Methodological Framework

D4.3

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Deliverable

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TWINERGY	**957736**	**Intelligent interconnection of prosumers in positive energy communities with twins of things for digital energy markets**

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D4.3

Methodological Framework

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Statement of Originality

This deliverable contains original unpublished work except where clearly indicated otherwise. Acknowledgement of previously published material and of the work of others has been made through appropriate citation, quotation or both.

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Executive Summary

This deliverable introduces the approaches adopted by the TwinERGY consortium, particularly with respect to implementing our innovative technology and deploying these in our pilot sites. We have set up an overall methodological framework based on the approaches of Design Thinking and Responsible Innovation, which are cornerstones for meaningful involvement of stakeholders, user engagement and participation as well as delivery of citizen-driven innovation.

Through the related Task, a number of stakeholder and business analysis methods and technology design/implementation tools have been identified as suitable to support digital innovation in the sector of emerging energy systems. Some are sector-specific, such as the Smart Grid Architecture Model (SGAM) framework (EC 2012) adopted by our consortium. Whilst others are generic analysis techniques such as System Dynamics but suitable to capture sectorial knowledge and generate insights for the energy sector, as demonstrated in relevant literature (Mutingi et al. 2017; Freeman & Tryfonas 2011 etc.). These are documented here along with the rationale of how their use will enable co-creation with stakeholders and in general support the project's objectives.

Besides state of art literature, we have also considered past results from European projects and transfer relevant experience and knowledge to our activities such as e.g., the adoption of The Bristol Approach to Citizen Sensing, as originally taking intervention form within the context of the Lighthouse Project REPLICATE (Grant agreement ID: 691735). We have also committed to on-going learning through the project activities that relate to building synergies with the BRIDGE initiative and relevant projects. Finally, the document also serves as a guide to explore interrelated tasks and points to deliverables of other work packages (WPs) that contain outputs of activities as described here.

Index

List of Figures

Twinergy has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 957736

List of Tables

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1. Introduction

1.1 Methodological Motivation and Deliverable Purpose

TwinERGY aspires to create the underpinnings of the future European energy marketplace, by providing a transactive framework, process and platform that enables key stakeholders to leverage on emerging energy technologies. In our project, developments such as micro- and local generation and storage, demand responsive systems, peer-to-peer trading, distributed ledger accounting and energy informatics are integrated in support of novel business models that democratise the future of energy and empower consumers and prosumers as cornerstones of the future energy market.

This is achieved through extensive stakeholder engagement and in particular of citizens and consumers of varied backgrounds, based on established practices derived by design thinking and systems modelling. We explore key issues of the future energy marketplace across our four pilot sites in Europe (Italy, Germany, Greece, UK), roll out and validate novel concepts and test their scalability and replicability within and across cities. The project will deliver a number of modules that will enable better understanding of energy behaviours, provide stakeholders with feedback on energy generation and use, support energy trading in emerging markets and engage consumers in a meaningful way in the whole process, especially with the use of Digital Twins as an engagement medium.

Key outcomes of TwinERGY will contribute to service innovation in the energy sector by enabling deep insight development through large scale system modelling and analysis, scenario building and participatory experimentation, combining real time data feeds with advanced analytics and modelling. Guided by the principles of standard openness, data protection, ethics and public value TwinERGY is part of the initiatives that enable the next generation of energy systems and services to flourish within and outside the European Union. In this context, the structured and methodical approach we take to enable such innovation to happen is in itself an enabler and so we have mapped here the key processes, different stages and key outcomes that facilitate collaboration and delivery of interventions, especially in pilot sites.

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The above characteristics of the TwinERGY project led to the need for an explicit methodological framework set up that will facilitate and guarantee the realization of the project objectives, tools, and consumer and participant engagement. This deliverable presents the methodological approach of the TwinERGY consortium, particularly with respect to implementing innovative technology in pilots.

1.2 Deliverable Structure and Contents

The document first introduces TwinERGY and why following and making explicit such methodology is important. Section 2 discusses the high-level use cases as specified in the context of the project. It identifies which of these have been selected to be implemented across pilots and explains why these are important and the interest of pilots in them. Section 3 introduces key elements of the overall approach and how these have been implemented within TwinERGY and followed by relevant partners.

Section 4 details the process of setting specific objectives and defining metrics for each pilot (the actual objectives and metrics have been documented in full detail elsewhere). Section 5 provides an inventory of methods and tools used to derive milestones of the project such as models, shared living documents, software and other artefacts so that transparency, reproducibility and scale up capacity is enhanced.

Section 6 revisits the assurances of ethical conduct for data processing, including research and analysis of the collected data, as well as the technical controls implemented to ensure its security and privacy. These are all essential for the success of a digital innovation project and so they are informing and complementing any activities and interactions that take place and depend on relevant data. Finally, Section 7 summarises the deliverable.

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2. TwinERGY Key Innovations and Use Case Specification Rationale

Before we delve into the methodological detail of the delivery approach and the methods and tools that are used in the process, we will review the key innovations at the heart of the project and the fundamental scenarios that these are enhancing. These Use Cases are specified in more detail in **D2.2** however here they illustrate how by supporting the delivery of innovative technology, the emerging energy landscape is transformed beyond the state of art and how this is possible across pilot sites through our methodological framework.

2.1 Key Innovation Concepts of TwinERGY and their Implementation

Distinct innovations that are prominent throughout the TwinERGY project include:

- *Stakeholder-driven innovation and customer-centricity*, both in terms of involving key stakeholders, such as citizens, in the innovation delivery process and through empowerment of consumers and prosumers to make better decisions with respect to the use of energy resources they own.
- The use of *Digital Twins*, in what constitutes a highly novel application of the concept in the energy marketplace and especially with the involvement of citizens; and
- *Digitally-enabled transactive energy* that will support emerging energy markets and enable the opening up of peer-to-peer trading to prosumers of all backgrounds. That includes leveraging the potential of distributed ledger applications, specifically tailored to energy markets' sectorial needs.

Prosumer Engagement and Citizen-driven Innovation

Our consortium is experienced in the implementation of 'Living Lab' approaches, where research and development are conducted situated within communities of interest which participate in the formulation of objectives and even specifying solutions for given challenges. A number of core principles have been adopted to enable us leverage on synergies that are created through such participatory approaches

- **Co-creation:** Co-creation is a cooperative process whereby people with a common interest, often with diverse skills and experiences, work together non-hierarchically towards the same aim or change they want to bring about. TwinERGY offers the opportunity for involved citizens, artists, technologists, academics, business, and public sector organisations to come together to co-create ideas around the use of promising digital tools and technologies such as Digital Twins and Transactive Energy. Participants will understand how to address local challenges and how to innovate and explore new possibilities with these innovations.
- **Multi-method approach:** For such approaches to succeed, methods and tools must be suitable and to enable local people, national and international networks, organisations, academics and individuals with expertise in relevant fields to come together and contribute (Venkatesh et al. 2016; Venkatesh et al. 2013).
- **Real-life setting:** Communities and their needs are at the heart of citizen-centricity and our approach to deploy, enact, test and continuously improve digital solutions in four pilot sites across Europe is consistent with that. Our focus is also to ensure the inclusion of individuals and groups at risk of social and digital exclusion and support them to become active citizens with equal access to each city's opportunities.
- **Multi-stakeholder participation:** Across out pilot sites and besides project partners, the consortium seeks and facilitates collaboration between participating communities, local businesses, researchers and educators, and public administration.
- **Active user involvement:** during the deployment of solutions and the active participation of local stakeholders, continual reflection and evaluation are built into the working process, and this enables us to be responsive to the changing needs of participant communities (Balestrini et al. 2017).

In supporting the implementation of these principles, we will explore later in this deliverable how suitable methods and tools, discussed here and elsewhere as indicated e.g., in **D2.1** (citizen engagement), facilitate this process.

Digital Twining at the Heart of Managing Energy Systems

Digital Twin technology will be employed at both a consumer and community level across all pilot sites. Each digital twin will be built within the IES ICL environment using input data from the appropriate site, both of the static and dynamic variety. Static data such as structural building information, typical energy usage patterns and occupancy rates are used to construct a digital replica of the site, with time series data, such as electricity consumption of a building, used to fine tune the digital twin and keep it up to date and as accurate as possible. At this point, the digital twin is a digital replica of the real-world building or community, with the ability of the end user to simulate different scenarios, forecast demand or renewable generation for the day ahead, and decide on the best actions to take to reduce both cost and carbon emissions.

Within the TwinERGY project specifically, the digital twins will be used to define explicit and implicit demand response actions at a building and community level. Explicit actions are instructions communicated to the end user to modify their behaviour, while implicit actions happen automatically. The digital twins will forecast the energy demand and generation for the day ahead, and this will enable the pilot sites to maximise the use of local renewable generation and thus reducing carbon emissions for the community, while also reducing costs for the consumers.

The digital twins can then also be used to simulate potential future scenarios and enable the community to make the best decision going forward to meet their energy needs and carbon emissions targets. This could include the connection of additional solar PVs or a CHP to the community grid, or how much battery storage is required to maximise the existing local generation. All of this data is then made available to the other TwinERGY platforms, such as the Transactive Energy Platform and Social Network module, so that it can be used to inform market prices or keep consumers up to date on the energy performance of their community.

Developing a Digitally-enabled Energy Marketplace (Transactive Energy)

TwinERGY Transactive Energy (TE) framework will be built for the 21st century grid, characterized by active "prosumer" (both producer and consumer of energy) participation in energy markets, bidirectional power flows (e.g., net metering of Behind-The-Meter (BTM) resources), and sophisticated financial transactions between prosumers, utilities, and third-party service providers is something that can create this positive improvement of value and is a business model worthy of a future. TE transactions BTM and In Front of the Meter (IFOM) are already on a hockey-stick shape of growth as they are now merging with the increased adoption of smart IoT devices, such as connected thermostats and other newly networked Distributed Energy Resources (DERs) such as renewable energy sources, electric vehicles (EV), and electric storage resources at the edge of the grid.

