# Energy efficiency enhancements in radio access networks

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**More users and a total increase in the use of Ericsson's telecommunications systems are putting greater demands on energy usage. Through extensive life-cycle assessments of its systems, Ericsson has learned that energy consumption in the usage phase of its radio access networks is the most critical factor relating to impact on the environment. At the same time, operators are becoming increasingly aware of their energy bills. Consequently, Ericsson is committed to developing solutions that reduce operating costs and effects on the environment. How? By increasing energy efficiency in radio access networks.**

**Taking the customer perspective, Ericsson has used site, network, climate, and traffic statistics from operator networks to accurately estimate enhancements to energy consumption in real network operations. Examples of product enhancements include reduced energy consumption in RBS equipment, climate systems, and radio access networks (during roll-out) and legacy networks (during operation). These short-term enhancements are part of Ericsson's commitment to strategic long-term improvements.**

## Background

In recent years, the Information and Communication Technology (ICT) industry has actively participated in public discussions about energy consumption in terms of the industry's role as a large consumer, and solutions for reducing impact on the environment from transports and other energy-consuming activities.

Rising usage and new product and service launches have undoubtedly increased energy consumption, while new technologies have improved energy efficiency (Figures 1 and 2). In 2001, commercial office and telecommunications equipment represented less than 3% of all electricity consumption in the US. Telecommunications represented about 7% of this figure or 0.21% of total electricity consumption.[1]

Compared to the first generation of mobile systems, the energy efficiency of today's sophisticated multimedia systems has increased significantly (Figure 3). Given the growing number of ubiquitous services and applications, opportunities abound for participants in the telecommunications market to function as enablers of a more resource-efficient society. When used properly, the positive effects of ICT applications have the potential to greatly outpace increases in energy consumption. Therefore, Ericsson is continuously striving to make its radio access networks more energy-efficient. Likewise, Ericsson recognizes and supports its customers' efforts to improve the energy efficiency of their systems.

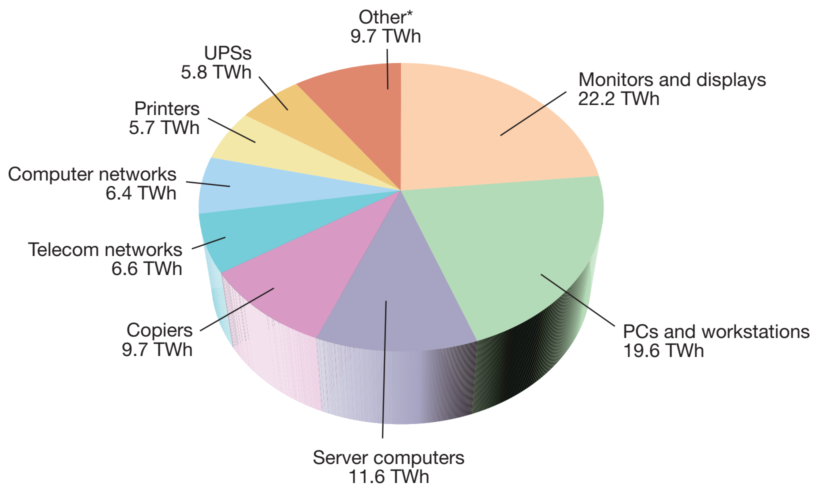
## Environmental performance

Since the mid-1990s, Ericsson has conducted several extensive life-cycle assessments (LCA) that cover different aspects of telecommunications systems—for example,

- radio access network (RAN) products;
- core network products; and
- activities associated with operating telecommunications systems.

The LCA results point to one thing: the most significant environmental impacts from Ericsson's systems are associated with ener-

**Figure 1**
**Electricity consumption attributed to information and communication technology in the USA (2001).**



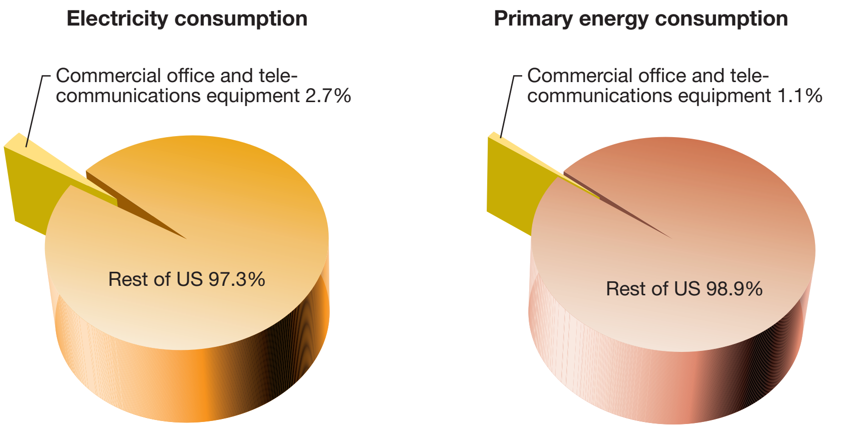



**Figure 2**
**Commercial office and telecommunications equipment represents less than 3% of the total electricity consumption (USA).**

gy consumption during their use. Radio base stations are the single largest consumers of energy. Consequently, measures taken to reduce this consumption can directly benefit society.

