



## D5.5. Intermediate WP5 scientific report

WP5 – Green Economy Models and Management Systems

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#### List of abbreviations

BEN	Beneficiary
Dn	Deliverable (number)
DoA	Description of Action
DS	Doctoral School
ESR	Early Stage Researcher
ETN	European Training Network
GA	Grant Agreement
IRP	Individual Research Project
ITN	Innovative Training Network
MSn	Milestone (number)
MSCA	Marie Skłodowska-Curie Actions
PC	Project Coordinator
REC	Research Ethics Committee
RSC	Recruitment and Secondment Committee
WPn	Work Package (number)





## 1. Executive summary

The present deliverable provides the first updates of scientific activities involved in WP5, including the main results obtained by Early-Stage Researchers (ESRs) in relation to their Individual Research Project (IRP). The objective of the deliverable is to present the scientific outcomes achieved by ESRs in the first reporting period (from ESRs hiring date till the 1st of September 2023) and provide information about what activities and tasks are planned for the next reporting period. In addition, a general evaluation of ESRs research progress in relation to WP5 objectives is provided.

The WP5 aims to support and coordinate WP2, WP3, and WP4 in terms of business models research and application in the field of collaborative and distributed renewable generation systems, microgrids, energy management and consumption control systems. Furthermore, WP5 aims to design synergic strategies to demonstrate the benefits of technologies and solutions developed in WP2, WP3, WP4 and provide policy recommendations to drive the energy system transformations. The WP5 entails four IRPs, namely IRP-12, IRP-13, IRP-14 and IRP-15 assigned to four ESRs.

- **ESR-12** focuses on IRP-12 about the “Development of sustainable strategies for Net Zero Energy Buildings and User Energy Awareness using Smart Appliances”.
- **ESR-13** focuses on IRP-13 concerning “Digital twins of prosumers using socio-economic factors and big data for Optimization of Customer’s bill savings and the adoption of concepts of self-consumption and presumption”.
- **ESR-14** focuses on IRP-14 regarding “Energy value chains and markets developed with the new paradigm of distributed EES”.
- **ESR-15** focuses on IRP-15 about “Identifying enablers and barriers to foster the replicability and transfer of business models for Green Energy Systems”.

ESR-12 official date of recruitment was December 15, 2022. ESR-12 research focuses on four pillars: (a) Nearly Zero Energy Buildings (nZEBs), (b) energy flexibility offered by smart appliances, (3) user-centric approach for energy awareness, and (4) collaborative energy ecosystems. ESR-12 worked in NOVA School of Science and Technology (FCT NOVA) at the Universidade NOVA de Lisboa. The ESR-12 research project aims to enhance buildings sustainability by using smart devices to achieve net zero energy use. The main contribution to WP5 is related to “D5.1 Development of sustainable solutions for Zero Energy Buildings and Energy Awareness using Smart Appliances”. So far, ESR-12 has not carried out any secondment. However, 2 secondments of 2 months at Università degli Studi di Salerno (USA) are planned in the months Jan-Feb 2024 and Sep-Nov 2024 to implement a digital platform for Energy Management System and Smart Buildings / Communities (The first one is postponed due to the residential permits). In terms of publication and academic achievements, ESR-12 has submitted two articles in academic journals: (a) The Potential of Residential Load Flexibility: An Approach for Assessing Operational Flexibility, and (b) Cooperative Stochastic Energy Management of Networked Energy Hubs Considering Environmental Perspectives.

ESR-13 was recruited on May 09, 2022, at the Research and Training Development Department of Siemens Industry Software SAS in France. The scientific outcomes have been achieved in the last 16 months. ESR-13 research aims to improve the understanding of technical, environmental, economic and behavioural factors that compromise the development of innovative models for prosumers participation in the electric grid. The final objective of ESR-13 project is to develop digital models and modelling methods for prosumers considering the interaction and influences of social, economic and environmental factors. Up until now, ESR-13 has developed a digital model framework for grids that allows the study of technical, social, and economic variables and their impact on the electric systems, as well as two models that demonstrate the effects of social and economic factors in performing prosumers activities. ESR-13 contribution to WP5 is linked to “D.5.2 Validated digital twins of prosumers based on socioeconomic factors”. ESR-13 has already finished the first two months secondment at the Universidade NOVA de Lisboa, Portugal (May-June 2023), where two real-cases’ digital twins based on university buildings were developed. Regarding academic achievement, the ESR-13 has published a conference paper, with the title “Multi-factor modelling of electric grids for social and technical impact studies,” at the 17<sup>th</sup> International Conference on Compatibility, Power Electronics and Power Engineering (CPE-POWERENG) held in Tallinn, Estonia on 14-16 June 2023.

ESR-14 was officially recruited on September 01, 2023 by the Centre for Research on Geography, Resources, Environment, Energy & Networks (GREEN), Università commerciale Luigi Bocconi, Milan, Italy. ESR-14 research topic aims to improve flexibility service for Energy Communities (ECs) in order to support the implementation of innovative





market solutions within the distributed Electrical Energy System (EES). The final research objective of ESR-14 is to propose flexibility services based on different facilities/technologies for ECs by checking the economic and technical feasibility, market profitability and political/regulatory viability. ESR-14 contribution to WP5 focuses to "D5.3 – Report including market solutions and business models to enable the growth and sustainability of distributed EES". So far, ESR-14 has completed the first two-months secondment at Universidade NOVA de Lisboa, where he collected data to design an Electric vehicle charging station (EVCS) for parking lots. Concerning the academic achievements, ESR-14 has published a conference paper "A Critical Review of District Heating and District Cooling Socioeconomic and Environmental Benefits" In Technological Innovation for Connected Cyber-Physical Spaces, DoCEIS 2023. In addition, ESR-14 gets the "Best Paper Award of the 14<sup>th</sup> Advanced Doctoral Conference on Computing, Electrical and Industrial Systems (DoCEIS 2023)".

