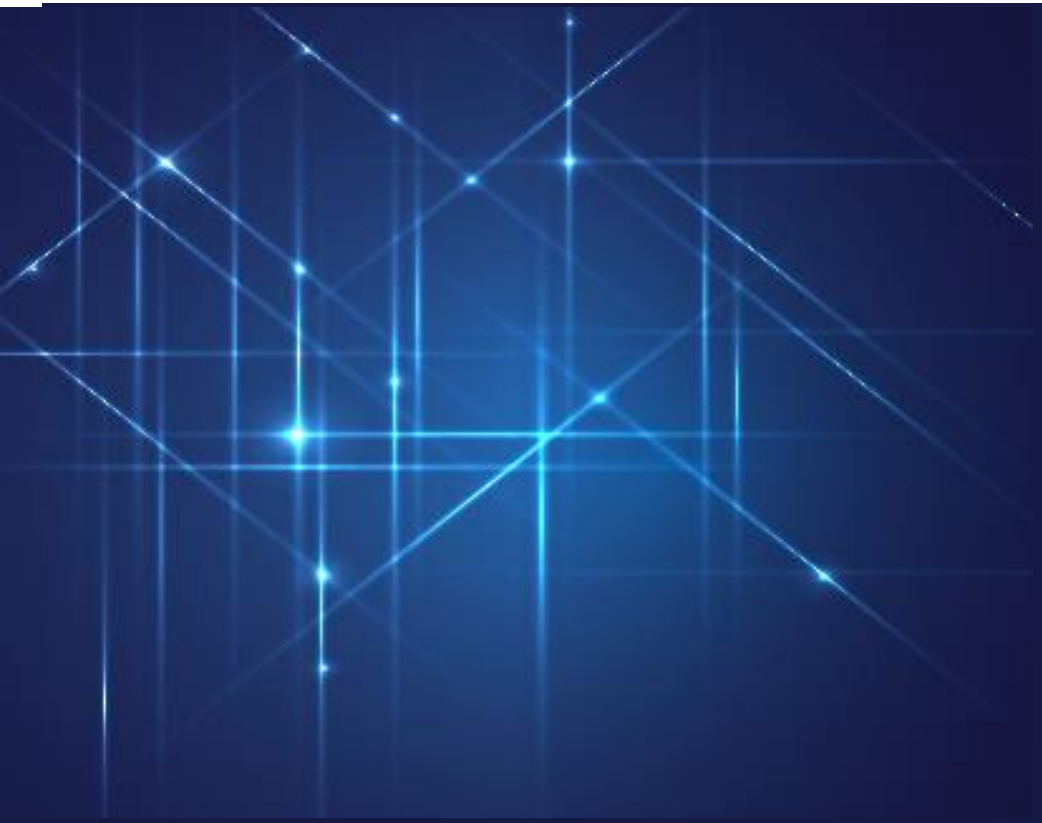
UNIUNEA EUROPEANĂ

GUVERNUL ROMÂNIEI

Instrumente Structurale 2014-2020



SCIENTIFIC EVALUATION
ACTIVITY 1.FUNDAMENTAL RESEARCH

Proiect co-finanţat din Fondul European de Dezvoltare Regională prin Programul Operaţional Competitivitate 2014-2020

INTELLIGENT SYSTEM FOR TRADDING ON THE WHOLESALE ELECTRICITY MARKET

SMARTRADE

Osman Bulent Tor, Adela Bâra

25 MAY 2017

Proiect co-finanțat din Fondul European de Dezvoltare Regională prin Programul Operațional Competitivitate 2014-2020

Agenda

- Project objectives
- Activity 1 - Fundamental research’s description
- 1.1. Conceptual model of the system
- 1.2. Propose the system's architecture
- Dissemination

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Project objectives

To design and develop an informatics **prototype** for **forecasting**, **analysis** and **decision support** for **energy providers grouped in Balanced Responsible Parties (BRE)**, in order **to estimate consumption and production** in a suitable way for the **efficient trading** on the wholesale electricity market.

