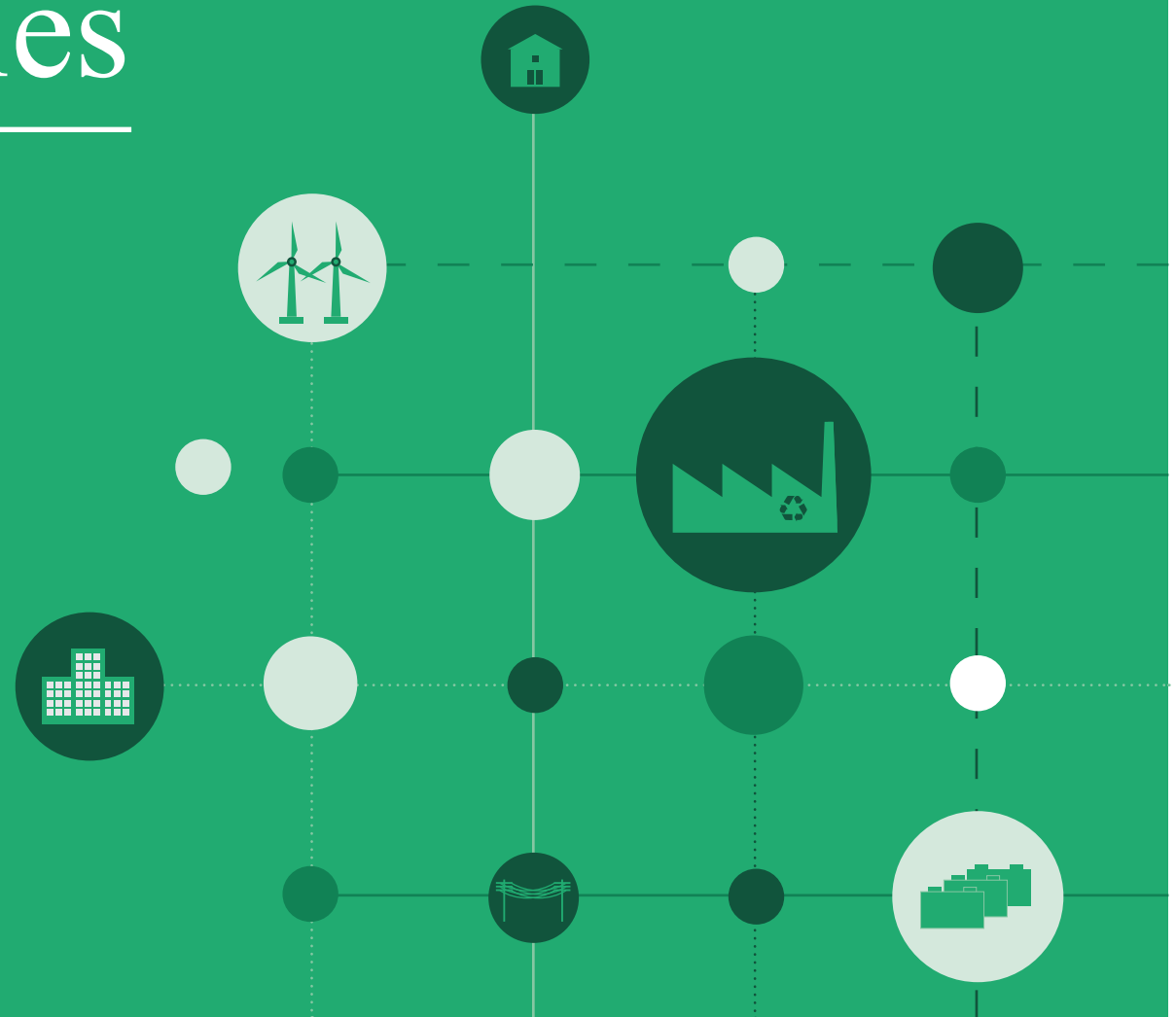


ARUP

Five minute guide

Energy in Cities



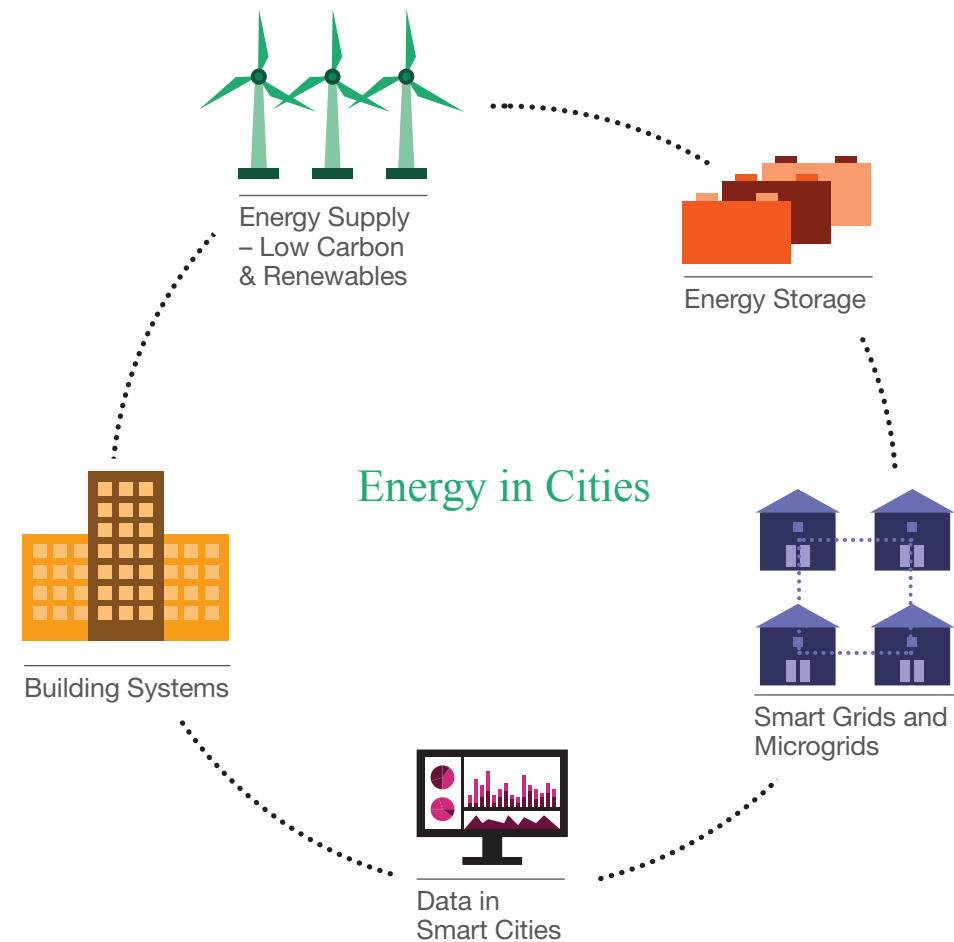
Introduction to Energy in Cities

The way we generate, distribute and consume energy is changing. The scale and rate of this change is a major challenge for existing and new cities alike, but also brings enormous economic, social and environmental opportunities.

Cities consume three-quarters of the world's energy and are responsible for 80% of its greenhouse gas emissions. Under conditions of resource scarcity and climate change, future cities will need to lower their energy demand and consumption whilst supporting larger, wealthier populations and meeting citizens' expectations for local environmental quality.

This guide provides a vision to help cities reduce energy demand, enhance efficiency of supply and increase use of low carbon and renewable energy. The systems and technologies featured in the guide were selected to show the the innovative energy solutions that could enable cities to achieve successful energy transitions.

1. Energy Supply – Low Carbon & Renewables
2. Energy Storage
3. Smart Grids and Microgrids
4. Data in Smart Cities
5. Building Systems



Introduction to Energy in Cities

Global energy demand is expected to double or even triple by 2050, by which time 70% of the world's population will be living in cities. Clearly, cities have a decisive role to play in tackling the energy challenges ahead and driving the transition towards a low carbon energy future.

