InStaFlex

D2.2 Overview Deferrable Loads

Submitted to: FOD Economy
Lead Partner: PropheSea

Instaflex Project – Results Report

1. Project Information

Project Title	InStaFlex
Client	FOD Economy
Lead Partner Report	Oktow
Partner Organisations	University of Antwerp, Royal Meteorological Institute, Oktow, PropheSea

2. Document Version History

Version	Date	Author(s)	Description / Changes	Final Approval

3. Executive Summary

This deliverable presents the results of the second part of Work Package 2 (WP2), focusing on the estimation of activation costs and boundary conditions of flexibility margins for four selected asset categories:

- HVAC systems (heating, ventilation, air conditioning)
- (Car) batteries
- Electric boilers (e-boilers)
- Water treatment processes

The objective is to quantify the minimum activation cost (€/kWhflex) and the technical and behavioral constraints associated with mobilizing flexibility in these assets.

The analysis builds upon the asset profiles developed in Deliverable D2.1, combining operational data, user surveys, and literature-derived performance models. Flexibility activation is assessed for three relevant market applications:

1. Day-ahead market participation
2. Capacity tariff optimization
3. Ancillary services (e.g., frequency regulation, reserve markets)

Results show significant variability in activation costs across asset categories, mainly due to differences in response times, comfort sensitivities, and equipment constraints. For instance, HVAC flexibility is low-cost but highly user-dependent, whereas e-boilers and batteries offer faster, more controllable but capital-intensive flexibility.

4. Introduction

The growing share of variable renewable energy sources (RES) in the electricity system necessitates flexible demand-side resources. Industrial and commercial assets can offer valuable flexibility, yet their activation costs and viability conditions remain insufficiently quantified.

This report contributes to that knowledge gap by:

- Estimating activation costs for representative flexible assets,

- Identifying boundary conditions for their activation,
- Evaluating their potential economic value under current and forecasted market conditions.

5. Methodology

5.1 Overview

The activation cost represents the minimum compensation or price reduction required for an asset owner to offer flexibility without compromising operational or comfort constraints.

The total cost includes:

- Energy-related costs: efficiency losses, additional energy use, or delayed consumption.
- Operational costs: wear and tear, maintenance impact.
- Comfort or process costs: perceived value of deviation from normal operation.
- Opportunity costs: loss of productivity or convenience.

The activation cost (AC) is expressed as:

AC = (Cenergy+Cop+Ccomfort+Copp) / Eflex

where Eflex is the energy shifted or curtailed (kWh).

5.2 Data sources

Data were collected from:

- Time-series and survey data compiled in WP1,
- Expert interviews with industrial clients (Oktow Energy),
- Literature benchmarks on activation and participation costs

5.3 Scenarios and Assumptions

Three flexibility market contexts were modeled:

1. Day-ahead optimization (hourly price response)
2. Capacity tariff avoidance (reducing peak demand)
3. Ancillary services (fast response, short duration)

Weather and process dependencies were incorporated using typical Belgian/Western European climate data and load profiles from 2022–2024.

6. Asset Category 1: HVAC Systems

6.1 Operational constraints:

- Comfort range: ±1–2°C
- Response time: 1–10 minutes
- Recovery time: 1–2 hours
- Building insulation quality influences flexibility margin.

6.2 Cost Components

Cost Component	Description	Typical Range (€)
Energy loss	Reheating after setback	0.01–0.03 €/kWhflex
Comfort impact	User tolerance to temperature change	0.005–0.02 €/kWhflex
Maintenance	Negligible for moderate use	<0.005 €/kWhflex

6.3 Activation Cost Estimate

Average **activation cost**: **0.02–0.05 €/kWhflex.** Viable mainly for **day-ahead** or **capacity tariff** applications.

6. Asset Category 2: (Car) Batteries

6.1 Operational constraints:

- Depth of discharge: 10–80% typical range for longevity
- Cycle life: 3,000–8,000 cycles
- Round-trip efficiency: 90–95%

6.2 Cost Components

Cost Component	Description	Typical Range (€)
Degradation	Cycle-induced capacity loss	0.04–0.10 €/kWhflex

Efficiency loss	Energy losses during cycling	0.005–0.01 €/kWhflex
Management	Control and communication overhead	<0.005 €/kWhflex

6.3 Activation Cost Estimate

Average **activation cost**: **0.05–0.12 €/kWhflex.** Highly suited for **ancillary services** and **tariff optimization**.

7. Asset Category 3: E-Boilers

7.1 Operational constraints:

- Process temperature range: 100–200°C
- Buffer capacity: 0.5–3 hours equivalent
- Ramp rate: near-instantaneous

7.2 Cost Components

Cost Component	Description	Typical Range (€)
Energy loss	Standby and heat loss	0.005–0.015 €/kWhflex
Operational impact	Limited (heating element cycling)	<0.005 €/kWhflex
Opportunity cost	Deferred process heat	0.01–0.03 €/kWhflex

7.3 Activation Cost Estimate

Average **activation cost**: **0.05–0.12 €/kWhflex.** Highly suited for **ancillary services** and **tariff optimization**.

8. Asset Category 4: Water Treatment Processes

8.1 Operational constraints:

- Batch-based operation: flexibility limited to cycle timing

- Storage capacity for treated/untreated water determines margin
- Process constraints: regulatory quality standards

8.2 Cost Components

Cost Component	Description	Typical Range (€)
Process delay	Extended treatment cycles	0.01–0.03 €/kWhflex
Equipment wear	Increased cycling or pump usage	0.005–0.02 €/kWhflex
Quality risk buffer	Reduced process robustness	0.01–0.04 €/kWhflex

8.3 Activation Cost Estimate

Average **activation cost**: **0.03–0.07 €/kWhflex** . Applicable mainly for **capacity tariff avoidance**, with limited market participation potential.

9. Comparative Overview

Asset Type	Activation Cost (€/kWhflex)	Main Application	Control Speed	Key Limitation
HVAC	0.02–0.05	Day-ahead, tariff	Medium	Comfort sensitivity
(Car) Batteries	0.05–0.12	Ancillary, tariff	Fast	Degradation cost
E-Boilers	0.015–0.04	Day-ahead, tariff	Fast	Buffer capacity
Water Treatment	0.03–0.07	Tariff	Slow	Process constraints

8. Discussion

- **Weather-dependence** strongly affects HVAC and e-boiler flexibility value.
- **Battery degradation cost** dominates total activation cost; business models must include cycle cost compensation.
- **User comfort and perception** remain significant non-technical barriers influencing real participation.
- For all categories, **aggregation** can lower transaction and management costs by 15–25%.

9. Conclusions

The estimated activation costs demonstrate that industrial and commercial assets can provide cost-effective flexibility under appropriate control strategies and incentive mechanisms.

The most promising categories in terms of low cost and controllability are e-boilers and HVAC, while batteries offer fast, dispatchable flexibility at higher cost.

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