Pilots Results and lessons learned from the implementation of PHOENIX solution

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The building sector is responsible for a significant amount of energy consumption and greenhouse gas (GHG) emissions. In existing buildings, the monitoring, control, and optimization of energy consumption will have a critical role in the coming years to improve energy efficiency and to reduce GHGs. Considering goals, the recent regulations established by the European Council (EC) in October 2023, adopted a minimum of 49% share of renewable energy in buildings by the year 2030 [1].

The PHOENIX project proposes a novel solution that aims to integrate existing legacy building systems and equipment into a scalable and connected energy management system, called the PHOENIX platform. The solution equips standard buildings with new services that optimize energy consumption, reduce costs, and improve user's comfort. In addition, the conjunction of them makes the building an active agent that can now interact with the grid to avoid peaks and other undesired situations (such as high emissions times or high energy prices periods). The proposed solution was implemented in five real demo-sites, in which smart devices were integrated into the PHOENIX platform together with legacy equipment that was upgraded. All allowed the monitoring and actuated the existing legacy equipment.

A key takeaway of the implementation process in the demo-sites is that the energy management upgrade obtained by the roll up of the PHOENIX solution, both in terms of legacy devices integration and energy services implementation, significantly increased their Smart Readiness Indicator (SRI) score. The SRI score increased - using the detailed calculation method as provided by the EC's guidelines [2]- by 23 percentual points in average.

A brief presentation of the pilots and their main achievements using PHOENIX solution is presented here along with the lessons learned from the processes of integration and services implementation.

Pilot Case – UMU

The University of Murcia (UMU) pilot is in the southeast of Spain, in Murcia, at the campus of the University on a three-floor building called Pleiades. The building is used for offices, laboratories and research, and has a space serving as library. This pilot's objective is to achieve improved energy management (as presented in table below) while maintaining the comfort of the occupants. Table 1 shows the smart services that were implemented to achieve the objectives of the demo-site.

Table 1 Pilot case UMU- implemented services

Pilot's requirements	Services implemented to address requirement
Optimisation of peak power demand	DR strategy for flexibility extraction (Tariffs scheme) DR strategy for flexibility extraction (Renewable scheme)
Smart thermostatic control based on crowdsourcing	Crowdsensing service
Identification of optimal use times of EVs, cooling and heating, and other thermal appliances.	DR strategy for flexibility extraction (Renewable scheme) Ventilation control DR strategy for flexibility extraction (Tariffs scheme) DR strategy for energy saving
Optimisation of generation – consumption – storage based on energy market, weather forecasting and consumption regimes.	DR strategy for flexibility extraction (Tariffs scheme) DR strategy for flexibility extraction (Renewable scheme)

To verify the effectiveness of PHOENIX solution in UMU pilot case, seven KPIs were established and assessed. A description of the KPIs can be found in the "KPIs Glossary" at the end of this section, while Table 2 displays the set targets and the calculated values of the KPIs during the implementation of services.

Table 2 Pilot case UMU KPIs- presentation

KPI	Target	Measured values
Energy Performance Measured	90%	100%
Load and demand shifted	15%	31%
Peak load reduction	20%	24%
Energy cost reduction	18%	36%
Energy savings	15%	35%
Registered users	100	155
Investment in sustainable energy	n/a	1.2M €

In Table 3 the SRI score prior and after implementing the PHOENIX solution was calculated using both methodologies found in EC's official technical report [2]: the full calculation methodology, where all 54 listed services are evaluated (regardless of their applicability on the pilot) and the normalized calculation methodology, where only the services that are present in the building are evaluated.

Table 3 Pilot case UMU - SRI calculations

Building type	Climate zone	Score prior PHOENIX		Score after PHOENIX implementation	
		SRI full	SRI normalised	SRI full	SRI normalised
Non- residential	South Europe	8%	12%	42%	63%

