BENEFFICE: Behaviour Change, Consumption Monitoring and Analytics with Complementary Currency Rewards †

Anastasia Garbi [1], Anna Malamou [1,*], Nassos Michas [1], Zisis Pontikas [1], Nikolaos Doulamis [2], Eftychios Protopapadakis [2], Thomas N. Mikkelsen [3], Konstantinos Kanellakis [4] and Jean-Luc Baradat [5]

[1] European Dynamics SA, 209, Kifissias Av. & Arkadiou Str., 15124 Maroussi, Athens, Greece
[2] School of Rural and Surveying Engineering, National Technical University of Athens, 15780 Zografou, Athens, Greece
[3] GECO Global, Skjoldenæsvej 1, DK-4174 Jystrup, Denmark
[4] KAFKAS, 1st Km Leoforos Markopoulou, 19002 Paiania, Athens, Greece
[5] Compte CO2, 11 rue de Poulizan, 29217 Plougonvelin, France
* Correspondence: anna.malamou@eurodyn.com; Tel.: +30-210-8094500
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Abstract: BENEFFICE designed (eco-)system aims to reduce wasted electricity by incentivizing long-term consumption savings. It leverages Internet of Things enabled, low cost devices, which capture electricity use patterns at the level of clusters of devices and of each individual consumer. An energy behavior model correlates these patterns with optimal, personalized comfort levels and geographic and energy use contexts to determine optimal energy use behavior to reduce wastage of energy and to increase the use of renewable resources. Personalised, real-time motivational paths and challenges are contributing to deliver sustainable reductions of electricity consumption. Voluntarily engagement is achieved by the provision of monetary rewards -CO_2 credits- in return of electricity savings and successful challenges. A novel ecosystem of like-minded actors of businesses who pay in CO_2 credits and consumers who act for earning them is established.

Keywords: electricity savings; energy behavior change; electricity monitoring; energy efficiency; monetary incentives

1. Introduction

When it comes to reducing energy consumption and in general fighting climate change, a classical economic problem occurs, that of free riding. Free riding occurs when those who benefit from consumption of certain goods or services do not take the full cost and consume excessively. We all benefit from reasonable energy consumption, but rarely pay for this as for all public goods. Not only humans are harmed as a whole without payment, but excessive energy consumption -human actions e.g. heating, transport- lead to exhaustion or destruction of this public good.

On the other hand, an important barrier to achieve the desired and designed impact -in the long term- to many energy efficiency projects, is the so-called rebound effect. "Buy a more fuel-efficient car, drive more" [1]. This is a significant consequence of projects about energy efficiency, often underestimated. It characterises the negative relationship between technology and consumption [2]; technological improvements in energy efficiency induce increase in demand and therefore production, and consequently energy consumption. Furthermore, other barriers do not allow to

achieve the desired impact: For example, companies, when asked to reduce energy, fear added costs and loss of competitiveness and threaten with relocation and job cuts. Environment ministers advocate high-level actions but industry ministers counter that they are not affordable—in fact, the former would suggest the best way to reduce energy waste would be to increase its price, but no other ministry would dare to implement this policy as it "sounds" less social.

Free-riding and rebound effect are among barriers critically undermining the Paris Climate Conference Agreement [3], which seeks to limit global warming increase to 1.5 °C, and EC policies that aim at reducing energy consumption. Several economic approaches and business models have been implemented to date. Despite all these and the submitted plans of countries—the objective of energy reduction is unreachable. Even if existing country commitments are all met, the CO_2 is forecasted to rise by 2.6–3.1 °C [4]. The risk for humanity due to global warming and climate change remains high, and the consequences dangerous and expensive. Time is getting short to find the appropriate approaches that will allow to rapidly overturn this trend.

Energy consumers have traditionally been considered passive users, rather than influential part of the Energy System [5]. Several efforts [6] that have studied user behaviour and the impact on energy, revealed that effective promotion of energy-conscious behaviour reduced energy consumption by over 10%, while energy efficient behaviours accounted for 51%, 31% and 11% of the variance in heat and electricity respectively. Consistent with EU's 2020 Energy Strategy, it is of utmost importance to place energy consumers at the center of the Energy System [7], engage them through better understanding, information and market transformation, and activate them through innovative products, services and incentives [8].

