Private Networks for Utilities & Energy Companies

Best practices in designing indoor and outdoor private networks.
A Disruptive Analysis thought-leadership eBook.

Disruptive Analysis

iBwave

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Summary

The utility and energy sectors have some of the most demanding requirements for communications networks of any industry vertical. They are fundamental parts of every country's national infrastructure, with intense requirements for uptime, reliability, and security. Many areas have health-and-safety impacts, both directly such as grid short-circuits and fuel leaks, or indirectly, for instance by outages impacting healthcare equipment, or water supply. In addition, *other* communications networks – including most fixed and mobile carriers – are themselves dependent on reliable power supply.

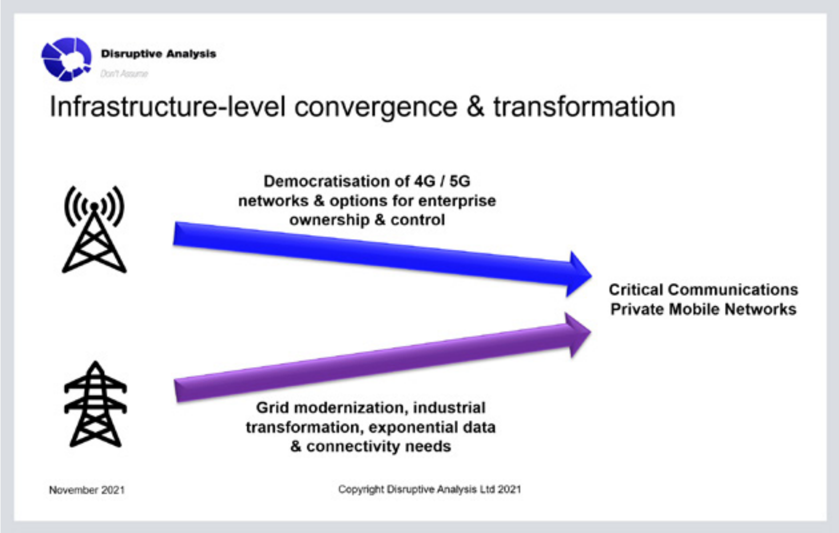
Many utility and energy companies have historically been owned by national or municipal authorities, with unique country-specific regulations and technical heritage. Most have developed their own proprietary network infrastructures to control and monitor their assets, employees, and sites.

Unlike most industries, energy and utility firms have long had sophisticated network infrastructure and internal skillsets. They have always had a focus on low latency requirements, with networks that might demand 6 or 7 nines of reliability (99.9999% uptime), as well as 20-30-year life cycles and in some cases full nationwide coverage. Often, they have extensive self-build fibre networks and VHF/UHF wireless for critical voice and push-to-talk. Many use private microwave links for remote M2M control and SCADA (Supervisory control and data acquisition) applications. Cybersecurity issues are of central importance.

In addition, utilities are also large-scale customers of MNOs' national 4G and soon 5G networks. They require broadband and mobile connectivity for vehicles, security cameras and consumer metering, which can be hard to support with legacy wireless networks. Increasingly, new applications will be better-suited to cellular networks – although as this paper describes, some of these will be best provided by private/dedicated networks. New domains, such as renewable solar and wind energy generation, mean infrastructure is distributed and covers broad areas beyond their traditional networks.

In essence, what is happening at the moment is a form of convergence:

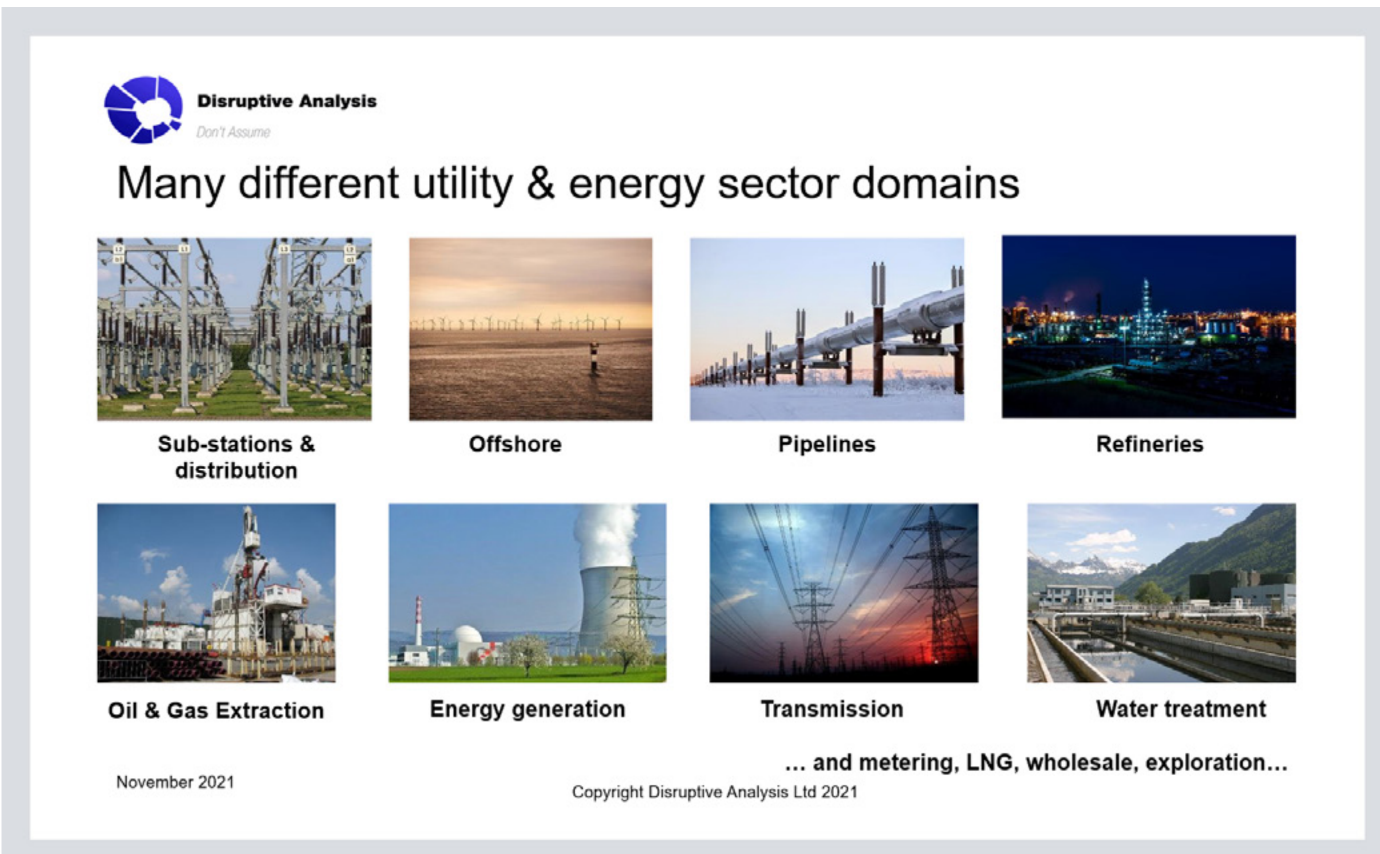
- Wireless networks are migrating to standard technologies, notably 4G and 5G cellular. These are becoming "democratised" beyond traditional MNOs by shifts in spectrum and equipment availability, Companies such as utility and energy firms are increasingly able (and willing) to build their own private networks.
- Utility / energy sector grids and assets are becoming more distributed, data-driven and interconnected. A range of industrial transformation programmes (and broader societal trends) are driving the need for more and better connectivity.



Together, this is creating a perfect match of supply and demand for private mobile networks, for critical communications and general IoT and operational needs. This paper outlines the main use-cases, deployment scenarios and paths to private 4G and 5G.