ESR-15 was recruited on January 01, 2023 by the Centre for Research on Geography, Resources, Environment, Energy & Networks (GREEN), Università commerciale Luigi Bocconi, Milan, Italy. ESR-15 research is related to IRP-15 since it plans to identify and assess the relevant factors that favour and hinder the diffusion of innovative business models related to sustainable energy systems and energy transition in the EU. ESR-15 focuses on Energy Communities (ECs). The main research objectives are: (a) to BMs face, (c) to provide policy solutions to overcome these barriers, and (d) to replicate successful innovative EC BM. ESR-15 main contribution to WP5 is to "identify enablers and barriers to foster the replicability and transfer of business models for Green Energy Systems", and to "D5.3 – Report including market solutions and business models to enable the growth and sustainability of distributed EES". So far ESR-15 has not carried out any secondment, but it is already planned the first secondment at **Universidad de Extremadura (UEX)** for two months (October 15 to December 15, 2023). Regarding academic achievement, ESR-15 plans to present the result of his research at the 16<sup>th</sup> International Conference on Energy and Climate Change-PROMITHEASnet, which takes place in Athens, Greece, 11-13 October 2023.

## 1.1. Objectives of the deliverable

The purpose of this deliverable is to present the progress of WP5 activities and the first achievements of ESRs involved in WP5. It aims to present the main goals of research projects carried out by ESRs, their scientific outcomes and the connections with WP5 ambitions. Finally, scientific achievements, such as experimental prototypes, publications, and participation in conferences as well as patents and awards are illustrated and listed.

## 1.2. Organisation of the deliverable

This report is organized as follows: First, the evaluation of ESRs progress as well as the progress of WP5 activities are reported. The in-depth research outcomes and activities of each ESR is presented in section 3, including research goal and achievements obtained in the first reporting period. ESRs contribution to WP5 is also provided and analysed in section 3. Finally, the scientific achievements, in terms of publications and awards, are listed in the chapter of references.





## 2. General progress of the action

### 2.1. WP5 Objectives and tasks

The WP5 focuses on “Green Economy Models and Management Systems” and aims:

- To coordinate WP2, WP3 and WP4 in terms of business models research, assessment and validating in order to support collaborative and distributed renewable generation systems, microgrids, energy management and consumption control systems.
- To design synergic strategies to demonstrate the benefits of systems and technologies developed in WP2, WP3 and WP4.
- To provide policy recommendations to guide energy system transition.

WP5 included 5 Tasks:

- Task 5.1: Development of sustainable strategies for Net Zero Energy Buildings and Energy Awareness using Smart Appliances (UB, UNL).
- Task 5.2: Generation of digital twins of prosumers using socioeconomical factors and big data for Optimization of Customer’s bill savings, (UB-SIEM-UNL).
- Task 5.3: Energy value chains and markets developed with the new paradigm of distributed EES (UB-UNL-CNR).
- Task 5.4: Identifying enablers and barriers to foster the replicability and transfer of business models for Green Energy Systems (UB, UNL, ECPE).
- Task 5.5: Elaboration of partial and final scientific reports (UB).

The following table lists the deliverables included in WP5, the lead beneficiaries and the due date.

Deliverable Number	Deliverable Title	Lead beneficiary	Type	Dissemination level	Due Date
D5.1	Development of sustainable strategies for Net Zero Energy Buildings and Energy Awareness using Smart Appliances	UB	Report	Public	M30
D5.2	Validated digital twins of prosumers based on socioeconomical factors	UB	Other	Confidential, only for members of the consortium (including the Commission Services)	M30
D5.3	Report including market solutions and business models to enable the growth and sustainability of distributed EES	UB	Report	Public	M45
D5.4	Identified enablers and barriers to foster the replicability and transfer of business models for Green Energy Systems	UB	Report	Public	M45
D5.5	Intermediate WP5 scientific report	UB	Report	Public	M24
D5.6	Final WP5 scientific report	UB	Report	Public	M48

### 2.2 WP5 – ESRs progress

The ESR progress is evaluated and reported in the following table according to three statuses:

- Inactive status: the ESR left the project or no data are available for the evaluation
- In progress status: the ESR is working on his research topic in line with the WP5 goals, but not all goals have been achieved yet.

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- Complete status: the ESR fulfilled all the project requirements, completing its training and research activities

ESR	Starting date	General evaluation	Status
12	15/12/2022	ESR-12 is on track with its declared research objectives, and the research topic is in line with IRP-12. Considering the time of his involvement in the project (9.5 months) the ESR-12 has made good progress. In terms of publications, he reaches the annual goal with two articles submitted for publication in academic journals.	In progress
13	05/09/2022	ESR-13 is on track with its declared research objectives, and the research topic is in line with IRP-13. Considering the involvement period (16 months), the ESR-13 produced the first scientific outcomes and fulfilled the annual goals in terms of the secondment. ESR-13 has already published one paper at an academic conference.	In progress
14	01/09/2022	ESR-14 is on track with the declared research objectives and the research topic is in line with the IRP-14. Since the ESR-14 has been in the project (13 months), he has achieved the preliminary scientific results and covered his duty in terms of secondment. In terms of publications, the ESR-14 has published a paper in a conference and got an award.	In progress
15	01/01/2023	ESR 15 research work is consistent with the IRP-15. Considering his involvement period (9 months), the ESR-15 is on track with his declared research objectives. The ESR-15 plans to present a paper at a conference on 11-13 October 2023.	In progress





### 3. WP5 Tasks progress

#### 3.1. Task 5.1 – IRP12 “Development of sustainable strategies for Net Zero Energy Buildings and User Energy Awareness using Smart Appliances”