Prototype	Cloud computing architecture
Models	Forecasting energy consumption and generation; Optimization; Decision Rules
User	BRE, TSO, DSOs

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Activity 1 - Fundamental research

- Analysis of the current situation regarding the activities of energy providers and BRP;
- Information flows on wholesale electricity market;
- Main smart metering systems and advanced tariffs systems;
- Studying consumption optimization models for household and non-household consumers;
- Analysis forecasting methods for renewable energy generation;
- Proposing the detailed architecture and the conceptual model of the prototype;

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Activity 1 - Fundamental research

Activity	Start	End	
1.1.Conceptual model of the prototype	05.09.2016	04.06.2017	Detailed report regarding the information processes flows analysis and the conceptual model; 1 paper in international journal
1.2. Propose the system's architecture	05.12.2016	04.06.2017	Detailed report regarding the prototype's architecture and the detailed specifications for the prototype's development 1 paper in international journal

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1.1. Conceptual model of the system

- Chapter 1 – Balance Responsible Parties: organization, management, market participation;
- Chapter 2 – Wholesale Electricity Market: components, transactions, information flows, indicators;
- Chapter 3 – Main methods for forecasting and optimization used in electricity consumption and generation.

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1.1. Conceptual model of the system

Wholesale Electricity Market:

- Includes: *intra-day market*, *day-ahead market*, *balancing market*, *bilateral contracts*, *green certificates market*.
- All transactions on the wholesale electricity market are coordinated and supervised by OPCOM, the Romanian gas and electricity market operator.

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1.1. Conceptual model of the system

Wholesale Electricity Market:

In order to participate on the OPCOM online trading platform, the market players have to send to TSO and OPCOM mainly the following data:

- total generation capacity installed for each dispatchable/undispatchable unit, differentiated on primary energy sources;
- notification about hourly generation;
- planned outages of the production units with installed capacity greater or equal to 50 MW (the start and end date of planned outage of capacity);
- level of the accumulation lakes;
- information regarding electricity consumption (forecast of total/ hourly peak consumption);

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1.1. Conceptual model of the system

Wholesale Electricity Market:

- The market players send their offers in terms of hourly generation/consumption and corresponding prices.
- OPCOM approves the offers, organizes the auction and at the end issues confirmations of transaction: a) the closing price; b) the total volume of transactions; c) aggregate demand and supply curves.
- For the concluded trades, OPCOM issues the settlement notes and sends them to the market players.

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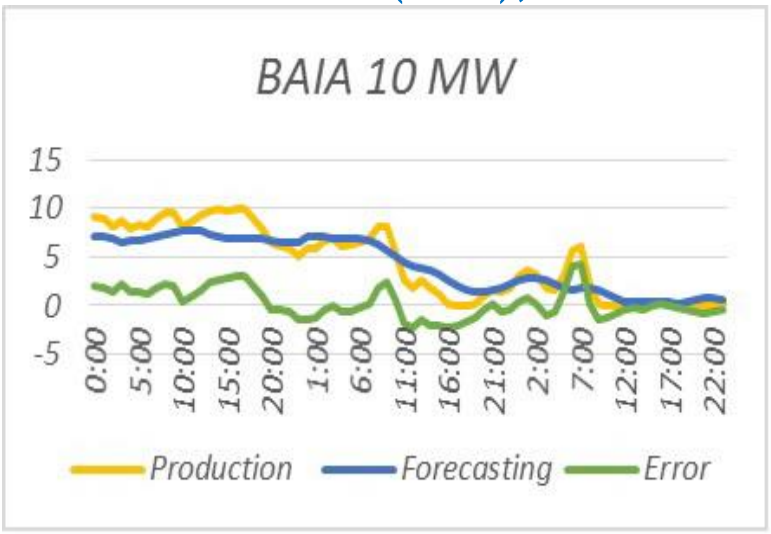
1.1. Conceptual model of the system

Forecasting methods for electricity generation based on RES:

- Distinct models for Wind Power Plants (WPP) and Photovoltaic Power Plants (PPP);
- Existing methods – average accuracy WPP 70% and PPP 85%;



- Our approach - Artificial Neural Networks (ANN);

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1.1. Conceptual model of the system

Forecasting methods for electricity generation based on RES:

Wind Power Plants (WPP) proposed model:

- Input vector: AMBIENT_TEMPERATURE - x1, HUMIDITY - x2, WIND_DIRECTION – x3, WIND_SPEED – x4, ATMOSPHERIC_PRESSURE – x5
- Output vector: TOTAL_ACTIVE_POWER;
- Algorithms: Levenberg-Marquardt (LM), Bayesian Regularization (BR) and Scalar Conjugate Gradient (SCG);
- ANN developed in MatlabR2015a;

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1.1. Conceptual model of the system

Forecasting methods for electricity generation based on RES:

Table 1. The comparison between the results obtained using the LM, BR and SCG algorithms (LGPO16)

The prediction period	MSE			R		
	LM	BR	SCG	LM	BR	SCG
2 Years	0.060908	0.057898	0.066406	0.9333	0.93474	0.92819
Spring	0.048176	0.036081	0.050792	0.96637	0.96722	0.96195
Summer	0.066927	0.059701	0.059853	0.95493	0.95735	0.94918
Autumn	0.073134	0.068371	0.11224	0.94789	0.93749	0.95076
Winter	0.059272	0.055915	0.063179	0.9603	0.96192	0.95458

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1.1. Conceptual model of the system

Forecasting methods for electricity generation based on RES:

Photovoltaic Power Plants (PPP) proposed model:

- Input vector: AMBIENT_TEMPERATURE - x1, HUMIDITY - x2, SOLAR_IRRADIATION - x3, WIND_DIRECTION - x4, WIND_SPEED - x5
- Output vector: TOTAL_ACTIVE_POWER;
- Algorithms: Levenberg-Marquardt (LM), Bayesian Regularization (BR) and Scalar Conjugate Gradient (SCG);
- ANN developed in MatlabR2015a;

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1.1. Conceptual model of the system

Forecasting methods for electricity generation based on RES:

Table 2. The comparison between the results obtained using the LM, BR and SCG algorithms (BGBP15)

Period	MSE			R			Errors interval		
	LM	BR	SCG	LM	BR	SCG	LM	BR	SCG
Year	0,201960	0,198060	0,235660	0,9573	0,9568	0,9496	-3506; 3983	-3440; 3698	-4610; 5083
May	0,053907	0,050544	0,064008	0,9980	0,9981	0,9975	-442,6; 393,7	-464,5; 375,3	-348,1; 479,1
June	0,070550	0,067576	0,086520	0,9991	0,9992	0,9989	-472,8; 296,2	-557,3; 557,8	-404,6; 341,2
July	0,043923	0,047421	0,057703	0,9967	0,9969	0,9962	-484,3; 377,5	-472,7; 400,5	-542,4; 669,3
August	0,087018	0,065867	0,101970	0,9991	0,9993	0,9989	-596,9; 583,9	-628,5; 470,8	-491,9; 604,3

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1.1. Conceptual model of the system

Forecasting methods for electricity generation based on RES:

Photovoltaic Power Plants (PPP) proposed model:

- Algorithm: Gradient descent (GD) algorithm developed in Oracle PL/SQL, median-MAD standardization and Momentum method.

Table 3. The results obtained using GD algorithm

Period	Max error	Average error	RMSE	R
May	29.86	2.07	4.57	0.9995
June	29.77	1.98	4.48	0.9994
July	28.55	1.85	4.15	0.9995
August	26.58	1.55	3.50	0.9997
May-August (summarized)	33.05	1.92	4.12	0.9995