### Scope, design, and limitations of the LCA

Ericsson's most recent system-level LCA investigated a pilot UMTS network for 1.5 million subscribers during one year of operation. The pilot system consisted of

- 3G terminals (for example, mobile phones) and other advanced terminals;
- a radio network with radio base stations;
- radio network control equipment;

**BOX A, TERMS AND ABBREVIATIONS**

| | |
|---|---|
| AC | Alternating current |
| BSC | Base station controller |
| BTS | Broadband telephony softswitch |
| CDF | Cumulative distribution function |
| DC | Direct current |
| EoL | End of life |
| GSM | Global system for mobile communication |
| ICT | Information and Communication Technology |
| LCA | Life-cycle assessment |
| PDF | Probability density function |
| RAN | Radio access network |
| RBS | Radio base station |
| RF | Radio frequency |
| RNC | Radio network controller |
| UE | Useful entity |
| UMTS | Universal mobile telecommunications system |
| WCDMA | Wideband code-division multiple access |

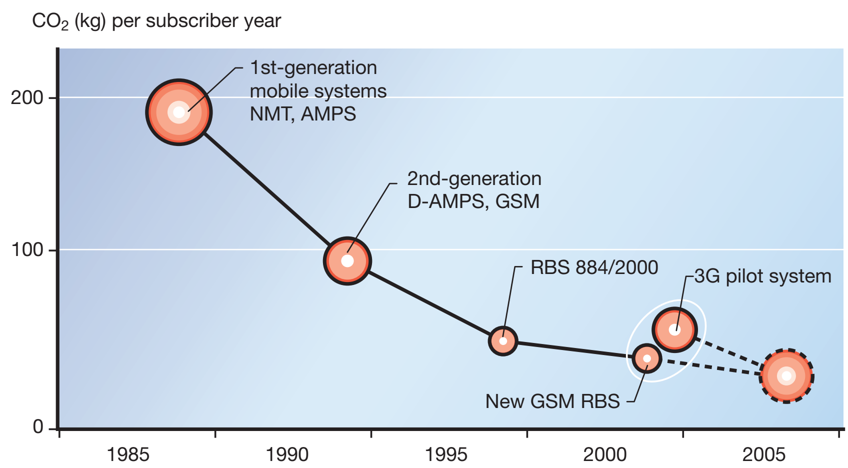



**Figure 3**
**Ericsson is continually striving to make its radio access networks more energy-efficient.**

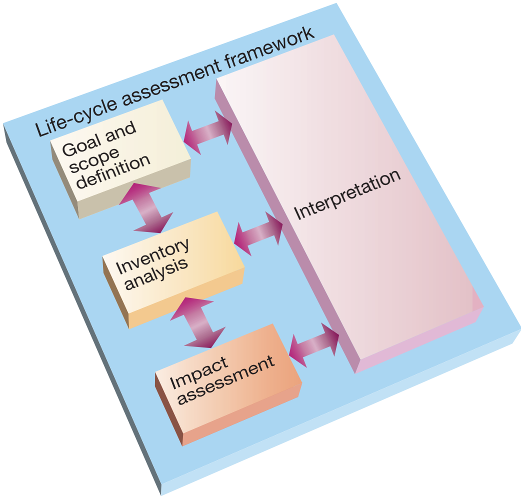
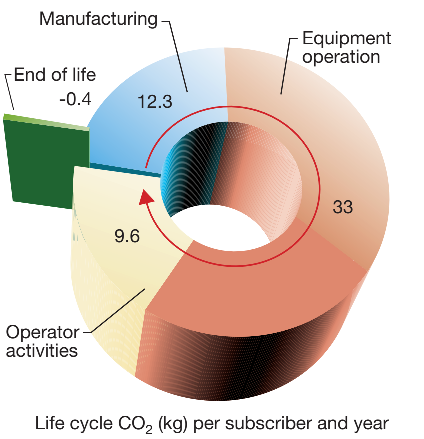



Figure 4
**Life-cycle assessment methodology.**

Figure 5
**Environmental impact of the phases in the life-cycle of the 3G pilot system.**




- a core network with switches, routers, servers, and workstations;
- transmission equipment, such as feeders and cable;
- various site materials, such as antennas; and
- climate-control equipment and site housing.

