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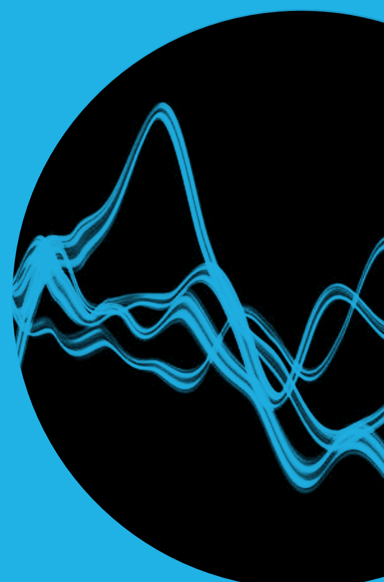

ENERGY-OPTIMIZED NETWORK MODERNIZATION

ERICSSON

Energy-optimized network modernization

Minimizing energy consumption and maximizing the use of sustainable energy sources at ICT sites requires a transition toward a smart energy setup and a holistic approach to energy management that includes close collaboration with the energy utility sector.

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The evolution toward a smart energy setup at Information and Communications Technology (ICT) sites is a key enabler for the creation of resilient, robust and cost-efficient radio access networks (RANs). At the same time, this approach also opens up new income streams for ICT site owners to support the electricity power system (power grid) with ancillary services.

■ While energy efficiency has always been an important consideration in network development, 5G includes an exceptionally powerful set of tools that communication service providers (CSPs) can use to minimize network energy consumption. As impressive as the 5G energy narrative is, however, it is only one part of the solution that the ICT industry needs to overcome in its energy challenge. Fully addressing the challenge will require broad action across the entire ICT network that includes the evolution of the energy setup to ensure alignment with the needs of the smart grid.

There are multiple interdependencies between ICT networks and the power grid. Alignment and collaboration between ICT site owners and power companies will open up possibilities for new services and income for ICT site owners, while simultaneously contributing to a more resilient and robust power grid.

Growing awareness of climate change [1] is driving a mindset shift in the ICT industry toward a more holistic approach to benchmarking the energy capability needs in a network. With this comes a desire to modernize telecom equipment to increase energy efficiency. Beyond using 100 percent renewable energy, the shift also includes new energy perspectives that focus on optimizing the energy setup at sites. The aim is to ensure high network availability for service assurance and enable intent-based energy management with the ultimate goal of achieving net-zero energy cost.

As the ICT network matures, ICT site owners have an ongoing opportunity to reflect on potential improvements from an energy setup perspective. While a wider range of options are available when building new ICT sites, there are many ways to reduce energy costs at legacy sites as well.

Figure 1 illustrates Ericsson's comprehensive energy perspective on network modernization where the focus evolves during the journey toward net-zero energy cost. The ICT site owner's focus will shift from pure energy consumption reductions in the first phase to enabling smart energy in the second, and ultimately gaining new income in the third.

As highlighted in Figure 1, there are five evolution steps toward net-zero energy cost and beyond:

1. Explore possibilities to reduce energy consumption in each network
2. Build and optimize for a low network energy consumption
3. Ensure autonomous, resilient and holistic energy usage in operations
4. Build power grid and ICT interdependency to ensure high availability
5. Open a new source of income by provisioning ancillary services for the power grid, such as an open energy bid and clearing support.

These steps provide opportunities to reduce energy costs as well as opening up the potential to turn energy generation into a new source of income.

Key definitions

ICT site – a distributed edge compute site with radio communication capabilities. Future sites that are located far out in the telecom network will include the kind of compute capacity that is currently only available in large, centralized data centers.

ICT site owner – ICT sites have traditionally been owned by CSPs, but it is increasingly common in many countries for ISPs to own ICT sites today. The meaning of site ownership varies from case to case, but it often includes responsibility for supporting equipment such as the shelter, energy setup and climate control, as well as application equipment such as radio and data servers.

