IETF Getting Ready for Energy Efficiency Networks WG

GREEN Framework
Video Streaming Use Case
GREEN Provenance (IETF #126 Hackathon)

"Cross-infrastructure measurement & signaling" Panel #4 - University of Passau - July 2026
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IETF GREEN WG - Goals and Scope

https://datatracker.ietf.org/group/green/about/

The GREEN Working Group will examine the **EMAN work** to re-use where applicable but also consider updated operator input and requirements over those previously documented in RFC 6988. Similarly, it will examine the framework previously described in RFC 7326.

It will develop new data models, **specified in YANG** rather than as MIBs.

It is necessary to support **heterogeneous deployment where energy-related statistics and management may be provided via other models and mechanisms**. Guidance will be provided to operators in these heterogeneous environments to cover the incremental deployment of energy-efficient features in both network devices and the management of energy-efficient networks.

The GREEN Working Group is chartered to explore use cases, derive requirements, and provide solutions for identifying and characterizing energy efficiency metrics, methods related to energy consumption of network devices, and optimizing energy efficiency across the network. The Working Group will concentrate on the following:

- Collecting and updating requirements for the management of **energy-efficient networks.**
- Defining **use cases for managing energy-efficient networks.**
- Defining terms and definitions related to energy efficiency metrics. Where possible, terms and definitions in existing RFCs will be reused.
- Developing YANG models to **enable measuring and reporting of energy usage t**hrough metrics and attributes at component, device, and network levels.
- Providing YANG models to allow operators to **optimize energy** usage in network components, devices, and across the network, via configurable energy efficiency capabilities.
- Developing or selecting a **framework** for energy efficiency monitoring, energy efficiency capability discovery, and management within a network domain.

Initially, the GREEN Working Group is expected to focus on simple foundational building blocks for new energy efficiency strategies for operators, such as the work items listed below, striving to illustrate industry implementation and adoption of the working group output before potentially considering more complex aspects of energy-efficient networks in a future charter.

GREEN Framework Reference Model

The GREEN Framework Reference Model is represented in Figure 1.

```
+---------------------------------------------------------------------+
|                                                                     |
|                 (3) Energy Management System (EnMS)                 |
|                                                                     |
+---------------------------------------------------------------------+
  ^               ^                                        |
  | (a)           | (b)        +- (c)                      |
  | Inventory of  | Monitor    | DataSheets/DataBase       |
  | identity and  | Energy     | and/or via API,           v API Service
  | Capability    | Efficiency | Metadata and other      (g) Interface
  |               |            | device, component and
  |               |            | network related           ^
  |               |            | information               |
  |               |            |                           |
  |               |            |                           |
  |               |            |                           |
  |               |            v                           |
+---------------------------------------------------------------------+
|                                                                     |
|        (2) Controller (collection, compute and aggregate?)          |
|                                                                     |
+---------------------------------------------------------------------+
  ^                   ^                          ^ |
  | (d)               | (e)                      | | (f)
  | Inventory         | Monitor power            | | Control
  | Capability        | Proportion               | | (Energy saving
  |                   | Energy efficiency        | | Functionality
  |                   | ratio, power             | | Localized mgmt/
  |                   | consumption,             | | network wide mgmt)
  |                   | etc)                     | |
  |                   |                          | v
+-----------------------------------------------------------------------+
|                                                                       |
|                       (1) Device/Component                            |
|                                                                       |
| +---------+  +-----------+  +----------------+  +----------------+   |
| | (I)     |  | (II)      |  | (III)          |  | (IV)           |   |
| |         |  |           |  | Legacy         |  | 'Attached'(PoE |   |
| | Device  |  | Component |  | Device         |  | end Point)     |   |
| |         |  |           |  |                |  |                |   |
| +---------+  +-----------+  +----------------+  +----------------+   |
+-----------------------------------------------------------------------+
```

