

Energy Consumption of Nomadic 5G Systems

Wolfgang Kiess, Tim Farnschläder, Maximilian Dietrich
(University of Applied Sciences Koblenz)

Daniel Schneider (University of Koblenz)
Dieter Novotny (aeroDCS GmbH)

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The logo for the Carl Zeiss Stiftung, featuring a stylized white 'CZS' monogram on a dark background.
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Motivation

We wanted to build a nomadic 5G system and faced concrete design questions:

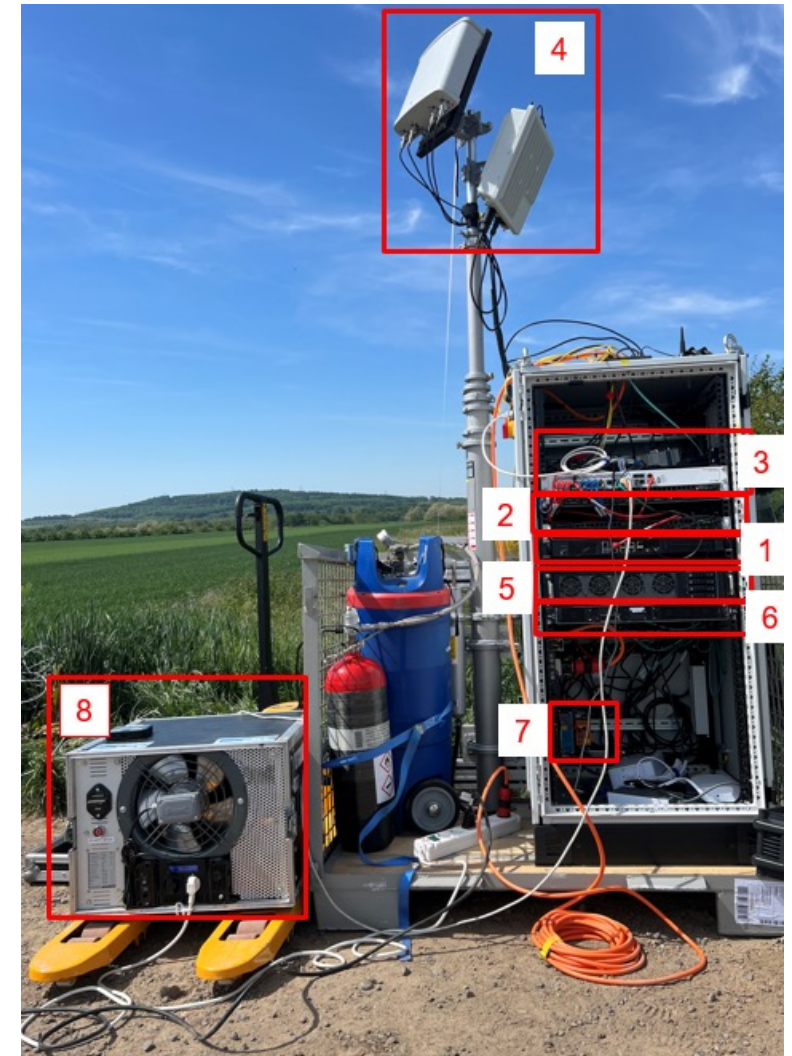
- How powerful does the power supply need to be?
- How much cooling capacity is required?

We searched for prior work.

We found nothing.

No measurements, no reference values despite active deployments in agriculture, construction, and disaster response.

So we measured it ourselves.



- 90% of cellular network energy is attributed to operation [6, 7]
- 50-73% of RAN energy use within operational networks [8]
- 70% of peak power consumed even at low utilization [6, 7, 9]

No prior work has systematically analyzed the power consumption of nomadic 5G systems

