

Aprendizaje automático

Casos de uso. Motivación.

Joaquín Luque. Universidad de Sevilla (España)



FACULTAD DE
INGENIERÍA



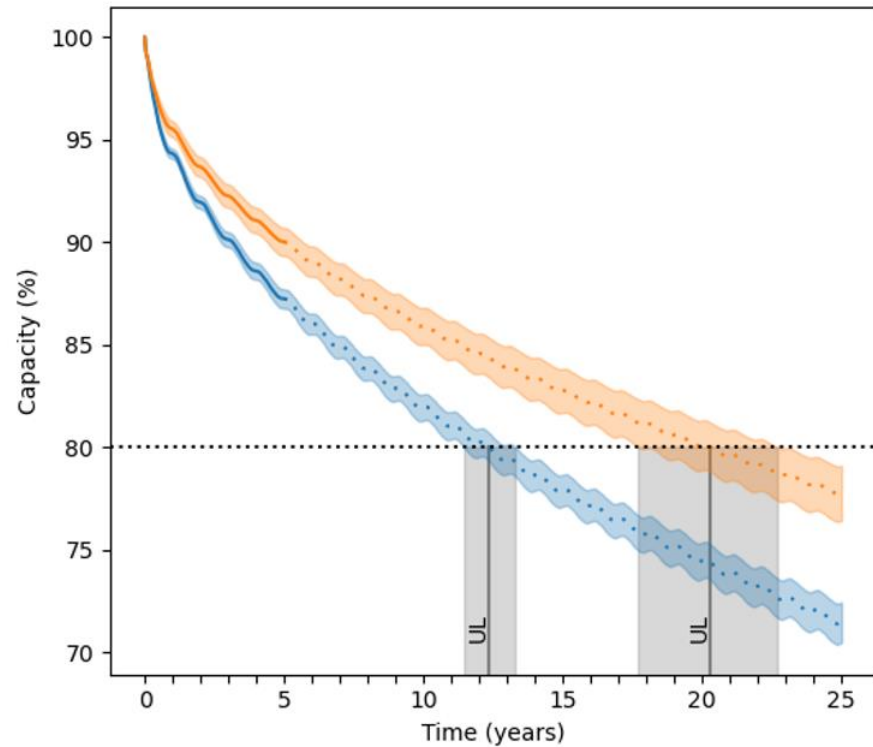
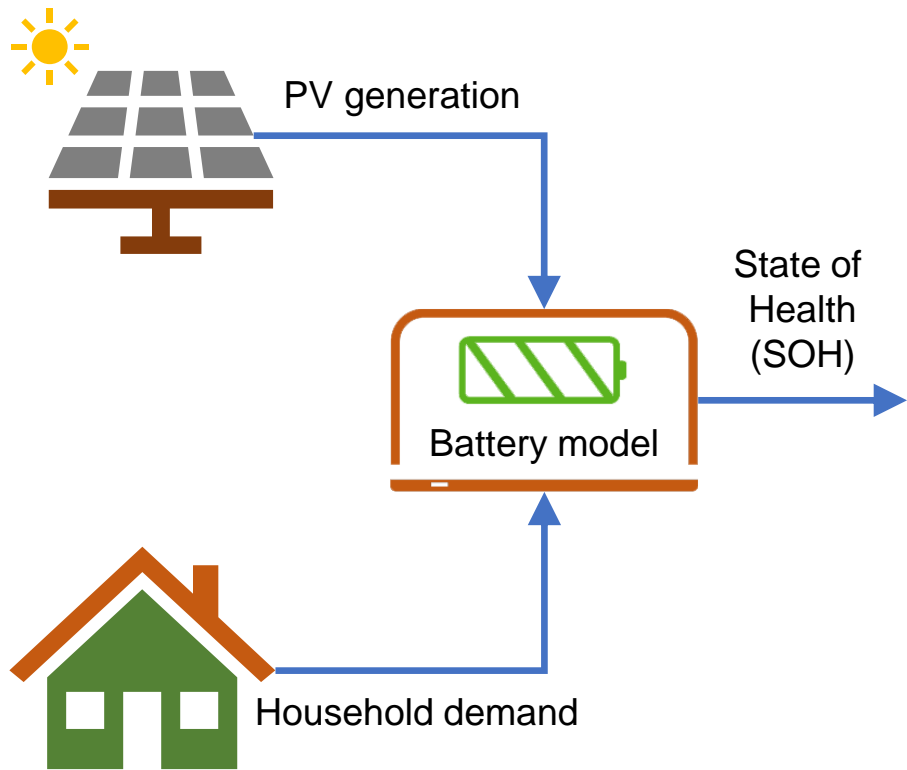
UNIVERSIDAD
DE LA REPÚBLICA
URUGUAY

Agenda

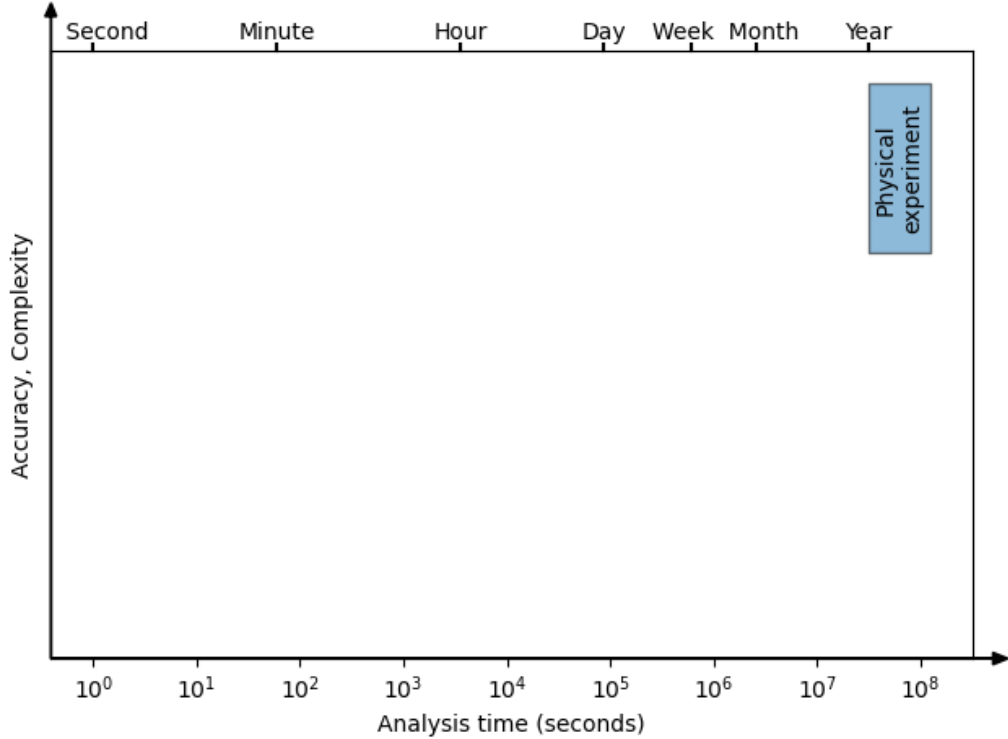
- Vida útil de baterías
 - Descripción del problema
 - Etapas del aprendizaje automático
 - Ingesta
 - Partición
 - Transformación
 - Entrenamiento
 - Evaluación
 - Registro
 - Generalización

- Elección de clientes

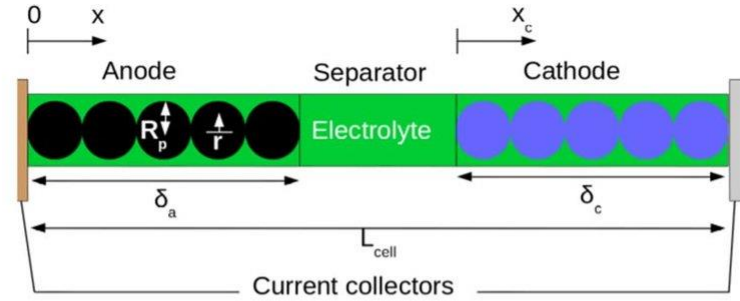
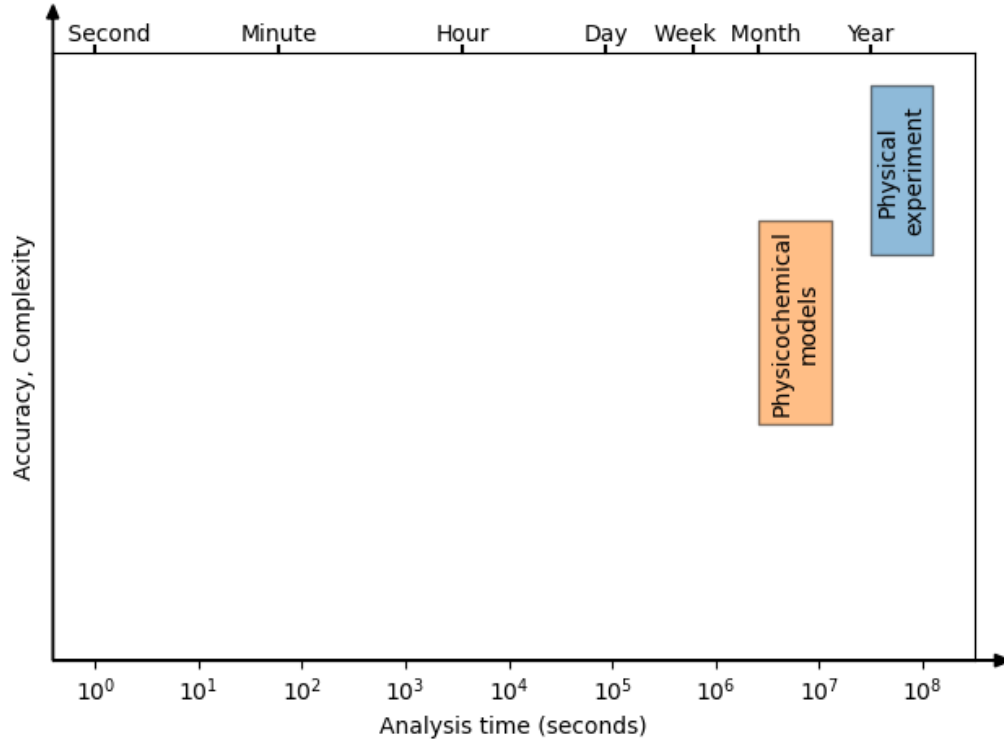
Vida útil de baterías



Vida útil de baterías



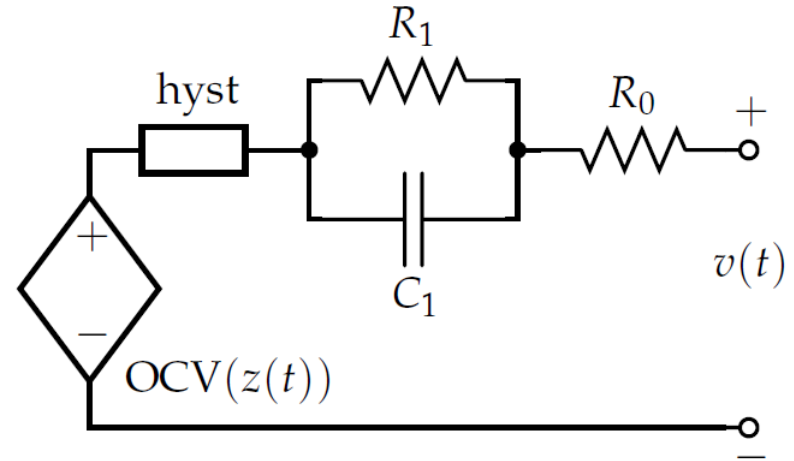
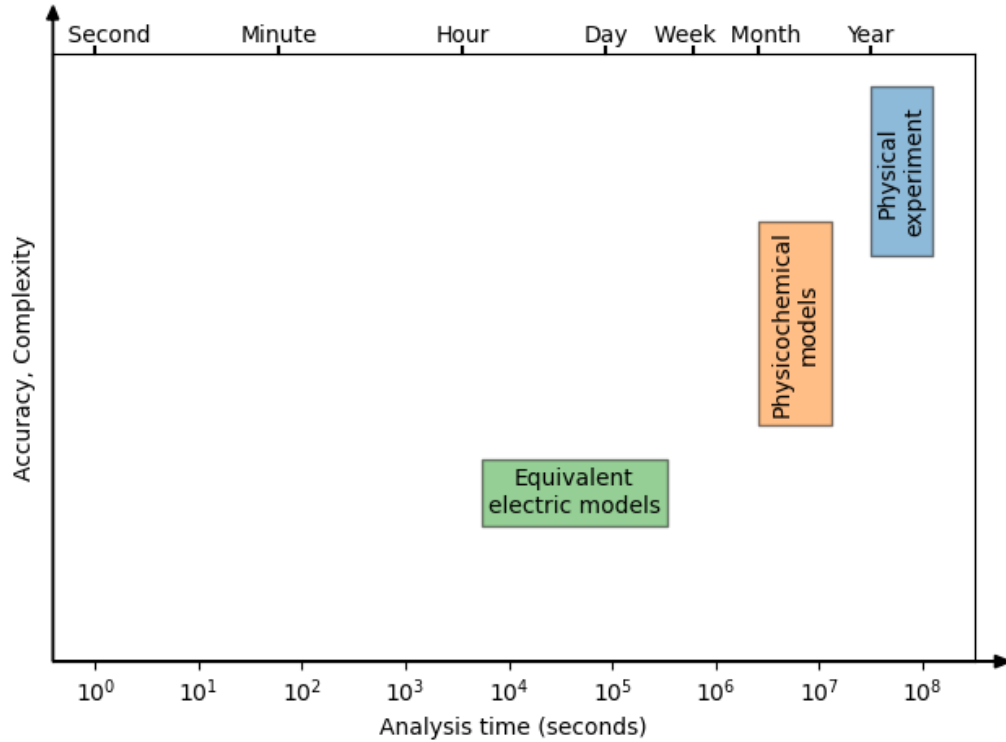
Vida útil de baterías



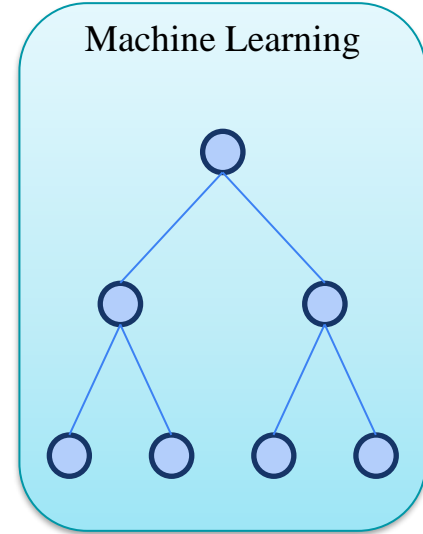
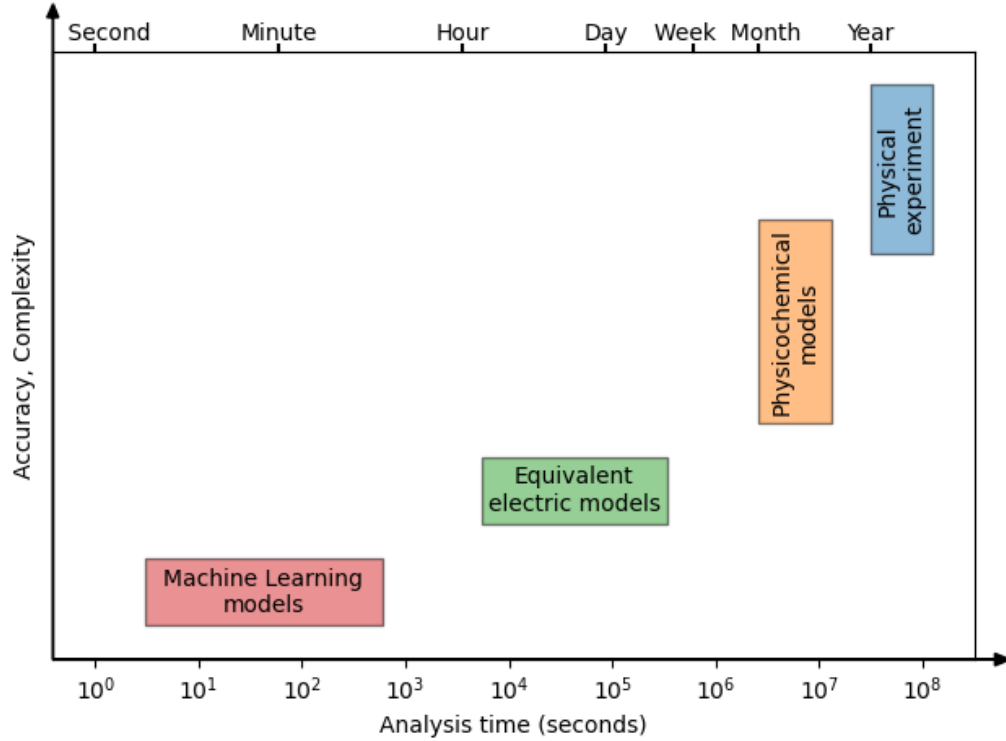
| | |
|--|--|
| Charge carrier transport in the electrodes | $J_s(x) = -\sigma_{s,eff} \cdot \frac{\partial \phi_s(x)}{\partial x}$ |
| Charge carrier transport in the electrolyte | $J_e(x) = -\kappa_{eff}^e(x) \frac{\partial \phi_e(x)}{\partial x} - \kappa_{eff}^{De}(x) \frac{\partial \ln(c_e(x))}{\partial x}$ |
| Li-diffusion in the electrodes | $\frac{\partial c_s(r)}{\partial t} = \frac{1}{r^2} \cdot \frac{\partial}{\partial r} \left(D_s \cdot r^2 \cdot \frac{\partial c_s(r)}{\partial r} \right)$ |
| LiPF ₆ -diffusion in the electrolyte | $\varepsilon \frac{\partial c_e(x)}{\partial t} = \frac{\partial}{\partial x} \cdot \left(D_e^{eff} \cdot \frac{\partial c_e(x)}{\partial x} \right) + (1 - t_{+}) \cdot \frac{j^{Li}(x)}{F}$ |
| Electrochemical reaction kinetics (Butler-Volmer eqn.) | $j^{Li}(x) = a_{sl} \cdot j_0(c_s, c_e) \cdot \left[e^{\left(\alpha_o \frac{F \eta(x)}{RT} \right)} - e^{\left(-\alpha_a \frac{F \eta(x)}{RT} \right)} \right]$ |

Lenze, G., Laue, V., & Krewer, U. (2019). Time-Efficient Reparameterization and Simulation of Manufacturing Impacts on Performance of Lithium-Ion-Batteries. *Journal of The Electrochemical Society*, 166(13), A2950.

