OIIO

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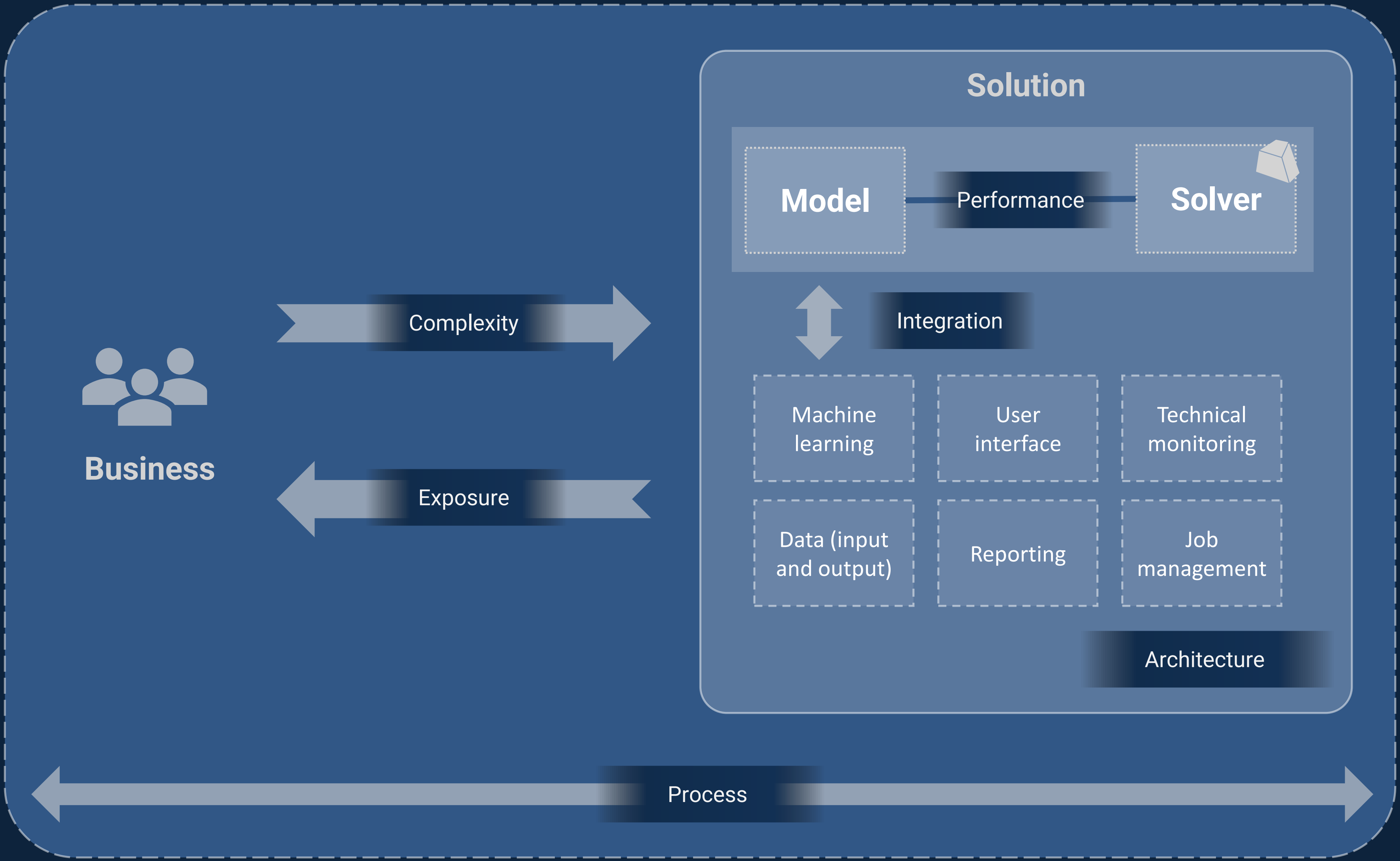
GUROBI SUMMIT

Christian Álvarez Peláez

Sara Neira Castro

Nov. 2024

360°-view on (implementing) optimization



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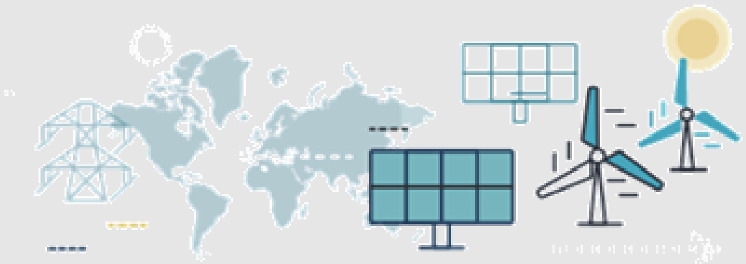
ENERGY INFRAESTRUCTURE MANAGEMENT AND DEVELOPMENT

OPERATING INFRASTRUCTURES

Management of essential basic natural gas network infrastructures in Spain, which guarantee energy supply security, diversify supplies and act as a backup for renewable technologies.

ENERGY TRANSITION PROJECTS

Development of projects in the field of renewable gases, renewable electricity generation and storage, which contribute to climate change mitigation and the transition to a circular economy.



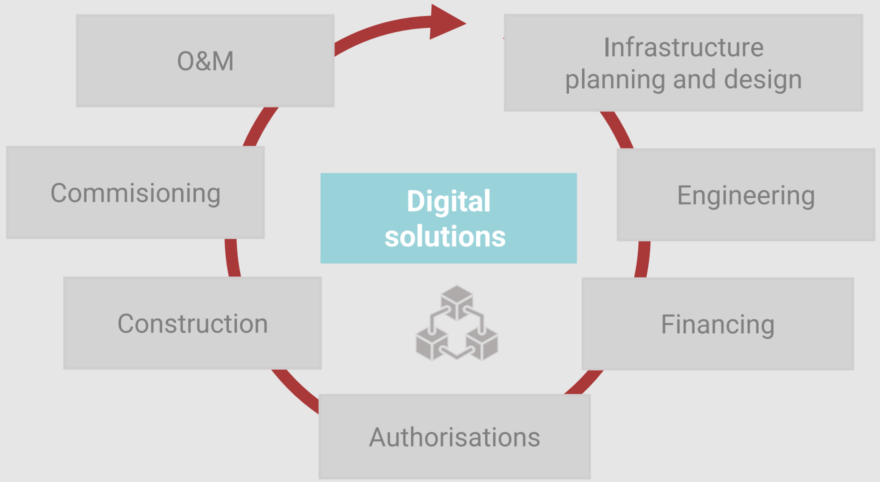
SERVICES

CONSULTANCY AND GLOBAL MANAGEMENT OF INFRASTRUCTURES

Consultancy and management throughout the life cycle of energy assets.

ENERGY EFFICIENCY

Tools and digital solutions developed internally to optimize the design and operation of energy and industrial projects.



Digitalization since 2011

2011

Start of the Development of Ganeso®

Collaboration with Itmati for the Development of Ganeso®, Gas Network Simulation and Optimization Software

2014

New Tariff System 2014

Proposal for a New Tariff System in European Natural Gas Transportation Networks Thanks to Ganeso®

2015

Success Case with Ganeso®

Design of the Kuwaiti Gas Pipeline Network. Efficiency and Supply Security Analysis

2016

Technology Transfer Award

Awarded Best Technology Transfer Success Case in Galicia 2016 for the Application of Ganeso®

2020

Start of Development DTSO

Start of the Development of DTSO, Energy Systems Simulation and Optimization Software, in Collaboration with Itmati

2021

Digitalization Unit

Establishment of the Digitalization Unit at Reganosa, with PhDs and Graduates in Mathematics, Physics, and Engineering

2021

Success Case with DTSO

Optimal Location and Sizing of Plants for the Circular Economy Project

2021

Zeppelin Project

Awarded the Zeppelin Project Funded by the CDTI Missions Call 2021

2024

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Market Launch of the OIIO App

POSITIVO

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AHORRO CERTIFICADO +20%

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OIIO: Your Energy Buddy

Our goal is to help you achieve the greatest savings on your energy bill by optimizing your tariff and power based on your needs.

POWER OPTIMIZATION PROBLEM: AN OVERVIEW

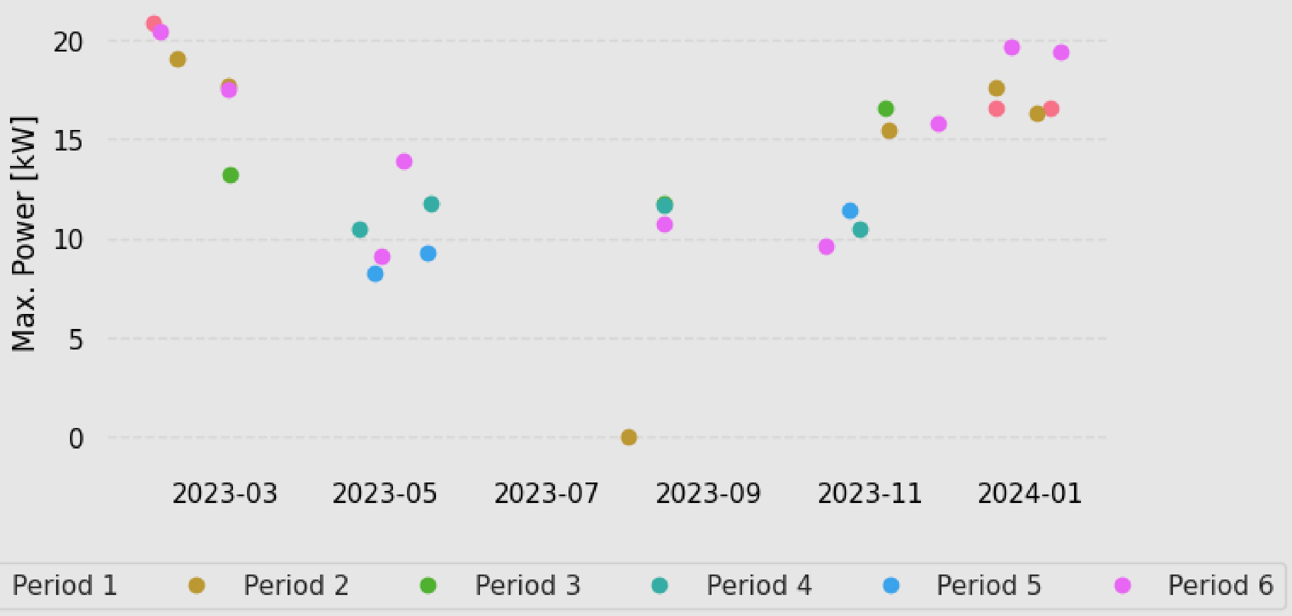
OBJECTIVE: OPTIMIZE THE CONTRACTED POWER FOR TWO TYPES OF CONSUMERS

- 3TD with power ranging between 15 kW and 50 kW.
- 6TD with power above 50 kW.

