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Building zero-emission radio access networks

White Paper

Targeting zero carbon network operations enables operators to state their green credentials, add shareholder value and help win concerned consumers. Even better, low carbon and low energy go hand-in-hand, so reducing the use of fossil-based energy creates attractive financial gains.

Moving from legacy base station sites to modern energy-saving systems reduces energy costs and carbon emissions, and also delivers many other cost-saving benefits. Ultimately, the goal is to achieve zero-emission radio access networks.

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Executive summary

Reducing network greenhouse gas (GHG) emissions has not typically been a high priority for most operators over the years. Faced with dramatic changes in their business environment driven by increasing competition, declining average revenue per user (ARPU) and exploding demand for data services, most operator investments have focused on network capacity and performance to improve the customer experience.

Yet the commercial and official pressure on operators to address their business-related GHG emissions can only grow.

The power utilities are on the front line and have stated aims to reduce the amount of carbon emitted per unit of energy generated. For example, Helen Oy in Finland states: ”We aim to produce energy in a carbon-neutral way in 2050. Our intermediate target is to reduce carbon dioxide emissions by 20% and to increase the share of renewable energy to 20% by 2020”.[1]

Meanwhile, network equipment vendors are constantly introducing more energy efficient infrastructure. On average, each new base station generation reduces energy consumption by about 35 percent.

These two examples show that operators have an expanding range of options to reduce their network GHG emissions. Only by adopting the latest energy-saving and renewable energy technologies can operators support emissions-reducing targets that align with the Paris climate change agreement’s stated goal of limiting global warming to 2°C

Feeling the heat of global climate change targets

There is compelling evidence that the burning of fossil fuels by our civilization is driving climate change. Global warming is a threat to every person on the planet, which is why governments have joined forces to address the challenge. The 2016 Paris Agreement to limit greenhouse gas (GHG) emissions under the United Nations Framework Convention on Climate Change (UNFCCC) came into effect in November 2016 following its agreement by more than 190 UNFCCC members, of which most have ratified the agreement.

“The Paris Agreement’s central aim is to strengthen the global response to the threat of climate change by keeping a global temperature rise this century well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius”.[2]

United Nations
Framework Convention on
Climate Change

The 2°C target means that countries will need to have net zero GHG emissions during the second half of the 21st century.

The agreement sends a strong and unambiguous signal to industry that, with governments committing to a long-term downward trend in carbon emissions, their investments must be focused accordingly.

As a result, more operators are committing to reducing their GHG emissions. Telefónica for example says: "Our commitment can be seen in the new energy and climatic change objectives we have set, in line with the global commitment to not exceed 2°C in temperature (2DS), according to the Paris Agreement."[3]

Finnish operator Elisa is another prominent, climate-concerned operator. It states: "Elisa wants to participate in creating a society with low carbon emissions. For us, environmental responsibility requires, above all, long-term and transparent operations to prevent climate change. Curbing emissions has been a part of our strategy since 2009. We monitor our objectives every six months through the CO_2 emission savings scorecard."[4]

Can zero carbon emission networks be achieved within a realistic timescale and budget, and how will the necessary investments benefit operators? This white paper aims to answer these questions.

A trillion-dollar saving in 15 years

It is estimated that US$90 trillion of global investment to renew and expand all infrastructure (transport, telecommunications, water/waste, electricity networks and energy end-use for buildings, industry and transport) will be needed between 2015 and 2030. Investing in low-carbon infrastructure would cost an additional US$4 trillion of investment, yet reduce operational expenditure over the same period by US$5.1 trillion. That's a saving of more than US$1 trillion primarily from savings in fuel expenditure.[5]

A positive environmental impact for mobile communications

With mobile communications becoming a core part of most people's daily lives, the industry has already been able to play a significant role in helping to limit the growth in carbon emissions that has dogged many other sectors. Information and Telecommunications Technology (ICT) accounts for around just 2 percent of all global emissions[6], yet helps to avoid emissions that are nearly ten times greater.

