Distributed Energy Systems

Flexible and Efficient Power for the New Energy Era

A research project carried out by Arup and Siemens

Foreword

The supply of reliable and affordable energy is an essential condition for economic growth and for achieving a good standard of well-being in any context: from the biggest megacities to the smallest villages. The past century has seen astonishing achievements by the energy sector to match ever-rising demand from growing populations and economies. Up to now, the basic system has remained essentially unchanged, with large-scale centralized plants supplying power via national and international transmission and distribution grids. It has served the global economy well.

Over the next decades, our need for energy will continue to grow, but we will need to find a way to accommodate this growth while maintaining affordability, reliability and environmental sustainability.

How can we reduce the local and global environmental impacts of generation and extend access to the estimated 1.2 billion people who are currently without access to energy? In itself a challenge, any potential solutions will also need to be implemented in a world of increasing volatility and risk from both manmade and climate change-induced natural hazard events.

Distributed Energy System (DES) technologies represent an important part of the solution: they offer building owners and energy consumers significant opportunities to reduce costs, ensure reliability and secure additional revenue through on-site generation and dynamic load management.

When deployed at scale, DES can also deliver significant economic, social and environmental co-benefits through better system resilience and efficiency, including lower cost grid balancing, reduced greenhouse gas emissions and affordable extensions of grids to unconnected communities. In societies which are increasingly dependent on digital services and tight supply chains, and a world facing the threat of climate change, these wider benefits are critical for everyone.

This research report was undertaken jointly by Siemens and Arup and draws upon both companies' global expertise in energy technology, building and energy systems design. The research aims to provide an insight into the world of decentralized energy with a special focus on economic viability and wider co-benefits of DES investment. The report explores the barriers and enabling actions which could stimulate an acceleration of deployment of DES solutions. Through four case studies, we showcase the kinds of applications suitable for DES investment and the returns which could be achieved.

We hope that this research will contribute to the wider discussion on the future design of our energy systems and inform decision making regarding the applicability of DES technologies.

Dr. Roland Busch
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Gregory Hodkinson
Arup Group Chairman

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Executive Summary

Distributed Energy Systems (DES) is a term which encompasses a diverse array of generation, storage, energy monitoring and control solutions. DES technologies represent a paradigm shift and offer building owners and energy consumers significant opportunities to reduce cost, improve reliability and secure additional revenue through on-site generation and dynamic load management.

Global energy consumption has grown steadily over the past century. This trend, driven by population and economic growth, is set to continue in spite of rising efficiency of both production and consumption. The IEA estimates that over the period to 2035 the investment required each year to supply the world's energy needs will rise steadily to $2,000 billion.[1]

However, the way our energy needs are being met is changing rapidly. These changes are in response to new opportunities - such as renewable energy and smart technologies - and new policy goals - to reduce emissions and extend energy access. The traditional centralized model of linear power generation and delivery through limited market or monopoly conditions is giving way to a more diverse, dynamic and complex system with multiple actors and multilayered energy, information and money flows.

This report identifies significant value opportunities for medium to large scale DES applications tailored to user requirements including cost reductions, energy efficiency, security of supply and carbon reduction.

This report investigates how DES solutions could be applied to manufacturing facilities, office buildings, urban residential districts and rural communities across the globe. **The numbers speak for themselves. Operational cost reductions ranging between 8% and 28% and a return on investment (ROI) between 3-7 years compared to a business as usual are observed. CO_2 emissions are reduced at similar scales.**

Wider uptake of DES can also deliver significant economic, social and environmental co-benefits through better system resilience and efficiency, including lower cost grid balancing, reduced greenhouse gas emissions and affordable extension of grids to unconnected communities.

Improving Security of Energy Supply & Resilience

Energy infrastructure all over the world is ageing and requires significant investment to replace and repair. The risks associated with such ageing assets coupled with shocks derived from large scale weather related events, could lead to potential failures in the network - blackouts and brownouts - or at best, poor environmental compliance.

Local, decentralized and controllable DES generation and storage sources can be designed to provide the end user with local resilience or even full independence from the grid. The benefits accrue to grid operators as well: DES can manage demand to reduce peak loads when infrastructure is nearing capacity, thus postponing the need for major grid reinforcement investments.

Energy Cost Reduction

Low but uncertain oil prices not only make overall energy costs unpredictable but increase risk on large investments in energy system upgrades, potentially obstructing the requirements of the end consumer. DES can be customized to match the consumer's requirements as well as enabling actors to shape local generation and consumption in response to market price signals to achieve the lowest overall cost of energy.

Low Carbon Energy and Energy Efficiency

DES includes renewable and low carbon generation and controls that enable the integration of such technologies into the network and as a result reduces the carbon intensity and impact on the local environment of the energy system.

At a local level, poor air quality can proliferate acute public health problems. The continuing reliance on fossil fuels for energy generation is one of the leading causes of significant air quality issues. DES that rely on clean energy generation or hybrid systems, have a reduced impact on air quality and helps maintain a greener and cleaner ecosystem.

Energy efficiency is one of the key steps towards reducing carbon emissions and cutting energy costs and also, arguably, the one with the most immediate and obvious returns.

DES coupled with other traditional energy conservation measures can improve efficiency across the energy system. Integrated real time data monitoring and multipoint controls at both plant, building and network level can improve asset utilisation and plant efficiency and ensure power, cooling, heating and lighting are used only when and where they are needed.

Access to Energy for All

The IEA estimates that 1.2 billion people, around 17% of the world's population, have no or very limited access to electricity[2] with the majority of this population located in Sub-Saharan Africa and East Asia. Smaller scale electrification projects based on DES and in particular off-grid microgrids can be implemented quicker and cheaper than major power infrastructure projects as there are fewer planning and regulatory constraints. DES offers the opportunity to provide clean, reliable energy to off-grid communities improving the quality of live and the economic development.

Delivery of Distributed Energy Systems

The emergence of new technologies presents an opportunity to develop tailored financial instruments and ownership models which can stimulate the uptake while absorbing some of the inherent risk.

DES financial models account for the current trends around outsourcing non-core processes and looking for ways to fund retrofits and upgrades off-balance sheets.

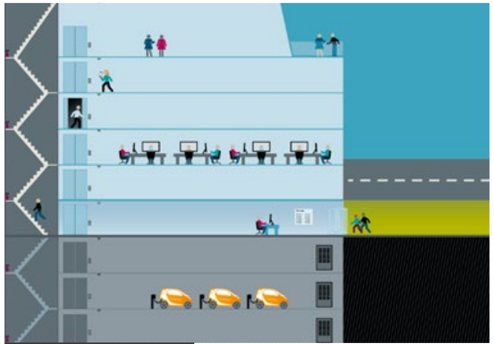
New ownership models have also emerged to address the initial CAPEX costs and the DES plant operation and maintenance. Energy Performance Contracts (EPCs) providers commit to improve the energy efficiency in buildings as an off-balance sheet cost for the owner. Energy cost savings, achieved through the reduction in energy consumption, are used to pay for the installed equipment, with the residual savings shared by the solution provider and the building owner.

Developers are also able to offer full turnkey solutions on DES projects depending on the end user requirements, capabilities and risk appetite. Through a Power Purchase Agreement (PPA), an external developer designs, delivers and operates a plant, e.g. a solar PV farm, at a consumer's property in exchange for an agreed tariff under which electricity is going to be bought. This enables the consumer to purchase electricity directly from the generator rather than from the utility. Similar services are offered in emerging economies by microgrid developers.

A newer breed of energy services companies (ESCOs) is also evolving, focusing more on innovative financing methods, including off-balance sheet vehicles, delivering cost reduction for clients through managed reduction in energy usage.

Doubling the share of renewables in the global energy mix by 2030 combined with improved efficiency, is necessary to keep global warming under **2°C**[3]

The report is underpinned by four case studies which present a collection of medium to large scale applications of DES for different end users. The case studies include a smart energy building integrating new technologies and controls, a manufacturing facility employing energy conservation measures, an urban community producing its own heat and electricity and a rural off-grid village looking for opportunity to reduce its dependency from fossil fuels. Leveraging on the applicability of DES in any geographical context, the four case studies are located in four different countries: Germany, China, U.S. and India.

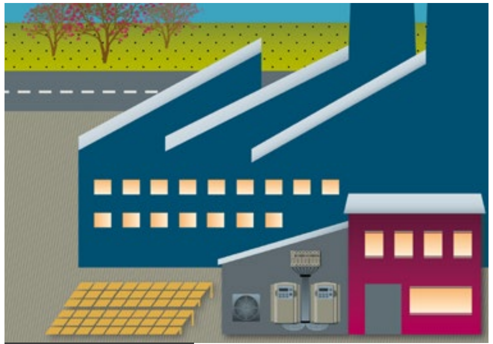


CASE STUDY 1

Smart Energy Building

Freiburg, Germany

A smart energy building is able to integrate and optimize both electrical and mechanical plants in order to lower energy costs, reduce carbon emissions and improve efficiency thus promoting sustainability. In combination, this can increase the value of the property. DES is at the heart of a smart energy building. The DES portfolio can be selected to achieve lowest annualized energy costs or to optimize a balance of cost and other environmental or security performance objectives.



CASE STUDY 2

Production Facility Energy Conservation Measures

Beijing, China

Reducing energy costs is fundamental for the manufacturing industry in order to remain competitive with production in countries where energy is cheaper. DES generation and storage technologies can be integrated with other Energy Conservation Measures to enable manufacturing to achieve cost reductions while at the same time work towards sustainability goals.

CASE STUDY 3

Urban Community Energy

New York City, U.S.

As cities grow, large scale mixed use developments can act as major player to meet housing needs and to stimulate wider development activity. Within urban development areas, the installation of DES technologies such as Combined Heat and Power (CHP) systems represents an opportunity to achieve high efficiency gains and financial benefits for customers. In the event of grid loss, CHP systems can provide power, thus increasing community resilience.

CASE STUDY 4

Anchor Microgrid

Bihar, India

The implementation of DES – and most specifically microgrids – can unlock energy access and economic development while addressing sustainability concerns. An "anchor" is typically a non-residential consumer that needs reliable power supply (i.e. telecom towers, manufacturing facility, etc.). When coupled with a local community microgrid, the anchor's creditworthiness and long term commitments increase the financial attractiveness of the microgrid projects.

1 The Dynamic Energy Era

Introduction

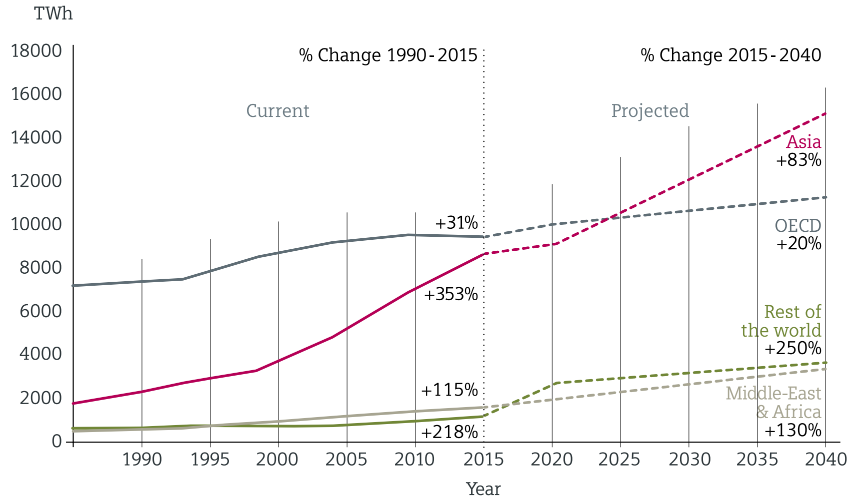
Global energy consumption has grown steadily over the past century, in response to the compounding effects of global population and economic growth. This growth is set to continue, in spite of rising efficiency of both production and consumption: the International Energy Agency (IEA) forecasts that global energy consumption will rise by one third over the next 25 years,[2] with most of this growth driven by the fastest growing economies.

On the supply side, the way our energy needs are being met is changing rapidly, especially in the power sector. For instance, renewable energy is expected to make up more than half of all new investment in electricity generation, and the installed capacity of distributed generation is projected almost to double over the next decade.[2,4] The ways we use electricity are also evolving, with rapid take-up of electric vehicles and heat pumps fueling growth in power consumption beyond the underlying conventional drivers of population and economic growth. In the UK, for example, it has been estimated that demand for electricity could double by 2050 as a result of electrification of heating and transport.[5]

The new diversity of energy generation options which are deployable across a wide range of scales represents both an opportunity and a challenge for energy consumers and producers. Taken together with new capability of control technology and emerging business models for energy services, the world appears to be on the brink of a new energy era, with traditional modes of centralized generation and strict separation of producers and consumers giving way to hybrid energy solutions and dynamic energy actors who can optimize their energy needs through local generation, demand side management and off-site supply.

This report presents a picture of the emerging landscape for Distributed Energy Systems (DES) which are widely applicable at the scale of cities, communities, campuses and buildings. The report aims to demonstrate the significant value opportunities and other benefits that DES deployment can deliver. It also discusses some of the challenges associated with DES, the available financing mechanisms and the impact of DES on a wider system-scale level.

Fig. 1 Global electricity consumption - current and future projections (Source: IEA, Enerdata)[2,6]



The power system today

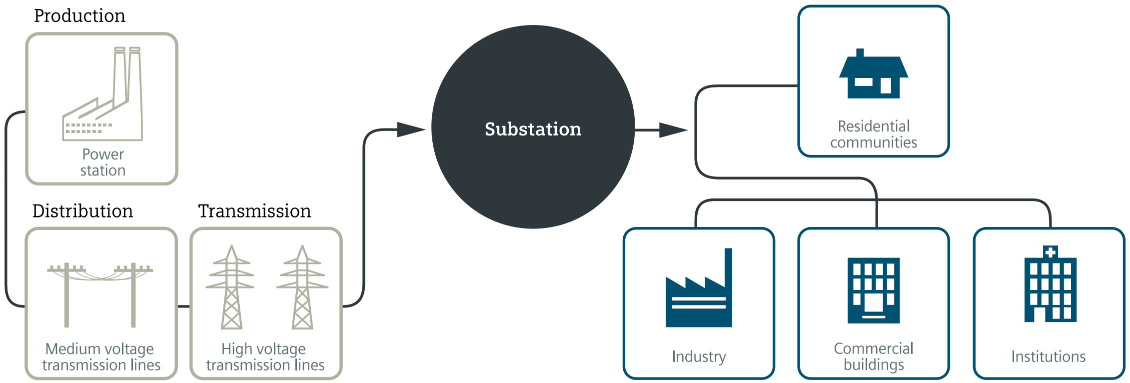
In most parts of the world, the basic model of electricity supply has changed very little since it was first introduced. Most power is produced by large, centralized plants and is transmitted over high voltage cables to centers of demand, where local distribution networks deliver it to final consumers. Unlike primary fuels such as oil and gas, power systems and their markets are generally localized, with distinct regulations and standards in effect in each country or region.

Power plants are typically sited away from population centres, with their locations selected for convenient access to primary energy sources (such as a coal mine or a major river) or for ease of operation (such as coastal locations to access plentiful cooling water).

Central power plants are linked to national transmission network infrastructure stretching over large distances. The Transmission System Operators (TSOs) convey the generated power at high voltages to feeder stations connecting into lower voltage distribution networks close the point of demand (consumption).

The TSOs are also responsible for keeping the system in balance, and typically have control over a portfolio of power stations to enable real time dispatching of generation to demand.

Fig. 2 Traditional vertical power systems model



When the transmission lines reach cities and towns, power is stepped down and transferred to the lower voltage distribution network. This physical transfer may also be coupled with an ownership transfer, from the TSO to the Distribution Network Operator (DNO). The DNO supplies individual consumer loads through its localized networks. Some forms of generation, such as energy from waste (EfW) plants or solar photovoltaic (PV) and wind farms can be connected directly into the distribution network. Nevertheless in most systems, most generation plant is connected into the transmission network, and it is the TSO which has primary responsibility for overall network balancing and control.

Power therefore flows in one direction, from centralized upstream generation down the network to the consumer. With the exception of the very largest energy users, the consumer's role is simply to receive (and pay for) power in accordance with the pattern of demand, with on-site generation limited to emergency back-up power such as diesel generators. Even when consumers install embedded generation technologies such as building-integrated solar PV, the relationship with the market remains simple, with the generated power either meeting on-site demand or being exported to the grid for a modest fixed rate.

Future challenges

Around the world, energy consumption is rising and power networks are growing in both size and reach. Exactly how that growth occurs will strongly affect the cost and quality of consumers' energy supply and will determine how well the energy system addresses global policy objectives and issues such as energy access and climate change.

