Smart energy flexibility for distribution grids

ebalanceplus

Imprint

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Ebalance-plus demonstrating solutions for the power grid of the future

Editorial

Dear reader,

it is an honour to introduce the work of the ebalance-plus project consortium over the last four years. This project has been a clear example of resilience, as the willingness and commitment of all partners from 10 different countries has allowed us to overcome the difficulties of covid restrictions, lack of supply of electronic components and Brexit, continuously looking for solutions and alternatives to achieve our goals. I would like to thank all of them because otherwise this project could not have been carried out. It is also a clear example that professionalism knows no cultural or border barriers.

Our project has demonstrated the benefits of an adaptable and replicable communications and control architecture for the challenges that power grids will face in the future, which enables the deployment of energy flexibility, reliability and resilience solutions. The open concept of ebalance-plus is especially interesting for DSOs, energy aggregators, suppliers and energy asset owners, who can deploy their own market solutions and manage customers and systems in a joint way. Despite the great challenges, the project has allowed all project members to improve their technologies and knowledge in this sector and are already exploiting their results in the market and this is certainly the best result we could have expected. You will find here solutions for energy storage, power electronics, electric vehicle charging, middleware, energy management algorithms, mobile applications, among others, as well as the results of social and market analysis.

Finally, I want to thank the European Commission and the Horizon 2020 program for their financial support, which we hope will serve as an example to collectively build a prosperous energy system for all Europeans.

With my best wishes, I hope you enjoy learning about the experience of our journey.

Juan Jacobo Peralta Escalante
Project Coordinator, CEMOSA

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Solutions and Impacts

Scan to download and read the deliverables related to this chapter

Modular and scalable energy balancing platform

"Many projects right now are dealing with digitalisation of the grid, offering the market more information about the grid.

Our focus is different – we are not operating with the market only. We are distributing the control of the grid to all levels, so that these levels can coordinate with each other from a technical point of view, of course, also considering economic variables.

But the core of the solution is based on the fair cooperation of all the players, from the customer to the energy operators to balance the grid."

Juan Jacobo Peralta Escalante
Project Coordinator, CEMOSA

Ebalance-plus increases the **flexibility** and **resilience** of electric grids (power system), by means of an **energy balancing platform**, which integrates smart production, storage, and consumption technologies. This energy balancing platform is based on a **fractal-like hierarchical architecture** that replicates the existing grid topology, including transmission-, distribution-, distributed energy resources- and customer domains. It has a bidirectional communication framework, assuring the scalability of the solutions.

The ebalance-plus platform is based on a middleware that allows creating a hierarchical architecture so that the **replicability** and **scalability** of software and hardware solutions is guaranteed and allows deploying services for both the electricity grid (Distribution System Operators/Transmission System Operators) and the markets (e.g. retailers and aggregators).

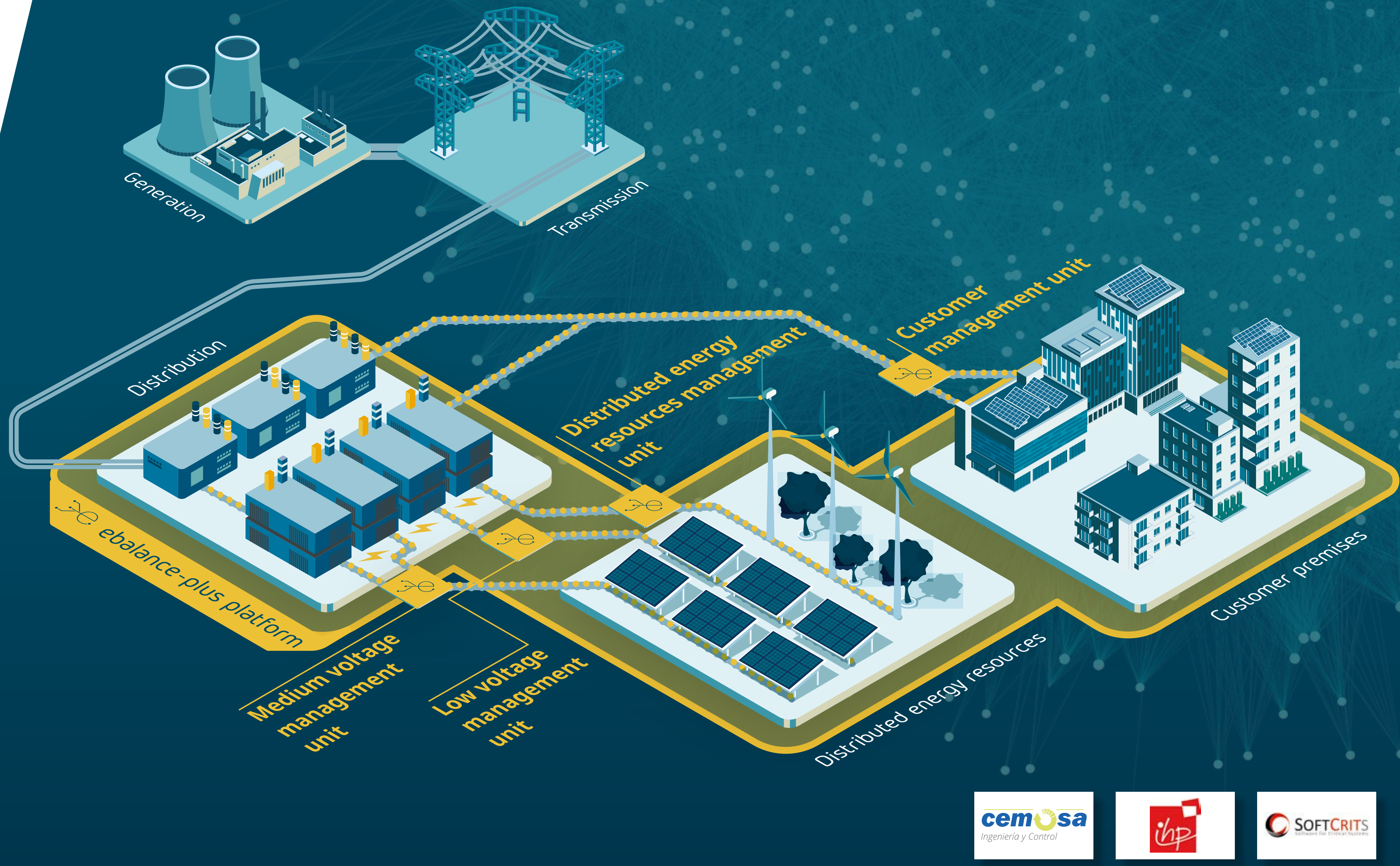
The results have shown that from a unified definition of flexibility profiles it is possible to **aggregate electrical loads from different equipment** (Battery Energy Storage Systems (BESS), Heating Ventilation Air conditioning (HVAC), Photovoltaics (PV), electric boilers, Electric Vehicles (EVs)...), which allows the solution to be generalised to any field of technologies demanded by consumers.

The project is aligned with a variety of EU strategies and roadmaps promoted in the last years to reduce CO_2 emissions, increase the energy efficiency at different levels and engage the customers in this kind of innovative solutions.

ebalance-plus hardware has been designed with recyclable products, for example the Management Units are >80% recyclable, guaranteeing a minimum environmental impact at the end of the lifecycle.

Target Users: Energy retailers, DER exploitation managers, energy aggregators, DSOs, energy consumers/prosumers (industry, tertiary, households)

Technological Readiness Level (TRL): 7


Generation
Transmission
Distribution
ebalance-plus platform
Medium voltage management unit
Low voltage management unit
Distributed energy resources management unit
Distributed energy resources
Customer management unit
Customer premises
cemosa
Ingeniería y Control
ihp
SOFTCRITS

Technologies enabling ebalance-plus innovative services

Grid management units

These ICT devices compose the whole system architecture and allow monitoring and control the downstream domains.

