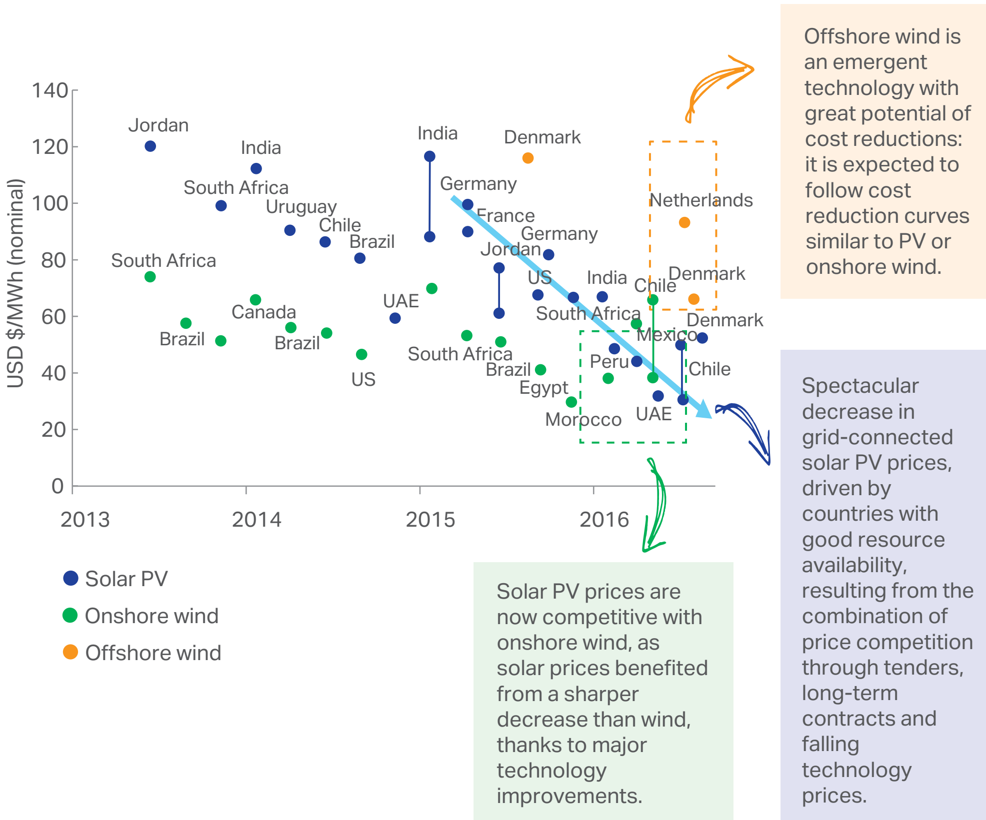
an equivalent decrease in the levelized cost of energy with the most recent utility-scale projects negotiating PPAs of around USD $40-50/MWh in a wide range of regions (California, South America, India, Middle East, or even Denmark - see Figure 5). Onshore wind price decreases have been less dramatic but have resulted in similarly low PPA power prices.

These price levels of renewable energy sources are competitive with fossil fuel-based generation technologies. C&I projects are usually more expensive compared to utility-scale solar given their smaller size, and additional space constraints. E.g. urban microgrids will typically require rooftop solar, which is more expensive than ground-mounted installations. However, C&I solar costs have also followed a similar downward curve.

Solar is usually the preferred technology for self-consumption and production, given its modularity. The typical size of a solar panel is a few hundred watts, making the systems highly modular (i.e. additional capacity can be easily added). This modularity has three key advantages for C&I applications: firstly, the C&I firm can adjust the size of the project to fit their needs and optimize profitability. Secondly, the modular nature of solar means C&I firms can install small areas of panels in multiple locations to efficiently use the available space and maximize local production. Finally, modular installations do not require high-skilled labor and are easy to construct using local employees.

The variable generation and low energy density of renewable energy sources need to be considered when planning a microgrid. Solar PV plants can only convert energy at certain times of the day, meaning that microgrids often use a storage system for backup and to increase self-consumption of solar energy. In addition, as with other renewable energy sources, solar PV has relatively low energy density (see Figure 6).