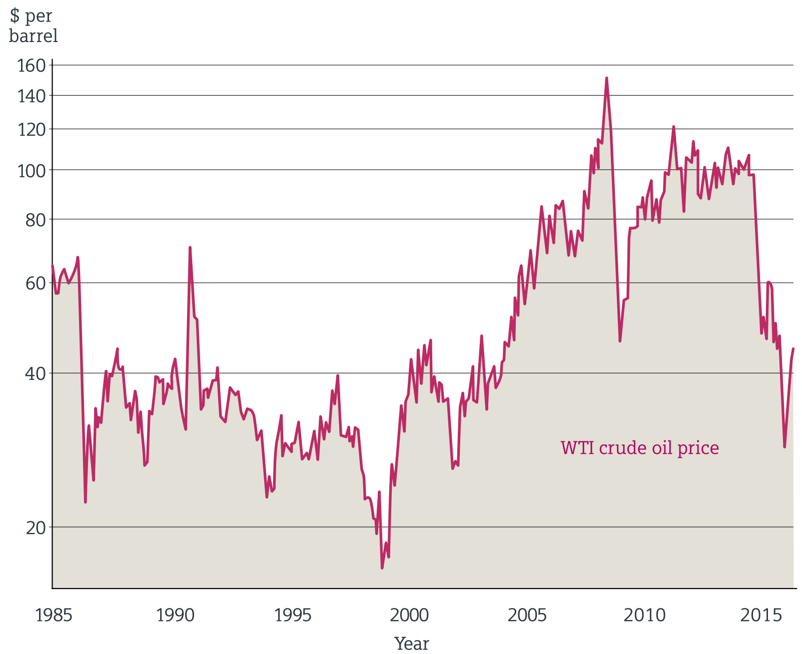
Energy costs

by **2040** the investment required to meet the world's energy needs will rise steadily to **$68 trillion**[2]

Through its New Policies Scenario, the IEA estimates that over the period to 2040 the investment required to meet world's energy needs will rise steadily to $68 trillion.[2] This translates to an annual average investment of around $2.7 trillion (from around $1.6 trillion in 2013).[1] Such investment will need to be recovered ultimately through the prices charged to customers or – where a wider economic case can be made – through government support mechanisms. Even while recent prices have been at their lowest level in a decade, energy prices have been historically volatile (Fig. 3).

Long-term economic performance is closely linked to the cost of energy; therefore energy stability and affordability is fundamental to economic stability. In order for energy systems to grow, to reduce their impact on the environment and to maintain affordability for consumers, the system needs to evolve from a conventional simple centralized supply model to a more diverse marketplace of solutions.

Fig 3. Global oil prices over the past 30 years (Source: Macro Trends)[7]



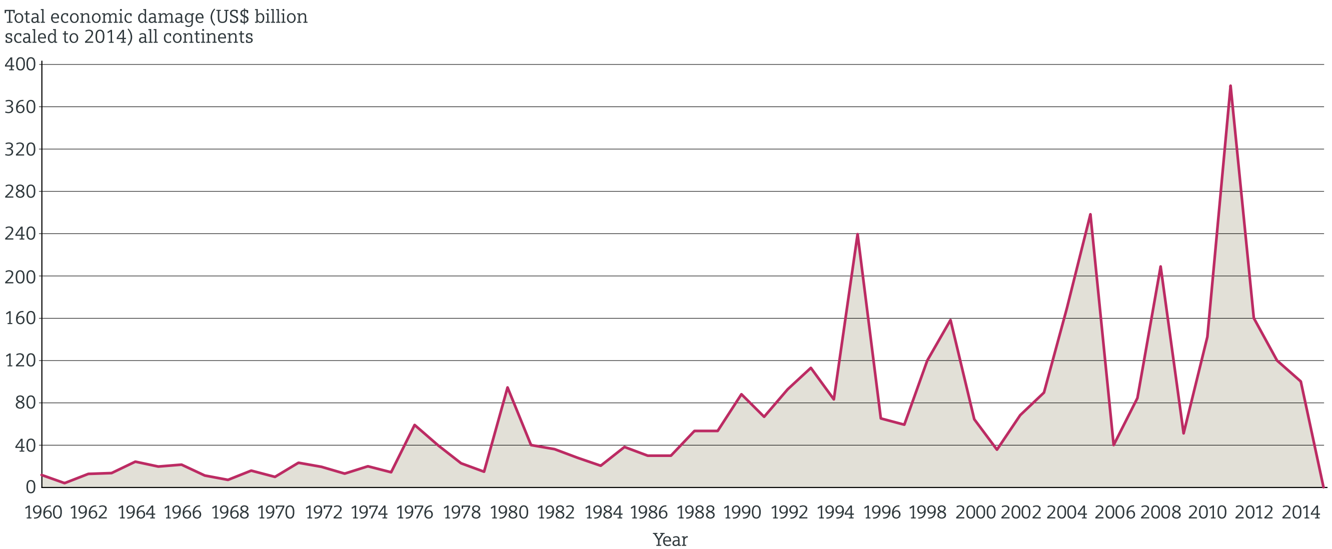
Reliable, resilient energy

Even with the best planning and operations, every energy system is exposed to a variety of natural and manmade hazards such as storms, floods, earthquakes and malicious attacks. The prospect of a rise in global mean temperatures above 2°C by the end of the century will lead to rising sea levels and increasing frequency and severity of weather events.[8] Such events in all their forms – storm surge, rain, wind, heat, drought – can cause direct and indirect damage to energy networks which leave consumers without power and other energy sources for days, weeks or even longer.

In many fast growing economies consumers experience regular power cuts and poor quality power resulting in personal hardship and economic losses.[9] Meanwhile, many developed economies are reliant on ageing infrastructure which is increasingly at risk of failure unless major renewal investment is undertaken.

For all consumers, reliability of power is essential, as in an increasingly digital world we become ever more reliant on continuous power supply to keep us connected. While operators will invest to increase the resilience of their networks, consumers can also consider a range of local cost-effective investments to enhance their own security and potentially to contribute to the resilience of the wider grid.

Fig. 4 Economic value of natural disasters, 1900-2015 (Source: EM-DAT)[10]



Sustainable, low carbon energy

Reducing the carbon intensity of the energy sector is crucial to reducing the rise in greenhouse gas emissions and averting catastrophic climatic change. Many renewable and low carbon technologies are well-suited to deployment at building scale or distribution network scale.

However, the intermittent nature of renewable power requires significant additional control and balancing systems to enable their penetration into the electricity supply at a scale which will achieve the required level of decarbonisation.

Access to energy for all

The IEA estimates that 1.2 billion people, around 17% of the world's population, have no or very limited access to electricity[1] with the majority of this population located in Sub-Saharan Africa and East Asia.

Lack of access to clean, reliable energy imposes enormous constraints on communities' ability to improve livelihoods and grow economies, as economic development is closely linked to energy accessibility.

Emerging trends & opportunities

Rapid technological advancements along with new and improved data and communications systems, consumer engagement strategies and business and financial models, create new opportunities for innovation in the way the sector is operated and expanded.

Technological advancements

Technical advances in renewable generation technology are changing the historic dominance of dependence on conventional fuel sources of energy generation such as coal, petroleum and natural gas. The Levelized Cost of Energy (LCoE)* for renewables is falling steadily, with some technologies achieving parity with fossil fuels depending on location and access (see Fig. 5).

The last decade has seen a rise of hybrid and Electric Vehicles (EV) and most automotive manufactures have at least one EV on their catalogues. Although their uptake has been stimulated by policies to reduce urban air pollution and transport-related Greenhouse Gas (GHG) emissions, these vehicles have batteries that when connected to the grid can act as external and mobile sources of energy storage.

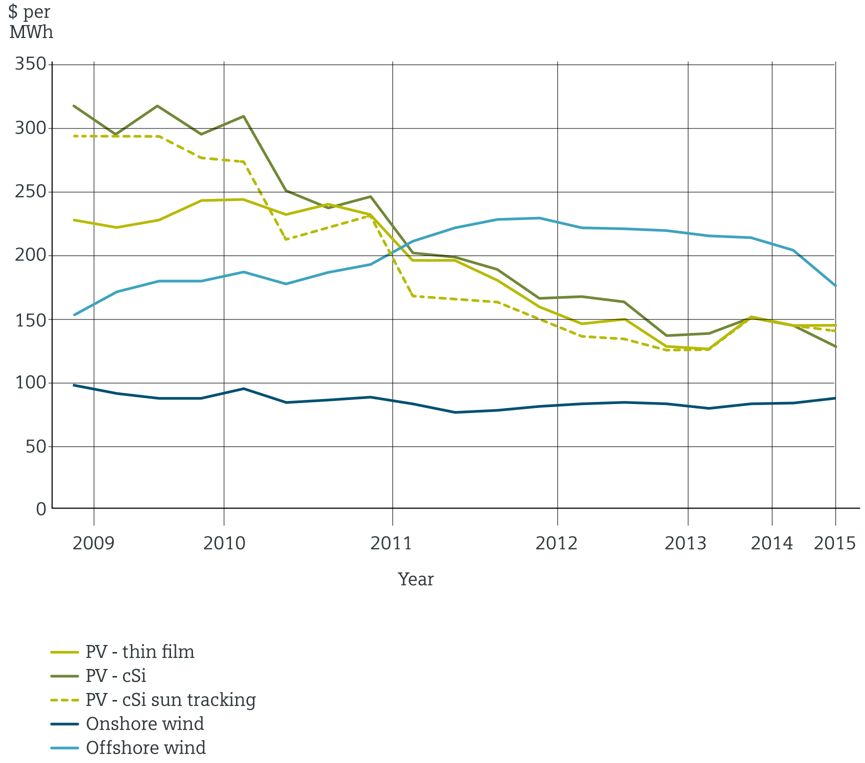
Innovation in data, communication & control

New system control and management technology for building owners such as smart meters and energy efficiency management software are becoming common, giving impetus to consumers to change their behaviours. As the user interface of these systems improve and transaction costs of data acquisition plummet, consumers of all sizes will have the ability to adopt sophisticated energy management strategies.

The application of information and communication technology to the power grid is dramatically increasing the access to real-time data. This information leads to increased understanding of the power system and thus opportunities for system optimization, efficient generation, reduced transmission and distribution losses and demand-side management.

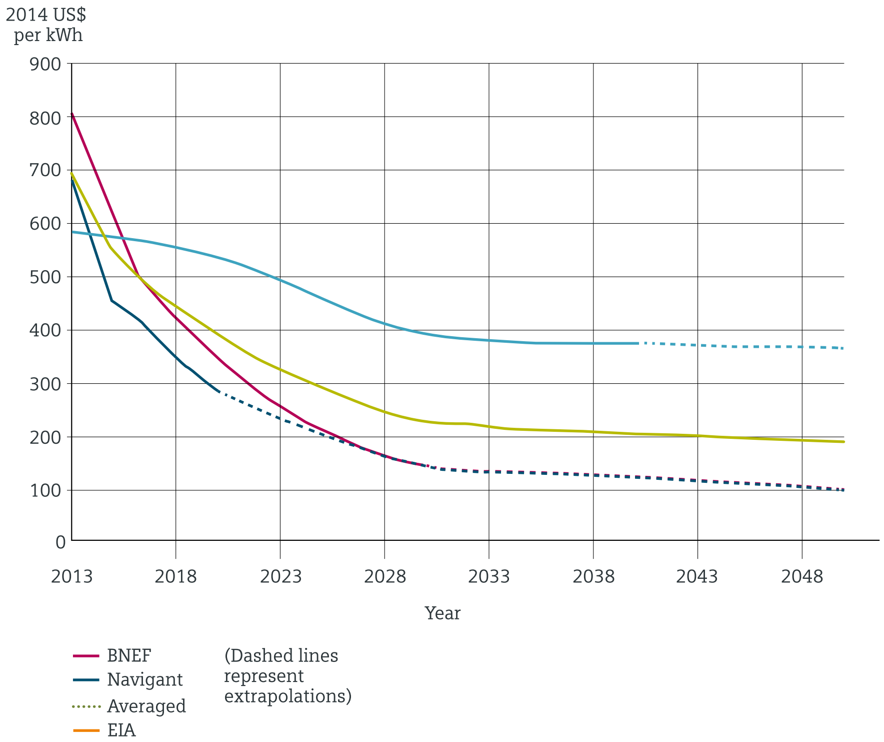
Data management can support system monitoring and fault correction in real time and increase reliability of the system. This capability is paving the way for more deployment of distributed and renewable energy generation.

Fig. 5 Global average Levelized Cost of Energy for Wind and PV (Source: FS-UNEP Collaborating Centre)[11]



*LCoE is a measure of the total cost to build, operate and maintain a generation plant over its lifetime divided by the total energy output over that lifetime.

Fig. 6 Battery price projections (source: Rocky Mountain Institute)[12]



Consumer engagement

The role of the consumer is evolving. The largest and most tech-savvy consumers now expect to have access to more information – more detail, in real-time– and a higher level of transparency. With that information, consumers have the ability to take an active part in managing their own demand.

On the other hand, less active or more time-poor customers may not be able or interested in taking such a role, but they could still gain savings and benefits from smart DES deployment.

New energy service models are beginning to emerge which respond to the needs of these different types of consumers. DES provides the means for these services to be delivered.

Innovative financing

Traditional financing instruments such as bonds and stocks that have been used by capital markets to finance energy generation and network assets are witnessing incremental innovation.The emergence of new technologies presents an opportunity to develop tailored instruments such as “green” bonds and “low carbon” indices.

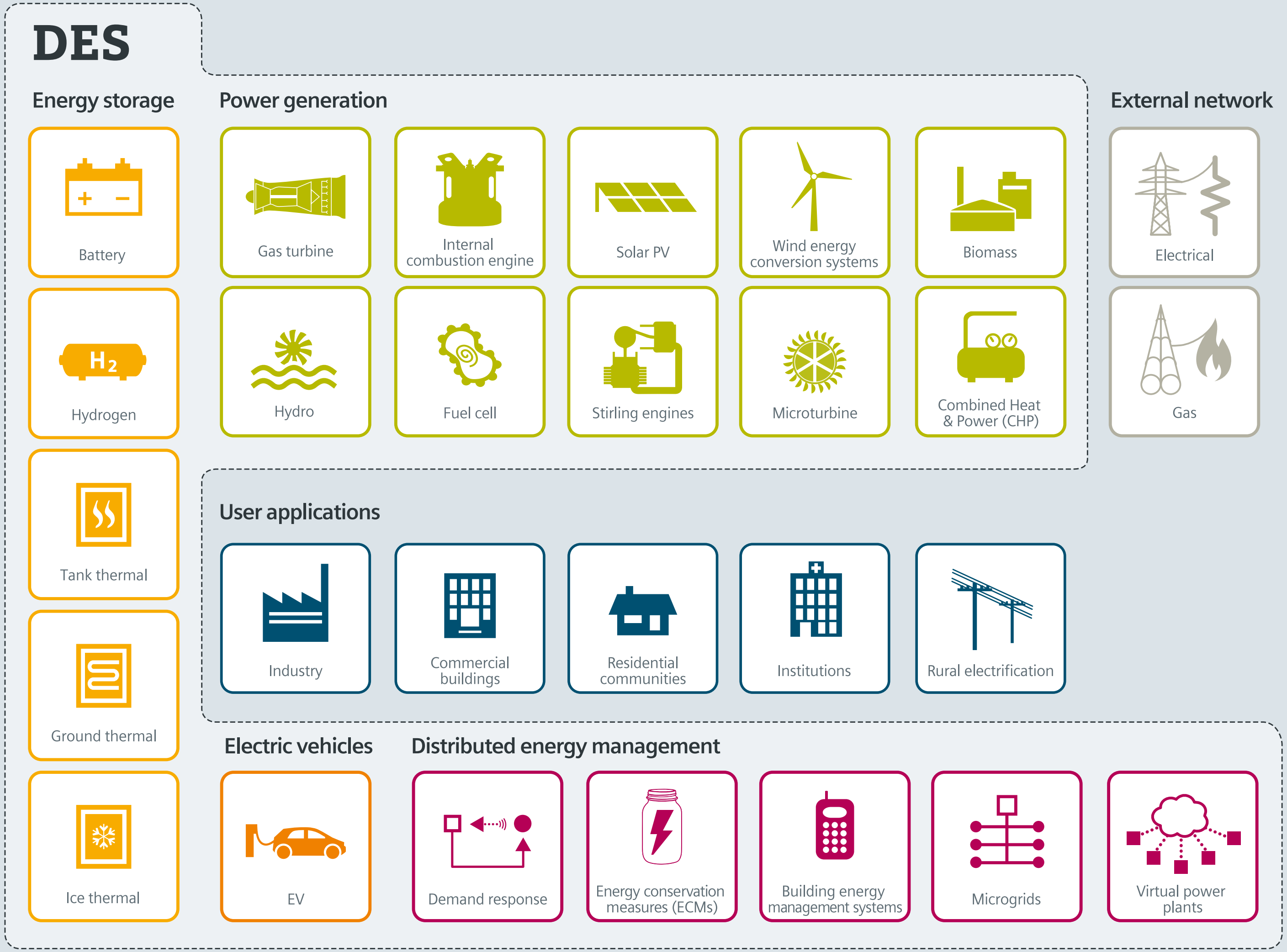
These can not only aid in raising debt and identifying equity based opportunities for institutional investors, but also stimulate the market towards green finance by distributing the inherent risk. In order to increase their uptake in the market, these financial instruments need to balance the transaction costs with an acceptable level of assurance.