Security and privacy technology

The system architecture protects the privacy and user's data against attacks and manipulation with the latest encryption technology.

Silicon-carbide high-efficient power converters

New semiconductors like silicon carbide offer the possibility to manage distributed energy resources that usually work at DC voltage in a cost-effective manner and with a high level of energy efficiency and reliability.

Vehicle-to-grid (V2G) infrastructure

This technology takes advantage of the batteries of electric cars to use them as flexible storage and support grid operation or minimize energy costs using available Renewable Energy Sources.

Data-exchange middleware

Software solution that assures the interoperability of heterogeneous communication protocols and databases.

Prediction models and flexibility algorithms

To manage energy flexibility as commodity in new energy markets and services, it is necessary to develop more accurate prediction algorithms that capture the variability of end-user behaviour, renewable energy generation and electric vehicle charging infrastructures. On the other hand, flexibility algorithms allow aggregation and management of heterogenous loads to make it available for energy aggregators and distribution system operators.

Smart-storage solutions for buildings.

The straightforward way to increase the energy flexibility of buildings is deploying smart batteries that allow deploying services based on energy arbitrage. Designed for buildings with large energy consumption and high rated power. They of course also provide the possibility to optimise costs and diminish CO_2 emissions for the building owners.

Home energy mobile app

Our **home energy management** mobile app engages users with its customised interfaces for stakeholders such as building users, **electrical vehicle** (EV) users, facility managers, and system operators. The design of the app includes the integration of various data streams and integration with a diverse set of algorithms. The app is compatible with market standards and other global market solutions. Its users can optimize their energy efficiency reduce energy bills and CO_2 emissions.

The app:

- simplifies the (interaction with) complex energy (flexibility) services from building and smart grid management platforms for users.
- provides, among other things, price-based notification, abnormal consumption alarms, and load shifting recommendations.

Target Users: Energy consumers / prosumers, building facility managers, campuses

Technological Readiness Level (TRL): 8

Smart storage solutions to unlock and manage building flexibility

The **smart storage solution** unlocks and manages building's energy consumption flexibility, either locally or by receiving flexibility requests from an external management system or platform like ebalance-plus. Locally, thanks to its own **Energy Management System**, it learns and estimates the **consumption and generation** patterns of the building, optimizing the charge and discharge profiles through the day, to get the most economic savings and self-consumption to the **prosumer**. In communication with the ebalance plus platform, it will be able to receive either price signals and flexibility requests, for either indirect or direct demand side management or flexibility services schemes.

This smart storage solution supports a great variety of use cases. Thanks to its state-of-the-art Energy Management System, it learns and estimates the consumption and generation patterns and uses these estimations to optimally plan charge and discharge through the day in order to get the most economic savings and self-consumption to the prosumer. It can also peak-shave, act as a reliable back-up or even follow commands sent to it by authorised parties. This last functionality renders the device easy to integrate into any third-party software, as being demonstrated in the ebalance-plus project.

Target Users: Aggregators, DSOs, Building facility managers

Technological Readiness Level (TRL): 7


Ampere Cloud
Smart batteries
ebalance-plus platform
«Store generated energy surplus to relieve the grid»
«Use stored energy because market prices are high»
Distribution grid
AMPERE ENERGY
UNIVERSIDAD DE MALAGA
ENFOR
SOFTCRITS

Smart Hub:
V2G, solar carparking, battery energy storage

Our **smart hub** is an integrated solar carpark with battery energy storage and Vehicle to Grid (V2G) electric vehicle charge management, delivering flexibility services.

Its **Unique Selling Point** is the use of innovative **Silicon Carbide (SiC)-based DC-DC V2G** chargers, which are based on DC/DC topology, and can thus be integrated in DC grids with PV systems and avoid non-beneficial AC conditions and eliminates conversion losses from conversion to/from AC.

The **value** of this solution lays in the integration of different components, but the components individually (e.g., the V2G DC/DC chargers etc.) can (and will) also be commercialized independently.

Benefits/Services achieved by the smart hub are:

- flexibility service for the distribution grid using EVs: overcoming grid constraints;
- enabling energy usage and supply flexibility to optimise energy costs in an environmentally friendly manner (optimise energy efficiency);
- avoiding conversion losses by improving power conversion efficiency;
- reducing grid connection costs;
- better energy management leading to benefits for both EV owners and parking lot owners.

Target Users: EV fleet owners, car park owners, aggregators, charge point operators, tertiary sector (e.g. hotels, universities, airports, etc.)

Technological Readiness Level (TRL): 6


Solar car parking
Direct Current-Direct Current (DC-DC)
Vehicle-to-grid (V2G) charger
Smart batteries
ebalance-plus platform
«Charge Electric Vehicle to optimise energy efficiency»
«Discharge Electric Vehicle because of grid constraints»
Distribution grid

Grid control and automation units

The **grid control** and automation units for medium (MV), low (LV) voltage grids, and distributed energy resources (DER), offer the Transmission System Operators (TSOs), Distribution System Operators (DSOs) and integrators an advantageous solution to support the increase of **renewable energy sources** (RES) penetration, seamless integration of field devices, backend applications, and end-users.

The **control and automation units** for MV & LV grids are based on a modular architecture and host enough processing power for edge intelligence with the goals to:

- increase the electric grid observability,
- increase the system's reliability and security
- exploit the available flexibility for the benefit of its users.

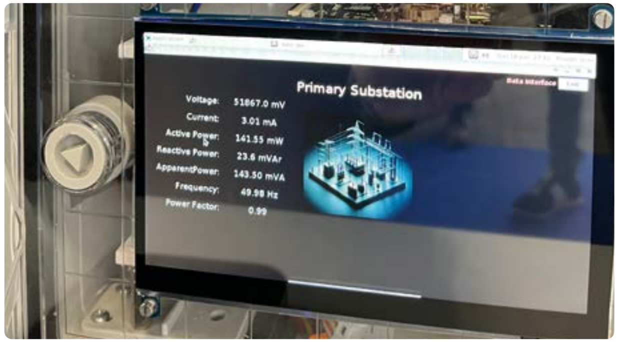
Target Users: DSOs, DER owners

Technological Readiness Level (TRL): 7

"Initially DSOs' interest in flexibility solutions was very localized, especially for entities with local or regional networks. However, due to the growing interest and deployment of distributed renewable energy and electric vehicle charging points, DSOs have reacted and considered solutions and approaches as proposed in ebalance-plus."

Juan Jacobo Peralta Escalante
Project Coordinator, CEMOSA


Balancing use of
Distributed Energy
Resources (DERs)
Management
units (MU)
Distribution grid
Getting real-time
info about the grid



In-lab emulator: security and safety for the grid

In the ebalance-plus project an **In-lab emulator** was build, which is a **scaled-down model of the power grid**.

The emulator is a modular approach designed in a form of connected blocks, attached to a tilting table to improve usability. In its current implementation there are 33 blocks that represent the primary/ secondary substations (PS/SS) and the prosumers (Pros). These blocks are equipped with touch displays to allow interacting with and observing their state. The **primary/secondary substation blocks** are mainly responsible for running algorithms that manage connection paths and respond to changes in the grid. The **prosumer blocks** contain a household simulator that helps to generate virtual resident behaviour and generates appropriate and physical consumption and production of electricity, depending on the set of chosen behaviour profiles.

Additionally, there are 12 blocks that represent the **transmission lines (TL)**, which transmit electricity between the other blocks. A transmission line provides the means to control the energy flow using the three relays and the three red-coloured diodes indicate the current state of each switch. Using this type of blocks it is possible to monitor energy flows and to influence the grid topology.