Application networks (mainly servers) were not included in the assessment. During the LCA, no full-scale commercial third-generation system was in operation. Therefore, the pilot system was sized using data from Ericsson's business operations—for example, data on subscriber behavior and system usage enabled the formulation of assumptions and predictions. Because the LCA only includes Ericsson equipment, no conclusions can be drawn about products or systems from other vendors. In principle, the LCA results are only applicable to the pilot system. Note: When interpreting the results, remember that an LCA is based on models that are simplifications of reality (Figure 6).

## Key indicators of effects on the environment

The LCA investigated several impact indicators, such as climate change, resource depletion, and acidification. An interesting, unforeseen result was the prevalence of electricity production in most environmental impact categories. Climate change, measured in carbon dioxide ($CO_2$) equivalents during the entire life cycle of a system, is the most widely accepted indicator.

### *System life-cycle phases*

Figure 5 illustrates the manufacturing, operational, and end-of-life (EoL) phases of the pilot system.

Product manufacturing (especially of electronics in user terminals) is a crucial activity within the manufacturing phase. This phase accounts for about 22% of the impact on the environment.

The operational phase, which is the most critical phase, includes actual equipment operation and operator office activities. During this phase, equipment operation and office activities account for about 78% of the total impact on the environment. The operation of telecommunications equipment accounts for about 60%.

The end-of-life phase has a positive effect on the environment thanks to recycling.

### *Third-generation system units*

The picture changes when the LCA results are re-analyzed in terms of the main units of the pilot system—RBS, user terminals, network equipment, and business operations. Figure 7 shows that the RBS site plays a key role concerning impact on the environment. This is not surprising because a radio access network (valid for all systems—NMT, GSM, CDMA2000, etc.) consists of many RBS sites. The RBSs, which are connected to user terminals via the air interface, must be constantly prepared to deliver services to the 1.5 million users.

Manufacturing of user terminals affects the environment more than operation, because terminals have shorter commercial life cycles compared to other units in the network. And user terminals contain more electronic components (measured per weight and user) than all other network equipment.

Besides the aforementioned units, the pilot system also comprises other network equipment, such as routers, switches, and servers. For the purpose of the LCA, this equipment was grouped into a network equipment unit.

The business operations unit covers the usage of operator offices and facilities, real estate management, travel, and transports.

## Initiatives continue

The LCA project created a unique model for telecommunications and an extensive database that contains information on materials,

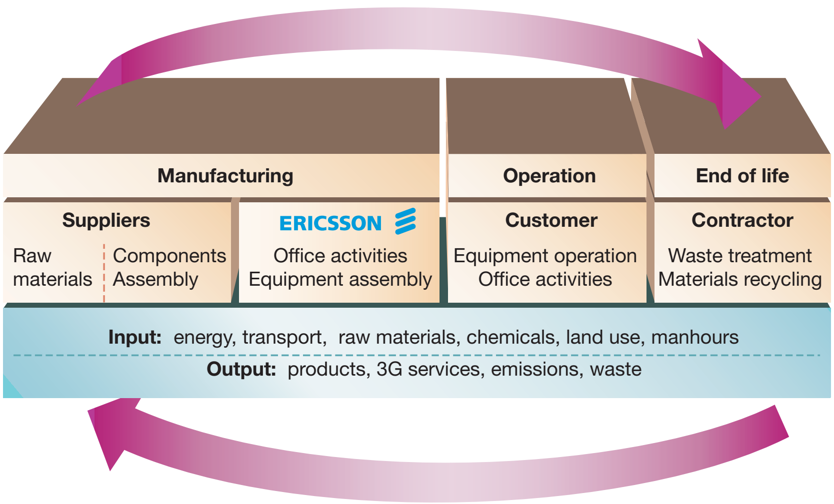



Figure 6
LCA of a 3G telecommunications system.

weight, energy consumption, and manufacturing procedures for every product in the pilot system. Ericsson intends to use these results

- to investigate and improve the way in which its products perform in terms of impact on the environment; and
- to cooperate with customers in future initiatives.

## Improving energy efficiency in field networks

As stated above, the electrical power consumption of radio access networks has a real and important impact on the environment and costs. Below, we will discuss opportunities and methods for reducing energy consumption. To improve energy efficiency in field networks, Ericsson must understand

- network performance—that is, the amount of power consumed in different parts of the network;
- the relationship between climate and power consumption;
- how energy efficiency is measured in the network; and
- the potential of future technology.

In addition, Ericsson must set measurable objectives for short- and long-term enhancements.

### Field network modeling

Ericsson gained extensive field experience from the estimations that came out of LCAs

**BOX B, LIFE-CYCLE ASSESSMENT METHODOLOGY**

Life cycle assessments (LCA) evaluate the potential impact that a product or service might have on the environment (Figure 4). Products or services are studied from cradle to grave—that is, throughout their entire life cycles from raw material extraction to production, distribution, use, and disposal.