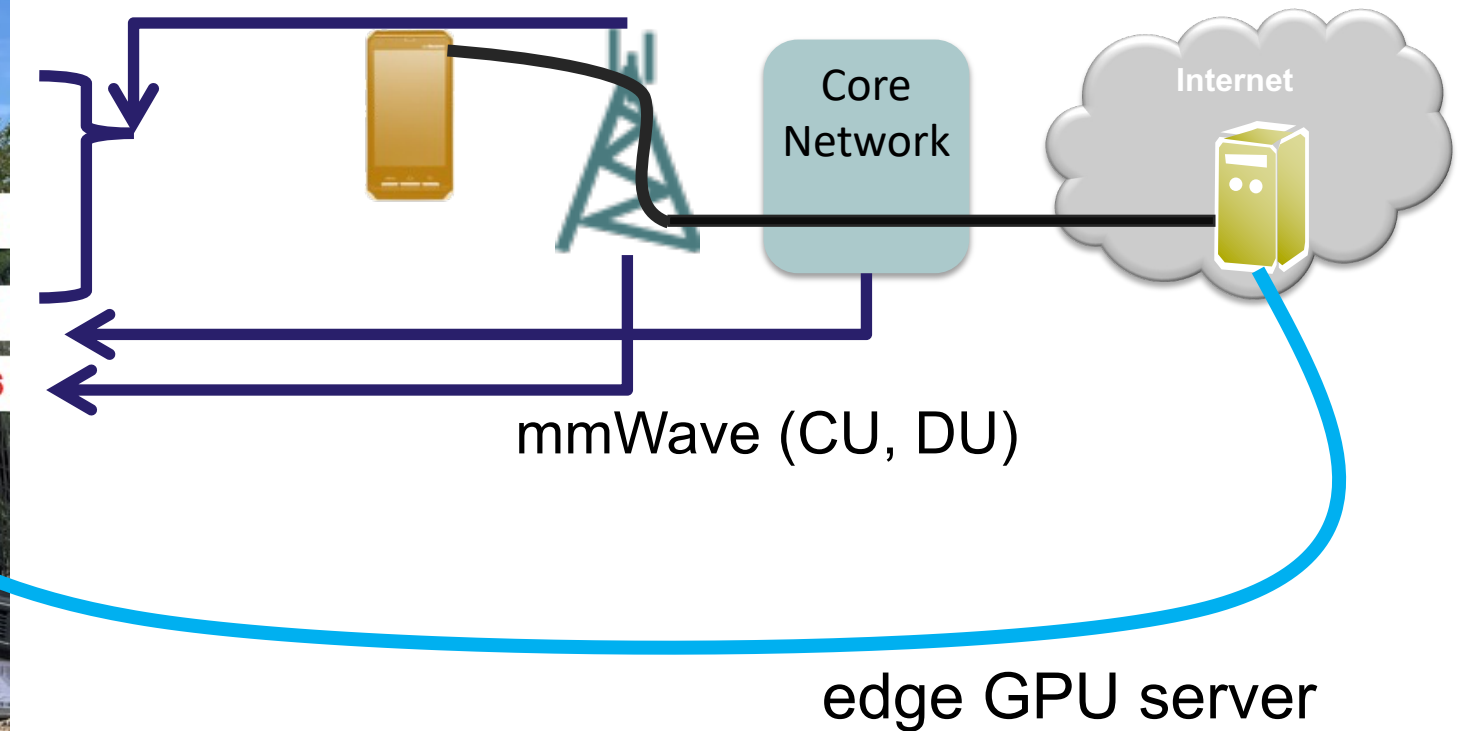
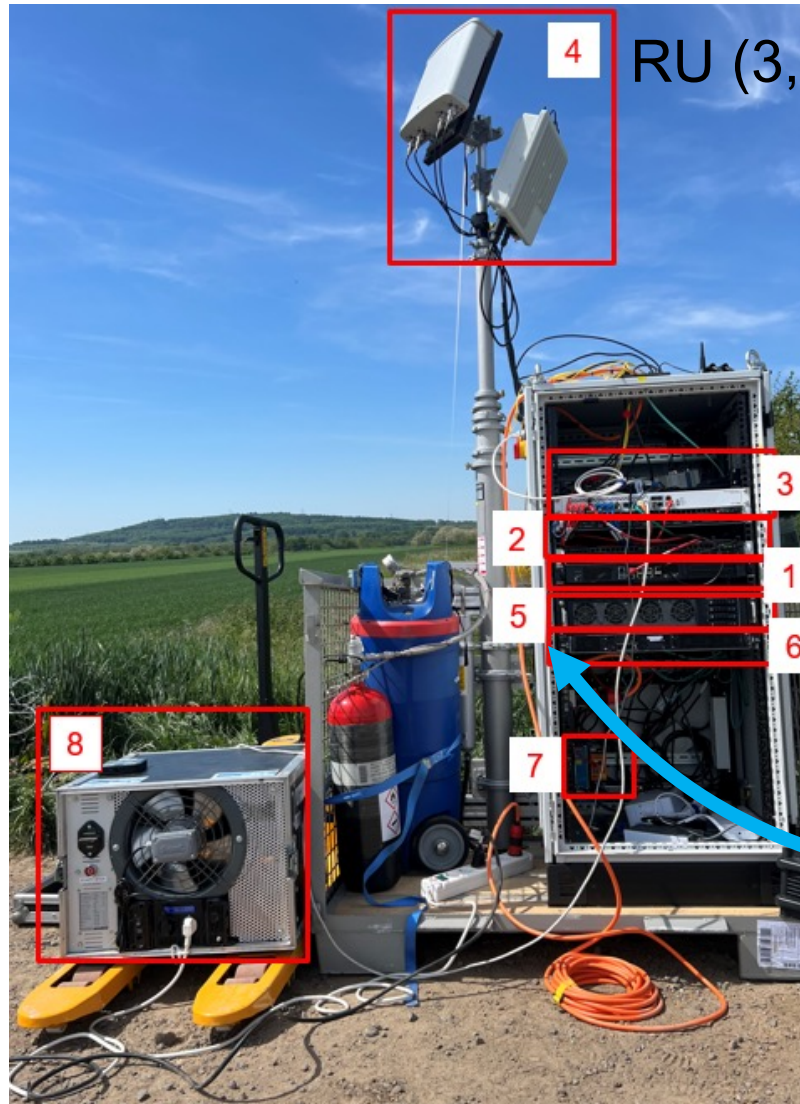
[6] Umweltbundesamt, *UTAMO*, 2023

