THE I-NERGY REFERENCE ARCHITECTURE FOR THE PROVISION OF NEXT GENERATION ENERGY SERVICES THROUGH ARTIFICIAL INTELLIGENCE

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Outline

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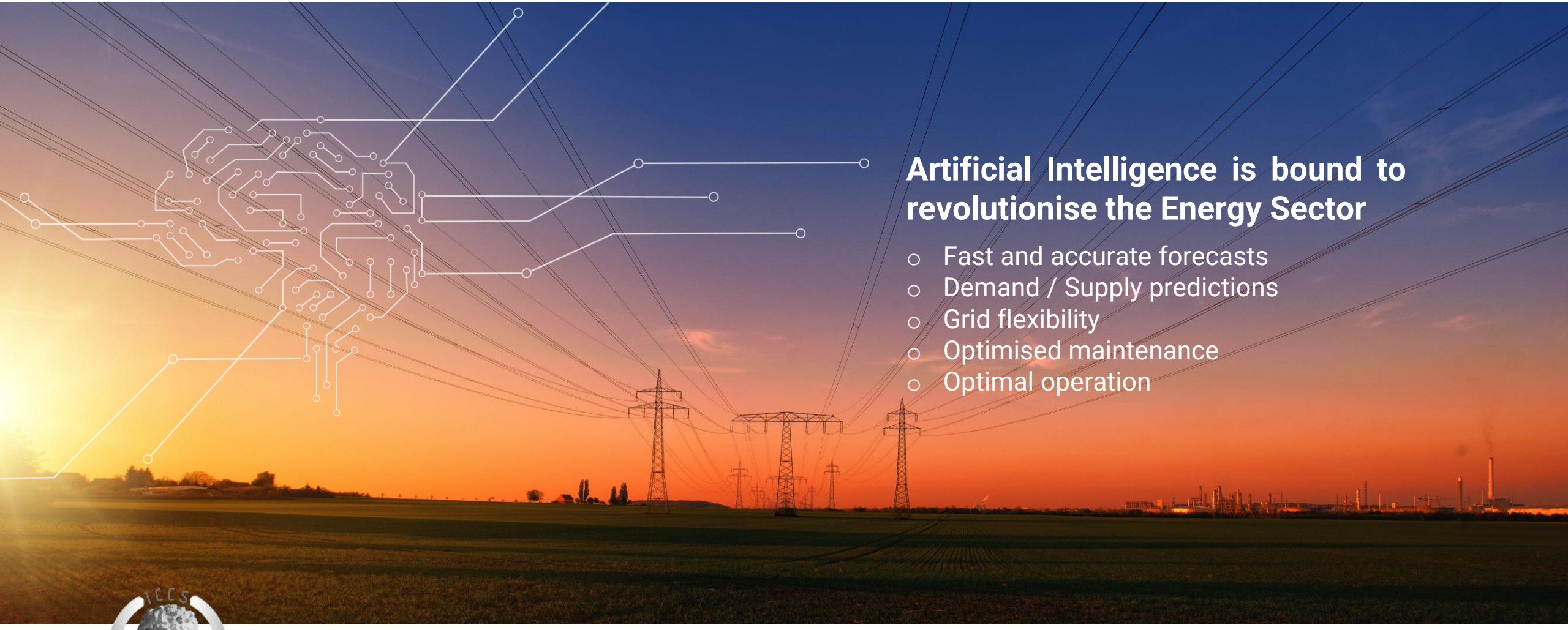
Introduction and Motivation (1/2)



Artificial Intelligence is bound to revolutionise the Energy Sector

- Fast and accurate forecasts
- Demand / Supply predictions
- Grid flexibility
- Optimised maintenance
- Optimal operation

Introduction and Motivation (2/2)

AI proliferation in the **energy** sector holds the premise for a larger **environmental** and **social impact**

- Decentralisation,
  Democratisation
  Digitalisation
  } of energy

- Environmental sustainability
- Alleviating energy poverty
- Fighting climate change and environmental degradation

Challenges to be addressed

- **EPES Community**
  - Lack of appropriate tools for capturing the real time dynamics
  - Scarcity of and competition for AI experts
  - Need for knowledge transfer to and for training AI in new contexts

