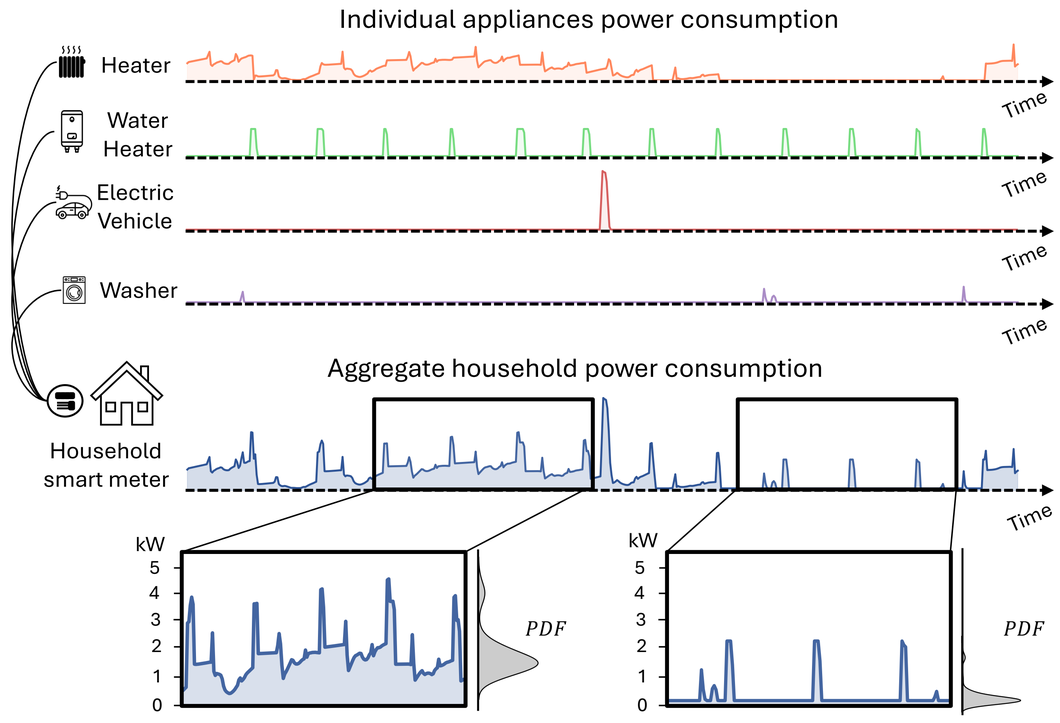
NILMFormer: Non-Intrusive Load Monitoring that Accounts for Non-Stationarity

Adrien Petralia[1,2], Philippe Charpentier[1], Youssef Kadhi[1], Themis Palpanas[2]
EDF R&D[1], Université Paris Cité[2]
adrien.petralia@edf.fr

Challenges & Motivation

- Smart meters ≠ insight: They only capture whole-home load, while decarbonization needs **appliance-level detail**.
- NILM in a nutshell: **Non-Intrusive Load Monitoring**[1] infers each appliance's usage from the **smart meter aggregate signal only**.
- Why it matters: Appliance-specific feedback cuts **consumption by ≈12%**[2,3], yet utilities still report in monthly or yearly chunks.
- EDF's monitoring solution: **E**lectricité **D**e **F**rance, the main electricity supplier in Europe, proposed "*Mon Suivi Conso*"[4] which uses time-series regression for monthly estimates—**still too coarse** for real-time action.
- Current gap: State-of-the-art deep-learning NILM falters due to **electricity consumption patterns drift** (non-stationarity).
- Our contribution: First deployed (at scale) NILM solution that learns to **correct subsequence distribution drift** while preserving **temporal context**—unlocking robust, detailed, appliance-level insights.

