

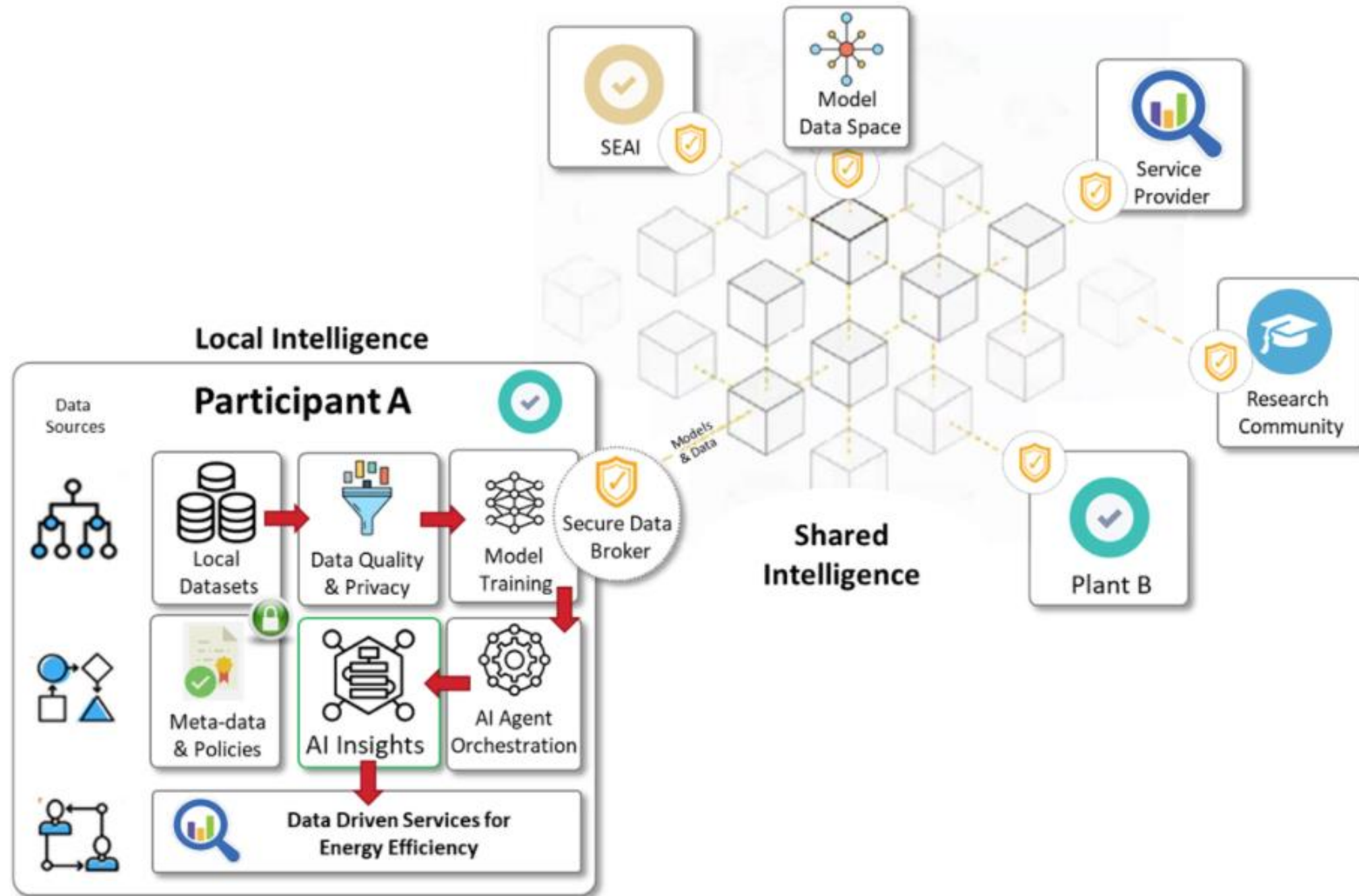
# A Semantic Interoperability Toolkit for Sharing Energy Data and Models in a Manufacturing Data Space

**Authors: Tharindu Ranathunga, Sourabh Bharti, Alan McGibney**

Munster Technological University, Ireland

# CORDS Idea

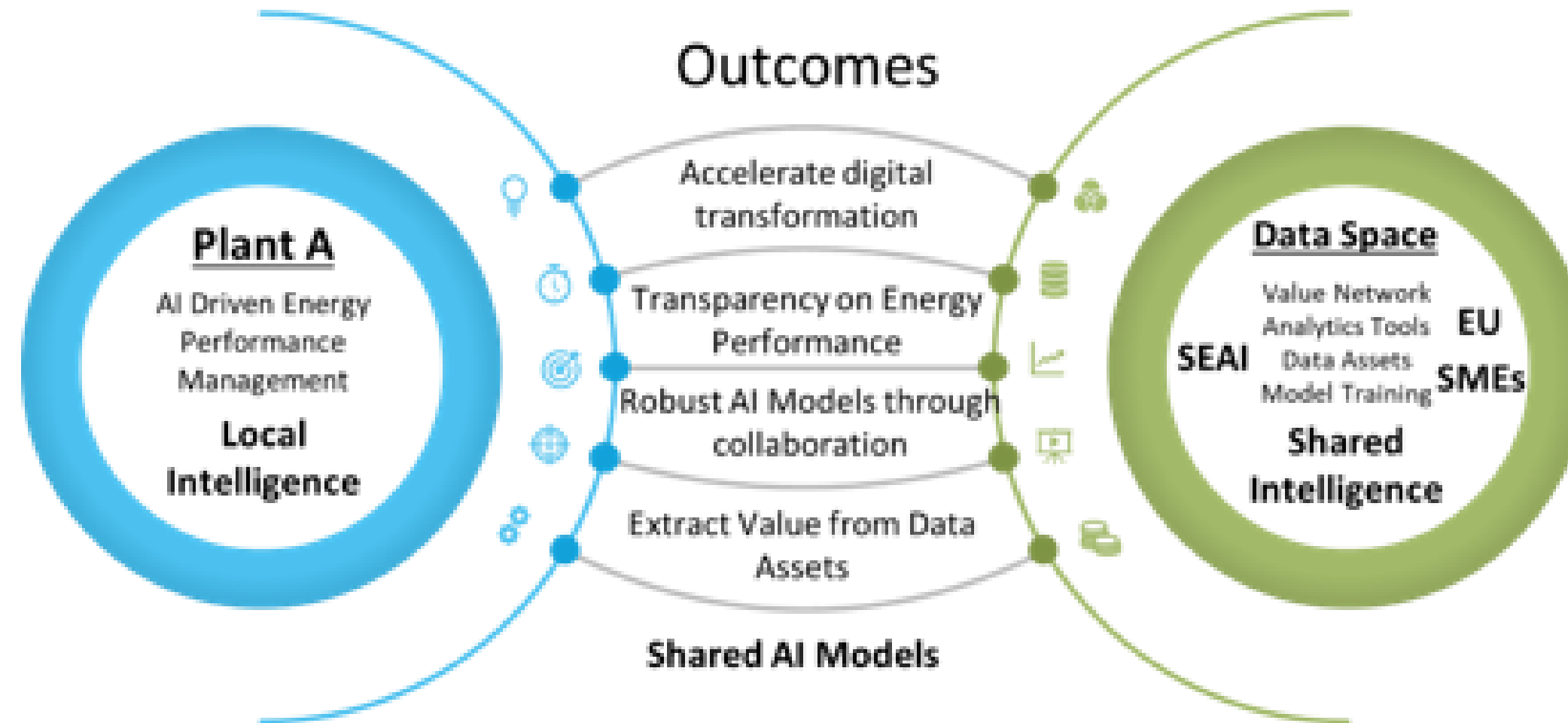
COllaboRative Data Space for distributed intelligence supporting energy performance management



