Department of Telecommunications

Visualizing Power TAC: how to Seize Dynamics of Electric Power Markets?

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ERIM Research Seminar
Erasmus University Rotterdam School of Management
March 12, 2012, Rotterdam, Netherlands

Outline

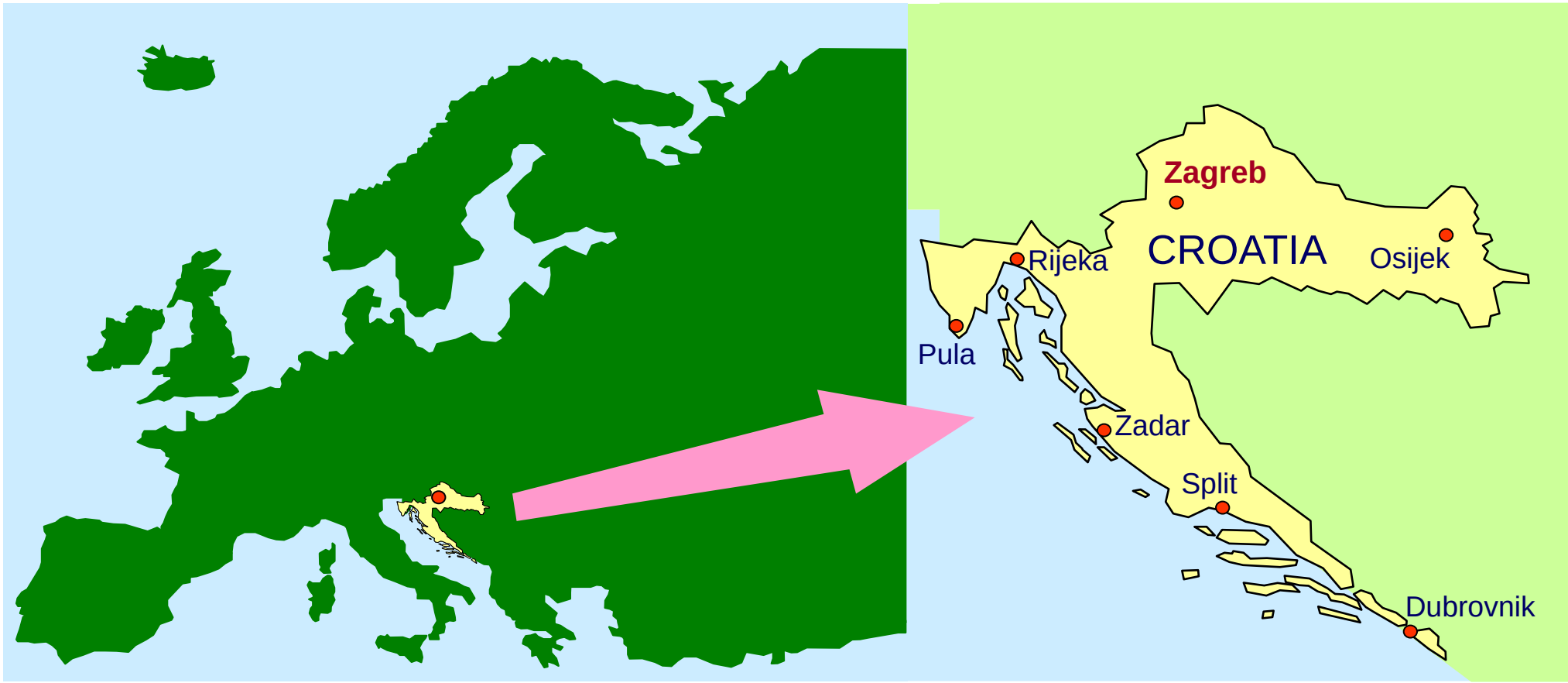
- University of Zagreb
  - Participation in TAC community
- Power TAC
  - Power TAC scenario
    - KPIs
  - Power TAC broker
    - CrocodileAgent
  - Power TAC Visualizer
    - Live demo

University of Zagreb (Uni Zg)

Facts about Uni Zg, Participation in TAC community

University of Zagreb (1)

Where is Zagreb?



University of Zagreb (2)

Higher education in Croatia

- Area land: 56594 km^2
- Area sea: 31067 km^2
- Population: ~ 4.44 million
- Population density: 78.5 /km^2
- Labor force: ~ 1.9 million
- Higher education students: ~ 135000
- Capital: Zagreb
  - population: 779145 (2001)

- 7 Universities by size: Zagreb, Split, Rijeka, Osijek, Zadar, Dubrovnik, Pula
- 4 Technology centers: Zagreb, Split, Rijeka, Osijek

University of Zagreb (3)

University of Zagreb in numbers

- University of Zagreb was officially founded in 1669
- 29 Faculties + 3 Art Academies
- 61,500 students (55% females)
- 46% of all students in Croatia
- Teaching and administrative full time staff: about 8,000
- Study programs
  - 140 BA
  - 170 MA
  - 100 PhD programs
- Postgraduate students: 5,500
- Foreign students: about 300

- *http://www.unizg.hr*

University of Zagreb (4)

Faculty of Electrical Engineering and Computing in numbers

- Professors: 154
- Assistants and researchers: 161
- Staff: 187
- 12 departments
  - Department of Telecommunications

