COM SENSUS

# EnCODE: Energy Consumption Disaggregation

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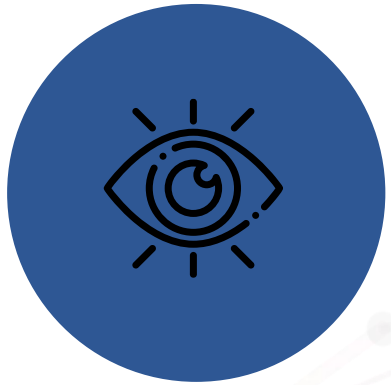
# EnCODE Overview

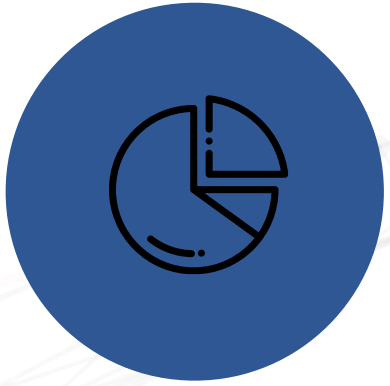
## Theme-Driven Challenge

The goal of this challenge is to disaggregate the energy consumption from central load to individual device loads in an unobtrusive manner.



## Consumption Disaggregation

Energy consumption disaggregation to inflexible (lighting, cooking …), flexible (EV, battery, heating …) and self-generation (PV) baselines.



## Consumption Prediction

Prediction of aggregated and per load future energy consumption and production.

## Data Management and Sharing

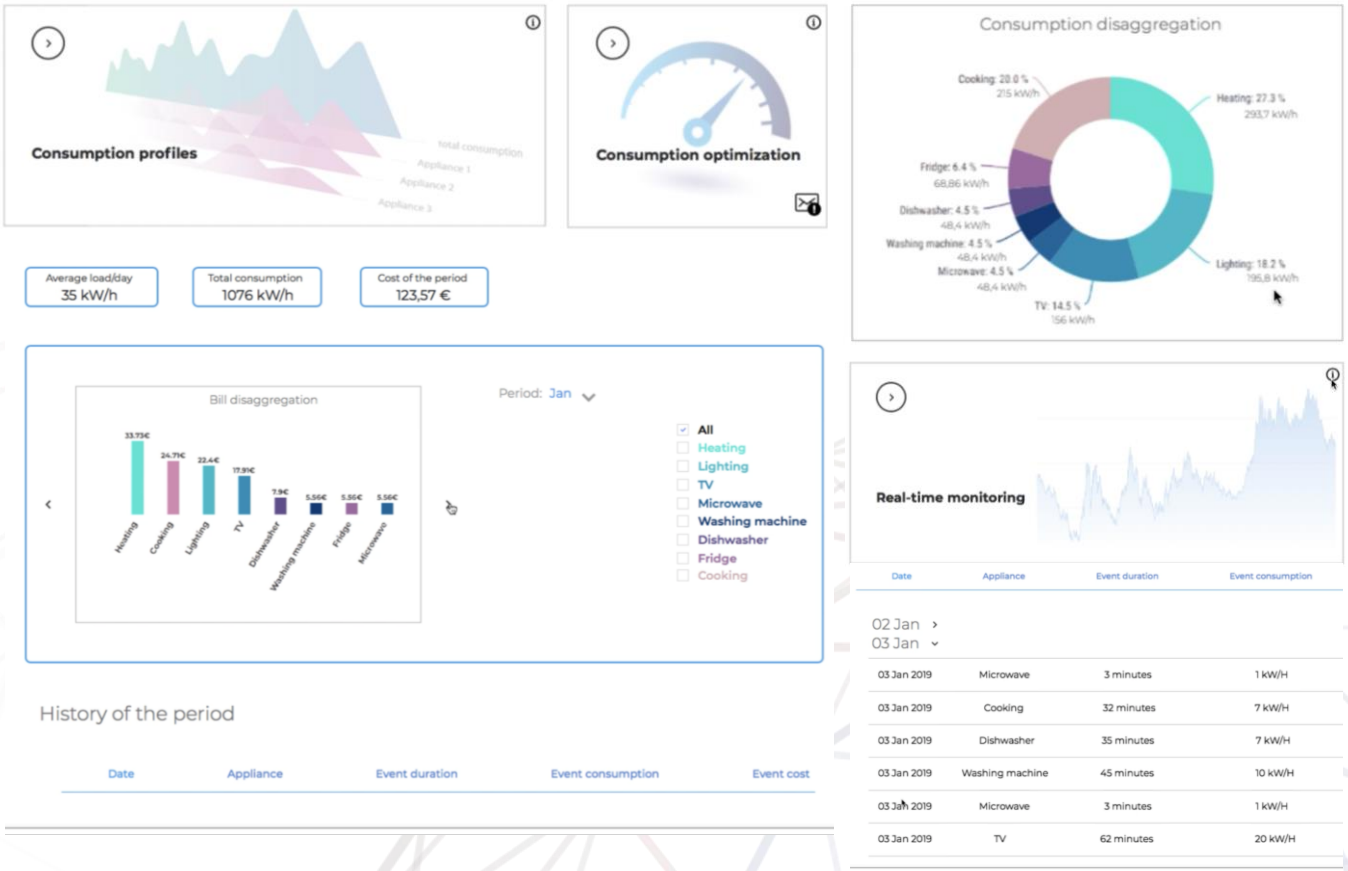
Private and confidential data management, exchange, and regulatory compliance.