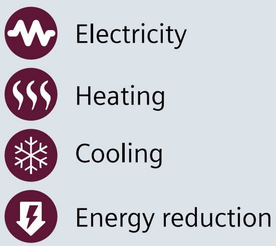
Combining old and new technology, DES solutions carry distinct opportunities and risks which could benefit from these instruments that facilitate global investment.

DES Definition

Distributed Energy Systems (DES) is a term which encompasses a diverse array of generation, storage and energy monitoring and control solutions. DES can be tailored to very specific requirements and users' applications including cost reductions, energy efficiency, security of supply and carbon reduction.

DES categories include: power generation, combined heat and power, energy storage (including electric vehicles) and distributed energy management systems. DES covers energy in the forms of electricity, heating and cooling.





Algonquin College of Applied Arts and Technology

Location: Ottawa, Canada

In January of 2014 Algonquin College, one of the largest institutes in Ontario with 18,000 full-time and 36,000 part-time students, commenced on a journey to become the pioneer in sustainable education. Focusing on reducing the use of electricity, water and gas, the college set up collaborations to push the boundaries of energy efficiency and signed off a $51 million investment over 20 years.

The college incorporated not just renewable generation but also sustainability courses as part of its core curriculum. Various improvements to the campus's water, heating and cooling systems are planned. In addition, the college intends to set up a research facility that targets the reduction of consumer power consumption. These changes have resulted in substantial cost saving, $3.7 million in annual operating costs, all while making the campus greener. Today, it stands as an example and a catalyst for educational institutions all over the world.[13]

DES Applications

Commercial Buildings

› DES find natural applications to address the various requirements of commercial customers. Targeting cost reduction while satisfying primary business needs is fundamental for commercial buildings such as offices, hotels and supermarkets.

› Data centres and banking sector particularly value business continuity.

› Energy efficiency adds value to real estate property portfolios.

Industrial Plants

› Manufacturing plants generally work around the clock to maximize productivity. A disruption in their activity results in financial loss.

› DES can offer continuity and reliability for large manufacturers while at the same time improving efficiency and reducing costs.

› Combined heat and power generation is an effective DES application where heating is required by industrial processes.

Residential Communities

› Residential developments, especially when part of mixed use developments, represent an important application for DES.

› Immediate benefits include energy security and reduction in utility bills for the residents.

Institutions

› Specialized campuses such as universities, hospitals and schools are implementing a range of DES technologies; from CHP with thermal storage to high-tech microgrids.

› Universities are among the first to invest in emerging technologies and act as centres for future development.

› Energy savings, cost reduction and sustainability are the key drivers.

Rural Electrification

› Off-grid electrification, especially in rural areas in fast-growing economies like India, is a significant market for DES.

› In the absence of a grid connection, communities usually rely on expensive and unsustainable fossil fuels to generate electricity.

› Harvesting local, green energy resources such as solar and wind power, DES in rural areas provides energy access and acts as an enabler of economic growth.

Why Distributed Energy Systems?

Cost savings

DES can be customized to match the consumer's requirements as well as enabling actors to shape local generation and consumption in response to market price signals to achieve the lowest overall cost of energy. For example a building with embedded generation and storage can implement a dynamic management regime: when network demand is low and the price falls, local generation can be switched off and energy can be taken from the grid for use and local storage. When there are peaks in network demand, the owner can reduce load, switch on local generation and earn income from higher value sales to the grid.

Energy efficiency

DES coupled with other traditional energy conservation measures can improve system efficiency. Integrated real time data monitoring and multipoint controls at both building, plant and network level can improve asset utilisation and plant efficiency and ensure power, cooling, heating and lighting are used only when and where they are needed.

Emissions and pollution reduction

DES includes renewable and low carbon technologies and controls which enable the integration of such technologies into the network and reduction in the carbon intensity and local environmental impact of the system. At a local level, poor air quality can proliferate acute public health problems. The continuing reliance on fossil fuels for energy generation is one of the leading causes of significant air quality issues. DES that relies on clean energy generation, or hybrid systems, have a reduced impact on air quality and help maintain a greener and cleaner ecosystem.

Building development consents and permits

Developers in many cities face stringent sustainable development standards when seeking permission for new development. Integrating DES into building designs can help achieve their energy efficiency, air quality and carbon emissions targets more cost effectively. The enhanced system controls which form part of the DES installation would also help in reducing the typical "performance gap" between the modelled building and the actual building in use.

Security and stability of supply

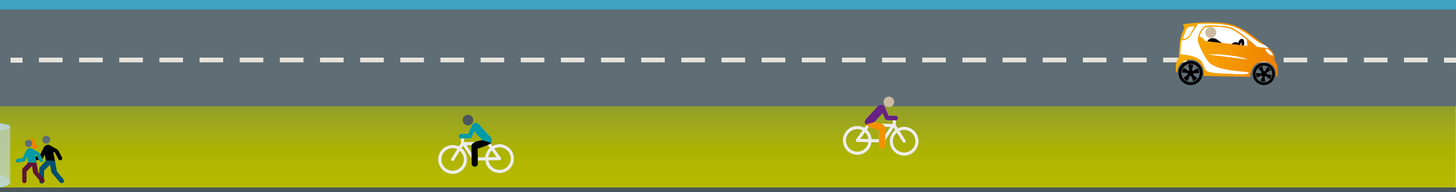
Local, decentralized and controllable DES generation and storage sources can be designed to provide the end user with local resilience or even full independence from the grid. The benefits accrue to grid operators as well: DES can manage demand to reduce peak loads and maintain power quality when infrastructure is nearing capacity, avoiding the risk of blackouts and postponing the need for major grid reinforcement investments.

Resilience for cities and communities

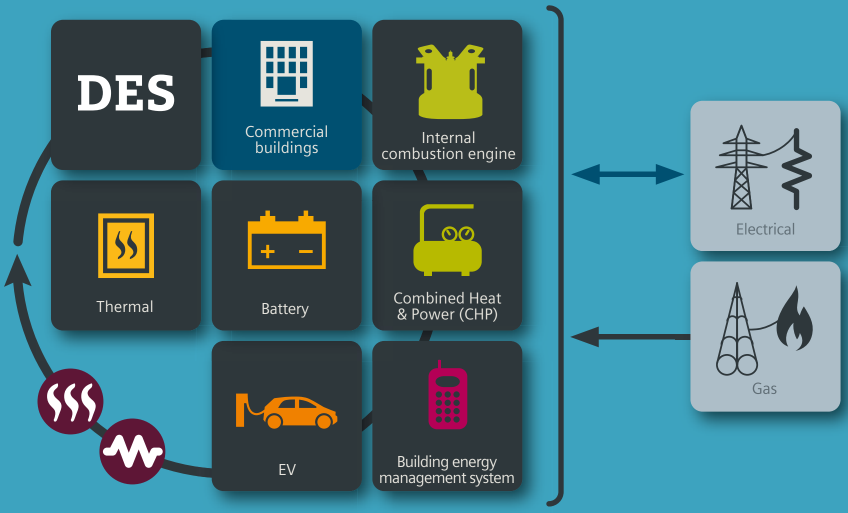
Rapid population growth is driving urbanization of increasingly dense cities with large energy demands. These trends coupled with large scale environmental changes make cities a priority for increased resilience to shock events. DES are a potential solution to this problem as energy could be stored in small pockets within the affected areas.

Extended access to electrification

Independent DES solutions can be deployed completely off-grid in areas where the grid expansion is not economically viable. Off-grid electrification enables economic development. Off-grid microgrids can "pump prime" economic growth, with full grid extension and connection taking place at a later stage, when the initial growth has reduced the grid investment risk profile.



Smart Energy Building



CO_2 8% emissions reduction

cost saving /year 8%

ROI 7 years

Savings of costs and CO_2 emissions under different DES investment scenarios compared to business as usual

Total savings (%)	Total annual energy costs (US million $)	Investment scenario	Total CO_2 emissions (1,000 t)	Total CO_2 savings (%)
	2.87	Business as usual	3.87	
8	2.64	Cost-minimization	3.57	8
-13	3.25	Emissions-minimization	3.20	17
4	2.75	Balanced (50% costs and 50% emissions)	3.48	10

Smart Energy Building

A smart energy building is able to integrate and optimize both electrical and mechanical plants in order to lower energy costs, reduce carbon emissions and improve efficiency. In combination, this can increase the value of the property.

DES are at the heart of a smart energy building.

Location:
Freiburg, Germany

DES user application:
Commercial building

System description:
Multi-tenant commercial office

DES benefits:
Cost savings, energy efficiency, emissions reduction

DES fast facts:

1000 kW internal combustion engine
250 kW CHP unit
360 kWh electrical stationary batteries
27 EV charging points
2720 kWh thermal energy storage
BEMS Building Energy Management System

DES Financial Investment

The DES portfolio can be selected to achieve lowest annualized energy costs or to optimize a balance of cost and other environmental or security performance objectives.

Business as usual: building fully grid and gas-supplied, central mechanical plant to supply heating and cooling demand;

Cost minimization: The DES portfolio is selected in order to minimize the Levelized Cost of Energy (LCoE).

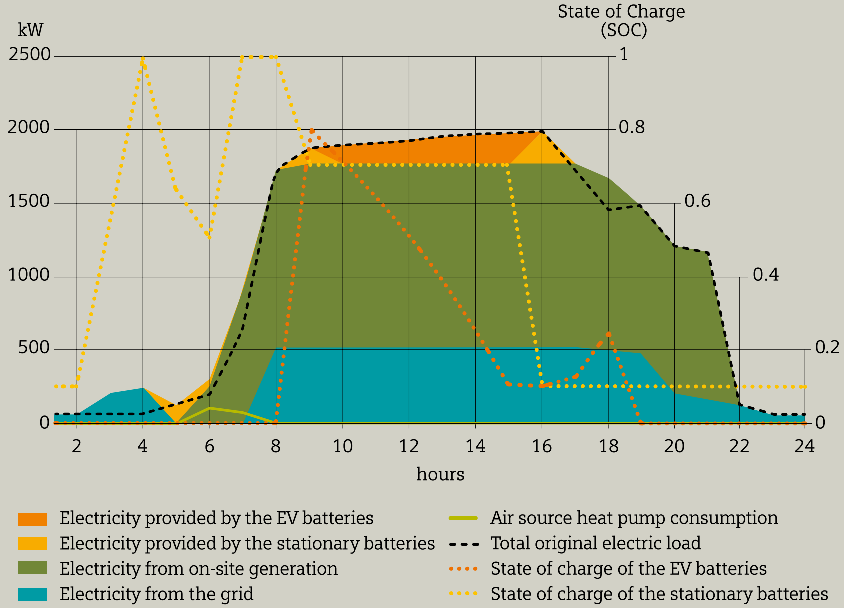
CO_2 minimization: The DES portfolio is selected in order to minimize the total produced building carbon emissions.

Balanced: The DES portfolio is selected by combining carbon and costs targets in a 50-50 proportion.

Every portfolio option leads to net cost savings compared to a 100% grid-supplied "business as usual" (BAU) case, but savings are reduced when more ambitious CO_2 reduction targets are used. Results do not take account of any CO_2 pricing policies, which could improve the financial performance of lower emissions scenarios.

Typical daily building power demand and on-site generation management under the DES Cost minimization scenario.

The BEMS meets the building's load profile while achieving cost minimization through control of on-site generation and batteries (including EV batteries) in response to changing price signals from the grid.



2 DES Technology Solutions

The DES term encompasses a diverse array of generation technologies and energy monitoring and control solutions. These systems can be tailored to very specific requirements and applications, supporting end consumer goals for cost reduction, efficiency and energy security.

Overview

DES generation and storage technologies are small in size compared with large power plants, not centrally controlled and not centrally planned. They are designed to provide local electricity and thermal energy. They include renewable energy technologies such as PV arrays and wind turbines; fossil fuel based systems such as gas turbines and diesel engines; and energy storage devices.

DES controls and performance solutions are designed and implemented to deliver more efficient use of the electricity system, reduce electricity-related costs and integrate local generation and storage technologies. They range from Building Energy Management System (BEMS) to demand response and microgrid control architecture.

Deployment of distributed generation is rising sharply. For example, in the U.S. the amount of DES, particularly solar PV, has risen sharply over the past few years. As of 2011, 4 GW of PV generation capacity had been installed[14] with an annual growth rate of 22% predicted to last up to 2020.[15]

Globally, distribution level generation capacity is expected to double over a ten year period, from 87GW in 2014 to 166GW in 2023.[4]

Technology maturity and commercialisation readiness of DES varies widely; some technologies like internal combustion engines are more than 150 years old, while others, like grid-support applications from electric vehicles, are at pilot implementation.

Distributed generation capacity is expected to increase[4]

2014
87GW

2023
166GW

Table 1 Types of distributed power generation

Technology	Renewable	Dispatchable	Heat and power
Gas turbine	✘	✔	✔
Internal combustion engine	✘	✔	✔
Solar PV	✔	✘	✘
Wind energy conversion systems	✔	✘	✘
Hydro	✔	✔	✘
Biomass	✔	✔	✔
Fuel cel	✘	✔	✔

Power Generation

Smaller in scale and not centrally dispatched, distributed power generators are a fundamental building block of DES. By empowering end users with the capability of planning, installing and generating electricity when and where needed, distributed generators are challenging traditional centralized power production.

DES generation technologies available on the market range from traditional power sources based on fossil fuels such as internal combustion engines and gas turbines to technologies based on renewable energy such as PV systems, wind turbines and biomass.

Synchronous generators are typically used by turbines, engines, and biomass plants. Induction generators are extensively used in wind farms while power electronic converters are used to interface PV systems, fuel cells and microturbines.

Fuel cells bring additional flexibility as they can be operated to generate power or store energy in the form of hydrogen. Also they can be used in combined heat and power applications.

Other DES generation characteristics to consider are dispatchability; grid connection versus islanded operation and the potential for combined heat an power, or cogeneration (discussed in the next section).

A power generator is dispatchable when it is capable of producing, at any given time, a set amount of power whose magnitude and duration can vary depending on the load.

In a diesel generator the governor regulates the amount of injected fuel to match power output to a varying load. On the contrary, the power output from a PV system is highly dependent on the solar source availability and therefore it cannot match a varying load unless coupled with some form of storage.

DES generators are usually connected to the main grid and follow the imposed voltage and frequency reference. However they can also be controlled to operate islanded from the grid if required.

Combined Heat and Power

Combined Heat and Power (CHP), or cogeneration, is an efficient way of using fossil fuels and biomass to provide energy needs for mixed use and industrial developments.

CHP typically uses natural gas in an engine or turbine (but can also include other fuels and technologies such as biomass and fuel cells) to provide local electricity generation, and to capture the heat rejected from the plant for building space heating and hot water, or for process heat in manufacturing and engineering operations.

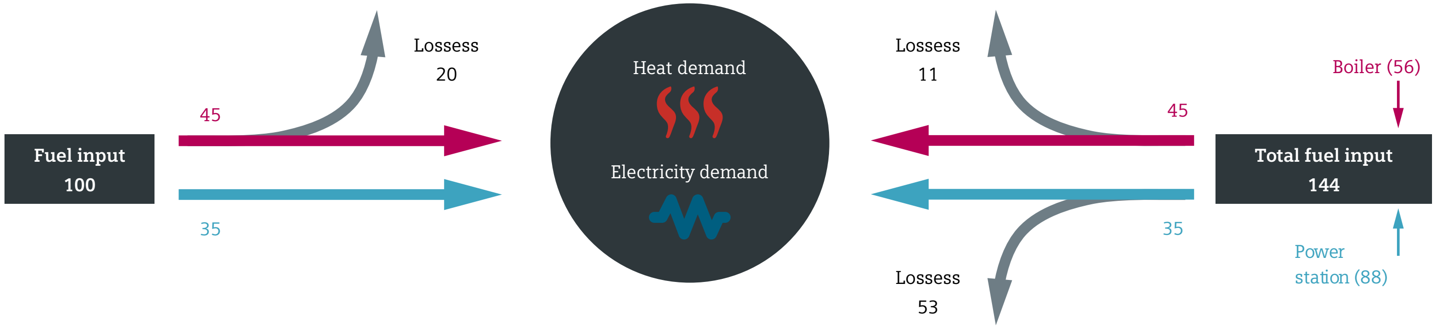
Because CHP uses the heat that would otherwise be rejected in traditional generation of electric and thermal energy, the total efficiency of these integrated systems is much higher when compared to separate systems.

CHP systems can reach an efficiency of more than 80% compared with around 35% of conventional power plants[16] see Figure below. This increased efficiency results in both lower net fuel consumption and reduced carbon emissions.

The thermal energy recovered can also be used for cooling purposes (absorption chillers which use heat as the primary mechanical energy source). Integration of cooling with a CHP – also called tri-generation – can provide seasonal balancing to allow CHP systems to run throughout the year. This increases system utilization and return on the initial capital investment.

CHP can also operate as a backup/emergency generator, thus improving system resilience and on-site energy security.

Fig 7 Efficiency of Combined Heat and Power generation



“Modern district energy systems could result in a **7** per cent reduction in overall capital investment in the power sector by **2030** - an investment saving of **$795 billion**”[7]

©Joe Mabel, Wikimedia Commons

University smart heating

Location: **Middletown, CT, U.S.**

Wesleyan University is a premier liberal arts college, with approximately 3,000 students, and comprising 307 buildings on 370 acres.

