**3GPP TSG-RAN WG1 Meeting #109-e R1-220xxxx**

**e-Meeting, May 9– May 20, 2022**

**Agenda Item: 9.7.1**

**Source: Moderator (Huawei)**

**Title: FL summary for performance evaluation for NR NW energy savings**

**Document for: Discussion and Decision**

# Introduction

Study Item (SI) for network energy savings for NR is approved in [1]. For the study of performance evaluation for this SI, the relevant objectives include below

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| 1. Definition of a base station energy consumption model [RAN1]
* Adapt the framework of the power consumption modelling and evaluation methodology of TR38.840 to the base station side, including relative energy consumption for DL and UL (considering factors like PA efficiency, number of TxRU, base station load, etc), sleep states and the associated transition times, and one or more reference parameters/configurations.
1. Definition of an evaluation methodology and KPIs [RAN1]
* The evaluation methodology should target for evaluating system-level network energy consumption and energy savings gains, as well as assessing/balancing impact to network and user performance (e.g. spectral efficiency, capacity, UPT, latency, handover performance, call drop rate, initial access performance, SLA assurance related KPIs), energy efficiency, and UE power consumption, complexity. The evaluation methodology should not focus on a single KPI, and should reuse existing KPIs whenever applicable; where existing KPIs are found to be insufficient new KPIs may be developed as needed.

Note: WGs will decide KPIs to evaluate and how.The study should prioritize idle/empty and low/medium load scenarios (the exact definition of such loads is left to the study), and different loads among carriers and neighbor cells are allowed. The following example scenarios (mapping between scenarios and network loads is left to the study) including single-carrier and multi-carrier deployments are used as the starting point for discussion on prioritized scenarios for the study. The following example scenarios are listed in no particular order.* Urban micro in FR1, including TDD massive MIMO (note: this scenario can also model small cells)
* FR2 beam-based scenarios (note: this scenario can also model small cells)
* Urban/Rural macro in FR1 with/without DSS (no impact to LTE expected in case of DSS)
* EN-DC/NR-DC macro with FDD PCell and TDD/Massive MIMO on higher FR1/FR2 frequency

Note 1: legacy UEs should be able to continue accessing a network implementing Rel-18 network energy savings techniques, with the possible exception of techniques developed specifically for greenfield deployments.Note 2: the study of energy savings specifically for IAB is not part of the scope.The study should coordinate with RAN4 as needed. |

For that purpose, the following email discussion is assigned:

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| [109-e-R18-NW\_ES-02] Email discussion on performance evaluation by May 20 – Yi (Huawei)* Check points: May 12, May 18, May 20
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This document provides FL initial observations on relevant discussion points and questions/proposals, by summarizing the contributions submitted to agenda item 9.7.1 [2]-[22]. Relevant contributions [23]-[29] submitted to agenda item 9.7.3 are also taken into account.

Draft(s) can be found in [Inbox](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Inbox/drafts/9.7.1) and will be updated per companies further input. The FL proposals starting with ‘study’ or ‘FFS’ consider the initial round of view summary based on contributions, thus can be possibly revised by extended proposals to be agreed/proceeded within this meeting once they are more converged. There is no intention to postpone those bullets in future meetings. When making comments and uploading the input, please see the guidance in [R1-2203012](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203012.zip) with recommended naming convention and [R1-2203013](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203013.zip) concerning the deadline(s) for each check point respectively.

Companies are invited to make your input for FL questions tagged with FL1 (all proposals in this round) concerning the first check point May 12, as well as to enter contact information in Annex.

# Energy consumption model for BS

## Framework for modeling BS energy consumption

Almost all contributions that have relevant discussion on this aspect confirm that on high level, some reference configurations (which could be differently represented in contributions e.g. as nominal configurations), and multiple BS power states including sleep/non-sleep states with relative power values are needed. In addition to what has been considered in SID, majority among these companies also confirm that the use of scaling for non-sleep state is needed. It appears to be commonly acknowledged that this framework similar to UE power saving model can be agreeable as the BS power consumption model framework. Therefore, the following proposal can be considered and it is noted that this proposal does not intend to preclude any finer modifications/differentiation among e.g. FR1 and FR2, UL and DL, other potential improvement etc. Other details for each ‘component’ can be further discussed in following sub-sections.