Definition of the sector

There are numerous sub-sectors and site types covered in this report. Although there are many common features – notably their inclusion as part of any country's critical infrastructure – there are also clear differences in physical terms, as well as applications/technology platforms and also regulatory oversight.



The key domains covered in this eBook include:

- Electrical utilities, from generation (renewable, oil/gas, nuclear, hydro etc) to transmission networks and local distribution.
- Water utilities, including reservoirs, pumping stations, treatment facilities and pipelines.
- Natural gas production, transport, and local distribution – including domestic and business supply, international LNG (liquefied natural gas) shipping and terminals, pipelines and storage facilities
- Oil and gas sectors, including exploration, production, shipping/pipelines, storage, refineries and end-product distribution and retail sites.

Key challenges and market drivers

The growing demand for, and deployment of private networks for utility and energy sectors is ultimately driven by a number of top-level national and global changes. Broadly speaking, these all create a greater requirement for connectivity, control, and information flows.

- **Infrastructure modernisation and reliability:** Many utility and energy assets have been in place for years or decades. It is common for equipment to be either unconnected or using legacy/proprietary networks for specific and narrow purposes alone. While originally reliable, the systems may not support modern demand patterns, while spares may be difficult to obtain – and skilled operators are starting to retire. Operation and maintenance processes are often manual and inefficient. Against this backdrop, many utility and energy companies are modernising grids, pipeline distribution systems and other assets. They are seeking connected systems with realtime data collection and control, greater flexibility and automation, and easier repair and restoration.

- **Improved employee safety and productivity:** Reliable communication between utility workers, especially while in the field or dangerous areas, is essential. As well as voice (push-to-talk) there is an increasing need for video communications and reliable access to enterprise applications. Improved network connectivity can increase productivity – and also improve safety, especially where humans and automated machines and robots work close together.

- **Climate change and decarbonisation:** Over the next decade, this sector (and all subsectors) will face profound change as the planet heads towards Net Zero carbon emissions. Old facilities will close, new ones will be built, and a vast array of new approaches will modify electricity generation and storage, as well as transform the oil and gas sectors. Many assets will be in unusual and unconnected locations – from rooftops and deserts to hilltops and offshore sites. All of the new plants – and many old systems – will need more connectivity for monitoring, control and data-collection. Localised wireless networks will be an important element for many sites – or indeed, national or wide-area private networks.

- **Cybersecurity:** Security challenges are becoming multi-layered and highly complex. Old IT and operational systems will be strengthened or retired if they have vulnerabilities, while networks will be examined for resilience and redundancy. Cellular networks may be used as backups in case of failure of fibre or other links.

- **Adverse weather and disasters:** Linked to climate change as well as shifting patterns of urban/rural development, there are likely to be more frequent storms, fires, and other extreme conditions in future years. These will mandate improved observation, greater network resilience, improved human critical communications and a variety of new protection / emergency systems. At the same time, public networks may be affected badly by these events, so cannot be relied upon by critical infrastructure operators. Again, wireless networks – especially those with direct control and ownership – are part of the solution.

- **Data and analytics:** Utility companies are rapidly transforming legacy analogue infrastructure. Better-connected equipment, IoT sensors and video input can improve asset management, enable fault management and diagnostics, and optimise maintenance. Often, equipment is in location without suitable public network coverage, or only limited connectivity from legacy technologies.
- **New business models:** Utility and energy companies are seeking new sources of revenues, in order to offset their costs of modernising infrastructure. Many potential new ventures will be connectivity-enabled – or even based on developing "semi-private networks" with external customers. Electrical vehicle charging, local fixed-wireless access and 5G neutral-host business models are all under consideration by companies in this sector – and may involve localised private cellular networks.

Combined, all of these broad factors, as well as company or country-specific trends, are combining to mean that networks need to be:

- High-capacity and low-latency
- Standardised where possible, with a diverse supply chain and widely held skillsets
- Available ubiquitously, either as-a-service, or on a privately-owned basis
- Secure and resilient
- Able to cope with mobility, the rapid addition of new sites/users and the adoption of new applications and services
- Suitable both for large utility / energy companies, and smaller suppliers and partners – and even consumers and "prosumers"
- Lower (or at least predictable) costs per-site or per-device.

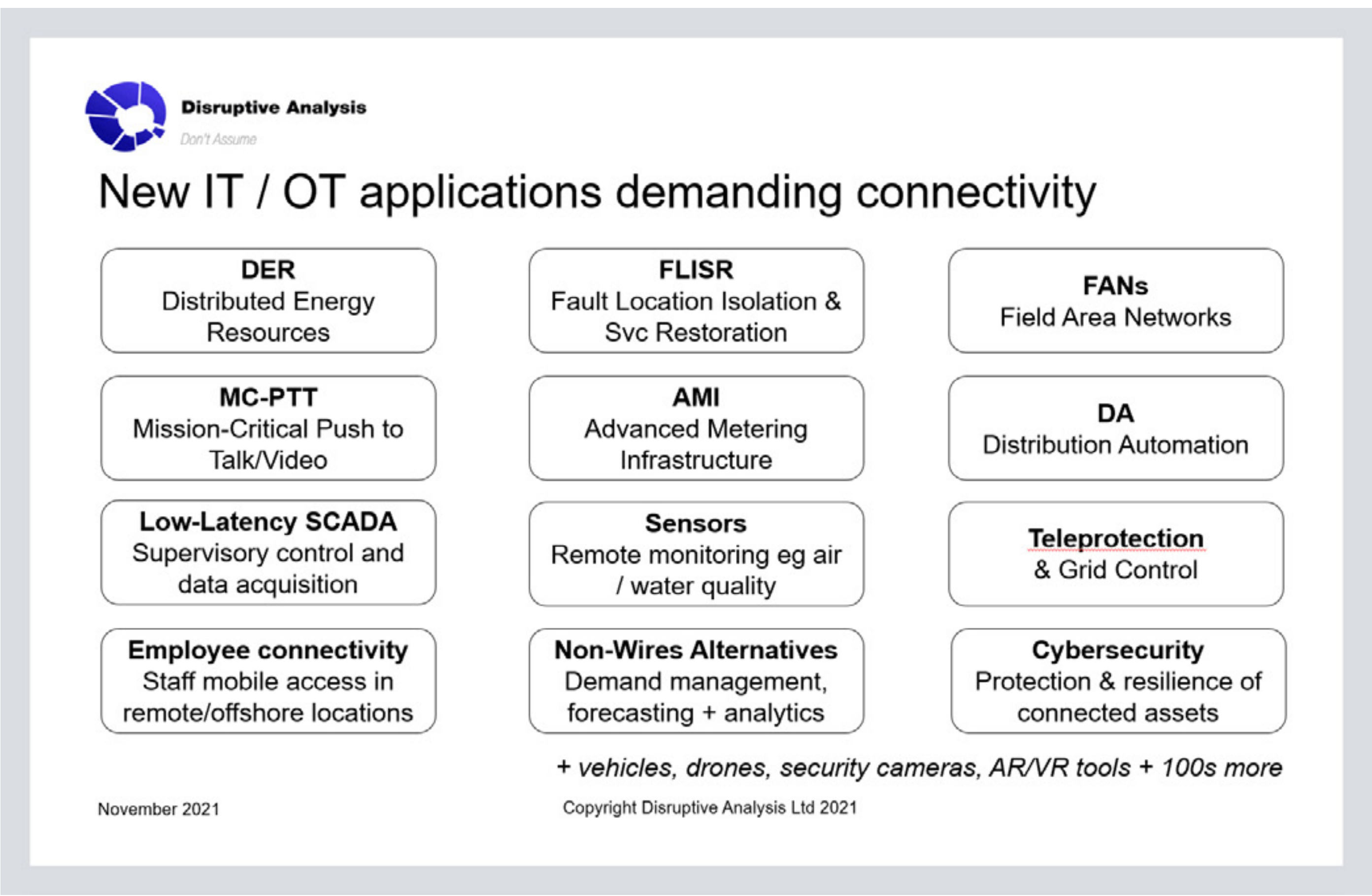
While the majority of energy and utility companies will still use traditional forms of connectivity – notably fibre for critical assets or Wi-Fi for office-based locations – there will be a growing demand for cellular connections, using either 4G or 5G technologies. Often multiple technologies will be used in combination, such as satellite backhaul for remote sites' local wireless connections, or Wi-Fi gateways connected via 5G.

