D2.1 | State-of-the-art analysis and Big Data Value Chain

WP2 – System Requirements and Specifications

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Modular Big Data Applications for Holistic Energy Services in Buildings

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Preface

MATRYCS focuses on addressing emerging challenges in big data management for buildings with an **open holistic solution** for Business to Business platforms, able to give a competitive solution to stakeholders operating in building sector and to open new market opportunities. **MATRYCS Modular Toolbox,** will realise a holistic, state-of-the-art AI-empowered framework for decision-support models, data analytics and visualisations for Digital Building Twins and real-life applications aiming to have significant impact on the building sector and its lifecycle, as it will have the ability to be utilised in a wide range of use cases under different perspectives:

- Monitoring and improvement of the energy performance of buildings - **MATRYCS-PERFORMANCE**
- Design facilitation and development of building infrastructure - **MATRYCS-DESIGN**
- Policy making support and policy impact assessment - **MATRYCS-POLICY**
- De-risking of investments in energy efficiency - **MATRYCS-FUND**

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2	NATIONAL TECHNICAL UNIVERSITY OF ATHENS	NTUA	GR	
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Abbreviations and Acronyms

Acronym	Description
AHU	Air Handling Unit
ALS	Airborne Laser Scanning
AI	Artificial Intelligence
ANN	Artificial Neural Networks
API	Application Programme Interface
AWS	Amazon Web Services
BAC	Building Automation and Control
BaU	Business as Usual
BD	Big Data
BDA	Big Data Alliance or Buildings Data Alliance (name to be defined)
BDVA	Big Data Value Association
BEMS	Building Energy Management System
BIM	Building Information Modelling
BMS	Building Management System
BPIE	Buildings Performance Institute Europe
BPNN	Back propagation neural network
BSO	Building Stock Observatory
BVC	Buildings' Value Chain
CCFI	Climate Change Financial Instrument
CF	Causal Forest
CoM	Covenant of Mayors
COM	Communication
CO2	Carbon dioxide
CRU	Climatic Research Unit
CT	Causal Tree
D2C	Dependency to Causality
DAIRO	Data, AI and Robotics
DEEP	De-risking Energy Efficiency Platform
DEMS	District Energy Management System
DH	District Heating
DHN	District Heating Network
DL	Deep Learning
DSO	Distribution System Operator
DSM	Data Storage Management
EC	European Commission
ECEEE	European Council for an Energy Efficient Economy
ECM	Energy Conservative Measure
ECTP	European Construction, built environment and energy efficient building Technology Platform

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Acronym	Description
EDGAR	Emissions Database for Global Atmospheric Research
EE	Energy Efficiency
EEA	European Environment Agency
EeB	Energy Efficient Buildings
EECC	Energy Efficiency Cost Curves
EEPA	Energy and Environmental Policy Analysis
EMS	Energy Management System
EnPC	Energy Performance Contract
ENPOV	EU Energy Poverty Observatory
EPBD	Energy Performance of Buildings Directive
EPC	Energy Performance Certificate
ERDF	European Union Regional Development Fund
ESCO	Energy Services Company
ETIP	European Technology and Innovation Platforms
ETL	Extract Transform Load
ETP	European Technology Platform
EU	European Union
GBP	Green Building Programme
GDPR	General Data Protection Regulation
HEMS	Home Energy Management System
HVAC	Heating, Ventilating and Air-Conditioning
ICT	Information and Communication Technologies
IDEES	Integrated Database of the European Energy System
IEA	International Energy Agency
IEQ	Indoor Environmental Quality
IMPVP	International Performance Measurement and Verification Protocol
IoT	Internet of Things
JRC	Joint Research Centre
JTI	Joint Technology Initiative
GDPR	General Data Protection Regulation
GIS	Geographical Information System
HVAC	Heating, Ventilation and Air Conditioning
KPCA	Kernel Principal Component Analysis
KPI	Key Performance Indicator
LOV	Linked Open Vocabularies
LSP	Large Scale Pilot
LS-SVM	Least Squares Support Vector Machines
ML	Machine Learning
M&V	Measurement and Verification
NGSI	Next Generation Service Interface
NUTS	Nomenclature des Unités Territoriales Statistiques
nZEB	Nearly Zero Energy Building

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Acronym	Description
OECD	Organisation for Economic Co-operation and Development
OLS	Ordinary Least Squares
OSM	Open Street Maps
PCA	Principal Component Analysis
PEB	Plus Energy Buildings
PSI	Public Sector Information
RBF	Radial Basis Function
REC	Renewable Energy Communities
RES	Renewable Energy Sources
RGB	Red Green Blue
SECAP	Sustainable Energy and Climate Action Plan
SfM	Structure from Motion
SME	Small and medium-sized enterprises
SRI	Smart Readiness Indicator
SRIA	Strategic Research and Innovation Agenda
SRIDA	Strategic Research, Innovation and Deployment Agenda
SVM	Support Vector Machines
TBM	Technical Building Management
UNSD	United Nations Statistics Division
WMS	Warehouse Management System
WoT	Web of Things
WP	Work Package

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Executive Summary

Current climate change threats and increasing CO_2 emissions, in particular from the building stock represent a context where it is necessary to act upon and provide efficient manners to manage energy consumption and generation in buildings and contribute to a decarbonised economy. In parallel to this trend, more and more data are being generated within buildings nowadays, due to the increasing adoption of leading-edge ICTs technologies, such as IoT, AI, DLT/blockchain and big data, thus, contributing to move forward towards a smart building landscape. By combining these new technologies and the exploitation of data towards solving real life problems surrounding buildings, the way could be paved towards a decarbonised future.

In this framework, **MATRYCS aims to provide modular big data applications for holistic energy services in buildings**, which will be validated in 11 large scale pilots covering several needs and perspectives around energy in buildings: performance, design, policy-making and funding. To this end, it is necessary to understand what technologies and solutions already exist to assure that what MATRYCS can provide remains, on the one hand, cutting edge and, on the other, also builds upon existing methods, technologies, data models and platforms.

For this reason, this Deliverable 2.1 main objective is to delve into current trends and provide a landscape review of all the concepts playing a role in MATRYCS, and also to provide a user-perspective and define what challenges are currently faced in the building sector (Part I), to finally be able to derive user stories and requirements (Part II). This document will be updated close to the project's midlife to assure that its contents remain cutting-edge and up to date.

To provide this vision, in the first place, the scope will be defined by identifying the **current trends present both in the building sector, as in the big data context**. Thus, the perspective and objectives presented by relevant organisations like the European Construction and Technology Platform (ECTP) or the Building Data Value Association (BDVA) will be presented. These will be complemented by the European Commission's perspective (twin transition, directives, reports, initiatives, H2020 projects and collaborative networks) and by a short introduction to potential engagement to third parties and a presentation of stakeholders to be addressed in this context.

Then the **landscape from a technical perspective** is presented. Firstly, by analysing what methods and tools are currently being deployed by the stakeholders in the building value chain. This will allow clearly identifying potential improvements to the building as usual procedures and proposing relevant solutions. As counterpart, this landscape overview is complemented by the **existing technologies** that could be deployed to answer the stakeholders' needs. With this in mind, first the digitalization in the built environment is explained and relevant concepts surrounding the digital building twin examined (i.e. existing data models, BIM and digital infrastructures, link to IoT, end-to-end process digitalisation, and how other scales could be tackled), as well as some examples of platforms for the built environment presented. Then, specific analytics that could target the previously identified challenges are presented. These are grouped in the same categories as the pilots and this literary review will be used as a basis for the development of analytics in the project. Finally, this landscape review is completed with an introduction to digital tools for data and knowledge management and cyber-security concepts.

Finally, once the context, an introduction to the needs and challenges to be addressed and the

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available technologies to tackle them have been presented, it is necessary to know **what data is available** to put into practice the shown analytics. This is the reason why this technical analysis concludes with a review of building related datasets and repositories available at different levels (EU repositories, EU member state repositories, regional/local and other private repositories).

All this analysis sets the adequate basis to delve into Part II of the report, where a methodology has been implemented to work with pilot leaders and extract from them relevant insights that lead to the in-depth characterisation of the stakeholders involved (by defining target groups and personas). This characterisation allows defining user stories, usage scenarios and, lasting but not least, the use cases that will serve as an input for the next steps of the project.

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1 Introduction

This document represents Deliverable 2.1 "State-of-the-art analysis and Big Data Value Chain", as initial outputs of two tasks of the MATRYCS project: Task 2.1 "MATRYCS Services, Tools and Methodologies Landscape Review", and Task 2.2 "User stories and requirements analysis". These findings will be updated close to the project's midlife to assure the relevance and accuracy of the inputs provided, which will be contained in the Deliverable 2.4 "MATRYCS reference architecture for Buildings Data". The two subsections below present the purpose of this document, as well as the structure it follows.

1.1 Purpose of the document

The objective of this document is twofold; therefore, it is divided into two parts. **Part I** provides a state-of-the-art analysis of relevant aspects related to the MATRYCS project and the big data value chain. To this end, it provides a detailed landscape review of all concepts playing a role in MATRYCS, from European Directives to specific technologies and challenges to be solved by the big data value chain. The main objectives of this part of the document are to: (1) realise a detailed landscape review of all concepts playing a role in MATRYCS, (2) place emphasis on similar services to the ones envisioned by MATRYCS and existing tools and methodologies that could constitute either competitors of foundations on the ones developed in the project, (3) provide an extensive review of existing datasets across EU, at national, regional or local level, (4) review European Commission directives and initiatives, reports and studies commissioned by the EC and (5) review existing frameworks and architectures

On the other hand, **Part II** presents the methodology followed to extract user requirements, which will be reported in Deliverable 2.2 "MATRYCS Technical and Security Specification". To this end, intensive work has been carried out with pilot leaders to derive user stories that depict the main challenges faced by multiple stakeholders of the value chain (national and local governments, network operators and suppliers, ESCOs, building managers and facilitators, construction and renovation sector, investors and financiers, policy makers and researchers). First, each stakeholder has been deeply characterised and their needs represented through user stories. Based on them, usage scenarios addressing these needs were drafted in each pilot. Finally, considering the functionalities to be provided through the MATRYCS services and these identified needs, usage scenarios were grouped and, from this grouping, use cases have been developed.

Both parts of this document will be updated in the project's midlife in order to ensure that MATRYCS developments remain innovative and cutting-edge, and that the user requirements are adequately captured.

1.2 Structure of the document

The document is divided into two Parts, related to the Tasks 2.1 and 2.2 respectively. **Part I** contains the following sections:

Section 2 (Scope and approach) includes the introduction to the landscape review of the concepts

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that play a role in the context of MATRYCS project that will be deployed in the following sections of the document (sections 3 and 4). It includes the ECTP (**2.1**) and BVDA (**2.2**) vision towards 2030, the Twin Transition (**2.3**), a compilation of EC Directives, initiatives, and reports and studies from the EC (**2.4**), and H2020 projects (**2.5**) related to the MATRYCS landscape; as well as Common European Digital Platform and collaborative networks (**2.6**), engagement with third parties (**2.7**) and the Stakeholders approach (**2.8**) followed in MATRYCS.

Section 3 (Big Data for Building: MATRYCS – Landscape) reviews the domain from two perspectives:

- **Section 3.1 (Existing technologies, tools, methodologies and procedures in real environments)** provides a description of the current methodologies, workflows and technologies used by the final users (represented within the Large-Scale Pilots, LSP) for offering the operations/services covered by the pilots, as they are offered right now (business as usual). It sets the starting point in order to introduce innovative technologies in the next section. Thus, the section is divided into the applications and cases related to increasing Performance at Buildings (3.1.1); to improving Design capabilities (3.1.2); to policy making (3.1.3), and to funding retrofitting actions (3.1.4), each of them linked to specific pilots addressing these issues.
- **Section 3.2 (Review of trends in the application of digital (data based) technologies on the built environment in the context of MATRYCS platform)** provides a description of the innovative services, applications and technologies that could constitute either competitors or foundations of the ones developed in the context of the project. The section then is related with the services to be developed in MATRYCS project, with sub-sections: Digitalization of Built Environment: Digital Building Twin (3.2.1) related to service s0.1 to be developed in Task 5.1, it includes the analysis of existing data models (3.2.1.1), BIM and Digital infrastructures (3.2.1.2), IoT integration with BIM-enabled platform (3.2.1.3), Transition from the IoT to the Semantic Construction Web of Things (3.2.1.4), End-to-end process digitalization (3.2.1.5), and City and regional scales (3.2.1.6); Platforms for the Built Environment (3.2.2) describing platforms that could constitute either competitors or foundations to the ones developed in MATRYCS; Analytics for the Built Environment and their technologies (3.2.3) including the analytics to be carried out in MATRYCS for Energy Performance (3.2.3.1), related to services in Task 5.2, for Building and related infrastructure (3.2.3.2), related to services in Task 5.3, for Policy making and Policy impact assessment (3.2.3.3) related to services in Task 5.4, for De-risking investments in Energy Efficiency (3.2.3.4), related to services in Task 5.5, and for the Geo-clustering service to support the BD Vision (3.2.3.5), related to service in Task 5.6; Digital tools for data and knowledge management (3.2.4), to provide a description of the digital technologies and tools for the data and knowledge management in the context of the project; and (Cyber) Security: Governance models for secure data and information delivery across lifecycle and supply chains (3.2.5), in the context of the project.

Finally, **Section 4 (Building related DATA SETs and repositories)** compiles well-known data sets and repositories across EU. Such repositories are identified and listed in the form of "simple" tables including relevant information. It is divided into four sub-sections and an additional one with a table to summarise the data sets and repositories to be potentially used by MATRYCS services and tools, with further description.

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- **Section 4.1: Public EU.** Including public European repositories.
- **Section 4.2: Public EU member.** Including public national repositories of the countries corresponding with the location of the MATRYCS pilots.
- **Section 4.3: Public Regional/Local.** Including public regional and local repositories.
- **Section 4.4: Other Private data sources.** Including private data sources that could provide useful information.
- **Section 4.5: Building related Dataset and repositories to be potentially used by MATRYCS.** Providing further description of the datasets and repositories to be potentially used in MATRYCS project.

Part II contains the following sections:

- **Section 5: User Stories and Use Cases** contains the developments related to the Task 2.2 User Stories and Requirements Analysis. The section is structured in three main sub-sections:
  - **Section 5.1: Description of the process**. It provides a detailed explanation of the process followed by MATRYCS to finally obtain the user requirements. It consists of three phase: Phase I (5.1.1) related to the Test Cards, Personas and User Stories; Phase II (5.1.2) related to the development of Usage Scenarios, and Phase III (5.1.3), where the Usage Scenarios are reviewed and finally the Use Cases are generated.
  - **Section 5.2: Results and statistics.** It gathers the final figures obtained in terms of Personas, User Stories, Usage Scenarios and Use Cases by the LSP.
  - **Section 5.3: Final Use Case(s).** It collects the Use Cases to be later developed and a high-level description (name of the use case, pilots to which it applies, Personas and Usage Scenarios involved, scope, objective and some comments to be considered for the later development).

In addition to these two Parts, several Annexes are provided to complement some of the sections in this document, which are listed below:

- **Annex I:** EC directives and initiatives – description, complements section 2.4
- **Annex II:** H2020 projects contributing to MATRYCS landscape, complements section 2.5
- **Annex III:** Existing data models – description, complements section 3.2.1.1
- **Annex IV:** End-to-end process digitalisation methodology example, complements section 3.2.1.5
- **Annex V:** MATRYCS target groups and personas, complements section 2.8
- **Annex VI:** Examples of test cards, personas, user stories and use cases, complements sections 5.1 and 5.2.
- **Annex VII:** Meetings and work done, complements section 5.1.

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2 Scope and approach

The main objective of this section is to introduce the landscape analysis to be presented within this document. For this reason, it is of the utmost importance to understand what the current context is in the field of energy in buildings, the use of data and digitalisation. To comprehend what the trends are, selected initiatives and projects are presented. This way, the current shared vision in Europe is presented through the eyes of the Energy Construction and Technology Platform (ECTP) and the Big Data Value Association (BDVA) (sections 2.1 and 2.2, respectively). This vision is based on addressing the challenges of the built environment and it is expected to be tackled, among other, by a Twin Transition, which strongly relies on the digitalisation of the built environment and the exploitation of data (section 2.3).

These trends should be observed in parallel to the European Commission activities, where not only Directives and initiatives should be analysed, but also the reports and studies commissioned by them in this field (section 2.4), H2020 projects (section 2.5), common European Digital Platform and Collaborative Networks (section 2.6) and engagement with third parties (section 2.7).

Finally, to complement this overview, an introduction to the stakeholders' approach implemented in MATRYCS is presented in the last subsection (section 2.8). This will complete the vision with a practical perspective of the building value chain by identifying and categorising the stakeholders whose needs should be addressed and will serve as an introduction to the in-depth analysis performed in Part II.