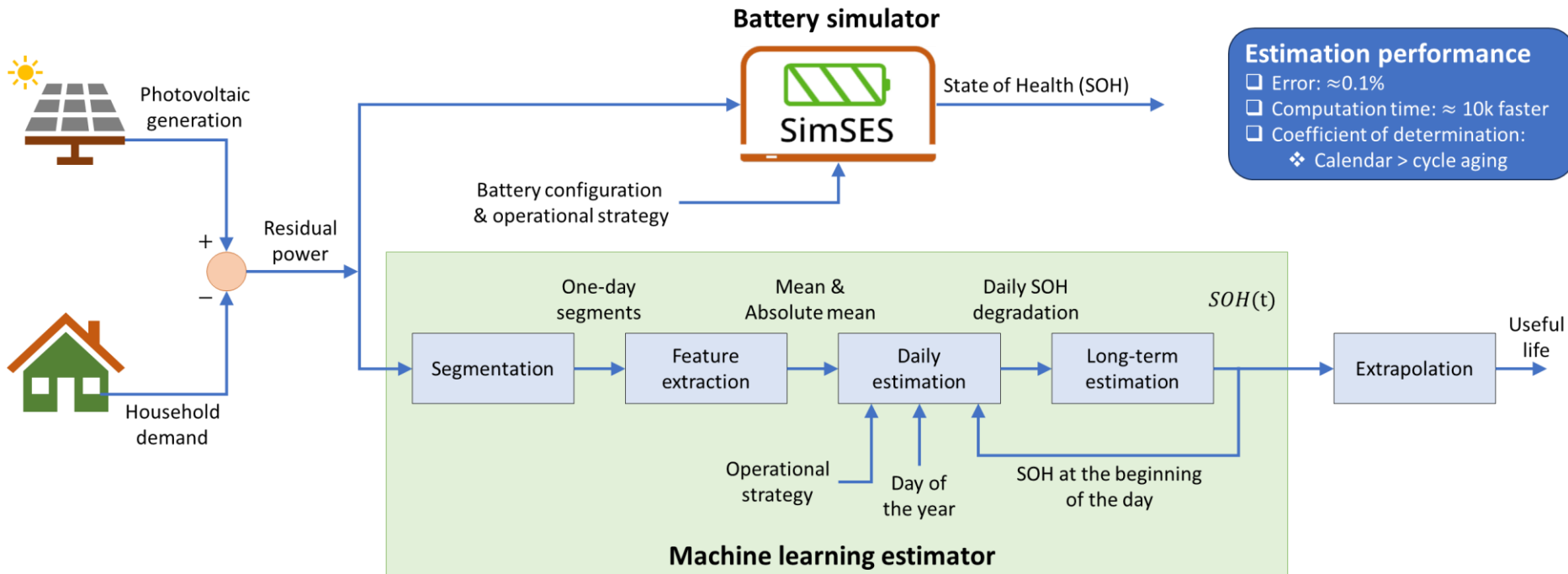
Vida útil de baterías



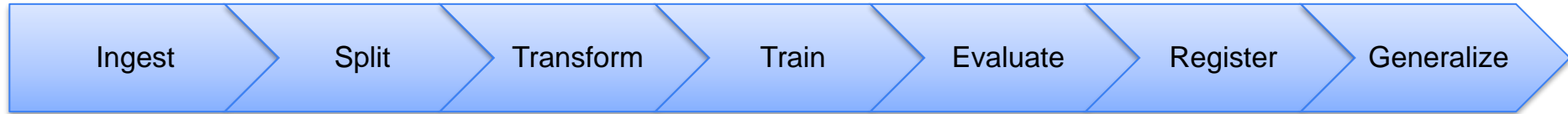
Vida útil de baterías



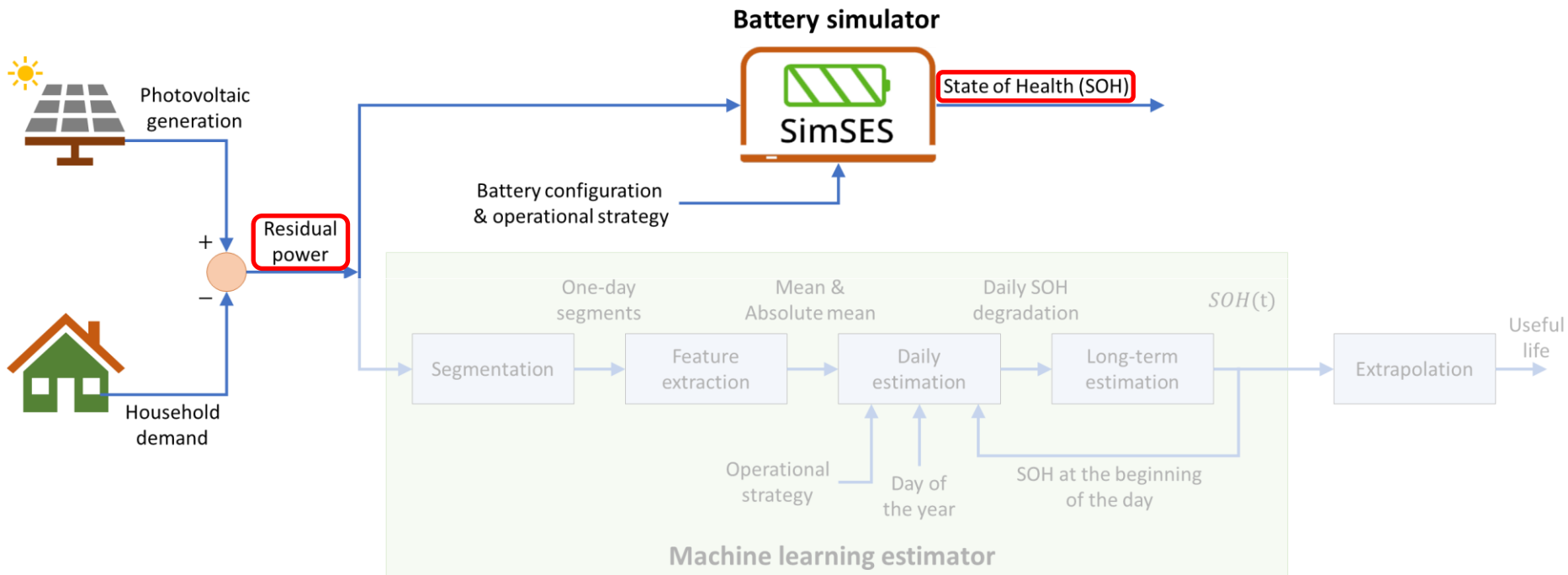
Vida útil de baterías



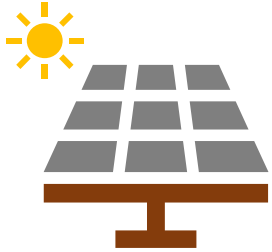
Vida útil de baterías



Vida útil de baterías. Ingesta.



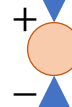
Vida útil de baterías. Ingesta.



| Power generated for a rooftop PV installation (Technical University Munich) | | | | | | | | | |
|--|---|---|---|---|---|---|---|-----|-------|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | ... | t_f |
| 1 | | | | | | | | | |



| Power demand of 74 families (HTW Berlin) | | | | | | | | | |
|---|---|---|---|---|---|---|---|-----|-------|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | ... | t_f |
| 1 | | | | | | | | | |
| 2 | | | | | | | | | |
| 3 | | | | | | | | | |
| ⋮ | | | | | | | | | |
| 74 | | | | | | | | | |



| Residual power | | | | | | | | | |
|----------------|---|---|---|---|---|---|---|-----|-------|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | ... | t_f |
| 1 | | | | | | | | | |
| 2 | | | | | | | | | |
| 3 | | | | | | | | | |
| ⋮ | | | | | | | | | |
| 74 | | | | | | | | | |

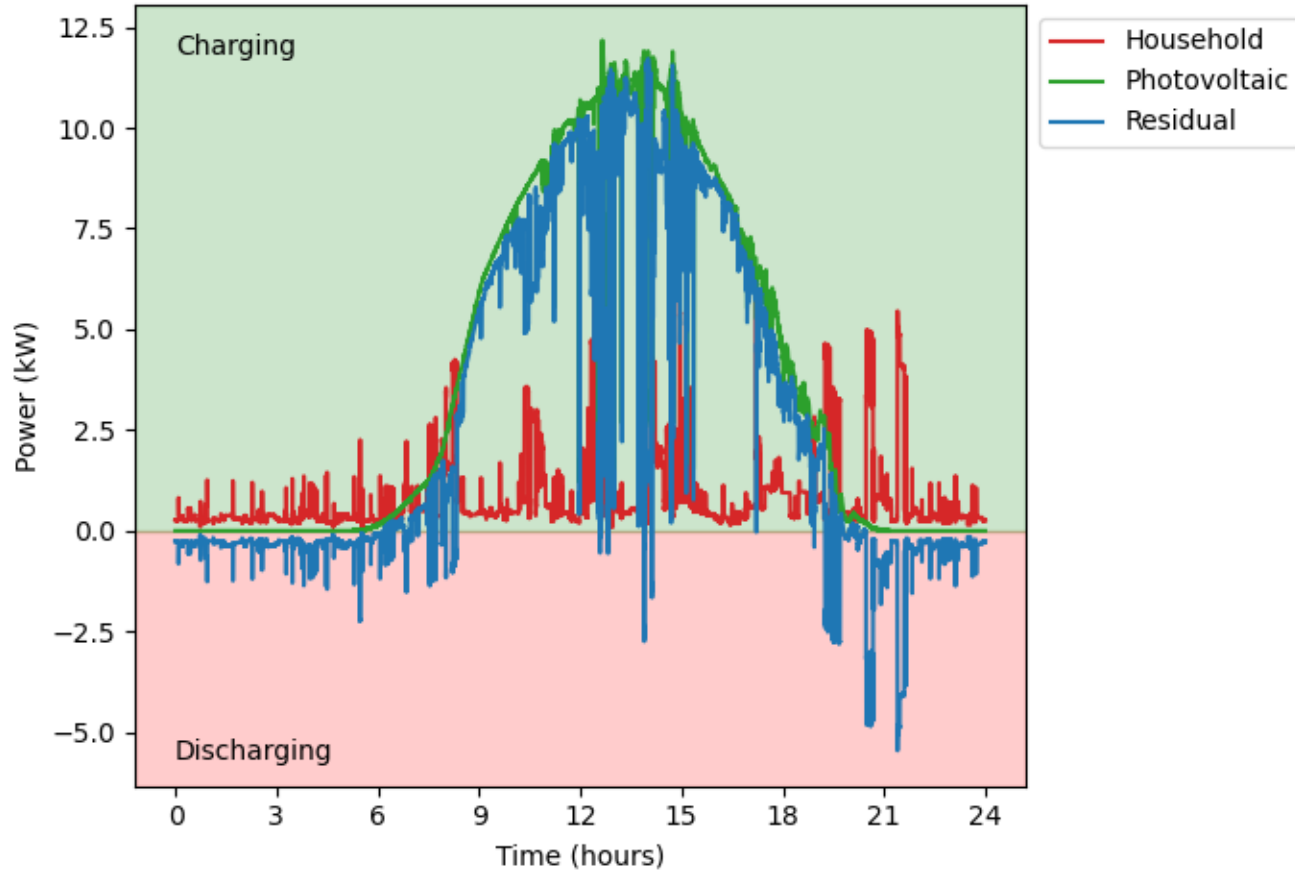


Time (5 years)

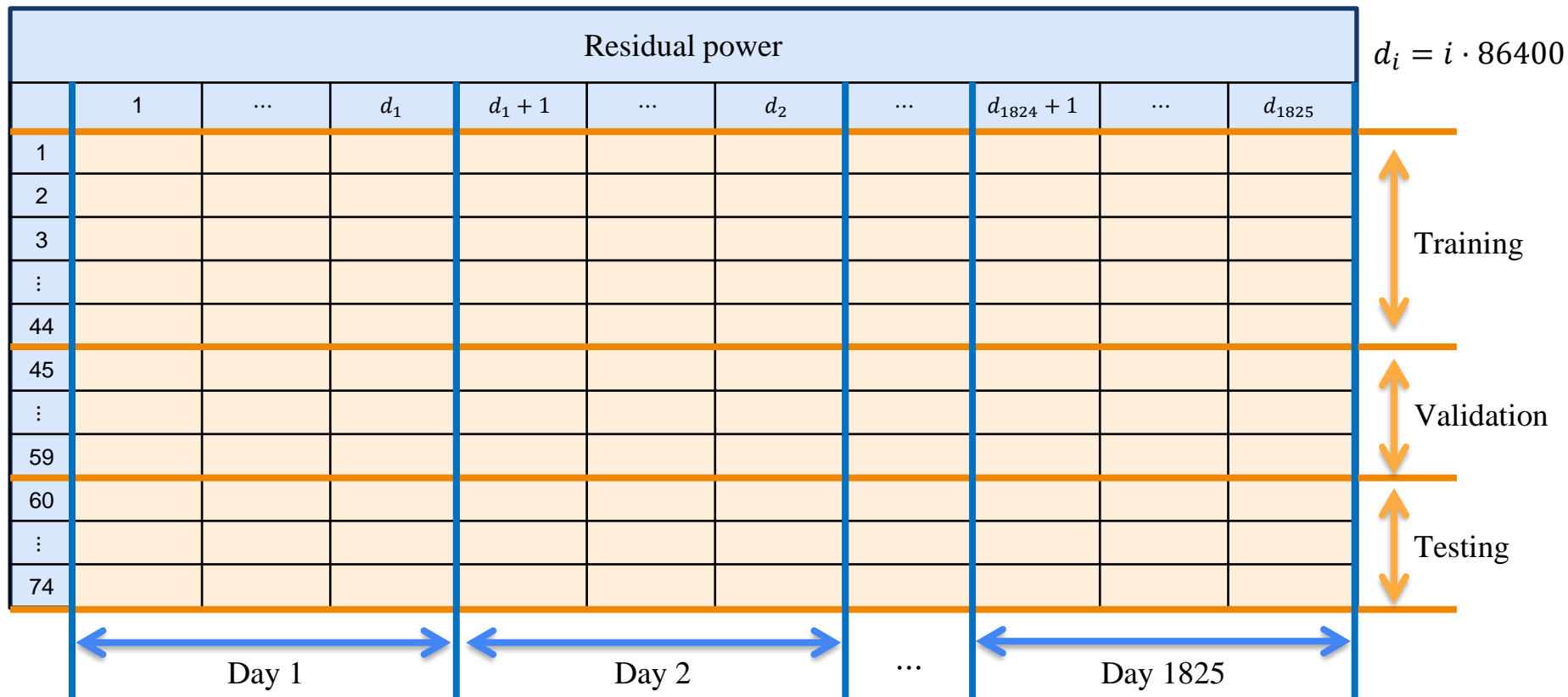
One-second resolution

$t_f = 157,680,000$ s.

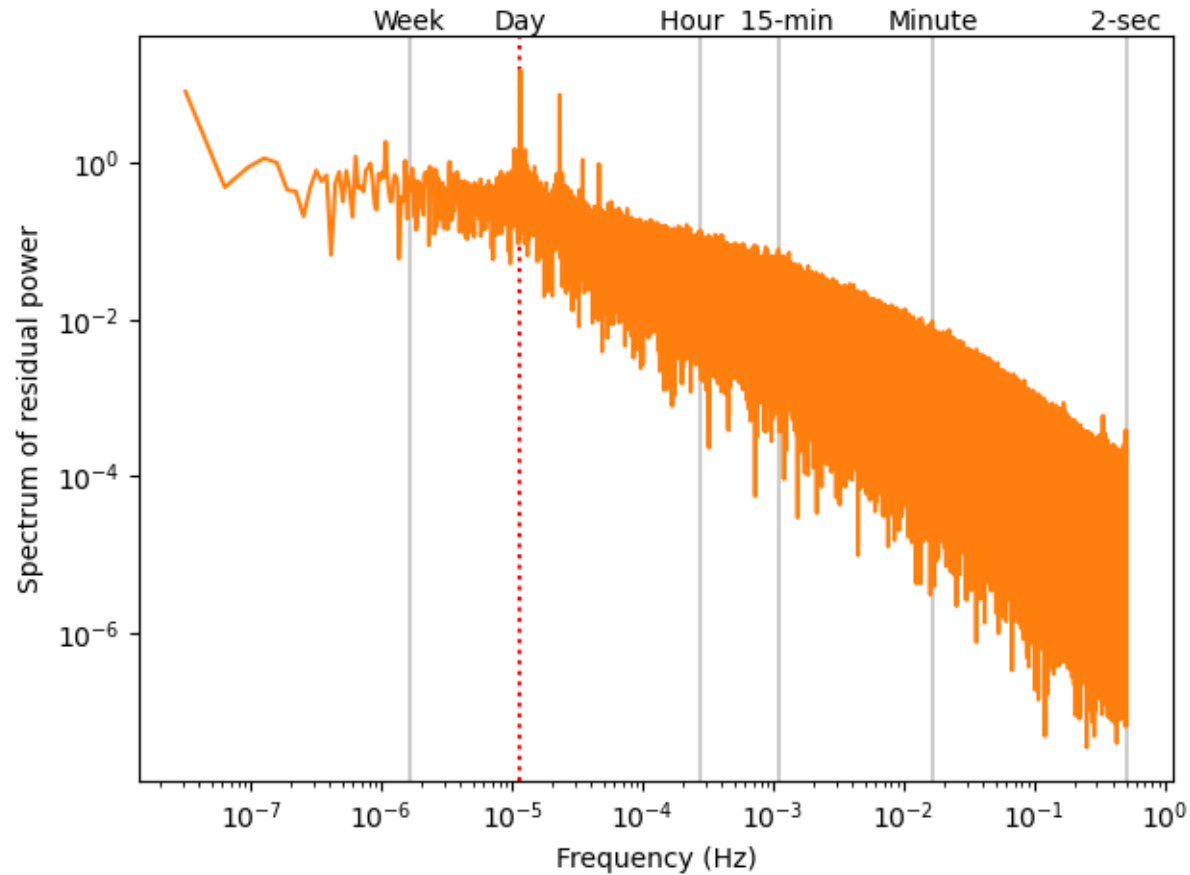
Vida útil de baterías. Ingesta.



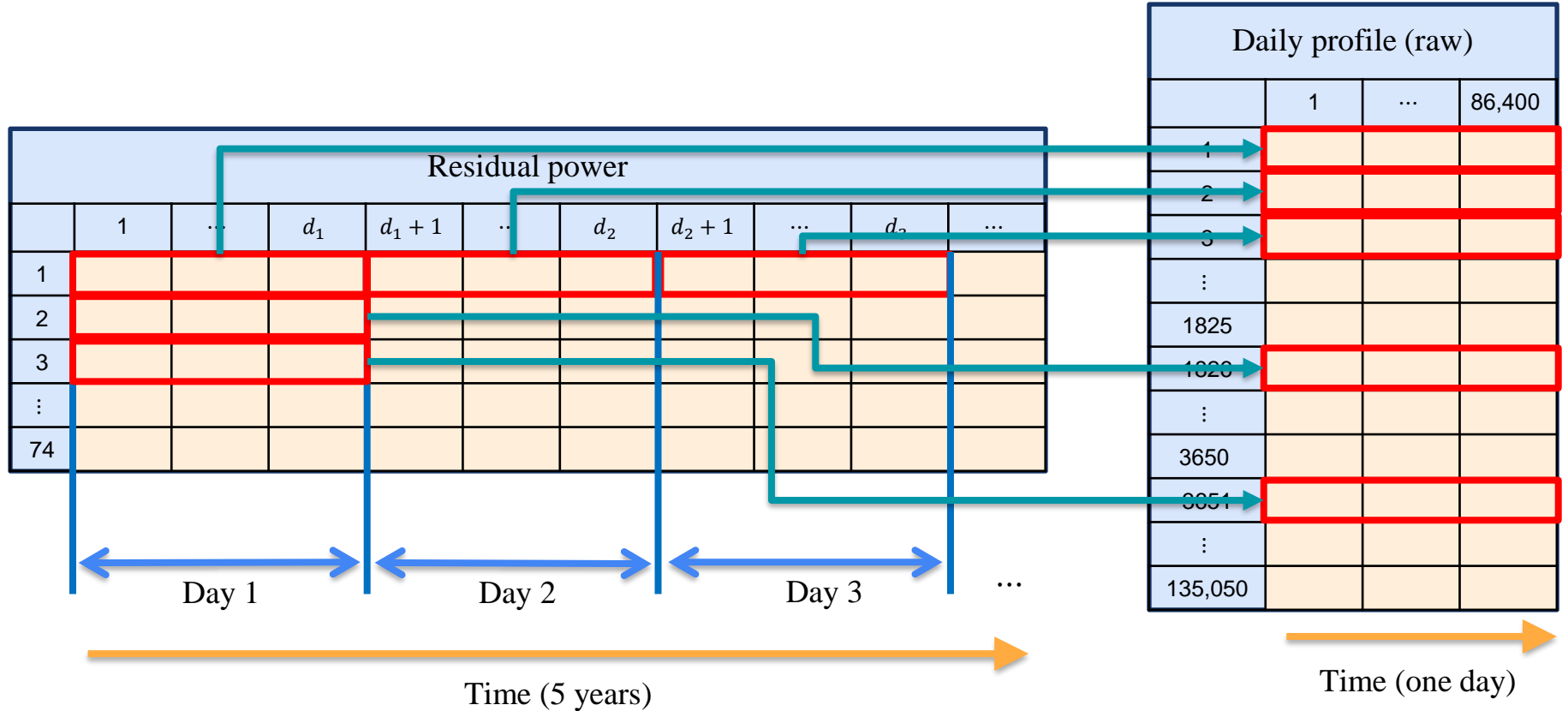
Vida útil de baterías. Partición



Vida útil de baterías. Partición



Vida útil de baterías. Partición



Vida útil de baterías. Transformación



Design matrix (raw)

Design matrix

| Daily profile (raw) | | | | | | | |
|---------------------|---|---|---|---|---|-----|--------|
| | 1 | 2 | 3 | 4 | 5 | ... | 86,400 |
| 1 | | | | | | | |
| 2 | | | | | | | |
| 3 | | | | | | | |
| 4 | | | | | | | |
| ⋮ | | | | | | | |
| 135,050 | | | | | | | |



| Daily profile (features) | | | | |
|--------------------------|---|---|-----|----|
| | 1 | 2 | ... | 29 |
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| ⋮ | | | | |
| 135,050 | | | | |



Time (one day)

One-second resolution

Vida útil de baterías. Transformación

Table 1

The expression of **time-domain** feature parameters.

| Feature expression | Feature expression | Feature expression | Feature expression |
|--|--|-------------------------------|--|
| $TF_1 = \frac{1}{N} \sum_{n=1}^N x(n)$ | $TF_5 = \frac{1}{N} \sum_{n=1}^N (x(n))^3$ | $TF_9 = \min x(n) $ | $TF_{13} = \frac{TF_8}{TF_4}$ |
| $TF_2 = \sqrt{\frac{1}{N-1} \sum_{n=1}^N [x(n) - TF_1]^2}$ | $TF_6 = \frac{1}{N} \sum_{n=1}^N (x(n))^4$ | $TF_{10} = TF_8 - TF_9$ | $TF_{14} = \frac{TF_8}{TF_3}$ |
| $TF_3 = (\frac{1}{N} \sum_{n=1}^N \sqrt{ x(n) })^2$ | $TF_7 = \frac{1}{N} \sum_{n=1}^N (x(n))^2$ | $TF_{11} = \frac{TF_2}{TF_4}$ | $TF_{15} = \frac{TF_5}{(\sqrt{TF_7})^3}$ |
| $TF_4 = \frac{1}{N} \sum_{n=1}^N x(n) $ | $TF_8 = \max x(n) $ | $TF_{12} = \frac{TF_8}{TF_2}$ | $TF_{16} = \frac{TF_6}{(TF_7)^2}$ |

Yan, X., & Jia, M. (2018). A novel optimized SVM classification algorithm with multi-domain feature and its application to fault diagnosis of rolling bearing. *Neurocomputing*, 313, 47-64.