Energy is essential to all city functions and services; it is at the centre of both the challenge and the solution to achieving healthier, more resilient and prosperous cities.

But while urbanisation drives economic growth, innovation and social progress, it also contributes to vulnerability in cities. Climate change is inextricably linked to urbanisation; a global problem with very local impacts for cities' energy services and beyond.

As the world urbanises, cities will need to provide more with less. Innovative approaches to energy delivery and management are fundamental to tackling that challenge.



Ho Chi Minh City

Energy Challenges in Cities

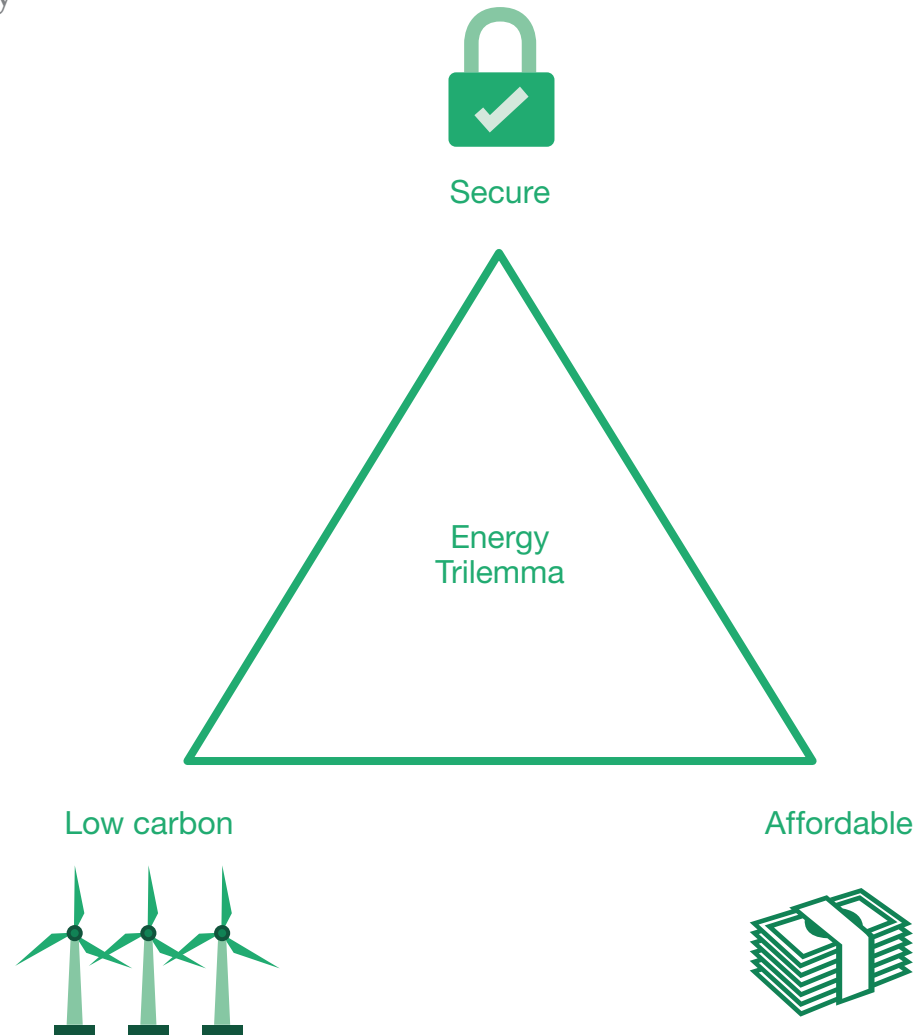
In addition to increasing population, cities are threatened by rising energy demand, ageing infrastructure, volatile energy markets and climate change impacts. The need to update and coordinate energy services has seldom been greater.

The “energy trilemma” encapsulates three distinct objectives for future energy systems while also recognising the tension between these objectives:

- (1) maintaining a reliable and secure energy supply,
- (2) ensuring long term affordability of the energy system and
- (3) drastically reducing GHG emissions associated with energy supply.

Cities can help solve this trilemma by adapting their energy delivery services to become more flexible, responsive and decentralised. These adaptations will enable a greater share of energy to be supplied by renewable and low carbon sources; however, they may also increase the complexity of urban energy systems.

Beyond the technical challenges, cities will also need to ensure regulatory conditions and governance are appropriate to encourage new business models under alternative market conditions.



Cities are Agents for Change

Cities are a powerful force for delivering action. They are increasingly showing they have the economic and political power to lead where nations and governments have failed.

Governance

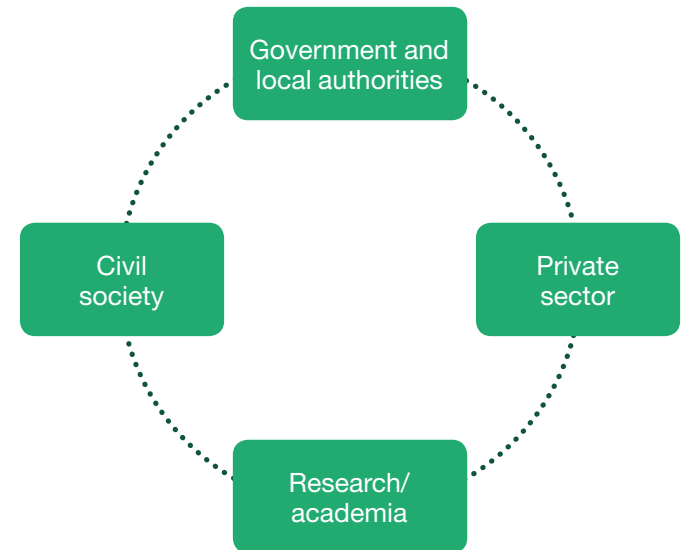
Energy assets such as wind farms, district heat networks and rooftop solar PV panels may be owned and operated by a range of stakeholders from state or city authorities, to private actors, community groups and individuals. Regulatory mechanisms will be needed to protect each group, whilst ensuring supply and demand is balanced in a predictable and reliable fashion.

As the energy transition gathers pace, cities must support the roll-out of evolving technical solutions with governance strategies that favour integration of assets and services and engagement from stakeholders at multiple levels. Resilience, efficiency and long-term cost savings are amongst the opportunities that may be achieved.

Knowledge Networks

Cities are already proving their capacity for sustained, transformative, and even radical action through networks like the C40 City Climate Leadership Group, 100 Resilient Cities and the Asian Cities Climate Change Resilience Network (ACCCRN).

Networks serve to connect the multitude of actors that operate at different levels of city governance, providing a platform for action and engagement and a medium for sharing knowledge and learning.



