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Roadmap for the replication of frESCO developments

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1 EXECUTIVE SUMMARY

The frESCO project is an innovation action that brings together 14 partners from 8 different EU countries, that span from Research Institutes to Energy Communities and Aggregators and aims to deliver the next generation of Energy Performance Contracting (EPC) under the Pay for Performance principles. The New EPCs will be disengaged from traditional savings-based contracts and exploit the new market opportunities by creating new revenue streams for the end user consumers or prosumers, allowing them to become active participants in the emerging new market structures.

Work Package 7 (WP7) aims to define the general exploitation strategy to ensure the market deployment, adoption, and replication of frESCO results. This deliverable offers a comprehensive exploration of the status of energy services in the European Union, particularly focusing on the evolving landscape of residential energy services. Notably, technological advancements, changing business models, and a heightened emphasis on sustainability have driven substantial shifts in this sector.

The document initiates with a detailed baseline analysis of the residential energy services market, emphasizing the pivotal role of Energy Service Companies (ESCOs) and the prevailing electricity market framework. A crucial component of this deliverable is the introduction of a methodology designed to assess the replication potential of innovative energy services across various European Union climatic zones. This framework incorporates a nuanced understanding of regional and climatic characteristics, offering decision-makers valuable insights for promoting energy efficiency and sustainability in residential areas. A significant aspect of this deliverable is the meticulous collection of information on enablers and barriers for replication within the EU. The assessment methodology, grounded in climatic zones and key parameters, is considered vital for the frESCO project. Addressing challenges in financial, market, and regulatory aspects is identified as crucial for achieving successful replication.

The document also examines the level of innovation from a business standpoint, emphasizing the combination of mature technologies to generate new streams of revenues and energy savings. This business innovation is seen as a crucial factor influencing the replication potential of frESCO energy services across EU countries, considering the diverse

climatic zones. The final chapter aims to qualitatively categorize the replication potential for different stakeholders and target segments involved in the frESCO project. These segments include ESCOs, technology providers, residential/commercial prosumers, and technology-dependent aggregators. The challenges recognized as barriers to innovation, coupled with the analyses of target segments developed in previous deliverables, will be integral to assessing the potential for replication across various EU countries.

2 ABBREVIATIONS

Abbreviation	Name
API	Application Programming Interface
CEN	European Committee for Standardization
CTE	Technical Building Regulation (Spain)
DR	Demand Response
DSM	Demand-Side Management
DSO	Distribution System Operator
EED	Energy Efficiency Directive
EPBD	Energy Performance of Building Directive
EPC	Energy Performance Company
ESC	Energy Supply Contracting
ESCO	Energy Service Company
ETS	Emission Trading System
EVO	Efficiency Valuation Organization
FiTs	Feed in Tariffs
GDPR	General Data Protection Regulation
GUI	Graphic User Interface
HMI	Human-Machine Interface
IEC	Integrated Energy Contracting
IoT	Internet of Things
KER	Key Exploitable Result
MQTT	Message Queuing Telemetry Transport
nZEB	Near Zero Emssion Building

P2P	Peer-to-peer
P4P	Pay for Performance
PMV	Performance and Measurement Verification
RD	Royal Decree (Spain)
REC	Renewable Energy Community
RED	Renewable Energy Diractive
RES	Renewable Energy Share
SRL	Smart Readiness Level
ToU	Time of Use
TRL	Technology Readiness Level
TSO	Transmission System Operator
VPP	Virtual Power Plants
XML	eXtensible Markup Language

3 INTRODUCTION

Energy efficiency has emerged as a cornerstone of contemporary global efforts to address climate change, enhance energy security, and promote sustainable development. The EU's journey towards comprehensive energy efficiency has not been mere happenstance but rather the result of a meticulously crafted framework. This framework, consisting of directives, regulations, and initiatives, lays the groundwork for optimizing energy utilization across different sectors, ranging from residential to industrial and encompassing commercial and transportation domains. Within this framework, stringent energy performance standards for buildings, energy labelling for appliances, and financial incentives for energy-efficient technologies form a comprehensive policy arsenal.

The EU's energy efficiency objectives are far-reaching, characterized not only by a reduction in greenhouse gas emissions but also by the promotion of economic competitiveness and energy independence. These objectives resonate with the broader international agenda, underpinning the EU's role as a global leader in sustainable energy policy formulation.

This introductory chapter aims to summarize a comprehensive examination of the EU's energy efficiency framework, contextualizing the frESCO project within this larger landscape to provide a comprehensive assessment of its role in advancing the EU's climate agenda in the following chapters. This Deliverable along Deliverables 7.2, 7.3, 7.5 and 7.6 successfully satisfies **Milestone 9** of the project: "Identified final description of KERs and exploitation strategies".

3.1 The Renewable Energy Directive (RED)

The Renewable Energy Directive (RED) is another cornerstone of EU energy policies. While primarily focused on the promotion of renewable energy sources (RES) across various sectors, it holds specific relevance to residential energy efficiency.

The RED encourages member states to promote the use of renewable energy sources for heating and cooling in the residential sector. This includes incentives for the installation of solar thermal systems, heat pumps, and biomass boilers. The chapter discusses the impact of such measures on reducing the carbon footprint of residential buildings and improving energy efficiency.

The directive also promotes residential electricity generation through renewables, particularly through measures such as feed-in tariffs and incentives for small-scale photovoltaic installations. This section explores the growth of residential renewable electricity generation and its role in enhancing energy self-sufficiency and reducing grid demand.

3.2 The Energy Efficiency Directive (EED)

The Energy Efficiency Directive (EED) is a pivotal piece of legislation within the EU's framework for enhancing energy efficiency. It aims to reduce energy consumption and lower greenhouse gas emissions by setting specific objectives for member states. These objectives primarily focus on achieving energy savings and improving energy performance across various sectors, including the residential sector. The EED outlines binding targets for energy savings that require EU member states to collectively achieve a 32.5% reduction in primary energy consumption by 2030 compared to a baseline. Within this overarching goal, specific targets are allocated to individual member states based on their historical energy consumption and economic conditions. EED employs a multifaceted approach to achieve its energy efficiency objectives, with a strong emphasis on the residential sector.

Key measures and provisions within the directive:

- National Energy Efficiency Action Plans (NEEAPs): member states are required to develop NEEAPs outlining their strategies and policies for improving energy efficiency. These plans encompass a range of measures specifically designed to enhance residential energy performance. They address issues such as building renovations, promotion of energy-efficient appliances, and the adoption of smart technologies in residential buildings.
- Energy Performance Certificates (EPCs): EED places a significant emphasis on the importance of Energy Performance Certificates (EPCs). These certificates provide

valuable information to homeowners, tenants, and buyers about the energy performance of residential buildings. Member states are obligated to implement and improve EPC systems to ensure transparency and facilitate informed decisions regarding energy-efficient housing. EPCs are also one of the key features of EPBD directive (paragraph 3.3).

- Renovation Obligations: one of the EED's key provisions is the requirement for member states to establish long-term strategies for renovating existing buildings to meet energy efficiency standards. The directive mandates the renovation of at least 3% of the total floor area of central government-owned buildings every year.

3.3 The Energy Performance of Buildings Directive (EPBD)

The Energy Performance of Buildings Directive (EPBD) is a pivotal piece of European Union legislation designed to improve the energy efficiency of buildings within the EU. Launched in 2002 and subsequently revised in 2010 and 2018, the EPBD plays a fundamental role in the EU's efforts to combat climate change, reduce energy consumption, and create more sustainable built environments.

The primary objective of the EPBD is to minimize the energy consumption of both new and existing buildings. It establishes stringent energy performance standards, which apply to new constructions and extensive renovations. These standards seek to ensure that buildings are constructed or renovated with a focus on energy efficiency, reduced greenhouse gas emissions, and increased use of renewable energy sources.

One of the key features of the EPBD is the requirement for Energy Performance Certificates (EPCs). These certificates provide valuable information to building owners, occupants, and potential buyers or tenants about the energy efficiency of a building. They include recommendations for improving energy performance and help consumers make informed choices regarding their energy use.

Furthermore, the EPBD encourages the development of nearly zero-energy buildings (nZEBs), which are structures with very high energy performance and a significant share of their energy consumption met by renewable sources. Member states are obliged to establish definitions and adopt national plans for nZEBs.

In summary, the EPBD is a critical instrument in the EU's energy efficiency policy framework. It strives to transform the building sector into a more sustainable and energy-efficient entity, thereby reducing the environmental impact of buildings while contributing to energy security and the EU's climate goals.

3.4 EU energy efficiency projects

The European Union (EU) is firmly committed to achieving a sustainable energy transition, and it has embarked on a multitude of projects aimed at realizing this ambitious goal. These projects are designed to promote innovative approaches to energy efficiency, flexibility, and environmental sustainability. frESCO is one of the projects funded under the call "LC-SC3-EE-13-2018-2019-2020 - Enabling next-generation of smart energy services valorising energy efficiency and flexibility at demand-side as energy resource". Together with frESCO it's worth mentioning AmBIENCe and SENSEI projects, which tackle replication potential of innovative energy services through the analysis of new hybrid business models and suggestions for policy makers in enabling new features replication through a more friendly regulatory framework.

AmBIENCe is a pioneering project within the frESCO consortium, focusing on the development of the Active Building Energy Performance Contract (AEPC) concept and innovative business models. Its primary characteristics include:

- Demand Response integration: AmBIENCe extends the traditional Energy Performance Contract (EPC) by incorporating Demand Response (DR) services, enhancing energy efficiency guarantees with the valorization of flexibility.
- Diverse building types: The project tailors EPCs to a broad spectrum of building types, including residential, commercial, educational, and healthcare facilities.

- Energy communities and aggregators: AmBIENCe explores the concept of Technical/Market Aggregators and local energy communities, extending the scope to groups of buildings and fostering collective approaches to energy efficiency and flexibility.
- Policy analysis: The project conducts a comprehensive analysis of directives, policies, and measures at the EU and national levels to identify gaps and best practices, thus paving the way for an innovative and more sustainable energy transition.

SENSEI explores the role of the Energy Efficiency Aggregator (EE Aggregator) within innovative Pay-for-Performance (P4P) schemes. Its distinctive characteristics encompass:
P4P programs: SENSEI focuses on P4P programs that offer payments for energy efficiency based on proven and measured savings, a relatively new approach, particularly in the residential sector.

- EE aggregator: The project introduces the concept of the EE Aggregator, which plays a pivotal role in aggregating buildings into portfolios of energy savings, thereby reducing transaction costs and fostering innovation in energy efficiency service delivery.
- Aggregation models: SENSEI explores aggregation models not only within the energy sector but also in various industries, emphasizing the role of aggregators in facilitating service delivery.
- Market facilitation: The project highlights the importance of a conducive market and regulatory framework for the successful implementation of P4P programs, offering valuable insights for policymakers and market players.

4 ENERGY SERVICES STATUS IN EU RESIDENTIAL SECTOR

The residential energy services landscape has evolved significantly in recent years, driven by technological advancements, changing business models, and a growing focus on sustainability. In this section, we provide an overview of the residential energy services market, with a particular emphasis on the role of Energy Service Companies (ESCOs) and the electricity market framework.

