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New business models for innovative energy services bundles for residential consumers

Deliverable D8.8
Final Publishable Report

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ABBREVIATIONS

Abbreviation	Name
AI	Artificial Intelligence
API	Application Programming Interface
BDP	Big Data Platform
CA	Consortium Agreement
D	Deliverable
DB	Database
DER	Distributed Energy Resource
DHW	Domestic Hot Water
DoA	Description of Action
DR	Demand Response
DSM	Demand Side Management
DSO	Distribution System Operator
EC	European Commission
EE	Energy Efficiency
EEM	Energy Efficiency Measure
EU	European Union
EPC	Energy Performance Contract
ESC	Energy Sales Contract
ESCO	Energy Service Company
FP	Framework Programme
GDM	Global Demand Manager
GUI	Graphical User Interface
H2020	Horizon 2020 EU Framework Programme for Research and Innovation
HVAC	Heating, Ventilation and Air Conditioning
IPMVP	International Performance Measurement and Verification Protocol
KPI	Key Performance Indicator
LDM	Local Demand Manager
MQTT	Message Queuing Telemetry Transport

P4P	Pay for Performance
PMV	Performance Measurement and Verification
PV	Photovoltaic
RES	Renewable Energy Sources
TRL	Technology Readiness Level
SRI	Smart Readiness Indicator
T	Temperature
TSO	Transport System Operator
VPP	Virtual Power Plant
WP	Work Package

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EXECUTIVE SUMMARY

This document is a publishable summary of the frESCO project main results and key developments and breakthroughs, their status at the end of the project and the market challenges ahead for the potential replication and market acceptance. Key project results are extracted from the demonstration activities and testing of the frESCO tool suit in several buildings of the three demonstration sites: Madrid, Thasos Island hotel and smart island of Krk.

The main project exploitable results are five:

- The creation and population of a Big Data Management Platform to ingest, curate, store and safeguard the residential building digital historical and real-time data.
- The innovative P4P energy service bundles for residential consumers including monitoring, energy efficiency services, explicit demand response flexibility services, and value-added non-energy services provided by ESCOs and aggregators.
- The multiservice package toolkit that enables the provision of the frESCO energy services. Several applications have been developed, three in the local demand manager utilising a common user interface, such as the energy performance monitoring and forecasting module, the personalised energy analytics module, the human-centric automation module, and two more using the ESCO interface, including the self-consumption optimization and the portfolio energy analytics module. The applications for flexibility feature the Virtual Power Plant configuration tool and the smart contract application.
- The smart energy box to serve as a flexible and interoperable data gateway, wifi connected and installed in premises.
- The novel Performance Measurement and Verification methodologies to ensure a seamless, fair and accurate assessment of the frESCO service performance and enable a Pay-for-Performance contract model.

Results of the deployment of these solutions in real building environments are provided per demo site and aggregated, compared with the initial project targets. Results showcase the difference performance achieved at every type of building. Buildings with continuous

occupancy fitted with PV for self-consumption and additional flexibility assets such as storage show the largest benefits out of the application of the frESCO innovative data-driven services. Overall, the calculated metrics demonstrate the feasibility of the business models, meeting all the initial targets of the project at its initial stage.

1 INTRODUCTION AND OBJECTIVES

This document summarises the frESCO project results and aims at maximising the dissemination impacts of the project activities and the measurable and non-measurable results obtained out of this work, carried out during 42 months by the 14 consortium partners. This document does not contain management aspects.

The document is structured in four main sections. In the first one, a comprehensive summary of the KPIs and results obtained at physical and extended demos site level, compared to the initial targets set at the project proposal stage. The second section is devoted to the thorough description of the main project results developed and tested during the project action period. The main results developed are the Big Data Management Platform (BDMP), the integrated energy service bundles for residential consumers, the multi service package toolkit composed by five applications and two differentiated visualisation interfaces, the flexible smart energy boxes used as data gateways in the demonstration sites and the novel Performance Measurement and Verification Methodology proposed for the Pay-for-Performance (P4P) services offered. The status of these results at the end of the project and an estimation of Technology Readiness Level and estimated Time-to-Market is provided.

The third section focuses on the replication of the frESCO solutions while the fourth section addresses the challenges for the project results maturity, outlining the limitations and detailing the pending work that should be done to achieve a fully marketable tool suit and the full deployment of the envisaged business models and energy services in the residential sector.

2 DISSEMINATION AND COMMUNICATION RESULTS

The table below presents an overview of the C&D KPIs set in the DoA, that guided the entire work developed in WP8 "Communication and Dissemination activities" in the 42 months of the project lifecycle.

The table allows a comparison between the KPIs set in the DoA, that were set as "goals" to be achieved (column "value") and the results we achieved in M42.

Looking at the overall results achieved, the C&D activities are qualifying in between good and Excellent in all the categories.

Channel/Content	KPI	Value	Achievements by M42
Project Promotional Video	Worldwide scale visibility	Visits: <750 = poor; 1500 = good; >2000 = excellent	>2000
Website	Worldwide scale visibility	Visits: <1500 = poor; 4500 = good; >6000 = excellent	11598
Promotional Material	Distribution	<500 copies = poor; 1,000 copies = good; >2,000 copies = excellent	800
Press Releases	Number of publications	<10 = poor, 20 = good, >30 = excellent	35
Papers	Number of papers submitted	<3 = poor, 6 = good, >9 = excellent	~~5~~6
Conference Presentations	Number of conference presentations	<5 = poor, 8 = good, >9~~10~~ = excellent	9
Workshops	Overall number of participants	<10 = poor, 20 = good, >30 = excellent	20
Final Conference	Overall number of participants	<30 = poor, 30-100 = good, >200 = excellent	50
Social media	Followers		Linkedin 213 Twitter 133

3 PROJECT IMPACTS AT DEMO SITES

This section compiles the project's expected impacts and the results ultimately achieved, both at the physical demo sites and at the extended demo sites. The reported Key Performance Indicators (KPI) stem from the frESCO evaluation framework developed during the project and is supported by the frESCO Performance Measurement and Verification

methodology. Results include energy metrics: primary and final energy savings, flexibility, RES generation and uptake, economic metrics (investments, economic revenue streams, payback times), environmental metrics (carbon footprint). Similarly other project targets related to the demonstration activities are compiled, such as social metrics like engagement and satisfaction. These metrics are assessed at two levels, the physical demo site buildings involved in frESCO's living labs, and the potential and straight forward replication in similar buildings accessible to the consortium demonstration partners.
The three physical demonstration buildings are contained in D6.3 "Report on frESCO demosite activities" and summarised below.

3.1 Physical demo site description and impact targets

3.1.1 Madrid demo site

The Spanish pilot site is located in the city of Madrid. The residential building is a multi-apartment located downtown, not far from the city centre.

Figure 1. Residential building for the Spanish pilot.