4G/5G use-cases in utilities & energy

Given the industry structure and changes outlined above, there are two layers of questions to address in this report:

- What use-cases are suitable for cellular 4G and 5G connectivity?
- When is a private 4G/5G network more appropriate than a public network service from an MNO/carrier?

This section highlights some of the emerging use-cases that can benefit from cellular connectivity in the utility and energy industries, especially electrical utilities, and oil producers, which are probably the largest customers for private 4G/5G at the moment. While there are likely hundreds of applications overall – and some such as general office IT are omitted for conciseness – the following are typical of the aspirations of many companies in these sectors.



Management of DER (Distributed Energy Resources)

Huge changes are occurring in energy production, storage, and consumption, driven by the response to climate change and the need for decarbonisation. This is changing the networking needs of many utility companies, as distributed renewable energy generation and storage are becoming essential.

Generation, storage, and control of power can occur at 10x or 100x more sites than was typical for traditional utility operation. There are many new physical locations for solar and wind resources, battery storage and new consumption locations such as electric vehicle (EV) charging stations. These locations need to be interconnected with the main grid and low/medium voltage distribution "micro-grids".

This demands efficient infrastructure, coupled with better control and visibility of systems for distributed frequency and voltage control. Without DER, it is hard to maintain stable micro/main-grid interconnections. This is driving a huge increase in the number of connected devices and data throughput required. Normal utility fibre or wireless technologies will be hard to deploy (for instance for solar panels on residential property or a farm), so cellular 4G/5G connectivity will be more important.

FANs (Field Area Networks)

FANs are used by utilities and energy companies for communications and automation across different layers of infrastructure, including distribution facilities, sub-stations, pumps, and many other sites. FANs enable multiple service functions, including some of the other specific applications discussed here:

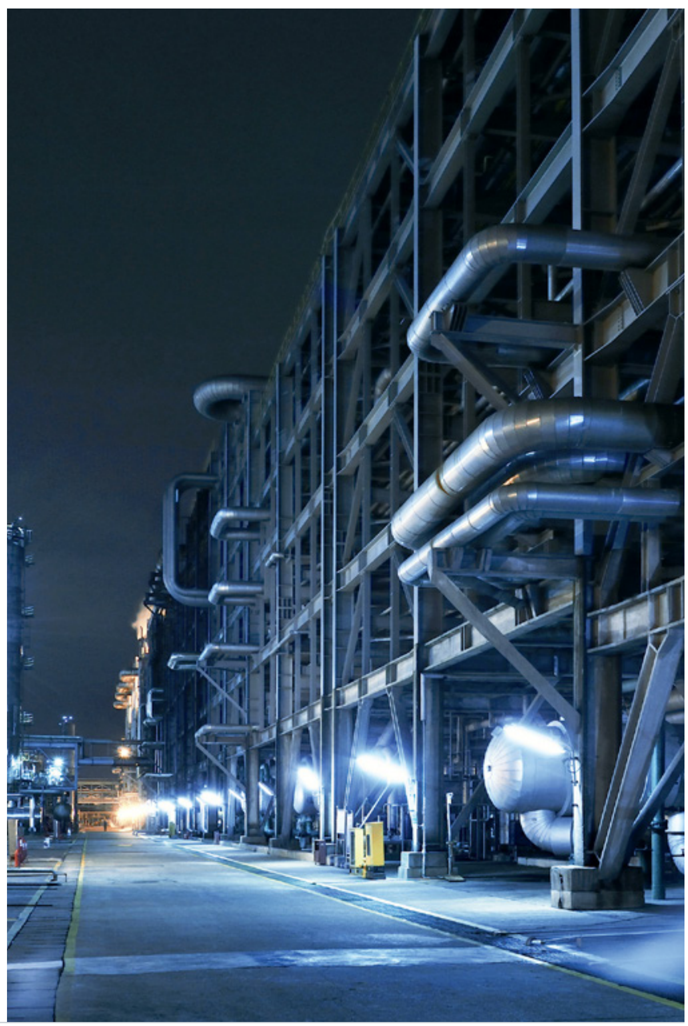
- **Operations**, such as asset monitoring and fault diagnostics, "situational awareness" of weather status, or metering.
- **Safety and security** - cameras, intrusion detection, fire, and smoke alarms etc.
- **General-purpose IT** such as Internet connectivity for on-site employees, or supply-chain management of parts and materials.

Historically, it was not unusual for utilities to operate several application-specific FANs. They are now hoping to combine these to reduce costs, integrate operations management, and deploy new capabilities. 4G/5G networks are well-suited for this, likely alongside existing fibre and microwave.

Workforce communications

Person-to-person communication is an absolute necessity for safe and effective utility/energy operations, especially in remote or dangerous environments. Voice push-to-talk (PTT), alerting systems and accurate geo-positioning are often mandatory and need reliable operation even during emergencies. Workers also need access to broadband data and (increasingly) video-based collaboration, to connect to fault-management and diagnostics platforms, remote experts, or to download safety information in realtime. Coverage is needed over wide areas of territory (and perhaps sea), as well as inside warehouses, vehicles and power stations or terminals.

Cellular 4G/5G networks are more flexible, as well as supporting data applications far better than traditional VHF radio or PMR (private mobile radio) systems, especially if sub-1 GHz spectrum is used for broad coverage. As well as PTT, there is also often a need for fieldworkers' devices to inter-operate with normal phone systems as well, to allow them to connect to customers, HQ sites, government agencies, transport providers or equipment suppliers.

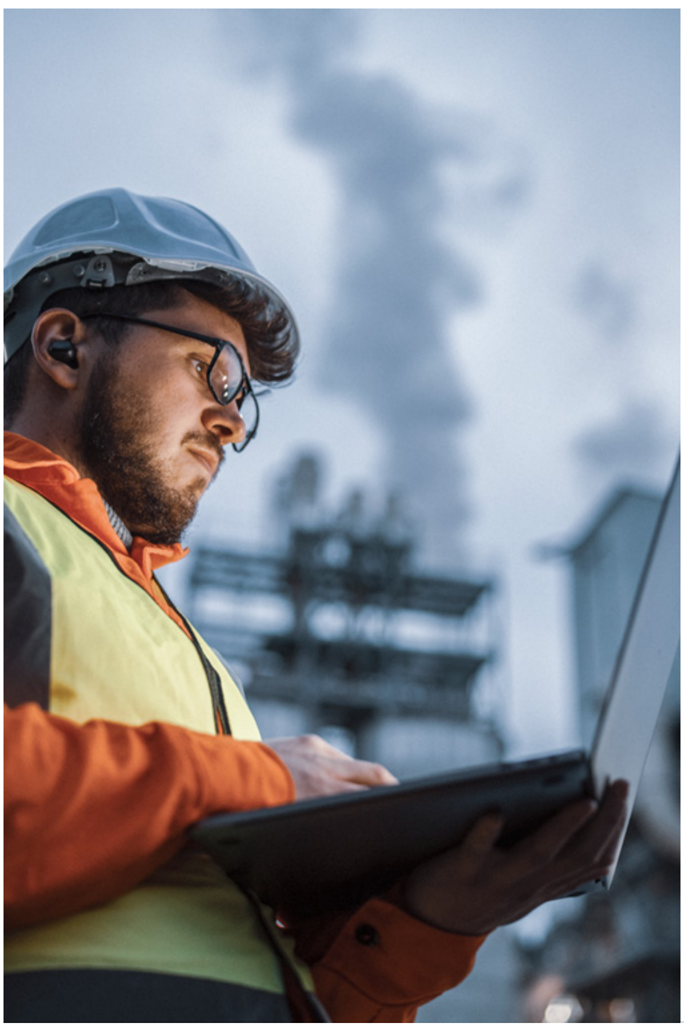


AMI (Advanced Metering Infrastructure)

AMI connects smart meters (consumer and business) with utilities' back-end billing and data systems, as well as demand-management in some cases. These include sensors for pressure, flow, voltage etc, enabling accurate measurements and diagnostics.