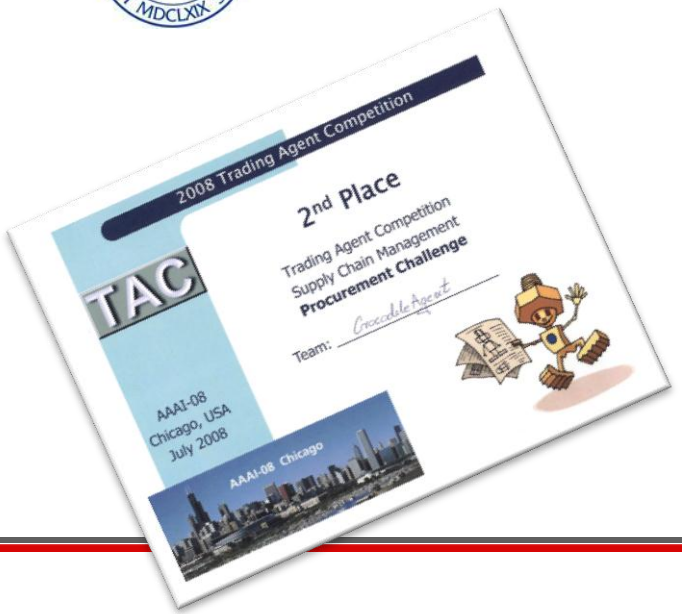
- Undergraduate students: ~ 4300
- Postgraduate students: ~ 450
- Freshmen each year: ~ 650
- Graduating students each year: ~ 550
- Graduated since 1956 (Dipl.Ing.): ~ 16000
- Graduated since 1956 (M.Sc.): ~ 2100
- Graduated since 1956 (Ph.D.): ~ 630

Participation in TAC community (1)

Since 2004

- TAC SCM
  - Since 2010 Game Master
    - Vedran Podobnik
  - Since 2011 Operations
- TAC AA
- CAT
- Power TAC
  - Competition platform development
    - Visualizer
  - Broker development
- *http://agents.tel.fer.hr/tac*

CrocodileAgent



Participation in TAC community (2)

Power TAC team 2012

- **Jurica Babic**, MSc student
  - Power TAC Visualizer developer
  - Team 2012 leader
- **Sinisa Matetic**, MSc student
- **Marin Matijas**, PhD student
- **Marija Mijic**, BSc student