Key lessons learned in UMU pilot case

- It is vital to carry out a **comprehensive assessment of existing hardware** prior to implementation of interventions. Equally important is a detailed planning to ensure that experiments are conducted within the specified timeframes and that actions are carried out effectively. This approach minimizes disruptions to operations and optimizes the chances of achieving desired outcomes.
- **Close monitoring of communication** with the gateways is mandatory, especially when they control critical subsystems such as ventilation. By keeping an eye on these gateways, problems can be addressed immediately, and the smooth operation of vital systems is ensured.
- In some cases, although the intention may be to centralise intelligence in services deployed on the platform, it is advisable to retain some **control over the gateways** (edge computing). This is particularly relevant for modules that aggregate multiple signals. Such an approach helps preventing major problems when temporary connectivity issues arise, ensuring that systems can react in real-time to alerts, regardless of platform communication status.
- It is recommended that a mechanism should be provided, where possible, to **convert actuator control to local "manual mode"**. This feature facilitates maintenance actions and allows to deal with situations where the platform encounters unexpected problems (such as implementation "bugs" or communication problems). In addition, the platform should be able to detect when control has been switched to "manual mode" to maintain situational awareness.
- **Effective communication with the grid** and flexibility negotiation requires a common and well-understood technical language that enables all involved parties to comprehend the information being exchanged.
- The development of a software component that provides **a standardized interface between a smart grid device and the platform** has been instrumental in addressing the challenge of needing many queries to explore context information stored in platform.
- A comprehensive and robust **modelling of contextual information is essential** for creating versatile and flexible services that can be used in a variety of buildings, devices, or assets.
- There is **lack of information and awareness surrounding the SRI**. This knowledge gap poses a significant challenge, particularly in the integration of external developers into the platform for the creation of SRI-related services.

Pilot Case – KaMa

The Kama demo-site is in Thessaloniki, Greece, and is a complex of eight 80-square-meter apartments owned by the Greek Army. All apartments are occupied by 27 tenants, and the main objectives at the beginning of the project were the enhancement of building's energy efficiency, the reduction of energy costs in facilities, and the improvement of occupants' quality of life and comfort. Table 4 shows the smart services that were implemented to achieve the objectives of the pilot.

Table 4 Pilot case KaMa- implemented services

Pilot's requirements	Services implemented to address requirement
Energy savings on site	Black-out support Simulated dynamic pricing
Flexibility for the grid and storage	Simulated dynamic pricing
Self-Generation	Simulated EV charging Black-out support
Comfort and convenience	Comfort and convenience
Information to occupants	PHOENIX dashboard

To verify the effectiveness of PHOENIX solution in KaMa pilot case, six KPIs were established and assessed. A description of the KPIs can be found in the "KPIs Glossary" at the end of this section, while Table 5 displays the set targets and the calculated values of the KPIs during the implementation of services.

Table 5 Pilot case KaMa- KPIs presentation

KPI	Target	Measured values
Self-sufficiency	30-50%	48%
Blackout support for specific loads	90% reliability	100%
Energy cost reduction	>30%	37%
Increased residents' satisfaction (Likert scale)	>3/5	4/5
Usage of EV charging point	>10%	74%
Total target energy saving	30%	21%

In Table 6 the SRI score prior and after implementing the PHOENIX solution was calculated using both methods found in EC's official technical report [2]: the full calculation methodology, where all 54 listed services are evaluated (regardless of their applicability on the pilot) and the normalized calculation methodology, where only the services that are present in the building are evaluated.

Table 6 Pilot case KaMa- SRI calculations

Building type	Climate zone	Score prior PHOENIX		Score after PHOENIX implementation	
		SRI full	SRI normalised	SRI full	SRI normalised
Residential	South Europe	12%	15%	51%	62%

Key lessons learned in KaMa pilot case

- **Effective coordination among end-users,** energy managers, and technology providers is crucial prior to solution deployment. This includes clear communication, setting expectations, and ensuring that all parties are on the same page in terms of goals, timelines, and responsibilities.
- **Continuous feedback** can be important for ensuring the successful deployment and adoption of new solutions. If end-users are not engaged with the deployment process, they may be less likely to use the new solutions, which can lead to low adoption rates and a lack of value.
- By **ensuring the proper functioning of the equipment** before each intervention, time loss can be minimised for the involved partners. This is important because it can help pilots to avoid delays and disruptions to their work.
- **Actuation tests are important prior trials** that require direct control of devices. Actuation tests are used to verify that devices are functioning properly and can be controlled as expected. This is important for ensuring the safety and reliability of smart home systems.
- **Managing the domestic intelligent batteries via Modbus can be challenging** and requires a good understanding of the inverter's capabilities. It is important to work with the manufacturer to ensure that the battery is managed properly.
- **Controlling demand** is crucial for the smooth operation **of the blackout support** due to the limitation in the maximum amperes that the battery can support. This means that it is important to ensure that the demand for power from the battery does not exceed its capacity.
- **EV charging is an important aspect of the building' self-sufficiency**, as it can help the residents to have access to power when they need it. However, residents may not always be motivated to charge their EVs on a recommended schedule, as it may not be convenient to their personal daily routine.
- For dynamic pricing schemes, **occupants need an incentive to shift demand**. Even small shifts in demand can result in significant decreases in electricity bills. The earlier people are informed about periods of high prices, the more ready they will be to participate in the demand-shifting system.
- Greater variety of **messages that cover more activities** and actions to improve comfort and convenience would be useful for residents. This could include messages that remind users to turn on the lights when they enter a room, turn down the thermostat when they leave, or lock the doors when they go to bed.