ISSUE: CONSUMERS FACE PENALTIES FOR EXCEEDING POWER LIMITS.

BILLING SYSTEM:

- Power usage is measured by periods.
- For 3TD the maximum power record is taken once per period and month.
- For 6TD we have hourly consumptions.



POWER PERIODS FOR 3.0TD CONSUMERS

Hour of the day	Jan, Feb, Jul, Dec	Mar, Nov	Apr, May, Oct	Jun, Aug, Sept	Weekends and holidays
00:00-8:00	P6	P6	P6	P6	P6
8:00-9:00	P2	P3	P5	P4	P6
9:00-14:00	P1	P2	P4	P3	P6
14:00-18:00	P2	P3	P5	P4	P6
18:00-22:00	P1	P2	P4	P3	P6
22:00-00:00	P2	P3	P5	P4	P6

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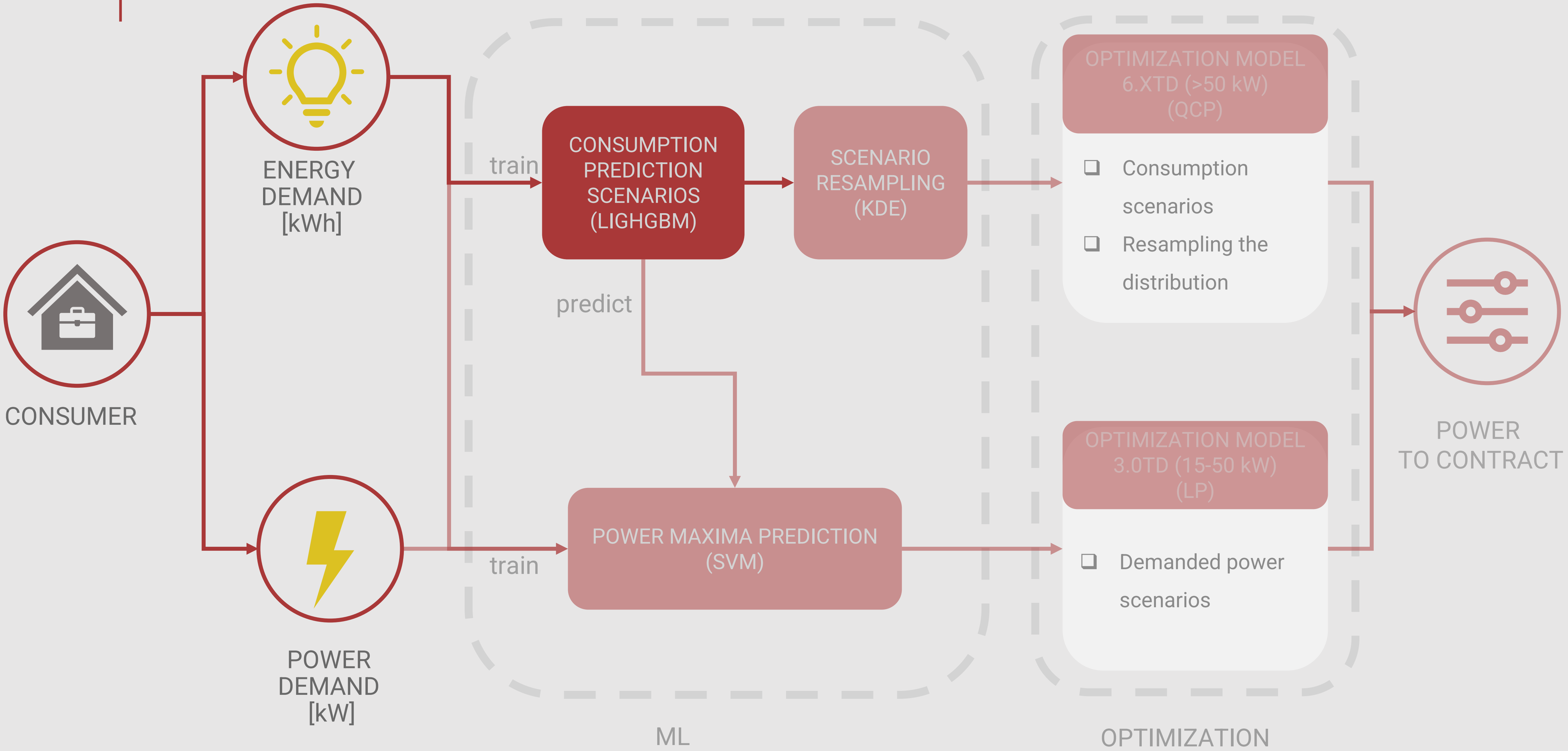
INTEGRATION

DIAGRAM



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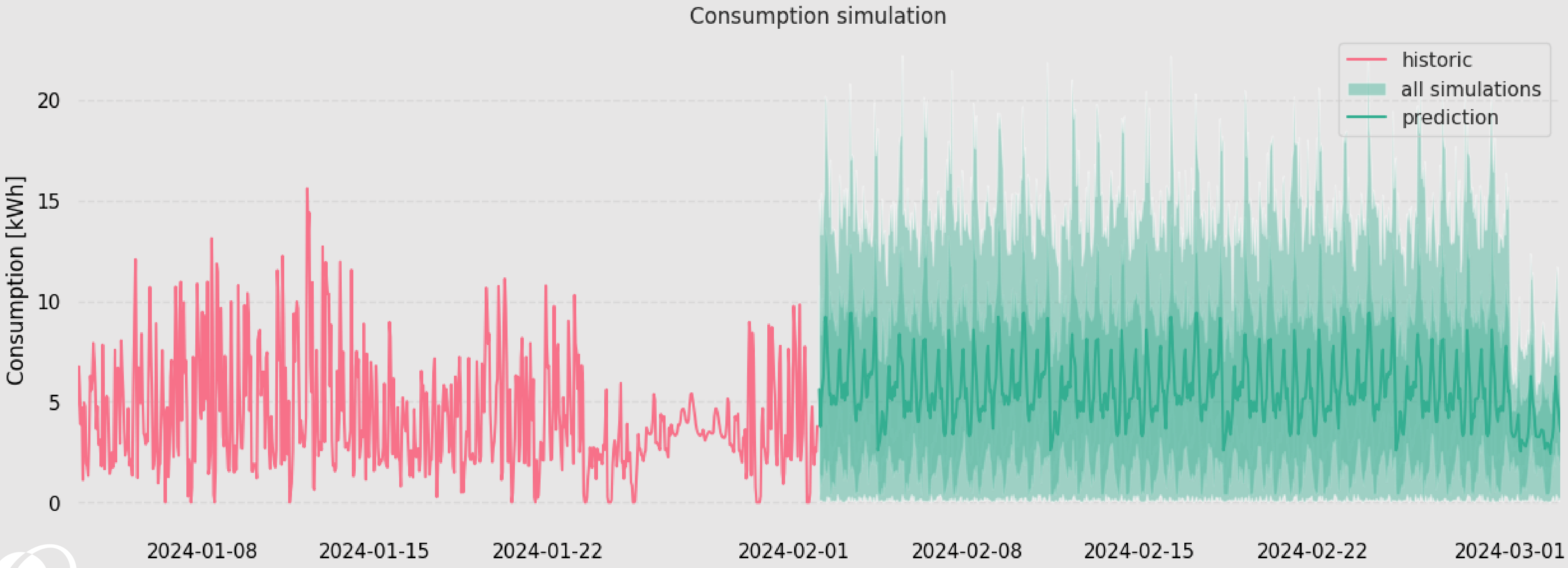
AUTOREGRESSIVE MODEL BASED ON LIGHTGBM

MODEL OVERVIEW:

- Autoregressive Model (AR): Use past values of the time series as an input to predict future values.
- Based on LightGBM (Light Gradient Boosting Machine): Gradient boosting algorithm based on decision trees, optimized for speed and accuracy.
- Prediction and simulation over a 6-month with hourly granularity.