**FL1 Proposal 2.1-1**

* **For evaluation purpose, the energy consumption modeling for a BS include at least the following:**
	+ **Reference configuration**
	+ **Multiple power state(s) including sleep/non-sleep mode(s) with relative power values/units, and associated transition times**
	+ **Scaling method to be applied for non-sleep mode.**

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| **Company** | **Y/N** | **Comments** |
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Another general aspect is that there is converged preference that the time domain granularity of BS energy consumption model should be in a dynamic level, e.g. per slot basis [2][3][4][7][9][10][11] etc.. The following can be considered.

**FL1 Proposal 2.1-2**

* **The BS energy consumption model can be used to evaluate the power consumption of BS per slot.**

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| **Company** | **Y/N** | **Comments** |
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To further adapt the framework of UE power consumption modeling to BS side, views seem to be a bit split in terms of the considerations of UL and DL and of corresponding channels, unlike what has been done at UE side. For example, [2] focus on the DL part while also mention that power consumption of UL part can be considered relative to that of DL. A few others generally consider that UL and DL are separately modeled while [6][17][26] consider the DL and UL should be modeled together (possibly depending on duplex, e.g. TDD). It seems that in the case of separate modeling, what mostly differentiates in the model presented in companies input is to have separate relative power values in DL transmission and UL reception at BS, for non-sleep model. And modeling/evaluation for DL only or UL only should be possible in order to verify the scheme/gains for one direction only. A gNB is generally considered as sleep when data is communicating in neither DL nor UL. Thus, the following can be considered.

**FL1 Proposal 2.1-3**

* **For evaluation, the BS energy consumption for DL and UL can be separately modelled, allowing DL-only transmission or UL-only reception at least for non-sleep mode.**
* **Study whether/how to adopt channel/signal-specific modeling for some cases**

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| **Company** | **Y/N** | **Comments** |
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There are also contributions proposing to consider different BS types or BS categorizations in the modeling [3][4][5][18][20][22], e.g. macro BS, small cell or AAS gNB, possibly accounting for different scenarios and relative power value variations. This is one aspect that is different from the UE power saving model. Similarly, [3][18] also consider split of a BS, e.g. radio unit (RU) vs. baseband unit (BBU), or functional blocks. Since macro BS is widely adopted in previous study in IMT-2020 and also included as in above, the following can be considered.

**FL1 Proposal 2.1-4**

* **At least macro BS can be assumed for energy consumption model.**
* **Study whether/how to further adapt the energy consumption model considering different BS types/categorizations/components.**

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[3][20] mention that the BS energy consumption model may need to reflect the technology trend for potential improvements or being future proof.

**FL1 Proposal 2.1-5**

* **Study whether/how to further adapt the energy consumption model in consideration of technology trend in e.g. a few years.**

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[3] proposes to clarify that the study does not consider multi-RAT mode. There was a relevant discussion in RAN plenary on consideration for LTE, and the outcome is that ‘no impact to LTE expected in case of DSS’. This proposal can be further considered if clarification is deemed necessary.

## Reference configuration

Generally both FR1 and FR2 are considered. And there is good convergence on the inclusion of frequency, BW size, antenna configuration, SCS, number of component carriers (CC), and power level. There are also channel/signal specific configurations proposed. In view of proposed parameters, the following can be considered. Note currently it is proposed with square bracket even if it is proposed by an operator. Some parameters may be missing due to lack of proposals but can be further discussed/determined within this meeting. TDD structure is listed in [5][18]. This can be further discussed/determined along with other (missing) parameters.