2.1 ECTP vision towards 2030

The European Construction, built environment and energy efficient building Technology Platform (ECTP), as a leading organisation shaping the future of the built environment and construction sector in Europe, recently issued its Strategic Research and Innovation Agenda (SRIA)[1], where long term and intermediate goals (for 2050 and 2030, respectively) have been established.

The research and innovation activities identified in the SRIA are the answer to the growing societal challenges and customer needs, as well as to the new opportunities unlocked by the technology and industry progress. Climate changes and associated policies towards a CO2 neutral society are among the main drivers for the transition in the building sector, which call for rethinking the design, maintenance and management of the built environment as well as for accelerating the renovation of the housing stock and the integration of renewable energy sources. These needs are further exacerbated by the ageing of the European population and the increasing urbanisation trend, which imply that European citizens will spend most of their time indoor, thus relying on the comfort and wellness offered by the building infrastructure.

Based on the above considerations, four main pillars have been identified as key for the European built environment and construction sector (see Figure 1).

1 ECTP, ECTP Strategic Research and Innovation Agenda 2021-2027, 2019, available online at: http://www.ectp.org/fileadmin/user_upload/documents/ECTP/Miscellaneous_doc/ECTP_SRIA_FINAL_20-11-2019.pdf

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Figure 1: ECTP 2030 objectives for the built environment and construction sector ***(source: ECTP)***

Clean built environment and cities. The 2030 objective, from this standpoint, is to reach the environmental and energy objectives set by the EU for 2030. To measure the achievements related to this objective, the following targets have been defined:

3% annual renovation rate for buildings and infrastructures; 40% CO2 reduction (with respect to 1990), 32% share of renewable energy sources in final building energy consumption and 32.5% energy savings; Contribute to obtain 100 carbon neutral cities; 80% reusable or recyclable materials for new buildings and infrastructures, and for renovation components.

Built for and with the people. The associated objective for 2030 is to adapt buildings and infrastructure to become age-friendly, inclusive and well-connected spaces. The measurable targets defined for this category include, among others, the following:

15% increase of participative processes in urban planning; Availability in all EU member states of a common evaluation/ certification framework for age-friendliness performances of buildings; 50% of building renovations consider 'age-friendliness' criteria and 75% of new build are age-friendly; Availability in all EU member states of a common evaluation/ certification framework for healthiness and wellbeing of the built environment.

Prosperous ecosystem. The 2030 objective is to increase productivity through upgraded and innovative industrialised construction processes derived from the integration and rationalisation of new technologies, designs and techniques in the manufacturing and construction processes. The measurable targets for this objective include (among others):

Increase productivity by 20%; Reduce building renovation time by 50%; Reduce by 40% the emissions of the construction process; 20% reduction of time & cost of interventions for maintenance; 20% cost reduction in conservation.

Digitalisation. This is a key objective, since it is seen as the game changer needed to pursue also the other intermediate and long-term objectives. The 2030 objective is that all European construction companies, including SMEs, adopt digital tools in a common and open framework, to deliver smart-ready buildings and infrastructures. Some measurable KPIs established in this direction are:

Full interoperability of all systems (BEMS, active components, RES) within new and renovated buildings (Plug & Play); Full interoperability (with open standards) between different software (e.g. simulation,

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BIM, 3D printing); Standardised framework for data management; Public procurements are fully digitalised (BIM based) in all Member States; Full data privacy and security for all EU citizens, including workers; Full integration of infrastructures in BIM.

2.2 BDVA vision towards 2030

The Big Data Value Association (BDVA) is an industry-driven international not–for-profit organization with more than 200 members coming from large, small, and medium-sized industries as well as research and user organizations. It is operative since the 2014, with the mission to develop the Innovation Ecosystem that will enable the data and AI-driven digital transformation in Europe delivering maximum economic and societal benefit, and, achieving and sustaining Europe's leadership on Big Data Value creation and Artificial Intelligence[2].

In 2020 BDVA members decided to strengthen the Association by giving it a new mandate, a new name and by expanding its scope and breadth of activities, so that in 2021, BDVA is becoming DAIRO (standing for Data, AI and Robotics). The DAIRO vision, according its SRIDA[3], is "*to boost European competitiveness, societal wellbeing and environmental aspects to lead the world in researching, developing and deploying value driven trustworthy AI, Data and Robotics based on fundamental European rights, principles and values*".

The DAIRO Partnership is therefore focused on creating a successful and cohesive eco-system that translates Europe's excellent academic skills into an economic, societal and environmental advantage that embodies European values and norms to achieve the best outcome for Europe. Its main objectives can be summarised as: 1) To secure European sovereignty over technologies and knowhow. 2) To establish European leadership with high socio-economic impact and 3) To reinforce a strong and global competitive position for Europe.

According this SRIDA, the DAIRO doesn't have a specific vision on big data for building, instead they state that the deployment of AI, Data and Robotics will impact several main areas, in every market sector, in terms of operational flexibility, usability of products and services, support for complex decision-making processes in dynamic environments etc.

The main challenge for the European Data Economy will be to be made available large volumes of cross-sectoral, unbiased, high-quality and trustworthy data. Significant technical challenges such as interoperability, data verification and provenance support, quality and accuracy, decentralised data sharing and processing architectures, and maturity and uptake of privacy-preserving technologies for big data is expected to have a strong impact on the data and their shareability.

In the BDVA position paper of November 2020[4], they envisage as main bottleneck for the exploitation of AI technologies, as primary driver of the data economy, the widespread, secure and effective data sharing. In fact, the success of widespread data sharing activities revolves around the central key concept of *trust*, usually linked to: the validity of the data itself and the algorithms operating on it; in

2 BDVA Strategic Research and Innovation Agenda - https://www.bdva.eu/sites/default/files/BDVA_SRIA_v4_Ed1.1.pdf/

3 Strategic Research, Innovation and Deployment Agenda- AI, Data and Robotics Partnership: https://ai-data-robotics-partnership.eu/wp-content/uploads/2020/09/AI-Data-Robotics-Partnership-SRIDA-V3.0.pdf

4 Towards a European-Governed Data Sharing Space. BDVA Position Paper https://www.bdva.eu/sites/default/files/BDVA%20DataSharingSpaces%20PositionPaper%20V2_2020_Final.pdf/

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the entities governing the data space; its enabling technologies; as well as in and amongst its wide variety of users.

The BDVA in this position paper introduce as possible solution for overcoming those barriers, with the creation of a *European data sharing space*, as a space that is composed of, or connects, a multitude of distinct spaces that cut across sectoral, organizational and geographical boundaries; where the lack of functional and trustworthy data sharing ecosystems that inspire immediate large-scale participation remain one of the main obstacles. In order to overcome it and to achieve the *European data sharing space* vision some developments in some domains will have strong impact. According the BDVA they are: the robust legal and ethical frameworks, governance models and trusted intermediaries that guarantee data quality, reliability, and its fair use, adherence to emerging best practices and standards (e.g., interoperability, provenance and quality assurance standards). In addition, from a technical point of view, data sharing solutions need to better address European concerns like ethics-by-design for democratic AI, and the rapid shift towards decentralized mixed-mode data sharing and processing architectures also poses significant scalability challenges.

2.3 Challenges of the Built Environment – The Twin transition

Achieving climate neutrality in Europe by 2050 is the main challenge to be addressed within the European Commission's strategic vision "A Clean Planet for All"[5], which aims to comply with the Paris Agreement[6] and the United Nations Sustainable Development Goals[7]. According to the EC, this transition is both an urgent challenge and an opportunity to build a better future for all, where all parts of society and economic sectors will play a role (power sector, industry, mobility, buildings, agriculture and forestry). Among them, the building sector represents one of the greatest challenges to be tackled, since it accounts for 38% of total global energy-related CO_2 emissions. Moreover, while global building energy consumption remained steady year-on-year, energy-related CO_2 emissions increased to 9.95 GtCO2 in 2019[8].

In order to address these challenges, the EU has the aim to lead the way by investing into realistic technological solutions, empowering citizens and aligning action in key areas such as industrial policy, finance and research, while ensuring social fairness for a just transition[9]. In particular, it a strong link is established between the move to climate neutrality and a faster digitalisation and accelerated economic and societal changes. Indeed, the progress in digital and industrial technologies shapes all sectors of the economy and society. They transform the way industry develops, produces new products and services, and are central to any sustainable future, and even more so to come out of the current crisis faster.

For these reasons, the European Commission has put into action several initiatives ('New Industrial Strategy for Europe', the Circular Economy Action Plan, digital strategies 'Shaping Europe's Digital Future', 'Data' 'Artificial Intelligence White Paper', among other, see section 2.4) that will contribute to

5 https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52018DC0773
6 https://unfccc.int/sites/default/files/english_paris_agreement.pdf
7 https://sdgs.un.org/es/goals
8 https://globalabc.org/news/launched-2020-global-status-report-buildings-and-construction
9 https://ec.europa.eu/clima/policies/strategies/2050_en

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deliver a green and digital transformation according to European values.

These intentions are specifically salient in the four objectives of the Horizon Europe programme, which will pave the way for research in Europe for the next six years. In particular, special relevance is placed in accelerating the **twin green and digital transitions** towards building a lasting and prosperous growth, in line with the EU's new growth strategy, the European Green Deal.

In order to implement these twin transitions new technologies, investments and innovations will be required. In this context, research and innovation will be fundamental to create the new products, services and business models needed to sustain or enable EU industrial leadership and competitiveness, and to create new markets for climate neutral and circular products.

In this respect, MATRYCS will propose innovative services and analytics that will contribute to supporting numerous building related cases at different scales. Among them, special emphasis will be placed on the **development of digital twins at different scales** (see section 3.2.1). Thus, the research and implementation of support systems proposed by MATRYCS are strongly aligned with the strategic view promoted by the European Commission, by strengthening the links between data and digitisation and the built environment.

2.4 EC Directives, initiatives and reports commissioned by the EC

MATRYCS objectives and results are taking place within and are strategically linked to the European energy efficiency, policy and research frameworks. Apart from the common framework established by the European Green Deal, of particular relevance are hereby the Energy Performance in Buildings Directive (EU) 2018/844 and the Energy Efficiency Directive (EU) 2018/2002, both part of the Clean energy for all Europeans' package.

In 2019, the EU completed a comprehensive update of its energy policy framework to facilitate the transition away from fossil fuels towards cleaner energy and to deliver on the EU's Paris Agreement commitments for reducing greenhouse gas emissions. This package is commonly known as the "Clean energy for all Europeans package".

The Clean energy for all Europeans package consists of eight legislative acts, with four Directives and four Regulations, including texts on the electricity market and consumers, Energy Efficiency and Energy Efficiency of buildings, Renewables & bioenergy sustainability as well as governance of the Energy Union.

The 8 Legislative Acts mentioned are listed below. As some are direct related to MATRYCS, their explanation is already in this section: Energy Performance in Buildings Directive (EU) 2018/844; Renewable Energy Directive (EU) 2018/2001; Energy Efficiency Directive (EU) 2018/2002; Governance of the Energy Union Regulation (EU) 2018/1999; Electricity Regulation (EU) 2019/943; Electricity Directive (EU) 2019/944; Risk Preparedness Regulation (EU) 2019/941; ACER Regulation (EU) 2019/942.

The **European Green Deal**[10] represents one of the six Commission priorities for 2019-2024, aiming to be the first climate-neutral continent by becoming a modern, resource-efficient economy. It is

10 https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en

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structured around three principles: (1) there are no net emissions of greenhouse gasses by 2050, (2) economic growth is decoupled from resource use and (3) no person and no place is left behind. Within this priority, it is worth to highlight the initiative of the Renovation Wave[11], which focuses on boosting building renovation for climate neutrality and recovery.

The **Energy Performance in Buildings Directive (EU) 2018/844** sets specific provisions for better and more energy–efficient buildings. It outlines specific measures for the building sector to tackle challenges and, in summary, its key elements are: low and zero emission building stock in the EU by 2050; Use of smart technologies (intelligent devices); supports the roll-out of the infrastructure for e-mobility; smartness indicator; long term building renovation strategies (requirements for EU Member States to establish comprehensive strategies, set roadmaps for 2050; and carry on a public consultation); mobilizes public and private financing and investment. On the other hand, the **Energy Efficiency Directive (EU) 2018/2002** sets a target of 32.5% for energy efficiency for 2030, compared to a baseline scenario established in 2007, with a possible upward revision in 2023. It also extends energy savings obligations for the next period 2021-2030 and beyond (0.8%/year of total volume sales) and defines new rules on individual metering and billing of thermal energy (clearer and strengthened rules, empowering and informing consumers).

As MATRYCS is a project related to thematic areas such as data, Big Data, Artificial Intelligence (AI) and Internet of Things (IoT), this section presents existing EC directives, regulations and initiatives related to such topics. All the links presented were last accessed in March 2021. A brief description of each of the directives, initiatives and reports and studies commissioned by the EC can be found in Annex I.

Table 1: EC directives and initiatives

EC directive / initiative name	Link
European Strategy for Data (COM(2020) 66)	https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52020DC0066
Proposal for a Regulation on European data governance (Data Governance Act) Nov. 2020	https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020PC0767
White Paper on Artificial Intelligence (COM(2020) 65)	https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020DC0065
Report on the safety and liability implications of Artificial Intelligence, the Internet of Things and robotics (COM(2020) 64) EU	https://eur-lex.europa.eu/legal-content/en/TXT/?qid=1593079180383&uri=CELEX:52020DC0064
Ethics Guidelines for Trustworthy Artificial Intelligence	https://op.europa.eu/en/publication-detail/-/publication/d3988569-0434-11ea-8c1f-01aa75ed71a1
The **Open Data Directive** (Directive (EU) 2019/1024)	https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32019L1024
General Data Protection Regulation (GDPR) (EU) 2016/679	https://eur-lex.europa.eu/eli/reg/2016/679/oj
Open source software strategy 2020-2023	https://ec.europa.eu/info/sites/info/files/en_ec_open_source_strategy_2020-2023.pdf

11 https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1603122220757&uri=CELEX:52020DC0662

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Table 2: Reports and studies commissioned by the EC

Reports and studies commissioned by the EC	Link
EU Building Stock observatory	https://ec.europa.eu/energy/eu-buildings-database_en/
EU Energy Poverty Observatory (ENPOV)	https://www.europeandataportal.eu/en/
European Data Portal	https://www.europeandataportal.eu/en/
De-risking Energy Efficiency Platform ("DEEP")	https://deep.eefig.eu/
ECEEE (European Council for an Energy Efficient Economy)	https://www.eceee.org/library/conference_proceedings/eceee_Summer_Studies/2017/8-monitoring-and-evaluation-building-confidence-and-enhancing-practices/can-big-data-drive-the-market-for-residential-energy-efficiency/
Smart Readiness Indicator for Buildings (SRI)	https://smartreadinessindicator.eu/
LEVEL(s) (The European framework for sustainable buildings)	https://ec.europa.eu/environment/topics/circular-economy/levels_es

2.5 H2020 projects contributing to the MATRYCS landscape

Under this section, a detailed reference of EU research projects (H2020 & FP7) that have potential to contribute to the MATRYCS landscape is presented. The research projects have been categorised by their objectives so as to clear map useful insights per project to take advantage of. The categories that follow refer to projects focusing on data, ICT and energy in buildings. The information provided includes short description along with methodology followed in order to produce tools (where applicable). Finally, the targeted stakeholders are mentioned.

Apart from sister projects (BIGG, BEYOND) and MATRYCS' father project (BuiltHub), other research projects could be used as a baseline for building up MATRYCS methodology in terms of energy in buildings, use of data and ICT insights for the MATRYCS toolbox development.