LCAs yield a set of impact indicators that represent local, regional, and global effects from the selected product or service. Examples of commonly used impact indicators are climate change, resource depletion, acidification, photochemical ozone generation, eutrophication, stratospheric ozone depletion, physical disruption of land, human toxicity, and ecosystem toxicity. Each LCA usually involves the following interactive phases:

1. Definition of goals and scope.
2. Inventory analysis of every activity associated with the product life cycle—data is gathered on energy usage, emissions, and waste treatment.
3. Environmental impact assessment through theoretical calculations.
4. Interpretation of results from inventory and impact assessment phases and synthesis of this information to draw conclusions.

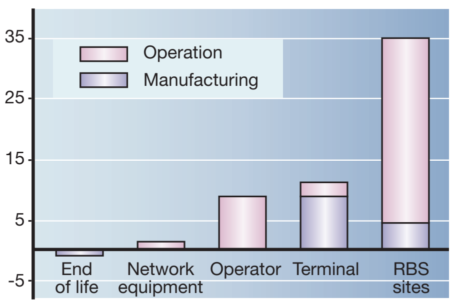



Figure 7
Environmental impact of sub-units of the pilot system.

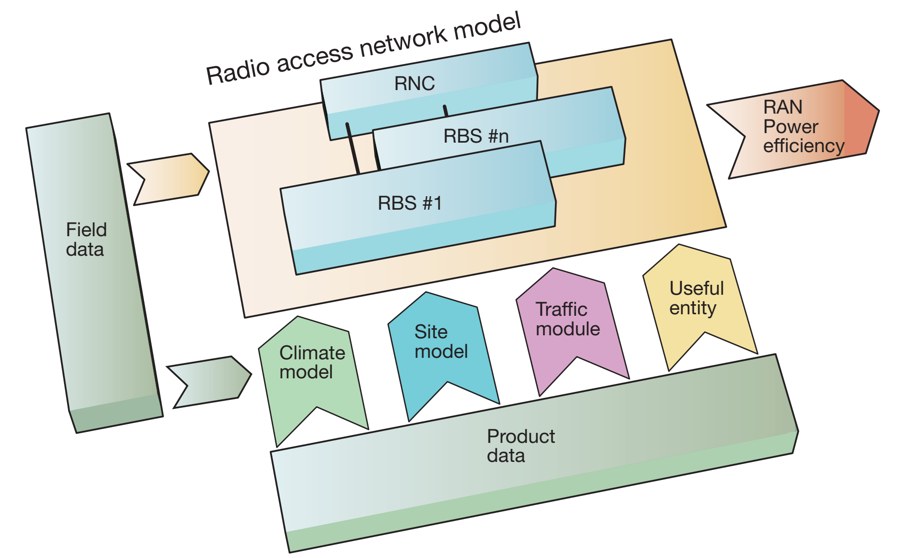



**Figure 8**
**Key elements for estimating RAN power efficiency.**

conducted in the mid-1990s when it gathered operational (site) and network data. Since then, Ericsson has developed a method for interpreting lab test data for its products—including all types of radio access network equipment—and for power consumption in the field. Estimations based on site equipment, such as air conditioners, also include equipment from other vendors.

Power consumption varies according to configuration, load, and environmental factors. Energy consumption (annual average power consumption) can be adequately estimated for field networks using several relevant models (Figure 8) for

- the WCDMA radio access network;
- site equipment;
- traffic load; and
- environmental temperatures.

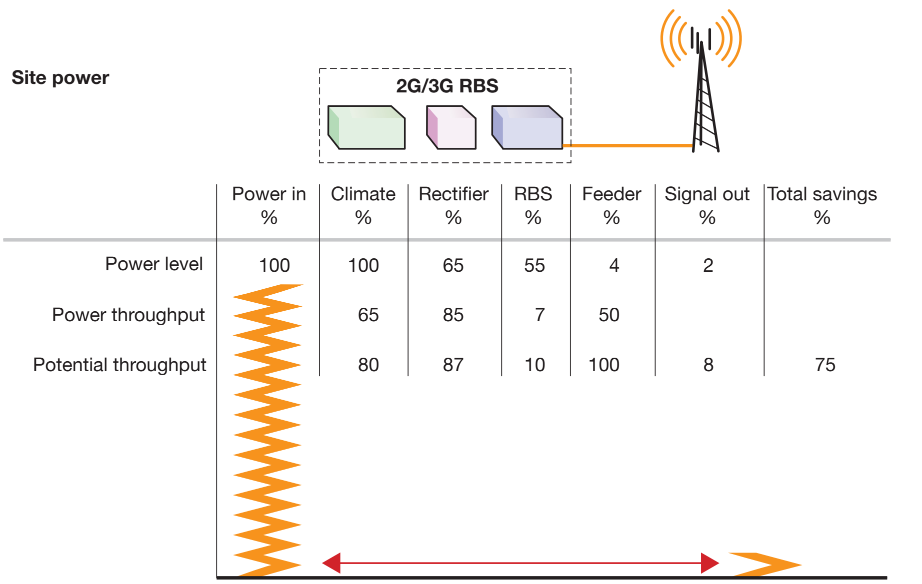
When these conditions are known, it is possible to estimate RAN energy efficiency from product lab test data. After calculating the power efficiency of new products and even complete radio access networks, Ericsson can set goals and measure the extent to which the energy-saving requirements are fulfilled as new hardware and software are delivered and rolled out into the network.

