

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

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# Background: Efficient Energy Management

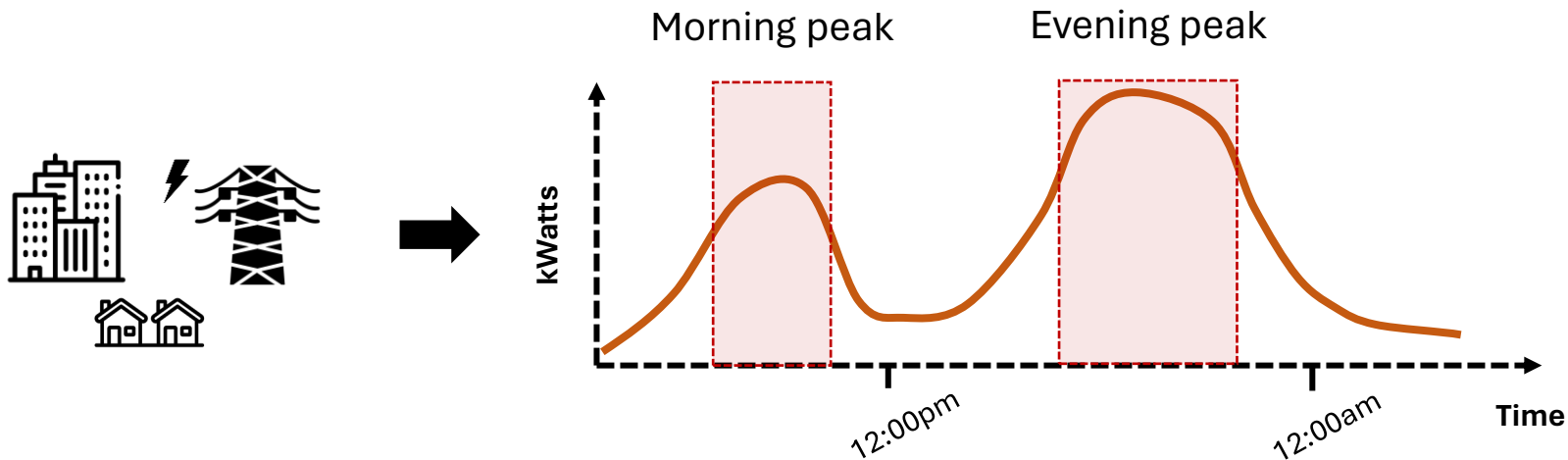
## Energy savings is crucial to fight against climate change



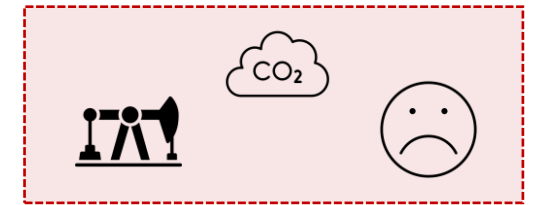
In the European Union (EU), **individual households** represented **26%** of final **energy consumption**



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



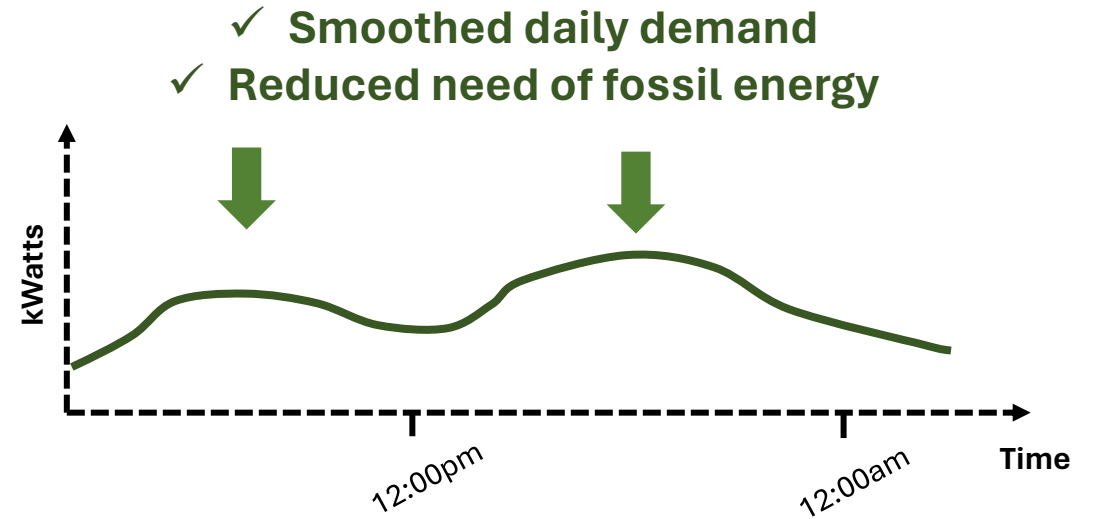
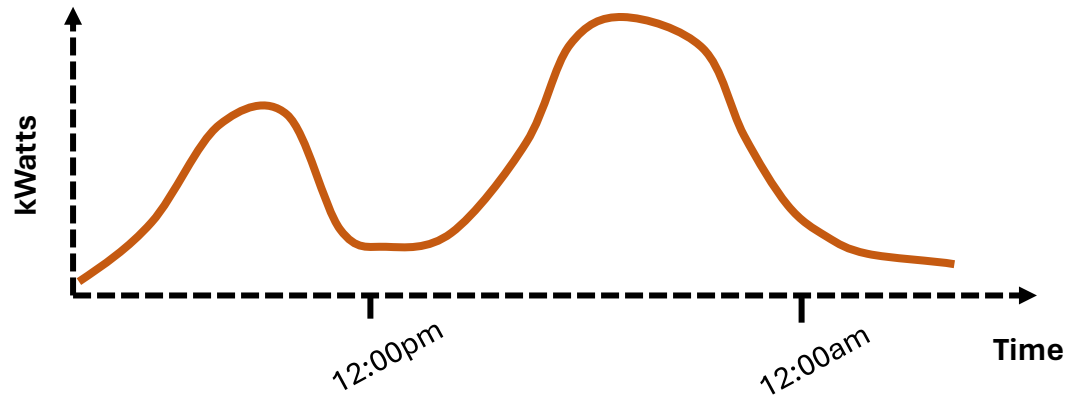
Typical **daily electricity grid demand** (load curve)