**FL1 Proposal 2.2-1**

* **At least TDD should be included for evaluation of FR1 and FR2. FFS FR1 FDD.**
* **For FR1, at least the following should be considered for reference configuration**
	+ **DL**
		- **frequency range [2.6 GHz]**
		- **system BW [100 MHz]**
		- **SCS [30 kHz]**
		- **number of CC [1]**
		- **TX [64]**
		- **Power level [FFS]**
		- **[common signal/RS, SSB periodicity 20 ms x 2 per slot]**
		- **FFS other channel/signal, e.g. PDCCH/PDSCH**
	+ **UL**
		- **system BW [100 MHz]**
		- **SCS [30 kHz]**
		- **number of CC [1]**
		- **RX [1]**
* **For FR2, at least the following should be considered for reference configuration**
	+ **DL**
		- **frequency range [28 GHz]**
		- **system BW [400 MHz]**
		- **SCS [120 kHz]**
		- **number of CC [16]**
		- **TX chain [2]**
		- **Power level [FFS]**
		- **[common signal/RS, SSB periodicity 20 ms x 2 per slot]**
		- **FFS other channel/signal, e.g. PDSCH**
	+ **UL**
		- **system BW [400 MHz]**
		- **SCS [120 kHz]**
		- **number of CC [16]**

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| **Company** | **Y/N** | **Comments** |
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## Power states and transition time

Relative power value should be clearly defined. A few companies mentioned that similar to UE power saving model, the deepest sleep mode consumes the least power and is considered as the basic power unit.

**FL1 Proposal 2.3-1**

* **In the evaluation, the power consumption value is normalized relatively to the deepest sleep mode to be defined for BS energy consumption model.**

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Views on different power states are quite diverse. For consideration of sleep mode, there are more sleep modes preferred in general. Particularly, 4 modes are considered in [3][6][16][18][20]. 3 modes are considered in [4][5][7][10][11][14][15][17][21] while two modes are considered in [2][8][18]. Depending on BS split/types, there may also be multiple preference from companies. More discussion is needed.

**FL1 Proposal 2.3-2**

* **Study how to define sleep modes and determine the characteristics for each mode from one or multiple of the below**
	1. **Relative power level range or power saving range**
	2. **Transition time range**
	3. **BS breakdown/components that can be turned off**
	4. **Other approaches are not precluded**
* **Study the assumption of order for BS entering/resume from a sleep mode to another mode (sleep or non-sleep), i.e. state machine which may have impact on the additional transition energy.**

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| **Company** | **Y/N,****Preferred option** | **Comments** |
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For non-sleep mode, which could possibly be split into DL and UL (if agreed), for each direction, there could be different approaches for determining the power value/unit. It is FL understanding that [21] may be proposing a different approach from those in [3]. Further, [3] proposes not to consider specially the case of simultaneous UL and DL.

**FL1 Proposal 2.3-3**

* **For evaluation purpose, the power consumption for DL/UL (if agreed) in active mode is determined based on one of the following**
1. **Explicit power consumption values per slot-type (FFS definitions)**
2. **A single power consumption value linearly scaled by the number of occupied symbols over 14**
3. **Interpolation between a base power state and a peak power state (FFS definitions)**
* **FFS dependency on other conditions e.g. scenario, RB utilization**
* **FFS whether there is need to adapt the model for simultaneous UL and DL in active mode for this SI.**

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## Scaling

The scaling approach is proposed to be reused by majority companies with same or different scaling factors. Among various aspects, the BWP size, number of CC in CA, antenna configurations and power spectrum density (PSD) gain most support. Again, if DL- and UL-only is agreed, scaling can be separately applied to e.g. DL BWP and UL BWP. The exact values need further discussion. In general, the following seems agreeable.

**FL1 Proposal 2.4-1**

* **For evaluation, the scaling in a BS energy consumption model can be applied based on the following,**
	+ **antenna port**
	+ **BWP in one CC and number of CC in CA**
	+ **PA related aspects.**
	+ **FFS other domain scaling**

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| **Company** | **Y/N** | **Comments** |
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# Methodology

## KPI

For evaluation methodology and KPI, the baseline may need to be clarified [5][13][17]. Due to lack of input and common view, companies are invited to share your answer for the question.

**FL1 Proposal 3.1-1**

* **Companies view are invited to clarify the baseline for evaluation for this SI**

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The SID has already listed multiple potential KPIs for consideration. In addition to the most natural KPI of energy/power saving gain, energy efficiency (EE) in unit of bit per Joule is drawing more interest. As this is a new KPI for PHY study, some discussion is needed. Companies are invited to share your consideration for the definition of EE.