The emulator and its hierarchy of interconnected blocks allow to **recreate many advanced grid scenarios** that use different topology configurations, depending on the needs of the algorithm under test. It can be done in a **safe manner**, with low voltages and **without compromising components of an actual power grid.**

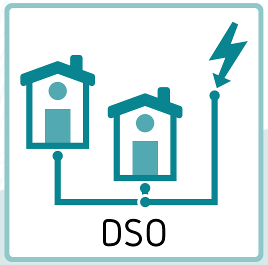
Target Users: Research institutes, Universities, DSOs, TSOs

Technological Readiness Level (TRL): 5-6

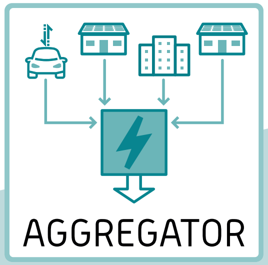
This solution allows researchers & innovators to define test conditions and scenarios that are hard and/or expensive to realize within a real energy network (shortcuts or cutting lines), but maybe even more important, it allows to define smart appliances that are far more advanced than any of those available on the market.

Added value for stakeholders

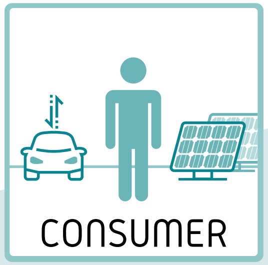
Ebalance-plus solutions provide benefits for different stakeholders:



Distribution System Operators (DSOs) will **not have to invest more** in the infrastructure. DSOs can use the existing flexibility to improve the **reliability** or under **resilience** scenarios. Example: establishing capacity thresholds.



Aggregators are enabled with an **Application Programming Interface** (API) to negotiate with customer's flexibility in **local flexibility markets**. The API looks for its customers and negotiates the flexibility with optimal costs.



Consumers will have **access to new services** and **more reliable electricity supply**. Consumers can use a mobile app to participate with **Vehicle to Grid (V2G)** in energy markets and account the flexibility as a commodity. Another mobile app can help consumers to participate with **smart home devices** flexibility in the energy market.

Wider system benefits

Impacts on the electrical system

Generation	Transmission	Distribution	Distributed Energy Resources (DER)	Consumption
• Decrease of fossil-fuel based generation (Except in times of major crises)	• Defer of new investments in infrastructure to host centralized Renewable Energy Sources (RES) farms • TSO-DSO interface for more efficient grid management	• Increase grid reliability • Increase quality of supply • Increase asset health • Low Voltage (LV) networks visibility	• Increase grid resilience • Lower technical losses (in Transmission & Distribution) • Decrease of curtailment • Provide grid flexibility	• Decrease of service interruptions

Key economic impacts

- **New cutting-edge products/services** offered developed by EU firms that enable more transactions on energy products (flexibility).
- **Increase competitiveness** of EU Small- and Medium Enterprises (SMEs) on a global scale.
- **Increase of self-consumption lowers energy bills**, additional income from participation in flexibility markets.

Key societal impacts

- **Increase in highly skilled jobs** (energy and ICT).
- **New knowledge** in innovation and research (user behavior), methods (control and optimization) and products (platforms, apps, management units).
- **Reduction of energy poverty** through self-consumption and communal practices.

Key environmental impacts

- **Reduction of emissions** through use of Renewable Energy Sources.
- **Transport and the use of energy:** Increase of decentralization, energy produced locally, reduction of technical losses.
- **Reduction of non-renewable energy sources.**

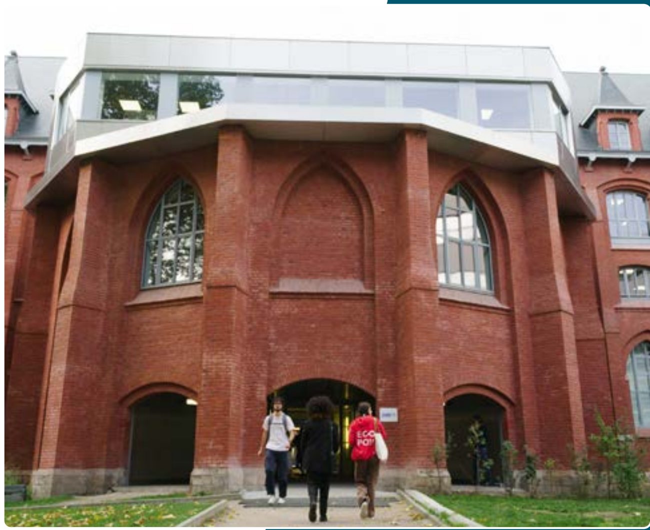
Demonstrations

Integrating and deploying flexibility solutions

DEMO: Université Catholique de Lille / JUNIA

Location: Lille, France

Building types: 19th century block of academic buildings



Final status:

- Deployment demand response services based on managing existing technical facilities
- Control of additional technical facilities (e.g. Heating Ventilation, Airconditioning) to be integrated in demand response services.

“Our aim is to achieve carbon neutrality for all our university buildings. We’re trying to use renewable energies and reduce our consumption as much as possible. So we have instrumented the various buildings to reduce our consumption, today we’re able to balance the constraints of the grid. When the network needs us to reduce energy consumption, we receive signals and we can either reduce or shift our consumption.“

Flovic Gosselin
LiveTree engineer IT developments
Université Catholique de Lille / JUNIA

DEMO: Università della Calabria

Location: Calabria, Italy

Building types: Laboratories, classrooms, administrative offices, library and student residences

Final status:

- Deployment of smart-storage units to increase the energy flexibility of two office buildings and a residential building
- Deployment of IoT devices and smart appliances to increase the SRI of residential apartments and manage electric loads.
- Deployment of management units to deploy ebalance-plus services.
- Increase distribution grid reliability with additional monitoring and control of primary and secondary substations.

"The end user makes the difference in achieving the 2050 targets set by the European Community. Only the change of habits will make the difference; so first of all by reducing the consumption and then by trying to meet this consumption with the energy production by renewable sources. That is why users' needs and concerns about energy use and innovation are also taken into account in the ebalance-plus project."

Prof. Anna Pinnarelli
Dept. of Electrical Energy Systems,
Università della Calabria

DEMO: Universidad de Málaga

Location: Málaga, Spain

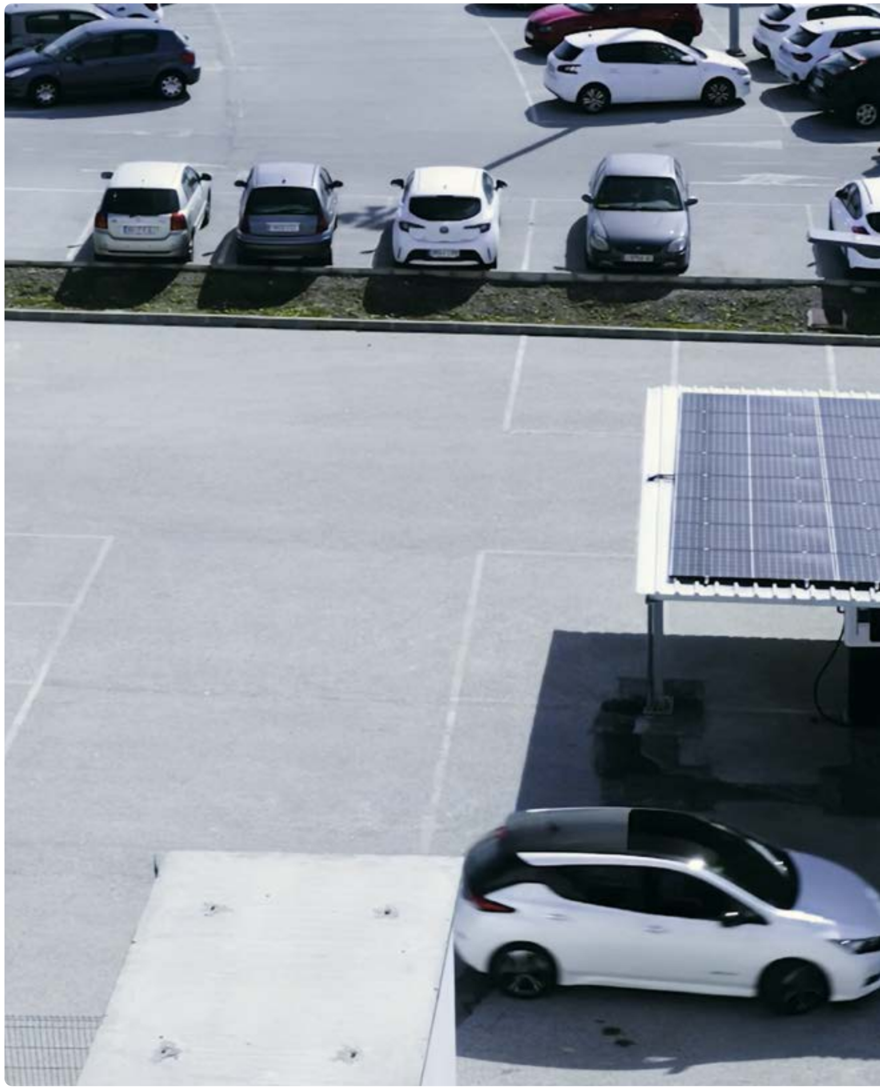
Building types: Faculties, research centre, sport centre