# Problem & Motivation

- Energy transition is imposing multiple challenges
- Massive amounts of renewable and DER
- Deficient low voltage grid observability
- Low coordination of energy management systems at different levels
- Hardware or data availability issues
- Inaccurate/nongranular consumption/generation models
- Secure data value chain management difficulties

# Proposed Solution

- **Exploit existing infrastructure and assets**
- **Disaggregation, NILM, consumption and production prediction, clustering**
- **AIaaS aimed at**
  - Flexible load detection and characterization
  - Load and user segmentation
  - Grid optimization and planning

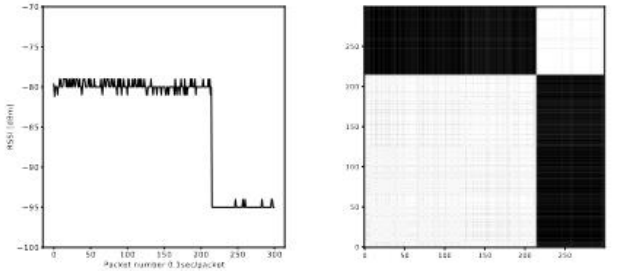


# Disaggregation & Prediction

- **Model development will base on several datasets**
  - CERTH energy, AMPds (REACH challenge)
  - UK-DALE, ECO, REDD, IAWE, REFIT, BLOND, PLAID (open)
  - Elektro Ljubljana, Elektro Celje, Energie Steiermark, ASM Terni, SONCE (partners)
- **Machine learning approaches applying deep learning**
  - Features for regression/classification models
    - Input: Aggregated and/or per appliance load profiles, consumption/production, weather, …
    - Target: ON/OFF and appliance type labels or energy consumption/production prediction for various time horizons (aggregated and per load type level)

# Disaggregation & Prediction

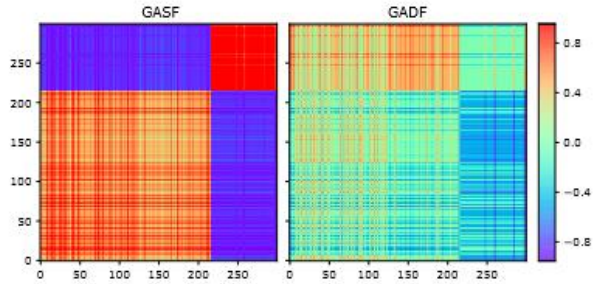
- Application of resampling strategies, windowing, transformation approaches (timeseries-to-image using recurrence plots, Gramian Angular Fields, …)
- Backbone models fine-tuning using transfer learning approaches