Our project aims at creating a TE market, which will likely alter the behaviour and perception of the participants in the electricity market as such and be able to improve the business models with the addition of the TE features. (Cazalet et al., 2016) The ability to create and hold value can be a leading factor in the decision-making process, much different from today's focus mostly orbiting around revenues. New business models will emerge to serve consumer needs in TE markets and others may change to meet the needs of those markets. Some new market participants will likely be customers or aggregations of customers that supply electric services to the transactive marketplace. (Cazalet et al., 2016)

Furthermore, with the TE model in TwinERGY project, we are also bringing to activation the concept of digitalization and how the digitization aspects can improve the current market situation, thus, bring new solutions to life. In a sector which is filled with complex operational models, integration of services and solutions is gaining relevance where digitisation is leading the road to transformation of the energy markets. Many new companies are entering the market with innovative products based on digital solutions. Companies from the information and communication sector and other companies from outside the industry increasingly drive the change. New entrants from other sectors can provide essential skills for the provision of innovative value propositions by entering the energy sector. However, traditional companies in the energy industry can also expand their product portfolio based on their expertise within their value creation network. (Giehl et al., 2020)

Blockchain, which involves decentralized transaction verification will potentially empower individual customers to trade power and make payments in a seamless way. Digitalization can help with better network and congestion management, assisting with the renewable generation intermittency challenge, allowing more effective network monitoring and more efficient network operation. It also provides digital platforms for demand response, and Peer-to-Peer (P2P) energy and carbon credit trading (Kufeoglu et al., 2019).

The Transactive Energy Platform, as illustrated in Figure 1, will use the Ethereum network and technology[1] to create a thrustless auction house where flexible capacity and demand from DERs will be auctioned off, through encrypted, shared, immutable, and publicly auditable Smart Contracts. A cryptocurrency ecosystem is created, which

[1] https://ethereum.org/en/

reserves the cryptocurrency asset value, solves volatility problems, and ensures high transaction processing speed.

Use Cases where the emerging transactive energy model will offer effective approaches for engaging DERs to achieve Demand response, balance the grid at various levels and maintain grid power quality and reliability are:

- Peak heat day and energy supply
- High penetration of Photovoltaics (PV) and Voltage Control
- Electric Vehicles (EV) on the neighbourhood transformer
- Islanded microgrid energy balancing
- Multi-bilateral trading with product differentiation (such as peer-to-peer trading based on prosumer preferences).

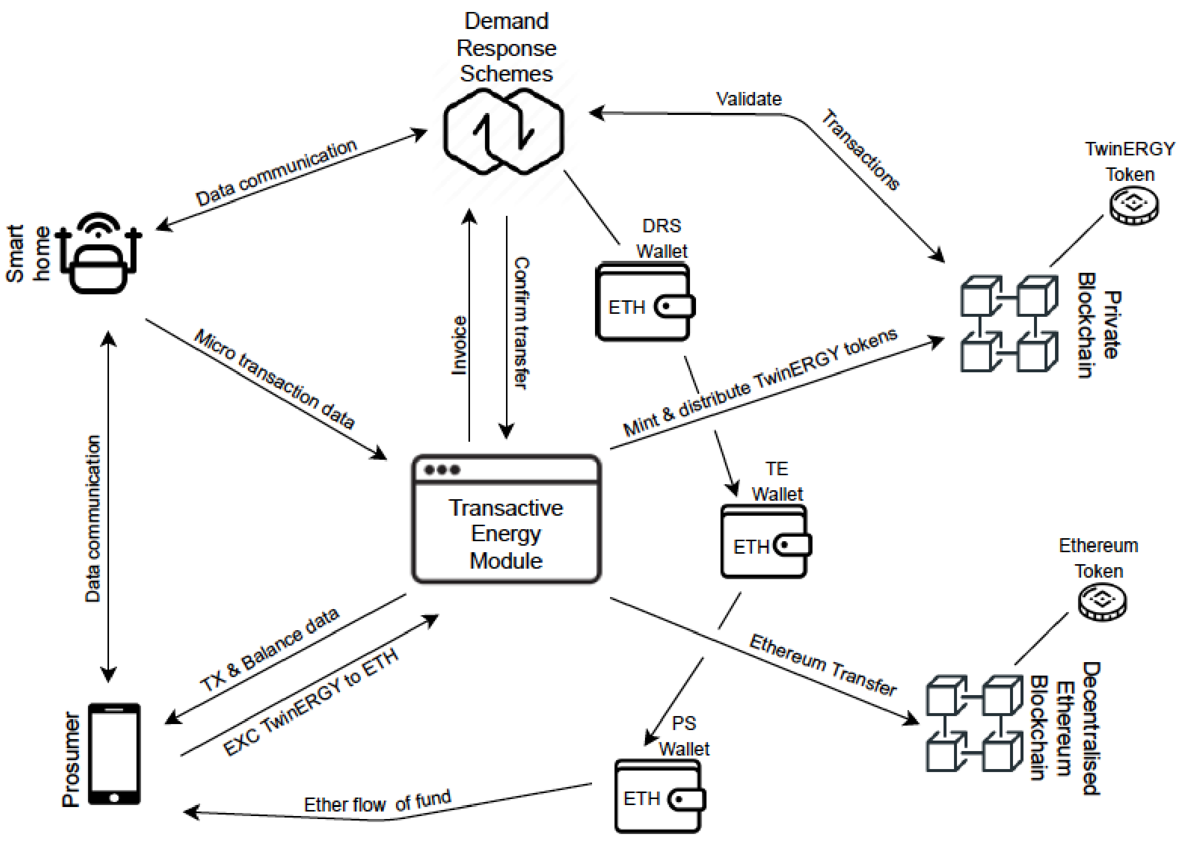

Figure 1 - WEC's Transactive Energy Platform

The benefits of the TE model (Figure 1) come, firstly, from the fact that there is a direct link between the consumer and the producer, with the scale tilted towards the consumer as they can choose, on their own, from where they will purchase their power. This decentralises the situation dramatically and provides additional value to the consumers because of the increased competition in the market. Secondly, the additional value proposition of this model comes through price-time-shifting as consumers have total visibility when they are purchasing power and from where. All this helps the market to achieve greater matching of demand and generation which can reduce network pressure and creates benefits for the consumers through flexibility markets, and reduced charges and enables generators to sell power at better prices in order to maximise their exposure. (Hall et al., 2020)

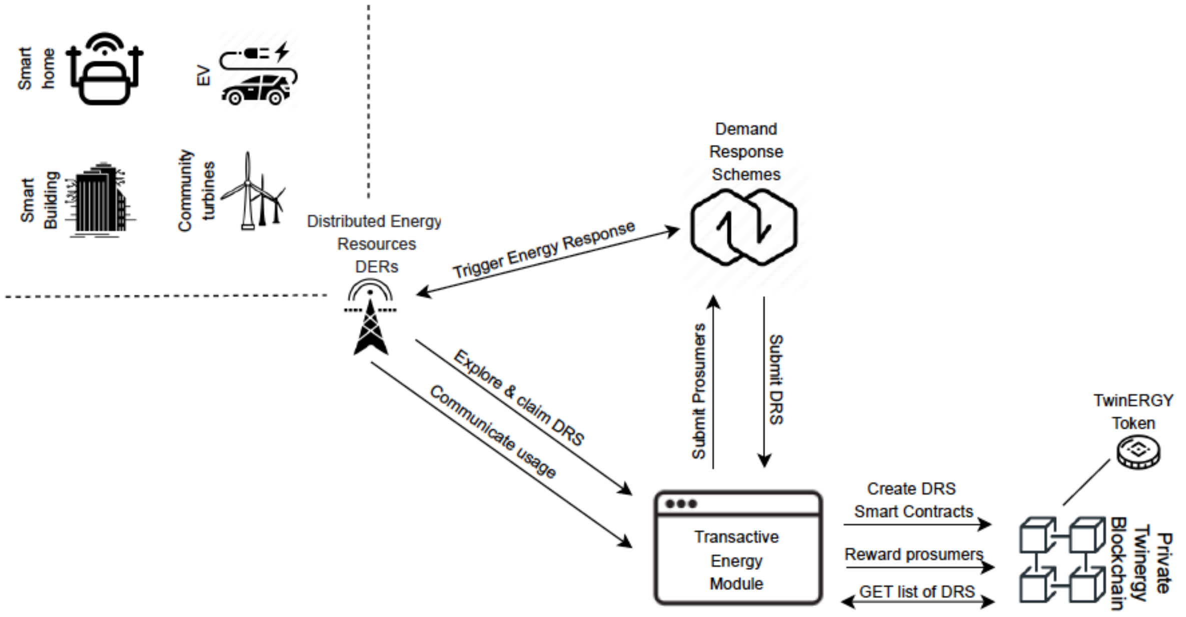

Figure 2 - The Transactive Energy Platform as implemented in TwinERGY for our Pilot Sites

In Figure 2 we have summarised how the TE concept is intended to be implemented through HLUC04 in the relevant pilot sites. The concept will be tested through prototyping in a way that is compliant with regulatory frameworks in the UK and Italy. Feedback will be returned to ideation workshops to elaborate on further possibilities for applications in potential business models and exploitation will be explored in **WP10** (Exploitation and Business Plans).

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2.2 Specification of Use Cases in Support of Innovation Delivery

The following scenarios have been selected as representative situations of interactions of prosumers with elements of energy systems in the future energy landscape. They have been codified in Use Cases, a systems and software specification technique used widely in research projects and product development. Before we discuss the choice of suitable methods and tools that will be used to implement these, it is important to explain what these are at high-level, in order to understand their aim and value in the emerging energy systems sector.

Key scenarios explored for value and impact

TwinERGY comprises nine different Use Cases that are aligned to address the different project's objectives. Mainly, these objectives are focussed on Consumer Empowerment as a target so that consumers can become potential active energy market players in order to tackle energy poverty as well as reducing their energy bills. Demand Response and end-use energy efficiency are going to stand as the pillars that are going to be implemented as an alternative to tackle entirely the supply side actions, situating the consumer as a key player in energy reduction. Specifically, these objectives can be listed as follows:

- Introduce residential energy consumers as active players in energy markets ensuring their benefits through human-centric demand response programs
- Protect distribution grid reliability and the transition to a fossil-free energy future promoting RES integration and effective demand response strategies
- Deliver a modular solution that complies with interoperability between smart grids, energy management and smart home devices.
- Enable intelligence enhancement of Smart Home systems
- Establishing local flexibility markets tackling at the same time market barriers for prosumers.