- **@ Application Level**
  - Lack of holistic view of how AI techniques can be integrated from the energy system perspective
  - Lack of a cross-stakeholder coordination perspective
  - Fear of AI and potential misuse

- **@ ML Models Level**
  - Lack of system-level data models (going well beyond the asset–level models)

- **@ Data Services Level**
  - Existence of consolidated functional / organisational silos combined with lack of semantic and business interoperability across data stream providers

I-NERGY Project Vision

Deliver an energy-specific **open modular framework for supporting AI-on-Demand in the energy sector (AI4 Energy)**

Based on state-of-the-art AI and Data technologies

Energy Commodities Networks: AI for energy networks optimised operation

Distributed Energy Resources: AI for RES generation, buildings, districts, communities

Energy Efficiency and Non-energy related Services: AI enabling synergies / implications on other energy and non-energy domains

… and Objectives

O1. Reinforce the service layer of the AI-on-demand-platform:

O1.1 **Strengthen European-wise Research and Innovation on AI** through synchronising, liaising, contributing and extending the AI4EU Platform service and research across a variety of cross-fertilisation activities, which bring AI4 Energy vertical center stage.

O1.2 **Deliver** a TRL 7 DLT/blockchain/smart contract-based implementation of an **energy data decentralised governance technological enabler**.

O1.3 Adapt, evolve, upscale and deploy a TRL 7 technology enabler for advanced AI-based data management, learning and analytics, and **deploy the I-NERGY Energy Analytics Applications** along different deployment modes, ranging from experimental on-premise sandboxes to AI-as-a-Service (AIaaS) Energy Analytics operation.

O2. Reach out to new user domains and boost~~ing~~ the use of the platform through use cases and small-scale experiments:

O2.1 **Validate** the I-NERGY analytics by developing a variety of near real time edge-level AI-based descriptive, predictive and prescriptive analytics, along a number of **cross-function, cross-stakeholders, cross-domain piloted applications.**

O2.2 Lay the foundation for p**an European AI for energy ecosystem**, boosting EU-scale data economy and use cases experiments by leveraging on systematic **community-building and financing support** to innovative technology/solution provider from **EPES community**.

Problem setting

Design and implementation of a software architecture that facilitates:

- Robust AI models and services development, training, and deployment for the energy sector
- Robust Big Data Analytics applications for the energy sector
- Data, knowledge, and AI models sharing across all over Europe
- Provide services covering the entire energy value chain

While addressing the commonly encountered issues of

- heterogeneity of data and data quality
- cybersecurity
- Access control and identity management