Vida útil de baterías. Transformación

Table 2

The expression of frequency-domain feature parameters.

| Feature expression | Feature expression | Feature expression |
|--|---|--|
| $FF_1 = \frac{\sum_{k=1}^K y(k)}{K}$ | $FF_6 = \sqrt{\frac{\sum_{k=1}^K [(f_k - FF_5)^2 y(k)]}{K}}$ | $FF_{11} = \frac{\sum_{k=1}^K [(f_k - FF_5)^3 y(k)]}{K(FF_6)^3}$ |
| $FF_2 = \frac{\sum_{k=1}^K [y(k) - FF_1]^2}{K-1}$ | $FF_7 = \sqrt{\frac{\sum_{k=1}^K (f_k^2 y(k))}{\sum_{k=1}^K y(k)}}$ | $FF_{12} = \frac{\sum_{k=1}^K [(f_k - FF_5)^4 y(k)]}{K(FF_6)^4}$ |
| $FF_3 = \frac{\sum_{k=1}^K [y(k) - FF_1]^3}{K(\sqrt{FF_2})^3}$ | $FF_8 = \sqrt{\frac{\sum_{k=1}^K (f_k^4 y(k))}{\sum_{k=1}^K (f_k^2 y(k))}}$ | $FF_{13} = \frac{\sum_{k=1}^K [\sqrt{ f_k - FF_5 } y(k)]}{K\sqrt{FF_6}}$ |
| $FF_4 = \frac{\sum_{k=1}^K [y(k) - FF_1]^4}{K(FF_2)^2}$ | $FF_9 = \frac{\sum_{k=1}^K (f_k^2 y(k))}{\sqrt{[\sum_{k=1}^K (f_k^4 y(k))] [\sum_{k=1}^K y(k)]}}$ | — |
| $FF_5 = \frac{\sum_{k=1}^K (f_k y(k))}{\sum_{k=1}^K y(k)}$ | $FF_{10} = \frac{FF_6}{FF_5}$ | — |

Vida útil de baterías. Transformación

Supervised learning

Regression

Design matrix

Target vector

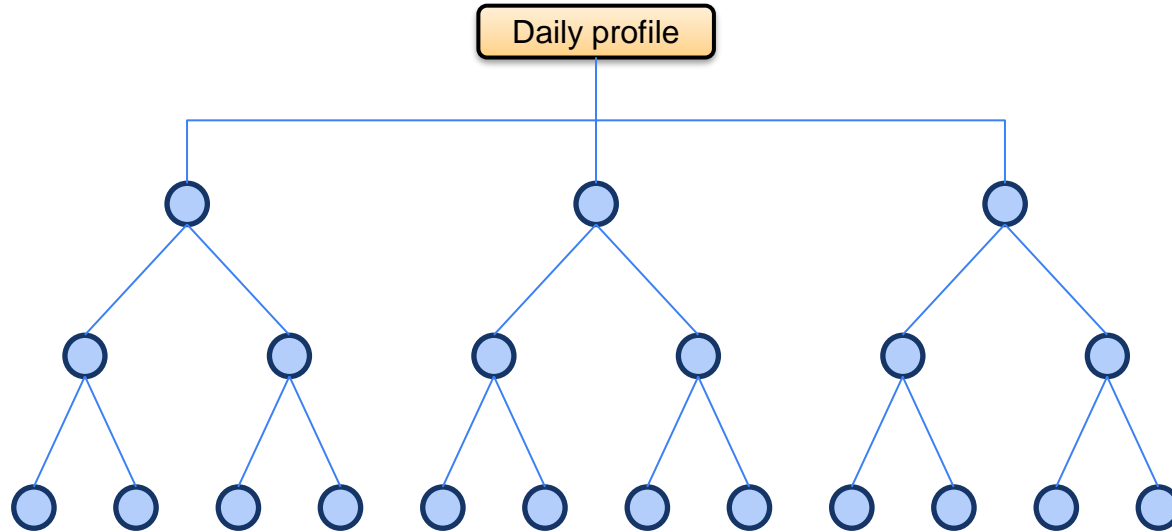
Instances

| Daily profile (features) | | | | | | | |
|--------------------------|---|---|---|---|---|-----|----|
| | 1 | 2 | 3 | 4 | 5 | ... | 29 |
| 1 | | | | | | | |
| 2 | | | | | | | |
| 3 | | | | | | | |
| 4 | | | | | | | |
| ⋮ | | | | | | | |
| 135,050 | | | | | | | |

| Daily ΔSOH | |
|--------------------|---|
| | 1 |
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| ⋮ | |
| 135,050 | |

