

ADF & TransApp: A Transformer-Based Framework for Appliance Detection Using Smart Meter Consumption Series

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Adrien PETRALIA^{1,2}, Philippe CHARPENTIER², Themis PALPANAS¹

¹Université Paris Cité, Paris, France

²EDF R&D, Palaiseau, France



Background: Efficient Energy Management

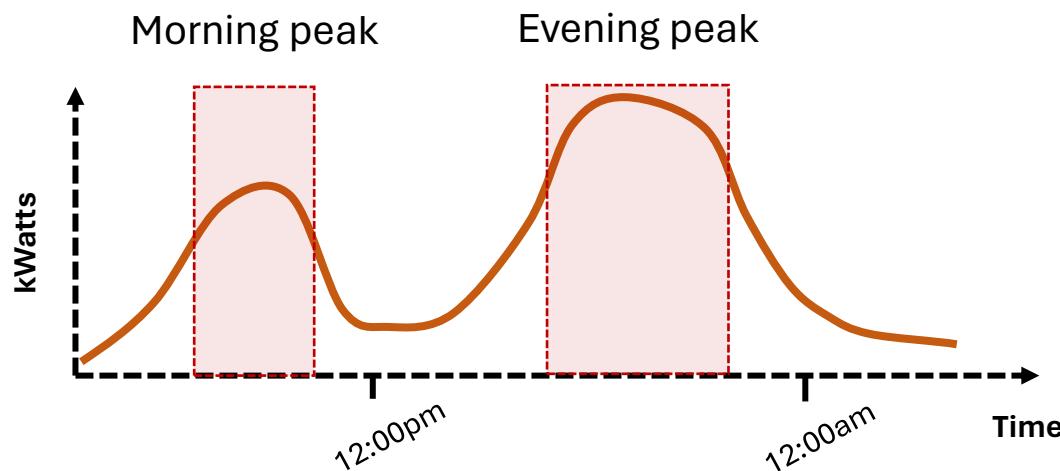
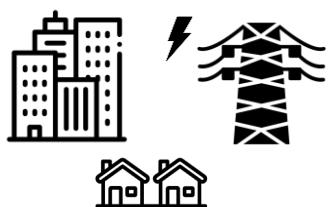
Energy savings is crucial to fight against climate change



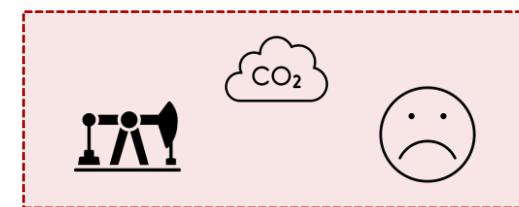
In the European Union (EU), **individual households** represented **26%** of final **energy consumption**



Electricity accounted for a **quarter** of total households energy consumption



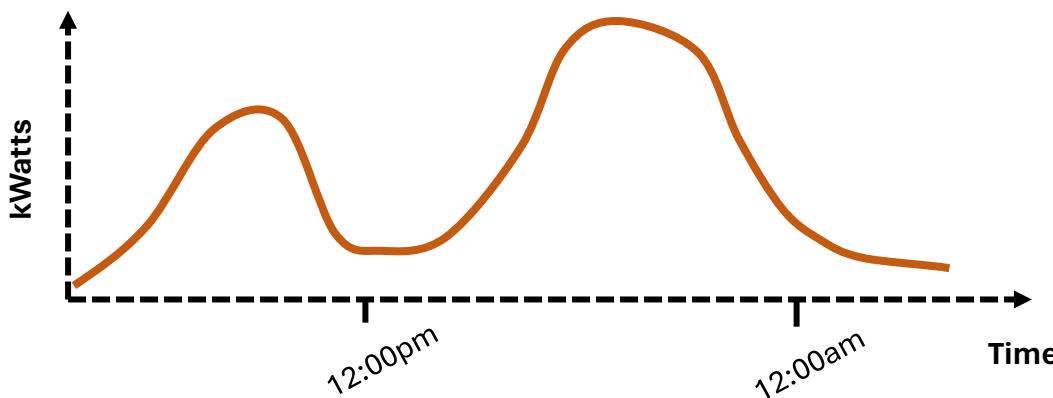
Typical **daily electricity grid demand** (load curve)



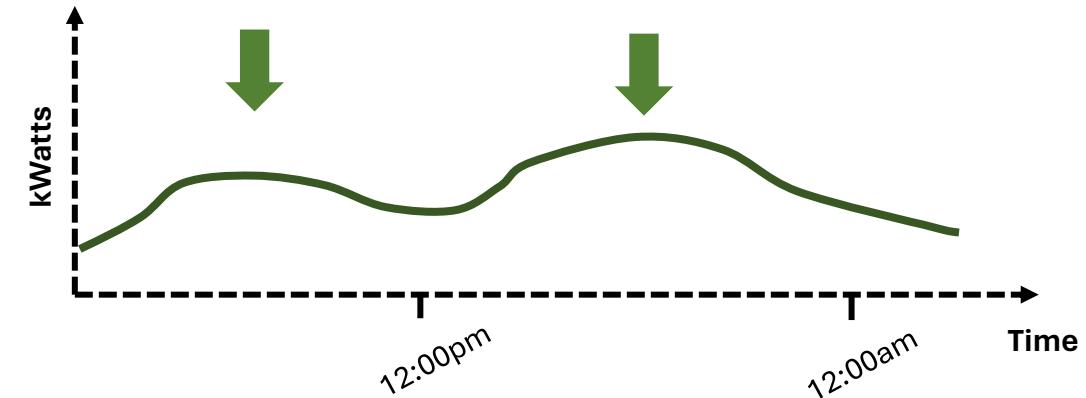
Use of **fossil energy** (oil, coal) to produce electricity to **absorb the peaks in demand**

Background: Efficient Energy Management

Reducing peak demand



- ✓ Smoothed daily demand
- ✓ Reduced need of fossil energy



Electricity suppliers need to play an **active role in this process**

How to convince clients to **change their consumption behavior** ?