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METHODOLOGY: TIME SERIES DECOMPOSITION

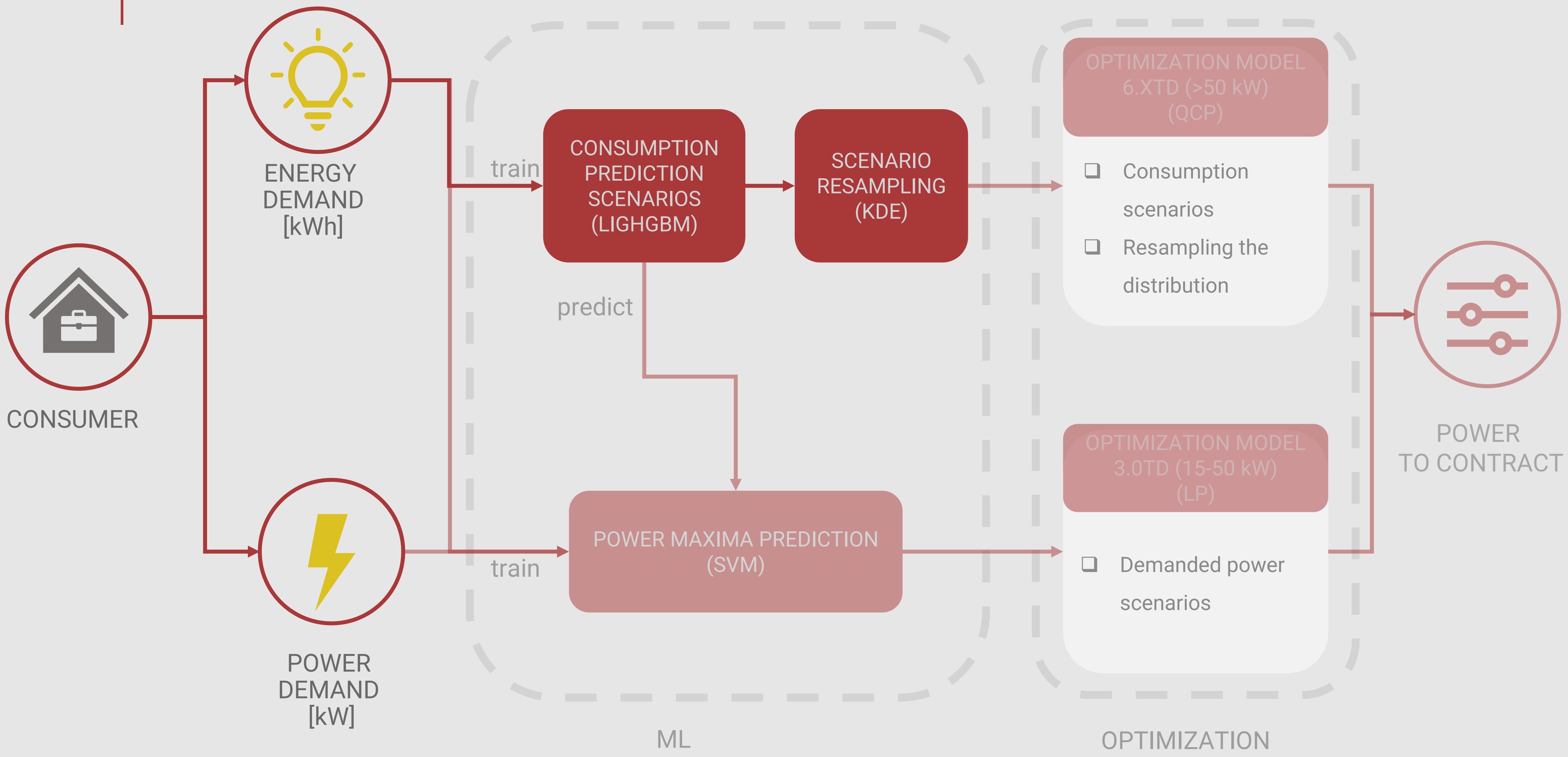
MODEL OVERVIEW:

- **Objective**: Decompose the energy consumption time series into two components:
  - **Deterministic Component**: Modeled using the autoregressive model to capture predictable patterns.
  - **Stochastic Component**: Modeled as a stochastic process, such as stochastic differential equations (SDEs), to represent random variations.

$$f(t) = \underbrace{f_{lightGBM}}_{\text{Deterministic}} + \underbrace{\epsilon}_{\text{Stochastic}}$$

INTEGRATION

DIAGRAM



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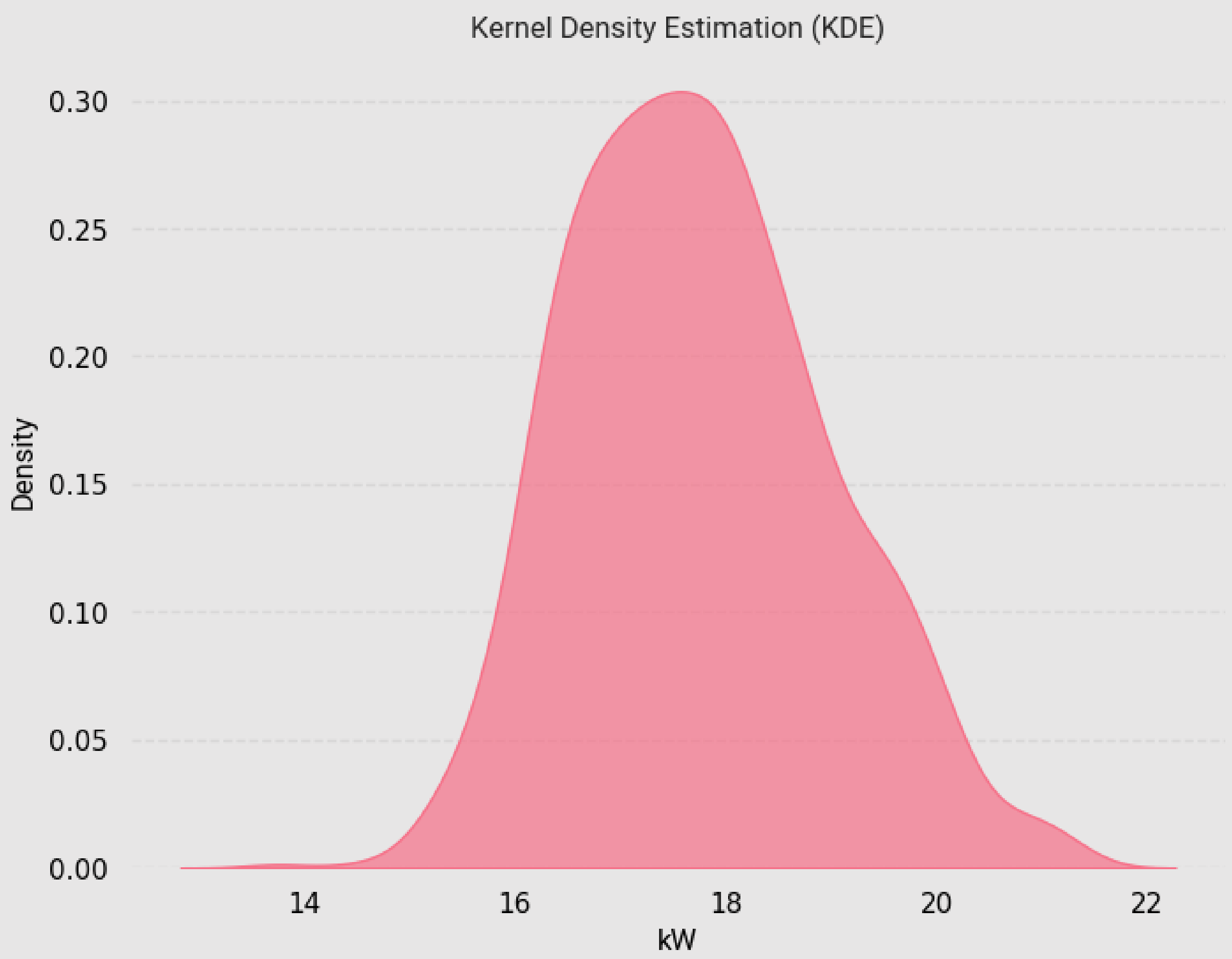
SCENARIO REDUCTION USING KDE ESTIMATION

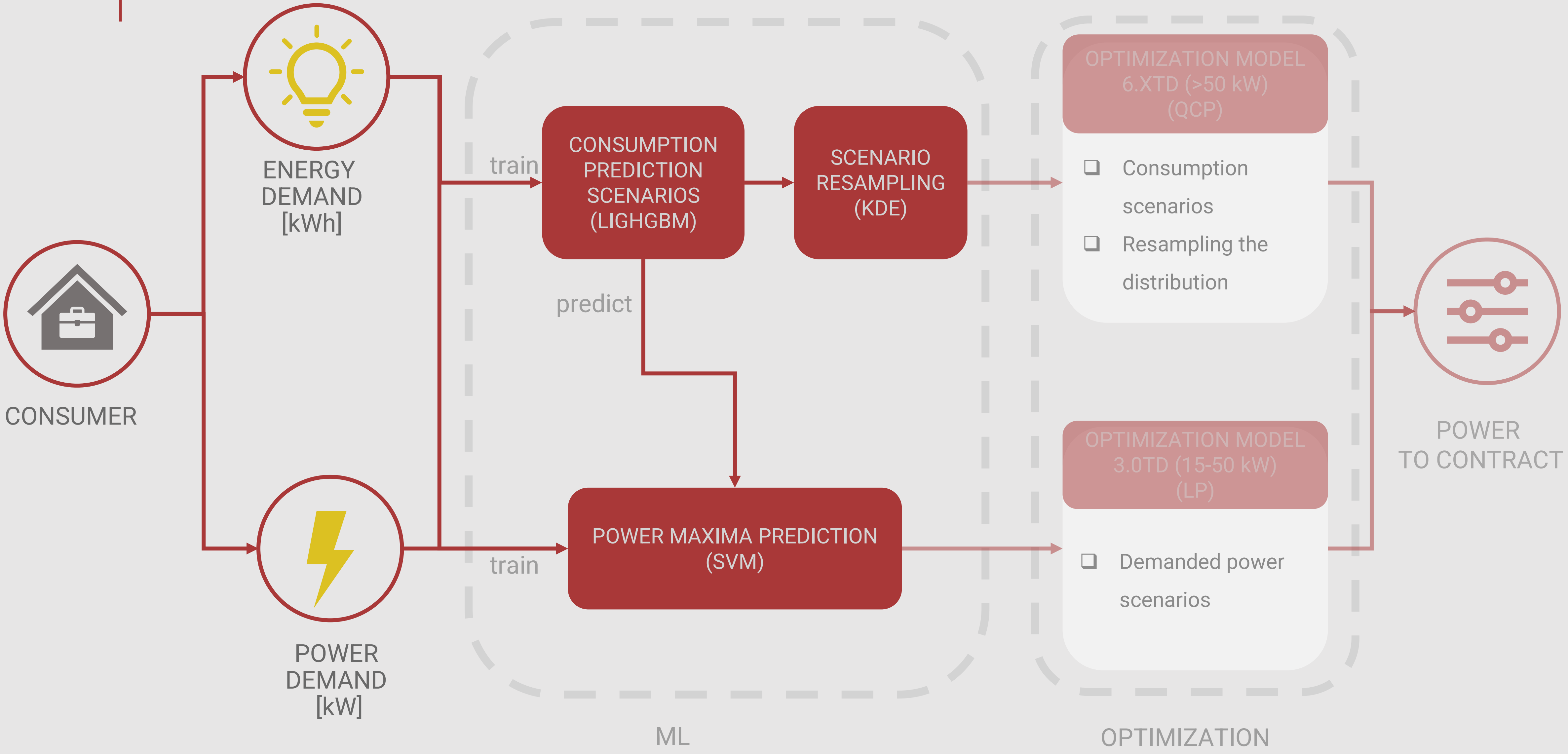
OVERVIEW:

- Stochastic programming problems can be **computationally expensive** due to the large number of scenarios generated.
- We apply **Kernel Density Estimation (KDE)** on the power scenarios and then resample from the KDE to reduce the number of scenarios.



INTEGRATION

DIAGRAM



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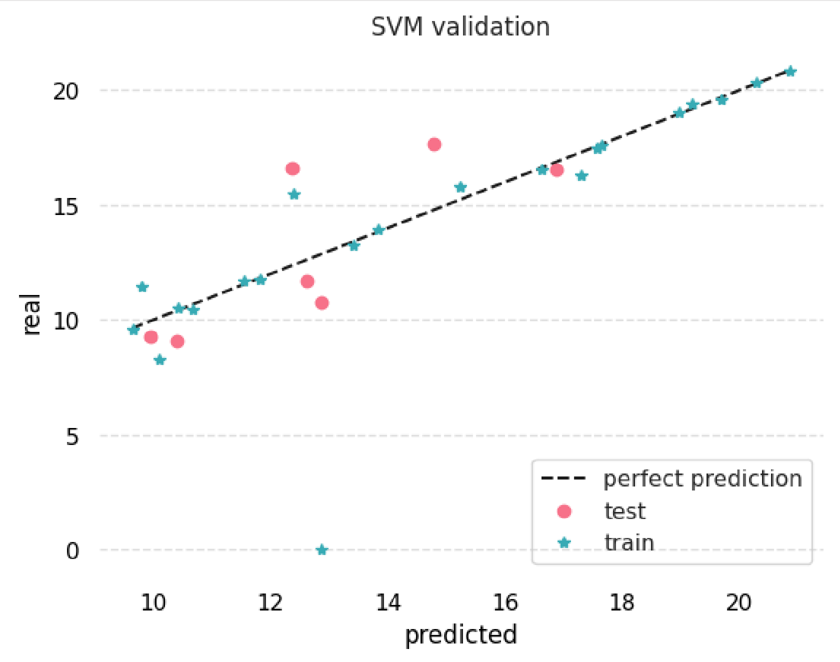
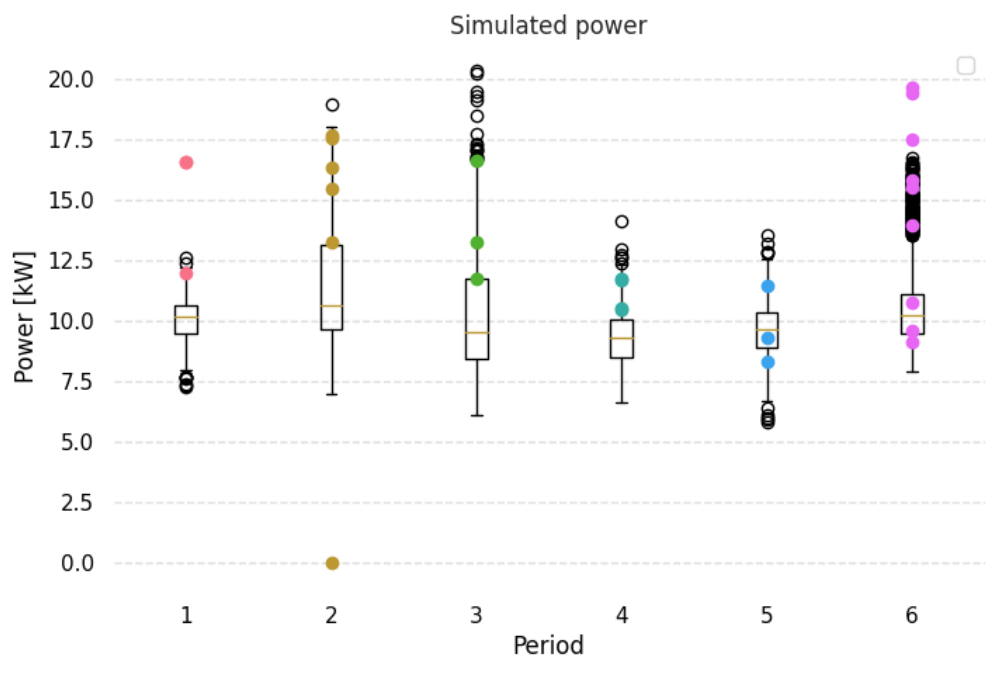
POWER PEAK PREDICTION AND SCENARIO GENERATION

OVERVIEW:

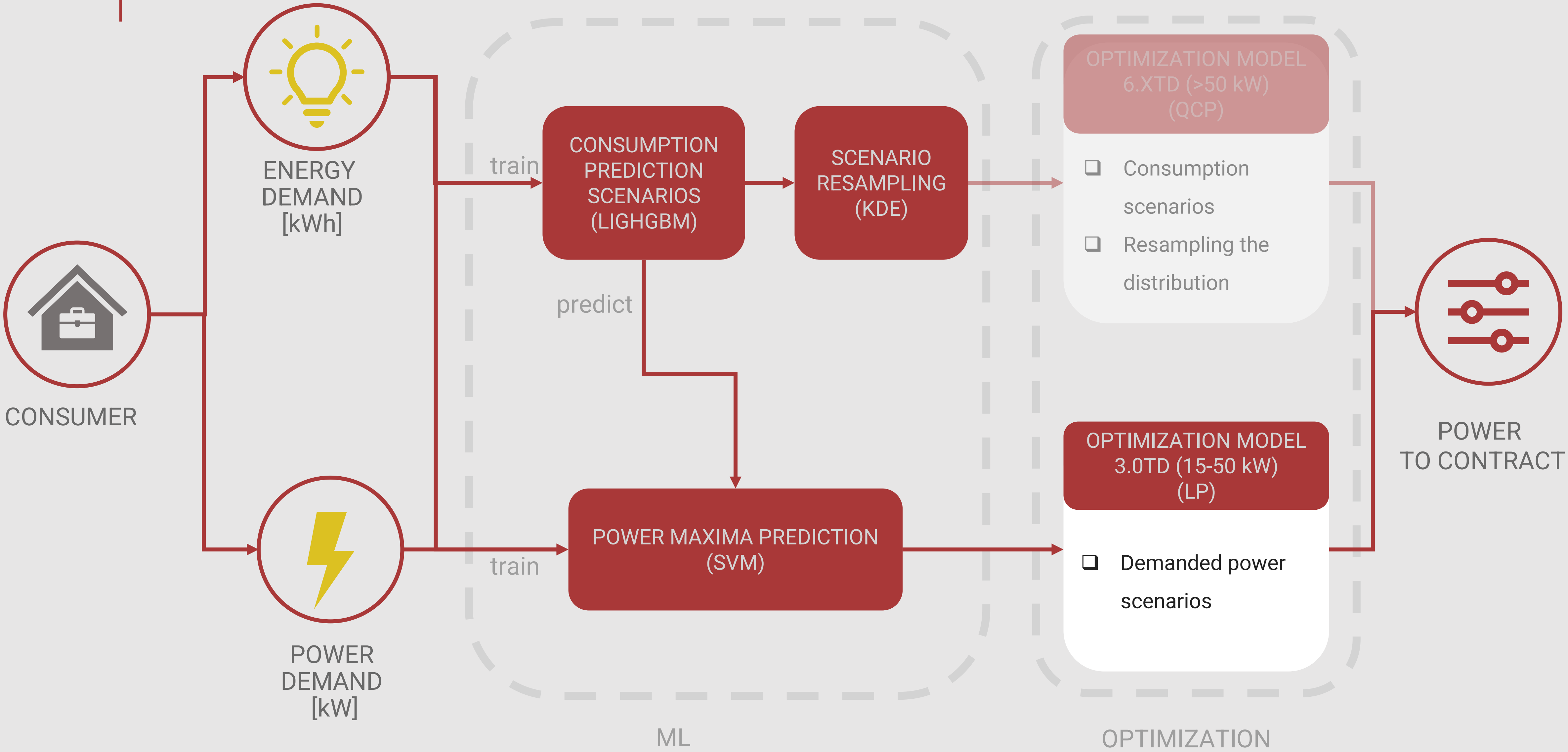
- SVM model for power maximums scenarios for the 3.0 TD problem
- Training from the consumption and maximums of demanded power data
- Prediction from the consumption scenarios generated with the LightGBM model





INTEGRATION

DIAGRAM



OPTIMIZATION MODEL

BEST POWER TO CONTRACT IN EACH PERIOD (3.0TD)