As commented, based on TwinERGY objectives, nine different High Level Use Cases (HLUC) have been defined so as to target those specific goals predefined.

- ***HLUC01 – Home Energy Management***

  The energy management in residential consumer premises is going to be tackled through the monitoring of energy flows, the maximization of self-consumption and self-sufficiency and the reduction of the costs for the users enhancing their active role in energy efficiency processes. For that purpose, data is going to be gathered (static and dynamic), processed and analysed. In order to go deeper into the objectives of this particular HLUC, it is going to be subdivided into different specific goals, which are called Primary Use Cases (PUC) and Secondary Use Cases (SUC):

- PUC01.01. Increase the building observability
- PUC01.02 Flexibility modelling
- PUC01.03 Optimal flexibility management system
- PUC01.04 Control of the smart devices
- SUC01.01 H&T EMS GUI development

- ***HLUC02- RES generation in domestic and tertiary buildings***

  This Use Case intends to create further Renewable Energy Sources (RES) and the appropriate infrastructure to share these resources both in public and private buildings. This HLUC is going to be developed in the four pilot sites, focusing on the possibility for this RES resources to participate in Demand Response campaigns and in the Energy trading platform. To delve further into this particular HLUC, it is going to be processed into different PUC:

  - PUC02.01 Dispatch of existing RES in domestic and tertiary buildings to minimise cost/carbon emissions
  - PUC02.02 Optimal future energy storage to maximise RES production
  - PUC02.03 Maximum future RES capacity according to the physical constraints of the pilot site, as well as present/future V2G capacity as determined by the TwinEV module
  - PUC02.04 Optimal CHP solution specific to the pilot site in terms of capital costs and network capacity
  - PUC02.05 Optimal scenario of future energy storage and RES to minimise energy costs for the end user/carbon emissions
  - PUC02.06 Optimal domestic and tertiary demand response, based on RES, to minimise cost/carbon emissions

- ***HLUC03- Grid capacity enhancement utilizing E-mobility***

  This Use Case intends to study the potential use of EV smart charging as an asset for Grid Purposes (stabilizing the integration of RES and allowing the participation in energy flexible markets). Furthermore, it is intended to promote the decarbonization of neighbourhoods using EVs. This HLUC can be also divided into different Primary Use Cases (PUC):

- PUC03.01. Booking a charge session
- PUC03.02. Smart Charging to follow grid requests
- PUC03.03. Smart Charging to maximize RES integration (green electricity)
- PUC03.04. Smart Charging to minimize charge costs
- PUC03.05. Smart Charging to minimize time of charge
- PUC03.06. Searching of the most suitable station
- PUC03.07. Grid Management

- ***HLUC04- Prosumer's empowerment in Local Energy Trading Markets***

  This Use Case intends to provide solutions to Transactive Energy Use Cases as well as enabling the gird decentralization and democratization by the connection of micro-grid operators, DER managers and end users. The core of this HLUC is to promote a transactional platform that would offer to sell flexible energy loads and excess capacity to an open market with micro-grid operators (e.g., IoT devices, buildings, substations) at a Local Energy Market (LEM). This HLUC is depicted into two different PUCs:

  - PUC04.01. Recording transactions of energy: Recording transactions of energy distributed back into the grid or to a private or public storage facility, recording transactions of energy between prosumers and Recording transactions of energy between prosumer consortia
  - PUC04.02. Calculation and broadcasting of LEM pricing compared to DNO/DSO pricing.

- ***HLUC05- Enhance grid flexibility through DER Management***

  This Use Case intends to determine how grid congestion management is operated and tested through the study of combined network data, loads and RES production and different forecasts. The aim is to improve the grid's flexibility and stability, as well as local RES share. This HLUC can be separated into three different PUCs:

  - PUC05.01. Grid status calculation and bottleneck detection
  - PUC05.02. Prediction of energy consumption and RES production
  - PUC05.03. Utilizing the Virtual-Power-Plant

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- ***HLUC06- Consumer's engagement in Demand Side Management Programs utilizing feedback mechanisms***

  This Use Case is expected to generate a demand-side intervention strategy to be applied at a residential level, describing how DSO/Retailers can provide a feedback mechanism increasing residential awareness, engagement to enhance the decrease of residential energy use and increase demand flexibility at residential places. For that purpose, this HLUC is going to be addressed through two distinct PUCs as follows:
  - PUC06.01. Increase residential demand flexibility
  - PUC06.02. Decrease residential energy use

- ***HLUC07- Consumer's engagement in Demand Response programs utilizing a socio-economic context***

  This Use Case is expected to implement a set of social context drivers for energy-related behaviour by exploiting social interaction and cultural values. The aim is to influence energy exchanges between households relying on consumer's attitudes towards benefits and comfort. This HLUC can be split into three different PUCs:
  - PUC07.01. Social marketing to engage customers via competition
  - PUC07.02. End users' engagement on utilization of shared DERs
  - PUC07.03. Enable co-creation for end consumers, service providers and public authorities.

- ***HLUC08- Consumer's engagement in Demand Response programs utilizing personalized comfort/health-oriented services***

  This Use Case intends to show the utilization of low-cost wearable devices from which physiological data can be obtained. This is intended to facilitate the utilization of classification techniques that comprise a combination of depicted consumer's comfort/well-being leading to the human-centric approach that can be utilized at Demand Response campaigns. This HLUC is realized in these Primary Use Cases (PUC):

  - PUC08.01. Wellbeing best practice for indoor environment conditions
  - PUC08.02. Physiological parameter and comfort feedback monitoring
  - PUC08.03. Comfort relation within DR optimal solution

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- ***HLUC09- Consumer Engagement in Demand Response Programs Utilizing Digital Twin Prediction Capabilities for Dynamic VPPs***

  This Use Case is expected to focus on consumer engagement in Demand Response programs, which are based on Digital Twins. In this HLUC, different dashboards will be created with the purpose of generating relevant information regarding home/building/community demand response campaigns based off price and carbon emission factor for electricity at a specific time. This HLUC can be addressed into two different PUCs:

  - PUC09.01 Explicit Demand Response Automation and display at a consumer and community level.
  - PUC09.02 Implicit Demand Response Calculation and Communication to the end user at both a community and consumer level.

The HLUCs have been documented in greater detail elsewhere (see deliverable **D2.2** under Use Case definition sections).

Use Case Distribution Across Pilot Sites

Table 1 below summarises the high-level use cases that have been adopted for implementation by the pilot sites. The composition of participants per pilot varies depending on the nature of the intended use cases, the type of buildings involved, the maturity of selected households with respect to energy systems use as explained previously and other contextual factors. Full details of implementation are provided elsewhere (see **D9.2** for full reference). The variation of commonality of scenarios selected to be implemented per site, also justifies the adoption of distinctive or similar methods and tools that may be required (e.g., use of specific modules, analytics or visualisation elements in some sites).

All pilot sites are implementing HLUCs 01 and 09 as they include key innovation aspects of the proposal (home energy management and use of digital twins) and provide a common spine for experimentation and innovation delivery as well as comparative studies. A number of other use cases are then distributed among our sites in a way that matches regional needs and interests. HLUCs 02 and 07 are common between IT, DE, UK where marketisation of generation from renewables and demand-response are mature and of emerging interest.

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Table 1: Use cases to be implemented per pilot

Use Case ***Pilot***	**UC1**	**UC2**	**UC3**	**UC4**	**UC5**	**UC6**	**UC7**	**UC8**	**UC9**
Bristol	X	X		X			X		X
Benetutti	X	X		X	X	X	X	X	X
Steinheim	X	X	X		X		X	X	X
Athens	X		X			X		X	X

Similarly, HLUC08 is shared between IT, GR, DE with interests in the interplay of extreme weather occurrences such as heatwaves and cold snaps, with perceptual energy needs. These are of particular importance in the Mediterranean and continental climate regions respectively. Other use cases are implemented in pairs as shown in the table. No use case is implemented in isolation at a single pilot site, to allow for shared learning, economies of scale and comparative studies to take place.

3. How we Deliver TwinERGY Innovation: An Overview of the Implementation Approach

3.1 Overall Delivery Approach

Applying Design Thinking and Responsible Innovation

At the heart of the TwinERGY approach is Design Thinking, an incremental and iterative process that seeks to understand user needs, evaluate alternatives and focus on solutions, rather than transferring and applying state of art established knowledge. Contextual factors are examined and taken into account and stakeholder, especially end user, feedback is sought before any technology is enacted as a response to a design challenge (Conway et al. 2017).

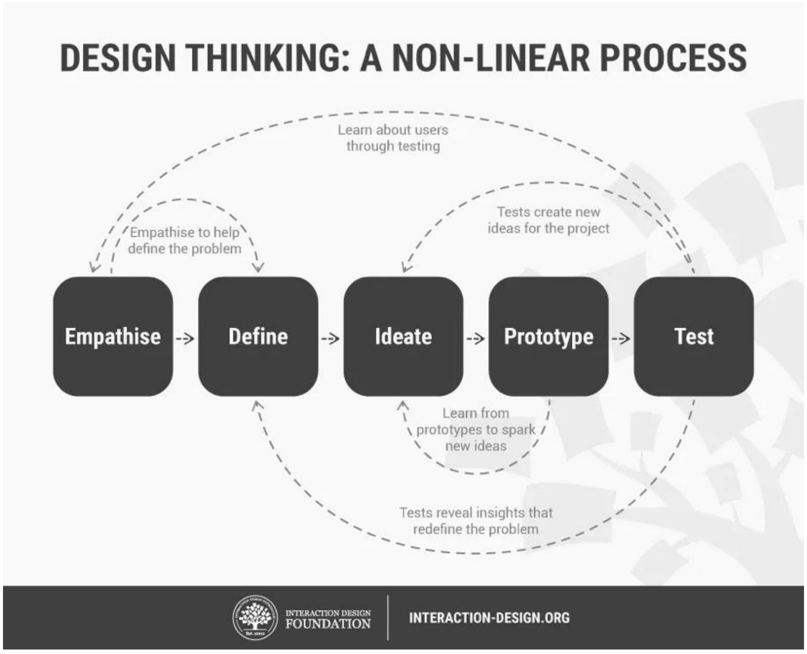

Figure 3 – Design Thinking [Copyright holder: Interaction Design Foundation. Copyright terms and license: CC BY-NC-SA 3.0]

The broad phases of the approach can progress from understanding of the user situation and needs toward viable solutions that have been conceived with these in context and participation of key stakeholders. The generic process can be seen in Figure 3.