Potentially, AMI can reduce the risk of outages, help customers control their spending, reduce theft/fraud, and integrate with digital channels such as utility websites, home displays and smartphone apps. Utilities can use data from smart meters to enhance planning and grid reliability, as well as expose it to governments and regulators.

Connectivity for AMI can use a variety of technologies. Depending on the market, 3G, 4G, NB-IoT or narrowband UHF/VHF and LPWA wireless systems have been deployed. In future, 5G offers potential benefits in system capacity, reliability, and density of meters supported per base-station. Low-frequency (sub-1 GHz) systems enable better coverage, so that AMI sensors can be located in pipes, beneath pavements and roadways, or in buildings' basement equipment rooms.



DA (Distribution Automation)

Distribution Automation is an important part of medium/ low voltage grids' transformation and upgrade journey. It refers to an integrated management system designed to improve electricity supply reliability, safety, and asset performance. A central aim is to reduce service disruptions' duration from hours or minutes to seconds or even less.

DA involves collecting and processing key grid data and metrics, such as frequency, voltage and current. Centralised systems make real-time adjustments automatically, linked to realtime loads, generation status and failure conditions – as well as demand insight from AMI. This reduces the need for human operator involvement. Connected intelligent electronic devices (IEDs) link to systems for monitoring, controlling, and automating grid functions on a granular basis, enabling rapid troubleshooting.

DA communications networks require ultra-low latency, extreme reliability, and ability to operate within local areas of the power grid in isolation, especially in emergencies. Cellular networks – especially later versions of 5G – offer significant opportunities in this domain.

A specific application of DA systems is FLISR (Fault Location Isolation & Service Restoration). This "localises" faults or outages, so that power can be restored rapidly to many users while the utility company is still fixing an issue. There are various types of FLISR, but all need very reliable communications between key equipment elements such as feeder terminal units (FTUs), relays, reclosers and switches. Latencies in the millisecond range are desirable, which points towards fibre or 5G.

Data collected from sensors and IEDs enables post-incident fault analysis to determine root causes of problems and feed into preventative maintenance efforts.

Tele-protection

Tele-protection is a critical use-case for communications, protecting high-voltage equipment against surges and other problems. Latencies below 10ms are needed for protection relays to avoid outages and possible harms such as electrical fires. Faulty power lines can be isolated instantly, with power rerouted for other users, limiting the scope for more widespread outages and damaged assets.

Given the grid distances, fibre is generally considered preferable – but can obviously be damaged by fire or other emergencies, so wireless backup is useful. Future 5G versions should be able to support such applications.

Low-Latency SCADA

Supervisory control and data acquisition (SCADA) systems are common throughout the entire utility and energy industry, for monitoring and operational control applications. They enable remote control of equipment (e.g., sensors, switches and breakers, pumps, valves), and telemetry for reporting status and key metrics to a central point. When incidents or emergencies occur, realtime information flow allows better responses to be coordinated.

SCADA systems have evolved and transformed, from isolated systems to networked infrastructure. Now, in the IoT/wireless era, they are becoming more open. Integrated platforms can collect, analyse, correlate and act on diverse inputs. Future grid systems will use fine-grained sensing and DA, needing latency times under 10ms. Cellular connectivity can be used in conjunction with wireline/fibre networks – or act as a backup in case of emergencies.

Oil and gas exploration & production sites

Localised 4G/5G networks are increasingly used on a localised basis, for oil and gas exploration and production sites, vehicles, and personnel. Deployment scenarios include:

- Onshore drilling sites, which are usually quite small and temporary
- Onshore production wells or fields, which can be spread over a wide area, with many unmanned facilities needing remote monitoring & control.
- Offshore exploration rigs, production platforms or ships

These types of local networks have many use-cases, such as:

- Cloud / server / edge computing access for uploading survey or production data
- Realtime operational IT applications used by crew on-site from laptops or handhelds
- Internet access for employees
- Voice, video, messaging, and collaboration tools – both locally and back to HQ
- A broad range of IoT connectivity needs
- Video monitoring for security and operational cameras

Video surveillance systems

Utilities and energy companies have major needs for video surveillance. These monitor security and safety risks such as fire, intrusion and potential terrorism activities, potentially over wide areas. As well as alerts, operational-monitoring video reduces travel for engineers for remote sites, especially by helping diagnose false-alarms.

Wireless connectivity with 4G and 5G allows extra capacity for high-resolution imaging, as well as reduced latency. Increasingly, cameras are attached to mobile assets such as vehicles, robots, and drones, which obviously necessitates wireless access. Over time, edge-computing with machine vision will enable additional automation.

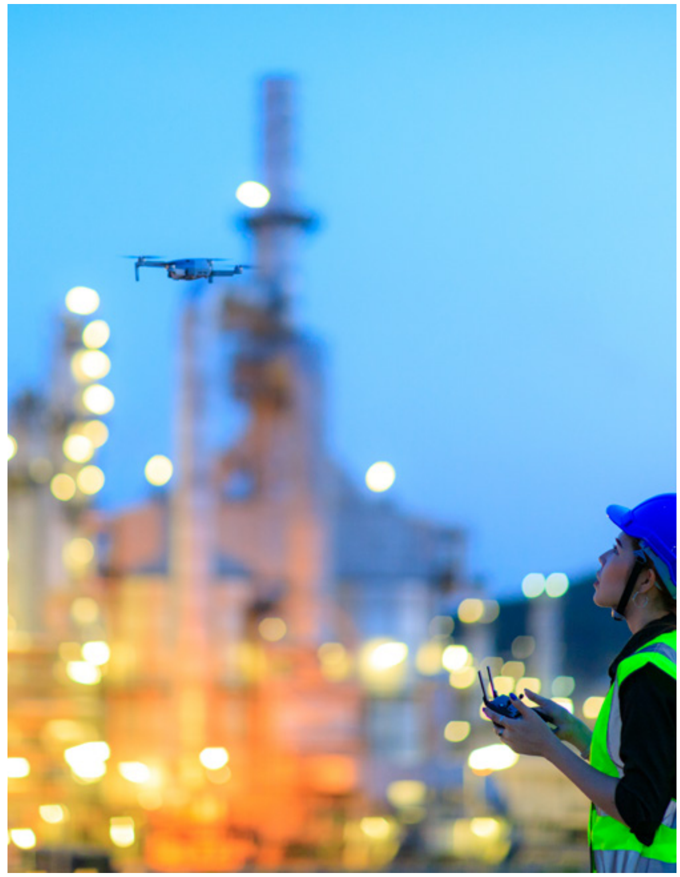
Leak detection

Water, gas, and oil leaks are a huge issue for the utility and energy industries. Gas and oil leaks represent major safety hazards, whether they occur in major pipelines, local assets, at processing/refining plants, or from storage tanks. Water leaks mean supply disruption, road closures and damage to property. Early detection of leaks enhances safety and reduces time-to-fix.

Wireless sensors along pipelines or inside tanks combine with hand-held leak detectors and mobile robots, as well as drones. Gas can be detected with laser-spectroscopy, while moisture or pressure sensors can pinpoint fluid leaks. Data from multiple locations can be correlated, and visible and infra-red cameras can allow rapid isolation of problems. Cellular connectivity can support both fixed and mobile sensor units, potentially over wide areas, such as for larger plants or along pipelines.