Additionally, a methodology for assessing the replication potential of innovative energy services in different European Union climatic zones is presented. This framework considers various parameters, considering the specific regional and climatic characteristics that influence the feasibility and scalability of energy-efficient solutions. It provides decision-makers with valuable insights for promoting energy efficiency and sustainability in residential areas.

Finally, main trends in markets, technologies, and the legal and permitting framework are explored: these are the key parameters which will shape the residential energy services landscape in the next future. Understanding these trends is essential for adapting to the evolving energy market and fostering the successful replication of innovative energy solutions in diverse EU climatic zones.

4.1 Energy services market

Residential energy services have undergone a significant transformation in recent years, driven by technological advancements, evolving business models, and a growing emphasis on sustainability. This section provides a comprehensive overview of the state of the art in the residential energy services market, with focus on Energy Service Companies (ESCOs) business models and electricity market framework.

4.3.1 Electricity Market

EU boasts a multifaceted energy market structure, characterized by a blend of both liberalized and regulated activities across its member states. This diversity reflects the EU's overarching goal of creating a sustainable, competitive, and interconnected energy ecosystem that can adapt to the evolving needs of its member states and their citizens, while at the same time promoting further market integration

At the core of the EU's energy landscape lies the wholesale market, where electricity and gas are traded on both regional and cross-border scales. This market is marked by a concerted effort to harmonize market mechanisms and foster cross-border energy trading in accordance with the EU's target model. It encompasses various market segments, including futures and day-ahead markets, which are managed by multiple market platforms across the continent. These markets serve as the cornerstone for price discovery, ensuring cost-effective energy supply for consumers. Transmission System Operators (TSOs) play a pivotal role in overseeing the wholesale market. Their responsibilities span beyond the mere operation of the transmission grid; they are also responsible for maintaining grid stability and ensuring a delicate balance between energy supply and demand. TSOs are charged with facilitating the seamless integration of renewable energy sources, a crucial element of the EU's commitment to a sustainable energy transition. Additionally, they face the intricate task of managing the ever-increasing complexities associated with grid management in the face of a changing energy landscape. Renewable energy holds a central position in the EU's energy mix, and its integration into the wholesale market stands as a top priority. Typically, renewable energy sources, once they surpass a certain capacity threshold, actively participate in the wholesale market. This participation entails taking on the responsibility for addressing imbalances, aligning with the EU's ambitious renewable energy targets. This not only furthers the growth of renewables but also enhances the resilience and flexibility of the grid as a whole.

Retail market serves as the interface where consumers engage with energy suppliers, offering a wide range of energy supply options. The EU's energy policy underscores competition and consumer choice as fundamental principles governing this retail market.

Member states operate a dual-market structure, affording consumers the liberty to select from both regulated and free-market energy supply options. This level of choice empowers consumers to make energy provider decisions based on their unique preferences, whether they prioritize cost, environmental sustainability, or other factors. In parallel, regulated social tariffs are prevalent in many member states, primarily designed to safeguard the energy access of vulnerable or energy-poor consumers. These tariffs play a critical role in ensuring that essential energy services remain accessible and affordable to all, irrespective of their economic circumstances. While these tariffs provide a safety net, they are also emblematic of the EU's commitment to social equity within the framework of its energy policy. However, despite the EU's commitment to fostering a competitive retail market, certain challenges persist. The adoption of advanced technologies, particularly smart metering, remains uneven across member states. These technologies serve as crucial enablers for unlocking the full potential of demand-side management and empowering consumers to make informed choices regarding their energy usage and providers.

Demand response (DR) is a strategy used in the energy sector to balance electricity supply and demand by encouraging consumers to adjust their electricity consumption patterns in response to signals from the grid operator or energy provider. During times of high demand or grid instability, consumers can voluntarily reduce or shift their electricity usage, helping to prevent blackouts and reduce the need for expensive “peak-hour” thermal plants. DR programs often involve financial incentives or price signals to motivate participants. This approach not only enhances grid reliability but also promotes energy efficiency and sustainability by optimizing resource utilization. DR landscape exhibits variations across member states. Typically, large industrial consumers actively participate in demand response programs, where they commit to adjusting their energy consumption patterns in response to grid signals. These programs bear a resemblance to interruptible load agreements and are designed to enhance grid stability, especially during periods of peak demand or supply constraints. However, the active engagement of residential consumers in demand response initiatives displays considerable diversity, often influenced by the prioritization of smart meter deployment. The gradual rollout of smart meters, enabling real-time data collection and communication between consumers and the grid, serves as a foundational element in unlocking the full potential of demand-side management. As the penetration of smart meters continues to rise, it is expected that more residential consumers will actively participate in demand response programs. This, in turn, can significantly contribute to grid flexibility and reduced energy costs for consumers.

Moreover, the EU has identified the potential of Energy Communities to aggregate demand response resources effectively. Energy communities have emerged as promising avenues for consumer participation in the broader energy transition. They enable individuals and local groups to collectively invest in renewable energy projects and share resources. These communities hold the potential to evolve into Virtual Power Plants (VPPs), aggregating distributed energy resources and delivering valuable grid services. The EU actively promotes self-consumption of energy, considering it a key element of its decentralized energy strategy. Self-consumption initiatives encompass specialized programs for buildings and net metering for rooftop installations of solar photovoltaic (PV) systems. These programs typically establish capacity limits, grid connection prerequisites, and netting agreements between PV system owners and energy suppliers. Special programs for buildings specifically encourage the installation of renewable energy sources, with a particular emphasis on solar PV systems. These systems often feature capacity limits to ensure grid stability and prevent excessive surplus energy generation. Netting agreements, governing the exchange of energy between PV system owners and suppliers, play a pivotal role in enabling self-consumption. These agreements may involve the purchase of excess energy generated by PV systems or energetic crediting for surplus energy, allowing consumers to offset their energy consumption over time. Net metering for rooftop installations functions in a similar manner, granting consumers the ability to either receive credits for excess energy generated or sell it back to the grid. This mechanism not only incentivizes the adoption of renewable energy sources but also fosters a sense of energy autonomy among consumers, reducing their reliance on conventional energy sources.

Financial incentives and schemes play a crucial role in driving the adoption of renewable energy sources, improving energy efficiency, and promoting sustainable practices in the energy sector. These mechanisms provide economic incentives for individuals, businesses, and governments to invest in clean energy technologies and reduce their carbon footprint.

One common financial incentive is feed-in tariffs (FiTs), which guarantee fixed payments to renewable energy generators for the electricity they feed into the grid. FiTs make renewable energy investments more attractive by offering stable, long-term revenue streams. Subsidies and tax credits are another set of incentives. Governments often provide subsidies to reduce the upfront costs of renewable energy installations, making them more affordable for consumers and businesses. Tax credits, on the other hand, reduce tax liabilities for individuals and companies that invest in renewable energy projects. Net metering is a financial scheme that benefits renewable energy users. It allows them to offset their electricity bills by crediting excess energy they generate and feed into the grid. This encourages self-consumption and the installation of residential solar panels. Energy efficiency programs, such as the Exoikonomo program, offer financial bonuses or incentives for implementing energy-efficient measures. These programs aim to reduce energy consumption, lower utility bills, and decrease greenhouse gas emissions.

4.3.2 ESCO Business Models

An Energy Service Company (ESCO) is a specialized entity that offers comprehensive energy solutions to commercial, industrial, and residential clients. ESCOs are entrusted with the task of improving energy efficiency, reducing consumption, and lowering operating costs for their clients. They typically employ a combination of technologies, expertise, and financing mechanisms to achieve these objectives. ESCOs often engage in energy audits, implement energy-efficient upgrades, and provide ongoing monitoring and maintenance services. Their goal is to optimize energy use and sustainability while delivering measurable energy and cost savings to their clients, making them a crucial component of the energy efficiency and sustainability landscape. ESCOs have emerged as pivotal players in enhancing residential energy efficiency. Their diverse business models, discussed below, have revolutionized the way energy services are delivered:

Energy Performance Contracting (EPC) is a cornerstone of ESCO business models. EPCs involve comprehensive partnerships between ESCOs and building owners or managers. In this model, ESCOs take on the responsibility for guaranteeing energy savings through the implementation of energy-efficient measures. Such measures may encompass a wide array of interventions, including upgrading heating and cooling systems, improving insulation, and enhancing lighting efficiency.

Data Collection in EPC: Central to the EPC model is data collection. ESCOs employ advanced monitoring and data collection systems to assess various factors affecting energy usage within residential buildings. These factors include the thermal performance of building envelopes, the efficiency of heating, ventilation, and air conditioning (HVAC) systems, lighting patterns, and renewable energy utilization. The data collected serves as the foundation for tailoring energy efficiency improvements to the specific needs of each building, ensuring that the proposed measures yield maximum energy savings.

Energy Supply Contracting (ESC) is another vital facet of ESCO models. In this approach, ESCOs take on the role of energy suppliers for residential buildings. Instead of simply delivering energy, these companies actively engage in optimizing energy generation, distribution, and consumption. Through data collection and analysis, ESCOs aim to provide a reliable and cost-effective energy supply while simultaneously enhancing energy efficiency.

Data Collection in Energy Supply Contracting: Effective data collection underpins the energy supply contracting model. ESCOs use real-time data from smart meters and other monitoring systems to track energy consumption patterns within residential buildings. This granular data allows for precise energy forecasting, load optimization, and the seamless integration of renewable energy sources.

Integrated Energy Contracting (IEC) represents a holistic approach to residential energy services offered by ESCOs. In this model, ESCOs combine elements of both EPC and Energy Supply Contracting to provide comprehensive energy solutions. Integrated Performance Contracting entails the implementation of a wide range of energy-efficient measures, coupled with the supply of energy tailored to the specific needs of the building.

Data Collection in Integrated Energy Contracting: data collection in integrated performance contracting is multifaceted. ESCOs leverage data from various sources, including on-site sensors, building management systems, and external weather data. This integrated data collection allows for a comprehensive understanding of energy consumption patterns and the seamless optimization of both energy supply and efficiency measures.

Residential common practices encompass a range of energy-efficient technologies and approaches adopted by homeowners and ESCOs. These practices include the widespread adoption of heat pumps and photovoltaic (PV) rooftop contracting.

Heat pumps are highly efficient heating and cooling systems that leverage renewable energy sources, such as air or ground heat, to provide indoor climate control. These systems have gained popularity in residential buildings due to their energy-saving potential. Data collection in heat pump systems involves monitoring system performance, energy consumption, and environmental conditions to optimize operation.

PV rooftop contracting: photovoltaic rooftop contracting allows homeowners to harness solar energy by installing solar panels on their rooftops. Often facilitated by ESCOs, these contracts involve data collection to assess the solar potential of rooftops, monitor energy generation, and optimize energy consumption within residential buildings.