Final status:

- Deployment of 2 smart-storage units to increase the energy flexibility of buildings.
- Deployment of management units to deploy ebalance-plus services.
- Deployment of high-efficient DC-Network with PV canopies, external Battery Energy Storage and Vehicle to Grid (V2G) charging points

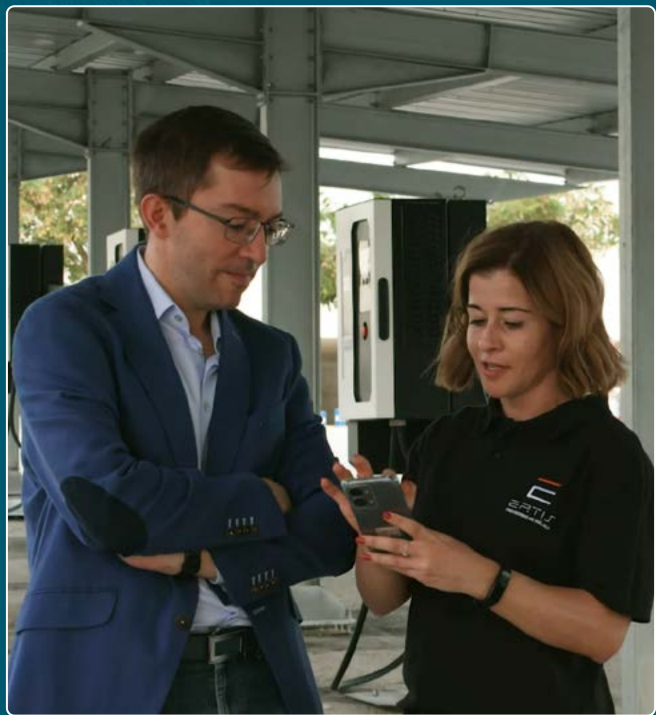
“The combination of power conversion technologies with flexibility services has enabled the integration of bi-directional charging devices (V2G) for electric vehicles whose main energy source has been solar photovoltaic (PV). In addition, the creation of a Direct Current (DC) network for this purpose has made it possible to reduce energy losses and serve as an example for future installations, both in terms of experience and the results obtained.”

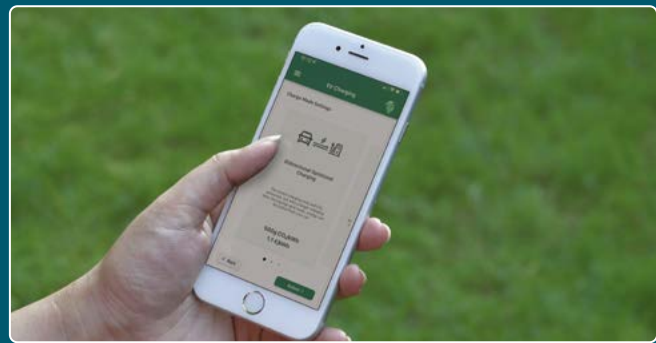
Juan Jacobo Peralta Escalante
Project Coordinator, CEMOSA



Energy app for EV users

The V2Go Mobile app served as an interface of ebalance-plus smart charging technologies for Electric Vehicle Users. With the V2Go App, users can use and manage the Electric Vehicle charging stations. It allows three charging modes with progressively lower prices: directly charger, flexible (that can be interrupted temporary) and Vehicle to Grid (V2G), guarantee the target energy in the departure time thanks to the optimization algorithms.





Some key demonstrator achievements

- **16 secondary substations** have been monitored.
- Energy prediction at local level have been improved between **26% - 81%** (depending on the building).
- On average (at the University of Malaga & Calabria) peak load reduction has been higher than **40%** (minimum capacity deployed by BESS in demo sites)
- Real deployment of **10 Vehicle to Grid (V2G) charging points** with **Photovoltaic (PV) generation and storage** have been demonstrated the reliability of combining these technologies to guarantee that most of the Electric Vehicle (EV) energy are provided by local Renewable Energy Sources.

Demonstrator Conclusions

The experience in the University of Málaga, University of Calabria and JUNIA demonstrates that **integration and deployment of flexibility solutions** entails a **significant economic and technical investment** that is sensible if the released flexibility can offer **Return of Investment (ROI) less than 12 years** (based on kWh/year released in flexibility and balancing markets).

Therefore, future energy management systems of buildings and IoT devices should be **smart-grid ready** (e.g., communication protocols, data exchange standards...) to motivate the participation of end consumers in flexibility markets. Otherwise, the investment needed will remain precluding the aggregation of this consumer that, at the end, constitutes the 40% of EU final energy consumption.

Power to heat in the Danish energy system

Demonstration in Denmark

Interview with Prof. Henrik Madsen (Technical University of Denmark)

In Denmark, around 60% (2022) of the electricity is coming from fluctuating renewables, mostly wind, which means that from time to time, we need to store the energy in a sustainable way. For the ebalance-plus project, we selected **15 Danish summer houses with swimming pools** and a year-round base load to ensure the water temperature remains above a certain threshold. These swimming pools – with an impressive amount of water that they store – offer an interesting thermal storage possibility, providing flexibility to the grid and at the same time lowering the carbon footprint of the summer houses.

From your point of view, what is the value of the ebalance-plus?
For me, the ebalance-plus project is extremely important because of the **focus on the end-user side of the energy system**, dealing with the **demand response technology**. Right now, the energy system is undergoing a transformation from a centralised system, where the flexibility was at central power plants to a decentralised system, where we don't have these massive power plants and the flexibility has to be on the end-user side. And this is exactly what the project is focusing on. Besides, it is not only the technology, but also the people that we are dealing with here: We investigate the incentives

Foto: Hanne Kokkegård, DTU Compute

"I believe that in order to ensure that the end users can become a part of the high-level electricity markets, we need a type of hierarchical system, like the one in ebalance-plus."

Prof. Henrik Madsen
Technical University of Denmark

for people to participate in this energy transition and provide flexibility. And this is crucial.

Move forward to 2027: How does the energy market look like in Denmark?

In Denmark, around **60% (2022) of the electricity** is coming from **fluctuating renewables**. Going beyond this mark will be a huge challenge, which requires us to **unlock a lot of flexibility**.