By offering **personalized contracts!**

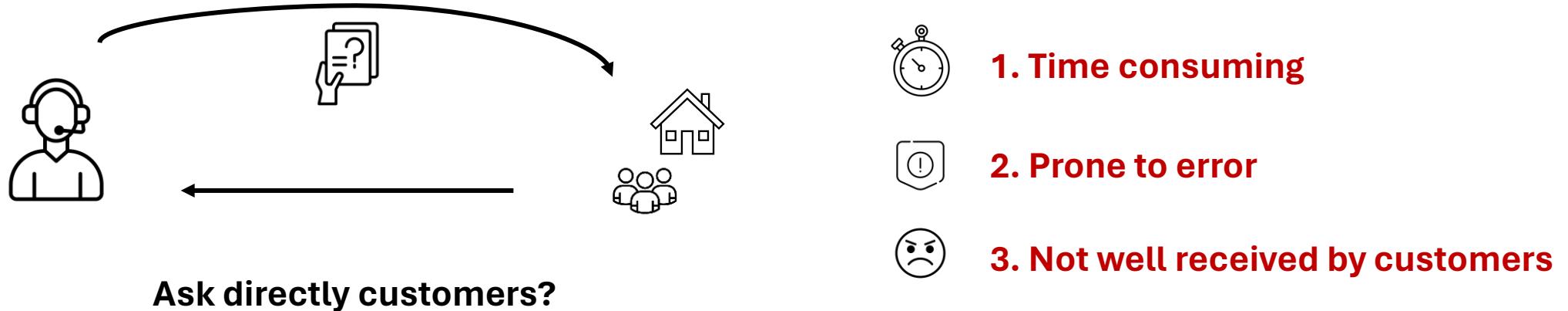


- 50% discount to charge your **electric vehicle by night**
- 50% discount to reduce your **heater usage during peak hours**

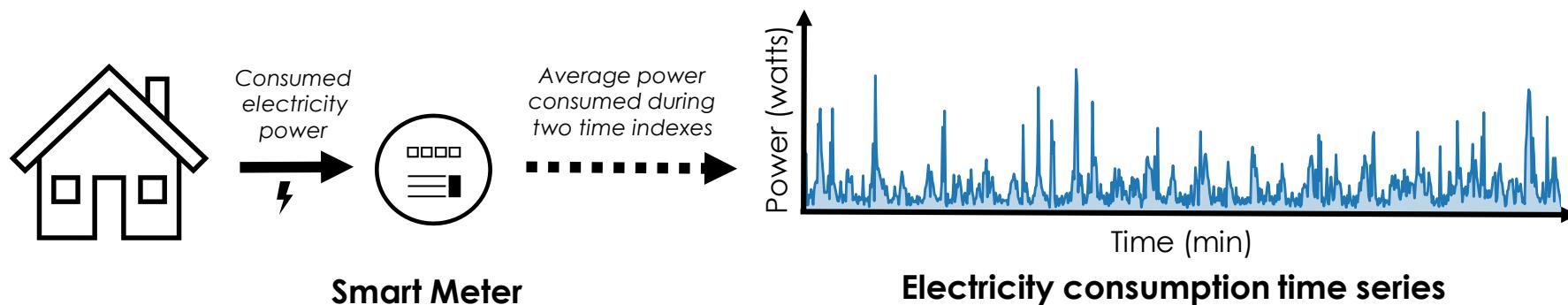


Background: Gathering consumers' data

However, suppliers need to know which appliances are owned by customers...

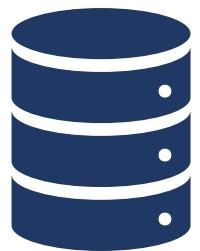


Millions of Smart Meters deployed in individual households

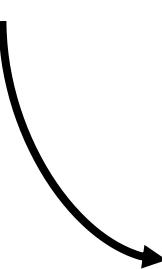


Background: Electricity consumption data

Suppliers collect increasingly larger amounts of **electricity consumption data**.



Electricity Consumption Database
(Millions of clients)



Client 1



Client 2



Client 3



Client 4



Client 5



:

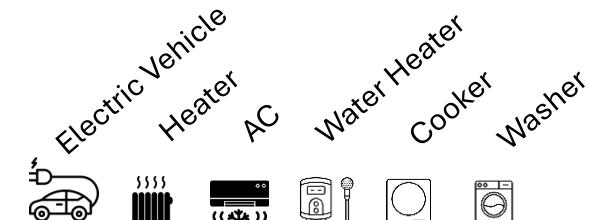


Client n



Recorded smart meter consumption

Only some household characteristics are
available and **trustable**



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Houses involved in
survey studies