4.2 Replication potential assessment methodology

The residential sector is a complex ecosystem influenced by a multitude of factors. In addition to the evident technological advancements, it is essential to consider the broader context in which these innovations will operate. The energy market landscape, characterized by supply and demand dynamics, regulatory frameworks, and evolving consumer preferences, plays a pivotal role in shaping the feasibility and scalability of energy-efficient solutions. The range of services offered, encompassing energy performance contracts, demand forecasting, grid flexibility, and non-energy-related services, contributes significantly to the holistic success of these solutions.

The aim of the methodology is to provide a comprehensive framework for analyzing the replication potential of innovative energy services in different European Union (EU) climatic zones. By examining a range of critical parameters, this methodology seeks to differentiate the analysis based on specific climatic and regional characteristics.

Climatic zones definition

The significance of defining climatic zones lies in the profound impact of climate characteristics on energy service replication. The unique weather patterns, temperature extremes, and seasonal variations within each zone directly influence energy needs, consumption patterns, and the suitability of energy services. Moreover, these climatic distinctions affect the availability of renewable energy sources, energy storage requirements, and the overall feasibility of implementing innovative solutions.

The goal is to tailor strategies that maximize the adoption and success of these energy services while addressing the unique challenges and opportunities presented by each zone.

In this first part of this methodology for energy service replication, we delve into the definition of climatic zones: Koppen Climate classification has been used as a reference. The aim of the following paragraphs is to address geographical ranges, key characteristics, and impact on energy services of the climatic zones.

Mediterranean Climatic Zone

The Mediterranean climatic zone encompasses southern European countries bordering the Mediterranean Sea, including Spain, Italy, Greece, southern France, and parts of Portugal. This region is characterized by warm temperatures throughout the year, with a pronounced dry season in the summer and wetter conditions in the winter. The scorching summers result in a high demand for cooling solutions. Energy-efficient air conditioning and intelligent cooling strategies are vital to mitigate energy consumption during peak temperatures. Additionally, the abundance of sunshine offers substantial potential for solar power generation, encouraging the integration of photovoltaic systems into buildings and infrastructure.

Given the dry seasons, energy services should prioritize water-efficient practices such as smart irrigation and graywater recycling. Furthermore, in response to heatwaves, services must incorporate heat-resilient features like cool roofing and energy-efficient building materials. Another challenge in this zone is the increased strain on the power grid during the summer months. Therefore, energy service providers must ensure grid stability and efficiency to meet the heightened demand.

Atlantic Zone

The Atlantic zone includes oceanic (maritime) climates found in parts of France, the Benelux countries, and the UK (England, Ireland). This zone is characterized by mild temperatures throughout the year due to the influence of the ocean. Precipitation is distributed relatively evenly across the seasons, resulting in moderate and consistent conditions.

The impact on energy services in the Atlantic zone is notable due to reduced heating and cooling demands compared to more extreme climates. The consistent climate allows for the development of diverse energy sources, including wind and hydropower. Grid stability and the implementation of demand response services become pivotal in ensuring a balance between energy supply and demand.

Continental Zone

The continental zone covers countries in central Europe, including Germany, Austria, Switzerland, France, the Benelux countries, and the Czech Republic. This region experiences a temperate continental climate characterized by distinct seasons. Winters are cold, with temperatures often dropping below freezing, while summers are warm to hot. Precipitation is distributed relatively evenly throughout the year, resulting in pronounced seasonality that significantly influences energy needs.

In this zone, winters demand efficient heating solutions, while summers introduce cooling requirements. Renewable energy sources like wind and solar offer diverse options for energy services, but their intermittency requires the leverage of energy storage solutions. Energy-efficient building materials and insulation are vital to reduce heating and cooling energy consumption. Additionally, grid management tools and demand response services play a pivotal role in balancing energy supply and demand throughout the seasons.

Arctic Zone

The Arctic zone covers countries in northern Europe, including Scandinavia (Sweden, Norway, Finland, Denmark), the Baltic States (Estonia, Latvia, Lithuania), and parts of northern Germany and Poland. This zone is characterized by a subarctic and boreal climate known for long, harsh winters with heavy snowfall and short, cool summers. Temperature extremes are common, with sub-zero temperatures during the winter months.

Energy services in the Arctic zone must focus on advanced heating systems, energy-efficient insulation, and technologies like heat pumps due to extended, frigid winters. Solar energy generation faces challenges during the limited sunlight of winter, prompting exploration of alternative renewable sources like biomass and wind power. Energy storage solutions are essential to meet high heating demands in winter and store surplus energy generated in summer. Additionally, energy services must incorporate measures to withstand extreme cold, such as frost protection systems and energy-efficient building envelopes. Grid stability is critical, particularly during winter peaks, necessitating enhanced grid infrastructure and demand management.

In conclusion, the following table summarizes the parameters and their average values in the climatic zones considered.

Climatic Zone	Mediterranean	Atlantic	Continental	Arctic
Köppen Climate Zone	BWh, BWk, BSh, BSk, Csa, Csb, Csc	Cfa, Cfb, Cfc	Dsa, Dsb, Dsc, Dfa, Dfb	Dfc
Hours of Sunlight (per year)	2500-3200	1600-2000	1600-2300	600-1000
Summer Avg Temp (°C)	25-35	15-25	18-28	0-10
Winter Avg Temp (°C)	10-20	2-12	-2 to -15	-10 to -30
Precipitation (mm/year)	400-800	800-2000	400-1000	200-500
Geomorphology	Varied (Coastal, Hilly)	Varied (Coastal, Plains)	Varied (Plains, Plateaus)	Varied (Tundra, Taiga)

TABLE 1 - CLIMATIC ZONES CHARACTERISTICS

Key parameters for replication assessment

This comprehensive methodology seeks to define the parameters that collectively determine the replication potential of innovative energy-efficient solutions in the residential sector. By scrutinizing each of these factors, we aim to provide a holistic understanding of how the interplay between market dynamics, service offerings, economic considerations, and environmental impacts shapes the landscape of residential energy efficiency.

Energy Consumption Rate

This parameter measures the amount of energy used within a specific region. In zones with high energy consumption, such as the Mediterranean, there is a significant demand for energy-efficient cooling solutions due to scorching summers. This high demand can stress power grids, making energy-efficient solutions crucial. Conversely, in colder regions where extended winters are common, energy services should prioritize heating efficiency. Furthermore, the number of end users that have access to energy must be considered: in regions with a large population and high energy accessibility, the replication potential may be higher.

Renewable Energy Share (RES)

RES reflects the percentage of clean and renewable energy sources in the energy mix of a region. In areas with a substantial RES, like Northern EU, energy services can leverage the reliability of renewable sources like wind and solar. This enables the integration of services that optimize energy use and storage. In regions with intermittent renewables, such as the Mediterranean, adaptable services are needed to manage energy fluctuations and ensure reliable supply.

Grid Stability and Reliability

Grid stability and reliability assess the quality and dependability of the energy grid infrastructure. In regions with stable grids like the Atlantic and Continental zones, energy services can more easily integrate advanced technologies. Conversely, areas with less stable grids may require sophisticated grid management solutions to maintain service reliability and prevent disruptions.

Building Renovation Rate

This parameter examines how frequently buildings undergo renovations or upgrades. In regions with a high building renovation rate, such as Continental regions, there are ample opportunities to incorporate energy services during these upgrades. This can lead to increased replication potential as energy-efficient solutions can be integrated into building designs and systems.

Building stock age

Building stock age significantly impacts retrofit effectiveness for older buildings, often requiring extensive upgrades like insulation and HVAC enhancements. Understanding their specific needs is essential for successful retrofits in diverse EU climatic zones, affecting regulatory compliance, economic viability, environmental considerations, and stakeholder engagement.

Smart Readiness Level (SRL)

SRL evaluates the technological readiness of buildings to support advanced energy services. Regions with higher SRL, like Continental and Arctic regions, possess the infrastructure and technologies needed to implement these services effectively. This readiness expedites the adoption of energy-efficient solutions, as the required infrastructure is already in place. The availability of access to the internet and smart meters is integral to determining the SRL, as it indicates the level of digitalization and connectivity within buildings, which are essential for advanced energy services.

Market Characteristics

Local market dynamics are essential in assessing the success of energy services. Zones with a growing demand, like the Mediterranean, present opportunities for expansion. Customizing services to align with market needs and enabling demand response mechanisms for users can enhance their success. This ensures services cater to specific needs and dynamics, increasing their potential for replication. Choice among energy suppliers is a crucial aspect of market characteristics. In regions where consumers have the flexibility to choose their energy suppliers, there may be more competition and innovation in energy services.

Data Availability and Infrastructure

Access to reliable data, robust IoT (Internet of Things) infrastructure, and digital platforms is fundamental. Regions with well-established data infrastructure are better positioned for successful replication. Data availability enables effective monitoring and scalability of energy services.

Technology Readiness Level (TRL)

TRL assesses the readiness and maturity of the technologies required for energy services. Regions with advanced and mature technologies may experience faster and smoother replication processes due to the availability of reliable solutions. The choice of technologies should align with the technological landscape of each region to facilitate adoption.

4.3 2030 SCENARIO

Future trends of the market are thoroughly discussed in deliverable D7.5 " Report on future trends and market potential for frESCO solutions". The detailed documentation highlights the current landscape of uncertainty influenced by disruptive factors affecting energy price developments and the ongoing energy and cost of living crisis, impacting European countries unevenly. In the present deliverable we provide some fundamental insights into the anticipated future trends that are poised to shape the European energy system and the residential sector up to 2030.

Key expectations from market trends:

- *Wholesale energy prices*: Despite a decline, final energy prices in Europe are expected to remain higher than pre-crisis conditions, impacting household energy costs. The rise is attributed to carbon pricing, taxation, electricity network costs, and new levies for storage installations.
- *Renewable generation*: The deployment of renewable generation technologies is expected to accelerate due to the energy cost crisis and policies aimed at reducing dependence on Russian fossil fuels.
- *Demand-Side Flexibility (DSF):* With a higher penetration of renewable energy technologies, the importance of the DSF market is set to increase. DSF could play a pivotal role in achieving higher renovation rates in the European residential sector by 2030.
- *Digitalization of the energy grid*: A key trend involves the digitalization of the energy grid, driven by the limited progress in big data and artificial intelligence deployment in the European energy sector. Challenges include smart metering technology standards and data availability requirements.

Political actions and expected measures:

- *ETS II introduction*: The introduction of the ETS II, expected by 2027, aims to accelerate the achievement of 2030 goals by enhancing energy efficiency and supporting the adoption of renewable energy technologies in the building sector.
- *Social Climate Fund*: Operational by 2026, the Social Climate Fund aims to address social effects on vulnerable households related to expanding carbon pricing. This may include fiscal aids for renovation projects in residential buildings.
- *Continuous policy revisions*: Ongoing revisions and progressive strategies at the EU and member state levels, exemplified by the heat pump strategy, are expected to drive changes in the policy framework.
- *Harmonization of technical requirements*: Efforts to harmonize technical requirements under a Europe-wide Minimum Energy Performance Standards (MEPS) and tools like the SRI are underway, facilitating market penetration of renewable energy technologies and energy service solutions.
- *ESCO business models*: ESCO business models, widely recognized across Europe, require regulatory adjustments to enhance their market development potential for energy efficiency projects in residential buildings.
- *Demand side Aggregatio*n: In parallel to the ESCO regulatory adjustments, legal and framework provisions have to take place for DR flexibility services as well. In most EU countries domestic level DR flexibility services are yet unregulated but are expected to mature.

