



**ENTROPY**

DESIGN OF AN INNOVATIVE ENERGY-AWARE IT ECOSYSTEM FOR MOTIVATING BEHAVIOURAL CHANGES TOWARDS THE ADOPTION OF ENERGY EFFICIENT LIFESTYLES

# ENTROPY

## Design of an Innovative Energy-Aware IT Ecosystem for Motivating Behavioural Changes Towards the Adoption of Energy Efficient Lifestyles

**Dimosthenis Kotsopoulos**

Researcher & PhD Candidate, ELTRUN Research Laboratory,  
Athens University of Economics & Business

[d.kotsopoulos@yahoo.com](mailto:d.kotsopoulos@yahoo.com)

Under the aegis of



### Projects and Funding Opportunities on Energy and Climate Change

12 OCTOBER 2018, Athens, Greece

PROMITHEASNET

11<sup>TH</sup> INTERNATIONAL SCIENTIFIC CONFERENCE ON ENERGY AND CLIMATE CHANGE



BSEC

GEN  
Green  
Energy  
Network

# At a Glance

- Funding mechanism: EU H2020, RIA, Grant agreement No 649849
- Total Cost: 2.439.467,50 €
- Duration: 36 months
- Start Date: September 2015
- Consortium: 9 partners from 8 countries
- Project Coordinator: Universidad de Murcia (Spain)

# The ENTROPY Consortium



Universidad de Murcia  
(Spain) **Coordinator**



ARVRtech  
(Serbia)



THE E-BUSINESS RESEARCH CENTER  
**ELTRUN**  
ATHENS UNIVERSITY OF ECONOMICS AND BUSINESS

ELTRUN Res. Center AUEB  
(Greece)



HES-SO Valais-Wallis  
(Switzerland)



Hyperborea SRL  
(Italy)



Intelen Services Ltd.  
(Cyprus)



**POLO TECNOLOGICO**  
Polo Navacchio S.p.A.  
(Italy)



STI · INNSBRUCK

STI Universitaet Innsbruck  
(Austria)



Ubitech - Ubiq Sol. Ltd.  
(Greece)

PROMITHEASnet

# The Challenge

- Energy efficiency via ICT identified as significant contributor to cutting CO2 emissions by 2020
- Design & development of novel energy efficient solutions and examination of their potential for energy saving considered crucial
- The greatest energy saving potential lies in buildings (Energy Efficiency Plan 2011)
- To exploit this potential, innovative solutions that take into account occupants' energy behavior needed

# Project Focus

- **Target:**

“To design and deploy an innovative IT ecosystem aimed at improving energy efficiency through consumers’ engagement and behavioral change.”

- **Focus:**

- collection & analysis of energy-related info from heterogeneous data sources
- provision of interactive services, apps and serious games to end-users towards:
  - (a) stimulating interest in energy efficient activities
  - (b) recommending actions for energy efficiency
  - (c) increasing energy consumption awareness

# Project Objectives

- ✓ **End-user engagement & Behavior Change** → more energy-efficient lifestyles
- ✓ **Innovative ICT solutions** → IoT- enabled energy consumption data aggregation, mobile crowd-sensing, advanced networking
- ✓ **Optimization & recommendation framework** → optimal energy consumption.
- ✓ **Energy data analytics framework** → meaningful analytics (consumption, efficiency & costs), detection of anomalies, corrective actions
- ✓ **Innovative serious games and personalized applications** → stimulation of collaboration & interaction towards energy efficiency & awareness
- ✓ **Personalized behavioral analysis & consumption disaggregation** → tools for monitoring & comparing energy-consuming sources in real time
- ✓ **Address key socio-economic issues** → towards large scale up-take & deployment of proposed ICT solutions
- ✓ **Validate & Evaluate the research results** → develop proof-of-concept showcases, to prove applicability & effectiveness of solutions

# Methodology

- Design & deploy an innovative energy-aware IT ecosystem to motivate user engagement and behavioral change towards the adoption of more energy efficient lifestyles, that builds upon:
  - IoT technologies for interconnecting devices & collecting energy-related information
  - advanced data modelling & analysis techniques that support the realization of semantic models and knowledge extraction
  - recommendation & gamification mechanisms to:
    - stimulate users' interest for energy efficient activities
    - increase awareness of daily energy consumption patterns
    - educate in adopting more energy efficient lifestyles
  - serious games and personalized mobile apps that:
    - provide energy-related information and recommendations
    - engage end users towards energy saving
- Evaluate the designed solution through application in 3x pilot sites

# 3 Pilot Sites / Workplaces

- Site 1: The Navacchio  
Technology Park  
(Business Incubator)  
*in Pisa, Italy*
- Site 2: The Technology  
park & University campus  
*in Murcia, Spain*
- Site 3: The Technopole  
(Technology Park)  
*in Sierre, Switzerland*





# 3 Pilot Sites / Workplaces

- Site 1: The Navacchio Technology Park (Business Incubator)  
*in Pisa, Italy*
- Site 2: The Technology park & University campus  
*in Murcia, Spain*
- Site 3: The Technopole (Technology Park)  
*in Sierre, Switzerland*



# 3 Pilot Sites / Workplaces

- Site 1: The Navacchio Technology Park (Business Incubator)  
*in Pisa, Italy*
- Site 2: The Technology park & University campus  
*in Murcia, Spain*
- Site 3: The Technopole (Technology Park)  
*in Sierre, Switzerland*



# 3 Pilot Sites / Workplaces

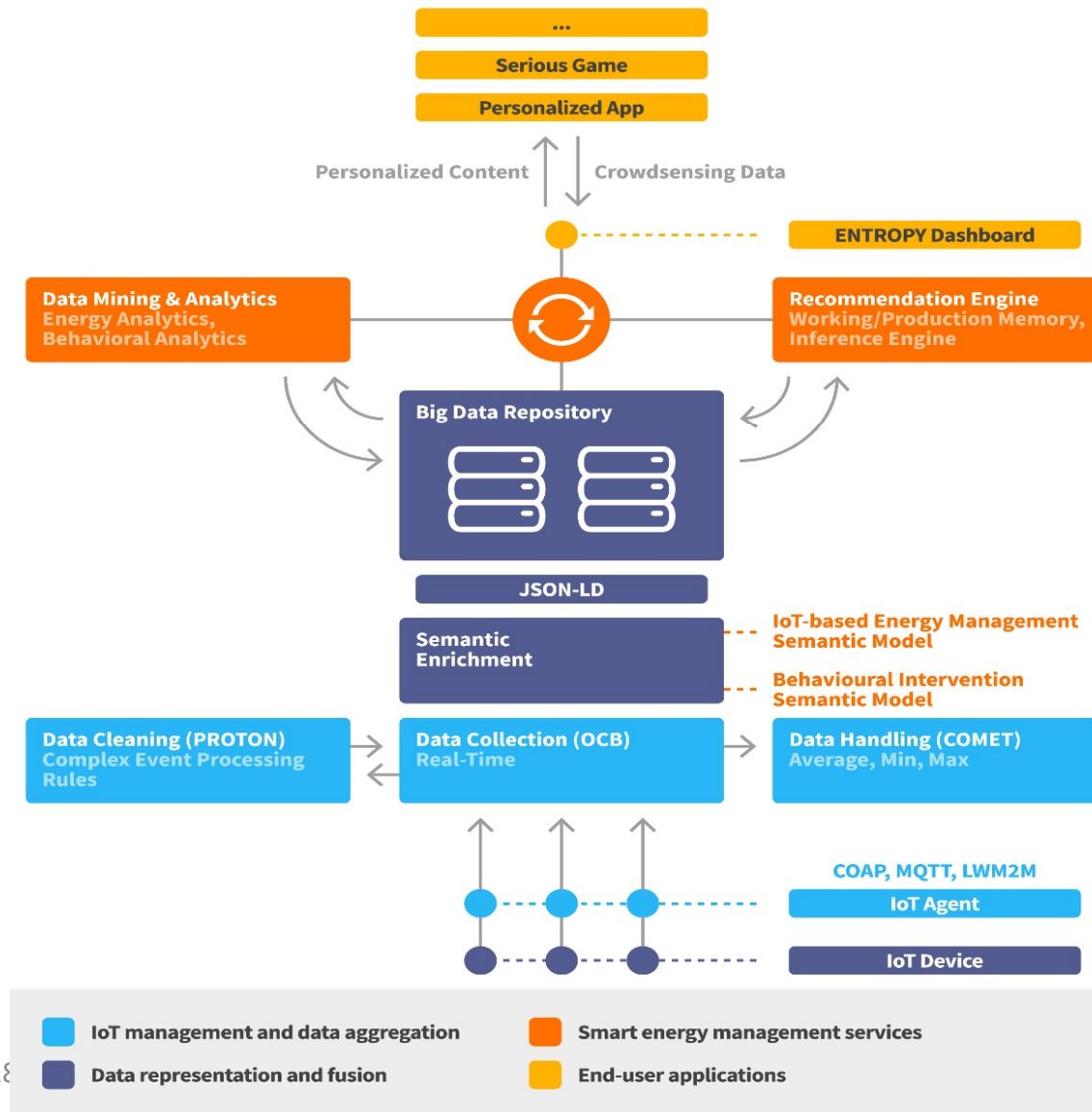
- Site 1: The Navacchio Technology Park (Business Incubator)  
*in Pisa, Italy*
- Site 2: The Technology park & University campus  
*in Murcia, Spain*
- Site 3: The Technopole (Technology Park)  
*in Sierre, Switzerland*



# Outcomes

- ✓ Open, generic ENTROPY Reference Architecture
- ✓ Innovative Energy-Aware Infrastructure Monitoring Parameters Semantic Model
- ✓ Innovative Citizens Environmental Friendly Behavioral Semantic Model
- ✓ Scalable, modular and extendable IoT-enabled ENTROPY Ecosystem, comprised of:
  - Data Modeling, Fusion & Analytics / Recommendation / Gamification / Behavioral Assessment Frameworks
  - ENTROPY Personalised Mobile Applications and Serious Games
- ✓ ENTROPY Pilots' results that will justify the utilization of persuasive technologies as sustainable energy behavior change drivers
- ✓ Educational content for energy behavior change, delivered through the ENTROPY services and tools
- ✓ Wide-scale dissemination & exploitation of project results to academic, scientific & industrial stakeholders