##### 3.1.1. Introduction

ESR-12 was involved in the project in December 2022 (15/12/2022) recruited by Universidade NOVA de Lisboa (Hosting Institution). ESR-12 obtained worked in NOVA School of Science and Technology (FCT NOVA) at the Universidade NOVA de Lisboa. ESR-12 is involved in the IRP-12 “Develop of sustainable strategies for Net Zero Energy Buildings and User Energy Awareness using Smart Appliances”. ESR-12 focuses on four main pillars: (a) Nearly Zero Energy Buildings (nZEBs), (b) energy flexibility offered by smart appliances, (3) user-centric approach for energy awareness, and (4) collaborative energy ecosystems. According to the Energy Performance of Buildings Directive (EPBD), “a “nearly zero-energy building” (nZEB) means a building that has a very high energy performance and the nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby”. Moreover, nZEBs are also capable of performing energy flexibility. According to the International Energy Agency in Energy in Building and Communities Programme (EBC) Annex 67, “the Energy Flexibility of a building is the ability to manage its energy demand and generation according to local climate conditions, user needs, and grid requirements. Energy Flexibility of buildings will thus allow for demand side management and load control and thereby demand response based on the requirements of the surrounding grids.” This energy flexibility can be offered in the energy market as an ancillary service through third parties (e.g., aggregators or Energy Communities - EC). The research aims to establish/design energy management systems and develop optimal operating strategies to manage energy flexibility in nZEBs and ECs. Also, given the scope, ESR-12 will investigate the energy awareness of home users in order to increase the potential of energy flexibility through the use of smart appliances considering the integration of smart appliances, grid operability and energy self-consumption.

The following activities will be performed by the ESR-12:

- Characterization of energy flexibility in buildings and ECs, taking into consideration user comfort.
- Adaptation of smart appliances to enhance energy flexibility through energy management systems, considering the IoT framework.
- Development of intuitive and interactive interfaces to increase user energy awareness, taking into consideration accessibility criteria.
- Development of integrated strategies to manage building/community flexibility.
- Development of cooperative strategies among EC members and market players to assure grid operation and energy self-consumption.

##### 3.1.2. Scientific outcomes

###### 1. Literature review and analytical framework development to characterize energy flexibility in buildings and ECs.

The ESR conducted a literature review in order to analyse and evaluate the current literature on energy flexibility at the building level. Scientific papers and reports, published in high-rank and prestigious journals in the past 10 years, have been surveyed. The literature review shows that most papers focus on evaluating specific smart appliances, or source of flexibility, while establishing a combined approach to evaluate the potential of energy flexibility of a building is not considered under real operation conditions. Additionally, there is a lack of study that consider indicators such temporal dynamics of flexibility. Hence, to characterize the energy flexibility of smart houses through a combined perspective, a quantifying framework has been developed by ESR-12 in which the energy management strategy is formulated by applying the mixed-integer linear programming (MILP) technique. The proposed MILP model considers the scheduling problem for shiftable appliances and energy storage units. Then, by scrutinizing the pattern of consumption of the smart house two novel flexibility indicators have been introduced to represent the potential operational flexibility of the building (smart house). By applying these indicators, energy management systems, including buildings and houses, can coordinate their interactions with the energy suppliers and/or grid operators. Also, the proposed framework preserves habitants’ comfort in terms of energy management strategy.





## 2. Literature review and integrated strategies development to manage the building/community flexibility.

An integrated framework has been developed by ESR-12 in an EC that includes two industrial and commercial Smart Energy Hubs as well as a residential hub representing nZEBs. Based on the structure of energy hubs, different demands, including heating, cooling, and power loads, can be supplied effectively from a techno-economic-environmental point of view. ESR-12 found a research gap in integrating of CO<sub>2</sub> emission management in the optimized energy management of energy hubs. Most studies considered this problem from just an economic perspective. In addition, in order to form a sustainable cooperation among different entities in an EC, allocating the benefits of cooperation in a fair manner is essential which has also been neglected in many studies. Consequently, through a mathematical programming framework, the problem of managing energy flow in the EC has been modelled aiming to reduce the operating costs of members as well as CO<sub>2</sub> emissions by implementing a fair cost allocation mechanism. Furthermore, the uncertainties associated with the generation of renewable resources as well as the energy price have been considered through a scenario-based stochastic programming approach.

## 3. Deviation of research work

ESR-12 had faced several issues including a delayed secondment. The planned secondment at Università degli Studi di Salerno (USA) has been delayed due to administrative barriers for residential permit. Moreover ESR-12 experiences technical compatibility issues between the simulation software and the operating system, resulting in a multiple-week delay in simulations. An unanticipated need for advanced training in software tools and optimization techniques to fulfil the research goals led to a delay of two months. The software tool's sophistication necessitated more training than anticipated.

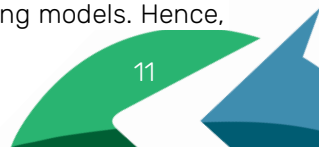
### 3.1.3. Future planned activities and goals

To achieve the research objectives of IRP-12, ESR-12 will participate in courses related to advanced optimization techniques and game theory for energy systems. Hence, it has been planned to participate in some of those courses to enhance the knowledge addressing new techniques and methods. In the meantime, ESR-12 will complete the first planned secondments in Italy. The planned activities of ESR-12 are summarized below.

- ESR-12 intends to develop sustainable strategies for nZEBs, as energy management frameworks, applying mathematical programming and machine learning techniques.
- ESR-12 will conduct research on how to improve the level of grid interaction, self-consumption, and self-sufficiency in nZEBs / ECs, by using smart appliances' energy flexibility.
- ESR-12 plans to participate in the preparation and submission of research grant/funding applications along with other researchers.
- ESR-12 expects to participate in the organization of international conferences along with other researchers.
- ESR-12 will prepare courses/workshops/tutorials for undergraduate and postgraduate students.
- Planned secondment of ESR-12: 2 months at Università degli Studi di Salerno (USA) in months Jan-Feb 2024 and Sep-Nov 2024 to implement a digital platform and a prototype for innovative Energy Management System focusing on Smart Buildings and ECs.

