Innovative Personalised Apps to Motivate and Support Behavioural Energy Efficiency

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Overview

Energy Behaviours

- Cooperatives
- Prosumers/Net metering
- Decentralized Energy
- Energy Democracy
- Micro-Grids
- Blockchain
- Digital Coins

Urban Environment
Energy Cooperatives

“Energy cooperatives are organizations that manage activities along the energy value chain”
Debor (2014)

REScoop MECISE

MECISE stands for: Renewable Energy Cooperatives Mobilizing European Citizens In Sustainable Energy.
## Energy Cooperatives

<table>
<thead>
<tr>
<th>Business goals of energy cooperatives</th>
<th>Total number of energy cooperatives</th>
<th>Number of energy cooperatives with a primary focus on renewable energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy production/investors in energy production</td>
<td>701</td>
<td>690</td>
</tr>
<tr>
<td>Implementation &amp; operation of small district heating systems</td>
<td>148</td>
<td>148</td>
</tr>
<tr>
<td>Marketing &amp; trading of energy</td>
<td>67</td>
<td>19</td>
</tr>
<tr>
<td>Marketing &amp; installation of energy technology</td>
<td>51</td>
<td>17</td>
</tr>
<tr>
<td>Operation of electricity grid or natural gas network</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td>Energy services</td>
<td>32</td>
<td>18</td>
</tr>
<tr>
<td>Acquisition or marketing of biomass</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>Not possible to determine business goal</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>Production &amp; marketing of biofuel</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>E-mobility</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Lobbying &amp; networking</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Operation of fuel station</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Research &amp; development</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Shareholder of municipal energy provider</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

Table 2: German energy cooperatives differentiated according to their core business goals as of April 2014 (more than one category per cooperative is possible). Debor, Sarah (2014)

**Simple Business Models**

Most energy co-ops focus on energy production
Energy Cooperatives
The example of Middelgrundens

- Cooperative in Denmark (1996)
- Around 8,500 members
- Owns 10 from the 20 turbines of the offshore park
- The cooperative produces earnings for the shareholders

The Danish Energy Policy adopted an energy transition approach.
Energy Cooperatives
Ελληνικό νομικό πλαίσιο

(Ν. 4513/2018)
Εντάσσει τις ενεργειακές κοινότητες ως αστικούς συνεταιρισμούς

Άνοιγμα αγοράς σε φυσικά πρόσωπα ΝΠΙΔ,ΝΠΔΔ, ΟΤΑ

Δυνατότητα σε ΟΤΑ για άσκηση κοινωνικής πολιτικής

➢ Ενεργειακή Δημοκρατία
➢ Ενεργειακή Αυτονομία
➢ Αποκεντρωμένη Παραγωγή

Μη κερδοσκοπικού σκοπού κοινότητες
Αυτοσκοπός η βελτίωση της ποιότητας ζωής των μελών της

Κερδοσκοπικού σκοπού κοινότητες

➢ Ενεργειακή Δημοκρατία
➢ Ενεργειακή Αυτονομία
➢ Αποκεντρωμένη Παραγωγή
“Prosumers are agents that both consume and produce electricity. “

Parag & Sovacool (2016)
Blockchain

“Blockchain is an information storage and transmission technology for data and transactions that uses a secure, distributed registry (ledger)”

**Advantages:**
- Security
- Immutability
- Availability and transparency
- Ability to automate processes that are currently time-consuming, at reduced cost
Blockchain
Applications on the energy sector

10%
- Metering
  - Data exchange between stakeholders of Smart Grid applications, intelligent control systems, as well as the standardization of data transfers

20%
- Grid management
  - Value exchanged between devices in the form of data, network access, currencies, compute cycles, contracts for ongoing service, trusted introductions to other devices

40%
- Decentralized Generation
  - Real-time metering of on-site energy generation and P2P transaction management

20%
- EV Charging
  - Develop EV Charging platforms that use Blockchain-based smart contracts to authenticate users and manage the billing process

10%
- IOT
  - Continuous identification of new applications of Blockchain for IoT and the Connected Home markets
Blockchain

Brooklyn Microgrid (peer-to-peer power trading)

Mengelkamp et al. (2018)
“Μια πρόσφατη εκτίμηση της συνολικής ετήσιας κατανάλωσης ενέργειας Bitcoin ανέρχεται προσεγγιστικά στις 30 TWh. Η κατανάλωση αυτή αντιστοιχεί στο 0,15% της ετήσιας κατανάλωσης ηλεκτρικής ενέργειας στον κόσμο.”