Environmental monitoring

Water and air quality monitoring is performed by utility companies on an ongoing basis, especially for water supply and pollution from plants. Probes are often in remote or inconvenient locations, making engineers visits expensive and time-consuming. Automated monitoring stations, with data sent wirelessly to a central facility, are a growing use-case for 4G and soon 5G connectivity.



Drone inspections

Utilities and energy companies need to regularly conduct routine inspections of assets, as well as assessing damage after storms, fires, and other events. While helicopters can be used for this role, this is very expensive – and some locations may be inaccessible.

Drones are proving to be a valuable alternative, but generally need realtime control and ability to stream video. Regulations on such aircraft vary, but it seems likely that a greater proportion will use cellular connectivity to enable remote piloting and telemetry. High-speed wireless data will also allow cloud-based machine-vision, navigation, and analytics, reducing weight and power-consumption of onboard systems in the drones.

Why deploy private networks?

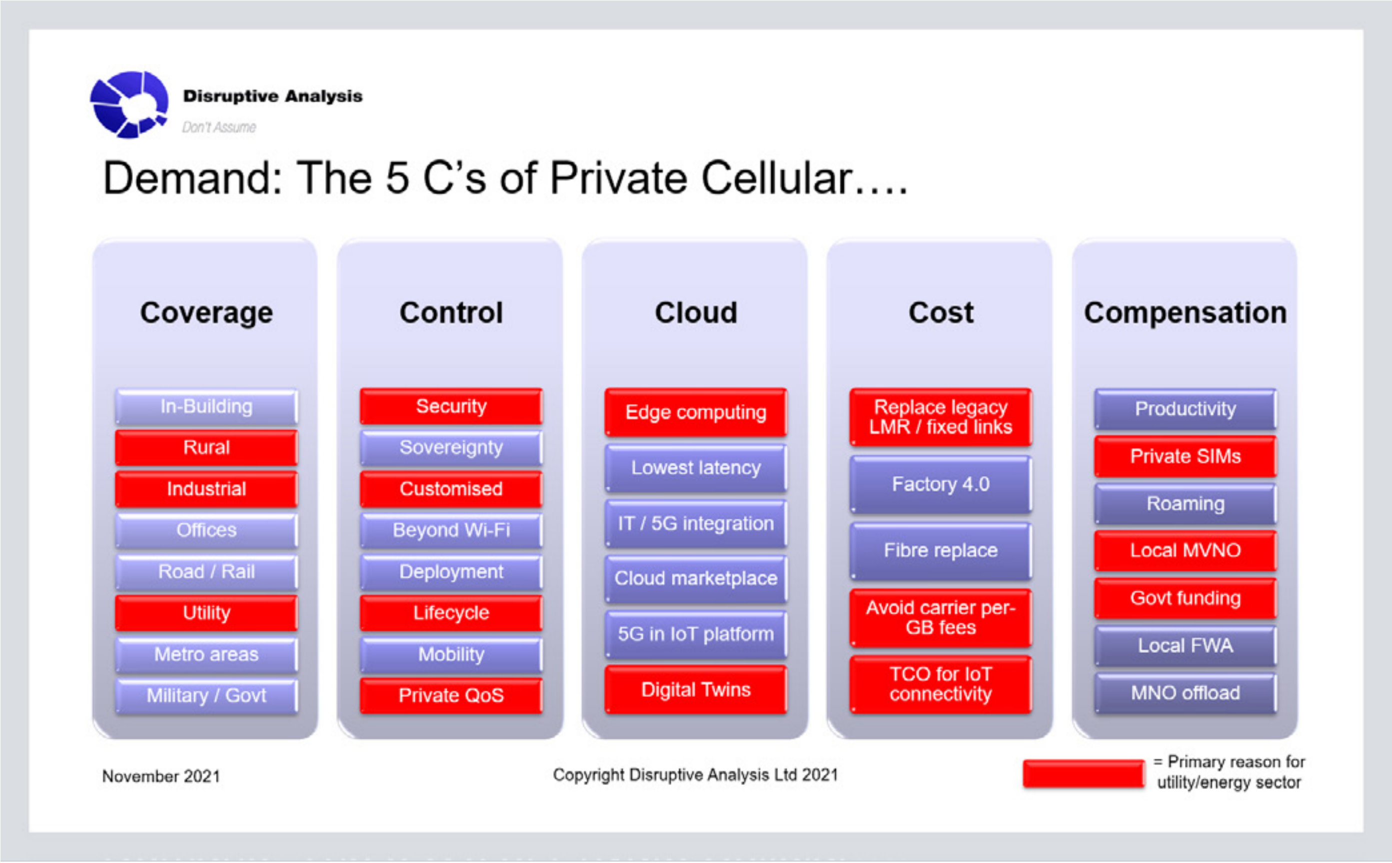
The second question mentioned above is at the core of this report. Why are these use-cases better suited to private 4G/5G rather than public network services from MNOs?

Looking across industry overall, there are many company and site-specific reasons that drive firms to look at private wireless solutions. However, broad patterns are visible.

There are five top-level rationales:

- Coverage
- Control
- Cost
- Cloud integration
- Compensation (or monetisation)

The following sections describe these in greater detail.



Coverage

The core reason for using private 4G/5G rather than public MNO services is the limitations of network coverage. MNOs tend to deploy network assets in areas with high population density, or along main roads.

Yet utilities and energy companies often need wireless connections in different places – transmission lines across open countryside, generation plants and reservoirs in remote locations, offshore windfarms and oil rigs, solar plants in deserts and so on. Often, utilities span a wider geographic area than telcos.

This implies that they require additional wireless infrastructure – and if they have to pay for customised coverage, then many will opt to own it, rather than rent. One variable here is that sometimes utilities will themselves be renting space on towers or poles to MNOs, so may obtain public network coverage indirectly.

Control

Owning and operating private wireless allows utility and energy companies to define and optimise many network parameters themselves, taking direct responsibility for security, reliability, performance, and reporting.

They can choose their own mechanisms for redundancy and cybersecurity, aligning with sector-specific best practices and regulations. For demanding applications like streaming video or low-latency grid control, they can customise and optimise radio resource management and redundancy.

They are also able to take a longer-term investment view than telcos, for instance building assets and communications systems intended for 20-30-year lifecycles, rather than 5-10 years.

Unlike most businesses, utility companies have long taken responsibility for mission-critical networks, so have many of the internal skillsets and processes required. In the longer term it may be possible for enterprises to obtain a "slice" of public MNO 5G networks and obtain better control and service-level agreements, but this remains an unproven model and is dependent on future iterations of the 5G technology.

Cost

As previously noted, many 4G/5G network connections in utilities will be used to replace or extend legacy wireless or wired alternatives. Often, there is a cost advantage as well as improved performance / flexibility with cellular, especially as older microwave and LMR/PMR systems reach their end-of-life, facing problems with obtaining new equipment or spares.

However, the larger cost advantage for private cellular revolves around resilience and the cost of downtime. In general, MNOs do not offer robust SLAs (service level agreements) or offer compensation for any costs incurred as a result of outages. Few customers, except perhaps public safety agencies, get automatic priority and "pre-emption" rights during emergencies.

Heavily regulated sectors such as electricity and water utilities could face severe financial or criminal penalties for the business or its directors if their services fail. They often cannot afford to rely on third parties that may have a different approach to service restoration after failures. Where possible, they may wish to manage their risk profile by deploying their own infrastructure – either as a backup to public services or engineered from scratch and operated/maintained by their own staff.

Cloud

In the wider enterprise marketplace, there is a growing link between enterprise private wireless and cloud platforms, as many software elements such as network cores are delivered via virtualisation and containers, rather than physical appliances. Often, manufacturing or logistics companies are considering cloud-based IoT or AI platforms, so cloud-based networking is often a good fit.

That said, many utility and energy companies are relatively conservative about adopting cloud-based systems, especially for mission-critical operational platforms. Remote locations of many sites tend to drive on-premises deployments of compute, rather than relying on distant datacentres.

