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How 5G is bringing an energy efficiency revolution

White paper

With traffic set to dramatically increase with greater use of 5G, it's important that the energy consumed by these networks does not rise at the same rate.

Fortunately, 5G is much more energy efficient than previous network technologies, with several features that help save energy. By aiding remote working, 5G can also help cut energy use in other industry sectors.

Nokia has also launched several solutions that help maximize the energy saving potential of 5G networks.

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Executive summary: a hundred times more traffic with less energy

Innovations in digital technology are not only reducing bad environmental effects but also producing benefits for industries, society and the lives of individuals. In the case of 5G technology that means more capacity and new use cases.

But what about the energy consumption and CO_2 emissions caused by this explosion in data traffic? This paper addresses the energy efficiency of 5G networks and their impact on global CO_2 emissions. The focus is on radio efficiency since most of the energy is consumed by the radio network.

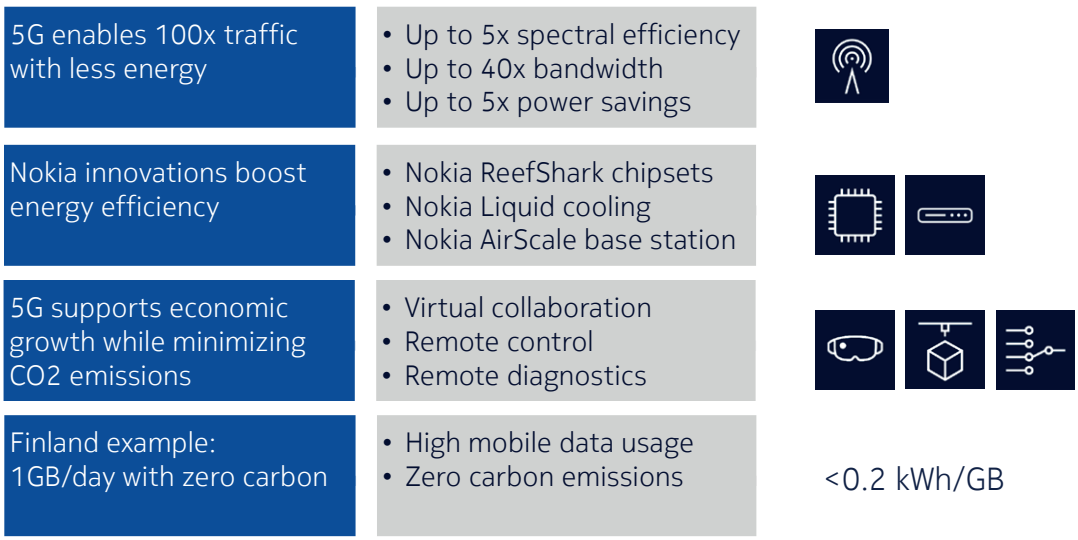
The good news is that with 5G, energy consumption does not grow even if traffic data explodes because 5G dramatically improves network efficiency. 5G can transmit a lot more data than 4G, with a similar or lower energy consumption, because of its higher spectral efficiency, larger bandwidths and features designed to cut power use. It is possible to carry up to a hundred times more traffic with a 5G network while reducing its power consumption.

The other good news is that Nokia has several innovations that enhance energy efficiency and minimize CO_2 emissions, such as AirScale solutions, liquid cooled base stations, ReefShark chipsets and power saving features based on artificial intelligence.

5G networks and the new use cases they can support, for example, remote work and remote-control capabilities, can also help to reduce CO_2 emissions in other sectors of society by reducing travel and increasing automation. It is estimated that digital technologies have the potential to save ten times more emissions than they produce by 2030.

The paper illustrates an example case study from Finland. The mobile data traffic is more than 1 GB per person per day with zero carbon emissions and with less than 0.2 kWh energy usage per GB. There is also a clear path for higher capacity with 5G networks and new spectrum allocations.

