“IoT-Enabled Gamification for Energy Conservation in Public Buildings”

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Problem Statement

- Buildings responsible for 40% of the final energy consumption in the EU and 36% of CO_2 emissions.

- More than one third of this demand: non-residential buildings (public buildings, offices, factories, schools, hospitals or hotels).

- EU supports improvement of energy performance of buildings for many years (legislative and financing mechanisms and instruments).

Problem Statement

Still important barriers exist especially for public buildings:

a) lack of expertise that leads to blind energy consumption (electricity, heating/cooling)

b) lack of time and interest

c) lack of incentives

d) lack of personal accountability on energy use (hesitant introduction of smart metering devices)

<u>Target: energy savings through behavioral change</u>

Challenges

No interest from energy consumers

- Occupants not the buildings' owners
- They don't pay bills.
- Little concern about energy spending.

Long return on investment

- Expensive and thorough monitoring solutions deployed in energy-intensive buildings not commercially viable for public buildings
- Payback (Investment Return) too long.

'Culprits' go unnoticed

- In industrial environments people are assigned to machines or areas - easy to associate waste/savings to a particular team or person.
- In public buildings, many people share areas and equipment (e.g. open offices) - difficult to associate energy spending to end-users.

No reward incentives

- Employees do not generally receive rewards from their institutions for environmentally responsible actions.
- Poor user engagement and failure of energy awareness campaigns.

Core Objectives

Propose a framework for achieving greater energy efficiency and reductions of wasted energy.

-An **IoT-enabled gamified approach** to alter consumption behaviors and conserve energy in public buildings.

-The proposed framework will **leverage IoT enabled, low-cost devices** (smart plugs/meters, NFC or Bluetooth Beacons) **to improve energy disaggregation mechanisms** that provide energy use and (consequently) wastages at the device, area and end-user level.

-These **wastages will be targeted by a gamified application** that feeds **personalized real-time recommendations** to each individual end user on a consumption event-driven basis.

-The design of the game will **implement a novel social innovation process,** based on human inceptives factors and should help users to **understand the environmental implications of their actions** and adopt a more green, active and responsible behavior.

-Enable social interaction and competitions to contribute to the user engagement **and commitment to generate savings in the long term.**

-Educate users on energy efficiency actions and their impact beyond the actual public building.

Related Work - SOTA

Market products or R&D projects that focus on similar concepts:

- Offering to consumers the ability **to remotely monitor household appliances and their energy-use information**, providing them also tips on managing energy.
- Enabling to view and analyze Energy scores of buildings and to **share building performance statistics on social media** networks like Facebook and Twitter.
- **Combining energy consumption monitoring with data driven educational content** for higher energy efficiency and lower peak demand leading to behavioral change.

- Investigating issues of **energy efficiency through behavioral change** and gamification.
- **Developing serious games related to the actual energy consumption** of the user's home and will be included in social media and networking tools.
- **Raising awareness** among **citizens through the implementation of a real time monitoring energy consumption platform** and the development of a serious game.

Related Work - Ambition

Our gamified approach advances the state of the art in a number of ways:

- Is employed in a corporate environment where multiple appliances are shared among multiple users.
  This fact makes energy disaggregation particularly challenging due to the vast area that needs to be monitored and the difficulty of correlating particular actions to particular users.

- Aforementioned apps are mostly destined for energy-consumption awareness assuming that the users are already interested in their energy consumption.
  - *In a public building, employees are primarily busy with their job activities and moreover they do not pay the energy bill.*
  - *Their engagement to our game app cannot be taken for granted and a carefully-designed gamified approach should be followed.*

- Aforementioned apps do not involve direct or indirect incentives for energy-consumption reduction, apart from awareness and tips.
  Both direct incentives and peer pressure to achieve the desired behavior regarding energy-consumption reduction, are included.