The building was built in 2019, it has the shape of a quadrilateral block. Regarding the architecture structure it has a ground floor, and 2-upper floors and a terrace in the top roof, which contains a total of 12 dwellings and several common areas. Regarding the sources of energy supplied to the building, it is based completely on electricity (around 50,000 kWh/year). To cover part of the electric energy consumed a 30 kW on-roof PV system is in place. Simulations estimate that the PV system will generate over 50,000 kWh annually, of which 20,000 kWh is consumed within the building. The excess energy generation is expected to occur in the summer months when energy consumption by the different apartments is at its lowest.

	
Figure 2. PV System	**Figure 3. DHW – Aerothermal System**

The heating and cooling systems, HVAC, for the dwellings are provided by individual split-type-air-to-air heat pumps with an indoor and outdoor unit. The outdoor units are located on the top roof of the building. The heat pumps use ecological refrigerant R32 and have a COP of 4.3-4.6 (heating) and 4.2-4.5 (cooling).

A Common facility for domestic hot water (DHW) is provided by means of a split-type air to water heat pump with two central storage tanks with a 930-litre capacity each one (located in the basement). The system operates with an electric power load of 6.25 kW, and it has a COP value of 4, which means that can deliver 25 thermal kW of nominal power. This common facility give service to all the dwellings and common areas within the building. The building does not feature battery storage capacities on site.

The frESCO energy services tested in this demo site are energy monitoring and advanced analytics for efficiency, PV self-consumption management, simulations of demand flexibility aggregation and non-energy services.

The quantifiable impact targets in this demo site are the following.

Table 1. Spain's demo site quantifiable targets

Physical and extended demo site objectives	Units	Spain targets	
		physical demo	full pilot
dwellings	number	10	30
Consumers	number	30	90
Final energy savings	MWh/y	14	42.1
RES production	MWh/y	22.9	68.7
Primary Energy Savings	MWh/y	43.5	130.5
Investment	€	11,000 €	93,000 €
GHG emission reduction	kg/y	9181	27542
Payback time efficiency with PV	years	4.4	-
Payback time efficiency + flex	years	4	-

The extended demo site is made up by two additional buildings in Madrid, both part of "La Corriente" energy cooperative customer base, making a total of 48 dwellings.

3.1.2 Thasos Island demo site

The Greek demo site is the Makryammos Hotel on the island of Thasos. Makryammos Hotel includes both conventional rooms as well as decentralised bungalows. For the pilot site needs, bungalow 250 was selected. Bungalow 250 is comprised of 5 separated rooms for guests' accommodation.

At bungalow 250, a 18.9 kWp rooftop solar plant is installed, connected to a 12 kW PV inverter on one side and 5 kW PV hybrid inverter with battery on the other, and a production capacity of approximately 15,000 kWh/year.

In addition to the solar installation, a battery with a capacity of 8.3 kWh and a maximum load of 5kW is also in place. The energy produced from the solar panels covers directly the consumption from the 250-bungalow rooms and any surplus energy is stored in the battery system. In case the battery is full and there still is a surplus of energy, it is directed to other hotel loads or to the grid. Domestic Hot Water (DHW) is provided by 3 electrical boilers that each contain a 300-liter tank and operated under a 12-kW load.

Use cases concerning the Greek demo site, involve energy control and monitoring, energy efficiency in seasonal touristic buildings, PV-self consumption optimization, service suitability in touristic facilities with uneven occupancy levels and non-energy services.

The quantifiable impact targets in this demo site are the following.

Table 2. Greece's demo site quantifiable targets

		Greece targets	
Physical and extended demo site objectives	**Units**	physical demo	full pilot
dwellings	number	3	40
Consumers	number	30	400
Final energy savings	MWh/y	8.4	112
RES production	MWh/y	0.2	3.3
Primary Energy Savings	MWh/y	16	213
Investment	€	10,850 €	144,667 €
GHG emission reduction	kg/y	5385	71801
Payback time efficiency with PV	years	11.2	-
Payback time efficiency + flex	years	7.7	-

The extended demo site comprises the 193 rooms available at the Makryammos hotel facilities in the island of Thasos, all managed by the project partner IOSA.

3.1.3 KrK Island demo site

The Croatian pilot consists of 7 individual residential buildings located mostly in the central and northern part of the Krk island, off the Northern coast of Croatia. The building sample vary consistently in terms of building energy performance characteristics, year of construction while the gross floor area is approximately similar (on average ~200 m^2). Concerning household compositions these are mostly families with more than 2 members. Building usage varies consistently – there are permanent and holiday users which means that building usage varies over seasons. Pilot houses are typically equipped with air conditioner systems, DHW boilers and heat pumps while few of them have solar panels and photovoltaic systems. None of the houses have an electric or thermal storage facility.

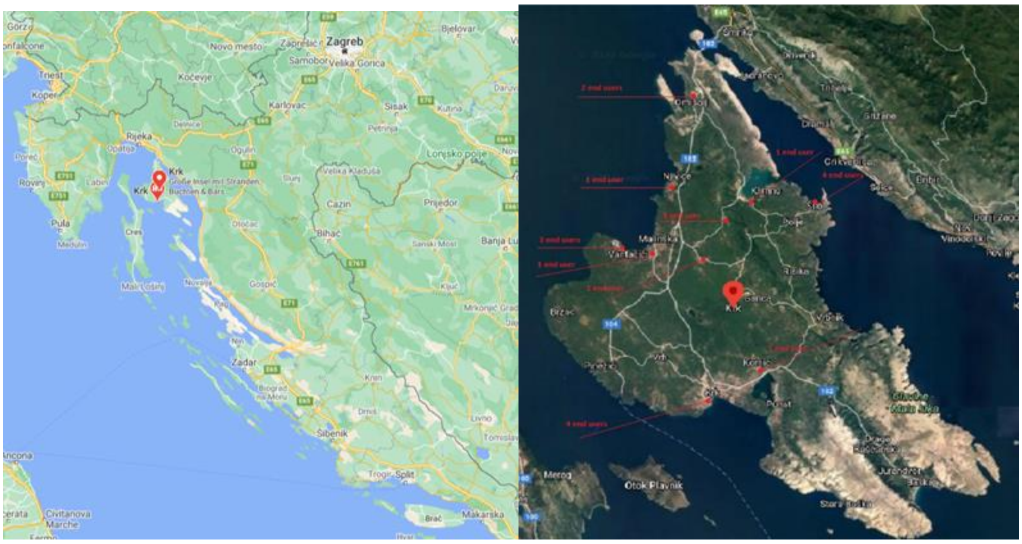

Figure 4. Location of demonstration buildings in Croatia (households spread across the island of Krk)

Digital metering equipment is not present at most of the Croatian demonstration sites. Dwelling 5 is fitted with a large size PV-generation facility of 8 kWp.

The testing objectives in the Croatian demo site comprise energy efficiency and monitoring, self-consumption in residential semi-detached buildings, smart retrofitting and monitoring in seasonal residences.

The quantifiable impact targets in this demo site are the following.