[7] Andersson et al., *Improving Energy Performance in 5G Networks*, Ericsson, 2022

[8] Mavenir & Intel, *Holistic Study of Power Consumption*, 2023

[9] Bertoldi & Lejeune, *Code of Conduct on Energy Consumption of Broadband Equipment*, 2021

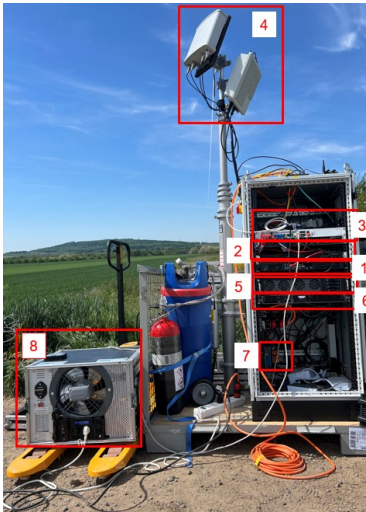
NoLa system: setup



Two Nomadic 5G Systems Under Study

NoLa 5G System

- Application areas: agriculture, disaster mgmt, road construction
 - Main use: connectivity in steep-slope vineyards
- Components: O-RAN CU/DU/RU (3.7 GHz & 26 GHz mmWave), 5G Core, Edge GPU server
- Coverage: up to 500 m range, ~400 Mbps DL
- Power supply: batteries + hydrogen fuel cell



755 – 907 W

Total power range
5 servers + RUs

Minimal Nomadic 5G System

- Application areas: student projects, PoC with industry partners
- Design: Smallest possible, single-person portable setup
- Components: Fanless IPC (Open5GS core) + Sercomm SCE5162-B78 femto cell gNB
- Coverage: ~70 m range, ~110 Mbps DL
- Powered via PoE / no active cooling



42 – 55 W

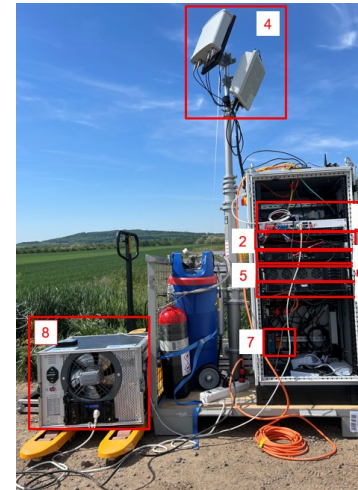
Total power range
2 components only

NoLa 5G System: 3.7 GHz (Sub-6G)