Following the massive storm that hit the Northeastern US in 2011, plus the aftermath of Hurricane Sandy wherein the university experienced severe power and heat outages, the estates team developed a plan to prevent similar power outages in the future. The university decided to take advantage of a Connecticut program which provides grants to organizations in the state that invest in microgrid or distributed generation projects. Wesleyan University was the first in the state to be approved for a microgrid project and was the only applicant that proposed a Combined Heat and Power (CHP) solution.

The new installed CHP plant was commissioned in March 2014 to serve the university athletic facility by providing heating with on-site power generation. The installed 676 kW gas engine is saving the university an average of $1,000 a day from lower gas and electricity usage.[18]

Energy Storage

Energy Storage offers a variety of benefits to consumers, depending on the investment driver.

Storage provides the ability to smooth peaks in demand and gives the consumer flexibility to allow for price responsive energy consumption.

It integrates intermittent renewable generation by storing excess energy when above grid capacity and releasing it at times of low production. By avoiding wasteful curtailments of renewable energy, energy outputs are maximized while contributing to further reducing carbon emissions.

Storage provides back up power supply in the event of loss of power.

Similarly, thermal storage can improve system efficiency by running Heating, Ventilation and Air Conditioning (HVAC) systems at optimal capacity and providing a buffer between heating supply and demand.

Different Storage for Different Needs

DES storage technologies range from electrical batteries, to thermal and ice stores. Electric Vehicles (EVs) are also a form of very decentralized, small scale storage.

Today, electricity storage ranges from the traditional batteries to the fast acting flywheels used to improve power quality by smoothing fluctuation in power supply. Other technologies such as flow batteries are suited for long output durations.

Thermal storage is a simple but fundamental technology which is commonly adopted in buildings and industrial processes where thermal energy can make up to half of the total energy consumed.[19]

Ice storage is quickly gaining popularity as an efficient way of cooling buildings while avoiding day-time premium electricity prices.

Hydrogen storage coupled with fuel cells offer the opportunity to store excess energy (compared to local demand) and to release it when required.

Storage and System Multi Energy Flows

Different in technology, size and energy medium stored (i.e. electricity, heat, cold), storage systems can be controlled together as the key energy buffer in the multiple energy flows experienced in systems such as buildings and process manufacturing.

Electric Vehicles

Road transport energy is almost entirely supplied by liquid fuels, but EVs are beginning to penetrate the market. This is due to a mix of pull factors, including improving vehicle design and battery performance and falling prices, and push factors, including policy support for EVs and restrictions on other vehicles to improve air quality. A few countries such as the UK, US, Canada, China, Japan, Germany and Norway have signed up to be a part of the Electric Vehicle Initiative (EVI). According to the IEA 95% of the global EV stock is present in the EVI countries.[20] Currently, EVs represent about 0.08% of total passengers cars in the world, however, looking forward recent research claims that by 2040, 35% of the new cars worldwide would have a plug.[21]

From a grid point of view, such growth could significantly increase total consumption and alter load profiles, especially in localized areas within distribution networks. Robust and sophisticated distributed energy control solutions offer the potential to manage the impacts of this transition and to capture its potential benefits.

EVs, including hybrid electric vehicles which can be plugged-in (PHEVs), act as very small distributed and mobile storage. The default situation is for the built-in batteries to begin charging as soon as they are plugged into the charging points, so the vehicle is fully charged as soon as possible. From a DES point of view, there would be value in controlling the timing and rate of recharge to smooth load demand or ease grid congestion at peak times, and even to make use of EVs as sources of energy. The value is amplified if the DES aggregates the collective capacity of many EV batteries and controls it as a single entity. These EVs can also support individual residential consumers during power outages.

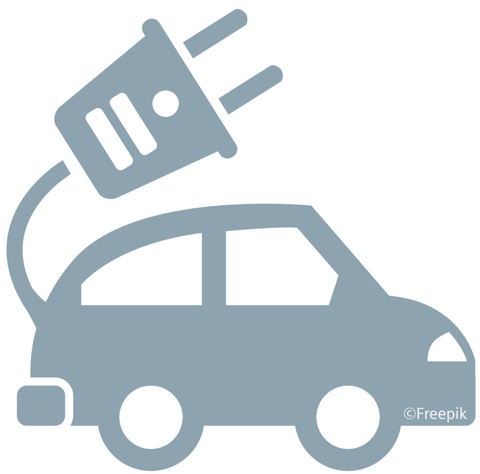
The scale of application of EVs in controlling load demand and being responsive the grid signals depends on numbers (e.g large car park), where the EV charging points are located and the associated controls (e.g. local or system wide).

Vehicle or fleet owner participation could be incentivized through pricing strategies, such as offering a lower unit price of energy if the owner committed to a defined dwell time at the charging point.

A system-wide application for EVs is the Vehicle- To-Grid (V2G) concept by which the charging and discharging of batteries for a large number of vehicles is centrally coordinated in order to provide specific services to the grid (e.g. capacity- and energy-based ancillary services including frequency regulation).

The recently completed European Union funded EDISON* project looked into the opportunities to use EVs to even out the unpredictable intermittency of power generation from wind farms. The project found that the best way forward would be to implement a virtual power plant that controls and manages the various DES and grid stakeholders.[22]

Although V2G implementation is in its infancy, it has been predicted that the V2G worldwide annual revenue will grow from $900,000 in 2013 to $190m by 2022.[23]



*EDISON stands for "Electric vehicles in a Distributed and Integrated market using Sustainable energy and Open Networks"

V2G worldwide revenue has been predicted to grow from the current **$900,000** to **$190m** by **2022**[23]

Integration of renewable energy systems

Location: Germany

Germany has an ambitious energy transformation ("Energiewende") target to meet 80% of its energy needs from renewable sources by 2050. Increasing the penetration of renewable generation into the existing grid requires innovative, intelligent solutions to balance intermittent power generation and consumption while distributing electricity to the final consumer.

In 2014, a European Union funded, three-year project entitled IREN2* was launched to test the technical and economic viability of distributed energy systems. Building on the success of the previous pilot project IRENE** which was implemented in the Bavarian town of Wildpoldsried, the project brings together a consortium of leading academic and industrial manufacturing experts.

One of the goals of the project is to develop microgrids for low and medium voltages, with particular focus on control systems, improving resilience (and system black start) and microgrid management. Development of robust and cost-effective management and control systems is vital to ensure the economic viability of both off-grid systems and grid-connected microgrids.[24,25]

The life of hybrids

Hybridization is the concept of integrating together two or more DES technologies to improve the overall system performance and achieve or enhance specific functionalities.

Advanced power converters with smart control architectures and some form of energy storage are the building blocks of hybrid systems.

A basic hybrid system might combine PV panels with batteries for storing surplus electricity for use later when the consumer needs it. The same system can be used to relieve the impact on weak distribution networks, specifically in rural areas.

Coupling of batteries to a diesel generator can result in system efficiency as high as 70%.[26] The batteries are capable of leveling the load demand during the day by storing and releasing power. As a result the generator can operate at higher efficiency (which is a function of the power produced).

A wind park coupled with fuel cells and hydrogen storage can mitigate the fluctuations in power generation from the wind but also limit the maximum export power in case of capacity constraints in the existing network.

Hybridization is implemented not just to improve the efficiency and stabilise the outputs but also to add extra functionality to the entire system. One such example is the capability of supporting start up of power plants from a cold state (referred to as "black starts") by integrating batteries into existing power plants. Such a solution improves the security of supply to the end consumer without requiring a complete plant upgrade.

In rural electrification and in the absence of grid connection, hybrid systems combining a mix of renewable and fossil fuel generation offer the end consumer the potential of a reduction on the levelized cost of energy and improved air quality.

* IREN2 stands for "future viable networks for Integration of RENewable Energy systems"

** IRENE stands for "Integration of Renewable ENergies and E-mobility"

Gardena manufacturing facility

Location: Ulm, Germany

Power demand management is increasingly important for industry because load peaks in production can be very expensive.

The Gardena Manufacturing facility which produces 500 million plastic parts a year in southern Germany is a prime example of peak load management. This facility, on average, requires 2 to 2.3MW of energy. However, when the machinery is restarted in unison after a short break, the power demand suddenly rises to 3.2MW.

In order to manage this power spike, nine monitoring devices to measure voltage, current and power were installed. This, coupled with the latest load management technology, monitors the average power use of the facility every fifteen minutes (which is the time span over which the utility company monitors the average used power) and caps it to a maximum of 2.86 MW. This is achieved with the use of a controller that scales back the power demand gradually in 200 kW stages.

The installed load management system has paid for itself within a year.[27]

Distributed Energy Management

Distributed Energy Management (DEM) is defined as a set of protocols and systems which monitor and control energy generation and consumption within a facility or building. DEM systems can deliver a range of benefits, including plant optimization, energy efficiency, energy cost savings and additional revenue from export of surplus energy to the grid.

Targeting Energy Efficiency

Energy conservation is achieved by first reducing consumption through passive design (taking advantage of solar energy for heating and cooling to maintain a comfortable temperature), then by introducing energy efficient technologies such as LED and variable speed drives on motors and ultimately by producing energy locally from renewable energy sources.

Energy Conservation Measures (ECMs) is a definition which collects all the above design approaches and technologies to reduce the energy usage.

Delivering Energy Efficiency

An efficient system is anything that uses fewer resources to deliver a certain volume of energy. This broad definition includes both an engineering perspective (i.e. how much fuel required to deliver an amount of useful energy to the end user) and an economic concept which looks at the overall resources going into the system including capital.

Achieving efficiency can release resources and reduce costs associated with fuel and electricity. Energy efficiency is a vital step that industry, businesses and building facilities take and it is often the first step towards sustainability and lower carbon emissions targets.

Energy Efficiency and Industry

At industrial and manufacturing level, energy conservation, reduction and usage shifting is key to reducing electricity prices. Lower bills result in lower cost of produced goods and therefore increased competitiveness.

Efficiency can be obtained in a number of ways from installing or upgrading equipment, to monitoring the energy usage of industrial processes and optimising them.

Typical industry ECMs to improve efficiency include:

- Waste heat recovery
- Intelligent load management
- Energy efficient automation and drive technologies
- Process automation and optimization

Table 2 Energy Conservation Measures (ECMs)

Envelope	The building envelope is the interface between the indoor and outdoor environments. A properly designed envelope helps to maintain the desired indoor conditions and may permit the use of natural ventilation, passive heating, and daylighting.
Materials	Materials selected for sustainable buildings should have appropriate performance, durability and environmental properties. Material selection can affect issues ranging from consumption of natural resources to occupant comfort and health.
Water	Responsibilities and opportunities exist with all water that passes through a building and site. Economic and environmental indicators tend to favor systems which work with the natural hydrological-cycle.
Lighting	The first principle of low energy lighting design is to make as much use as possible of natural light. Switching lighting units to LED lighting is often the easiest and most cost effective measure available to a building. Motion sensors and timers, and variable level lighting can reduce energy and extend equipment life even further.
Passive	A passive system uses the building characteristics to mitigate negative effects of the external environment or to enhance the internal environment. Systems do not generally have controls so trade-offs are made between desirable outcomes for different seasons.
Active	Active systems involve energy input to modify and control the building environment. Active ECMs tend to focus on changes to building mechanical, electrical and public health systems.
Operations	Better operation and control of building energy management system can yield significant energy and cost savings, sometimes without any investment in plant or equipment. Building energy management systems can be programed to optimize building systems to achieve energy and cost savings or to balance these objectives with other performance requirements.

Energy Efficiency and Buildings

At building level there are many opportunities for developers, owners and facility managers to cut costs by reducing energy consumption.

Typical ECMs in buildings include:

- Installation of efficient Light Emitting Diode (LED) lighting
- Intelligent lighting control
- Building Energy Management System
- Smart metering and informed consumers
- High efficiency motors with Variable Speed Drives (VSD)

Building Energy Management System

The Building Energy Management System (BEMS) is the key enabler in buildings for improving the energy efficiency and at the same time integrating the various DES technologies. A BEMS is a computer-based system that controls and monitors the energy-consuming equipment within a building such as HVAC plant and lighting. Solutions characterized by a BEMS allow to direct both automated and manual improvements to system operations by extending the capabilities of sensing, control, and automation hardware.

According to the DOE "Better Plants Programme", energy efficiency has saved large manufacturers in the United States an estimated **$2.4 billion** in energy costs by **2014**, and could generate over **$11 billion** in annual energy savings by **2020**[28]

Smart Green Tower

Location: Freiburg, Germany

Born from a collaboration between Frey architects, Fraunhofer Institut, Siemens AG and power supplier Badenova, the Smart Green Tower is a new mixed use residential and commercial building designed to challenge the conventional paradigm of buildings as passive energy users.

The 16,000m² tower aims not only to generate its own electricity but also to feed excess renewable energy back into the grid. The design incorporates PV generation, energy storage, grid peak load control and energy monitoring with the aim of reducing energy costs and carbon emissions without sacrificing occupants' comfort.[29]

Demand Response

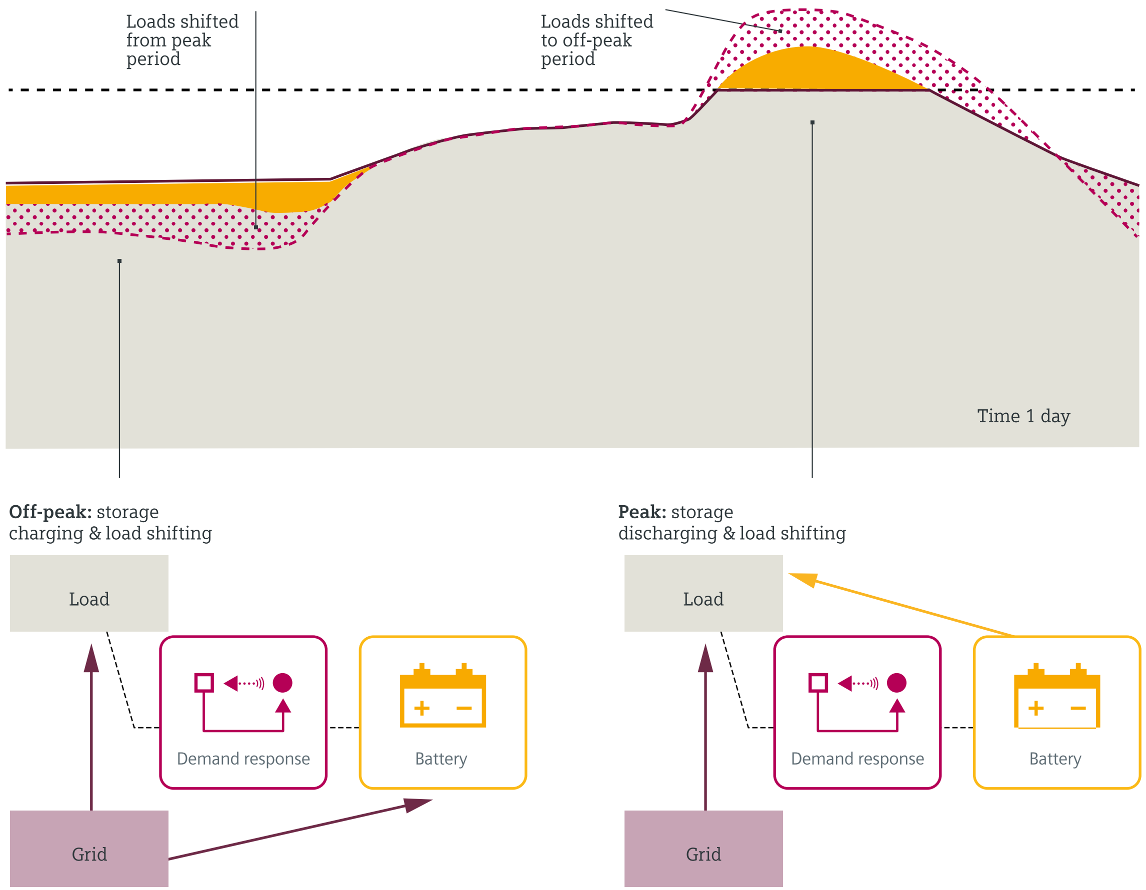
Demand Response (DR) is a methodology which aims at modifying final users' power consumption through different approaches, including direct load control, operation of storage devices and financial incentives.

Although DR can result in an overall reduction of power consumption (through better informed consumers) here, what is meant by DR is the shifting, re-distributing and levelling of load demand profiles over a time period (usually within a 24 hour period or less).

DR brings a number of advantages to both end consumers and grid operators. By introducing flexibility in the load demand, the building or facility can be responsive to electricity prices and therefore avoiding paying a premium. At network level, DR facilitates the integration of more renewable intermittent power sources, eases network congestion, reduces reserve capacity and therefore increases grid efficiency and reduction in carbon emissions.

For a typical commercial building, opportunities around DR would include controlling large mechanical loads (i.e. the chillers). Storage, both electrical and thermal, could provide additional financial return. Also, in the event the future tenants' space provision is not utilized, additional local distributed generators or batteries could be installed.