Most energy consumers are currently not engaged, believe they have little to gain from engaging and have little confidence in market actors [9]. It is a reality that for most people their only interaction with the energy supply is when they must pay a bill or deal with a big problem [10]. Consumers need appropriate frames of reference to determine if their energy consumption is excessive. They should have a good understanding of the effort needed to achieve energy efficiency and the resulting advantages in terms of energy consumption [11]. However, today consumers have little way of knowing which of their everyday behaviour contributes most to their energy consumption, or what the simplest ways to reduce their energy footprint are [12]. And still, even when householders have access to information regarding their energy use, these should be coupled with tips on the most effective ways to waste less energy, by motivating people to take action [13]. Their awareness should also be raised as to that comfort and energy efficiency are not conflicting goals, but can be pursued simultaneously [14].

However, awareness and guidance alone are not enough; further incentives are needed to actually change the consumer's behaviour. In this paper, a framework that is composed of a system and business ecosystem that aim to change consumers' behavior at home in the long term, towards reduced wastage electricity and increase the use of renewable resources in the energy mix is described. This framework has been developed as part of the BENEFFICE project (http://www.beneffice.eu). BENEFFICE designed (eco-)system aims to reduce wasted electricity by incentivizing long-term consumption savings. It leverages Internet of Things (IOT) enabled, low cost devices which capture electricity use patterns at the level of clusters of devices and of each individual consumer. An energy behavior model correlates these patterns with optimal, personalized comfort levels and geographic and energy use contexts to determine optimal energy use behavior to reduce wastage of energy and to increase the use of renewable resources. Personalised, real-time motivational paths and challenges are contributing to deliver sustainable reductions of electricity consumption. Voluntarily engagement is achieved by the provision of monetary rewards - CO_2 credits- in return of electricity savings and successful challenges. A novel ecosystem of like-minded actors of businesses who pay in CO_2 credits and consumers who act for earning them is established.

The remainder of this paper is organized as follows: in Section 2, the BENEFFICE architecture and system design is presented. In Section 3, the BENEFFICE components that comprise the architecture are described in terms of functionality and brief implementation approach. In Section 4, the BENEFFICE business models are presented in terms of a model ecosystem which presents the

role and value of the actors involved. In Section 5, a discussion on the innovation that BENEFFICE aims to bring is presented as a concluding paragraph.

2. BENEFFICE System Architecture and Design

The BENEFFICE project provides a low- cost, integrated IOT solution for the measurement and monitoring of the residential energy consumption with aim to incentivise energy efficient behavior. It exploits behavioural model analysis, non-intrusive load monitoring and disaggregation algorithms, green energy scheduling, personalised recommendations/ challenges and the use of an alternative CO_2 currency.

The residential consumers procure a set of devices that will be easy to install in their residences, connect and communicate with. The measurements are retrieved through a local gateway device and stored to the BENEFFICE platform backend. Data processing applications -Energy Disaggregation, Data Analytics, Behavioural model, Recommendation Engine, Green energy scheduling-, access the data in the BENEFFICE platform backend through provided APIs.

The residential consumers use the BENEFFICE mobile application, create a profile providing some information related to their energy consumption and are able to continuously monitor their energy consumption. In addition, they receive recommended actions and challenges for improving consumption based on their personal preferences. Successfully adopting them in everyday life results in earning CO_2 credits, which can be exchanged to Euros or spent within the BENEFFICE ecosystem, by using the CO_2 Credit Management System. The BENEFFICE eco-system unifies different actors and interdisciplinary modules which will be presented in Section 3 and converges into an overall framework that aims to incentivise voluntarily actions to the residential consumers related to energy efficiency by providing a friendly and useful mobile application.

In a high level the BENEFFICE platform consist of four main parts which are the following:

1. **Residential Components**: These consist of:

    - The sensing components (Internet of Things devices) to be installed in the consumers' residences and measure: the total energy consumption of the residence, the indoor temperature and the gas consumption related to heating.
    - The external systems that provide additional data and measurements namely the region climate conditions and the Energy production from Renewable Energy Sources (where available).
    - The BENEFFICE gateway device to be installed in each residence in order to collect and forward all measurements to the backend for storage and further processing.

2. **BENEFFICE platform backend (Esthes.is)**: This is a multi service platform which handles the data collection of the sensing components and the external systems through the gateway device and is responsible to store the data, to manage the deployed residential gateways and to provide APIs access to all the other Data Processing Applications. In addition, the platform backend is responsible to store the consumer's input (i.e. profile, preferences, energy consumption related behaviour etc.) and also sent the outcomes of the Data Processing Applications (i.e. disagreggation results, recommendations, challenges, notifications etc.) for display to the BENEFFICE mobile application.