5 LEVEL OF INNOVATION IN THE ENERGY SERVICES LANDSCAPE

The level of innovation in the new frESCO smart services is an important factor that can affect the replication potential of the solutions. In theory, innovations are badly needed to increase the currently low level of penetration of ESCO services in the residential sector. However, too disruptive models may entail some rejection from the social point of view in a traditionally conservative sector.

Technically, frESCO solutions have been designed and developed on matured technologies such as digital data-based tools, data capturing and transmission on real time and the contracts based on energy performance and savings. The main innovation by frESCO is the use of these technologies to design hybrid advanced services based on AI in residential buildings, where EPC models had not been very successful so far.

In this chapter, we will delve into the key innovative features developed within the frESCO project, shedding light on how these features operate, their application within the frESCO context, and an assessment of their innovation levels. The aim is to provide a comprehensive understanding of the technologies and concepts driving the frESCO initiative, ultimately contributing to the advancement of energy efficiency and residential services in Europe.

5.1 Key Innovative Features

This section provides a concise overview of data management and analytics tools. The practical application of these data-driven technologies within the context of frESCO are investigated, with a particular emphasis on data collection from the project's pilot sites and the analytics employed to enhance energy efficiency. Finally, the section scrutinizes the level of innovation intrinsic to these technologies, emphasizing their potential to revolutionize the residential sector.

As indicated in D4.7 "Final release of integrated platform", which depicts the final version of the ***Big Data management Platform*** (BDP) and all the relevant features, the BDP plays a central role in the frESCO project, serving as the essential ICT framework for seamless data collection and processing. It ensures interoperability and security, thereby enabling the introduction of innovative energy services. The platform allows for detailed communication and data exchange among diverse sources, including buildings, DER management systems, weather data sources, and wholesale energy pricing. Furthermore, it efficiently handles the mass ingestion and storage of the substantial data assets associated with these sources.

To guarantee top-tier performance and the adaptability needed to meet the diverse needs of stakeholders, the platform employs effective procedures and methodologies for data importing, curation, and semantic harmonization. Additionally, the Big Data Platform incorporates a dedicated big data analytics module, which not only supports the creation and execution of analytics algorithms but also the reporting of findings. It leverages a catalogue of pre-trained analytics models to deliver new insights and knowledge to all parties involved in the frESCO project.

The frESCO Big Data Management Platform offers an extensive array of features, providing a comprehensive solution for effective and secure data management:

- *Collector*: Users have versatile data ingestion options, including file uploads, APIs, and through data streaming to MQTT pubsub mechanism. They can also select file formats (e.g., CSV, JSON) for file uploads.
- *Harmonization*: The platform ensures data consistency by harmonizing it to adhere to the frESCO Common Information Model (CIM). A harmonization playground simplifies the process, providing recommendations, confidence levels, and validation for precise data alignment.
- *Curation*: Users can define curation rules and constraints for data attributes, enhancing data quality and value. Robust validation options are available to verify the accuracy of curation, ensuring that the data is of the highest quality.
- *Anonymiser*: Sensitive data is safeguarded through anonymization, which allows users to protect personally identifiable information and select which data attributes require anonymization. Users can set anonymization rules and thresholds to balance privacy protection with data utility.

- *Data Storage*: The platform provides robust data storage capabilities with diverse indexing methods. It collects metadata to improve data accessibility and maintains logs for efficient platform operation and administration.
- *Data asset Profile Definition*: Users can create data asset profiles with titles, descriptions, tags, and comprehensive details such as coverage, granularity, type, format, language, and spatial/temporal information.
- *Data Security*: Users on the frESCO platform have the flexibility to configure the visibility and access policies for their data assets. When providing a data asset, the data asset provider has the option to choose between two access modes, namely Exclusive and Universal access.

As indicated in D4.5 "frESCO baseline data analytics - Draft Release" and D4.6 "frESCO Integrated Platform – Beta release", ***Big Data analytics*** are set to revolutionize the building sector, particularly in optimizing energy management through data-driven insights. The key objectives of building analytics are:

- *Enhanced Decision-Making*: Providing data-driven insights for informed decisions regarding building renovations and investments.
- *Optimized Building Operation*: Leveraging building data to enhance energy savings, occupant well-being, and the participation of buildings in energy markets through flexibility transactions.
- *Advancing Energy Performance Contracts*: Improving predictions and transparent verification of energy savings, coupled with Demand Response services and flexibility transactions to enhance the financial viability of Energy Performance Contracts.

frESCO is introducing a comprehensive set of baseline analytics through its Big Data Platform. They are designed to equip frESCO's end-user modules with essential knowledge and data-driven insights to enhance the energy performance of buildings and optimize hybrid contracts, including energy savings and flexibility agreements between ESCOs and building owners/managers.

Moreover, the introduction of HVAC Flexibility Analytics in the context of the frESCO project is driven by the need to maximize consumer acceptance in Demand Response programs, ensuring flexibility utilization in the energy system. The aim is to achieve ambitious decarbonization goals while maintaining the resilient operation of the energy system, even under the uncertainty introduced by Renewable Energy Sources.

The innovative aspect of the frESCO Big Data Management Platform lies upon its all-in-one solution. It brings together data management and analytics under a single roof, simplifying the entire process. From collecting data to making it available for retrieval, to both serve the needs of the applications and the creation of enhanced analytics, while securing it through anonymization, the platform offers a comprehensive solution. This approach enhances data quality, streamlines operations, and provides a user-friendly experience by having everything in one place.

Data is collected from three pilot sites (Thassos, Madrid, KrK), capturing real-time and historical data related to energy consumption, occupant behaviors, and environmental conditions. The collected data form the basis for further analysis.

Data analytics are developed and customized for two of the pilot sites (Thassos, Madrid) within the frESCO project. These analytics include PV Generation Forecasting, Devices Profiling, Short-term demand forecasting, Comfort analytics and Flexibility Analytics. They are specifically designed to provide insights and knowledge that cater to the energy performance optimization and occupant comfort aspects of these sites.

The data analytics created for the two pilot sites are made accessible to module development partners within the frESCO project. These partners can search and retrieve data, insights, and knowledge generated by these analytics to inform the development of their respective modules. This allows for a collaborative and data-driven approach in the development of various project modules.

The frESCO project relies on the Big Data Management platform, developed within WP4, to manage and process data effectively. The platform serves as a central repository for collecting data streams, performing anonymization, curation, and semantic harmonization, and facilitating the execution of analytics algorithms to be further retrieved and utilized by other modules.

The level of innovation for the Big Data Management Platform of the frESCO project is considered very high, with the target to reach the value of 8, in the level of TRL scale, at the end of the project.

There are two types of ***smart gateways*** used in frESCO, a commercially available and flexible gateway (Develco) used in Greece and Croatia, and the specifically developed Energy Box (Ebox) used in Spain and Greece. Both had pros and cons, and the purpose of this difference is to test the compatibility of frESCO architecture with commercial components, and the development and adaptation of a new gateway tailored for the frESCO components.

The frESCO Ebox is a flexible multi-environment gateway with external feeder, input/ouput channels and a Raspberry microprocessor capable of storing and executing software programs and prepare the data before it is actually sent out to the BDP. It also has internal memory to keep data in case of miscommunication issues. The system is fitted with the most widely used communication protocols to accept a large number of commercial equipment. It has wired and non-wired communication channels compatible with the communication technologies most commonly available in residential buildings.

The main advantages of the frESCO Ebox over its commercial alternatives are the capacity to modify and adapt the data treatment software and communication libraries to the specific needs of the ESCo and the frESCO living labs, which is of paramount importance for researchers in the development of new innovative solutions. This flexibility is not provided by third party devices with no access to the internal code.

Although the Ebox showed some lack of stability, specifically when communicating with some sensors of the Zigbee family, it proved to be a versatile product, very close to market readiness. The level of innovation for this result of the frESCO project is considered as very high, achieving a TRL of around 8 (see D8.8 for more details on this rate).

5.2 Key business innovations

One of the critical dimensions of innovation in frESCO solutions lies in the ***hybrid business models*** developed within the framework of the project (D3.3 "Definition of novel Business models for EPC extension towards P4P schemes"). Hybrid business models represent a fusion of multiple approaches and strategies, synthesizing the strengths of different paradigms to create a novel and effective model. They have been designed to encompass a broad spectrum of services, including smart retrofitting, energy efficiency, flexibility, and non-energy services, all of which are essential components of the frESCO vision for the residential sector. Innovative mixed "ESCO/aggregator" business models within the frESCO context involve bundling various energy services into packages based on consumer needs and primary actors involved. These packages encompass smart retrofitting services, energy efficiency services, flexibility services, and non-energy services. These services aim to enhance energy efficiency, provide flexibility, and ensure consumer comfort.

- *Smart Retrofitting Services (RT):* These services require real-time data collection and continuous energy metering, often involving IoT equipment. They include smart equipment retrofitting, data monitoring, and personalized informative billing, as well as smart readiness assessment and certification.
- *Energy Efficiency Services (EE):* These services focus on energy savings and can be implicit or explicit, involving user guidance or full automation. Examples include energy management for energy efficiency, personalized energy analytics for energy behaviour optimization, holistic self-consumption maximization, and automation with optimal device scheduling.
- *Flexibility Services (FL)*: These services enable residential consumers to participate in demand flexibility markets and contribute to grid management. They include flexibility analytics services, explicit automatic demand response services, and the creation of Virtual Power Plants (VPPs) for optimal flexibility activation scheduling.
- *Non-Energy Services (NE)*: These services enhance consumer comfort and include features related to thermal comfort, indoor air quality preservation, noise reduction, and security and surveillance services.

- Revenues generated from these services include charges for information and behavior change services, additional charges for guaranteed savings, remuneration for flexibility, charges for self-consumption optimization, and income from non-energy services. These revenues are typically shared between the end-users and the service providers, which can be either an ESCO, an Aggregator, or both.
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The adoption of frESCO business models offers a range of benefits to all stakeholders involved in the residential energy services sector. The major benefits are summarized in the tables below.

Stakeholder	Benefit	Description
Residential consumer	Energy savings	Empowerment of consumers to make informed decisions about energy usage, leading to reduced energy bills and increased savings
	Comfort and Convenience	Non-energy services such as improved indoor air quality, noise reduction, and security enhance the overall living experience.
	Flexibility and Control	Consumers have the flexibility to participate in demand response programs, providing potential additional income
	Smart Retrofitting	The deployment of smart retrofitting solutions leads to more efficient and sustainable energy usage, contributing to environmental benefits.