## Challenges Addressed - Breaking Data Silos

- Disparate Energy Data Sources
- Data Consolidation
- Extracting Meta Data
- Local intelligence to shared intelligence
- Semantic Interoperability
  - Energy Data
  - ML Model Reusability

# Project Impact

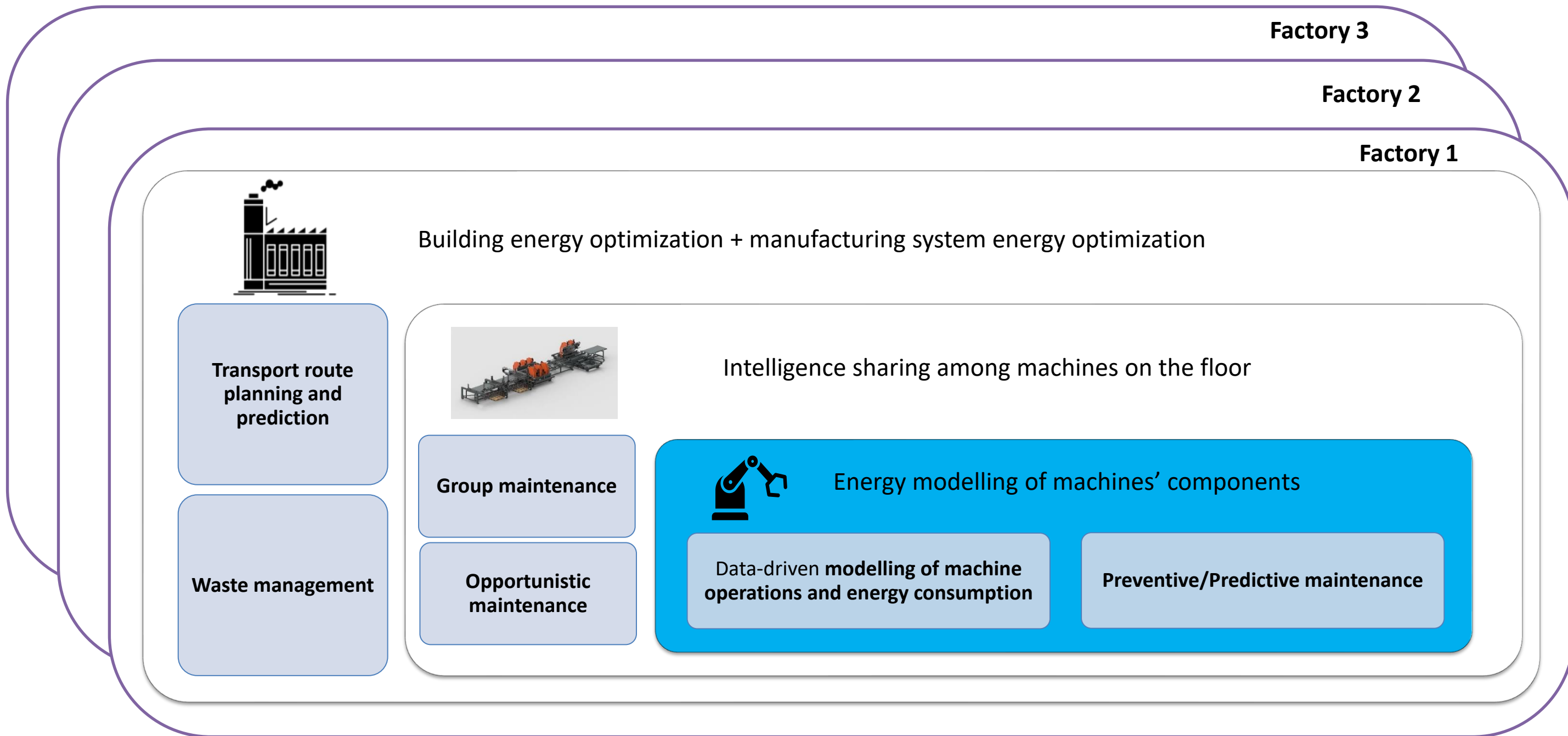


**Strategic Goal 1:**  
Develop and open collaborative data space.

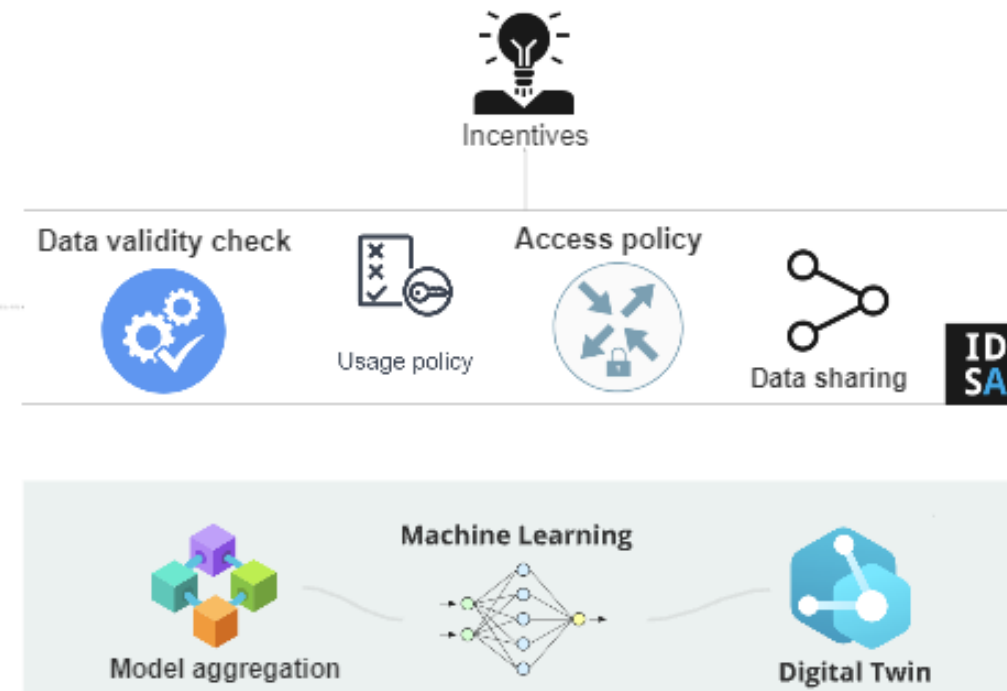