Table 3: List of EU-funded projects on data, according to the B4E-6 call objectives

EU-funded projects on data	Link
BigDataOcean (Exploiting Ocean's of Data for Maritime Applications)	http://www.bigdataocean.eu
AEGIS (Accelerating EU-US Dialogue for Research and Innovation in Cybersecurity and Privacy)	https://aegis-project.org/
PLATOON (Digital PLAtform and analytic TOOls for eNergy)	https://platoon-project.eu/
MUSKETEER (Machine learning to augment shared knowledge in federated privacy-preserving scenarios)	https://musketeer.eu/

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EU-funded projects on data	Link
INFINITECH (Tailored IoT & BigData Sandboxes and Testbeds for Smart, Autonomous and Personalized Services in the European Finance and Insurance Services Ecosystem)	https://www.infinitech-h2020.eu/
BIGG (Building Information aGGregation, harmonization and analytics platform)	https://www.bigg-project.eu/
BEYOND (A reference big data platform implementation and AI analytics toolkit toward innovative data sharing-driven energy service ecosystems for the building sector and beyond)	Not available yet
BuiltHub (Dynamic EU building stock knowledge hub)	Not available yet
C-TRACK 50 (Putting regions on track for carbon neutrality by 2050)	https://www.c-track50.eu/node/35/
BD4NRG (Big Data for Next Generation Energy)	Not available yet
I-NERGY (Artificial Intelligence for Next Generation Energy)	Not available yet

Table 4: List of other EU-funded projects on ICT (contribution to the development of the MATRYCS modular toolbox

EU-funded projects on ICT	Link
4RINEU (Robust and Reliable technology concepts and business models for triggering deep Renovation of Residential buildings in EU)	https://4rineu.eu/
BREASER (Breakthrough solutions for adaptable envelopes for building refurbishment)	http://www.bresaer.eu/
CYBELE (Fostering Precision Agriculture and Livestock Farming Through Secure Access To Large-Scale Hpc-Enabled Virtual Industrial Experimentation Environment Empowering Scalable Big Data Analytics)	https://www.cybele-project.eu
EnerGAware (Energy Game for Awareness of energy efficiency in social housing communities)	http://energaware.eu
eQuad	https://www.eu.jouleassets.com/
ELISE Energy Location Applications	https://ec.europa.eu/isa2/actions/elise_en
EXCEED (European Energy Efficient building district Database: from data to information to knowledge)	http://www.exceedproject.eu/
ICARUS (Integrated Climate forcing and Air pollution Reduction in Urban Systems)	https://icarus2020.eu/
INSITER (Intuitive Self-Inspection Techniques using Augmented Reality for construction, refurbishment and maintenance of energy-efficient buildings made of prefabricated components)	https://www.insiter-project.eu/

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EU-funded projects on ICT	Link
IRIS (Integrated and Replicable Solutions for Co-Creation in Sustainable Cities)	https://irissmartcities.eu
LinDA workbench semantic component (Enabling Linked Data and Analytics for SMEs by renovating public sector information)	https://linda-project.eu/
Net-UBIEP (Network for Using BIM to Increase the Energy Performance)	http://www.net-ubiep.eu
OptEEmAL (Optimised Energy Efficient Design Platform for Refurbishment at District Level)	https://www.opteemal-project.eu/
OPTIMUS (OPTIMising the energy USe in cities with smart decision support system)	https://www.optimus-smartcity.eu/
PHOENIX (Electrical Power System's Shield against complex incidents and extensive cyber and privacy attacks)	https://phoenix-h2020.eu/
Quantum (Quality management for building performance - improving energy performance by life cycle quality management)	https://www.quantum-project.eu/
Shelter (Sustainable Historic Environments hoListic reconstruction through Technological Enhancement and community-based Resilience)	https://shelter-project.com
SMARTEES (Social innovation Modelling Approaches to Realizing Transition to Energy Efficiency and Sustainability)	https://smartees.eu/
SMARTPARTICIPATE (Empowering smart customers to participate in active demand and energy system efficiency)	https://www.smarticipate.eu/
SOFIE (Secure Open Federation for Internet Everywhere)	https://www.sofie-iot.eu/
THERMOS (Thermal Energy Resource Modelling and Optimisation System)	https://www.thermos-project.eu/
TOREADOR (TrustwOrthy model-awaRE Analytics Data platfORm)	http://www.toreador-project.eu/
Triple-A (Enhancing at an Early Stage the Investment Value Chain of Energy Efficiency Projects)	https://aaa-h2020.eu/
TripleA-reno (Attractive, Acceptable and Affordable deep Renovation by a consumers orientated and performance evidence based approach)	https://triplea-reno.eu/

Table 5: List of other EU-funded projects on Energy / Building (contribution to the development of the analytics building services)

EU-funded projects on Energy / Building	Link
SWIMing (SWIM Technical Infrastructure)	www.swim-h2020.eu/
MORE-CONNECT (Development and advanced prefabrication of innovative, multifunctional building envelope elements for MOdular REtrofitting and CONNECTions)	www.more-connect.eu/

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EU-funded projects on Energy / Building	Link
STREAMER (Semantics-driven Design through Geo and Building Information Modelling for Energy-efficient Buildings Integrated in Mixed-use Healthcare Districts)	www.streamer-project.eu/
BIM4REN (Building Information Modelling based tools & technologies for fast and efficient RENovation of residential buildings)	www.bim4ren.eu/
BIM-SPEED (Harmonised Building Information Speedway for Energy-Efficient Renovation)	www.bim-speed.eu/
ENCORE (ENergy aware BIM Cloud Platform in a COst-effective Building REnovation Context)	www.encorebim.eu/
BIM4EEB (BIM based fast toolkit for Efficient rEnovation in Buildings)	www.bim4eeb-project.eu/
BIMEER (BIM-based holistic tools for Energy-driven Renovation of existing Residences)	www.bimerr.eu/
Pro-GET-OnE (Proactive synergy of inteGrated Efficient Technologies on buildings' Envelopes)	www.progetone.eu/
ASHVIN (Assistants for Healthy, Safe, and Productive Virtual Construction Design, Operation & Maintenance using a Digitial Twin)	http://www.ashvin.eu/
CULTURAL-E (Climate and cultural based design and market valuable technology solutions for Plus Energy Houses)	https://www.cultural-e.eu/
E2VENT (Energy Efficient Ventilated façades for Optimal Adaptability and Heat Exchange enabling low energy architectural concepts for the refurbishment of existing buildings)	http://www.e2vent.eu/
eDREAM (enabling new Demand REsponse Advanced, Market oriented and Secure technologies, solutions and business models)	https://edream-h2020.eu
EEnvest (Risk reduction for Building Energy Efficiency investments)	http://www.eenvest.eu/
ELSA (Energy Local Storage Advanced system)	https://www.elsa-h2020.eu/
Energy in Time (Simulation based control for Energy Efficiency operation and maintenance)	https://www.energyintime.eu/
EnergyMatching (Adaptable and adaptive RES envelope solutions to maximise energy harvesting and optimize EU building and district load matching)	https://www.energymatching.eu/
GROWSMARTER (GrowSmarter: transforming cities for a smart, sustainable Europe)	https://grow-smarter.eu/
Houseful (Innovative circular solutions and services for new business opportunities in the EU housing sector)	http://houseful.eu/
mySMARTLife (Smart Transition of EU cities towards a new concept of smart Life and Economy)	https://www.mysmartlife.eu/mysmartlife/
Success (Strategic Use of Competitiveness towards Consolidating the Economic Sustainability of the european Seafood sector)	https://www.success-energy.eu/
RemoUrban (REgeneration MOdel for accelerating the smart URBAN transformation)	http://www.remourban.eu

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EU-funded projects on Energy / Building	Link
Sinfonia (Smart INitiative of cities Fully cOmmitted to iNvest In Advanced large-scaled energy solutions)	http://www.sinfonia-smartcities.eu/
SmartEnCity (Towards Smart Zero CO2 Cities across Europe)	https://smartencity.eu/

2.6 Common European Digital Platform & Collaborative Networks

The objective of this section is to introduce existing digital platforms and collaborative digital networks in Europe. These entities aim to gather information on good practices and achievements by each centre involved, as well as work in line with other European initiatives. Some have the ultimate goal of defining the future of Europe based on data, and create more transparency and visibility of cutting-edge Big Data research in Europe, while others focus on energy in buildings with the objective of gathering knowledge and fostering exchange and take up of innovative and effective measures. Some of the partners involved in MATRYCS are members of some of them such as BDVA, AI4EU and BUILD UP. These initiatives are important to the MATRYCS project as they provide potential platforms where to discuss topics of relevance to the project and act as catalysts for networking and identifying partners on specific topics.

Table 6: EU digital platforms and collaborative networks

Platform	Short description	Key stakeholders
BUILD UP The European Portal for Energy Efficiency in Buildings (https://www.buildup.eu/)	The BUILD UP initiative was established by the European Commission in 2009 to support EU Member States in implementing the Energy Performance of Buildings Directive (EPBD). It is funded and managed by the Executive Agency for Small and Medium-sized Enterprises (EASME) on behalf of the European Commission. The BUILD UP web portal is intended to reap the benefits of Europe's collective intelligence on energy reduction in buildings for all relevant audiences, encouraging to exchange best working practices and knowledge and to transfer tools and resources.	Professionals working in the building sector with an interest in energy efficiency
European Commission Joint Research Centre European Energy Efficiency Platform (E3P) (https://e3p.jrc.ec.europa.eu/)	The European Energy Efficiency Platform serves as the Commission online platform as described in the Energy Efficiency Directive Article 25. The E3P among other tasks facilitates the practical implementation of the Energy Efficiency Directive at national, regional and local levels, with data collection and analysis. The E3P also supports the exchange of experiences on practices, benchmarking, networking activities, as well as innovative practices. Thematic areas include 'Buildings'. It includes a data hub, a WikEE for sharing knowledge and publications, and a community comprising different working groups.	Energy efficiency experts in a wide range of thematic areas

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Platform	Short description	Key stakeholders
Coalition for Energy Savings (http://energycoalition.eu)	The Coalition for Energy Savings brings together stakeholders with an interest in energy efficiency. It is at the same time a common advocacy platform to promote and mainstream energy efficiency at the European level, a centre of expertise on energy efficiency, and a forum to exchange intelligence on energy efficiency.	Businesses, professionals, local authorities, trade unions, consumer and civil society organisations
Housing Evolutions Hub (https://www.housingevolutions.eu/)	The Housing Evolutions Hub was set up by Housing Europe with support from The European Investment Bank, ARA – the Housing Finance and Development Centre of Finland, the Irish Housing Agency, and the EU Houseful project as part of EU's Horizon 2020 Research and Innovation programme. This on-line platform highlights the latest innovations in the field of social, public, affordable and responsible housing. Additionally, it provides a place for communities of experts and practitioners to share and learn. Among others, it features themes that are relevant for MATRYCS including 'Environment and Natural resource', 'Data and ICT solutions', and 'Construction and Development'	Practitioners and policymakers in the area of housing/energy efficiency/sustainability of buildings and neighbourhoods
Big Data Value Association (BDVA) (https://www.bdva.eu/)	The Big Data Value Association (BDVA) is an industry-driven international not–for-profit organisation with more than 200 members all over Europe and a well-balanced composition of large, small, and medium-sized industries as well as research and user organizations. BDVA is the private counterpart to the EU Commission to implement the Big Data Value PPP program. BDVA and the Big Data Value PPP pursue a common shared vision of positioning Europe as the world leader in the creation of Big Data Value.	Large industries, SMEs, research organisations and data users and providers
AI4EU (https://www.ai4eu.eu/)	The AI4EU consortium was established to build the first European Artificial Intelligence On-Demand Platform and Ecosystem with the support of the European Commission under the H2020 programme. Its activities include the creation and support of a large European ecosystem spanning the 28 countries to facilitate collaboration between all Europeans actors in AI, and the design of a European AI on-Demand Platform to support this ecosystem and share AI resources produced in European projects.	Wide range of actors including scientists, entrepreneurs, SMEs, Industries, funding organizations, citizens…

2.7 Engagement with third-parties

The creation of an engaged community of interested parties ensures the relevance of MATRYCS not only during the project's duration but also to the value generated by its results beyond the project duration.

MATRYCS communication, dissemination and exploitation activities aim the continuous engagement of stakeholders and third parties for identifying and creating synergies. MATRYCS official communication channels (website, newsletters and social media) as well as the development of targeted events such as webinars, workshops, hackathons focus in the increasing engagement of partners and third-parties in order to support the joint exploitation of the project undergoing activities, its results, and as mechanisms for future collaborations. The communication and dissemination plan (D8.1) encompasses the guidelines for a continuous monitoring process in order to

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increase the size of the impacted community and the strategy of engagement between the initial identified target groups and third-parties, including transparent engagement rules to increase collaboration among stakeholders and potential joint work. The same document supports the creation of a community of practice entitled "Buildings Big Data Analytics Alliance" (BDA) to engage individual members of the initial identified target groups and third-parties in order to maximize the exploitation of project results via an active interaction and engagement platform.

MATRYCS encompasses the setup of the BDA as a vibrant data-driven ecosystem for attracting new data hubs and SME service providers, enabling thus EU-wise take-up and replication. The BDA has a view to cross-fertilize MATRYCS activities via liaisons with ICT-oriented Big Data & IoT associations, with standardization bodies, with the other H2020 funded projects, and aiming to achieve a critical mass of members of communities of practitioners, innovators, and SMEs and other key stakeholders in the building sector (local and national governments, etc.) interested to federate for supporting joint exploitation of MATRYCS outcomes. Specific BDA events are planned for M18, M24, M30 (online workshops) and M36 (MATRYCS Market Uptake Launch Event).

The Engagement and Consultation Plan (D8.4) is another instrument of engagement with third-parties and has the key goal of creating a strategy for the execution of MATRYCS' Task 8.3 Community and Ecosystem Building. To ensure that MATRYCS engages with the external world effectively, this plan presents a framework for relevant parties identification; analysis and visualisation of their needs; and stakeholders prioritisation. This plan also defines a method and levels of engagement for the stakeholder groups that will take part in the BDA.

In the IT infrastructure point of view, in order to allow third-parties to consume MATRYCS data, APIs exposed to external services will be specified to allow integration with other platforms.

In addition, in case of licensing agreements with third parties are necessary, issues related to Intellectual Property Rights (IPR) are encompassed in Task 7.1 to avoid any infringement.

Finally, also ensuring proper engagement with third-parties, MATRYCS consortium members will represent the project at external events to increase its visibility and develop synergies with other initiatives. This will include making presentations, disseminating materials, building relations with exhibitors, contributing to peer reviewed conferences and holding exhibition stands in industry/energy innovation events.

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2.8 Stakeholders approach

Stakeholders in MATRYCS drive the needs to be addressed and guide the direction in which big data and analytics should be exploited in order for them to be useful and applicable. This is the reason why special attention is placed to stakeholders and their needs in different contexts surrounding the building's life cycle and scales, which are represented by the Large-Scale Pilots addressed in the MATRYCS project, as it will be later observed.

In general terms, a **Stakeholder** is a party that has an interest in a company (or project) and can either affect or be affected by the business. The primary stakeholders in a typical corporation are its investors, employees, customers and suppliers. However, with the increasing attention on corporate social responsibility, the concept has been extended to include communities, governments, and trade associations[12]. In particular, the International Standard providing guidance on social responsibility, ISO 26000[13], defines a stakeholder as an "individual or group that has an interest in any decision or activity of an organization)". In order to identify who a stakeholder might be, ISO 26000, suggests that the following questions should be asked (in this case, adapted to the MATRYCS project's context):

- To whom does the project have legal obligations?
- Who might be positively or negatively affected by the project's decisions or activities?
- Who is likely to express concerns about the decisions and activities of the project or project results?
- Who has been involved in the past when similar concerns needed to be addressed?
- Who can help the project address specific impacts?
- Who can affect the project's ability to meet its responsibilities?
- Who would be disadvantaged if excluded from the engagement?
- Who in the value chain is affected?

As previously mentioned, stakeholders in MATRYCS are strongly related to the 11 Large Scale Pilots (LSPs) and their main goals, which are classified into four main categories: performance, design, policy and fund. In order to illustrate the contexts surrounding the building's lifecycle and scales (building, district, city, region, nation, EU) addressed by MATRYCS, and, consequently, understand the corresponding stakeholders involved, the following figure is presented:

12 From Investopedia: https://www.investopedia.com/terms/s/stakeholder.asp

13 https://www.iso.org/obp/ui#iso:std:iso:26000:ed-1:v1:en/

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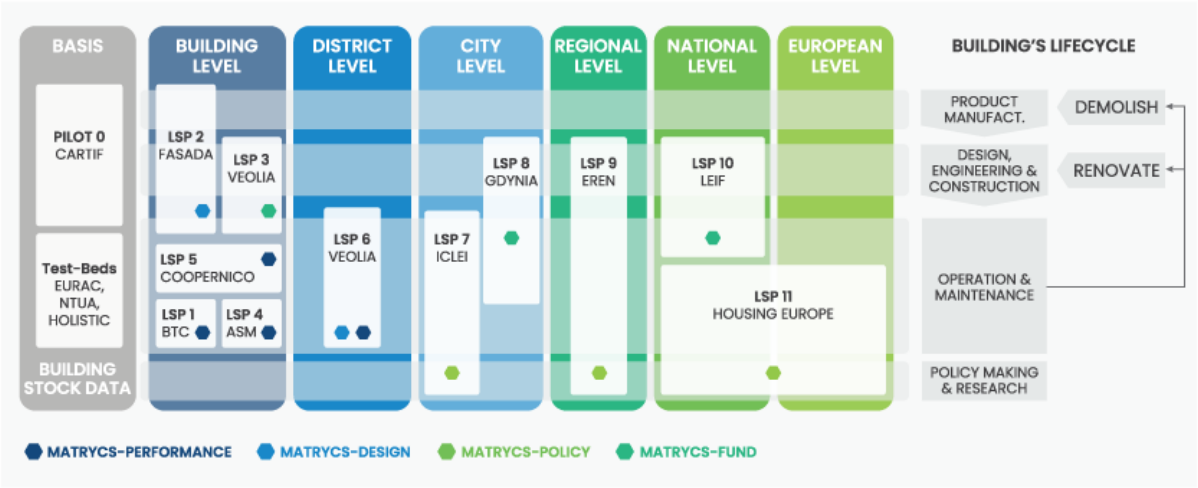

Figure 2: MATRYCS LSPs classification and scope

For the generation of the Stakeholders a process has been carried out as part of Task 2.2 in each of the Pilots. The stakeholders' approach has been developed as a twofold process: firstly, by identifying the Target groups that apply to each Large-Scale Pilot, and then, by assigning different Personas to each of the Target Groups defined.