Features

Vida útil de baterías. Entrenamiento

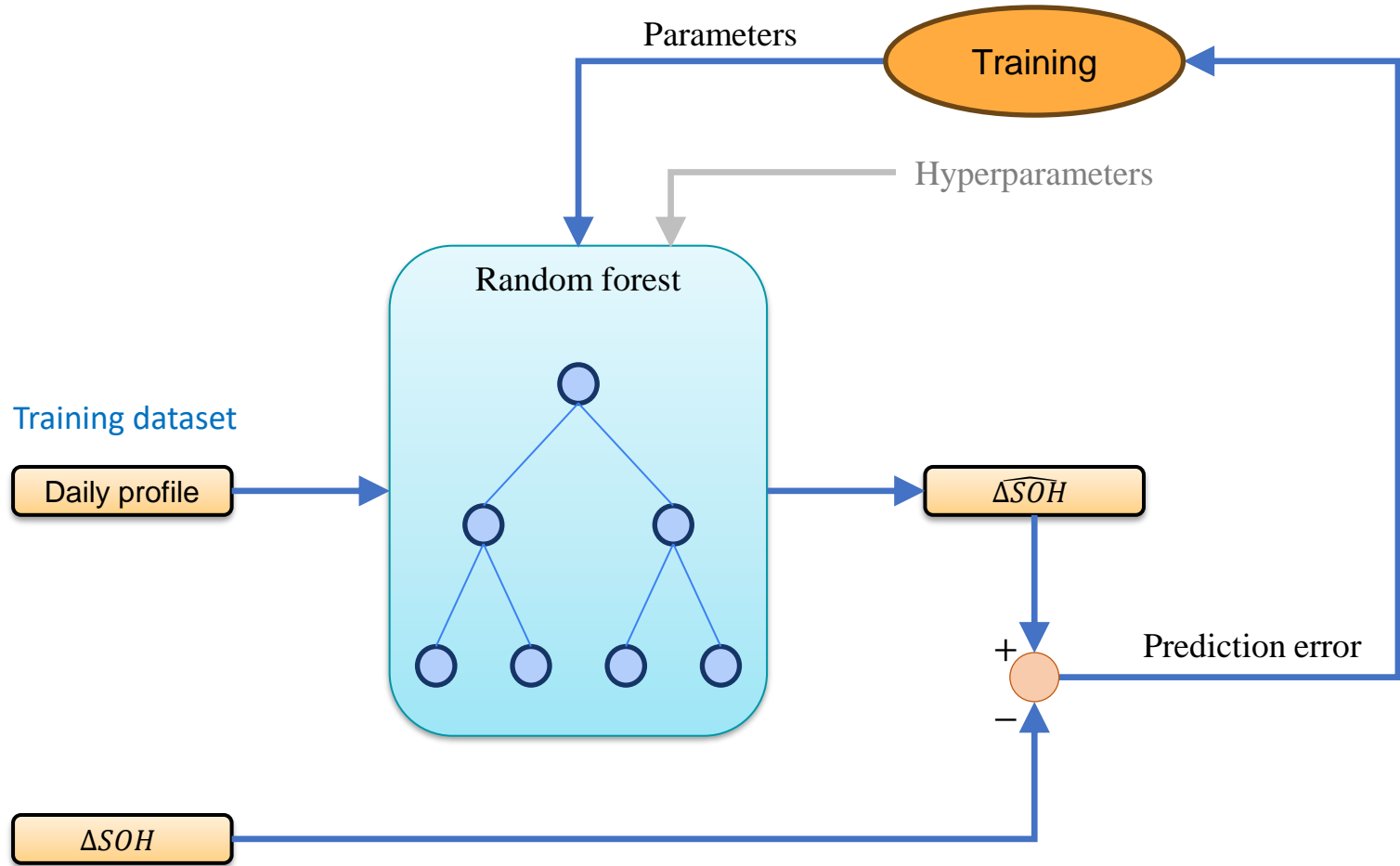


Decision tree

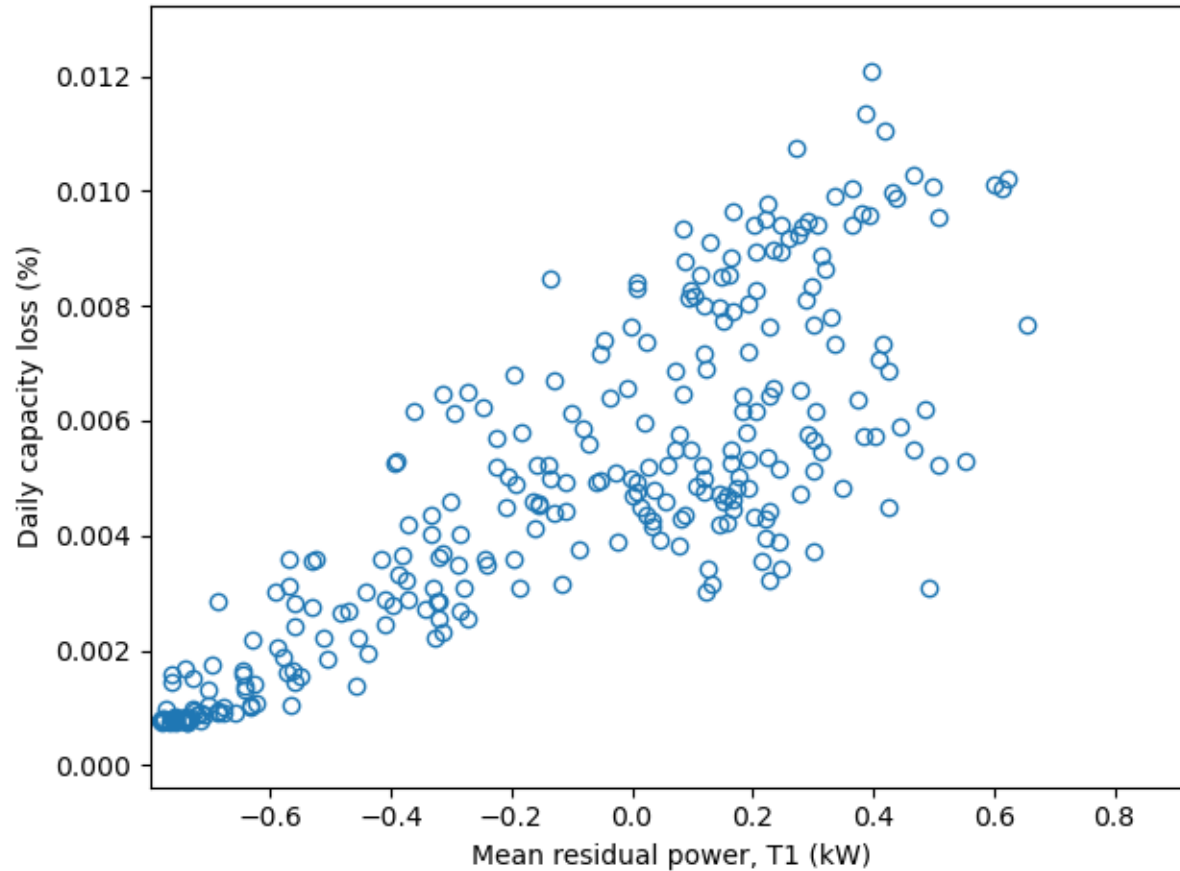


Random forest

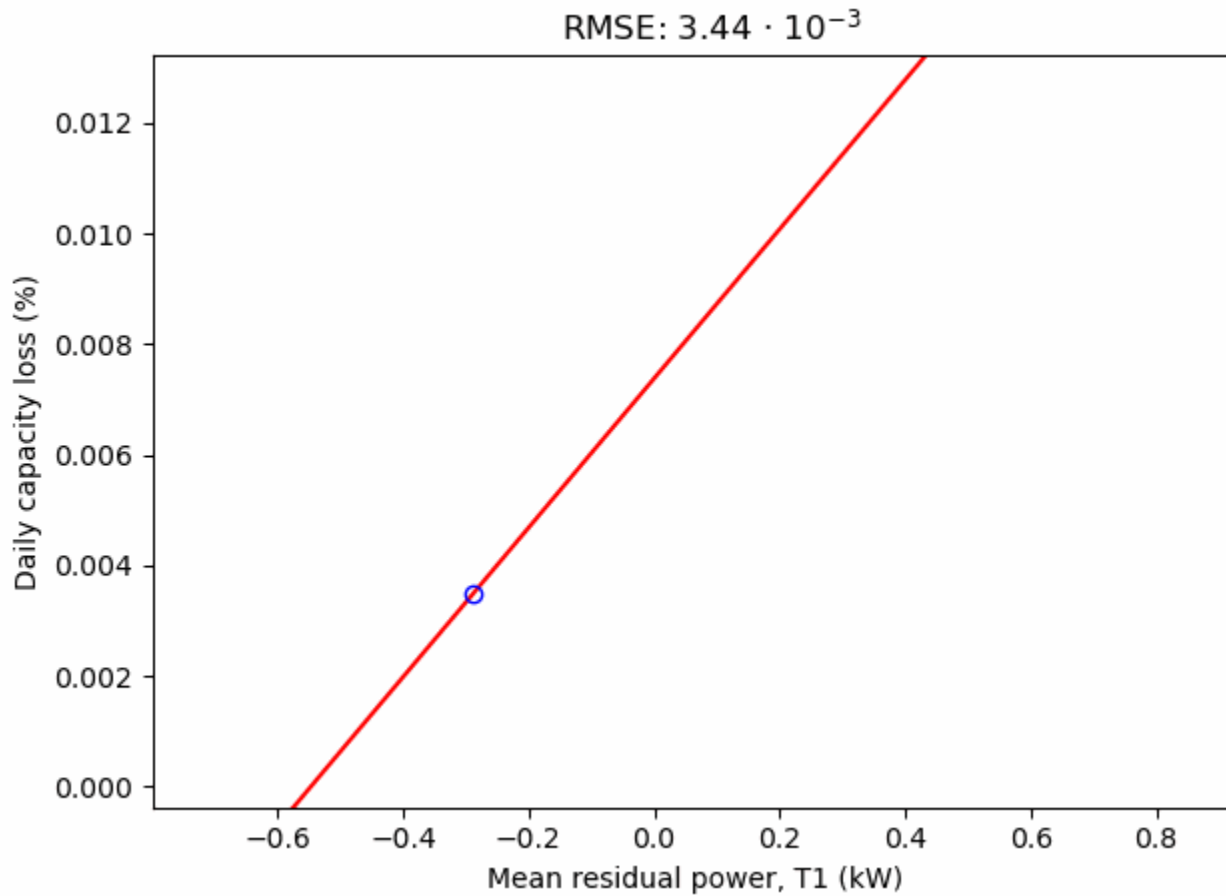
Vida útil de baterías. Entrenamiento



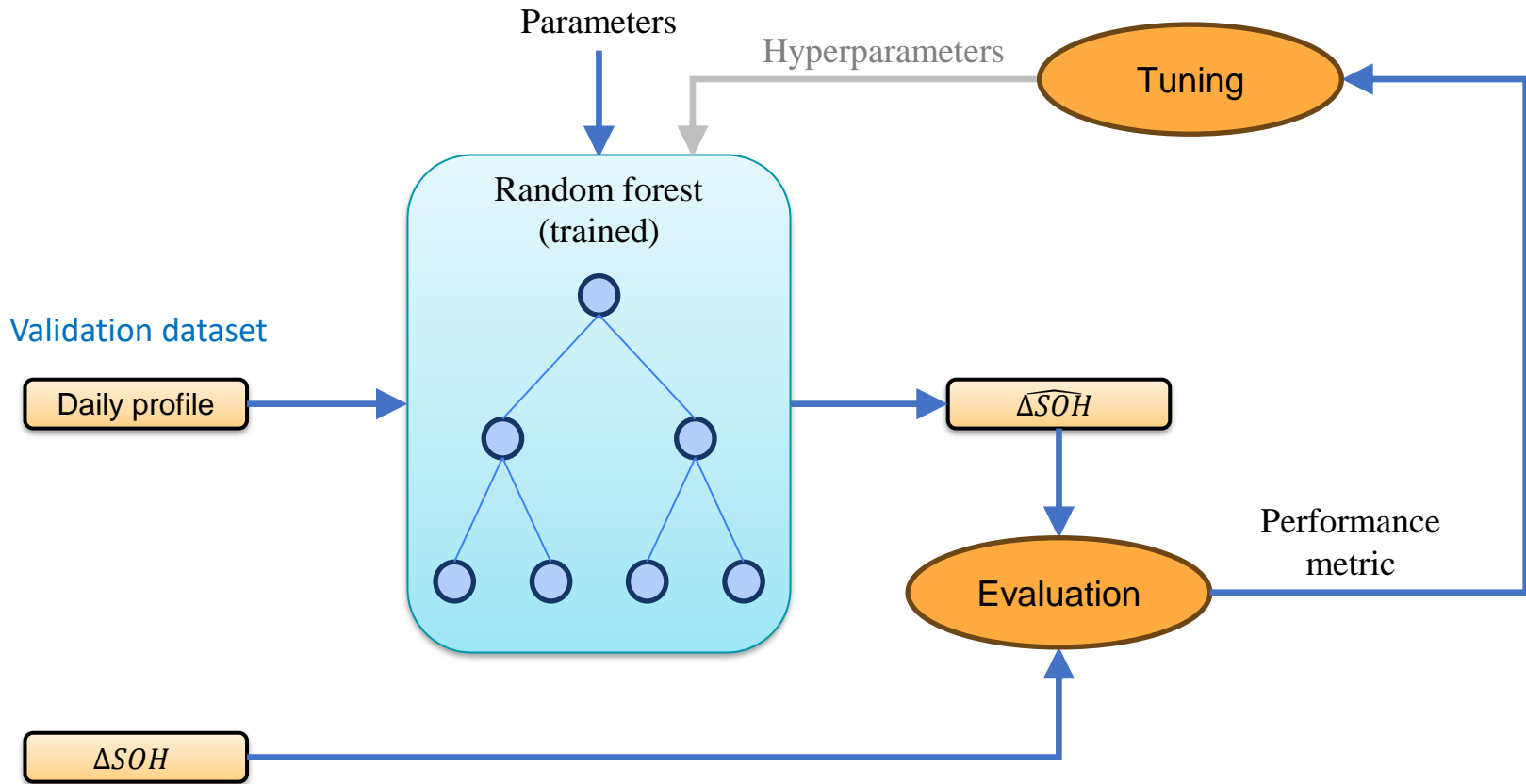
Vida útil de baterías. Entrenamiento



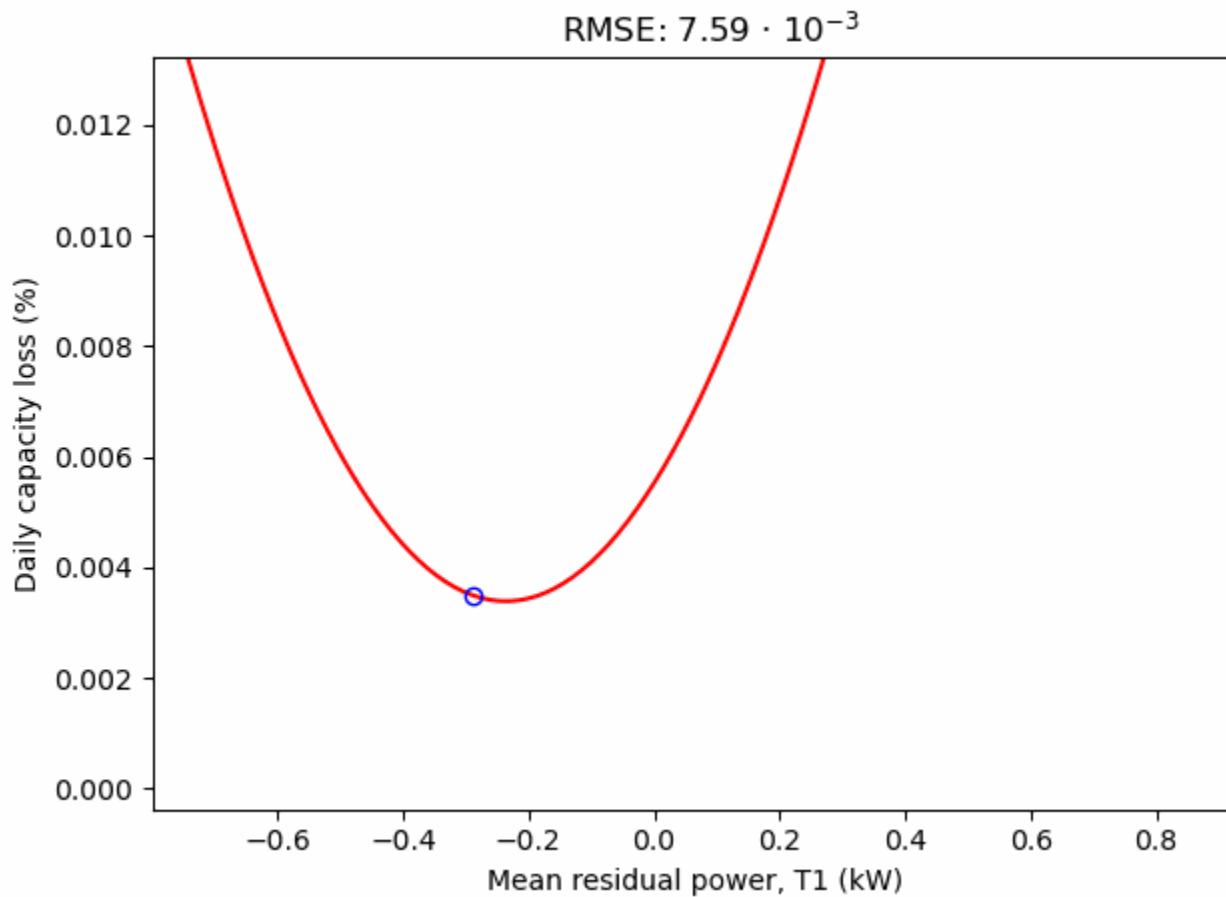
Vida útil de baterías. Entrenamiento



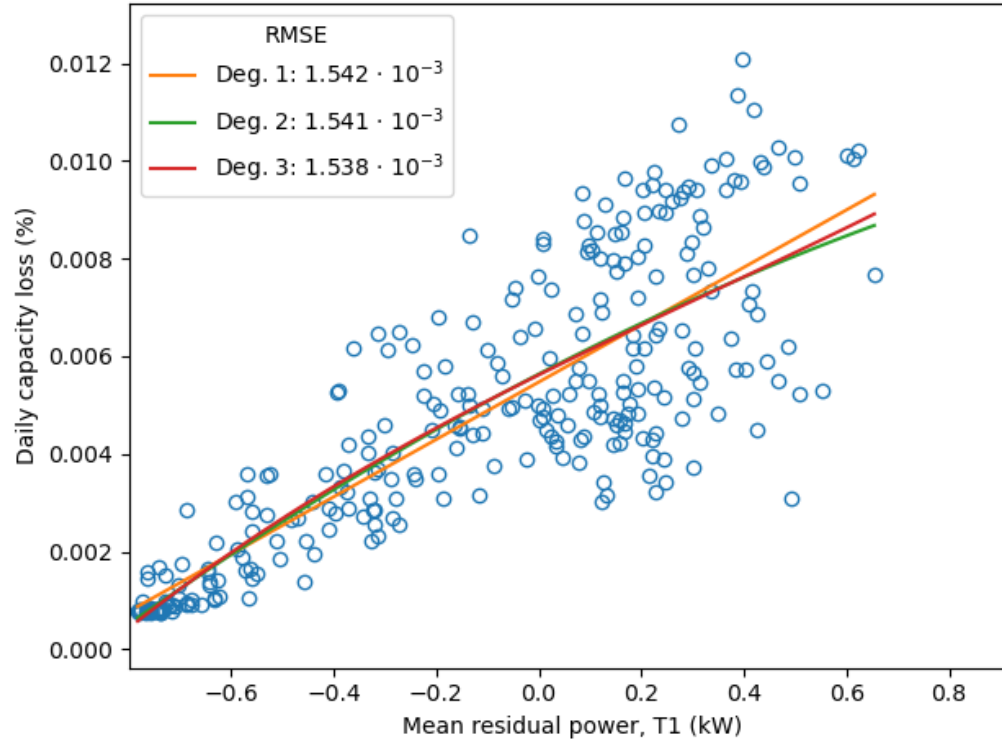
Vida útil de baterías. Evaluación



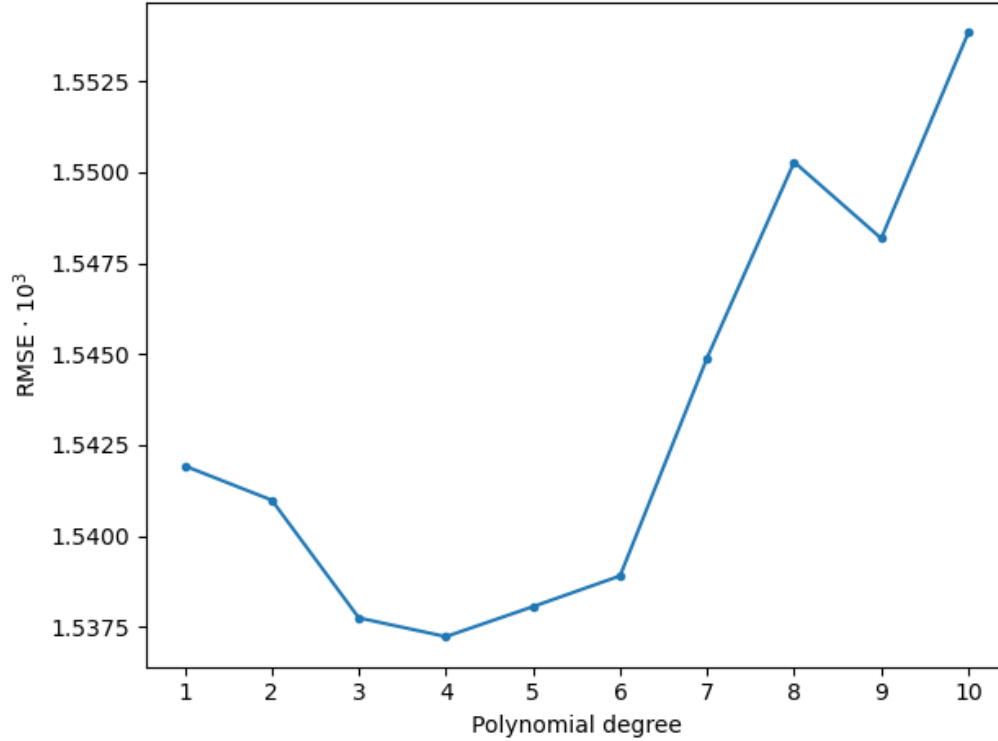
Vida útil de baterías. Evaluación



Vida útil de baterías. Evaluación



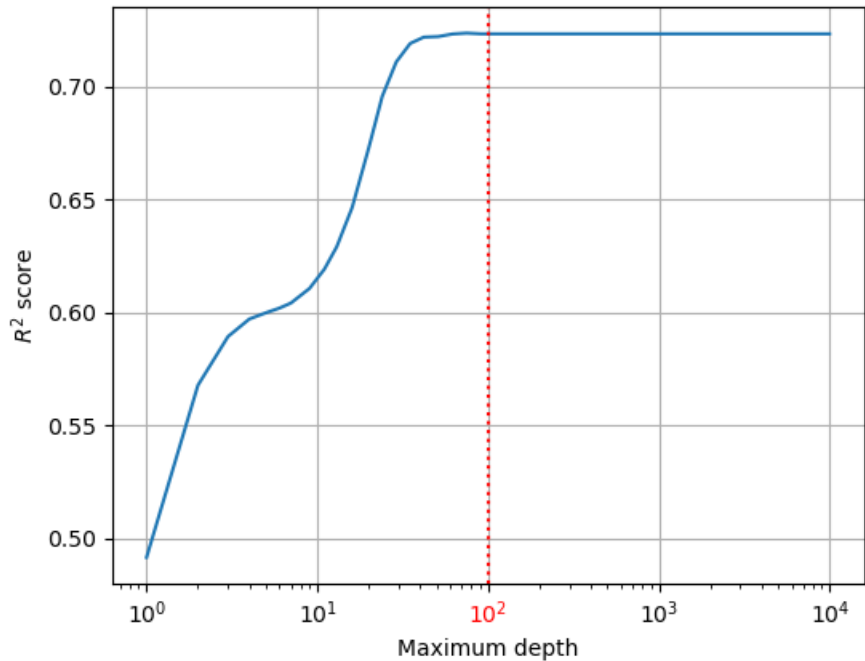
Vida útil de baterías. Evaluación



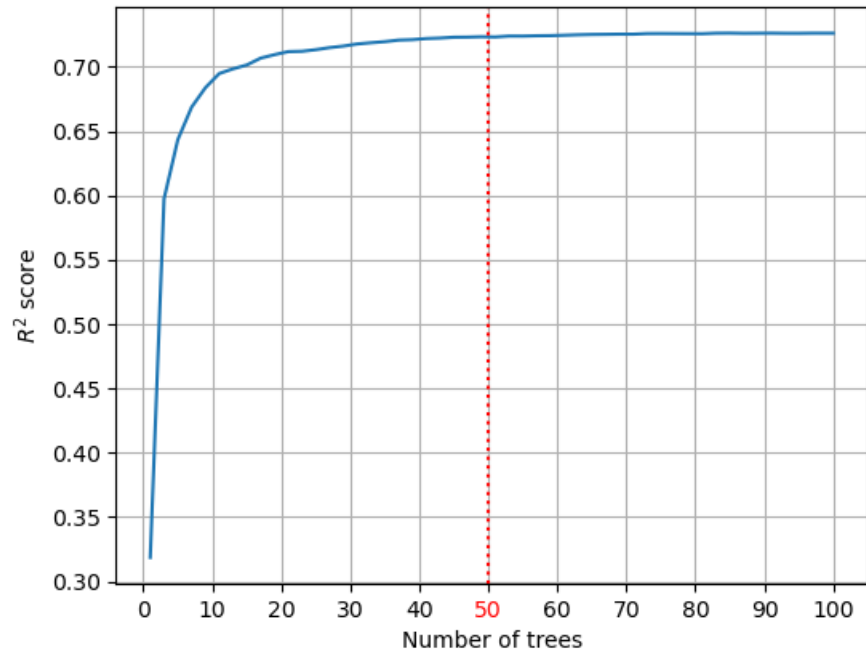
Vida útil de baterías. Evaluación



Number of trees: 50



Maximum depth: 100



Vida útil de baterías. Registro

Ingest

Split

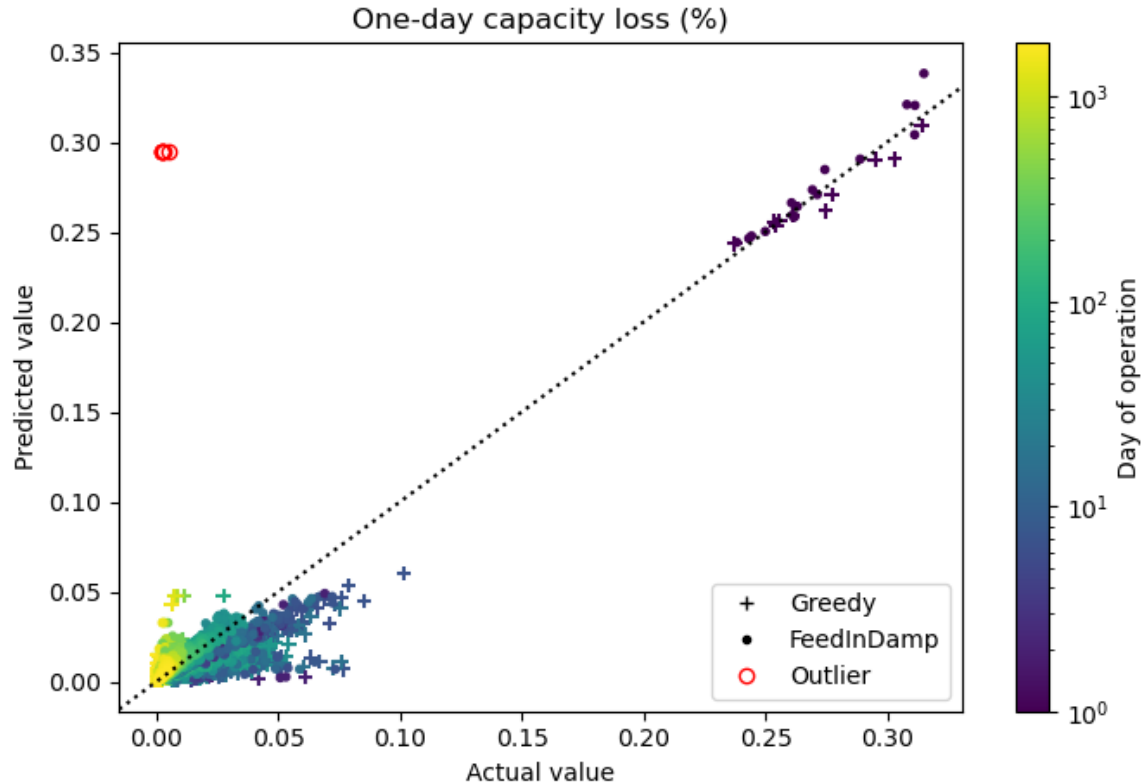
Transform

Train

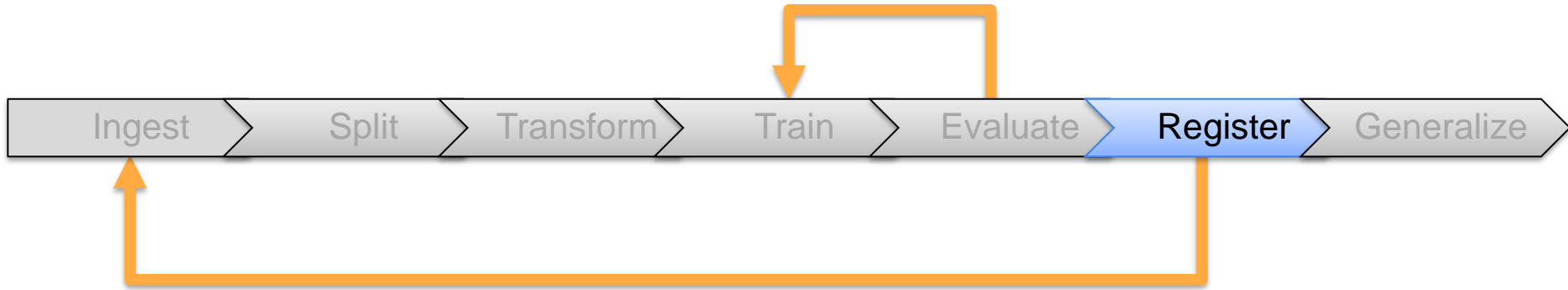
Evaluate

Register

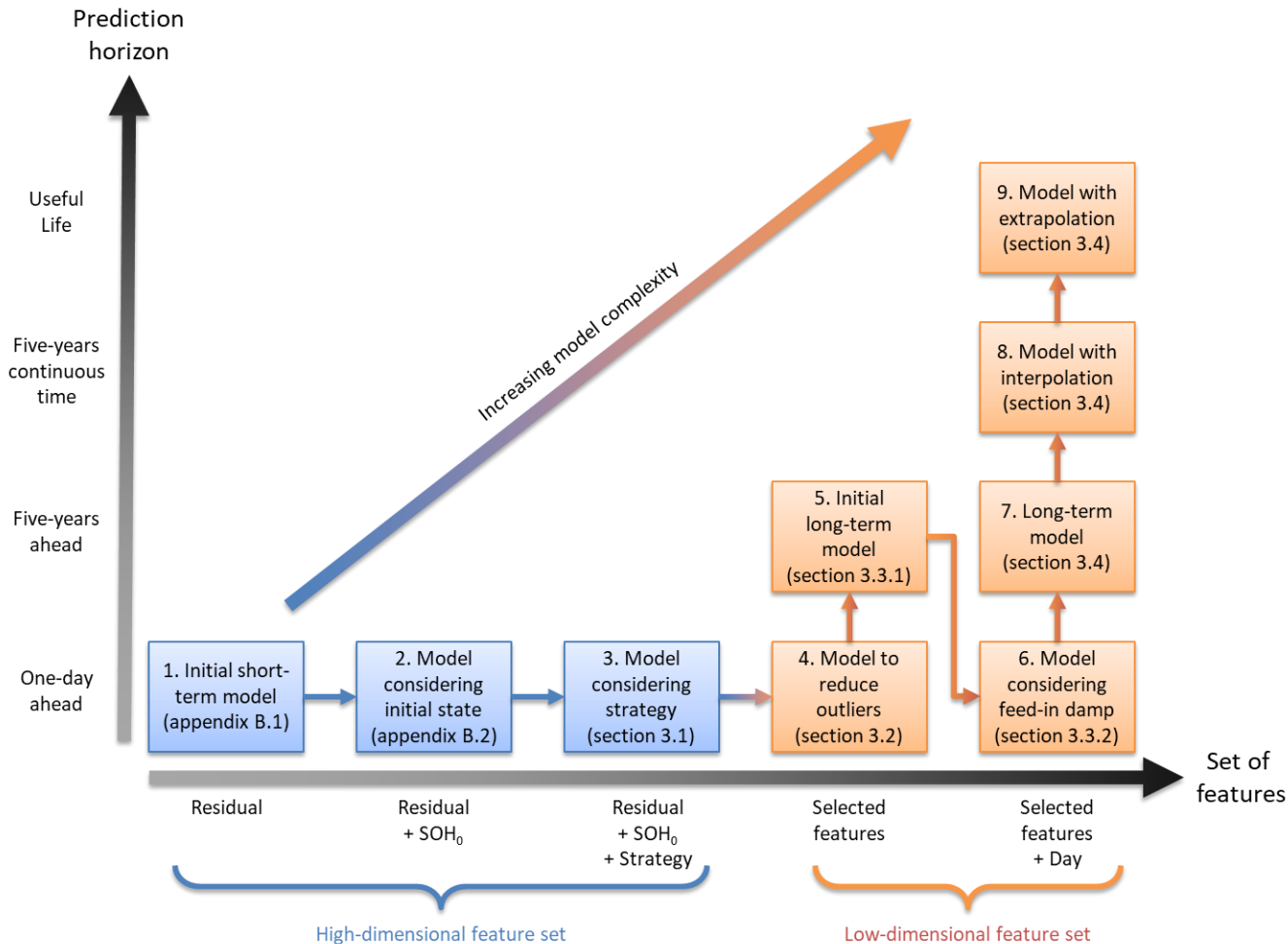
Generalize



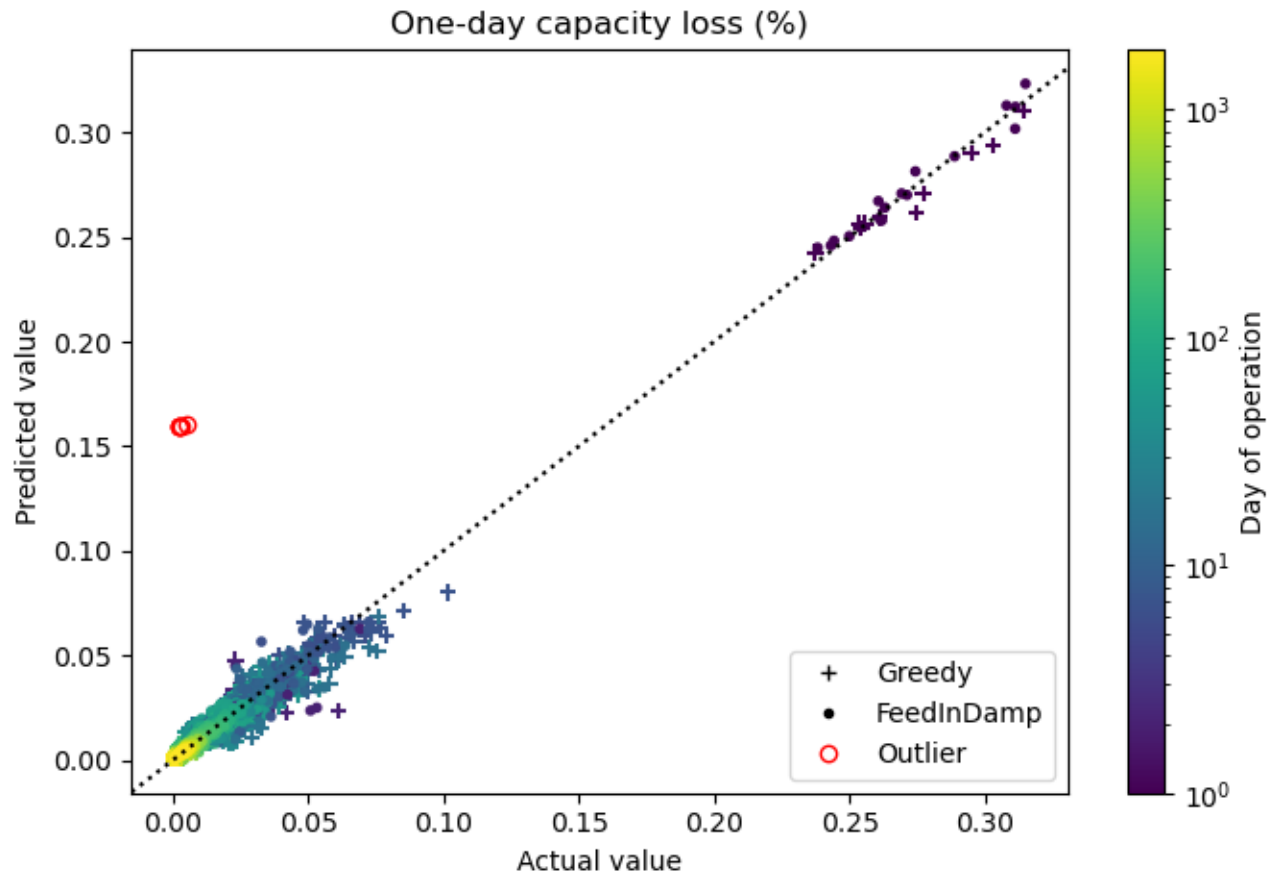
Vida útil de baterías. Registro



Vida útil de baterías. Registro



Vida útil de baterías. Modelo #3



Vida útil de baterías. Reducción de dimensionalidad

| Matrix design | | | | | | | | |
|---------------|-------|-----|----------|-------|-----|----------|---------|--------|
| | T_1 | ... | T_{16} | F_1 | ... | F_{13} | SOH_0 | Strat. |
| 1 | | | | | | | | |
| 2 | | | | | | | | |
| 3 | | | | | | | | |
| 4 | | | | | | | | |
| ⋮ | | | | | | | | |
| 135,050 | | | | | | | | |