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

# Background: Efficient Energy Management

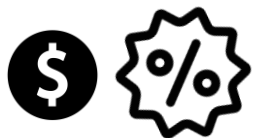
## Reducing peak demand



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

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

**By offering personalized contracts!**

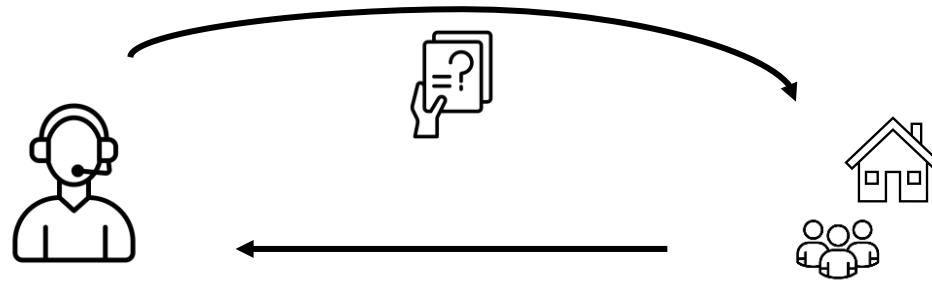


- **50% discount** to charge your **electric vehicle** by night
- **50% discount** to reduce your **heater usage** during peak hours



# Background: Gathering consumers' data

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



Ask directly customers?



**1. Time consuming**

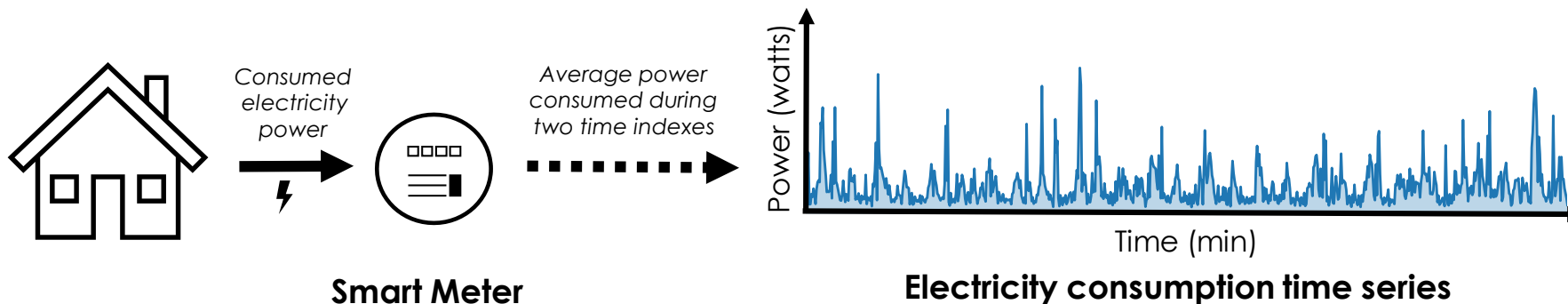


**2. Prone to error**



**3. Not well received by customers**

Millions of Smart Meters deployed in individual households



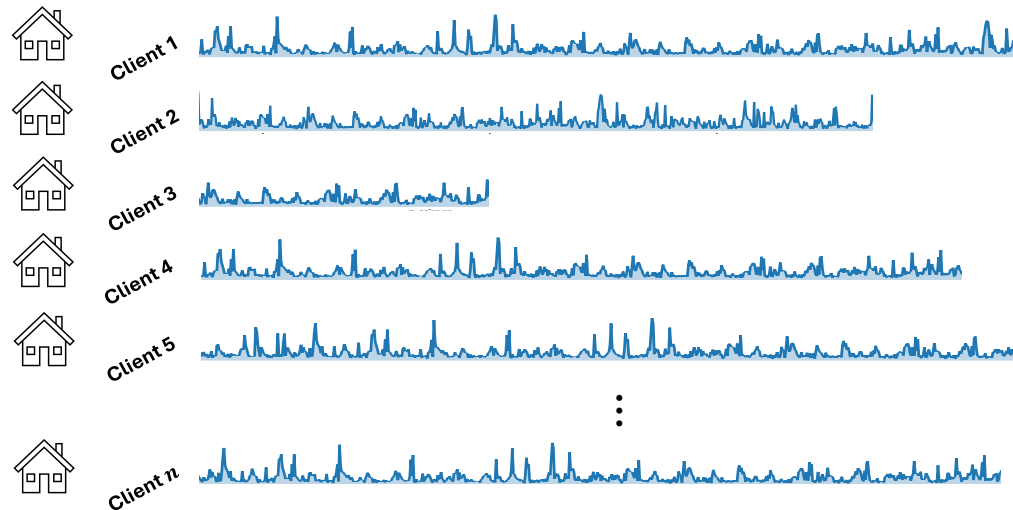
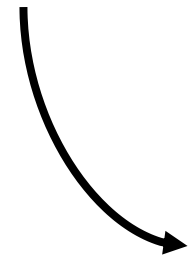
# Background: Electricity consumption data