Telecommunications has had a dramatic impact, such as helping to reduce business travel through the greater use of online meetings, or by helping to make logistics operations more efficient. The future is looking even brighter with new mobile technologies promising to bring new efficiency through the deployment of smart cities, healthcare and improved remote control in industrial processes.

Yet mobile operators, along with all commercial organizations, are coming under public and legislative pressure to reduce the environmental impact of their own operations. For example, the first quarter of 2016 saw a record number of shareholder votes in the US relating to climate change.[7] While the focus is currently on energy companies and utilities, investor pressure on all organizations to address how their activities impact climate change can only grow.

Radio network energy use is the key focus

Most of a mobile operator's carbon emissions come from the radio access network, making it a prime target for environmentally-friendly improvements. About 80 percent of a mobile network's energy is consumed by base station sites. Running a typical urban base station site in Europe for ten years accounts for more than 84 percent of its GHG emissions, with logistics and production making up the remaining 16 percent.[8]

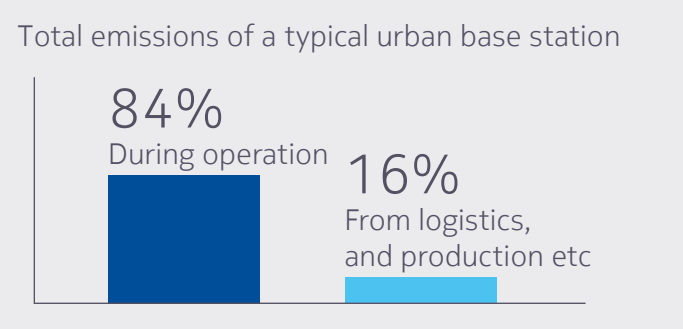

Figure 1: 84 percent of a typical urban base station's greenhouse gas emissions occur while it is in operation.

To lower GHG emissions, there needs to be a focus on reducing network energy consumption, which also helps to cut network operational expenditure (OPEX) through lower energy bills and operational efficiency improvements. In parallel, the deployment of renewable energy production to power base station sites will be vital in moving towards zero carbon emission networks.

How feasible is it for operators to implement zero emission radio access networks quickly enough to meet rising consumer and legislative pressures while still being commercially realistic? Nokia believes it is practical and that although the journey to a fully zero emission radio access network will take many years, at each step the improvements made will bring their own benefits through lower costs and improved brand image.

A growing role for renewable energy

The prime goal that needs to be achieved to make radio access networks emissions-free is to eliminate their dependence on fossil-based fuels by deploying renewable energy. A decade ago, trials of base station sites powered purely by a mix of solar and wind power seemed to herald a new era of zero-emissions networks. Yet most of these early test deployments were not deemed successful because of higher costs and lower reliability of power than expected.

Such experiences have contributed to a view that renewable energy has an unacceptably high capital cost and is unable to provide continuous power sufficient to run a base station without back up from the electricity grid or Diesel generator set.

However, the picture for renewables is very different to that of a decade ago. There has been a quiet revolution that makes renewables much more attractive today.

Costs come down as efficiency goes up

Firstly, the perceived high capital cost of renewables has fallen substantially over the last decade. The most prominent renewable technology today is solar power and the initial cost of solar panels has dropped by a factor of ten. Furthermore, the size of solar cells has shrunk considerably, helping to eliminate the need for large areas of expensive and hard-to-acquire land at a base station for their installation.

Secondly, there is a growing acceptance that it is unnecessary to deploy renewable capacity for 100 percent of a base station site's power needs in order to benefit from the lower operational costs and zero emissions of renewable energy. Operators can benefit by starting small and deploying just one or two solar panels to benefit from reduced grid electricity consumption or by reducing the need to run costly Diesel generator sets.

World's first solar powered call on 4 October 1955

Nokia Bell Labs invented silicon-based solar panel in 1954

Industry leading products covering any need from full solar to hybrid sites

Today 2.2 MWp installed solar power

Renewables can be deployed at any base station site and deliver worthwhile economic benefits:

Off-grid sites: Typically, an off-grid site will be powered by a Diesel generator set. Adding renewable power will deliver a fast payback of typically six to 12 months. Even a small amount of renewable energy will reduce fuel use, cut the frequency of refuelling visits and extend generator maintenance intervals.