A **target group** is the group of potential users of the service(s) that is going to be provided by the pilots. They are the stakeholders or other kind of users/beneficiaries from the service. Target groups have been categorised in order to have a common classification and naming that has been refined when pilots provided their inputs. The classification is aligned with the first classification of stakeholders of BuiltHub father project, in order to have common insights and make alignments with it since the very beginning. The classification is also aligned with the building value chain, defined both in 'Driving Transformational change in the construction value chain' from BPIE[14] and in the 'Energy-efficient buildings: multi-annual roadmap for the contractual PPP under horizon 2020' from the ECTP[15].

Personas are fictional characters created to represent the needs, wants and behaviours of the target groups to ensure that we are thinking from their perspective. Each Persona captures a different point of view of each target group. Thus, for each target group several personas or characters can exist.

Table 38: MATRYCS Stakeholder approach: Target groups and Personas in Annex V presents the final classification of target groups and the different Personas that have been assigned to them by pilot leaders. Personas from each LSP are deeply analysed by considering their context, goals and pains in the section of Pilots (Section 5.1.1), and it is the common thread also to Part II of this deliverable (user stories analysis).

14 Driving transformational change in the construction value chain, BPIE, 2016. https://bpie.eu/wp-content/uploads/2016/01/DrivingTransformationalChangeCVC2016.pdf

15 http://ectp.ectp.org/cws/params/ectp/download_files/36D2981v1_Eeb_cPPP_Roadmap_under.pdf

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3 Big Data for Building: MATRYCS – Landscape

The landscape surrounding the MATRYCS project is analysed from two different perspectives. First and foremost, by understanding what the current practices are. To this end, section 3.1 presents the current challenges faced in the context of each of the 11 MATRYCS Large-Scale pilots and how they are currently addressed with existing technologies, tools, methodologies or procedures. These are grouped into four categories, namely, those related to: (1) increasing performance in buildings, (2) improving design capabilities, (3) policy making and (4) funding retrofitting actions.

To complement this vision, section 3.1, provides potential technological solutions that could address the identified challenges. First of all, the focus is placed on the digital building twin, to support the green and digital transition the European Commission is aiming for (section 3.2.1) and some platforms for the built environment are presented (section 3.2.2). Then, analytics for the built environment and related technologies are explained in section 3.2.3. These are classified and aligned with the categories of services to be provided within MATRYCS, namely, (1) analytics for energy performance, (2) building design and related infrastructure, (3) policy making and policy impact assessment, (4) de-risking investments in energy efficiency and (5) geo-clustering as support to the big data vision.

3.1 Existing technologies, tools, methodologies and procedures in real environments

This section aims at providing a description of the current methodologies, workflows and technologies deployed by the **final users** (the stakeholders represented in the Large-Scale Pilots) for offering the operations/services covered by the pilots, as they are performed right now (**business as usual**). It will set a **starting point** to later on delve into innovative technologies in section 3.2.

As abovementioned, this section is divided into four subsections, which are related to specific large-scale pilots, as it can be seen below. For a clearer picture of the large-scale pilot structure, please refer to Figure 2: MATRYCS LSPs classification and scope.

- **Section 3.1.1** presents applications and cases related to **increasing performance in buildings**. It is linked to four LSPs in MATRYCS: **LSP1** on **building operation** (facility and resources fingerprinting for efficiency and optimal balancing of energy vectors), **LSP4** on **smart buildings as active nodes of a smart grid** (smart building comfort-aware predictive energy management and coordination with smart grids and local res generation), **LSP5** on **energy communities** (services for the better management of self-production systems) and **LSP6** on **operation of district heating networks** (energy demand prediction to optimize the operation).
- **Section 3.1.2** introduces applications and cases related to **improving design capabilities**. It is linked to two LSPs in MATRYCS: **LSP2** on **building refurbishment** (sustainable building assessment and optimization of refurbishment options) and **LSP6** on **design of district heating networks** (energy demand prediction to optimize the operation).

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- **Section 3.1.3** presents applications and cases related to **policy making**. It is directly related to three LSPs in MATRYCS: **LSP7** on **Sustainable Energy and Climate Action Plans (SECAPS)** (services to support SECAPs impact assessment, implementation and monitoring, **LSP9** on **Energy Performance Certificates** (next generation energy performance assessment and certification) and **LSP11** on **policy making and impact assessment** (data-driven policy making and policy impact assessment for energy-efficient buildings).
- **Section 3.1.4** shows applications and cases related to **funding energy efficiency retrofitting actions**. Three LSPs are linked to these applications: **LSP3** on **ESCO support services** (energy saving verification for increasing trust on energy performance contracts), **LSP8** on **one-stop-shops** (enablers of the financing of refurbishment actions in the building stock at local level) and **LSP10** on **de-risking energy efficiency investments** (reliable, cost-effective and better-quality energy performance contracts and investments).

3.1.1 Applications and cases related to increasing Performance in Buildings

Buildings performances have gained a great importance in social energy and environmental management, in particular with regard to the waste management, waste water and air, effective and rational use of energy. The possibility of monitoring and controlling the air and water conditioning systems and lighting in a near real time way allows new sophisticated techniques to achieve relevant increase in energy performances. The RES penetration has also highlighted new paradigms in energy management, with the opportunity to produce and consume energy locally. Big Data and Machine Learning techniques can play a key role in facing these new challenges.

3.1.1.1 LSP1: BUILDING OPERATION: Facility and Resources Fingerprinting for Efficiency and Optimal Balancing of Energy Vectors

The BTC d.d. is one of the leading commercial property development companies in the Central and Southeastern Europe. The company is managing a range of business, commercial and recreational, entertainment and cultural activities with wide range of logistics services. With its content and scope, it is classified as one of the largest business centers in Europe, covering an area of approx. 475.000 m^2 and combining more than 450 shops, market, water park, sport center, casino etc. Currently, the company has more than 350 employees, who take care that work processes and services are conducted smoothly. It is aware of the great importance of energy and environmental management and devotes special emphasis to waste management, wastewater and air, effective and rational use of energy. The BTC has already established its quality management system according to EN ISO 9001:2008, environmental management system according to EN ISO 14001:2015, energy management system according to EN ISO 50001:2018 and asset management according to EN ISO 55001:2014.

BTC also runs a logistic service business unit, which holds the leading market position in FMCG logistics in Slovenia. It also provides first-class property management services for the largest Slovenian clients in the commercial real estate service sector.

LSP 1 includes three facilities: the Business tower BTC City, which is entirely occupied by tenants of business premises, the Atlantis water park, which consists of indoor and outdoor pools, various saunas

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and water attractions and the Logistics center, which consists of warehouses and cold storages. All facilities have different control systems.

The Business tower BTC City is equipped with several air handling units (AHU) that are used to regulate and circulate air as part of a heating, ventilating, and air-conditioning system (HVAC) and chillers. Operation of room convectors and lighting are controlling by two different BMSs. In the old BMS temperatures in premises are controlled by room thermostats. It also includes modules for controlling of indoor lighting. The new BMS is responsible for the control of AHU units, chillers, a heating sub-station and a backup power supply. Separately from the BMSs, there is also an energy management system (EMS). EMS collects data from electricity meters and from calorimeter in the heating sub-station. The access control system is also installed in the building and it is used to control and monitor access to the premises and record working time of employees. The operation of AHU and chillers are controlled by temperature and humidity sensors and through operating schedules that are set on day and night mode. Facility manager monitors devices included in BMS on a daily basis. Tenants have also an option of fine-tuning of the desired room temperature. In the event of system failures BMS notifies facility manager via E-mail and SMS. Unfortunately, there is no energy consumption data in the BMS. The data from the EMS is used for monitoring and targeting and determining deviations in the operation of devices using M&T diagrams, which are built into the EMS. Additionally, data from the EMS is used for the monthly evaluation of energy costs and their breakdown per tenant. Unfortunately, there are no links between BMS, EMS and access control data.

The Atlantis Water Park has also a separate BMS, EMS and access control system for visitors. The BMS manages swimming pool equipment, AHU, heating sub-stations and lighting. The BMS collects data from various sensors and it is responsible for the execution of the operating schedules that are set by the facility manager. It also provides notifications in the event of errors. Once again there is no energy consumption data in the BMS. In the EMS are included electricity meters, billing calorimeters and water consumption meters. The data from the EMS is used for monitoring and targeting and determining deviations in the operation of devices using M&T diagrams, which are built into the EMS. Access control system is used to control and monitor access to the water park and contains the data about the number of visitors in each part of the water park. Unfortunately, there are no links between BMS, EMS and access control data.

The Logistics center is the third element of the BTC d.d. that is included in the MATRYCS project. Unfortunately, only cold storages are equipped with BMS. BMS is used for operation of refrigeration units and for control of temperature in the refrigeration chambers. The area is partially covered by EMS and there is no energy consumption data in BMS. In EMS electricity consumption in warehouses and cold storages is monitored. Also, a part of warehouse heating and water consumption is included in the EMS. Access control system is responsible for monitoring and control of the access in the warehouses. There is also a warehouse management system (WMS) which is responsible for the planning and management of the warehouse occupancy. Within the WMS the data about the occupancy of pallet places is available. Unfortunately, there are no links between BMS, EMS, WMS and access control data.

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Table 7: LSP1 – Building Operation Applications

LSP1: Necessities, actors, methods and procedures, and main difficulties encountered		
Necessity addressed	Creation of reliable implementation action plans for identified energy efficiency and facility management measures	
Actors involved and process followed	**Facility Manager**	Need to connect existing systems (BMS, EMS, Access control system, Warehouse management system)
	Energy Manager	Creation of the model for the calculation of the key performance and sustainability indicators for all identified/implemented energy efficiency and facility performance improvement measures
	Owner	Creation of the model for the calculation of the environmental footprint for all identified/implemented energy efficiency and facility management measures
		Definition of the cost-effectiveness selection criteria
		Definition of additional selection criteria and requirements for the pre-feasibility analysis of the selected performance improvements
Methods, tools, procedures deployed in BaU practice		BMS, EMS, Access control system and Warehouse management system
Main difficulties encountered	The main goal of the BTC is to enable integration of available data and enrichment of the energy consumption with information about its context – this will the basis for the identification of energy profiles and optimisation. Regarding the data acquisition and processing BTC wants to shift from single to multi-purpose use of data. Calculation of new KPIs (for example smart readiness indicators), advanced visualisation and better performance monitoring system is vitally important for the facility and energy managers. Pilot actions and verification of performed actions (energy savings, maintenance, flexibility, etc.) is important for all identifies users.	
Necessity addressed	Creation of the reliable list of potential energy efficiency and flexibility projects that can implemented through energy performance contracting	
Actors involved and process followed	**Utility**	Model/software for pre-feasibility analysis of selected projects
	ESCO	Definition of the selection criteria (energy efficiency, money savings, user comfort, etc.)
	Facility Manager	Creation of the model/procedures for the follow-up of selected projects
	Energy Manager	Preliminary identification of potential energy efficiency and flexibility projects through regular energy management operations and periodical energy auditing activities. Creation of the model for the preliminary evaluation and verification of selected projects based on energy efficiency and flexibility potential.
Methods, tools, procedures deployed in BaU practice		BMS, EMS, Access control system and Warehouse management system

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LSP1: Necessities, actors, methods and procedures, and main difficulties encountered	
Main difficulties encountered	Existing data management is not enabling Utility or ESCO to identify energy efficiency and flexibility projects that are suitable for energy performance contracting on a selected Building This is also connected with the main goal of the BTC and requires integration of available data and enrichment of the energy consumption with information about its context – this will the basis for the identification of energy profiles and optimisation and the first step in creation of the potential portfolio of projects that are suitable and interesting for the Utility or ESCO (energy efficiency, DSM, flexibility, etc.).

3.1.1.2 LSP4: SMART BUILDING AS ACTIVE NODE OF A SMART GRID: Smart building comfort-aware predictive energy management and coordination with smart grids and local RES generation

The ASM headquarter presents a Smart Building that aims to perform a building comfort-aware predictive energy management and coordination with smart grids and local RES generation. The ASM headquarter is becoming an active node for the medium voltage distribution system and the main goals of this pilot are the following:

- Building management optimization: improve the capability to deploy optimal comfort-aware building energy consumption management services
- Operational efficiency: the local smart distribution grid needs to be coordinated with the building consumption
- Decentralized grid management: optimization of building management to exploit RES generation

The ASM pilot will show its capability to act as an active node in relation with the achievement of the Effectiveness of energy consumption prediction, building occupants comfort prediction, local RES generation prediction and weather forecasting, the reduction of reverse power flows, the improvement of building and smart grid coordination, the optimization of building energy consumption.

Table 8: LSP4 – Smart Building as active node of a Smart Grid

LSP4: Necessities, actors, methods and procedures, and main difficulties encountered		
Necessity addressed	Improvement of the air conditioning and lighting systems so that workplace conditions can be improved through a new innovative system.	
Actors involved and process followed	**Citizens and owners**	Definition of the most important variables. Collection of comfort level considerations by the office employees.
	Utilities	Creation of the air conditioning and lighting systems models. Data analysis based on historical data. Evaluation of new set points for increasing the performances. Data collection related to the optimised systems. Report about the pre and post comfort conditions.

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LSP4: Necessities, actors, methods and procedures, and main difficulties encountered		
Methods, tools, procedures deployed in BaU practice		Data analysis software and interaction with BEMS.
Main difficulties encountered	The subjective feature of employees comfort level makes the set points individuation harder. The ethical and personal aspects will assume an important role in the success of the MATRYCS Services	
Necessity addressed	Need to have an investment plan to implement a new system of monitoring and control	
Actors involved and process followed	**Utilities**	Recognition of DSO Head needs. Individuation of the suitable technical solutions. Implementation of a test case of the selected system. Data acquisition and analysis. Economic aspects investigations. Redaction of the investment plan.
Methods, tools, procedures deployed in BaU practice		Technical-economic analysis software and interaction with SCADA.
Main difficulties encountered	The economic aspects are fundamental for the Utilities to invest in innovative systems. The investment plan shall be accurate in order to instil a positive approach to the MATRYCS Services.	
Necessity addressed	Necessity of minimization of the congestions in a district related to the increase of EVs. so that I have a charging sessions rescheduling infrastructure to manage the power flows	
Actors involved and process followed	**Citizens and owners**	Model elaboration of EVs charging sessions shifting to minimize reverse power flow. Infrastructure upgrade to manage charging sessions
	ESCO	Data analysis related to the EVs absorption and to the reverse power flow. Charging sessions shifting test to reduce inverse power flow. Evaluation of the shiftings strategy benefits with the production and consumption prediction of the asset. Report on the minimization of revers power flow.
Methods, tools, procedures deployed in BaU practice		Data analysis software and interaction with smart meters.
Main difficulties encountered	A critical issue is related to the forecasting technique reliability which can affect the effective congestion resolution.	
Necessity addressed	Deep analysis of the energy models and increase the energy efficiency of customers.	
Actors involved and process	**Citizens and owners**	Data analysis about the energy performances of Energy Manager client.

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LSP4: Necessities, actors, methods and procedures, and main difficulties encountered		
followed	**ESCO**	Forecasting technique implementation in order to simulate the future profiles. Infrastructure upgrade to better monitor the energetic variables. Evaluation of the energy performances in the various types of technical solutions. Report on the benefits of each type of solution.
Methods, tools, procedures deployed in BaU practice		Data analysis software and interaction with smart meters.
Main difficulties encountered	The main difficult consists of modelling customer energy behaviour and consequently identifying the better management strategy, in order to increase the energy performances.	

3.1.1.3 LSP5: ENERGY COMMUNITIES: Services for the better management of self-production systems

At present, most European electrical system are in the process of digitalization: citizens and SME are starting to access more information about their consumption data. However, there is still a lack of available instruments for small consumers to analyse these new available data to extract insights to better manage citizens' and SMEs' energy assets, both consumption and production sides. Currently, the market focuses on delivering energy service solutions for big clients, leaving behind a significant share of population and buildings stock.

The LSP5 will involve 850 citizens, of which at least half will be Coopérnico's members and a third prosumers. This pilot will aim to collect all available information – including EPCs, consumption and production profiles, weather data and more – to provide tools that can help small consumers, citizens and SMEs, improve their energy efficiency standards and better manage their energy assets.