OBJECTIVE FUNCTION

$$\mathit{min}$$

$$\underbrace{\mu + \frac{1}{(1-\alpha)N_s c}\sum_{sc} z_{sc}}_{\text{Conditional value at risk}} + \underbrace{\underbrace{\sum_t \mathrm{Price}_t^{pc} \cdot pc_t}_{\text{Cost of the contracted power}} + \underbrace{\frac{1}{Nsc}\sum_{sc}\sum_m\sum_t 2 \cdot \mathrm{TEP} \cdot p_{t,m,sc}^{abv}}_{\text{Cost of the excess power}} + \underbrace{Rights \cdot p^{diff}}_{\text{Penalty term}}}_{\text{Expected value}}$$

OPTIMIZATION MODEL

BEST POWER TO CONTRACT IN EACH PERIOD (3.0TD)

CONSTRAINTS

$pc_{t-1} \leq pc_t$	Ascending power
$P^{bmin} \leq pc_{t=6} \leq P^{bmax}$	Power boundaries
$p^{wth}_{t,m,sc} \leq pc_t$	Demanded power within the contract
$P^{max}_{sc,p,mo} = p^{wth}_{t,m,sc} + p^{abv}_{t,m,sc}$	Flow balance
$z_{sc} \geq \sum_{t,m} excess\_cost_{t,m,sc} + \sum_{t} contracted\_cost_t - \mu$	Conditional Value at Risk
$contracted\_cost_t = Price^{pc}_t \cdot pc_t$	Cost of the contracted power
$excess\_cost_{t,m,sc} = 2 \cdot TEP \cdot p^{abv}_{t,m,sc}$	Cost of the excess power
$p^{diff} = \lvert pc_6 - cc_6 \rvert$	Power upgrade

SETS

$t \in \{1, 2, \dots, 6\}$	power periods
$m \in \{1, 2, \dots, 12\}$	billing months
$sc \in \{1,2, \dots N_{sc}\}$	scenarios

VARIABLES

$pc_t \; \forall t \in \{1, 2, \dots, 6\}$	contracted power
$p^{wth}_{t,m,sc} \; \forall t, m, sc$	dem. within contr.
$p^{abv}_{t,m,sc} \; \forall t, m, sc$	dem. above contr.
$p^{abv}_{t,m,sc} \; \forall t, m, sc$	dem. above contr.
p^{diff}	power upgrade
z_{sc} and μ	CVar linearization

PARAMETERS

TEP	excess coef.
$Price^{pc}_t$	price contr. pow.
$P^{bmax/bmin}$	power boundaries
$P^{max}_{sc,p,m}$	demanded power
cc_6	current power in p=6
α	probability

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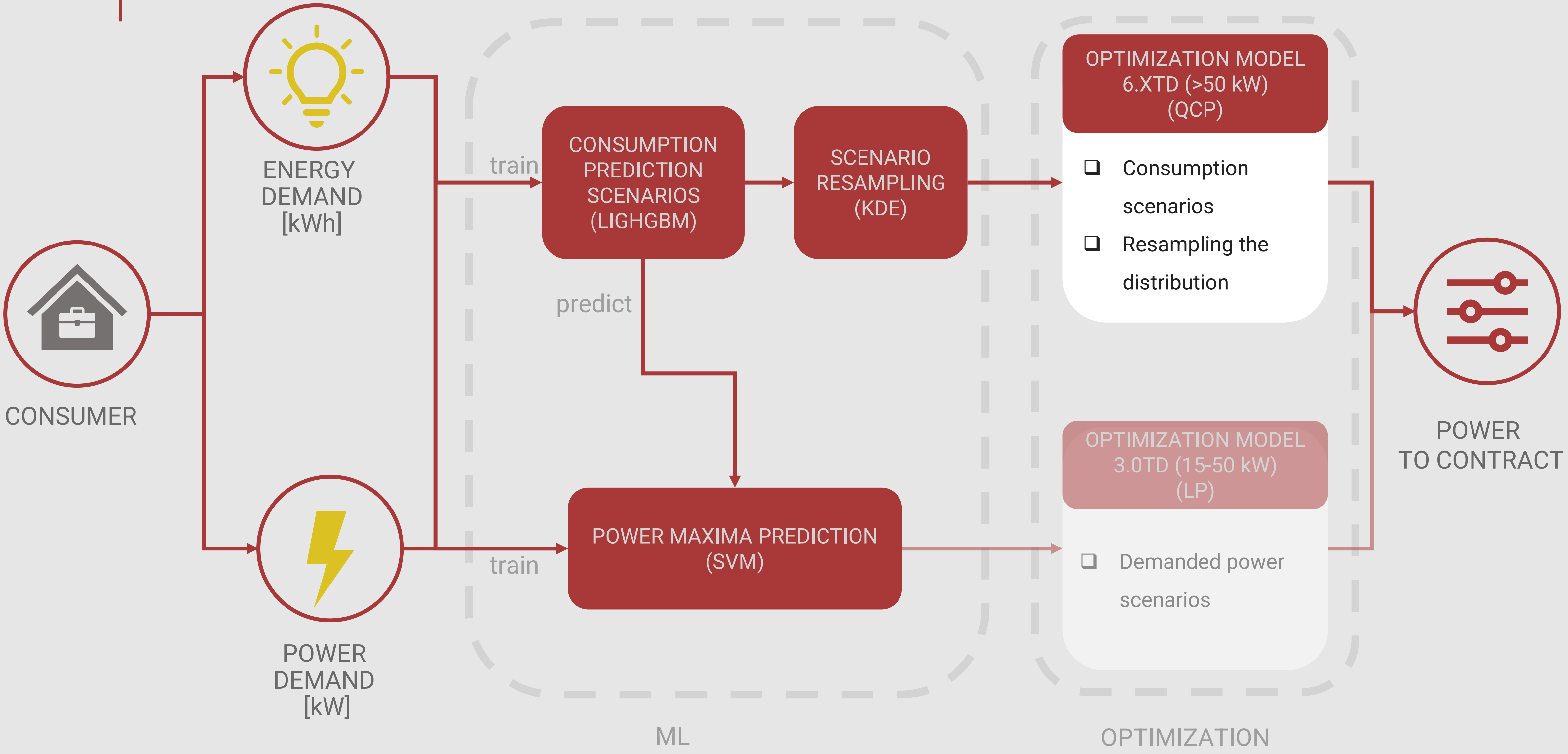
INTEGRATION

DIAGRAM



OPTIMIZATION MODEL

BEST POWER TO CONTRACT IN EACH PERIOD (6.XTD)

- ❑ Most of the constraints are analogue to the 3.0TD problem
- ❑ The power demand is measured with ¼ or 1 hour discretization → Time indexation
- ❑ A different method for billing the excess power term → The problem becomes QCP
- ❑ Hypothesis: the power demand is equal to the (simulated) consumption

OBJECTIVE FUNCTION

Cost term of the excess power	$\sum_{t} \mathrm{KP}_t \cdot \mathrm{TEP} \sqrt{\sum_{i} \mathrm{w}_{i,sc} \left(\mathrm{p}_{i,sc}^{abv}\right)^2}$

PARAMETERS

$w_{\{i,sc\}}$	distribution weights
$P_{i,sc}^{dem}$	hourly demanded power

SETS

$i \in \{1, 2, \dots, \mathrm{N_i}\}$	time

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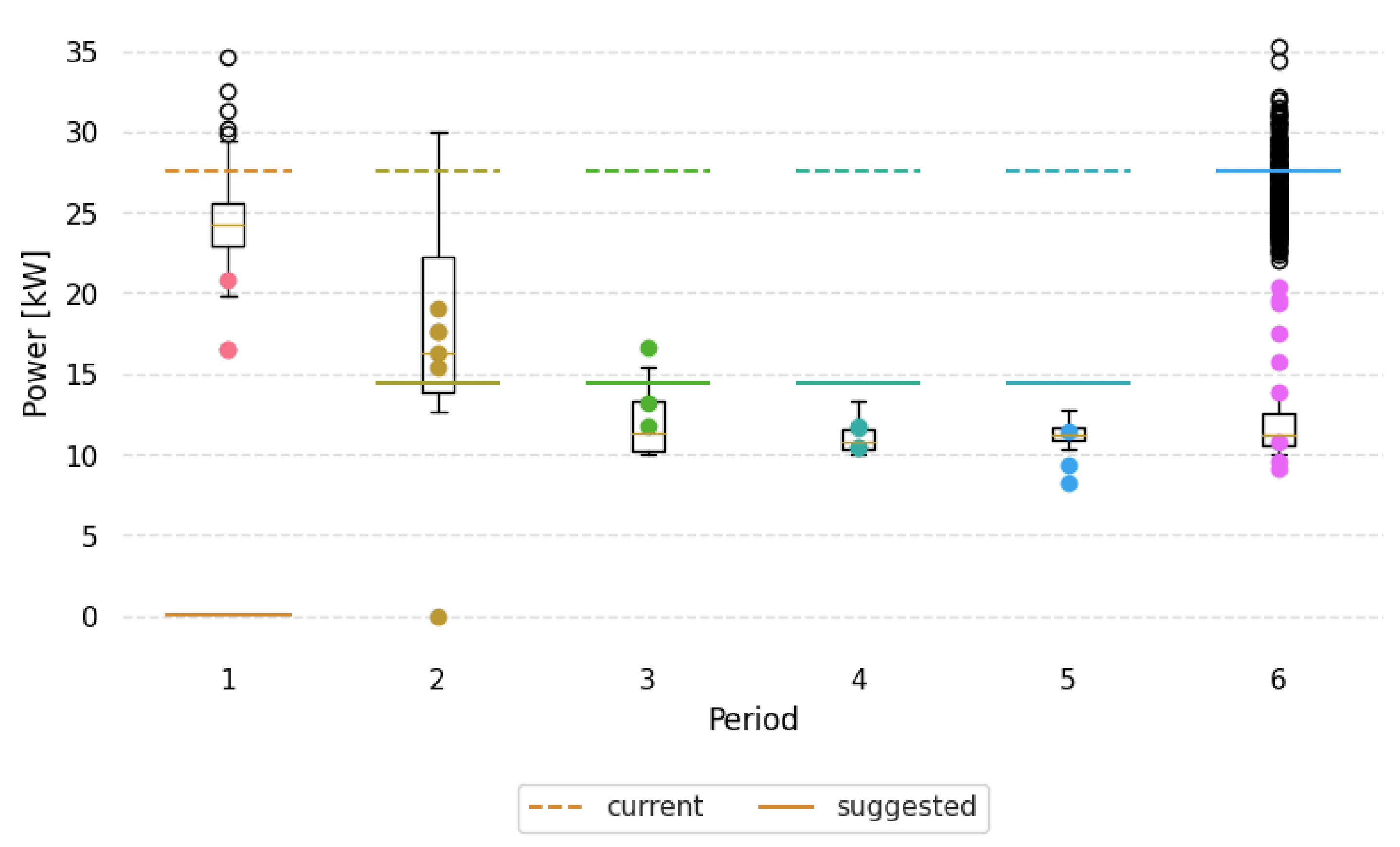
RESULTS