### 3.1.4. Contribution to the WP objectives

ESR-12's main contribution to WP5 is connected with advanced sustainable strategies as well as interactive user-friendly interfaces that pave the way for actual nZEBs. In order to deploy these strategies in real cases, they should be techno-economically beneficiary for end users. Also, these strategies should be able to reflect real constraints and limits and consider uncertain economic parameters in providing decision-making variables for energy management systems. Hence, to validate the functionality of the developed strategies, applying simulation software and deploying strategies as the core of energy management systems is considered by ESR-12. The validation process can demonstrate the real economic-environmental benefit and effectiveness of the models for the nZEBs. Finally, after the validation and verification procedure, the developed models, as value propositions, can be implemented as sustainable and green strategies for energy management systems by engineers and operating system managers. Also, developing optimal energy management strategies for ECs, in the form of a decision-making operation framework, enhances their collaboration and sustainability. A part of developing sustainable strategies for the EC is to make them greener. A greener future requires a rethink of production, consumption, and trading models. Hence,





reducing emissions should be considered as a goal in the proposed models. In addition, establishing and developing cooperative strategies among members of ECs can enhance the role of nZEBs. Enabling nZEBs as active players in power markets can bring economic benefits by participating in day-ahead and real-time schemes or offering flexibility in ancillary service markets. Consequently, modeling interactions among players from technical and economic perspectives is important for sustainable and secure cooperation. Through these frameworks, the benefits of different systems can be evaluated.

### 3.1.5. Scientific achievements

#### Publication

#	Title, incl. citation information	Type (Conference, journal, book chapter)	Status (Submitted, accepted, published)	DOI
1.	The Potential of Residential Load Flexibility: An Approach for Assessing Operational Flexibility	Journal	Submitted	<a href="https://dx.doi.org/10.2139/ssrn.4527303">https://dx.doi.org/10.2139/ssrn.4527303</a> - preprint
2.	Cooperative Stochastic Energy Management of Networked Energy Hubs Considering Environmental Perspectives.	Journal	Submitted	<a href="https://dx.doi.org/10.2139/ssrn.4341763">https://dx.doi.org/10.2139/ssrn.4341763</a> - preprint





## 3.2. Task 5.2 – IRP13 “Generation of digital twins of prosumers using socioeconomic factors and big data for Optimization of Customer’s bill savings”

### 3.2.1. Introduction

ESR-13 was recruited to the project in May 2022 (09/05/2022), at the Research and Training Development Department of Siemens Industry Software SAS in France. Therefore, the obtained scientific outcomes have been achieved in the last 16 months.

ESR-13 is involved in the IRP-13 about “digital twins of prosumers using socioeconomic factors and big data for optimization of Customer’s bill savings, and the adoption of concepts of self-consumption and presumption”. ESR-13 focuses on prosumers, which are entities seen by the electric grid as consumers and producers of energy. His research regards the physical modelling of grids and the impact of social and economic aspects on the grid and its models.

ESR-13 research connects with IRP-13 by aiming to improve the understanding of the factors that affect the development of accurate models of prosumers in the electric grid, so that public statistics can focus on gathering relevant information for the development of future projects and, on the other hand, so that developers take into consideration the social and economic aspects of the location of their projects.

Therefore, ESR-13 contributes to the objectives of IRP-13 by including social, economic, and technical factors into the modelling approach of prosumers in electric grids with the objective of reducing consumer expenses. The final objective of ESR-13 is to develop models and modelling methods of prosumers considering the social and economic environment.

### 3.2.2. Scientific outcomes

The scientific outcomes of ESR-13 are:

#### 1. Literature review outcomes (6-month first year):

ESR-13 initially performed a literature review on the different modelling approaches for electric systems, with a special focus on small grids, residential networks, and prosumers, as well as social and economic factors influencing electric consumptions. In particular, ESR13 analysed literature regarding household energy consumption and techniques to replicate the stochastic behaviour of occupiers interacting with common appliances. He also reviewed literature covering the factors that influence electric consumption, like household size, energy price, house insulation, etc. Furthermore, he categorized and assessed the modelling tools used to design and simulate electric systems, prosumers, and grids, in order to identify their capabilities and gaps.

#### 2. Development of a modelling and simulation framework for grids

Next, ESR-13 developed a modelling and simulation framework for grids that allow the study of technical, social, and economic variables and their impact on the electric systems, as well as the implementation of the synthesizing technique for residential loads. The tool developed was validated with load flow analysis on benchmark grids from Pandapower Python. The ability of the model to incorporate renewable energy systems as well as economic and social factors was demonstrated by incorporating wind and solar models, the hourly price of energy, and the consumption of residential zones. The tool was presented during the CPE-POWERENG conference in Tallinn in the section on “Renewable energy and smart grids”.

#### 3. Development of models for the demonstration of social and economic factors.

The demonstration of the modelling framework required the development of further elements by ESR-13.

The first one was a model that translates the behaviours and activity of a household into an electric load profile using Richardson’s method. The second were models or digital twins of the renewable systems that would be connected to the grid (photovoltaic panels and wind energy systems).





#### 4. Results achieved during the first secondment at Universidade NOVA de Lisboa in Caparica, Portugal.

During the first secondment at Universidade NOVA de Lisboa, ESR-13 developed digital twins of two real world case of university buildings: 1) Building F of UTBM (Université de technologie de Belfort Montbéliard) in Belfort; 2) Electronics building of NOVA University in Caparica.

For the Building F at UTBM, work started in gathering and requesting access to relevant data that will ease the digitalization of the building and its hybrid local energy systems like the lithium iron phosphate battery, the photovoltaic installation, the electrolyser, and the fuel cell in the laboratory.

For the Electronics building at NOVA, the objective is to obtain a digital twin of the full building to evaluate the possibility to use a large water deposit for the fire emergency system as thermal energy storage chiller to assist the cooling of the building during high energy cost hours or to provide flexibility by delaying or anticipating the consumption.

**The digital twins will improve the ability to better understand how future developments will perform and optimize them before their implementation.**

##### 3.2.3. Future planned activities and goals

The planned tasks of ESR-13 for the next reporting period are:

Developing a model of building F at UTBM involving:

- Generation equipment with solar or hydrogen technology
- Movement of people into and out of the building
- Factors like day of the week, season, etc.
- Environmental factors like temperature, irradiance, wind speed, etc.
- Economic considerations of energy prices and conditions for generation.

Presentation of Model of building X at Universidade NOVA de Lisboa.

- The model developed during the 1<sup>st</sup> year led to a proposal to use existing regulatory infrastructure for load-shifting tasks without impacting the reliability of the underlying infrastructure and improving the consumption times and possibly improving the lifetime of the cooling system of the building.
- An article detailing the proposed model and the improvements achieved will be prepared.