Additionally, due to the on-going transposition of the REDII directives, European legislators are now paving the way to allow consumers to organize collective self-consumption or Renewable Energy Communities (RECs) projects. Linking to these new developments, the LSP5 will explore solutions to foster collaborations between local energy consumers to support the creation of new RECs and collective self-consumption projects.

Table 9: LSP5 – Energy Communities

LSP5: Necessities, actors, methods and procedures, and main difficulties encountered		
Necessity addressed	Increase efficiency of current energy assets	
Actors involved and process followed	**Prosumer**	(1) Contacting Energy companies, energy experts (2) web research/self-made solution
	EV Owner	
Methods, tools, procedures deployed in BaU practice		Web, excel, calculator

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LSP5: Necessities, actors, methods and procedures, and main difficulties encountered		
Main difficulties encountered	(1) Resource intensive (Expensive, time-consuming) (2) analysis performed by private entities → lack of trust (3) lack of transparency when sharing private data	
Necessity addressed	Identity energy efficiency opportunities	
Actors involved and process followed	**Environmentally-conscious Citizen**	(1) Contacting Energy companies, energy experts (2) web research/self-made solution
	Eco-Friendly SME	
Methods, tools, procedures deployed in BaU practice		Web, excel, calculator
Main difficulties encountered	(1) Resource intensive (Expensive, time-consuming) (2) analysis performed by private entities → lack of trust (3) lack of transparency when sharing private data	
Necessity addressed	Collaborate with local entities to foster collective improvements in management of local energy assets (existing or new ones)	
Actors involved and process followed	**Prosumer**	New possibility introduced by the concept of collective auto-consumption/REC – no mature market/solutions yet
	EV Owner	
Methods, tools, procedures deployed in BaU practice		
Main difficulties encountered	(1) Lack of knowledge about regulation (2) lack of technical skills to quantify benefits (3) lack of channels to connect with potential "partners"	
Necessity addressed	Map local electricity consumption to identify citizens in energy poverty condition	
Actors involved and process followed	**Local Authority**	Research study performed by university/research entities
Methods, tools, procedures deployed in BaU practice		Sample home audit, literature reviews, reports…
Main difficulties encountered	(1) expensive (2) static view – only show the situation of a fixed period of time (3) long time to be performed	

3.1.1.4 LSP6: DISTRICT HEATING NETWORK: Energy Demand Prediction to optimize the operation

The optimized operation of thermal facilities is a key aspect to achieve the required comfort levels for the consumers in the most effective way; this means, with the minimum energy consumption, reducing both the costs and the environmental impact. Being able to foresee the energy demand, the facility manager would be able to adapt the operational modes in order to achieve the most efficient operation for the facility. An accurate energy demand prediction would have other positive side effects, as easing the predictive maintenance of the facility (avoiding or reducing unexpected breakdowns) and anticipating the acquisition of biomass, among others.

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LSP6 will be represented by Torrelago DH, a biomass-based district heating network that provides heating and DHW to near 4.500 people in Laguna de Duero (Spain). A total of 1.482 dwellings in 31 buildings are connected to the network, which is fed by two separate boiler rooms. This DHN has been recently renovated and now the facility is monitored at district, building and home level.

One boiler room has 3 gas boilers with a total capacity of 8,7 MW. Its main work nowadays is to support the biomass-based boiler room, covering the consumption peaks and providing flexibility to the facility.

The other boiler room has 3 biomass boilers with a total capacity of 3,4 MW. It is fed with wood chips and covers 80% of the total energy consumption of the facility.

Facilities of this size generate a high amount of data and require continuous data inputs of different typologies to operate. They need baseline data (static), monitoring data (dynamic) and weather data (dynamic).

Table 10: LSP6 – District Heating Network

LSP6: Necessities, actors, methods and procedures, and main difficulties encountered		
Necessity addressed	DHN operation and optimization	
Actors involved and process followed	**Owner**	Identify discomfort. Provides feedback to the facility manager.
	Facility manager	Analyse the defined KPIs to identify if the facility is underperforming. To analyse the existing monitoring data to identify possible parameters that may be improved. Study different operational modes that may improve the performance or the operation of the DHN. Test the preferred solution and check if it improves the operation of the facility.
Methods, tools, procedures deployed in BaU practice		**Owner:** Continuous communication with the facility manager **Facility manager:** DEMS, BEMS, HEMS, Data bases with historical monitored data, Excel based models
Main difficulties encountered	**Owner:** Does not have knowledge about energy efficiency. **Facility manager**: Insufficient monitoring data, inaccuracy in the predictions of the effectiveness of the operational modes, difficult to test the different solutions proposed.	
Necessity addressed	M&V of energy savings	
Actors involved and process followed	**Owners**	Requires checking the energy savings obtained due to an intervention or a change in the operational model.
	Facility manager	Implements energy efficiency measures. Implements a M&V protocol (e.g. IPMVP) to prove the effectiveness of the implemented measures. Shows and explains the results to the owners and investors.
	Investor	Analyse the profitability of the investment. Propose the most suitable financial options to the owners.

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LSP6: Necessities, actors, methods and procedures, and main difficulties encountered	
Methods, tools, procedures deployed in BaU practice	**Owners:** Continuous communication with the facility manager **Facility manager & Investor:** DEMS, BEMS, HEMS, Data bases with historical monitored data, Excel based models
Main difficulties encountered	**Owner:** Does not have knowledge about energy efficiency **Facility manager:** Insufficient baseline data. **Investor:** It is not an expert in energy efficiency, uncertainty about the return the investment.

3.1.2 Applications and cases related to improve Design capabilities

Application and cases to support the design process are related with the monitoring and improvement of the energy efficiency of buildings (with a view to refurbish them). In order to reduce energy consumption in buildings, the most efficient renovation scenario fulfils requirements of the investor and is adjusted to the technical building features and possibilities need to be selected. The energy requirements for new buildings have been constantly tighten up, therefore new buildings today use far less energy than old ones. Moreover, buildings have a very long life – often 100 years or more and the vast majority of the buildings that exist todays will be still in use in 2050. Energy renovation should be a means of improving and developing buildings to meet the needs and challenges of the future and of making home-owners and tenants less vulnerable to rising energy costs in the future. There also needs to be a shift in the energy supply to these buildings from fossil fuels to renewable energy. Energy renovations also help to increase the utility value and quality of buildings, as they can improve the indoor climate and daylight conditions, making the buildings healthier and better to live and work in. Energy renovations also need to take account of the architectural value of the buildings. In many cases, energy renovations will actually mean an architectural improvement to the buildings. Finally, energy renovation plans need to take account of the environmental objectives for reuse and sustainability in the building industry[16].

3.1.2.1 LSP2: BUILDING REFURBISHMENT: Sustainable building assessment and optimisation of refurbishment options

Building refurbishment aims to protect the building from heat loss and to drastically reduce the energy consumption needed to heat the building and to heat the water. In the vast majority of cases, excessive heat loss is one of the reasons for the high operating costs of buildings. These are the result of poor insulation of external walls, leaky windows and insufficiently efficient heating systems. That is why many buildings need to be renovated (in some cases need to go under the deep-renovation). Renovation activities contribute to reduction of the energy demand of a building. Building refurbishment concerns already existing buildings, which due to their age and technical condition do not meet modern requirements. What is important, renovation is carried out not only in buildings that are several dozen years old, but also in those several years old. This is caused by the fact that before, the regulations were not as strict as they are now, and the construction process was focused on savings rather than heat loss aspects.

16 Strategy for energy renovation of buildings, The route to energy efficient buildings in tomorrow's Denmark, May 2014, Danish Government

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Old buildings often do not have actual building documentation, therefore the first step that is done by the building owner or the company that manage the building is performance of building survey in order to have digital as-built building documentation. It is often done with the use of laser rangefinder or 3D laser scanning.

Building refurbishment is not a cheap undertaking, so to be sure that the money spent on it will translate into concrete results, it is best to conduct an energy audit of the building. The energy audit will give the answer what is the current technical condition of the building and its installations. The auditor will perform an energy performance and indicate the elements to be improved with an indication which of them will give the best effect. This is important when building refurbishment cannot be carried out comprehensively for financial reasons. An important part of the energy audit is the economic evaluation of planned investments. In general, the energy audit is the first step that is undertaken by the building owners in the building refurbishment process. During the energy audit, the auditor provides minimum thickness of the insulation and material specification so that the building after renovation fulfils all the national thermal requirements. For example, the auditor checks if the maximum thermal transmittance value (U W/m^2K) for external walls will be fulfilled. This process needs to be done for all the main building components that will be refurbished (e.g., roof, basement walls, external walls, doors, windows). The energy audit is done based on the as-built building documentation and visual inspections.

Next step is the performance of the renovation design. The design needs to be performed by the architect and in general it is based on the results of energy audit. The designers select the specific technical system that will be applied and performs 2D drawings (in digital format). Also the designer needs to adjust the design to the fire safety issues, wind and snow loads.

The most common interventions on the building are:

- Insulation of the basement walls
- Insulation of the external walls above the ground
- Change of windows
- Roof insulation
- Modernisation of the heating system and installation of the renewable sources
- New ventilation system

It needs to be highlighted that the process of the refurbishment of various type of the building differs. When it comes to the residential buildings, the cost is the most important criteria and often the cheapest types of system are chosen. While in the office building, the investor is often willing to invest in more durable and better-quality solutions.

After the renovation design is ready, the building owner or the company that operates and manage the building is looking for the contractor for making the renovation. Here the criterion for selection of the contractor is price. After acceptance of the offer of the contractor, the company (mainly SMEs) start to perform the renovation activities. At the end the renovation work needs to be commissioned by the Investor. Often in this process the representative of housing association also participates.

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Table 11: LSP2 – Building Refurbishment

LSP2: Necessities, actors, methods and procedures, and main difficulties encountered		
Necessity addressed	Developing BIM models or digital twin	
Actors involved and process followed	**Management staff of educational buildings in the City of Gdynia**	Normally the BIM is not used by the investor due to the high cost of obtaining it. In order to have the building geometry, the digital as built-building documentation in CAD is ordered.
	Designers/ Architects	Based on the energy audit and digital as-built 2D documentation, the architect develops the design and he/she proposes concrete technical solutions
Methods, tools, procedures deployed in BaU practice		Autocad, adobe, Revit
Main difficulties encountered	**Management staff of educational buildings:** No actual and digital documentation for the buildings. **Designers**: Problems with the access to the most actual information about the building and proposing the most efficient renovation scenario (incl. Scenario for NZEB). Designer needs CAD drawings of the building (information about the geometry) and information about thickness and thermal properties of the materials that need to be used.	
Necessity addressed	Selection of the renovation scenario	
Actors involved and process followed	**Designers/ Architects**	Designer/Architect specifies the technical solution based on the energy audit and guidelines from the investor. No analysis of LCC is done only the initial purchase cost is considered.
Methods, tools, procedures deployed in BaU practice		Simple software's and excel adjusted to polish regulation for energy consumption by buildings, Autocad, no tools for matching results of the building monitoring with BIM model
Main difficulties encountered	The architect/designer chooses the most typical renovation solutions.	

3.1.2.2 LSP6: DISTRICT HEATING NETWORK: Energy Demand Prediction to optimize the operation

This pilot will aim to study and analyse the actual DHN in order to develop an accurate model that helps to define the optimal ECMs to be implemented and to refurbish the installation like, for example, update parts of the current system or modify the boilers rooms, and therefore increase de EE. Also, it will seek to survey to implement a new branch so as to connect other buildings to the existing DHN.

More details about the LSP6 are provided in the section 0 (LSP6 related to MATRYCS-PERFORMANCE).

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Table 12: LSP6 – District Heating Network

LSP6: Necessities, actors, methods and procedures, and main difficulties encountered		
Necessity addressed	Implementation of ECMs	
Actors involved and process followed	**Owners**	Recognise a necessity (discomfort or want to save energy). Discuss with ESCO the different possible ECMs that may be implemented. Analyse the cost effectiveness of the different ECMs and choose the most adequate.
	Facility manager	Identify a possible improvement in the facility. Analyse the efficiency of different ECMs. Propose the most interesting ECMs to the owners, attending to different criteria (cost effectiveness, energy consumption reduction, GHG emissions reduction…), and help them decide the most suitable one. Implement the chosen ECM.
	Designer	Help facility manager to evaluate the possible measures that may be implemented to improve the operation of the facility. Define the final solution to be implemented.
	Investor	Analyse the profitability of the measures to be implemented. Propose different financial options.
Methods, tools, procedures deployed in BaU practice		DEMS, BEMS, HEMS, Data bases with historical monitored data, Excel based models
Main difficulties encountered	**Owners**: Lack of knowledge about energy efficiency, lack of trust in the ESCO, unable to cover the upfront costs of the implementation. **Facility manager**: Insufficient monitoring data, inaccuracy in the impact analysis of the ECM. **Designer**: insufficient monitoring data **Investor**: it is not an expert in energy efficiency, may encounter difficulties with linking energy savings to economic savings, uncertainty about the return the investment.	
Necessity addressed	Implementation of a new DHN branch to connect new buildings	
Actors involved and process followed	**Owners of the dwellings**	Recognise a necessity (discomfort or want to save energy). Discuss with ESCO the different possible solutions, including renovation of the thermal facility or the connection to the DHN. Analyse the cost effectiveness of the solution.
	Facility manager	Identify a possible expansion of an existing DHN within a group of buildings. Analyse the possibilities and choose the most interesting ones attending to different criteria (profit, cost, management, feasibility…). Implement the new branch and connect the buildings to the DHN.

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LSP6: Necessities, actors, methods and procedures, and main difficulties encountered		
	Designer	Help facility manager to evaluate the possible different options for the intervention. Define the final solution to be implemented. Design the new DHN branch.
	Investor	Analyse the profitability of the intervention. Propose different investment options.
	Public body	Study the proposed intervention. Issue the different permits.
Methods, tools, procedures deployed in BaU practice		DEMS, BEMS, HEMS, Data bases with historical monitored data, Excel based models
Main difficulties encountered		**Owners of the dwellings:** Lack of knowledge, lack of trust, no capacity to cover the upfront costs. **Facility manager:** Insufficient historical data of the new buildings to be connected, physical difficulties to connect a building to the DHN, permits and licenses. **Designer:** Little information about the new buildings to be connected, physical obstacles to deploy the new branch of the DHN. **Investor:** Not an expert about EE, difficulties with linking the economic with the energetic benefit; uncertainty about the return the investment. **Public Body:** Slow management of the permits.

3.1.3 Applications and cases related to Policy making

The applications and cases to support policy making are focused on tree different scales: Sustainable Energy and Climate Action Plans (LSP7), Energy Performance Certificates (LSP9) and impact assessment of EU policies for buildings (LSP11).

3.1.3.1 LSP7: SECAPS: Services to support SECAPs impact assessment, implementation and monitoring

Currently, the most common framework used by local & regional governments to develop their Sustainable Energy and Climate Action Plans (SECAP) is provided by the Covenant of Mayors for Climate and Energy (CoM), the mainstream European voluntary movement involving local authorities in the development and implementation of sustainable energy and climate policies. This guideline is presented in form of a document and provides signatories with a set of methodological principles, procedures and best practices for cities and regions to develop their SECAP. The document is available on the European Commission website (EU SCIENCE HUB: The European Commission's science and knowledge service) and it is divided three parts:

- Part 1 relates to the SECAP process: a step-by-step guide towards low carbon and climate resilient cities by 2030;
- Part 2 provides an insight on the elaboration of municipality assessments: Baseline Emission Inventory (BEI) and Risk and Vulnerability Assessment (RVA);

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- Part 3 describes technical issues, measures and policies that can be implemented at local level: policies, key actions, good practices for mitigation and adaptation to climate change and financing SECAP(s).

Additionally, in order for cities and regions to annually report their data about Climate Adaptation and Mitigation Plans, GHG emissions inventories, policies and regulations about energy efficiency, among other topics related to sustainable energy and climate policies, platforms such us My Covenant/EU Mayors and/or the ICLEI Unified Reporting System can be used.