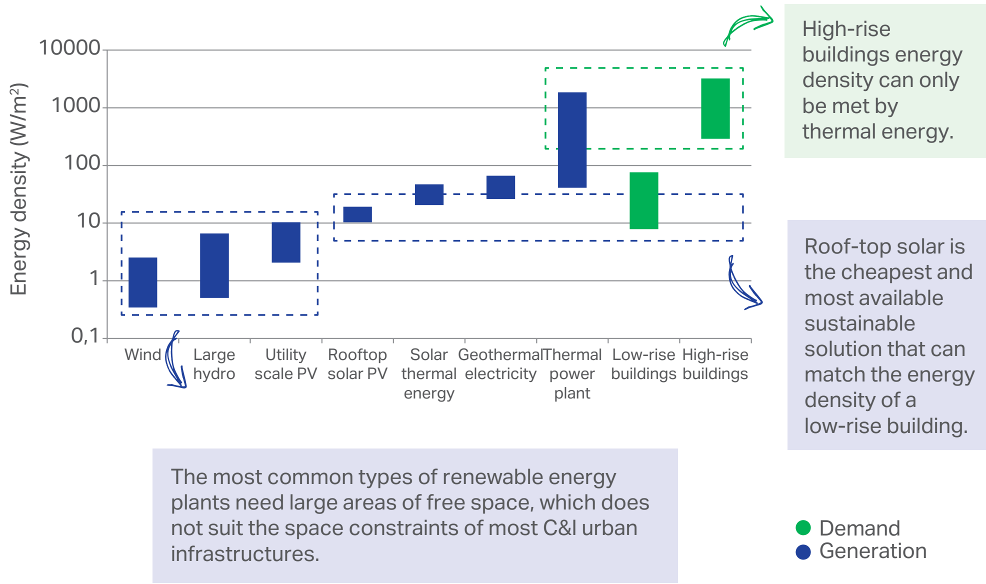
Figure 5: Recently announced long-term contract prices for new renewable power projects to be commissioned over 2016-2019 [32]



As power needs of industrial sites can be large, the installation of a PV microgrid for industrial use will likely involve a very large surface area, and as such might be not suitable in an urban environment. Companies can decide to supplement the microgrid by wheeling in off-site utility-scale renewables via long-term PPAs. This hybrid model with a microgrid would act as an enabler for companies seeking to achieve a high renewables supply.

C&I microgrids can also use wind and hydropower, depending on the availability of resources near the site. C&I firms that demand high levels of energy may choose to build dedicated wind and hydropower installations. These technologies have limitations in terms of location, particularly the availability of water for hydropower, and high wind speeds for wind power. Companies therefore use these technologies in a limited number of cases. Barrick Gold Corporation, a mining company, chose this solution in 2011 to partially supply its Veladero Mine in Argentina with a 2 MW wind turbine.

Figure 6: Energy density of typical renewable electricity sources compared with typical ranges of electricity demand [33]



6.2.2 Hybrid renewable-fossil fuel microgrids

Microgrids have traditionally used fossil fuel-based power sources, such as diesel and gas. Diesel has been the prominent base source of energy in most existing off-grid electricity systems. C&I firms requiring both heat and power often opted for gas microturbines – this is particularly the case in urban areas, given the proximity to gas distribution networks. In addition, new technologies are emerging, such as hydrogen fuel cells.

The reduction in cost of renewable energy is encouraging C&I firms to implement hybrid fossil fuel renewable systems, adding solar into their existing diesel-based systems. As Figure 7 shows, solar systems are already cheaper than diesel-based systems. When considering gas microturbines, companies have been slower to integrate renewable power given current low gas prices. However, the volatile nature of gas prices means firms may want to install renewable solutions going forward, to increase long-term price stability. **While hybrid systems are not zero-carbon, they still represent a significant decrease in the carbon intensity of a microgrid.**

Replacing diesel with renewable energy increases the complexity of microgrids. Short-term power reserves are necessary to compensate for the variability of renewable production (e.g. when there is a cloudy period). Significant long-term energy reserves are necessary to meet autonomous energy needs of the C&I site – i.e. in case of multi-day power outage, the microgrid will need to have sufficient long-term reserves to run for the entire period.

Given these challenges, microgrids still typically use a certain level of fossil fuel, even as decreasing battery costs enable higher renewable penetration, and eventually 100% renewable and storage.

Figure 7: Indicative levelized cost of energy of thermal solutions compared to C&I solar [34] [35][A]

[A] Assumptions used for these calculations are available on request.