Pilot Case – ARDEN

The Irish pilot consisted of three demo-sites in Dublin, including two domestic and one commercial building. The commercial building serves as a research centre, workshop, café, and shop for repurposed bikes and furniture. The main objectives for the pilot sites are to improve energy management at each site, implement demand response and improve flexibility for grid optimization, and enhance comfort in each building.

Table 7 Pilot case ARDEN - implemented services

Pilot's requirements	Services implemented to address requirement
Energy savings on site	Self-consumption evaluation Validation of flexibility benefits Validation of cost reduction benefits -Flexibility,
Demand response and flexibility for grid optimisation	Self-consumption evaluation Validation of flexibility benefits Validation of cost reduction benefits -Flexibility,
Comfort and convenience	Evaluation of comfort and convenience
Monitoring and control system	PHOENIX dashboard

To verify the effectiveness of PHOENIX solution in ARDEN pilot case, five KPIs were established and assessed. A description of the KPIs can be found in the "KPIs Glossary" at the end of this section, while Table 8 displays the set targets and the calculated values of the KPIs during the implementation of services.

Table 8 Pilot case ARDEN - KPIs presentation in domestic and commercial sites

KPI	Target	Measured values Domestic	Measured values Commercial
Energy performance improvement (Peak load decrease)	20%	86%	61%
Energy cost reduction	20%	12%	10%
Demand shifted	20%	39%	4%
Energy savings	20%	5%	13%
User acceptance of smart controls	n/a	4/5 (Likert scale)	4/5 (Likert scale)

In Table 9 the SRI score prior and after implementing the PHOENIX solution is calculated (for domestical and commercial sites respectively), using both methods found in EC's official technical report [2]: the full calculation methodology, where all 54 listed services are evaluated (regardless of their applicability on the pilot) and the normalized calculation methodology, where only the services that are present in the building are evaluated.

Table 9 Pilot case ARDEN - SRI calculations on domestic and commercial sites

Building type	Climate zone	Score prior PHOENIX		Score after PHOENIX implementation	
		SRI full	SRI normalised	SRI full	SRI normalised
Residential	West Europe	4%	7%	27%	39%
Non-residential	West Europe	14%	19%	34%	45%

Key lessons learned in ARDEN pilot case

- Financial **incentives** for flexibility based **on dynamic pricing is considerably lower** compared to incentives offered in current by Irish Distributed System Operator (DSO) pilot programs. It will be important for service providers to stay informed about the development of local and national flexibility service programs and offer beneficial options to end-users.
- An industry **challenge arises when interfacing with domestic flexible assets** in the domestic sector. Numerous RES/Smart Grid Vendors inadequately design assets, hindering their control functionality for flexibility services. Additionally, these vendors often limit functionality to non-commercial partners, restricting wider access.
- **The commercial site required the building management system (BMS) to be upgraded** with software and an Application Programming Interfaces (API) module to allow for connectivity with the PHOENIX platform. Considering the fact there is many different types of BMS systems with bespoke design (communications interface, integrated sensing devices/assets), developing an ICT solution for each BMS would need to be considered carefully.
- Incorporating **flexibility measures in residential environments** has been shown to be a viable strategy for achieving **energy cost reductions**, especially when dynamic pricing mechanisms are used wisely. It is worth noting, however, that the realisation of cost savings through dynamic pricing depends on end-users' awareness of peak electricity consumption times and their willingness to adjust their consumption patterns accordingly.
- Self-consumption at domestic site can be improved with increased awareness, however as PV production occurs mostly when residents are out of **house storage would be required** to maximise self-consumption.
- Within the PHOENIX project, research and development efforts have revealed that the integration of **flexibility elements**, such as electric vehicles and water heaters, **can deliver tangible energy cost reductions** by leveraging the principles of dynamic pricing. However, a comprehensive analysis of smart pricing practices showed that, in the absence of modifications to consumer behaviour, there is a relatively modest difference in electricity cost reductions between standard and smart pricing.

