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The Sleeping Network: Energy Savings from the Spec Sheet to the Field

Inside the Rel-18/19 energy toolkit — the five power states of TR 38.864, what cell DTX/DRX actually switches off, why deep sleep costs 50 milliseconds or 10 seconds depending on your silicon, and how to read an "up to 70%" claim with the denominator attached.

AUTHOR
5G/6G Academy Research

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The Sleeping Network: Energy Savings from the Spec Sheet to the Field

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***Abstract*—A 5G base station is a machine that cannot stop talking: synchronization bursts every 20 ms, system information, paging, random-access listening — occupied or empty. 3GPP's energy study prices that habit with a five-state power model, and the numbers are stark: a radio in micro sleep, transmitting nothing, still draws about a fifth of its active-downlink power, and the only deep escape costs 50 ms to 10 s of transition depending on hardware generation. This paper reads the Rel-18/19 toolkit as what it really is — not standardized sleeping (vendors shipped sleep modes for a decade on their own) but standardized coordination: telling UEs the cell will nap, letting CSI reports cover muted-antenna hypotheses, making neighbours energy-aware in handover and, in Rel-19, finally making SSB and SIB1 themselves on-demand. We print the study's savings the only honest way — as ranges with their throughput cost attached; the same technique evaluates anywhere from 0.9% to 84.8% — and tabulate the field results with their denominators: 15% commercial (radio units), up to 33% daily in trial (select sites), 8× at radio level (vendor-stated). No operator has published a verified network-wide figure; we say so plainly, and close with a four-question checklist for every savings claim an engineer will meet.**

1. Why Energy Became a Radio-Layer Problem

For most of cellular history, energy was a facilities problem — rectifiers, cooling, diesel logistics — while the standards people optimized spectral efficiency. What moved it into the radio layer is arithmetic. 3GPP's own energy study opens by quoting GSMA: energy is roughly **23% of total operator cost**, and most of it is consumed by the radio access network, in particular the active antenna unit [1]. Honesty requires a caveat the brochures skip: published estimates of the opex share range from about 15% to 40% depending on the year, the market and what sits in the denominator — "roughly a fifth to a quarter, higher in diesel-heavy markets" is a fair summary [1], [7].

Where the watts live is better established. Operator-reported data published by GSMA — seven operators, 31 networks, 28 countries — puts **73% of network energy in the RAN** [6]; Ericsson states the RAN typically exceeds 75% of a service provider's network power [8]. So every energy feature in the RAN specs carries a direct opex line.

And the villain has been on record for years. Field measurements of live macro sites found power follows a flat line plus a small slope — one measured sector fit P = 581 W + 11.9 W per Erlang of load, meaning an **idle site burned about 49% of its peak power**; even with every transceiver switched off, constant draw remained [14]. That was GSM/UMTS-era hardware, so treat the numbers as history — but the shape of the curve survived into 5G, and it is precisely the shape 3GPP finally modeled.

2. The Model: What a Base Station Costs When It Says Nothing

The Rel-18 study, TR 38.864, did something quietly valuable before proposing any feature: it agreed on what a base station costs. Three reference configurations (the canonical macro being Set 1: FR1 TDD, 100 MHz, 64 transceivers, 55 dBm) and **five power states** — deep sleep, light sleep, micro sleep, active uplink, active downlink — expressed in relative units with deep sleep defined as 1 [1]. Fig. 1 draws the ladder, and two readings of it explain this whole field.