Χ. Δούκας, Π. Ξυδώνας (2018)

### Proof of Work vs. Proof of Stake

<table>
<thead>
<tr>
<th>Proof of Work</th>
<th>Proof of Stake</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block reward given to first miner</td>
<td>Chance of solving block proportionate to staked wealth</td>
</tr>
<tr>
<td>More computing power = more mining power</td>
<td>More wealth = more mining power</td>
</tr>
<tr>
<td>High energy cost</td>
<td>Low energy cost</td>
</tr>
<tr>
<td>Miners pool and mining becomes centralized</td>
<td>Mining is decentralized</td>
</tr>
<tr>
<td>Must provide proof to solve block</td>
<td>Must stake wealth to solve block</td>
</tr>
<tr>
<td>Miner receives block reward</td>
<td>Validator receives block transaction fees</td>
</tr>
</tbody>
</table>

Source: [https://powercompare.co.uk/bitcoin/](https://powercompare.co.uk/bitcoin/)

The map above shows which countries consume less electricity than the amount consumed by global bitcoin mining.
Energy Coins
Solarcoin – Energy Cryptocurrency

€0.0039  -35.39%

Energy generation enables circulating SolarCoins
Energy Coins
NRGCoin – Academic Approach

(Mihaylov et al., 2014)
Create a loyalty program where participants receive bonuses in the form of a virtual energy currency for saving energy.
Digital Energy Currency Approach

**Static (one-way) incentive**

- Incentive
  - Fixed monetary incentive
  - Prize
  - Voucher

- Action
  - Triggered behavioural energy efficiency
  - Does everyone respond to an incentive?

**Dynamic (cyclic) incentive**

- Incentive
  - Incentive triggers behavioural energy efficiency

- Action
  - Behavioural energy efficiency defines the incentive

Better User Engagement

Research Gap 1

Research Gap 2
Digital Energy Currency Principles

Incentives on behavioural economics

1. Subsidise efficient behaviour
2. Penalise non-efficient behaviour
3. Provide the opportunity to trade the rights
Digital Energy Currency Mechanism

\[ C_{i,l} = p \times \frac{B_T}{EST} \times \left( 0.5 \times \frac{\sum_{j=1}^{N} \left( \sum_{i=1}^{K} \left[ (\sum_{l=1}^{24} E_{ij,l}) - (c_c - c_b)(l-1) \right] \right)}{\sum_{i=1}^{K} \left[ (\sum_{l=1}^{24} B_{i,l}) \times \frac{B_T}{EST} \right] \times e - C_{i,l-1} \times (c_c - c_b)(l-1)} + 0.5 \times \frac{\sum_{j=1}^{N} \sum_{i=K-5}^{K} \sum_{l=1}^{24} E_{ij,l}}{\sum_{i=K-5}^{K} \sum_{l=1}^{24} B_{i,l}} \right) \]
Case Study 1: Bahrain

Research Question
Assuming an energy efficient behaviour, can the ATOM mechanism produce a financial reward for the citizens in Bahrain?
Case Study 1: Bahrain

General information

- Island country in the Persian Gulf
- Population: **1,494,090** (2017)
- Total consumption: **16,559 GWh** (50% domestic sector)

<table>
<thead>
<tr>
<th>Energy Mixture</th>
<th>Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural oil/Fuel oil (OCGT+CCGT+ST)</td>
<td>3920 MW</td>
</tr>
<tr>
<td>Wind</td>
<td>2 MW</td>
</tr>
<tr>
<td>Solar</td>
<td>4 MW</td>
</tr>
<tr>
<td>Interconnection</td>
<td>600 MW</td>
</tr>
</tbody>
</table>
Case Study 1: Bahrain

Demographic Estimations (UN Household Size And Composition around the World 2017)