Component	Idle [W]	Control Plane [W]	User Plane [W]
Core Server	62	61	64
CU Server (3.7 GHz)	189	193	224
DU Server (3.7 GHz)	193	271	281
RU/Antenna (3.7 GHz)	37	43	53
mmWave Server (off)	26	26	26
Edge GPU Server	61	59	66
OAM System	7	7	7
Switches/Starlink/Cooling	180	176	186
TOTAL	755	836	907

CU + DU dominate
123 W of 152 W increase
comes from CU & DU servers

**Attention
to static
loads**



**IDLE to full load
total power increases by 20%**
(+152 W out of 755 W)

Only +8.5%
increase from control → user plane

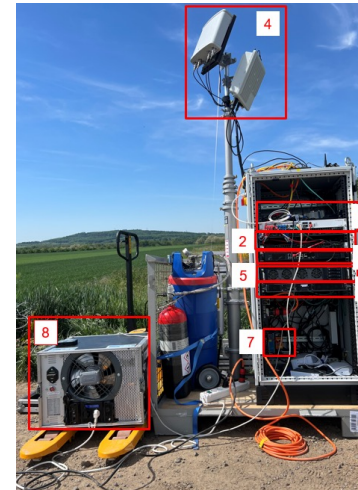
NoLa 5G System: 26 GHz (mmWave)

Component	Idle [W]	Control Plane [W]	User Plane [W]
Core Server	63	61	71
CU Server (switched off)	47	16	16*
DU Server (switched off)	45	16	16*
mmWave RU (26 GHz)	112	109	113
mmWave Server	27	216	227
Edge GPU Server	67	61	71
OAM System	7	7	7
Switches/Starlink/Cooling	194	216	226
TOTAL	562	702	747

nearly load-independent

due to IPMI/BMC
standby losses

Dominant
consumer
(replaces
CU/DU role)