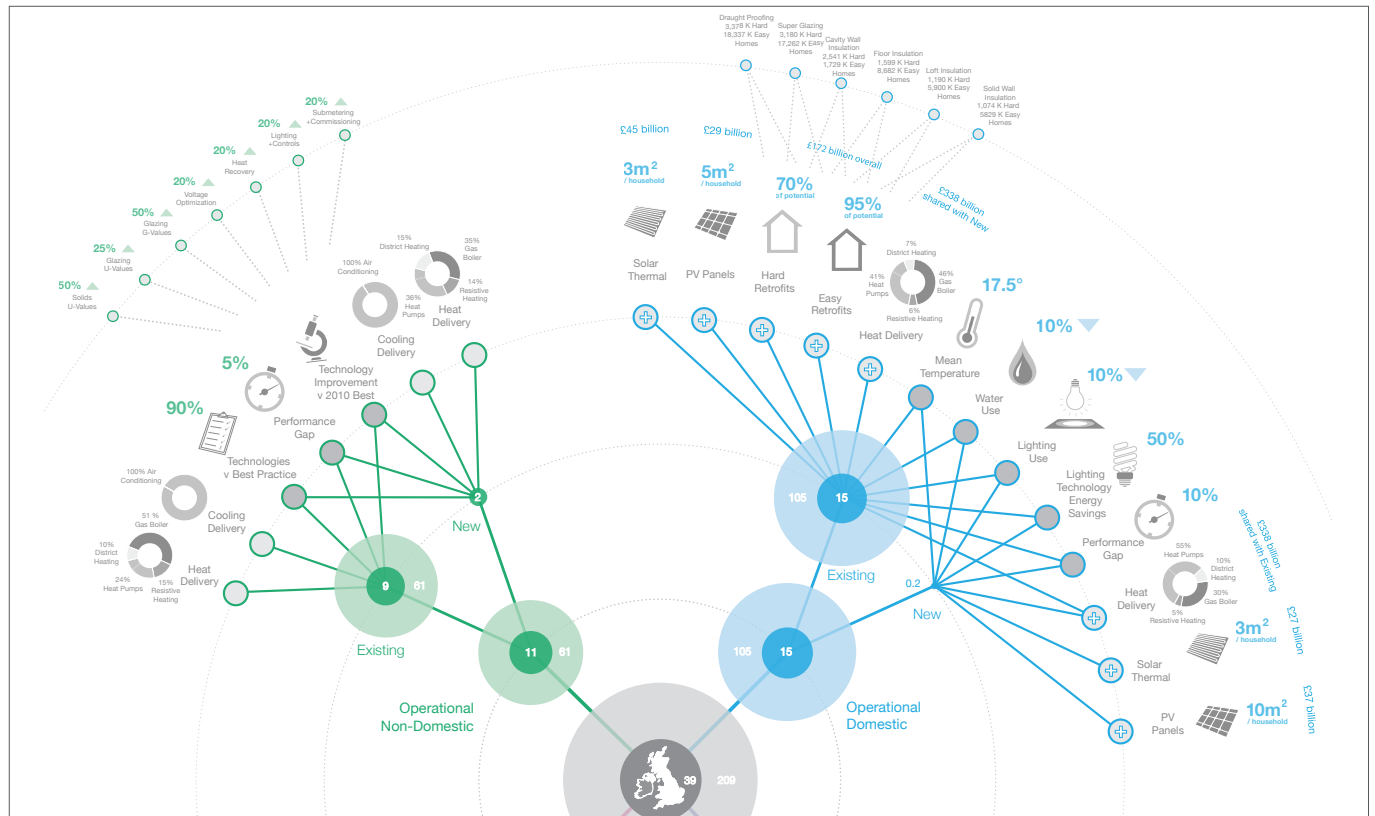
Energy Transition Planning in Cities

Cities have a key role to play in the shift towards a sustainable energy future.

The energy transition will not happen overnight. For the foreseeable future, cities will continue to rely on legacy systems and fossil fuels to help meet basic energy services including heating and transport. The transition process needs to be well thought-out to guide the change, helping us go from where we are now to where we want to get to.

Modelling and Scenario Planning

Energy modelling and scenario planning will help cities set out targets and create realistic plans and programmes to transition to a low carbon future.



» The Low Carbon Routemap uses scenario modelling to illustrate the policies, targets and actions required for the built environment to meet the UK government’s targets to deliver an 80% reduction in greenhouse gas emissions by 2050.

Energy in Cities - Summary of Solutions

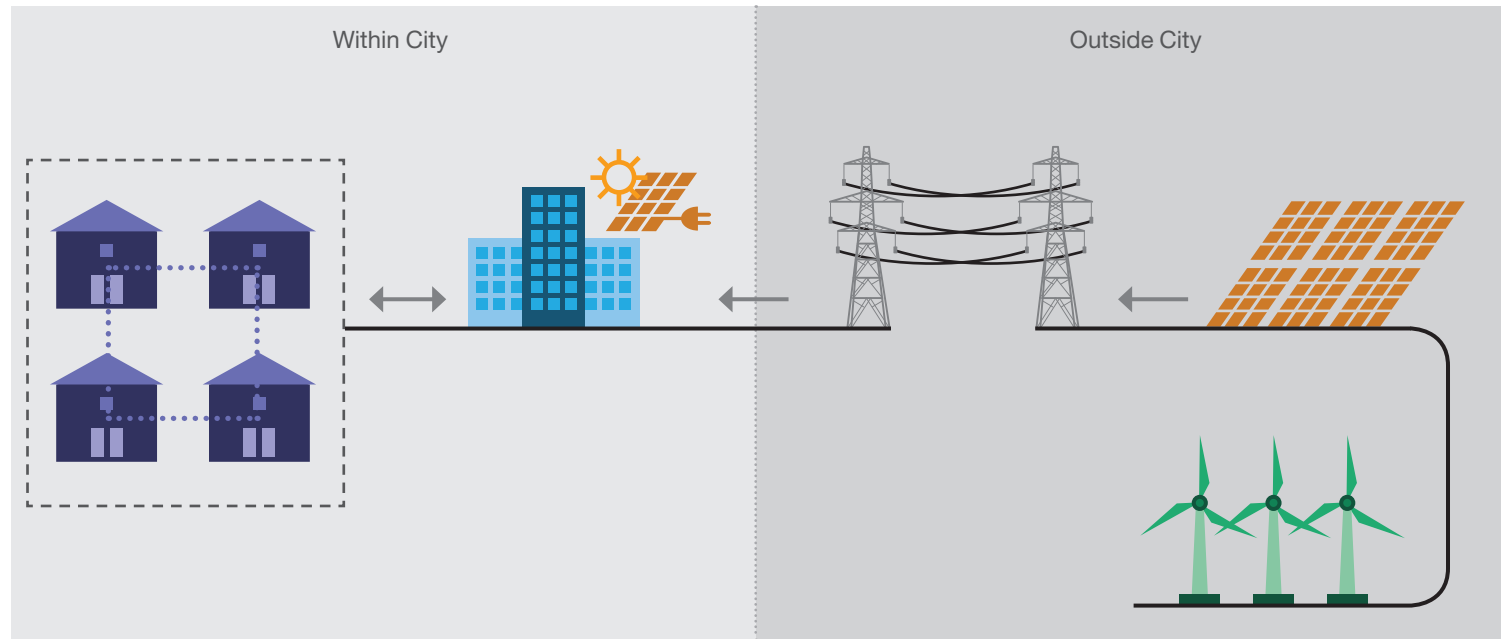
Solution	1 Energy Supply – Low Carbon & Renewables	2 Energy Storage	3 Smart Grids and Microgrids	4 Data in Smart Cities	5 Building Systems
Capability and Benefit to Cities	<p>Renewables will be deployed at both the national grid scale (in the form of large-scale biomass, wind, solar, hydro and tidal plants based outside the city) to replace traditional centralised power stations; and at the distribution or building scales (in the form of micro renewables and low carbon heat sources such as heat pumps, biomass and waste CHP and solar thermal), within the city. Both will help cities meet growing energy demand while reducing GHG emissions.</p>	<p>Energy storage enables optimisation of supply and demand, helps mitigate grid infrastructure constraints and assists the seamless integration of renewable energy. Storage helps increase efficiency and reliability at various points on the system using solutions including batteries, compressed air, flywheels, hydrogen and supercapacitors. District heating with heat storage can provide additional balancing (when supplied from heat pumps or CHP).</p>	<p>Smart grids is an umbrella definition which includes a number of technologies and operational strategies implemented into power networks which enable the delivery of flexible, affordable, reliable and efficient power. The bidirectional flow of power and data is the key operational feature in smart grids. Microgrids (a subset of smart grids) assist localised electricity distribution with smart coupling of decentralised electricity generation and demand response for reliable and high quality supply.</p>	<p>Smart cities use technology to transform infrastructure and make better use of energy and resources. Information and communications technologies (ICT) can be deployed to create new intelligent ways of making urban centres more efficient. Real time data informs smart systems which facilitate the shift towards behaviours that contribute to the development of the low carbon economy.</p>	<p>Energy reduction in buildings can make a significant impact on the overall energy use of a city. Increasing operational efficiency in existing and new building stock may be achieved through a combination of design, regulation, materials and technical solutions. For example, integrated building management systems allow energy use and demand to be monitored and optimised which can result in lower energy usage, costs and carbon emissions.</p>

1 Energy Supply – Low Carbon & Renewables

Supplying low and zero carbon energy will require a combination of centralised and decentralised sources to meet growing demand and global greenhouse gas emission targets.