Figure 1. Lower energy consumption and CO_2 emissions with 5G technology



5G technology improves energy efficiency

Maximizing energy efficiency is one of the basic principles of 5G - there is a clear aim to keep the energy consumption of the mobile network at current levels, or even lower, despite increases in data traffic and the number of base stations.

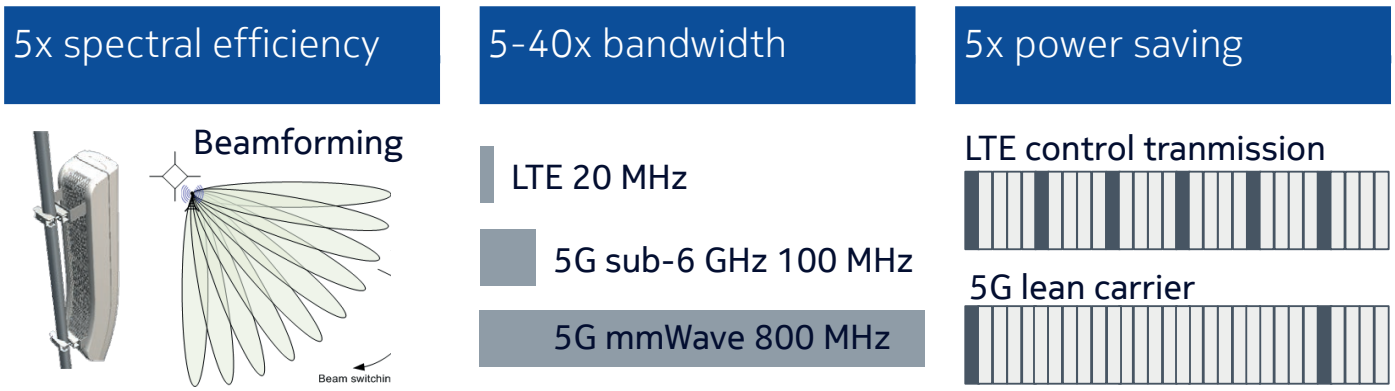
5G has a number of solutions designed to achieve this target:

- 5G brings higher spectral efficiency by using beamforming antennas, by higher spectrum utilization and by using solutions to minimize interference. Average 5G spectral efficiency with a beamforming antenna can achieve 10 bps/Hz, five times higher than today's typical 4G Long Term Evolution (LTE) network.
- 5G supports more capacity per cell using wider bandwidth: LTE bandwidth is up to 20 MHz, 5G mid-band is up to 100 MHz and 5G millimeter wave is up to 800 MHz. Wideband radios can carry much more data for a similar power consumption.
- 5G enables power saving features to minimize the power consumption of base stations.

5G networks include more efficient system level solutions to cut power consumption, with a particular focus on energy efficiency during low loading. LTE networks have shown that the average network level utilization is typically 10-25% over a 24 hour, 7-day period for the whole network. This low utilization is caused by an unequal distribution of traffic, both over a 24-hour period and over the geographical area. Network loading is low at night and several cells are needed for coverage and will carry only low traffic volumes.

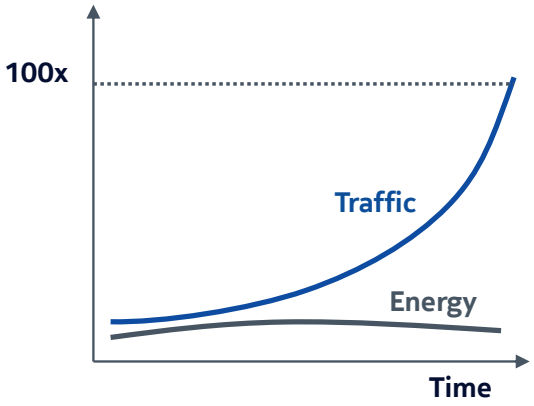
All this means that base station resources are generally unused 75-90% of the time, even in highly loaded networks. 5G can make better use of power saving techniques in the base station, offering great potential for improving energy efficiency across the network.