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

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



**Electricity Consumption Database**  
(Millions of clients)



**Recorded smart meter consumption**

Electric Vehicle	Heater	AC	Water Heater	Cooker	Washer
?	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	?	<input checked="" type="checkbox"/>	?
<input checked="" type="checkbox"/>	?	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	?	<input checked="" type="checkbox"/>
?	<input checked="" type="checkbox"/>	?	?	<input checked="" type="checkbox"/>	?
?	?	?	?	?	?
?	?	?	?	?	?
⋮					
?	?	?	?	?	?

Houses involved in  
**survey studies**

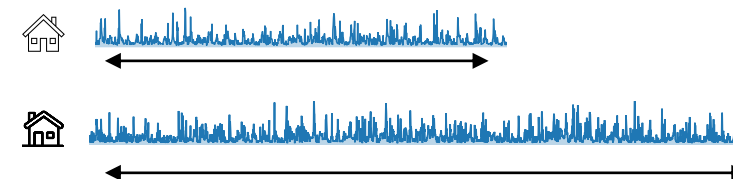
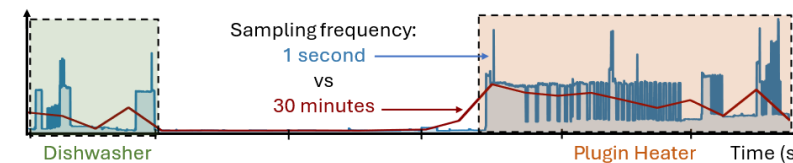
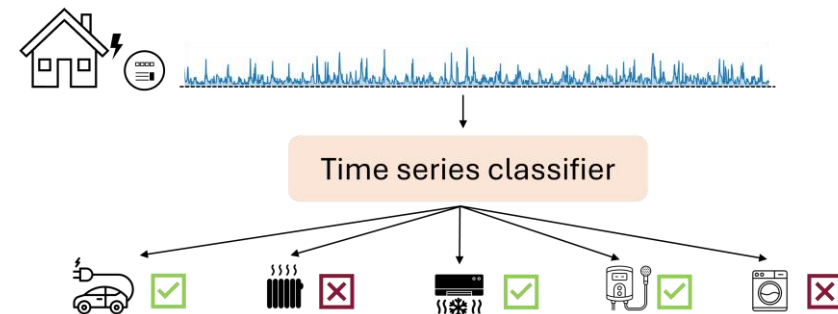
**Households' characteristics**

# 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?*

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## 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

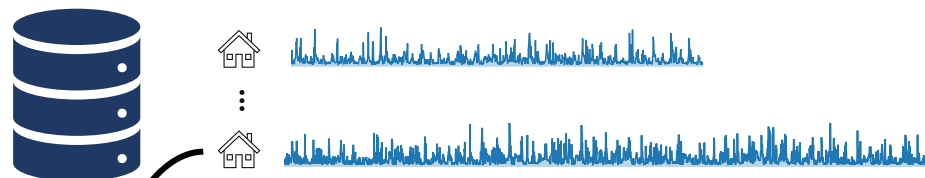
- ✓ The **Appliance Detection Framework (ADF)**
  - **Improve** classifiers detection accuracy
  - Make classifiers **insensitive to the length**
- ✓ **TransApp**: a deep-learning time series classifiers
  - **Pretrained** on large amount of non-labeled data to improve its accuracy
  - **Scalable** to large database of long series (thanks to ADF)