Large scale renewables such as solar farms (PV and solar concentration) and wind farms, as well as hydro and tidal technologies that operate outside of city boundaries will need to be integrated with distribution scale systems within cities.

This will require smart interfaces between intermittent renewable sources and storage mechanisms to ensure a reliable supply and a stable, balanced system.



District heating and cooling networks provide low carbon energy to communities and combined heat and power plants can export electricity back to the grid.

Upgrading of ageing electrical infrastructure is required to enable cities to transition to a low carbon future.

Combining centralised and decentralised supplies will increase resilience and energy security.

Integration of multiple renewable and low carbon technologies will reduce dependency on fossil fuels.

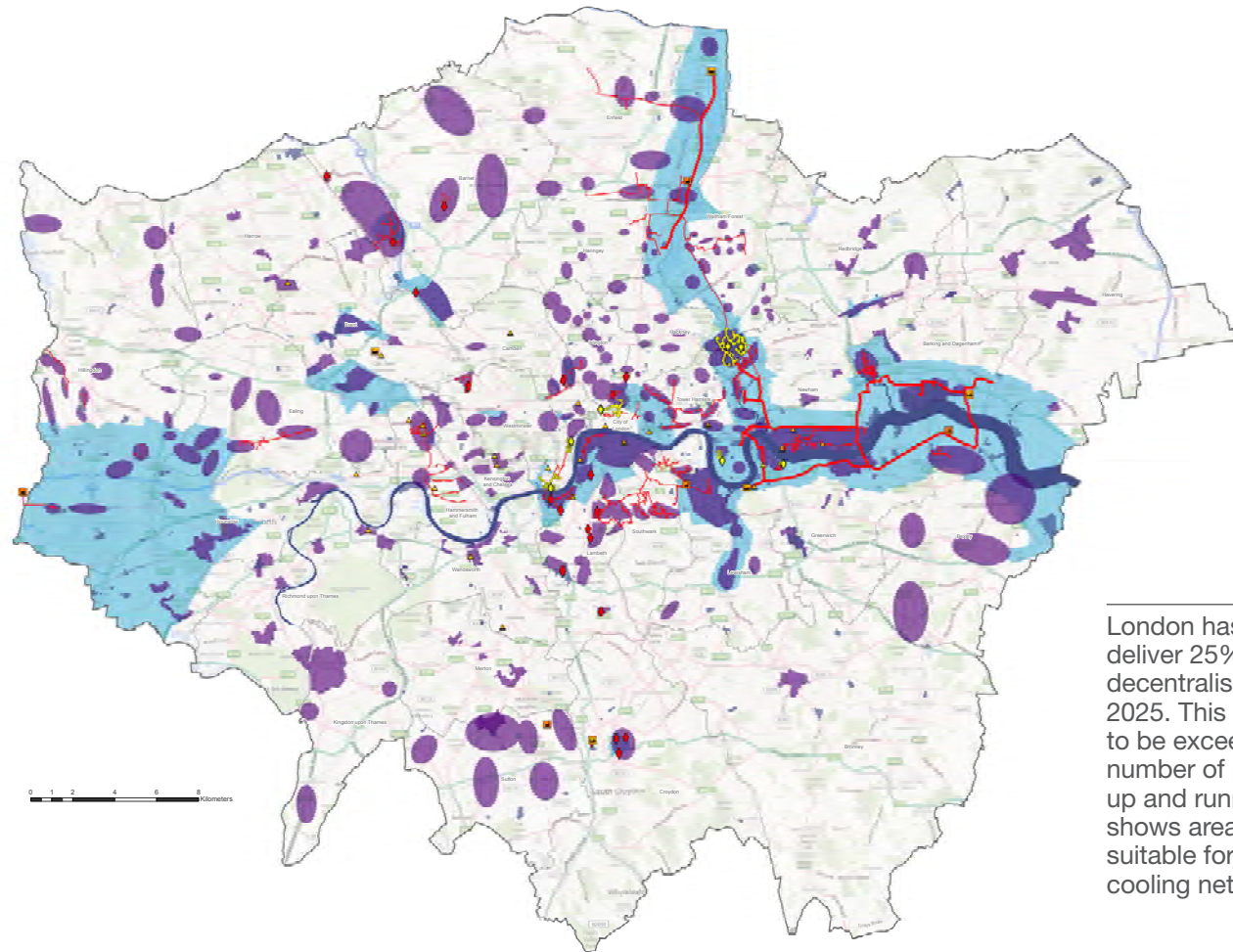
1 Energy Supply – Decentralised Energy in Cities

Decentralised energy (DE) schemes offer an affordable way of achieving low carbon energy supply in densely populated cities.

Decentralised energy is generated locally and off the conventional electricity grid.

Electricity: Decentralised energy can be provided by small scale renewables or low carbon technologies at a household or community level.

Heating/Cooling: District energy networks can provide heating/cooling for whole communities and even cities. DE systems can also increase resilience by helping cities cope with fuel price shocks and manage heating and electricity demand more accurately.



London has a target to deliver 25% of energy from decentralised sources by 2025. This target is on track to be exceeded due to the number of projects already up and running. The map shows areas identified as suitable for district heating/cooling networks.

- » DE is rapidly deployable relative to centralised supplies.
- » DE can be deployed at the building or community level, with networks eventually becoming interconnected.
- » DE provides valuable opportunities for scaling renewable generation in cities.
- » Local solutions help meet increasing demand in cities whilst improving energy security and reducing emissions.
- » Interconnecting generation technologies ensures security of supply and increases resilience.