Since we have a cold climate in Denmark, we need heating 6-7 month of the year. To a large extend the heating relies on district heating systems (which involves a lot of water in pipes). Now, in the ebalance-plus Danish demo site, we tested solutions based on water in swimming pools and use of heat pumps. Without going into too many technical details, I think the technology can more or less be copy-pasted from the ebalance-plus demo site to the Danish system with its district heating system. So that's my expectation and hope.

What is unique about the ebalance-plus project compared to similar projects and solutions?

The unique characteristic of the ebalance-plus project is its **strong focus on the demand side**. And what is important, the focus is both on the technology, which allows to achieve flexibility and resilience, as well as on the user engagement.

Furthermore, this project is important to us because **it gives us a possibility to further develop and test our Smart-Energy OS**, which is characterised by the **indirect control approach based on one-way communication of prices to the end-users**, and a more elaborate description of the flexibility using the so-called Flexibility Function.

Another important aspect is the fact that, the Danish ebalance-plus pilot zooms in on the capabilities of the buildings to provide grid services for the DSOs.

What is the biggest challenge of the project?

I think, **the biggest challenge is to link the flexibility on the end-user side to the markets**. The current conventional market thinking is too simple. If we want the new solutions to be accepted and used, **we need to create new mechanisms to link the flexibility at the end user side with a high-level electricity market**. And that's a challenge.

What has to be done to integrate the end users into the high-level electricity market?

I believe that in order to ensure that the end users can become a part of the high-level electricity markets, we need a type of hierarchical system, like the one in ebalance-plus. Probably we also need specialised technical low-level aggregators, which could take advantage of expertise in certain segments, like summer houses, wastewater treatment plants, and supermarkets.

Scan for further related reading material


ebalanceplus

Societal Impact

Obstacles to transformation in the electricity sector

Article by Mara van Welie (ESCI)

The success of technological innovation projects does not just rely on the development of new technologies. Successful implementation of new technological systems such as the ebalance-plus energy balancing platform requires transformation in multiple dimensions. **We identified a broad range of obstacles that flexibility solutions currently face in the European electrical power sector.**

Ebalance-plus is part of a larger transition process that is currently taking place: **the decarbonisation of the electricity sector**. Changes needed in the electricity sector are inherently "*socio-technical*": technological innovation must go hand-in-hand with necessary "*social*" transformation processes in regulatory frameworks, consumer behaviour, culture, financial structures, capabilities, business models, and markets (see Table on opposite page).

For example, **the change from large-scale centralised power plants to decentralised technologies** based on renewable energy asks for **new skills and capabilities** of installers and maintenance technicians. Next, **the electricity market needs to be restructured**, as more and more smaller players such as aggregators will enter the market and sell energy flexibility of households. This in turn asks for **changes of regulatory frameworks** at European and Member State level that have so far regulated big energy suppliers as main market players. **Finally, cultural and behaviour changes from end-users** are also necessary, as they need to change from passive consumers to actively responding to dynamic electricity tariffs to help balancing the grid.

As changes in all these dimensions is a complex and contested process that takes many years, technological innovations such as those developed in ebalance-plus, face many obstacles in their implementation that are not just technical.

Within the ebalance-plus project, several activities ensure that the project partners take these barriers into account in the development of the solutions.

Dimension	Conventional fossil-fuel based electricity sector	Changes towards a decarbonised electricity sector
Energy supply	Large energy producers	Increasing number of small prosumers
End-users	Passive consumers	Prosumers participating in markets
Technologies & infrastructures	Centralised & large-scale, little use of IT in the electricity grid	Decentralised & small-scale, use of IT to create a smart grid
Market structure	Suppliers sell to consumers	Plurality of stakeholders entering the markets, consumers sell energy flexibility via aggregators
Regulations & standards	In line with centralized technologies and infrastructures and large market players	Regulations and standards need to adapt to the inclusion of DER, use of large amounts of data, and variety of small market players
Financial	Investments and tariffs based on large-scale power production and centralised infrastructure	Investments in renewables; new tariffs structures needed that value energy flexibility
(Technical) capabilities	Based on current system	Increasingly IT and communication skills required
Culture	Trust in the large centralized system based on fossil fuels and large players	Sustainability and decarbonisation is important, small-scale customers can be active players in the electricity sector

First, IPI researched end-user behaviour and developed propositions to motivate users engage with the ebalance-plus flexibility solutions. Second, barriers for the optimal deployment and operation of business models based on the project solutions are analysed as well.

The results of the obstacle to innovation analysis conducted in the ebalance-plus project can be categorised into four overarching themes: 1) communication and data, 2) energy flexibility assets, 3) DR, aggregation and flexible consumers, 4) DSO deploying flexibility.

Below we provide a summary of obstacles in the four focus countries of the ebalance-plus project (Spain, France, Italy, and Denmark) and the UK, which has a high potential for the role out of flexibility solutions.

The largest differences regarding obstacles between countries are related to **Demand Response and aggregation** participation in **electricity markets**.

Category	Obstacle	ES	IT	FR	DK	UK
Communication & data	Lack of internet access	2	2	2	1	1
	Smart readiness of buildings	3	2	2	1	2
	Smart meters	1	1	1	1	2
	Metering data access for third parties	3	3	2	2	2
Energy flexibility assets	Electricity storage	2	2	1	2	2
	V2G	2	3	3	1	2
DR, aggregation and flexible consumers	Demand response and aggregation	3	2	1	2	1
	Dynamic tariffs	2	2	2	2	2
	Flexible consumers (self-consumption)	2	2	2	2	2
DSOs deploying flexibility	DSOs incentives to use flexibility	3	2	1	2	1
	Local flexibility markets	2	3	2	2	1
TOTAL SCORE		**25**	**24**	**19**	**18**	**18**

Generally, the implementation of the Clean Energy Package is lacking behind and there are large gaps between the European framework and the national realities. Regulation related to **independent aggregation** and (small-scale) demand response needs to be further developed in most of the analysed countries. The possibilities of Demand-side Flexibility to participate in the electricity markets is highest in France and the UK, followed by Denmark, and lacking most behind are Italy and Spain, but in both countries, legislation is changing rapidly. DSOs have more incentives and possibilities to deploy flexibility in the UK than in the other countries.

In sum, at the level of Member States, Spain and Italy have the most obstacles for the ebalance-plus flexibility solutions. France has fewer obstacles, and the least obstacles are found in Denmark and the UK. However, important to note is that not all obstacles have the same weight.

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Attitudes towards energy saving in Denmark, France, Italy and Spain

Research by Jaroslaw Kowalski & Zbigniew Bohdanowicz (NIPI)

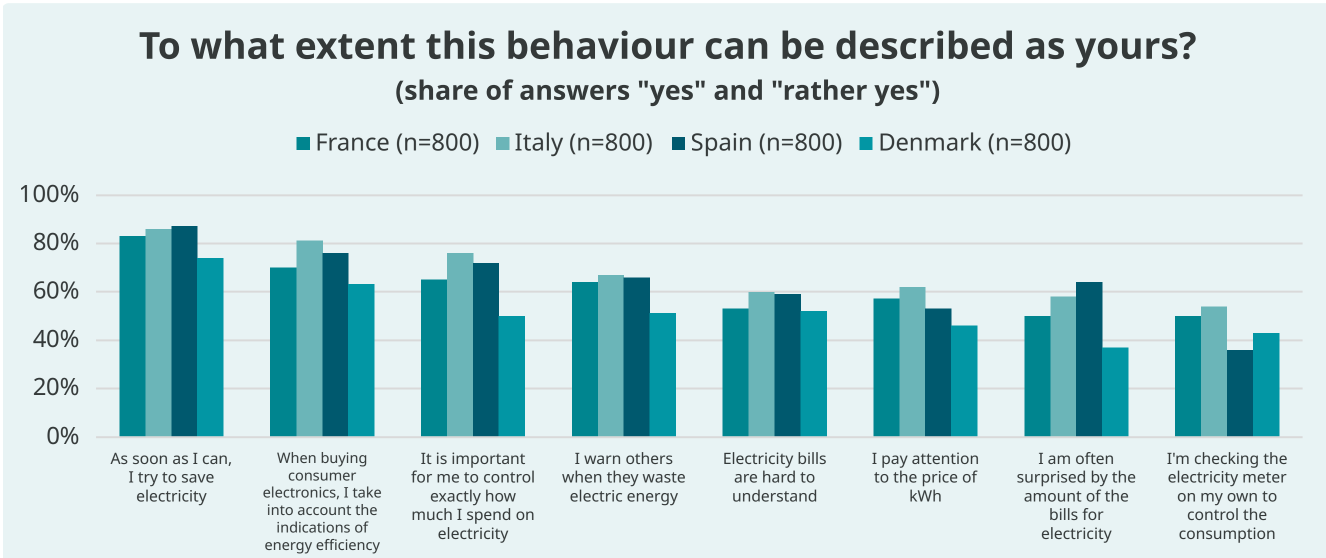
To a large extent, the real performance and success of technological systems depend on the users, their behaviour and willingness to change their established routines. Consumer resistance can delay or even obstruct the implementation of innovative technologies and measures, if human factor is not considered.