3. **Data Processing Applications**: these include all BENEFFICE modules which consume /process data that are stored in the platform back end (obtained from the sensing components, the external systems or provided by the consumer). These are the Energy Disaggregation algorithm, the Data Analytics, the Behavioural model, the Recommendation Engine and the Green energy scheduling.

4. The **BENEFFICE mobile application** is the main interface that the residential consumers use in order to interact with the BENEFFICE platform. It collects the consumers' input (i.e. information about their energy consumption behaviour, preferences or actions) and send it to the platform backend to be stored. It also displays energy measurements, disaggregation results, recommendations, challenges and earned CO_2 credits to the consumers. The CO_2 credit

management system enables the circulation of the CO_2 currency within the BENEFFICE ecosystem.

The overall BENEFFICE functional architecture is presented in Figure 1.
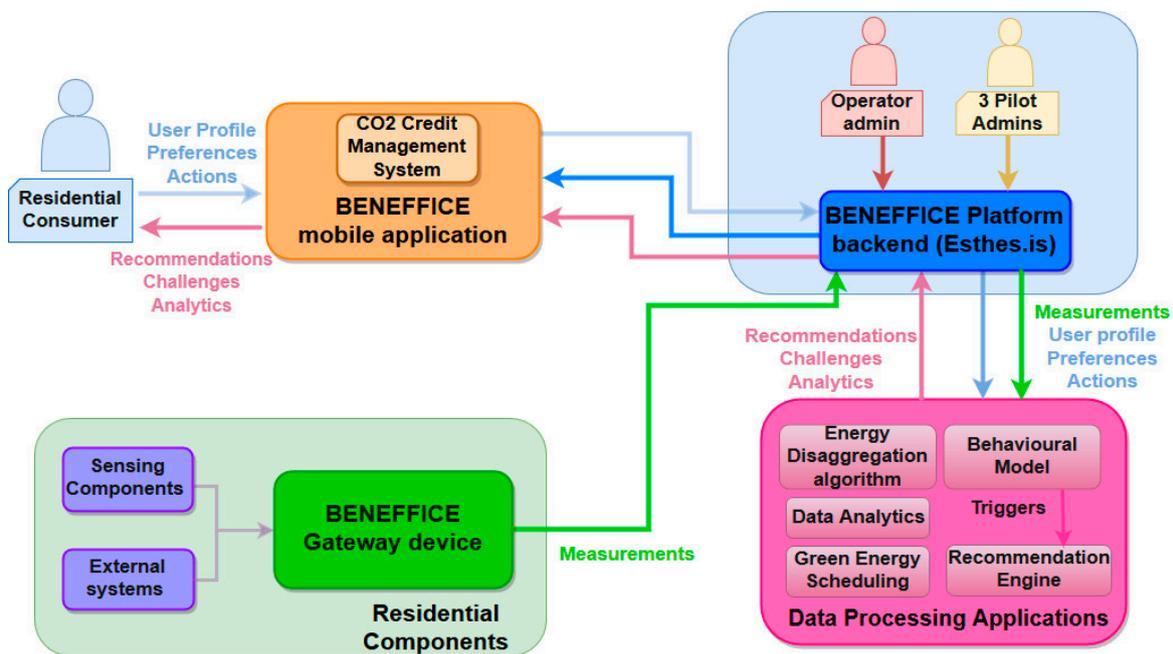

Figure 1. BENEFFICE system architecture and design.

3. BENEFFICE Components Description

As presented in the previous Section, the BENEFFICE platform is formulated by various modules. A functionality overview of each of these modules is provided below.

The **Sensing Components** (Sensing hardware and software gateway) are based on existing, inexpensive commercial sensors and technologies integrated within the Esthes.is modular platform. The hardware kit that is easy to install and directly interconnected with the platform backend, is low cost suitable for wide-scale adoption.

The **Energy disaggregation** algorithm disaggregates the total consumed power, providing information about energy usage per cluster of devices (9 categories in total) in each residence. The disaggregation approach allows consumers to identify the most energy consuming devices and activities which are targeted by the recommendations and challenges [15].

The **Data Analytics** technologies and techniques aim at identifying patterns (i.e. seasonal, temporal and at appliances' cluster's level) of consumer's behavior. Then, a higher-level analysis is performed among consumers, exploiting statistical distances, and comparison of individual patterns. Thus, data analysis is a complex procedure, where the information gained per consumer is a combination between statistical analysis from energy disaggregation outcomes and information derived from external data and basic consumer profile information. The Data Analytics also calculates the energy savings and CO_2 Credits earned per consumer.