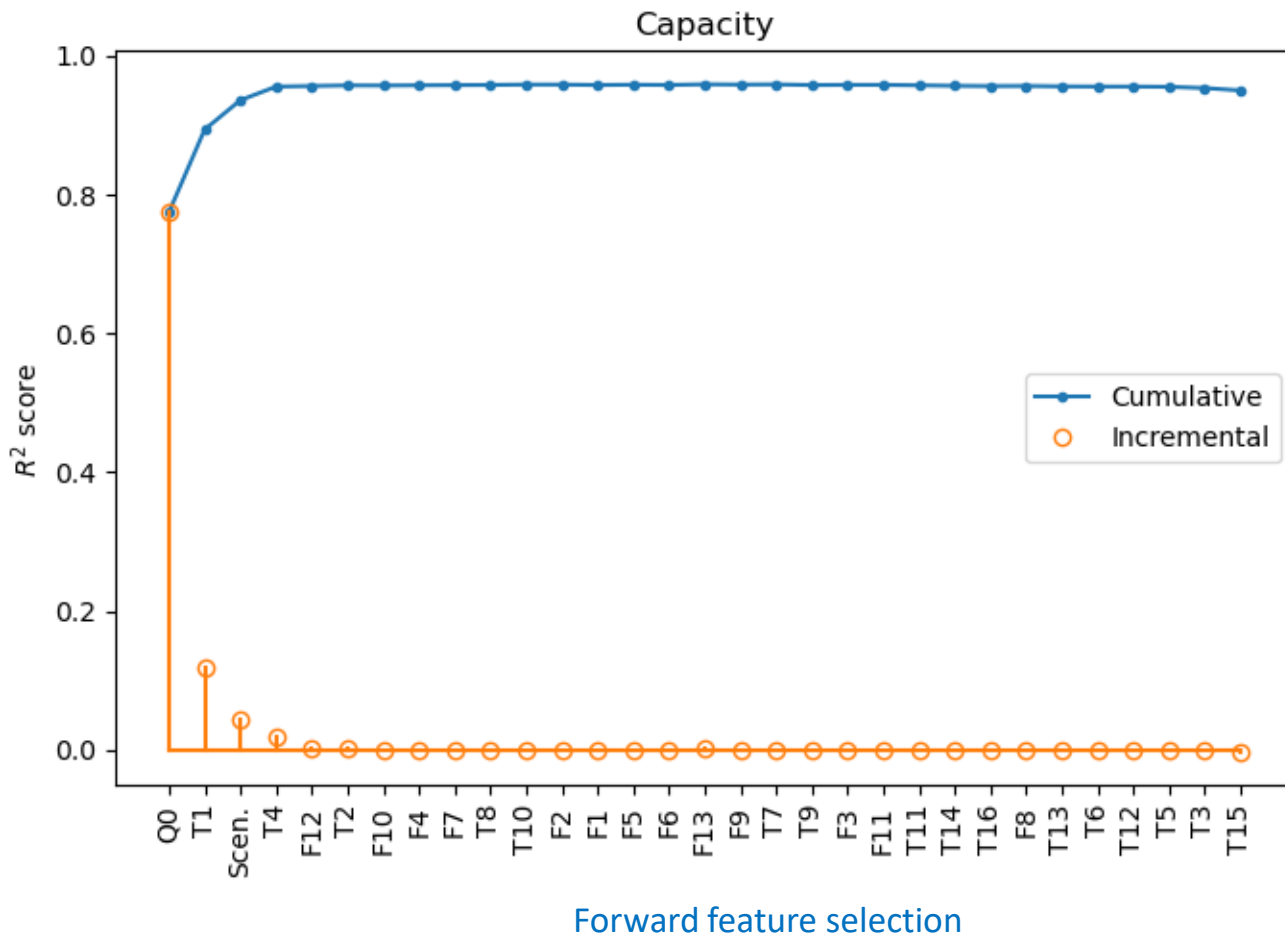
Dim.
reduction

| Matrix design | | | | |
|---------------|---------|-------|--------|-------|
| | SOH_0 | T_1 | Strat. | T_4 |
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| ⋮ | | | | |
| 135,050 | | | | |

High-dimensional
features

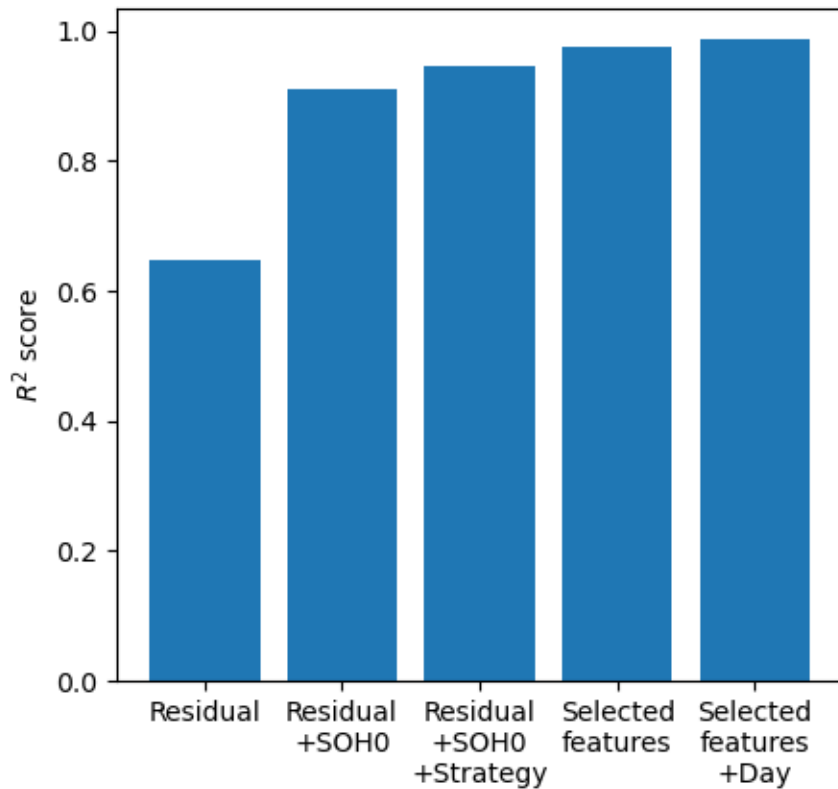
Low-dimensional
features

Vida útil de baterías. Reducción de dimensionalidad

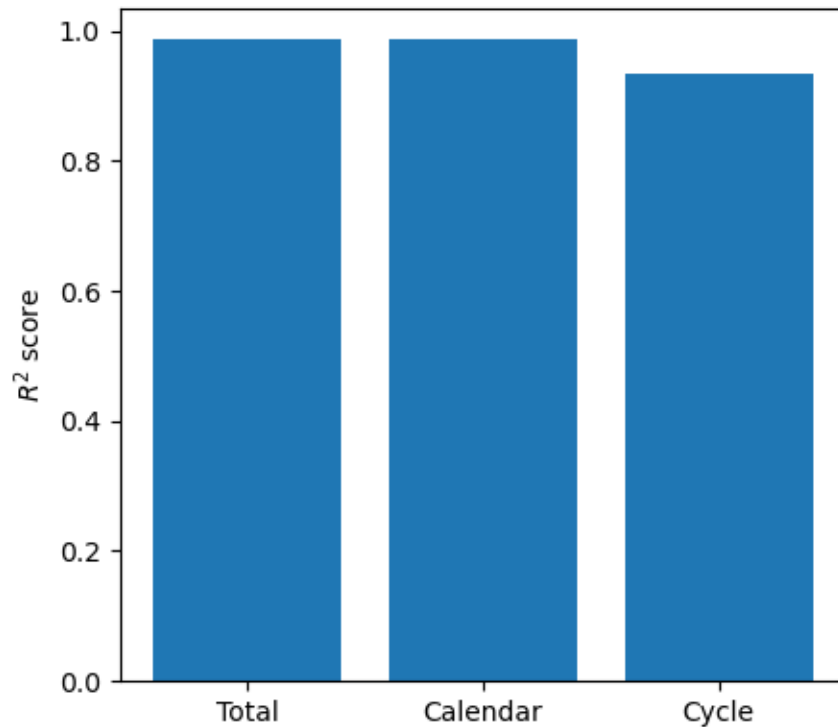


Vida útil de baterías. Registro

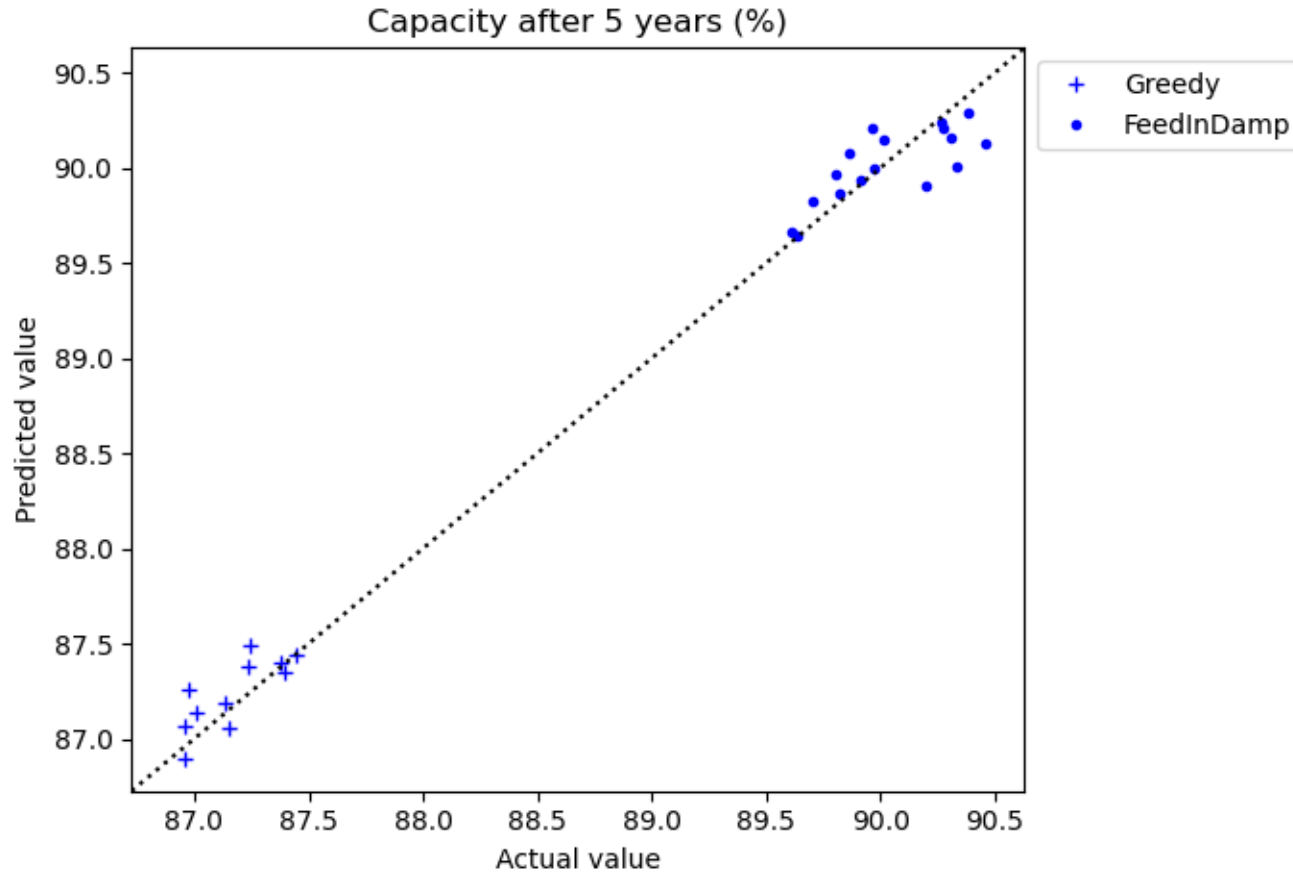
Total daily SOH degradation



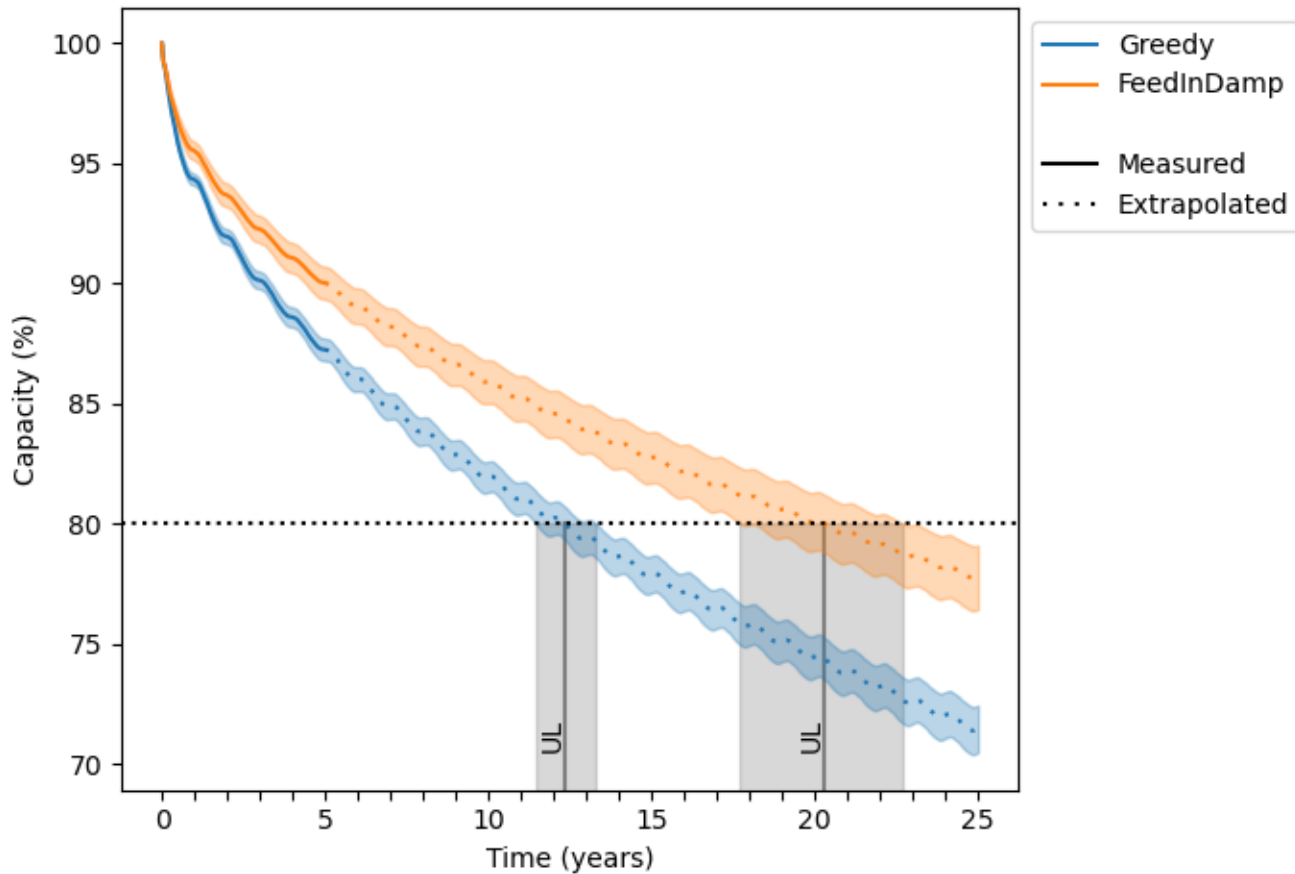
SOH daily degradation
(Selected features + Day)



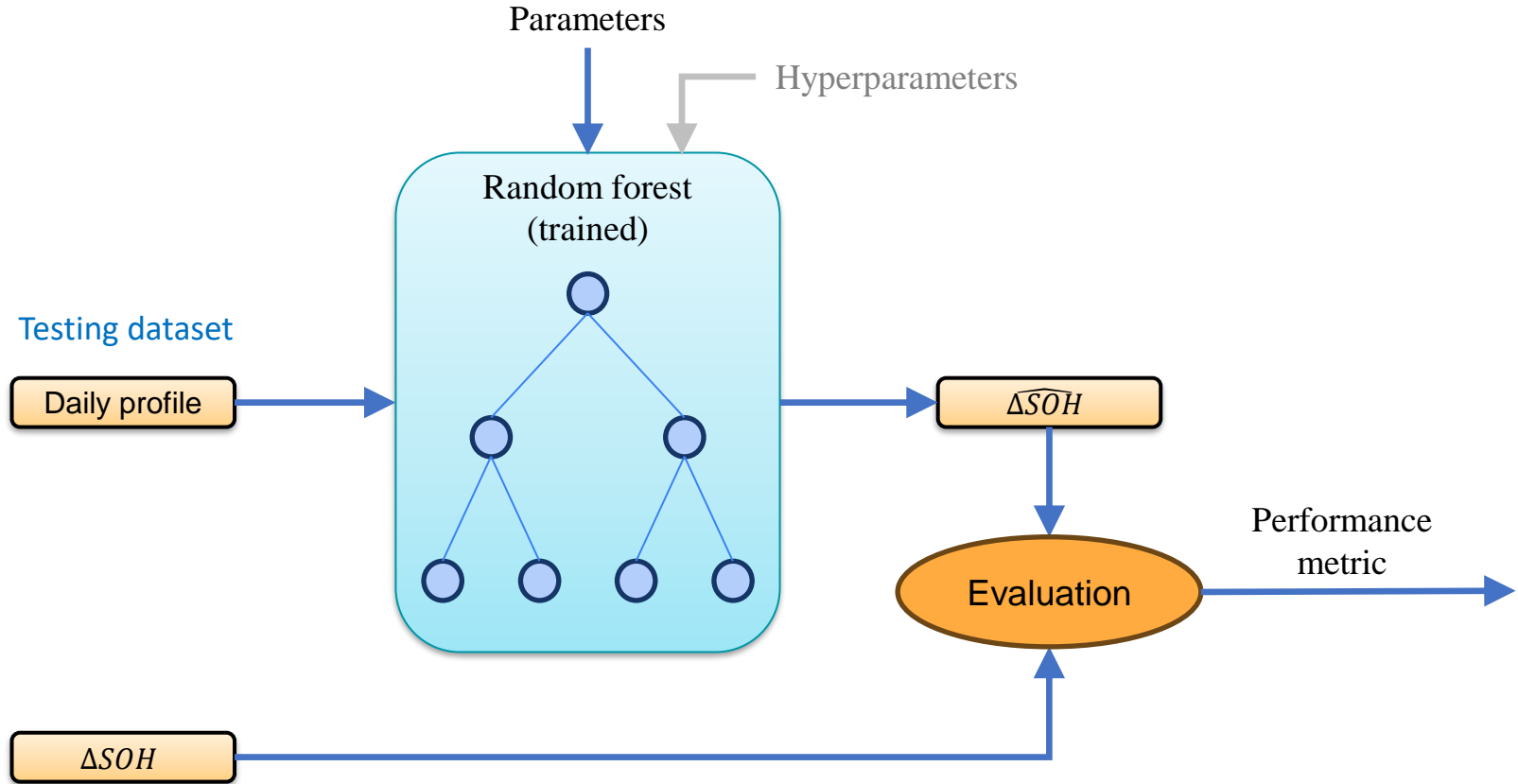
Vida útil de baterías. Predicción de largo plazo