Figure 1: GREEN Framework Reference Model

YANG Data Model
(Controller level)
Starting…

YANG Data Model
(Device/Component level)
80% of the work already DONE

https://datatracker.ietf.org/doc/draft-ietf-green-power-and-energy-yang/

Use Cases mapping

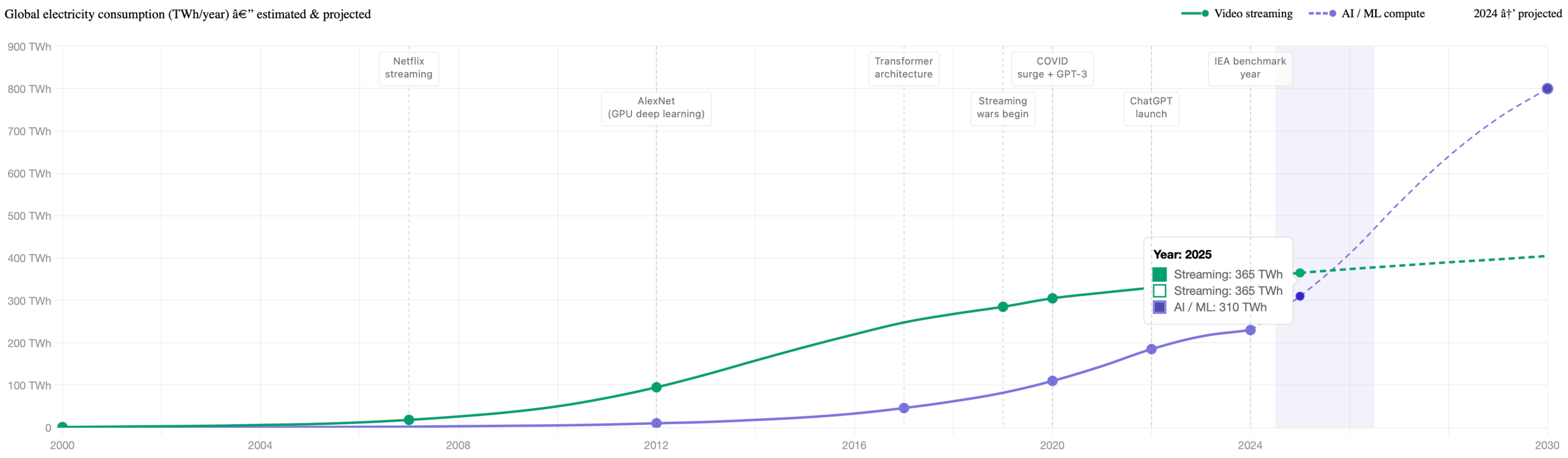
(In progress…)

https://datatracker.ietf.org/doc/draft-ietf-green-framework/

https://datatracker.ietf.org/doc/draft-ietf-green-framework/

Global streaming traffic grows year on year, and the industry still lacks reliable methods to understand its energy impact, and **relies mostly on estimates.**

Line chart showing global energy consumption growth of video streaming and AI from 2000 to 2030, with AI surpassing streaming around 2025.