The **multi-factorial Behavioural Model** is the strategical layer of the BENEFFICE engagement approach and based on continuous interventions, communications and incentives triggered by observations of data, actual consumer behaviour and responses in correspondence with them. A segmentation profile is created, which determines the way the communication is presented.

The **Recommendation Engine** implements the behavioural model derived recommendations and challenges that motivate a consumer to reduce energy consumption, in a meaningful way according to his/her consumption patterns. It exploits all available information from energy disaggregation, data analytics and provides personalised recommendations and challenges to improve energy consumption performance and earn CO_2 Credits. The system is dynamic, as the recommendation/challenges are based on the consumer's behaviour. If the system observes a

changing consumer's behaviour during the process, it adapts its recommendations/challenges so as to fit with consumer's modified profile.

The **Green Energy Scheduling** promotes the utilization of appliances in a household, according to specific consumers' patterns considering the forecasted renewable energy production. It is implemented by adopting the concept of sources reallocation using a variety of algorithms as greedy algorithms and convex programming. Given a set of tasks that has to be done during a day (e.g. cooking, laundry, vacuum, etc.), the Green Energy Scheduling aims to minimize operational overlaps, which result in consumption peaks, ensuring that the energy demand is covered using the existing renewable energy sources. Additional constraints imposed by the consumer explicitly or implicitly are considered, exploiting the outputs of the Data Analytics.

The **Platform Backend** (Esthes.is) is a collection of services, databases and front-end clients that provides access to the stored measurement and consumer related data as well as to the deployed gateway devices. The access is provided by REST APIs specifically tailored to the needs of the modules that call them. The platform backend is designed in an open, modular and scalable architecture and ensures the communication with the gateway device, the mobile application and the Data Processing applications. Moreover, two web applications/interfaces are available: a) the operator admin application that handles the over-the-air (OTA) updates and the remote management of gateways (remote support, updates, debugging etc.) and b) the pilot admin application that provides an admin page customised for each one of the pilot admins in order to monitor the connected devices linked to their residential customers.

The **Mobile Application** offers the direct communication with the consumers providing energy near real-time consumption information through an easy-to-understand visualization and comparative feedback regarding their progress in relation with other consumers. Personalised recommendations and challenges guide the consumers towards a more energy efficient behavior. If the challenges are successfully completed and the goals of increased energy savings or maximized use of renewable energy source are reached, the consumers are awarded with CO_2 credits.

The CO_2 **Credit Management System** is a neo-banking application which enables the management of the CO_2 accounts, and allocates CO_2 Credits upon verified electricity reduction or increased use of renewable energy, i.e. arising from customer actions to reduce energy wastage and/or replace fossil fuel energy with renewables. This system allows consumers to spend their earned CO_2 credits or exchange them with Euros and thus circulate this new currency within the BENEFFICE ecosystem. This system provides incentives to people to fight climate change by circulating the new currency.

BENEFFICE engages with consumers in a wide range of cases, conditions, profiles, etc. while its modular and reconfigurable architecture ensures the wide deployment and applicability.

4. BENEFFICE Business Models and Ecosystem

The BENEFFICE ecosystem aims to realise a business shift towards the provision of integrated product-services, or credit-based advertising as opposed to the so-far product focus of energy. In this scenario, a utility increases its service portfolio by offering consumption information services - facilitated by BENEFFICE framework-, as well as, tailored support for efficient usage -facilitated by the challenges and recommendations-, and CO_2 credit rewards and exchanges within its ecosystem. This contributes to increase revenue and recover loss resulting out of imposed lower energy consumption. The BENEFFICE ecosystem includes partnerships with established businesses-who act as catalysts in the energy landscape-that recognize the potential offered by CO_2 credits both to promote reduced consumption of fossil fuels and to extend their market share by offering a new service with a real environmental added value.