TwinERGY's delivery framework is broadly conceived and based on the phases of Design Thinking as it can be seen in Figure 4. This is divided in four key incremental stages, from analysis to scale up, details of which are provided in turn. Our approach is also iterative where required, in the sense that for example, feedback from a particular module's prototyping stage can inform the ideation stage of another module, the enactment of which succeeds the former. As pilots will roll out activities in stages, such iterations will allow learning on what works or not to permute through life of the planned interventions.

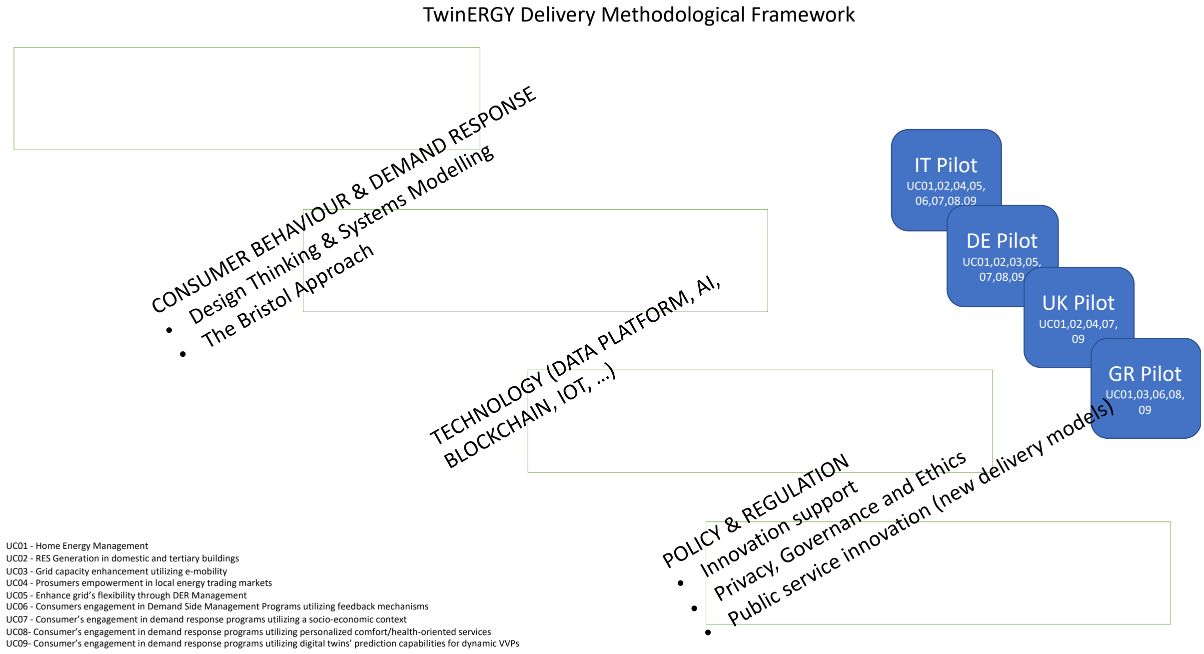

Figure 4 – Design Thinking approach as practiced in TwinERGY to deliver innovation in pilots.

The four phases broadly define a progression from understanding the emerging energy systems and markets ecosystem, its stakeholders and the ways to engage with them, how state of art technologies can make a difference in the way that benefits the individual and the public and finally how such innovations can be scaled up and replicated across geographies. Implementation of key concepts across pilot sites provides insights and evidence of the potential impact and value of these interventions.

Throughout the identified phases, innovation and its impact are considered through the lenses and principles of Responsible Innovation, a framework that seeks to promote creativity and opportunities for science and innovation that are socially desirable and undertaken in the public interest (Stilgoe et al. 2013).

A Responsible Innovation approach is one that seeks continuously to (EPSRC):

- Anticipate – describing and analysing the impacts, intended or otherwise, (for example socio-economic, environmental etc.) that might arise. This does not seek to predict but rather to support an exploration of possible impacts and implications that may otherwise remain uncovered and little discussed.
- Reflect – reflecting on the purposes of, motivations for and potential implications of the research, and the associated uncertainties, areas of ignorance, assumptions, framings, questions, dilemmas and social transformations these may bring.
- Engage – opening up such visions, impacts and questioning to broader deliberation, dialogue, engagement and debate in an inclusive way.
- Act – using these processes to influence the direction and trajectory of the research and innovation process itself.

In this respect we have e.g., devised guidelines and metrics for considering inclusivity and diversity in our pilots (as per **D2.1**, citizen engagement) and we review continuously the potential to engage with participants for feedback and for providing them further opportunities to influence the direction of innovation.

3.2 Phases and their outcomes

A: Ecosystem Analysis Phase

The Ecosystem Analysis Phase contains all the activities related to the initial research undertaken to understand the make-up and needs of an inclusive, balanced, emerging energy markets ecosystem.

A1. Stakeholder Analysis: Each pilot site is distinct in its geographical characteristics, historical importance, energy requirements, main vulnerable groups, local energy systems, and organisational and administrative structure of the energy marketplace, so it's important to explore the links between the individual stakeholders in the ecosystem (e.g. consumers, governments, energy aggregators, distribution system operators, service providers, community organisations and other non-government actors), the information flow between them and any influencing factors/drivers such as legislation (e.g. privacy, accessibility), and standards (e.g. cybersecurity, data formats, metadata). The initial information for the analysis comes from relevant Consortium partners and desktop research in order to generate a tangible output early in the life of the project; however, the Stakeholder map will be updated based on the work with stakeholders themselves throughout the rest of the activities.

> ***Stakeholder Analysis Outputs*** *– Future Energy 'Canvas' depicting (a) key stakeholders that affect the Future Energy ecosystem, (b) the relationships between them and (c) points where challenges occur and what these may be. These outputs are contained largely within deliverables* ***D2.1*** *(Stakeholders and their Engagement),* ***D2.2*** *(Stakeholder Analysis),* ***D2.5*** *(Challenges and Drivers) and* ***D6.1*** *(Stakeholders and Market Dynamics, Interdependencies).*

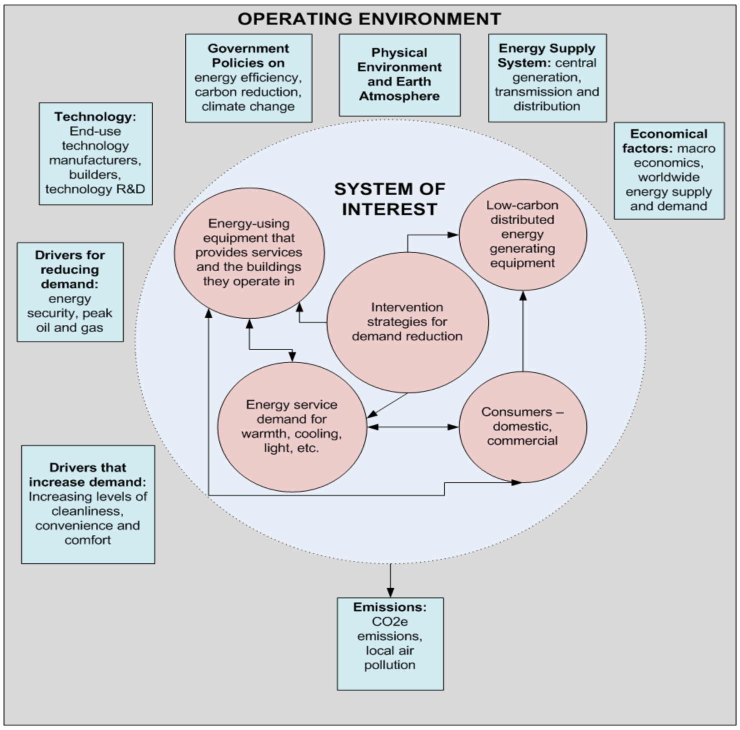

Figure 5 – System-of-Interest modelling for the built environment (Freeman & Tryfonas, 2011)

A2. System-of-Interest Modelling and Ecosystem Mapping: This includes definition of the local Future Energy Marketplace building blocks and level of maturity assessment, so we can first identify the stage of play of each pilot with respect to a set of maturity criteria. This will be achieved first by creating an ontology of the energy ecosystem to guide data collection efforts in the 4 pilot areas. This will essentially map the System-of-Interest in a way that externalises discreet entities and their interdependencies (an

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example of which is shown in Figure 5). This will act as a template that pilots can update to produce consistent results. The aim of the subsequent maturity assessment, whereby 'maturity' is a term describing the level of sophistication of the technology used, is to understand the degree of emerging technology use in the (whole) system by looking at its parts (modes) individually and as a whole, captured in a radar map. Each mode will be assigned a maturity score (as per 'MATURITY LEVEL' column of Table 2) in order to make intra- and inter-pilot comparison easier. The results can be used to narrow the gap between leaders and laggards through cross-border learning (e.g., exchange of best practices, solutions, policies from stronger areas to less strong ones).

Table 2: High level systematisation of potential participant groups along technology maturity criteria

Area	**Groups**	**Energy Ecosystem/Digital services & consumer empowering**			**Needs stage**	**Influencing factors Influencing factors**
Inner city Urban Suburban …	Elderly Young People Women Minorities Low income …	*MATURITY LEVEL*	Consumer-end	Generation-side	Lower use Reduce bill Greening Optimal trade Change behaviour …	Age Gender Culture Language Digital Literacies Social status Policy Supply/Demand Price
		Monitoring	Smart metering	None		
		Feeding back	Smart metering/online and mobile presentation	Basic (e.g. PV feeding to grid)		
		Actuating	Encouraging sustaining behaviour via 'nudges' (offers, advice etc.)	Sophisticated (e.g. local storage ability and trading)		
		Twining	Empowerment to make impactful decisions	Demand responsive		

Relevant information will come from a round of interviews with energy experts from the pilot sites. Input will be used to help understand where each city is positioned and will help develop the ontology and ecosystem map for every pilot city, while subsequent rounds will serve for updating the results with any new information and to assess TwinERGY's role in improving inclusivity of the ecosystem. Interview questions focus not only on city energy managers but also on non-governmental entities such as private companies and research bodies working in the energy sector (as per A1), so all elements relating to ethical and regulation considerations are also captured. The results are shared to make all members of the ecosystem aware of strengths, weaknesses and opportunities.