# Proposed Approach: ADF

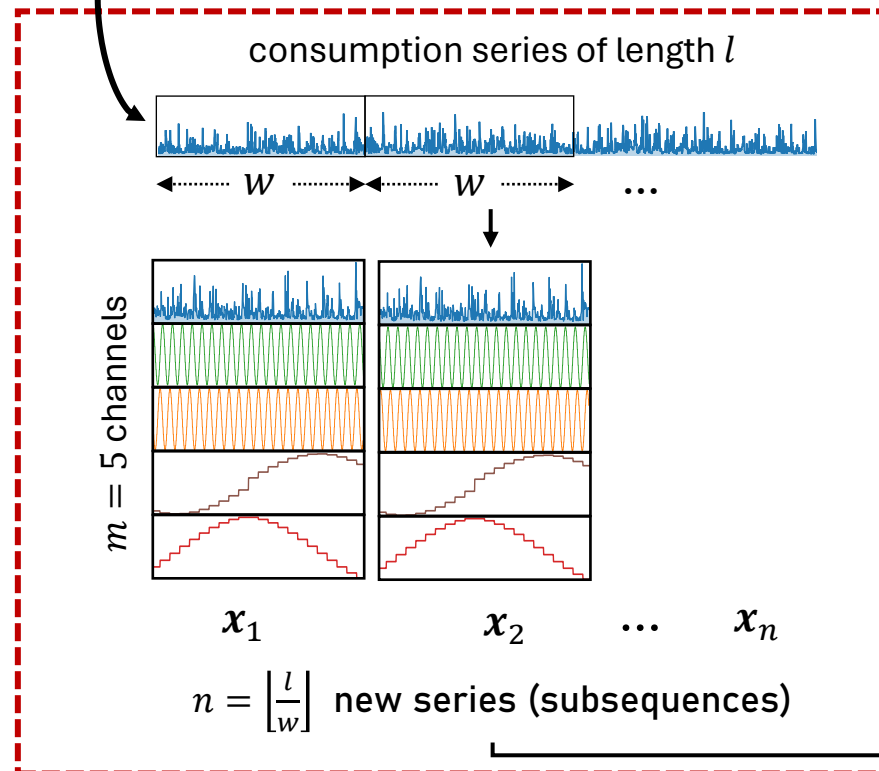
## The Appliance Detection Framework

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

Electricity consumption database



Extraction



Update



$$Q_{P_X}(\alpha_a^*)$$

$(\alpha_a^* - th \text{ quantile of } P_X)$

$$P_X = (p(x_1), \dots, p(x_n))$$

**TransApp**  
(or any trained time series classifier)

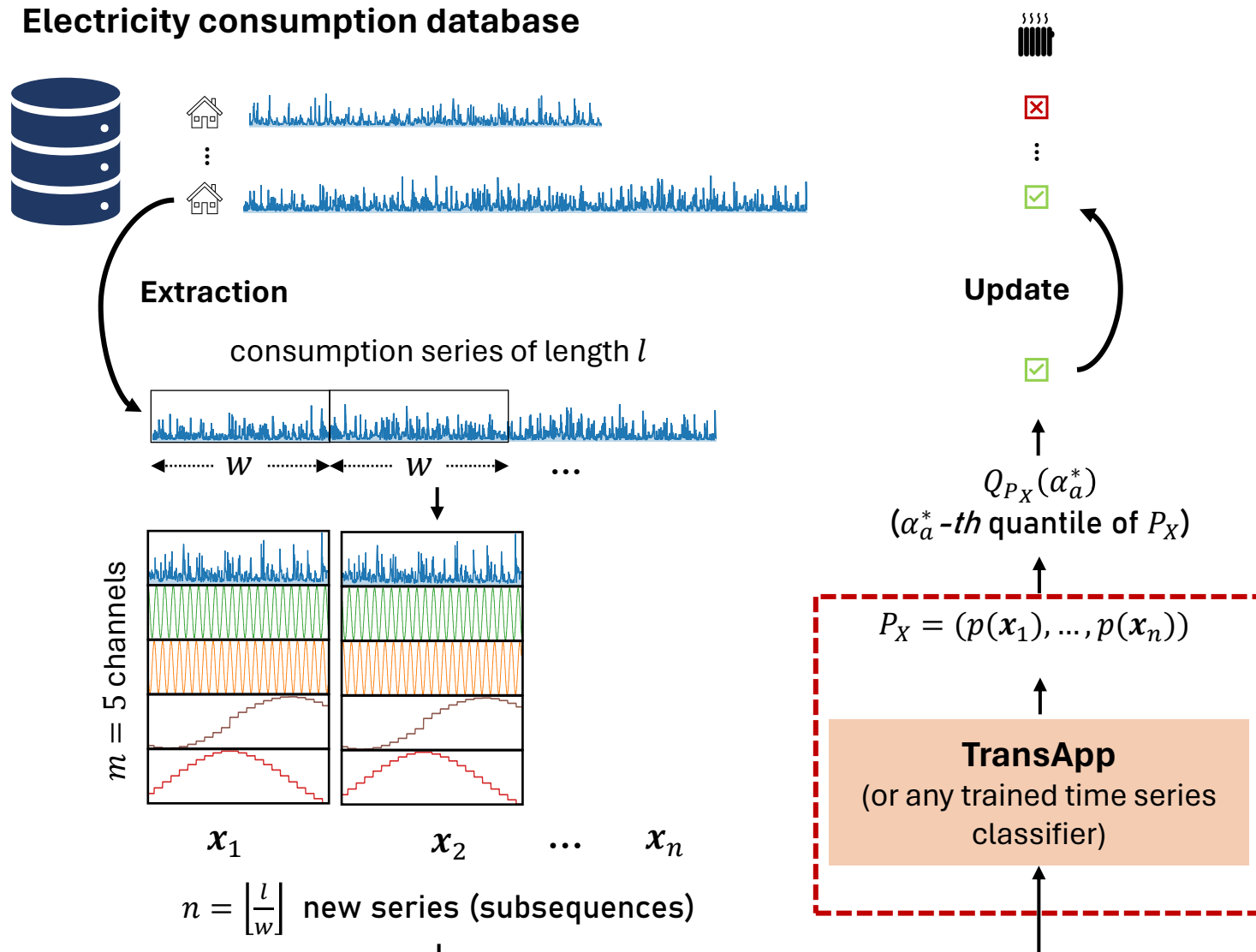


# Proposed Approach: ADF

## The Appliance Detection Framework

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

2. TransApp predicts probabilities for **each** subsequences