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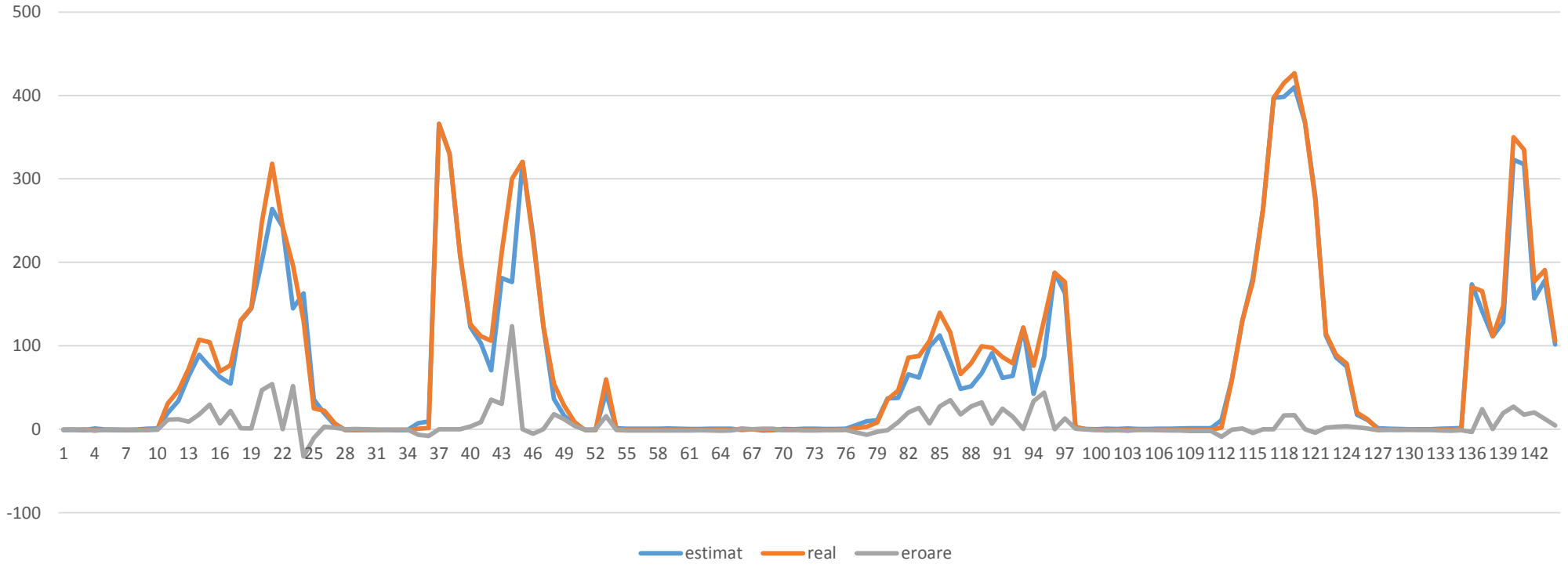
1.1. Conceptual model of the system

Forecasting methods for electricity generation based on RES:



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1.1. Conceptual model of the system

Consumption optimization methods:

- The electricity consumption optimization problem is a MILP problem which is defined by an objective function, variables, bounds and linear equality and inequality constraints.
- MILP is a particular form of the more relaxed linear programming (LP) algorithm, by tightening the LP relaxation since some of the variables (x) must be integers.

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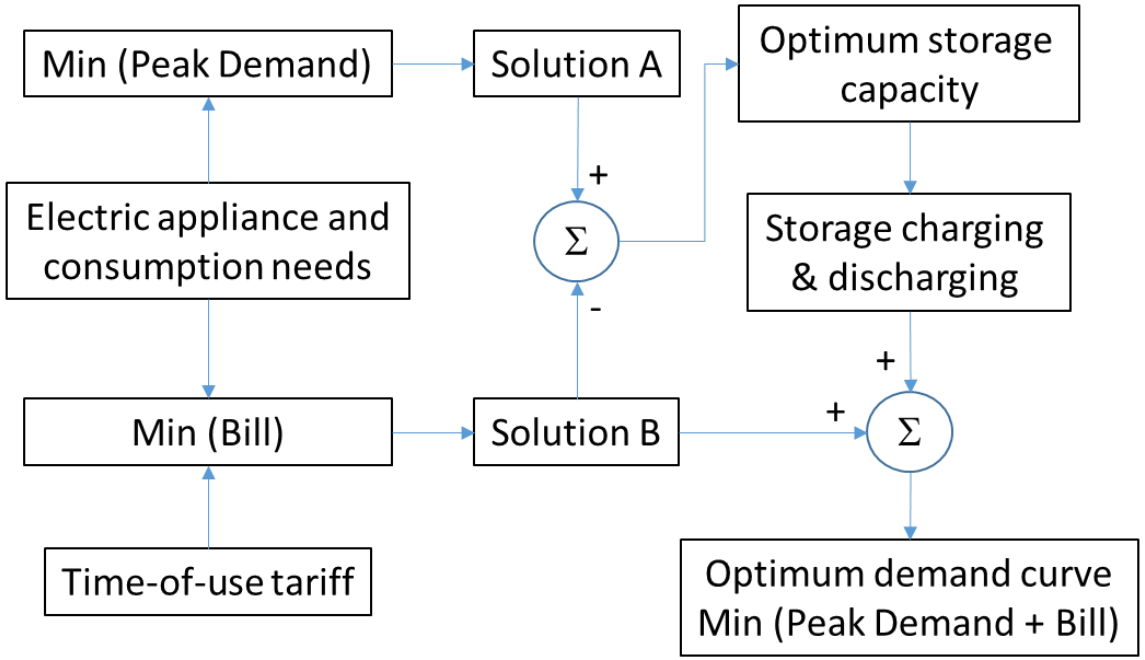
1.1. Conceptual model of the system