The role and value of each actor in this model ecosystem, is depicted in a business radar as presented in Figure 2, adopting the base/X methodology [16]. The new service is the minting of CO_2 credits for a green cause; it is a collaborative service delivered by several actors who need to adopt a differentiated business strategy. The business model radar is explained in Tables 1–8.
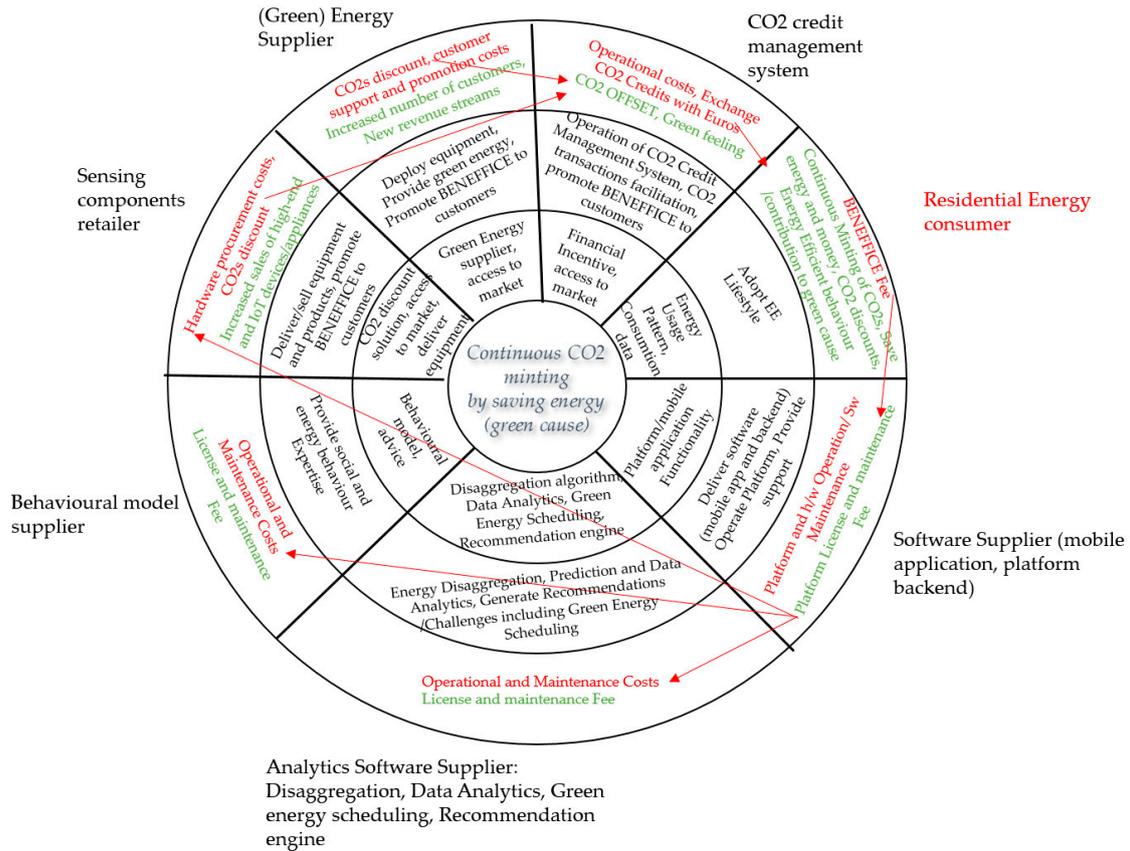
Figure 2. BENEFFICE business model radar.

Table 1. BENEFFICE service (Centre of the Radar).

Service	BENEFFICE offers a minting CO_2 service to incentivize long term energy efficient behavior and is providing services to help consumers to reduce their energy/electricity consumption. It is offered jointly by traditional (utility) and new players in the energy market that act as catalysts for the adoption of BENEFFICE solution and benefit from it. Each consumer could become a "hero" of climate change by continuously minting CO_2s, saving energy and contributing to this green cause.

Table 2. Software Supplier (mobile application, platform backend).

Value Proposition	The software supplier acts as a data broker which collects data from the sensing components, external systems and gateway. It offers the united BENEFFICE service that gathers, stores and makes available all data to the data processing applications. Moreover, the mobile application enables the interaction with the residential consumers.
Co-production activity	Software delivery (BENEFFICE platform and mobile app) and integration. Operation and maintenance of the platform
Cost (−)/ benefit (+)	(−) development, maintenance, operation and technical support costs (+) license and maintenance fees

Table 3. Analytics software supplier: Disaggregation, Data Analytics, Green energy scheduling, Recommendation engine.

Value Proposition	Offers the services of Energy Disaggregation and data analytics, implements the recommendation engine and the green energy scheduling modules.
Co-production activity	Software analytics delivery
Cost (−)/ benefit (+)	(−) development, maintenance, operation and technical support costs (+) license and maintenance fees

Table 4. Behavioural Model Supplier.