## Model network

Comparing networks is a challenging task. Ericsson uses a model network based on the most common RBS and broadband telephony softswitch products (BTS), and typical radio network controllers (RNC) and base station controllers (BSC).

The relationship between control nodes (RNC and BSC) and base stations reflects Ericsson's product offerings. The delivered mix of hardware is recalculated into delivery of model network parts. Because an RNC can handle more than 100 RBS nodes, the most significant consumption from the RBS

**Figure 9**
**The RBS site model indicates current losses and potential for improvement.**




| | Power in % | Climate % | Rectifier % | RBS % | Feeder % | Signal out % | Total savings % |
|---|---|---|---|---|---|---|---|
| Power level | 100 | 100 | 65 | 55 | 4 | 2 | |
| Power throughput | | 65 | 85 | 7 | 50 | | |
| Potential throughput | | 80 | 87 | 10 | 100 | 8 | 75 |

and BTS nodes is in the radio access network. Therefore, energy-saving efforts must target RBS sites. The support of energy-saving radio network functions also affects the RNC and BSC nodes.

## Site models

Energy consumption, or annual average power consumption, is estimated from an operator perspective under normal operating conditions. The power estimate includes the consumption of direct current (DC) by the RBS and the consumption of alternating current (AC) by rectifiers and climate equipment. Product data is used in the power estimate for Ericsson's outdoor RBSs. Field data, or key data from operator measurements, is used in the power estimate for climate and rectifier equipment from other vendors.

Approximately 2% of the AC input power at an RBS site is converted into radio frequency (RF) power to the antenna connector. Aside from rectifiers, the potential for improvement is substantial in every part at the site. If costs are disregarded, the total potential for improving power efficiency is 400%—that is, compared to a given output, it should be possible to reduce energy losses by 75%.

## Climate models

A climate model is used to calculate the energy consumption of the climate system. Depending on power dissipation and the triggering temperature for different devices, such as fans, heat exchanger, and air conditioner, it is possible to calculate the portion of time during a year when various devices are used.

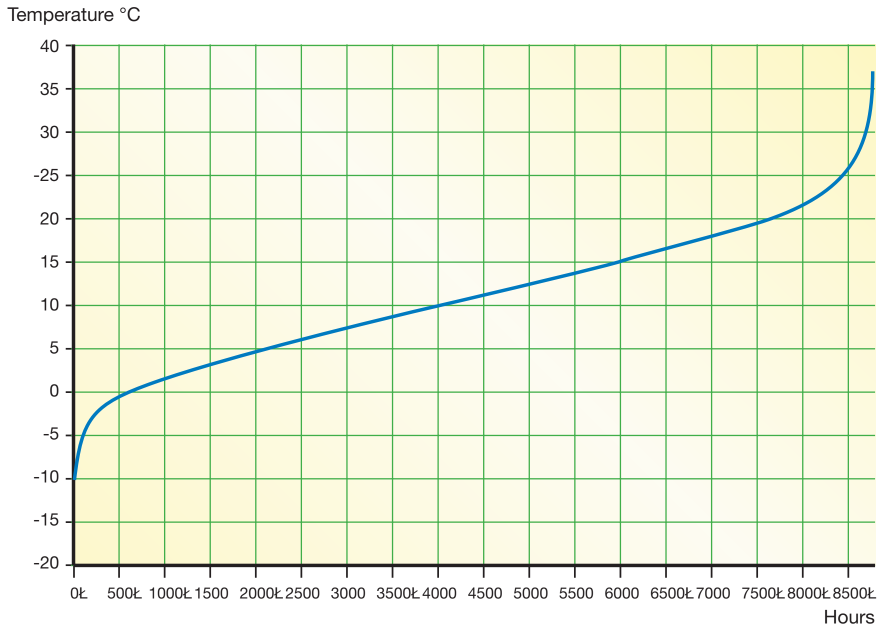



**Figure 10**
**Central Europe climate model. Temperature given as a cumulative distributed function (CDF) over one year.**