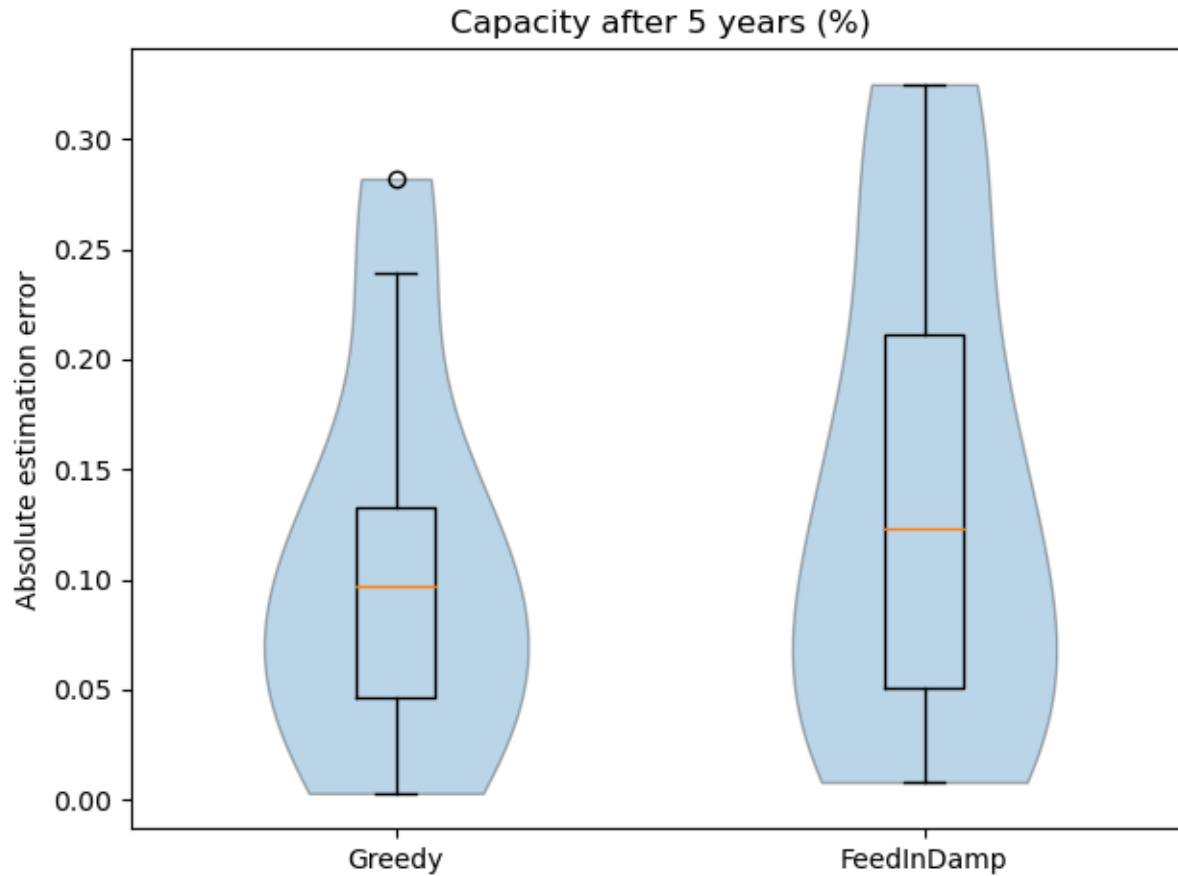
Vida útil de baterías. Predicción de largo plazo



Vida útil de baterías. Generalización



Vida útil de baterías. Generalización



Vida útil de baterías. Referencias

- Luque, J., Tepe, B., Larios, D., León, C., & Hesse, H. (2023). Machine Learning Estimation of Battery Efficiency and Related Key Performance Indicators in Smart Energy Systems. *Energies*, 16(14), 5548.
- Luque, J., Tepe, B., Carrasco, A., Heidarabadi, H., León, C., & Hesse, H.. Machine Learning Estimation of Battery State of Health in Residential Photovoltaic Systems (in progress)

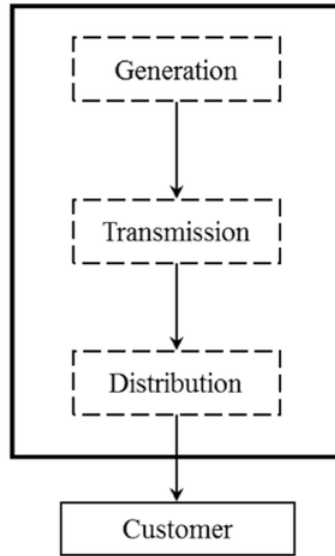
Agenda

- Vida útil de baterías
- Elección de clientes
 - Descripción del problema
 - Ingesta y transformación
 - Reducción de dimensionalidad
 - Representación 1D y 2D
 - Identificación de perfiles por actividad y ubicación

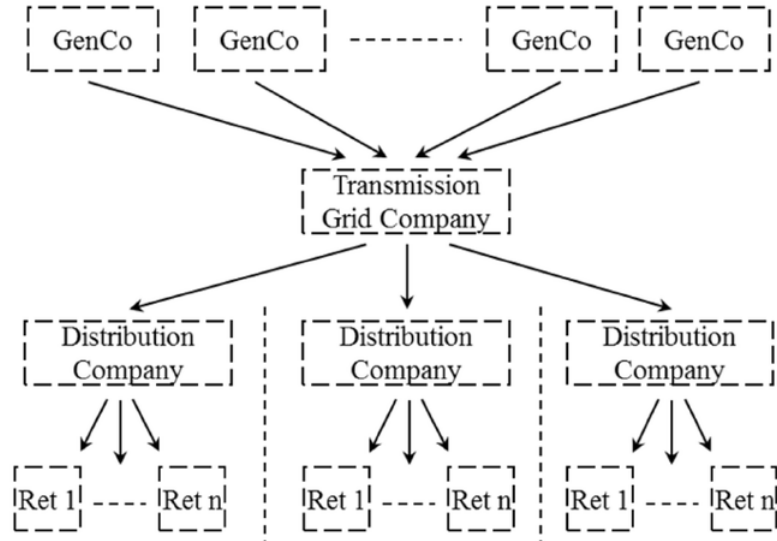
Elección de clientes

BEFORE LIBERALISATION

One vertically integrated company



AFTER LIBERALISATION



Elección de clientes

Bases de datos de consumidores x +

sede.cnmcc.gob.es/tramites/energia/bases-de-datos-de-consumidores-y-puntos-de-suministro-sips-de-gas-y-de

Español Ayuda

Sede Electrónica
COMISIÓN NACIONAL DE LOS
MERCADOS Y LA COMPETENCIA

Buscar en sede.cnmcc.gob.es






Inicio [Trámites](#) Notificaciones Información y Normativa Mis gestiones Tablón de anuncios

Inicio > Trámites > Energía > Bases de datos de consumidores y puntos de suministro (SIPS) de gas y de electricidad

Bases de datos de consumidores y puntos de suministro (SIPS) de gas y de electricidad

Energía

 Ir al Trámite

-  Descripción
-  Instrucciones
-  Documentación requerida
-  Normativa
-  Requisitos técnicos
-  Enlaces de interés
-  FAQ

Descripción del trámite

Sistema de intercambio de puntos de suministro de gas natural y electricidad.

Instrucciones

Para la adecuada cumplimentación de la solicitud ponemos a su disposición la documentación específica de la misma:

- [Descripción formato SIPS](#)
- [Portal de documentación](#)

Documentación requerida

Darse de alta **Comercializadoras** **Retailers**

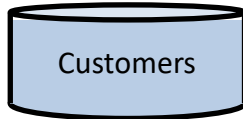
Para las entidades receptoras, el alta la debe efectuar el representante legal.

Es necesario disponer de un **certificado digital** y enviar por **registro electrónico**:

Elección de clientes

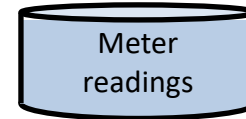
Customers

| feature | type |
|----------------------|---------|
| cups | text |
| Location code | numeric |
| Activity code (NACE) | numeric |
| ⋮ | ⋮ |

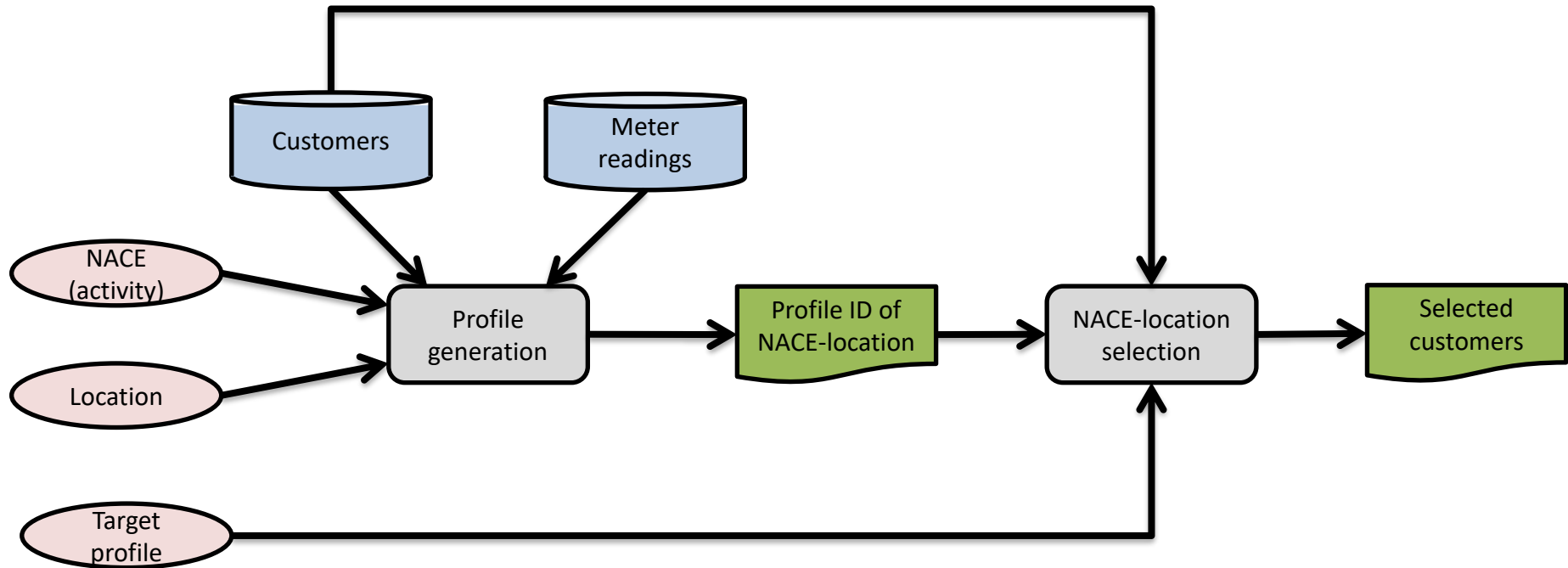


Meter readings

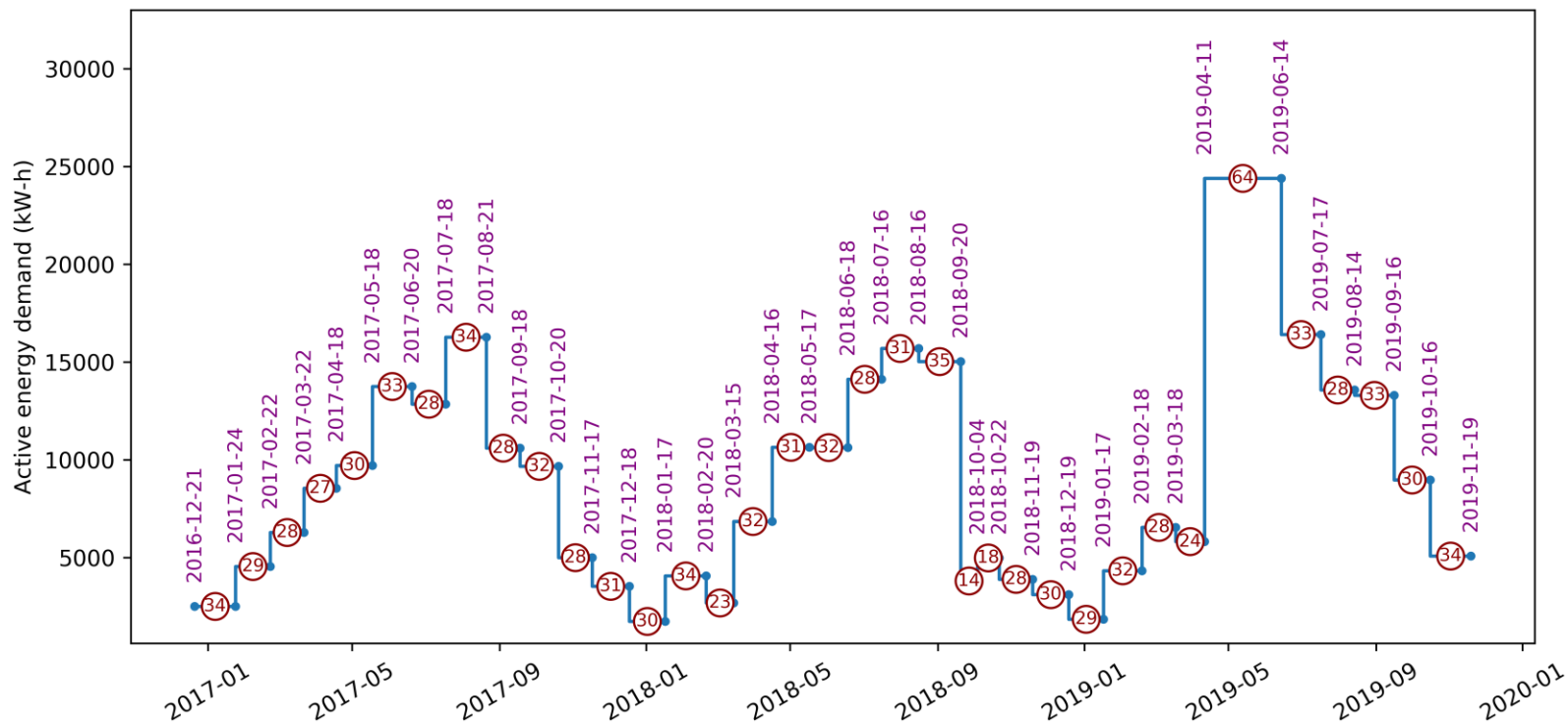
| feature | type |
|----------------------|---------|
| cups | text |
| Initial date | date |
| Final date | date |
| Energy demanded (Wh) | numeric |
| ⋮ | ⋮ |



Elección de clientes

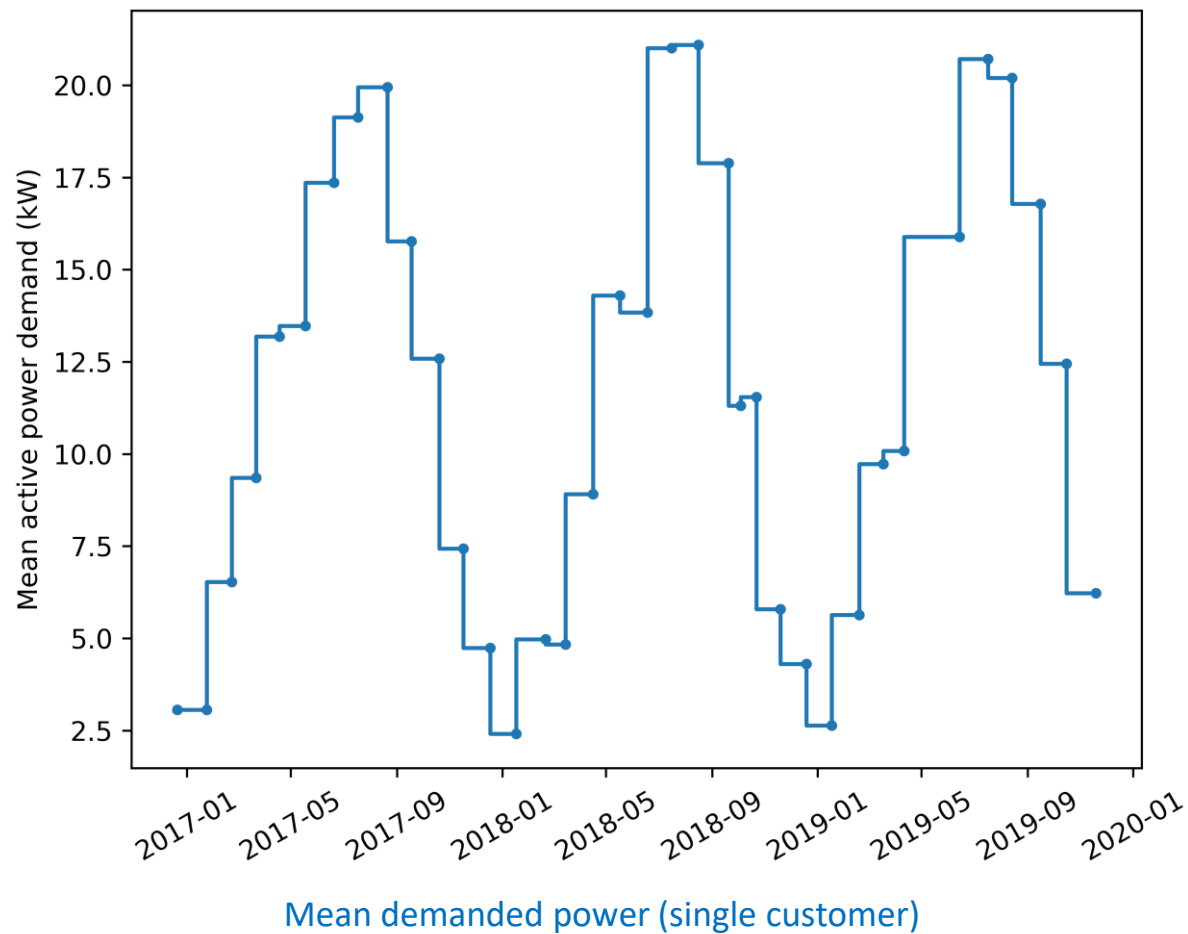


Elección de clientes. Ingesta y transformación

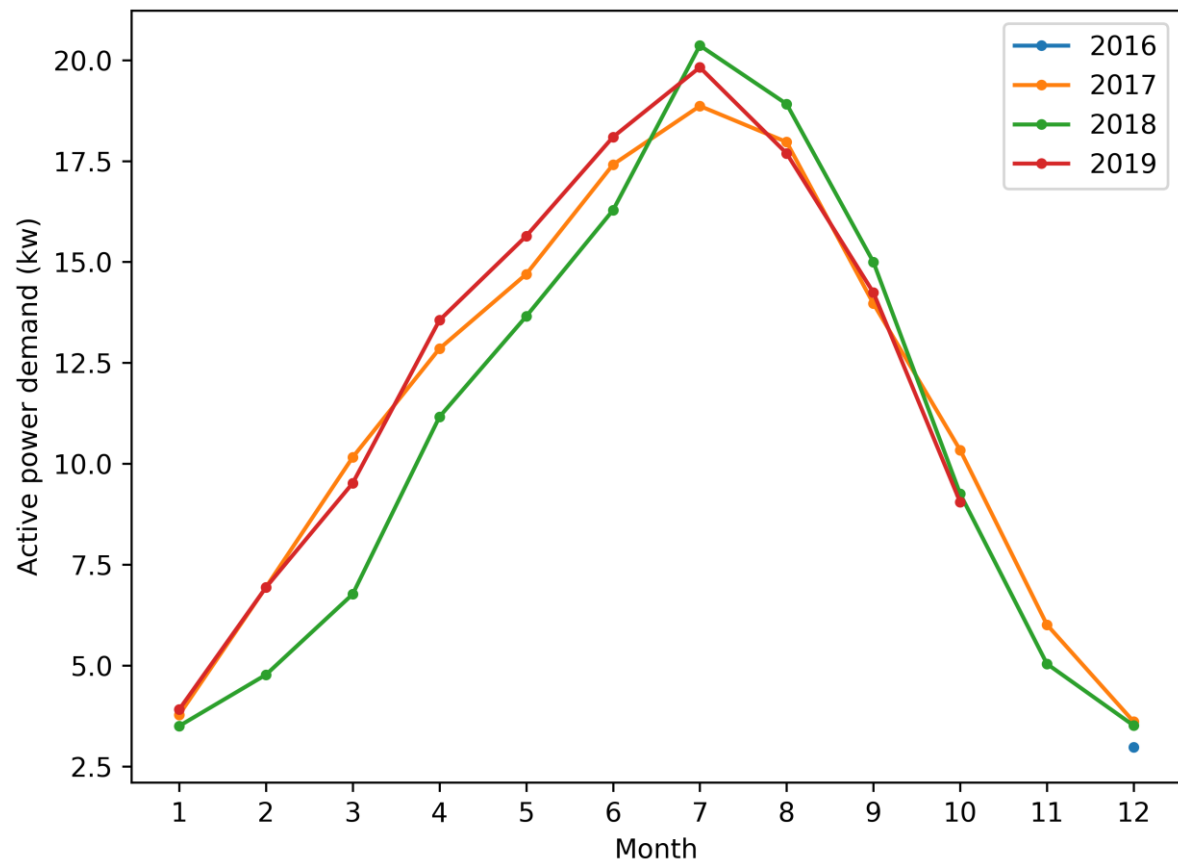


Meter reading information (single customer)