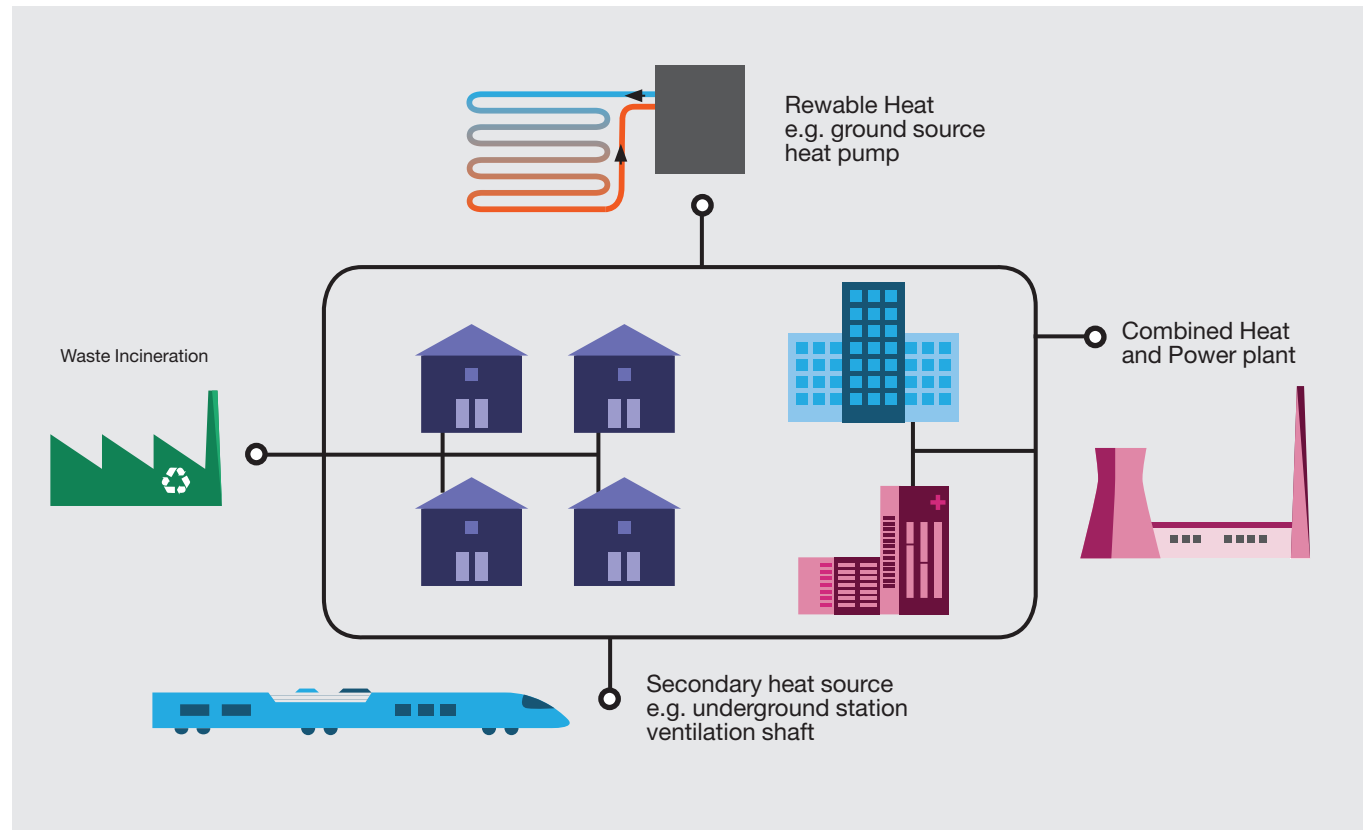
1 Energy Supply – Heat and Cooling Networks

Heat and cooling networks represent an affordable, efficient, low carbon, resilient solution to the comfort and hot water needs of domestic and non-domestic buildings in densely populated areas.

These systems consist of a distribution network carrying heated or cooled water from the generation source to the end users thereby avoiding the need for individual systems. As a result, these networks can facilitate deployment of a larger amount of renewable heat than by individual stakeholders.

The cost and energy efficiency benefits of such networks also make them a potential tool for cities to tackle social challenges such as energy poverty.

Energy sources for heating and cooling networks include conventional options such as local power stations and smaller scale CHP engines, but also natural sources such as water bodies and geothermal resources; urban infrastructure sources such as underground train ventilation shafts, wastewater in sewer pipes and electricity substations; and coupled heating and cooling loads where the rejected heat from a cooled space (such as a data centre) can be captured and used in a heated space (such as a residential unit).



2 Electricity Storage in Cities

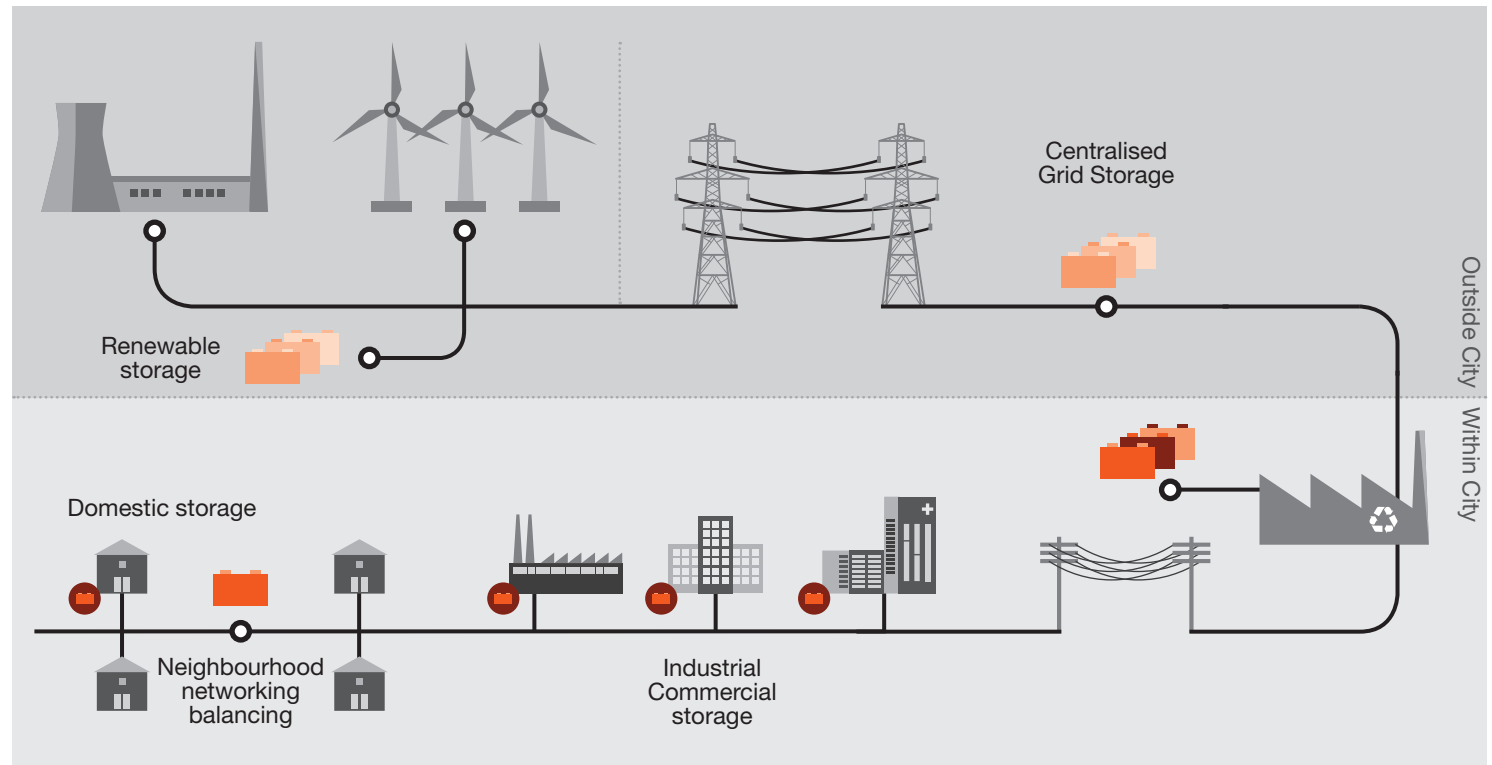
City storage - facilitating the integration of low carbon and renewable technologies.

How does electricity storage contribute to the energy transition?

One of the biggest challenges for renewable generation is matching supply and demand. The current system relies on switching fossil fuel generation on/off as required, particularly at peak demand. Storage in cities will therefore add redundancy and flexibility to the system and contribute to city resilience and the transition to a low carbon future.

Different storage technologies can be installed at various points on the network from the point of generation to points of use. Benefits of electricity storage include:

- Allowing renewable energy to be generated when it is most efficient, and stored until there is demand for it.
- Providing reserve capacity in the event of system failure.
- Maintaining quality of supply.
- Avoiding investment in gas assets.



» **Storage at point of generation:** Adding storage at urban power plants such as Energy from Waste plants.

» **Neighbourhood storage:** Adding storage to substations could be practically implemented.

» **Decentralised storage in buildings:** At the scales achievable in cities this could dramatically reduce peak demand.