Transmission system operator – a natural or legal person who is responsible for operating, ensuring the maintenance of and, if necessary, developing the transmission system in a given area.

Distribution system operator – a natural or legal person who is responsible for operating, ensuring the maintenance of and, if necessary, developing the distribution system in a given area.

Energy system setup – a technical solution at an ICT site that provides the applicable type of energy and the interface to the power grid, which can provide energy backup and relies on autonomous central or distributed energy management.

Net-zero energy cost – the reduction of an ICT site owner's energy bill (the opex cost) to zero.

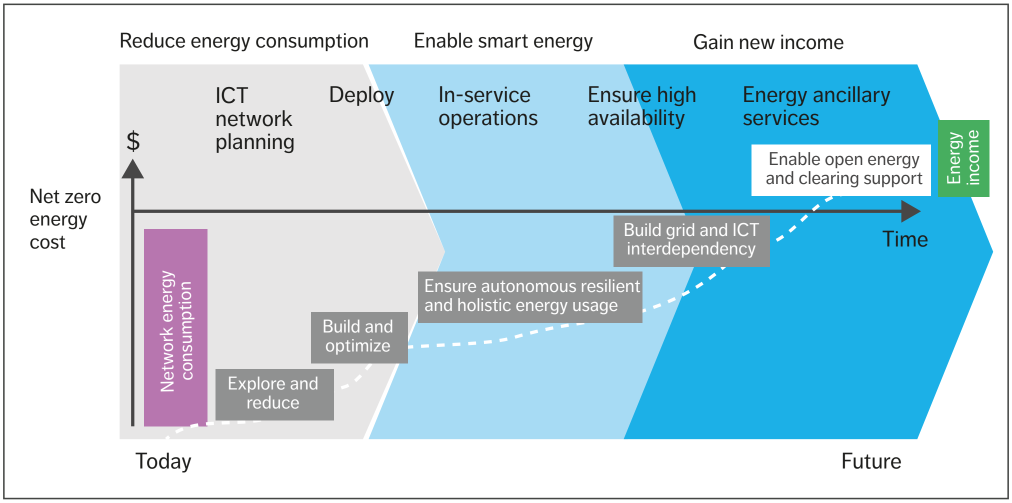

Figure 1 Ericsson's comprehensive energy perspective on network modernization

Approaches to reducing energy consumption

There are four primary aspects that must be considered when reducing network energy consumption:

1. Hardware modernization and new software features
2. Energy-saving software features and artificial intelligence (AI) enabled automation
3. Network energy optimization services
4. The support of digital twins.

Hardware modernization and new software features

The biggest reductions in network energy consumption to date have resulted from the introduction of new hardware and the removal of old systems. Major hardware modernization projects are usually triggered by new releases of spectrum and/or new releases of network technology (such as 5G). Looking ahead, one of the best ways that CSPs and infrastructure service providers (ISPs, also known as tower companies) can speed up their progress toward net-zero energy cost is to consider energy consumption when performing traffic simulations at the network planning stage.

Energy-saving software features and AI-enabled automation

The continuously expanding scope and growing complexity of 5G applications is putting greater demands on networks to deliver high availability, ultra-reliability, low latency and high security. More

Terms and abbreviations

AI – Artificial Intelligence | **CSP** – Communication Service Provider | **DC** – Direct Current | **ICT** – Information and Communications Technology | **ISP** – Infrastructure Service Provider | **Li-ion** – Lithium-ion | **PV** – Photovoltaic | **RAN** – Radio Access Network | **VDC** – Volt Direct Current automation is essential to cope with these demands. To be successful, this automation must be built on a solid understanding of site capability, capacity, performance, user demand, weather conditions and energy availability at any point in time.