Table 3. Croatia's demo site quantifiable targets

		Croatia targets	
Physical and extended demo site objectives	**Units**	physical demo	full pilot
Dwellings	number	10	20
Consumers	number	30	60
Final energy savings	MWh/y	8.4	24
RES production	MWh/y	0.6	11
Primary Energy Savings	MWh/y	14.6	40.6
Investment	€	15,500 €	55,000 €
GHG emission reduction	kg/y	1880	7355
Payback time efficiency with PV	years	12.4	-
Payback time efficiency + flex	years	8.2	-

The extended demo site is made up by the initial 19 dwellings engaged and initially characterised, of which the 7 physical demo buildings are a subset. These buildings make part of the Smart Island of Krk (SIK) customer base.

3.2 Physical and Extended demo sites impact

The physical demo site results are described in detail in frESCO deliverable D6.4 "Socio-economic, environmental and technological impact assessment". This is a summary of the individual and aggregated results obtained in the demonstration and testing activities along one full year of data collection and testing in the demo sites. The multiplying effect of the potential scalability to the identified buildings of the extended demo sites is reported in the tables, along with a comparison with the above initial project targets.

Energy, economic and environmental metrics

The aggregated energy, economic and environmental metrics of the three physical demo sites are summarised below:

- Energy Efficiency Services: meant to assess the results in energy management and efficiency. The efficiency sources reviewed include self-consumption savings, demand verified savings according to D3.4 "Definition of the frESCO PMV PMV methodology", and specific service savings such as the day-ahead PV-storage optimization strategies in the Thasos demo site bungalow. The total annual final energy savings in the three demo sites reach 31 MWh/y, reaching the initial target.
- Demand Response Services: addressing the performance of demand flexibility aggregation. These services have been tested in the Madrid demo site building, and calculated following the frESCO PMV methodology from D3.4. Based on the simulation demand response tests carried out in the building, an estimation of over 1 MWh/y of upwards demand response flexible HVAC energy may be offered, providing annual incomes close to 1,000 €/y
- Economic and Business metrics: these metrics show in economic terms the results of the energy and non-energy services, the investments triggered and the payback periods of these investments. Overall project investments in the demo site buildings amounted to 20,732 €, to be added the owners' investments on PV facilities and storage. This is 56% of

the planned investment and, hence, we can conclude that the frESCO data collection system in buildings is 44% cheaper than initially expected.

The revenues obtained in the different demo sites are different, depending on the building capacities and the services tested. So, it is the payback obtained at each demo site is calculated with respect to the frESCO investment plus the PV-estimated investment. The Madrid demo site payback time is 2.7 years vs 4 years target, the Thasos demo site payback time is 9.4 years vs 7.7 years and the Krk demo site payback time is 7.2 years vs 8.2 years target.

- Environmental impact: The conversion of the energy savings into carbon footprint is another relevant metric of the frESCO project. It includes all CO2 emissions avoided due to energy savings and RES generation. The total emission avoidance in a year is calculated to be 17,394 kg CO2/y vs 16,446 kg CO2/y target.

Extended pilot site objectives are a clear multiplier of the impacts measured in the physical demo sites. Targets for the extended pilot sites are also achieved in buildings with similar characteristics as those in the physical demo site sample. The aggregated physical and extended targets and results of the three demo sites are displayed in the table below.

Table 4. Physical and extended demo site total objectives and results (3 demos).

		Total targets		Total results	
Physical and extended demo site objectives and results	**Units**	physical demo	extended demo	physical demo	extended demo
dwellings	Number	23	90	29	260
Consumers	Number	90	550	258	7,953
Final energy savings	MWh/y	30.8	178.1	31.0	329.3
RES production	MWh/y	23.7	83	73.0	748.2
Primary Energy Savings	MWh/y	74.1	384.1	86.0	557.07
Investment	€	37,350 €	292,667 €	20,732 €	166,120 €
GHG emission reduction	kg/y	16,446	106,698	17,394	264,276

3.2.1.1 Madrid demo site

Results in the Madrid physical demo site building and the extended demo site buildings exceed the expected initial targets in all categories. The target for investment initially included a PV facility that was not finally needed with the demo site building change at the beginning of the project. The total investment being lower than the initial amount is a sign of cost efficiency in the commissioning and installation of the frESCO system infrastructure with respect to the initial budget estimation.

Table 5. Physical and extended Madrid demo site objectives and results.

		Spain targets		Spain results	
Physical and extended demo site objectives	**Units**	physical demo	extended demo	physical demo	extended demo
dwellings	number	10	30	17	48
Consumers	number	30	90	30	120
Final energy savings	MWh/y	14	42.1	22.85	64.5
RES production	MWh/y	22.9	68.7	56.3	159.0
Primary Energy Savings	MWh/y	43.5	130.5	70.83	199.99
Investment	€	11,000 €	93,000 €	11,506 €	32,488 €
GHG emission reduction	kg/y	9,181	27,542	9,921	28,014
Payback time efficiency (with PV)	years	4.4	-	3.08	-
Payback time efficiency + flex	years	4	-	2.70	-

It is remarkable the low estimated payback time of the frESCO efficiency measures (that include the investment in the PV facility), that is further lowered by adding the revenues of a potential retribution of the participation in aggregated demand response schemes. This hybrid model applied to a highly efficient building shows payback periods below 3 years which is a remarkable project result.

3.2.1.2 Thasos Island Demo site

Results in the bungalow 250 of the Thasos Island hotel are very satisfactory in most categories. Energy efficiency in the bungalow is affected by the low generation yields of a badly oriented PV facility shadowed by numerous trees, and by the seasonality of the hotel services, only in use for 3.5 months a year in summer, and hence not including heating and winter demands in the annual balance of energy savings. This is totally compensated by the high scalability potential should the new services be extended to the totality of the hotel rooms and bungalows of the full or extended pilot.

Table 6. Physical and extended Thasos demo site objectives and results.

		Greece targets		Greece results	
Physical and extended demo site objectives	**Units**	physical demo	extended demo	physical demo	extended demo
dwellings	Number	3	40	5	193
Consumers	Number	30	400	199	7,776
Final energy savings	MWh/y	8.4	112	6.8	260.9
RES production	MWh/y	0.2	3.3	15.2	585.2
Primary Energy Savings	MWh/y	16	213	12.7	491.6
Investment	€	10,850 €	144,667 €	3,026 €	116,804 €
GHG emission reduction	kg/y	5,385	71,801	6,019	232,315
Payback time efficiency (with PV)	Years	11.2	-	9.6	-
Payback time efficiency + flex	Years	7.7	-	9.4	-

Payback periods are however very acceptable. However, limiting the flexibility activation to cooling systems in a very mild weather location by the sea for a few months a year hinders the potential revenues estimated from an eventual demand response market participation and thus, having a moderate effect on the overall (efficiency + flexibility) payback period.

3.2.1.3 Krk Island demo site

Krk Island demo site was first designed to have 19 dwellings, and all of them subscribed to the demonstration activities and were characterised at the early stages of the frESCO project. However, the lack of expert personnel in the island to give support and troubleshoot the rather high installation issues pushed the decision to limit the number of physical demonstration dwellings to 7. In addition, the low number of PV facilities, not directly dedicated to self-consumption also limited the energy savings coming from self-consumption, staying below the initial target. Part of the low savings are due to the only PV facility being used for wholesale market generation instead of self-consumption due to regulatory low incentives. PV legislation in Croatia is soon to change to more friendly schemes for self-consumption. The seasonal usage of many of the dwellings, many occupied only in holiday and occasional periods, also hinder the achievement of higher energy savings. This discontinuous occupancy also restrains the possibility of higher demand response flexibility potential, mainly limited to summer cooling demand.