2 Electricity Storage in Cities

Technology Snapshot

Storage Mechanism	Description	Application for cities
Battery technologies	The most common form of battery storage is lead acid batteries. Batteries have two electrodes and electrical energy is released when the electrodes are flooded with electrolytes.	Battery storage is scalable and can be installed either at point of generation or end use. Batteries could be used individually in micro-grids to balance variable decentralised energy sources or multiple batteries could provide larger storage for utility scale technologies outside of cities.
Pumped Hydro	Pumped hydro uses the differential in height between two reservoirs to store energy and drive turbines when electricity is required. During times of low demand the water is pumped to the upper reservoir.	This is a utility scale technology that can be used to balance variable large scale renewable resources (e.g. wind). The technology's rapid response time can help meet peak loads or sudden changes in demand.
Hydrogen	Electrical energy is stored by electrolysing water to produce hydrogen and oxygen. Oxygen is then released and hydrogen is stored. For grid energy storage applications the hydrogen is then passed through a fuel cell that recombines the hydrogen with oxygen to produce electricity. Heat and water are also released as a by product.	Hydrogen storage can be used either for grid storage or to power vehicles. Fuel cell technologies are currently expensive but could offer cities the opportunity to de-carbonise transport and balance microgrids.
Super Capacitors	Capacitors store static electricity between two plates. A thin insulator separates these two plates. Super capacitors are unsuitable for long term storage solutions due to self discharge.	Capacitors as energy storage devices are more suited to short term storage applications. Their ability for rapid charge and discharge cycle makes capacitors particularly suited for use in network frequency stabilisation. This makes them suitable for application in microgrids to stabilise frequency variations from decentralised energy sources.

3 Smart Grids

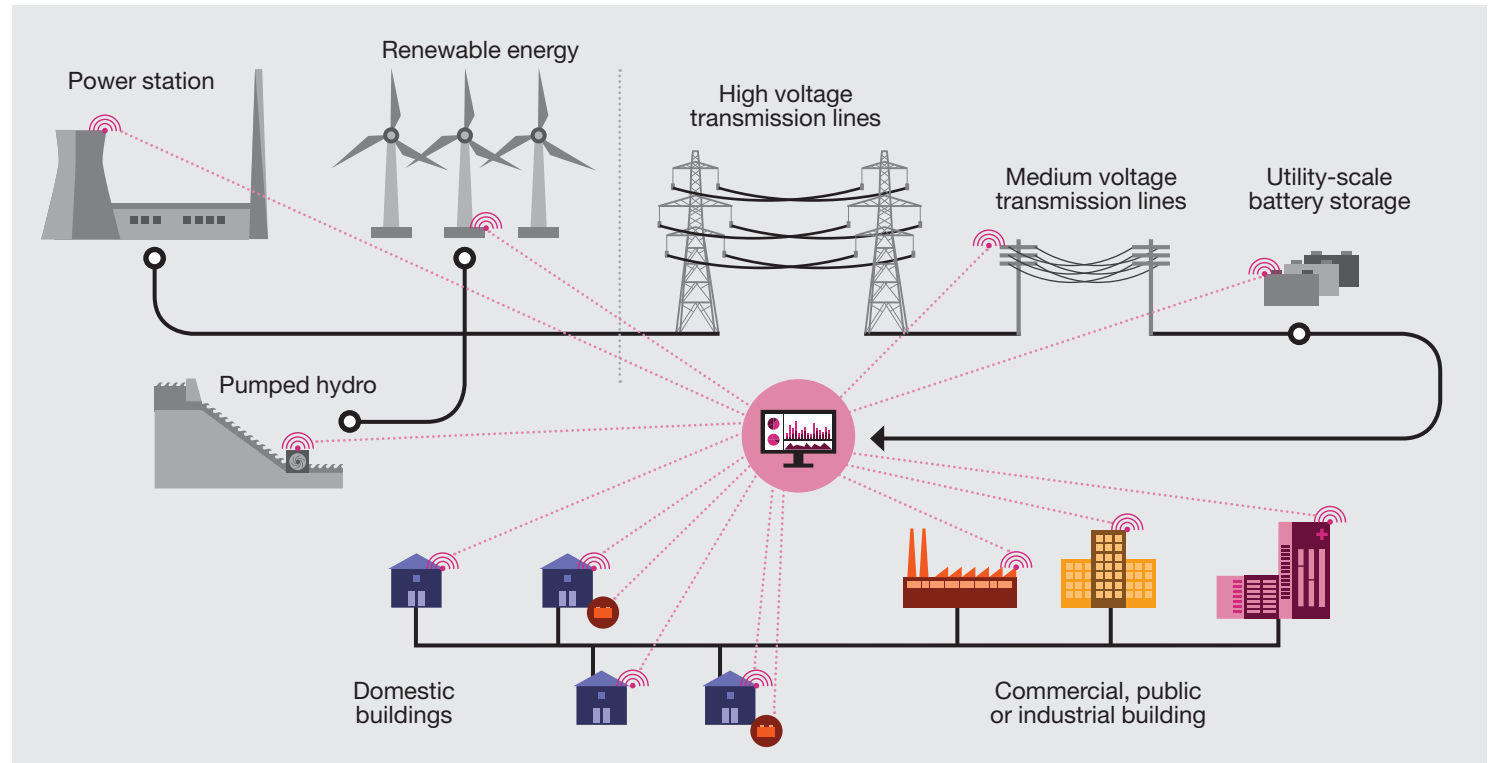
Smart grids enable responsive energy distribution that is better able to cope with growing demand and new supply technologies.

A smart grid is an electricity network incorporating electricity and communications systems that can intelligently respond to nodes connected to it. Smart grids can also include storage and decentralised generation but their salient feature is the integration of high-speed bi-directional communications between systems and the grid.

Why are smart grids important for cities?

Cities are driving increases in electricity demand against the existing, aged and congested grid infrastructure.

It is critical that communication-enabled controls are integrated into urban networks to improve their operation and realise a more sustainable interaction with the power end users.



» Potential to better predict electricity supply and demand at specific locations.

» Monitor condition of grid and major assets.

» More efficiently utilise labour and materials.

» Interact with users to actively manage demand.