However, this is changing, especially for data-heavy applications such as IoT monitoring, preventative maintenance and "digital twins". With the rise of distributed energy resources, as well as performance-management of new assets such as energy-storage units, the role of cloud-delivered functions will increase in utilities and energy sectors.

Where these overlap with coverage or other network constraints, it is likely that private wireless coverage and management will often be integrated with the same cloud/edge platform in many cases, or at least share supplier/integrator systems.

Compensation / Monetisation

The final argument for private cellular is around its potential for increasing revenues, beyond the internal needs of the utility firm. Once a company has deployed 4G/5G infrastructure in a facility or region, it may be able to monetise that capacity.

The most obvious source of additional business is from other utility or similar workforces. A critical communications network deployed for an electricity company could also be adopted by the water utility in the same area, or perhaps the roads/highway agency.

Other options include providing fixed wireless access (FWA) to homes or businesses in remote areas or offering various types of asset or property services to public MNOs. Electrical poles and water towers have long been rented to carriers as "passive" cell-sites, but a variety of new neutral host models are emerging that can add more value.

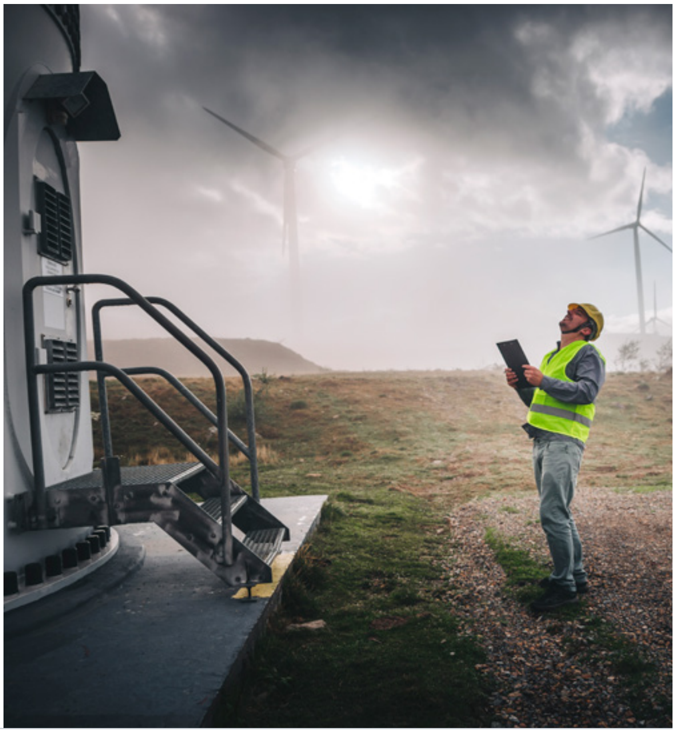
Depending on the sophistication of the network owner – and regulatory consent – it may be possible for utilities to become wholesale mobile networks with local spectrum and infrastructure. They could provide "coverage as a service" to more traditional MNOs, either via roaming arrangements or various technical approaches to network-sharing, either at the RAN level, or via a separate core platform.

Network scale for private networks

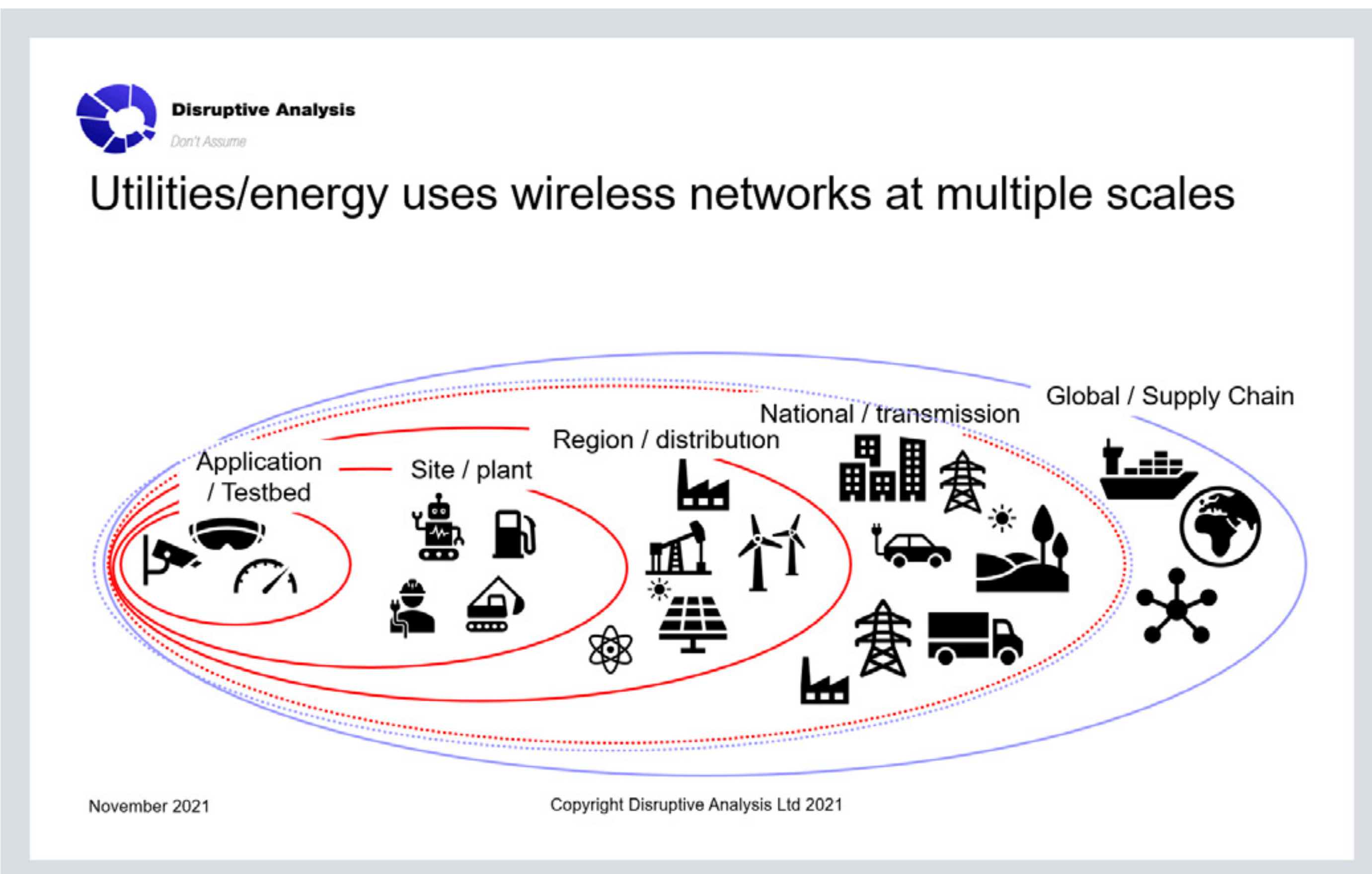
Utilities and energy companies can deploy private cellular networks at hugely variable scales, spanning perhaps 3 or 4 orders of magnitude, both of size and cost. Some applications and deployments are highly localised – perhaps just for a single building or structure – while others can be nationwide. The exact scenarios are linked to the spectrum, which is available, but it is important to recognise that the trend towards private 4G/5G is far from uniform.

This will drive a variety of considerations from budget to partnership with different types of vendors, systems integrator and service provider. There are also implications in terms of the methods used for design, testing and service-assurance – as well as the need for regulatory oversight.