Fig. 8 Demand response can control loads to reduce peaks



Isle of Eigg community microgrid

Location: Eigg, Scotland, U.K.

The Isle of Eigg is part of the Scottish Hebrides archipelago. Until 2008, electricity on the small island (which is not connected to mainland grid) was supplied through small diesel generators and a few micro-hydroelectric generators. Started in 2004 and successfully completed in 2008, The Isle of Eigg Electrification Project is a pioneer example of modular flexible microgrid architecture which is designed to allow for generation expansion and load growth. The microgrid incorporates wind, PV, hydro, batteries, and diesel generators, plus load management (including visual "traffic lights" energy monitors at consumers' premises). A passive droop control operating strategy manages the batteries as well as heating public buildings when there is an excess of energy produced. Financing through a number of private, government, and non-government sources has allowed for active community involvement since project inception, as well as increased environmental awareness and led to a reduction in utility costs for the residents, creating a fertile ground for many other sustainable initiatives.[30]

Virtual Power Plants

By definition a DES is a relatively small, localized and distributed system. A Virtual Power Plant (VPP) is a collection of DES sources which are operated, controlled and dispatched as a single entity. The VPP is "virtual" because the system is an heterogeneous collection of various DESs including different technologies, sizes and geographical locations. The VPP is a "power plant" because the collection of DESs is aggregated to the scale of power plant.

The core of the VPP is an energy management control system based on real time data and forecasts. The energy management is capable of optimally dispatching the generation and storage portfolio in the VPP in order to achieve specific goals such as revenue maximization, reduction in carbon emission and system reliability. The energy management can also implement demand response and is designed to ease the integration into energy markets.

University Campus of Savona

Location: Genoa, Italy

The University of Genoa is running the "Energia 2020" project which involves the development of a microgrid in the Savona Campus. The project has various goals including improving energy efficiency, reducing emissions, smart energy management and renewable generation. The microgrid incorporates a number of DES technologies including gas micro-turbines, solar power plant and PV installation. Load demand is managed through two thermal storage buffers, electric batteries and four electric vehicle charging stations.

The heart of the microgrid is the intelligent energy management system which monitors the entire system, forecasts energy demand and power produced from renewable sources. The university's investment not only delivers energy cost savings but also spreads sustainability awareness amongst the university's students.[31]

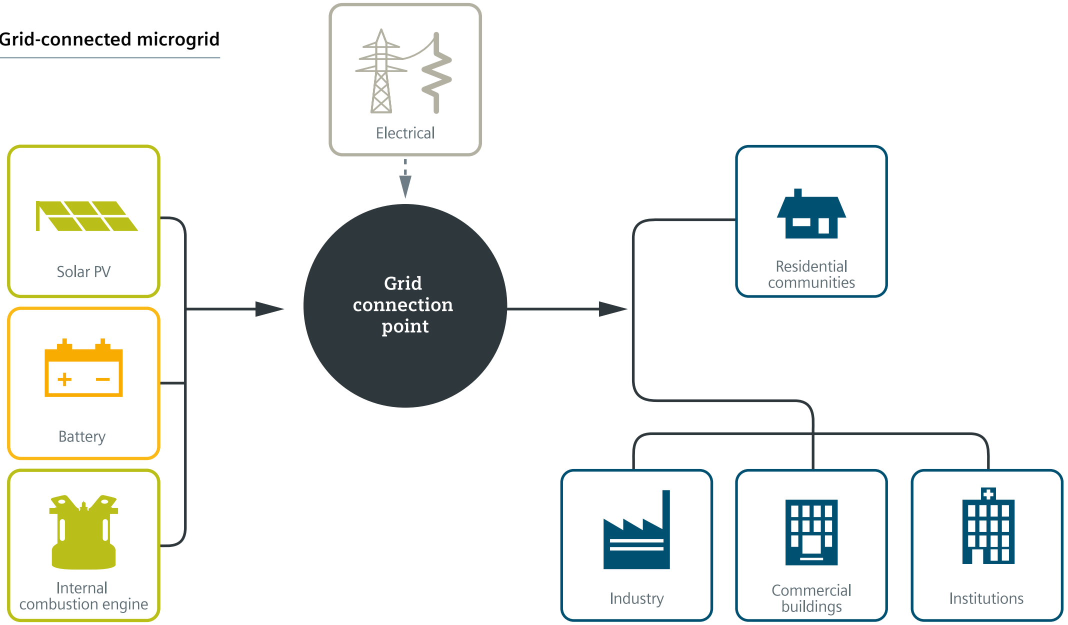
Microgrids

A microgrid is a cluster of loads and distributed sources (including generation and storage) capable of operation as a single controllable unit. Usually a microgrid is a small part of the medium voltage or low voltage distribution network where the power is supplied by DES technologies.

A microgrid can be connected to the main grid or can be off-grid. When connected, it imports or exports any deficit or surplus of power from or to the grid. Depending on the requirements of the end consumers, a grid-connected microgrid is also capable of disconnection from the main grid and operation in island mode.

The simplest, oldest and most common type of microgrid is a system formed by the load user connected to a back-up diesel generator. Modern microgrids are designed to address the specific needs of consumers, whether basic additional power provision is required (e.g. off-grid rural electrification) or whether reliability and quality of power are required (e.g. power supply to mission critical facilities).

Fig. 9 Grid-connected microgrid



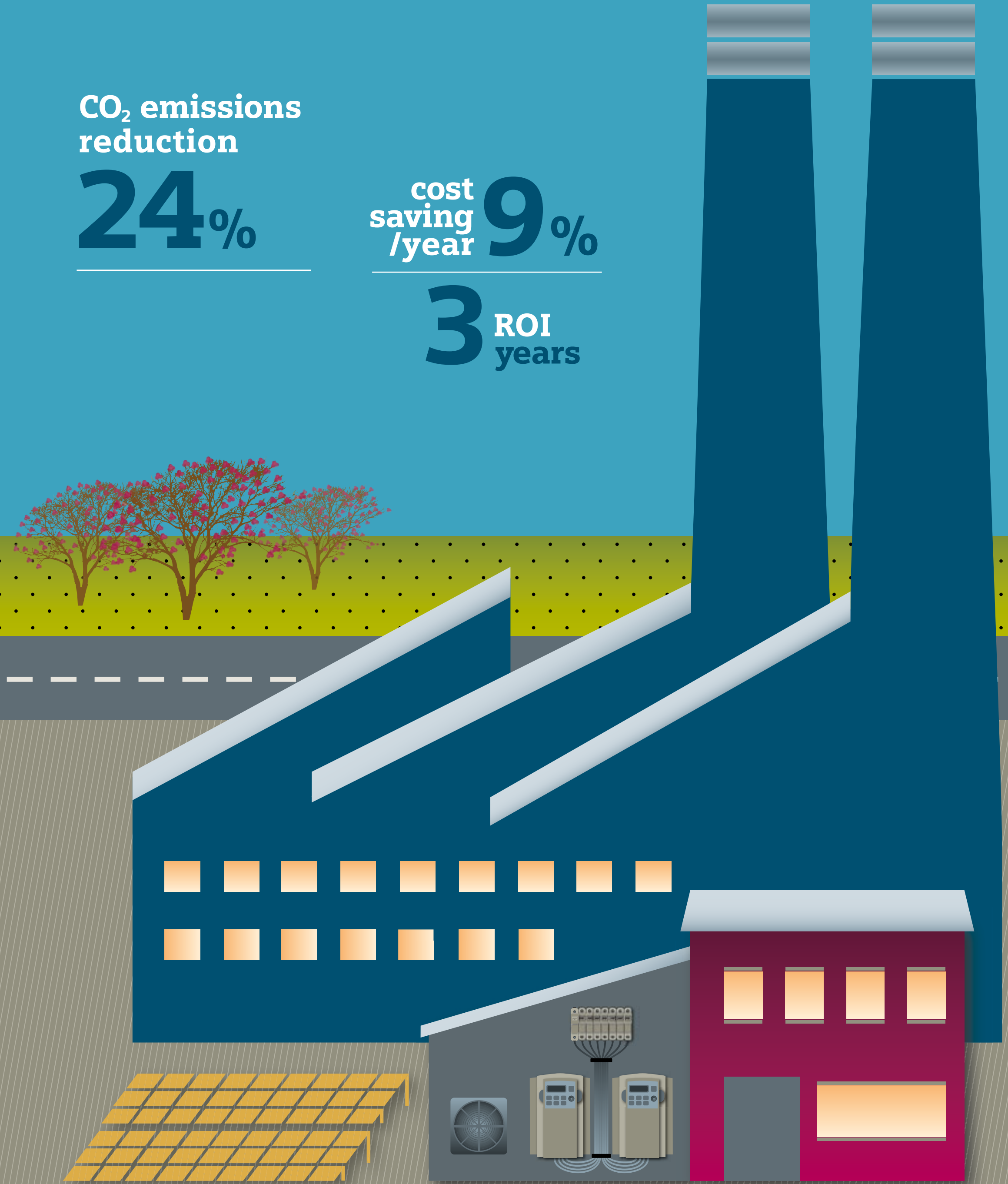
CO_2 emissions reduction

24%

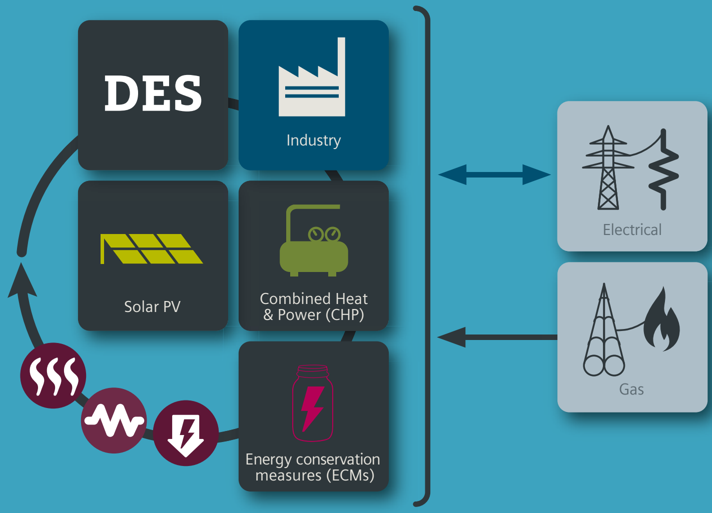
cost saving /year

9%

3 ROI years



Production Facility ECMs



	Energy Conservation Measure (ECM)	% Energy savings	Annual savings (1000 US$)	Simple payback (years)	CO_2 Savings (1000kgCO_2/year)
Demand side	Energy Efficient LED Lighting	8.0%	121	<1	684
Demand side	VFDs on chillers and AHUs (HVAC)	1.5%	21.1	<1	117
Demand side	Heat Recovery Wheel (HVAC)	0.5%	2.30	3.7	8.93
Demand side	Reflective white roof	0.1%	3.50	<1	22
Supply side	Combined Heat & Power (CHP)	N/A	26	8.3	313
Supply side	Solar Photovoltaic (PVs)	N/A	56.5	6.9	235
	Combined/ Cumulative *	8.9%	213	3.4	1.277

*Cumulative energy model run for demand side ECMs 1-4 with supply side ECMs 5 and 6 added on

Production Facility Energy Conservation Measures

CASE STUDY

Reducing energy costs is fundamental for the manufacturing industry in order to remain competitive with production in countries where energy is cheaper. DES generation and storage technologies can be integrated with other Energy Conservation Measures (ECMs) to enable manufacturing to achieve cost reductions while at the same time working towards sustainability goals.

Location:
Beijing, China

DES user application:
Industrial plant

System description:
24/7 production facility including office space

DES benefits:
Cost savings, energy efficiency, emissions reduction

DES fast facts:
280 kW PV
100 kW CHP unit*
Energy Conservation Measures: energy efficient lighting, variable speed drives, heat recovery wheel, reflective white roof.

*scalable subject to heat and electrical demands

ECMs Investment Analysis

The results of the chosen six ECMs show strong absolute energy savings and short simple payback periods. On the demand side, the implementation of energy efficient LEDs is by far the most beneficial ECM, with a modest up front investment yielding $120,000 in annual cost savings and a reduction of almost 700 tonnes CO_2/year. The two energy supply technologies of gas CHP and solar PV together deliver net annual savings of about $82,000 per annum and about 550 tonnes CO_2/yr, but these measures also involve a significant upfront capital investment.

If all four demand side ECMs were implemented, the facility's annual energy reduction could be almost 9% (or around 15% of the building's non-process energy demand). With full integration of process load management with building energy management and on-site generation, the total energy savings for the facility could be significantly higher.

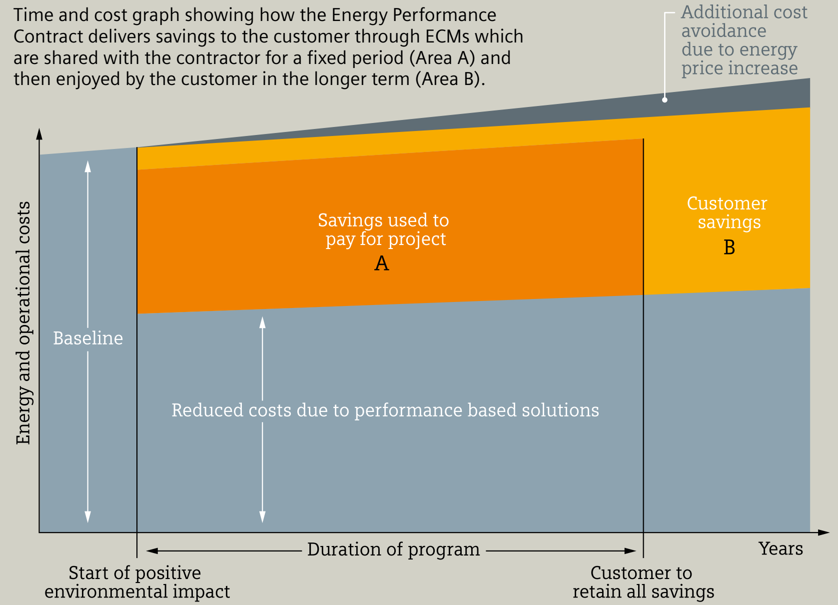
Delivering Energy Efficiency

Substantial energy savings and the associated reduction in costs are relatively easy to obtain, however they require capital investment, especially when considering ECMs with large but longer term payback periods. Securing capital and board commitment for these investments, when companies are focused on delivering immediate value to the shareholders, can be challenging.

Innovative embedded financing solutions such as Energy Performance Contracts (EPCs) address this gap by packaging the finance and implementation of ECMs into a single contract which transfers the risk and capital investment off the company's balance sheet.

The model works by having a third party contractor responsible for designing, implementing, operating and maintaining the portfolio of energy efficiency measures. The third party finances the CAPEX and OPEX. The resulting revenues from energy savings pay for the investment and then are shared between the end user and the third party as shown in the diagram below.

Time and cost graph showing how the Energy Performance Contract delivers savings to the customer through ECMs which are shared with the contractor for a fixed period (Area A) and then enjoyed by the customer in the longer term (Area B).



3 DES Current Markets & Opportunities

Market Outlook

Falling prices of components and increasing availability of data to manage system response to external pricing signals are propelling the implementation of DES and stirring interest in the entire energy industry. The majority of DES players are relatively new in the market, ranging from 5 to 15 years. However, these businesses have undertaken multiple transformations to their original models in order to keep up with the dynamic market.

Where DES was originally mainly adopted by the manufacturing industry for load shifting and process heat consumption optimisation, current growth is particularly focussed on the residential and commercial development sectors.

A recent independent report projected that the worldwide capacity of DES would increase from 87.3 GW in 2014 to 166 GW in 2023.[4] In addition, in 2015 the IEA estimated that worldwide investments in energy efficiency in buildings would total $90 billion.[32]

As well as the large potential in mature markets of developed economies such as the US, UK and Germany, DES has the potential to display an even higher growth rate when implemented in fast growing and transition economies.

Developed Economies

DES has achieved significant penetration in many countries both in Europe and North America.

For example, in the UK current investments into DES stand at about $2.5 billion with an installed capacity of 3.7 GW in 2013. This is set to reach by 2019 a capacity of 7 GW, although investors remain sensitive to perceptions of a complex policy and regulatory environment with an uncertain direction of travel.[33]

Since 2011, the German Energiewende (“energy transition”) is changing the orientation of the national energy policy from demand to supply and encourage a shift from centralized to distributed generation.[34] Key important milestones include:

- Greenhouse gas reductions to 80–95% by 2050
- 60% renewable generation share by 2050
- 50% electricity efficiency improvements by 2050

The US has continued to promote DES-friendly policies, especially through the Environmental Protection Agency (EPA) and Department of Energy (DOE). The EPA commissioned The Clean Power Plan in 2015, to meet the proposed 30% carbon emission reduction goal by 2030.[35] It has deployed energy management and efficiency programs as well as promoted use of zero-carbon energy sources in power plants. This is seen as significant step in reshaping the U.S. energy strategy as it has customized goals for states to cut their carbon pollution and encourages accountability for each state’s energy policies.[36]

America’s sub-divided market and regulatory structure – where most regulation occurs at state level – gives it consideration scope for innovation, as different markets test different pricing models and delivery vehicles. The emerging winners could provide a set of replicable models for many markets around the world.