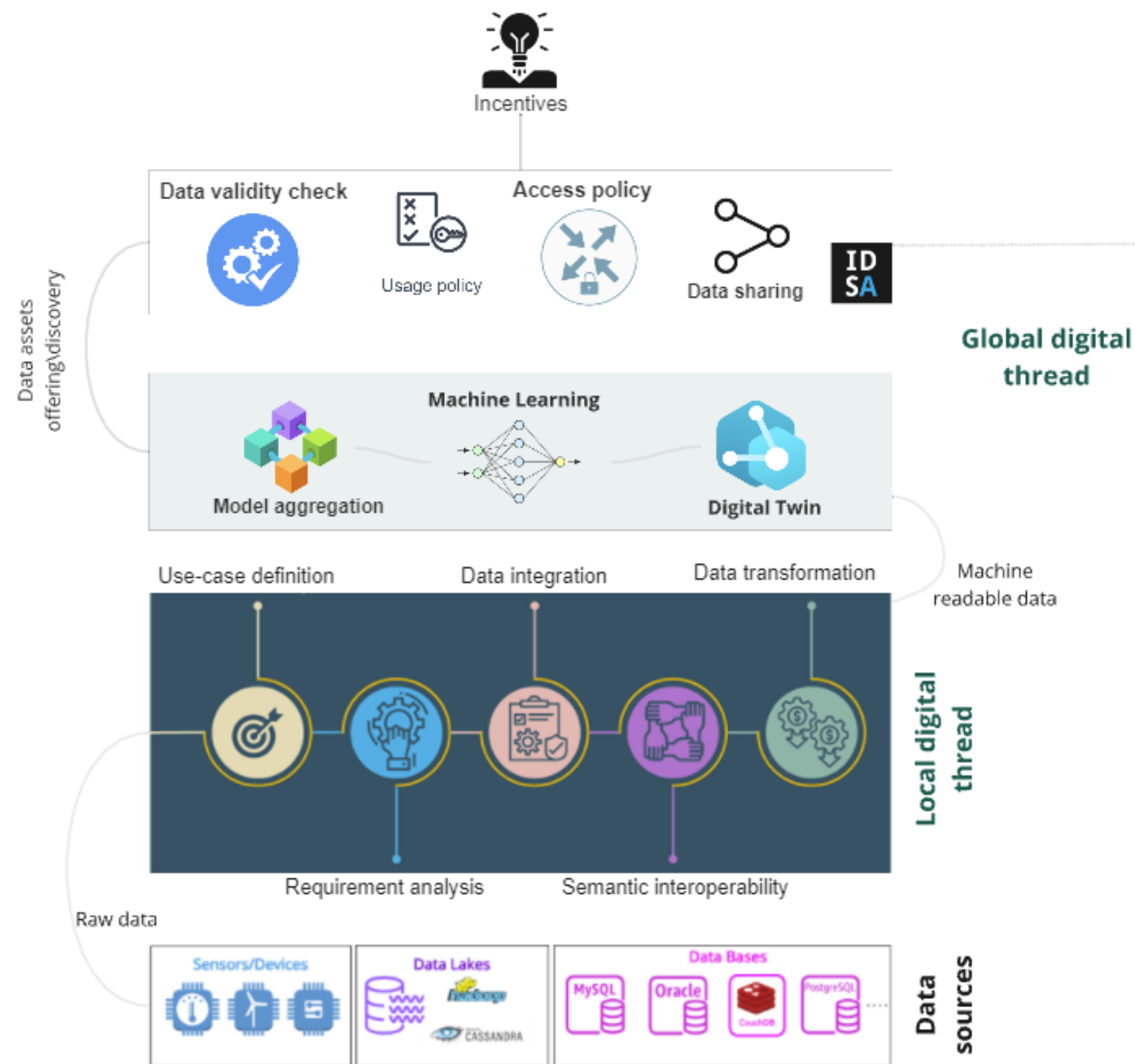
**Strategic Goal 2:**  
Demonstrate the value of 'untapped' data to unlock potential energy savings

# Enhancing decision making

Data Space as an Overlay



# Solution: Digital Threads



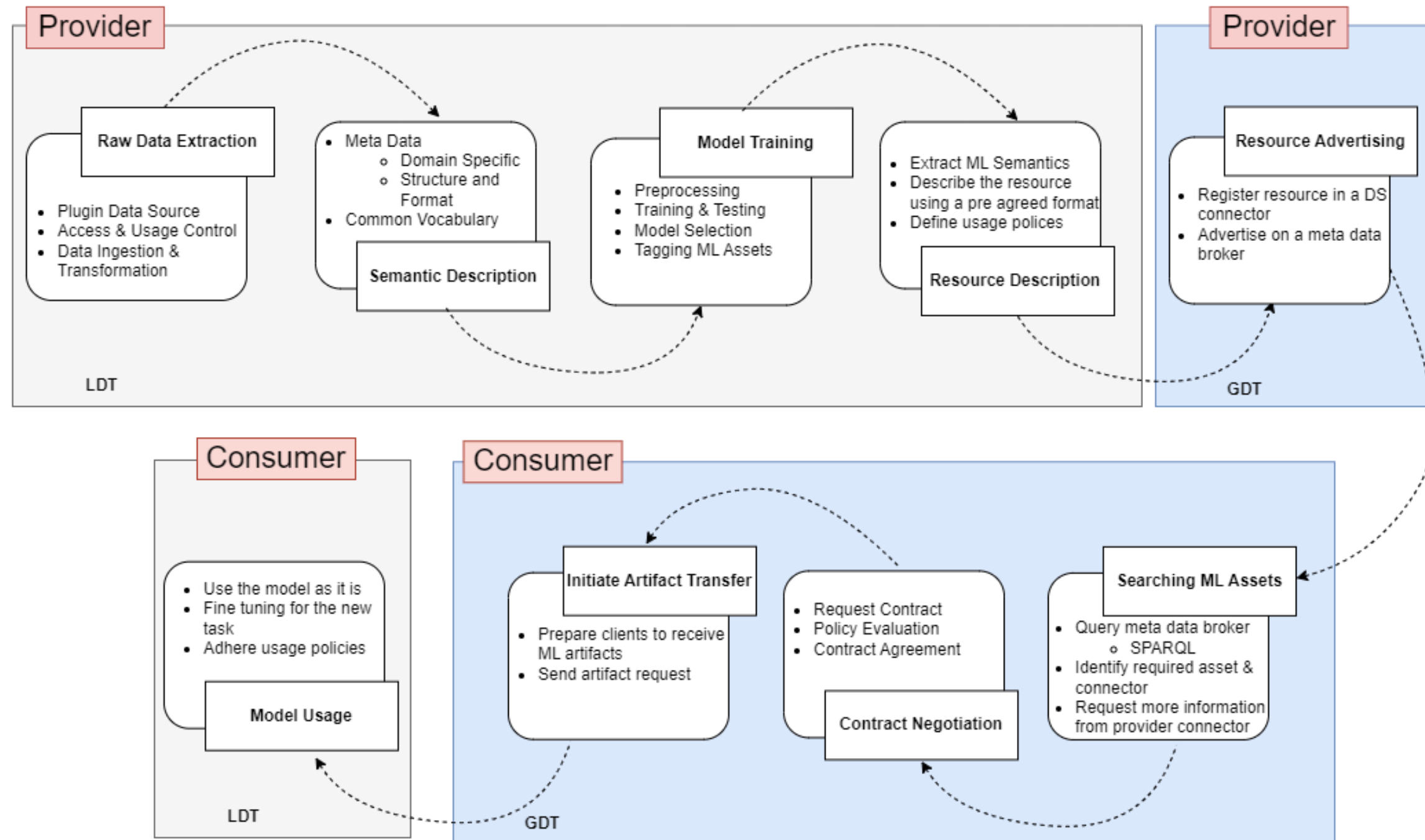
## Local Digital Thread

- Consolidate Data Sources
- Prepare data for ML
- Preserve semantic interoperability