Poor-grid sites: Numerous base station sites connected to electricity grids prone to interruption use Diesel generator sets to keep mobile services running during outages. The payback of adding renewable energy depends on grid reliability, but will cut OPEX by reducing the use of Diesel and support costs.

On-grid sites: Even base station sites connected to a reliable power grid will benefit from renewable energy, by reducing electricity bills and carbon emissions. The more renewable capacity you build, the lower your OPEX.

Hybrid sites that combine carbon-free and fossil fuel energy are the most cost-effective option in the short to medium term. Combinations of renewable technologies, including solar, wind, hydropower and even fuel cells will be deployed according to their cost and suitability for each site.

In addition, network modernization has reduced, and continues to reduce, the amount of renewable capacity required for a base station site, lowering the overall amount of investment in renewables that operators need to make.

The developments to reduce renewable energy costs and increase infrastructure energy efficiency also lower the need for battery back up capacity. Hybrid sites that combine the use of renewables with power from the electricity grid or use a Diesel generator set can be minimally dimensioned with battery back up capacity – further reducing the operator's investment.

The development of new battery technology will mean battery costs will fall dramatically in the next decade, accompanied by substantial rises in performance. The lithium iron phosphate (LiFePO4) battery, or LFP battery was first introduced for base station sites by Nokia in 2015. LFP batteries support up to five times more charging cycles than lead acid batteries, lowering the cost of renewable deployments.

The next section of this white paper looks in more detail at the technologies and developments in base station energy efficiency.

Energy-saving in the RAN

With energy consumption accounting for as much as 50 percent of the total costs of a base station site in some countries, there are clear benefits to be gained by improving the energy efficiency of infrastructure.[9]

Yet Nokia estimates that around 70 percent of all installed base stations remain 'unmodernized', using outdated, energy-hungry hardware. These legacy base stations waste some 80 percent of the energy they take from the electricity grid, emitting more than 70 tonnes of CO_2 annually – a figure that could be cut to just 17 tonnes by using a modern base station.

Base station site modernization can achieve up to 70 percent energy saving by reducing or eliminating the need for cooling systems.

Base station sites have multiple energy-consuming systems and finding the most effective ways to raise the efficiency of the entire site crucially depends on an understanding of how much energy is being used. Accurate energy monitoring is a first step that can identify power-sapping faults and reveal new opportunities to reduce energy consumption.

Sharing base station hardware

One of the most significant developments in base station modernization is the sharing of multi-purpose hardware, with functionality determined by shared software. Commonly called Single RAN (Radio Access Network), the technology cuts through growing network complexity by moving from separate installations for each radio technology with its own transport and operational needs, to single installations with a common transport and operational and management system.

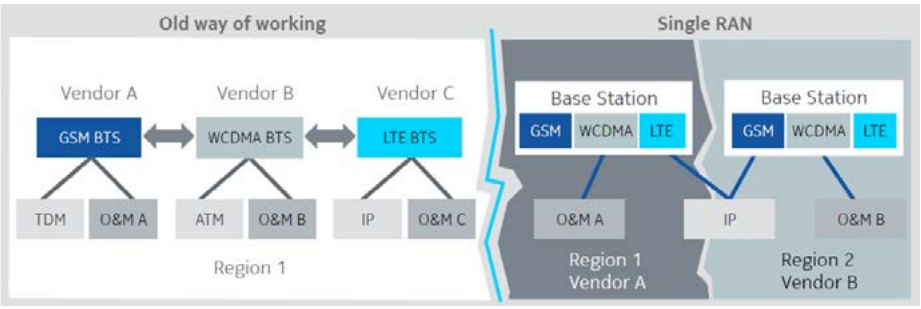

Figure 2: Single RAN is changing network business by introducing much-simplified base station site structures with common transport and operational support.