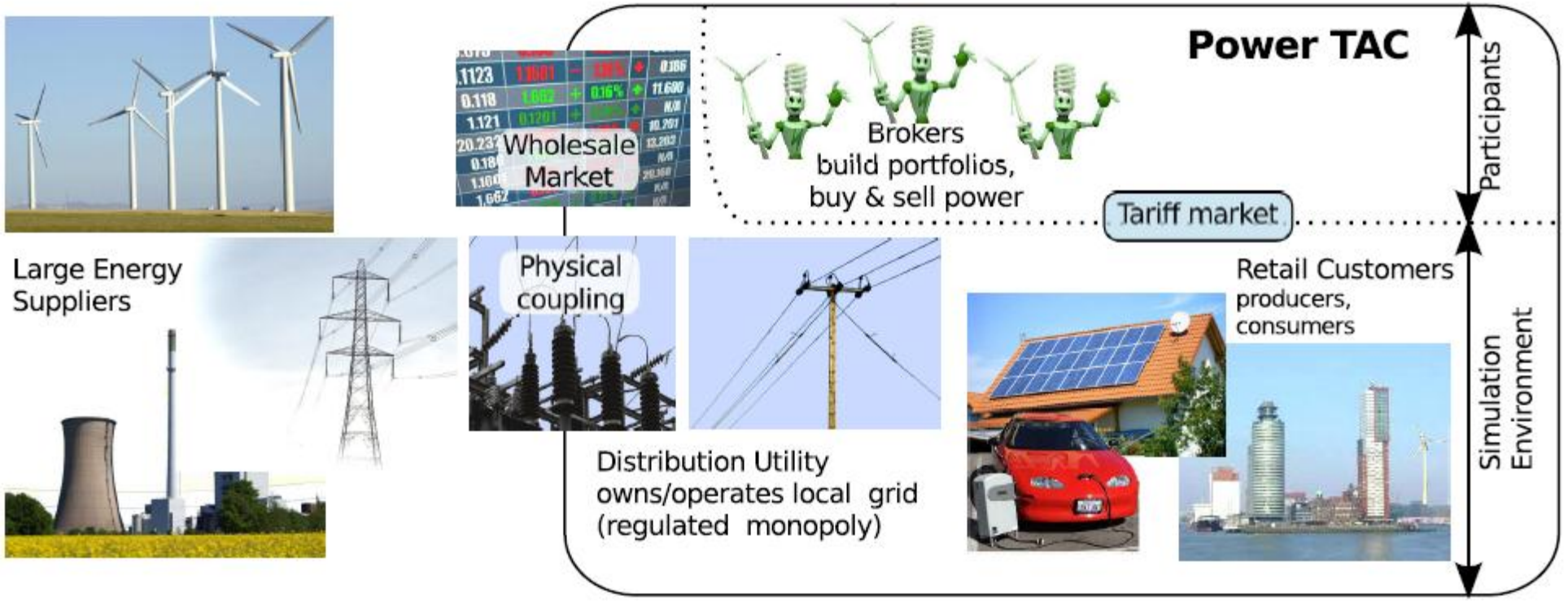
- *http://agents.tel.fer.hr/power_tac*

Power TAC scenario

Game scenario, KPIs

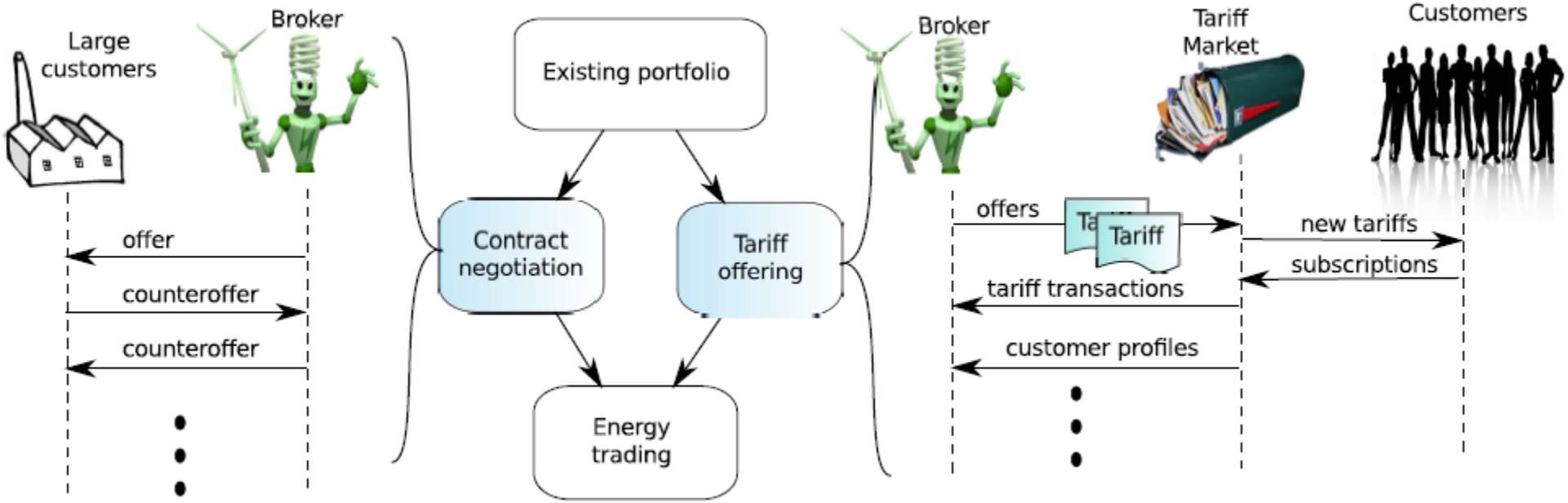
Power TAC scenario (1)

Major stakeholders & activities



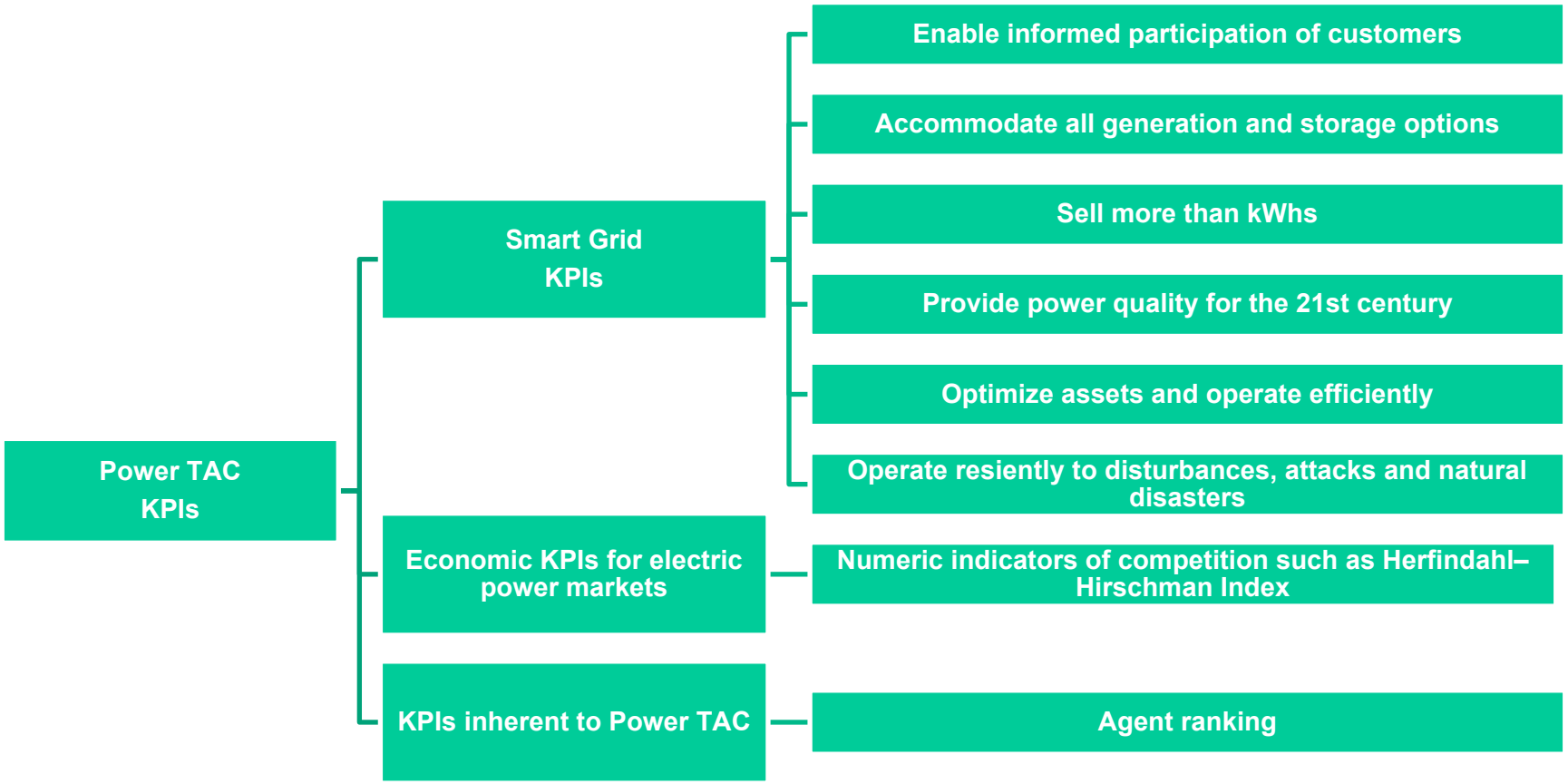
Power TAC scenario (2)