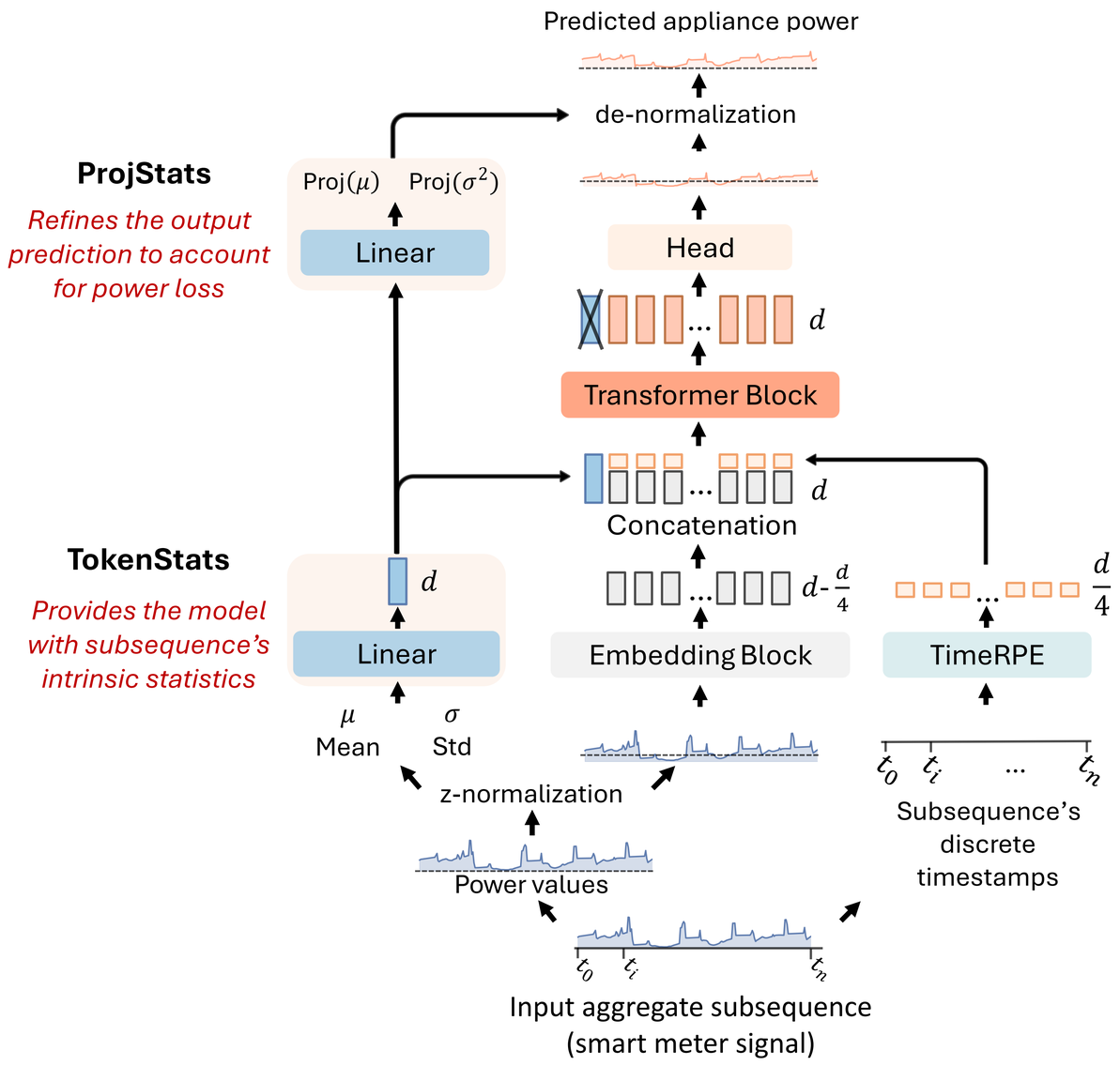


Electricity consumption data are highly non-stationary as appliances turn on and off throughout the day

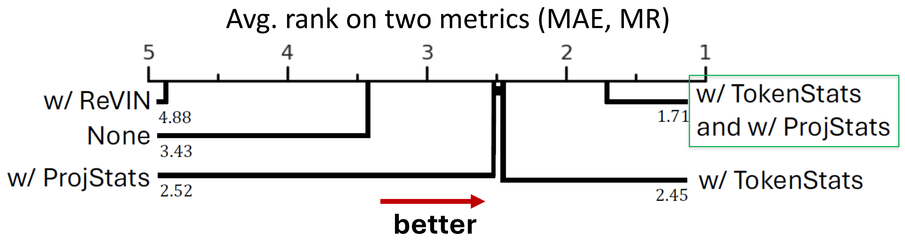
NILMFormer architecture

Key idea — decompose the input **subsequence** to mitigate data drift in **3 different components**