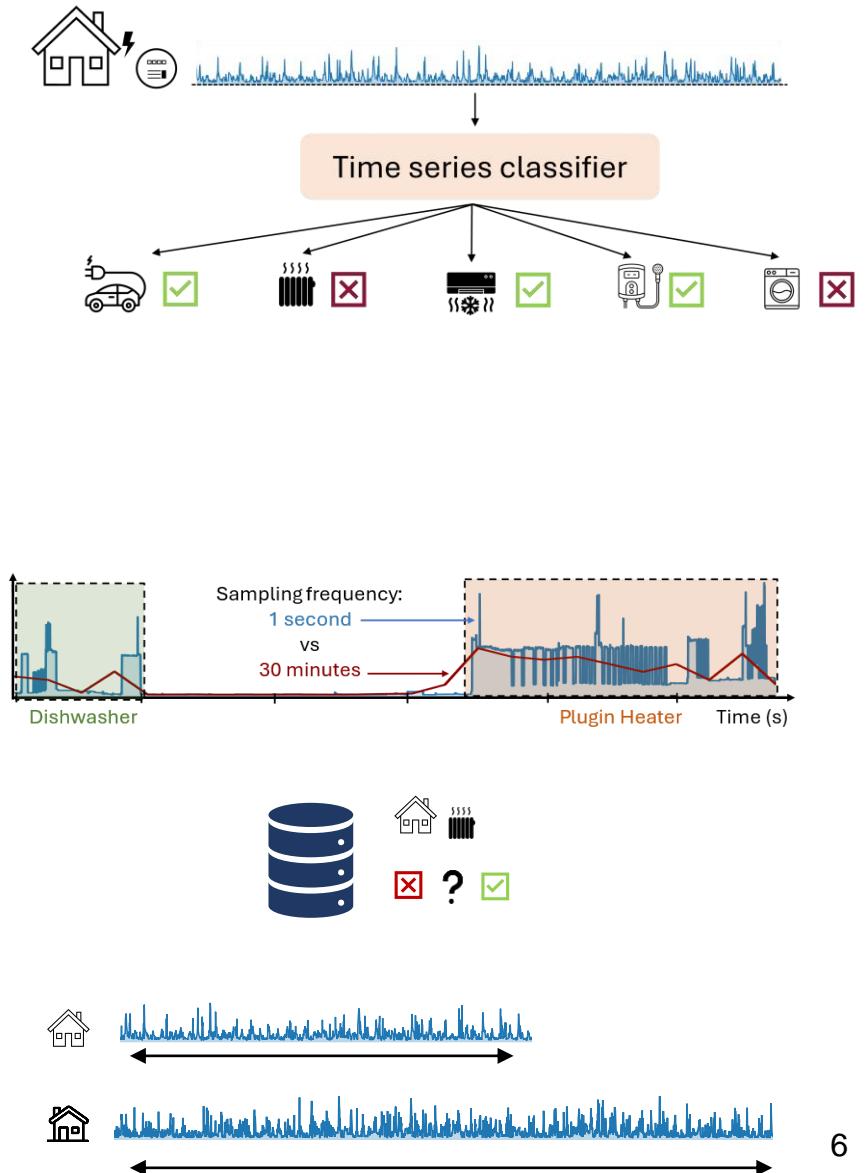
Households' characteristics

Background: Appliance Detection

Detecting appliances using Smart Meters series can be cast as a **Binary Time Series Classification Problem** [Deng et al. 2022, Petralia et al. 2023].

However, reported **accuracy is rather low...**

1. **Very low frequency samples** used by Smart Meters
2. **Lack of accurate labeled data**
3. Doesn't take into account the **variable length aspect** of recorded **consumption series**



Challenges

*How to **accurately** and **efficiently detect the appliances** present in households using the recorded smart meter signal?*

Challenges

1. Nature of electricity consumption data

Very low frequency reading used by Smart Meters
Long and variable length consumption series

2. Data size

Few labeled data for training a solution
Large amount of non labeled data

Solutions

✓ The Appliance Detection Framework (**ADF**)

- **Improve** classifiers detection accuracy
- Make classifiers **insensitive to the length**

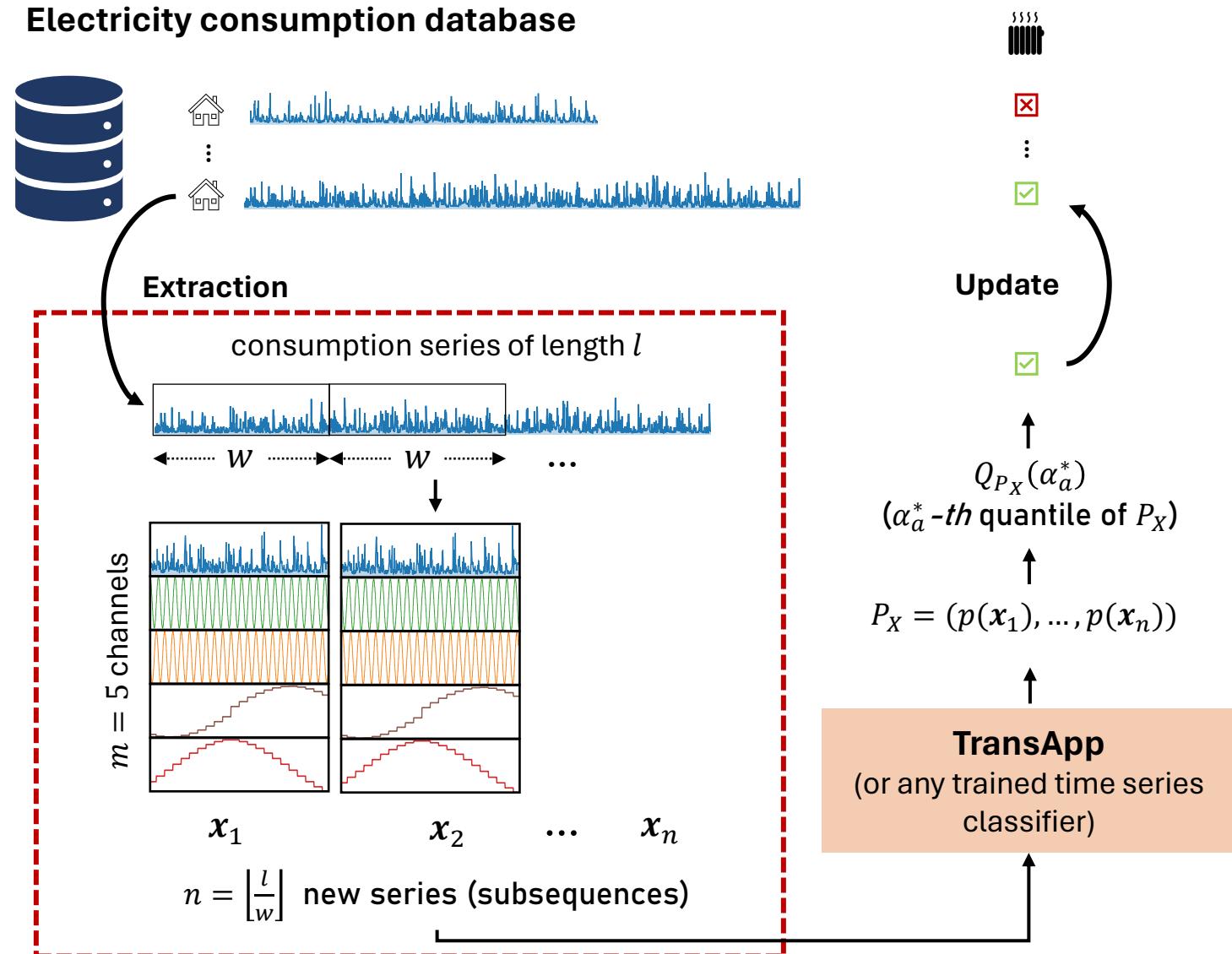
✓ **TransApp**: a deep-learning time series classifiers