- Number of households around 250,000
- Average household size 5.9
- Distribution of size of household (according to number of members):

![Distribution Chart]

- Percentage
- No. of members
- 1 2 3 4 5 6 7 8 9 10 11 12
Case Study 1: Bahrain

Business-as-usual (baseline scenario)

Average out of sample error: **6.7% (MAPE)**
Case Study 1: Bahrain

Scenario

- Number of households around **250,000**
- Bahrain adopted an energy saving target of 6% by 2025. We simulate the real energy consumption of the participants by using random number following a normal distribution around 94% of the predicted with a standard deviation of 10%
- Anticipated savings: **539.8 GWh**
- Budget: 50,000,000 $
- reg = 0.093 $/kWh
- \( p_{kWh} = 29\text{ fils/kWh} \times 0.0027 $/\text{fil} = 0.0783 $/kWh \)
Case Study 1: Bahrain

Results

Energy saved from the scenario: **691.5 GWh** > Anticipated

<table>
<thead>
<tr>
<th>Ratio Statistics</th>
<th>max</th>
<th>0.102679</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>min</td>
<td>0.075570</td>
</tr>
<tr>
<td></td>
<td>average</td>
<td>0.089813</td>
</tr>
</tbody>
</table>

Average ratio > \( p_{\text{kWh}} \)
Case Study 1: Bahrain

Results

✓ Progressive earnings of a random household with 6 members (around the estimated average) taking account the change of the rate and the penalties
Case Study 1: Bahrain

Results

More consumption
More capability for savings
Greater Profit
More variance
Case Study 2: Greek residential sector

Research Question
Should monetisation of behavioural change be considered as a policy measure to support energy management in the residential sector?
Case Study 2: Greek residential sector

Methodology

1. **ATOM**
   - Digital energy currency for behavioural energy efficiency

2. **Scenario parameterisation**
   - Population, Socio-economic assumptions, Building stock

3. **BAU Household Consumption Scenario**

4. **DREEM**
   - Demand side management model for building simulations

5. **Consumption under Behavioural Energy Efficiency Scenario**

6. **Monetising behavioural change to support energy efficiency in the residential sector**

7. **Integrated behavioural energy modelling simulation**

8. **Step 4**
   - **Scientific Outcomes**
     - Quantification of behavioural patterns in monetary terms
   - **Policy Outcomes**
     - Insights for policy implications on the national and household level
Case Study 2: Greek residential sector

Baseline Scenario

Climate Zone B

Climate Zone C

<1980  
1980>

4 reference typologies simulated in DREEM: https://webtool.building-typology.eu/#bm

Then aggregated to the national level: ~4 million households
Case Study 2: Greek residential sector

Behavioural energy efficiency scenario

Households can adjust an analog non-programmable thermostat (€20) from 3 to 6 hours a day based on the profile of the household and the day.

Stochastic nature accounts for the existing variation in the thermostats’ setpoints set by different users.
Case Study 2: Greek residential sector

Results – Energy Efficiency Implications

- Estimated **5.3%** energy savings on a **national level**
- Potential of **10%** on the **household level**
Case Study 2: Greek residential sector

Results – Monetary Implications

✓ Average household earnings: €200
✓ Cross-reference with literature: Reward can be found adequate for certain groups of end-users (e.g., low-income)
✓ Behavioural patterns quantified and monetized:
  o Peak load hours
  o Higher potential during weekends
  o Higher potential during winter months (heating-focused action implemented)
Conclusions

✓ Energy cooperatives are an innovative mechanism that involves the public in the decision-making process of a more democratic and decentralized energy system.

✓ Digital energy currencies can play an important role in further engaging end-users toward behavioural energy efficiency, without significant costs.

✓ Possible **10% behavioural energy efficiency potential** with a specific energy management action. Potential for the full set of actions could even reach up to **20%**.

✓ Monetisation is found to provide a lucrative incentive (€200) for certain categories of end-users to actively reduce their energy consumption.

✓ It also allows to quantify important social aspects in monetary units to then feed modelling exercises in support of energy policymaking.

✓ Engaging citizens through surveys and other forms of deliberation or **field studies** could help provide additional empirical data on the level of incentives each citizen group considers adequate
References

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