1. Intrinsic statistics *2. Shape* *3. Timestamps information*

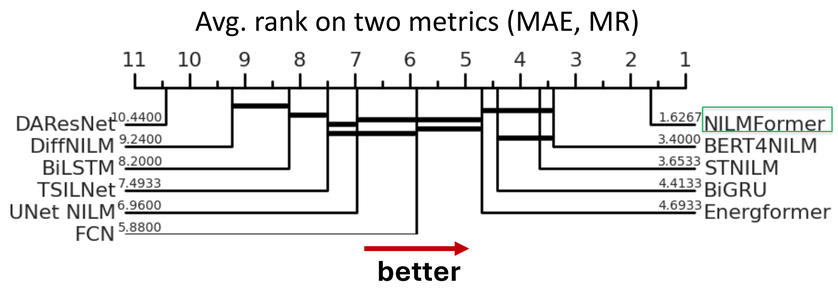


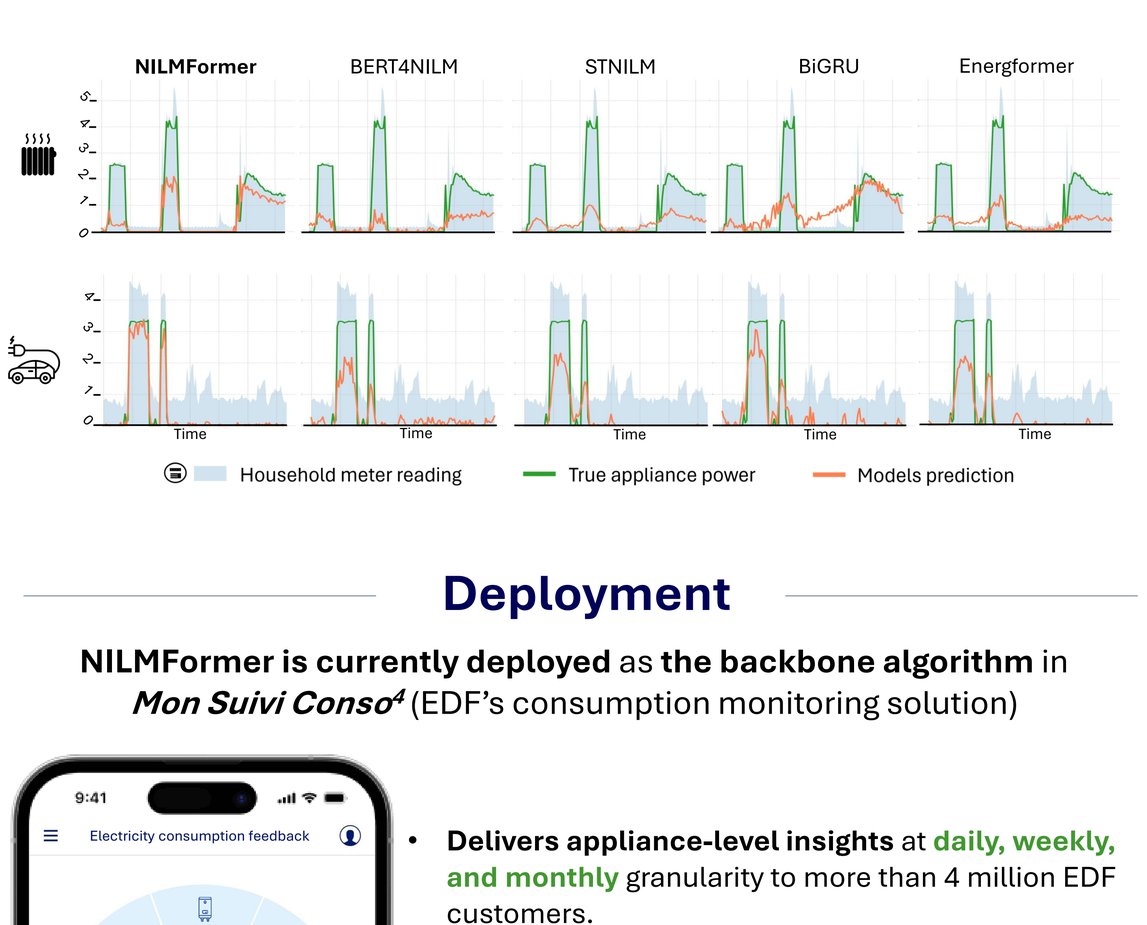
Impact of the proposed **mechanisms** for **mitigating data non-stationarity on model performance**



Performances

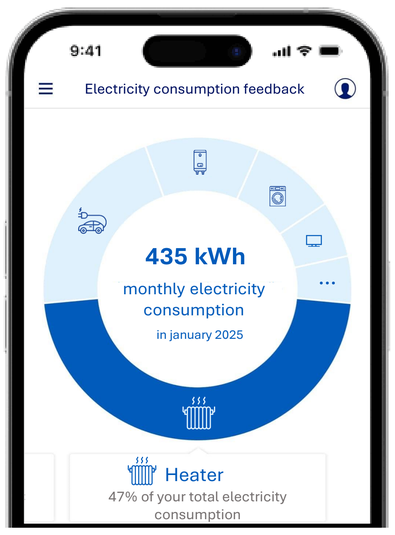
Results averaged across **4 datasets** and **14 appliance-disaggregation scenarios** (REFIT, UKDALE, plus two private EDF datasets)





Deployment

NILMFormer is currently deployed as **the backbone algorithm** in ***Mon Suivi Conso***[4] (EDF's consumption monitoring solution)



- **Delivers appliance-level insights** at **daily, weekly, and monthly** granularity to more than 4 million EDF customers.
- **Raises monthly-level accuracy** by **154 %** over EDF's previous deep-learning time-series regression backbone.
- Processes the entire EDF database (4M clients) in **11-hours**, demonstrating **industrial-grade scalability**.

References

[1] A review of current methods and challenges of advanced deep learning-based non-intrusive load monitoring (NILM) in residential context, Hasan Rafiq, Prajowal Manandhar, Edwin Rodriguez-Ubinas, Omer Ahmed Qureshi, Themis Palpanas, Energy&Building, 2024.

[2] Martinez et al., Advanced Metering Initiatives and Residential Feedback Programs, 2010.

[3] Allcott et al., Social norms and energy conservation, Journal of Public Economics, 2011.

[4] Solution Mon Suivi Conso – EDF's Consumption Monitoring Solution, https://particulier.edf.fr/fr/accueil/bilan-consommation/solution-suivi-conso.html, 2025..

Github

Promotional Video