TABLE 2 - RESIDENTIAL CONSUMER BENEFITS FROM FRESCO BUSINESS MODEL

Stakeholder	Benefit	Description
ESCOs	Savings and Efficiency	By implementing energy efficiency measures and demand response, ESCOs can guarantee savings to consumers, fostering trust and long-term contracts.
	Market Expansion	ESCOs can enter new markets and offer innovative solutions, positioning themselves as leaders in the rapidly evolving residential energy services sector.
	Data-Driven Insights	Continuous data collection and analytics provide valuable insights into energy usage, enabling ESCOs to tailor their services for maximum efficiency.

TABLE 3 - ESCOs BENEFITS FROM FRESCO BUSINESS MODEL

Stakeholder	Benefit	Description
Aggregators	Market Participation	Aggregators can leverage flexibility services, participating in demand response programs and grid balancing, contributing to grid stability.
	Data Management	Access to real-time data allows aggregators to make informed decisions and optimize their services.
	Consumer Engagement	Aggregators play a crucial role in engaging and educating consumers about demand response and flexibility
Grid Operators	Grid Stability	The participation of residential consumers in demand response programs enhances grid stability and reduces the need for costly infrastructure investments

TABLE 4 - AGGREGATORS AND GRID OPERATORS BENEFITS FROM FRESCO BUSINESS MODEL

Pay-for-Performance (P4P) contracts within the frESCO project represent a revolutionary advancement in the residential energy sector. The central innovation lies in the provision of real-time data to various energy stakeholders, such as ESCOs and aggregators, setting frESCO apart from conventional and traditional Energy Performance Contracts (EPCs). A defining feature of the frESCO project is its commitment to ensuring a reliable and continuous supply of data; this commitment distinguishes frESCO from typical EPCs, where data collection and accessibility are often limited, less frequent, and less comprehensive. In frESCO, the availability and quality of data supply see a significant enhancement, empowering participating energy players to make real-time, informed decisions and optimize their services.

The frESCO platform adeptly collects various types of data that are commonplace in large commercial and industrial buildings but historically underrepresented in the residential sector. This comprehensive approach to data collection plays a pivotal role in driving energy efficiency and demand response initiatives in residential buildings.

The innovation introduced by P4P contracts in the frESCO project is intrinsically linked to the accessibility and quality of real-time data supply in the residential sector. The ability to collect various data types through a cost-effective platform, typically associated with larger buildings, represents a paradigm shift in residential energy services. This data-driven approach not only augments the efficiency of energy consumption but also revolutionizes the residential living experience, rendering it more comfortable, cost-efficient, and environmentally conscious.

The success of the P4P approach adopted in frESCO and subsequently the value produced, is linked to the duration of the payback period rather than a strictly defined time period. Savings benefit directly the end user by reduced energy bills (via the supplier). Flexibility services are compensated by the TSO/DSO or Market Operator to the aggregator. Then the aggregator, in turn withholds the service fee and passes through the remaining flexibility income to the end user as a direct payment (Figure 1).

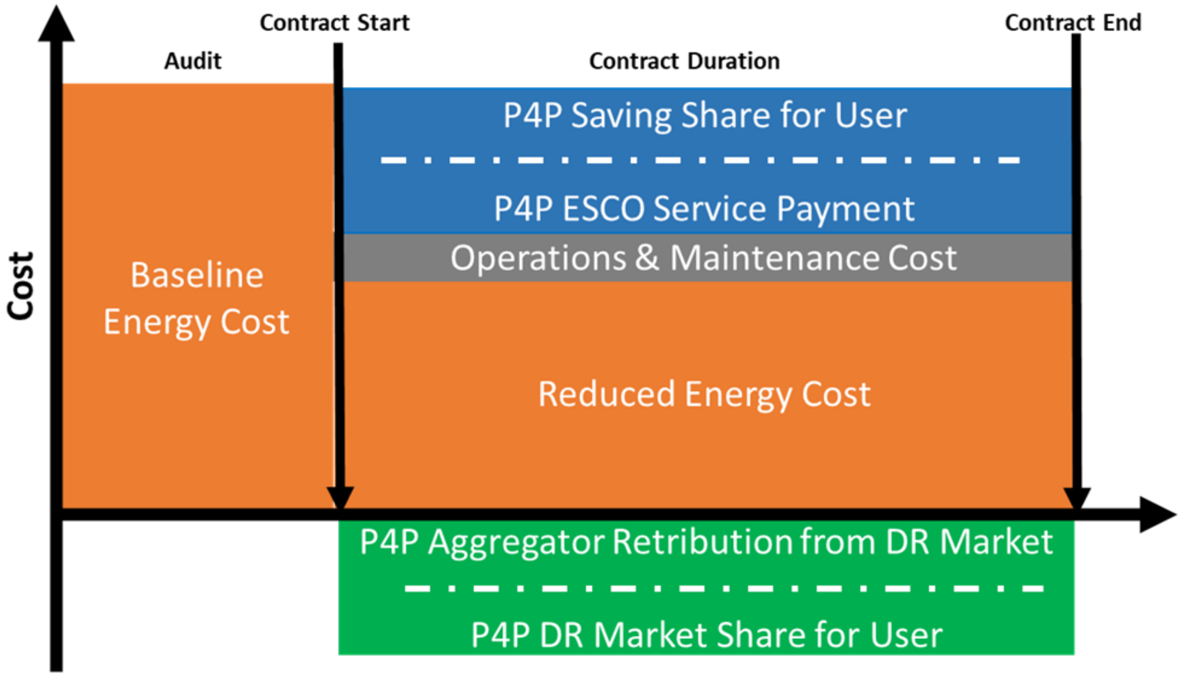

FIGURE 1 - REVENUES AND SAVINGS VS CONTRACT DURATION

Furthermore, frESCO project attempted to accomplish this result while keeping costs at an accessible level. It's important to recognize that the costs associated with the residential application of energy savings can be a substantial challenge. High payback periods, as documented in the data from D6.4, indicate that realizing substantial returns on investment within the residential sector is often more protracted than initially anticipated (7 to 11 years). This realization underscores a valuable lesson learned, emphasizing the need for further exploration and refinement in residential energy services.

A key component in the P4P approach is how to assess the performance of the different digital services. ***Protocols for Measurement and Verification (PMV)*** are numerous and adapted to the regular EPC contracting. They are mainly designed to assess the energy efficiency derived from energy retrofitting in buildings but cannot be used directly to assess the performance of the new frESCO energy services. The innovations in frESCO about the PMV are twofold: one important innovation is to leverage from the existing PMV methodologies and use the available data to assess the different efficiency services (behaviour change, monitoring and optimization) in a holistic approach, using static seasonal baselines with adjustments. Another critical innovation is the use of advanced analytics to provide short term forecasts for flexibility event dynamic baselines at asset level. This enables a fair and accurate assessment of the flexibility delivered by the explicit aggregator services. Finally, it is worth to mention that the same data-driven approach can be used to evaluate the performance of non-energy services as a direct comparison between the parameters to be monitored and the thresholds set for comfort, noise, or air quality, to mention a few. The application of frESCO PMV has been tested in the demo sites and it is the base of a fair remuneration of the service provider and the full-service value chain, but also it is key to ensure a proportional incentive to end users who benefit from the energy savings, the non-energy services while receiving a payment for the delivered flexibility to the grid operators. The continuous provision of data allows for the automation of the verification protocols and the monthly settlements of the services for the end users. More details can be found in D3.4 “Definition of the frESCO PMV methodology”. Nowadays, there is a long number of measurement and verification protocols oriented to energy efficiency assessment but those about flexibility assessment are fewer and not applicable in practice. EPCs in the residential sector, with few exceptions, are not performance driven and usually involve the payment and maintenance of an energy renovation project along an exploitation period, usually 10 years. Savings are initially estimated and taken for granted but there is usually no verification of the savings in the contract period. The innovations brought forward by frESCO are the automation and application of such protocols to the residential sector to implement a P4P approach, and the versatility of the dynamic baseline, applicable to different loads and demands. The level of innovation in both cases is deemed high in the residential sector.

6 FACTORS AFFECTING REPLICATION POTENTIAL

Collecting information on the enablers and barriers for replication within the EU using the assessment methodology based on climatic zones and key parameters is a vital activity for the frESCO project. The assessment methodology takes into account various factors and critical parameters to evaluate the replication potential of innovative energy services. To achieve successful replication, it's crucial to address challenges in different areas such as financial, market, and regulatory aspects.

6.1 REGULATORY

The regulatory barriers affecting the deployment of the frESCO energy services in the demo sites were thoroughly described in D2.2 "Overview of the regulatory and market framework for energy services in the residential sector". The summary of these barriers still outstanding that affect the replication efforts throughout the EU are the following:

- Closed flexibility markets to aggregated demand response of small consumers in many countries, and only partially open in some countries like France. Today's active EU directives already ask Member States to regulate in favour of independent demand response aggregators and local flexibility markets and it is a matter of time before the markets accept this demand-side resource in equal conditions than energy resources now. Overcoming the challenge of the market's hesitancy to accept aggregated flexibility involves the development of forecasting tools and methodologies for real-time flexibility assessment, promoting greater accuracy and acceptance.
- Real time metering availability. Although smart meter rollouts is almost completed in most EU member states, the access to this data in real time is still a concern. This issue has been mitigated in frESCO by the installation of dedicated meters and submeters, increasing the cost and complexity of the installation. Regulatory issues about sharing of data by DSOs. Based on T2.2 and T6.5 activities
- Lack of Specific Standards: The absence of clear European or national standards for PMV (Predictive Maintenance and Virtualization) commercialization and exploitation

poses a challenge. A potential solution is to propose the frESCO protocol as a standard for a hybrid methodology, fostering consistency and clarity in the market.

- Data Privacy Compliance: Ensuring compliance with data protection laws, such as GDPR, is crucial when working with consumer data for PMV. Overcoming this barrier entails the implementation of data anonymization and encryption procedures to ensure user confidentiality and consent, promoting data security.
- Lack of Common Market Environment: Differences in regulatory frameworks among European countries can lead to varying levels of competition. A solution involves advocating for regulatory changes within Europe to create common market environments, fostering fair competition and innovation.
- Standardization and Interoperability: The lack of standardization and intentionally closed systems that are not interoperable among data-driven smart devices can hinder the deployment of PMV. A solution is to ensure ongoing work, improvements, and updates to the solution to adapt to emerging and changing standards, promoting greater flexibility and adaptability in the market.

As regulations are inherently rooted in national laws, the methodology presented in this analysis draws upon specific countries from diverse climatic zones, extracting key enablers and barriers from the sources D2.2 of the frESCO project. Furthermore, insights regarding Portugal and Belgium have been gleaned from the research conducted in D1.1 of the "Analysis of directives, policies, measures, and regulation relevant to the Active Building EPC concept and business models" within the AMBIENCE project. This approach provides a more comprehensive understanding of the impact of national regulations on the deployment of energy-efficient solutions.