C&I firms have chosen diesel generation historically for its ability to provide large energy storage reserves (in tanks). Without a large electric storage system, off-grid microgrids need to keep a fossil fuel generation set running to be able to take over immediately and avoid production stoppages. Diesel generators usually have to run at 30% minimal running load at all times to ensure they can provide instantaneous backup. This minimal load limits the amount of penetration of renewables. However, by adding an electricity storage solution, the C&I firm can reduce the need for diesel for short-term power reserves. Further falls in storage cost may result in pure PV and storage systems (see following Section 6.3).

6.3 STORAGE

The development of energy storage technologies is another game-changer, driving the uptake of low-carbon microgrids. The falling costs, increased dependability and longevity of storage technologies make it much easier to add energy storage solutions to a microgrid. From a user point of view, they present several key advantages:

- Very quick response time (several milliseconds);
- Ability to increase local self-reliance by storing renewable energy production; and
- No local externalities (noise, fumes, etc.).

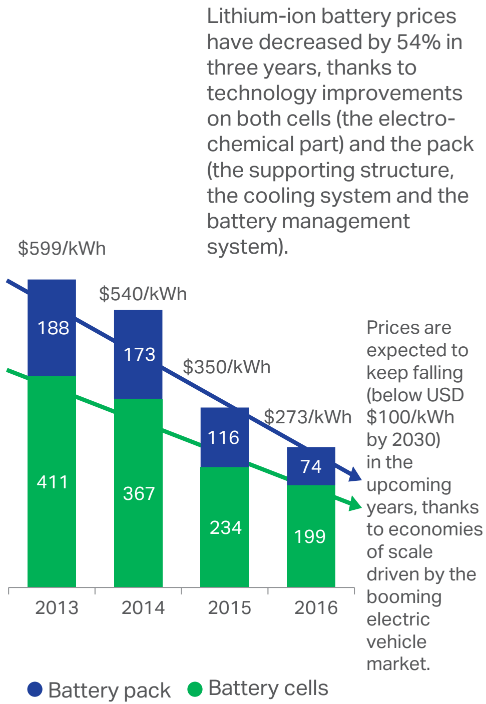
For batteries, the rapid decrease in cost of lithium-ion cells, spurred by the emergence of large-scale industrial production of batteries for electric vehicles, has led to the progressive disappearance of lead-acid technology. The costs of lithium battery packs have halved in four years between 2013 and 2016 (see Figure 8).

Lithium-ion batteries have become the predominant storage technology for microgrids, but flow batteries are also emerging. The advantages of lithium-ion batteries include higher storage density (per weight and volume), reduced maintenance requirements, longer lifespan due to low self-discharge rates and smaller mass and size. Flow (or electrolyte-circulating) batteries, based on the use of water-soluble organic compounds like electrolytes, have reached technological maturity making their industrial production a viable proposition. As such, flow batteries could be an interesting storage technology for future microgrids.

Flywheels, another storage technology, are best used to provide short-term reserve and fast islanding capabilities. A flywheel involves the mechanical, rather than chemical, storage of energy. It is a mass rotating around a fixed axis in a vacuum, thereby reducing energy losses from friction to a minimum. The typical size of flywheels means they can only supply power for a few minutes. Although requiring a considerable initial investment, flywheels have high energy yields and long lifetimes. Their inertia, resulting from their mechanical architecture, also helps stabilize networks and ensures the transition between two modes of power supply.

Companies need to compare the costs of storage with their autonomy requirements, to assess what will be the most economically viable storage solution for a project. While an increase in storage capacity allows for higher on-site consumption and dependability of supplies, it can have a negative impact on the project's levelized cost of energy, despite

Figure 8: Decrease of battery pack costs[B] 2013-2016 (USD $/kWh installed) [11]



[B] Does not include all components required for a storage system (e.g. cost of converters, other electrical balance of plant and labour costs) recent falls in storage cost. Figure 9 at the end of this section explains these options comprehensively.

6.4 ENERGY MANAGEMENT SYSTEMS AND POWER ELECTRONICS

Renewable energy sources and storage solutions are essential components of microgrids. Equally required are advanced energy management systems and power electronics, the performance of which have increased significantly.