# The ENTROPY Reference Architecture



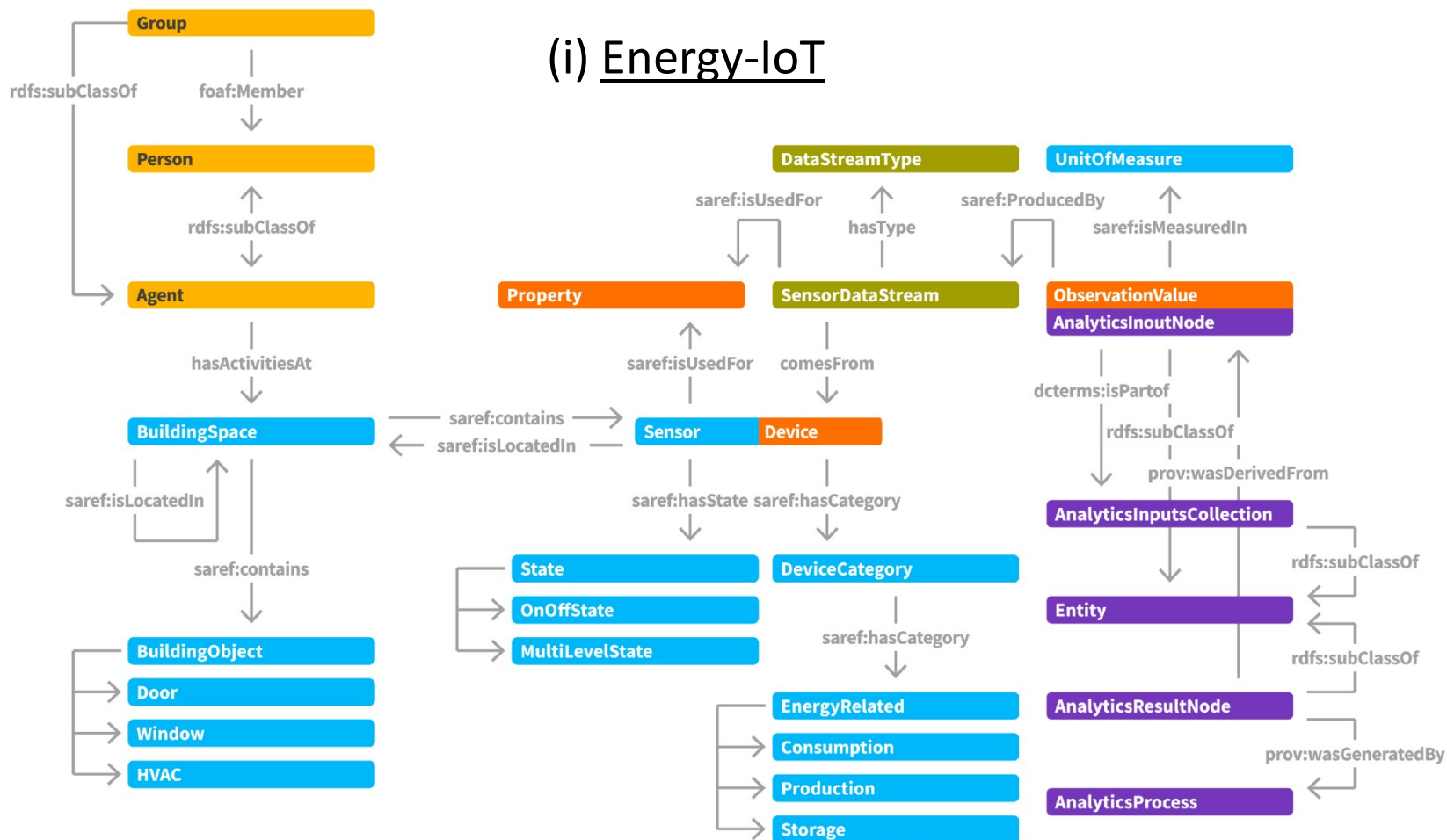
Composed of 4 layers:

- ENTROPY apps
- Smart energy management services: (a) data mining & analytics (b) Recommendation Engine
- Data processing and storage in big data repository
- Sensor management and data aggregation

# The ENTROPY Semantic Models

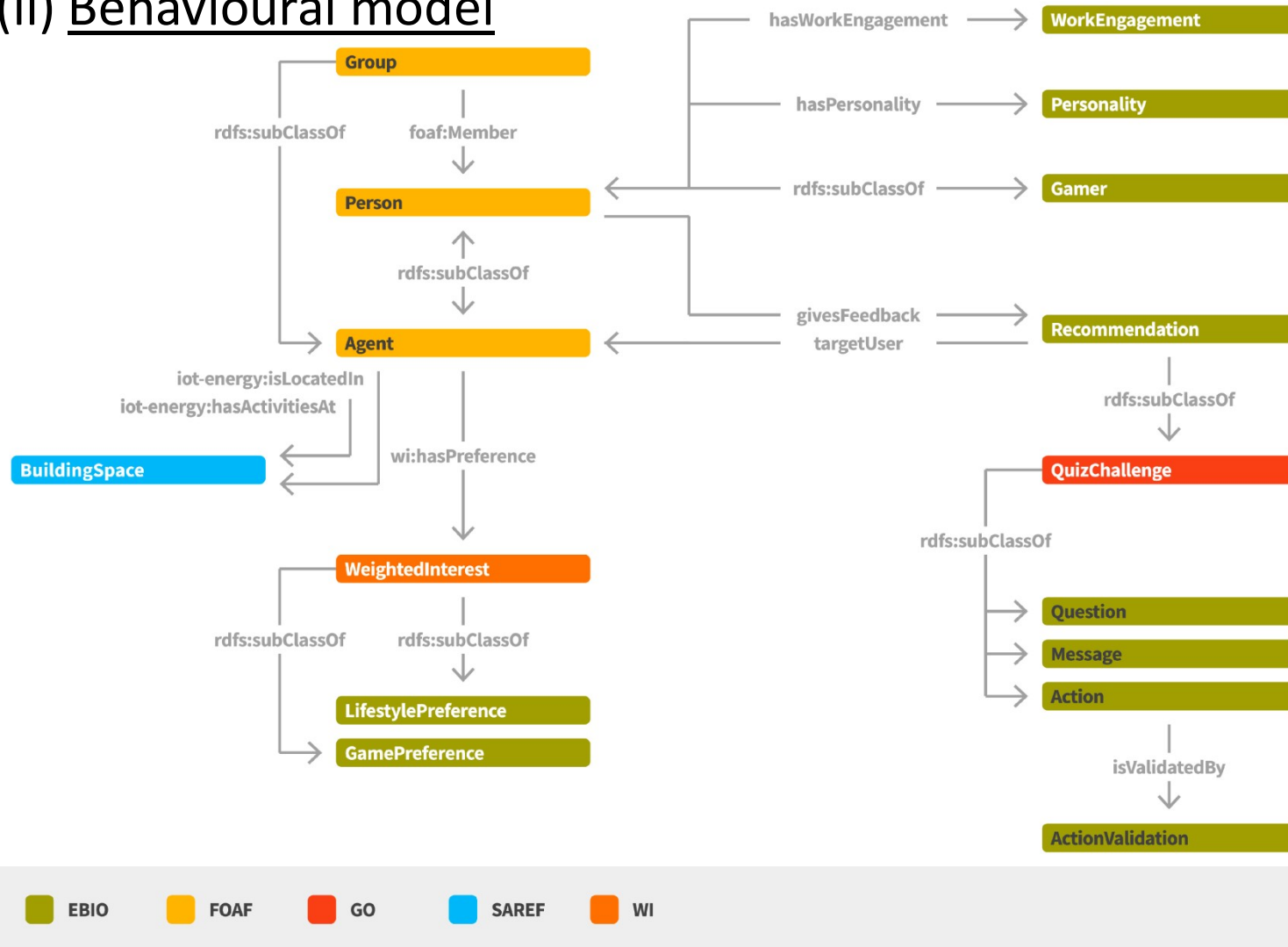
## 2x interconnected models:

### (i) Energy-IoT

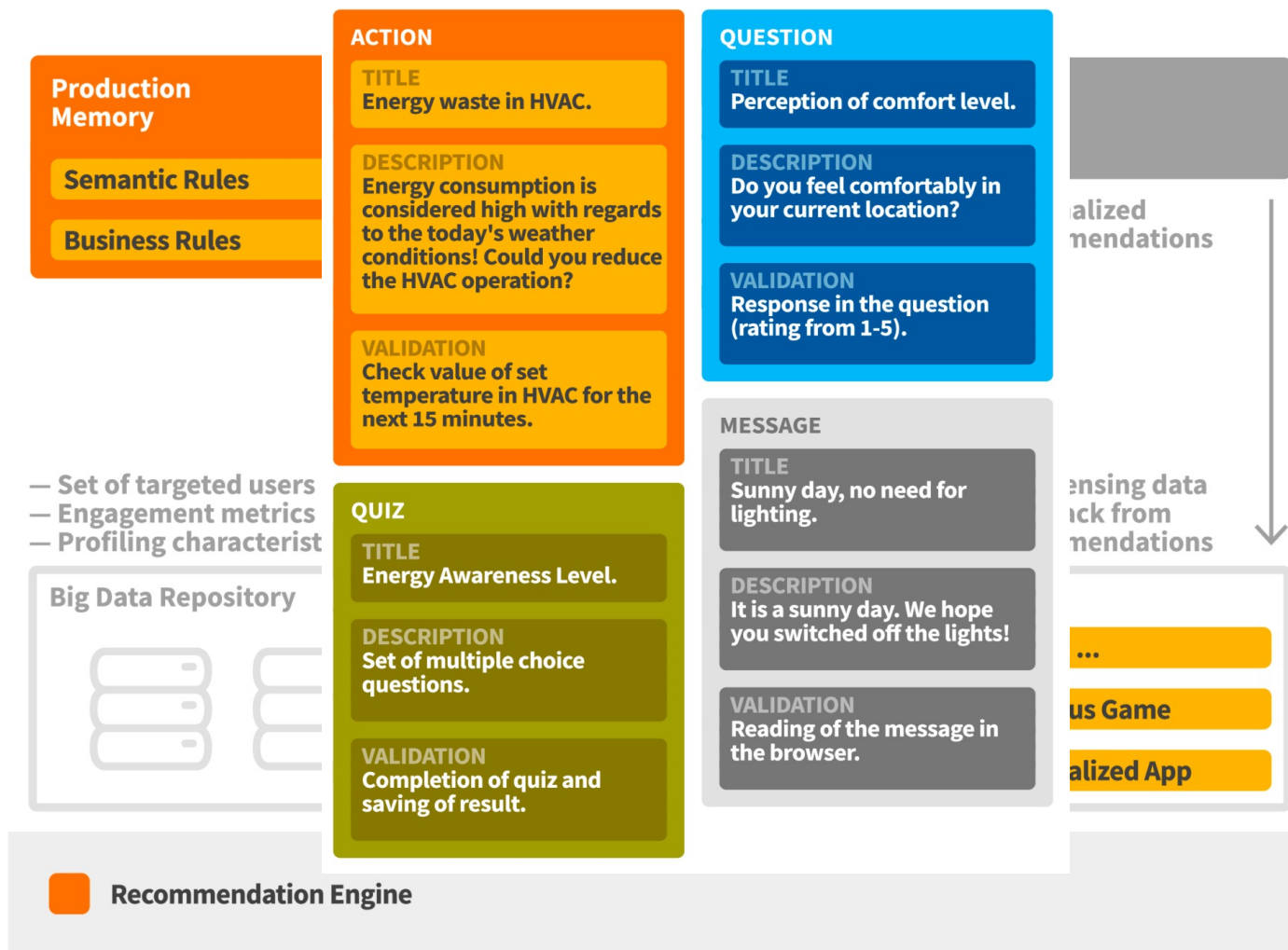


# The ENTROPY Semantic Models

## (ii) Behavioural model

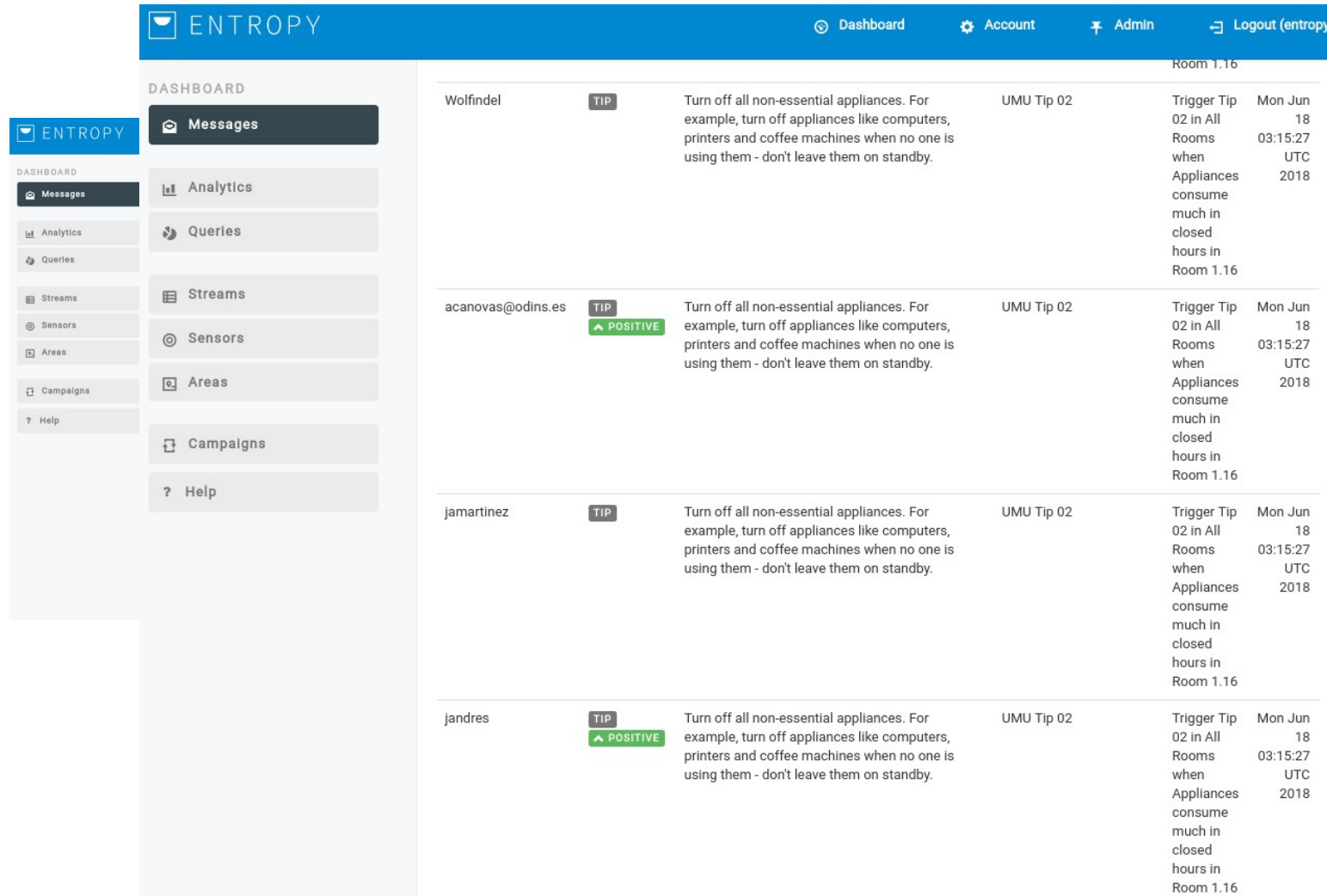


# Recommendation Mechanisms





# Recommendation Mechanisms

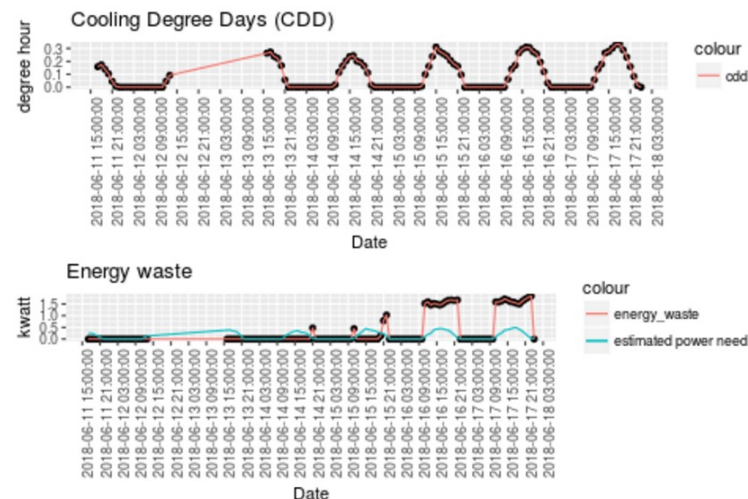
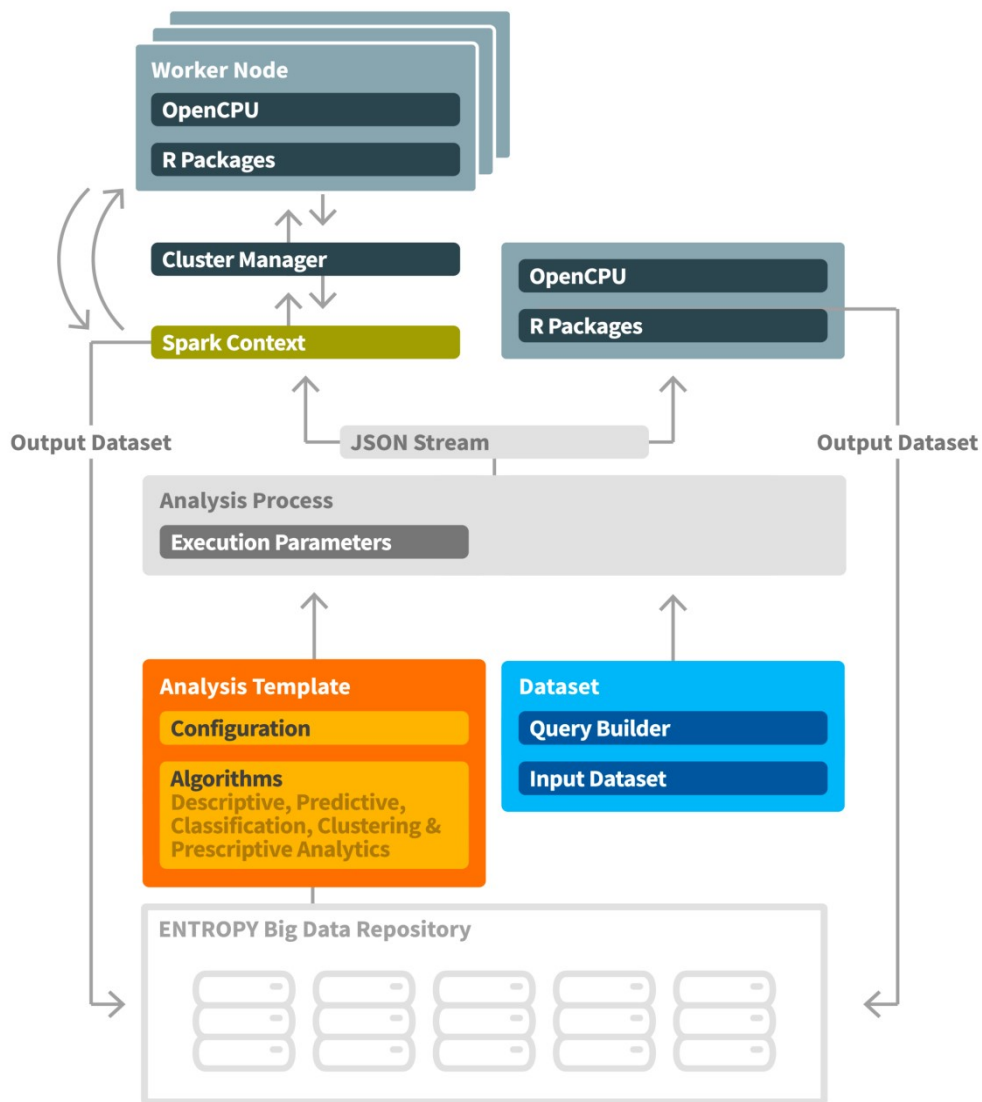


The screenshot shows the ENTROPY dashboard interface. On the left is a navigation sidebar with options like Messages, Analytics, Queries, Streams, Sensors, Areas, Campaigns, and Help. The main content area displays a list of messages under the heading 'Room 1.16'. Each message is a 'TIP' from 'UMU Tip 02' regarding energy efficiency. The messages are identical, advising users to turn off non-essential appliances like computers, printers, and coffee machines when not in use. The messages are sent to users: Wolfindel, acanovas@odins.es (marked as 'POSITIVE'), jamartinez, and jandres (marked as 'POSITIVE'). Each message includes a timestamp: 'Mon Jun 02 in All 18 Rooms 03:15:27 when UTC Appliances consume much in closed hours in Room 1.16'.