Consumption optimization methods:



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1.1. Conceptual model of the system

Consumption optimization methods:

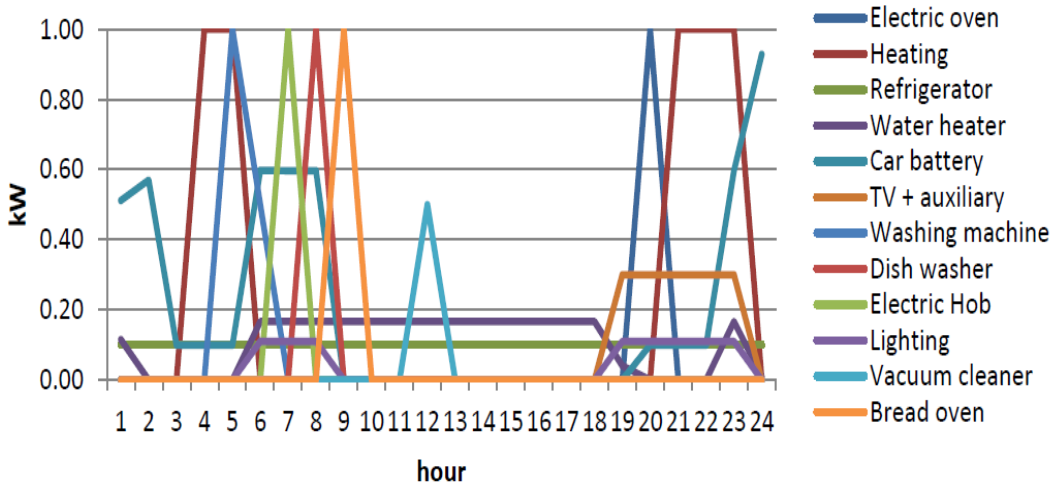

Figure 3. Hourly consumption of the appliances (reference)