Table 13: LSP7 – SECAPs

LSP7: Necessities, actors, methods and procedures, and main difficulties encountered		
Necessity addressed	Development of Sustainable Energy and Climate Action Plan (SECAP)	
Actors involved and process followed	**Local & Regional Government Urban development professional**	Key elements to developing a SECAP are: • Formal adoption of the plan by the municipal council or equivalent decision-making body; • Definition of clear mitigation and adaptation target(s) / goal(s); • Assessment of the local situation based on BEI and RVA; • measures addressing the key sectors of activity – as identified on BEI and RVA; • Definition of strategies and actions until 2030, mobilization of internal departments, citizens and stakeholders involved; Financing acquisition, when applicable.
	Policy-makers at any level	Need of political and technical information for promoting the SECAP among other policy-makers willing the approval and adoption of the policy package.
Methods, tools, procedures deployed in BaU practice		**Local & Regional Government Urban development professional:** Guidebook 'How to develop a Sustainable Energy and Climate Action Plan (SECAP)', developed by the Covenant of Mayors for Climate & Energy (CoM) and available at the European Commission website **Policy-makers at any level:** No technologies applied; procedures can vary according to government (e. g. type of government, political party, country are variables that influence the SECAP development and adoption process).
Main difficulties encountered	**Local & Regional Government Urban development professional:** Lack of reliable data; Lack of in-house expertise; Hiring external service providers is sometimes bureaucratic and expensive. **Policy-makers at any level:** Discussion process among policy makers, experts and citizens is long and approval process by council/decision-making body is sometimes bureaucratic	

3.1.3.2 LSP9: ENERGY PERFORMANCE CERTIFICATES: Next generation energy performance assessment and certification

The Spanish regulation sets up the obligation to make available to buyers or users of buildings an energy performance certificate (EPC) which shall include objective information on the energy performance of the building and reference values such as minimum energy performance requirements,

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so that owners or tenants of the building or a unit of it, can compare and assess its energy performance. In this way, by assessing and comparing the energy performance of buildings, the promotion of energy-efficient buildings and investments in energy savings will be encouraged. In addition, it contributes to reporting CO2 emissions from residential sector, which will facilitate the adoption of measures to reduce emissions and improve the energy rating of buildings.

The implementation of the EPCs for the different member states are based in the same European directive (EPDB) but this directive let certain autonomy for each organism, so EPCs datasets for different region and members are not entirely the same. Specifically, in Spain the Energy Performance Certificate scheme has been defined at national level, so all the regions have the same EPC scheme, but each region is in charge of gathering the EPCs for this region. Spanish EPC provides a double energy rating to each building, which is based on its non-renewable primary energy consumption and its CO2 emissions, on a scale from A to G, with A being an indicator of maximum efficiency (lower consumption and lower emissions) and G being the lowest. The CO_2 emissions rating is not usually present in the EPCs scheme for other member states.

The Energy Performance Certificates of buildings located in the region represented by LSP9 pilot must be registered in the *Energy Performance Certificates Regional Register of buildings in Castilla y León*, accessing on-line through the web application CEREN (personal digital identification is required) and providing the EPC in xml format, exported by the energy rating calculation software approved by the National government.

Energy performance certificates for buildings are issued by technicians (architects or engineers), for which they must use calculation software tools approved by the central administration. The calculation files and the documentation generated by these tools must be uploaded in the EPC regional repositories. Once it is officially approved, certificates can be used by the end users in the selling or renting process.

The LSP9 is intended to support the different participants in the EPC value chain: (i) to technicians, increasing the quality of the calculations and the proposed improvements; (ii) to the Administration, registering higher quality certificates with more reliable data, having tools for the verification of EPCs and improving promotion of the energy rehabilitation of buildings; (iii) to planners of regional or local energy strategies, being able to design their policies based on a higher quantity and quality of data; (iv) to end users of buildings, where they will be able to make the most of tools that facilitate their decision making process for energy rehabilitation investments.

Table 14: LSP9 – Energy Performance Certificates

LSP9: Necessities, actors, methods and procedures, and main difficulties encountered		
Necessity addressed	– Supporting data share and harmonisation. – Facilitating compliance and checking. – De-risking investments with better EPC proposals. – Calculating actual energy savings	
Actors involved and process followed	**Energy Performance Certification (EPC) issuers**	Different programmes for calculating the energy performance of buildings (official software)

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LSP9: Necessities, actors, methods and procedures, and main difficulties encountered		
	EPC's Regional Registry Management Service.	A web-based tool for registering and managing files and data associated with EPCs
	Regional Energy Efficiency Strategy planners.	Management and monitoring of energy consumption data for each sector in the region, from statistical databases.
	Buildings' buyers and sellers, landlords and tenants.	EPC end-users. Key actors as they are the ones who make the final decision to undertake reform investments
Methods, tools, procedures deployed in BaU practice		**EPC's issuers:** Official software in Spain: ce3x, HULC, ce3, sg-save, cype-therm plus. **EPC's Regional registry management service:** Verification by the Administration staff of the files and non-technical data provided **Regional EE Strategy planners**: Spreadsheets with statistical data and calculation of energy savings and regional energy consumption trends **Building tenants:** Website and mobile application for consulting the energy label data of certified buildings
Main difficulties encountered		**EPC's issuers:** Unintentional errors in the data introduction in the EPCs software; Verification by comparison with EPCs of similar buildings. **EPC's Regional registry management service:** Lack of a deep technical supervision of registered certificates **Regional EE Strategy planners**: Designing regional policy for energy efficiency in buildings based on real data on buildings characteristics **Building tenants:** Lack of confidence in the qualification of the certificate and in the improvement measures it includes

3.1.3.3 LSP11: POLICY MAKING AND IMPACT ASSESSMENT: Data-driven policy making and policy impact assessment for energy-efficient buildings

Over the last 5 years, social housing providers have increased the used of data-gathering tools to set up renovation strategies but also to implement cost-efficient techniques such factory-built panels for the refurbishment of buildings. Furthermore, there is a growing belief among social housing providers that to make more energy savings quickly and sustainably, it is necessary to invest beyond insulation, in digital technologies, which make it possible to monitor consumption, control equipment and provide new services such as renewable energy production and storage.

Among some of the most commonly used tools, we can mention:

- **EPC databases**

Essential tools remain the Energy Performance Certificates databases. An energy performance

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certificate describes the building or dwelling (surface, orientation, walls, windows, materials, etc.), as well as its heating, domestic hot water production, cooling and ventilation equipment. It indicates, depending on the case, either the amount of energy actually consumed (on the basis of invoices) or the estimated energy consumption for a standardized use of the building or the dwelling.

The European Commission intends to improve at the occasion of the revision of the Energy Performance of Buildings Directive: "central part of the revision is an update of the framework for Energy Performance Certificates with a view to increasing their quality and availability, for example through greater harmonisation, the inclusion of additional information and more stringent provisions on availability and accessibility of databases".

At national level, databases are being set up.

For an overview of existing public EPC registers at national and regional level see https://ec.europa.eu/energy/content/public-epc-registers_en and http://enerfund.eu/wp-content/uploads/2018/04/D5.1-List-of-EPC-databases-and-open-data-sources.pdf. For instance, in France: https://data.ademe.fr/

- **Building Information Modelling (BIM)**

For several years now, social housing companies have been using BIM for design and construction, but also for management, operation and maintenance or demolition. It basically can work as a large calculation engine that is fed with geometric data from the 3D modelling to which criteria of energy performance, budget and technical solutions are applied. By varying certain parameters, it is possible to obtain different scenarios to improve energy performance while minimizing costs.

Other tools are developed that integrated the carbon dimension.

- **Lifecycle Assessment**

Life Cycle Assessment allows knowing the impact of a building on the environment, including its carbon footprint, not only during its useful life, but also during the extraction of raw materials at the time of its construction, up to waste treatment upon demolition.

Table 15: LSP11 – Policy Making and Impact Assessment

LSP11: Necessities, actors, methods and procedures, and main difficulties encountered	
Necessity addressed	Development of cost-effective renovation strategies for the social, cooperative and public housing sector (also a part of a district approach) • select the optimal set of policy options (cost efficient, feasible, and ambitious at the same time) to include in the National energy and climate plans (NECPs) and Long-term renovation strategies • make informed decisions based on a set of feasible and data-tested options • make reliable predictions about outcomes

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LSP11: Necessities, actors, methods and procedures, and main difficulties encountered		
Actors involved and process followed	**Local & Regional Government Urban development professional /Social housing providers**	Large scale renovation strategies are usually discussed with local authorities when they involve a district approach, since they might address different housing tenures (including co-ownership buildings), public spaces and energy systems. Social, cooperative and public housing providers will prepare different scenario based on types of buildings, availability and costs of material, availability of funding, available energy sources, tenants preferences.
	decision-makers at any level	At EU level, the Affordable Housing Initiative can support data-driven renovation strategies by supporting the development of practical planning tools for social, cooperative and public housing. • Review country-level data such as EPC databases + databases mentioned in section 4.2 of this document • Consider data and analysis provided by different stakeholders/third parties • Evaluate impact of past/current policies • Compare with cross-country analysis of data sets and menus of policy options, including some of those listed in section 4.1 of this document (https://www.odyssee-mure.eu/) • Use all of the above to make informed decisions and predictions
Methods, tools, procedures deployed in BaU practice		**Local & Regional Government Urban development professional and social housing providers**: • On-site assessment of the state of the buildings and energy performance diagnosis (in relation to the Energy performance certificates) • National/EU databases, incl EPC databases • Modelling/building scenarios • Heat mapping: Heatmaps are valuable regarding the urban and energy planning of a geographical area; it helps locating energy sources and needs and connect them, designing infrastructures, plan the refurbishment in some areas • other factors are considered such as the socio-economic status of residents

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LSP11: Necessities, actors, methods and procedures, and main difficulties encountered	
Main difficulties encountered	**Local & Regional Government Urban development professional/ Social Housing Providers:** Lack of information on the availability and costs of renovation material that meet current and future standards (in particular in relation to carbon impact); lack of sufficient information on the state of the building stock (in particular as part of a district renovation) difficulty to choose between different options (for instance green district heating or heat pumps); necessity to take comfort and affordability dimensions into account (for instance creating new common spaces or balconies); how to combine the use of the existing tools at EU level : Smart readiness indicators, Level(s) for environmental sustainability; uncertainty about the benefits of using BIM for renovation **Policy-makers at any level:** • Lack of reliable and up to date data • Different (sometimes conflicting) policy objectives, i.e. energy efficiency vs affordability • Unclear evaluation of different policy measures (individually and combined) based on the outcomes achieved

3.1.4 Applications and cases related to Funding retrofitting actions

Improving energy efficiency, de-carbonising heating and cooling, and increasing renewable microgeneration in existing residential buildings, is crucial for meeting social and climate policy objectives. More and more cities are committing to delivering zero carbon building standards, requiring increases in the energy performance of buildings alongside a shift to a clean energy supply. To achieve this, cities can set performance standards, reporting and disclosure requirements, and implement support programmes. However, homeowners' ability to retrofit their buildings for energy efficiency has so far been hampered by the high cost of retrofitting and lack of adequate financial resources.

This section looks and analyses the interaction and role of the different stakeholders in the retrofit financing market.

3.1.4.1 LSP3: ESCO SUPPORT SERVICES: Energy Saving Verification Service for increasing the trust on Energy Performance Contracts

The energy performance contract (EPC) is a tool that allows the financing of energy efficiency interventions. The EPC involves an ESCO that provides the client with different services, such as finances and guaranteed energy savings. The benefit the ESCO obtains is directly related with the achievement of the guaranteed savings. The ESCO is involved also in the measurement and verification process for the energy savings in the repayment period. The use of EPCs allows home owners to implement energy efficiency measures in their buildings without the need to face the upfront costs of the intervention.

LSP3 involves 3 different buildings of 3 different typologies: a residential building, an educational building and an administrative building. These are three different typologies that may benefit from the use of an EPC. The aim of this LSP is to generate analytics to improve the ESCO model, obtaining a proper balance between the investment and the energy savings achieved, in order to reduce the ROI

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and improve the energy efficiency of the buildings as much as possible.

In the process of deciding if a project is economically feasible, the data are relevant, i.e., data from potential ECMs, cost, energy cost, prediction of future energy behaviour or performance, etc. Regarding the energy performance contracts, and their compliance, the energy service verification is crucial, so methods to estimate savings need data: static and dynamic data to build simulations, estimations or statistics approach or real data from the monitoring system.

Table 16: LSP3 – ESCO support services

LSP3: Necessities, actors, methods and procedures, and main difficulties encountered		
Necessity addressed	Consumption prediction	
Actors involved and process followed	**Owner**	Check the consumption. prediction provided by the ESCO and adapt its behaviour accordingly.
	ESCO	Develop a mathematical model of the facility consumption. Feed the model with monitoring data to predict the energy. consumption. Provide consumption prediction to the customer and provide recommendations.
Methods, tools, procedures deployed in BaU practice		DEMS, BEMS, HEMS, Data bases with historical monitored data, central energy monitoring system
Main difficulties encountered	**Owner:** Lack of knowledge about energy efficiency. **ESCO:** Insufficient monitoring data; inaccuracy in the predictions of the result due to the lack of data and/or a low-quality model; communication problems with the owner.	
Necessity addressed	M&V of energy savings	
Actors involved and process followed	**Owner**	Requires a periodical check of the energy savings obtained due to an intervention or a change in the operation.
	ESCO	Implements energy efficiency measures. Implements a M&V protocol (e.g. IPMVP) to prove the effectiveness of the implemented measures. Shows and explains the results to the owners and investors.
	Investor	Analyse the profitability of the investment. Propose the most suitable financial options to the owners.
Methods, tools, procedures deployed in BaU practice		**Owner:** Continuous communication with the facility manager **ESCO & Investor**: DEMS, BEMS, HEMS, Data bases with historical monitored data, Excel based model, Central energy monitoring system
Main difficulties encountered	**Owner:** Does not have knowledge about energy efficiency. **ESCO:** Insufficient baseline data. **Investor**: It is not an expert in energy efficiency, uncertainty about the return the investment.	
Necessity addressed	Continuous KPIs calculations	
Actors involved	**Owner**	Follow up of the operation and performance of the facility

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LSP3: Necessities, actors, methods and procedures, and main difficulties encountered		
and process followed	**ESCO**	Define the relevant KPIs. Read data from the monitoring platform. KPIs calculation. Benchmarking between similar facilities to identify possible operation improvements.
Methods, tools, procedures deployed in BaU practice		DEMS, BEMS, HEMS, Data bases with historical monitored data, central energy monitoring system
Main difficulties encountered		**Owner:** Does not have knowledge about energy efficiency. **ESCO:** Insufficient data from the public sources, inaccuracy in the predictions of the result, communication problems with the owner.

3.1.4.2 LSP8: ONE-STOP-SHOPS: Enablers of the financing of refurbishment actions in the building stock at local level

In recent years, environmental awareness has increased among the residents in Gdynia. More and more people are interested in environmental protection and air protection. This awareness mainly concerns the actions taken regarding the way of life, changes in everyday habits and decisions regarding the immediate environment. Such decisions include the energy improvement of building. Residents are more and more interested in improving the quality living and the quality of their place of residence, as well as lowering the cost of electricity and heat usage, with the lowest possible financial outlay, as well as in energy modernization when the building is not energy efficient. In the case of modernized buildings, residents are increasingly interested in the installation of renewable energy sources.

Energy modernization of buildings and the installation of renewable energy sources involves investing a relatively large funds. Therefore, planning the entire investment is preceded by a detailed, step-by-step analysis of the entire project. Such analysis concerns the whole aspect of improvements, starting from the type of renovation activities to the materials used, as well as financial issues. The costs of materials and services as well as the possibility of obtaining financial support are important for a potential investor. Currently, there are many financing options and small grants as well as tax credits for investments on the market. They depend on the type of beneficiary and the scope of the investment. Sometimes subsidies can be combined, in other cases they cannot. The investor must be familiar with the currently applicable rules to be able to use a specific grant or choose the one that will be most beneficial for him.

When planning investments in the field of increasing the energy efficiency of a building, it is extremely important to obtain substantive support. The investor may not know how to carry out the investment, what type of renovations should be included in the modernization and what materials should be used for its implementation. Carrying out energy modernization requires knowledge of possible investment options and knowledge of the benefits and disadvantages of the technologies and materials used. Often the investor does not know how much energy his building consumes or should use. In such cases, the investor tries to find a reliable source of information, with varying success. There is a wide range of materials available on the market, from articles in trade magazines to offers of potential contractors, which sometimes constitute only a commercial offer of selected knowledge and services.

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Another possibility is to hire an energy auditor who will help in the selection of equipment and materials - this option is the most reliable but also expensive. The auditor's advisory service is usually payable if it does not involve further cooperation. Materials available on the Internet are an indispensable, usually free, help for a potential investor. In this case, the investor must independently search for information and establish its reliability. A potential investor is also looking on the Internet to use tools that will help them with the investment, such as calculators, e.g. co-financing, payback period, potential savings, assessment of the building's energy condition.

When planning energy modernization or installation of renewable energy sources, the investor must carry out the entire investment on his own. This gives him a free choice, but it makes it difficult for him to access any support. There is a free of charge energy consultancy in Gdynia, under which the residents of Gdynia can apply for advices. As far as the knowledge and possibilities of municipal advisers are concerned, the necessary information is provided to investors. However, the content of the information may differ depending on the person providing the advice. Additionally, the municipality cannot recommend any potential contractor, auditor or designer as it cannot promote the services of private companies. Therefore, some information may not be available to the investor at present. Residents often use energy consultancy to know which subsidies can be used. It is often necessary to know the law or to find reliable information. Municipality is a well-known reliable information source for residents. In this matter, residents are also looking for information on the applicable law related to the rights of residents of apartments in multi-family buildings and the rights of home owners. They want to know their rights and obligations in the field of energy management, construction law, billing and sharing costs between residents.