The energy-saving software features in 5G enable CSPs and ISPs to minimize energy consumption during low traffic periods, reduce energy waste during peak traffic hours and turn equipment on and off at exactly the right time [2]. Software functionality with AI agents at the site will improve the CSP's/ISP's understanding of the energy perspective, identify the root causes of inefficiencies and take autonomous action to turn assets on and off when needed.

More advanced software functions will make it possible to reduce manual work, find faults early and maximize network availability. The use of sensors at each site to measure temperature, humidity and electrical characteristics will provide valuable information about the local conditions that make it possible to optimize energy utilization and maximize the life cycle of site equipment.

Intelligent agents capable of handling complex processes are needed to optimize trade-offs between long-term benefits of the agent's behavior and short-term benefits from the immediate steps to be taken; for example, how to optimize a network in multiple steps and how to operate a network. These processes must be learned autonomously, without the intervention of a human domain expert.

Network energy optimization services

Network energy optimization services help CSPs/ISPs explore the full potential of reducing energy consumption in each technology network (4G and 5G, for example). CSPs/ISPs gain the confidence to activate RAN energy-efficiency features by learning how optimization cycles, radio KPI monitoring and the tracking of crowd-sourced consumer experience data ensure that the network's Net Promoter Score remains high. A network energy optimization service can also analyze the system-embedded energy metering and network-wide hardware installed base to evaluate the need for hardware modernization.

> “DIGITAL TWINS ARE AN IDEAL SOLUTION FOR ICT SITE OWNERS THAT WANT TO AVOID THE EFFECTS OF ERRATIC INITIAL EXPLORATIONS ON LIVE MOBILE NETWORKS”

The support of digital twins

Digital twins are an ideal solution for ICT site owners that want to avoid the effects of erratic initial explorations on live mobile networks. A good example of where they can be useful is in the case of network parameters that are configured on a per-cell level but may have a strong impact on the performance of surrounding cells. A change in any of these parameters also affects users served by the surrounding cells.

Finding the optimal configuration for these types of parameters is a complex exercise. Digital twins make it possible to test on an external entity that mimics the behavior of the live network. Once the agent has acquired all the necessary knowledge from the digital twin, the achieved policy can be safely applied to the live network.

Looking ahead, AI will be fundamental in the digital transformation of many sectors as they optimize or introduce new services to use energy more efficiently, to plan and predict maintenance.

Optimizing the energy setup at ICT sites

Energy experts predict more frequent disturbances in the power grid in the years ahead due to extreme conditions such as wildfires, heavy rain and flooding. Increasing reliance on renewable energy sources and the growing popularity of electric vehicles is also expected to have a volatile impact on the power grid. With this in mind, CSPs/ISPs that want to ensure high network reliability without increasing the energy cost should review the capabilities of the