Figure 2. 5G solutions for higher energy efficiency



The expected rises in traffic volumes and network energy consumption are illustrated in Figure 3. 5G technologies allow a hundred times more traffic to be carried, without increasing the total energy consumption of the network. Early deployments of 5G may lead to increases in energy efficiency if 5G is added on top of an existing network without modernizing the underlying 2G/3G/4G networks.

Figure 3. Traffic growth and target energy usage



Innovations minimize power consumption

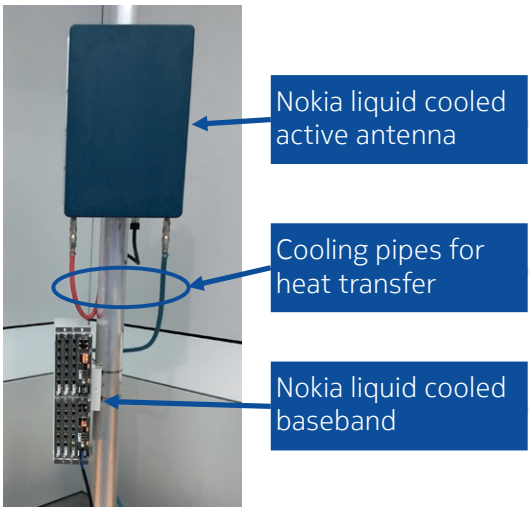
Achieving a zero-emission radio access network can be done using two methods employed in parallel: use less power through increased energy efficiency and decarbonize the network through greater use of renewable energy.

5G has an incremental effect on existing mobile networks in several ways. The additional equipment required means that a 5G roll-out typically increases the energy consumption of existing sites. To offset this effect, Nokia advocates its Zero Emission solution. Modernizing a typical legacy base station site to Single RAN can achieve an energy saving of up to 70% and reduce its annual CO_2 emissions from more than 70 tonnes to just 17 tonnes. Furthermore, a Single RAN base station can reduce the Total Cost of Ownership by up to 30% compared to a 5G or LTE overlay solution.

Liquid cooling can reduce energy consumption of a typical base station site by up to 66%, compared to traditional air-cooling systems – the excess heat can even be sold as useable energy. All this can be achieved simply by shifting to a more efficient cooling system, with no adverse effects on network performance.

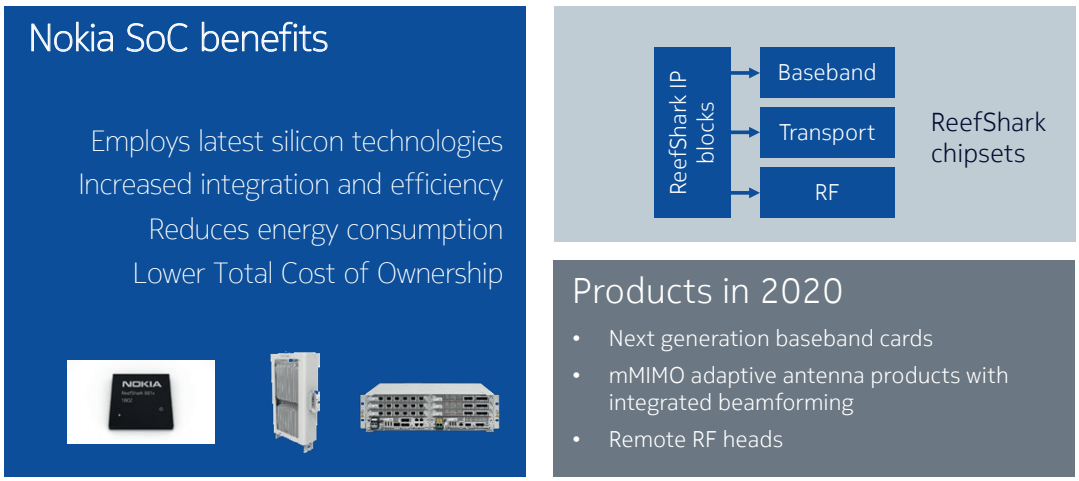
Nokia is the first vendor to introduce a liquid cooled base station with the world's first 2G, 3G and 4G base stations, which is already in commercial operation with Elisa, Finland. Elisa co-operation has been expanded in 2020 by world's first commercial liquid cooled 5G base station located in Helsinki, Finland.