Elección de clientes. Ingesta y transformación



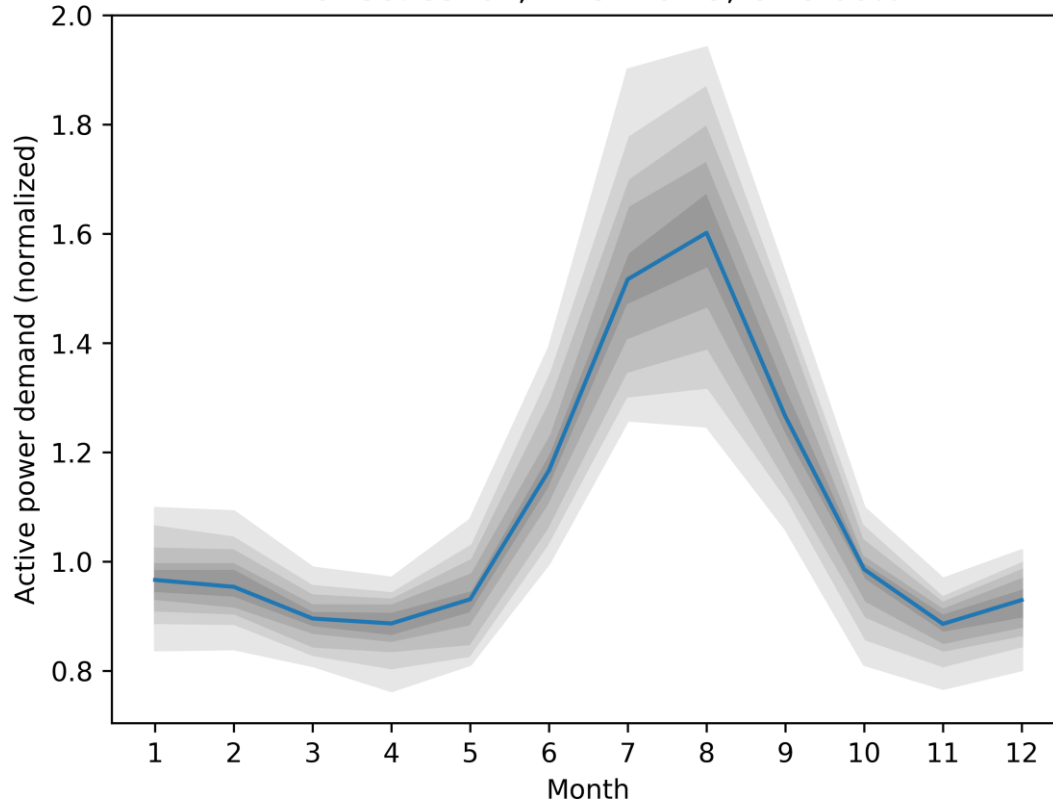
Elección de clientes. Ingesta y transformación



Mean demanded power (single customer)

Elección de clientes. Ingesta y transformación

NACE-Location: I5510;03014
of CUPSs: 67; RMSD: 0.15; CI: 3.06%



Hotels; Alicante city

Normalized demand profile (aggregated customers sharing activity and location)

Elección de clientes. Reducción de dimensionalidad

of activity codes: 1,011
of location codes: 8,203
of activity-location pairs: 8,293,233

Instances
(activity-location pairs)

| Matrix design | | | | | | |
|---------------|---|---|---|---|-----|----|
| | 1 | 2 | 3 | 4 | ... | 12 |
| 1 | | | | | | |
| 2 | | | | | | |
| 3 | | | | | | |
| 4 | | | | | | |
| ⋮ | | | | | | |
| 8,293,233 | | | | | | |

Dim.
reduction

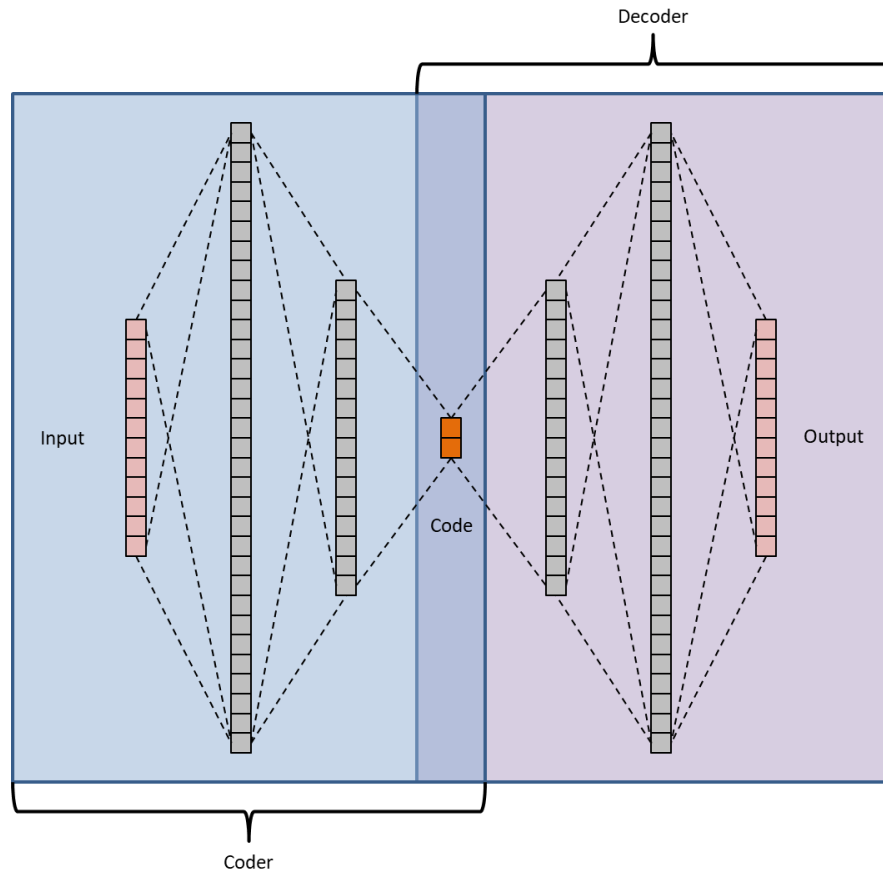
Unsupervised learning
No target vector

| Matrix design | | | | |
|---------------|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| ⋮ | | | | |
| 8,293,233 | | | | |

High-dimensional
features

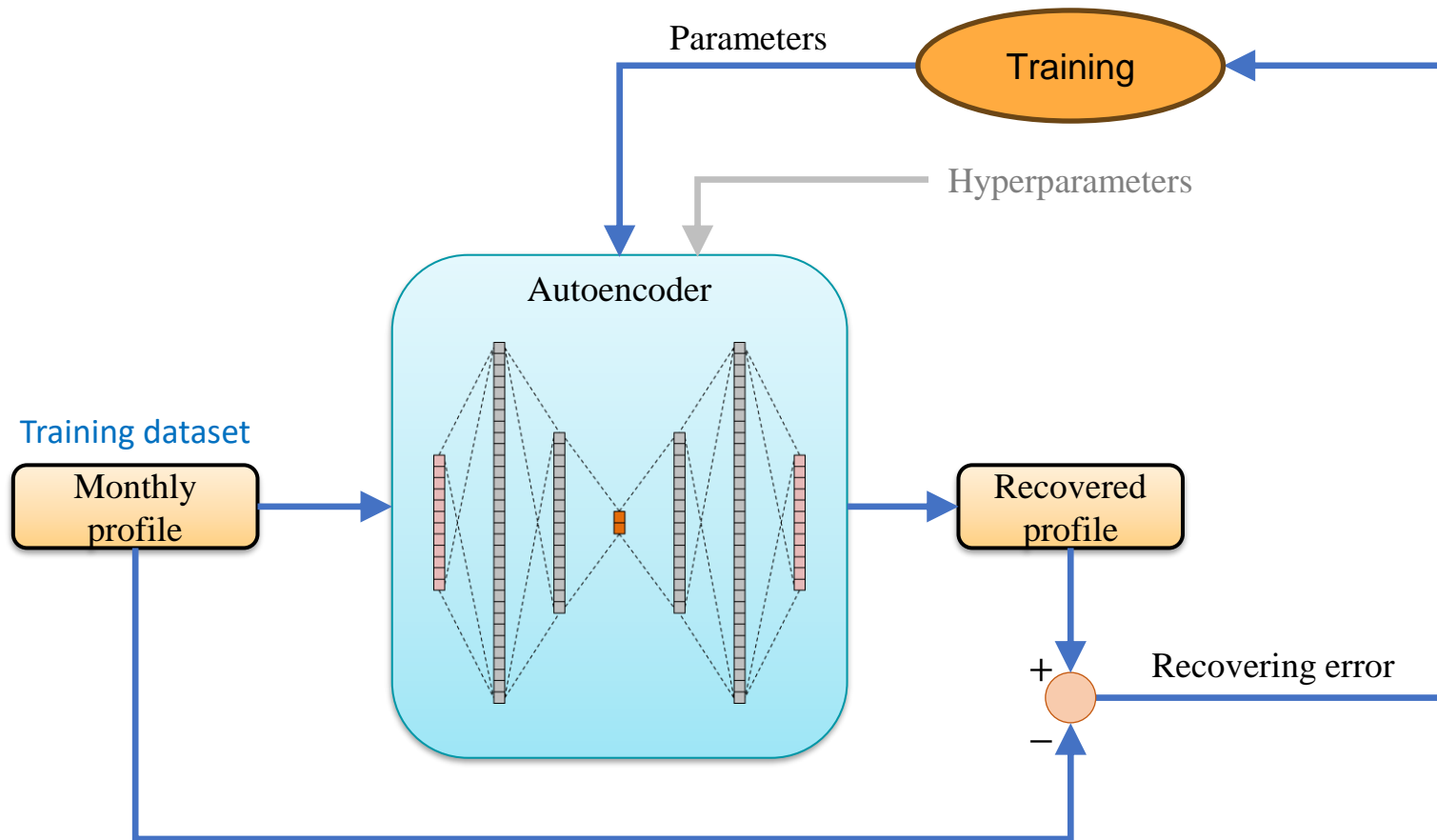
Low-dimensional
features

Elección de clientes. Reducción de dimensionalidad

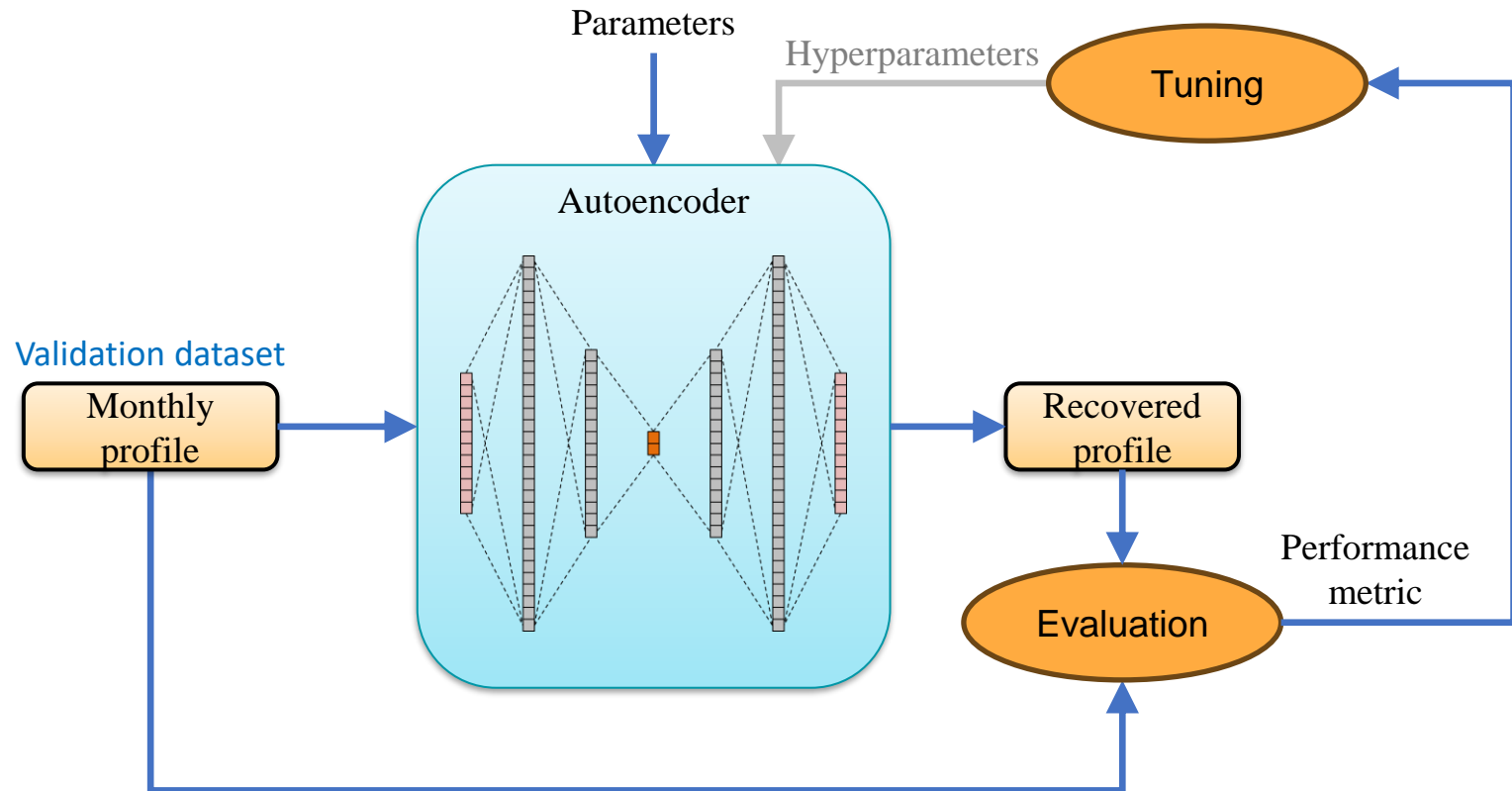


Autoencoder

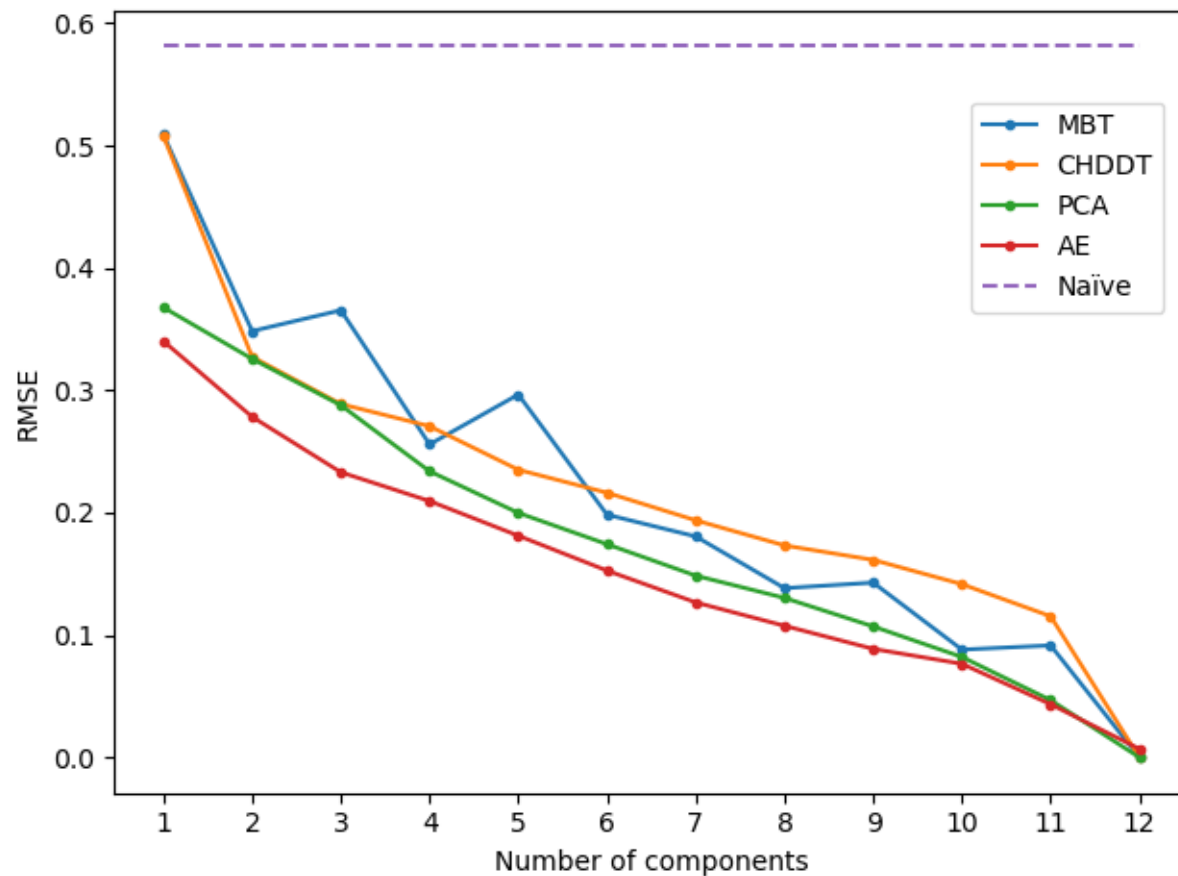
Elección de clientes. Entrenamiento



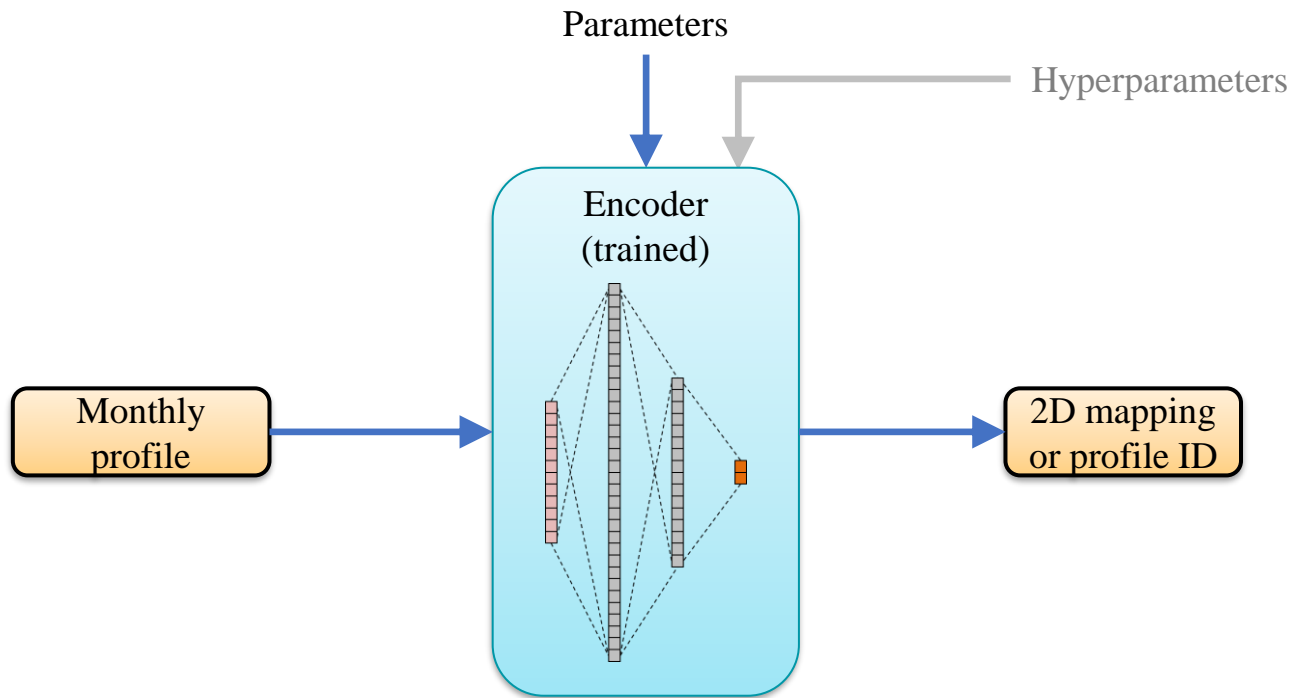
Elección de clientes. Evaluación



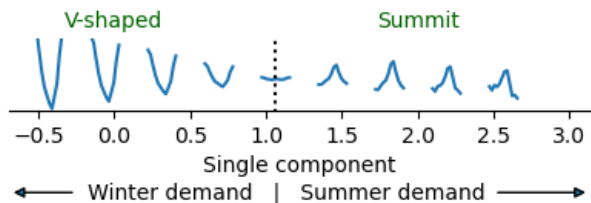
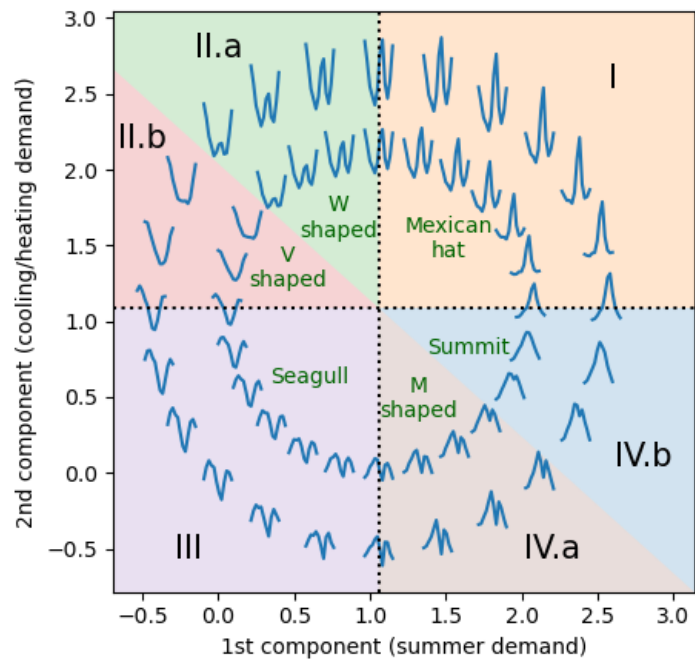
Elección de clientes. Registro