CONTRACTED

PERIOD	POWER [kW]	POWER COST [€]	EXCESS COST [€]
P1	27.6	213.8	0
P2	27.6	130	0
P3	27.6	63.4	0
P4	27.6	56.4	0
P5	27.6	31.1	0
P6	27.6	21.14	0
TOTAL		515.84 €	0 €

SUGGESTED

PERIOD	POWER [kW]	POWER COST [€]	EXCESS COST [€]
P1	0.1	0.8	68.6
P2	12.8	60.2	6.9
P3	12.8	29.4	8.04
P4	12.8	26.1	0.03
P5	12.8	14.4	0.03
P6	27.6	21.1	0.0
TOTAL		152.0 €	83.8€



RESULTS

CURRENT POWER COST **516 €**

SUGGESTED POWER COST **236 €**

CURRENT BILL **2152 €**

SUGGESTED BILL **1796 €**

356 €

SAVINGS

CHALLENGES

COMPLEXITY

LACK OF DATA

Unavailable or poor-quality data

- Imputation methods
- Power approximation
- Heuristic workflows

LARGE DATASET

A High number of scenarios and fine discretization

- Resampling methods

PENALTIES

Penalties for power change

- Penalty for small increases
- Penalty for decreases
- Non-included penalties

WHAT DOES THE USER SEE?

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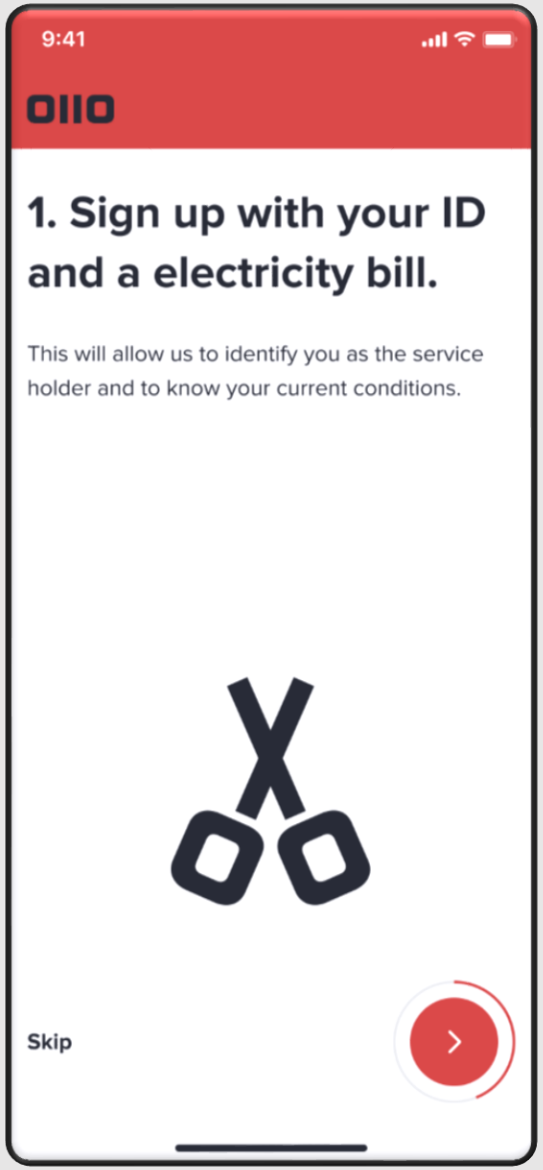
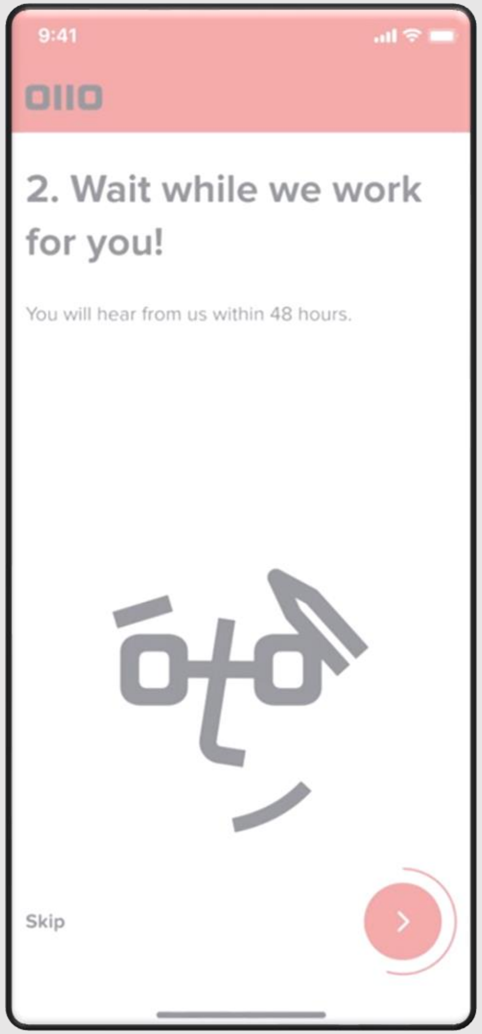
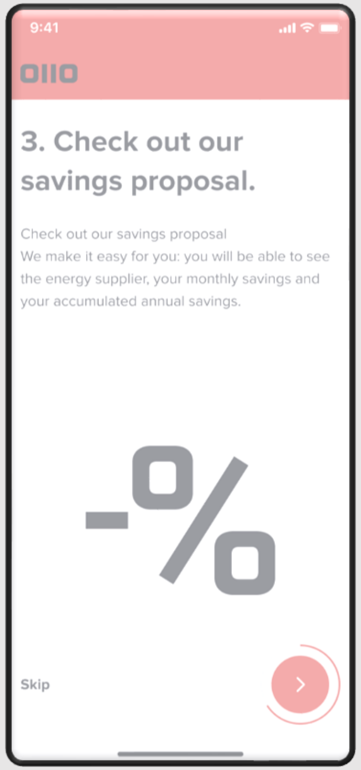
WE REDUCE YOUR BILL IN FIVE STEPS

REGISTRATION

- ❑ Identification card
- ❑ Electric Bill
- ❑ Authorization







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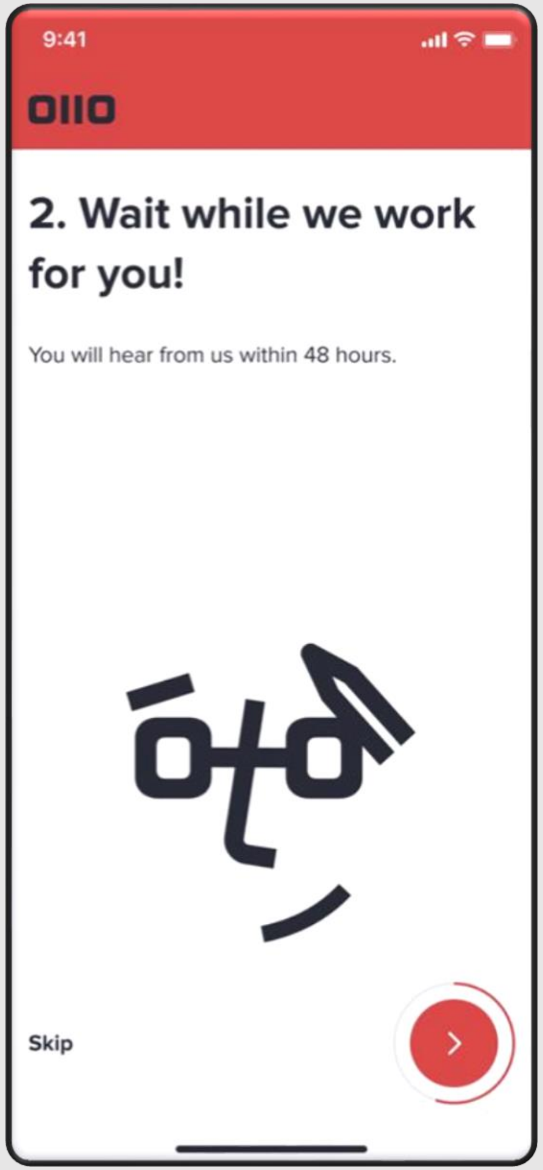
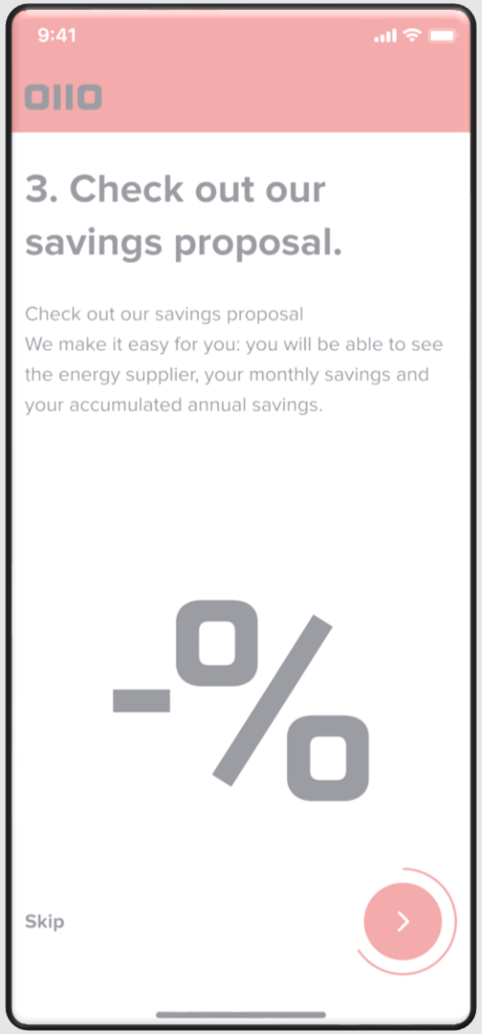
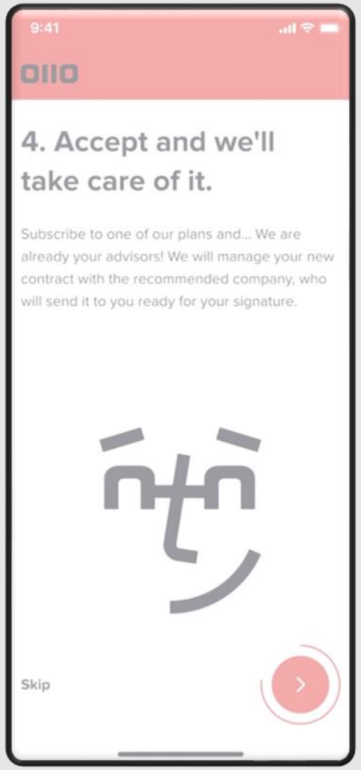
WE REDUCE YOUR BILL IN FIVE STEPS