Secondment at Universidade NOVA de Lisboa to test real-time simulation of digital twins.

- Development of an article on the real time capabilities of the digital twins.

Collaboration with ESR-15 during his secondment at Siemens Industry Software SAS

- Development of a model of an energy community and its financial mechanisms or business models.

##### 3.2.4. Contribution to the WP objectives

ESR-13 contribution to WP5 is related to the creation of digital twins, which will consider not only technical but also socio-environmental factors. His contribution therefore is connected to Task 5.2. "Generation of digital twins of prosumers using socioeconomical factors and big data for Optimization of Customer's bill savings". Specifically, ESR-13 has created a digital twin of Building X at Universidade NOVA de Lisboa and the modelling of the solar panel and



battery pack to Building F at UTBM. Indirectly it has also helped in easing the development of sustainable strategies by means of the proposition of load shifting with thermal storage on the former building.

Furthermore, according to the current direction of ESR-13 research, 3 digital twins will be developed considering more than just technical factors. In addition, according to the current plan for the next reporting period, ESR-13 aims to develop collaboration with other WP5 ESRs. Therefore, a connection with Task 5.3: "Energy value chains and markets developed with the new paradigm of distributed EES" and Task 5.4: "Identifying enablers and barriers to foster the replicability and transfer of business models for Green Energy Systems" will be implemented and ESR13 will contribute to deliverables related to these tasks (D 5.3 and D 5.4).

However, this collaboration is at a very early stage, and no scientific outcome has been achieved yet in terms of developing specific methodologies and research collaborations.

### 3.2.5. Scientific achievements

#### Publication

#	Title, incl. citation information	Type (Conference, journal, book chapter)	Status (Submitted, accepted, published)	DOI
	Multi-factor modelling of electric grids for social and technical impact studies, Tallinn, Estonia, 2023, pp. 1-6,	Conference	Published	<a href="https://doi.org/10.1109/CPE-POWERENG58103.2023.10227407">https://doi.org/10.1109/CPE-POWERENG58103.2023.10227407</a>





### 3.3. Task 5.3 – IRP14 “Energy value chains and markets developed with the new paradigm of distributed EES”

#### 3.3.1. Introduction

ESR-14 research activities have been conducted for thirteen months since his recruitment by Università Commerciale Luigi Bocconi (Hosting Institution) in September 2022. ESR-14 worked in the Centre for Research on Geography, Resources, Environment, Energy & Networks (GREEN), Università Commerciale Luigi Bocconi. ESR-14 also completed his first secondment at the Universidade NOVA de Lisboa (two months, June–July, 2023). ESR-14 worked on the IRP-14 “Energy value chains and markets developed with the new paradigm of distributed EES”. ESR-14 research topic aims at improving the effectiveness of flexibility service for Energy Communities (EC). According to FEDARENE “Energy communities are initiatives led by citizens, allowing them to take control of their energy production and consumption”. ECs can play a pivotal role in enhancing RES generation and consumption and increasing energy security for the EU member states. Moreover, the EC is one of the crucial disruptive innovations within the Electric Energy System (EES). ECs can provide different services to their members such as energy generation, energy storage, and toward energy market players such as flexibility service which is considered a key aspect of managing energy flow among users. Flexibility services are intended as the ability of power systems to cope with renewable energy variability and uncertainty through peak demand shifting to avoid overloads and reduce electrical grid stress. Examples of flexibility services in the EU are based on demand response management and energy storage technologies, e.g., batteries and EVs with high technology costs and small stand-alone capacity. Flexibility service will help to reduce energy consumption, manage energy more efficiently, attract investors to invest in EC and provide several advantages to fight energy poverty. Within this research framework, ESR-14 explores and investigates flexibility services' technical and business feasibility. The final research objective is to propose flexibility services based on different technologies and solution and check their economic feasibility and market profitability, which will be validated by executing techno-economic analysis. Besides the profit obtained from these services, ESR-14 will focus on low-income families to tackle energy poverty, considering it as a value proposition in EC BM and evaluating different revenue streams and investment strategies.

In detail, ESR-14 goals are:

- Assessing policy and regulations framework of ECs (REC–Renewable Energy Communities & CEC–Citizen Energy Communities).
- Reviewing market players and stakeholders of the energy value chain and ECs in different EU contexts.
- Assessing and categorizing existing innovative services for ECs including EV charging facilities and energy storage system - reviewing current literature and comparing them.
- Developing new feasible and sustainable flexibility services and BMs for ECs.
- Testing and assessing BM impacts/benefits. Analysing barriers and enablers which will assist in scaling up opportunities for ECs.
- Delivering policy recommendations to support ECs.

The final beneficiaries will be ECs members, and EES stakeholders, including energy suppliers, DSO, municipalities, EV charger providers, aggregators, investors, etc. The main innovation of this work is to explore the flexibility services capacity based on different innovative technologies (EV charging and energy storage). Also, this research will utilize real data obtained from various ECs and provide them with feasible combination of solutions and services. A key outcome will be the development of simulation tools that will be useful for stakeholders or EC members to check their return on investments (ROI), payback period and other aspects before investing in an EC by utilizing the economic model (combining machine learning and optimization methods). This work will assist investors in understanding their profitability before investing in the EC.

#### 3.3.2. Scientific outcomes

##### 1. Policies and barriers analysis of ECs

ESR-14 conducted a literature review on the topic “Policy framework and barriers for ECs” and he discovered barriers hindering EC development in the EU. Barriers were categorized in this research into four including financial, administrative and legal, technological and social. Based on this work, some key barriers include a) difficulties in





finding investors for small scale ECs, b) the absence of a definition of the term “proximity” in the regulatory framework of ECs in the EU which creates confusion, and c) inefficient energy infrastructures.