ebalance-plus project conducted a study to assess the motivation of people to reduce energy consumption and detect main barriers to energy saving in Denmark, France, Italy and Spain, the four countries where the ebalance-plus pilot sites are located. The examined countries are very diverse in terms of the property ownership structure, the number of people in an average household, the level of income and the equipment of the households with devices that increase energy efficiency.

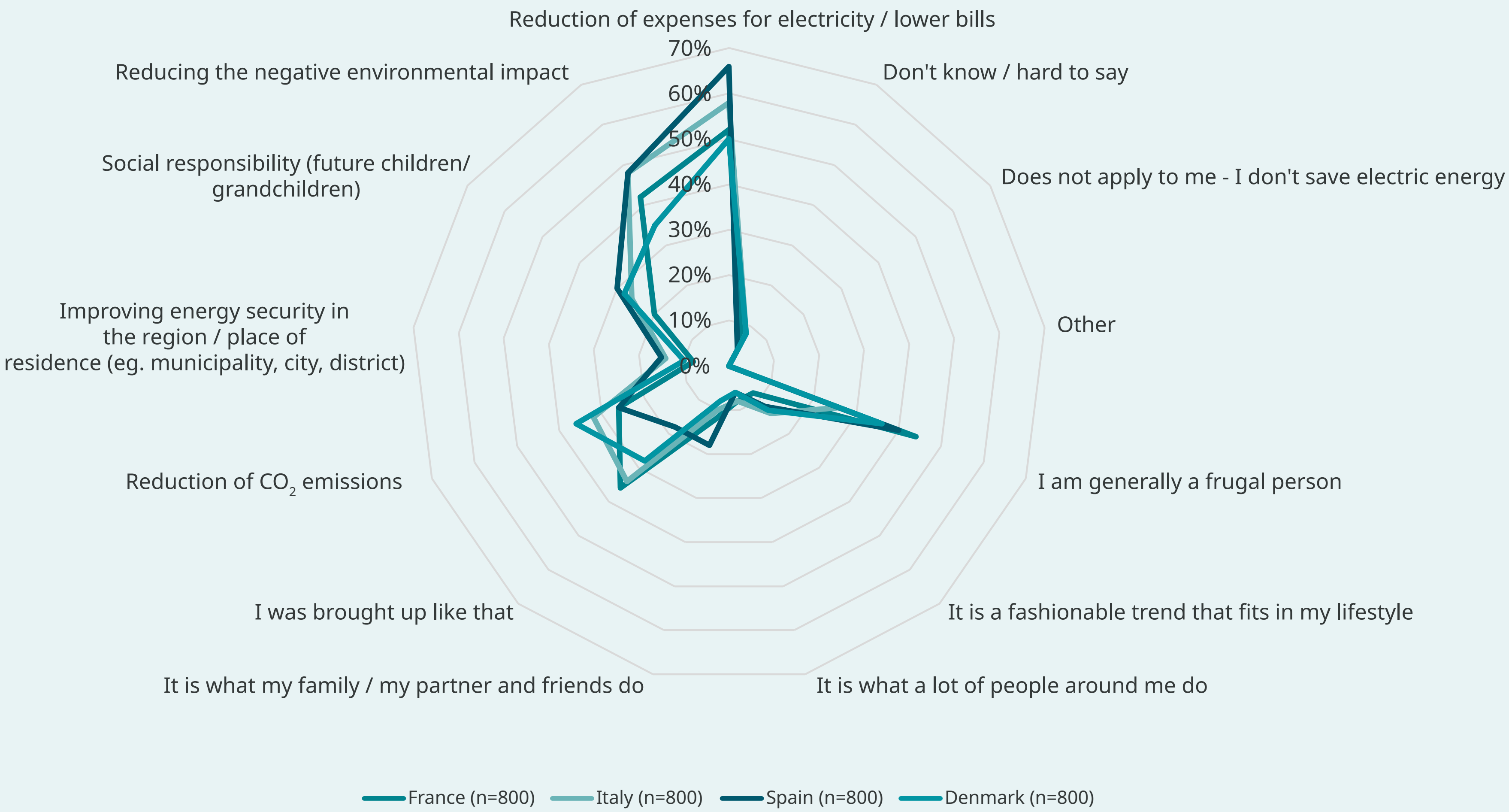
Attitudes Towards Using and Saving Energy

More than 80% of energy consumers in the countries surveyed declare that they try to save energy, whenever they can, they take into account the energy efficiency indicators of the electronic equipment and control their spending on energy.

Italians seem to be the most concerned about saving energy (they check indications of energy efficiency on purchased products, pay attention to the price of kWh and other). The least attention to energy bills and the need to save energy is paid by the Danes. The reasons for that should be checked in a subsequent study; one of the hypotheses is that Denmark is already very advanced in terms of usage of the renewable sources of energy and perhaps the Danes believe that further measures are no longer needed. Another explanation may be



Question: Please mark up to three reasons to save electric energy that are applicable to you.



that, given the relationship between the electricity cost and earnings, in Denmark electricity is the most affordable of the four countries surveyed, so the potential energy savings are the least significant for Danes.

The main factor influencing the willingness to save energy is financial; ecological considerations come second. This pattern mainly refers to France, Italy and Spain. In Denmark, environmental considerations seem to be less important, and the attempt to reduce the bills is explained by the general frugal attitude. In all countries the tendency to indicate environmental considerations increases with education.

When it comes to the disincentives to save energy, the answers vary significantly from country to country. In case of Spain, we can clearly see lack of information about energy saving measures. Interestingly in Italy a big number of respondents stated to be saving energy whenever they can, while in other countries this answer was rarely selected.

Role of Social Network

As for the question of whether friends of the respondents take action to reduce energy costs, the percentage of respondents in whose case at least some friends or family members take such action is the highest in Spain and Italy. These are also the countries where the smallest group of respondents indicated that they do not consider taking any actions to reduce cost of energy. **Own actions go hand in hand with actions in the immediate environment, as well as interest in whether such actions are taken by family and friends.**

In all countries surveyed, more than half of the respondents talk about saving energy with other people, the most in Spain (70%) and the least in France (55%).

Most often, people with higher education and rather better financial situation talk about saving energy, more often from big cities than from the countryside. In all countries, these are more often prosumers than not prosumers, those who plan to buy or expand energy production facilities, but also, interestingly, among energy producers, these are more often unhappy with energy production facilities, the effect being most visible in France, while the opposite tendency is in Spain).

The discussions about saving energy are most often held with members of the household (in particular in Spain and Italy), spouses/partners and closest friends, and rarely with salesmen/ technical advisors. Such conversations are, therefore, encouraged by strong ties and frequent contact.