STREAMING 2024
~355 TWh
+3â€“5% per year

AI / ML 2024
~230 TWh
+25â€“50% per year

CROSSOVER (EST.)
2025â€“26
IEA central scenario

AI 2030 (PROJECTED)
~800 TWh
Goldman Sachs estimate

Sources: IEA Electricity 2024; Goldman Sachs Power Up (2024); Malmodin & LundÃ©n (2018); Cisco VNI (2022); Epoch AI compute trends; Lawrence Berkeley National Lab. AI figures = training + inference workloads in data centres. Streaming = end-to-end system (device + network + DC). Dotted lines = projections based on current growth rates. Uncertainty range is significant â€” see source contrast document. Good data foundation from the slides. Now let me build the chart â€” pulling together IEA, Goldman Sachs, Malmodin, Cisco VNI, and the key inflection points your presentation covers.Seven data points to anchor the chart in the source literature: **Streaming trajectory** is anchored to Malmodin & LundÃ©n (2018) for the 2015 era (~190 TWh), IEA Data Centres (2022) for the 2020â€“2022 range (~300â€“320 TWh), and Cisco VNI annual traffic growth reports as a volume proxy. Growth has been decelerating â€” down from ~15%/year during the streaming wars (2019â€“2021) to ~3â€“5%/year now, primarily because market penetration in high-broadband economies is near saturation. **AI trajectory** stayed near-invisible until 2012 (AlexNet/GPU deep learning), then began accelerating with the Transformer architecture (2017), then inflected sharply at GPT-3 (2020) and near-vertically after ChatGPT's launch (December 2022). The 2024 anchor is IEA *Electricity 2024*'s estimate of ~200â€“250 TWh for AI-specific data centre workloads. The 2030 projection (~800 TWh) comes from Goldman Sachs *Power Up* (April 2024), which projects a 15Ã— increase in AI data centre power demand by 2030. **The crossover zone (shaded, ~2025â€“2026)** is where IEA's central scenario has AI surpassing streaming in absolute annual electricity consumption. This is the most important structural fact â€” AI took 20+ years to reach what streaming built over the same period, but is growing 5â€“10Ã— faster now. Two things to keep visible in presentations: the chart shows *total system energy* for streaming (device + network + DC) but *data centre only* for AI â€” because the user's device contributes under 0.1% of AI energy. If you normalised streaming to data-centre-only (~25â€“40% of its total), the AI crossover already happened in 2022â€“2023.

Video Streaming Use Case (#2.8 in GREEN UC)

Five Segment - Energy Data Across Streaming Framework

Encode / Origin
ESTIMATED

→

CDN / cache
ESTIMATED

→

Telco / ISP
ABSENT

Future mobile coverage 3GPPP

→

CPE / Last Mile
ABSENT

→

Viewer Device
ESTIMATED

The problem is not just data quality. It is the absence of **TRUST Infrastructure**. No standard exists to establish the interoperability, provenance, integrity, or verifiability of energy data exchanged between any of these operators.

REGULATORY CONTEXT

EU Omnibus I — Scope 3: What Changed, Why Data Quality Gets Worse

80%	Only apply	100%	Mar 27	Sep 26	FY 27
companies removed	>1,000 employees	Scope 3 GHG	Transposition	Revised ESRS	First applicable
from mandatory CSRD scope		preserved in revised ESRS	deadline for member states	expected adoption date	reporting year

CHANGE 1 · Reporting Companies

Methodology Substitution

Omnibus I gives EU legal standing to estimation methods ESRS E1 was pushing away from. GHG Protocol always permitted these, now they are explicitly CSRD-compliant.

CHANGE 2 · Small Suppliers

The VSME Shield

Smaller companies can legally refuse any data request beyond what the Voluntary SME Reporting Standard requires.

⚠ Large companies get less from suppliers — legally

CHANGE 3 · Banks & Investors

Fewer Points. One New Signal.

Revised ESRS cuts ~61% of mandatory data points. Scope 3 GHG survives. One disclosure requirement is entirely new:

NEW: Primary vs. Secondary Data Split

Companies must now publicly disclose what % of their Scope 3 data is:

Primary:	Supplier-specific, measured, verified
Secondary:	Estimated, modelled, sector average

Data quality is now a mandatory, visible, comparable number in every disclosure.

✓ Data quality now visible in every report

THE PARADOX

Omnibus I does not reduce demand for Scope 3 data quality — it reveals who has invested in the infrastructure to produce it and who hasn't. Making the format lighter makes the gap more visible, not less important.

Greening of Streaming

Global, member-driven non-profit uniting the streaming industry to reduce its energy footprint.

MISSION

Reduce the environmental impact of streaming through energy - efficient solutions and industry collaboration.

COMMITMENT

NO GREENWASHING. Every public claim is backed by verifiable data and real-world implementation.