Country (Climatic zone)	Enablers	Barriers
Spain (Mediterranean)	• Introduction of RD 244/2019 promoting self-consumption. • Technical Building Regulation (CTE) setting energy standards. • Smart metering rollout for energy management • Hourly-based retail tariffs and ToU plans.	• Closed electricity markets for demand response • Ban on flexibility aggregation. • Challenges accessing real-time metering data. • High stock of energy-inefficient buildings.
Croatia (Mediterranean)	• Croatian TSO pilot project for demand response. • Legal provisions for energy savings through demand response.	• Unresolved terms and definitions in regulations • Absence of smart metering regulation • Unclear communication between operators and aggregators
France (Atlantic)	• Inclusive participation in various energy markets • Consideration of thermo-sensitiveness in Capacity Market	• Specific rules in the day-ahead market limiting aggregation. • Demand response operators bearing full compensation costs. • Synchronization constraints by TSO • Inability to participate simultaneously in all markets due to specific rules
Portugal (Atlantic)	• Legalization of local energy communities and flexibility aggregation. • Simplified licensing for self-consumption sites below 1 MW • Facilitation of generation units with capacity below 1 MW	• Inactive state for DR products trade • Lack of defined roles for independent Demand Response Providers • Uncertainty in aggregation due to lack of legal framework • Lack of specific measurement and verification status
Belgium (Continental)	• Subsidy schemes for renewables encourage aggregation • Regulatory provisions and definitions introduced for flexibility services	• Need for alignment of rights and responsibilities for flexibility service providers • Unspecified rights and responsibilities for aggregators • Complex administrative qualification procedure

TABLE 5 - REGULATORY ENABLERS AND BARRIES FOR EU COUNTRIES

6.2 TECHNICAL

The following lines provides a comprehensive overview of the technical enablers and barriers associated with deploying innovations discussed in the previous chapter.

The integration of the End-to-End frESCO solution has profound technological implications encompassing various domains. This integration comprises several integral essential components, each of which plays a distinct role in this sophisticated system, as outlined below:

- Smart Energy Boxes and Local Field Sensors. These components serve as the "eyes" of the system, hold the critical responsibility of capturing data at the local level.
- Platform. This acts as the central hub; the platform serves as a data repository and a server for the applications that rely on the data for their various functions. It ensures data accessibility, security, and reliability.
- Bundled Applications for Residential Consumers. These applications offer Integrated Energy Services, they handle data processing, optimization, and presentation, offering residential consumers a streamlined experience.
- Advanced Measurement and Verification Methodology. A novel methodology developed explicitly for frESCO.
- Multiservice Package Toolkit for ESCOs and Aggregators. This toolkit is designed to streamline the operations of Energy Service Companies (ESCOs) and Aggregators. It simplifies their interactions with the system, promoting efficiency and ease of use.

As we delve into the integration of technology into residential buildings, it becomes evident that this transformative process is not without its challenges. Digitalizing residential buildings necessitates the integration of technology equipment. Smart Energy Boxes represent the bridge between local architecture and IT cloud infrastructure. However, market fragmentation and regulatory differences among European countries hinder the adoption of standardized energy boxes. The lack of standardization in data-driven smart devices further complicates integration. Additionally, concerns related to data protection, security, and privacy can restrict the application of data-driven solutions. While efficient data transfer methods like API RESTful, MQTT, XML, and file downloads exist, developing specific standards and protocols for such systems becomes an enabler due to the growing data sources and market complexity. Anticipated regulatory changes in Europe could lead to common market environments for data-driven services, impacting compatibility with existing communication protocols, such as GDPR implementation enhancing user confidence in data protection.

In this digitalization landscape, the central platform acts as "hub" data server for the entire ecosystem. The growing market for big data creates a demand for innovative platform solutions. Investments in digital transformation foster a conducive environment for adopting big data platforms. The proliferation of smart devices and sensors is leading to a data-rich environment, that generates more data for analysis, driving the increased adoption of big data, AI, and analytics for decision-making and process optimization. As for the Big Data Management Platform, the encountered technical barriers are listed below:

- The need to support various technologies and data collection streams and methods, increases complexity and resources utilization.
- Ensuring the accuracy and quality of the data processed by the platform is a persistent challenge. Poor data quality can lead to erroneous insights and decisions, damaging the platform's reputation.

However, the complexity also grows due to the increasing number of data sources, sensors, and data standards. Resource utilization challenges arise due to the resource-intensive nature of the platform. Therefore, an emphasis on data security is essential to encourage investments in secure data management platforms, ensuring data sharing reluctance doesn't limit data availability for analysis and decision-making.

Another pivotal element of the frESCO solution is Integrated Energy Services, responsible for data processing and optimization in residential users. Technological advances have made cost-effective energy services possible, reducing application costs. Nevertheless, insufficient renewable energy and dependence on fossil fuels can lead to energy price volatility, affecting the economic viability of Integrated Energy Services. Reducing energy consumption through price signals, energy efficiency measures, or voluntary efforts remains an effective strategy to reduce reliance on fossil fuels and support security of supply. A core element of this service is the implementation of a results-oriented Pay for Performance (P4P) contract strategy, prioritizing performance outcomes over processes. Service providers are compensated based on predefined performance levels and outcomes, incentivizing improved results and enhancing efficiency for consumers and flexibility for grid operators.

From a societal perspective, the adoption of Integrated Energy Service bundles holds the potential to foster awareness among potential customers, stakeholders, and participants regarding sustainability, the circular economy, and renewable energies. This heightened awareness can pave the way for more sustainable and environmentally conscious practices.

On the other end of the spectrum, another key aspect of energy services is the measurement and verification methodology, the basis for innovative energy services for domestic consumers. The Pay-for-Performance concept relies on precise dynamic baselining, facilitating the calculation of the value added through energy services by measuring energy performance fairly. Thus, one of the main issues when applying PMV methodologies is how baselines are estimated. Baselines are mathematical models that describe the energy performance of a building or system as a function of one or more contextual dependent variables, so any development must adhere to private standards like the EVO protocol or at least to compliance with any other known standard and protocols. A barrier to overcome it is the absence of clear European or national standards which can complicate the utilization of a methodology. Standards should quantitatively measure energy savings, whether in new projects or retrofit projects. The goal of any standard worth it must be able to quantify the energy savings during a specific period, both, in new projects or retrofit projects. In the case of frESCO a novel advanced methodology has been developed, where the energy savings are determined by comparing measured, calculated, or simulated energy consumption before and after and/or without implementation of a project and by adjusting parameters in case of changes in relevant variables (routine adjustment) or in static factors (non-routine adjustment).

In any digitalization project that engages with end-users, the components associated with the Human Machine Interface (HMI) play a pivotal role. In the context of frESCO, the Multi-Service Package Toolkit provides access to stakeholders through four dashboards (prosumers, aggregators, smart contracts, and ESCOs). These web-based applications feature user-friendly Graphical User Interfaces (GUIs), should ensure an intuitive and efficient user experience. However, creating GUIs that are user-friendly yet comprehensive requires iterative design, incorporating user feedback. Domestic users may require interfaces that are easy to navigate and understand, while professional users like ESCOs may seek advanced technical features to effectively manage their user accounts. Thus, creating a user interface that caters to both novice and expert users is crucial to achieving seamless user interaction within the frESCO ecosystem.

Finally, it's worth noting that technologies involved in the frESCO project are not influenced by climate zones or geography, so it is not accurate to say that there are technical enablers or barriers. Instead, the availability of technology for the implementation of innovative solutions depends on the smartness and technology readiness of a country. This is discussed as a market aspect in the next section.

6.3 MARKET

One of the most significant aspects with far-reaching market implications, is the integration of renewable energy sources. As the cost of photovoltaic (PV) facilities continues to decline, there has been a notable surge in the adoption of solar power for self-consumption across EU countries. This transition not only fosters sustainability but also empowers ESCOs to harness the advantages of renewable energy integration, providing consumers with sustainable energy solutions. However, the low equipment level of flexible and controllable assets in the residential sector (such as PV facilities for self-consumption, battery storage, electric heat pumps) hinder the potential of high benefits by the control and management of these assets. This is slowly improving as the cost of PV goes down and the national regulations become more friendly to self-consumption in buildings.

As anticipated above, another crucial enabler lies in the improving regulatory frameworks across EU nations. National regulations are gradually aligning with the goal of encouraging self-consumption in residential buildings. These regulatory advancements foster a more supportive environment for ESCOs, enabling them to deploy advanced technologies like PV facilities, battery storage, and electric heat pumps more effectively. Regulatory frameworks encompass aspects such as energy community guidelines and national subsidies, which collectively influence market dynamics. Furthermore, the unification of energy markets within the EU, governed by EU laws and directives, is a significant enabler for the market. This harmonization ensures equity, fosters cross-border energy trade, and promotes healthy competition. Regulatory enablers and barriers are deeply analysed in the 6.1.1 paragraph.

One of the prominent barriers is in general connected with technological aspects: besides the technologies themselves (as described thoroughly in 6.1.2 paragraph), it’s necessary to consider the smart readiness of residential buildings across the EU. Many residential structures lack the essential smart technologies required to efficiently collect and manage energy and comfort parameters. This deficiency restricts ESCO activities primarily to large-scale energy renovation projects, overlooking the valuable opportunities for everyday energy management and optimization. Access to real-time metering data also remains a persistent concern, despite the widespread rollout of smart meters across most EU member states. ESCOs encounter obstacles in obtaining real-time data, leading them to resort to the installation of dedicated meters and submeters, which complicates operations and escalates costs. Moreover, Distribution System Operators (DSOs) hold crucial data, granting them a competitive edge in the market and making data-sharing a contentious issue. Furthermore, technology adoption varies across EU countries, with northern nations typically outpacing their southern counterparts. This discrepancy is influenced by diverse economic strengths and other regional aspects.

In conclusion, the EU's energy aggregation market is a complex tapestry of enablers and barriers. The integration of renewable energy sources, supportive regulatory frameworks, and the unification of energy markets offer promise. However, challenges like the low smart readiness of residential buildings, limited equipment for demand response, and real-time metering concerns persist. The successful evolution of energy aggregation in the EU necessitates navigating these intricacies while capitalizing on the enablers and adapting to the ever-changing regulatory landscape. The path forward requires a harmonious synergy between market dynamics and regulatory guidance, fostering a sustainable, efficient, and competitive energy ecosystem.

6.4 SOCIAL

The success of frESCO solutions is not only dependent on technical aspects but heavily influenced by social enablers and barriers. The following paragraphs will summarize what has already been developed in D2.3 “Set of stakeholders’ and end-user requirements: Results of external surveys”. The following insights highlight the importance of a nuanced, region-specific approach to implementing frESCO solutions, emphasizing the role of ESCOs, and aligning with the social and cultural dynamics of each country.