- **Site-specific networks:** There are many current and future utility and energy sites that require connectivity for human staff, static M2M systems and mobile IoT. Many occupy areas that are 1-3km scale, ideal for localised private 4G/5G networks especially in midband spectrum. Examples include:
  - Gas, nuclear, hydro-electric, and other traditional power generation sites
  - Medium-to-large solar plants
  - Onshore and offshore windfarms
  - Oil and LNG (liquefied natural gas) terminals and storage facilities
  - Water treatment facilities
  - Oil refineries
  - Oil and gas production facilities (e.g., offshore rigs)
- **Regional networks:** The structure of utility providers varies by country and state, but many feature community-level or metropolitan providers, with considerable autonomy in purchasing and deploying networks, perhaps at a 5-50km scale. Depending on the specific applications, these could exploit either mid-band or <1 GHz spectrum for building private cellular networks.
  - Critical communications for community-level utilities
  - Smaller / local utility distribution networks
  - Metro-level smart metering
  - Smart city energy management and environmental monitoring
  - Environmental monitoring (e.g., for a large reservoir)
  - Oil fields with distributed well-heads and pipes
  - Extra-large wind and solar facilities



- **National / wide-area networks:** Often, utilities use long-distance transmission grids or other infrastructure, spanning entire countries or states. They have growing needs for employee communications, SCADA systems, new classes of IoT and monitoring systems, and vehicle connectivity – perhaps covering areas 100s of km across. While many key assets are arranged linearly, there also needs to be access to sub-stations and local distribution (and increasingly, distributed generation/storage). While fibre or microwave is usually present already, there is a need for greater mobility, higher capacities, and network redundancy. Most private networks at this scale will use <1 GHz frequencies for 4G/5G, if available. Key examples of wide-area applications include:
  - High-voltage electricity transmission networks
  - Mission critical communications for workers and their vehicles
  - Pipelines for water, gas, or oil
  - Distributed environmental sensor grids (e.g., for air/water/fire monitoring)
  - State/national-scale advanced metering
- **Indoor/hotspot networks:** Although much of the utility and energy sector operates at outdoor/industrial facilities with large scale, there are also specific connectivity requirements that are smaller – but perhaps with localised high-capacity/performance needs. While many assets are fixed in place and can use fibre, others will need reliable wireless connections – and, increasingly, private cellular networks as well as Wi-Fi. Over time, some of these will likely use mmWave 5G as well as midband connections. Examples include:
  - Underground facilities such as dams' turbine halls
  - Warehousing facilities
  - Local hotspots for automated machinery and robotics
  - Networks inside power stations or refinery tanks, with stringent safety requirements
  - Mobile private networks deployed on safety/emergency vehicles used by utilities
  - On-ship networks for vessels building or maintaining maritime assets
  - Gigabit fixed-wireless between buildings or structures on a single site.



Spectrum options and trends

Overview

A key ingredient for private networks is access to suitable spectrum for 4G/5G. This introduces a huge range of trade-offs in terms of coverage, capacity, cost, device availability – and also politics and regulation.

Historically most spectrum suitable for cellular networks has been awarded on an exclusive regional/national basis to public mobile operators (MNOs), often through auctions procedures.

Utilities have typically used different (non-cellular) bands for fixed wireless links, usually obtained with individual point-to-point licenses for specific locations. For critical communications, their LMR/PMR systems have used low-frequency, low-capacity bands suitable for push-to-talk and little more.

Enterprises and other organisations have had little direct access to such mainstream bands, while early versions of mobile networks (2G and 3G) had few devices supporting more unusual – and more available – frequency options. This is now changing significantly, as more bands are being made available, while 4G and 5G device and network equipment support for multiple bands is somewhat more common.

For wide-area coverage, sub-1 GHz bands have the best range for private wireless, especially for supporting national/regional critical communications capability. Mid-band spectrum between 2-6 GHz is generally optimal for mid-size private networks such as specific sites up to 10km scale but can also be extended for broadband use more broadly to county-sized regions, or along roads or pipelines.

Although higher mmWave bands are widely discussed for 5G, for the sectors covered here they are generally only useful for highly-concentrated applications requiring huge bandwidth – for instance inside a plant or warehouse with robots and cameras.

CBRS and mid-band options

For site-specific or regional coverage, a growing number of countries are making sections of mid-band spectrum available for utility and energy companies (as well as other enterprises). Typically, this is based on some form of spectrum-sharing, with either manual or database-driven licensing for specific areas and band rights.

Among the most important examples are:

- **US**: In the US, the CBRS band between 3.55-3.7 GHz has been made available on a shared and multi-tiered basis, with dynamic access managed by a number of automated SAS (Spectrum Access System) providers. The top tier of incumbent users (especially the Navy) has ultimate pre-emption rights, but a number of utility and energy companies have acquired PAL (Priority Access Licenses) which give almost-guaranteed access to sections of the band on a county-area basis. This is well-suited to private networks and can be supplemented by using the on-demand GAA (general authorised access) tier. At present only 4G LTE equipment is available for use with CBRS, but that is likely to be extended to 5G products in the next 1-2 years. This band has attracted a large ecosystem already and is probably the closest to "spectrum-on-demand" and the wide democratisation of private networks.

- **Germany**: The 3.7-3.8 GHz band has been reserved for localised private network licensing, either with 4G or 5G infrastructure. Licensees can request rights for specific locations from the national regulator – typically for campus-sized facilities.
- **France**: A 40MHz section of the 2.6 GHz band has been made available for critical communications and industrial broadband use.
- **UK**: The 3.8-4.2 GHz band is available for local 5G use, subject to protecting incumbent licensees. There are also small allocations at 1.8 GHz (the original DECT guard band) and 2.3 GHz.
- **Japan**: Spectrum is available between 4.6-4.9 GHz for local 5G

Other markets have the potential for local leasing of MNOs' allocated national spectrum (for instance in Australia, Finland, and Denmark), or the ability for regional operators specialising in industrial networks to obtain ordinary licenses in sparsely populated areas (for instance in parts of Canada).

A number of other countries in Europe and the EU regulatory advisory body RSPG have also suggested the 3.8-4.2 GHz band for future potential shared use.

It is also worth noting the potential for using unlicensed bands at 2.4 GHz, 5 GHz and increasingly 6 GHz as well for private 4G/5G – although the lack of interference protection may limit the scope for mission-critical applications.

Sub-1 GHz options

While mid-band spectrum is good for fairly concentrated sites or smaller regions, national or broader deployments of private connectivity – especially for mobile/critical PTT use – ideally needs lower frequencies, below 1 GHz.