Our approach

- **Multi- level energy disaggregation** using commercial smart meters, smart plugs, sensors, NFCs, iBeacons, for:

-Accurate consumption monitoring at the *appliance level*

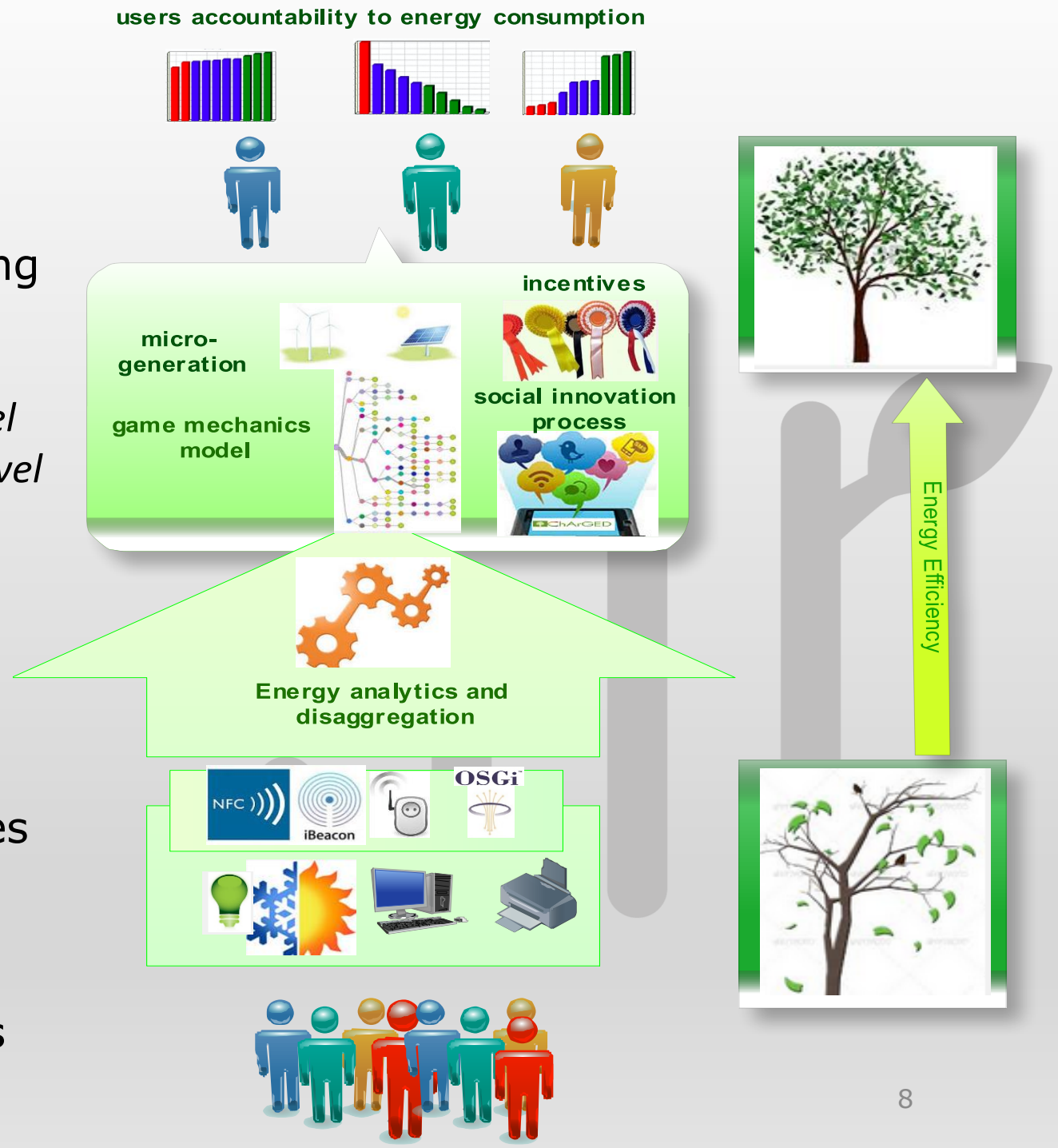
-Non-intrusive event monitoring at *distribution board level*