Up to 30 percent of the energy entering a site will often be consumed by site-level facilities such as cooling. Another 20 percent is dissipated in power systems, leaving around 50 percent of the site's energy consumption to run the base station itself.

Operators adding overlay LTE base station sites have seen that base station site energy consumption is increased typically by 20 percent. With Single RAN capable base stations, the rise in energy consumption caused by the LTE rollout can be reduced by modernizing the old GSM and HSPA base station components. For example, a Single RAN base station consumes up to 60 percent less energy compared to traditional single technology base stations through the deployment of key sharing technologies that include:

- **Radio Frequency (RF) sharing for up to 34 percent reduction in carbon emissions:** RF sharing is enabled by Single RAN base station hardware, changing from Single Carrier Power Amplifiers (SCPA) in GSM to Multi Carrier Power Amplifiers (MCPA) as used in LTE and HSPA networks. This enables the existing base station RF to be used simultaneously for both GSM and LTE, or GSM and HSPA, depending on the frequency band.
- **Baseband sharing for up to 38 percent reduction in carbon emissions:** The same baseband hardware is used for multiple RF technologies, with one software platform at a time, which simplifies installation and maintenance.
- **Transport backhaul sharing for up to 66 percent reduction in carbon emissions:** Transport backhaul sharing simplifies the network with one shared IP/Ethernet transport that can support GSM, HSPA and LTE, thus eliminating the need for TDM transport links for GSM and ATM transport links for HSPA.

The drive for more energy efficient hardware

Industry advances in both power electronics and data processing electronics are helping to improve the energy efficiency of base station hardware. For example, modern battery-charging rectifiers typically run at 96 percent efficiency compared to just 80 percent just a few years ago.

A significant trend has been the ever-tighter integration of electronics systems, which use less energy than separate components. The most prominent example is the use of the latest System on Chip (SoC) technology in base stations that achieve a 10-20 percent gain in efficiency, while the wider use of Gallium Nitride GaN semiconductor technology is adding 5-10 percent efficiency gain.

Base station electronics hardware today also better supports the efficient sharing of resources and introduces features that make it easier to switch off during periods of low traffic.

Outside the base station itself, advances in site-level systems are helping to bring down energy use further. The ability of base stations to run in higher ambient temperatures and the development of shelterless base stations has enabled sites to run without power-hungry air conditioning and cooling systems.

Further advances in the use of base station site waste heat are being made by Nokia Bell Labs in the shape of liquid cooling technology. Base station sites are conventionally cooled by air, yet a far more efficient medium is water that has orders of magnitude higher heat capacity than air. Using water to extract waste heat from a site produces low-grade hot water that could be used in a variety of external applications. With many base stations mounted on or adjacent to buildings, there is a ready source of local demand for this heat. The value of this heat to the operator could be as high as the cost of the energy consumed by the site itself.

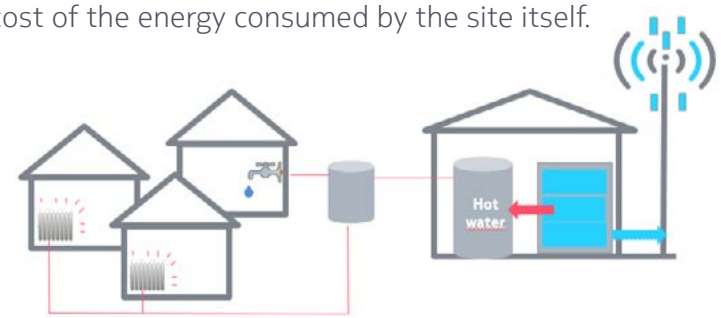

Figure 3: Heat extracted from a base station site by liquid cooling could be used for a variety of local heating applications.

Another critical system, especially to enable the wider use of renewable energy sources, is battery back up. Nokia expects battery costs to fall dramatically in the next decade, accompanied by substantial rises in performance.

More rapid development of base station efficiency

In October 2016, Nokia acquired ETA Devices, a US company specializing in power amplifier efficiency solutions for base stations, access points and devices.