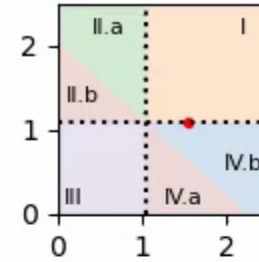
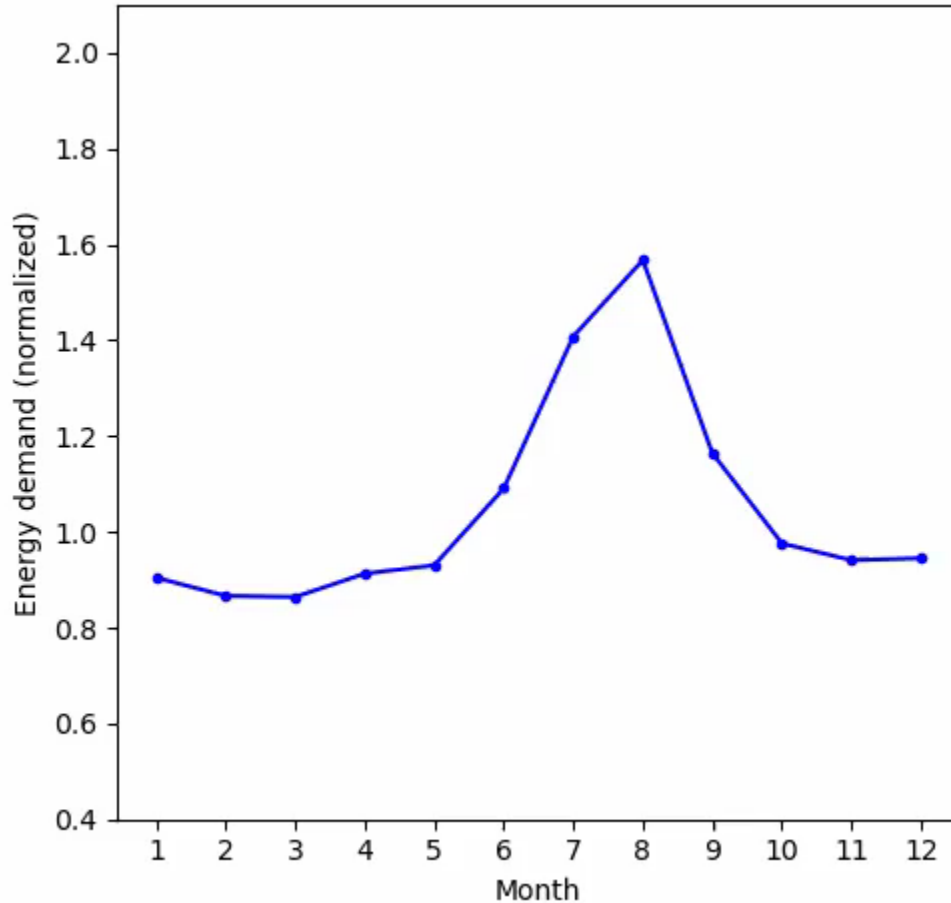
Elección de clientes. Representación 1D y 2D



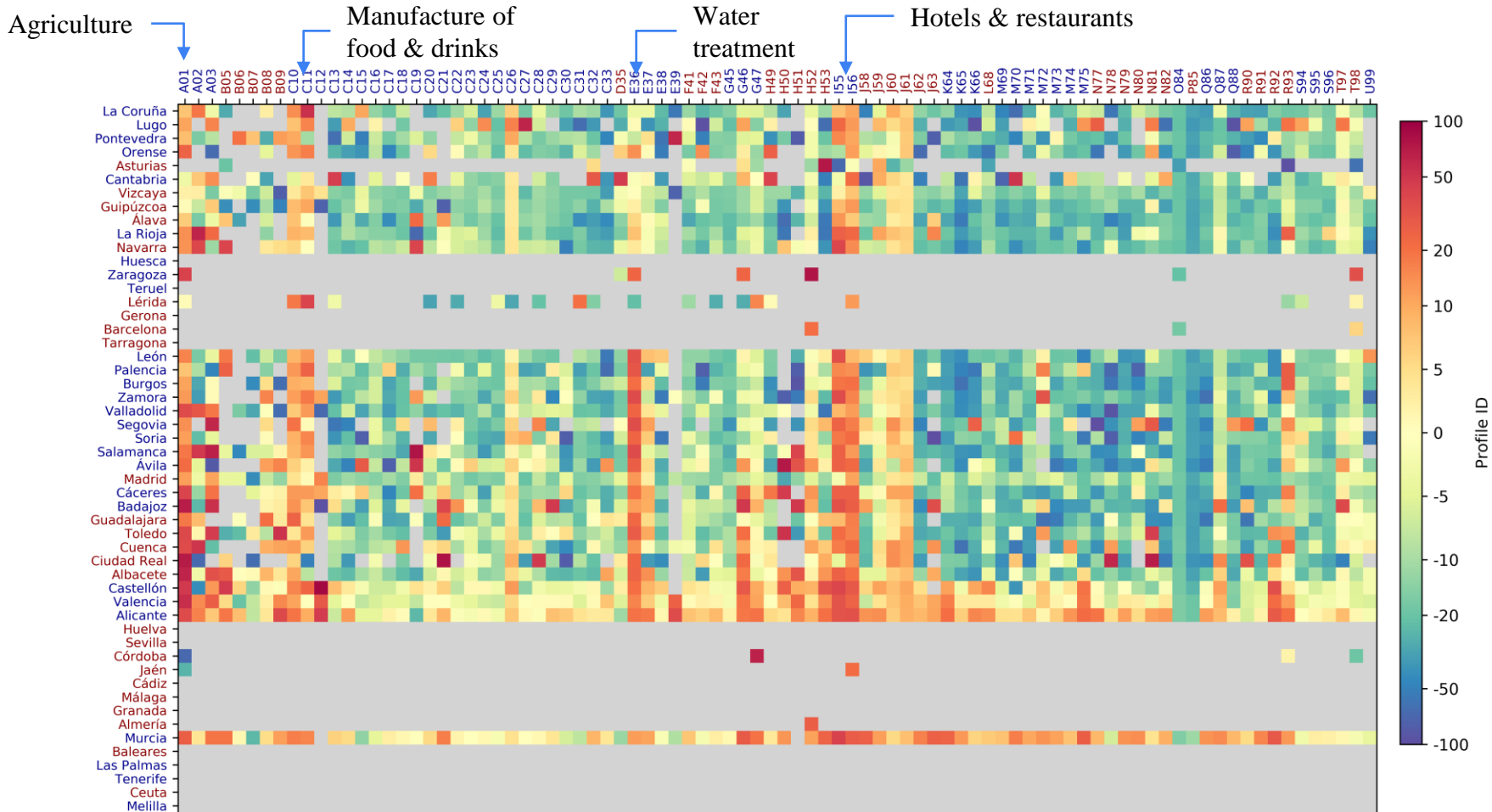
Elección de clientes. Representación 1D y 2D



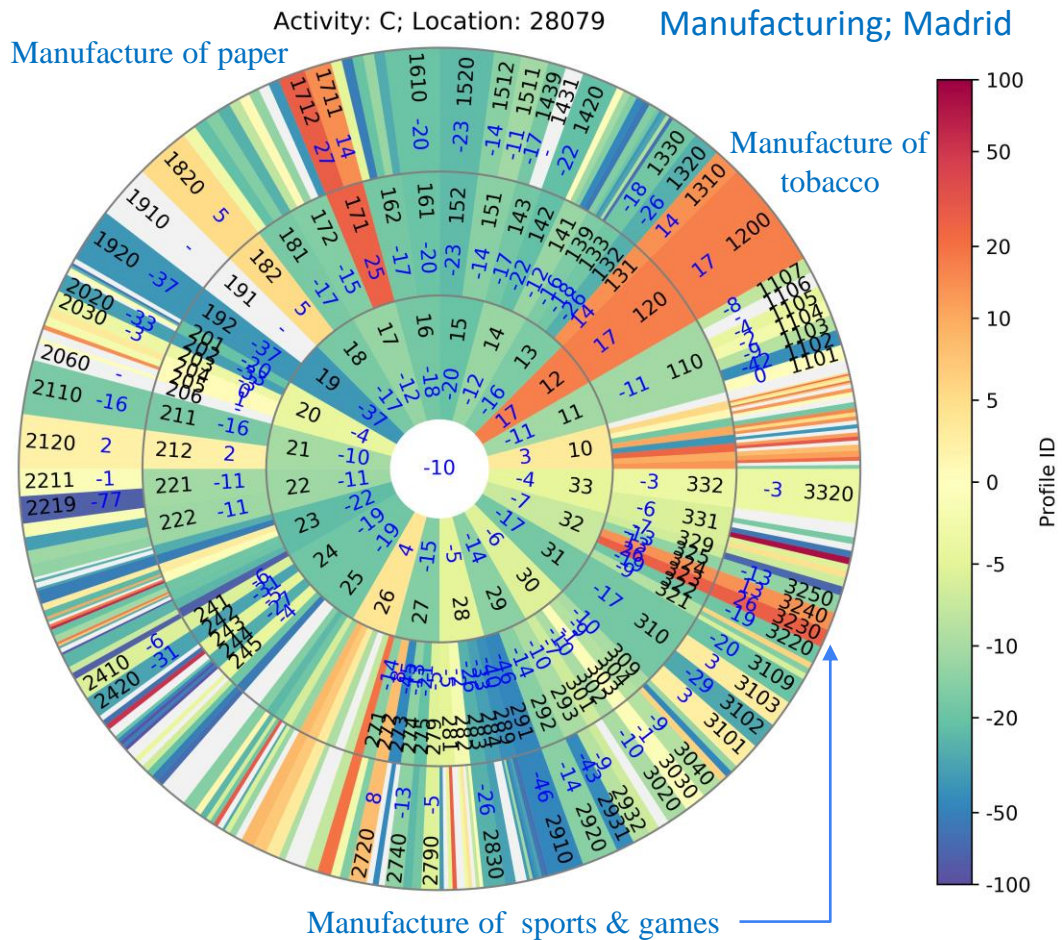
Elección de clientes. Representación 1D y 2D



Elección de clientes. Identificación de perfiles por actividad-ubicación



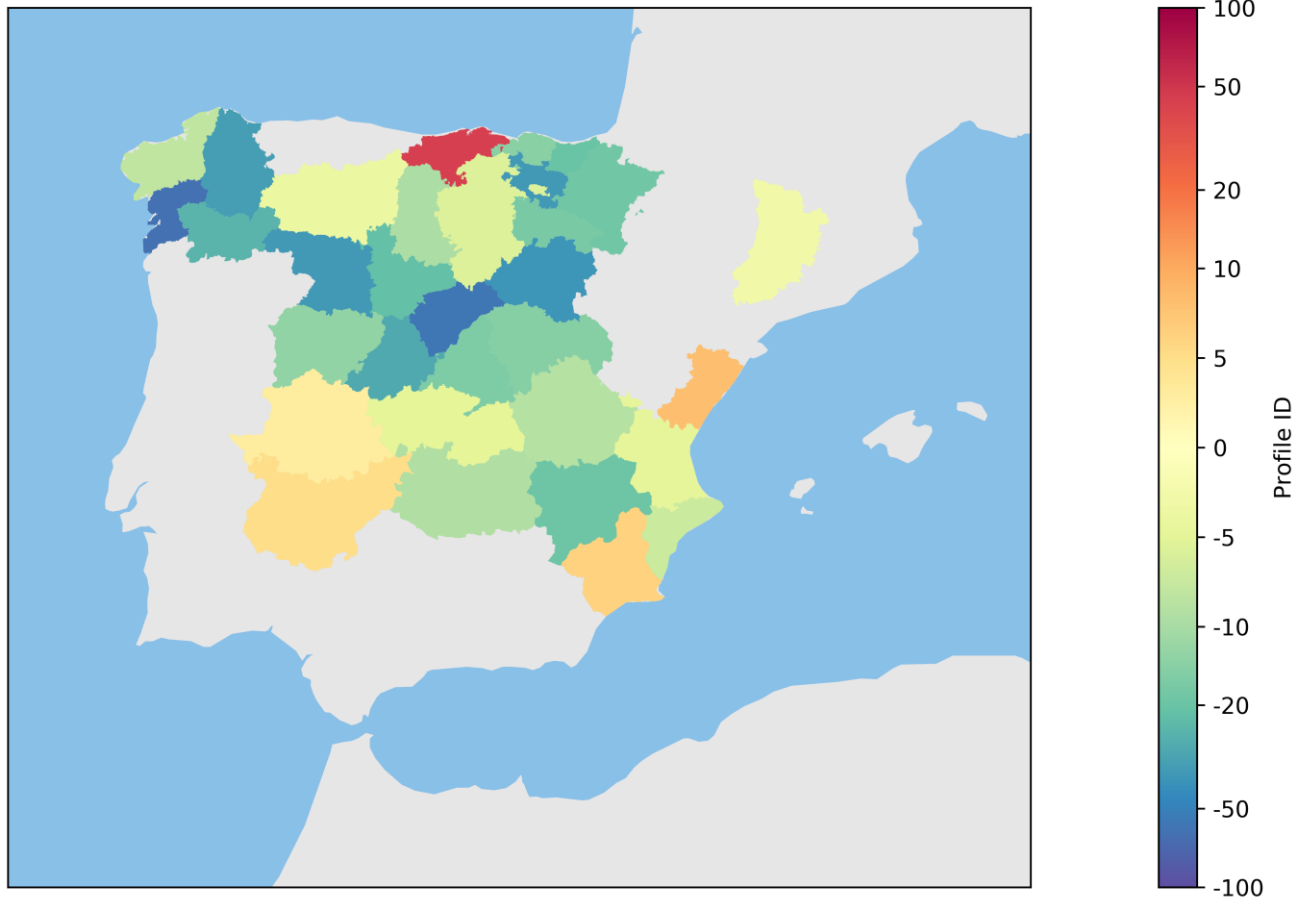
Elección de clientes. Identificación de perfiles por actividad para una ubicación



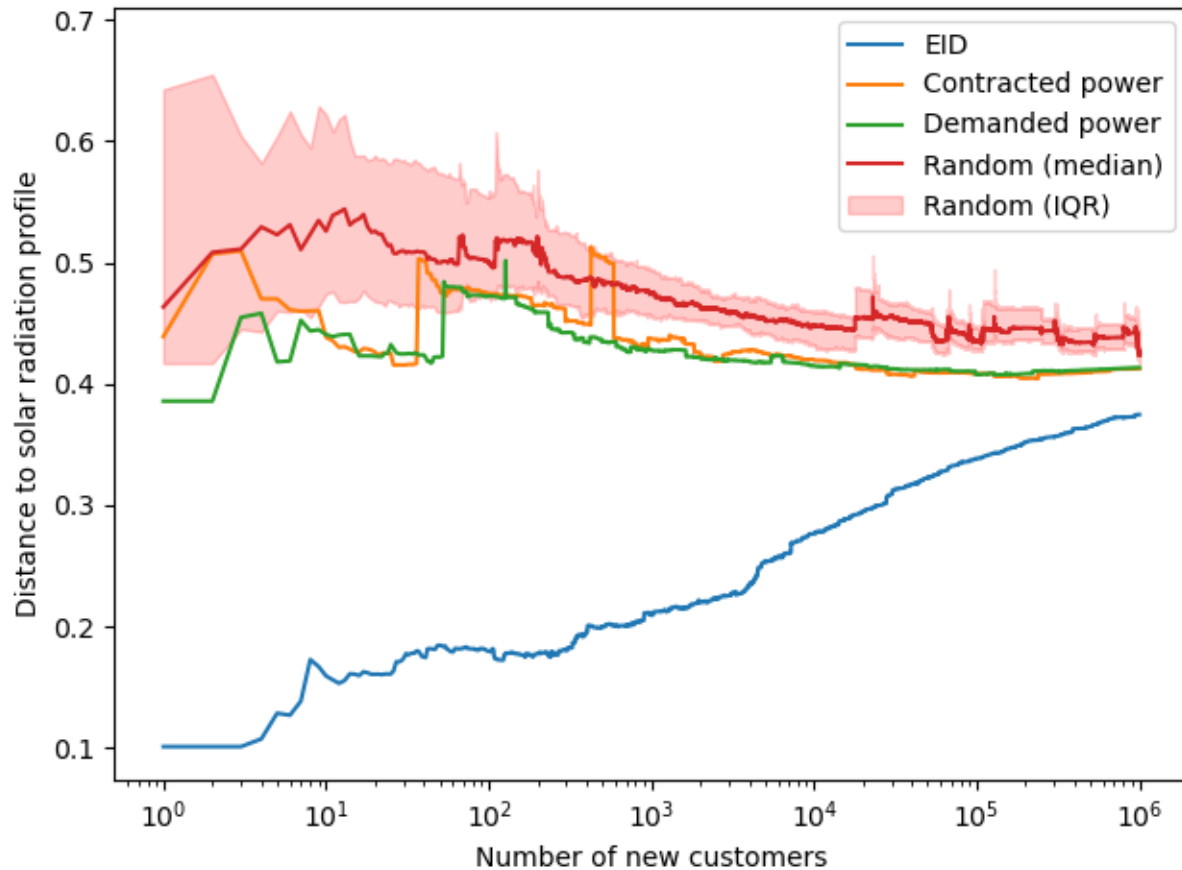
Elección de clientes. Identificación de perfiles por ubicación para una actividad

NACE: C13

Manufacture of textiles



Elección de clientes. Mejora obtenida



Elección de clientes. Referencias

- Luque, J., Personal, E., Garcia-Delgado, A., & Leon, C. (2021). Monthly electricity demand patterns and their relationship with the economic sector and geographic location. *IEEE Access*, 9, 86254-86267.
- Luque, J., Personal, E., Perez, F., Romero-Ternero, M., & Leon, C. (2023). Low-dimensional representation of monthly electricity demand profiles. *Engineering Applications of Artificial Intelligence*, 119, 105728.
- Luque, J., Carrasco, A., Personal, E., Pérez, F., & León, C. (2023). Customer Identification for Electricity Retailers Based on Monthly Demand Profiles by Activity Sectors and Locations. *IEEE Transactions on Power Systems*.

P&R

Aprendizaje automático

Casos de uso. Motivación.

Joaquín Luque. Universidad de Sevilla (España)



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