Ecosystem Modelling Outputs – *(a) Future Energy Ecosystem mapping outlining each pilot's emerging energy system make-up and (b) Maturity Assessment visualised e.g., using Radar-plots or similar visualisations. These outcomes are captured through* ***D6.1*** *(Dynamics and Interrelations),* ***D2.3*** *(Business Models) and* ***D9.2*** *(Pilot Management and Local Testbeds Outline).*

A3. Field Research and consumer engagement: Field research centres on consumers and their experiences in using energy services. Some may already use advanced solutions to manage their energy needs, but many are outside the digital bubble, either because of lack of skills and awareness or because the required solution simply isn't available through their supplier. A wide set of techniques is adopted to help deeply understand users' experiences, both positive and negative, within the future energy ecosystem. The results will help identify and understand the needs and attitudes of all societal strata of energy users.

For example, TwinERGY research targets both 'digital natives' who have installed smart meters and have access to on-line dashboards and those who continue to rely on paper bills, since research that only engages the former risks perpetuating long-standing inequalities in the energy sector. Where possible users that are potentially the most vulnerable to these inequalities, such as the elderly, will be prioritised. Each pilot will identify such potential groups through their engagement activities.

Research will observe consumers as they experience different elements of the marketplace, from understanding billing information and adjusting behaviour to related information, to peer trading and energy systems investment. Data collection and engagement techniques that will be considered in this project include, but are not limited to:

<u>Unmoderated</u>

- **Surveys:** these are the simplest tool to deploy to understand more about a user's behaviour and service preferences. They are kept short and use clear, easy-to-understand language.
- **Energy Use Diaries:** volunteer participants may be asked to complete a diary over the course of a few weeks explaining their experience during their use of energy, from heating their home to making a cup of tea.
- **Biometrics:** understanding how a user feels when interacting with different parts of the ecosystem can also help identify issues. Wearable devices can help pin-point stress levels to identify times of frustration. Volunteer participants may be asked to

record heart rate at different points of their energy consumption experience (use of TwinERGY Module M1 in particular).

Moderated

- **Contextual Interviews:** these are interviews conducted whilst the user is consciously consuming energy. The moderator gives no specific instructions, but just watches and listens to the user's experience, noting down key observations.
- **Focus Groups:** a small group (5-10) of users are brought together for a planned discussion around their thoughts and feelings of using digital twins.
- **Heatmap Tracking:** users are asked to perform an online task independently (e.g. reviewing their energy use, paying a bill) and a software programme tracks their experience providing a heatmap that shows where a user has clicked on a page. At the end the moderator sits with the user to review their experience through the heatmap and asks targeted questions.

The results are analysed using advanced analysis tools (see Section 6 on methods and tools for a more detailed list). For instance, qualitative data obtained through interviews, focus groups and energy use diaries will be analysed using the NVivo software; survey data using SPSS; geo-referenced data using established mapping tools like ArcGIS, WebGLayer or equivalent. All use of data for research purposes will be covered by use of participant information sheets (PIS) informed consent forms issued by the partner conducting the analysis and in accordance with the agreed scope under deliverable **D12.1** (Legal and Ethical Guidance). and especially for academic partners, the applicable ethics procedures of the home institution.

This task also provides an opportunity to apply an inclusivity diagnostic based on the metrics of inclusivity and diversity that have been identified in deliverable **D2.1** (Best Practice Guidelines) for all the pilots as their inclusivity levels will be mapped against their maturity score (from A2). Research results will be compared against the perceived level to understand correlations between digital maturity and inclusion. The results will help provide awareness about the importance of inclusiveness in the future energy marketplace agenda and will highlight the broad areas for improvement. For example, if energy use monitoring scores highly on the digitisation scale, but a small percentage of respondents demonstrate behavioural change and enjoy reductions in monthly bill charges, there is clearly an issue to be investigated. The difference could be due to the lack of skills/awareness or service deficiency. The issues identified (broad areas and specific challenges encountered by the users) will be passed to the next phase of the project for further investigation.

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The results will be represented visually on multi-layered maps and end user videos so they can be easily understood by all and communicated to a wide range of stakeholders including policy makers.

> ***Consumer Engagement Outputs –*** *(a) List of user-related challenges and issues to be addressed; (b) concerns of Inclusiveness per pilot and their societal readiness level for improvement. These outcomes are captured within deliverables* ***D2.1*** *(Citizen Engagement Guidelines and Metrics for Diversity and Inclusion) and* ***D2.5*** *(Main Barriers as pertain to Citizens).*

B: Design Thinking Phase

The aim is to understand in more detail the user uptake of, as well as the attitudes towards, digital twining solutions and to begin to come up with solutions to address these needs. This phase takes the broad areas identified by the Inclusivity Diagnostics and drills down into needs to generate pragmatic solutions for specific challenges. Citizen-related activities take place both in workshops and online given the circumstances.

B1. Empathise: The first stage of the design thinking process is for all involved in creating solutions to gain an empathic understanding of the users for whom they are being designed. This means engaging with and observing in the real-world the experiences, emotions, motivations and challenges that the user encounters, to gain a deeper understanding of their world, and needs and issues they encounter. This empathetic approach helps designers/developers set aside assumptions about the user and instead step into their shoes to gain the best possible insights into their needs. Much of the foundational observational work will have been undertaken during the Field Research (A3) so here the aim will be sharing the results with other designers/developers, bringing them up to speed on the core challenges and exchanging results across target groups. This is achieved through story share- and-capture techniques and the creation of use experience 'maps' that will supplement the Inclusivity Diagnostic.

> ***Empathise Phase Outputs –*** *The outputs include use experience maps with the identification of the specific touchpoints where challenges occur. Common problem areas experienced by multiple groups will be defined. These are captured predominantly through pilot activities timelines as shared working documents between relevant partners.*

B2. Define: To begin the solution process each pilot must define a meaningful and actionable problem statement or design challenge which is SMART – specific, measurable, achievable, relevant and time bound. These engage and inform the designers and kickstart the problem-solving process. Statements and a descriptive scenario description to illustrate the challenge has been created through a mix of workshops and collaborative document working and conference calls to ensure everyone in the pilot's initial ecosystems are in agreement. Challenges for pilot participants usually fall into one of four main possibilities:

- Simplify: This experience is difficult – 'make it easier for me'
- Pre-plan: What shall I do if something happens to me (e.g., service interruption)
- Solve it: This is easy to use, but doesn't include a solution for my own problem
- Enrich: I would like more and better choices available to me

Different pilot sites may deal with these differently (e.g., with dedicated project sub-teams or via equipment and service supplier contracts) but all knowledge will be shared to ensure accelerate learning and adaptation.

> ***Define Phase Outputs –*** *Concerns for pilot roll out management have been captured in deliverables **D9.1** (Quality Management Plan) and **D9.2** (Technology Management Plan). Deliverable **D4.3** (System Architecture) captures broadly technical architecture issues at system level and is informed partly by these discussions.*

B3. Ideate: Facilitated ideation workshops with stakeholders (energy consumers, designers, developers, energy organisations etc.) will help generate a large number of ideas to solve the problems defined in the previous steps. Participants are encouraged that 'no idea is a bad idea' and are asked to be creative in the breadth and width of their thinking. Creativity and innovation is unlocked through a variety of exercises using new technology and data cards to stimulate thinking and go beyond the normal ways of problem solving to find more appropriate, tailored and satisfying solutions to user challenges with digital twining. These ideas will be explored and refined into the most practical, innovative best-fit ones that can move to prototyping. Techniques here include brainstorming, storytelling, mind-mapping etc.

> ***Ideation Phase Output –*** *Baseline of solution ideas. These will be captured in working documents used to improve local testbeds and the delivery of TwinERGY functionality. Some high-level concerns are captured in **D6.1** (Dynamics and Interrelations). Data use and permissions related issues are captured in deliverable **D12.5** (Data Use Licences).*

C: Innovation Lab Phase

This comes after identifying the main challenges and common solutions. During the operations of this, TwinERGY delivers its solution prototypes that can be rolled out, tested and improved in a real-life setting. The users from the field research (A3) will be asked to use the new solutions, i.e., local testbed hardware and relevant TwinERGY software applications/modules. After rolling out the new solutions in the pilots, the effectiveness of these solutions will be measured, using both qualitative and quantitative methods of analysis and KPIs as particularly specified per pilot (see Section 6 and the outcomes in **D9.1/9.2),** and best practices are suggested.

C1. Prototyping: The prototyping phase is where the ideas from the previous phase can be quickly tested and improved. TwinERGY platform provides a set of data, new technology tools (IoT, blockchain, AI and analytics) and approaches for stakeholders to work together, both via workshops and remotely to test and explore the ideas through simple mock-ups, apps and other forms, which can be used to validate ideas in a cost-effective manner before they are turned into more viable market-ready solutions along with an appropriate business model. Here, the conceptual ideas are brought to life in a form that users can take and adopt for testing during their day-to-day energy use. The prototyping phase ensures that many different solutions can be trialled quickly, so designers/developers do not throw all their eggs into one basket and end up with one solution that does not meet user needs as expected. This way, prototypes can be quickly moulded and shaped into more appropriate solutions which offer more options to users.