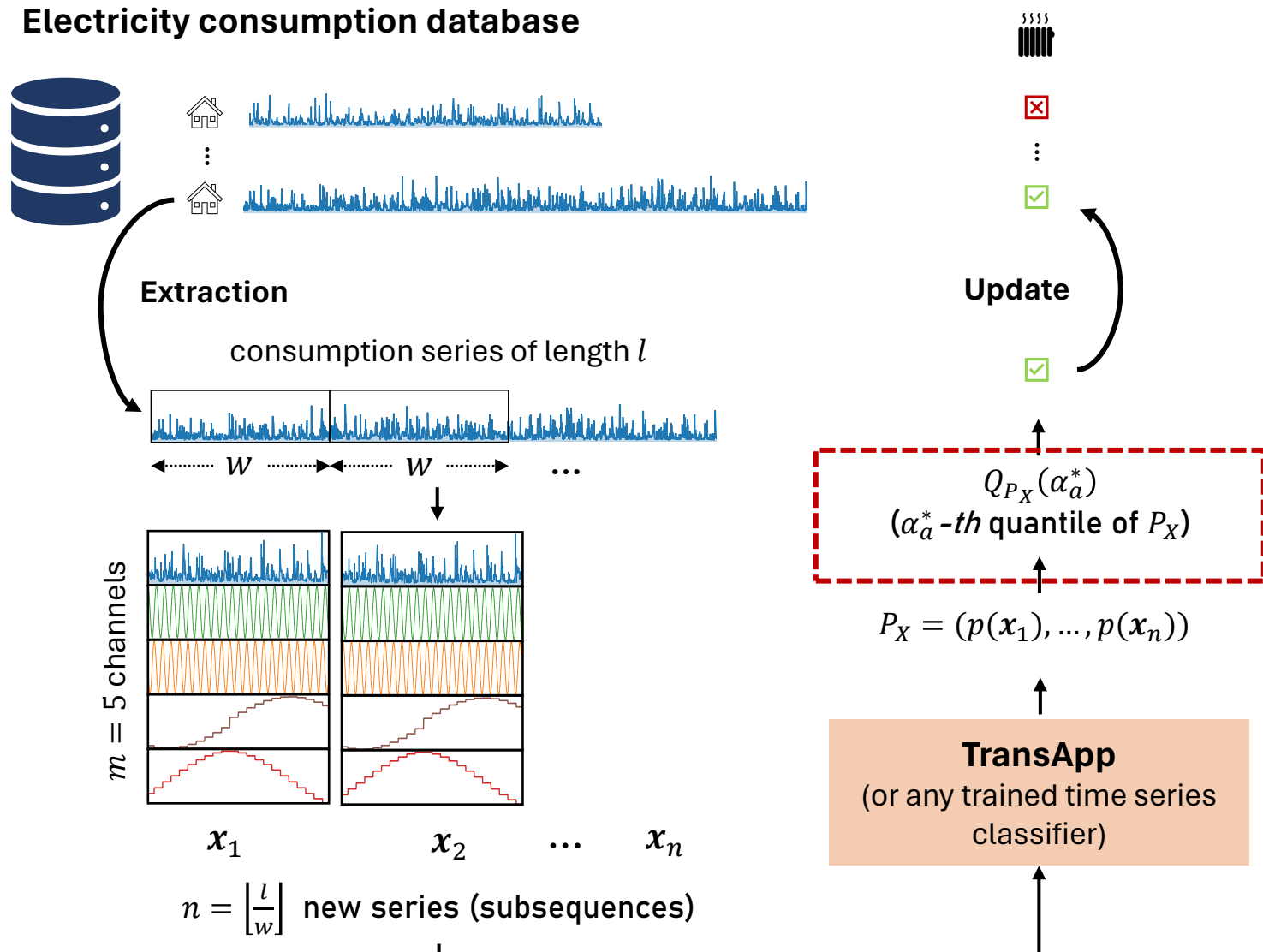
# Proposed Approach: ADF

## The Appliance Detection Framework

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

2. TransApp predicts probabilities for **each subsequence**

3. **Merge predicted probabilities** by extracting best quantile



# Proposed Approach: ADF

## The Appliance Detection Framework

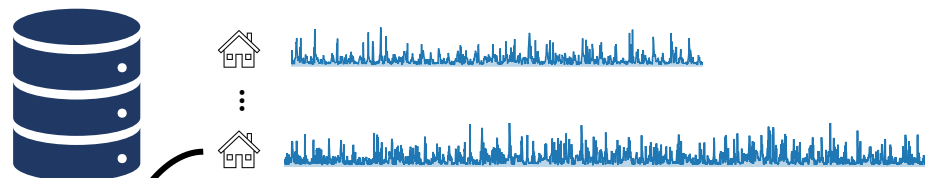
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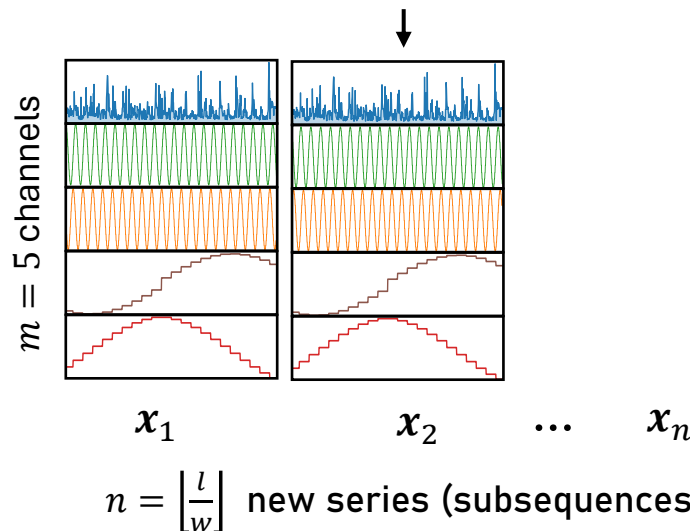
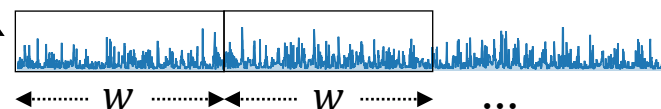
4. Determine the final **label prediction**