Table 7. Physical and extended Krk demo site objectives and results.

		Croatia targets		Croatia results	
Physical and extended demo site objectives	**Units**	physical demo	extended demo	physical demo	extended demo
dwellings	number	10	20	7	19
Consumers	number	30	60	29	57
Final energy savings	MWh/y	8.4	24	1.42	3.8
RES production	MWh/y	0.6	11	1.5	4.1
Primary Energy Savings	MWh/y	14.6	40.6	2.40	6.51
Investment	€	15,500 €	55,000 €	6,200 €	16,829 €
GHG emission reduction	kg/y	1880	7355	1455	3948
Payback time efficiency (with PV)	years	12.4	-	7.5	-
Payback time efficiency + flex	years	8.2	-	7.2	-

The return period of the investments (PV facility included) is however quite acceptable and within the initial predicted targets.

Social, technical and other relevant project impacts

Other relevant project metrics gathered at the physical demo site activities consolidated in D6.4 are summarised here below:

- Non-Energy Services: this set of metrics assesses the performance of the non-energy services. In the demo sites, comfort and air quality monitoring and preservation implicit services were tested. Comfort temperature was within range between 90% and 94% of the time. VOC concentrations were within healthy limits 88.5% of the days.
- Social impact: The participation and overall satisfaction of end users are also measured to know the social acceptance of the new frESCO services. The most relevant remarks made by end users are:
    - Usability. There is a shared concern about the difficulty for non-familiarised users to understand some metrics and parameters reported by the User Interface. For this reason, a user manual has been edited and translated into Spanish. Personal assistance by project partners have also helped in this issue.
    - Unavailability of some services. Technical issues, data gaps and delays, already solved by now, have resulted in a perceived unreliability of some of the App functionalities.

- Explicit DR by third party automation of loads are of little interest for building users, despite the human centric approach and a potential remuneration from open flexibility markets.
- An important acceptance factor for the frESCO solutions is the data usability in terms of availability of proper dashboards and analytics for each user. Users want to see their energy related metrics evolution on real-time. To implement effective energy efficiency measures and improve self-consumption, it is essential to have suitable tools that enable analytics and optimization.

- Smart Readiness impact: The Smart Readiness Indicator is used to assess the evolution of the involved buildings from the starting point to the end of the project. A significant increase in SRI has been quantified in the three demo site buildings. All impact criteria have significantly improved during the implementation phase. The most notable changes have taken place in the technical domains "cooling / heating system", "electricity", "lighting" and "monitoring and control". The reason lies on the frESCO new metering and submetering equipment, device remote control and scheduling of HVAC and the monitoring and forecasting centralised capabilities of smart energy management put in place by the frESCO tool suit.
- Technical data and platform metrics: This set of metrics measures the quality and amount of available data and the technical performance of the data platform and modules. The frESCO BDP contains 460 data sets as the result of 230 data collection jobs created up to November 2023. The total amount of data stored from the three demo sites goes up to 32.4 Gb and growing every day. 95% of the technical requirements have been addressed by the Apps, that consume data through the 405 data retrieval queries created. The platform features three input data methods (file upload, MQTT and API) and is accessible through various browsers. The embedded forecasting algorithms reduce the forecast errors from 30% to 53% with respect to the most widely used prediction methodologies up to now.

4 FRESCO PROJECT RESULTS

This section summarises the most relevant frESCO project Key Exploitable Results, the innovation level and the market maturity achieved during the project development and testing phases. The identification of the Key Exploitable Results of frESCO resulted in the following topics, thoroughly described in D7.2 "Final Version of the Exploitation Plan"

Table 8. frESCO KER list

KER	KER Leader	Interested Partners	Brief Description
Integrated energy service bundles for residential consumers	COMSA	MOH, VOLT, KRK, KONCAR, La Corriente	New service bundles combining EE services with other energy services and associated business. models that will utilize enhanced incentives for the smart transformation of buildings/ consumers/ prosumers and the enhancement of the energy autonomy of prosumers with the installation of distributed renewable sources, together with storage devices.
Novel PMV methodology	CIRCE	MOH	A new PMV methodology that will utilize real-time data streams to ensure (i) objective validation and assessment of the feasibility and effectiveness of the new business models and (ii) transparent remuneration of the involved actors for the achievement of energy savings and the provision of flexibility to the grid
Multi-service package toolkit	UBITECH	CIRCE, CARTIF, S5, UBE	The Visualization Platform and End-User Toolkit components are the front-end applications that will be made available to all stakeholders involved in frESCO.
Big Data Management Platform	Suite5	UBITECH	These components form the back-end of the new integrated service bundles and enable the exploitation of the huge amount of new data generated by devices deployed in smart homes and beyond.
Smart Energy boxes	CIRCE	~~VOLT~~	It is a Smart Home Gateway/ EMS module, enabling end-to-end interoperable communication between the control centre of the service provider and individual smart home devices (through sensors and actuators)

4.1 Summary of project results

Big Data management Platform

Data management and handling, combined with data analytics to serve the needs of the frESCO project, are enabled via the Big Data Management platform, implemented in the context of WP4 of the project. This platform acts as a high-level data repository for the collection of data streams, followed by curation and semantic harmonization actions, that enable the preparation and execution of analytics algorithms, to be further retrieved and utilized by other modules.

To serve these needs, the frESCO Big Data Management platform provides to its users an extended variety of innovative services in the areas of data collection, data curation, data storage, data security and data governance, constituting one of the Key Exploitable Results of the project. Targeting the huge potential of addressing the massive growth of data streams that is generated by an increasing amount of data sources, such as smart devices and sensors, advanced big data technologies are utilized, preparing the data to be effectively turned into knowledge, through the execution of analytics algorithms on top of them.

More details about the frESCO Big Data Platform can be found at frESCO D4.6 "frESCO Integrated Platform - Beta Release".

Integrated Energy Service Bundles for Residential Consumers

A new generation of hybrid energy services for ESCOs and aggregators that combine both the provision of energy efficiency and demand flexibility in the residential sector. The new energy services are designed under the Pay-for-Performance (P4P) principle, that ensure an accurate and transparent performance measurement to assess the energy savings and the demand flexibility dispatched for grid congestion and management. These new P4P energy services build upon the existing Energy-Performance Contracts model currently offered by ESCOs but scarcely developed in the domestic consumer sector due to the low energy demand and high transaction costs, which render the current model economically unfeasible in a large number of cases.

The new energy services are supported by Artificial Intelligence algorithms that run on a digital big data platform. Variables like real time energy consumption, temperature and comfort parameters will be continuously read from on-site meters and sensors installed at the consumers' premises. These data are used in advanced forecast algorithms to assess energy efficiency potential at medium and short terms, and demand flexibility at short terms to provide services to the grid (congestion management, grid balancing and ancillary services).

