Remote Energy Measurement (REM)

by Greening of Streaming

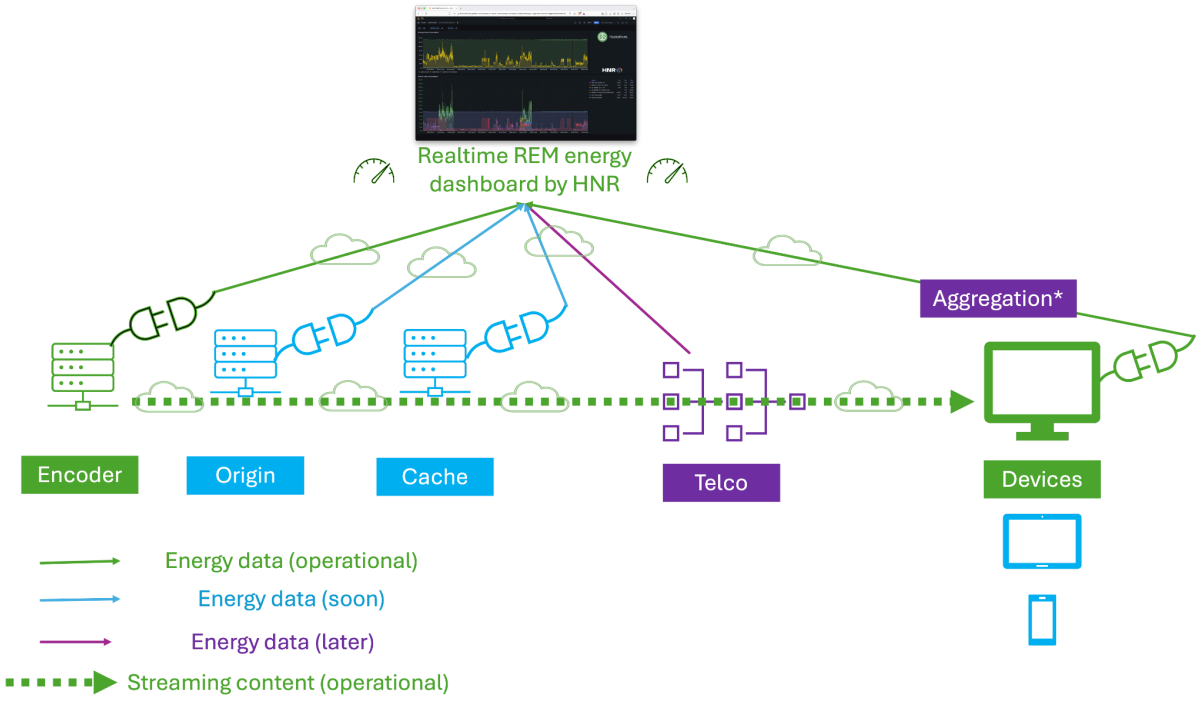
Project Overview

REM is a core Greening of Streaming initiative providing near real-time, scalable insights into streaming infrastructure energy consumption. The project significantly transitions from theoretical models to practical, real-world measurements across consumer devices and network infrastructure. This shift is crucial because theoretical models, while valuable, often fail to capture the complex interactions and real-world variables that influence energy consumption in streaming ecosystems.

Goal

The Remote Energy Measurement (REM) project addresses a critical gap in streaming media sustainability: the lack of real-world Consequential Life Cycle Assessment (CLCA) data. While Attributional LCA approaches have dominated industry discussions, they often fail to capture the complex, system-wide impacts of streaming infrastructure decisions (see our detailed analysis at greeningofstreaming.org/publications). REM aims to provide the comprehensive, measured data needed to build accurate CLCA models, enabling engineers and decision-makers to

understand and optimise the actual environmental consequences of technical choices across the streaming ecosystem. This approach marks a shift from theoretical estimations to actionable, real-world measurements.



REM creates a robust, repeatable measurement infrastructure linking streaming activity to real-time energy consumption across:

- Consumer Premises Equipment (CPE): TVs, mobile devices, and media players represent the endpoint of the streaming chain where content is ultimately consumed. Understanding their energy patterns is crucial as they represent millions of devices operating simultaneously. (Note: as measurement scales, we anticipate *Aggregation (as seen in the diagram above) - in a similar way to that of QOE metrics - will become essential)
- ISP and Network Layers: Telco and CDN infrastructure form the backbone of content delivery, with multiple handoffs and processing points contributing to the overall energy footprint. However, traditional energy assessments often overlook these layers.
- Content Origination and Encoding: Servers and content sources represent the starting point of the streaming journey. Initial encoding decisions can have cascading effects on downstream energy consumption.