Electricity consumption database



Extraction

consumption series of length  $l$



Update

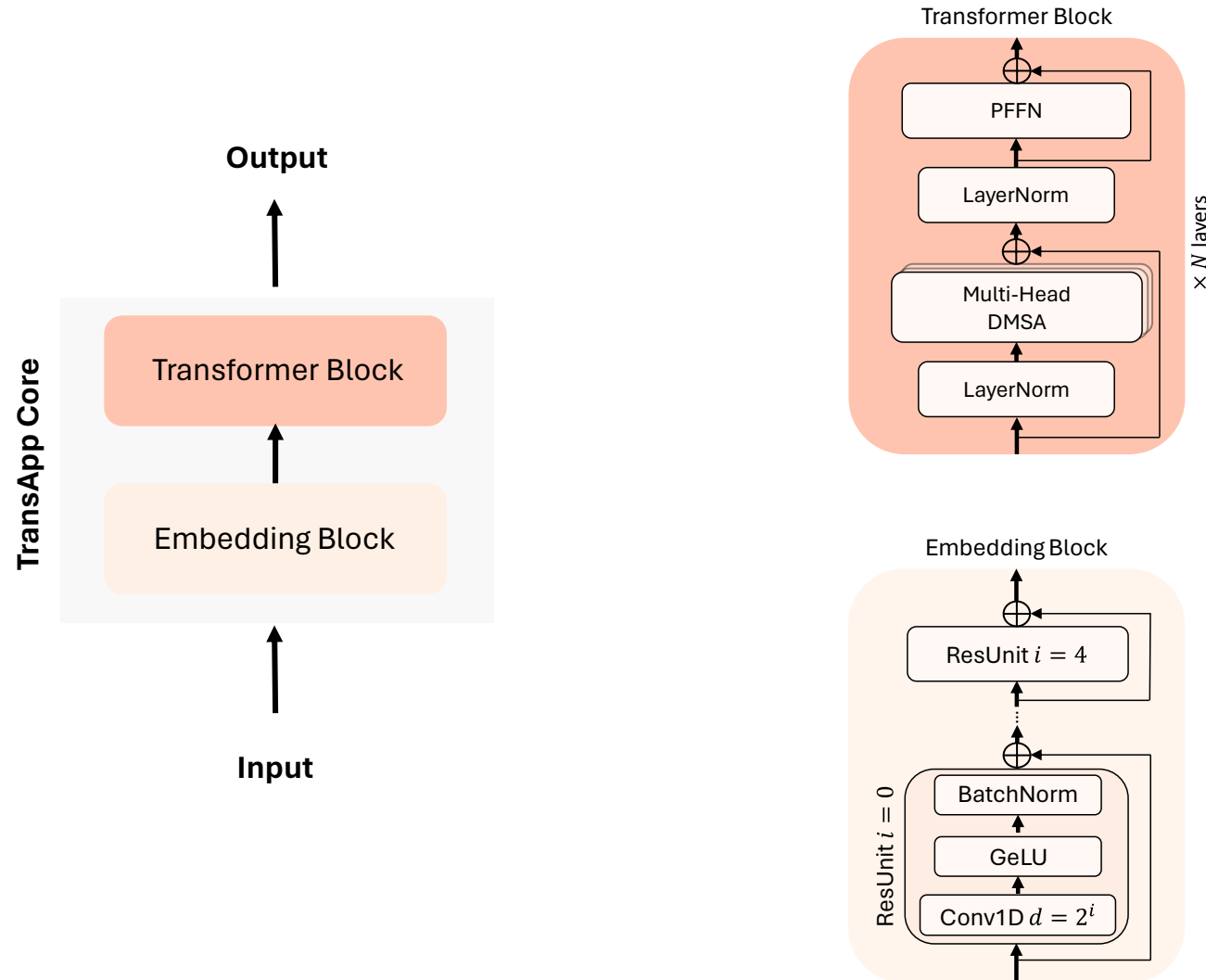
$Q_{P_X}(\alpha_a^*)$   
( $\alpha_a^*$ -th quantile of  $P_X$ )