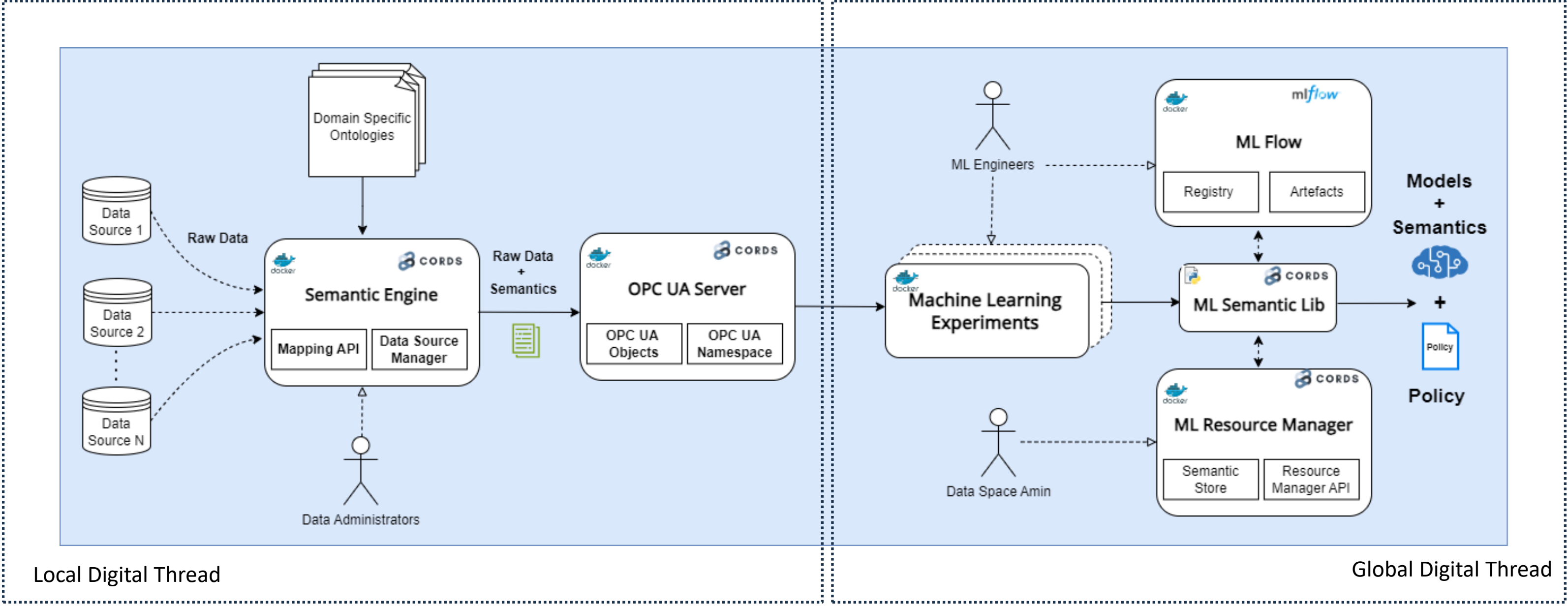
## Global Digital Thread

- Manage model training
- Model advertising and discovery
- Transfer Learning/Federated Learning

# CORDS Information Flow



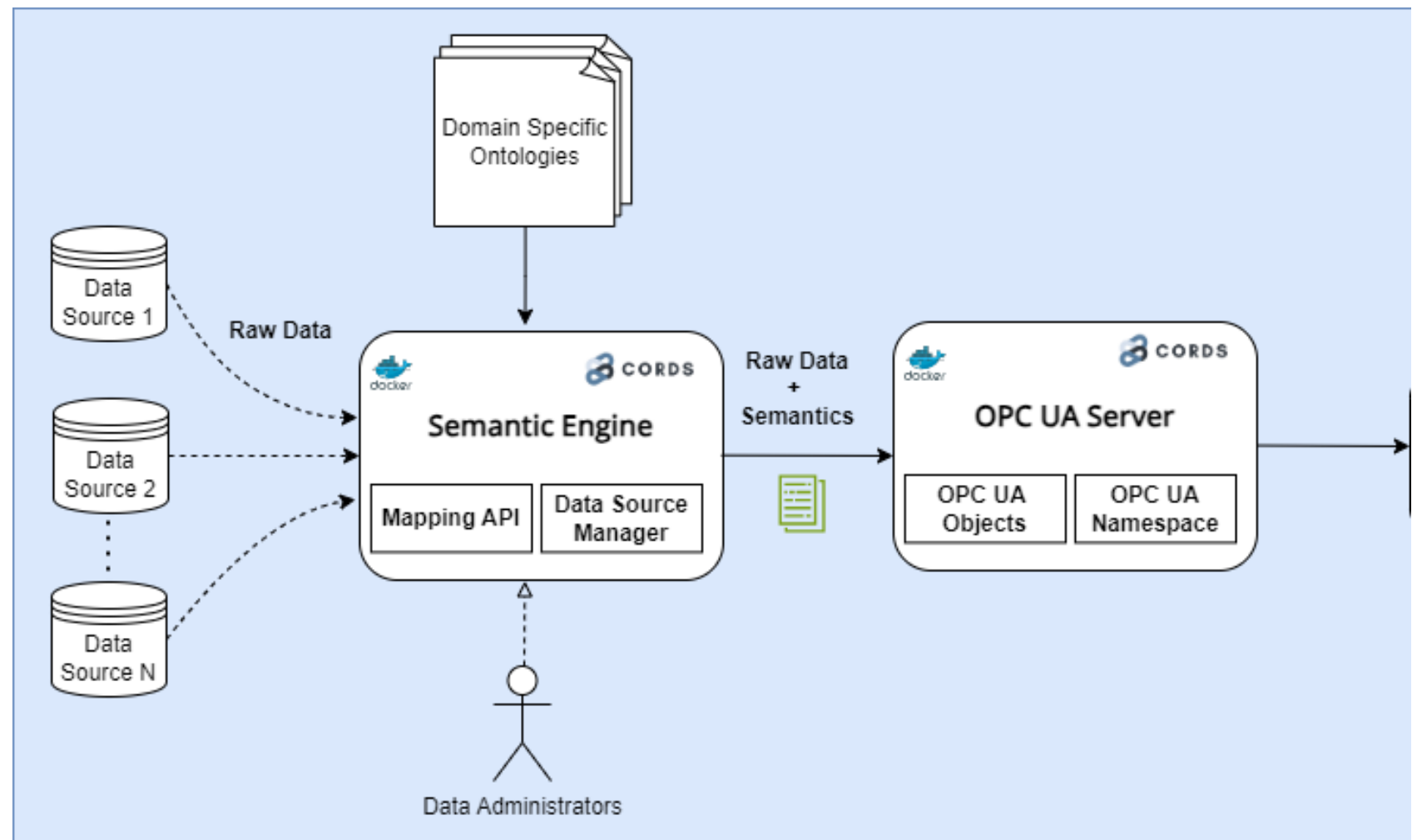
# Interoperability Toolkit



# Local Digital Thread

## Semantic Interoperability

- Common Information Model (CIM) for Energy Data
- Semantic Engine/API
  - Connecting to data sources
  - Mapping existing schema to CIM
- OPC UA Server
  - Data consolidation
  - Data Access through pub/sub model
  - OPC UA Namespace based on the CIM