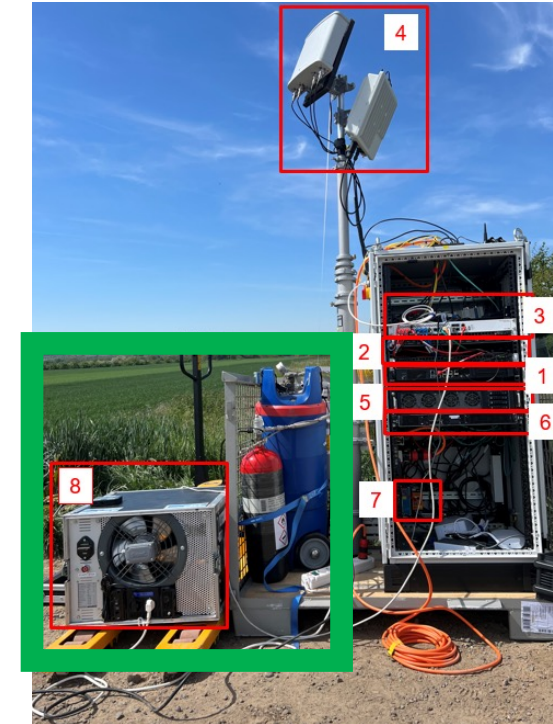
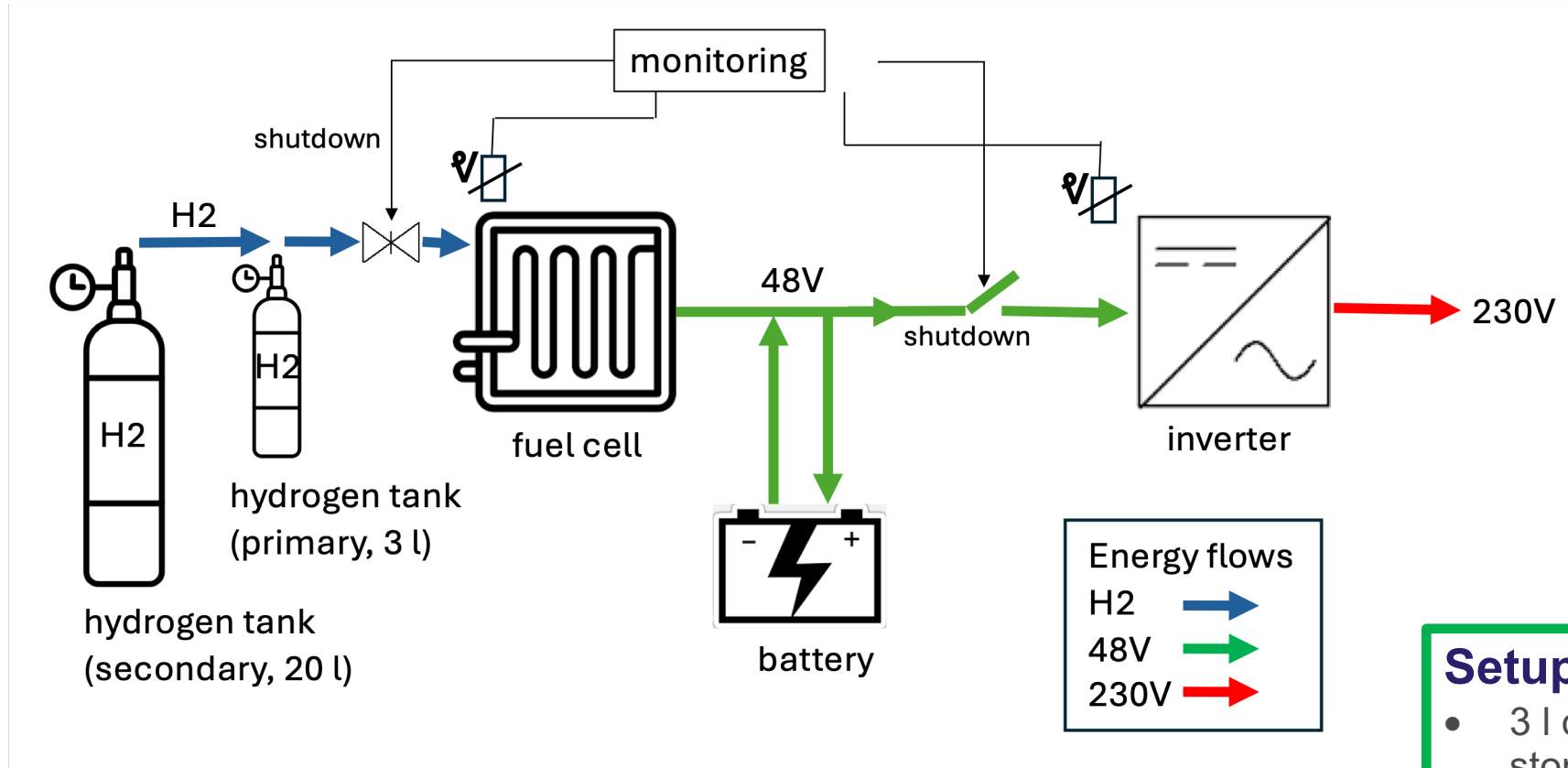
IDLE to full load
total power increases by 33%
(+185 W out of 562 W)