**FL1 Proposal 3.1-2**

* **Companies view are invited to clarify the definition of energy efficiency for evaluation.**

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For study of the impact on system performance, UPT can be considered as adopted in UE power saving study and proposed by majority contributions. It may also be combined for joint consideration with EE. Other KPIs for system impact evaluation may vary depending on techniques and scenarios, and companies view are split.

For UE side impact evaluation, it seems the below can be considered.

**FL1 Proposal 3.1-3**

* **For network performance impact evaluation, at least UPT should be considered,**
	+ **FFS in combination with other KPIs e.g. UTP-aware EE, UPT/latency, UPT-UE power etc.**
* **For UE performance impact balance, UE power consumption/access delay/latency can be considered,**
	+ **FFS in combination with energy consumption of BS.**
* **Note, this does not preclude to consider other KPIs when found appropriate for certain techniques/scenarios**

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## Evaluation scenario

Among the listed example scenarios in SID, i.e.

* Urban micro in FR1, including TDD massive MIMO (note: this scenario can also model small cells)
* FR2 beam-based scenarios (note: this scenario can also model small cells)
* Urban/Rural macro in FR1 with/without DSS (no impact to LTE expected in case of DSS)
* EN-DC/NR-DC macro with FDD PCell and TDD/Massive MIMO on higher FR1/FR2 frequency

The first and third scenario gain most of support in the initial round of contrition view summary. If we go with this approach for down-selection, FR2 will be completely deprioritized which may be less preferable since it is expected to establish more insight of the saving potential especially for scenario with large energy consumption. Therefore, companies are invited to further consider your priority for evaluation scenarios. Note it is not necessary to be limited by the exact bullet from the above scenarios – as they are examples in no order, other combinations from/than those can also be considered.

**FL1 Proposal 3.2-1**

* **Companies are invited to further consider priority for evaluation scenarios for BS energy saving study.**

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## Traffic model

One of the objective of SID is highlighted as below:

*The study should prioritize idle/empty and low/medium load scenarios (the exact definition of such loads is left to the study), and different loads among carriers and neighbor cells are allowed.*

Several contributions contribute to this. In general, there is an aligned understanding that the load at least refers to the PRB utilization while there is proposal that it also concerns other factors e.g. number of UEs per cell. [3] propose to agree on a definition used in other standard, i.e. the load levels defined by ETSI in ES 202 706-1, which may be reasonably reused. To allow unbalanced load, [6][18] propose to adopt non-uniform UE distributions.

**FL1 Proposal 3.3-1**

* **The load for evaluation for BS energy saving study refers to the network load levels defined by ETSI in ES 202 706-1, where ‘idle/empty’ refers to ‘unloaded’ cell, ‘low load’ refers to ‘low load’ utilizing 30% PRB and ‘medium load’ refers to ‘medium load’ utilizing 50% PRB.**
* **Non-uniform UE distribution can be considered. Other approaches that are used for achieving different loads among carrier/cells should be clearly stated.**

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The proposed traffic models based on contributions for the study include:

1. FTP3: 0.5MB, 200ms
2. FTP3 IM: 0.1MB, 2s
3. VOIP
4. XR: 30/45Mbps
5. C-DRX: 40/160/320ms cycle, on-duration 4/8/10

Similar to UE power saving study, multiple models can be considered.

**FL1 Proposal 3.3-2**

* **FTP3, FTP3 IM and VOIP can be considered in the evaluation.**
* **FFS other traffic models that can be optionally considered.**

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| **Company** | **Y/N** | **Comments** |
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## Simulation assumption

SLS is explicitly mentioned in the SID thus should be considered. Additionally, [7][14] propose numerical methods for e.g. handover drop rate analysis and [10] propose LLS for e.g. power saving signal detection. The following can be considered.

**FL1 Proposal 3.4-1**

* **At least SLS should be considered in the evaluation. Other method, including numerical analysis and LLS for KPI(s) other than UPT can also be considered.**

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For other assumption parameters, the following are proposed in contributions: IMT-2020, 38.802, 38.840 and 38.830. It may be good to look into the overall SLS parameters first to check if some of them can be referred to.