- **Pretrained** on large amount of non-labeled data to improve its accuracy
- **Scalable** to large database of long series (thanks to ADF)

Proposed Approach: ADF

The Appliance Detection Framework

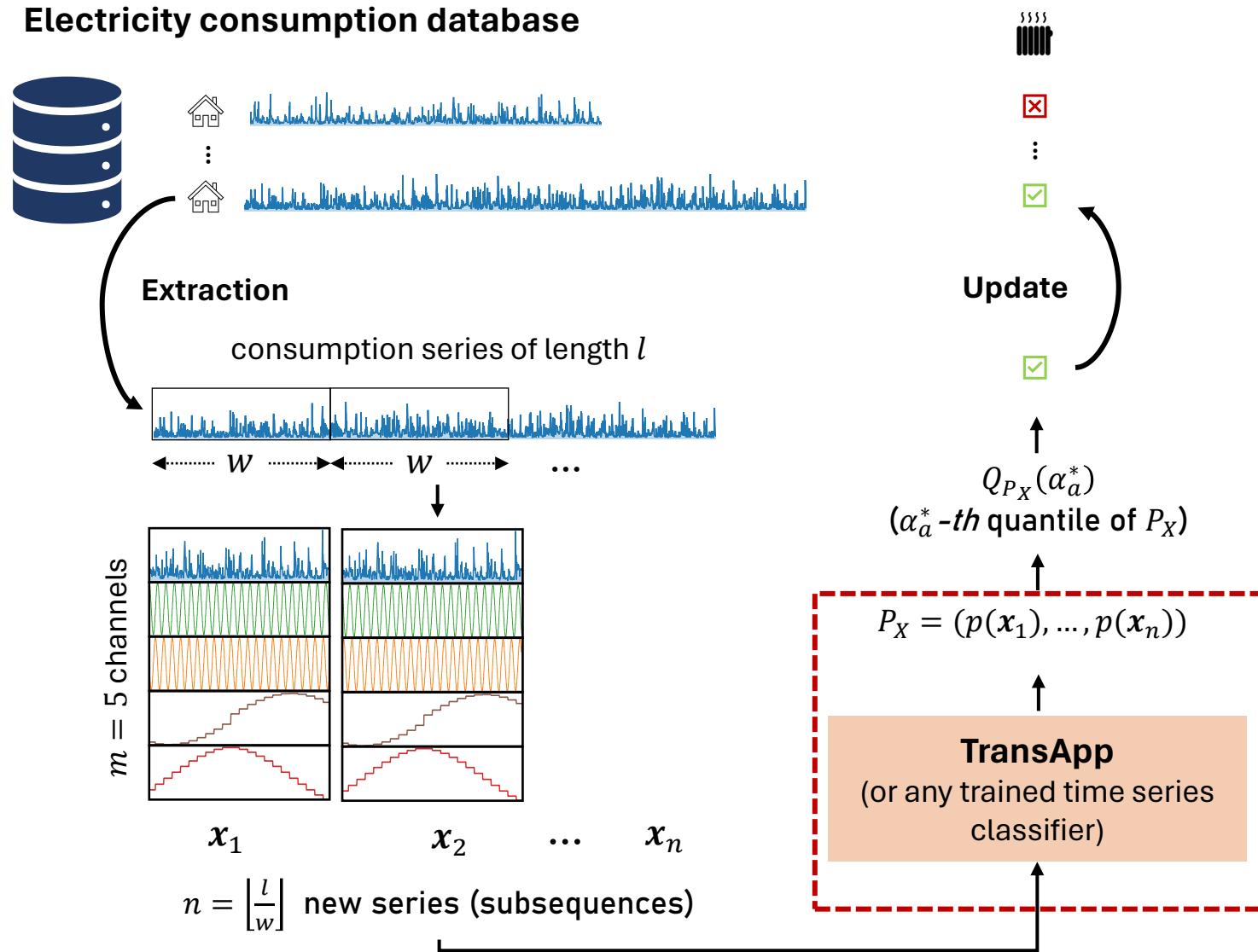
1. **Slice** series into subsequences and **concatenate** with timestamp-encoded information