It can be assumed that **talking about saving energy is an important form of searching for information on the subject.** So, social networks can be seen as an important channel through which energy saving can be popularised.

The quantitative survey was carried out in June 2020, in the four countries where the ebalance-plus pilot sites are located: France, Spain, Italy and Denmark. The data was collected by an online questionnaire, self-filled by respondents (CAWI), on a random stratified sample (by gender, age, city size, region, and level of education). People who are responsible or co-responsible for paying electricity bills or purchasing electrical appliances in the household were qualified to participate in the survey. A total of 3200 people took part in the survey, 800 in each country. The sample was gender-balanced (51% women and 49% men), people aged 18-65 years were surveyed (average age in the sample was 42 years).

User engagement strategies

Research by Jaroslaw Kowalski & Zbigniew Bohdanowicz (NIPI)

The successful implementation of technological innovations at universities is a process that must consider both aspects: the **technical** and the **social** one. If universities are treated as socio-technical systems, they appear as complex entities in which technological elements, such as equipment, functionality, and software, are closely linked to social conditions. It is important that the motivation and involvement of ebalance-plus users is considered in the context of their own perceptions of the system.

Systems like ebalance-plus have **impact on electricity end users**, such as students and academic and administrative staff at campuses who can, to some extent, change their **energy consumption habits**. In the classical paradigm, electric **energy is a background service** that is used when needed. Reflexivity is hardly present in this case – users are limited to deciding whether to switch on certain appliances and consume energy.

In the case of systems where consumer decisions hinge on flexibility, digital devices may assume a certain degree of autonomy. **The new paradigm of electric energy use** marks a **change** for end consumers, transitioning from a status quo in which assessing decision benefits and optimality is unnecessary to a scenario **demanding proactive decision-making and cognitive effort**. It might also entail reduced comfort.

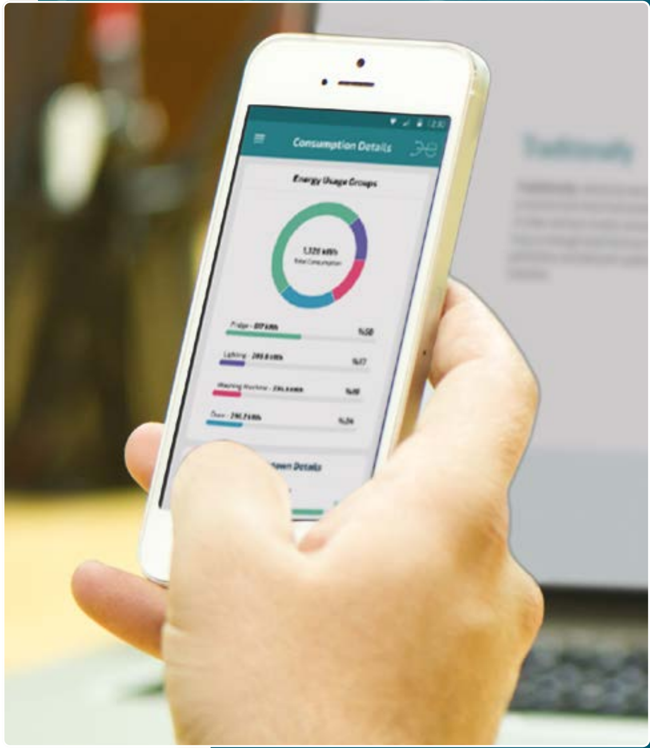
When facing decisions, such as whether to actively use the functionalities tested within ebalance-plus, users are likely to adhere to their customary behaviours to minimise the cognitive load. By default, people are inclined to persist in working within an established paradigm. When electric energy is not noticeably cheaper, individuals need **different kind of encouragement** to sacrifice some of their autonomy. When implementing ebalance-plus functionalities at university campuses, the challenge is to convince the users of the system functionality to **surrender their autonomy to the automated system**.

101 people participated in interviews in the ebalance-plus project.

The **ebalance-plus approach** to user engagement focussed on embedding **values** (related to nature, energy efficiency, benefits for the planet and future generations) and **intrinsic motivation** (services as a stable and persistent source of energy use behaviour) need to be triggered.

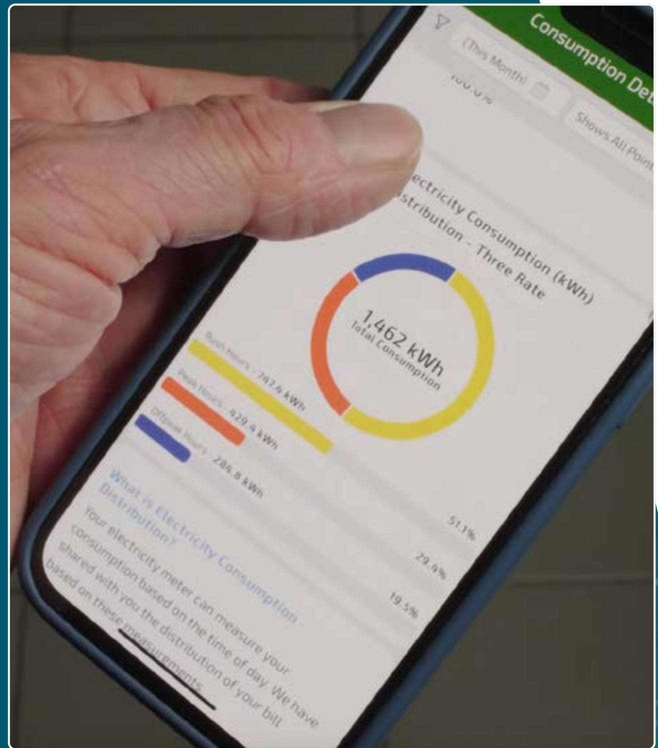
This approach has been tested mainly in the University of Calabria and the University of Málaga, with the following use cases:

1. **Bi-directional charging of electric cars** (**Vehicle-to-Grid**) – enabling the system to draw energy from car batteries (University of Málaga)
2. **Setting the range of temperatures** at which heating and air conditioning can operate in students’ rooms in a dormitory, instead of rigidly sticking to one temperature (University of Calabria);
3. **Actively using smart appliances**, such as for example dishwashers in dormitory rooms; in other words, setting a range of times when pre-loaded washing machines or dishwashers can be activated by the ebalance-plus system (University of Calabria).



The standard graphical interface of ebalance-plus mobile app. Its colour scheme creates a neutral context. its purpose is to convey information in a simple, straightforward form.

The eco graphical version. It is functionally identical to the standard version. A green colour scheme and a leaf symbol are incorporated to create an ecological context and trigger relevant associations in its users.



Some of the **lessons learned:**

- The challenge of building engagement is different in the case of building impact for students and in the case of building impact for academics. **Students**, mostly young people starting university and beginning dorm life, are relatively open to change and accept many things on campus as part of the 'student package' or the 'dormitory resident package'. Engaging teachers and academics is a more difficult task. This group of users includes adults with an established life situation and certain habits and expectations of comfort. It is more difficult to build their long-term commitment, fears of reduced comfort or self-efficacy and old habits being major barriers.

- **Electric car owners** revealed their concerns over the use of V2G stations: Unlike combustion engine cars, electric vehicles (EVs) reduce the autonomy and freedom of users due to the need for frequent battery charging, the lengthy charging process, and the serious consequences of discharged batteries. A fully charged battery not only elevates users' agency, but also increases the driving range and overall mobility. All these factors make users constantly dependent on charged batteries. The Vehicle-to-Grid (V2G) concept seems to compound this concern, potentially adding to the disadvantages of electric car ownership. Another obstacle that might prevent the adoption of the V2G technology is its complexity. Despite these doubts, the current **declarative willingnes**s to use the charging stations at the campus of the University of Málaga is high (most probably also because charging electric cars is free).