Pilot Case – MIWenergia

MIWenergia pilot sites are in the Region de Murcia (Spain) and includes two different types of buildings, one commercial and one residential. The demonstration activities for the commercial building took place in a business incubator building that focuses on start-up and early-stage innovative companies. A total of 16 spaces between the company's offices and lecture rooms participated in the PHOENIX project. The residential building is located at the city centre of Murcia, and four apartments were involved in the pilot site. Each apartment has approximately 125 m^2 and was equipped with common domestic appliances. The objectives of the Spanish pilots focus on improving smartness and energy efficiency on the buildings while allowing the user to become a prosumer and take full advantages of these improvements.

Table 10 Pilot case MIWenergia - implemented services

Pilot's requirements	Services implemented to address requirement
Energy savings on site	Flexibility Extraction - notifications
Flexibility for the grid	Flexibility extraction with pre-heating/pre-cooling, Flexibility Extraction w/o pre-heating
Comfort and convenience	Comfort and convenience and wellbeing
Information to occupants	PHOENIX dashboard

To verify the effectiveness of PHOENIX solution in MIWenergia pilot case, five KPIs were established and assessed. A description of the KPIs can be found in the "KPIs Glossary" at the end of this section, while Table 11 displays the set targets and the calculated values of the KPIs during the implementation of services.

Table 11 Pilot case MIWenergia - KPIs presentation

KPI	Target	Measured values
Energy Performance Measured	100%	100%
Investment in Sustainable Energy	n/a	100K €
Total Energy savings	20%	20%
Load Shifted from high to low tariff	15%	74%
Energy cost reduction	20%	25%

In Table 12 the SRI score prior and after implementing the PHOENIX solution was calculated in the two demo-sites, using both methods found in EC's official technical report [2]: the full calculation methodology, where all 54 listed services are evaluated (regardless of their applicability on the pilot) and the normalized calculation methodology, where only the services that are present in the building are evaluated.

Table 12 Pilot case MIWenergia - SRI calculations on residential site

Building type	Climate zone	Score prior PHOENIX		Score after PHOENIX implementation	
		SRI full	SRI normalised	SRI full	SRI normalised
Residential	South Europe	5%	10%	15%	28%
Non-residential	South Europe	3%	5%	31%	43%

Key lessons learned in MIWenergia pilot case

- Maintaining motivation and **engagement among end-users is crucial** to increase their involvement in project activities. However, excessive interactions can hinder progress, so it is essential to strike a balance.
- **Engaging in co-creation during the development** of user and building manager tools has the potential to yield positive results. This approach not only enhances the solution (provided there are sufficient resources) but also fosters a deeper mutual understanding between technical developers and demo managers/end-users, helping to manage expectations more effectively and avoid unrealistic ones (soft-landing).
- To **minimize the risk of delays** or potential supply issues with smart devices, it is advisable to initiate the procurement process as early as feasible.
- **Adapting legacy equipment can be a challenging** task, as the equipment may not be designed to work with modern technology or may have outdated software or hardware. In such cases, partnering with experienced industrial equipment automation providers can be beneficial.
- **In-person meetings can be an important tool** for team building and solving issues with project development or within the consortium. They provide an opportunity for team members to communicate, build relationships, and identify and solve problems together.

Pilot Case – LTU

The LTU pilot case is located in Skellefteå, in northern Sweden. It is a residential building with 12 apartments covering an area of 1278m^2. The main objectives are to improve energy management, reduce energy consumption and improve the quality of comfort and life of the residents. Table 13 shows the smart services that were implemented in order to achieve the objectives of the project.

Table 13 Pilot case LTU - implemented services

Pilot's requirements	Services implemented to address requirement
Energy savings on site	Simulated dynamic pricing
Comfort and convenience	Comfort and convenience
Information to occupants	PHOENIX Swedish mobile app

To verify the effectiveness of PHOENIX solution in LTU pilot case, three KPIs were established and assessed. A description of the KPIs can be found in the "KPIs Glossary" at the end of this section, while Table 14 displays the set targets and the calculated values of the KPIs during the implementation of services.

Table 14 Pilot case LTU - KPIs presentation

KPI	Target	Measured values
Increased residents' satisfaction	60%	85%
Total target energy saving	20%	21%
Integration of equipment	90%	100%

In Table 15 the SRI score prior and after implementing the PHOENIX solution was calculated using both methods found in EC's official technical report [2]: the full calculation methodology, where all 54 listed services are evaluated (regardless of their applicability on the pilot) and the normalized calculation methodology, where only the services that are present in the building are evaluated.