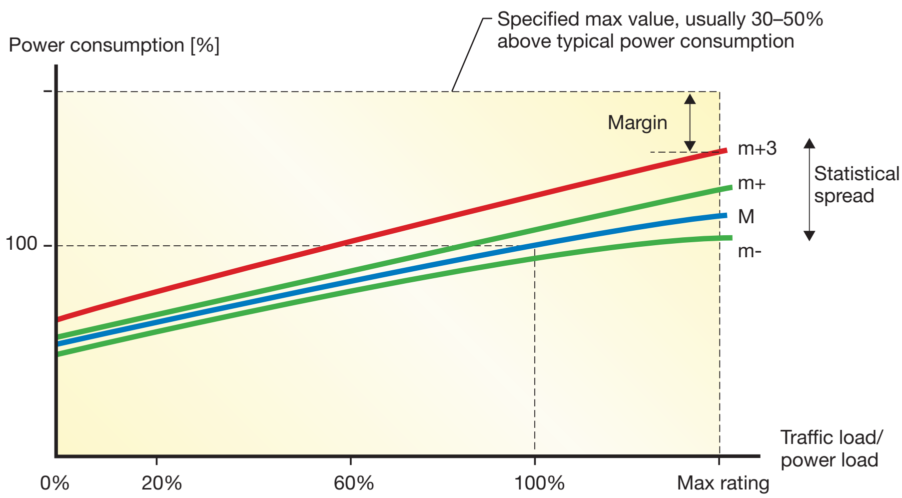
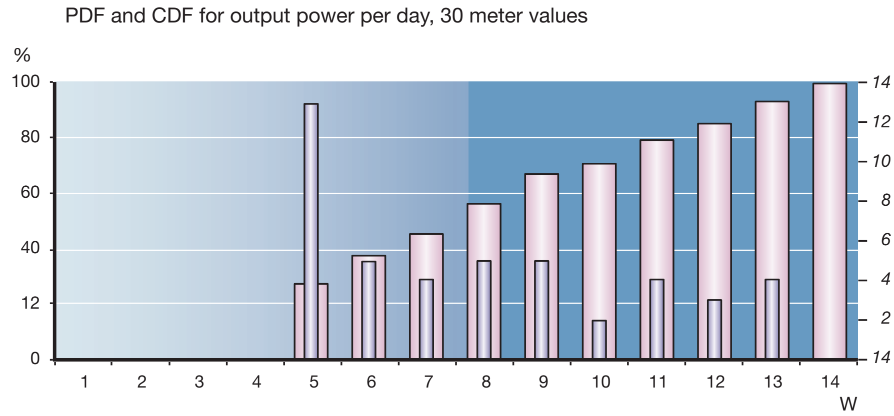



**Figure 11**
**Schematic slide showing the impact of traffic load and product variations on power consumption.**




**30m values**

| *Erlang* | | *Power W* | |
|---|---|---|---|
| Average | 30.0 | Average | 7.9 |
| Max | 57.1 | Max | 13.9 |
| Min | 2.2 | Min | 4.1 |
| Stdv | 17.4 | Stdv | 3.1 |

**Figure 12**
**Cumulative distributed function (CDF) for WCDMA power usage for the traffic model employed.**

### Traffic load and spreading factor

The power consumption of any node depends on traffic load and statistical spread. Average values are used. Spread is disregarded when estimating energy consumption. Load is determined by a traffic model based on field traffic measurements. When idle, the minimum load of the WCDMA pilot signal is 20% of nominal power. Admission- and congestion-control parameter settings limit maximum power. Nominal power, which can solely be reached during short intervals, averages 50-60% during busy intervals.

**BOX C, POWER EFFICIENCY AND USEFUL ENTITY**

Power consumption is measured as specific power consumption—that is, compared to the useful output capacity of nodes in the radio access network. The useful entity for RAN equipment in second- and third-generation systems is the product of coverage and capacity (voice equivalents). RF power efficiency of the site is the most important factor for achieving high power efficiency.
Useful entity (UE) = Coverage x Capacity

Figure 12 shows the WCDMA traffic model. A similar model has been developed for GSM. Power consumption in the WCDMA model has a basically linear dependency on traffic—that is, the 24-hour average value or 39.5% of nominal RF output power can be used to calculate average power consumption. The same can be said for CDMA2000, because WCDMA and CDMA2000 behave similarly in this regard. Power consumption in the GSM model is not linear (GSM uses several transceivers), and several steps must be integrated into the calculation to achieve correct results.

## Potential solutions

Below follows some potential improvements to second- and third-generation RBS hardware and software. The improvements include climate and rectifier equipment on site, and the application of traffic and climate models. The reference site is an indoor site equipped with

- rectifier and climate equipment chosen by the operator; and
- indoor RBS.