Eta Devices' ETAdvanced power management technology can reduce heat waste drastically through the use of a new amplifier that works like an automatic gearbox, adjusting energy use by constantly providing the right amount of power required for a radio signal.

The technology reduces the need for backup power, translating into smaller base station cabinets and reduced equipment breakdown rates, and supporting Nokia's target to continuously strengthen the base station power efficiency of its products.

The energy-saving power of software

Software advances are contributing substantially to improving the energy efficiency of base station sites and lowering their GHG emissions. By continuously upgrading the software used in their base stations, operators can rapidly and cost-effectively take advantage of the latest developments.

Software improves RAN energy efficiency in two key ways – increasing the capacity and coverage to enable operators to serve more demand and more subscribers using existing base stations; and reducing the actual energy consumption of base stations.

Improved coverage and capacity is achieved through techniques that include interference cancellation, uplink and downlink throughput increases, reduced signalling, more efficient use of spectrum, carrier aggregation and load balancing.

Meanwhile, increasingly sophisticated ways to reduce base station energy consumption include dynamic muting of dormant resources, energy monitoring, envelope tracking, content-aware Peak to Average Power Ratio reduction, content-aware clipping and micro DTX. For example, Nokia 'Zero Traffic - Zero Energy' can reduce RF energy consumption up to 85 percent by switching off RF units when there is no traffic. In addition, radio unit energy use can be reduced through software that ensures the power amplifiers work at optimum efficiency in all traffic conditions.

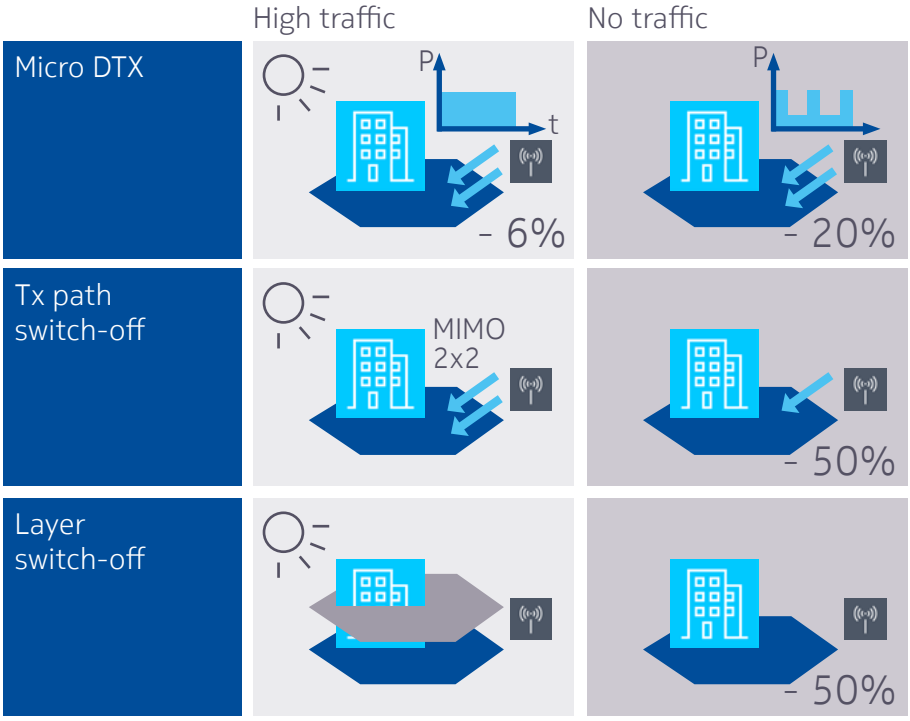

Figure 4: Shutting down base station functions during low traffic periods saves significant energy and emissions.

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Ten benefits of the journey to zero emissions networks

While the principal aim of moving from legacy base station sites to modern energy-saving systems and ultimately to zero emissions radio access is to reduce operational costs and GHG emissions, there is a substantial set of other cost-saving benefits for operators. These include network simplification, easy installation, more efficient integrated operations, improved services for customers and greater business flexibility.