The simulation assumptions proposed by companies for this meeting may be provided later.

# Other issues/discussion points/missing proposals

If there is any other important issue/discussion point/missing proposal that you consider should be discussed, please share your proposal below.

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| **Company** | **Domain (optional, for potential categorization)** | **Issue content/comments/questions** |
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# Simulation results

It seems there is no strong need to treat the initial simulation results submitted for the first meeting for this SI. Therefore, there is no particular proposal set along that.

# References

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| --- | --- | --- | --- |
|  | RP-[220297](https://www.3gpp.org/ftp/TSG_RAN/TSG_RAN/TSGR_95e/Docs/RP-220297.zip) | Revised SI: Study on network energy savings for NR | Huawei |
|  | [R1-2203172](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2203172.zip) | Discussion on performance evaluation for network energy saving | Huawei, HiSilicon |
|  | [R1-2203224](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2203224.zip) | NW energy savings performance evaluation | Nokia, Nokia Shanghai Bell |
|  | [R1-2203341](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2203341.zip) | Discussion on performance evaluation of network energy savings | Spreadtrum Communications |
|  | [R1-2203481](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2203481.zip) | Evaluation Methodology and Power Model for Network Energy Saving | CATT |
|  | [R1-2203575](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2203575.zip) | Discussions on NW energy savings performance evaluation | vivo |
|  | [R1-2203603](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2203603.zip) | Discussion on NW energy saving performance evaluation | ZTE, Sanechips |
|  | [R1-2203662](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2203662.zip) | Discussion on network energy saving performance evaluation methods | China Telecom |
|  | [R1-2203830](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2203830.zip) | Discussions on performance evaluation of network energy saving | xiaomi |
|  | [R1-2203919](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2203919.zip) | NW energy savings performance evaluation | Samsung |
|  | [R1-2204073](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2204073.zip) | On network energy savings evaluation methodology and power model | Panasonic |
|  | [R1-2204100](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2204100.zip) | Base station energy consumption model, evaluation methodology, and KPIs for network energy saving | FUTUREWEI |
|  | [R1-2204256](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2204256.zip) | On NW energy savings performance evaluation | Apple |
|  | [R1-2204318](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2204318.zip) | Discussion on network energy saving performance evaluation | CMCC |
|  | [R1-2204391](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2204391.zip) | Discussion on NW energy savings performance evaluation | NTT DOCOMO, INC. |
|  | [R1-2204628](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2204628.zip) | Discussion on performance evaluation for network energy savings | LG Electronics |
|  | [R1-2204686](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2204686.zip) | NW energy savings performance evaluation | MediaTek Inc. |
|  | [R1-2204811](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2204811.zip) | Discussion on Network Energy Saving Evaluations | Intel Corporation |
|  | [R1-2204831](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2204831.zip) | Performance evaluation for network energy saving | InterDigital, Inc. |
|  | [R1-2204881](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2204881.zip) | Modeling and evaluation methodology for network energy saving | Ericsson |
|  | [R1-2205045](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2205045.zip) | NW energy savings performance evaluation | Qualcomm Incorporated |
|  | [R1-2205083](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2205083.zip) | Initial views on NW energy savings performance evaluation | Fujitsu Limited |
|  | [R1-2203226](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2203226.zip) | Others | Nokia, Nokia Shanghai Bell |
|  | [R1-2203605](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2203605.zip) | Consideration about NW energy saving | ZTE, Sanechips |
|  | [R1-2204320](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2204320.zip) | Discussion on network energy saving scheme in deployment | CMCC |
|  | [R1-2204883](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2204883.zip) | Other aspects related to network energy saving | Ericsson |
|  | [R1-2204918](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2204918.zip) | Disucssion on information assistance for network energy saving | Huawei, HiSilicon |
|  | [R1-2205160](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2205160.zip) | Evaluation results of network energy saving | CATT |
|  | [R1-2205175](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Inbox/R1-2205175.zip) | Initial evaluation results for network energy saving scheme | vivo |

# Annex

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| **Company** | **Contact** | **Email address** |
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