Energy efficiency services will provide quantifiable energy savings while demand response services will exchange demand flexibility for a fair market remuneration. The joint revenue streams of both services should cover the service delivery costs plus the digital platform set up costs, thus, should deliver a benefit for both the energy service provider (ESCOs and aggregators) and the consumers / prosumers, who are the ultimate beneficiaries of the services. Besides, other non-energy services can be offered within the same bundle, among which some related to comfort, air quality, noise control or surveillance.

The result is a complete, splitable, and comprehensive set of new energy services that can be offered in parallel to traditional EPC services, thus completing the service portfolio of ESCOs in the domain of residential buildings, with possible extension to flexibility services to the grid and non-energy services to building residents.

A thorough description of frESCOs innovative service bundles are provided at D3.1 "Definition of the novel energy services for residential consumers".

Multi Service Package Toolkit

The multi-service package toolkit provides a bundle of business tools for ESCOs and flexibility aggregators. On the same time, it provides a plethora of energy and non-energy services to building occupants.

To this aim it monitors, analyses, recommends and delivers energy efficiency measures, respecting the behavioural needs of the consumer, but with a scope towards increased energy savings. The exploitation of big data in advanced concepts enables the maximization of self-consumption and lead to better building energy performance. It also provides flexibility services (with the introduction of storage and electric vehicles as means for enhancing flexibility), accompanied with the monitoring of the corresponding terms of their smart contracts. The non-energy services to the building occupants boosts comfort preservation through monitoring of indoor Air Quality, Security, Well-being, Emergency notification services, etc.

More information is available at frESCO D5.8 “frESCO multi-service package toolkit”.

Smart Energy Boxes

The Smart Energy Box from CIRCE acts as the gateway between the in-house sensors/actuators and the online infrastructure. It enables the collection and aggregation of data streams and communication between the onsite devices such as sensors, meters, smart equipment, actuators, and the frESCO Big Data Platform through a range of communication protocols, aggregating and forwarding this information via an Internet connection. Communication works both ways, also allowing for the management of smart-ready devices from the control centre via the Energy Box.

In the frESCO project, CIRCE has their own hardware/software solutions known as the Energy Box (CIRCE). It is the data gateway installed onsite in the demonstrators, and these or similar devices must be used in all the different energy services and business models proposed in frESCO (Insulae H2020 project).

More information about the smart Energy Box can be found at FrESCO D4.2 “frESCO Building Gateway & Extensions for integration with legacy equipment”.

Novel Performance Measurement and Verification Methodology

The Performance Measurement and Verification (PMV) approach followed in frESCO project had three objectives: a) to perform an objective and accurate baselining of current energy performance/ consumption of the involved prosumers and normalize it against varying occupancy patterns, energy uses and climatic conditions, b) to measure and verify energy savings and demand side flexibility achieved due to the project energy services a, and c) to estimate the short/mid-term impact of project activities through a socio-economic analysis.

In this context, the methodology is further enriched to follow a pooled baseline regression analysis model creating a variable relationship between event days and baseline consumption. The aim of this approach is to create a common PMV model to represent the customer’s load shape on an event day. The development of the baseline is accomplished by using a pooled data series that distinguishes between event-based and non-event-based interventions and appropriately normalizing them to address occupancy and weather variations. In this way, objective measurements allow more accurate energy consumption baseline adjustment and verification of the response of demand in trigger signals thus enabling the definition of dynamic baselines (to consider evolving alterations of demand profiles due to energy efficiency services) and clear differentiation of performance modifications caused by the participation of prosumers in demand response schemes.

In the current market there are other PMVs (Performance Measurement and Verification) that are already offered. Not all methodologies have the same characteristics nor offer the same type of service for the potential customer. There are differences in terms of the target audience, the way in which the measures are carried out and the extent of the implementation or service.

The Methodology meets the needs of all stakeholders namely ESCOs and Aggregators of demand flexibility. The main difference from the PMV Methodology being developed in the frESCO project from the others that are available in the market is the combination of standard long-term holistic energy efficiency approaches with dynamic short-term Flexibility measurements based on advanced forecasting analytics. This measurable Demand Flexibility PMV offers the capability to accurately assess the aggregated domestic consumer demand flexibility made available to grid operators for congestion management and grid balancing services. This algorithm also allows the fair retribution settlements according to the actual flexibility delivered to the grid.

A detailed description of frESCO's PMV methodology is available at D3.4 "Definition of the frESCO PMV methodology".

4.2 Final status of project results

The table below shows the initial and final TRL status of the different KER developed in the project.

Table 9. KER's TRL

KER name	Initial status (M1)	Final status (M42)
Big Data management Platform	6	8
Integrated Energy Service Bundles for residential Consumers	6	8
Multiservice Package Toolkit	6	8
Smart Energy Boxes	7	8
Novel PMV Methodology	7	8

Estimated Time to Market

4.2.1 Big Data management Platform

In the context of the frESCO project, five Tasks and seven related Deliverables were undertaken to develop the backbone infrastructure of the Core Big Data Management Platform, supporting ingestion, curation and management services. Built with different layers for data security and privacy assurance, the user is able to take advantage of the available energy data to receive the results of pre-trained algorithms for personal, industrial and real-time edge analytics.

Based on the project's plan, the frESCO Big Data Management platform has been made available since February 2022 (Beta release) and January 2023 (final platform release) and the time to market for the commercial version, with advanced functions to capture the needs of additional target groups, as identified in frESCO's initial targets, as well as data model domain-specific enhancements on top of the frESCO Common Information Model, will be January 2025. Until this milestone, extra activities need to be undertaken, covering performance improvements of the platform, UI/UX enhancements, marketing of the platform and the establishment of a sales business unit.

4.2.2 Integrated Service Bundles for residential Consumers

An initial 2- year commercial strategy to launch the new services to the market would involve 4 main steps:

- Market analysis and evaluation: Market segmentation analysis, competition analysis and profile of Buyer/User must be constantly re-checked due to the changing and active renewable energy market at a global context.
- Screening: will focus on a proper Marketing Plan for the solutions, tools like inbound and outbound Marketing can be used to reach the defined profiles of buyer/user. A creation of a Beta Version of the new Service bundles is essential to be tested with a selected group of real customers before launch it to the market. After this, a clear overview of the product positioning and branding will emerge.
- Selling: the creation of a Sales Model will be necessary to scale the solution into a real-customer market. Taking the marketing strategy as a tool to achieve this, the Sales Model will include internal sales, field sales and other channels like B2C and B2B. Implementing the beta version with a group of real customers before launch it to market is a good strategy in order to track the customer experience and feedback from them. Gather and analyse insights about the customer journey, pain points, and objections, then modify the overall go-to-market strategy if necessary to address them and shorten the sales cycle.
- Implementation and launch: a constant review of the performance of the product/service is compulsory. Measurement and Verification activities must be done to check possible improvements and updates. Operation and Maintenance tasks are considered as a technical assistance service related to the global solution. The Licensing and IPR issues must be considered since is a new solution implemented in the market and future competitors will appear.