### 3. Literature review on EV charging and energy storage services for ECs

After analysing current literature, some studies suggested that people are highly enthusiastic about changing their traditional vehicles to EVs. However, the main barrier is the lack of EV charging infrastructure. Energy storage is crucial to reduce energy consumption during peak load. After analysing several recent studies, it is found that EV charging and energy storage facilities are quite essential for EC members. However, these facilities can be controlled by the EC energy management system. More precisely, this EC energy management system can balance the energy flow and offer flexibility service through EV charger and energy storage towards DSOs/utility companies. DSO/utility companies can provide economic benefits (reduction in energy bills or services payments) to EC members. These are ways to generate revenues for EC members. To do so, EC members need to do load shifting during peak load use appliances or charge their EVs during extra generation for energy balancing of the distribution grid, which will be informed in advance to EC energy management manager by DSO/energy suppliers/utilities. To understand the potential of EV chargers in performing flexibility services, ESR-14 collected data on EV facilities placed at the Universidade NOVA de Lisboa parking lot. This was part of ESR-14 first secondment.

### 5. Deviations with the plan

Several deviations were faced during the last year, including work permit delays, visa delays, housing problems, administrative barriers for a residential permit. The data availability for planned research was delayed due to the GDPR rule compliance. Furthermore, it would be much easier if the information was without the name of the person.

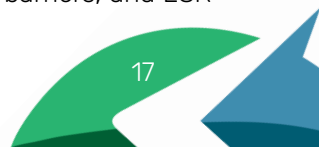
#### 3.3.3. Future planned activities and goals

ESR-14 is planning to learn some specific techniques through courses, training and workshops which will help ESR-14 to conduct the next phase of the research. Specifically, ESR-14 is planning to learn machine learning algorithms, statistical analysis, and optimization techniques. Moreover, ESR-14 will learn optimization methods with either mathematical modelling or simulation tools to conduct feasibility analysis of selected facilities of flexibility service. Also, ESR-14 is working on preparing a survey to collect data from four EU countries ECs including Italy, Portugal, Sweden and Greece. On the other hand, ESR-14 is also working on a review paper related to EVs chargers in different EU countries. Besides, ESR-14 will also work on the collected data from the Universidade NOVA de Lisboa (during secondment) parking lot to design a suitable and profitable EV charger system within the next reporting period. This will be utilized to understand the overall cost (CAPEX, OPEX) and possible technical requirements. Ultimately, the proposed method of this research work will be deployed to different ECs to validate flexibility service for ECs. The planned activities and possible outcomes of ESR-14 are briefly described below.

- 1<sup>st</sup> Journal Article: Extension on the paper “A Critical Review of District Heating and District Cooling Socioeconomic and Environmental Benefits” in the SN Computer Science (Springer Nature).
- Literature review regarding “Available EV services and charging facilities and technologies with regulatory barriers in Europe” to submit in the Renewable and Sustainable Energy Reviews (ELSEVIER)
- Planned Second Secondment January 2024 – April 2024.
- Conference Paper “Techno-Economic analysis of EV charging station (EVCS) of Universidade NOVA de Lisboa, Caparica Campus”
- Data Collection for Case Studies from the EU ECs

#### 3.3.4. Contribution to the WP objectives

ESR-14 research topic is significantly connected with WP5 goals as this topic will cover energy-related services and innovative BM within the electric value chain. Also, current available energy-related technologies for specific services will be reviewed to construct sustainable and innovative services for EES. Precisely, the results obtained from one year (stakeholder analysis, reviewing services for EES and policy analysis) and the planning activities for the next year (collecting data from ECs, preparing methods to conduct techno-economic analysis, and proposing new services for ECs) will help to accomplish the task of WP5’s “Task 5.3: Energy value chains and markets developed with the new paradigm of distributed EES”. Besides, ESR-14 conducted research on regulatory framework and barriers, and ESR-





14 discovered some key barriers which hinder EC development in the EU. Eventually, this will contribute to "Task 5.4: Identified enablers and barriers to foster the replicability and transfer of business models for Green Energy Systems".

### 3.3.5. Scientific achievements

#### Publication

#	Title, incl. citation information	Type (Conference, journal, book chapter)	Status (Submitted, accepted, published)	DOI
1.	(Ahmed, S.M.M., Croci, E., Bagaini, A. (2023). A Critical Review of District Heating and District Cooling Socioeconomic and Environmental Benefits. In: Camarinha-Matos, L.M., Ferrada, F. (eds) Technological Innovation for Connected Cyber Physical Spaces. DoCEIS 2023. IFIP Advances in Information and Communication Technology, vol 678. Springer, Cham.	Conference	Published	<a href="https://doi.org/10.1007/978-3-031-36007-7_1">https://doi.org/10.1007/978-3-031-36007-7_1</a>

#### Awards

Best Paper Award of the 14<sup>th</sup> Advanced Doctoral Conference on Computing, Electrical And Industrial Systems (DoCEIS 2023)



### 3.4. Task 5.4 – IRP15 “Identifying enablers and barriers to foster the replicability of business models for Green Energy Systems”

#### 3.4.1. Introduction

ESR-15 was recruited to the project in January 2023 (01/01/2023) by Università commerciale Luigi Bocconi (UB) at GREEN (Centre for Research on Geography, Resources, Environment, Energy & Networks) in Milan, Italy. Thus, the scientific outcome was obtained over a period of 8 months, and the main partner in charge is Università commerciale Luigi Bocconi (UB).

ESR-15 is involved in IRP-15 which aims to “Identify enablers and barriers to foster the replicability of business models for Green Energy Systems”.

ESR-15 research connects to IRP-15 since it plans to identify and assess the relevant factors that favour and hinder the diffusion of innovative business models related to sustainable energy systems and energy transition in the EU. Considering the current research direction, ESR-15, in order to achieve the objectives of IRP-15, decided to narrow down his research focus to the analysis of Energy Communities (ECs) in the EU context. Energy communities are collaborative schemes about power energy systems with a particular focus on Renewable Energy Systems, that can be characterized by different business models. ECs can perform various activities such as energy generation and storage, but also provide services to the grid such as demand-response. In addition, they aim to deliver also socio-environmental benefits, addressing current challenges such as the climate crisis, energy poverty, etc. ECs incorporate different types of actors, with citizens being at the centre but also involving other actors with different purposes, motives, and interests.

The analysis of Energy Communities by ESR-15 will be done from a business model perspective. Based on the foregoing, ESR-15 research objectives are to:

- taxonomize different types of Energy Community Business models
- analyse barriers that specific EC business models face
- provide policy solutions to overcome these barriers
- provide recommendations for a successful replication of innovative Energy Community business models.