Table 15 Pilot case LTU - SRI calculations

Building type	Climate zone	Score prior PHOENIX		Score after PHOENIX implementation	
		SRI full	SRI normalised	SRI full	SRI normalised
Residential	North Europe	7%	9%	15%	27%

Key lessons learned in LTU pilot case

- Typically, **older users** tend to be less active in using their computers to monitor the dashboard but are **more open and engaged in using the mobile application** of PHOENIX to receive notifications, control the thermostats, and provide feedback with ratings.
- **Motivating** residents to participate in services **can be challenging**, but by communicating the benefits, involving residents in the planning process, providing incentives, making the services accessible, and building relationships, it is possible to increase participation and to ensure that the services are successful.
- **Testing equipment** in a timely manner is important to ensure that it meets the required specifications and performs as expected. It is important to test the equipment thoroughly to identify and address any issues before they become a problem in the field.
- **Ordering equipment at early stages** of project is important to ensure that it is available when needed and can be used to meet project deadlines.
- In a building with **district heating,** additional **energy can be saved** if the building manager receives services to better **optimize the building's district heating curve**. This is most important in autumn and spring when the temperature can vary between about -10 and +10 degrees.
- The **Fiware-to-Fiware integration** of two IoT platforms was the most important learning which is carried forward from the PHOENIX projects to other national projects within Sweden that LTU is part of.

KPIs glossary

- **Blackout support for specific loads**

This KPI refers to the ability of the building to maintain critical operations during a power outage by ensuring that essential equipment and systems continue to operate. It indicates the reliability of the battery backup solution and its ability to provide uninterrupted power during blackout.

- **Energy cost reduction**

This KPI measures the reduction in energy costs achieved through energy efficiency improvements and demand shifting strategies implemented in a building over a period. It provides insights into the effectiveness of demand shifting strategies and the impact on energy costs.

- **Energy performance measured**

This KPI measures the energy performance of a building by comparing the energy use from connected devices to a baseline, considering factors such as weather and occupancy. This KPI helps to identify areas for improvement in energy efficiency and track progress over time.

- **Increased residents' satisfaction**

This is a KPI that is closely tied to the pilot's objective of enhancing the occupants' quality of life and comfort. A survey is circulated to residents to assess their level of satisfaction with the implemented services and achieved comfort levels.

- **Integration of equipment**

The Integration of Equipment KPI measures the successful consolidation and functionality of various building's devices. This metric assesses the extent to which equipment, such as smart meters and legacy equipment, seamlessly communicate to PHOENIX platform to achieve intended objectives.

- **Investments in sustainable energy**

This KPI measures the amount of capital invested in sustainable energy projects (such as solar and wind). It is used to evaluate the impact of PHOENIX outcomes in enhancing the sustainability of pilot's premises.

- **Load and demand shifted**

This KPI measures the amount of load and demand that is shifted from high tariff to low tariff, and the resulting energy cost reduction. It also provides insights into the effectiveness of demand shifting strategies and the impact on energy costs.

- **Peak load reduction**

The KPI helps to identify areas for improvement in energy efficiency and track progress towards meeting energy cost reduction targets. It measures the reduction in peak power loads, which are the highest levels of energy demand that occur during a specific period, such as a day or a month.

❖ **Registered users**

This KPI measures the number of individuals who have registered to use a product or service. This KPI is typically used to track the adoption and popularity of a product or service and can be expressed as a raw number of the targeted audience.

❖ **Self- sufficiency**

This KPI measures the ability of the demo-site to meet its energy needs through the installed renewable energy sources, such as solar panels or battery system. By measuring and tracking their progress towards greater self-sufficiency, occupants can identify areas for improvement and make informed decisions about their energy strategies.

❖ **Total Energy savings**

The "Total Energy savings" KPI measures the reduction in energy consumption achieved through the retrofitting of controls and optimal operation. It provides insights into the effectiveness of retrofitting and demand shifting strategies and the impact on energy consumption.

❖ **Usage of EV charging point**

By The usage of EV charging point KPI measures the amount of electric vehicle (EV) charging that takes place at a specific charging point. This can include the number of vehicles charged, the amount of energy consumed, and the frequency of charging. It is an important KPI to support the adoption of EVs and promote sustainable transportation.

❖ **User acceptance of smart controls**

This KPI refers to the level of satisfaction and willingness of users to adopt and use smart controls in their daily lives. This KPI is important because smart controls are a coherent element for the wider integration of smart controls.

References

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