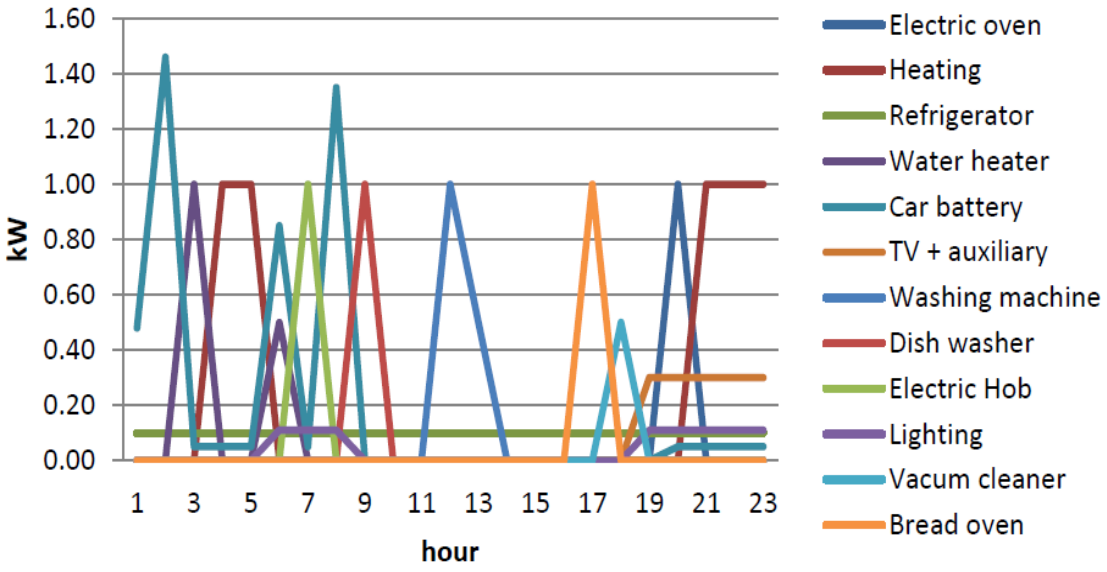

Figure 4. Daily operation curves of the appliances - peak shaving

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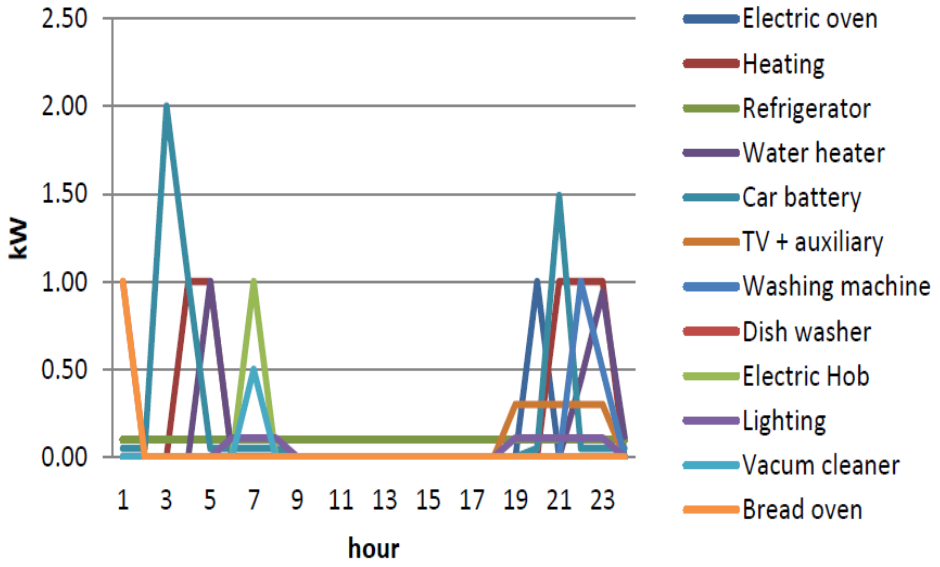
1.1. Conceptual model of the system

Consumption optimization methods:



Scenarios	Peak [kWh]	Peak difference [%]	Payment [m.u.]	Payment difference [%]
Reference (no optimization)	2.27	-	3.50	-
Peak minimization	1.56	-31%	3.47	-1%
Payment minimization	3.00	32%	2.86	-18%

Figure 5. Daily operation curves of the appliances - electricity payment minimization

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1.1. Conceptual model of the system

Consumers profiles:

- Electricity consumption data, hourly recorded during 2014: different appliances (heating, cooling, ventilation, ovens, interior and exterior lightning, water heating and other appliances such as washing machines, refrigerators, TVs, audio systems, computers);
- Three methods: Self-Organized Maps (SOM), clustering, classification;

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1.1. Conceptual model of the system

Consumers profiles:

Criterion\Method	Classification	Clustering	SOM
Number of profiles	6 with 35 de leaves	10 profiles and patterns	6 profiles clearly delimited
Sensitivity to individual consumption variations	High	High	Medium
Capacity of profiles' details	High (sub-types of profiles)	High (by patterns of O-cluster)	Low
Performance	Medium	High	High
Volume of data	High	High	Medium