OPTIMIZATION

- ❑ Data processing
- ❑ Optimization
- ❑ Suggestion







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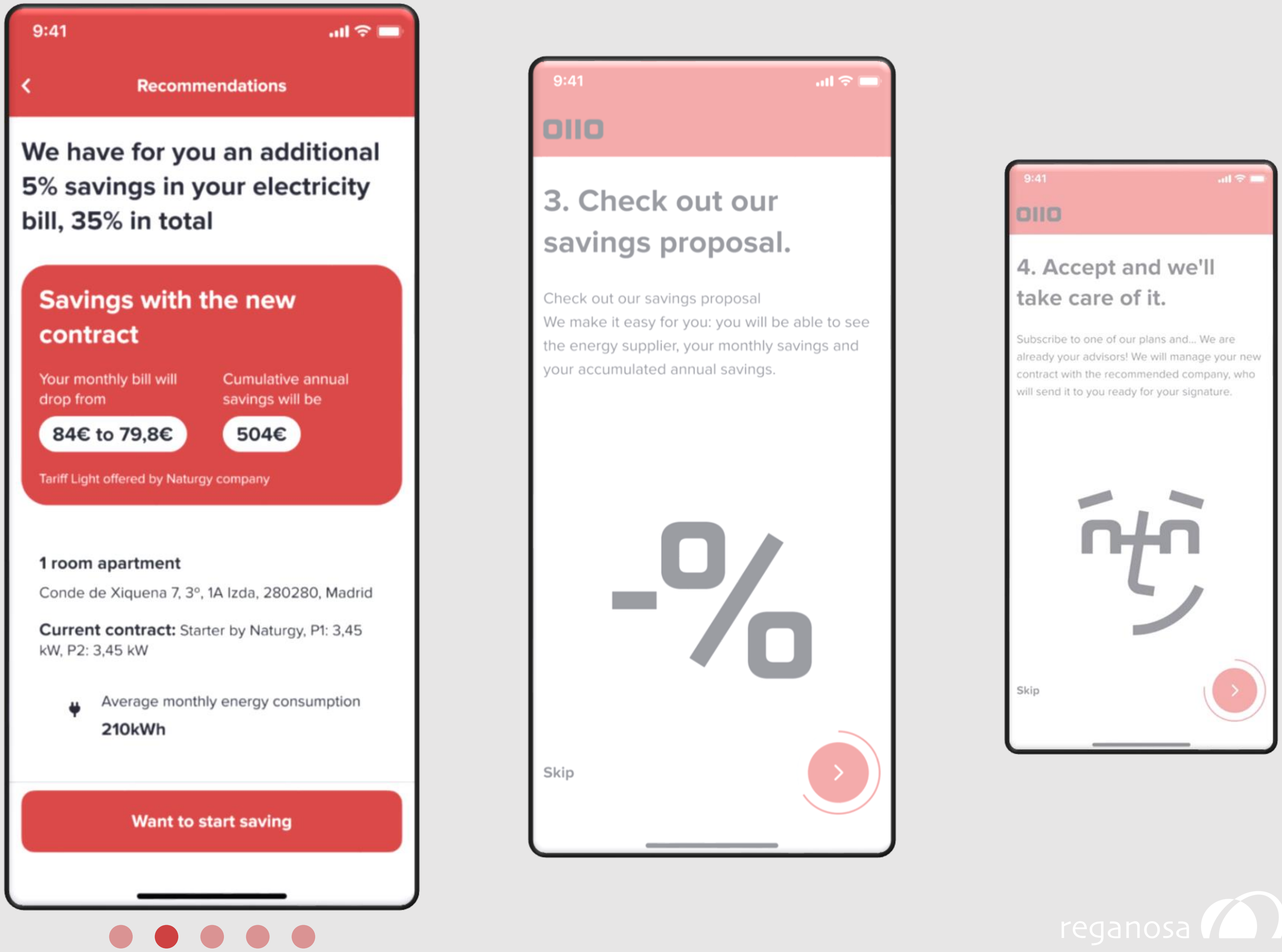
WE REDUCE YOUR BILL IN FIVE STEPS

OPTIMIZATION

- ❑ Data processing
- ❑ Optimization
- ❑ Suggestion



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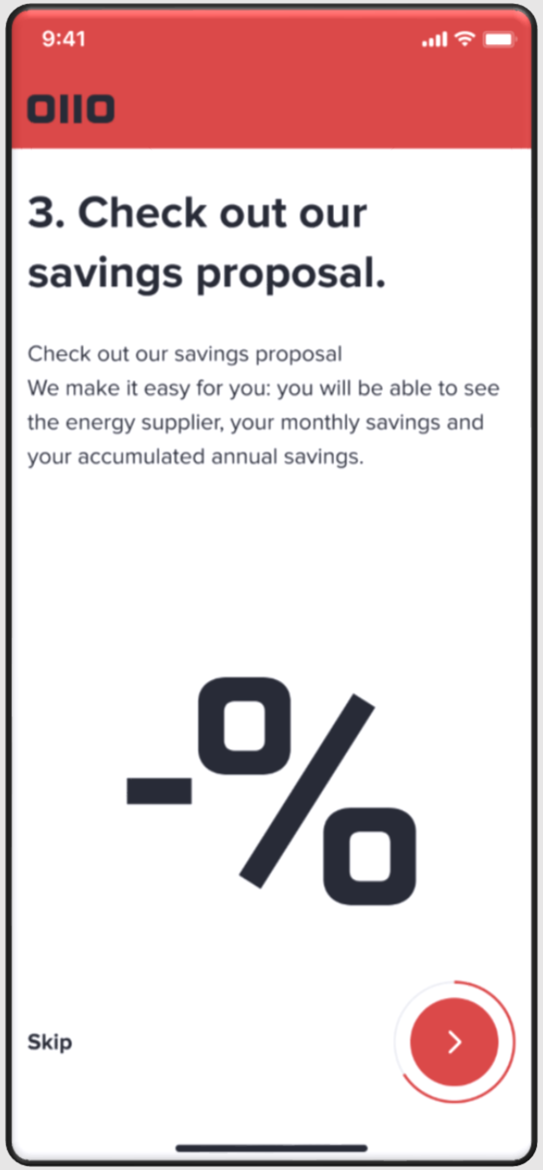
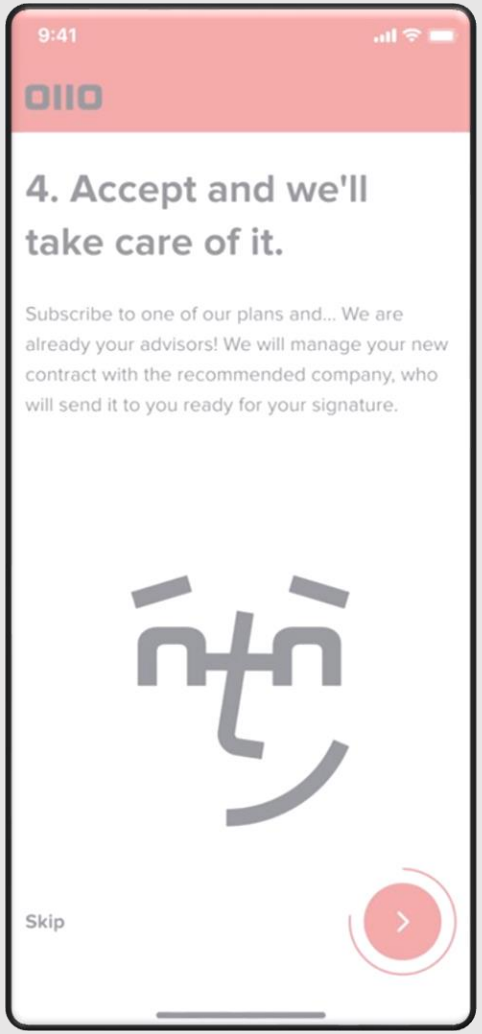
WE REDUCE YOUR BILL IN FIVE STEPS