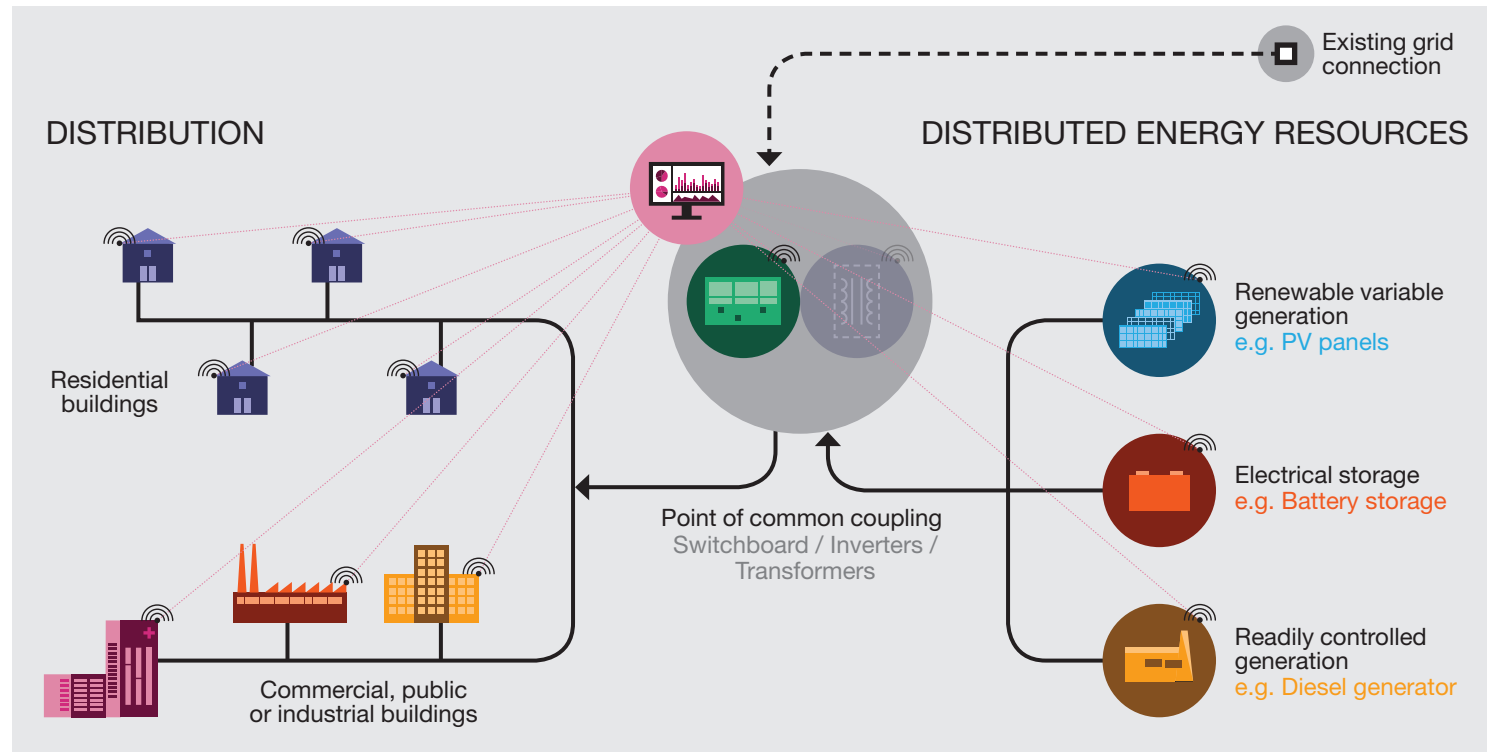
3 Microgrids

A microgrid is a way to simultaneously address energy security, affordability and sustainability through dispersed, locally controlled, independent energy systems tailored precisely to end-user requirements.

A microgrid is a distributed level energy system which includes all the necessary components to operate in isolation of the grid. It is a microcosm of the broader energy network, but at a distributed level.

Microgrids incorporate generation, storage and demand management systems so that supply and demand are matched in a safe, effective and reliable way. The ‘smartness’ of microgrids means that these are compatible with renewable energy generation.

Microgrids also alleviate pressure on the grid and enable more efficient supply thanks to optimised demand and supply balancing and reduced transmission losses.



How can microgrids be part of the solution?

- » Enable cities to take ownership of their generation and adoption of renewable energy systems.
- » Can be designed for future connection to main grid. Opportunity for suburbs with poor quality or no connection to electricity supply to improve electricity access.
- » Enhances resilience against threats including climate change and market volatility.

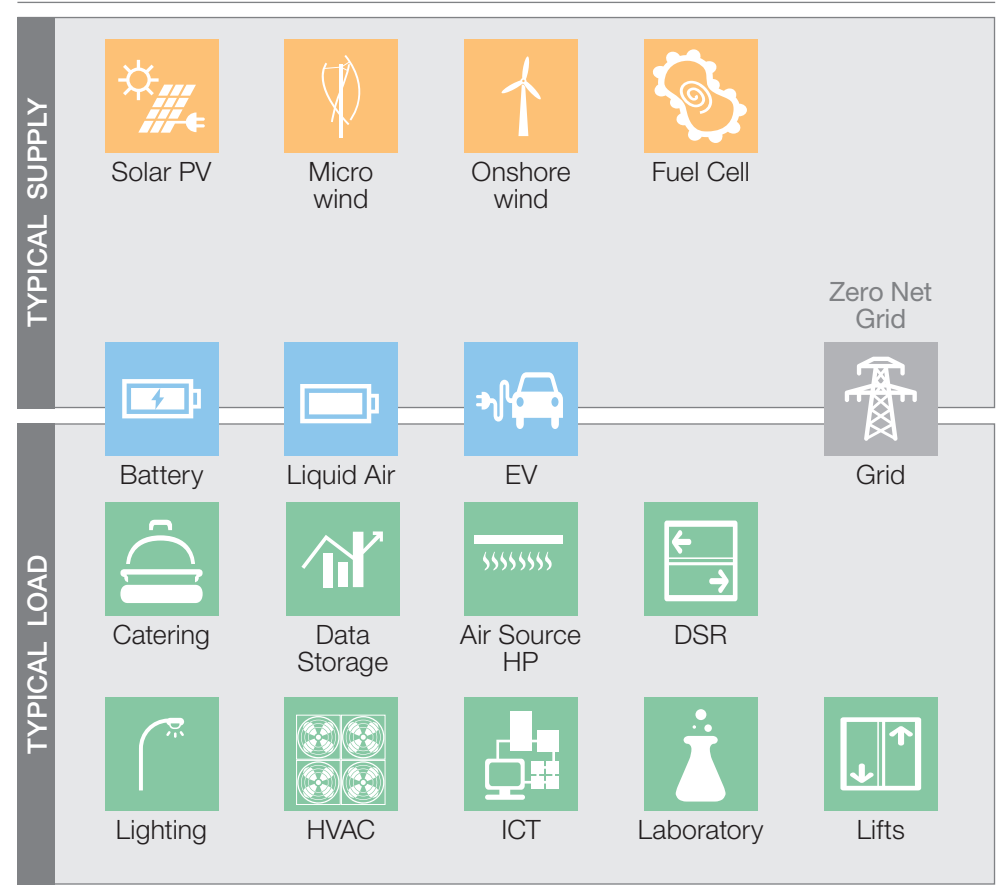
3 Microgrids

Microgrids (μ G) have a range of city applications including high-tech industries, mission critical operations and low carbon commerce.

Cities are increasingly becoming low carbon leaders keen to demonstrate their environmental responsibility while also positioning themselves as pioneers in adoption of sustainable technologies. In terms of their own real estate, this could be reflected in maximum deployment of renewable energy and demand side response (DSR) within microgrids.

Cities could accelerate wider adoption using policy and regulation to target users with high loads and available capital. These users might include real estate developers, universities and business parks. Microgrids are compatible with these high performing organisations as they enable maximum onsite sustainable energy contribution while providing the same level of reliability of supply as the conventional grid based supply.

The ability to synchronise and dispatch energy to the distribution network or to rapidly reduce demand when ‘Negawatt’ prices make it commercially attractive are also important features of this type of microgrid.