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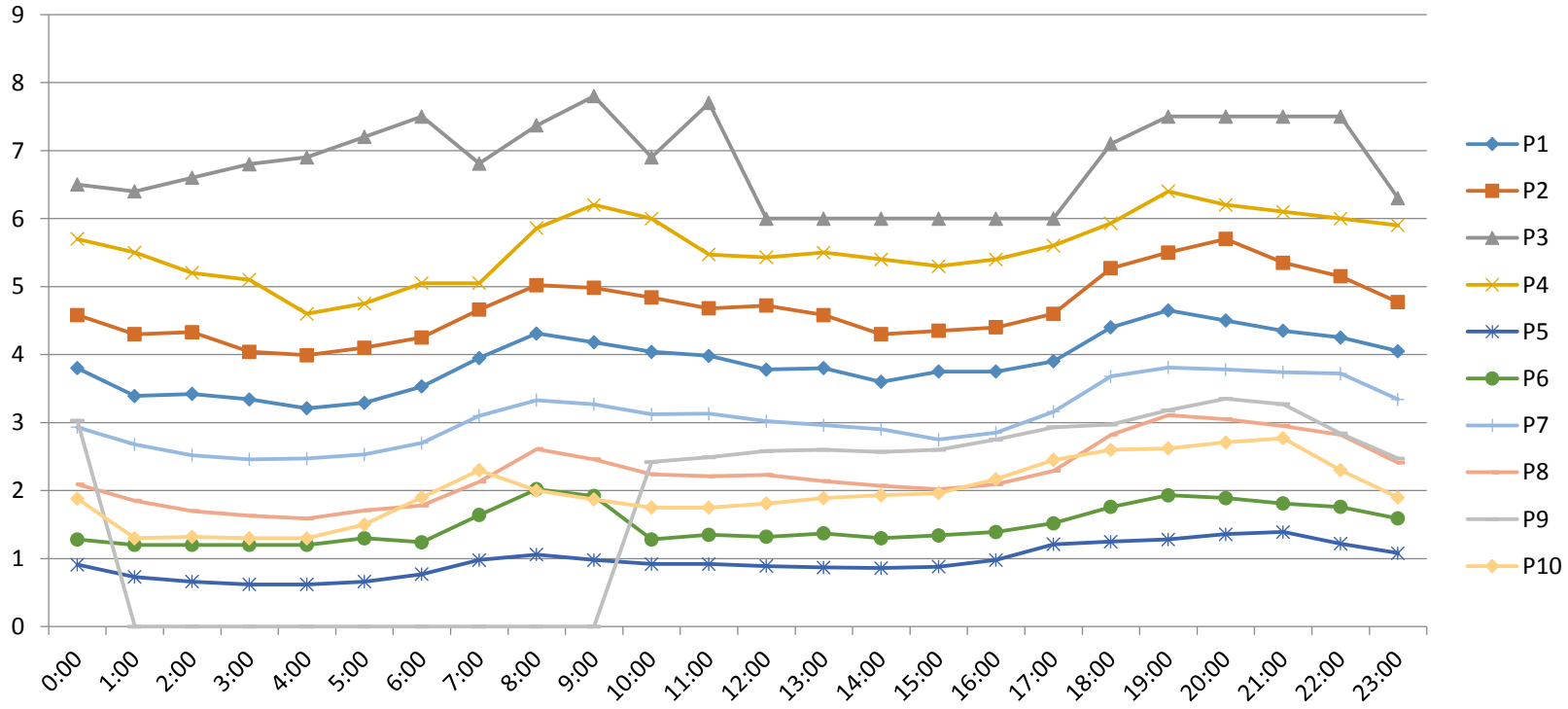
1.1. Conceptual model of the system

Consumers profiles:



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1.2. Propose the system's architecture

- Chapter 1 – Software solutions for wholesale electricity market analysis;
- Chapter 2 – Prototype’s architecture;
- Chapter 3 – Main technologies for prototype’s implementation.