Portfolio management process



Power TAC scenario (3)

Key Performance Indicators (KPIs)



Power TAC scenario (4)

KPIs: Enable informed participation of customers

Enable informed participation by customers	
Advanced Meters	1A: Number of advanced meters installed
	1B: Percentage of total demand served by advanced meters
Dynamic Pricing Signals	2A: The fraction of customers served by RTP tariffs
	2B: The fraction of load served by RTP tariffs
Smart Appliances	3A: Total yearly retail sales volume for purchases of smart appliances [€]
	3B: Total load capacity in each consumer category that is actually or potentially modified by behaviours of smart appliances [MW]
Demand Side Management	4A: Fraction of consumers contributing in DSM [%]
	4B: Percentage of consumer load capacity participating in DSM [MW/MW]
	4C: Potential for time shift (before start-up and during operation) [h]
Prosumer	5A: Total electrical energy locally (decentralised) produced versus total electrical energy consumed [MWh/MWh]
	5B: Minimal demand from grid (maximal own production) versus maximal demand from the grid (own production is zero) [MW/MW]
	5C: Fraction of time prosumer is net producer and consumer [h/h]

Dupont, B., Meeus, L., Belmans, R. *Measuring the "smartness" of the electricity grid*. In the Proceedings of the 7th International Conference on the European Energy Market (EEM), Madrid, Spain, 2010, pp. 1-6.

United States Department of Energy. *2010 Smart Grid System Report*. US, 2012.

Power TAC scenario (5)

KPIs: Accommodate all generation and storage options

Accommodate all generation and storage options	
Distributed Generation and Storage	6A: Amount of production generated by local, distributed generation (MW/MW)
	6B: Potential for direct electrical energy storage relative to daily demand for electrical energy [MWh_{el}/MWh_{el}]
	6C: Indirect electrical energy storage through the use of heat pumps: time shift allowed for heating/cooling [h]
PHEVs	~~7A: The total number and percentage shares of on-road light-duty vehicles, comprising PHEVs~~
	7B: Percentage of the charging capacity of the vehicles that can be controlled (versus the charging capacity of the vehicles or the total power capacity of the grid) [MW/MW]
	~~7C: Percentage of the stored energy in vehicles that can be controlled (versus the available energy in the vehicles or the total energy~~ consumption in the grid) [MWh/MWh]
	7D: Number of charging points that are provided to charge the vehicles
DER Interconnection	8A: The percentage of grid operators with standard distributed resource interconnection policies

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Power TAC scenario (6)

KPIs: Sell more than kWhs

Sell more than kWhs	
New Energy Services	9A: Number of customers served by ESCO's
	9B: Number of additional energy services offered to the consumer
	9C: Number of kWh that the consumer saves in comparison to the consumption before the energy service
Flexibility	10A: The number of customers offering flexibility to aggregators
	10B: The flexibility that aggregators can offer to other market players [MWh]
	10C: The time that aggregators can offer a certain flexibility [h]
	10D: To what extent are storage and DG able to provide ancillary services as a percentage of the total offered ancillary services
	10E: Percentage of storage and DG that can be modified vs. total storage and DG [MW/MW]
Customer Choice	11A: Number of tariff plans available to end consumers
Support Mechanisms	12A: The average percentage of smart grid investment that can be recovered through rates or subsidies
	12B: The percentage of smart grid investment covered by external financing
Interoperability Maturity Level	13A: The weighted average maturity level of interoperability realised among electricity system stakeholders

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Power TAC scenario (7)

KPIs: Provide power quality for the 21st century

Provide power quality for the 21st Century	
Power Quality	14A: Amount of voltage variations in the grid [RMS]
	14B: Time of a certain voltage variation [h]
	14C: The percentage of customer complaints related to power quality problems (excluding outages)
Required Power Quality	15A: Range of frequencies [Hz] contracted and range of voltages [V] contracted
Microgrids	16A: The number of microgrids in operation
	16B: The capacity of microgrids [MW]
	16C: The total grid capacity of microgrids to the capacity of the entire grid [MW/MW]

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United States Department of Energy. *2010 Smart Grid System Report*. US, 2012.

Power TAC scenario (8)

KPIs: Optimize assets and operate efficiently

Optimise assets and operate efficiently	
T&D Automation	17A: Percentage of substations applying automation technologies
Dynamic Line Rating	18A: Number of lines operated under dynamic line ratings
	18B: Percentage of kilometers of transmission circuits operated under dynamic line ratings [km]
	18C: Yearly average transmission transfer capacity expansion due to the use of dynamic (versus fixed) line ratings [MW-km]
Capacity Factors	19A: Yearly average and peak generation capacity factor (%)
	19B: Yearly average and average peak capacity factor for a typical kilometer of transmission line (%-km per km)
	19C: Yearly average and average peak distribution transformer capacity factor (%)
Efficiencies	20A: Efficiency of generation facilities [energy output (MWh) / energy input (MWh)]
	20B: Energy losses in transmission and distribution [MWh/year]

Dupont, B., Meeus, L., Belmans, R. *Measuring the "smartness" of the electricity grid*. In the Proceedings of the 7th International Conference on the European Energy Market (EEM), Madrid, Spain, 2010, pp. 1-6.