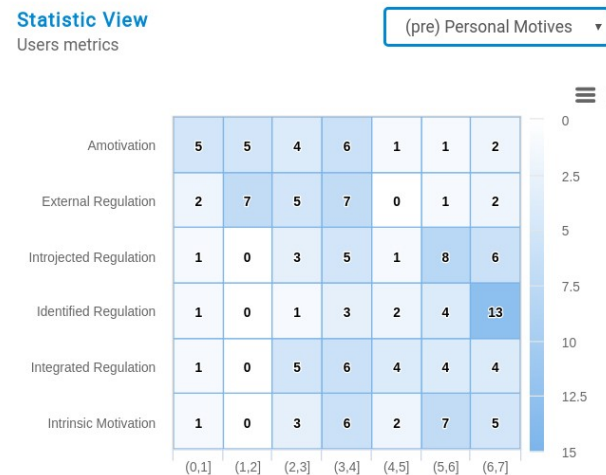
PROMITHEASnet

11<sup>th</sup> International Scientific Conference on Energy and Climate Change  
 Athens, 12 October 2018

# Energy & Behavioral Data Analytics

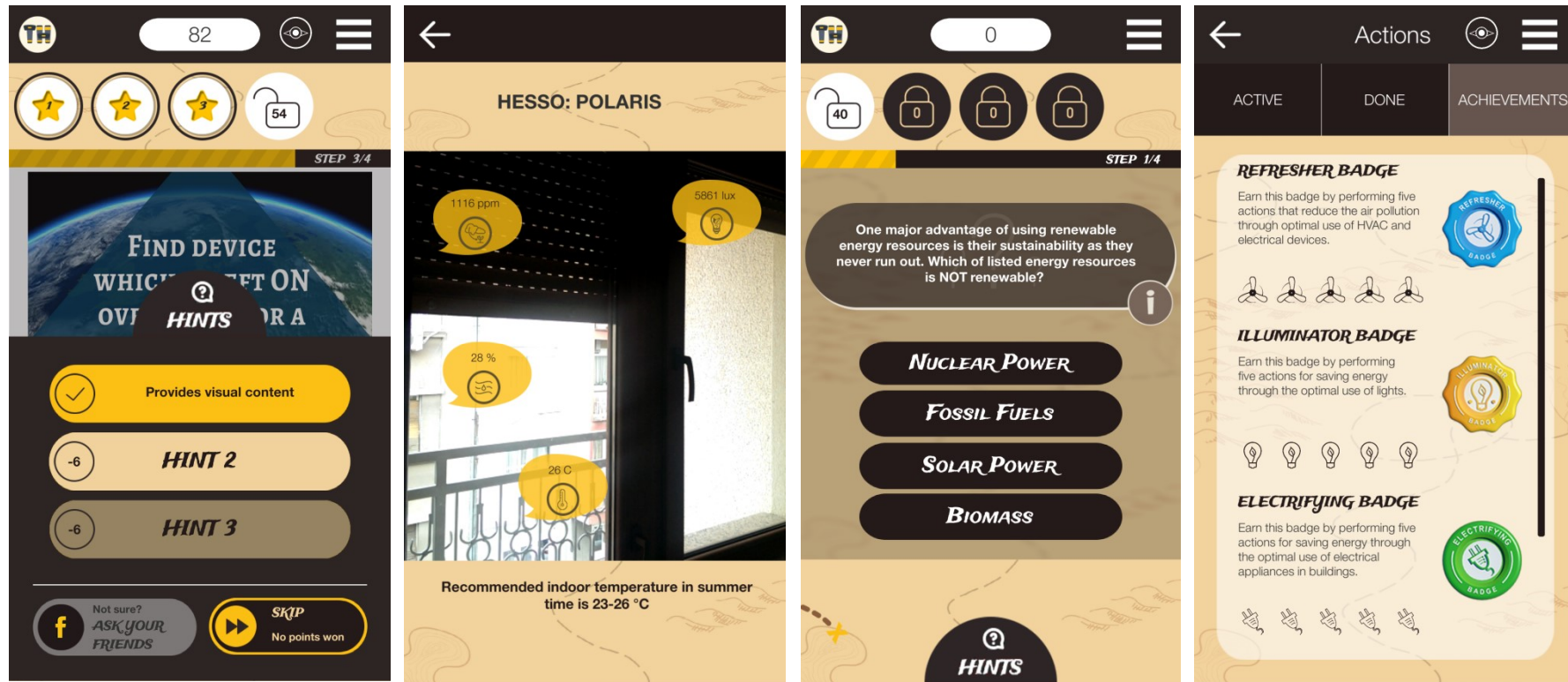


Calculation of cooling degree days & energy waste

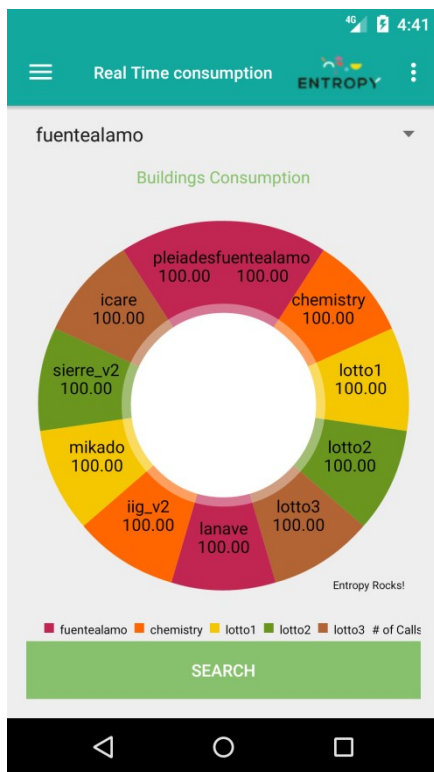
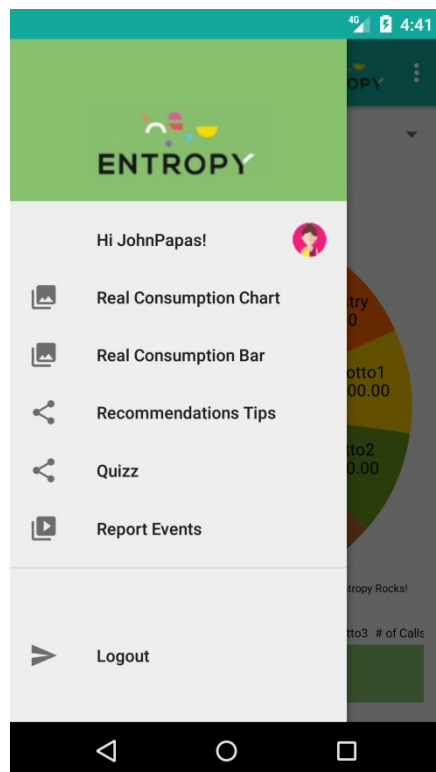


Heatmap with behavioral characteristics

# The ENTROPY AR “Treasure Hunt” Serious Game



# The ENTROPY Personalized GamifiedApp

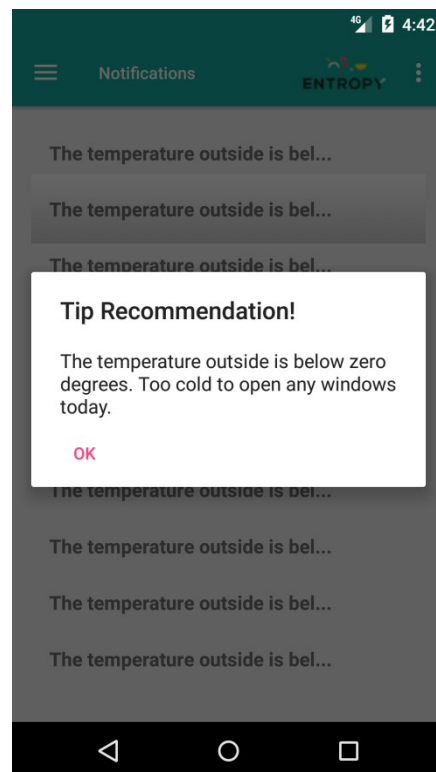



ENTROPY

Hi JohnPapas!

- Real Consumption Chart
- Real Consumption Bar
- Recommendations Tips
- Quizz
- Report Events

Logout

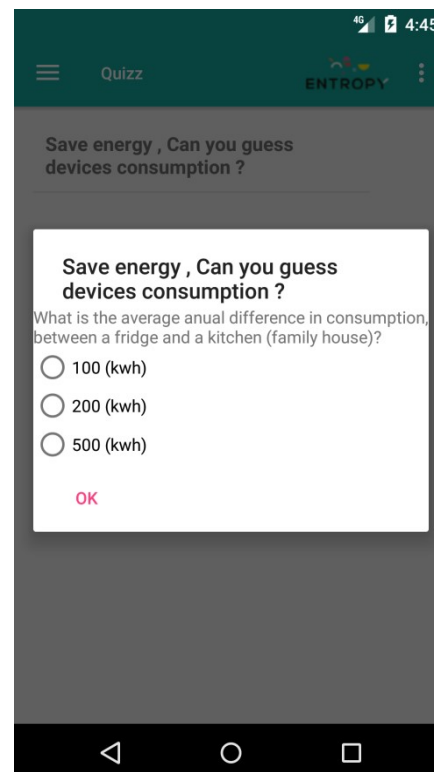


Notifications

The temperature outside is below zero degrees. Too cold to open any windows today.