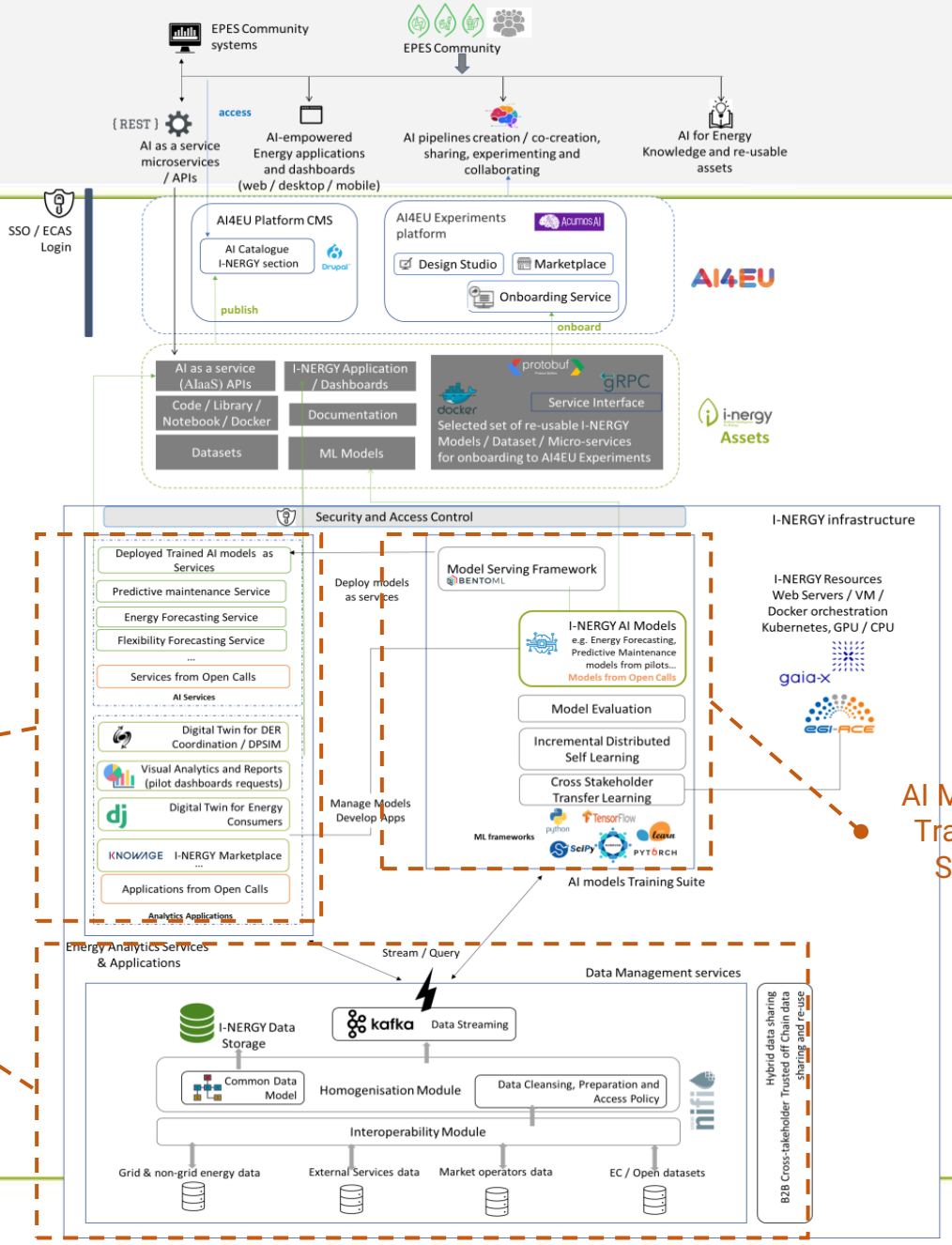
Related work

- BRIDGE
  - multi-layered, cross-sectoral architecture model based on Smart Grid Architecture Model (SGAM).
  - five layers of functionalities: **the Component Layer**, that includes all connected devices and data sources; **the Communication layer** that has to do with standardization of protocols and formats; **the Information Layer** that is responsible for forming the data according to the selected data models to facilitate interoperability; the **Function Layer**, which is responsible for decision making processes based on available data; and the **Business Layer**, which is responsible for business associations, roles and processes
- IDS-Reference Architecture Model (IDS-RAM)
  - focuses on **secure and trusted data exchange** between organizations paying special attention to data sovereignty
  - 5 layers, similar to BRIDGE
- GAIA-X
  - focuses on **decentralization and transparency** of cloud services and infrastructure
  - Can be integrated in a common approach with IDS-RAM
- BD4NRG
  - Based on BRIDGE RA
  - four layers for the different layers of the data value chain (that map to BRIDGE layers) and one vertical pillar that includes **different dataspace enablers**
  - aligned with the design principles of IDSA and GAIA-X
- MATRYCS
  - high-level architecture focusing on **big data management in the building domain**, that facilitates data sharing, interoperability and seamless operation of big data-enabled services
  - four layers of functionalities: the **Infrastructure** Layer, the **Data Governance** Layer, the **Processing** Layer and the **Analytics** layer
  - Uses well-known open-source technologies
  - Similar approach with I-NERGY RA

I-NERGY Requirements

- Connecting with different and heterogeneous data sources
- Preprocessing and harmonizing incoming data according to a common data model
- Providing efficient big data storage and querying capabilities
- Accessing real-time data streams and facilitating access to the latter to related analytics services
- Efficiently training, evaluating and serving AI models
- Providing transfer learning capabilities
- Providing utilities for incremental (online) learning
- Serving multiple stakeholders, providing access to authorized users
- Addressing cybersecurity
- Reinforcing the AIoD platform by sharing I-NERGY assets