New energy management systems (EMS) analyze large sets of data, produce accurate production and consumption forecasts and then optimize microgrid performance. EMS are advanced IT systems which use algorithms and powerful computing power to optimize the functioning of electricity installations, including microgrids. These systems enable companies to, for example, maximise the amount of on-site renewable energy consumed by considering future weather forecasts. **This optimization improves the economic attractiveness of microgrids.**

New types of power electronic controllers also make microgrids easier to run. A C&I microgrid usually has two types of inverters: grid-following and grid-forming inverters. The grid-following inverters' main role is to inject the output of solar panels and transmit the produced energy by the PV plant to the C&I site. Grid-forming inverters connected to batteries maintain frequency and voltage in microgrids with no operating spinning energy sources (i.e. conventional gas/diesel units). Large-scale grid-forming inverters operating for a long time are still relatively rare as existing microgrids typically run on thermal units to set a stable frequency and voltage.

The flexibility of a microgrid can be used to optimize energy consumption and production and hence reduce costs. Companies benefit from the technical flexibility of energy storage, and can use controllable energy demand to further optimize energy use. C&I firms can adjust or shed energy demand, depending on the availability and price of energy. For example, by reducing consumption of energy when renewable energy is scarcer, and ramping up systems at times of high renewable energy production, the microgrid owner can maximize the amount of renewable energy they use.

6.5 TECHNOLOGY SUMMARY

Figure 9 describes the various technology options C&I firms have in terms of integrating low-carbon microgrids.

Figure 9: Overview of technology options

Solar PV

Convenient for the vast majority of microgrids*

(in urban and rural areas, and in countries with medium to high irradiance levels)

	ON-GRID	OFF-GRID
+ Solar PV + Battery	$ $ $ ↘ (high emissions reduction) **When to use?** • For peak demand management (high demand charges & high load peaks) • For weak grids with short interruptions *N.B.: size of battery based on demand charges and/or the length of typical outage*	$ $ $ ↘ (high emissions reduction) **When to use?** • For C&I companies that have high sustainability goals • For isolated sites much impacted by the unreliability and the price fluctuation of diesel supply *N.B.: In both cases, very large batteries required to supply the totality of loads*
+ Solar PV + Diesel	$ (medium emissions reduction) **When to use?** For any grid-connected C&I site with an economically attractive feed-in tariff *N.B.: Diesel for backup only* *Size of solar depends on space constraints and the amount of initial CAPEX that can be invested*	$ (medium emissions reduction) **When to use?** For any C&I site relying on diesel generation *N.B.: Diesel as the main source of energy. Maximum instant renewable penetration is between 20% to 60% (which results in over 15% solar energy or 30% wind energy throughout the year)* *Sizing of solar depends on the amount of initial CAPEX that can be invested*
or Solar PV + Gas	$ (medium emissions reduction) **When to use?** Relevant for greenfield sites connected to the gas network	$ (medium emissions reduction) **When to use?** Recommended for greenfield sites if: • Heat and power needs • Low gas prices are available and the site benefits from gas pipeline (option of a virtual pipeline with LNG carriers)
or Solar PV + Fuel Cell	$ $ $ ↘ (medium emissions reduction) **When to use?** • Same as above • Or other local renewable fuel production (e.g. hydrogen through electrolysis), combined with high sustainability goals	

*Other renewable energy sources are also potential options for microgrids.

Legend

- $ $ $ High upfront cost – Medium profitability
- $ $ Medium upfront cost – High profitability
- $ Low upfront cost – Very high profitability
- ↘ Upcoming price decrease thanks to ongoing technology cost reductions
- (3 leaves) High level of GHG emissions reduction
- (2 leaves) Medium level of GHG emissions reduction

Solar PV

Convenient for the vast majority of microgrids*

(in urban and rural areas, and in countries with medium to high irradiance levels)

		ON-GRID		OFF-GRID
+ Solar PV + Diesel + Battery	$ $ ↘	**When to use?** • For any grid-connected C&I sites with economically attractive feed-in tariff and profitable peak demand management strategy or services to the grid • For C&I companies with high sustainability goals *N.B.: Diesel for backup only* *Size of solar based on space constraints and the amount of initial CAPEX that can be invested*	$ $ ↘	**When to use?** • For C&I companies with sustainability goals • For C&I sites with fluctuating load/solar power *N.B.: Maximum instant renewable penetration can reach 100%, thanks to storage capacities (which results in over 50% of solar energy or 70% of wind energy consumed from solar throughout the year)* *Size of solar and storage depends on load profile and amount of initial CAPEX that can be invested.*
or Solar PV + Diesel, Gas or Fuel Cell with Flywheel	$ $ $	**When to use?** Only if services to grid require high-power injection/consumption for a short time (less than ½ hour)	$ $ $	**When to use?** Only if loads have short and sharp fluctuations
or Solar PV + Diesel, Gas or Fuel Cell with Thermal Storage	$	**When to use?** • Only if existing thermal load • Or if existing gas CHP		

*Other renewable energy sources are also potential options for microgrids.