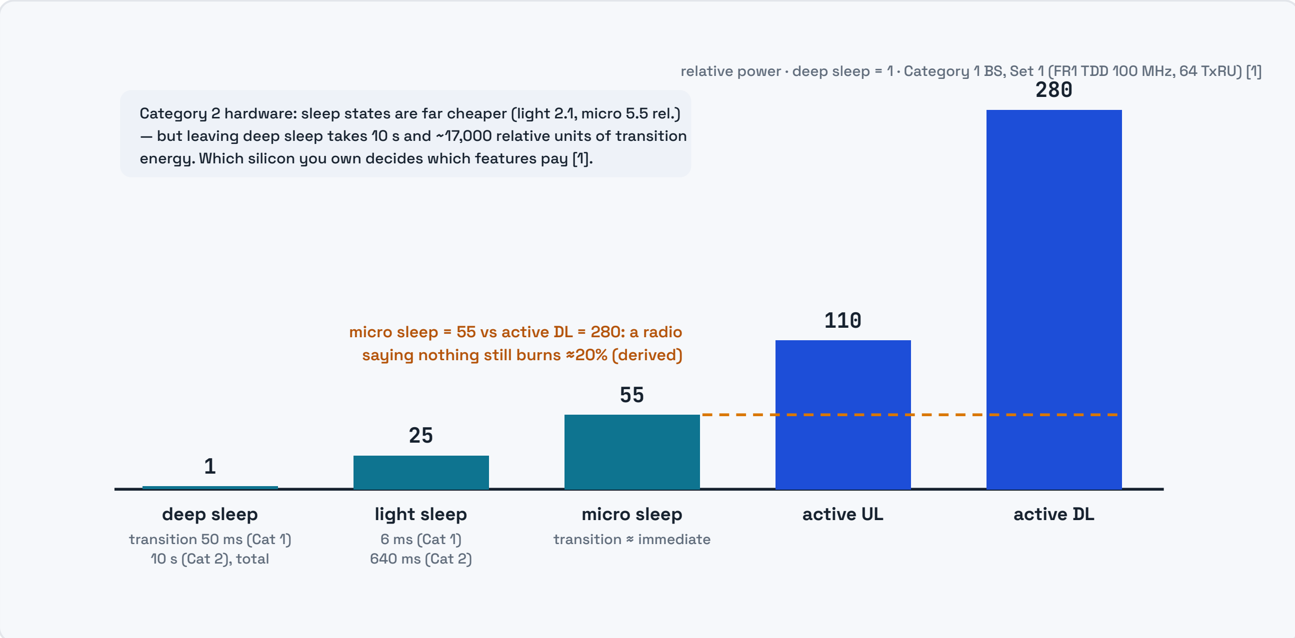

Fig. 1. The price of silence: relative power of the five states for a Category 1 baseline BS (Set 1, FR1), with total transition times. The dashed line is the awkward fact — micro sleep, the only sleep a live cell can use freely, still costs ≈20% of active-downlink power (derived from the table values). Data: TR 38.864 clause 5.1 [1].

First: **silence is expensive.** Micro sleep — no transmission, no reception — still draws 55 relative units against active downlink's 280: about 20% (a derived ratio, not a spec line). Deep sleep is 280 times cheaper than transmitting, but the model charges **50 ms of total transition time for Category 1 hardware and 10 s for Category 2**, plus a separate transition-energy bill (1,000 and 17,000 relative units respectively) [1]. Deeper sleep is cheaper rent with a worse commute.

Second: **the silicon decides.** The 50 ms versus 10 s gap between categories is not a protocol parameter — it is a hardware generation. A feature that drops a cell into deep sleep between paging occasions is a triumph on one category and unusable on the other, which is the quiet reason "5G-Advanced energy features" so often arrive bundled with a hardware refresh. One boundary note for later: the model stops at deep sleep — states below it ("hibernating", quasi-off) are explicitly out of scope [1]. Keep that in mind when vendor marketing reaches for "extreme deep sleep" (§6).

3. What the Study Found: Ranges, Not Points

TR 38.864's conclusions (clause 7) report, for each technique family, the evaluated base-station energy saving *as a range across companies, load points and assumptions* — and, next to it, the user-perceived-throughput cost. Fig. 2 reprints both columns together, because they are only honest together.