Overall, investments in DES are delivering savings for the consumer, but they are also impacting market capitalization of some utilities where infrastructure costs are static (or rising) but Use of System (UoS) revenues are falling. There is therefore a need to find ways to strike a balance between the growth of DES and the technical and economic impact on the existing distribution network.

The “Effizienzoffensive” is a **$19.4 billion** new campaign launched in May **2016** by the German energy minister with the aim of halving the country’s energy consumption by **2050**[37]

New generation from an old factory

Location: Portadown, Northern Ireland, U.K.

The 35-year old, 25 hectare roof of a large manufacturing facility of thermal insulation products was leaking and approaching the end of its life. Rather than just replacing it with a new one, it was decided to turn it into a power plant and install 4,900 PV panels generating 1.1GWh of electricity per year.

This generated energy is enough to meet 30% of the site's daytime annual energy demand resulting in an annual saving of £40,000 ($61,000). The facility's owner is now committed to roll out this intervention in the facilities portfolio as a part of the plan to become a zero net energy company.[45]

Fast-growing and Transition Economies

Fast growing economies such as India and transition economies such as China show vast untapped potential for DES.

Rural India currently has 77 million households who lack complete access to the grid, while a further 20 million households only receive electricity for a few hours a day.[39] Limited infrastructure, remote locations and low power load densities mean that electrification is often uneconomical;[40] therefore energy needs are mainly met by fossil fuels (e.g. diesel) or locally sourced biomass (e.g. wood).

The Indian government is supporting distributed generation through 'The Electricity Act' of 2003 and the "Rajeev Gandhi Grameen Vidyutikaran Yojna" rural electrification scheme. These policies not only identify decentralized solutions based on local distributor collaborations but also provide up to 90% capital subsidies for rural electrification projects using decentralized systems.[41] Furthermore, at COP 21 in Paris, India's Prime Minister announced a global alliance of nations and industry committed to increase the uptake of solar energy generation in countries located across the tropics.[42] The Indian government has pledged $30m initial funding with the ambition to help raising $400m in the future.

The Indian market for microgrids and other "clean energy consumer products" is set to reach **$2 billion** annually.[38]

From large, fast growth, China's economy is entering a transition phase leading into a consumer economy which will drive investments in the housing and commercial buildings stock (as the sector of "services" increases).

Currently in China, a strong focus is around reducing energy intensity (energy consumption per unit of GDP).[43]

Typical interventions include supporting energy saving projects such as energy efficient buildings, surplus heat utilization and petroleum substitution. There is also a strong focus around energy efficiency in industrial manufacturing plants. Following the success of the "Top 1000 programme" (which looked at reducing the energy consumption of the 1000 largest enterprises in China), the 12th Five-Year Plan has made mandatory the savings for 10,000 enterprises responsible for using two thirds of the total energy national consumption.[43]

Planning into the future, China has said it will reduce emissions of major pollutants from the power sector by 60% in the next five years.[44]

New actors and business models

The rise of DES is fostering new actors in the energy industry and is redefining the roles of the previously existing ones.

Prosumers

As the uptake of DES increases and data is widely available and accessible, energy consumers are changing their role from passive to active. Referred as prosumers, this group not only consumes energy but can also produce it by local generation or by planned "released production" (i.e. controlled and timed load reduction or shifting as a result of real-time market signals).

Performance-Based Solution Providers

Reduction in DES equipment costs, the savings associated from energy efficiency solutions, the need to retrofit existing properties and the lack of opportunities to raise CAPEX are fertile ground for third party providers who deliver Energy Performance Contracts (EPCs) or similar packages. Typically such providers commit to improve the energy efficiency in buildings as an off-balance sheet cost for the owner. Energy cost savings, achieved through the reduction in energy consumption, are used to pay for the installed equipment, with the residual savings shared by the solution provider and the building owner.[46]

Developers and 3rd Party Ownership

Depending on the application, the implementation of DES can be capital intensive. After installation completion, competent operation & maintenance are also required. Financing and ownership models have emerged to address both issues and provide feasible and profitable solutions for all parties involved (e.g. consumer, provider, owner, etc.).

Developers are able to offer full turnkey solutions on DES projects depending on the end user requirements, capabilities and risk appetite. Through a Power Purchase Agreement (PPA), an external developer designs, delivers and operates a plant, e.g. a solar PV farm, at a consumer's property in exchange for an agreed tariff under which electricity is going to be bought. This enables the consumer to purchase electricity directly from the generator rather than from the utility. Similar services are offered in emerging economies by microgrid developers.

A newer breed of Energy Services Companies (ESCos) is also evolving, focusing more on innovative financing methods, including off-balance sheet vehicles, delivering cost reduction for clients through managed reduction in energy usage.

Community integrated DES

Location: Kisielice, Poland

Many DES technologies can be integrated into community energy systems to supply residents and businesses with local, efficient and cost-effective energy. While CHP is ideal for high density urban areas, solar PV and wind power may be well suited to smaller and lower density communities.

The small town of Kisielice is surrounded by farmland. Over the past years, the town has taken steps to achieve new energy goals: move away from coal-generated electricity, reduce utility cost, reduce carbon emissions, modernise transport and improve air quality.

Following the installation of three wind farms, for a combined capacity of 95 MW, in December 2013, construction of a biogas power plant was completed. The plant produces combined heat and power and is fuelled by silage corn supplied from local fields, providing additional income to many residents. The unit's waste heat supplies the village with hot water during the summer months.

The works were financed through grants and private funds and aim to recover costs over time through energy savings.[47]

Aggregators

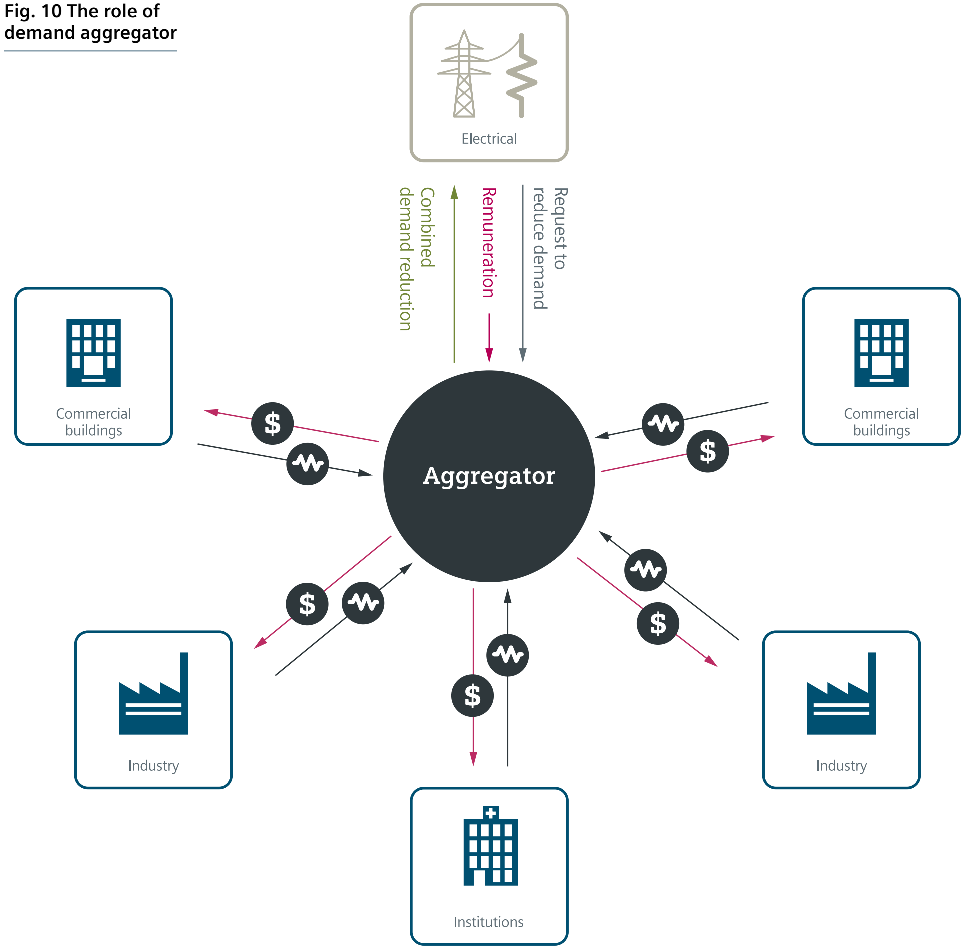
In many countries, such the UK, typical end users, besides large industrial plants, have limited opportunities to participate in the energy market. Energy aggregators act as consumer representatives in the wholesale and retail electricity arena by pooling together a number of consumers, bidding for their aggregated demand elasticity (e.g. how much and how long) and operating it when required.

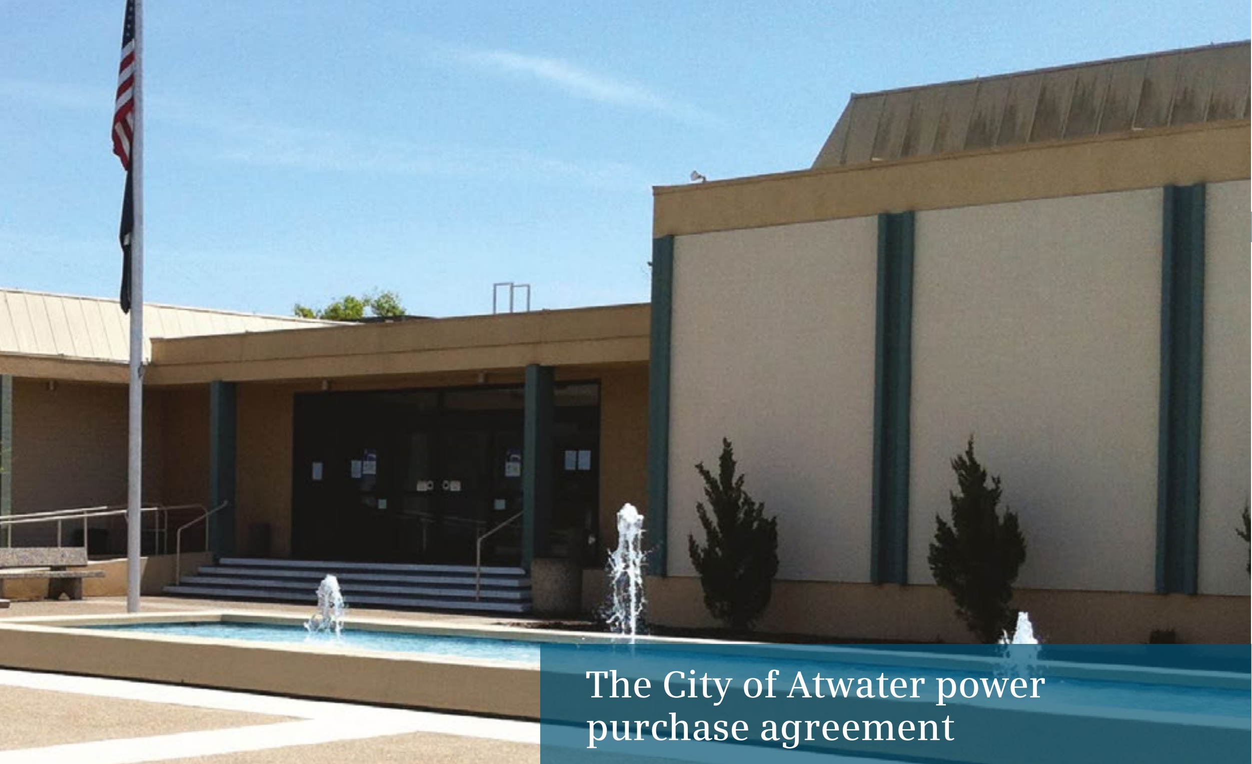
Upon receiving signals (ramp down or up) from the national grid operator, the aggregator evaluates the best dispatching approach and then sends control signals to individual equipment (both distributed generators and controllable loads) located at the end-users' premises.

Community Energy

The concept of community energy is one that has been gathering support both in developed and fast-growing economies. It is based on the scenario of a community which is independently meeting its own energy requirements - being heating, cooling, electricity or all three - through decentralized generation. Excess energy, where available, is sold back to the grid.

Fig. 10 The role of demand aggregator





The City of Atwater power purchase agreement

Location: Atwater, California, U.S.

The City of Atwater, which is home to approximately 28,000 people, is currently completing the process of building a new regional wastewater treatment plant in order to uplift the sewage services of the city. As the facility was projected to require a large amount of power for its operation, officials of the city sought a cost effective solution that offered a reduction in electricity prices, offloaded some of the treatment plant's demand, took advantage of a clean sustainable resource and maintained a sustainable business model. All these goals were attained through a PPA with an equipment manufacturer who effectively owns, operates and maintains 1.1MW PV farm located adjacent to the new waste treatment plant and sells the solar energy back to the city at a competitive rate.

Such an agreement is now set to save the city $1 million over the course of the 20 years.[50]

The A-B-C Model

In developing economies, new business models, which can mitigate the risk associated with rural electrification (e.g. lack of reliable stream of revenues) need to be created in order to attract private investors.

One model which creates opportunities for business developers to differentiate their offerings and revenue stream is the "A-B-C model."[49] Promoted by the World Bank, the A-B-C Model brings three electricity consumers together in a microgrid: the Anchor, local Business groups and the Community:[49]

- The **Anchor** load is a large user which values security of supply (e.g. telecom tower) and represents the main revenue stream for the microgrid investor.
- Local **Businesses** are small- to medium-size users (e.g. car workshops and bakeries) which value cheap electricity supply but would benefit from a more reliable grid supply.
- The **Community** includes the largest number of users who have very limited access to electricity. Their consumption is relatively low but have high unit costs of energy and would benefit most from being connected to the microgrid.

This model recognises the synergistic benefits which can be delivered through an integrated approach to grid development.

"Over **70** per cent of India's **425,000** telecom towers experience power outages of approximately eight hours per day."[48]

DES old and new financing mechanisms

Besides the traditional mechanisms available to end consumers (e.g. manufacturing facilities, commercial buildings and residential communities) to raise capital for financing new plants and retrofits, DES implementation can benefit from additional new emerging financing mechanisms. Also, when aligning with local and national renewable, energy efficiency and carbon reduction targets, DES projects can benefit from incentives and tax abatement.

Old financing mechanisms

Own Financing
Debt Financing
Equity Financing

Table 4 New financing mechanisms

Build-Own-Operate Models	Incentives as direct subsidies	Green Banks & Bonds	Crowdfunding
Third-party financing solutions combine a different menu of options around building, ownership and operation of DES assets which can be applied to a wide range of project from manufacturing to rural electrification. Also they can be tailored on the customer's needs, technical expertise and capital availability. Further specific examples can be found in the report including Energy Performance Contracting (EPC), Energy Service Companies (ESCos), Power Purchase Agreements (PPAs) and the World Bank's A-B-C model in rural electrification.	DES uptake is being supported by a number of programmes and incentives in order to deliver on national and local targets including carbon reduction and renewable energy generation. In Germany, the government has been incentivized the installation of energy storage units coupled with new or existing PV systems since May 2013.[51] Owners can obtain a low interest loan on storage units up to 30kW and receive a rebate on installation costs up to 30%.	Green banks are an upcoming source of sustainable financing. New York has launched a green bank to generate $220 million for clean energy projects.[52] Green bonds are another concept that has received support from the World Bank, the International Finance Corporation and local government bodies. Specifically designed for environmentally friendly projects, the labelled green bonds market has grown substantially and in 2015 alone $40 billion in green bonds were issued.[53]	Crowdfunding DES has the potential to unlock pockets of investments and in particular be beneficial for small to medium community-led energy projects. It has been projected that crowdfunding will raise close to five billion dollars in the U.S. with an estimated growth rate of more that 75% within the next 5 years.[54] In the UK, utility company Good Energy launched an initiative with a target to raise $1.6 million through renewable energy crowdfunding platform Trillion Fund.[55]

How to apply

DISTRIBUTED ENERGY SYSTEMS DES

Feasibility

Project objective and scoping

- Cost savings
- Energy efficiency
- Security of supply
- Emissions reduction
- Electrification

Technical analysis

- Location
- Resources availability
- Space planning
- Technology options
- Grid availability
- Environmental impact

Financing & operation

- Cost analysis (CAPEX, OPEX)
- Regulatory analysis
- Ownership mechanism selection
- Delivery mechanism selection
- Financing mechanism selection

Design

Implementation

Operation

Design

- Client kick-off meeting
- Site survey
- Equipment condition assessment
- Stakeholder engagement
- Design development
- Detailed cost evaluation
- Specifications production
- Issue tender
- Evaluation of returns

Delivery

- Main contractor appointment
- Design reviews
- Equipment procurement
- Installation
- Site testing
- Commissioning & handover

Live operation

- Performance assessment
- Operation & maintenance strategy
- Financial returns
- Contractual closure
- Decommissioning

CO_2 **13%** emissions reduction

cost saving /year **25%**

5 ROI years

Urban Community Energy

CASE STUDY

As cities grow, large scale mixed use developments can act as major player to meet housing needs and to stimulate wider development activity. Within urban development areas, the installation of Combined Heat and Power (CHP) systems represents an opportunity to achieve efficiency savings and financial benefits for customers. In the event of grid loss, CHP systems can provide power locally thus increasing the community's resilience to shock events.