Key Features and Current Capabilities

1. **Scalability**: It supports hundreds of measurement points and is expandable to thousands. The infrastructure is designed with cloud-native principles, allowing rapid

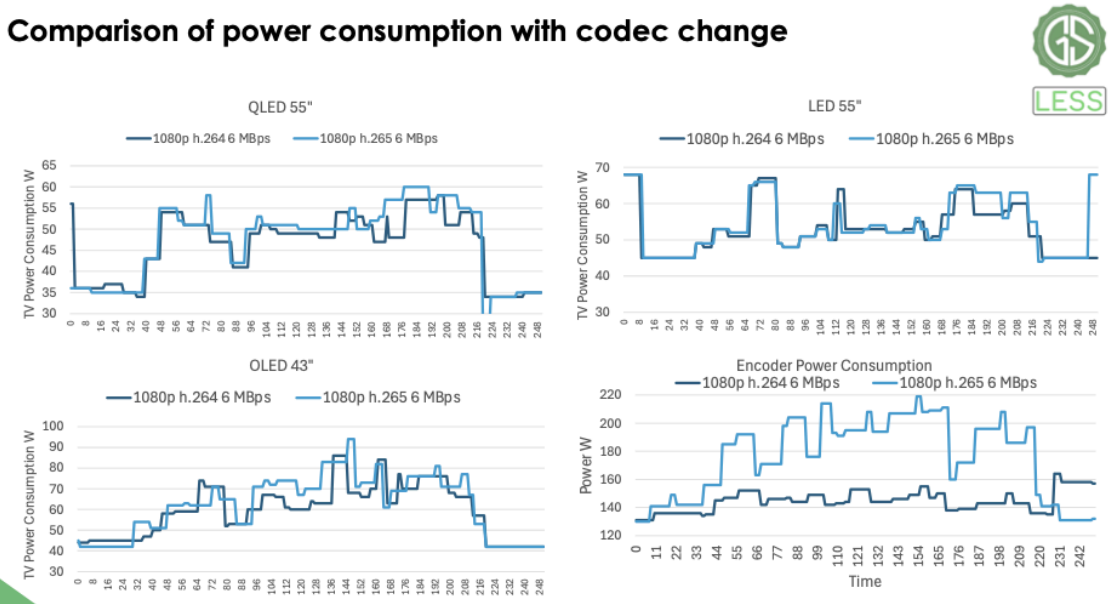
deployment of new measurement nodes and real-time data aggregation without compromising accuracy.

2. **Real-Time Analytics**: We capture near real-time energy data via network-connected smart plugs for CPE and IPMI in data centre environments. We are working on a generic network protocol to simplify this for the industry (stay tuned; publications will be available in 2025, but you can get a sneak lighthearted preview here). This approach provides unprecedented visibility into energy consumption patterns as they occur, enabling immediate response to inefficiencies and anomalies.

3. **Automated Testing**: Uses pre-scheduled encoding and streaming with unique energy "signatures". These signatures allow us to correlate and synchronise specific test sequences with energy consumption, creating a detailed map of cause-and-effect relationships in the streaming infrastructure.

4. **Device Compatibility**: The system supports diverse device types with minimal user intervention. It is designed to be plug-and-play, reducing barriers to adoption and enabling broad participation across different geographic regions and device ecosystems.

5. **Visual Insights**: [See image below] Early testing has demonstrated clear patterns in energy consumption related to content type, delivery methods, and device characteristics.



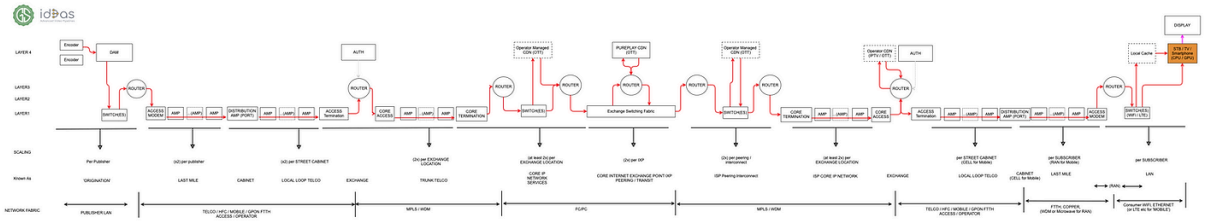
Progress and Scalability Goals

Current achievements and targets:

- We have validated end-to-end workflow across diverse environments, proving the concept's viability in real-world conditions.
- Targeting 10-second data polling intervals to capture fine-grained energy consumption patterns that might be missed with longer intervals.
- Implementing detailed device metrics normalisation, enabling meaningful comparisons across different device types and form factors.