4.2.3 Multi service Package toolkit

All the algorithms that are part of the applications would have to be generalised to be able to launch the service to the market. The final product would require software updates in order to have accessibility to more data formats compared to the ones tested in the project.

This would require around 1 year in order to assess the initial efficiency of the forecasting and optimization algorithms, the effect on the targeted stakeholders' profit, as well as the level of holisticness of the provided services, and finally the verification and testing of the updated version. It should be noted that the time to market depends on the maturity of the markets in general. For example, the flexibility markets do not exist in most of the countries yet. It is expected that for the final version of the market assessment the information will be updated, and the estimated time to market will be able to be estimated more clearly.

The biggest challenge is to put the multi-service package toolkit into use in such a way that it will be fully utilized. Utilization process refers not only to adjusting/customizing/improving but also to maintaining and integrating technologies for synergy. This means that some steps are going to be made both during and after the frESCO project depending on the technical readiness of the initial version. Utilization processes consist of the following steps:

- Measure and assess the multi-service package toolkit utilization/performance.
- Identify priorities according to business requirements beyond the frESCO project stakeholders and develop a business case to improve utilization.
- Provide a technical software plan improving the accuracy of the envisioned services based on the results of the assessment.
- Update the dashboard/visualization of the insights according to the assessment.
- Update the analytics algorithms accuracy and performance according to the assessment.
- Testing of the update with new data for at least a year.
- Launch of final market product.

This exploitation route, which includes licensing and service provision, will also be the basis for further research regarding the multi-service package toolkit.

4.2.4 Smart Energy Boxes

The Energy Box is fully operational as tested in two demo sites, with minor random and infrequent connection issues with some devices in some cases. CIRCE is the IP owner of the design and the manufacturer. The technical readiness is considered to be TRL 7, but it is still not launched to the market because an external market beyond CIRCE's service catalogue has not been found. Today it is a tool to complement and add value to services to public and private customers. The main drawback is that the energy box is still rather expensive for domestic use. During the project, the minimum necessary functionalities were evaluated with the aim of lowering the manufacturing cost. Value engineering promotes the substitution of materials and methods with less expensive alternatives, without sacrificing functionality. The intention is to reduce the functions to what is essential to make the cost of the technology more accessible. Also, the development is in a prototype state and industrialization of the manufacturing process would reduce significantly the cost of the equipment.

By the end of the project, the technology is assessed to be more widely available and accessible for homes, achieving TRL 8.

In some situations, the proposal of a software solution separated from the hardware would help to introduce the monitoring and control service at a lower cost.

4.2.5 Novel PMV Methodology

In the context of the frESCO project, the target market would be ESCO and demand response aggregator companies providing the services and running the new business models. Other stakeholders would be those within the value chain of the business models from DSO´s and TSO´s through the intermediary parties to the end user that will provide the flexibility. Remuneration is allocated by the market according to the performance of the service, or flexibility verified by each consumer / prosumer, by means of the application of the PMV Methodology to every participating asset in a flexibility event. The frESCO PMV methodology for assessing holistic medium- and long-term efficiency performance is partially based on the EVO methodology and develops a hybrid methodology to also assess short-term events of explicit demand side management per asset, thus reaching a wider range of energy services in the building sector and enabling the hybrid energy service approach of frESCO. The PMV methodology in the frESCO context is aimed to be implemented in the building and domestic residential sector but it could be extrapolated to any energy consumer. The final potential market consumers of the PMV are, in consequence, the energy service providers (ESCO, DR Aggregator) basing their service on a P4P approach, and hence, relying on a proven methodology to assess that performance and settle the retributions to the services and the building residents proportionally and fairly to that verified performance. Addressing the energy service market involved in the residential sector to make a study of the size of this market is a tough task. The energy consumed in the residential sector in Europe is about 40%

of the primary energy consumption in Europe and, although the energy service market in the residential sector is still very low. The potential growth in a near future is nevertheless huge. CIRCE would offer training and consultancy services to service providers and other organisations interested in using the new PMV method for the verification of the performance of the novel energy services. Moreover, CIRCE would explore the potential exploitation of this methodology through a certification scheme. The deployment of the PMV methodology in market conditions would be possible 1 year after the end of the project.

5 REPLICATION OF FRESCO SOLUTIONS

D7.4 “Roadmap for the replication of frESCO developments” assessed the replication potential of frESCO solutions throughout the EU. The assessment of frESCO's replication potential in Europe reveals optimistic outcomes, particularly for regulatory, financial, technological, and political stakeholders. High regulatory and financial support in Spain and Portugal, along with Belgium's subsidy schemes, sets the foreground bases for high replication potential. Technologically, frESCO's commitment to innovation, including mature technologies for the provision of advanced energy and non-energy services, aligns well with the growing market demand. This sets a high potential for technology providers, ESCOs, and aggregators.

Political commitment within the EU towards decarbonization, coupled with anticipated policy frameworks, aligns with future trends, indicating a high potential for political stakeholders. Thorough assessments for various target segments, such as demand flexibility aggregators, ESCOs, and technology developers, provide a nuanced understanding. The acknowledgment of potential barriers demonstrates a realistic assessment of challenges, with a medium potential for these stakeholders. Explicit Demand response technical and social issues, closed markets for residential prosumers, and potential data transaction risks add to the criticalities. Overcoming these barriers and addressing challenges is crucial for the successful replication of frESCO in diverse European contexts. Strategic recommendations given in D7.4 enhance the project's potential, emphasizing a proactive approach for higher replication potential across diverse European contexts.

In conclusion, the frESCO overall positive results at varied demonstration sites and the replication potential assessment of frESCO’s Key exploitable results, including advanced services and mature technologies, indicate a high replication potential in the residential sector, which is acknowledged by the EC to be a fundamental contributor to the Union's decarbonisation targets. External factors such as high and volatile energy prices and the cost reduction of a matured technology further contribute to a positive outlook for the frESCO project replication in Europe, while recognizing and addressing criticalities remains pivotal for success.

6 CHALLENGES FOR PROJECT RESULTS MATURITY

The project results were successful but subject to a number of barriers listed as "lessons learned" in D6.5 "frESCO Implementation Guidelines and Recommendations". A summary of them is offered hereinafter.

Dealing with streaming data from domestic users always comes with challenges related to the quality of data (missing values and incomplete data due to connectivity loss). This brings forward the need for introducing additional quality enhancement mechanisms, to support the extraction of more valuable knowledge and insights and drive even more accurate predictions for the triggering of flexibility and energy management events. Third-party commercial equipment may experience failures, leading to replacements under warranty in demo buildings.

6.1 Demo related and user engagement challenges

The buildings and equipment exhibit significant heterogeneity, making it challenging to apply a uniform frESCO solution across all residential buildings in the EU. The Croatian pilot experience suggests that a gradual roll-out is necessary, as fully equipping all dwellings would pose a substantial obstacle to project success. Emphasizing a smooth implementation and testing process, without causing disruptions to end users, is crucial for enhancing their experience and service utilization. Conducting prior visits to understand the characteristics and details of each family and household is important, requiring attention to detail.