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1.2. Propose the system's architecture

The prototype development:

- Online environment on a cloud computing infrastructure;
- Java with Application Development Framework (ADF) with Business Intelligence (BI) elements, in order to build interactive interfaces, easily configurable and accessible through mobile devices;
- Three layers: *data, models and presentation*;

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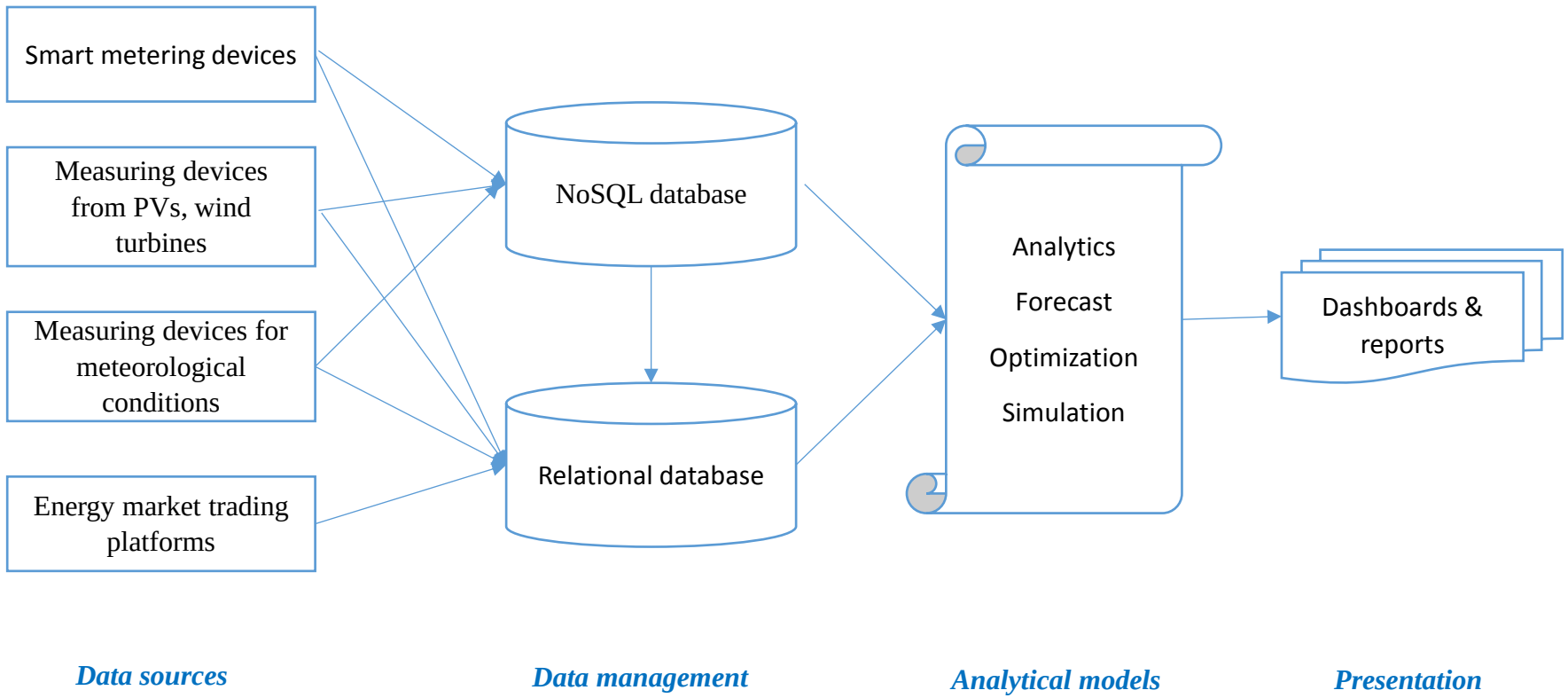
1.2. Propose the system's architecture



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1.2. Propose the system's architecture

Main technologies:

- Oracle Database 12c;
- NoSQL;
- Data warehousing;
- Java platform;

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Dissemination

1. Alexandra FLOREA, Anda BELCIU - Study on electricity markets in Romania, Database Systems Journal, Vol. VII, Issue 4/2016, ISSN 2069 – 3230, http://dbjournal.ro/archive/26/26_2.pdf
2. Adela BÂRA, Simona Vasilica OPREA, Iuliana ȘIMONCA (BOTHA), Osman Bülent TÖR- Conceptual design and architecture of an informatics solution for smart trading on wholesale energy market in Romania, Database Systems Journal, Vol. VII, Issue 4/2016, ISSN 2069 – 3230, http://dbjournal.ro/archive/26/26_1.pdf

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Q&A

Thank You!