Vision for Extending Collaboration

ISPs and Network Providers

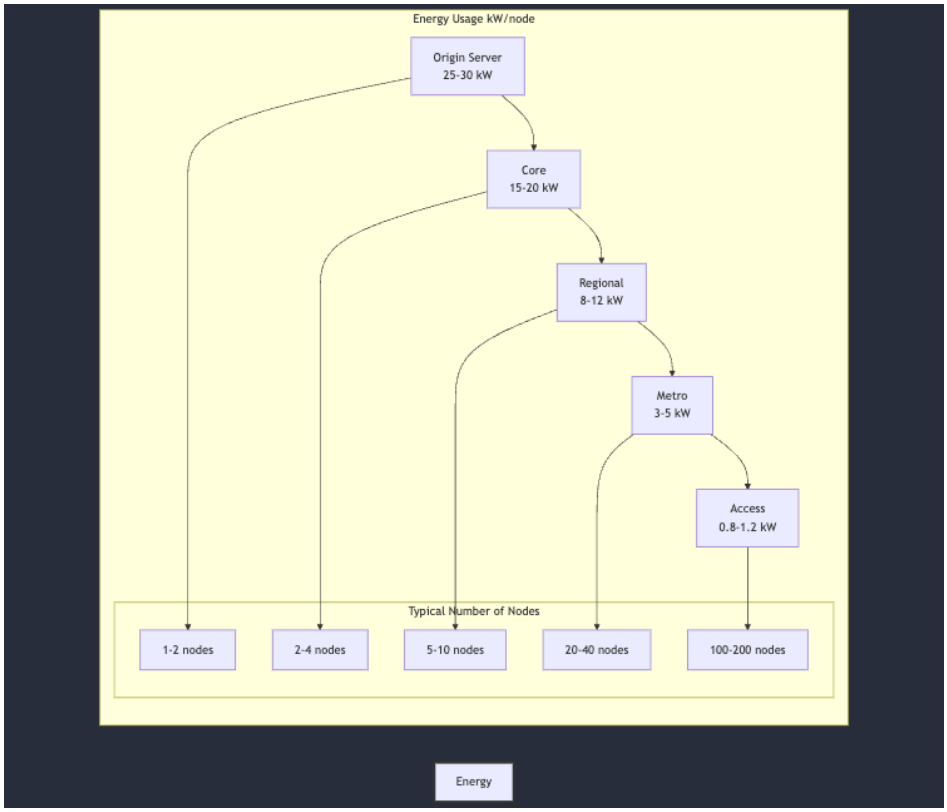


We seek ISP partnerships for network layer measurements, acknowledging several key realities:

- Medium-term limitations on network layer access, reflecting both technical and organisational constraints
- Need for rapid implementation (months, not years) to address pressing sustainability concerns
- Data confidentiality requirements that necessitate careful handling of sensitive network information

Requirements from ISPs:

1. Network diagram adaptation for operational accuracy, ensuring our models reflect real-world deployments
2. Instance scaling approximations (core to edge), helping understand the multiplicative effect of energy consumption
3. Average/peak energy usage per network device, establishing baseline metrics for optimisation (See following diagram)



Streamers

As key decision-makers in the media supply chain, streaming service providers have unprecedented opportunities to influence end-to-end energy consumption patterns. Streamers can gain deep insights into how their technical and content decisions impact energy usage across the entire delivery ecosystem through participation in REM.

Our vision for streamer collaboration encompasses the following:

1. Content and Testing Support
   - Provision of diverse test content representing different genres and technical specifications
   - Access to pre-release content for energy impact assessment
   - Collaboration on creating specific test patterns that help identify energy signatures of different encoding decisions

2. Community Panel Development
   - Support in building diverse test panels across different geographic regions
   - Help to reach out to subscriber communities for participation in energy measurement programs
   - Creation of incentive programs to maintain long-term panel engagement
   - Distribution and management of REM measurement devices to panel participants

3. Strategic Benefits
- Unprecedented visibility into real-world energy impacts of streaming decisions
- Data-driven insights to support technology strategy and infrastructure planning
- Ability to assess energy implications of new codec adoptions or delivery mechanisms
- Enhanced understanding of the relationship between content characteristics and energy consumption