In Spain, the development of frESCO solutions is underpinned by several social enablers and barriers. Expert interviews with Spanish ESCOs reveal that corporate social responsibility acts as a powerful motivator for organizations to enhance their energy efficiency. This insight provides an opportunity for frESCO to leverage corporate responsibility as a selling point for collaboration with Spanish ESCOs. Key actions for the frESCO project in Spain should address demand-side management (DSM) and the lack of information about the future demand flexibility market. ESCOs highlighted the need for better clarity regarding mechanisms and pricing in this area, making it a clear target for frESCO solutions. The Spanish pilot site in a large apartment building in Madrid primarily consists of residents who own their homes. This demographic characteristic raises questions about the adoption of energy-efficient technologies, as ownership rates of energy-efficient appliances were relatively low. Nevertheless, it points to an untapped market for energy efficiency measures and the potential for the frESCO solution to make a substantial impact. Survey results indicate a high willingness among Spanish end-users to participate in DSM.

Furthermore, preferences for receiving energy-related data monthly and in kWh format suggest that the implementation of dynamic smart meters might find success in the Spanish market. Social acceptance of DSM programs can be boosted by clearly articulating their environmental benefits and their contributions to the integration of renewable energy into the grid.

In Croatia, the field trial encompasses 19 residential houses on the island of Krk, offering a unique perspective on energy efficiency and ESCO opportunities. Regulatory risks emerge as a significant barrier in the development of the energy services market, as highlighted by expert interviews and previous reports. An additional hurdle is the need for improvements in digital infrastructure and related technologies.

Survey data from Croatia reveals a high willingness among residents to participate in DSM, with compensation or without, indicating the potential for DSM programs' success. Ownership rates for smart meters and energy management systems are also promising for the implementation of DSM programs.

This Croatian sample's attitudes reflect a population that may be less responsive to environmental messaging and more oriented toward personal financial benefits, local economic gains, social status, and new technology, which should be considered when developing frESCO solutions.

In France, expert interviews with housing company leaders indicate that financial barriers and regulatory limitations are obstructing the expansion of the energy services market. The low ownership rates of energy-efficient appliances present an opportunity for new energy services. The presence of smart meters and energy management systems also suggests potential success for DSM-oriented frESCO solutions.

Survey results from a small sample of French residents suggest that energy services should prioritize comfort enhancement or maintenance. Residents emphasized that any energy solutions should work harmoniously with their daily routines and mitigate the seasonal nature of their industry.

The pilot site in Greece is a beachfront hotel with environmental appeal, surrounded by pristine nature. However, the COVID-19 pandemic temporarily hindered data collection from end-users. Nevertheless, expert interviews with hotel managers and Greek ESCOs provide valuable insights.
Hotel managers emphasize the importance of maintaining or enhancing guest comfort while improving energy efficiency. The Greek ESCOs identify the lack of regulation and complex regulatory frameworks as barriers that impede market entry and operation.

Furthermore, lessons learned about the relationships between stakeholders and frESCO technologies have been gathered in D6.5 “frESCO Implementation Guidelines and Recommendations”. Here below the main lessons learned are listed:

- *Low interest in digital energy services*: frESCO project encountered a challenge with low interest from residents in the initial demosites within residential buildings. This lack of enthusiasm was a recurring theme, reflecting a broader societal reluctance towards engaging with digital energy services. The lesson learned emphasizes the need for targeted strategies to increase awareness and understanding among residents, addressing the fundamental reasons behind this disinterest, such as reluctance to embrace new technologies and a lack of comprehension regarding the potential benefits.
- *Difficulty in implementing energy efficiency measures*: research reveals a significant barrier to user participation in implicit Energy Efficiency measures due to difficulties in understanding them and platform usability. This highlights the importance of designing energy efficiency measures that are easily comprehensible to end users. The lesson learned underscores the necessity of user-friendly interfaces, coupled with effective communication strategies, to overcome challenges related to understanding and utilizing energy efficiency measures.
- *Hotel user engagement challenges:* implementation of demand response in hotel rooms posed unique challenges, primarily stemming from the distinct expectations and priorities of hotel guests. The lesson learned emphasizes the need for flexible engagement strategies tailored to the specific context of hotel environments. Factors

such as guest preferences for comfort, short stays, and concerns about privacy necessitate a nuanced approach. The lesson underscores the importance of clear communication, customization options, and aligning programs with the expectations and behaviors of hotel guests.

- *Communication challenges for homeowners*: articulating tangible advantages for homeowners, particularly in emerging energy markets, emerged as a significant challenge. The lesson learned emphasizes the need for effective communication strategies tailored to diverse homeowner contexts. The development of user-friendly dashboards, as demonstrated by the KONČAR team, provides a practical solution. This highlights the importance of enhancing visibility, addressing potential acquisition errors, and making the advantages of frESCO technologies easily understandable for homeowners.

Finally, it's worth mentioning the work developed within the tracks of Task T7.5 "Future trends of the market for the provision of energy services". Within the said task, a stakeholder workshop took place online on October 30th, 2023. The objective was to collect informed advice and valuable insights from the practical experiences in the field of energy services, specifically discussing the potential trends and challenges relevant to frESCO business models. This expert discussion revolved around four primary subject areas: general market trends influencing frESCO Business Models (BMs), the increasing role of digitalization, the innovative nature of frESCO BMs concerning new technologies, and the anticipated risks for future frESCO operations.

The main replication enablers and barriers that came out from the workshop are listed and briefly described:

- *Growing need for demand-side flexibility services*: the observed increase in demand for demand-side flexibility services among residential customers signifies a positive trend. Trust in these solutions suggests a readiness among consumers to embrace innovative approaches.
- *Awareness and role of energy cooperatives*: energy cooperatives emerge as significant contributors to the replication potential. Their pivotal role in raising

awareness of ESCO/aggregator solutions at the local level underscores the importance of community engagement.

- *Trust in digital solutions and new techonologies*: building trust in digital solutions, particularly demand-side flexibility services, is a noteworthy enabler. The growing confidence among residential customers indicates a positive trajectory for the adoption of frESCO technologies. Furthermore, high expectations among residential consumers for new technologies, such as real-time access to consumption records and market prices, present an optimistic outlook for frESCO technologies.
- *Limited market penetration and awareness*: the limited market penetration of aggregator/frESCO business models in the residential sector poses a significant barrier. Overcoming the lack of awareness among residential customers and financial institutions is a key challenge.
- *Perception of limited costs/benefits ratio and paybacks*: despite offering multiple benefits, the perception that these innovative solutions may have limited or intangible benefits for residential customers represents a notable obstacle. The cost of energy emerges as a high-risk factor. Anticipated falls in wholesale energy prices may lead to longer payback periods, impacting the overall profitability of energy efficiency projects. Uncertainty in both energy markets and economic conditions, including high interest rates impacting the construction sector, adds another layer of risk to the success of frESCO business models.
- *Lack of standardization*: lack of standardization in technical requirements for residential buildings poses a challenge. Standardization efforts are crucial for ensuring consistent implementation across diverse regions.
- *Transaction risks and complex contracts*: transaction risks remain high due to the complex nature of contractual and financial instruments involved. The lack of awareness among residential customers further complicates these transactions.

The full review of the workshop is reported in deliverable D7.5 “Report on future trends and market potential of frESCO solutions”.

7 REPLICATION POTENTIAL ASSESSMENT

In the project WP7, the primary goal is to ensure the replication of project results in diverse EU markets and environments. Deliverable D7.1 “First Version of the Exploitation Plan and exploitation Strategy Seminar outcomes” recorded and identified Key Exploitable Results (KERs) during a seminar conducted in T7.1 “Exploitation routes and Business Strategy.” The identified KERs encompass the Big Data Management platform, Integrated energy service bundles for residential consumers, the Multi-service package toolkit, the Smart Energy Boxes, and the Novel PMV methodology.

Deliverable D7.2 “New business models for ESCOs/aggregator for energy services in the residential sector“ is designed as a complementary document to D7.1, collectively forming the Exploitation Plan for the frESCO project's exploitable results. This deliverable focuses on identifying and addressing key aspects related to business models, financial considerations, commercial strategies, and legal frameworks for each Key Exploitable Result (KER) identified in the project.

In this final chapter, D7.4 aims to perform a qualitative categorization of replication potential for different stakeholders and target segments involved in the frESCO project, such as ESCOs, technology providers, residential/commercial prosumers, and technology-dependent aggregators. It's noteworthy that the challenges recognized as barriers to innovation and exploitation, coupled with the analyses of target segments developed in D7.1 and D7.2, will be employed in conjunction with the methodology developed in the preceding chapter of this deliverable to assess the potential for replication across various EU countries.

7.1 KER1: Big Data Platform Management

The successful implementation of efficient energy practices faces a mix of barriers and enablers. Closed electricity markets and real-time metering challenges impede progress by limiting competition and hindering the adoption of innovative pricing models. Conversely, hourly-based tariffs, Time-of-Use plans, Technical Building Regulation (CTE), and smart metering offer a pathway to energy efficiency. However, a ban on flexibility aggregation disrupts the potential for leveraging distributed energy resources collectively. The high stock of energy-inefficient buildings poses a significant barrier to achieving overall energy efficiency goals but can be addressed through the regulatory frameworks established by CTE. From a software development and data analysis point of view, efficient energy practices encounter a mix of barriers and enablers. Regulatory provisions in countries like Belgium offer a supportive environment, while complex administrative qualification procedures pose challenges. Availability of pre-trained analytics models is an enabler, yet unspecified rights and responsibilities for aggregators present a barrier. Simplified licensing for self-consumption sites below 1 MW (Spain) and regulatory provisions (Belgium) are positive factors, but lack of defined roles for independent Demand Response Providers (Spain) and unspecified rights and responsibilities for aggregators are limiting factors. Availability of pre-trained analytics models is an advantage, but a lack of clear standards for PMV commercialization and inactive state for DR products trade hinder progress. The Croatian TSO pilot project for demand response (Croatia) is a positive factor, yet unresolved terms and definitions in regulations (Croatia) and lack of specific measurement and verification status present challenges.

Target Segment: Energy Stakeholders

Combining these elements, overcoming barriers requires opening markets, overcoming resistance to real-time metering, and lifting restrictions on flexibility aggregation. Simultaneously, enforcing building standards and promoting retrofitting initiatives can transform the high stock of energy-inefficient buildings into contributors to energy conservation. The synergy of addressing these barriers and leveraging enablers is vital for creating a resilient, sustainable, and responsive energy ecosystem, fostering innovation, and mitigating environmental impact. As there are significant regulatory and infrastructure constraints beyond the initiatives of the Energy Stakeholders, the imminent replication potential is relatively low.

Target Segment: Software Developers

For Software Developers, unlocking the replication potential in efficient energy practices involves simplifying administrative procedures and defining aggregator roles. Simultaneously, harnessing regulatory support and integrating pre-trained analytics models amplifies the likelihood of successful replication. This streamlined approach addresses key barriers and empowers Software Developers to contribute effectively to the adoption of efficient energy solutions.

Target Segment: Data Scientists

The implementation of efficient energy practices for Data Scientists faces a complex landscape of barriers and enablers. Overcoming these barriers requires advocating for clear standards and active states for DR products trade. Simultaneously, leveraging available pre-trained analytics models and positive projects like the Croatian TSO pilot can enhance the replication potential.