The final beneficiaries of the research will be ECs members and key stakeholders, as well as policy makers at various levels. The main innovation of this work is to explore business models of ECs considering the role of different actors and their capacity to generate different types of values. The research will utilize literature but also real data obtained from various ECs, providing to the final beneficiaries a set of recommendations on the implementation and replication of innovative EC business models.

#### 3.4.2. Scientific outcomes

##### 1. Literature review analysis and formulation of the research topic (January – April 2023)

ESR-15 performed a first literature review concerning business models and business models for sustainability, which led to the following outcomes:

1. Categorization of different theories and perspectives concerning business models and business models for sustainability
2. Identification of different frameworks for business model analysis, such as business model canvas, lean canvas framework, sustainable business model's canvas. etc.

A second literature review was conducted, on business models and green energy systems. Through this activity, ESR-15 decided to focus his research on Energy Communities (ECs) and formulated a research topic based on the gaps identified in the literature, which relates in particular on the ownership models and financial mechanisms of Energy Communities.

Energy Communities have been defined by two EU directives; the Renewable Energy Directive (REDII) introduced Renewable Energy Communities (RECs) and the Internal Electricity Market Directive (IEMD) introduced Citizen Energy Communities (CECs). Despite the difference between the two definitions, they share common elements as setting as main goal the active participation of citizens in the energy transition, but also to address social inequalities such as energy poverty.





ECs involve various actors as members, such as citizens, Small and Medium Enterprises (SMEs), municipalities, etc., with different interests and motivations, and they can have different legal forms, governance structures and ownership models. Based on the literature review conducted and the gaps identified, ESR15 decided to focus the research on the analysis of the ownership models of ECs and their relations with financing mechanisms. The definition of "ownership model" used is based on the International Energy Agency (2020) and consists of four key elements:

1. *Ownership structure*, which is about the type of actors who are members of the EC.
2. *Level of democratic governance*, which is based on the principle of one member, one-vote.
3. *Local distribution of benefits*, which refers to whether or not the benefits produced by the EC are distributed locally.
4. *Purpose of the organization*, which refers to the primary goal set by the ECs, such as tackling energy poverty, return of investment, and additional income to members of the EC. etc.

Financial mechanisms of ECs can be defined as the type of finance, equity and debt finance, used by different actors, public or private, in order to raise capital and fund the EC activities.

Although the ownership model and financial mechanisms of energy communities are related to each other, there is no academic literature that discusses them. In addition, although there is extensive literature that discusses the financial barriers that ECs face, there is still a lack of knowledge of what financial barriers these different types of ECs face, apart from some reports.

Hence, ESR-15 decided to investigate the relation between ownership models and financial mechanisms of Energy Communities and formulated the following research questions to guide the research:

- *What are the ownership models of ECs that exist in the EU?*
- *What kind of financing mechanisms have these ECs developed?*
- *What are the barriers associated with the financing mechanisms developed by ECs in terms of raising funds to finance their projects?*

In order to answer the research questions, ESR-15 decided to conduct a questionnaire survey targeted to ECs in EU.

## **2. Survey design and data analysis (April 2023–August 2023)**

ESR-15 designed a questionnaire survey aimed to investigate ownership models and financial mechanisms of ECs in the EU. The main focus of the survey was energy generation plants that have been developed by ECs, excluding other activities, such as energy storage, demand-response etc.

The questionnaire was divided into three main sections:

- 1) general characteristics of ECs, such as the year of establishment, the type of actor participating in the EC, etc.;
- 2) characteristics of energy generation plants, such as size, number of end-users, etc.;
- 3) financial aspects, focusing on the financial mechanisms and the barriers they face in order to fund their project.

The questionnaire was implemented and disseminated through the electronic platform "Qualtrics".

The questionnaire was sent to 144 ECs directly; in addition, 10 international and national associations were contacted in order to distribute the questionnaire to their members. In total, 36 ECs responded, and 25 completed the survey.

Based on the survey results, ESR-15 identified different ownership models and types of finance used by ECs. In addition, the most relevant barriers concerning the ability to raise capital and fund ECs projects were identified.

### **3.4.3. Future planned activities and goals**

**ESR-15 goals and activities for the next reporting period includes the following:**

- Participation in a Scientific Conference and presentation of the survey's results.





ESR-15 plans to present the results of the study conducted in the previous months at the 16<sup>th</sup> International Conference on Energy and Climate Change- Promitheas, which takes place in Athens, Greece, 11-13 October 2023.

- 1<sup>st</sup> Secondment for two months at the UEX. (15 October-15 December, 2023)

ESR-15, during the secondment at the UEX, will focus on the analysis of Value Capture (VC) mechanisms that ECs have developed. In addition, the ESR-15 plan to study and choose the appropriate indicators for the analysis of the cost structure and revenue stream of ECs (i.e., Capital Expenditure (CAPEX) and Levelized Cost of Electricity (LCOE), Internal Rate of Return (IRR), Net Present Value (NPV)).

- Collaboration with ESR-13 regarding ECs business models.

ESR-15 will analyse existing EC business models using techniques developed by ESR-13 and integrating social, environmental, and economic aspects. A potential research focus could be a case study analysis of an existing EC that could be modelled and validated. The results could be used to modify and optimize the model in order to better integrate the economic, social, and environmental factors mentioned earlier.

#### 3.4.4. Contribution to the WP objectives

The research objectives and the research strategies developed by ESR-15 contribute to the objectives of WP5, as they focus on innovative business models for Energy Communities, which are collaborative schemes about power energy systems with a particular focus on Renewable Energy Systems. Especially ESR-15 research contributes to Task 5.4: "Identifying enablers and barriers to foster the replicability and transfer of business models for Green Energy Systems" and Task 5.3: "Energy value chains and markets developed with the new paradigm of distributed EES" and related deliverables (D 5.3 and D 5.4).