Proposed Approach: ADF

The Appliance Detection Framework

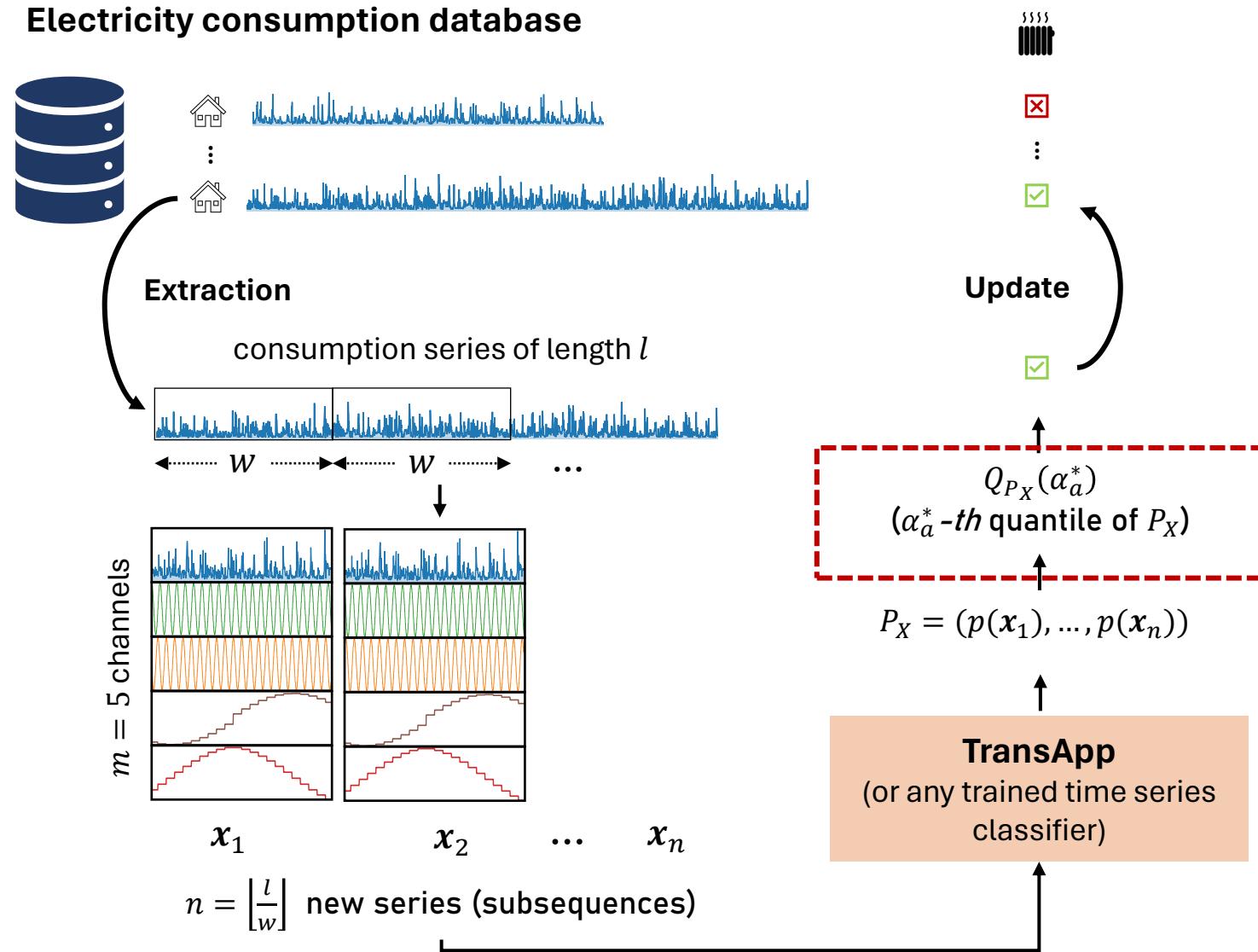
1. Slice series into subsequences and concatenate with timestamp-encoded information
 2. TransApp predicts probabilities for **each subsequences**



Proposed Approach: ADF

The Appliance Detection Framework

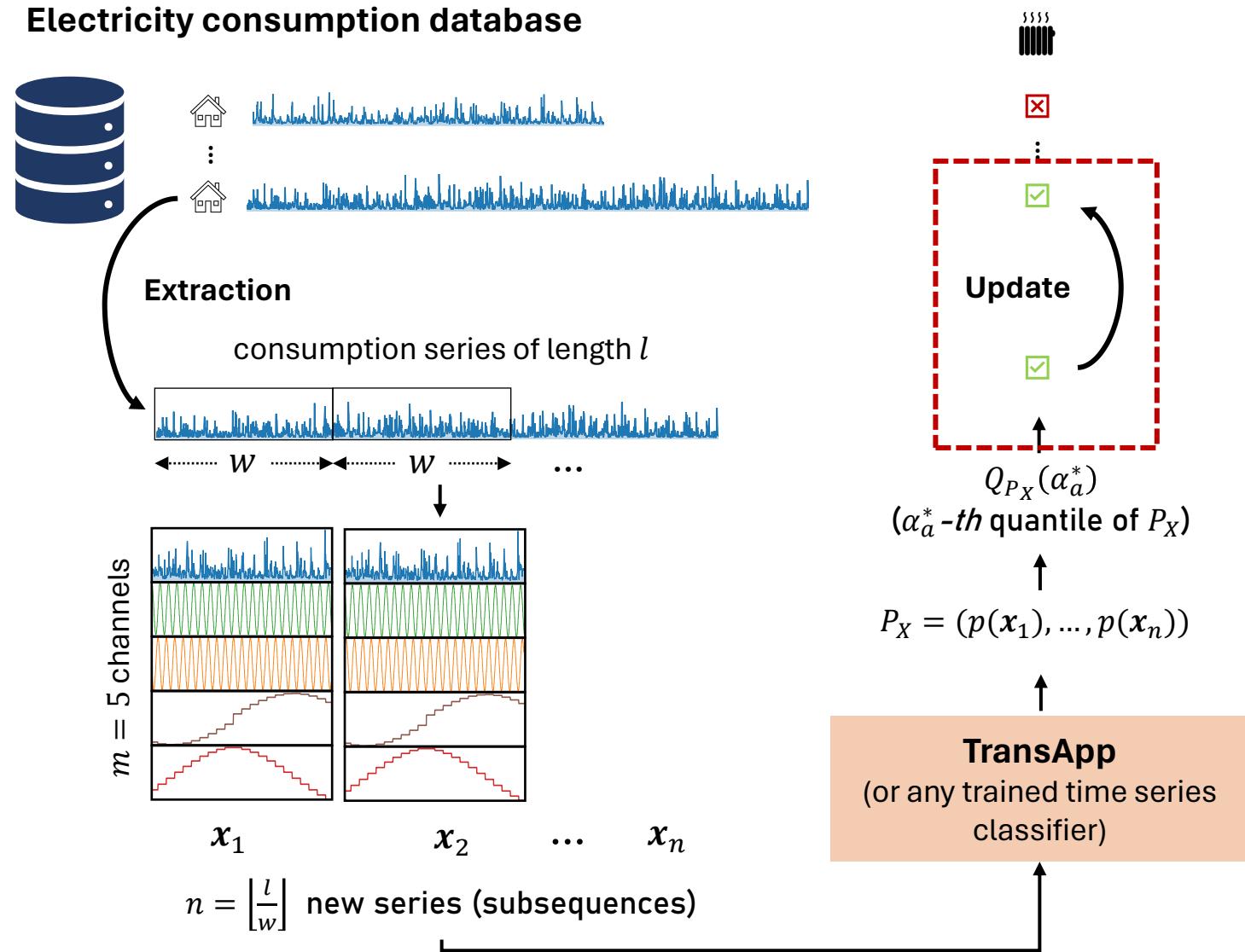
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3. Merge predicted probabilities by extracting best quantile