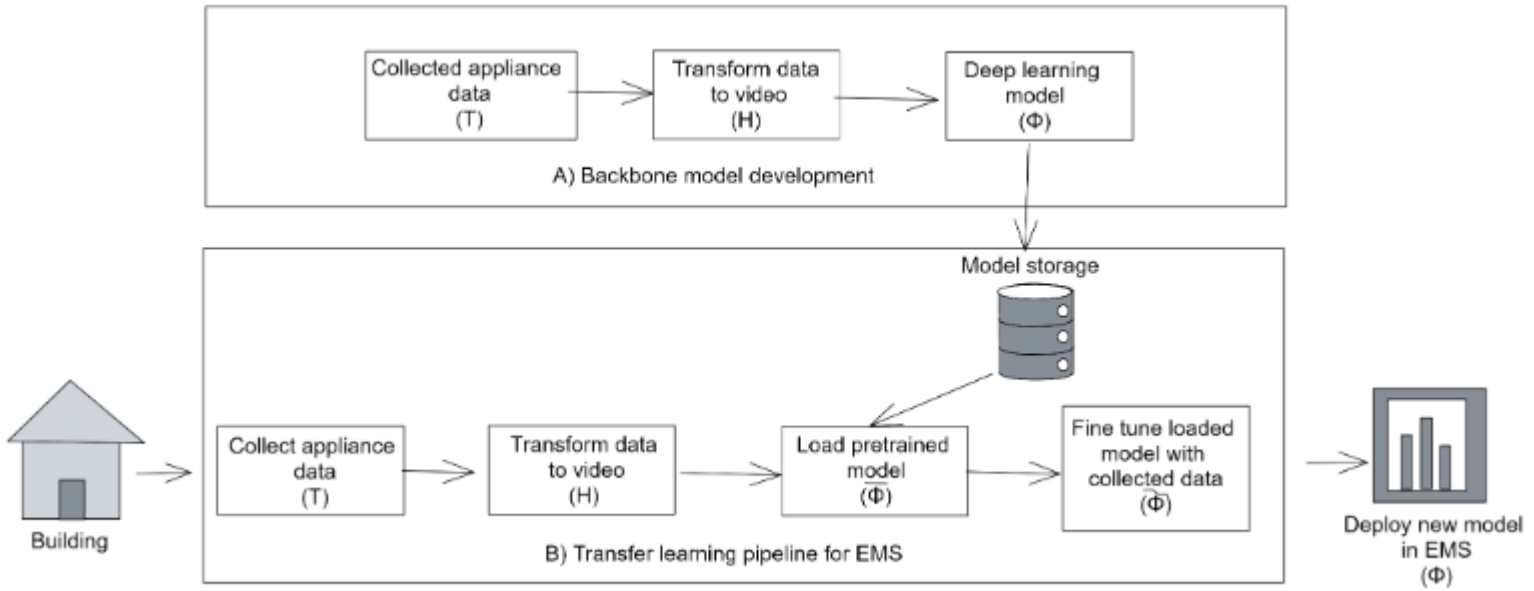
(a) Time-value perspective



(b) Recurrence plot transformation




(c) Gramian angular fields transformation

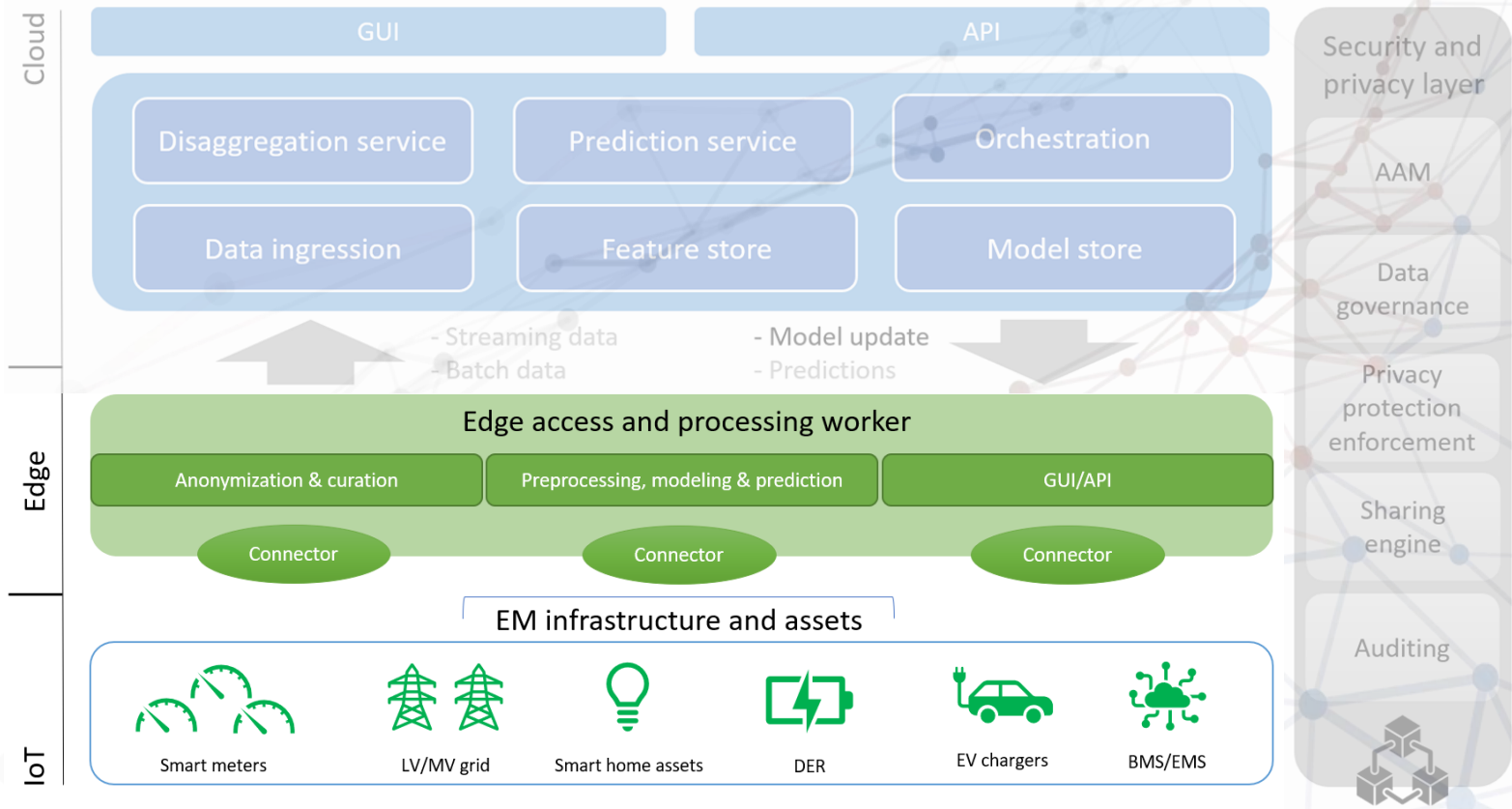


# Disaggregation & Prediction

- **The ML pipeline will be built using state-of-the-art toolbox**
  - Python, Keras, PyTorch, Tensorflow
  - AutoML, Neural Architecture Search
- **Flexibility of the solution is ensured through**
  - Swapping the data pre-processing pipelines
  - Transfer learning, backbone models adaptation (grid parameters, load profiles, …)
  - Generic time series prediction models (e.g., water, heat or gas consumption)
  - Disaggregation algorithm application to event detection/classification (e.g., water tap on, heat loss, gas leak, …)
- **Scalability approaches employing data sampling and windowing techniques as a trade-off between accuracy/granularity and computation/storage**