-Individual energy consumption monitoring at *user level*

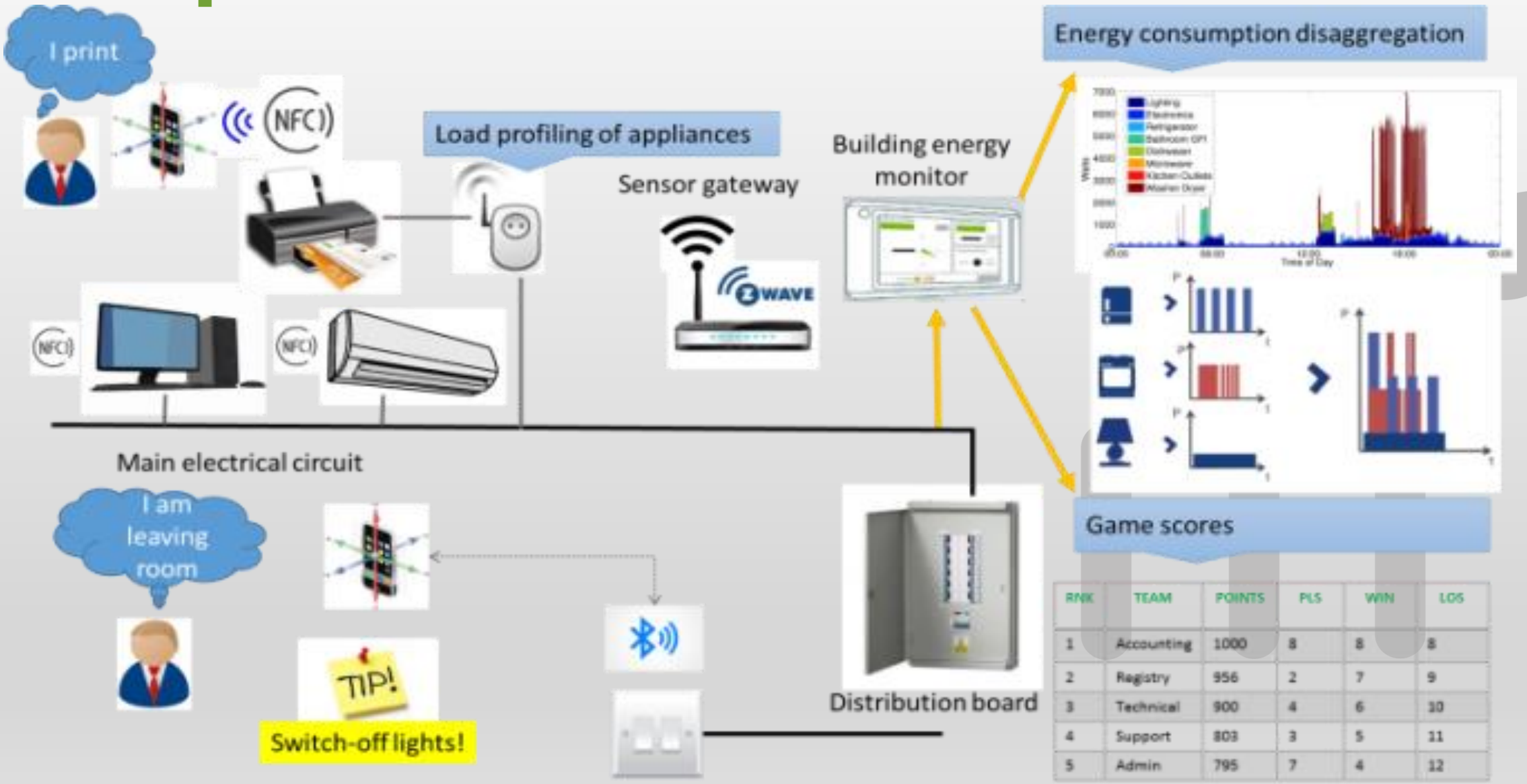
- An **IoT-based, SOA** and OSGi technology to interconnect subsystems

- **Cloud-based backend system,** on commercially available cloud infrastructures

- A **cleanweb gamified application for portable / mobile devices** with novel concepts for attracting and engaging users



Conceptual Architecture



RNK	TEAM	POINTS	PLS	WIN	LOS
1	Accounting	1000	8	8	8
2	Registry	956	2	7	9
3	Technical	900	4	6	10
4	Support	803	3	5	11
5	Admin	795	7	4	12

Our approach in high-level: energy-consumption events are translated into in-game scores or trigger tips to the users.

Energy Consumption and User-context Mining

Energy disaggregation: *discovering the constituent electrical load of each individual device in the overall energy consumption of a building*

Energy disaggregation techniques based on a single smart meter have low accuracy →

need for hybrid approaches:

- employ smart plugs and low-cost sensors;
- combine analytics software;
- develop a smart app to assist the disaggregation of electrical loads →

→*identify individual energy consumption*

→*give personalized advice beyond each particular equipment to the personalized use of them*

Energy Consumption and User-context Mining

Multi-channel smart meters

- Commercial and industrial buildings are supplied with three-phase power

→ install power-meters on the circuits of interest to capture information on their electrical energy use

→ Meters usually provide pulse or Modbus output or automatically send readings to a central database using push protocols such as HTTP

BLE

- Energy efficient; act as lighthouse and alerts smartphones of its presence.
- Beacons will be used to provide indoor user localization; combination with Wi-Fi, NFC sensors to offer better accuracy.