**Tip Recommendation!**

OK



Quizz

Save energy , Can you guess devices consumption ?

Save energy , Can you guess devices consumption ?

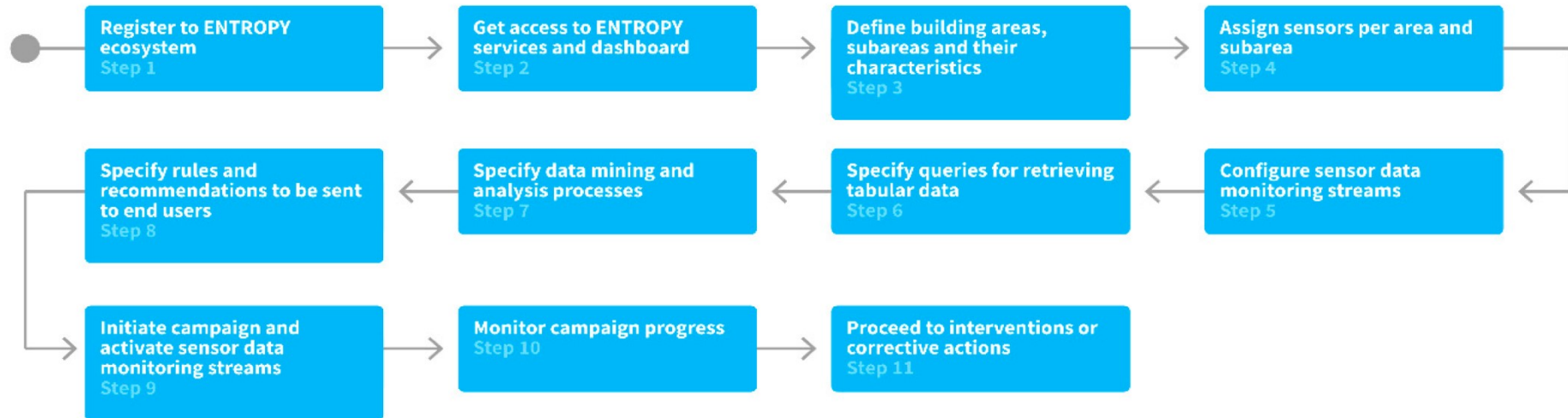
What is the average annual difference in consumption, between a fridge and a kitchen (family house)?

- 100 (kwh)
- 200 (kwh)
- 500 (kwh)

OK

# Campaign Workflow

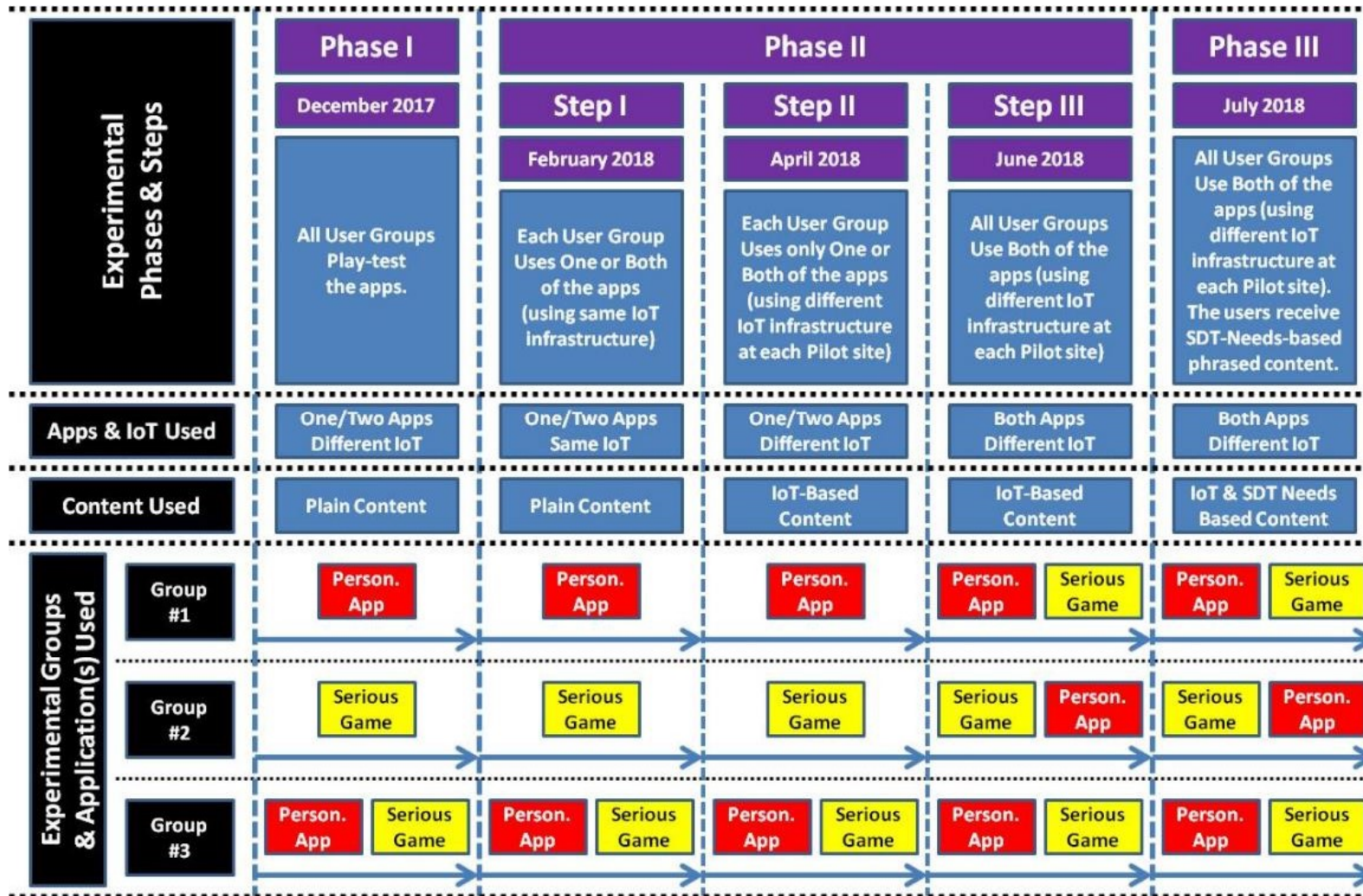
## CAMPAIGN MANAGER



## END USER



# Pilots' Execution



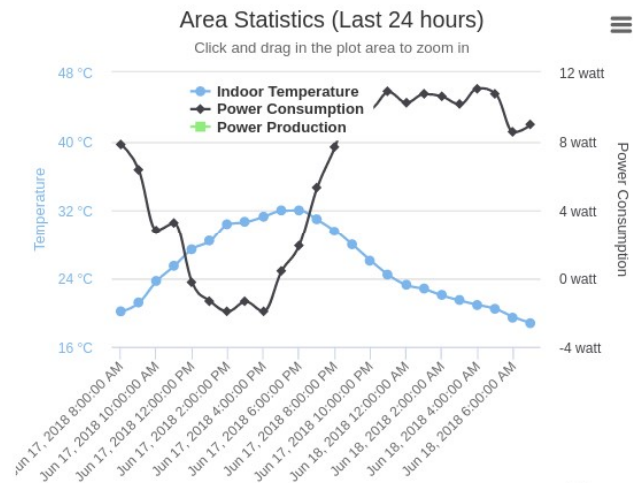
# Campaigns Execution – University of Murcia