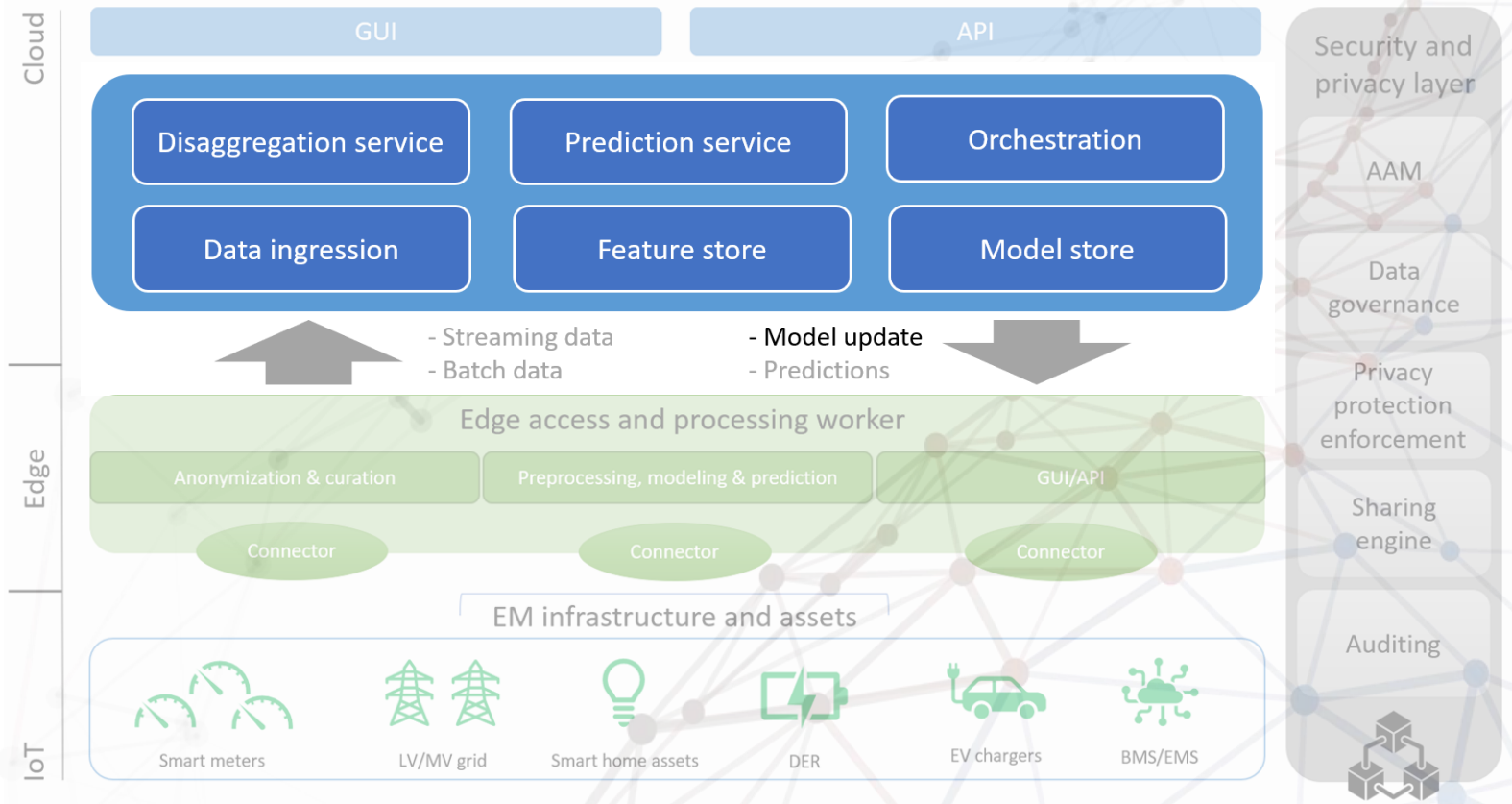
# Technical Approach

- **Layered architecture**
  - IoT, edge, cloud
- **Existing infrastructure**
  - Data connectors
  - Smart meters, LV/MV, …
- **Edge processing worker**
  - Distributed approach
    - On-premises processing
    - Anonymization, federated learning, edge prediction
    - Vertical and horizontal scalability, reduced transfer