$P_X = (p(x_1), \dots, p(x_n))$

**TransApp**  
(or any trained time series classifier)

# Proposed Approach: TransApp

**TransApp:** A simple deep-learning architecture



**A Transformer Block** to learn electricity consumption series representation

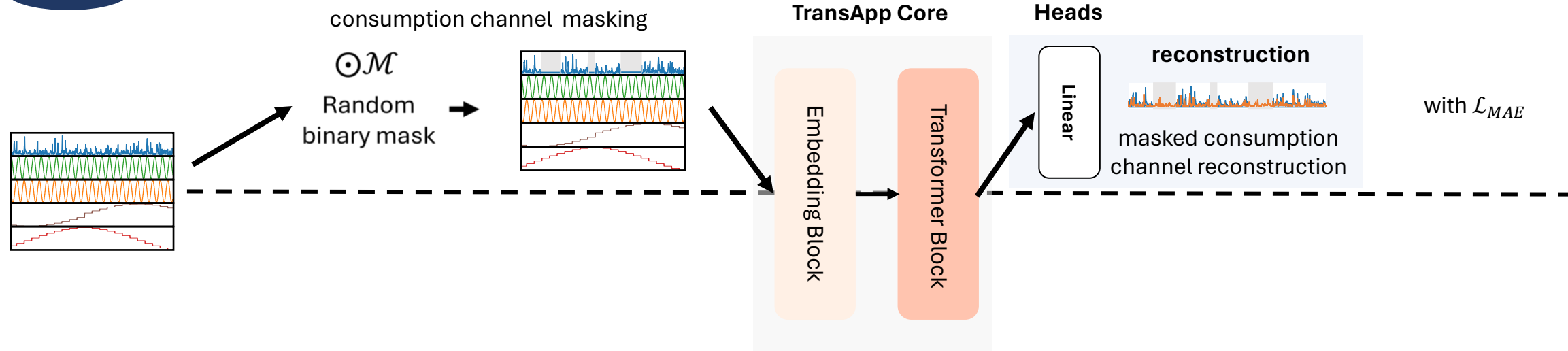
**A strong convolutional Embedding Block** to extract localized patterns