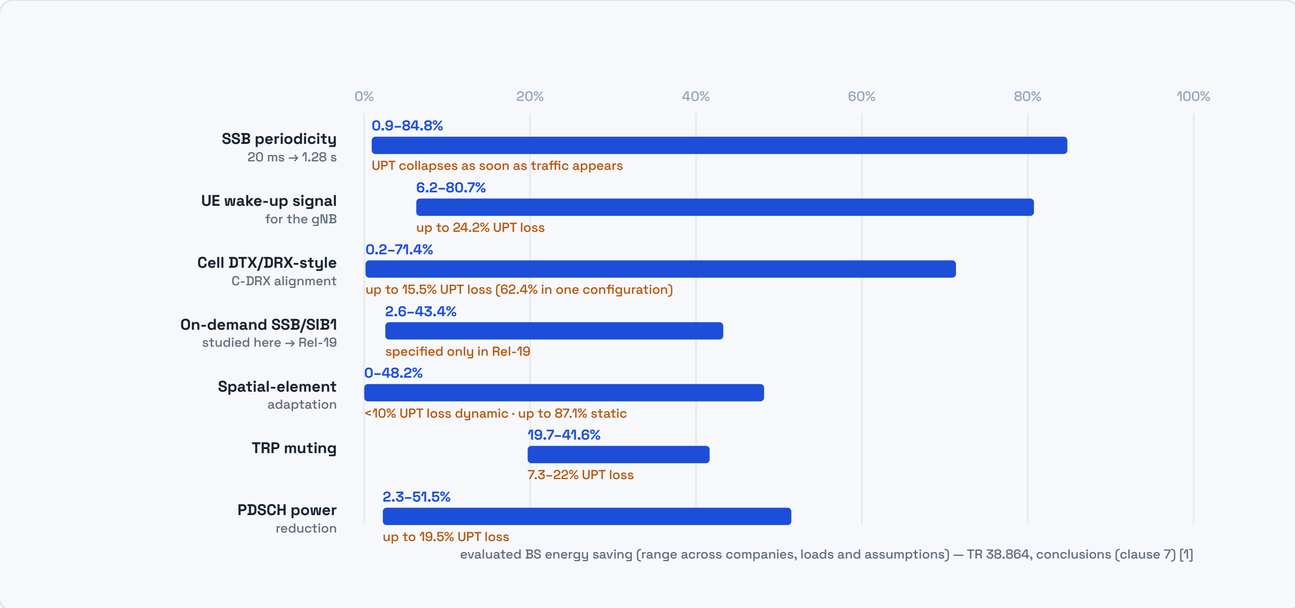

Fig. 2. What the study actually found: evaluated BS energy-saving ranges per technique family, each paired with its worst-case user-perceived-throughput (UPT) cost — the column vendor decks omit. Per-company simulation results, frequently at zero or low load. Data: TR 38.864 clause 7 [1].

Read the first bar slowly. Stretching SSB periodicity evaluates anywhere from **0.9% to 84.8%** — and that is not measurement error; it is the same technique at two different hours of the day, on two different hardware categories, under two different baselines. The 84.8% end comes with the note that throughput collapses the moment traffic appears. The same pattern repeats down the chart: TRP muting buys 19.7–41.6% and charges 7.3–22% of UPT for it; static spatial adaptation can cost up to 87.1% of throughput [1].

This yields the one rule that makes every later section legible: **never accept a network-energy percentage without its load scenario and its UPT companion**. The TR itself is scrupulous about this. The genre it spawned is not.

4. Rel-18: Not Breaking Things While Sleeping

Here is the contrarian fact about the Rel-18 work item: vendors did not need 3GPP's permission to sleep. Symbol-level shutdown shipped on LTE years before this study existed [8]. What radios could not do alone is sleep *without side effects* — a UE that misses enough of a silent cell declares radio-link failure; a CSI report measured against a 64-antenna cell mis-prices a 32-antenna one; a neighbour list that ignores napping cells hands traffic to them. The five tools 3GPP specified in TS 38.300 §15.4 are, one by one, fixes for those side effects [2], [12].

Cell DTX/DRX gives the cell an announced nap schedule — a periodic pattern of active and non-active periods, common to all configured UEs, applicable in RRC_CONNECTED only. The spec sentence that matters most is a limitation: the pattern "does not impact Random Access procedure, SSB transmission, paging, and system information broadcasting" [2]. The cell rests; it does not go dark. Activation is by RRC or by a new group-common message — **DCI format 2_9**, CRC-scrambled with a dedicated *cellDTRX-RNTI*, which can switch the pattern on or off for one or multiple cells and UEs at once [4].

Spatial and power-domain adaptation solves the mis-pricing problem: the UE is configured with two or more **CSI sub-configurations** (TS 38.214 §5.2.1.6), each corresponding to an antenna-subset hypothesis or a reduced PDSCH power offset — so the network sees what muting half its transceivers would cost *before* muting them [2]. **SSB-less SCell** lets a CA booster carrier drop its own beacon entirely, borrowing timing and gain control from another serving cell [2]. And **NES-aware conditional handover and camping restrictions** let a cell empty itself before resting, and keep idle UEs from camping on it while it does. The honest summary of Rel-18: 3GPP did not standardize sleeping — it standardized *not breaking things while sleeping*.

5. Rel-19: Always-On Becomes On-Demand

There is a clean symmetry across a decade of NR. Rel-15 taught the *UE* to sleep (C-DRX, then wake-up signals); Rel-18 taught the *cell* to rest between obligations; Rel-19 attacks the obligations themselves — the signals that made the cell always-on in the first place. The work item, RP-234065, was approved at RAN#102 in December 2023 and is now normative text in TS 38.300 V19.2.0 [3], [5].