- When communicating the V2G technology to potential users, it is important to **consider the term 'Vehicle-to-Grid'**. The technical nature of this term may lead users to believe that the use of vehicle batteries in this mode (battery-to-grid energy transfer) will be frequent and intensive.

- It is worth considering **hiding the real-time display of battery charge and discharge status**, such as the one used in a mobile app. Judging by the descriptions of concerns over discharging batteries, it can be inferred that watching the battery discharge causes anxiety.

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> **Energy-efficient technology is the key! But technology alone is not enough.**

Ebalance-plus serious board game

Game developed by Benoît Durillon (Junia)

Net zero emissions in 2050 cannot be achieved without people's consent and active support. Some of these are one-off events, a mix of low-carbon technologies and people's engagement, such as buying an electric vehicle or insulating an attic.

However, behavioural changes are also needed. They are particularly important in richer parts of the world, where energy-intensive lifestyles are the norm. With the development of a serious board game the ebalance-plus team focusses on energy consumption in our daily life at home.

In our ebalance-plus game, the player is asked to use exclusively the renewable energy, produced locally that same day. For all chores and other activities at home the energy should be used sparingly and smartly. Of course, the refrigerator runs 24 hours a day, but the washing machine and the dishwasher are programmable. If things get tight, one can fall back on the energy in the battery of the electric car.

The players quickly realise: energy is not infinite. With a good strategy and planning, a look at the weather forecast and a battery storage system, it is possible to manage our consumption efficiently.

Scan to learn more about the ebalance-plus serious board game

Behavioural change

Behavioural change refers to the process of modifying an individual's actions, attitudes, and habits. In terms of energy savings this includes cycling or walking instead of driving, turning down the heating and taking holidays closer to home.

Serious board game

A serious board game is a game designed for a primary purpose other than pure entertainment. In serious games a serious storytelling is applied. The game emphasises the pedagogical value of fun and competition by simulation and a thoughtful progress.

European women in STEM

Article by Sabine Alexandre-Klein (ESCI)

9 women, one message: "We want to give girls and women the confidence to succeed in Science, Technology, Engineering and Maths fields".

Ebalance-plus produced an interview series with female leaders from **Science, Technology, Engineering and Mathematics (STEM)** fields, aiming to be a role model for girls and women.

Engineers design and develop valuable technologies and machinery that advance our society and improve our way of life. But even in 2024 women are still underrepresented in engineering and computing in the EU – depending on the country, the figures vary from **15.5% to 41% of female employees**.

ebalance-plus has **many successful STEM women** in leadership positions. You can meet 9 of these women in our interview series, learn more about their careers, the support they received (or not), the obstacles they had to overcome (or not) and much more.

"My father is a mechanical engineer, so I was exposed to that world from a young age. Many have attempted to change my career path, believing engineering to be a male-dominated profession and women incapable of such work. However, my father has been an exemplary role-model, inspiring me to pursue a career in mechanical engineering."

Tuğçe Aker
product manager from Reengen
based in İstanbul, Türkiye

First episode:

- Dilara Goker, Reengen (Turkey)
- Noemi Jimenez Redondo, CEMOSA (Spain)
- Julia Robles, Universidad de Málaga (Spain)

Second episode:

- Gloria Calleja-Rodriguez, CEMOSA (Spain)
- María del Carmen Bocanegra, CEMOSA (Spain)
- Mara van Welie, ESCI (Germany)

Third episode:

- Pilar Rodriguez, Universidad de Málaga (Spain)
- Anna Pinnarelli, Università della Calabria (Italy)
- Tuğçe Aker, Reengen (Turkey)

Scan to watch all three episodes of our "Women in STEM" series and discover related material

Demand side flexibility business models for smart grid solutions

Article by Georgios Stravopodis (ESCI)

The ebalance-plus project from its conception up to its implementation focuses on one the most challenging issues of the energy transition: how the trends of energy decentralisation, decarbonisation and digitalisation can leverage flexibility for the benefit of the system, environment, economy, and society.

In the design of the technologies and algorithms the developers have considered the different actors and stakeholders for the future exploitation, such as **consumers, aggregators, energy retailers and DSOs** among others. For all of them, there are specific solutions that are useful with added value and, although they need a higher level of development (the project reached in general a Technical Readiness Level 7), most of them can enter the market now.

To support the project´s complex technological solutions uptake by relevant stakeholders, **4 demand side flexibility business models** (BMs) were developed based on the ebalance-plus platform and its capabilities (see opposite page).

As the business models show, **energy retailers** and aggregators are the key important stakeholders to **adopt and commercialize the ebalance-plus solutions**. These actors are in a great position to offer the flexibility to the local markets.

Energy flexibility - BM1

Demand response type: Implicit

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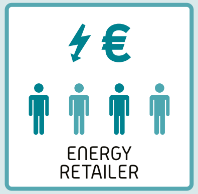

Offered to:

(All buildings)

The retailer sends price signals to its customers for peak saving or load shifting in exchange for lower bills.

Energy flexibility - BM2

Demand response Type: Explicit

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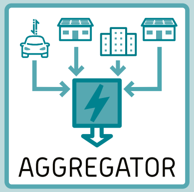


Offered to:

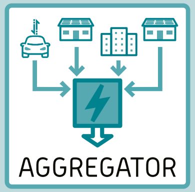
(Mainly residential)

The aggregator bids the flexibility offered by customer resources to markets and they receive direct payments.

V2G - BM3

Demand response type: Implicit & Explicit

Provided by:



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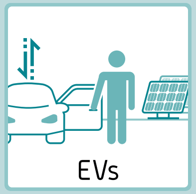


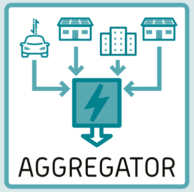
(All buildings)

The aggregator can bid the flexibility offered by EV owners (fleets) to markets or send price signals for load shifting (charging in off-peak hours).

Non-frequency ancillary services - BM4

Demand response Type: Explicit

Provided by:



Offered to:

(All buildings)

The aggregator provides non-frequency ancillary services (NFAS) to local flexibility markets facilitated or operated by the DSO to increase its network stability and reliability.

Scan for further information

Future outlook & reflections

Ebalance-plus came to an end, but efforts to develop and deploy energy flexibility, reliability and resilience solutions will continue. From the ebalance-plus perspective, we share some reflections on remaining challenges and what different stakeholders can do, or need, to accelerate the use of energy flexibility in power grids:

- **DSOs** still have a number of real problems; they need more visibility in their grids and DER management.
- **Energy Management Systems** and electric devices are not ready to manage flexibility: interoperability and standards are needed.
- **Aggregation** and optimisation are crucial, but we do need to raise **customer awareness**. (Raising customer awareness does not mean creating new problems for users!)
- **Energy retailers** could integrate flexibility schemes in the energy bills.
- **Technology developers** could develop algorithms that are more tailored to each customer profile.
- The **Electric Vehicle Industry** need to increase efforts to convince EV users of the benefits of vehicle-to-grid services.
- **Users/consumers** could benefit from additional applications (apps) giving hints on how to behave to save money and become more energy savvy.
- **Business models** need to include quantified value propositions to users/customers.
- There is still a need for **new regulations**/new energy acts, especially for new local flexibility-based markets.
- **Energy investors** would need to put money in new energy storage systems to balance the grid and phase out quicker fossil fuels.

Ebalance-plus Core Team

Who are the people behing ebalance-plus

The project brought together 15 entities – SMEs, research centres and industry representatives – from Denmark, France, Germany, Greece, Italy, Poland, Portugal, Spain, Turkey and the United Kingdom.

Meet our team of researchers and experts.

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In memory of our colleague and friend Jaime Chen.

This project would not have been the same without him.

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