## Area View

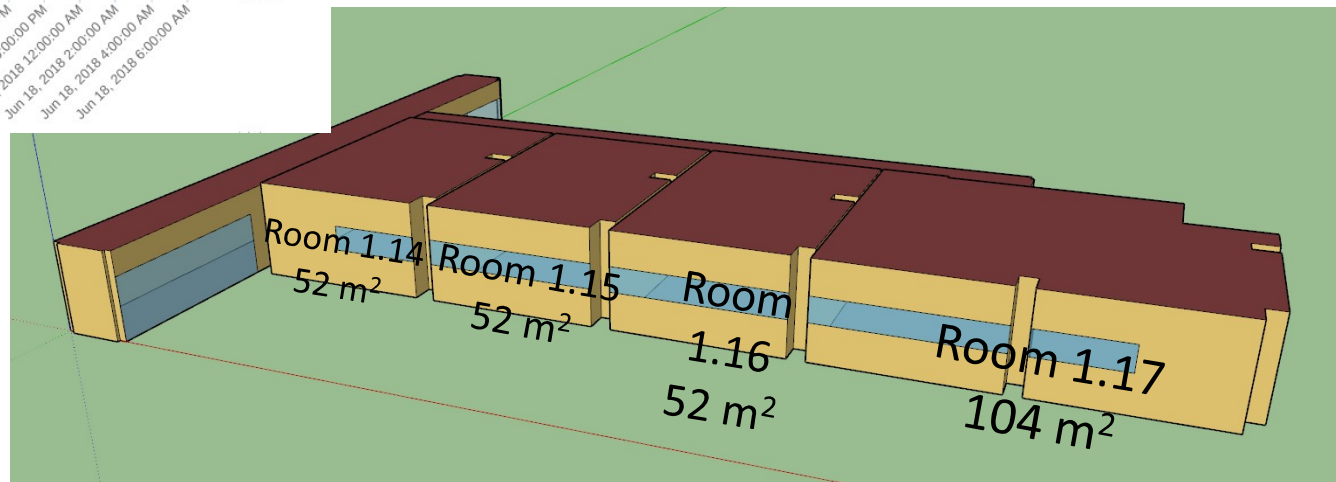
Defaults Streams per area

# pleiades

260 m<sup>2</sup> / 30 people / University\_Building

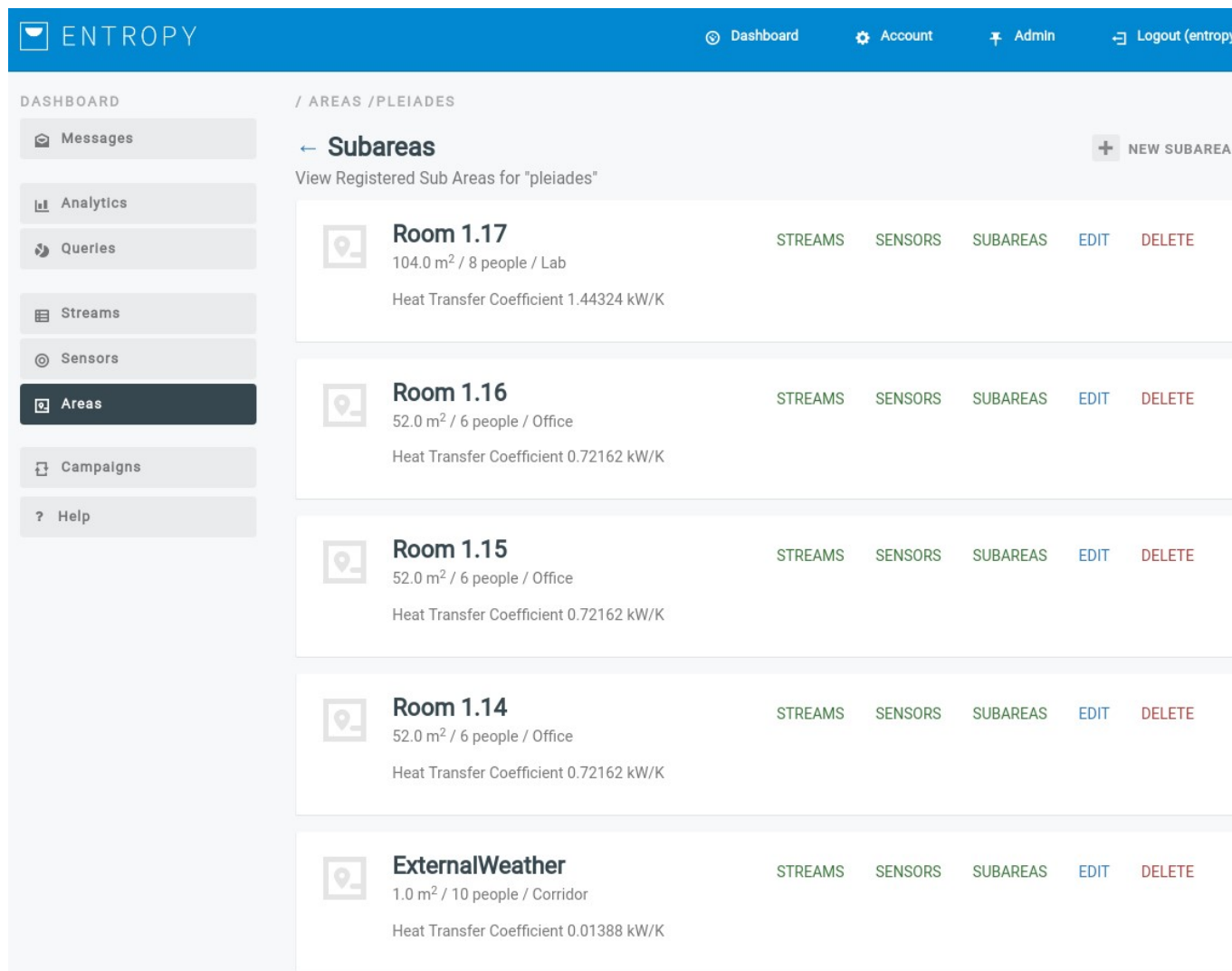


## Pleiades Building



PROMITHEASnet

# Campaigns Execution – University of Murcia



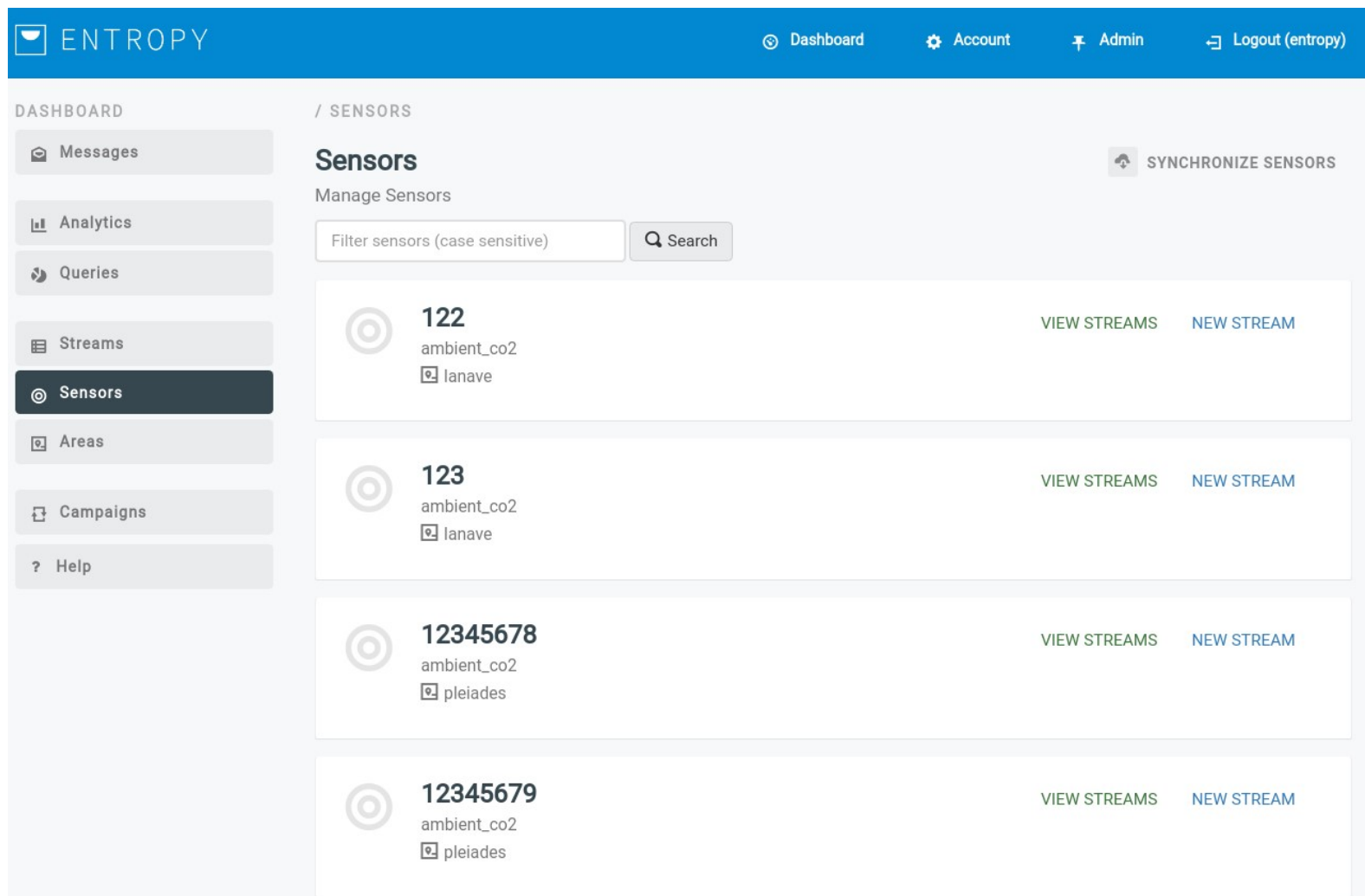
The screenshot shows the ENTROPY web application interface. The top navigation bar includes 'ENTROPY', 'Dashboard', 'Account', 'Admin', and 'Logout (entropy)'. The left sidebar contains a 'DASHBOARD' menu with options: Messages, Analytics, Queries, Streams, Sensors, **Areas**, Campaigns, and Help. The main content area is titled '/ AREAS / PLEIADES' and shows a 'Subareas' view for 'pleiades'. A '+ NEW SUBAREA' button is visible. The subareas are listed as follows:

Room	Area	Streams	Sensors	Subareas	Edit	Delete
Room 1.17	104.0 m <sup>2</sup> / 8 people / Lab Heat Transfer Coefficient 1.44324 kW/K	STREAMS	SENSORS	SUBAREAS	EDIT	DELETE
Room 1.16	52.0 m <sup>2</sup> / 6 people / Office Heat Transfer Coefficient 0.72162 kW/K	STREAMS	SENSORS	SUBAREAS	EDIT	DELETE
Room 1.15	52.0 m <sup>2</sup> / 6 people / Office Heat Transfer Coefficient 0.72162 kW/K	STREAMS	SENSORS	SUBAREAS	EDIT	DELETE
Room 1.14	52.0 m <sup>2</sup> / 6 people / Office Heat Transfer Coefficient 0.72162 kW/K	STREAMS	SENSORS	SUBAREAS	EDIT	DELETE
ExternalWeather	1.0 m <sup>2</sup> / 10 people / Corridor Heat Transfer Coefficient 0.01388 kW/K	STREAMS	SENSORS	SUBAREAS	EDIT	DELETE