I-NERGY Reference Architecture

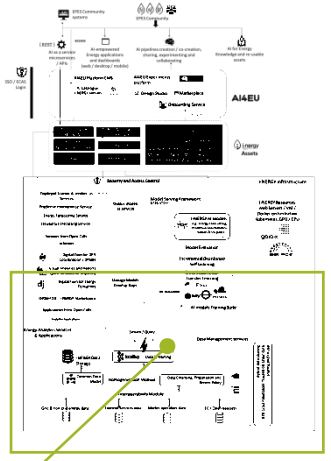


Energy Analytics Services and Applications

Data Management Services

AI Models Training Suite

I-NERGY Refence Architecture in more detail (1/3)

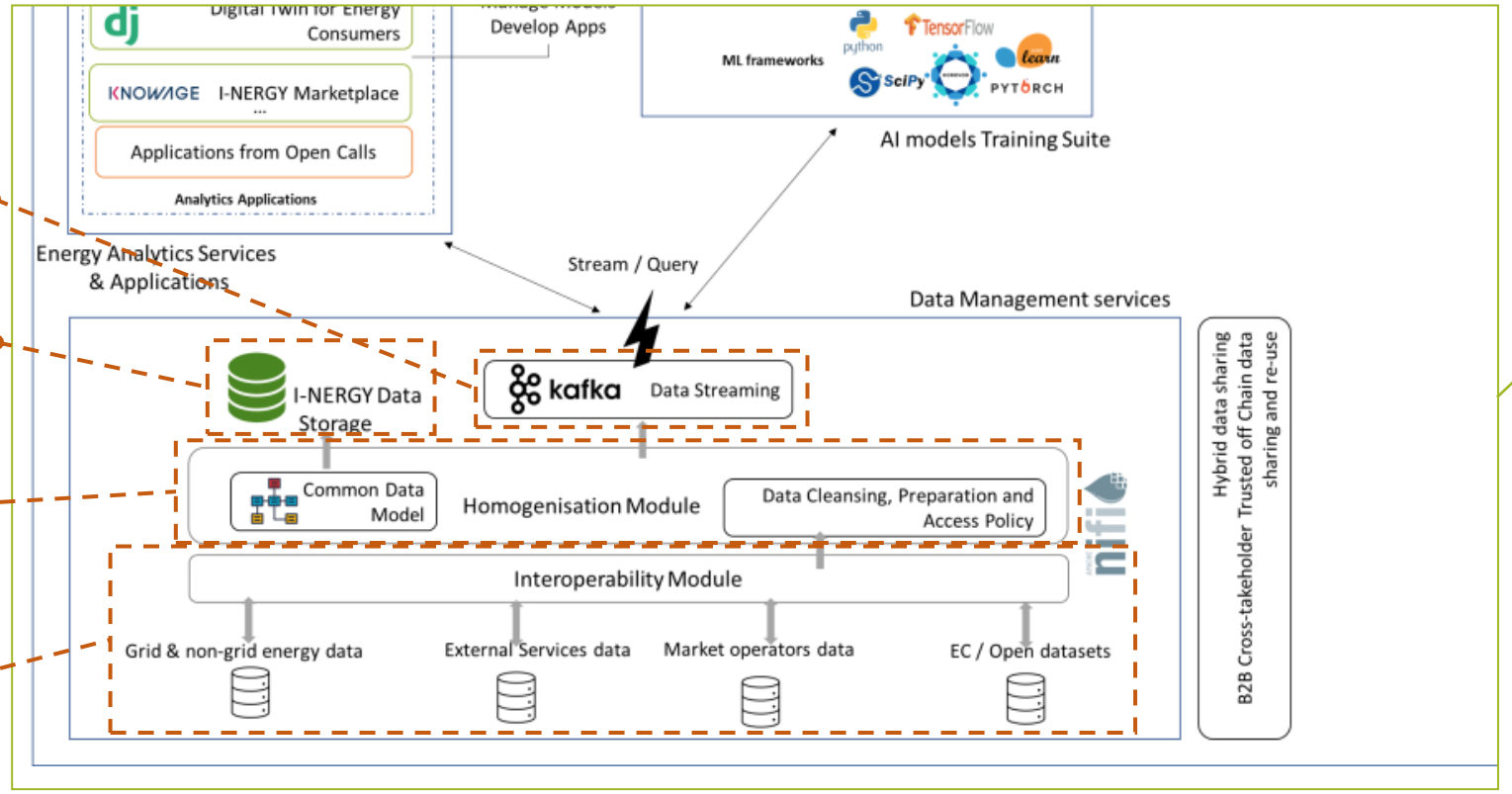


Data Streaming: Low latency near real time in-memory processing

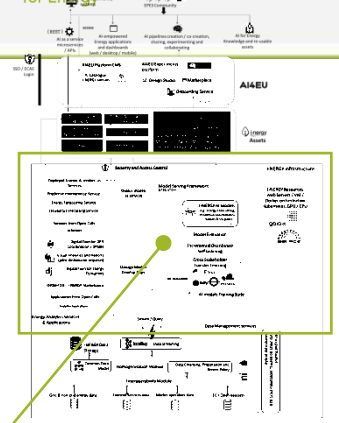
Data Storage: According to the needs of services and tools

Data Harmonisation: Homogenisation and data pre-processing

Data Ingestion: Integration from heterogeneous sources



I-NERGY Reference Architecture in more detail (2/3)



Energy Analytics Apps and AI Services: Independent microservices providing inference endpoints

Energy Data & Services Innovation Hub Model/Resources Selection Cockpit

Security and Access Control

I-NERGY infrastructure

Deployed Trained AI models as Services

Predictive maintenance Service

Energy Forecasting Service

Flexibility Forecasting Service

...

Services from Open Calls

AI Services

Digital Twin for DER Coordination / DPSIM

Visual Analytics and Reports (pilot dashboards requests)

Digital Twin for Energy Consumers

KNOWAGE I-NERGY Marketplace

...

Applications from Open Calls

Analytics Applications

Energy Analytics Services & Applications

Deploy models as services

Model Serving Framework BENTOML

Manage Models Develop Apps

I-NERGY AI Models e.g. Energy Forecasting, Predictive Maintenance models from pilots... Models from Open Calls