Location:
New York City, USA

DES user application:
Residential Community

System description:
Urban development consisting of 10,000 residential units, retail and commercial units, leisure centre and schools

DES benefits:
Cost savings, energy efficiency, security of supply, emissions reduction

DES fast facts:

13 MW gas turbine with CHP operation
Thermal energy storage
BEMS Building Energy Management System
District Heat Network

The development operates a centralized energy centre with a gas CHP turbine and back up and top-up gas boilers. Heat is used on site and distributed via hot water pipes, and the power is used either on site or exported back to the grid for additional income for the development. When demand for heat is low (as in the summer), the gas turbine is switched off and electricity is supplied from the grid.

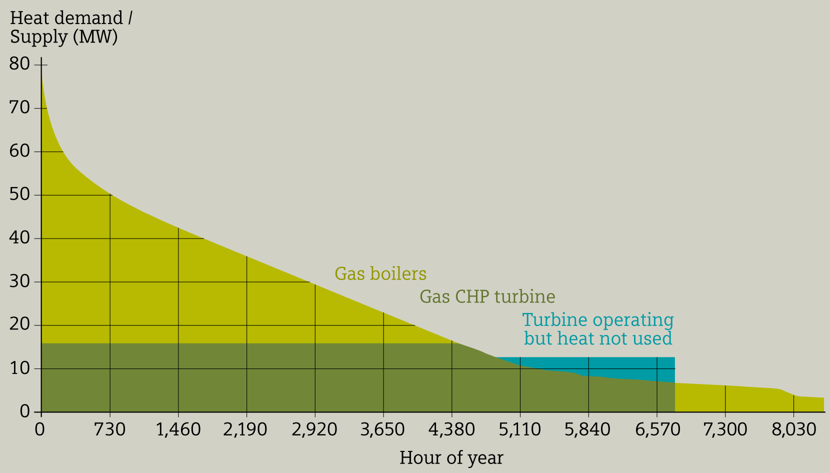
Ownership and Delivery Models

Providing heat and power to a residential development can be an attractive opportunity to third party suppliers due to the certainty of demand over the long term.

A variety of ownership and procurement models can be considered to determine the optimal allocation of risk and responsibility. An Energy Services Company (ESCo) is a general term used to describe a wide range of delivery and ownership structures. An ESCo can be a single company fully responsible for generation, infrastructure and energy sale to final customers. Alternatively an ESCo can be a public sector organisation or a third party commercial entity.

When an active market in CHP and district heating is not already in place, cities can adopt a "promoter" role to bring forward projects and package them up for energy service companies to finance, deliver and operate; they can secure their own sources of finance and procure a contractor to build and operate the network on their behalf; in this model the city takes on more risks but also gets the financial returns from a successful scheme.

How heat demands are supplied by the centralized heating plant



4 Impact on Wider Energy Ecosystem

With increasing penetration of DES in the market there will be wider ranging interactions with the energy industry. DES particularly bring rapid change to rural areas, introducing electrification and building resilience. The role of information technology and data access will be crucial to the effective utilisation and integration of DES into the existing network grid.

DES and the Grid

DES challenge the way the grid is being traditionally designed and operated.

Multiple, smaller, grid integrated power sources help better meet the local demand, reducing the amount of power required from large centralized plants and reducing the power flow on the grid at peak hours through demand response.

DES can also offer support to the grid by providing ancillary and operability services. Besides the more established load shifting control in large manufacturing facilities, now through the advent of smart inverters, even intermittent renewable sources such as PV can provide voltage support and frequency control. Research carried out by the Electrical Power Research Institute and the Solar Electricity Power a Association has demonstrated that a system wide roll-out of new and retrofitted inverters with enhanced control capabilities (the so-called "smart inverters") can offer to utilities a cost-effective improved grid operation and even avoid network upgrades.[56]

On the other hand, improper integration of DES can have adverse effects on the grid, such as voltage limit violations and loss of protection system coordination. These can lead to higher maintenance costs and even equipment upgrades.

DES and the Utility Industry

Utility providers are being forced to reshape their business models as some of their most profitable consumers are looking into distributed energy. These consumers still heavily depend on the central grid but the rising number of grid-connected generation systems reduces income to the grid while still requiring it to have the same level of reliability.

This in turn raises prices even further for other consumers. In countries like Germany, the utility industry is forecast to see a 20% decline in profits by 2020.[57]

In some markets, regulators and utility providers have joined forces to develop a pricing model that is based on connectivity and capacity instead of usage. For example in New York State, Reforming the Energy Vision (REV) is an ambitious effort to shift the focus of the current state electrical power system from large generation and delivery infrastructure to the end customers both users and producers.[58] Utilities are set to change their cost-of-service approach and provide new added-value services including a coordinated market platform which is

Solar-battery systems are expected to reach grid parity before **2030** in many U.S. states.[59]

accessible by the end customers. These are the first steps in the implementation of the Transactive Energy (TE) concept which aims at developing an enabling environment with clear investment signals, where traditional providers and end customers including distributed generator owners can buy and sell electricity.

It is vital moving forward that the utility industry cultivates new capabilities and with regulatory support, redefines its position in the market.

Utilities capability expansion will further lead to higher customer satisfaction which is crucial in a diverse market that is becoming increasingly competitive. One option includes third party services such as demand management, equipment installation and maintenance. Joint ventures and partnerships may also hold value. This would allow companies to broaden their reach in competitor markets and invest with confidence in the distributed energy value chain.[57]

DES and Resilience

There are many examples where extreme weather related events have disrupted power systems all over the world, such as super storm Sandy in New York, Hurricane Katrina in Louisiana and prolonged flooding in Bangkok. In a study conducted in 2001 and updated in March 2013, the Electric Power Research Institute estimated that power disturbances cost US businesses around $119 billion annually with California experiencing the highest costs.[60]

These incidents adversely effect the energy security of any nation by altering the energy demand, obstructing the energy supply and harming the energy infrastructure. In such situations, resilient distributed energy systems can play a vital roles in supporting the energy requirements of the population.

As an example, rising sea levels could threaten not just the existing coastal energy infrastructure, but also the on-shore transmission and distribution networks. Here, the development of independent microgrids can help isolated potentially problematic areas and facilitate counter active methods.

©Wikimedia

Hospital CHP-led energy strategy

Location: London, U.K.

The Royal Free NHS Hospital in London has partnered with a strategic outsourcing and energy services company, to operate an energy efficient CHP plant at the 900 bed hospital.

The distributed energy strategy is set to save the hospital £13.7 million over 15 years. Besides the cost reductions, it has been projected that the carbon emissions will reduce by 23%, this equates to about 7,000 tonnes of carbon per year.

Furthermore, the hospital is leading by good example, providing the surplus energy to Camden Council for local residential use.[61]

DES and Digitalization

Greater integration and utilisation of information and technology within the utility and equipment manufacturing industries is a growing trend.

IT and the availability of big data sets have specific applications that can cater to almost every node of the energy value chain. Some of these roles include:

- Data aggregation, modelling & analysis
- Data & system management
- System reliability and cybersecurity
- Effective cost reductions

Digitalization is expanding through technologies like smart meters which automatically upload user consumption data for rapid access and greater transparency. The EU aims to replace at least 80% of standard electricity meters with smart meters by 2020. Member states are rolling out around 200 million smart electricity meters and 45 million smart gas meters for an investment of €45 billion.[62]

Once detailed load data becomes available to consumers and suppliers, the next challenge is to process these large volumes of data with advanced analytics. The development of cloud-based parallelized computing-based architectures allow for seamless flow of big data between stakeholders, further reducing costs and increasing accuracy.

Similar large investments are currently being made by utilities in deploying smart grid technologies and improving the "visibility" of the grid. In April 2016, Con Edison announced a $663 million investment in smart grids to improve the existing infrastructure and reduce outages.[63]

Utilities are also enhancing energy efficiency programs in order to reduce portfolio costs. Here, effective data analytics helps to detail performance and reduce human input.

DES and in particular the DEM applications such as demand response, virtual power plants and microgrids are based on the assumptions of data availability and in-depth, close to real-time processing. Modern IT is enabling distributed control at customer's premise and making power consumption and generation behind the meter more visible and accessible to the wider grid.

DES can become even a lot more effective with good management; software platforms have the ability to be optimized to provide comprehensive solutions for peak load reduction, demand response, regulating energy sources and creating virtual power plants.

DES and Leapfrogging Electrification

Many fast-growing economies all over the world are still establishing their power networks, especially in rural areas. In the absence of grid electricity, the primary source of lighting in many cases is kerosene which has a negative impact not just on the public health but on the environment as well.

Growing awareness, falling prices and greater access to finance are pushing national governments towards the implementation of electrification projects. This is a major challenge as energy infrastructure requires significant capital investment which in some cases can not be supported by government bodies and requires private sector involvement.

Smaller scale electrification projects based on DES and in particular off-grid microgrids can be implemented much quicker due to fewer planning and regulatory constraints compared with major power infrastructure projects.

In most cases, the drive is for business models that can deliver energy at a cost and scale that is acceptable to the market and consumer alike. In these cases DES is one of the more obvious choices, as it can rely on locally available resources for energy generation. Furthermore, many innovative ways of reimbursing capital equipment costs such as "anchor load" strategies have paved the way for the deployment of DES.

It is estimated that the market size for DES in India alone might approach £100 million by 2018. A wide mixture of DES technologies such as solar PV, small-hydro and biomass gasification have already been installed.

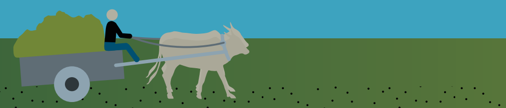
However, with 70% of the population living in rural areas, there still remains significant scope for a deeper penetration of DES.[40].

DESI Power Anchor Load Model

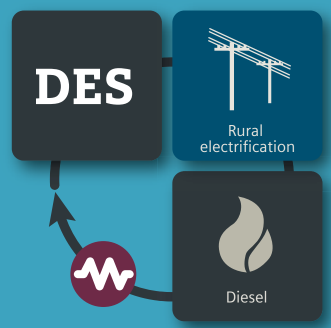
Location: India

DESI Power is a developer focusing on the installation of biomass gasifiers and solar PV, in single and/or hybrid modes, along with microgrids in rural communities in India, with limited or extremely unreliable access to the grid.

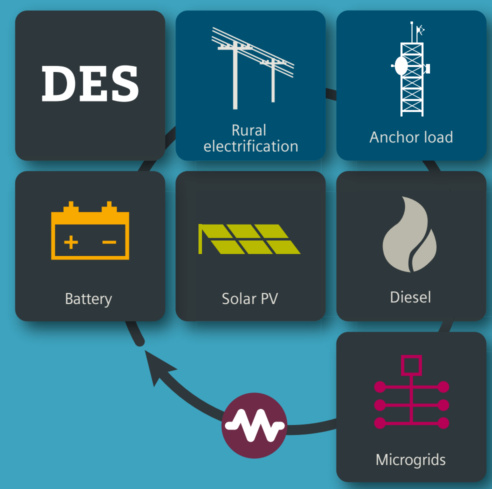
Similar to the model developed in this report (Case Study 4), DESI Power business model promotes and utilises anchor consumers to underpin demand. Each of the generating plants with biomass gasifiers and/or solar PV units provides electricity for irrigation water pumping, agribusinesses and shops with or without or telecom towers. These high demand users are individually metered and charged on a per unit basis and generate the majority of revenue. Microgrids are then built around these anchor consumers to provide electricity to unserved residential consumers on a flat tariff structure. DESI Power also builds tiny grids outside the range of microgrids to pump irrigation water for small farmers and for lighting to nearby unserved villagers.[64]



Diesel Microgrid



DES Microgrid

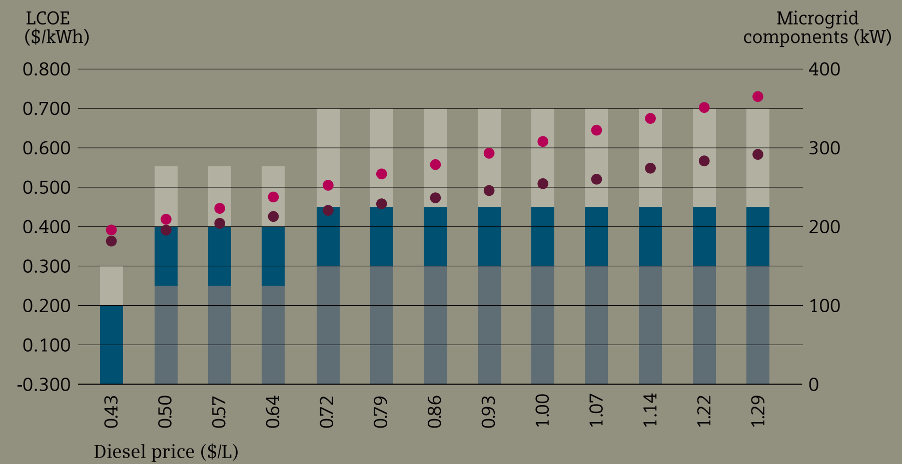


Batteries (kW)
Generator (kW)
PV (kW)

Diesel only
Mix

* The Levelized Cost of Energy (LCOE) is defined as the average total cost to build, operate and maintain a generation plant over its lifetime divided by the total energy output over that lifetime. LCOE is often used to asses very different technologies such as diesel generators, wind turbines and electrical batterieson a comparable basis.

Cost of energy for DES Microgrid vs Diesel Microgrid – Anchor Load Case



38%
CO_2 emissions reduction

OPEX cost saving/year 28%

LCOE $0.4/kWh

Anchor Microgrid

The implementation of DES – and most specifically microgrids – can unlock energy access and economic development while addressing sustainability concerns. An "anchor" is typically a non-residential consumer that needs reliable power supply (i.e. telecom towers, manufacturing facility, etc.). When coupled with a local community microgrid, the anchor's creditworthiness and long term commitments increase the financial attractiveness of the microgrid projects.

Location:
Bihar State, India

DES user application:
Rural Electrification

System description:
Rural village including 300 households, a school, a community center, four small businesses (2kW each) and an anchor factory (55% of total microgrid load). Daily average electricity demand is 1400 kWh

DES benefits:
Cost savings, emissions reduction, rural electrification

DES fast facts:
75 kW Diesel Generator
125 kW PV array
75 kW Batteries converter
280 kWh Batteries

The Case Study

Microgrids are often referred to as "hybrid systems" as the power is supplied by a mix/portfolio of different DES generation and storage technologies. In rural off-grid communities, the conventional, business as usual, approach is to install a diesel generator supplying all power loads. This exposes the community to fuel dependency, high costs and air pollution.

The case study shows the impact of supplying the microgrid through a mix of both renewables and fossil fuel-based generation and then the impact of introducing the factory (The "anchor") to the microgrid. The factory's anchor load increases the total size of the system, capturing the benefits of economies of scale in energy network investment.

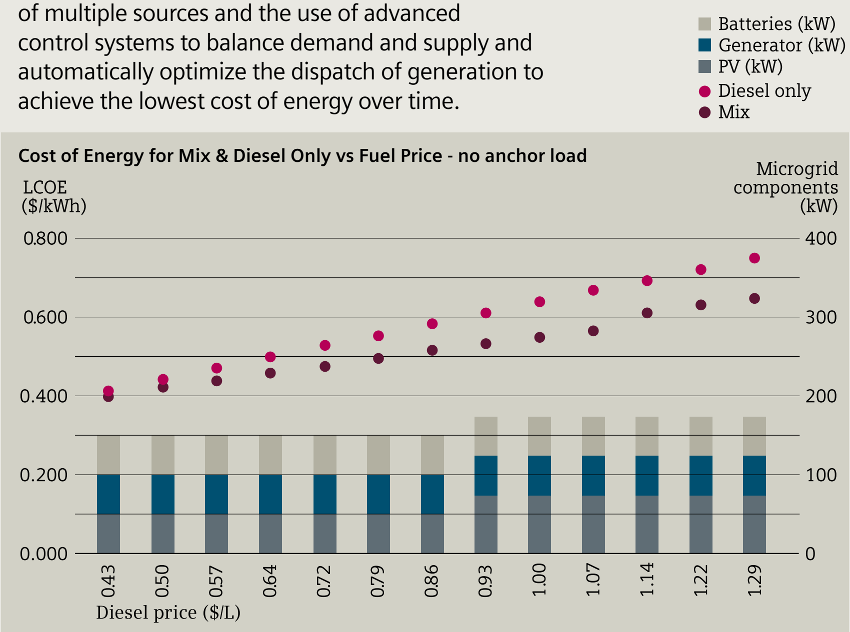
Investment Performance

Even without the factory operating as the community's anchor load (as shown in the diagram to the right), the analysis highlights how the mixed supply DES solution can deliver significant cost savings against a diesel-only option. At local diesel prices of 64c/litre, the mixed DES option provides almost a 10% lower levelized cost of energy for the community (0.45 $/kWh to 0.50$/kWh). Should the price of diesel rise higher, the relative benefits of the mixed solution become even greater.