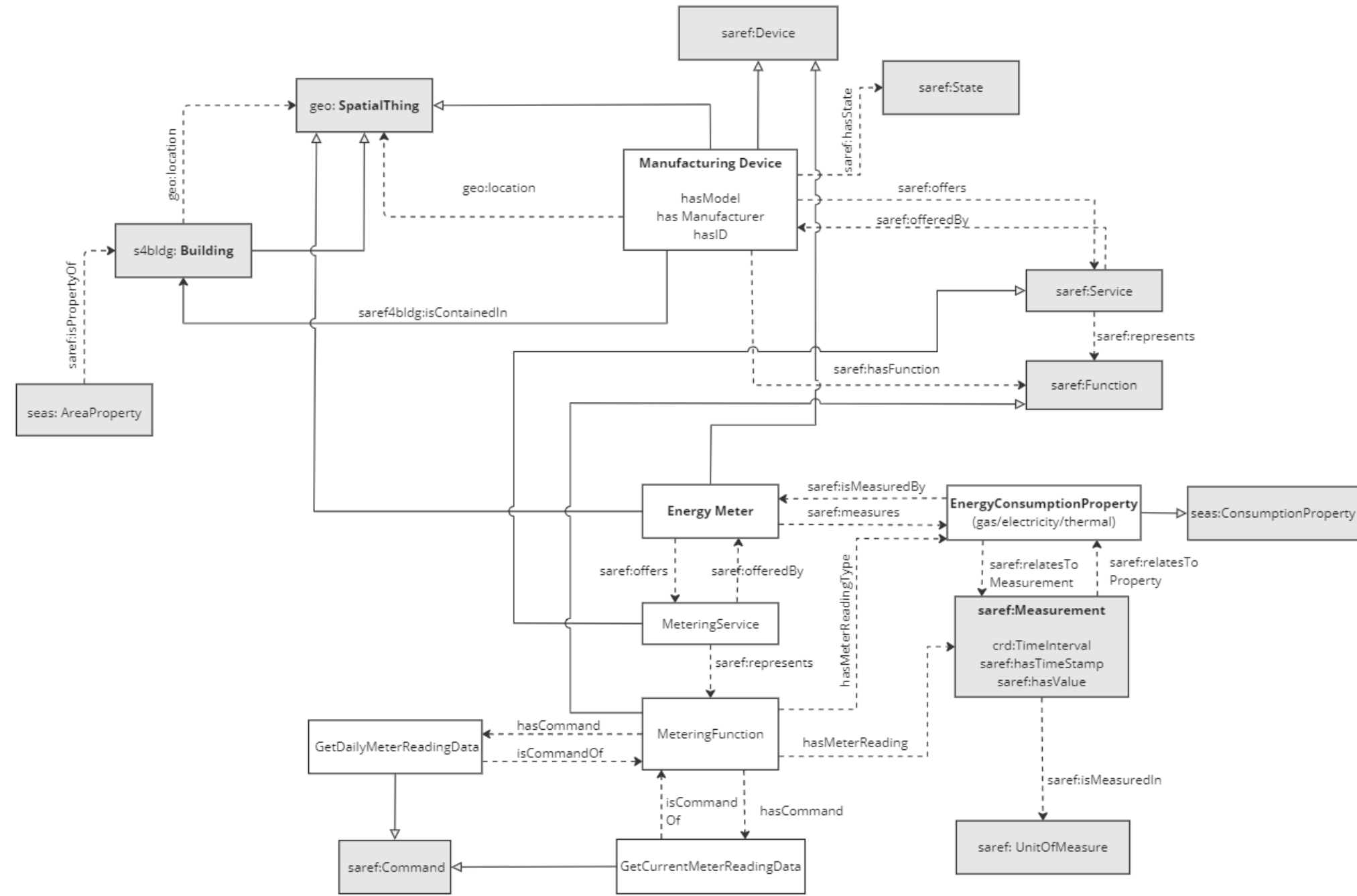
Toolkit: Local Digital Thread



# CIM for Energy Data

- Reused ontologies:

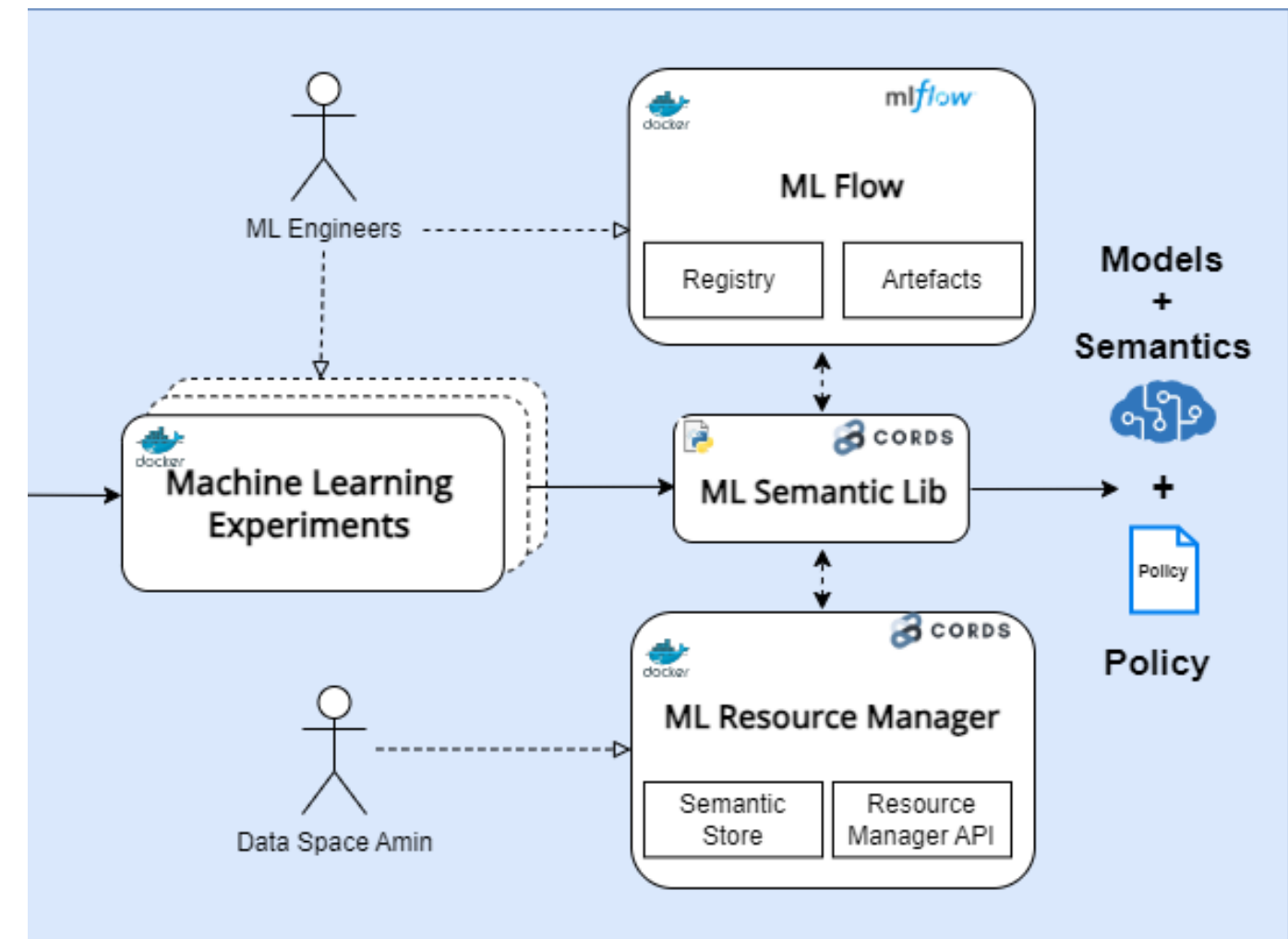
- SAREF
- CIM
- SEAS



# Global Digital Thread

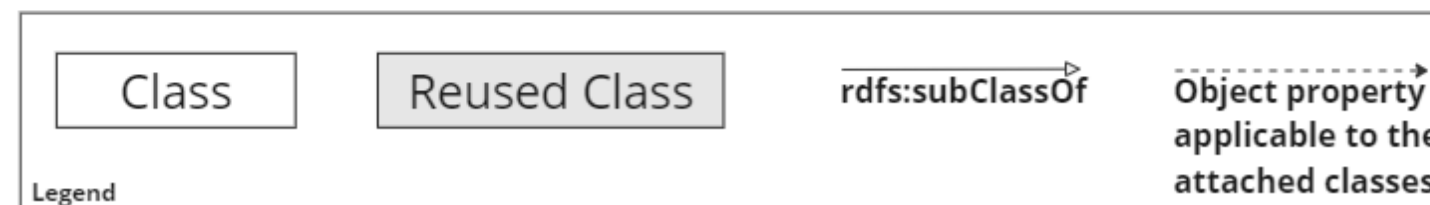
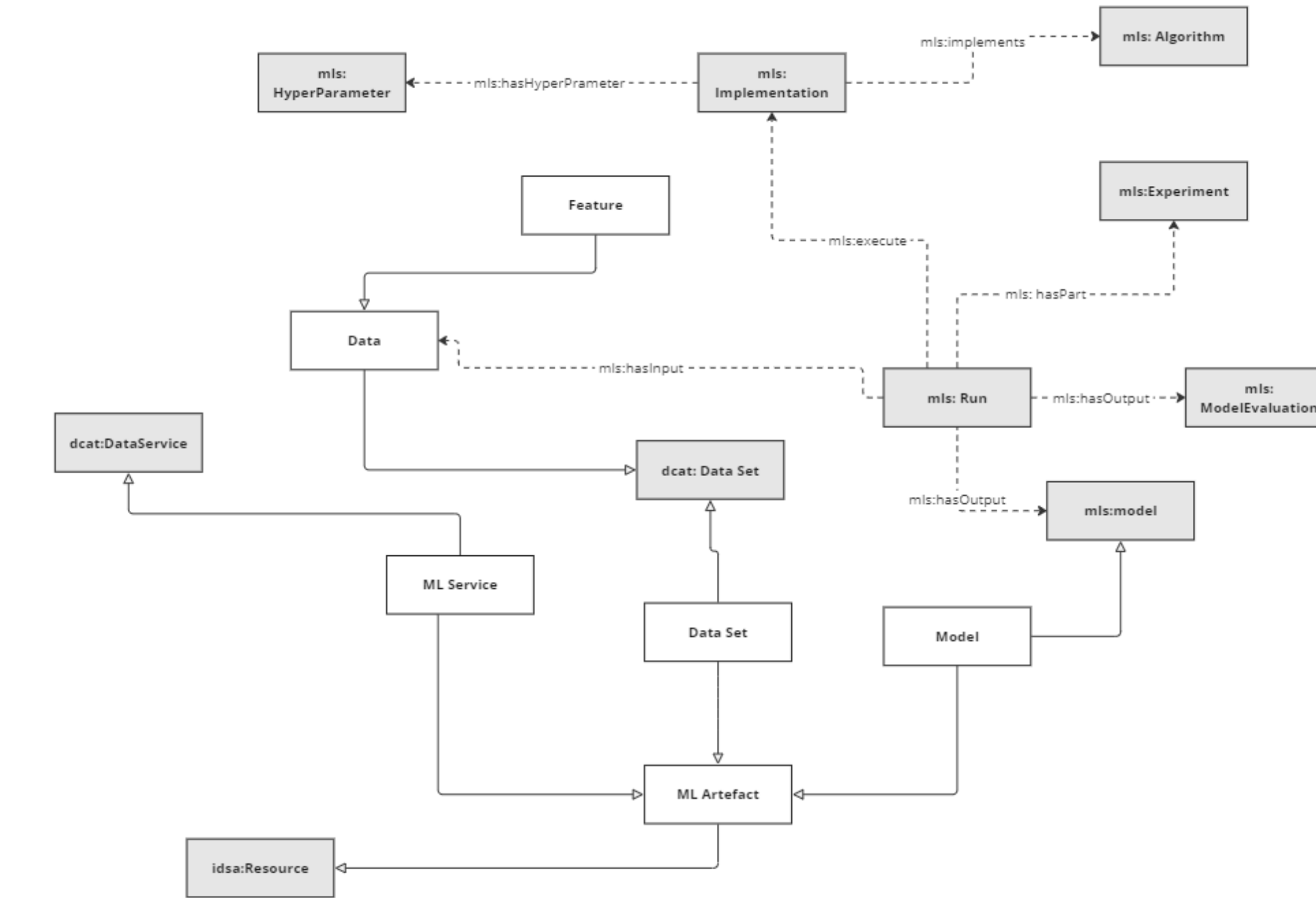
## Semantic Interoperability

- ML Semantic Library
  - Python based
  - Facilitate ML engineers to describe experiments
  - CIM for ML assets
- ML Flow Integration
  - Model tracking and repository management
  - Meta data visualization
- ML Resource Manager
  - Extracting metadata
  - Translating to RDF/IDSA compatible format
  - Policy management