United States Department of Energy. *2010 Smart Grid System Report*. US, 2012.

Power TAC scenario (9)

KPIs: Operate resiently to disturbances, attacks and natural disasters

Operate resiliently to disturbances, attacks and natural disasters	
Advanced Sensors	21A: Number (or percentage) of grid elements (substations, switches, …) that can be remotely monitored and controlled in real-time
	21B: The percentage of substations possessing advanced measurement technology
	21C: The number of applications supported by these various measurement technologies
Information Exchange	22A: Total SCADA points shared per substation (ratio)
	22B: Fraction of transmission-level synchrophasor measurement points shared multilaterally (%)
	22C: Performance (bandwidth, response speed, availability, adaptability, …) of the communication channels towards grid elements
T&D Reliability	23A: SAIDI represents the average number of minutes customers are interrupted each year [Minutes]
	23B: SAIFI represents the total number of customer interruptions per customer for a particular electric supply system [Interruptions]
	23C: CAIDI represents the average outage duration that a customer experiences [Minutes]
	23D: MAIFI represents the total number of customer interruptions per customer lasting less than five minutes for a particular electric supply system [Interruptions]
Standards in telecommunication infrastructure	24A: The compliance of electric power industries with European and international telecommunication standards and protocols.

Dupont, B., Meeus, L., Belmans, R. *Measuring the "smartness" of the electricity grid*. In the Proceedings of the 7th International Conference on the European Energy Market (EEM), Madrid, Spain, 2010, pp. 1-6.

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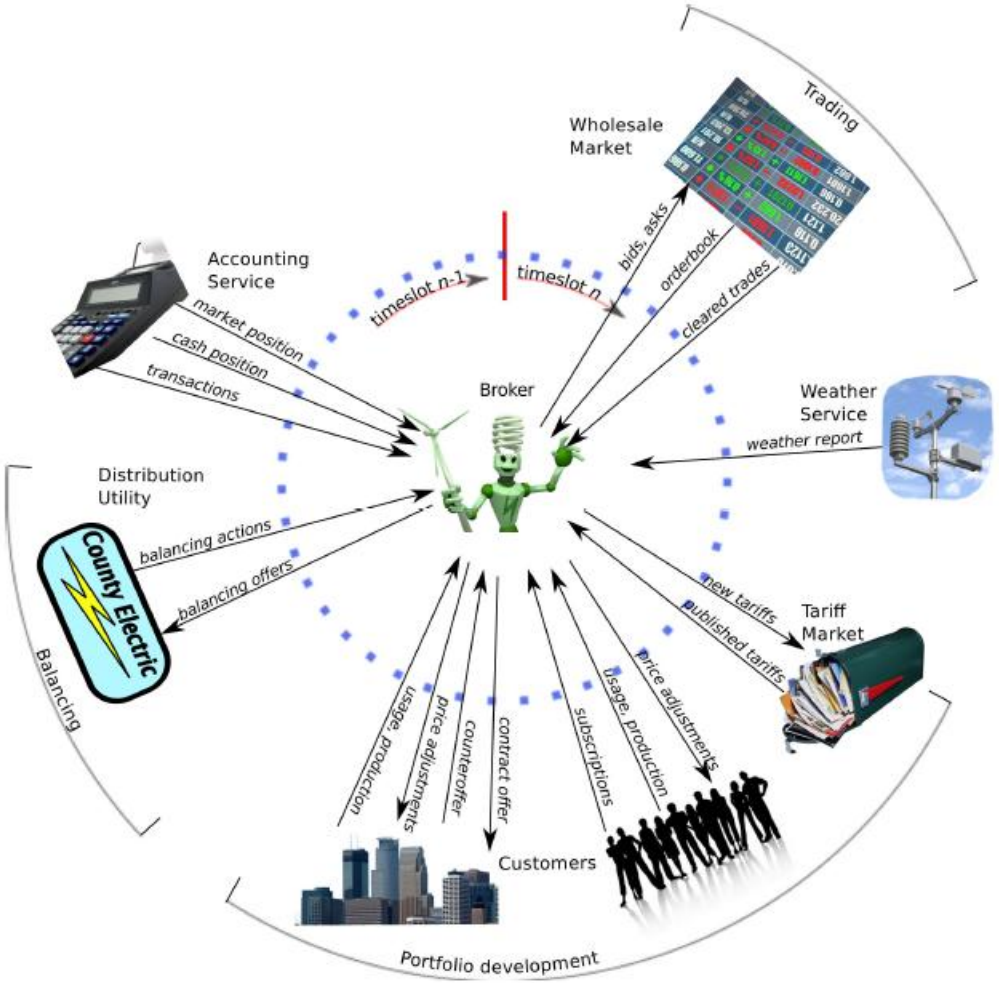
Power TAC broker

Broker activities, Crocodileagent

Power TAC broker (1)

Activities of a Power TAC broker during one timeslot



Power TAC broker CrocodileAgent (1)

Problem definition

- Goal: $\max \pi$
  - Given a constraint $\sum_{i=1}^{D} \pi_i \geq 0,\ D = 24$
  - Where profit $\pi = R + C = T + C_W + C_B$
    - R is revenue
    - C is cost
    - T is profit from activities
    - C_W is cost at the wholesale market
    - C_B is balancing market cost

Power TAC broker CrocodileAgent (2)