Figure 4. Nokia liquid cooled AirScale base station



Upgrading to the latest, next generation radio access brings further reductions in emissions. Nokia AirScale Base Stations have 60% lower energy consumption than Nokia's previous generation radio access solution. ReefShark chipsets can also significantly improve performance, allowing smaller massive MIMO antennas as well as lower power consumption. Additionally, ReefShark chipsets reduce power consumption in baseband units.

Figure 5. Nokia ReefShark helps to minimize power consumption



Artificial Intelligence and Machine Learning solutions (AI/ML) will further help to minimize network power consumption by shutting cells down in an intelligent way. AI-based optimization can learn from live network traffic patterns to set up specific schemes for power saving groups for different regions in different time zones. These schemes include optimized power saving trigger conditions. The solution makes the best use of energy while minimizing any effects on quality of service.

5G minimizes CO_2 emissions

5G networks enable new use cases for consumers, enterprises, homes and for public domains. These new use cases could potentially minimize the need for people to travel, further cutting overall CO_2 emissions.

With its enhanced mobile broadband capabilities, 5G will offer remote video surveillance with analytics, allowing security personnel to monitor large campus premises and multiple locations without constant vehicle patrols. Immersive experiences will also be supported by 5G, providing 360 degree live streams that allow people to attend sports and music events remotely, and providing guided tours of remote locations and places that can have certain access restrictions, such as construction sites or factories.

The ultra-reliable low latency capabilities of 5G will allow the automation of many physical industries. For example, in transportation, assisted and autonomous vehicles could help ease traffic congestion, minimizing emissions. Machine remote control and robotic and process automation for agriculture and manufacturing industries could help reduce the waste of raw materials and optimize machine operation to reduce energy consumption. This would create a more efficient supply chain, with the ability to respond more quickly to changing demand for products.

Figure 6. Example 5G use cases

Energy consumption per GB – case study Finland

This example case study is from Finland, a country with a very high mobile data usage of 1.5 GB per person per day (8000 Terabytes in total). Total network energy consumption of all mobile networks combined is approximately 500 GWh per year, giving an energy consumption of 0.17 kWh per GB. We will compare this real-life number to the estimated energy consumption and illustrate the future path to 5G.

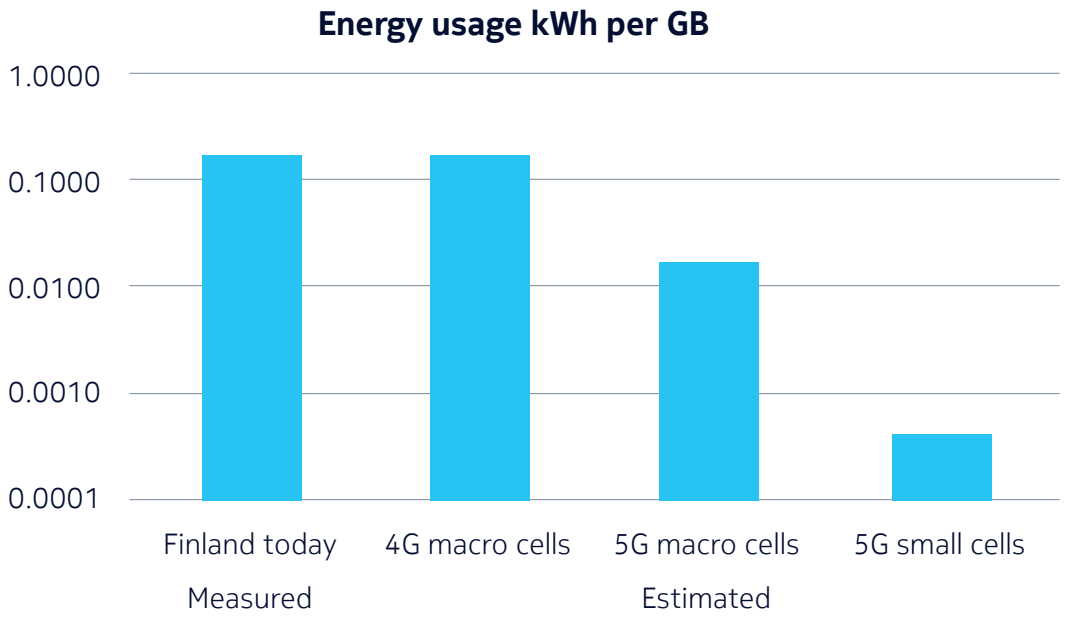
Our estimate assumes that a 4G macro base station has on average a 40 MHz bandwidth with Frequency Division Duplex (FDD) and a spectral efficiency of 2 bps/Hz. The 5G macro base station is assumed to have 100 MHz of bandwidth with Time Division Duplex (TDD) and a spectral efficiency of 10 bps/Hz. We assume three sectors and an average base station power consumption of 2 kW in both 4G and 5G cases. Average busy hour load is 80%, the busy hour carries 7% of daily traffic and 15% of sectors in the network carry 50% of the traffic.