# CIM for ML

- Reused ontologies:
  - ML Schema
  - DCAT

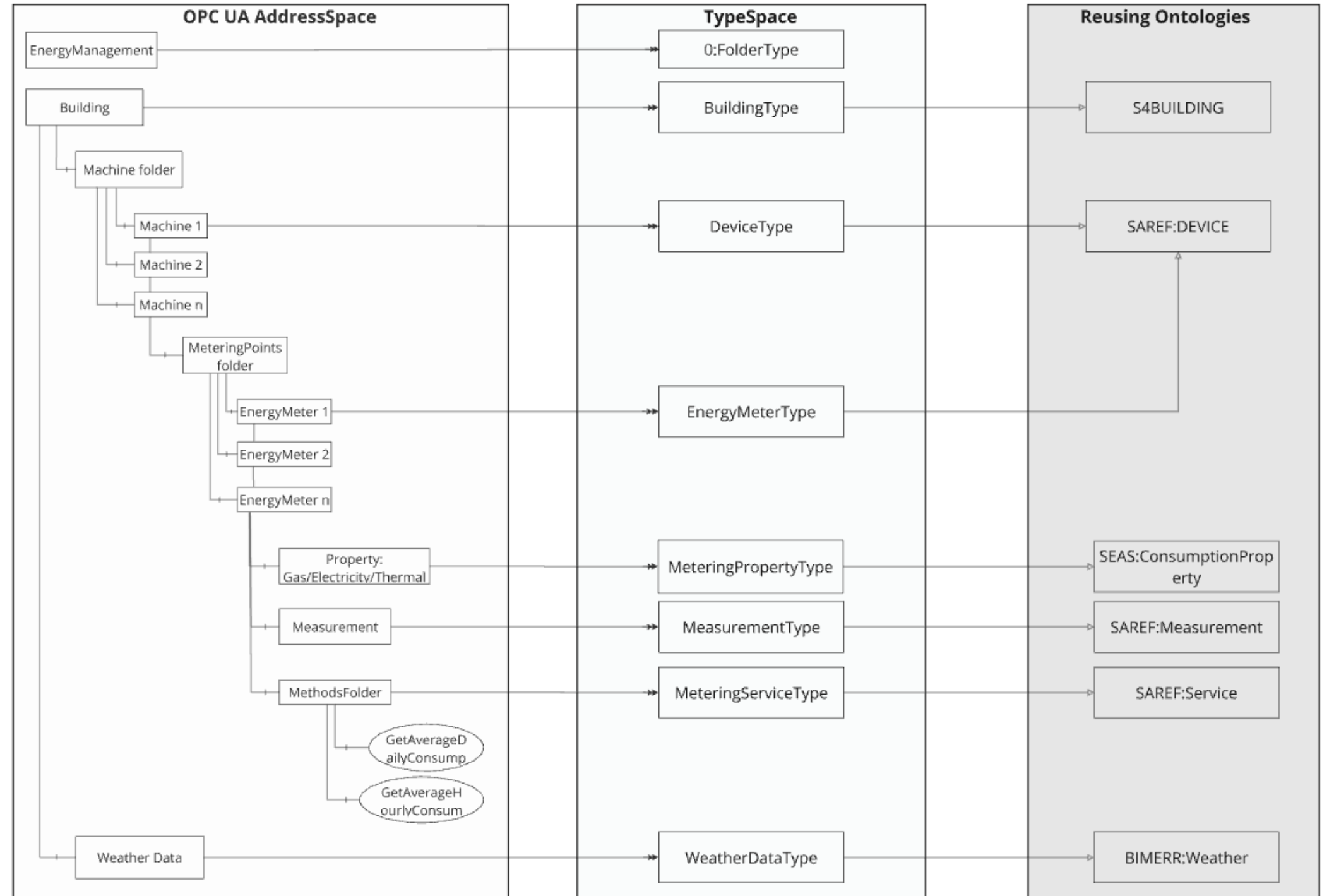


# Toolkit in action

```

POST http://127.0.0.1:5000/mapping
Body
[
  {
    "Buildings": [
      {
        "BuildingArea": "5000 sqm",
        "BuildingID": "Bldg-12345",
        "BuildingLocation": {
          "Latitude": "40.7128",
          "Longitude": "-74.0060"
        },
        "BuildingName": "West Wing Building",
        "Machines": [
          {
            "DeviceID": "AuxiliaryService1",
            "DeviceManufacturer": "",
            "DeviceModel": "",
            "EnergyMeters": [
              {
                "DeviceID": "AuxEnergyMeter1",
                "DeviceManufacturer": "Honeywell International Inc",
                "DeviceModel": "TEW Emlite - Single Phase Digital",
                "MeteringService": {
                  "CurrentMeasurement": {
                    "MeasurementTimeInterval": "1s",
                    "MeasurementUnit": "Kw/h",
                    "Transformation": {
                      "mapping_type": "database",
                      "connector": "connector_mysql_local01",
                      "dbname": "energymeters",
                      "table": "block_13",
                      "mapping": {
                        "MeasurementTimeStamp": "tstp",
                        "Measurementvalue": "energy"
                      }
                    }
                  }
                }
              }
            ]
          }
        ]
      }
    ]
  }
]
  
```

Mapping API



OPC UA Server Abstract View

# Toolkit in action

```
#Importing CORDS Tags
import cords_semantics.tags as cords_tags

with mlflow.start_run(run_name = run_name) as mlflow_run:
    mlflow_run_id = mlflow_run.info.run_id

    mlflow.set_experiment_tag("second best_model", "K-Neighbors Regressor")
    mlflow.set_tag("tag2", "K-Neighbors Regressor")
    mlflow.set_tag(cords_tags.CORDS_RUN, mlflow_run_id)
    mlflow.set_tag(cords_tags.CORDS_RUN_EXECUTES, "K-Neighbors Regressor")
    mlflow.set_tag(cords_tags.CORDS_IMPLEMENTATION, "python")
    mlflow.set_tag(cords_tags.CORDS_SOFTWARE, "sklearn")

    mlflow.sklearn.log_model(models['K-Neighbors Regressor'], "knnmodel")

    mlflow.log_metric("test_RMSE", rmse_scores.loc[rmse_scores['Model Name'] == 'K-Neighbors Regressor'])
    mlflow.log_metric("test_MAE", mae_scores.loc[mae_scores['Model Name'] == 'K-Neighbors Regressor'])
    mlflow.log_metric("test_R2_Score", r2_scores.loc[r2_scores['Model Name'] == 'K-Neighbors Regressor'])

    mlflow.log_input(dataset, context="training")

print("MLFlow Run ID: ", mlflow_run_id)
```

Tagging in ML Experiments



mlflow 2.15.0 Experiments Models

Federated-Learning-Energy-Prediction >  
20240606\_141928

Overview Model metrics System metrics Artifacts

Description

This model was trained to predict energy consumption of CNC machines

Details

Created at	2024-06-06 14:26:37
Created by	Tharindu.Ranathunga
Experiment ID	156115389049841703
Status	Finished
Run ID	c257b8e4f4af4df89400f76a09aa1b4d
Duration	44.6s
Datasets used	—
Tags	<code>cords.Implementation: python</code> <code>cords....: Adam (Parameter Group 0 amsgrad: Fals...</code> <code>cords.Run: c257b8e4f4af4df89400f76a09aa1b4d</code> <code>cords.Run.executes: ANN</code> <code>cords.Software: pytorch</code>
Source	client.py  a87f89f
Logged models	pytorch
Registered models	—

ML FLOW

# Toolkit in action

```
CORDS Model Manager / Create_Resource_Descriptions

POST http://localhost:5000/api/dataspace_resource/create_resource_description/786b5446265c0e7a09f75186afa8ff8aef31017dbef74be20877b289a8df861b

Params Authorization Headers (10) Body Scripts Settings
none form-data x-www-form-urlencoded raw binary GraphQL JSON

1 {
2   "title": "Example IDS Resource1",
3   "description": "This is an example IDS Resource",
4   "keywords": ["cords", "energy prediction"]
5 }

Body Cookies Headers (5) Test Results Status: 200 OK
Pretty Raw Preview Visualize JSON

4 "@context": {
5   "cords": "https://www.cords.ie/ontologies/cordsml",
6   "core": "http://www.w3.org/2004/02/skos/core",
7   "dcat": "http://www.w3.org/ns/dcat",
8   "ex": "http://example.org",
9   "ids": "https://w3id.org/idsa/core/",
10  "idsc": "https://w3id.org/idsa/code/",
11  "mls": "http://www.w3.org/ns/mls",
12  "prov": "http://www.w3.org/ns/prov"
13 },
14 "@id": "https://w3id.org/idsa/autogen/dataResource/cords_4ce8c21c-c6bf-4cbc-b995-46acfa6265db",
15 "@type": "ids:DataResource",
16 "cords:mlmetadata": [
17   {
18     "@id": "http://example.org#6a7cf4d3ba1b47b3b3abf32b06abf6c6",
19     "@type": "mls:Run",
20     "mls:executes": {
21       "@type": "http://www.w3.org/2001/XMLSchema#string",
22       "@value": "K-NeighborsRegressor"
23     }
24   },
25   {
26     "@id": "http://example.org#sklearn",
27     "@type": "mls:Software"
28   },
29   {
30     "@id": "http://example.org#modelEvaluation_test_RMSE",
31     "@type": "mls:ModelEvaluation"
32   }
33 ]
34 }
```