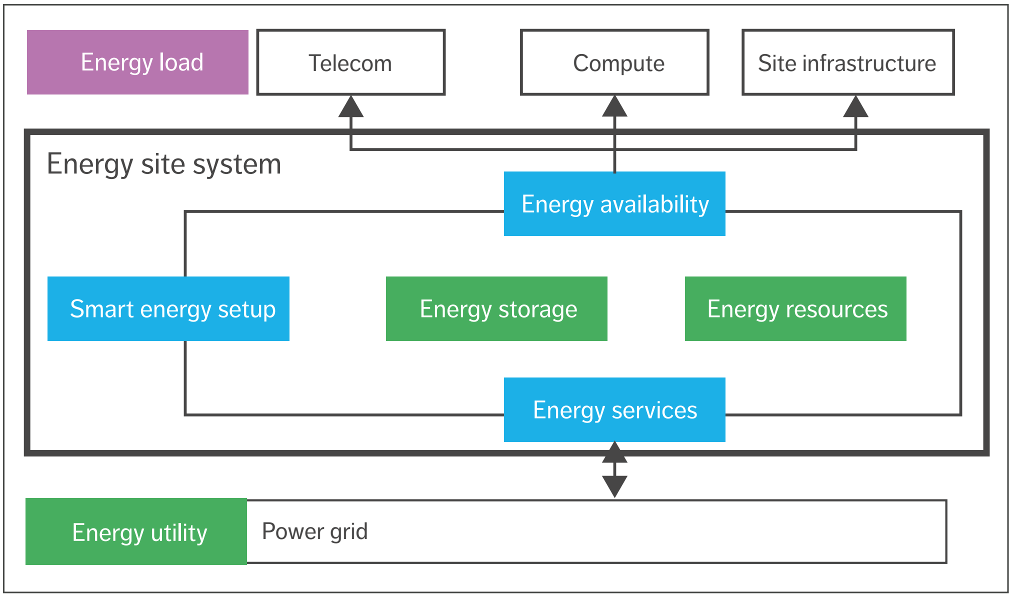

Figure 2 Energy system setup at an ICT site

energy setup at their ICT sites and look for opportunities to improve their resilience.

There are three core actions that ICT site owners can take to ensure the provision of a robust and reliable ICT network, while simultaneously minimizing their impact on the climate and the environment:

1. Introduce local renewable energy generation (solar and/or wind) and add services such as weather forecasting where AI predicts the control of energy storage to optimize the usage of renewables.
2. Improve the overall efficiency of the power system by reducing the number of conversion steps, improving the efficiency/unit and/or increasing system voltage.
3. Establish a smart energy setup capability, where the energy availability at the site is based on the power grid, storage and resource status, and optimize the utilization of site assets.

Figure 2 illustrates the energy system setup that we recommend for ICT sites. The creation of a robust autonomous energy solution makes it possible for ICT site owners to ensure energy availability even at the sites that are furthest out on the edge.

Traditionally the telecom network has only had radio and core equipment at network sites and has relied on data centers for compute capacity. As more advanced use cases are introduced in 5G and beyond, the need for compute at network sites on the far edge will arise, and network sites will turn into ICT sites. The implication of this is that the energy site system needs to evolve in parallel to ensure the allocation of the available energy is done in an intelligent way. A smart energy setup will be key to achieving resilient and sustainable energy usage.

Energy storage and resource technology

The power grid is the most common source in the energy setup at today's ICT sites, with complementary sources utilized when and where required. At off-grid sites and for sites with seasonal variations, diesel-powered combustion engines are still the main complementary source, although ethanol and liquefied petroleum gas are replacing diesel in some countries. In locations with available space, photovoltaic (PV) silicon panels are sometimes used. While lead acid batteries continue to be the most common choice for backup, batteries based on lithium-ion (Li-ion) technology are becoming increasingly popular.

To make the site energy setup more sustainable, multiple evolutions paths are possible, but some of them may have limitations. To reduce the usage of diesel, fuel cells can be used with fuels in gas, liquid or solid form. Combustion engines will also use fuel variants that have lower greenhouse gas emissions.

The need for Li-ion batteries in the coming years will exceed the production capacity and that will open up for new battery chemistries. PV panels will have improved efficiency by tandem cells or other chemistries. Even if the efficiency of low-cost, thin-film PV technologies is lower than traditional technologies, they could gain market share and be suitable for areas with fewer site restrictions.

Future evolution steps in excessive solar locations will hopefully generate hydrogen that can be stored and used as long duration backups. Combustion engines that can run on hydrogen are also expected to emerge. A future wind turbine design that can harvest low wind speeds while still being robust enough for high winds would make wind turbines a potential contributor to the energy mix at ICT sites.

The energy setup for ICT equipment includes power supply units with remote access and has intermittent peak shaving capability. The energy evolution will provide the hybrid control and intelligence to impact the peak load. The system operational voltage may move from 54VDC (volt direct current) to 57VDC, including DC/DC (direct current) backup. The next step is to evolve from 48VDC to nominal 400VDC. The higher system voltage introduces a reduced size of the cable area and decreases the deployment cost of DC distribution at ICT sites.