Legend

$ $ $ High upfront cost – Medium profitability
$ $ Medium upfront cost – High profitability
$ Low upfront cost – Very high profitability

↘ Upcoming price decrease thanks to ongoing technology cost reductions

High level of GHG emissions reduction
Medium level of GHG emissions reduction

7 Next steps

Should a C&I customer be interested in investigating microgrid opportunities, they can use the following checklist to collate initial project information:

1. Current situation (operational conditions in facility):

b. Technical setup: current/historic levels of power supply reliability, current power generation mix, type of distribution grid, typical load profile, identification of critical loads versus controllable loads, heat loads, chill loads, available space for a microgrid;

c. Environmental considerations (emissions rates, emissions targets);

d. Financial considerations - operating costs: fuel costs, electricity prices, fuel price volatility, proportion of electricity costs as a share of total cost of sold goods, opportunity costs of outages caused by historic levels of reliability; and

e. Project objectives: minimize energy bills, reduce outages, reduce emissions, provide spinning reserve, peak demand reduction, etc.

2. Project feasibility:

a. Applicable policies: planning and permitting regulations, power tariff structure, grid connection charges, grid use of system charges;

b. Renewable resource: wind speeds, solar irradiation, shadow effects;

c. Site information: land availability, thresholds that trigger planning permission, environmental impact assessment, visual impact assessment, timescales for development, supply chain lead times, etc.;

d. Commercial structures: self-ownership, infrastructure fund, IPP, PPA, returns to owners;

e. Financing structure: balance sheet, debt/equity, PPP, etc.; and

f. Technical viability: grid integration principles, technology choices and optimum size, site layout, ability to feed power back to grid or not, etc.

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WBCSD's REscale business solution

Through REscale, leading companies are working together on solutions to accelerate the deployment of renewables beyond average growth and transition to a low-carbon electricity system. The group shares the view that renewable energy is reliable and increasingly competitive and that 3.5 TW of capacity can be deployed by 2025.[C]

In 2016, REscale published the report 'Business Case for Low-Carbon Microgrids' which demonstrates the viability of low-carbon microgrids using real project examples to raise awareness and promote market growth of renewables in decentralized systems.
This report continues our work and emphasizes the potential for a significant up-take of low-carbon microgrids by commercial and industrial companies.

To find out more about REscale, the Corporate Renewable PPA Forum and previous reports, visit our website.

[C] The 3.5 TW figure is based on the International Energy Agency's 2° scenario.

About the World Business Council for Sustainable Development (WBCSD)

WBCSD is a global, CEO-led organization of over 200 leading businesses and partners working together to accelerate the transition to a sustainable world. We help make our member companies more successful and sustainable by focusing on the maximum positive impact for shareholders, the environment and societies.

Our member companies come from all business sectors and all major economies, representing combined revenues of more than $8.5 trillion and 19 million employees. Our global network of almost 70 national business councils gives our members unparalleled reach across the globe. WBCSD is uniquely positioned to work with member companies along and across value chains to deliver impactful business solutions to the most challenging sustainability issues. Together, we are the leading voice of business for sustainability: united by our vision of a world where more than 9 billion people are all living well and within the boundaries of our planet by 2050.

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Disclaimer

This publication is released in the name of the World Business Council for Sustainable Development (WBCSD). This document is the result of a collaborative effort between WBCSD, ENEA Consulting and representatives from companies participating in the REscale business solution.

A wide range of REscale members reviewed the material, thereby ensuring that the document broadly represents the majority view of the REscale business solution.

It does not mean, however, that every company within the working group agrees with every word.

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This report was drafted by ENEA Consulting. The report has been prepared for general informational purposes only and is not intended to be relied upon as accounting, tax, legal or other professional advice.

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The REscale business solution currently consists of the following companies supporting this report:

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