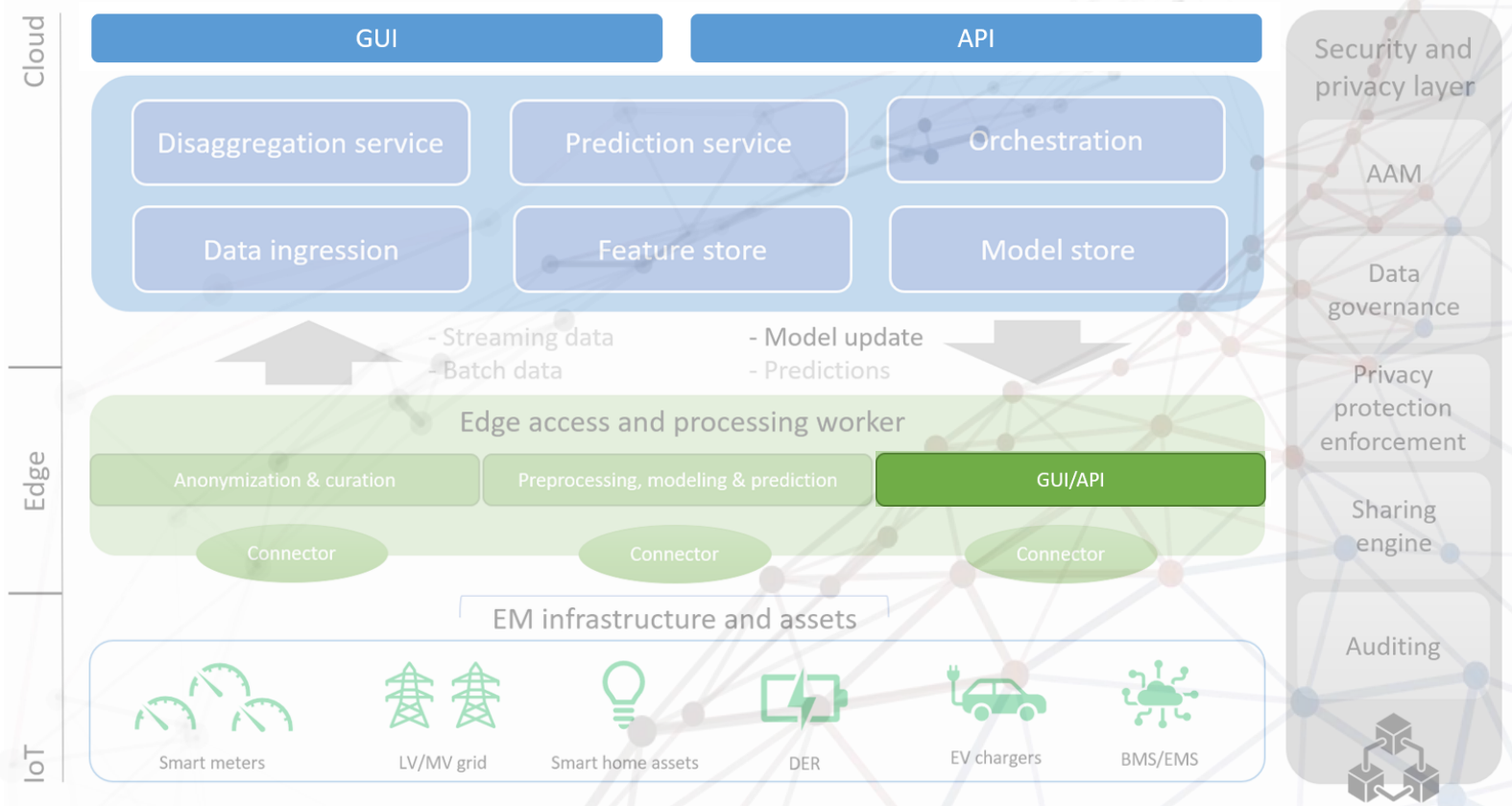
# Technical Approach

- **ML pipeline**
  - Data ingression
    - Streaming, batch
  - Feature/model store
  - Evaluation, monitoring
  - Services
    - Disaggregation, prediction