> THE ICT NETWORK HAS THE POTENTIAL TO PLAY A SIGNIFICANT ROLE IN REDUCING ENERGY CONGESTION AND ENSURING STABLE FREQUENCY

Collaborating for greater resilience and robustness

The transformation of power generation from a centralized model to a decentralized one, characterized by the generation and storage of vast amounts of renewable energy sources, creates new challenges that require reforms to the electricity market. Looking ahead, it will be the responsibility of the transmission system operator [3] not only to ensure resilience and robustness in the power grid, but also to enable interactions in a wider electricity sector/community.

Government strategies will have a big impact on how energy markets can develop flexibility in energy services at international, national and regional levels. Given the opportunity, the ICT network has the potential to play a significant role in reducing energy congestion and ensuring stable frequency.

Collaboration will be required to ensure an optimized and interoperable path that enables adaptive energy consumption by the infrastructure at the ICT sites to contribute to balancing energy services at the national level.

ICT and power grid interdependency

Many of the requirements on the operational performance of ICT networks are similar to those of energy utilities, particularly the new decentralized power grid from the transmission and distributed system operators. Both need to provide capabilities that enable the generation and storage of renewable energy, boost operational efficiency and increase resiliency and reliability.

In terms of renewable energy and storage

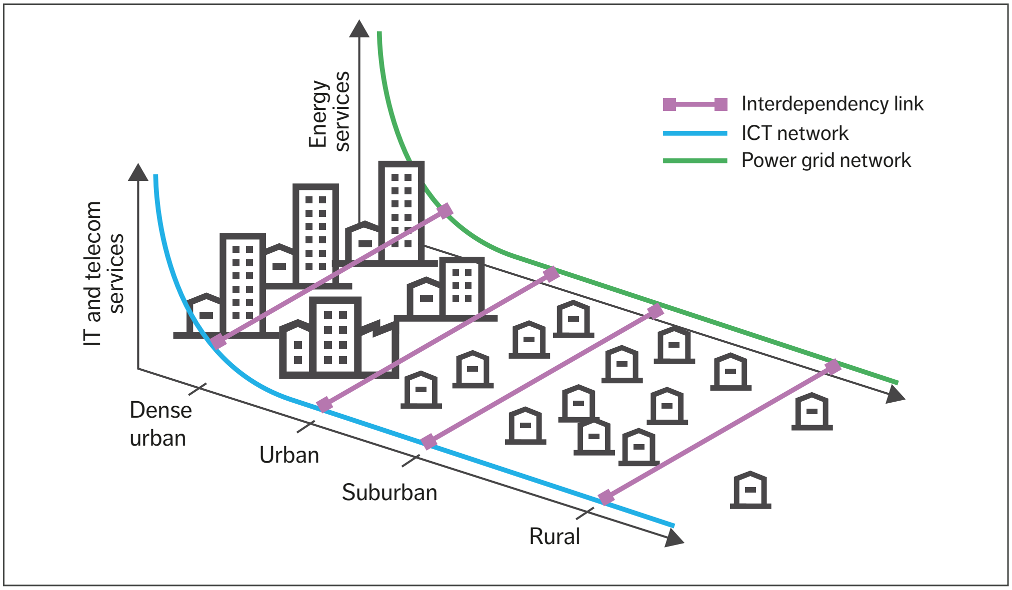

Figure 3 The interdependency between ICT and the power grid

resources, there is a need to adapt and utilize what is available at the edge or local area with small-scale production intermittent availability and reduce/increase energy consumption from time to time. Operational efficiency requires capabilities that optimize assets and utilization, as well as providing high network and service availability. Automation to mitigate service disruptions and power outages and redirect traffic/power flow in case of disasters is key to ensuring resiliency and reliability.

Figure 3 illustrates the interdependency between the ICT network and the power grid. Significant mutual gains can be achieved by enabling communication and service collaboration between the two. Reliability, availability and resilience are essential to ensure high network availability and service assurance, as well as increasing robustness and improving maintainability, which reduce total cost of ownership in the long run.