# Proposed Approach: TransApp

## TransApp: Two-steps training process

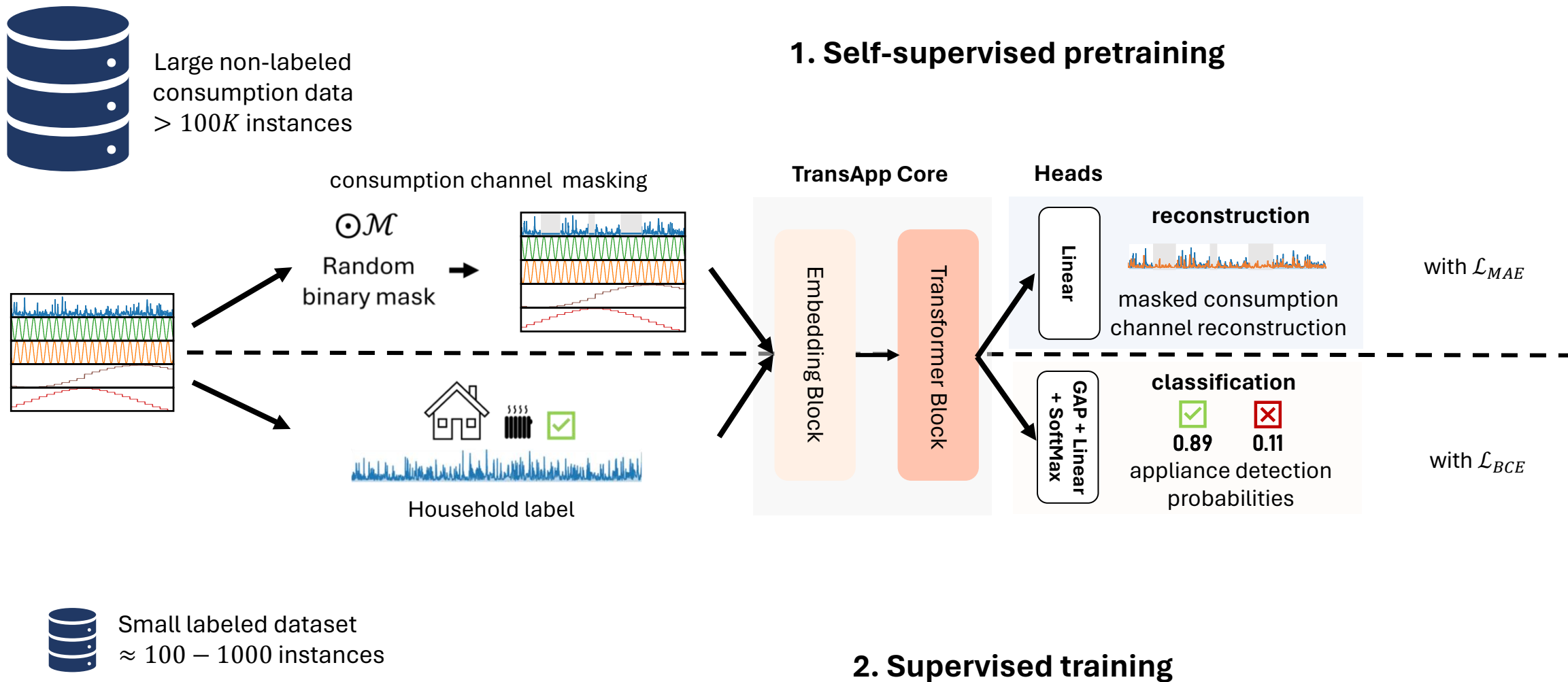


Large non-labeled  
consumption data  
> 100K instances



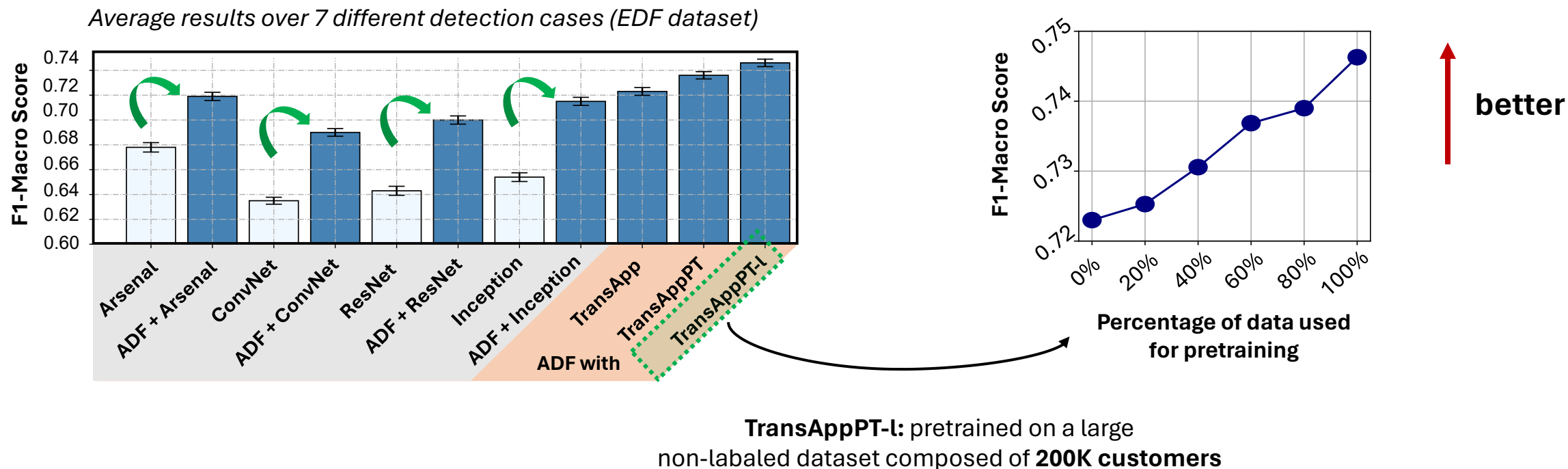
# Proposed Approach: TransApp

## TransApp: Two-steps training process



# Experiments: appliance detection quality

## Detection Accuracy Results



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



Electric Vehicle



Heater



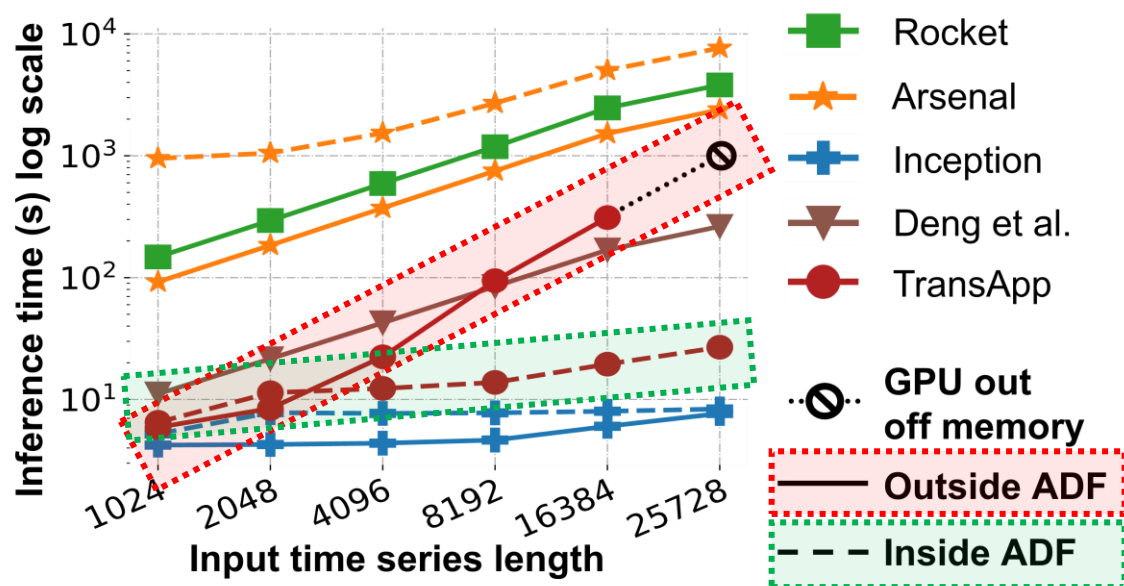
AC/Heatpump



Water Heater

# Experiments: scalability

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



**EDF database**

20M clients recorded  $\approx$  1 years

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



**ADF & TransApp**

**ADF & Arsenal**  
(2nd most accurate solution)

$\approx$  4.5days

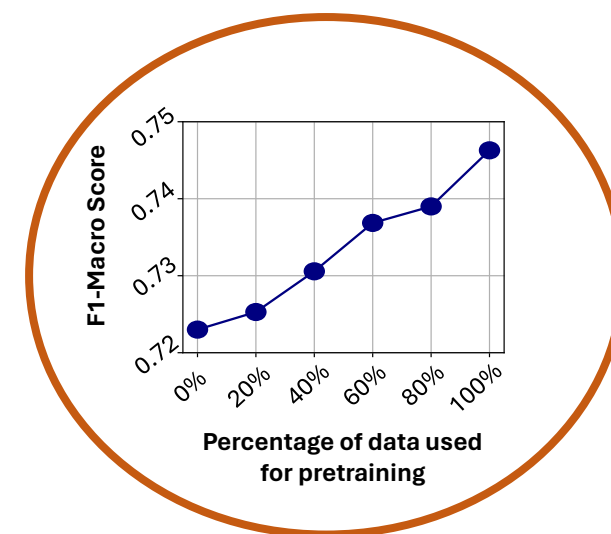
<<<

$\approx$  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



*Want to learn more about  
our work?*

**ADF & TransApp Github and Paper**



Very  
Large  
Data  
Bases



*or join me at the poster  
session!*