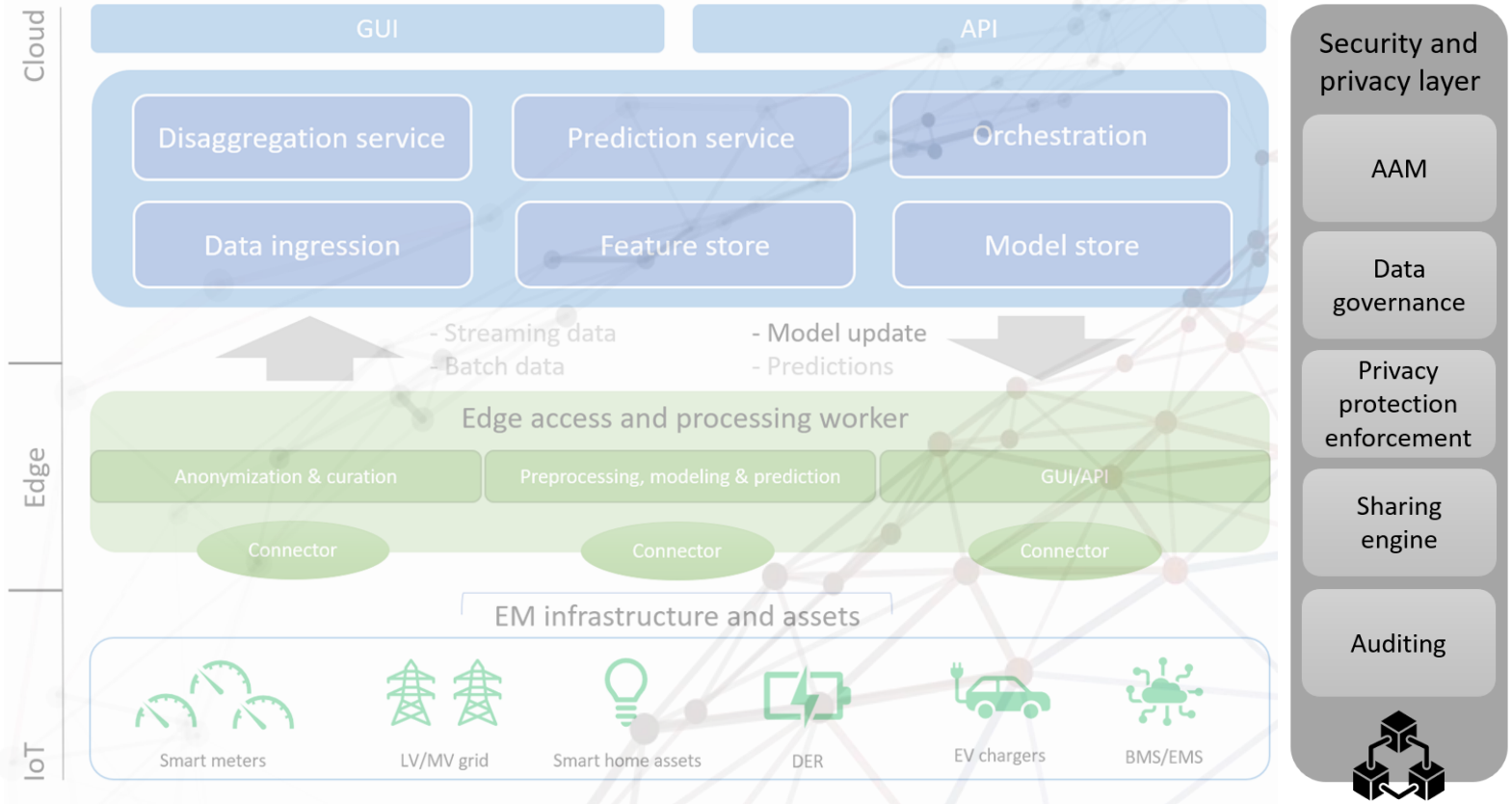
# Technical Approach

- **GUI, API**
  - Cloud, edge



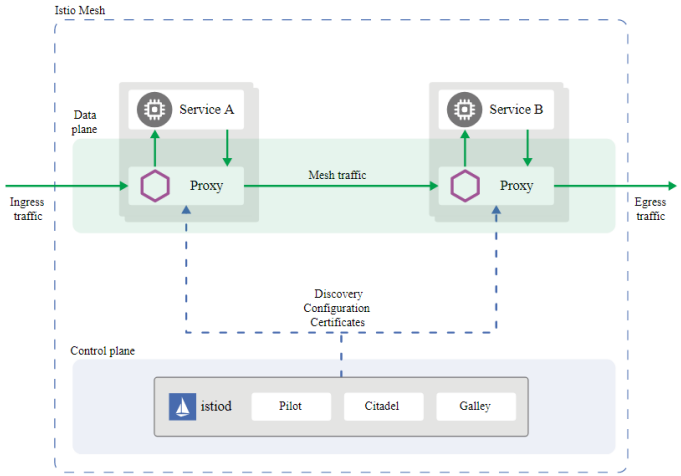
# Technical Approach

- **Security/privacy vertical**
  - AAM
  - Auditing
  - Sharing
  - Data governance
  - Privacy



# Security

- **Authentication, authorization, and auditing mechanisms**
  - Open-source Identity and Access Management tool – Keycloak
  - Blockchain-enabled authorization policies, reputation, and auditing tool
    - Privacy Protection Enforcement (H2020 PHOENIX)
- **Application of cryptographic methods**
  - Public key infrastructure (PKI)
  - Data encryption at rest and in transit
- **Service mesh for service-level security and monitoring**
  - Open-source service mesh tool – Istio
- **REACH Toolbox for Secure and Trusted Data Services**
  - BaaS, Audit Messages Storage Platform, Smart Contracts Verifier, ProRegister