Proposed Approach: ADF

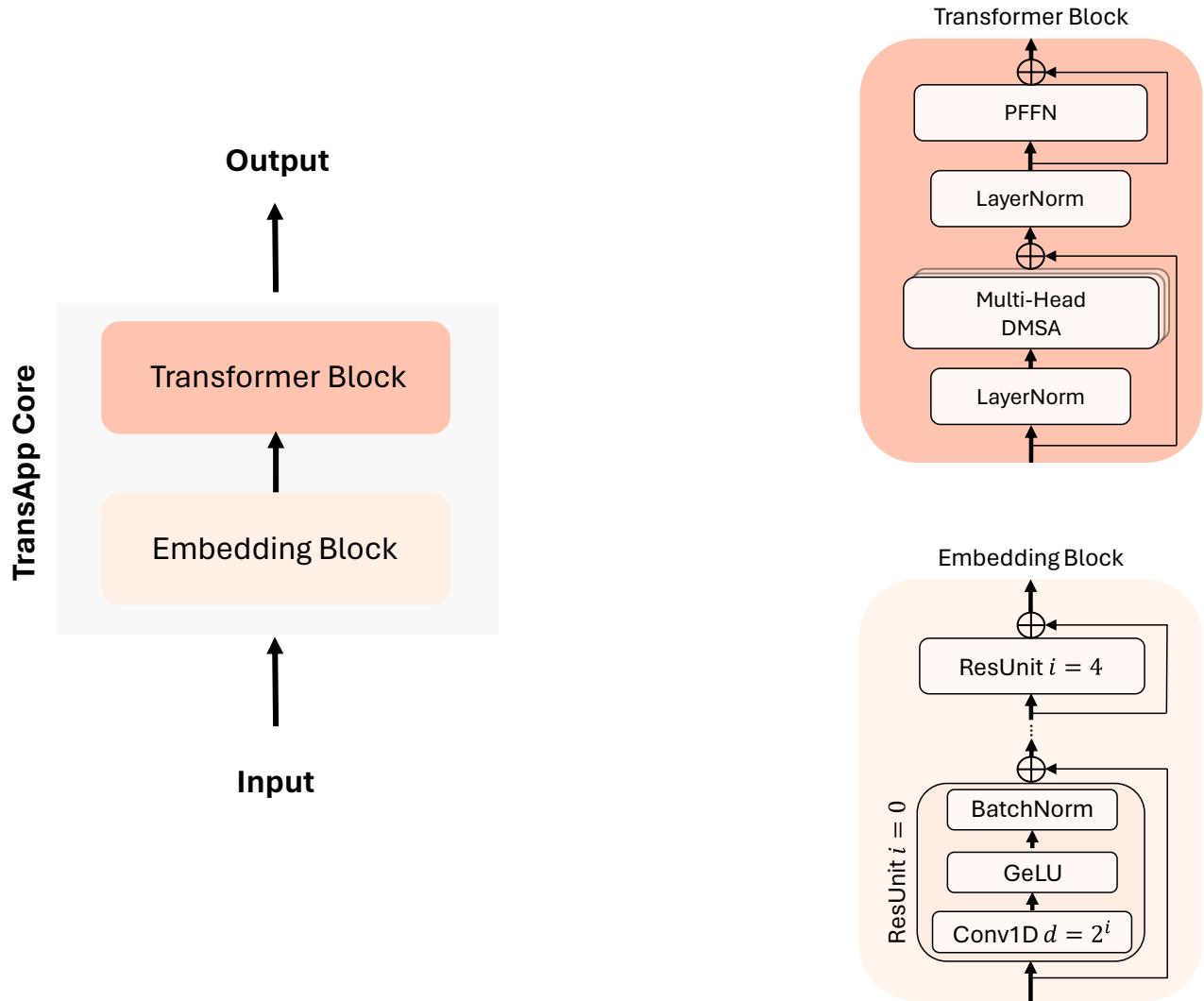
The Appliance Detection Framework

1. Slice series into subsequences and concatenate with timestamp-encoded information
2. TransApp predicts probabilities for each subsequences
3. Merge predicted probabilities by extracting best quantile
4. Determine the final **label prediction**