Current progress & plans for future

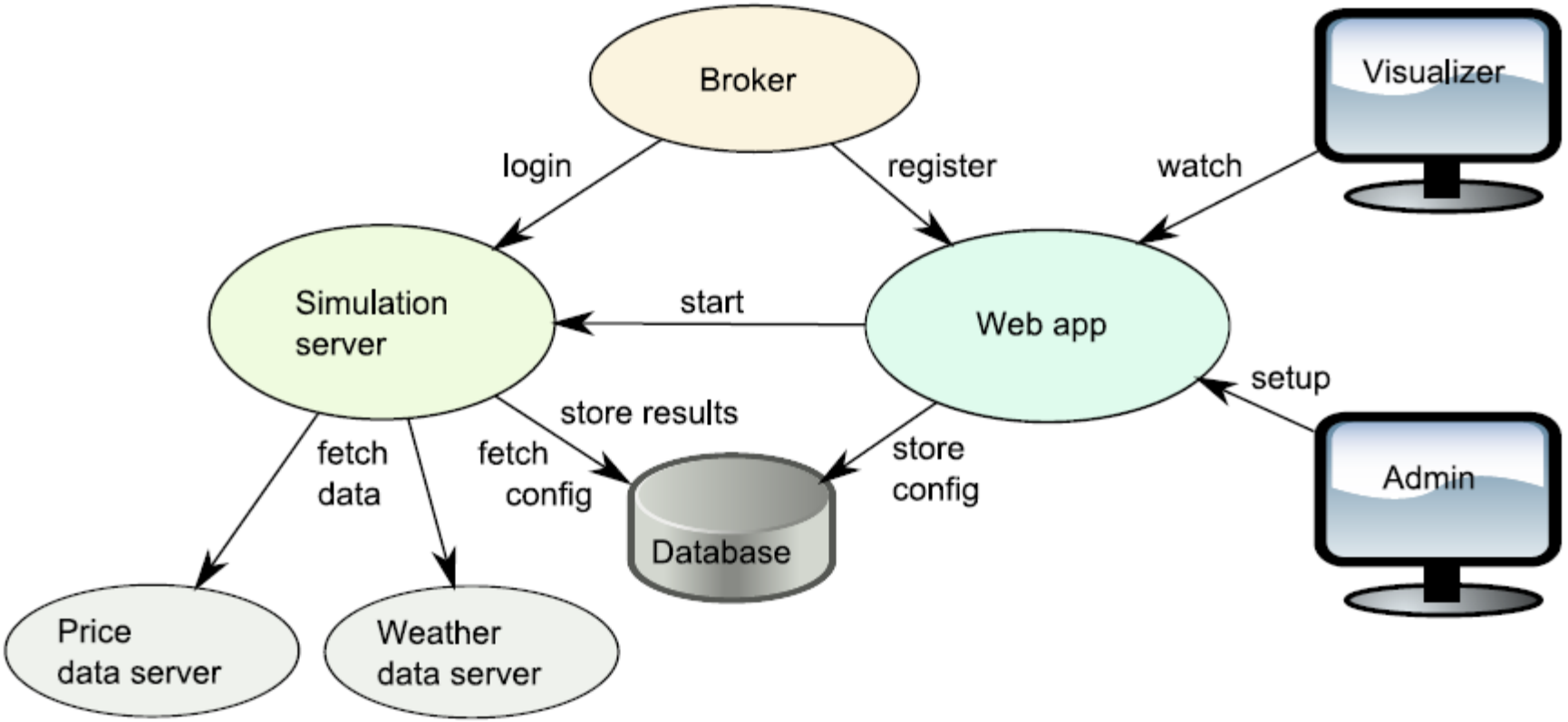
- Current focus is on creating different tariff models to satisfy different types of customers: tariff publishing strategy
  - Periodic posting of new tariffs
  - Default margin variations
  - Signup payment variations
  - Periodic payment variations
  - Early withdrawal rates
  - Minimal tariff duration
  - Multiple rate tariffs
- Plans for future
  - Wholesale market bidding strategy
  - Effective balancing
  - Environment models for intelligent learning and behaviour
    - Neural Networks, Support Vector Machines and Decision Trees