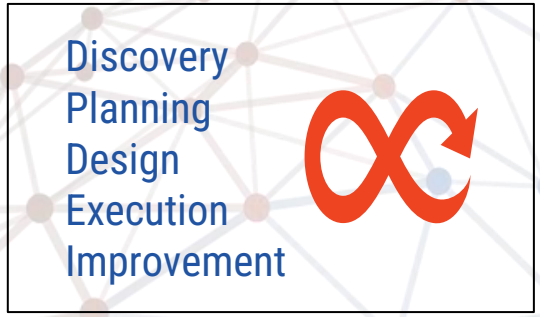
Istio Architecture

# Compliance & Data Governance

- **Application of privacy techniques on personal/confidential data**
  - Data anonymization and curation process
  - On-premises data processing, federated machine learning
- **Blockchain-based GDPR-compliant sharing/exchange of data**
  - Data registration, consent exchange, data access/usage policy definition, comprehensive auditing functionalities and actor reputation assessment
  - Control and transparency over entire data lifecycle, and data sovereignty
- **Adoption of additional complementary components**
  - International Data Spaces (IDS) components
    - IDS Connector
  - Other components of the REACH toolbox (Data Sharing Tool, FedEHR Anonymizer)

# Quality Process

- **Agile quality process**
  - Continuous risk/concern assessment, evaluation, and mitigation
- **Design, development and testing according to standards and best practices**
  - Continuous integration and delivery (CI/CD)
  - Automated testing (unit, integration, security)
  - Shift-left paradigm implementation
  - Focus on user experience, bug prevention and reliability
  - Continuous verification/validation according to specification and requirements
- **Continued monitoring of production deployment, alarms**
- **Certification of components where applicable (e.g., IDS)**



# Potential Risks

| Risk | Mitigation |
|---|---|
| Insufficient/inappropriate model training data. | Ongoing discussions with relevant data providers and potential pilots. |
| Computational complexity of number of assets that need to be characterized. | The window function and the calculation time step will be adjusted. |
| Inadequate horizontal and vertical scalability. | Shift to commercial cloud solutions (e.g., AWS, Google Cloud, …). |
| Incompatibility of IDS and REACH toolbox. | Extend in-house solutions or adopt other identified commercial/open-source solutions. |
| Insufficient developed model performance. | Use existing in-house solution, collect more data, apply different data transformations and algorithms. |

# Our Related Work

- **Review**
  - A. Belay, S. Puranik, R. Gallart-Fernández, H. Tuiskula, J. Melendez, I. Lamprinos, F. González-Díaz, and M. Smolnikar: ***Developing Novel Technologies and Services for Intelligent Low Voltage Electricity Grids : Cost–benefit Analysis and Policy Implications***, Energies, 2022 [DOI: 10.3390/en15010094]
  - A.E. Saldaña-González, A.Sumper, M. Aragüés-Peñalba, and M. Smolnikar: ***Advanced Distribution Measurement Technologies and Data Applications for Smart Grids: A Review***, Energies 2020, [DOI: 10.3390/en13143730]
  - D. Sodin, U. Rudež, M. Mihelin, M. Smolnikar, and A. Čampa: **Advanced Edge-Cloud Computing Framework for Automated PMU-Based Fault Localization in Distribution Networks**, Applied Sciences, 2021 [DOI: 10.3390/app11073100]
- **NILM**
  - D. Lorbek Ivančič, B. Bertalanič, G. Cerar, and C. Fortuna: **Learning to Automatically Identify Home Appliances**, SiKDD conference, October 2021
  - L. Ogrizek, B. Bertalanič, G. Cerar, M. Meža, and C. Fortuna: **Designing a Machine Learning Based Non-Intrusive Load Monitoring Classifier**, ERK Conference, September 2021
- **+ some in submission**

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# Thank you!

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# Vision

- Now
  - Technology building blocks
  - GDPR+AI
- REACH
  - Break silo approach
  - B2B2C
- Beyond
  - Create revenue opportunities
  - C2B2B