Proposed Approach: TransApp

TransApp: A simple deep-learning architecture

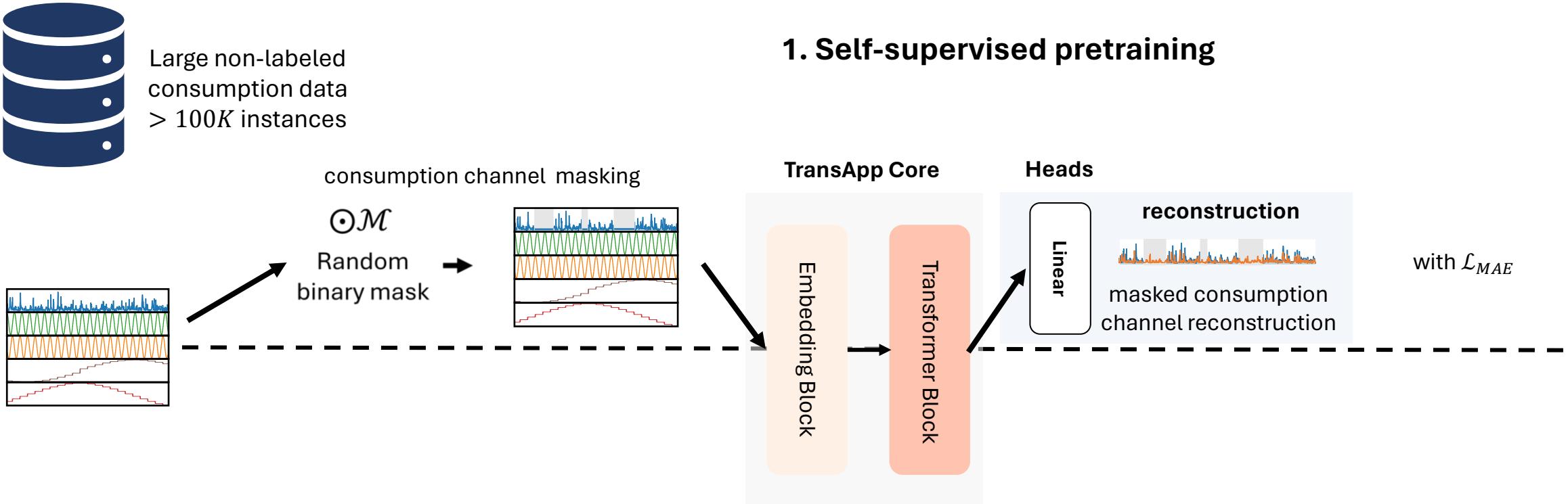


A Transformer Block to learn electricity consumption series representation

A strong convolutional Embedding Block to extract localized patterns

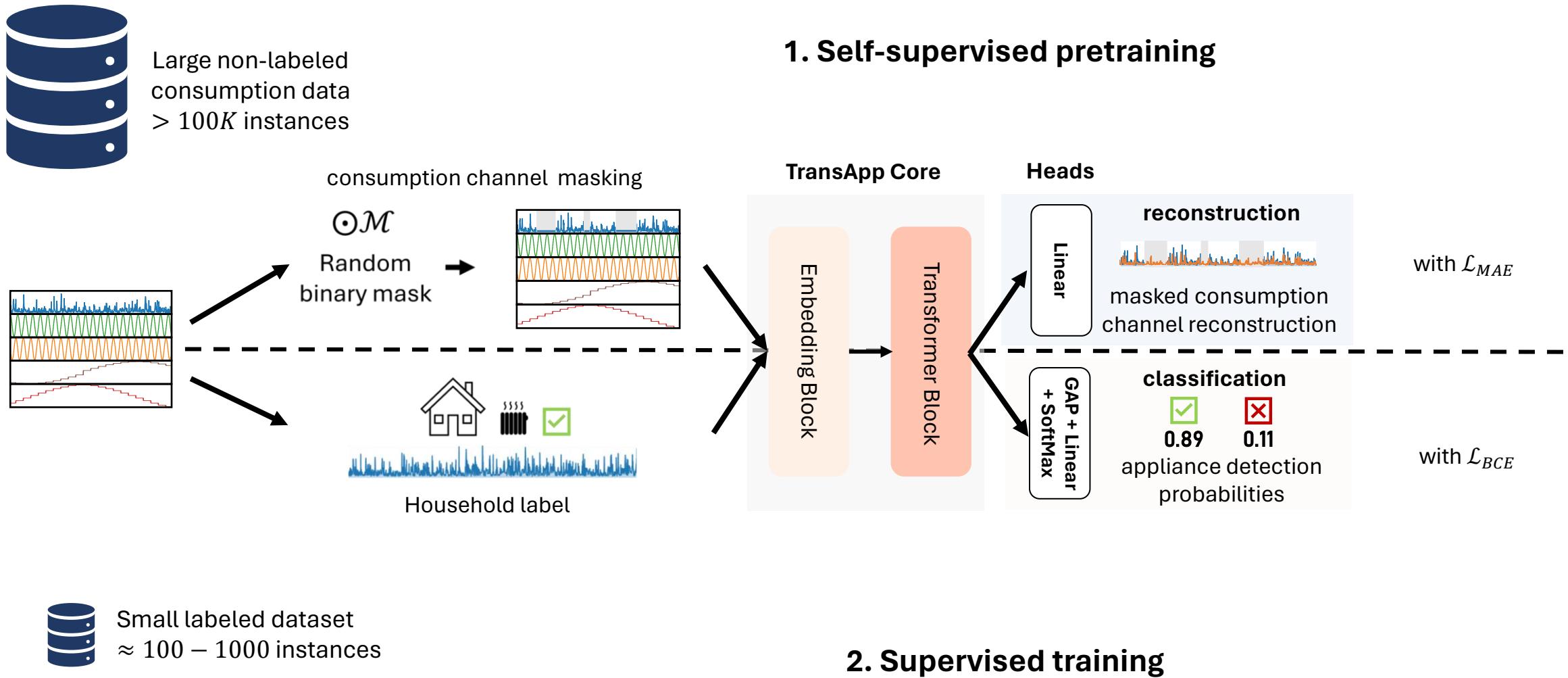
Proposed Approach: TransApp

TransApp: Two-steps training process



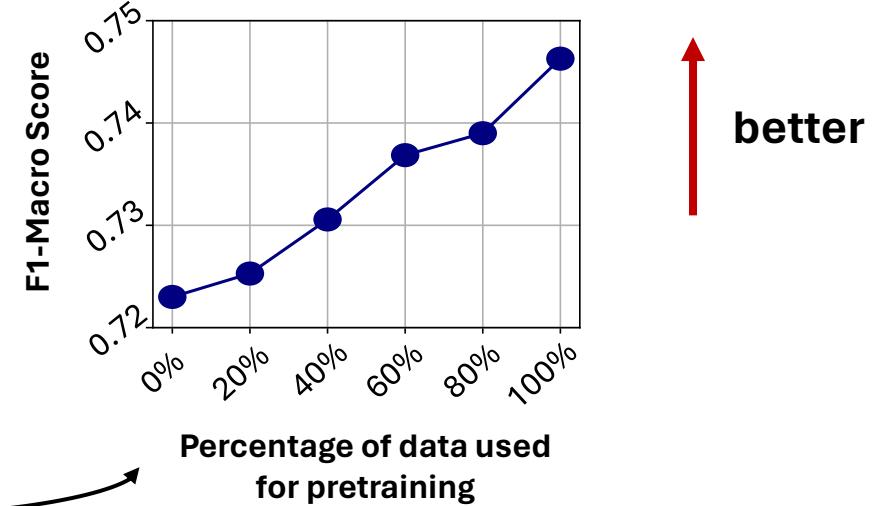
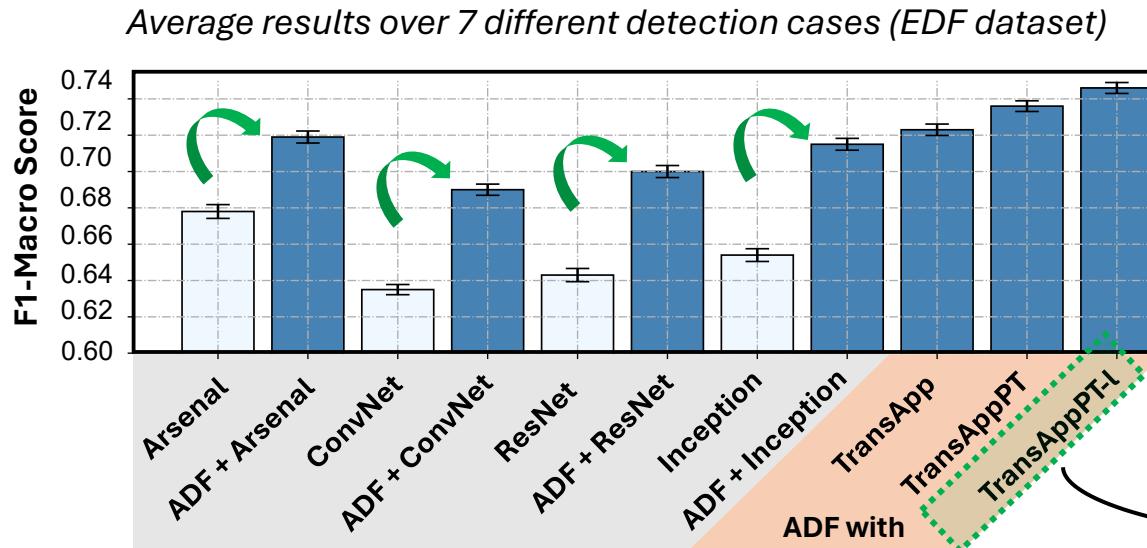
Proposed Approach: TransApp