Three mechanisms. **On-demand SSB for SCells** (§15.4.2.8): a secondary cell's beacon is switched on and off by RRC or MAC-CE, in FR1 and FR2 on non-shared spectrum, with measurements supported on the on-demand SSB itself [3]. **On-demand SIB1** (§15.4.2.9) is the bolder one: the gNB transmits SIB1 *only when a device asks for it*, the request carried inside a random-access procedure, supported for idle and inactive UEs [3]. **Common-signal adaptation** (§15.4.2.10) stretches what remains: extended paging-frame parameters, DCI-indicated SSB adaptation for SCells, and PRACH-resource adaptation for four-step random access [3]. The gain estimate cited in the work-item discussion for on-demand SSB is **8–20%, decreasing as SCell load rises** [15] — a refreshingly modest, load-qualified number by this genre's standards.

What survives all of this is the floor: a primary cell still beacons for initial access — somebody has to be findable. How far below that floor a network can go is, as of mid-2026, a research question rather than a release number.

6. The Field, With Denominators

Table 1 collects the verifiable public results — and attaches to each the denominator the headline quietly relies on. They are good results. They are also, without exception, *radio-level* results.

TABLE 1 · Field and vendor results — with the denominators attached [8]–[13]

Claim	Headline	What it actually measures	Status
Micro Sleep Tx — Ericsson + stc	−15%	remote radio units, all LTE bands	commercial network, Feb 2023 [8]
AI energy features — Vodafone UK + Ericsson	up to −33% daily	5G radio units, select London sites	trial, Mar 2025 [9]
"5G Deep Sleep" — same trial	up to −70%	radio units, low-traffic hours only	trial, Mar 2025 [9]
"Extreme deep sleep" — Nokia + Orange	~8× lower	radio-unit level, vs the prior deep-sleep mode; no % given	announced Feb 2024; Orange rollout planned from H2 2024 [10]
Time-domain sparsification — Ericsson	≈16% · >75%	gNB energy: SSB/SIB1/PRACH 20→40 ms; sparse SSB+PRACH at low load	vendor simulation, Nov 2024 [11]
RF-channel switch-off — O-RAN use case	150–180 W	per O-RU at low load, survey-reported figure	O-RAN analyses, via survey [13]
Any operator, network-wide annual saving	—	none published with a verifiable baseline that we could find, as of June 2026	

Read the qualifiers as load-bearing. stc's 15% is the strongest entry — a commercial deployment, across all LTE bands — but it measures remote radio units, not sites [8]. Vodafone UK's "up to 33%" is a trial, at select London sites, on the radio-unit meter; the "70%" belongs to low-traffic hours only [9]. Nokia's "factor of eight" compares one sleep mode to its predecessor at radio level — a mode, recall, that lives *below* where the 3GPP model stops modeling [1], [10]. Ericsson's strongest numbers ("over three-quarters of gNB energy") are simulations at low load [11]. And the last row is the finding we want on record: **we could not find any operator publishing a network-wide savings percentage against a verifiable baseline**. If one exists, we will gladly correct this — the editorial address is on the cover.

Why pursue it anyway? Because the arithmetic compounds politely (illustrative, using the §1 figures): a 15% radio-unit saving attacks roughly 15% × 73% ≈ **11% of network energy** — low single digits of total operator cost. Per network, per year, that is real money; across an industry, it is the rare sustainability program that pays for itself.

7. An Engineer's Honesty Checklist

Every savings claim you will meet — in a vendor deck, an RFP response, a conference keynote — can be priced with four questions.

(1) Against what baseline? A radio with no sleep features is a generous opponent. Ask which modes were already enabled in the "before" measurement. **(2) At what load?** Savings peak at midnight; revenue does not. An annual average and an off-peak showcase can differ by the full width of a Fig. 2 bar. **(3) What is the denominator?** Radio unit, site and network are three different meters — a site adds baseband, rectifiers and cooling; a network adds core, transport and data centres. Each step down the chain shrinks the headline, which is why headlines stay upstream. **(4) What did it cost?** TR 38.864 prints a throughput-loss column next to every gain [1]. Demand the same column from anyone selling you the gain. Be wary, too, of per-bit efficiency claims — efficiency per bit can improve while absolute consumption grows, and usually does.

What to watch from here: silicon that makes Category-1-class transitions ordinary, because the 10-second deep sleep is what stands between clause 15.4 and its potential [1]; the first commercial on-demand SSB/SIB1 deployments, which will tell us whether Rel-19's modest 8–20% estimate survives contact with real SCell load [15]; AI-driven orchestration of all of the above via rApps and SON — energy is already the lead use case AI brings to the RAN, a theme this series examined in Nº04; and fresher operator-reported splits as GSMA's benchmarking updates land [6]. The watt, on its own, is not the unit that matters here. The honest unit is watts-at-a-stated-load, against a published baseline, with the throughput bill attached. Insist on all three, and this field gets simpler — and somewhat smaller — very fast.

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