Successful demo implementation and user involvement hinge on establishing personal relations, addressing user needs and inquiries, and clearly communicating the project's role to users. Maintaining motivation and engaging users interested in learning are vital. Establishing a robust network involving various stakeholders such as utilities, installers, building managers, promoters, architects, and maintaining a main contact at the demosite are crucial for obtaining additional information.

The low interest of building residents in digital energy services led to the replacement of two demo site buildings in Madrid and France and posed challenges in finding suitable buildings in Croatia. The absence of interest from building residents in flexibility services, due to closed markets, resulted in low usage of the smart contracts applications. Residential buildings without PV show limited potential for energy services. Implementing shared PV assets in a building is proven complex, requiring agreement among residents and prepayment for a long payback-time investment. The first building in Madrid lacked such agreement in the initial six months, leading to its exclusion.

Building residents exhibit moderate rejection of external explicit operation of DERs for flexibility activation. Open markets with attractive remuneration of both flexibility capacity and provision is key to engage users to take part in active demand response schemes.

On the other hand, there is in general low participation in implicit Energy Efficiency measures mandated by the system. Installation challenges and costs are amplified in remote holiday resorts like Krk and Thasos islands, contingent on dwelling occupancy and limited to testing periods during summer and occasional holidays. Holiday resorts are less inclined to participate in energy savings or flexibility events during vacation periods, deeming them less appealing in these environments.

6.2 Key Exploitable Results Market Challenges

Big Data Platform

The Big Data Management platform's final version, encompasses all previously discussed features. However, additional development efforts, incurring extra costs, are necessary to prepare a commercial release within the next two years. These endeavors involve market analysis to identify new functional and non-functional requirements, ensuring the incorporation of enhanced features for improved data ingestion, curation, and management. Crucial aspects include securing funding for performance improvements to handle increased data flows, code refactoring for enhanced quality, UX/UI enhancements, improved quality assurance, and marketing the platform. The competition analysis underscores the challenges of commercializing the frESCO Big Data platform ina market with established players and rapidly evolving technologies. To address these challenges, developing a flexible platform capable of easily adopting new technologies and expanding services is imperative. Additionally, compliance with data privacy regulations, such as the EU's General Data Protection Regulation (GDPR), poses a significant challenge to the platform's exploitation. These regulations necessitate careful analysis, considering they may restrict the platform's offerings and deter potential customers. The estimation of commercial costs becomes feasible only when real-time data and analytics are ingested in the platform and utilized from relevant partners.

Integrated Service bundles for residential consumers

Despite the potential for energy savings in residential buildings, economic barriers hinder the widespread adoption of energy efficiency services. A major obstacle is the high transaction costs for Energy Service Companies (ESCOs) when compared to the relatively small energy savings (and subsequent revenues) achieved per residential household. This situation results in a lower economic return compared to other market segments. Although digital applications do not heavily rely on capital expenditures (CAPEX), the dispersed nature of residential consumers means that a higher number of devices need to be installed, especially in buildings with low smart readiness. Additionally, securing funding for performance enhancements or increased services is crucial to ensure the development of an attractive and marketable product/service.

The development of frESCO Integrated Energy Services aligns with the Energy Efficiency Directive (EED), which sets binding measures to help the EU achieve its energy efficiency targets by 2030. While the directive aims to stimulate investments in energy efficiency, its transposition, along with other national and local regulations, has created barriers for ESCOs, particularly in the utilization of Energy Performance Contract (EPC) models. These barriers encompass legal considerations related to equipment installation, procurement procedures for public authorities, and legal issues related to tenancy laws.

The estimation of costs for the successful commercial deployment of frESCO Integrated Energy Services depends on the speed of implementation, target countries, and the chosen access channels. Despite employing digital marketing for promotion, establishing a minimal sales channel structure is necessary to manage commercial relationships with representatives or agents of various stakeholders. However, the primary challenge lies in providing a concrete Proof of Concept for the value of energy services deployment, despite the significant upfront costs.

Multiservice package toolkit

The financing challenges for the multi-service package toolkit are multifaceted, encompassing hardware maintenance, software development, personnel, and support costs. Hardware maintenance costs, ranging from €20,000 to €50,000 annually, are contingent on specific equipment needs. Similarly, software development costs, spanning €50,000 to €100,000 per year, hinge on licensing and upgrades. Personnel costs for development, verification, and testing may reach €200,000 to €300,000 over 1.5 years for a small team. Post-market launch, additional costs, notably support and maintenance, are expected, varying based on customer needs. To navigate these challenges, funding options include seeking support from venture capitalists, applying for grants, forming partnerships with energy industry giants, or exploring revenue-sharing models with customers. In addition, regulatory and legal compliance is critical. The toolkit must adhere to GDPR, consumer rights, intellectual property protection, and environmental regulations. Challenges arise from legal compliance and the regulatory framework, with GDPR and evolving regulations posing potential hindrances. Overcoming these barriers involves meticulous GDPR compliance, adherence to energy market design regulations, intellectual property protection, and environmental compliance. Collaboration with legal experts is essential, along with user training for legal framework operation. Cooperation with regulatory bodies ensures alignment with the toolkit's needs. Establishing a more favorable regulatory framework for small Energy Service Companies (ESCOs) and aggregators is advocated to facilitate market entry. The toolkit's advertising and customer engagement costs depend on chosen channels, such as digital marketing, events, conferences, and partnerships. A targeted budget is advisable based on audience and goals. Commercially, the toolkit's value proposition distinguishes it: personalized energy analytics for ESCOs, streamlined processes for aggregators, and increased revenues for consumers/prosumers through demand response and self-consumption optimization. Acknowledging potential competition, differentiation through a unique value proposition is emphasized, increasing benefits to customers. Crucial to market launch is collaboration with utilities, suppliers, and service providers for distribution, installation, and maintenance. Establishing strong partnerships with industry leaders enhances credibility.

In summary, successful market launch requires meticulous financial planning, regulatory compliance, targeted marketing, and strategic partnerships, underlining the toolkit's unique value proposition and differentiation in a competitive landscape.

Smart Energy Boxes

The main financial challenge facing Energy Service Companies (ESCOs) and aggregators in domestic markets is the high transaction costs, which outweigh the relatively small energy savings per residential household, resulting in a less favorable economic return compared to other sectors. However, the Energy Box emerges as a solution, offering smart energy savings with minimal or no investment costs. Its real-time monitoring and analytics capabilities enhance energy management, identifying and rectifying inefficiencies for increased savings and reduced costs. Designed for compatibility with a diverse range of energy assets and systems, the Energy Box facilitates seamless integration for ESCOs and aggregators. These favorable attributes make the solution more attractive and feasible for adoption in residential energy efficiency initiatives. In terms of estimated costs, the Energy Box presents a cost-effective option, with yearly production costs ranging from 200-500 EUR per unit and an estimated selling price of 500-800 EUR per unit. This affordability enhances its appeal to ESCOs and aggregators, positioning it as a viable solution. Regulatory variations across European countries pose challenges, but potential future regulatory changes may harmonize market environments. Compliance with data privacy requirements, notably the General Data Protection Regulation (GDPR), adds to user confidence. The challenge of lacking standardization and interoperability among data-driven smart devices is addressed by the

Energy Box's compatibility with various standards. Constant updates ensure alignment with emerging standards and protocols, underscoring the solution's commitment to staying current. In the Spanish market, competitors like powerMAX for Mobile Microgrids and GridOS™ smart grid system exist, while internationally, Revolution Pi serves as an alternative solution. The Energy Box stands out as it undergoes value engineering during freSCO to reduce costs, making it more accessible for home use. An additional challenge is energy price volatility, impacting short-term return estimations. However, the Energy Box's low-cost system, coupled with low maintenance and a long operating life, counterbalances this challenge, ensuring its viability as an investment despite short-term uncertainties.