Power TAC Visualizer

Requirements, proposed design, live demo

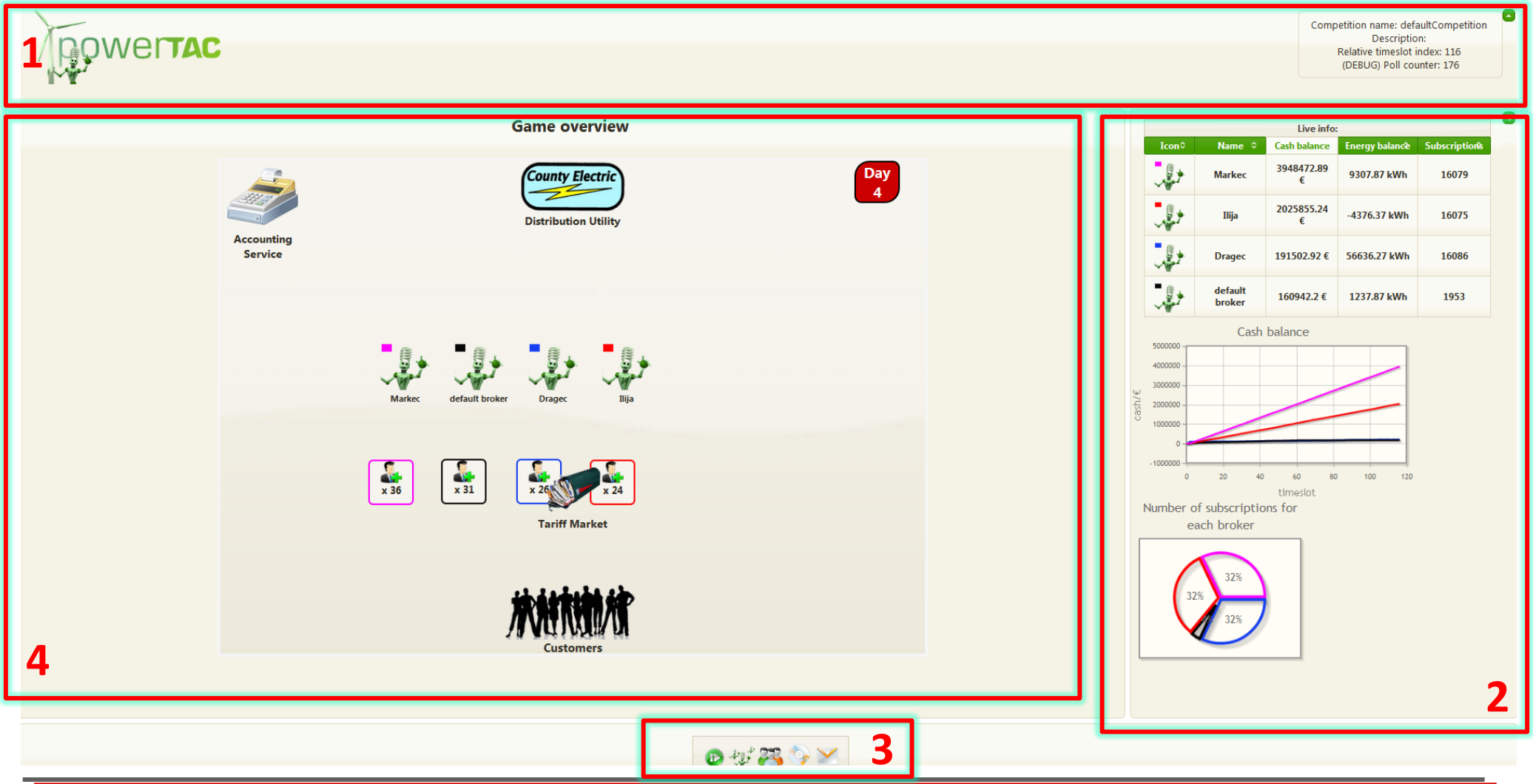
Power TAC Visualizer (1)

Competition systems architecture



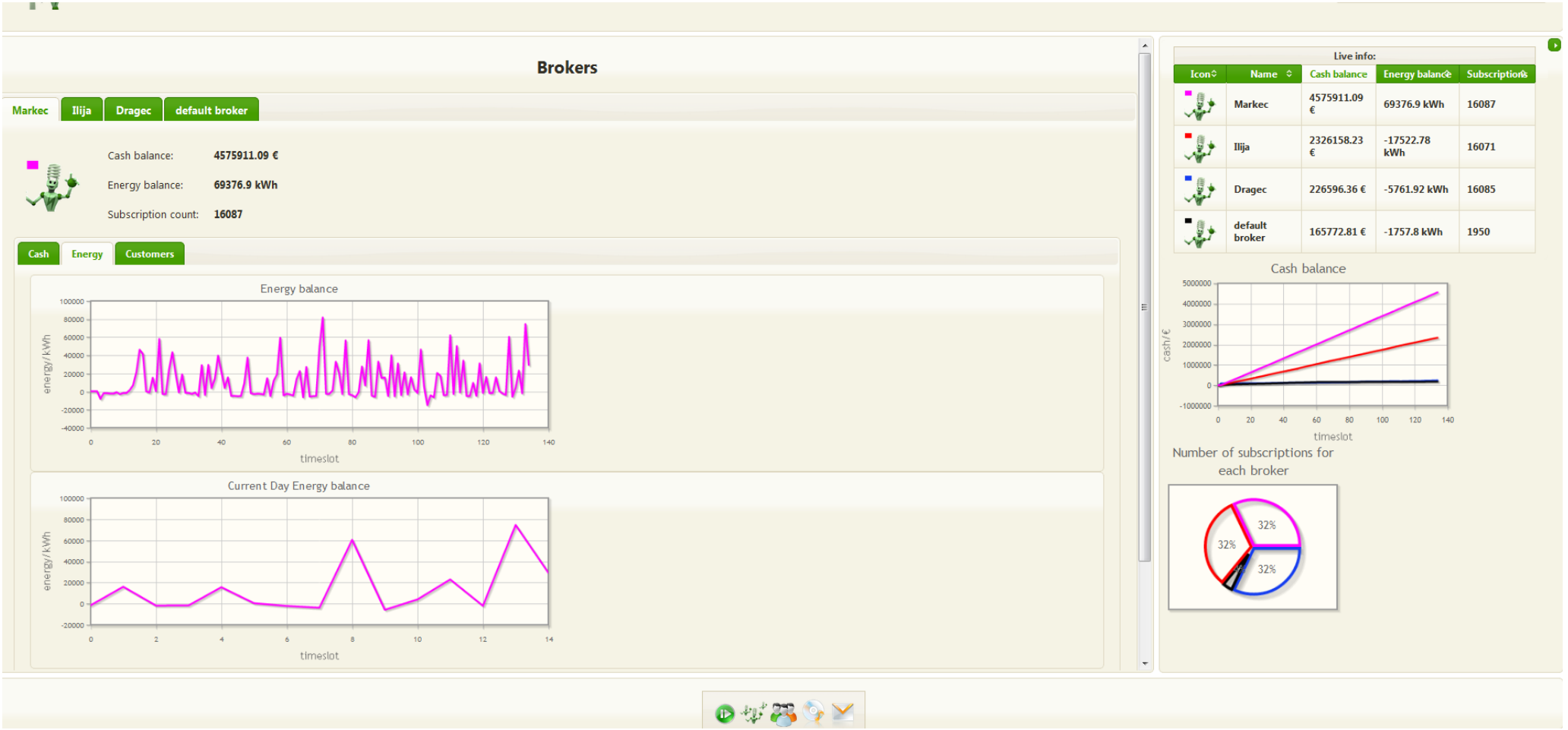
Power TAC Visualizer (2)