OPERATING MODEL

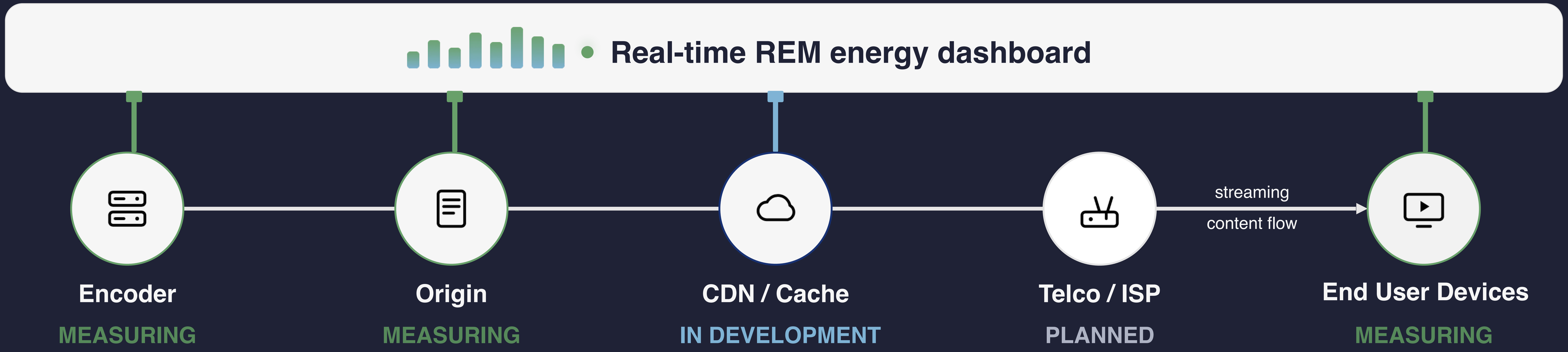
A member network collaborating through Labs - working groups that produce research, build measurement tools, and publish recommendations.

REM — Remote Energy Measurement

Greening of Streaming

WATT LAB · FLAGSHIP PROJECT

Multi-system, end-to-end measurement of how energy behaves across the live streaming chain — **real operational behaviour**, not estimates.



OWL — Online Watt Lab

Greening of Streaming

WATT LAB · FLAGSHIP TOOL

Single-system, lab-grade energy measurement at **high granularity** — built for encoders and well-defined compute tasks.

01

Controlled environment

Defined workloads, stable conditions, dedicated machines.

02

Wall-power metering

Actual physical draw — not software telemetry.

03

Encode-optimised

Built for encode & transcode experiments.

04

Transparent data

Public & member access; outputs never hidden.

OWL — Online Watt Lab

Greening of Streaming

OWL

Online WattLab · GoS1

76.0 W

GoS1 live telemet

Device layer only · Tapo P110 + lm-sensors

54°C	45°C	18
CPU TCTL	GPU JUNCTION	GPU

H.264 CPU

libx264 · 4000 kbps ABR · 1080p · 24 cores

ENCODE

Duration	7.2 s
Output size	22.45 MB
VMAF	93.97

▸ ffmpeg command

POWER

Baseline	75.68 W
Task mean	131.49 W
Peak delta	53.64 W
Energy (ΔE)	0.1073 Wh
CO_2e INDICATIVE	4.40 mg EST Paris (France) · 41 g/kWh · 2025 mean
Polls	7

THERMALS

CPU base → peak	54.7 → 61 °C
GPU base → peak	46 → 46 °C
GPU PPT mean	18.6 W

GPU self-reported · meter ΔW is full system delta.

H.264 GPU

h264_nvenc · 4000 kbps ABR · 1080p · full pipeline

ENCODE

Duration	3.3 s
Output size	24.21 MB
VMAF	94.63

▸ ffmpeg command

POWER

Baseline	76.52 W
Task mean	109.29 W
Peak delta	26.77 W
Energy (ΔE)	0.0245 ✓ Wh
CO_2e INDICATIVE	1.00 mg EST Paris (France) · 41 g/kWh · 2025 mean
Polls	3

THERMALS

CPU base → peak	57.1 → 56.6 °C
GPU base → peak	46 → 47 °C
GPU PPT mean	48.2 W

GPU self-reported · meter ΔW is full system delta.