4 Data in Smart Cities

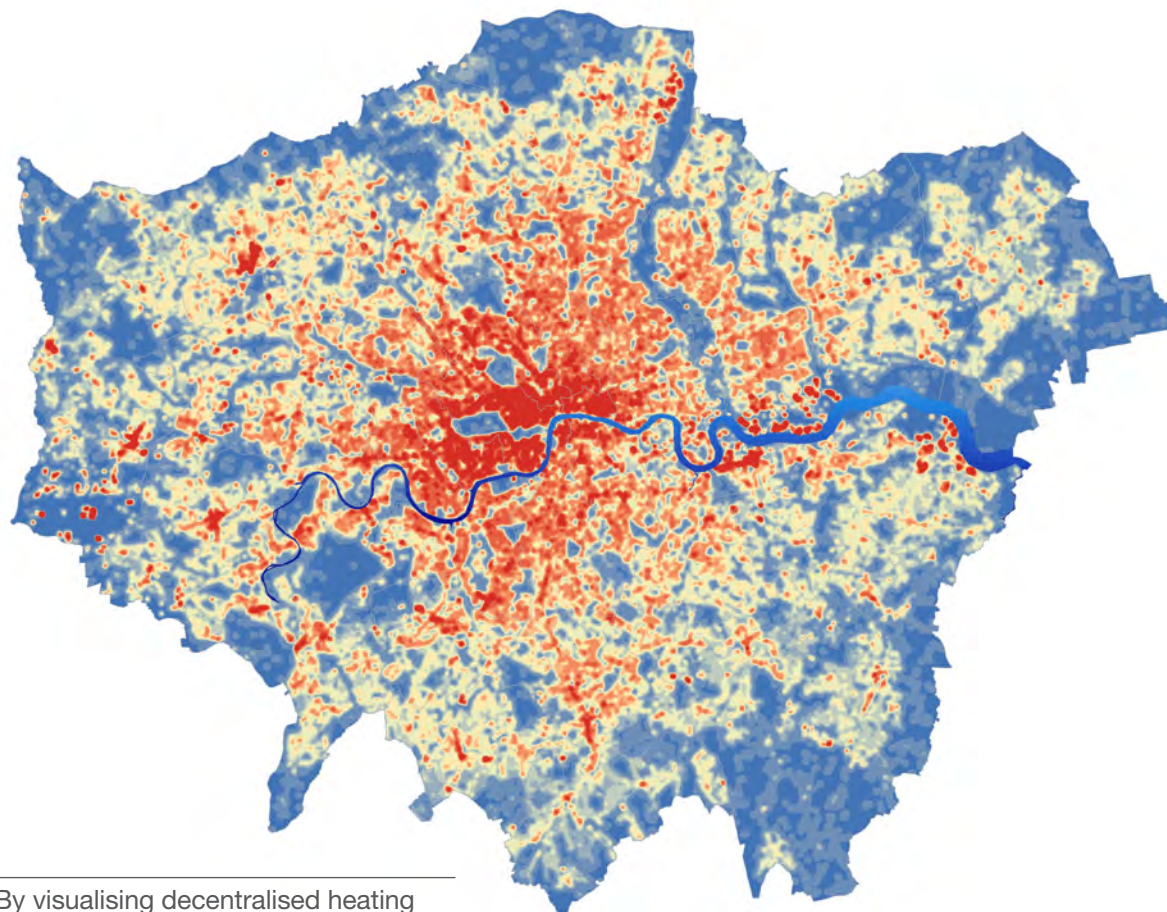
Data enables two-way communications between energy systems facilitating proactive responses and increasing efficiencies.

Maximising the value of energy data in cities

Cities are generating new data every second of every day. Real time data availability is also growing, with the potential for improving energy management and enhancing the efficiency of other city functions too.

Digital information services, e.g. data analytics, and visualisation will improve cities capacity to identify risks, opportunities and future requirements for energy, allowing them to respond more effectively to urban challenges such as social inequality and fuel poverty.

To support cities identifying opportunities and planning for sustainable energy projects, some data-driven planning tools are now available to the public, for example, the UK National Heat Map, and the London Heat Map. As data proliferates and technologies to utilise it advance, opportunities for more accurate energy balancing will increase, helping to lower costs and carbon and improve reliability of energy supply in cities.



By visualising decentralised heating planning data, social housing density data and policy indicators, the **London Heat Map** allows stakeholders to identify opportunities and assess the feasibility of decentralised energy deployment in London.

4 Data in Smart Cities

Smart approaches, founded on technical expertise, sustainable, integrated thinking and policy considerations, pave the way for city decision-makers to respond effectively to energy related issues that impact climate change.

Smart systems encourage changes in behaviours which prompt new choices and activities, creating a shift in the way we consume and share energy and, hence, contribute to the development of low carbon urban economies and societies.

A new generation of integrated hardware, software, and network technologies will provide systems with real time information of the world. Advanced analytics will help people to make more intelligent decisions about alternatives and actions that will improve how we use energy and resources.

The increasing penetration of smart and data-driven technologies is helping to drive smart cities. Cities must facilitate expansion of the industry through appropriate regulation, incentives and governance.



An urban development project in Helsinki features a wide range of informatics strategies and services aimed at reducing the energy demand and carbon footprint of the local community.

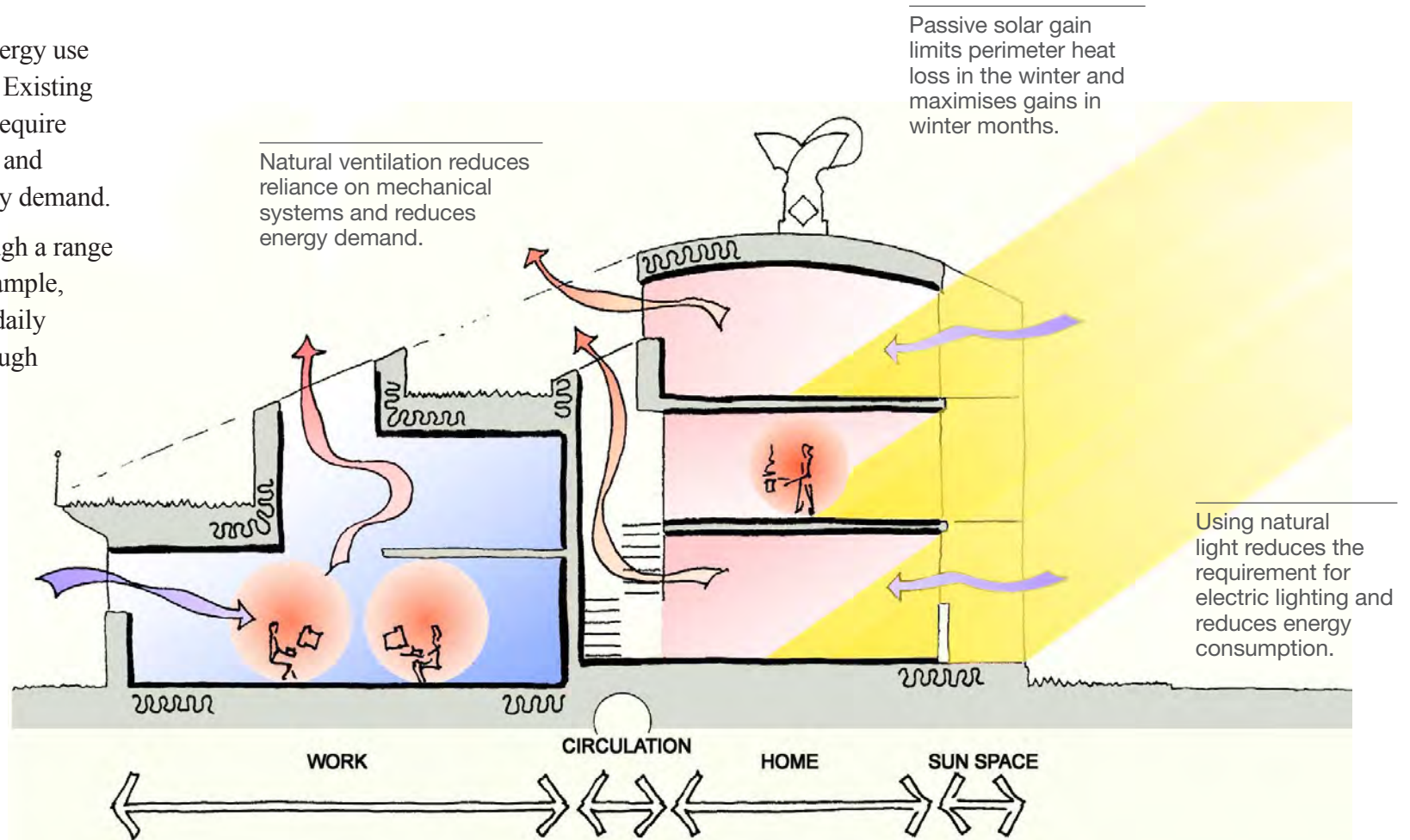
5 Buildings Systems

There is enormous potential for demand reduction at the building scale in both new and existing buildings, using both passive and active systems.

Buildings account for 32% of total energy use and 19% of GHG emissions globally. Existing and new building stock in cities will require improved energy efficiency measures and building performance to reduce energy demand.

Energy savings can be achieved through a range of technologies and solutions. For example, detailed monitoring and reporting of daily energy consumption in buildings through a user interface allows occupants to better understand and manage their energy use.

Enhanced fabric thermal performance can reduce the requirement for heating and cooling demands.



For more information please contact:

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