Figure 13 shows that the RBS has a 30% potential for improvement. An even greater potential exists for the climate system and feeder. Realization of this potential is related to design—some solutions will require major redesign that is too expensive to pay off.

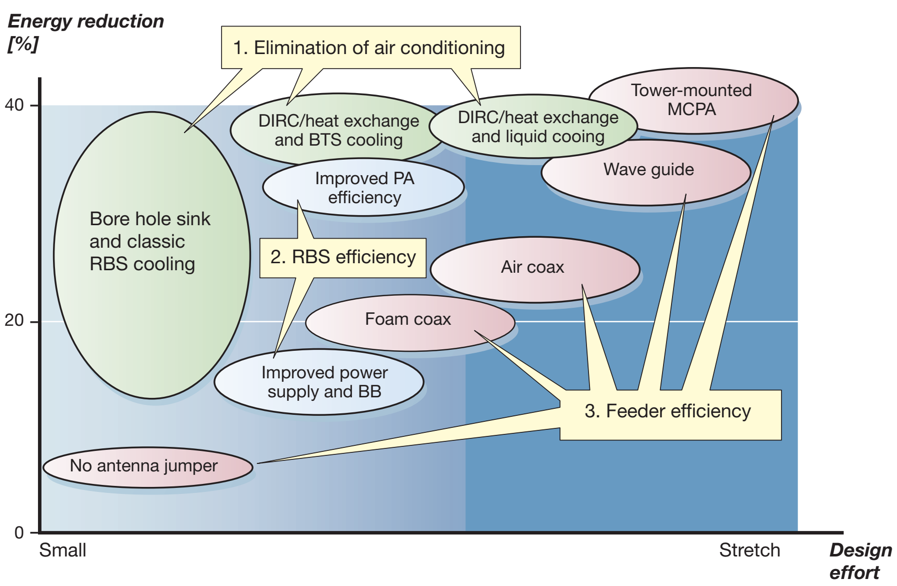



Figure 13
Potential for improvement—RBS site energy consumption.

A bore hole sink, used by a Swedish operator, is a relatively simple solution that offers efficient cooling. In temperate climates, this is a cost-effective solution. A combination of heat exchanger and air conditioner, which is used in GSM, CDMA2000 and WCDMA outdoor cabinets, cuts down on energy usage because the air conditioner must only operate when temperatures are high.

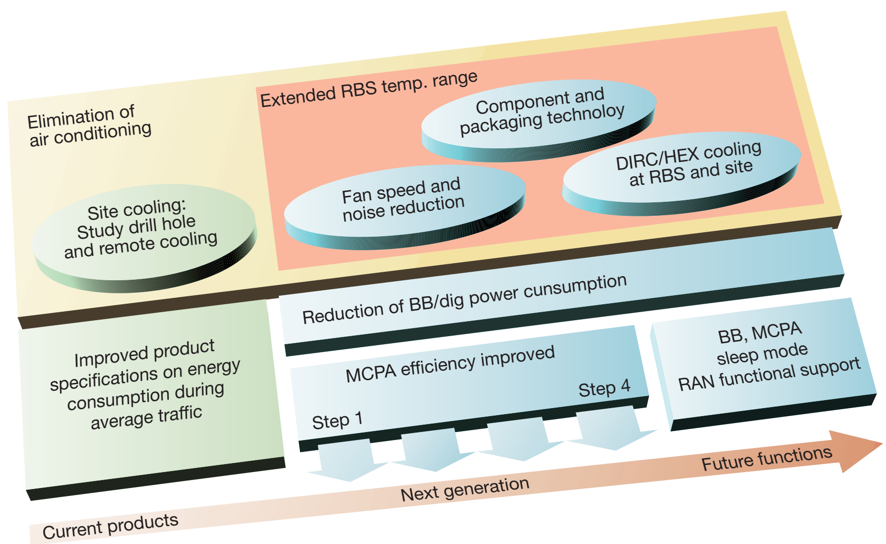
Heat transfer at the RBS, from transistor chip to cooling air, can be improved to the extent that air conditioning can be omitted. In most climates, heat-exchange cooling is sufficient. Liquid cooling and thermally improved transistor packaging are other examples of enhanced cooling.

Ericsson's goal to offer greater performance from a smaller footprint requires improved energy efficiency, because power loss is the most important factor for physical volume. The greatest losses occur during RF amplification and combination, and can be reduced by using more sophisticated amplifiers. The digital parts are being improved continually, which results in reduced consumption and greater functionality.

The use of different feeders—from thick, foam-insulated cables to wave guides—can reduce feeder losses of, say, 50% of RF power to just 7% of RF power. This change introduces a dramatic increase in weight and cost but does not affect the RBS design.