The answer to solving the problems related to the search for information may be the creation of the ONE-STOP-SHOP platform for Gdynia.

Table 17: LSP8 – One-Stop-Shops

LSP8: Necessities, actors, methods and procedures, and main difficulties encountered		
Necessity addressed	Creating a public knowledge base for residents ONE-STOP-SHOP	
Actors involved and process followed	**Real estate owner**	Searching for information on the Internet, in publications – information on renovation, renewable energy sources, funding programs. Creating their own analysis of the building – current condition, possible actions, renovation and investment.
	Building administrators and managers	
	Renovation contractors and auditors	Publication of offers for a wide range of recipients – Internet, magazines, leaflets.
	Workers of Gdynia & other municipalities	Searching for information on possible financing in programs and from institutions providing financial support. Providing information to residents.

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LSP8: Necessities, actors, methods and procedures, and main difficulties encountered		
Methods, tools, procedures deployed in BaU practice		The municipality provides information through the energy consultancy of Gdynia – directly or through telephone or email contact. Only some information is published on the Gdynia website – including information on municipal subsidies. The solution cannot be implemented – the municipality cannot promote the services of private companies.
Main difficulties encountered	**Real estate owner & building administrator and manager:** Residents need to look for information on their own, there is no single reliable source of information, information is scattered. **Renovation contractors and auditors**: Possible problems may be related to the inability to reach potential customers. **Workers of Gdynia and other municipalities**: Workers need to look for information on their own, there is no single reliable source of information, information is scattered.	
Necessity addressed	Creation of a tool for the analysis of communal buildings	
Actors involved and process followed	**Workers of Gdynia**	Searching for information on buildings – from building administrators, invoices and different departments and units.
Methods, tools, procedures deployed in BaU practice		Analysis of available data depending on the needs.
Main difficulties encountered	Data is difficult to access, incomplete, and limited possibilities of analysis and reporting. Currently, analyzes and reports are time consuming. Distributed knowledge about the technical condition of buildings.	

3.1.4.3 LSP10: DE-RISKING EE INVESTMENTS: Services to support reliable, cost-effective and better-quality Energy Performance Contracts and Investments

Public funding for the implementation of energy efficiency improvement projects is provided from the European Union Structural Funds *(European Union Regional Development Fund - ERDF*) and the Cohesion Fund (*CF*), the state budget program *Climate Change Financial Instrument (CCFI*) and *Emission Auctioning Instrument (ETS)* as well as other financial instruments. Funding for improving the heat resistance of multi-apartment residential and social housing is provided from the *European Union Structural Funds (ERDF)* managed by *the Ministry of Economics (MoE),* while measures to increase the efficiency of district heating systems were financed from the *Cohesion Fund (CF).*

Many by these public funds are administrated ALTUM - a state development financial institution that provides financial instruments (loans, guarantees, investments in venture capital funds, etc.) in areas that the state has identified as important and supportable, and where sufficient funding from credit institutions is not available. Latvian and EU funding is used for the implementation of the programs. ALTUM is an intermediary between the European Regional Development Fund and the beneficiaries.

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ALTUM offers to cover 50% of the project eligible costs with the help of an EU grant. ALTUM can also serve as a guarantor for a credit institution that provides a loan for renovation.

Funding for the improvement of energy efficiency of state and municipal institutions, businesses and private buildings, as well as for the improvement of energy efficiency in production technological equipment is also provided from the state budget program *Climate Change Financial Instrument (CCFI)* and *Emission Auctioning Instrument (ETS),* under *the Ministry of Environmental Protection and Regional Development* and are administered by LEIF.

One of widely applied methods for determining the technical and economic energy efficiency potential is Energy Efficiency Cost Curves (EECC). It has been applied in both industrial and household sectors in Latvia, and for the analysis of individual technologies or systems such as electric motor systems and industrial steam systems.

The EECC method is an analytical approach to graphically depict the potential energy savings, where each individual step in the curve describes the specific cost of the measure, shows the relative rank of this measure and the total extent of the curve describes the energy efficiency potential of considered system. The total costs of the measures consider both the costs of implementing the measures and maintaining the technology, as well as the savings made over the life of the measures. In addition, the EECC can simultaneously characterize the technical and economic perspective of energy efficiency and can be used at national and sectorial level.

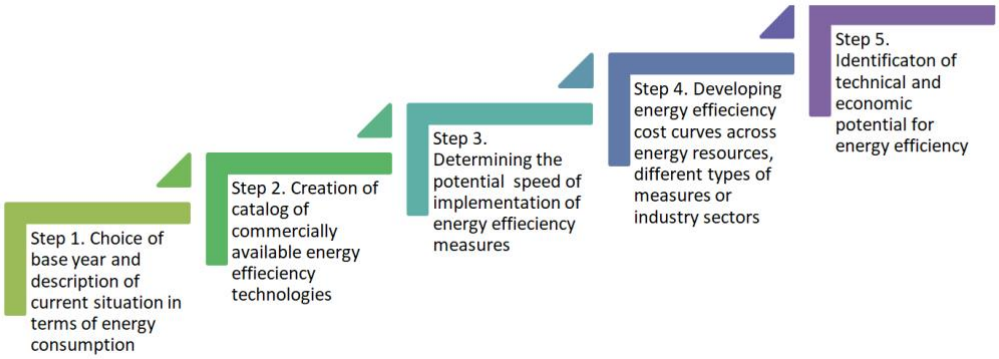

Figure 3: Steps of applying the energy efficiency cost curve (EECC) method

〉 Project evaluation stage (before receiving funding)

The main activities of LEIF and its financial instruments are regulated by the requirements of the approved legal acts by Latvia:

- Law "On the Participation of the Republic of Latvia in the Flexible Mechanisms of the Kyoto Protocol" (in force since 13 December 2007),
- Cabinet Regulation No. 312 "Regulations of the Consultative Council of the Climate Change Financial Instrument",
- Cabinet Regulation No. 644 "Procedure for Implementation, Report Submission and Verification of Projects Financed by the Climate Change Financial Instrument".

Beneficiaries (local municipalities etc.) set up projects considering the above-mentioned legislation, as well as considering the energy audit of the specific building and EECC method. After that projects are

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submitted to LEIF for evaluation. Preference is given to those who are able to achieve the best heat savings and CO_2 reduction with the required amount of money.

The greatest risks arise in situations where energy audits are not designed accurately or in good faith. If the beneficiary indicates greater CO_2 savings in order to receive more funding, in a monitoring period of the project the problems may arise. If the project results are not achieved, a financial correction may be applied in latter stages.

〉 **Project monitoring stage (after receiving funding, evaluating energy consumption data)**

The EMSI (electronical monitoring system) system has been created with the aim to provide an opportunity for the Beneficiaries to electronically prepare and submit monitoring (post-evaluation) reports on completed LEIF funded projects. Every year financial beneficiaries will submit data in EMSI system regarding their building energy consumption monthly.

Table 18: LSP10 – De-risking EE investments

LSP10: Necessities, actors, methods and procedures, and main difficulties encountered		
Necessity addressed	Historical data collection	
Actors involved and process followed	**Institutions**	Gather historical energy data consumption to have full understanding of the building regarding their energy consumption
Methods, tools, procedures deployed in BaU practice		Data bases with historical monitored data Electronical monitoring system
Main difficulties encountered	Insufficient historical monitoring data.	
Necessity addressed	Smart metering data and contextual data collection	
Actors involved and process followed	**Institutions**	Gather smart metering real time data about energy consumption to have full understanding of the building regarding their energy consumption and collect contextual data (cadastre, weather services, EPC databases) as well.
Methods, tools, procedures deployed in BaU practice		Smart metering data collected and contextual data collected from relevant databases
Main difficulties encountered	Insufficient smart meters deployed to monitor buildings.	
Necessity addressed	Defined list of the energy efficiency measures and their costs	
Actors involved and process followed	**Institutions** **Facility managers**	Help users to decide which energy efficiency measures to deploy on a building regarding their budget
Methods, tools, procedures deployed in BaU practice		Contextual data collected from relevant databases
Main difficulties encountered	Insufficient knowledge of energy efficiency issues	

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LSP10: Necessities, actors, methods and procedures, and main difficulties encountered		
Necessity addressed	Calculation of KPIs, energy performance, investment risk and cross-domain financial and energy consumption analytics	
Actors involved and process followed	**Director of finance**	Analytics are most important aspect for the cross-domain financial and energy consumption analytics. Users calculate their KPIs and analyse the profitability of the investment. Representations of the obtained results to the stakeholders. Offering the best possible solutions.
	Policy makers, Institutions	
Methods, tools, procedures deployed in BaU practice		Data bases with historical monitored data, Electronical monitoring system, Smart metering data collected and contextual data collected from relevant databases.
Main difficulties encountered	Insufficient knowledge of energy efficiency issues. There is no certainty about the return on investment.	

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3.2 Review of trends in the application of digital (data based) technologies on the built environment in the context of MATRYCS platform

This section aims at providing a description of the innovative services, applications and technologies that could constitute either competitors or foundations of the ones developed in the context of the project.

3.2.1 Digitalization of Built Environment: Digital Building Twin

The digitalization of the built environment is a current trend that is exponentially growing nowadays and even more so with the technological advancements and data exploitation capabilities available. On this basis, the generation of digital twins as digital data repositories to support specific processes is becoming more and more frequent. However, relevant challenges need yet to be overcome: building data is only partially available, rarely up-to-date and almost never integrated into a single platform so that informed decisions can be made at the micro and the macro scale. However, a wealth of opportunities exists through the combination of both static and dynamic data through the generation of analytics, leading to more accurate and cost-effective solutions, as well as the ease of analysis processes.

This section aims at providing a description of the innovative services, applications and technologies that could constitute either competitors or foundations of the ones developed in the context of the project related to the Digital Building Twin.

3.2.1.1 Existing data models

This section presents existing data models that are relevant in the context of the building sector when observed from different perspectives: individual buildings, as group of buildings (districts), as group of districts (cities), etc.

In particular, the following existing data models are analysed and presented in Annex III:

- **FIWARE Smart data model**
- **Industry Foundation Classes (IFC)**
- **CityGML**
- **INSPIRE Directive**
- **SAREF**
- **BRICK**

3.2.1.2 BIM and Digital Infrastructures

Building Information Modelling (BIM) is defined as a digital toolset used to digitally map building or infrastructure facility for various purposes: visualization, scheduling, communication and collaboration

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between stakeholders through a building/facilities life cycle[17]. According to the Associated General Contractors of America (AGC), BIM is a data rich object orientated parametric digital representation of a building, which allows various users to extract and analyse the data to make decision and improve the process of delivering the building[18].

Implementation of BIM within the company can generate many benefits; nevertheless, some obstacles also need to be overcome. Implementing BIM within the company requires a considerable build-up expertise, especially appropriate employee training and substantial IT upgrading. This also can be especially challenging for Small and Medium enterprises, for them extra investment in new technologies and training may be difficult and not always possible. According to publication of Poljansek[19] in order to successfully implement BIM in construction sector, interoperability must be ensured, in this way various stakeholders can share the information and cooperate the planning. Building owners and investors will slowly adopt the BIM technology until they manage to understand all the benefits of using BIM. In BIM, data is created and shared in a more collaborative way, which leads to further issues regarding data ownership and liability. The benefits of large-scale BIM can only be realized when all participants along the value chain get involved; without this interlinking effect, there is a little benefit for the first movers. Possible application of the BIM along the engineering and construction value chain is shown in Figure 4.

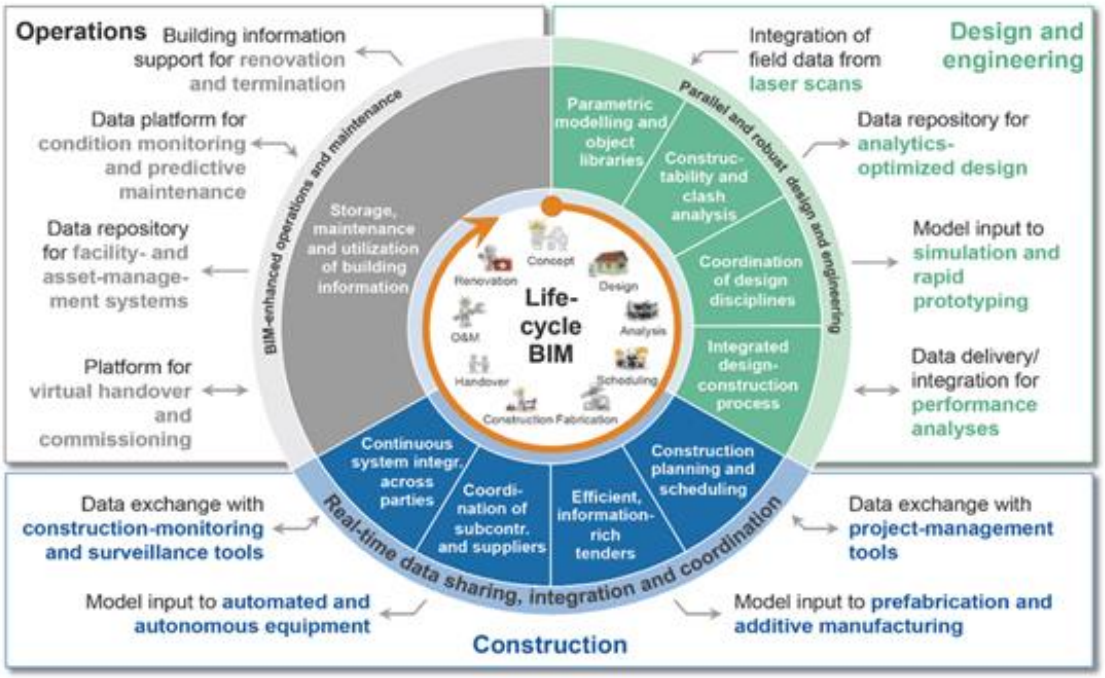

Figure 4: Application of BIM in construction industry ***(source: Shaping the future of construction)***

There are different levels of shared collaboration in a project that are known as BIM maturity levels (Figure 5). The BIM maturity is often presented as a "wedge". To evaluate which level is reached special indicators are introduced by Poljansek in his BIM levels of Maturity graph: the content, the

17 Anon. (2011): A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractor, Wiley, Hoboken, NJ, (ISBN:9780470541371)

18 Succar and Bilal (2009): Building information modelling framework: A research and delivery foundation for industry stakeholders, Automation in construction 18.3

19 M. Poljansek (2017): Building Information Modelling (BIM) standardization, Joint Research

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digitalization, the interoperability, and the collaboration.

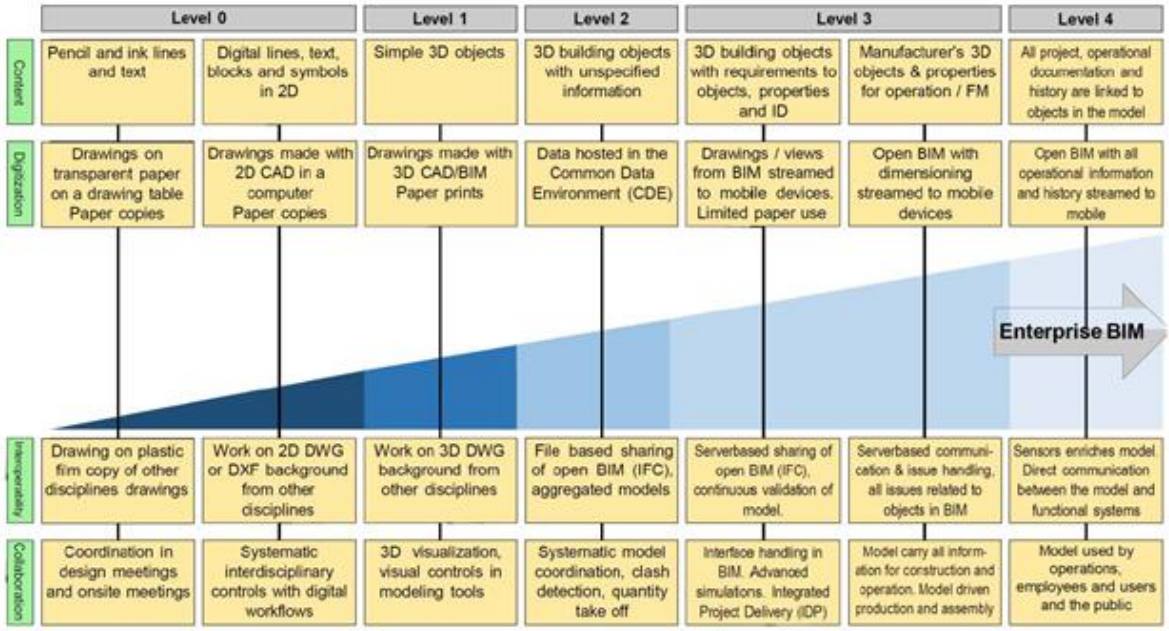

Figure 5: BIM maturity levels ***(source: M. Poljansek (2017): Building Information Modelling (BIM) standardization, Joint Research)***

The update of BIM varies from country to country. For example, with government support, the UK has radically adopted BIM strategy that has glorified the global image of UK designers, contractors, and other professionals. In April 2016, government mandated BIM Level 2 on all the public projects. UK's construction industry is one of the most technologically advanced and digitized industry in the world. After the initiative taken by the government, it is estimated that around 20 percent of the industry have adopted it successfully and have gained a 12% increase since 2017. Finland implemented BIM technology in the year 2002. In 2007, Senate Properties, a significant government entity that is responsible for managing the country's property assets, and they mandated IFC compliance and BIM models in all their projects. BIM implementation is highest in this country because, in 2007, 93% of architectural firms and 60% of engineering firms were using BIM in their routine[20].