> SIGNIFICANT MUTUAL GAINS CAN BE ACHIEVED BY ENABLING COMMUNICATION AND SERVICE COLLABORATION BETWEEN THE ICT NETWORK AND THE POWER GRID

The ICT network and the power grid can mutually benefit in their respective service sectors by sharing relevant performance and status information at multiple intersection points, particularly when the situation at sites is challenged by extreme situations like wildfires. This approach enables both networks to maintain service in the local geographical area, ensuring their ability to support local residents and businesses when they are needed most.

Creating ancillary services for the power grid

ICT site owners can start now to prepare for the possibility to support the power grid's needs of different types of ancillary services, thereby opening up a new source of income [4]. This can be done in five steps:

1. Establish an energy profile for the site and optimize site power system capacity.
2. Introduce a segmentation usage capability of energy storage for different purposes such as ICT network backup and ancillary services. Consider adding storage to increase the income potential from the energy ancillary service.
3. Optimize the ICT site's own energy consumption and local energy production while balancing it with energy storage at the site.
4. Manage the energy consumption of multiple grid-connected ICT sites as one entity to maximize the impact on the power grid.
5. Utilize energy arbitrage by producing energy at the ICT sites and sharing it with the power grid when needed.

An efficient deployment includes AI-based automation to best optimize business intents and support the smart energy capabilities for both the ICT network and the power grid [5].

Supporting the digital transformation of the energy sector

Energy utilities currently use a variety of telecommunication technologies including fixed, fiber, microwave and mobile. In all cases, the communication has to be secure and highly available, as energy services must be reliable and in balance, according to the redundancy policy in operation.

Looking ahead, it is clear that the digital transformation of the energy utility sector would benefit from the introduction of LTE/5G technology [6]. These technologies make it possible for ICT sites to provide energy utilities with insights for the geographically distributed low-voltage power grid with characteristics of outages and performance degradation. Further, with the help of AI agents, LTE/5G networks can help predict performance degradations/deviations and their potential impact.

5G networks are particularly well suited to smart-grid management [7]. The 5G network can be either commercial or private depending on preferences on the energy utility. With a 5G network in place, an energy utility can ensure that its critical functions are implemented in a resilient, reliable and secure way. A 5G network is also the most efficient way for an energy utility to establish a cost-effective strategy for connecting grid assets over a wide geographical area. All new devices in the power grid use wireless technology for communication. Long-term, stable technology evolution is guaranteed, in alignment with the long life-cycle considerations of the telecom segment.

Conclusion

Whenever the need or desire to modernize ICT sites arises in a local or regional area, new energy-related opportunities arise with it. A holistic approach is key to maximize the potential for energy consumption reductions in existing and future ICT networks across the whole service life cycle. To be successful, it is essential that ICT site owners explore and identify candidates to reduce energy consumption as early as possible – ideally in the network planning stage. During the deployment stage, it is crucial to build and optimize for low energy consumption. With respect to in-service operations, artificial-intelligence-based automation, together with active network energy optimizations, make it possible to minimize energy consumption without negatively impacting quality of service (QoS) in the networks.

As they plan for the future, ICT site owners also need to consider the fundamental changes that are taking place in power generation and distribution. These changes, along with new energy consumption patterns, have created multiple challenges for the electricity utility sector. Mitigation alternatives will be costly and take a long time to deploy. By investing in a smart energy setup at ICT sites, ICT site owners can gain access to a resilient energy source that reduces their energy costs to net zero, while simultaneously opening up a promising new income stream by connecting with the smart grid.

Further reading

- **Ericsson Technology Review, Building robust critical networks with the 5G system, available at:** *https://www.ericsson.com/en/reports-and-papers/ericsson-technology-review/articles/building-robust-critical-networks-with-the-5g-system*
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