PROMITHEASnet



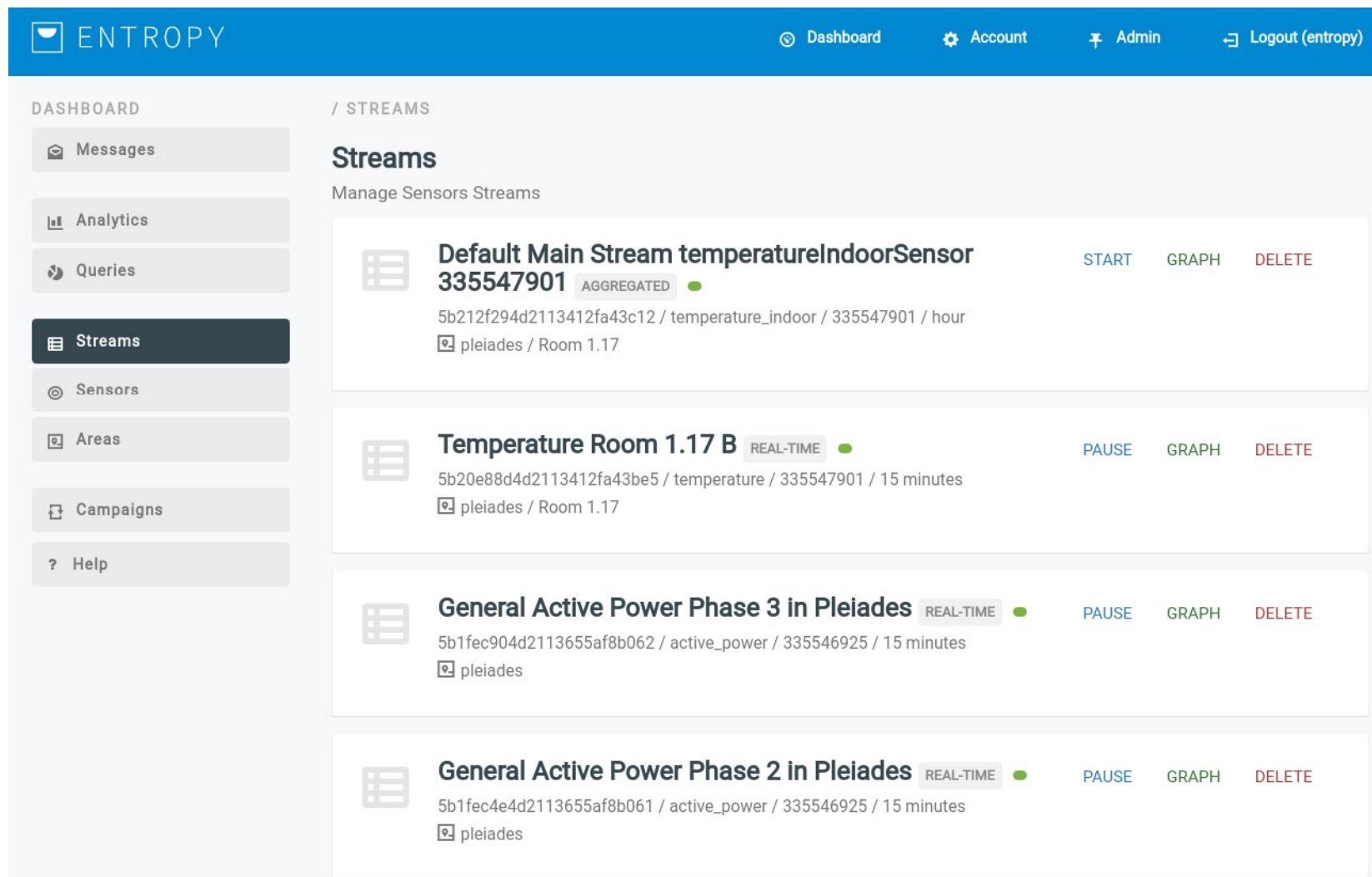
# Campaigns Execution – University of Murcia



The screenshot shows the ENTROPY web application interface. The top navigation bar includes 'Dashboard', 'Account', 'Admin', and 'Logout (entropy)'. The left sidebar contains a 'DASHBOARD' menu with options: Messages, Analytics, Queries, Streams, Sensors (selected), Areas, Campaigns, and Help. The main content area is titled '/ SENSORS' and 'Sensors'. It features a 'Manage Sensors' section with a search bar labeled 'Filter sensors (case sensitive)' and a 'Search' button. A 'SYNCHRONIZE SENSORS' button is also present. Below the search bar, there is a list of four sensors, each with a target icon, a sensor ID, a name, a location icon, and two action buttons: 'VIEW STREAMS' and 'NEW STREAM'.

Sensor ID	Name	Location	Actions
122	ambient_co2	Ianave	VIEW STREAMS, NEW STREAM
123	ambient_co2	Ianave	VIEW STREAMS, NEW STREAM
12345678	ambient_co2	pleiades	VIEW STREAMS, NEW STREAM
12345679	ambient_co2	pleiades	VIEW STREAMS, NEW STREAM

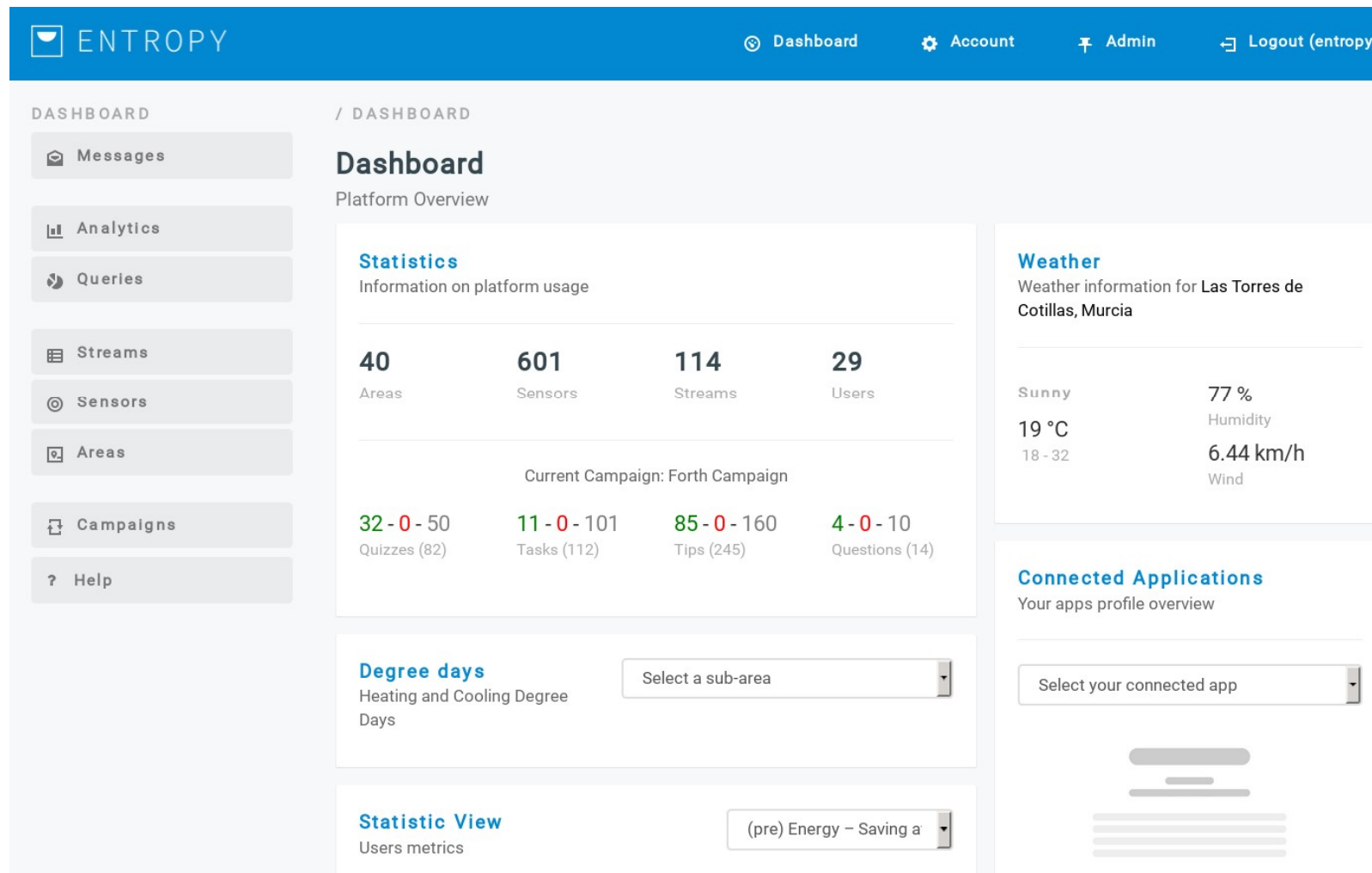
# Campaigns Execution – University of Murcia



The screenshot shows the ENTROPY web application interface. The top navigation bar includes 'Dashboard', 'Account', 'Admin', and 'Logout (entropy)'. The left sidebar contains a 'DASHBOARD' menu with options: Messages, Analytics, Queries, Streams (selected), Sensors, Areas, Campaigns, and Help. The main content area is titled '/ STREAMS' and 'Streams', with a sub-header 'Manage Sensors Streams'. It displays a list of four sensor streams:

- Default Main Stream temperatureIndoorSensor 335547901** (AGGREGATED): 5b212f294d2113412fa43c12 / temperature\_indoor / 335547901 / hour. Location: pleiades / Room 1.17. Actions: START, GRAPH, DELETE.
- Temperature Room 1.17 B** (REAL-TIME): 5b20e88d4d2113412fa43be5 / temperature / 335547901 / 15 minutes. Location: pleiades / Room 1.17. Actions: PAUSE, GRAPH, DELETE.
- General Active Power Phase 3 in Pleiades** (REAL-TIME): 5b1fec904d2113655af8b062 / active\_power / 335546925 / 15 minutes. Location: pleiades. Actions: PAUSE, GRAPH, DELETE.
- General Active Power Phase 2 in Pleiades** (REAL-TIME): 5b1fec4e4d2113655af8b061 / active\_power / 335546925 / 15 minutes. Location: pleiades. Actions: PAUSE, GRAPH, DELETE.