5G mmWave small cells are assumed to have 800 MHz bandwidth with TDD, a single sector and a power consumption of 50 W. We assume that base stations consume 80% of the total network energy. This estimate brings 4G energy efficiency to 0.17 kWh per GB, which is very similar to the measured network level value. We need to note that the measured value also includes legacy 2G and 3G networks, which are not considered in the estimated energy usage.

5G macro cells reduce energy usage per GB by nearly a factor of ten, to 0.02 kW per GB. 5G small cells can reduce the energy usage by more than 100 times compared to 4G macro cells. The challenge with 5G small cells will be the limited coverage area and how to collect enough traffic. If small cells utilization is low, energy usage per GB will be higher.

In addition to higher energy efficiency, the Finnish operators use electricity from carbon neutral sources, leading to zero CO_2 emissions caused by the mobile network.

Figure 7. Energy usage per gigabyte today and with 5G evolution. Note that operators in Finland use green sources of energy and the network CO_2 emissions are zero



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Conclusion

5G technology combined with Nokia innovations make it possible to carry much more traffic in the mobile networks without increasing the overall network energy use. The important technology components include wideband transmission, beamforming techniques, lean carrier, Nokia ReefShark chipsets and liquid cooled base stations.

The case study in Finland shows that the energy consumption in today's 4G networks is less than 0.3 kWh per gigabyte, and 5G technology can lower the consumption by a factor of 10 in macro cells, and by a factor of 100 in small cells.

5G networks can also help reduce CO_2 emissions by reducing travel through the greater use of remote working and by allowing more efficient use of our transportation systems and industrial processes.

References

5G New Radio Network, 5G white paper https://onestore.nokia.com/asset/205407

Nokia zero emissions https://www.nokia.com/networks/technologies/zero-emission/

Nokia liquid cooled base station https://www.nokia.com/about-us/news/releases/2018/12/10/a-world-first-nokia-elisa-and-efore-commercially-deploy-a-liquid-cooled-base-station-that-can-reduce-co2-emissions-by-up-to-80-percent/

Digital contribution to delivering long-term Climate Goals, Digital Europe https://www.digitaleurope.org/resources/digital-contribution-to-delivering-long-term-climate-goals/

5G use cases https://www.nokia.com/networks/5g/use-cases/

Abbreviations

AI	Artificial Intelligence
FDD	Frequency Division Duplex
GB	Gigabyte
GWh	Gigawatt hours
kWh	kilowatt hours
LTE	Long Term Evolution
ML	Machine Learning
RAN	Radio Access Network
TDD	Time Division Duplex

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Our communications service provider customers support more than 6.4 billion subscriptions with our radio networks, and our enterprise customers have deployed over 1,300 industrial networks worldwide. Adhering to the highest ethical standards, we transform how people live, work and communicate. For our latest updates, please visit us online www.nokia.com and follow us on Twitter @nokia.

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