Model Evaluation

Incremental Distributed Self Learning

Cross Stakeholder Transfer Learning

ML frameworks

AI models Training Suite

I-NERGY Resources Web Servers / VM / Docker orchestration Kubernetes, GPU / CPU

gaia-x

EGI-ACE

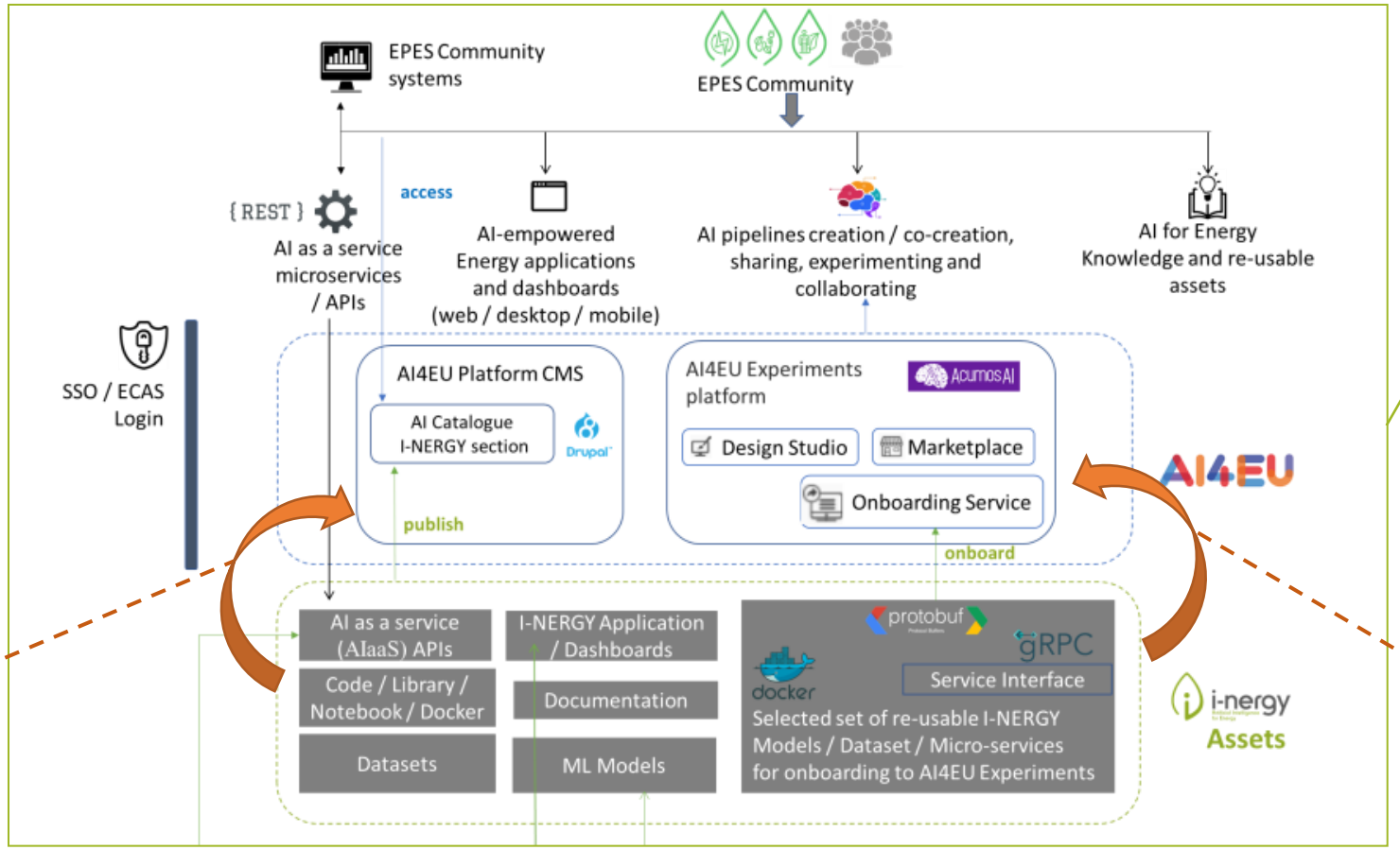
Stream / Query

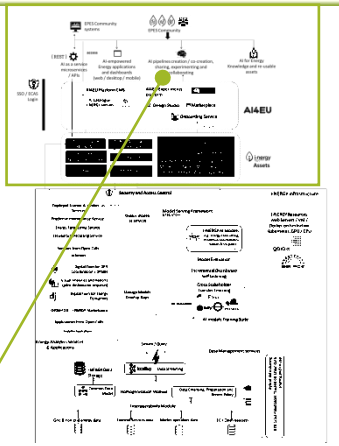
Data Management services

Datasets and AI services hosted to GAIA-X; Services and resources from EGI-ACE for training complex AI models

Model Evaluation and Transfer Learning: Evaluate already trained models and adaptation for use in other domains

I-NERGY Reference Architecture in more detail (3/3)





I-NERGY assets can be published to AI4EU catalogue and used by different EPES users

I-NERGY services (docker) + protobuf configuration can be onboarded to AI4EU Experiments platform

I-NERGY services

- Energy Load Forecasting
- Predictive Maintenance
- Operation planning
- Digital Twin for DER
- Digital Twin for Electrical Communities
- Energy Flexibility Forecasting and Demand Response
- Anomaly Detection in citizen patterns from Smart Meters
- Energy Efficiency Action Plans Evaluation and Prioritisation
- Decision Support
- Forecasting Changes in Solar Radiation

Implications

I-NERGY RA provides energy analytics services and applications (static and near real-time) to the entire energy value chain, serving a variety of energy stakeholders, covering all the requirements presented earlier using well-known open-source technologies.

Compared to the presented architectures I-NERGY RA:

- addresses the entire big data value chain
- proposes specific open-source technologies for each functionality instead of generic description of functionalities without related technologies and implementation details
- IDS-RAM and GAIA-X focus mostly on data exchange, sovereignty and transparency, not paying attention to other crucial functionalities of the big data value chain
- BRIDGE and BD4NRG RAs focus on smart grid applications of Big Data, without proposing specific technologies for addressing each layer of functionalities
- MATRYCS follows a similar approach with I-NERGY, covering the entire big data value chain, but does not address some of the presented requirements, e.g., AIoD platform, Transfer Learning.

Future outlook and next steps

- validation of the entire platform by different energy stakeholders
- elicitation of new requirements for improvements
- compliance with GAIA-X and IDSA will be further examined to facilitate efficient and effective data sharing among different organizations

i-nergy
Artificial Intelligence for Energy

Thank you!

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