Segment	Replication potential
Energy Stakeholders	Low
Software developers	Medium
Data Scientists	High

7.2 KER2: Integrated Energy Services

Efficient energy practices in the residential sector benefit from regulatory support in Spain, specifically through the introduction of RD 244/2019 promoting self-consumption. The Technical Building Regulation (CTE) in Spain further contributes by setting energy standards, creating a supportive regulatory framework. Additionally, the EU-wide rollout of smart metering enhances data availability, a critical aspect for effective Integrated Energy Services in residential areas. The adoption of hourly-based tariffs and Time-of-Use plans on a pan-European level facilitates demand response, a key component of Integrated Energy Services. In Portugal, the legalization of local energy communities and flexibility aggregation provides a favourable environment for the growth of Integrated Energy Services in offices, commercial businesses, and hotels. Simplified licensing processes for self-consumption sites below 1 MW in Portugal act as an additional enabler. Furthermore, regulatory provisions and definitions in Belgium create a supportive framework for the deployment of Integrated Energy Services in this segment.

Challenges arise from the closed electricity markets, hindering the aggregation of demand response for small consumers across many countries. The limitations on flexibility aggregation poses a significant challenge, restricting the full potential of leveraging distributed energy resources in the residential sector. Persistent challenges in accessing real-time metering data complicate the implementation of real-time flexibility assessment. Moreover, the high prevalence of energy-inefficient buildings across countries adds a barrier to achieving optimal results with Integrated Energy Services in residential areas. The lack of clarity on the rights and responsibilities of aggregators poses a significant barrier to the seamless operation of Integrated Energy Services in offices, commercial businesses, and hotels. Administrative hurdles, including complex qualification procedures in Belgium, may impede the widespread adoption of Integrated Energy Services. The inactive state for demand response (DR) products trade in several countries hampers the efficient functioning of Integrated Energy Services. Additionally, ambiguity regarding the roles of independent Demand Response Providers creates uncertainty and acts as a limiting factor for Integrated Energy Services in this segment.

Target segment: Residential

Despite challenges related to closed markets and flexibility aggregation limitations, supportive regulatory measures, and widespread smart metering enhance the potential for successful replication.

Target segment: Offices, Commercial Business and Hotels

The replication potential is influenced by a mix of supportive regulatory measures and persistent barriers. While enablers exist, the presence of unresolved issues and lack of clarity in crucial areas lowers the overall replication potential. Continuous efforts to address these barriers are essential for widespread success in replicating Integrated Energy Services in these segments.

Segment	Replication potential
Residential	Medium
Offices, Commercial Businesses, Hotel	Low

7.3 KER 3: Multiservice package toolkit

Regulatory support, such as the introduction of RD 244/2019 in Spain promoting self-consumption and the legalization of local energy communities and flexibility aggregation in Portugal. Financial incentives in Belgium, where subsidy schemes for renewables encourage aggregation. Standardization initiatives, with the potential adoption of the frESCO protocol as a standard for PMV, promoting consistency and clarity. Regulatory clarity in Portugal, with simplified licensing for self-consumption sites below 1 MW, and support in Belgium through introduced provisions for flexibility services create a conducive environment. Financial incentives in Belgium, in the form of subsidy schemes for renewables, further encourage aggregation.

However, challenges such as market hesitancy and data availability persist. Closed electricity markets for demand response in Spain and restrictions on flexibility aggregation pose hurdles. Issues like difficulty accessing real-time metering data and regulatory concerns about data sharing by Distribution System Operators (DSOs) further complicate the landscape. The absence of specific standards, particularly for PMV commercialization and exploitation, and regulatory fragmentation in countries like France contribute to the complexity. Challenges are also evident in Croatia, marked by an uncertain regulatory environment with unresolved terms and definitions, and the absence of smart metering regulation. In France, regulatory challenges, including financial barriers and limitations, obstruct market expansion. Spain faces market complexity, characterized by a high stock of energy-inefficient buildings and challenges in Demand-Side Management (DSM), along with a lack of information about the future demand flexibility market.

Target segment: ESCos

Strong regulatory and financial support create a favourable environment, but challenges like market hesitancy and regulatory concerns require strategic interventions for successful replication.

Target segment: Aggregators

Clear regulatory support and financial incentives exist, but challenges in specific regions, such as regulatory uncertainties and market complexity, need careful consideration.

Target segment: Prosumers

Positive regulatory support and financial incentives are present, but technical integration challenges and data privacy concerns pose medium-level barriers.

Segment	Replication potential
ESCos	Medium
Aggregators	High
Prosumer	Medium

7.4 KER 4: Smart Energy Boxes

In the context of Smart Energy Boxes integration, regulatory support in Spain, exemplified by RD 244/2019 and the Technical Building Regulation (CTE), acts as a significant enabler. Despite this support, challenges arise from closed electricity markets and restrictions on flexibility aggregation, demanding strategic interventions for successful implementation.

Portugal's regulatory landscape contributes to a favourable atmosphere with the legalization of local energy communities and simplified licensing. However, challenges emerge due to uncertainties in aggregation processes and the absence of specific measurement and verification standards, necessitating careful consideration and resolution for effective replication.

Belgium's subsidy schemes and regulatory provisions establish favourable conditions for the integration of Smart Energy Boxes. Still, challenges persist in the form of unspecified rights for aggregators and administrative complexities, highlighting the need for careful consideration and strategic planning to ensure seamless replication.

In Croatia, the conducive environment for Smart Energy Boxes is supported by a pilot project for demand response and legal provisions for energy savings. However, challenges arise from regulatory uncertainties and the absence of smart metering regulations, emphasizing the need for resolution to facilitate successful replication.

France provides favourable conditions for Smart Energy Boxes with inclusive participation in energy markets and considerations for thermo-sensitiveness. Nevertheless, challenges in the form of specific rules limiting aggregation and financial barriers hinder the expansion of Smart Energy Boxes, necessitating strategic interventions and regulatory adjustments.

Target segment: Distribution System Operators (DSOs)

The potential for Smart Energy Boxes in DSOs is deemed high in Spain, given the supportive regulatory landscape and established infrastructure. However, addressing challenges related to closed market, real-time data access and administrative complexities is imperative for successful replication in several EU countries.

Target segment: Industrial sector

The overall replication potential for the industrial sector can be assessed as moderate, emphasizing the need for careful regulatory improvements and strategic interventions to overcome market limitations.

Target segment: Domestic sector

Analogously to industrial sector, the overall replication potential for domestic sector can be assessed as moderate with the need for careful regulatory improvements, such as open markets, data access and standardization challenges.

Segment	Replication potential
DSOs	High
Software developers	Medium
Data Scientists	Medium

7.5 KER 5: Novel Performance Measurement and Verification Methodologies

In Spain, a forward-thinking approach supports innovation, particularly in self-consumption. Portugal's legalization of energy communities opens new avenues, and Belgium's subsidy incentives drive aggregation initiatives. The deployment of Smart Energy Boxes and Local Sensors ensures the capture of crucial data. A secure platform and cost-effective Integrated Energy Service apps further fortify the technical landscape. The rise of photovoltaic facilities and evolving regulatory frameworks encourage renewable integration. The unification of the EU's energy market promotes healthy competition. Spain aligns with energy efficiency goals, Croatia and Spain exhibit high Demand-Side Management (DSM) interest, and regulatory advancements provide crucial support to Energy Service Companies (ESCOs).

Closed flexibility markets and limited real-time metering pose challenges. The absence of PMV standards complicates regulatory frameworks, while disparities hinder standardized energy box adoption. The lack of data-driven device standardization and privacy concerns impede technological integration. Regulatory disparities and privacy concerns hinder the adoption of standardized energy boxes. Challenges in data-driven device standardization persist. Low smart readiness poses challenges in efficient energy management, and hurdles persist in demand response equipment and real-time metering. Challenges in digital service adoption, implementing efficiency measures, and communication issues for homeowners pose hurdles.

Target segment: Aggregators

The adoption of forecasting tools and real-time flexibility assessment methods acts as a catalyst to mitigate market hesitancy. The proposed standardization of PMV protocols by frESCO establishes a solid foundation for consistent methodologies, enhancing the potential for widespread adoption.

Target segment: ESCOs:

Overcoming regulatory and financial barriers is paramount for successful replication in the ESCO sector. Clear communication strategies and the development of user-friendly interfaces are pivotal to ensuring effective engagement with end-users.

Segment	Replication potential
Aggregators	High
ESCOs	Medium

8 CONCLUSIONS

The replication assessment provides a mix of challenges and opportunities. While political actions and commitments towards decarbonization create a favourable environment, uncertainties related to political consensus and economic conditions pose challenges. The potential for replication across various EU countries relies heavily on addressing barriers recognized in innovation and regulation allignment. Recommendations span policy alignment, awareness campaigns, and adaptive technologies to ensure frESCO's relevance and resilience.

The overall replication potential of the frESCO project in Europe appears promising, providing that the main challenges are adressed. Several factors contribute to this positive outlook:

- *Regulatory support and financial incentives:* The project benefits from regulatory support in various EU countries, such as Spain and Portugal, where initiatives promoting self-consumption and local energy communities have been legalized. Financial incentives, including subsidy schemes in Belgium, further create a favourable environment for replication.
- *Innovative features and technology integration*: the frESCO project demonstrates a commitment to innovation by leveraging mature technologies such as digital data-based tools, real-time data processing, and AI. The focus on hybrid advanced services indicates a forward-thinking approach to residential energy solutions.
- *Market readiness and technological maturity*: the frESCO solutions, built on mature technologies, address specific needs in the residential sector, particularly in enhancing energy efficiency and enabling demand-side flexibility. The project's readiness to deploy smart services aligns with the growing demand for energy solutions in the market.
- *Political commitment and future trends*: the recognition of political commitment within the EU towards decarbonization of the residential building sector, coupled

with anticipated policy frameworks and interventions, bodes well for the frESCO project. The alignment with future trends, including the deployment of renewable technologies and the increasing importance of demand-side flexibility, positions frESCO favourably.

- *Comprehensive replication assessments*: the thorough assessments conducted for various target segments, including DSOs, aggregators, ESCOs, software developers, and data scientists, contribute to a nuanced understanding of challenges and enablers. This comprehensive approach enhances the project's adaptability across diverse contexts.
- *Consideration of potential barriers*: the acknowledgment of potential barriers, such as economic uncertainty, uneven competitive conditions, and slow policy implementation, demonstrates a realistic assessment of challenges. Identifying and addressing these barriers is crucial for successful replication.
- *Strategic recommendations for overcoming challenges*: the conclusion chapter provides strategic recommendations for overcoming identified challenges, emphasizing the importance of addressing financial, market, and regulatory aspects. This proactive approach enhances the project's potential for overcoming hurdles.

In conclusion, the replication potential of frESCO in Europe is a dynamic interplay between an evolving energy landscape and the innovative features embedded in frESCO solutions. This document provides a methodology for replication potential of the frESCO solutions, while at the same time , emphasizing the importance of policy alignment, proactive awareness campaigns, and continuous technological innovation; addressing challenges and capitalizing on enablers will be crucial for successful replication across diverse European contexts.

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