only
+6.4%

Same pattern, different hardware

Sub-6G and mmWave show comparable load
increase → consistent system behavior

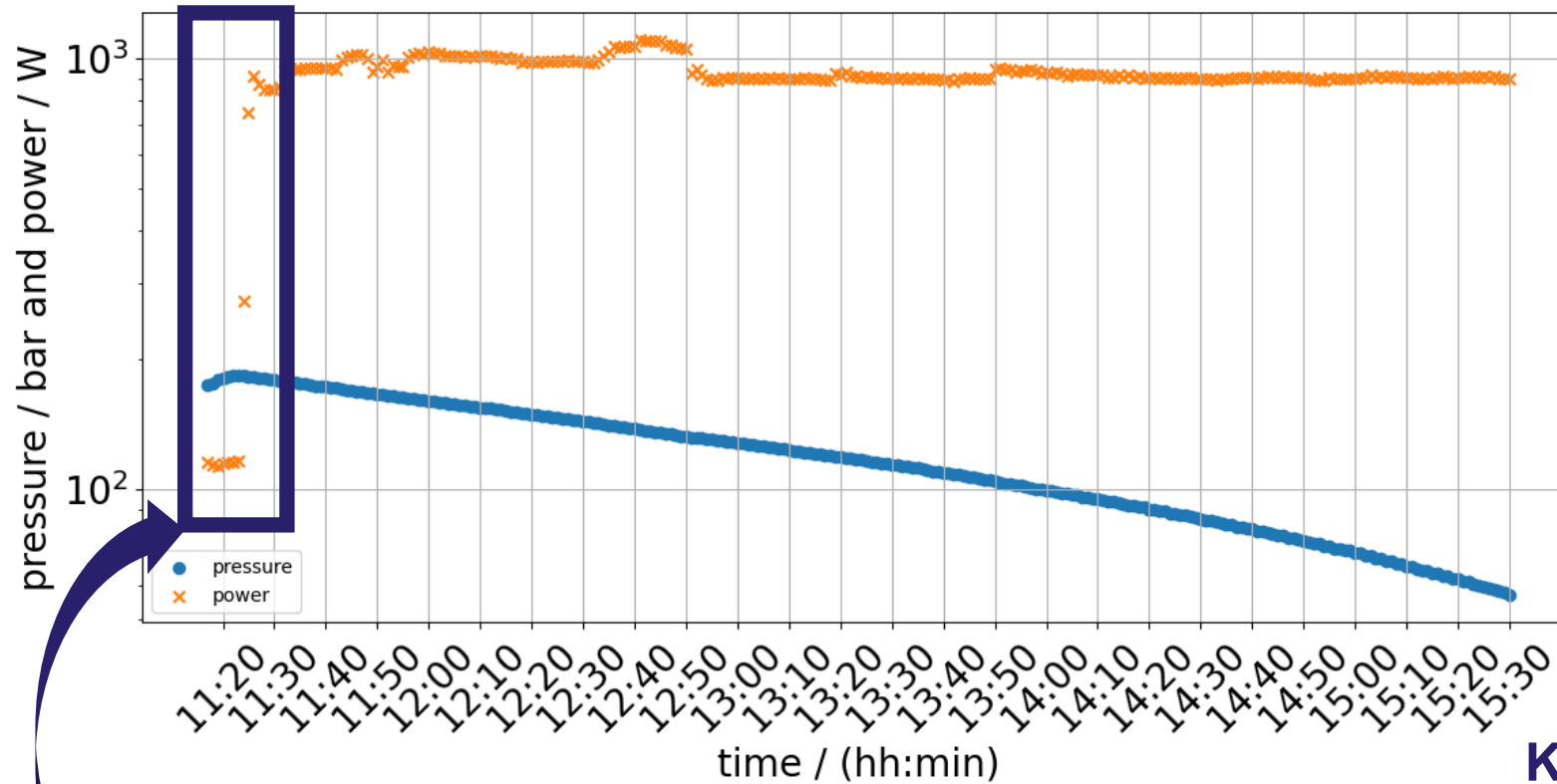
NoLa 5G System: Hydrogen Cell Setup



Setup

- 3 l operating tank + 20 l (200 bar) storage
- Buffer battery for peaks up to 3 kW
- Battery fully charged at start

NoLa 5G System: Hydrogen Cell as Power Source



Tank pressure (3 l) & fuel cell power output over time

Initial spike: fuel cell startup and ramp-up to operating power output



Key Findings

- Virtually constant ~1000 W consumption
→ ideal for fuel cells
- 20 l tank sufficient for full 8-hour working day
- Two-bottle design enables hot-swap without service interruption
- No power peaks → buffer battery rarely needed