Value Proposition	Delivery of the multifactorial behavioural model and advice on how to organise the communication with the residential consumers (recommendation engine).
Co-production activity	Based on the expertise in social aspects and energy behavior: creation and update of the multifactorial behavioural model, identification of segments of residential consumers and provision of advice on the communication with each segment in order to achieve the maximum engagement.
Cost (−)/ benefit (+)	(−) development, maintenance, operation and technical support costs (+) license and maintenance fees

Table 5. Sensing Components Retailer.

Value Proposition	Delivers the equipment (sensors, meters, gateway, hardware), Offers CO_2 discount to the residential consumers for certain products (as BENEFFICE ecosystem stakeholder) Contributes its customers (to increase the BENEFFICE market penetration)
Co-production activity	Promoting and selling the BENEFFICE product in its stores and provision of further advice on how to be more energy efficient (for example the residential consumer will be advised to buy appliances with optimum energy consumption using the CO_2 discount).
Cost (−)/ benefit (+)	(−) Hardware procurement costs, CO_2 discount (+) Increased sales of high-end and Internet of Things devices/appliances

Table 6. (Green) Energy Supplier.

Value Proposition	Offers green energy Contributes its customers (to increase the BENEFFICE market penetration)
Co-production activity	Assist with the deployment of the equipment (meters, sensors, gateway, hardware) in the residential consumers and promote BENEFFICE product in its customers.
Cost (−)/ benefit (+)	(−) CO_2 discount, Customer support costs, Promotion costs (+) Increased number of customers, new revenue streams

Table 7. CO_2 credit management system.

Value Proposition	Operates the CO_2 credit management system Facilitates the CO_2 transactions enabling the CO_2s to Euros exchange Contributes its customers (to increase the BENEFFICE market penetration)
Co-production activity	Development and Operation of the CO_2 credit management system (neobanking application), Balance maintenance of CO_2 Credits, CO_2 credits transactions facilitation, promotion of BENEFFICE to its customers.
Cost (−)/ benefit (+)	(−) Operational costs, Exchange costs (CO_2 credits with Euros and vice versa) (+) CO_2 offset, CO_2 circulation/transactions, engagement of new consumers to CO_2s (possible new customers), leading role in the formulation of a new ecosystem, Contribution to the fight for climate change

Table 8. Residential Energy Consumer.

Value Proposition	Residential energy consumers offer their energy usage pattern and energy consumption measurements for further analysis and training of the disaggregation algorithm and the behavioural model.
Co-production activity	Residential energy consumers can adapt their lifestyle for a green cause, adopt a more energy efficient behaviour, save energy and money and earn CO_2 credits.
Cost (−)/ benefit (+)	(−) BENEFFICE fee (+) CO_2s credits earned by adopting proposed recommendations and challenges, energy and money savings (reduced energy bills), CO_2 discounts, energy efficient behavior/ Contribution to a green cause

This is an indicative theoretical ecosystem, which in reality does not have to include all actors for a specific service. The roles can be played by other actors or some of them can be removed, during the actual development of the use cases. This analysis demonstrates the potential market opportunities for each partner that drive the BENEFFICE ecosystem establishment. In addition further exploitation opportunities and the possible involvement of other stakeholders (industry, policy makers and market catalysts in general) will be explored.

5. Conclusions

BENEFFICE integrates a revolutionary perspective to the stimulation of Energy Efficient (EE) behavior, based on CCO_2 digital currency and addresses existing drawbacks in EE adoption. Monetary innovation is known to be a powerful tool for behavioural change which BENEFFICE adopts to affect human choices in terms of energy efficiency. Consumers are either unsure or just do not perceive the outcomes of energy-efficient behaviour as having real positive effects on them. BENEFFICE framework may favour the desired choice by creating an impression of advantage and certainty, raising its attractiveness and engaging more people to it. Energy efficient behaviour is sustainable in the long term, as a neutral stimulus can acquire a reinforcement value through an association with a primary reinforcer – e.g. exchange with real goods or real currency – and can change behaviours even after the primary reinforcer is removed.

Finally, the BENEFFICE service-oriented ecosystem stimulates the supply of and demand for the digital currency from the perspective of an entire ecosystem comprising diverse end users and service suppliers. It builds on technological innovation that creates new opportunities for progress on efficiency. Digitalization, disaggregation and energy savings are considered to provide a significant impact on the energy sector and energy efficiency is emerging as a key arena for innovation. BENEFFICE ecosystem is built to create exciting new opportunities for integrated solutions where efficiency and renewable energy work together to deliver clean energy outcomes at the lowest cost.

Conflicts of Interest: The authors declare no conflict of interest.

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