Game overview window



Power TAC Visualizer (3)

Brokers window (1)



Power TAC Visualizer (4)

Brokers window (2)

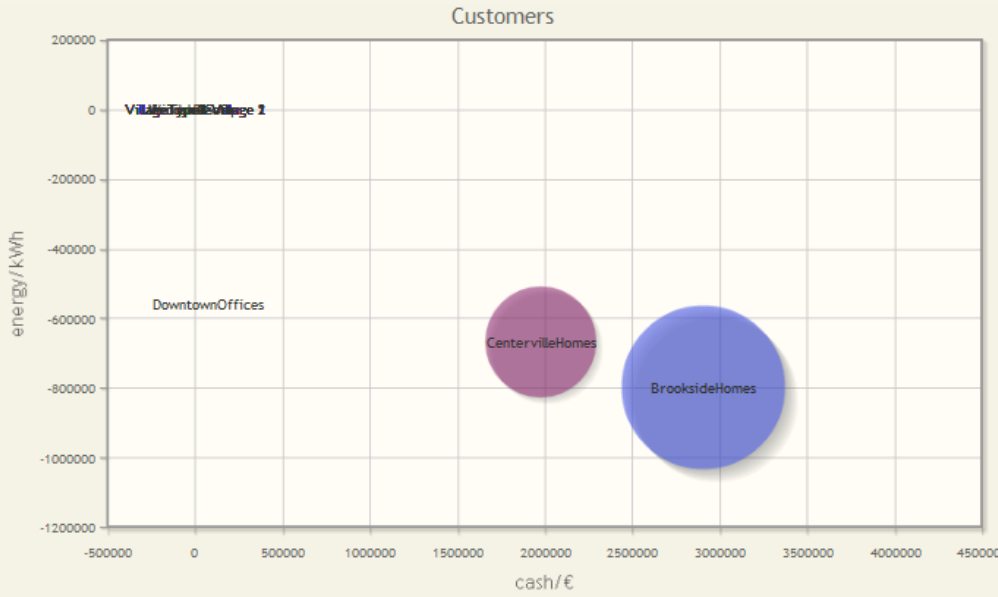
Markec | Ilija | Dragec | default broker

Cash balance: **4882807.53 €**

Energy balance: **-2530.65 kWh**

Subscription count: **16072**

Cash | Energy | Customers



Customer	Subscription count	Total energy [kWh]	Total cash [€]
MedicalCenter	0	0	0
VillageType1 Village 1	0	-427	1004
DowntownOffices	20	-559324	77072
WindmillCoOp	0	0	0
SunnyhillSolar	0	0	0
VillageType1 Village 2	4	-1251	3009
CentervilleHomes	6469	-669719	1985623
BrooksideHomes	9565	-800698	2911579
VillageType4 Village 2	0	-1043	2207
VillageType4 Village 1	4	-587	1574
VillageType3 Village 2	6	-465	1009
VillageType3 Village 1	2	-1159	1710
VillageType2 Village 2	2	-696	3176
VillageType2 Village 1	0	-574	1223

Daily Values

Power TAC Visualizer (5)

Wholesale market window

powerTAC

Competition name: defaultCompetition
Description:
Relative timeslot index: 150
(DEBUG) Poll counter: 240

Expand rows to see detailed information

1 2 3 4 5 6 7 8 9 10

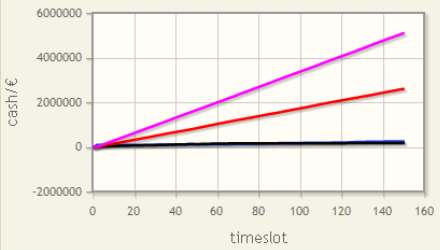
Name	TTQ (MWh)
Market361	10.28
Market362	34.01
Snapshot360	12.22
Snapshot361	21.79
Market363	43.09
Market364	57.08
Market365	34.49
Market366	33.86
Market367	86.05
Market368	30.41
Market369	37.77
Market370	52.94
Market371	49.35
Market372	52.43
Market373	83.59
Market374	113.91
Market375	137.73

1 2 3 4 5 6 7 8 9 10

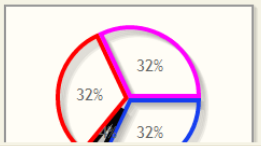
Total traded quantity: 16030.8 MWh

Live info:

Icon	Name	Cash balance	Energy balance	Subscriptions
	Markec	5122492.53 €	38629.59 kWh	16065
	Ilija	2612860.67 €	-5259.1 kWh	16085
	Dragec	246612.95 €	-4165.59 kWh	16089
	default broker	171014.97 €	-3380.06 kWh	1954



Number of subscriptions for each broker



Power TAC Visualizer (6)

Live demo

- Participants
  - Default Broker
  - Markec
  - Dragec
  - Ilija

Different versions of Power TAC CrocodileAgent broker

Instead of conclusion…

… please provide your feedback about the Power TAC Visulizer

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- *Personal homepage:* **http://agents.tel.fer.hr/vedran.podobnik**
- *CrocodileAgent team homepage:* **http://agents.tel.fer.hr/tac**