Minimal Nomadic 5G System



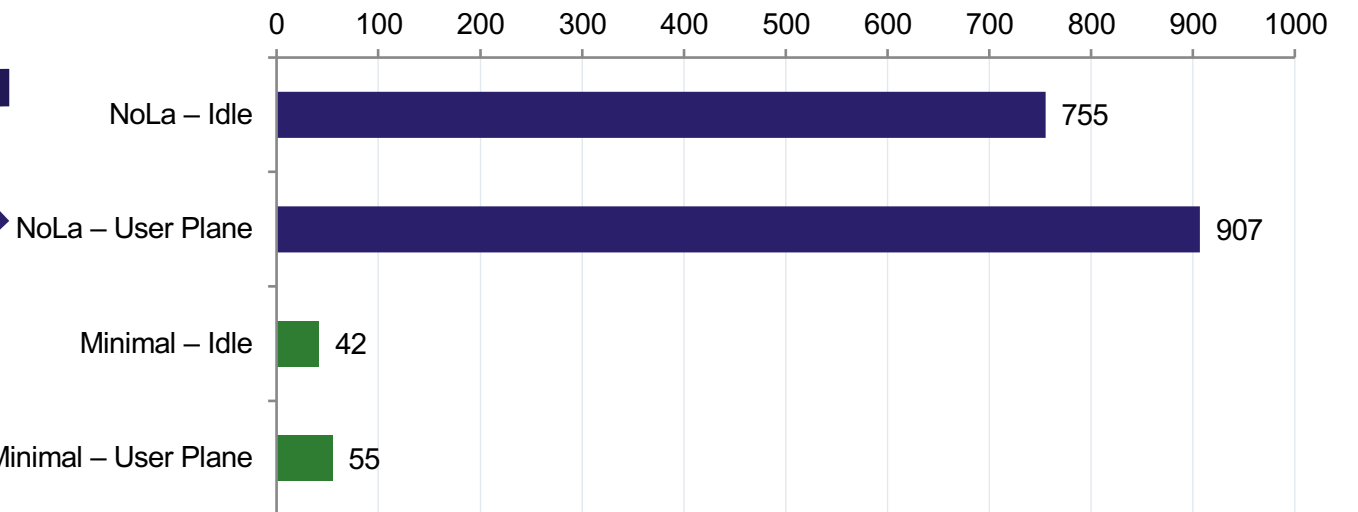
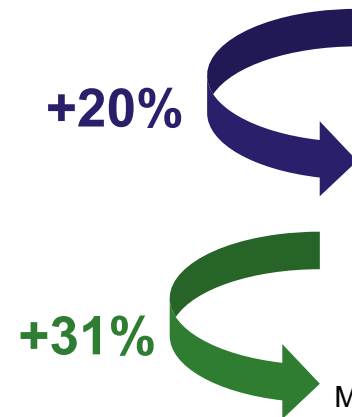
Minimal system: fanless PC + Sercomm gNB

Power Comparison: NoLa Setup vs. Minimal System

Component	Idle [W]	Control Plane [W]	User Plane [W]
Core Server (IPC)	16	19	26
gNB (Sercomm)	26	27	29
TOTAL	42	46	55

Core server contributes +10W
Radio only +3W
under full load

Minimal system: +31% idle to full load (vs. +20% for NoLa)
 higher relative increase, but absolute difference only 13 W



1 Low load adaptability

- Only 20–33% more power at full load vs. idle
- CP → UP: only +8.5% (NoLa) / +19.6% (minimal)
- Load-dependent scaling is a critical gap for future work

2 CU/DU are the main drivers

- At 3.7 GHz, CU and DU account for 123 W of the 150 W total increase
- At 26 GHz, the mmWave server takes this role (27 → 227 W)

3 Alternating consumption pattern

- At full load, NoLa alternates between ~850 W and ~930 W ($\Delta \approx 80$ W) likely a transmit/receive switching artifact

4 Hydrogen is viable

- Constant consumption fits fuel cells perfectly
- Two-bottle design allows hot-swap
- 20 l tank covers a full 8-hour shift

5 Hardware selection matters

- Industrial rack servers (NoLa) vs. fanless embedded PC (minimal): 907 W vs. 55 W
- Active cooling adds significant baseline

6 Consolidation & virtualization potential

- 5 separate servers each with own power supplies
- Containerized deployment (Kubernetes) + dynamic resource scaling could drastically cut energy

Conclusions & Future Work

Summary:

- NoLa system consumes 560–907 W depending on configuration and frequency band
- Power consumption remains high even at idle limited load
- Hydrogen fuel cells are well-suited for nomadic 5G constant load

Future Work:

- Investigate software virtualization (Kubernetes) and component consolidation for energy savings
- Study 3GPP-specified energy-saving functions (sleep modes, wake-up signals) in nomadic context
- Target: more compact design with longer off-grid operation
- Next Steps: work on load adaptability in campus networks in **EcoCampus6G** project, funded by Carl-Zeiss-Stiftung, 2026-2030

Questions ?

Maximilian Dietrich, PhD Student @
Hochschule Koblenz

Contact me



project website