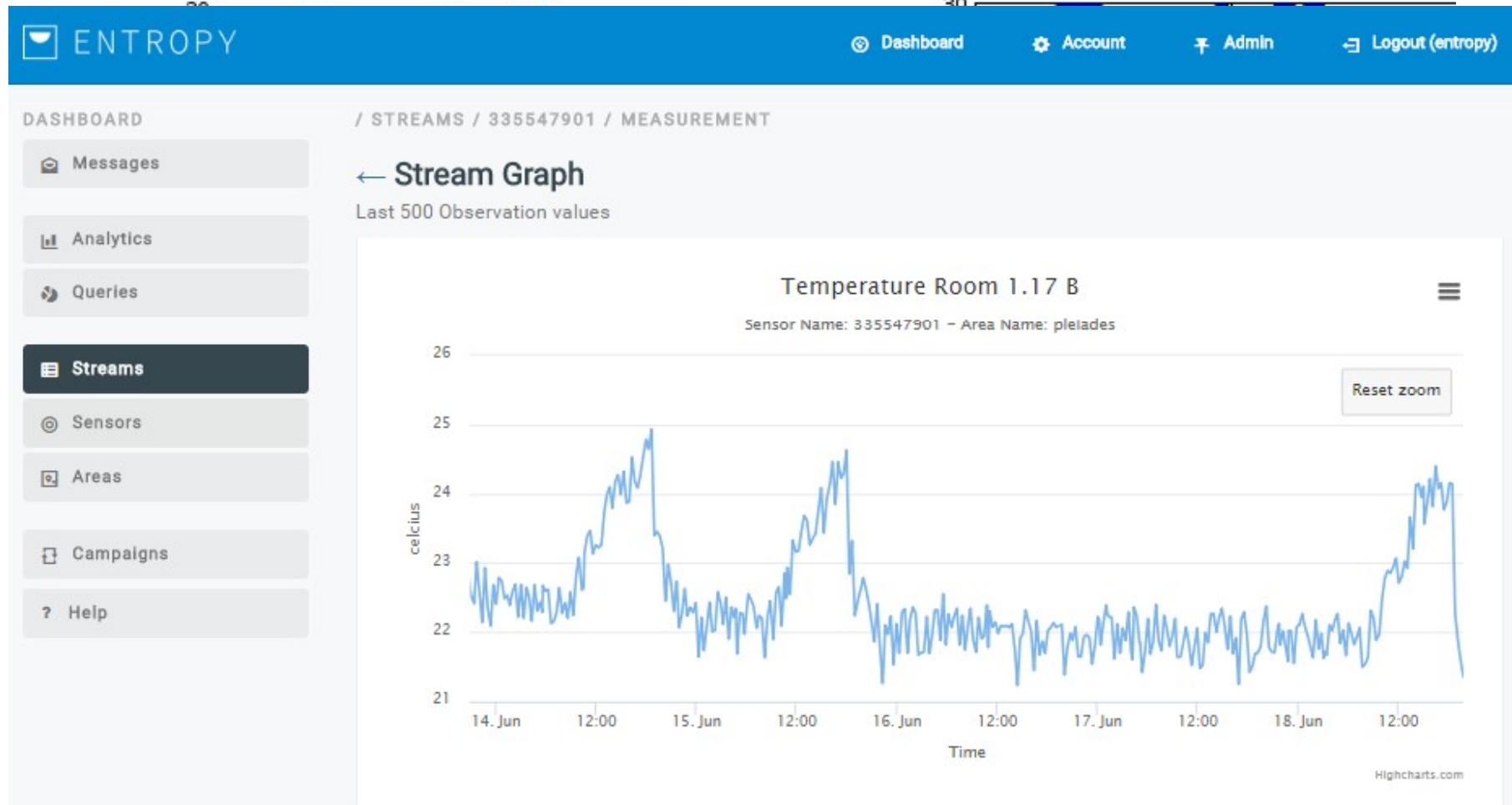
# Campaigns Execution – University of Murcia



The screenshot shows the ENTROPY dashboard interface. At the top, there is a blue navigation bar with the ENTROPY logo on the left and links for Dashboard, Account, Admin, and Logout (entropy) on the right. Below the navigation bar, the main content area is divided into several sections:

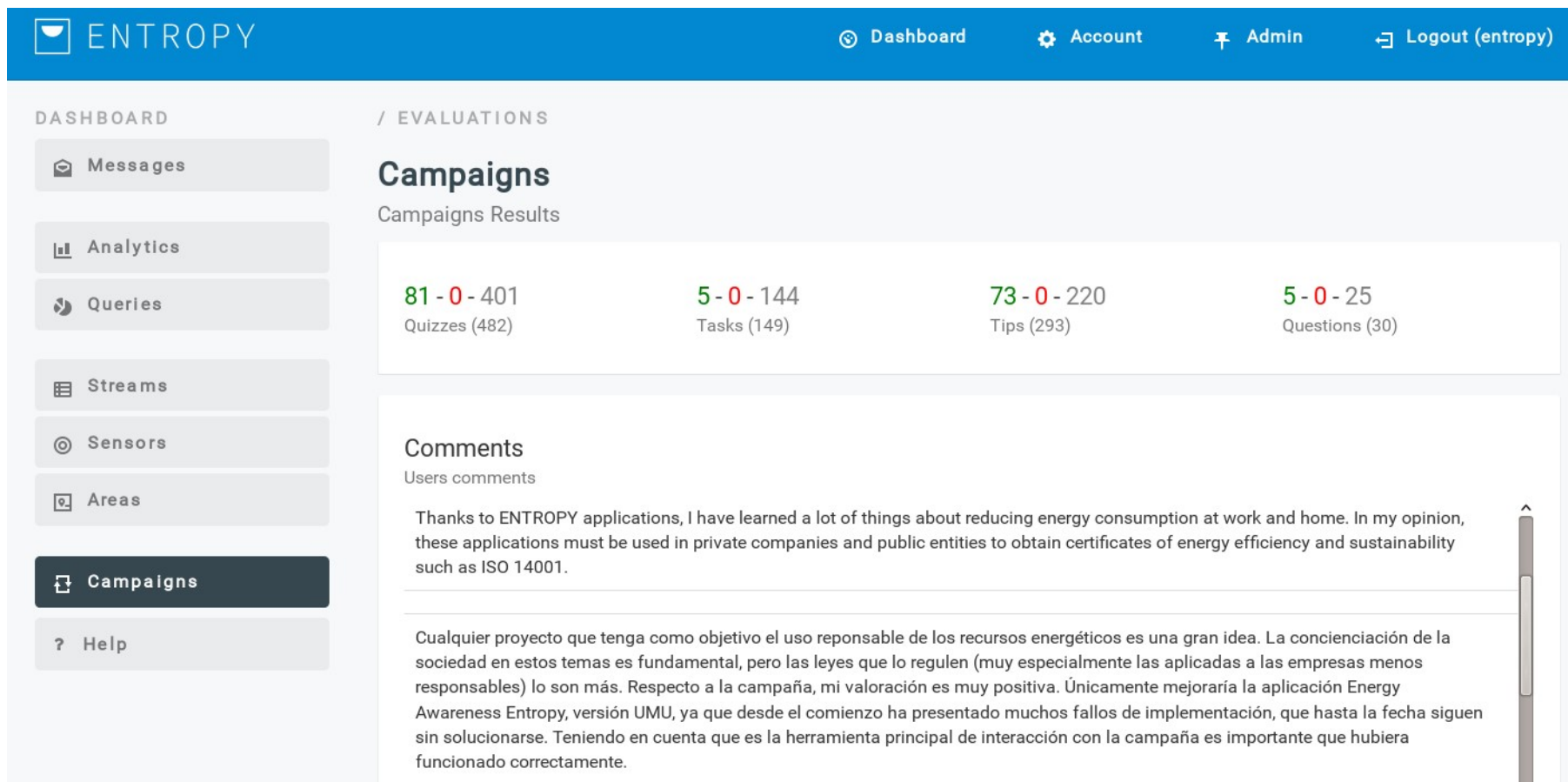
- Left Sidebar:** A vertical menu with buttons for Messages, Analytics, Queries, Streams, Sensors, Areas, Campaigns, and Help.
- Dashboard Header:** A section titled "Dashboard" with a subtitle "Platform Overview".
- Statistics:** A section titled "Statistics" with the subtitle "Information on platform usage". It displays four key metrics: 40 Areas, 601 Sensors, 114 Streams, and 29 Users. Below this, it shows the "Current Campaign: Forth Campaign" with four sub-metrics: 32-0-50 Quizzes (82), 11-0-101 Tasks (112), 85-0-160 Tips (245), and 4-0-10 Questions (14).
- Weather:** A section titled "Weather" with the subtitle "Weather information for Las Torres de Cotillas, Murcia". It displays "Sunny" weather, 19 °C temperature (range 18-32), 77% Humidity, and 6.44 km/h Wind.
- Connected Applications:** A section titled "Connected Applications" with the subtitle "Your apps profile overview". It features a dropdown menu to "Select your connected app".
- Degree days:** A section titled "Degree days" with the subtitle "Heating and Cooling Degree Days". It includes a dropdown menu to "Select a sub-area".
- Statistic View:** A section titled "Statistic View" with the subtitle "Users metrics". It includes a dropdown menu to "(pre) Energy – Saving a".

# Campaigns Execution – University of Murcia



PROMITHEASnet

# Campaigns Execution – University of Murcia



The screenshot shows the ENTROPY web application interface. The top navigation bar includes 'ENTROPY', 'Dashboard', 'Account', 'Admin', and 'Logout (entropy)'. The left sidebar contains menu items: 'Messages', 'Analytics', 'Queries', 'Streams', 'Sensors', 'Areas', 'Campaigns', and 'Help'. The main content area is titled 'EVALUATIONS / Campaigns' and displays 'Campaigns Results' with four statistics: 81 - 0 - 401 Quizzes (482), 5 - 0 - 144 Tasks (149), 73 - 0 - 220 Tips (293), and 5 - 0 - 25 Questions (30). Below this is a 'Comments' section with the title 'Users comments'. The first comment reads: 'Thanks to ENTROPY applications, I have learned a lot of things about reducing energy consumption at work and home. In my opinion, these applications must be used in private companies and public entities to obtain certificates of energy efficiency and sustainability such as ISO 14001.' The second comment, in Spanish, discusses the importance of energy efficiency and the user's positive experience with the campaign, despite some implementation issues with the 'Energy Awareness Entropy' application.

# Introduction to ENTROPY (Video)



<https://youtu.be/PC5fQuXsQI4>

**Thank you for your attention!**

# Questions

<http://entropy-project.eu/>

<https://twitter.com/EntropyEu>

<https://www.facebook.com/entropyproject>

**Contact:**

[dkotsopoulos@aueb.gr](mailto:dkotsopoulos@aueb.gr)