4. Optimization Opportunities
- Potential to optimise encoding ladders based on energy efficiency
- Ability to correlate content production decisions with downstream energy impacts
- Insights into the energy cost of quality decisions
- Understanding of how content preparation choices affect the entire delivery chain

Our ask from streamers:
1. Technical Collaboration
- Share representative content libraries for testing
- Provide access to different encoding profiles and ABR configurations
- Support deployment of measurement infrastructure within content preparation workflows

2. Community Engagement
- Help establish test panels within their user base
- Support communication with communities about energy measurement initiatives
- Assist in deploying and managing measurement devices to panel participants

3. Data Sharing
- Contribute anonymised viewing pattern data to correlate with energy measurements
- Share technical metadata about content preparation and delivery
- Provide feedback on energy optimisation opportunities identified through testing

While we cannot guarantee specific outcomes, participation in REM offers streamers the potential to:
- Develop energy-aware content preparation strategies
- Optimize technical infrastructure for improved sustainability
- Make informed decisions about technology adoption based on energy impact
- Contribute to industry-wide sustainability goals while potentially reducing operational costs
- Generate valuable data supporting environmental impact reporting and sustainability initiatives

This comprehensive approach to energy measurement could provide streamers with unprecedented insights into their environmental impact and offer practical pathways to optimising their operations for sustainability.

CDN Operators

CDN operators play a vital role in the content delivery chain, managing vast networks of servers that significantly impact overall streaming energy consumption. Building on our founding partnership with Akamai, we seek to:

1. Measure energy consumption across different CDN node types:

    - Edge servers, which represent the majority of CDN nodes and are closest to end users
    - Regional servers that aggregate and optimise content delivery across geographic areas
    - Core infrastructure handling primary content ingestion and distribution

2. Analyse the energy impact of:

    - Cache hit ratios, which directly influence server workload and energy consumption
    - Geographic distribution of content and its effect on network efficiency
    - Load balancing strategies and their energy implications
    - Content popularity patterns and their relationship to energy usage

Our ask from CDN operators:

1. Share aggregated power consumption data from representative nodes
2. Provide access to energy metrics from different geographic locations
3. Collaborate on measuring the impact of different caching strategies
4. Help validate energy efficiency improvements from optimisation efforts

Sample Use Cases and Benefits

Members can leverage REM for transformative insights:

- Conduct A/B tests for component energy efficiency, identifying opportunities for optimisation at every level of the streaming infrastructure.
- Assess end-to-end distribution chain energy consumption, understanding the cumulative impact of technical decisions.
- Participate in sustainable media streaming standards development, helping shape the future of eco-efficient content delivery.

Licensing and Partnership Opportunities

The following are available to all members as a combined collaborative effort within Greening of Streaming, but we are also open to offering the REM platform to third parties. Engagement options include comprehensive support for:

1. Measurement campaign design tailored to specific research questions or optimisation goals
2. Panel recruitment, ensuring representative sampling across user bases
3. Infrastructure adaptation for unique measurement requirements
4. Custom reporting to meet specific analytical needs
5. Cloud infrastructure provisioning and management
6. Smart plug deployment and maintenance
7. Analysis and reporting with actionable insights

Campaigns typically require several weeks for definition and multiple test iterations to ensure statistical validity and reliability of results.

Roadmap

Key developments on our horizon:

- Extended device and environmental context collection, incorporating factors like ambient temperature and network conditions
- Unified testing media with embedded markers for precise correlation of content delivery events with energy consumption
- Enhanced device compatibility to support an ever-growing ecosystem of streaming devices

No Greenwashing

REM is a collaborative initiative, not a competitive differentiator. Success in reducing streaming's environmental impact requires genuine industry-wide cooperation - we either succeed or fail together.

Call to Action

REM addresses the critical need for real-world energy consumption data in media streaming, providing scalable, real-time measurement capabilities. By partnering with industry leaders, we're building a comprehensive understanding of streaming's energy impact and creating pathways to a more sustainable future.

Annex 1: Device Support List

- Smart plug compatibility across major markets:
    - EU: 3,680W, 16A for continental European deployments
    - UK: 2,990W, 13A meeting British standards
    - US: 1,800W, 110V, 15A supporting North American requirements
- Supports all mains-powered viewing devices, from small displays to large-format screens
- Android mobile device support in development, addressing the growing mobile streaming segment
- Custom integration is available for devices exceeding power ratings, ensuring comprehensive coverage of the streaming ecosystem.

Annex 2: Authors:

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