1. Energy metering provides a precise understanding of how much energy the radio access network is using, enabling targets to be set and efficiency improvements to be tracked.
2. Modernizing legacy base station sites provides a substantial lowering of energy costs for lower radio access network OPEX.
3. Deploying any amount of renewable energy capacity at base station sites will cut the cost of supporting off-grid and poor-grid sites for a guaranteed return on investment.
4. Modernization of base station sites reduces their complexity, making them simpler to run and maintain with reduced breakdowns and fewer site visits needed, leading to lower operational costs.
5. Modernization and upgrading of software improves coverage and capacity of the network using existing infrastructure. This enables an operator to serve more customers without needing to build new sites, which is typically costly and time-consuming.
6. Investing in zero-emission radio access networks adds value to a brand as an environmentally-responsible operator.
7. As well as helping to improve profitability, deploying emissions-reducing upgrades helps to meet growing shareholder concern about how company activities affect the environment.
8. It is inevitable that governments and regulators will roll out more stringent legislation and increased levies to encourage the commercial sector to reduce emissions. Starting now on the path to a zero-emission network helps operators to be ready.
9. Being seen to be environmentally-responsible can be a powerful marketing strategy to attract the growing numbers of consumers concerned about the environment.
10. In the high-tech world of telecommunications, an operator's image is enhanced by being a leader, not a follower. It is likely that all operators will eventually be forced into investing in ways to lower their emissions; being seen to be at the forefront of the trend is good for an operator's image, benefiting the business in many ways, from market valuation to being seen as an attractive employer.

The next generation radio access

For its part, Nokia is committed to helping operators to evolve their radio access networks to zero emission operation. For example, operators globally benefited from 45 percent less energy consumed on average by radio access networks modernized by Nokia during 2015.[10]

Also in 2015, Nokia launched its zero carbon emission base station solution, making it possible for the first time to achieve zero carbon emissions for all electricity grid situations – from good grid to no grid.

The most recent development is the launch in 2016 of Nokia AirScale Radio Access. This next-generation RAN system takes the energy-saving benefits of resource sharing to its extremes by running all radio technologies, from 2G to 5G and even Wi-Fi, simultaneously in the base station.

AirScale Base Stations have 60 percent lower energy consumption than Nokia's previous generation radio access solution. AirScale Base Stations also comprise fewer units, making them easier and faster to install for 60 percent less hardware and installation costs and enabling them to blend into the background for almost invisible, environmentally friendly sites. The base stations also feature new software that reduces their energy consumption and even uses zero energy when there is no traffic.

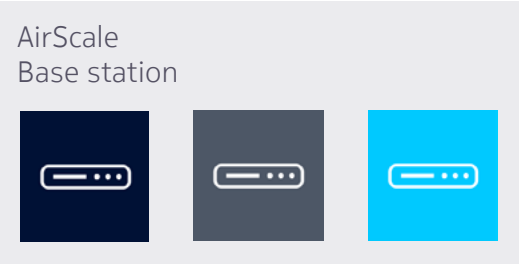

Figure 5: Nokia AirScale Base stations run all radio technologies simultaneously on shared hardware and software.

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Conclusion

Targeting zero carbon network operations is a powerful way for operators to state their green credentials, add shareholder value to their brand and help win concerned consumers. Even better, low carbon and low energy go hand-in-hand, so reducing the consumption of fossil-based energy creates attractive financial gains.

The telecoms industry is entering an exciting new era in which 5G will affect every industry and be a driving force for new applications that use massive broadband capabilities. The Internet of Things (IoT) will require networks to support a diverse range of billions of connected devices. The impact on radio access networks will be profound as they are called upon to deliver huge capacity and high performance that is both cost-effective and sustainable.

By investing now in a step-by-step approach to reduce and ultimately eliminate GHG emissions caused by radio access network operations, operators will be better prepared to succeed in a more environmentally-concerned and digitally-transformed market.

Nokia will continue to focus on helping operators to achieve zero-emission networks through investments in new platforms that will enable further innovation and create capabilities that cannot be imagined today.

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