The mixed system – using solar PV and battery to store surplus generation and smooth the profile of the diesel generator – reduces the diesel's running hours by a third thus reducing by a third both running costs and carbon emissions.

With the introduction of the anchor load, the total installed generation more than doubles and diesel's share of that mix reduces to around 30%. This leads to a greater divergence in levelized cost between the DES mix and a diesel-only system. With the anchor scenario and at today's diesel prices, there is an 10% reduction for the DES mix and a 16% reduction in levelized costs between the DES mix with anchor load and the diesel-only without anchor load.

As with the other case studies presented in this study, the selected technologies are proven and reliable and widely used already. The difference here compared with a typical community microgrid is the integration of multiple sources and the use of advanced control systems to balance demand and supply and automatically optimize the dispatch of generation to achieve the lowest cost of energy over time.



5 Enabling Framework

Expansion of DES presents both a significant opportunity but also a significant driver of change for the operation and character of the electricity sector.

Taking a broad perspective across the global landscape, this chapter presents some key ideas about the enabling actions by planners, regulators, investors and consumers which are needed at multiple scales and geographies to realise the potential value of DES for both consumers and suppliers.

Drivers of Change

A combination of technological innovation, policy incentives and empowered consumer choices are driving the uptake of DES at a global scale. The applications from the largest urban megacity to the smallest electrified village give DES broad appeal and scope for growth.

But this growth is not without its challenges; there are several key areas where action by governments and regulators is needed to bring DES into the mainstream.

Network Integration

Distributed generation has a role to play in an effective energy solution for the future. In the short term, uptake is likely to be focussed on specific types of consumer under specific conditions such as critical business need for continuity of supply or an opportunity of an available local energy source.

The integration of DES generation and storage technologies into distribution networks requires careful planning, design and management. As DES penetration increases, the traditional passive distribution network (designed assuming the power always flows "downstream" from a central location to consumer loads) becomes an active network, with typical associated problems such as network congestion, voltage level violations and loss of protection coordination.

DES integration planning is particularly acute where there is planned extension or reinforcement of the central grid. When a microgrid or other DES installation in an area precedes the extension of the main grid, planned integration into the main grid is critical to avoid stranded assets and wasted investment. When DES integration is planned


©NREL

from the start, all parties can benefit, including the incumbent grid operator. With certainty of future grid connections, DES investments can "pave the way" for the slower and more capital-intensive main grid extensions by building up demand for electricity services ahead of full grid connection.

Looking at the specific case of microgrids, planning for DES integration would require action and coordination by multiple actors and agencies:

- Regulators and parastatals should structure markets to reduce barriers to entry for microgrid operators
- Grid operators should provide clear guidance and standards for microgrids to be "connection ready"
- Investors should ensure that microgrids project funding is adequate to cover costs of future proofing
- Central grid operators and microgrid operators should engage and coordinate to align plans for network growth and integration

Knowledge Transparency

Planning for integration requires improvements in modelling and analysis, so that the simulation and economic evaluation tools reflect the greater complexity and flexibility of an integrated grid. The viability of DES integration will depend on being able to compare a DES solution with a central generation one using equal and consistent parameters. To facilitate this, the vast data on costs, operations and benefits of each of the distributed generation systems requires standardizing, at least on a market level if not across wider, interconnected geographies.

Analysis of the integrated grid, as outlined here, should not favor any particular energy technology, power system configuration or power market structure. Instead, it should make it possible for stakeholders to identify optimal architectures and the most promising configurations – recognizing that the best solutions vary with local circumstances, goals, and interconnections.[65]

DES facilitation through standardization

The new emerging business models operating around DES often require bespoke transaction documents and processes. These new transactions can drive up costs mainly associated with lawyers, accountants and consultants fees.

Supported by the U.S. National Renewable Energy Laboratory (NREL) for solar projects, the "TruSolar" working group has developed a set of model contracts, which incorporate 3rd part leasing and power purchase agreements.[66]

Government interventions play major role in clean energy transitions

Location: Barbados

Barbados boasts one of the highest per capita rates of Solar Water Heating systems (SWH) ownerships in the world, serving close to 40% of all households.

Since 1974 the government has actively looked for ways to reduce oil dependency and reduce energy costs. In this pursuit it provides import duty exemptions for all SWH raw materials such as tanks and collectors. It also lowered the cost of installation by 10% and raised taxes on conventional water heaters by 30%.[67]

Markets & Business Models

DES can potentially reduce and at times reverse the flow of power from the grid to consumers. However, the central grid will always be a critical part of an overall resilient and robust energy system. DES can operate in stand-alone mode but most users will value the added security and flexibility of a hybrid, grid-connected DES solution.

Therefore, in order to ensure adequate long-term investment in reinforcing and modernizing the grid, wholesale market and retail rate structures will need to evolve so that they adequately value both capacity and energy from central and distributed system components and operators. This will ensure that as DES deployment grows, all users continue to pay – and earn – a fair share for the value provided by each part of the integrated grid.

It is vital moving forward that the utility industry cultivates new capabilities and redefines their position in the market. Options include third party services such as demand response, equipment installation and maintenance. Joint ventures and partnerships may also hold value.

In emerging markets, rural electrification projects involving DES pose a financial risk to small enterprises being unable to repay their loans. These enterprises can struggle to meet affordability and reduce operational costs. High default rates in the sector can deter financial institutions.[39]

A number of business and delivery models have emerged to offer a choice for the optimal allocation of risk and responsibility for DES. The more innovation there is in this space, the more adaptable and integral DES will become.

Finance & Funding

Although the price of renewable energy generation and batteries is reducing, larger distributed systems still attract high costs. Hence, the payback period can potentially be long and unattractive particularly in developed economies where a reliable grid-connection is available.

DES systems in the off-grid sector are generally looked to be financed over a period of 7-10 years. Financial institutions are hesitant to provide these loans due to the lack of adequate financial history associated with DES. Furthermore, the institutions granting funding for these systems tend to charge a higher annual premium (13-18%). This further adds a challenge to the accessibility of DES.

New and different funding mechanisms are now emerging, such as green bonds, asset-backed securitization and crowdfunding. But more could be done to educate and inform investors about the real risks and returns of DES to bring these into the mainstream.

Government Policy & Regulation

National energy policies and utility regulations vary widely between geographies and over time from one government to the next. DES need a policy and regulatory framework which supports innovation and reduces barriers to new entrants with new business models but, like other long-term investments, it also needs a stable certain policy environment. Even generous subsidies or other support mechanisms will have little stimulus effect if they follow a period of policy volatility.

The recent abrupt reductions in UK subsidies for some renewables and the current policy uncertainty on building energy efficiency standards, for example, is likely to leave a legacy of caution in the market even in the face of restoration of such cuts.[68]

Specific policy initiatives which could support take-up of DES and capitalization of benefits for the grid as a whole include:

- Clear and reliable interconnection regulations and standards, coupled with capacity building and support through the permitting process
- Mandating that distributed generators may export surplus power to the grid
- Shifting the balance of remuneration of the central grid towards availability rather than consumption
- Structuring markets to reward energy efficiency, resilience and carbon reduction
- Treating demand response measures on a level basis to generation during periods of low capacity margin
- Rolling out digital automatic meters ("smart meters") across all consumers and enabling net metering
- Reducing barriers to entry in the power supply market such as through reduced or shared licensing regimes or facilitating
- private wire connections (while still ensuring the stability and safety of the grid).

Interconnection-friendly policies ensure long-term value of microgrid investments

Location: Sri Lanka

Sri Lanka's central grid has been expanding rapidly, but in this mountainous nation, many hundreds of communities operate small stand-alone hydropower microgrids of less than 10 MW installed capacity. As part of Government plans to link these communities to the grid, the Sri Lanka Sustainable Energy Authority produced a guidebook to help communities develop their microgrids to be ready for future interconnection.

The interconnection guidebook helps ensuring the long term value of small-scale investments in local power generation and help accelerating the expansion of the grid to provide greater access to power for all its citizens.[9]

Appendix

Smart Energy Building

Modelling Methodology & Software

DES technologies (such as CHP) are capable of supplying the three energy flows in a building (i.e. heating, cooling and electricity) by mixing energy sources both renewable and non renewable.

Energy flows are not separated but through DES are transformed in one form to another, shifted in time, stored in space in order to maximise efficiency, harness the most of renewable energy and reduce costs.

The various DES options within the building are modelled and optimized by using the Distributed Energy Resources Customer Adoption Model (DER-CAM) software developed at Berkeley Lab.

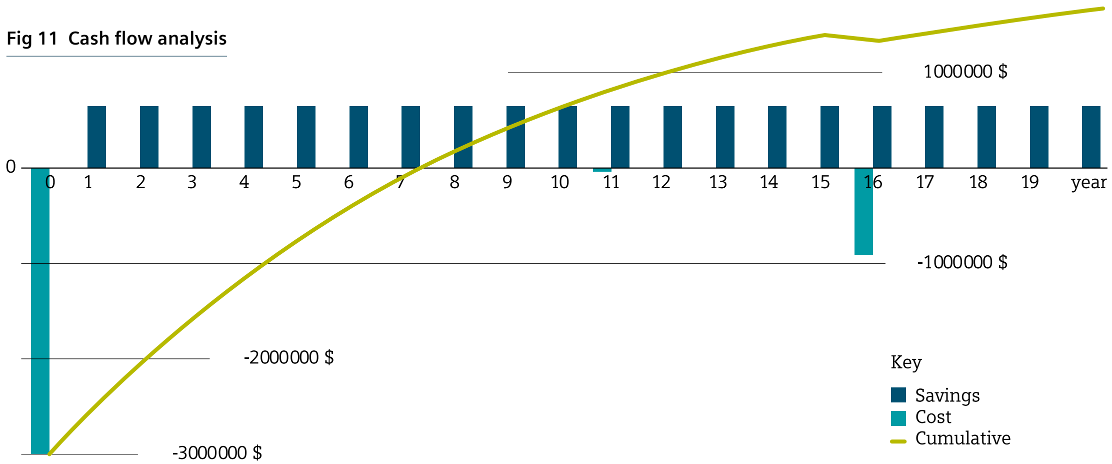
https://building-microgrid.lbl.gov/projects/%20%20der-cam

DER-CAM is an optimization tool for investment and planning DES in buildings and microgrids. The DES optimization function can be set to minimize total energy costs, carbon dioxide emissions, or a weighted objective that simultaneously considers both criteria. The output results from DER-CAM include optimal DES portfolio and daily dispatching.

The multi Criteria DES portfolio investment analysis was carried out to model various scenarios such as Business As Usual (BAU),

Cost-Minimization, CO^2-Minimization and Multi-objective Minimization. The cash flow model of the cost-minimization scenario can be seen in below.

Fig 11 Cash flow analysis



Production Facility Energy Conservation Measures

Modelling Methodology & Software

The model used to simulate this facility is an Arup in-house evaluation tool which uses the software eQuest v 3.64 as the embedded building energy simulator.

http://www.doe2.com/equest/

The base building characteristics and location are inputted into eQuest to determine the baseline energy use. The Consumption breakdown can be seen in the table to the right.

The four "demand side" ECM iterations are then run in eQuest (LED Lighting, VFDs on chillers and AHUs, Heat Recovery Wheel and Reflective White Roofs) to determine the % and kWh savings compared to the baseline building. The two "supply side" ECMs are calculated outside of the energy modelling software based on local conditions to determine how much energy they are able to supply.

The kWh saved for each ECM is converted into a CO_2 reduction and also a yearly cost saving. This is compared to the estimated capital outlay for each ECM to calculate a simple payback period.

Energy Consumption Breakdown

Misc Equipment inc Process Loads	49%
Area Lights	19%
Ventilation Fans	10%
Space Cooling	9%
Process Hot Water	7%
Space Heating	4%
Pump and Auxiliaries	2%

Urban Community Energy

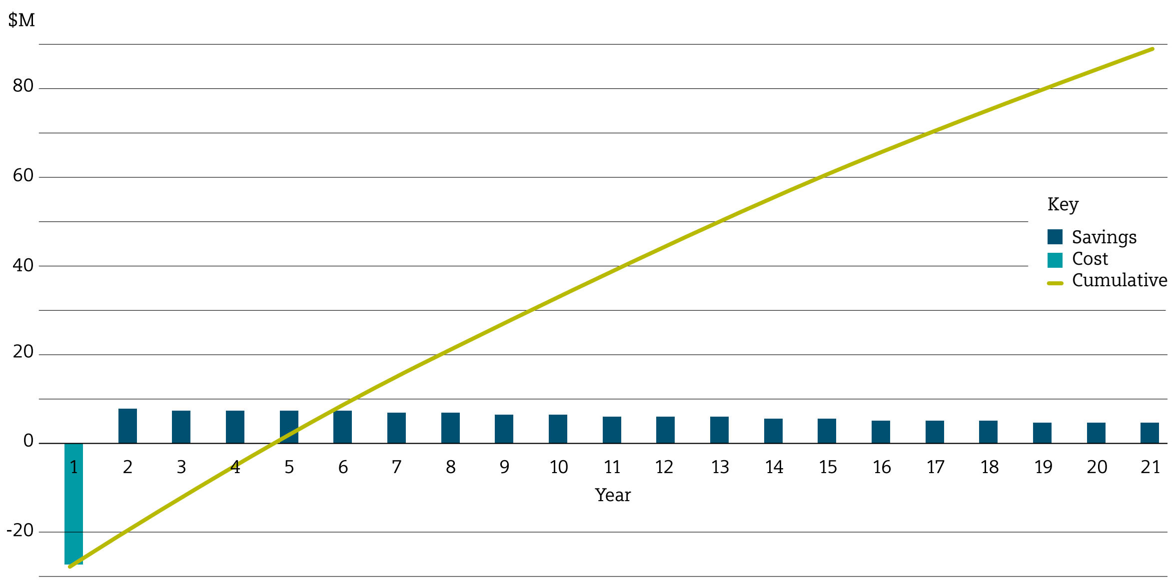
Modelling Methodology & Software

A central energy centre generates hot water and electricity, which is distributed to buildings on site via a district heat network. This provides cost savings to all heat and electricity users as well as a reduction in the site carbon dioxide emissions.

The urban community scheme is developed using an Arup in-house techno-economic modelling tool which models the system heating, cooling and electricity demand and production.

A discounted cash flow model is used to demonstrate the financial viability of the energy centre and distribution infrastructure, relative to a 'conventional' approach with individual boilers in each residential unit and electricity supplied by the grid. The discounted cash flow graph shows a five year payback period for the proposed DES system.

Fig 12 Cash flow analysis



Anchor Microgrid

Modelling Methodology and Software

The anchor microgrid model is built using the Hybrid Optimization Modelling Software HOMER PRO. HOMER is a program developed by United States' National Renewable Energy Laboratory (NREL) and is used for designing and analysing hybrid power systems.

http://homerenergy.com/HOMER_pro.html

Once the microgrid architecture is built, weather data selected and load profiles are uploaded, HOMER runs thousands of permutations, calculating the economic attractiveness of each of the myriad system combinations, and sorting the optimized results.

"Optimized" in HOMER refers to those combinations that have superior life cycle costs, judged expressly by the LCOE metric. HOMER also yields other useful results, such as total CAPEX, total OPEX, the percent of energy supplied by renewable energy systems, Carbon reductions, etc.

Nomenclature

AEC	Annualized Energy Cost
AHU	Air Handling Units
BEMS	Building Energy Management System
BAU	Business As Usual
BEV	Battery Electric Vehicle
CAPEX	Capital Expenditure
CCGT	Combined Cycle Gas Turbine
CHP	Combined Heat and Power
CO_2	Carbon Dioxide
DECC	Department of Energy and Climate Change
DEM	Distributed Energy Management
DES	Distributed Energy System
DG	Distributed Generation
DR	Demand Response
DOE	Department of Energy
ECMs	Energy Conservation Measures
EPA	Environmental Protection Agency
EPC	Energy Performance Contract
ESCo	Energy Service Company
EV	Electric Vehicle
GDP	Gross Domestic Product
GHG	Green House Gas
GT	Gas Turbine

GW	Gigawatt
HVAC	Heating, Ventilation and Air Conditioning
ICE	Internal Combution Engine
IEA	International Energy Agency
IT	Information Technology
kWh	Kilowatt Hour
LCOE	Levelized Cost of Energy
LED	Light Emitting Diode
LV	Low Voltage
MW	Megawatt
MWe	Megawatt Electric
NHS	National Health Service
OECD	Organization of Economic Cooperation and Development
OPEX	Operational Expenditure
PPA	Power Purchase Agreement
PV	Photo Voltaic
ROI	Return of Investment
TE	Transactive Energy
TSO	Transmission System Operator
V2G	Vehicle-To-Grid
VSD	Variable Speed Drive
VPP	Virtual Power Plant

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Dr Chau Chak Wing Building, University of Technology Sydney (UTS)

Awarded a 5 Star Green Star Design rating Certified by the Green Building Council of Australia, the building is an example of energy efficient design married with high architectural specifications. The University of Technology Sydney is now planning to source 12 per cent of its annual electricity from a solar farm in the Hunter Valley through a power purchasing agreement.