> ***Prototyping Phase Outputs –*** *novel future energy market solution prototypes, specific to the needs of each pilot. KPIs for pilots are specified and monitored in* ***D9.1*** *(Quality Management) and* ***D9.2*** *(Technology/Operations Management).*

C2. Deploying: The European Commission defines demonstration as a "*stage of validation [which] will use a sufficiently large sample of users in a real-life situation to provide information on cost-effectiveness, user friendliness and similar issues, as well as testing the feasibility of the solutions when used on a large scale*."[2] With this in mind, TwinERGY has defined its demonstration stages as a series of cycles concentrated on testing the functioning, accuracy and effectiveness of technical and non-technical solutions in meeting the needs of the different user groups e.g. people with different skills, backgrounds and needs, people that are in one way or another associated with

[2] European Commission - DG XIII (1994b). Telematics Applications Programme (1994 - 1998)

the project and people outside the consortium circle who are new to it. Deployment will be accompanied with training activities designed to build capacity among end users to use newly created solutions.

> ***Deployment Outputs –*** *Testing scenarios, training materials, webinars, consultation clinics. These are largely captured in on-going working documents and pilot ongoing documentation* ***(T9.5)*** *and progress reporting.*

C3. Validation

The Innovation Lab Phase concludes with a validation stream during which local residents/citizen testers from A3, test the developed prototype solutions. This will include project partners undertaking research to understand the differences the solutions make, as well as additional techniques focused specifically on the solutions themselves and their business models. Validation methods to be applied at this stage will vary depending on output type. Qualitative outputs like the Future Energy Ecosystem Maps and Diagnostic will be updated during new focus groups and interview rounds, whereas technical outputs (modules, dashboards) will be tested during scenario-based activities. The analysis that takes place here will support the uptake of project recommendations into policies and strategies for inclusive design (e.g. social, educational, cybersecurity).

> ***Validation Outputs –*** *Ex post evaluations measuring user satisfaction with the newly created future energy solution prototypes and recommendations for further inclusive design. A lot of these analyses and discussions will be captured in the form of academic outputs (e.g., peer reviewed journal articles, referred conference announcements), so that the results are exposed to subject expert review and peer scrutiny. Such output will all be logged and documented under records of activity in Dissemination Planning as stipulated in deliverable* ***D11.2*** *(Comms & Dissemination). Especially with regards to academic publications, open access provision will be ensured, as required by the Commission.*

<u>D: Scale Phase</u>

During the final phase, TwinERGY aims to support the validated pilot solutions to become mainstream by widening their use and providing exploitation support. New solutions will be sought for challenges on a pan-European basis, and observations related to users' energy consumption behaviour will help inform new policy recommendations for an inclusive future energy ecosystem, thus providing policy makers with an effective solution for commonly benefiting all from the digitization era.

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Finally, the TwinERGY consortium will work in collaboration with the BRIDGE initiative and other associated projects towards creating a sustainable marketplace, by sharing experiences and insights from the rollout of our new services across pilots. This will also be achieved by continuing stimulating the discourse about inclusive innovation in energy services.

D1. Solution Replicability

TwinERGY pilots may be based in different countries but share many common aspects. Some may have overlapping vulnerable groups and policies, others digital tools or specific elements. These similarities allow TwinERGY study areas to be grouped based on criteria other than geographic location, e.g., the needs of vulnerable citizens, regulatory requirements, barriers to inclusion. Clusters with similar characteristics can therefore use the same solution to effect change in all places. The methodological phase D1 aims to develop such clusters based on the outcomes of previous tasks, to facilitate replication of ideas across pilots. The underlying idea is that a solution created for one city may be just as relevant for another one with similar needs. Accordingly, pilot solutions will be tested both in the city for which they were originally created and considered in cities beyond – where they may be deemed relevant. Such validation of replicability will be carried out in C3.

> ***Replicability Outputs –*** *Pilot cluster maps, business models evaluation. Largely captured in deliverables* ***D10.1*** *(Exploitation Plans) and* ***D10.2*** *(Opportunities Validation). Collaborative opportunities with other projects as identified in deliverable* ***D3.1*** *(Cooperation with other European Projects).*

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4. Pilot Objectives Setting and KPI Definition

4.1 Process of deriving objectives and specifying KPIs

Following the methodology as presented earlier, representatives from the four pilots have elaborated on objectives and metrics for the local implementations. High level objectives have been specified through working meetings, stakeholder workshops and with input from earlier deliverables on key stakeholder perspectives and user-related challenges. The partners then formulated a template to structure these objectives and elaborate on these to make them

- more specific and measurable,
- associated with the desired outcomes,
- mapped across HLUCs and the technical components of the local testbed that implement these,
- achievable via a series of defined tasks.

This exercise has resulted in the derivation of specific objectives and key performance indicators (KPIs) per pilot, which have been documented extensively in the relevant deliverables under WP9, namely in **D9.1** (Pilot Quality Control) and **D9.2** (Pilot Management Plan).

We will avoid reproducing the information from these deliverables here and cross-reference these as a pointer to the interested reader instead. The template used (shown below populated for Bristol in Figure 6) provides a shared, living record of objectives and KPIs and is meant to be updated, if needed, through-life of the pilot delivery period.

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New objective	Tasks	Outcomes	Use case	Technology required	Specified locally or centrally?	New KPI homes	New KPI UOB buildings
OB1. Install or make use of existing home energy generation/ storage assets to maximse self sufficiency in up to 12 homes	Define technologies to be installed (UoB/BCC) Create participant information sheet and research ethics (or consent) form (UoB/KWMC) Recruit participants (KWMC lead and BCC) Manage participant sign up and develop understanding of data ethics (GDPR requirements) (UoB/KWMC) GDPR sign off and done in a easy to interpret way (UoB/KWMC) Gather, manage, analyse data from participants / Work with participants to create data use licenses (KWMC/BCC/UoB) Install equipment (UOB) Ongoing management of equipment function (UOB) Organise 2nd line support (UOB?) Confirm warranty arrangements for participants (?) Terms and conditions for participants (KWMC/BCC/UoB) Procure equipment (UOB/BCC)	Residents maximize self-consumption and self sufficiency City Council has a better understanding of the potential value streams and benefits to residents in domestic dwellings Participants feel confident in how the project is using their data and for what purpose	UC01-Home Energy Management UC02 -RES Generation in domestic and tertiary building	Home energy management system including communication hub, smart plugs to devices, wifi connectivity, method of sending data out of home. Smart meter linked to dynamic tariff. Home interface device or app. New solar/ battery/ other energy assets where required	local	- Self-consumption ratio 42-60% (42% uk average if they have PV) - Measures the reduction of the largest daily power consumption value. - 25%	TBC
OB2. Deployment of home energy management devices to work with energy flexibility services, link to the transactive energy platform and engage households in up to 12 homes	Test any equipment before going in to homes (UOB lead) Confirm APIs etc required for TEP (UOB) Deployment of smart plugs or similar controlling devices Deployment of HEMS/ energy monitors Collection of data out of home	Residents participate in demand response programs / smart energy tariffs to minimize energy costs and support grid balancing Data retrieved from homes and analysed as part of evaluation activities Informed decisions about supplier and tariff choices; Change behaviour to more sustainable patterns Encourage decisions about taking a more active role (e.g. prosumer) and invest in energy systems	UC07 -Consumer's engagement in demand response programs UC06 -Consumers engagement in Demand Side Management Programs utilizing feedback mechanisms	Smart plugs, HEMS, API, wifi. PV hardware . Home interface device or app	local	- No of households receiving analysis about the impact of a dynamic price tariff on their household bills and carbon footprint - % of households agree or strongly agree that they would consider switching to a dynamic price tariff if it was shown to be beneficial - Active participation rate through user engagement and acceptance Measures the sum of the number of users actively participating in the pilots in relation with the total that accepted participating 11 of 12 homes - Customer responsiveness Measures how many customers have responded to a DR program following a DR signal sent to them, like a change in price, as the total number of signals sent back by the customers. as an absolute number or a percentage. 11 of 12 homes of participants to have responded **- Demand Flexibility Measures at each pilot the increase of the amount of load capacity participating in demand side management 10%?**	TBC
OB3. Flexibility modelling using digital twinning to understand buildings' potential to participate in flexibility services in up to 12 homes and up to 2 other large scale buildings	Household survey digital/ other (?) Installing and gathering sensor data from households / analyse Retrieving any existing data / analyse Engagement with households to understand process and share outcomes including data Household survey management of collation and analysis of data (IES/UOB)	Digital Twin modules inform flexibility modules Encourage decisions about taking a more active role (e.g. prosumer) Households have a better understand and engagement around their home energy management	UC04-Prosumers empowerment in local energy trading markets UC07 -Consumer's engagement in demand response programs UC09-Consumer's engagement in demand response programs utilizing digital twins'	Smart plugs, HEMS, API, wifi, Home interface device or app	Transactive platform is central but we would need backup local option, something commercially available?	Number of households who self reported a greater understanding of energy management in their home Number of households who have self reported to have changed their behaviours around energy useage in their household	TBC
OBJ4. To better understand and respond to citizens needs in participating in energy flexibility programmes and deploying energy technologies through co-design methodologies and engagement	Qualitative evaluation process and outcome capture (?) Quantitative data analysis to report against KPIs (UOB?) Supporting households to understand tariffs and energy supplier Giving information about digital twin exercise and gathering data required for this	Understanding their energy issues/needs and feeding this into the design of the system and pilot study generation and contribution to community schemes Informed decisions about supplier and tariff choices; Change behaviour to more sustainable patterns Encourage decisions about taking a more active role (e.g. prosumer) and invest in energy systems, Instituting scenario-boarding to understand micro-generation/peer-to-peer market landscapes	UC04-Prosumers empowerment in local energy trading markets UC07 -Consumer's engagement in demand response programs UC09-Consumer's engagement in demand response programs utilizing digital twins'	Miro boards, communications tools	local	- Customer satisfaction 9/10	TBC

Figure 6 – The tabular template used to elaborate on individual pilot objectives and relate to outcomes and metrics.

4.2 Comparability and potential for cross-site study

The use of this approach allows for greater comparability of pilot outcomes, even though contextual circumstances may differ across sites. Besides the comparability around groups of HLUCs that are common as presented and discussed earlier, transparent setting of specific objectives and metrics derivation as explained here facilitates opportunities for further discourse.

The latter opens up the possibility of transferring learning across sites under use cases that are not common by project definition and are not intended to be delivered through this project. As an example, should circumstances and resources allow it, this could encourage some activities around the use of wearables (UC08) or electric vehicles (UC03) to be considered in Bristol, at least at conceptual level – and similarly across sites.