TransApp: Two-steps training process



Experiments: appliance detection quality

Detection Accuracy Results



TransAppPT-L: pretrained on a large non-labeled dataset composed of **200K customers**

Our solution **accurately detects** different appliances in real-world scenarios



Electric Vehicle



Heater



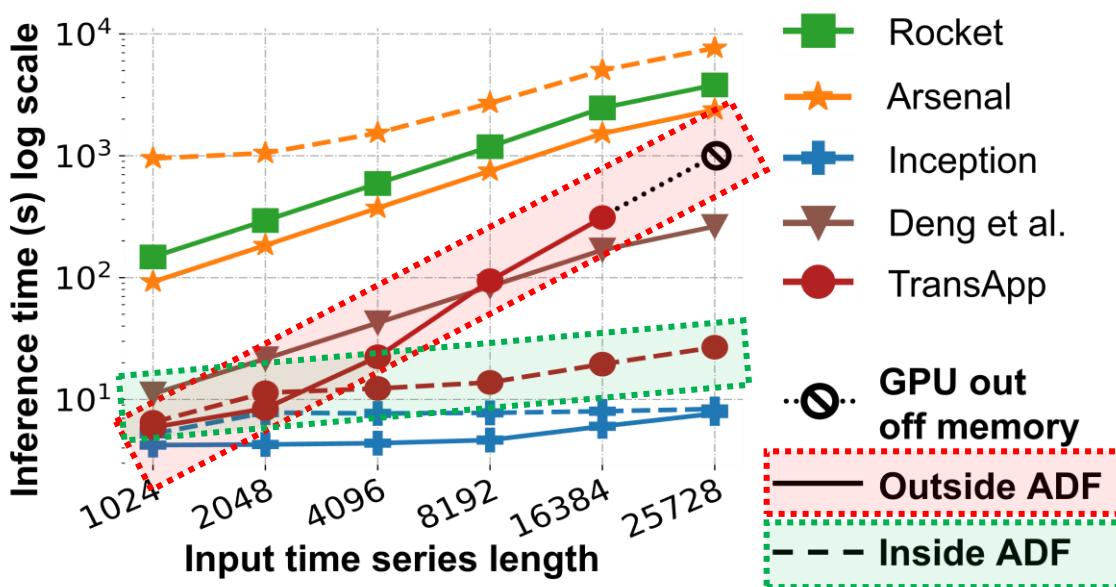
AC/Heatpump



Water Heater

Experiments: scalability

ADF makes TransApp scalable to large electricity databases of long consumption series



EDF database
20M clients recorded \approx 1years

To run through the **entire EDF's client consumption database**



ADF & TransApp

\approx 4.5days

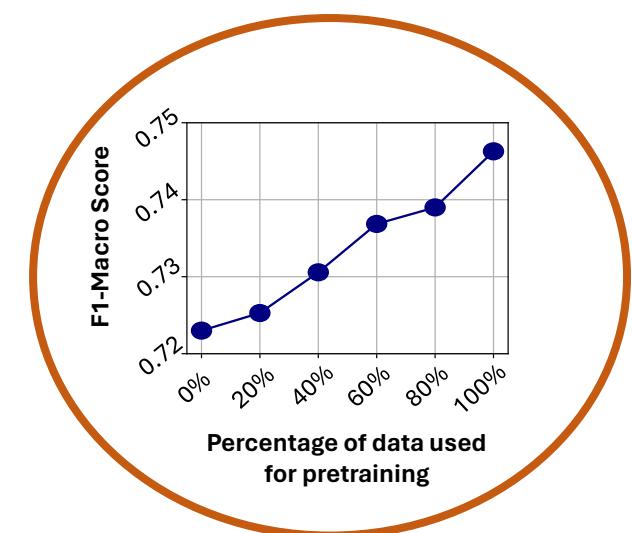
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ADF & Arsenal
(2nd most accurate solution)

\approx 210days

Conclusions

1. ADF improves quality detection of time series classifiers on appliance detection problem.
 2. TransApp effectively exploits large amount of unlabeled data.
 3. ADF renders TransApp scalable to real world consumption series databases.
- ADF & TransApp is an accurate and scalable solution to detect appliances using real-world consumption smart meter signal.
 - Promising open research direction: large time series model for electricity consumption data analytics.



Thank you!

Contact: adrien.petralia@gmail.com



Université
Paris Cité



*Want to learn more about
our work?*

ADF & TransApp Github and Paper



Very
Large
Data
Bases



*or join me at the poster
session!*