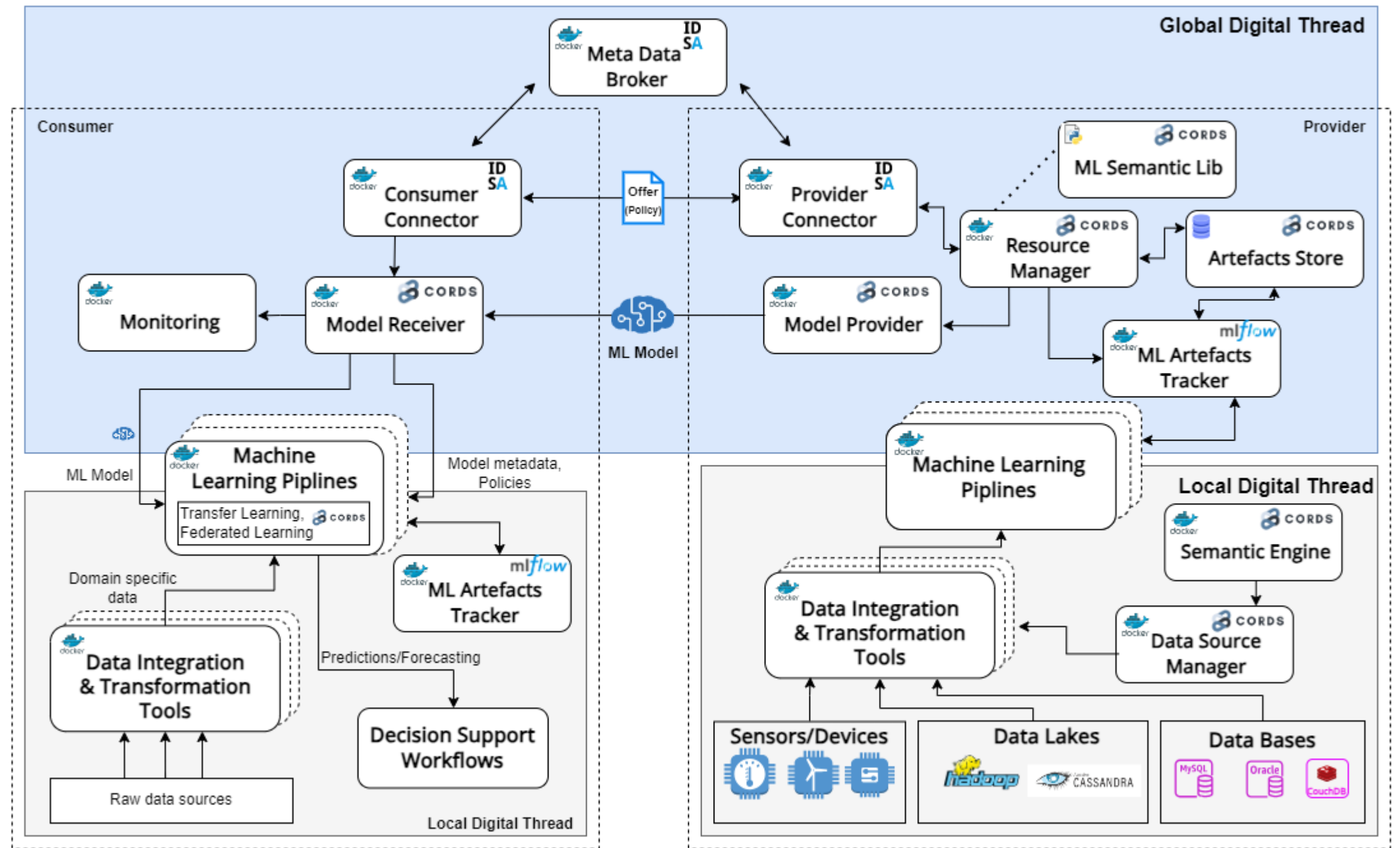
```
1 {
2   "@context": {
3     "cords": "https://www.cords.ie/ontologies/cordsml",
4     "core": "http://www.w3.org/2004/02/skos/core",
5     "dcat": "http://www.w3.org/ns/dcat",
6     "ex": "http://example.org",
7     "ids": "https://w3id.org/idsa/core/",
8     "idsc": "https://w3id.org/idsa/code/",
9     "mls": "http://www.w3.org/ns/mls",
10    "prov": "http://www.w3.org/ns/prov"
11  },
12  "@id": "https://w3id.org/idsa/autogen/dataResource/cords_4ce8c21c-c6bf-4cbc-b995-46acfa6265db",
13  "@type": "ids:DataResource",
14  "cords:mlmetadata": [
15    {
16      "@id": "http://example.org#6a7cf4d3ba1b47b3b3abf32b06abf6c6",
17      "@type": "mls:Run",
18      "mls:executes": {
19        "@type": "http://www.w3.org/2001/XMLSchema#string",
20        "@value": "K-NeighborsRegressor"
21      }
22    },
23    {
24      "@id": "http://example.org#sklearn",
25      "@type": "mls:Software"
26    },
27    {
28      "@id": "http://example.org#modelEvaluation_test_RMSE",
29      "@type": "mls:ModelEvaluation",
30      "mls:hasValue": {
31        "@type": "http://www.w3.org/2001/XMLSchema#string",
32        "@value": "2.7181378412972808"
33      },
34      "mls:specifiedBy": {
35        "@type": "http://www.w3.org/2001/XMLSchema#string",
36        "@value": "test_RMSE"
37      }
38    },
39    {
40      "@id": "http://example.org#modelEvaluation_test_RMSE",
41      "@type": "mls:ModelEvaluation",
42      "mls:hasValue": {
43        "@type": "http://www.w3.org/2001/XMLSchema#string",
44        "@value": "2.7181378412972808"
45      }
46    }
47  ],
48  "ids:contentType": {
49    "@id": "https://w3id.org/idsa/code/SCHEMA_DEFINITION"
50  },
51  "ids:contractOffer": [
52    {
53      "@id": "https://w3id.org/idsa/code/SCHEMA_DEFINITION"
54    }
55  ],
56  "ids:created": [
57    {
58      "@id": "https://w3id.org/idsa/code/SCHEMA_DEFINITION"
59    }
60  ],
61  "ids:description": [
62    {
63      "@id": "https://w3id.org/idsa/code/SCHEMA_DEFINITION"
64    }
65  ],
66  "ids:keyword": [
67    {
68      "@id": "https://w3id.org/idsa/code/SCHEMA_DEFINITION"
69    }
70  ],
71  "ids:language": [
72    {
73      "@id": "https://w3id.org/idsa/code/SCHEMA_DEFINITION"
74    }
75  ],
76  "ids:modified": [
77    {
78      "@id": "https://w3id.org/idsa/code/SCHEMA_DEFINITION"
79    }
80  ],
81  "ids:representation": [
82    {
83      "@id": "https://w3id.org/idsa/code/SCHEMA_DEFINITION"
84    }
85  ],
86  "ids:theme": [
87    {
88      "@id": "https://w3id.org/idsa/code/SCHEMA_DEFINITION"
89    }
90  ],
91  "ids:title": [
92    {
93      "@id": "https://w3id.org/idsa/code/SCHEMA_DEFINITION"
94    }
95  ],
96  "ids:version": "1.0.0"
97 }
98 }
```

Resource Description Generation

IDS Compatible Resource Description

# Further Research Directions

- Integration to CORDS Minimum Viable Data Space.
- Explore automated tagging
- Usability improvements



# Acknowledgement



Website: [cords.ie](https://www.cords.ie)

This project has received funding from the Sustainable Energy Authority of Ireland under the SEAI Research, Development & Demonstration Funding Programme 2021, Grant number 21/RDD/688.