SAME ENERGY (0.025 WH (H.264) / 0.107 WH (H.264)), ON OTHER GRIDS (EMBER 2025 ANNUAL MEANS)

	H.264	H.264		
Copenhagen (Denmark)	2.79 mg	12.23 mg	2.8×	114 g/kWh
London (UK)	5.32 mg	23.28 mg	5.3×	217 g/kWh
Berlin (Germany)	8.09 mg	35.41 mg	8.0×	330 g/kWh
Warsaw (Poland)	14.43 mg	63.20 mg	14.4×	589 g/kWh
	3.77 mg	16.52 mg	3.8×	154 g/kWh

marisol.ietf@gmail.com · Sign out

THROUGH HISTORY — SAME ENERGY ON THIS ZONE'S PAST GRIDS

	H.264	H.264		
France · Jan 2020	1.61 mg	7.06 mg	1.6×	65.8 g/kWh
Pre-Covid winter.				
France · Jun 2020	1.34 mg	5.86 mg	1.33×	54.6 g/kWh
Covid-lockdown summer — industrial demand dipped.				
France · Jun 2022	1.46 mg	6.38 mg	1.45×	59.5 g/kWh
Energy-crisis-era summer (nuclear fleet partly offline).				
France · Jan 2024	1.31 mg	5.73 mg	1.30×	53.4 g/kWh
Winter, post-recovery — cleaner than Jan 2020 despite the season.				
France · Jun 2024	659.05 µg	2.89 mg	0.66×	26.9 g/kWh
Recent summer — nuclear back, solar buildout reflected.				

Same lifecycle methodology as the live number above (Eco2mix consolidated × IPCC AR6 factors). Curated dates illustrate the range of grid evolution; not exhaustive.

PARIS (FRANCE) GRID MIX (41M AGO, VIA ECO2MIX (RTE/ETALAB))

Nuclear	39022 MW	71%
Hydro	6177 MW	11%
Wind	5097 MW	9%
Gas	3299 MW	6%
Bioenergy	988 MW	2%
Oil	35 MW	0.1%

https://wattlab.greeningofstreaming.org/

IETF Hackathon GREEN Provenance

`draft-ietf-opsawg-yang-provenance`

Scenario

A Madrid data centre draws 1,240 kW from three sources at once: the Spanish national grid (REE — external authority), rooftop solar (controller-managed), and a UPS battery bank (controller-managed). We prove the composite carbon intensity figure used in a GREEN compliance report is genuine and traceable to each source.

Source A — REE grid

842.7 kW · 87 gCO_2/kWh · 61% renewable

external-ca

Source B — Solar PV

87.3 kW · 0 gCO_2/kWh · 100% renewable

controller

Source C — UPS

310 kW · 9 gCO_2/kWh · 91% renewable

controller

each source can be independently signed and verified

Based on a Java reference implementation (Telefónica) that attaches cryptographic provenance to YANG-modelled network data. It uses COSE (RFC 9052) to sign XML/JSON-serialised YANG data, so a receiver can verify exactly who produced a set of network telemetry and that it has not been tampered with. A serverless version is live for the hackathon, supporting both JSON and XML, and full verification.

“GREEN Provenance” Hackathon

```
module: ietf-green-provenance

  augment /eo:energy-objects/eo:energy-entry:
    +--ro provenance-key-id?            string
    +--ro provenance-key-owner?         identityref
    +--ro traceability-verified?        boolean
    +--ro traceability-last-verified?   yang:date-and-time
    +--ro traceability-failure-reason?  string

  identities:
    key-owner-type (base)
      +-- key-owner-device        (device self-attests, TPM-backed)
      +-- key-owner-controller    (controller fallback for legacy devices)
      +-- key-owner-external-ca   (grid provider, carbon intensity service)
```

https://datatracker.ietf.org/doc/html/draft-madpr-green-provenance-00

"GREEN Provenance" Hackathon

```
Grid : 842.7 kW (68.0%) CI=87 gCO2/kWh
Solar : 87.3 kW (7.0%) CI=0 gCO2/kWh
UPS : 310.0 kW (25.0%) CI=9 gCO2/kWh

► Composite CI : 61.4 gCO2eq/kWh
► Renewable : 71.2%
```

This is the number that goes into the **CSRD/ESRS E1** compliance report. Without provenance on the three inputs, this number is **unverifiable**.

Then step 4 shows the correlation record signed and verified:

```
verify: ✓ VERIFIED
```

If the ISP controller signs this correlation record, referencing the **kid** of each source. An auditor, six months later, can take this signed document, fetch the three input signatures, and independently verify the full chain

Call for Adoption/POC proposal to include the GREEN provenance draft