Other opportunities for cross-site studies will come from exploring the root causes of what works well across sites and the sharing of learning from challenges faced and improvements made through-life. Relevant deliverables that have captured the regulatory environment and barriers to innovation (in particular **D2.3** and **D2.5** that studied business models and societal challenges respectively) are the first port of call to identify such opportunities.

5. Methods and Tools Assisting in Project Outcomes Delivery

5.1 Key Items and Selection Rationale

Throughout the duration of this Task, partners reflected on the use of methods and tools that will enable the activities planned and the project outcomes to be delivered. As stressed earlier, key concerns were the utilisation of means that would allow both co-creation as well as inclusivity and diversity. A lot of emphasis was therefore given to open and participatory approaches and methods, besides any traditional modelling techniques that would suit the energy sector.

The **Bristol Approach**[3] is an issue-led and people-led 6-step framework with a City Commons at the heart of it (a pool of community managed resources) that helps groups to tackle the pressing issues in their community. This is an approach aligned with the principles of Design Thinking and Responsible Innovation and by developing the notion of the Commons around local energy resources and the TwinERGY platform, we enable participation of citizens in the sector of energy systems. The approach has been used successfully in other European projects making for example urban sensing technology as the Commons to tackle air pollution challenges, such as in the Lighthouse project REPLICATE[4].

As innovations such as Digital Twins and blockchains facilitating transactions in the energy market are currently of emerging interest and at centre stage of our efforts, understanding participants' attitude towards these and the possibility of their adoption is essential. A widely accepted fundamental tool for exploring these issues is the **Technology Acceptance Model** (TAM) as developed by Davis (1989). TAM is a widely used and tested approach that is malleable to allow for specific sectorial aspects to be represented when customised accordingly, e.g., as in the study of smart meter adoption in the US by Chen et al. (2017). In our project context TAM is combined with a number of other state-of-art theories, such as the Theory of Planned Behaviour (Ajzen 1980). To facilitate consumer engagement by analysing the main drivers and obstacles to the use of key technologies, and profiling consumers, these different models are integrated

[3] https://www.bristolapproach.org/bristol-approach/
[4] https://kwmc.org.uk/projects/replicate/

effectively under principles of mixed-method research (Venkatesh et al. 2016; Venkatesh et al. 2013).

Fast developments in energy systems mean that interrelations between fundamental actors (suppliers, consumers, prosumers, municipalities and citizens at large) and energy assets (battery technologies, photovoltaic systems, smart appliances, tariffs etc.) become increasingly larger. The emerging picture of issues explored becomes more complex and so the exploration of challenges is difficult to be done based on any single-issue analytical method. We have therefore adopted the approach of **System Dynamics** (SD). Energy systems are complex dynamic systems that are often associated with uncertain system behaviour. The latter is influenced by several dynamic parameters, uncertainties, nonlinear relationships between system variables, time lags and interactive feedback loops that are inherent in the energy system (Mutingi et al. 2017). SD modelling has been successfully employed in past European funded activities, e.g., the FP7 STEEP project[5] (Systems Thinking for comprehensive city Efficient Energy Planning) with emphasis in allowing stakeholders to co-develop models and plans for interventions which can be taken to meet ambitious energy and carbon targets. For the purposes of our project, we will use causal mapping based on causal loop diagram techniques (CLD), as well as stocks-and-flows modelling as described in state of art texts (Meadows 2015; Sterman 2000; Forrester 1994; Senge 1990 etc.).

When past ideation stages however, technical systems ought to be described in specifications that would allow technical partners to implement the technology in a transparent and efficient way. In the domain of energy systems, European efforts have culminated in the **Smart Grid Architecture Model** (SGAM) and methodology (EC 2012) and so in adopting this framework we find a natural fit. There is already a significant number of project publications that have demonstrated its value (Santodomingo et al. 2014; Uslar et al. 2019; etc.).

Finally, the phased and iterative, where required, nature of TwinERGY's functionality rollout in pilot testbeds calls for an agile approach in the development and deployment of modules and other coded artifacts (Digital Twin, energy data dashboards etc.). Therefore, a natural approach to volatile requirements is widely accepted to be **SCRUM,** an agile development methodology used in the development of software, based on an iterative and incremental process. Scrum is an adaptable, fast and flexible framework designed to deliver value to the customer throughout the development of the project,

[5] https://cordis.europa.eu/project/id/314277

not only in the end.[6] Due to our project nature and requirements we follow broadly the SCRUM framework principles as documented in the latest version of the SCRUM Guide (Schwaber & Sutherland 2020), adjusted as required per module implementation leading team and the development environment used (e.g., Python, MATLAB etc.)

For all methods mentioned here, the actual tools that will be used to develop related artefacts (documentation, models, simulations, code etc.) are mentioned in more detail in the annex.

5.2 Process for Method and Tool Identification and Inventorying

As part of an effort to increase transparency of analysis results, ensure repeatability of experiments and develop scale up capacity, the pilot partners developed a 'methods and tools' inventory, documenting the use of such means. Information about origins, purpose of use, format of outcomes, licensing, cost, where to acquire from as well as pointers to key related resources has been collected through a structured template. It is intended to remain live through-life of the pilot delivery, as more tools or approaches may be used along the way through iterations of prototyping and ideation that are required. The full inventory is shared among partners as a spreadsheet, but its current snapshot is included in the annex.

5.3 Existing results, on-going learning and synergies development

Throughout the previous sections, we have already alluded to the inspection and adoption where necessary of other relevant European project outcomes, as they have been documented in their deliverables, reports and websites. Our consortium will also focus on enabling further learning through our participation to the BRIDGE initiative as documented in deliverable **D3.1** (European cooperation roadmap) and with other projects across the European Union and Partners.

[6] https://www.scrum.org/resources/what-is-scrum

6. Ethics, Privacy and Data Security Assurance

6.1 Research and Implementation Ethics and Privacy Compliance

For a project depended on the success of digital and data innovation, a special mention is finally required to the assurances of ethical data collection, privacy protection and the secure storage and processing of relevant data. The principles discussed here and elsewhere in project outcomes are topics that are kept firmly in mind and in sight of the consortium throughout stages of innovation and delivery.

Overall Approach

Secure collection of data from pilot sites and its ethical processing is covered by the procedures stipulated as part of WP12 (Ethics, Legislation, Standardisation) and documented in **D12.1** (Compliance Guide). Participants are fully informed about what data is collected and for what purpose. They consent for the generated data from the range of activities, in which they agreed to partake, be shared as needed between consortium partners through the TwinERGY platform. The platform offers a range of security controls and services that assure reasonable protection. These are discussed in turn in the next section in more detail.

Their anonymised energy consumption and other contextual data (environmental monitoring etc.) are uploaded on the platform to enable delivery of the relevant functionality. Aggregate or other derived data may also be shared within the TwinERGY consortium. However, participants' personal information (e.g., names, addresses, ...) is always kept strictly with local responsible partners and prohibited from being included in any public releases of materials.

Aggregate or other derived datasets, which may become public as product of research through planned dissemination activities, will be always examined for instances of potential inadvertent leakages through the application of anonymity metrics. Such instances may include, for example, occasions where other publicly available data of the participants such as in social media, exist independently of the anonymised TwinERGY datasets and may provide clues to their identities. Each such set will be examined independently prior to release.

Special Considerations

Further to platform functionality delivery and demonstration purposes, for any research in relation to collected data from pilot participants, research ethics procedures of the undertaking organisation are followed. For example, research analysis of Bristol-related data will happen in accordance with research ethics guidance and the applicable rules of the University of Bristol. The same will apply to other academic partners TH-OWL, UoP and UNL, as required.

Regardless of the existence of a local academic or industrial partner with research expertise both in Benetutti and Athens, ethical approval for data collection for research and analysis purposes is covered through the participants' signing of the consent forms which refer to that case.

6.2 Data Security

Any kind of data generated from the TwinERGY pilot assets will be initially handled and processed by the TwinERGY Core Data Management Platform (CDMP). The TwinERGY CDMP will introduce appropriate components and mechanisms for the effective management of the data that will be collected in the CDMP. These features will ensure the provision of the relevant encryption and anonymization rules, the establishment and definition of explicit data access control policies, while allowing for the secure storage of the collected data

More specifically, the TwinERGY platform will offer data encryption mechanisms to data providers (those that wish to upload their data as encrypted objects) as a means for the protection of their data, ensuring that no data will be accessed by a non-authorized user. The purpose of data encryption in TwinERGY is to ensure that the data will be securely transmitted from the various legacy systems, applications etc. and external data sources to the TwinERGY Platform and to the applications standing on top of it, without any alterations from unauthorized parties.

In this context, TwinERGY will setup the required mechanisms and associated components for the configuration of appropriate encryption rules by data providers (demonstrators) during the ingestion of their data in the CDMP. Through these mechanisms, data owners will be able to encrypt whole datasets that they share with the platform, or specific parts of a dataset, allowing other contents to remain unencrypted if they are not security sensitive.

The encryption mechanisms in TwinERGY will enable symmetric encryption of selected datasets and contents, allowing for the generation of the associated encryption keys and, subsequently, for the actual encryption of the underlying datasets thus enhancing data sovereignty and allowing data owners to keep full control of their encrypted data assets. Moreover, it will enable the sharing of the decryption keys with data consumers that are eligible to access the encrypted data through secure SSL handshakes (attribute-based encryption for the symmetric key) in coordination with the Access Policy Control Mechanisms that will be configured.

With regards to the latter, the development of appropriate authorization and access control functionalities will ensure that the users of the platform will be granted access rights over specific datasets, in compliance with the potential restraints that will be imposed by the data providers, in order to minimize the security risk of unauthorized access. The configuration of these mechanisms and functionalities will enable user-centric definition of rules and constraints around the sharing of selected datasets with data consumers that are legitimate to gain access to such datasets. Access Policy and Control mechanisms will be setup and regulated on the basis of Attribute-Based Access Control policies, thus allowing access only to data consumers (organizations) that satisfy specific attributes that have been defined (in the form of straightforward rules) by the data owners.