To eliminate practically all feeder losses, RF amplifier parts can be located at the tower close to the antenna. Examples of such products are the GSM Maxite RBS, with active antenna, the WCDMA main-remote RBS, and the CDMA2000 RBS 1127.

Figure 14
Solutions for improving energy efficiency at WCDMA RBS sites.



## Potential problems

One problem with heat exchangers is that the cooling air is 5-10°C above the environmental temperature. Direct cooling solves the problem of rising temperatures but is susceptible to problems arising from dust, moisture and corrosive gases. Energy is saved, but a filter is required. If the filter is not designed to last the full operating lifetime of the equipment it serves, then the operator must make allowances for additional maintenance expense.

The drawback of current solutions that employ maintenance-free micro-pore filters is that corrosive gases are not filtered. Pressure increases over the filter will thus increase 800-1000% during its lifetime. Powerful fans are needed that are noisy and will consume excessive electric power. A sophisticated regulation system can reduce these problems, but at present, Ericsson is not satisfied with this technology.

## Success stories

### GSM macro base solution reduces energy consumption by 35%

The RBS 2206 for GSM, which succeeds the RBS 2202, was designed specifically to maximize traffic capacity and RF power on a limited footprint. Reducing power losses was not the primary goal of designing the RBS 2206, but by optimizing internal cabling, digital parts and RF parts, Ericsson improved power efficiency by about 50% at minimum load and close to 35% during normal operation.

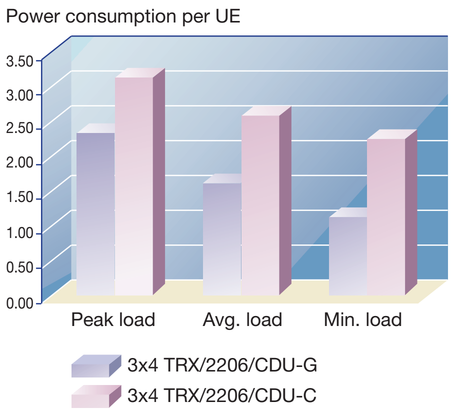
### New RBS main remote will save 13MWh/year per site

The new RBS is a split unit with a main, central part and a remote part that can be located elsewhere. For example, the remote unit can be placed close to the antenna to eliminate feeder losses. In that case, a half-size, 10W power amplifier unit will do the same job as a 20W power amplifier unit in a regular RBS, thanks to virtually non-existent feeder losses.

### New macro base outdoor solution reduces energy consumption by nearly 20%

The most common type of site is an indoor site location with air conditioning. This is also the worst type of site in terms of environmental considerations, because the heat generated indoors must be evacuated using an air conditioner, adding about 50-65% to the energy consumption of the indoor RBS. The outdoor shelter for GSM, CDMA2000 and WCDMA uses a more sophisticated solution that combines air conditioning with heat-exchanger cooling. Depending on the

**Figure 15**
**Improved energy efficiency in the RBS 2206 for GSM.**



RBS configuration, this solution reduces power consumption by 10-20%.

### Software features cut power consumption 10-30%

The GSM downlink power-control function typically reduces RF output power by 3-5dB, which cuts RBS 2206 power consumption by 25-30%. The function has been on the market for some time but some operators are not using it yet. WCDMA and CDMA2000 have very efficient power control.

A new function for fan control in WCDMA RBSs cuts power consumption by up to 10%. This reduction is even greater where environmental temperatures are low and at sites with small RBS configurations.

## Conclusion

Greater usage and new launches of telecommunications products and services have led to increased energy consumption. When used properly, however, the positive effects of applications from the ICT industry have the potential to greatly outpace increases in energy consumption.

Ericsson has conducted several extensive life-cycle assessments of its systems. The results of these assessments all point to one thing: the most significant environmental impacts are associated with operations, and radio base stations are the single largest consumers of energy.

With this information in hand, Ericsson is doing its part to make its systems more energy-efficient.

This article describes the scope, design and limitations of Ericsson's most recent system-level LCA of a pilot UMTS network for 1.5 million subscribers during one year of operation. The LCA looked at the various phases of the system life cycle. A key indicator of effects on the environment is climate change, measured in $CO_2$ equivalents.

Using data from the LCA, Ericsson developed a method for interpreting lab test data for its products and for power consumption in the field. The method consists of a field networking model, a model network, site models and climate models. It also considers traffic load and spreading factors.

Armed with real data from the LCA and a method for interpreting lab test data, Ericsson began enhancing the energy efficiency of its products—starting with the radio access network, where energy consumption is highest and has the greatest impact on the environment. Examples of new products with enhanced energy efficiency include the RBS 2206, a new RBS main remote, a new macro base outdoor solution, and software features that cut power consumption.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