NFC

- Near-Field Communication allows the incorporation of the RFID technology into mobile devices; used in ubiquitous computing to obtain different kinds of information and services from different sources anytime and anywhere.
- Association of the user to a particular device through the swiping of the smartphone of the user to an NFC tag on the device.

Probability of User/Device Association

<u>The accuracy of the association between users and devices may in some cases be a challenge</u>

- An employee could be probabilistically associated to the device based on prior history.

gateway middleware software

Discover Energy-saving Potential and Behavioral Change

Software engine

to profile a specific use of energy

to construct models to diagnose deviations from the desirable patterns

e.g., electrical appliance left powered on after working hours

to generate an associated event and further process

e.g., computer screen is switched-off upon departure by an employee that used to leave it on, then it should proceed to score updating

Recommender system

to process the deviation output

to trigger load management actions for the end-user to rectify the undesired deviation.

→enables non-experts to participate with limited time and expertise

Discover Energy-saving Potential and Behavioral Change

Modeling

The modelling engine requires time-series data, and takes as input:

- Energy measurements (electricity, water, gas, fuel, heat consumption, etc.);
- real-time data (active/apparent/reactive power, flow, voltage, current, etc.);
- environmental data (temperature, humidity, occupancy etc.);

for normalization of the energy/real-time data before modelling

- user data (NFC swipes, etc.).

Run-time event recognition

- an event recognition engine will compare new measurements against the model to identify unexpected deviations.
- When detected, a message is sent to the user to point to the anomaly and the potential energy saving opportunity.
- Various degrees of tolerance can be considered for issuing notifications, so as to avoid spam and false positives.

Gamification

To maximize effectiveness of the gamified application

- ethnographic-style studies
- online surveys

… to better understand

- the situation regarding the individual factors that influence energy consumption for the employees;
- their current energy-consumption habits;
- their in-game preferences.

Gamification

In terms of individual behavioral factors, the majority of employees :

- Exhibit positive environmental awareness and environmental worldviews.
- Exhibit activated environmental personal norms, acknowledging that conserving energy and resources is important to them and their own problem.
- Show sensitivity to social norms, claiming that saving energy is a collective effort (doing it alone does not have an impact).
- Are willing to help their organization and to change their daily routine to conserve energy.
- Consider their personal comfort at work of crucial importance.

Employees are positively positioned towards pro-energy conserving behavioral changes, as long as their personal comfort is not significantly affected

Gameplay I

Printing

The employee sends a print job to a particular shared printer.

By reading the log file of the printer, the gamified application is able to associate all device usage to individual employees.

However, when the employee prints from a USB device or photocopies some pages, the user gets associated to the printer by swiping her/his smartphone over the NFC tag of the printer.

An energy-consumption event is registered for the user and the associated energy consumption is metered.

The user swipes again her/his smartphone for disassociating herself/himself from the device.

If overall printing behavior of an individual amounts to a positive behavioral change, as compared to her/his baseline, then positive game points are registered for the user

proportional to the fraction of the energy saved, and vice versa

Team score and leaderboards are updated in real time based on the updated individual score.

Gameplay II

Having a Meeting

The employee may occasionally use a meeting room.

There, she/he will employ a number of appliances, e.g., projector, large LCD screen, videoconferencing equipment, lights, HVAC, etc.

The gamified application should provide her/him with a tip to turn-off all unused devices when she/he leaves

e.g., "please, do not forget to turn-off the lights after your meeting"

BLE beacons are employed to discover when a particular employee is in the meeting room.

Energy consumption for the devices in the meeting room is associated to all users participating in the meeting.

For devices that are left on after the meeting, i.e., energy wasting, all employees that participated in the meeting are held responsible.

Energy wasting is associated to negative points in the game.

Desirable/undesirable user behavioral changes are detected and each employee is assigned positive/negative points.

Conclusions – Next steps

IoT-enabled gamification approach to realize:

energy-disaggregation at device and user level

employing a multi-channel plug-level meter, NFC tags, BLE beacons and the user smartphones

for behavioral changes towards saving energy in public buildings.

The employees in public buildings are motivated

by means of peer-pressure based on a team competition and by means of direct (non-monetary) rewards

The game scores reflect individual energy consumption and desirable/undesirable energy-consumption behavioral changes based on prior consumption baselines.

It will be experimentally validated through pilot studies.

Thank you for your attention

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