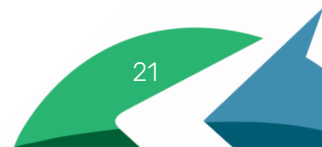
Up until now, the research of ESR-15 has been mainly descriptive in nature, as it provided data regarding the type of ownership model, the financial mechanisms Energy Communities used, and the barriers they faced. These data would be very useful since they can illustrate a map of energy communities in the EU and can support future research.

In addition, ESR-15 plans to collaborate with other ESRs from WP5 therefore, in the future, an expansion of its contribution is expected. A contribution to Task 5.2: "Generation of digital twins of prosumers using socioeconomical factors and big data for Optimization of Customer's bill savings" and related D 5.2. "Validated digital twins of prosumers based on socioeconomical factors" could be possible. Nevertheless, this collaboration hasn't yet provided any scientific outcome and cannot be considered for this reporting period.

#### 3.4.5. Scientific achievements

##### Publication

#	Title, incl. citation information	Type (Conference, journal, book chapter)	Status (Submitted, accepted, published)	DOI
	Pantazis K., Croci, E., Molteni, T. (2023, October) Energy Communities in the EU: analysis of different ownership models and financing mechanisms, In 16th International Conference on Energy and Climate Change - Prometheus	Conference	Submitted	





## 4. Conclusions

In this report WP5 progress, ESRs' scientific outcomes and contribution to WP5 along with scientific achievements are summarized. Four ESRs are involved in the WP5, working on different topics concerning green energy systems and business models.

ESR-12 is working on energy flexibility in Net Zero Energy Buildings. ESR-13 research focuses on models for Energy Systems under the concept of Digital Twin and the socioeconomic factors involved. ESR-14 research topic focused on improving better flexibility service for ECs through EV charging facilities. The ESR-15 research aims to identify and assess the relevant enabling and hindering factors affecting the diffusion of innovative business models related to sustainable energy power systems in the EU with a focus on ECs.

ESR-12 submitted two articles in journals: 1. "The Potential of Residential Load Flexibility: An Approach for Assessing Operational Flexibility" and 2. "Cooperative Stochastic Energy Management of Networked Energy Hubs Considering Environmental Perspectives". Activities done by ESR-12 will contribute to WP5's "Task 5.1: Development of sustainable strategies for Zero Energy Buildings and Energy Awareness using Smart Appliances". ESR-12 has not carried out any secondment due to visa and residential permit issues.

ESR-13 developed a model that translates the activity and behaviour of a household into an electric load profile. Furthermore, a digital twin's model of a renewable system connect to the grid was developed. The results of his study were published at the 17<sup>th</sup> International Conference on Compatibility, Power Electronics and Power Engineering (CPE-POWERENG) held in Tallinn, Estonia on 14-16 June 2023, with the title: "Multi-factor modelling of electric grids for social and technical impact studies". ESR-13 contribution to WP5 related to "Task 5.2: Generation of digital twins of prosumers using socioeconomic factors and big data for Optimization of Customer's bill savings". Furthermore, ESR-13 has already completed the first secondment at Universidade NOVA de Lisboa in Caparica, Lisbon, Portugal.

ESR-14 has performed many activities since his recruitment by Università Commerciale Luigi Bocconi. ESR-14 gained knowledge of systematic literature reviews and snowball tactics while doing this research. As an outcome of this work, ESR-14 published one conference paper, "A Critical Review of District Heating and District Cooling Socioeconomic and Environmental Benefits" which was also selected for the best paper award of the conference "14<sup>th</sup> Advanced Doctoral Conference on Computing, Electrical and Industrial Systems (DoCEIS-2023)", held in Caparica, Portugal on July 05-07, 2023. Furthermore, ESR-14 will contribute to "Task 5.4: Identified enablers and barriers to foster the replicability and transfer of business models for Green Energy Systems". Furthermore, ESR-14 has already completed the first secondment at Universidade NOVA de Lisboa in Caparica, Lisbon, Portugal.

ESR-15 has developed a survey that aims to analyse the ownership model of ECs that exist in the EU and the financing mechanisms developed by ECs. For this purpose, ESR-15 developed a questionnaire using the Qualtrics software, which was distributed to several ECs across the EU. A total of 25 responses from eight EU countries were received and analysed. The results of the survey are planned to be presented at the 16<sup>th</sup> International Conference on Energy and Climate Change - Promitheas, taking place in Athens, Greece, on 11-13 October 2023. The ESR-15 will contribute to "Task 5.4: Identifying enablers and barriers to foster the replicability and transfer of business models for Green Energy Systems". In addition, the outcome of his study can facilitate the achievement of "Task 5.3: Energy value chains and markets developed with the new paradigm of distributed EES". ESR-15 has not carried out any secondment due delays in the recruitment process.

In summary, all activities done by the four ESRs are quite in line with WP5's main objectives. Moreover, ESRs of WP5 have started collaborating with each other, which eventually will help to achieve WP5 objectives.

## 5. References

1. Akbari, S., Amaral Lopes, R., & Martins, J. The Potential of Residential Load Flexibility: An Approach for Assessing Operational Flexibility. Available at SSRN 4527303. [Submitted]
2. Akbari, S., Hashemi-Dezaki, H., & Martins, J. Cooperative Stochastic Energy Management of Networked Energy Hubs Considering Environmental Perspectives. Available at SSRN 4341763. [Submitted]





3. Marentes-Ortiz, R., Sellier, F., Gao, F., Martins, J., & Curci, Y. (2023, June). Multi-factor modelling of electric grids for social and technical impact studies. In 2023 IEEE 17th International Conference on Compatibility, Power Electronics and Power Engineering (CPE-POWERENG) (pp. 1-6). IEEE. [Published]
4. Ahmed, S. M., Croci, E., & Bagaini, A. (2023, June). A Critical Review of District Heating and District Cooling Socioeconomic and Environmental Benefits. In Doctoral Conference on Computing, Electrical and Industrial Systems (pp. 3-18). Cham: Springer Nature Switzerland. [Published]
5. Pantazis K., Croci, E., Molteni, T. (2023, October) Energy Communities in the EU: analysis of different ownership models and financing mechanisms, In 16<sup>th</sup> International Conference on Energy and Climate Change – Prometheus, [Submitted].