With regards to data anonymisation, an additional mechanism that will be introduced in the TwinERGY platform, aiming to prevent any undesired exposure of personal or corporate information. The different datasets that will be ingested in the platform, may contain sensitive information, therefore the data providers will be notified promptly and will be provided with the functionalities to anonymise this information, as well as any field of their data that they might consider as containing any identifying information (individually or in conjunction with other fields). Depending on the type of the field (sensitive, identifying, partly identifying) and the data type, the data providers are offered with the possibility to define the anonymisation method that should be applied in a simple and understandable way, together with the provision of indicative examples. However, it is important that the data provider acknowledges how the anonymisation rules that will be applied, will affect the data. A utility function which is used to compute data loss caused by the anonymisation process will be offered, enabling the provider to perform the appropriate adjustments to safeguard sensitive information without making the data unusable. In this case, the data provider will be asked to check again the anonymisation rules that have been defined.

Finally, concerning data storage, the collected data deriving from the four pilot sites of the project (Athens, Benetutti, Hagedorn and Bristol) will be stored in a secure storage space in the TwinERGY CDMP, after they are mapped to the TwinERGY Common Information Model. The Data Storage component will store the data in a NoSQL database, in favour of scalability and big data management optimization. Specifically focusing on sensitive data and their storage in the TwinERGY platform (after being anonymised), the platform will provide dedicated secure spaces where sensitive information together with similar information referring to API tokens or user credentials, will be stored towards enhancing data privacy and security.

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7. Conclusions

In summary, in this project we build upon established approaches that facilitate the participation of key stakeholders in both the formulation of objectives and the delivery of innovation in communities. Design thinking is an approach that allow us to discuss and identify issues with citizens and consumers, ideate solutions, try out in the field innovative technologies that are deemed to realise these solutions and then revisit these, based on feedback from real life use.

In TwinERGY, these activities take place under an ethos and culture of Responsible Innovation that brings to the foreground both aspects of diversity and wide participation, as well as fairness and equity in the exploitation of results. For example, our Consumer Digital Twin demonstrates how such innovation can empower citizen-prosumers in scenarios of future energy markets, where local and peer-to-peer trading may emerge as a practice in the sector.

Approaching the market through the lenses of Transactive Energy and supporting its implementation with a distributed ledger tool, further provides opportunity to make this concept more transparent and accessible by a wider range of stakeholders. For all innovations proposed, rigorous analysis and modelling is performed in order to enable the identification and eventual deployment of testbeds and demonstrators, through a combination of equipment procurement and module development.

A range of business analysis and systems design methods and tools have been adopted for use throughout the project, some sector-specific and some more generic but suitable for the energy domain. From SGAM to TAM, System Dynamics modelling and the Bristol Approach to Citizen Sensing, our methods and tools inventory provides the necessary capabilities for analysing, modelling and implementing concepts in line with our project's objectives.

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Annex

Table 3: Methods as used by partners (current as of 31.AUG.2021; may be updated in the future as required)

	Method	(Version)	Type	Used for	Outputs	Key Partner	Resources	Use in the project	Tasks	Rationale
[M1]	System Dynamics	n/a	An approach to understand complex systems	Complex systems modelling	Models, diagrams	UNIVBRIS	'Thinking in Systems', D Meadows 'System Dynamics', J Forrester 'The Fifth Discipline', P Senge 'Business Dynamics', J Sterman	To facilitate group model building of future energy systems & explore inderdependencies	T6.1	Key stakeholders will co-produce models of future energy systems that will allow them to develop common understanding of challenges and system interdependencies. Key insights may influence TwiinERGY modules development and interventions in relevant Use-Cases.
[M2]	The Bristol Approach	n/a	Toolset for community-led problem structuring	stakeholder engagement, solution co-production	Use-case narratives, concept designs	KWMC	https://www.bristolapproach.org/	To facilitate consumer engagement and co-production of the project pilot testbeds	T2.1, T2.2, T9.1, T10.1	Consumer groups engaged with the project will contribute in a structured way to the co-creation of the pilot testbeds to ensure maximum relevance and impact.

	Method	(Version)	Type	Used for	Outputs	Key Partner	Resources	Use in the project	Tasks	Rationale
[M3]	SGAM methodology		Procedure of modeling	Model and define the architecture of the project Twinergy	Set of layers composing the architecture of the project, set of elements and roles actuating in each element. Relationships among elements and roles.	ETRA I+D	"Smart grid reference architecture" - European comission	To model all aspects related to the project architecture	T4.4, T2.2	The definition of the architecture covers: the Use case definition (what is going to be done), the definition of elements and people (who and which are going to participate), and the relationships among them (how they interact each others). Besides organize architecture in layers allows us to have a clear picture of the scope of the project. This is a key step in the process, so following a methodology makes easier to define well all these components
[M4]	Mixed-methods approach	n/a	A qualitative and quantitative approach to understand consumer behaviour in	Understand consumer behaviour regarding key susainable energy	Sustainable energy solutions/consumer behaviour model; Recommendations	UNL	UTAUT2 (Venkatesh, 2012) Mixed methods guidelines (Venkatesh, 2016) TAM (Davis, 1989) TPB (Ajzen, 1980)	To facilitate consumer engagement by analyzing the main drivers and obstacles to the use of key	T4.1; T4.2	The identification of consumers' motivations/barriers, and its profiling, will contribute to better engagement strategies, to ensure

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	Method	(Version)	Type	Used for	Outputs	Key Partner	Resources	Use in the project	Tasks	Rationale
			the 4 country pilots (plus Portugal)	solutions for use cases and pilots				technologies, and profiling consumers		a successful implementation of the solutions.
[M5]	SCRUM		Project management method	Planning tasks	n/a	TH-OWL		Plannins and assigning tasks to project participants	Throughout	To coordinate the various tasks coming up during the project, it is useful to follow a specific concept. SCRUM with ist agile approach is a good way to react to changing requirements during the months while working in a small team.

Table 4: Applications and tools used (current as of 31.AUG.2021; may be updated in the future as required)

	App	Version	Type	Vendor	License	Cost	Used for	Outputs	Lead Partner	Other Partners Using	Access from
[A1]	Loopy	n/a	On-line modelling tool	Nicky Case	Open source	Free	System Dynamics modelling	Causal loop diagrams and simulation results	UNIVBRIS	tbc	https://ncase.me/loopy/

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	App	Version	Type	Vendor	License	Cost	Used for	Outputs	Lead Partner	Other Partners Using	Access from
[A2]	Vensim	Personal Learning Edition	Modelling & Simulation package	Ventana Systems	Academic/Personal use	Free	System Dynamics modelling	SD models (causal loop and stocks-and-flows, simulations)	UNIVBRIS	tbc	https://vensim.com/vensim-personal-learning-edition/
[A3]	Mural	n/a	On-line collaboration tool	MURAL	Structured fees apply, but free starter edition	Typically US$144 per annual membership	Stakeholder engagement	Digital whiteboards/post-it notes	KWMC	tbc	https://www.mural.co/
[A4]	Enterprise Architect	14.0.1421	Modelling	Sparx System	Propietary	229 $	Modeling of the SGAM architecture	Navegable diagrams of the different layers of the architecture in the project. Exportable to HTML	ETRA I+D	None, used by ETRA I+D shared contents to the rest of partners	Desktop application
[A5]	Moqups		Modelling	S.C Evercoder Software S.R.L.	Freee	0	Design of graphical user interfaces	Pictures per each view or screen in a application	ETRA I+D	Unknown	https://moqups.com/
[A6]	Smart PLS (software)	3	Structural equation modelling software	SmartPLS	Academic use	Free (for academic use)	Structural equation modelling - test consumer behaviour model	Statistical analysis (measurement and structural model)	UNL		https://www.smartpls.com/

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	App	Version	Type	Vendor	License	Cost	Used for	Outputs	Lead Partner	Other Partners Using	Access from
[A7]	MATLAB	R2020	Scripting and mathematic modelling	Mathworks	Enterprise	n/a	Mathematical calculations, scripting	General data, diagrams	TH-OWL	tbc	http://www.mathworks.de/products/matlab/index.html
[A8]	PyCharm	2020.3	Python DIE	Jetbrains	Community	free	Python scripting	General data, diagrams	TH-OWL	tbc	https://www.jetbrains.com/pycharm/
[A9]	Python	3.8	Python interpreter		Open Source	free	Python scripting	see above	TH-OWL	tbc	http://www.python.org
[A10]	Microsoft Notes	2016	Digital notebook	Microsoft	Education license	n/a	Gathering project info in one place, project management	none	TH-OWL	tbc	http://www.microsoft.com
[A11]	Webex	41	Video communication	Cisco Systems	University License	n/a	Holding video calls across the teams	none	TH-OWL	During video calls organized by TH-OWL	https://www.cisco.com/c/de_de/index.html
[A12]	Zoom	823+	Video communication	Zoom Video Communications	Basic (unlimited meeting runtime and up to 100 participants for free during COVID-pandemic)	Free	Holding video calls across partners, for workshops, discussions etc.	none	TH-OWL	During video calls organized by TH-OWL	https://zoom.us/
[A13]	AASX Package	2021-05-02.alpha	AAS Editor/Viewer	Festo AG & Co. KG	Eclipse Public License - v	Free	Viewing and editing AAS DT models	AAS models as AASX, JSON or XML	TH-OWL	tbc	https://github.com/admin-shell-io/aasx-package-explorer

	App	Version	Type	Vendor	License	Cost	Used for	Outputs	Lead Partner	Other Partners Using	Access from
	Explorer				2.0 (EPL-2.0)						
[A14]	AASX Server	2021-05-08.alpha	AAS Online Viewer	Festo AG & Co. KG	Eclipse Public License - v 2.0 (EPL-2.0)	Free	Viewing AAS DT models via web interfaces (REST, MQTT, OPC UA)	none	TH-OWL	tbc	https://github.com/admin-shell-io/aasx-server
[A15]	Eclipse BaSyx	Java Release 1.0	AAS SDK	Eclipse Foundation	Eclipse Public License - v 2.0 (EPL-2.0)	Free	Developing active AAS submodules and integrating functions within them	Applications, implemented functions	TH-OWL	tbc	https://wiki.eclipse.org/BaSyx_/_Download