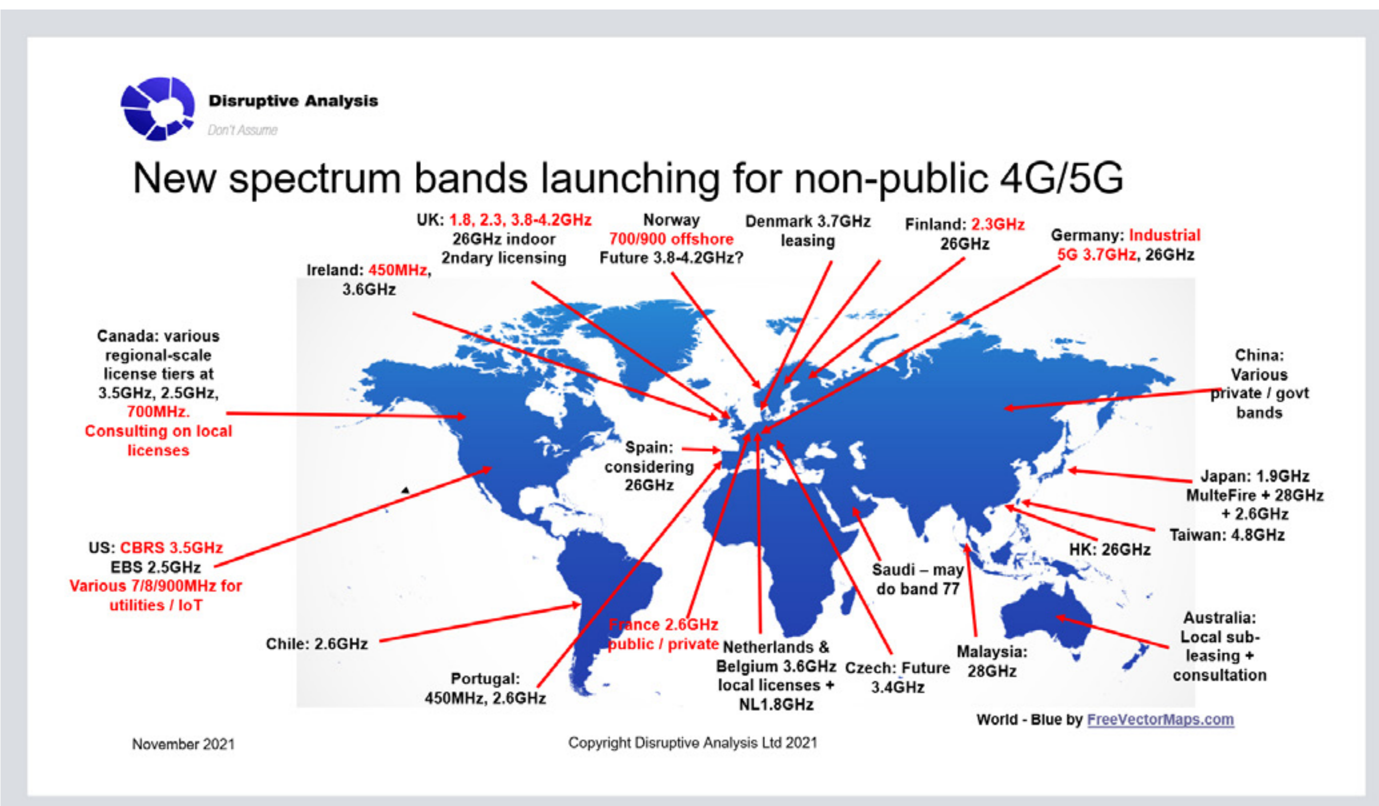
A number of markets have made such bands available to utility and energy companies.

- **US**: Following an FCC ruling in 2020, a number of licensees have access to 900 MHz spectrum, with 6 MHz for broadband use and 4 MHz for narrowband use. In particular, a major spectrum-holder, Anterix, works with a number of local utilities to create suitable infrastructure.
- **Norway**: A number of oil and utility companies hold 700 MHz and 900 MHz spectrum for private offshore networks
- **Global**: The 450 Alliance organisation is promoting 450 MHz (or in some regions 410 MHz) as a worldwide band for critical communications in utilities, public safety and similar sectors. Around 25 live or trial networks LTE are operational, notably in Europe but also in Asia and Latin America. There are also many other legacy CDMA networks in these bands. Handhelds for PTT use, small routers and utility metering are the main use-cases.

It is also possible to use narrowband IoT versions of 4G (NB-IoT & LTE Cat-M) in the various sub-GHz allocations, either licensed or unlicensed.

mmWave

A number of countries, including Germany, UK, Finland, Malaysia and Japan, have made 26 GHz, 28 GHz or other spectrum available for local use. This is mostly targeted at indoor/campus sites such as factories, warehouses, and mines. That said, there may be some use-cases for utilities and energy companies in future as well – perhaps inside power stations, or for local high-capacity usage on certain sites with vehicles or many cameras.



Conclusion & long-term futures

Utility and energy sectors have already been leading the adoption of private cellular networks for critical communications and IoT connectivity. The growing maturity of 5G technology, plus the wider availability of local or dedicated spectrum for enterprise use suggests a continued healthy dynamism for many years to come. By 2025 there may be 100s of private networks, with appreciable scale, in these industries alone.

The demands and challenges of industrial transformation, climate-change responses and the need for reliable and well-monitored utility grids and other assets points the way to ever more data-generating and -consuming applications and devices, higher levels of mobility and physical automation, and more distributed generation, storage, and control infrastructure.

Yet despite similarities across sub-sectors and countries, what seems likely is that the specific use-cases and deployment scenarios will vary considerably. Some markets are focusing on releasing mid- and low-band spectrum for enterprises, while others are more focused on mmWave or new unlicensed options.

Table: Examples of Utility & Energy company private 4G/5G deployments/trials

Company	Country	Sector/Purpose	Spectrum/Owner
Ameren	US	Multiple grid / workforce applications	900MHz LTE (Anterix)
Centrica	UK	Gas storage terminal connectivity	LTE/5G with Vodafone
EDF	France	Nuclear power stations	2.6 GHz Private LTE
Enel	Italy	Power station (multiple apps)	Private LTE
Equinor	Norway	Offshore oil/gas	900MHz LTE
ESB	Ireland	Smart grid & distribution networks	410MHz LTE
Evergy	US	Grid modernisation	900MHz LTE (Anterix)
NY Power Authority	US	Multiple grid / workforce applications	900MHz LTE (Anterix)
Phillips 66	US	Oil refinery	700/1900MHz (AT&T)
S California Edison	US	Fire monitoring	CBRS
San Diego G & E	US	SCADA, PTT, Metering, Falling circuit	CBRS+ 900MHZ PLTE
Southern Linc	US	Push-to-talk critical comms	800MHz LTE
TampNet	North Sea	Industrial mobile network – oil/wind	700/900/1800MHz LTE
Vilicom	UK	Moray East offshore wind farm	Private LTE (band N/A)
Western Power Dist	UK	SCADA + PTT	410MHz LTE

Source: Disruptive Analysis

This is driving a split in the market between highly localised networks for specific sites (or even inside specific buildings and structures), versus regional/national deployments. Over time, we can expect most developed economies to offer a variety of spectrum options for private 4G/5G, just as they intend to do for public 4G/5G. However, the path to that point will vary – as will the role of the MNOs in addressing the utility/energy sector themselves.

Low-band is good for wide area coverage and vehicular connectivity (especially off of main roads). Mid-band will be optimal for cities, campus / industrial sites, or along specific corridors such as high-voltage grid lines or pipelines. mmWave is likely to have uses indoors or for specific high-capacity / low-latency fixed wireless uses.

The arrival of new wind and solar facilities, as well as battery storage and LNG transformation, is changing the utility landscape. There is also renewed interest in nuclear power, tidal generation, and biofuels. Coupled with massive fiscal stimulus for infrastructure investment, it is likely that many greenfield sites will be IoT-centric and equipped with the latest IT/OT and networking solutions – with a likely heavy use of private (and public) cellular.

While obviously focused on phasing out fossil fuels, the recent COP26 summit highlighted new interim responsibilities as well – especially limiting methane leaks – which may require new sensors and connectivity. While the oil industry is facing massive changes in coming years and decades, it will be continuing to develop infrastructure for natural gas and carbon capture.

In summary, it can be expected that the energy and utility sectors will be major drivers of private LTE/5G, especially as more countries release suitable spectrum, and the ecosystem of network and device vendors and systems integrators continues to expand.

About iBwave

iBwave Solutions, the standard for converged indoor network planning is the power behind great in-building wireless experience, enabling billions of end users and devices to connect inside a wide range of venues. As the global industry reference, our software solutions allow for smarter planning, design and deployment of any project regardless of size, complexity or technology. Along with innovative software, we are recognized for world class support in 100 countries, industry's most comprehensive components database and a well established certification program. For more information visit: www.ibwave.com.

About Disruptive Analysis

Disruptive Analysis is a UK-based research and advisory firm, founded and run by Dean Bubley, an independent industry analyst and futurist with a long background in consulting and commentary on the telecoms industry. It provides consulting and advisory services on technology evolution, regulatory policy, market and competitive dynamics, with a particular focus on 5G, Wi-Fi and private networks arenas.

Disruptive Analysis has clients across the telecoms, cloud, regulatory and investment universe and has followed private and enterprise cellular networks since 2001.

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