SUGGESTION

- ❑ User acceptance

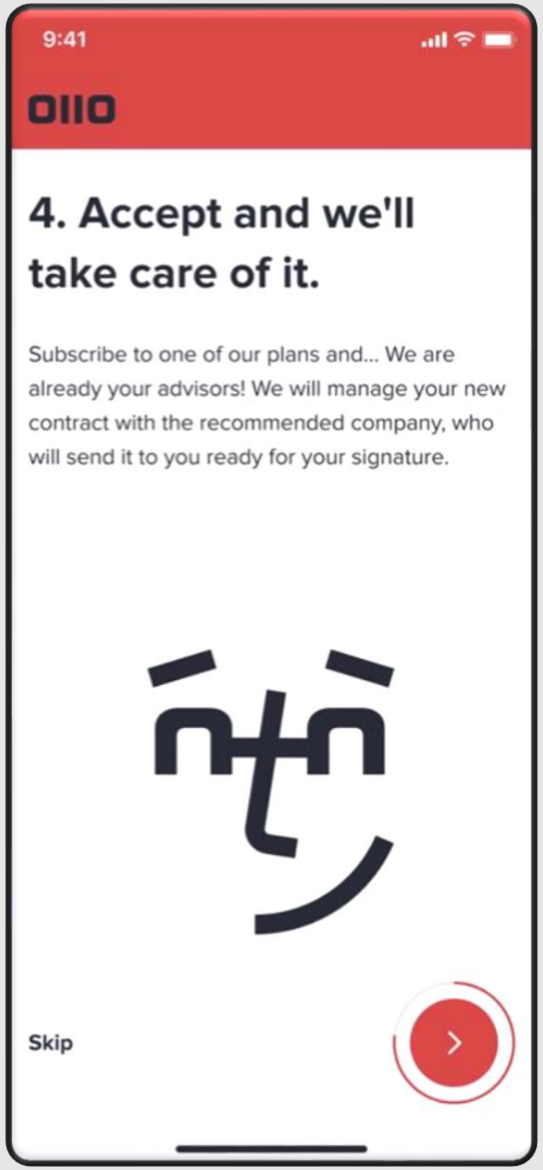


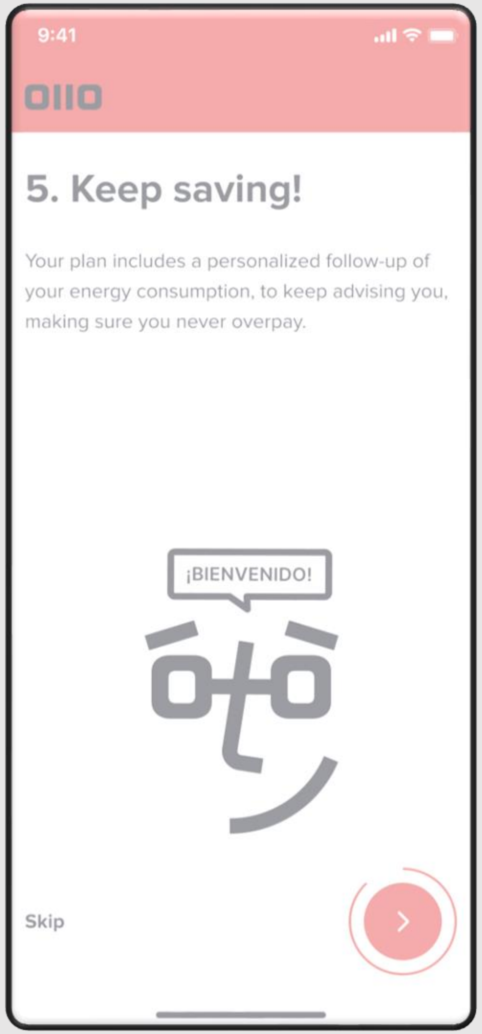


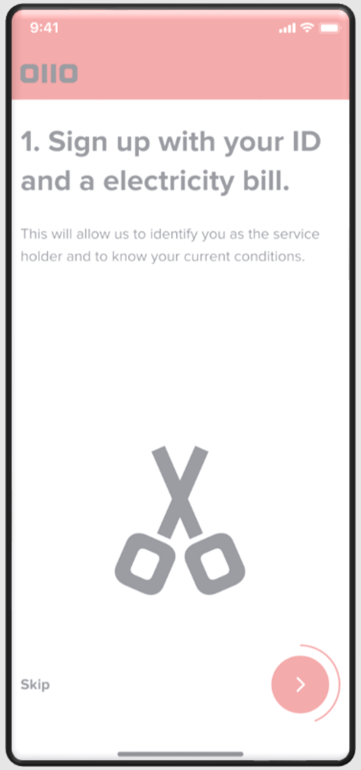
WE REDUCE YOUR BILL IN FIVE STEPS

NEW CONDITIONS

- ❑ Power supplier and rate change
- ❑ New conditions







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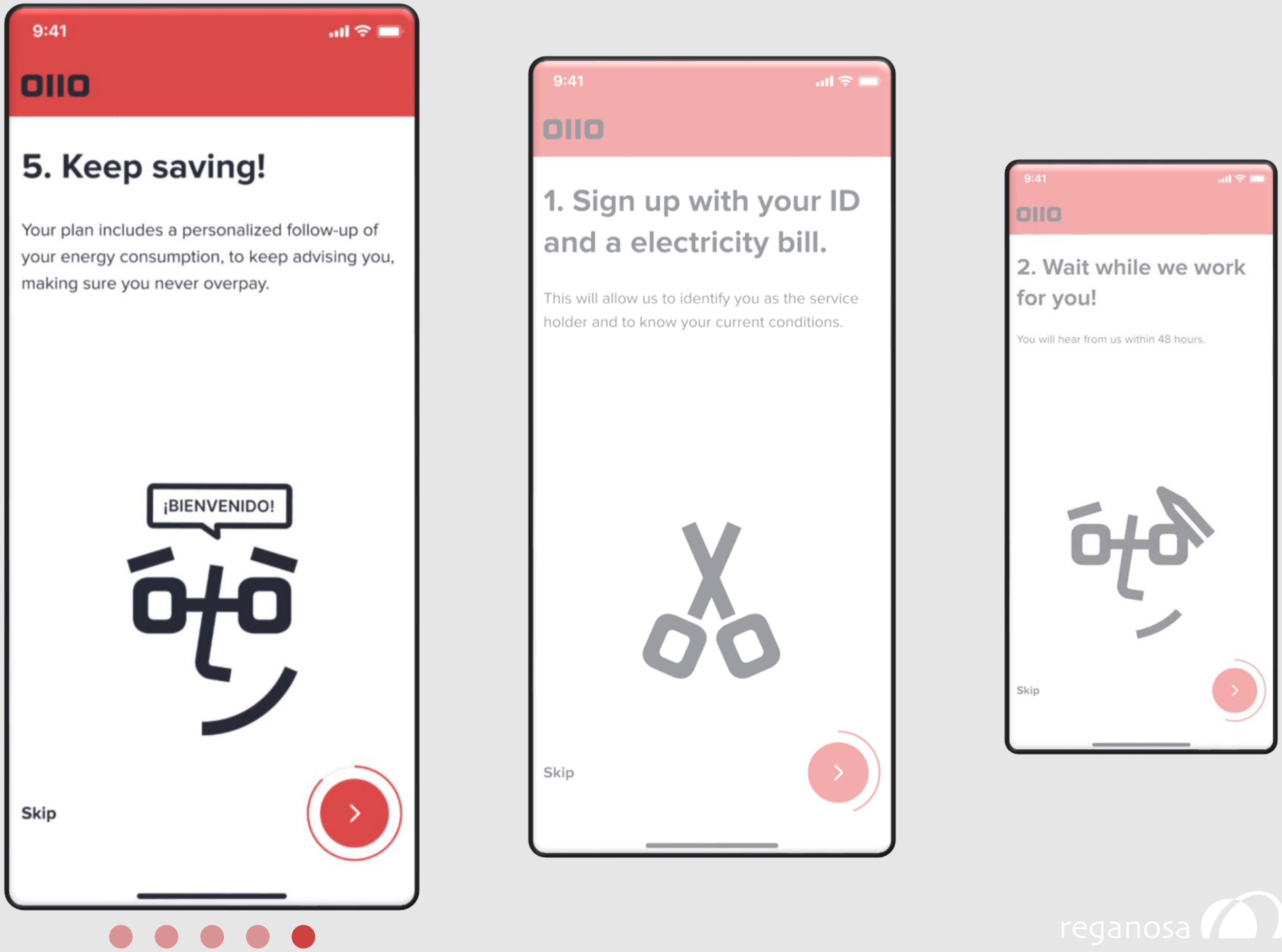
WE REDUCE YOUR BILL IN FIVE STEPS

FOLLOW UP

- ❑ Real-time savings
- ❑ Real-time costs



SUCCESS CASES

26% OF SAVINGS

28% OF SAVINGS

18% OF SAVINGS

56% OF SAVINGS

FUTURE WORK

1 ENERGY COMMUNITIES

Communities of consumers that generate and consume their own energy through renewable sources

2 SMART METERS

Installation of digital smart meters for quality data collection

3 DATA VISUALIZATION

Data visualizations in the app to improve the follow up of the energy demand, cost and savings

4 ARTIFICIAL INTELLIGENCE

Create an AI in a chat based on LLM model to improve user experience

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THE ENERGY YOUR ENERGY NEEDS

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