Novel Performance Measurement and Verification Methodology

The successful deployment of the PMV solution faces a significant financing challenge due to the high costs associated with current services. To address this, a viable solution involves leveraging low-cost, technically available data collection systems to implement the innovative PMV protocol effectively. This is the case of the frESCO Platform and tool suit. Costs per user largely depend on the number of users being served from the same platform and system. (Data collection system investment is around 720 €/dwelling). For ESCOs dealing with domestic users, an additional cost challenge arises as each user requires an ex-ante analysis of historical data to establish a mid-term baseline for efficiency. This necessitates algorithmic adaptations based on individual customer needs or service requests. Model training requires also a period of time with continuous data ingestion and computation which needs to be prolonged along the whole energy service duration.

Considering the market launch of PMV, several barriers need careful consideration to ensure the solution's smooth exploitation. One notable challenge is the limited or no acceptance of aggregated flexibility in today's markets. The proposed PMV solution includes the option of aggregating flexibility to the grid, underlining the importance of providing robust forecasting tools and methodologies for real-time flexibility assessment. Another obstacle is the absence of specific European or national standard references that sufficiently facilitate the commercialization and exploitation of PMV. Current recommendations emphasize the need for a fair, effective, and accurate system. To overcome this, the suggestion is to position the frESCO protocol as a reference standard for for a hybrid methodology for new P4P data-driven energy services in buildings. Data protection laws must be observed when offering a service involving PMV, requiring strict adherence to consent and confidentiality. Overcoming this barrier involves employing data anonymization and encryption procedures for end-user data. Another commercial challenge relates to low penetration of Energy Performance Contract (EPC) models in the residential sector, mainly due to a lack of interests by the ESCOs. To address this, there is a need to evolve current EPC models into new P4P (Pay for Performance) Energy Performance Contracts, aligning with the compatibility of the new frESCO PMV methodology.

7 CONCLUSIONS

This document summarises the frESCO project results obtained by the 14 consortium partners during the 42 months that the project has been running since June 2020. The consortium developed a Big Data Platform and five applications that were tested in 3 physical demo site buildings and in several additional and similar buildings making part of the extended demo sites in the same locations.

Jointly, the quantitative results of the demonstration activities meet or exceed the initial committed targets in user engagement (+26%), primary energy savings (+16%), gas emissions reduction (+6%), and payback time (-3%). Investments of the frESCO system were 44% lower than initially budgeted, but the number of gateways installed are 17% more. Results have been uneven in the three demo sites, being very remarkable in Madrid, quite positive in the Thassos hotel bungalow building and a little behind in the dwellings of the Smart Island of Krk with lower PV self-consumption profitability, highly seasonal occupancy and the limitation of the demo size due to technical reasons having prevented the obtention of better results.

The main project results and their technical readiness level are thoroughly described in the document. The current readiness level for all the results is assessed to be 8, or close to market readiness. These results are:

- Big Data Management Platform. Moving from TRL 6 to 8.
- Integrated Energy Service Bundles for Residential Consumers. Evolving from TRL 6 to 8
- Multi Service Package Toolkit. Moving from TRL 6 to 8.
- Smart Energy Boxes. Stepping from TRL 7 to 8

- Novel Performance Measurement and Verification Methodologies. Going from TRL 7 to 8.

The necessary steps in order to fully deploy frESCO Key Exploitable Results are identified throughout the project. Depending on the market readiness of each KER at this point, the time required varies from 1 year -in the case of the PMV methodology and the Multiservice Package Toolkit- to about 2 years – in the case of the Big Data Management Platform and the Integrated Energy Services. The case of the Energy Box is rather different since, from a functionality perspective, the EB can be regarded as ready-to-market, but issues such as lowering cost while maintaining the quality of the services provided, have to be addressed.

The market challenges for the frESCO results reside on the difficulty to replicate the frESCO solutions in a wide variety of residential buildings with low smart readiness and fitted with highly diverse legacy equipment. frESCO demonstration results prove that the solutions can be adapted to a variety of buildings but with different results depending on the environment. Best results are obtained in permanently occupied buildings fitted with PV and storage capabilities, and large electricity demands. The usage of the services by building residents is uneven showing that facility and energy managers are more prone to interact with the system than average users or hotel guests. Homogeneity of smart retrofitting equipment ensures an easier data ingestion and consumption. Technical problems can be better addressed in accessible locations and by open access gateways remotely operated and monitored.

As far as user engagement is concerned, the heterogeneity of buildings and equipment makes a uniform solution difficult. The success of demo implementation and user involvement relies on establishing personal relations, addressing user needs, and clear communication messages. Motivating and engaging users interested in learning is vital. Low participation in implicit energy efficiency measures is observed. Challenges in installation and costs are amplified in remote holiday resorts, where participation in energy savings or flexibility events is less appealing during vacation periods.

The assessment of frESCO's replication potential in Europe is overall optimistic, frESCO's technological innovation and alignment with market demand create a high potential for technology providers, ESCOs, and Aggregators. The EU's political commitment to decarbonization and anticipated policy frameworks align with future trends of citizen engagement and involvement of residential buildings. These factors indicate a high potential of frESCO solution replication in the residential building sector. Thorough assessments of various target segments reveal interesting insights, with a realistic acknowledgment of potential barriers and challenges, resulting in a moderated potential for specific groups. Critical issues such as demand response challenges, closed markets for residential prosumers, and potential data transaction risks are highlighted. Successfully overcoming these barriers is crucial for the widespread replication of frESCO in diverse European countries.

We can conclude that the new P4P energy services tested in frESCO have shown their technical and economic feasibility and constitute a success story about the use of data-driven solutions to involve the residential sector in the EU's decarbonisation goals for 2030 and beyond.

8 REFERENCES

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FrESCO D4.6 "frESCO Integrated Platform - Beta Release"

FrESCO D5.8 "frESCO multi-service package toolkit"

FrESCO D6.3 "Report on frESCO demosite activities"

FrESCO D6.4 "Socio-economic, environmental and technological impact assessment"

FrESCO D6.5 "frESCO Implementation Guidelines and Recommendations"

FrESCO D7.2 "Final Version of the Exploitation Plan"

FrESCO D7.4 "Roadmap for the replication of frESCO developments"

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