3.2.1.3 IoT and integration with BIM-enabled platform

Nowadays IoT devices, systems and platforms are widely deployed allowing users, among other capabilities, having knowledge on the physical signal that devices are measuring; some examples of this sort of devices could be smart thermostats (NEST, Tado, Netatmo, Ecobee4, Honeywell evohome, etc) and smart energy meters (eMylo, InteHome, KKmoon, etc) and others. Usually these devices are able to be connected and accessed by the user through a mobile app to visualize and download data, many times these devices and platforms offer to the users an API REST which allows getting data by external ICT systems and use these data in other third party applications. Also, these devices can be integrated into Alexa, Google Assistant, Siri, etc. expanding the possibilities of the user who has the possibility to interact with those devices remotely, and if necessary, users are able to switch on/off devices, such as gas boilers through this integration and the use of the thermostat capabilities.

20 https://www.united-bim.com/leading-countries-with-bim-adoption/

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IoT devices make use of several protocols to connect to the internet and send data to the data repository (usually data repositories are proprietary software from companies). Examples of these protocols are LoraWan, Sig-Fox, MQTT, NB-IoT, etc. What they have in common is the light use of bandwidth; usually devices transfer few information, such as temperature in a not very high frequency.

These data are very useful in the development of a digital twin of a building (district or city when data are available) because it is possible to know the behaviour of the building by means of study the data evolution in time, but there is a quite important lack of information regarding the location of the IoT devices, usually this information is not used by the IoT companies/platforms and then it is not incorporated to the datasets available to download. Commonly only information about name (that is selected by the particular user as desired) is available in the dataset and usually it is not representative. To make a proper match among devices, its measurements and the digital twin it is necessary to know where these devices are installed and what they are measuring. In the particular case of a building and having in consideration the standard IFC4 and the definition of spatial structures and the definition of devices included on it, it is needed to match devices into spaces.

To this end an IFC-compliant database structure would be developed, integrating both disciplines, the real and static world, coming from the definition of the building on the standard IFC and the dynamic data (evolution in time) coming from IoT devices. This database structure will follow the scheme defined in the next Figure 6.

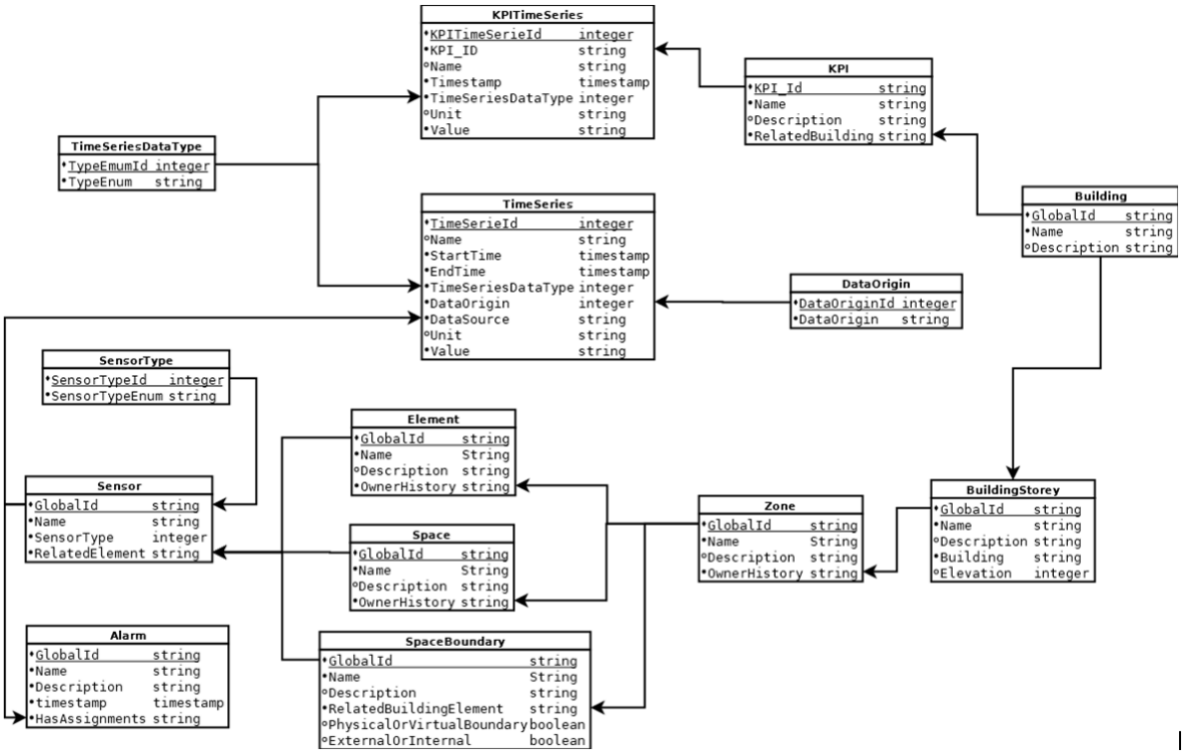

Figure 6: IFC compliant database architecture for dynamic data

3.2.1.4 Transition from the IoT to the Semantic Construction Web of Things

Information generated by IoT (Internet of Things) systems is communicated in very different and even non-standardized formats. This lack of consensus makes difficult it to describe the meaning and context of the data, and a uniform way of proceeding is lacking. However, IoT data can potentially

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generate business value. That is the reason why semantic interoperability has gained so much attention, and recently the application of semantic interoperability principles applicable to the IoT and WoT (Web of Things) landscapes has been recently deeply studied.

Interoperability refers to the ability of two or more systems or components to exchange data and information. On the other hand, semantic interoperability refers to allowing diverse agents, services, applications, to exchange data, information and, in addition, knowledge in a meaningful way. This can be done on and off the Web. Thus, the latter extends the meaning of the former, and is achieved when the same meaning is assigned to an exchanged piece of data, ensuring its consistency (where its meaning can be based on pre-existing standards or agreements, following a schema or an ontology and using a shared vocabulary) and regardless of the individual data format[21].

Interoperability between IoT systems is especially important to capture maximum value, and semantic interoperability can be seen as a key value enabler for IoT. Current IoT ecosystem is composed by non-interoperable products and services. The WoT continues IoT advancement, enabling users to interact with the IoT ecosystem by using the open and standard web technologies. (the web itself does not solve interoperability issues). Examples of ontology catalogues relevant for IoT and WoT, are Ready4SmartCities, OpenSensingCity, LOV and LOV4IoT[22].

3.2.1.5 End-to-end process digitalisation

BIM allows combining information on buildings with geometrical/spatial data derived from other technologies. Geometrical/spatial information might be collected via manual onsite measurements as well as by using automated devices like laser-scanners or other equipment (e.g. drones) using photogrammetric techniques. The two most used technologies for digitalisation can be described as follows:

- **3D laser scanning**: Non-contact and non-destructive technology that digitally captures the shape of opaque, non-absorbing and non-mirroring objects using laser light. Laser scanners create point clouds of data from the surface of buildings, making them accessible into the computer world as a 3D digital representation.
- **3D image-based modelling** (also known as SfM: Structure from Motion): is an extension of traditional photogrammetry which does not require photographs taken by calibrated cameras with known parameters but the explicit identification of target locations in each photograph. This technique identifies and marks distinct features appearing in multiple photographs. These features are then automatically referenced in three-dimensional space and matched together, generating point clouds.

Point clouds are one of the most common ways to provide as-built 3D information and also a proper base for 3D modelling. The data from the point clouds are difficult to interpret and, therefore, a correct analysis of the acquired data is needed to obtain one or more products able to meet the user needs.

21 Murdock, Paul & Bassbouss, Louay & Kraft, Andreas & Bauer, Martin & Logvinov, Oleg & Alaya, Mahdi & Longstreth, Terry & Bhowmik, Rajdeep & Martigne, Patrica & Brett, Patrica & Mladin, Catalina & Chakraborty, Rabindra & Monteil, Thierry & Dadas, Mohammed & Davies, John & Nappey, Philippe & Diab, Wael & Raggett, Dave & Drira, Khalil & Khan, Imran. (2016). Semantic Interoperability for the Web of Things. 10.13140/RG.2.2.25758.13122.

22 A. Gyrard, S. K. Datta and C. Bonnet, "A survey and analysis of ontology-based software tools for semantic interoperability in IoT and WoT landscapes," *2018 IEEE 4th World Forum on Internet of Things (WF-IoT)*, Singapore, 2018, pp. 86-91, doi: 10.1109/WF-IoT.2018.8355091

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Several approaches have been proven to be adequate to allow obtaining BIM-compatible models from point clouds to tackle the study of existing buildings for rehabilitation and improvement.

A methodology to process point clouds in order to manage and extract useful information for existing buildings in a BIM environment from point clouds is detailed in Annex IV.

3.2.1.6 City and regional scales

Digital twin technology has also been applied to city and regional scales. It is important to highlight that at these scales the level of detail expected is not the same that at building scale: it is unlikely to have all the needed information available for doing a perfect BIM model for all the buildings in the city or region.

Using a digital twin as a city model is an exceedingly concept. In product and plant design digital twins have been used for decades, to create, test and build everything first in a virtual environment. The use of digital twins in a city concept is a larger vision compared to industrial design or Building Digital Twin. It could help with simulations and analysis of present and planned city environments, maintenance and administration systems, emergency planning and management, and the construction production chain, to name a few.

Additionally, the impact of the pandemic COVID-19 is forcing cities to accelerate their digital transformation. Interactive virtual environments and digital twins can support citizens to engage from the safety of their own home on new development projects in their local communities. These technologies build adaptable and scalable solutions that will set the standards for the future of planning and public engagement in cities.

City Digital twin are based fundamentally in topographic and geometric models of the infrastructure in the cities. In the recent past, CityGML has been used as data model for the representation of urban objects in 3D. It defines classes and relationships for the most relevant topographic objects in city models with respect to properties: geometries, topologic and semantic data. An example of this is Helsinki's 3D data model[23] (and offered also as Virtual Helsinki[24]), a Digital City twin that in part has been created using CityGML 2.0 (especially for the Kalasatama Digital Twin, explained in the final report of the project[25]).

Besides, 2D Geographic Information Systems (GIS) models have been widely used for the representation of cities, since in many of the scenarios the 3D characteristics are not necessary, and open GIS data are becoming more and more common.

Lately, initiatives for the combination of the city and building digital twins in the same model have appeared. ESRI[26] and Autodesk[27] are working together in the development of a combined tool for enabling the digital twin for cities. Other initiatives are following the same approach, as SuperMap GIS[28], which integrates 2D and 3D technologies which work with full spatial data model.

23 Helsinki's 3D city models: https://www.hel.fi/helsinki/en/administration/information/general/3d/3d/

24 Virtual Helsinki: https://www.virtualhelsinki.fi/

25 The Kalasatama Digital Twins Project, the final report of the KIRA-digi pilot project: https://www.hel.fi/static/liitteet-2019/Kaupunginkanslia/Helsinki3D_Kalasatama_Digital_Twins.pdf/

26 Esri: https://www.esri.com/en-us/home

27 Autodesk: https://www.autodesk.com/

28 Supermap: https://www.supermap.com/en-us/list/?152_1.html

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3.2.2 Platforms for the Built Environment

This section aims at providing a description of platforms that could constitute either competitors or foundations of the ones developed in MATRYCS.

3.2.2.1 FIWARE Open Initiative

FIWARE is an open initiative aiming to create a sustainable ecosystem to grasp the opportunities that will emerge with the new wave of digitalization caused by the integration of recent Internet technologies. This section aims to describe the FIWARE Open-source initiative and the relevant pillars which it is based providing a brief description of the:

- FIWARE Technologies
- FIWARE Foundation
- FIWARE Accelerator
- FIWARE Mundus
- FIWARE iHUBs

FIWARE TECHNOLOGIES

FIWARE is a curated framework of open source platform components to access and manage heterogeneous context information through open API. FIWARE fully implements a standard for exchange of context information: FIWARE-NGSI (Next Generation Service Interface). The open standard nature of FIWARE NGSI offers programmers the ability to port their applications across different "Powered by FIWARE" platforms and a stable framework for future development. The FIWARE Community also plays an active role in the evolution of ETSI NGSI-LD specifications which were based on NGSIv2 and commits to deliver compatible open source implementations of the specs. Additional functionality can be easily added to a Smart Solution simply by using additional FIWARE Generic Enablers or third-party components for which the integration with the FIWARE Context Broker component is solved. This integration is simplified since all components comply with the FIWARE NGSI standard interface, which eliminates vendor lock in. The component-based nature of a FIWARE based solution allows for re-architecting as the solution evolves according to business needs.

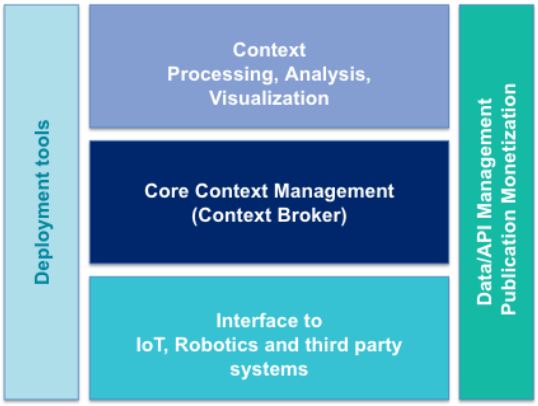

Figure 7: FIWARE Framework

Among the services provided by FIWARE, FIWARE Lab is a free and non-commercial sandbox

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environment where innovation and experimentation based on FIWARE technologies take place. Entrepreneurs and individuals can test the technology as well as their applications on FIWARE Lab, exploiting Open Data published by cities and other organizations. FIWARE Lab is deployed over a geographically distributed network of federated nodes leveraging on a wide range of experimental infrastructures.

FIWARE Foundation

FIWARE Foundation is a non-profit organization that drives the definition and encourages the adoption of open standards (implemented using Open Source technologies) that ease the development of smart solutions across domains such as Smart Cities, Smart Energy, Smart AgriFood and Smart Industry, based on FIWARE technology. Founded in 2016, the foundation has Atos, Engineering, NEC, Red Hat, Telefónica, and Trigyn Technologies among its Platinum members.

FIWARE Accelerator

The FIWARE Accelerator Programme promotes the up-take of FIWARE technologies among solution integrators and application developers, with a special focus on SMEs and start-ups.

FIWARE Mundus

The objective of the FIWARE Mundus is to promote the adoption of FIWARE in European regions and internationally reaching countries outside Europe where the take-up of Internet innovation can occur and impact local markets.

FIWARE iHubs

FIWARE iHubs is a centre dedicated to the adoption of FIWARE technologies, with the aim to drive it within a certain business area, connecting it to an educational and innovative ecosystem. It offers and facilitates start-ups, SMEs and big companies the access to a global market. By focusing on improving their competitiveness using open source technology, it promotes the diversification of local and regional economies. A FIWARE iHub consists of one or more competence centres, which carry out a range of activities to educate, train and help SMEs, start-ups and entrepreneurs. These activities include promoting FIWARE through organised events and engaging the local technology and business community, as well as building connections between universities, businesses, institutions and governments, offering technical support, consulting, coaching, training, testing and certification on FIWARE technologies.

3.2.2.2 BEMserver

BEMserver is a Building Energy Management platform developed during the European H2020 project HIT2GAP. It is a modular and open source platform built according to classical IoT concepts. It has a multi-layers architecture composed of:

- A connectivity module for the collection of data from the sensors and other possible devices installed at building level.
- A middleware with different software components responsible for data harmonization according to standard ontologies and for data storage.
- A set of modules based on model-based or artificial intelligence approaches for energy management and other advanced applications

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- Visualization tools for the presentation of the results.

Figure 8 shows high-level view of the BEMserver architecture.

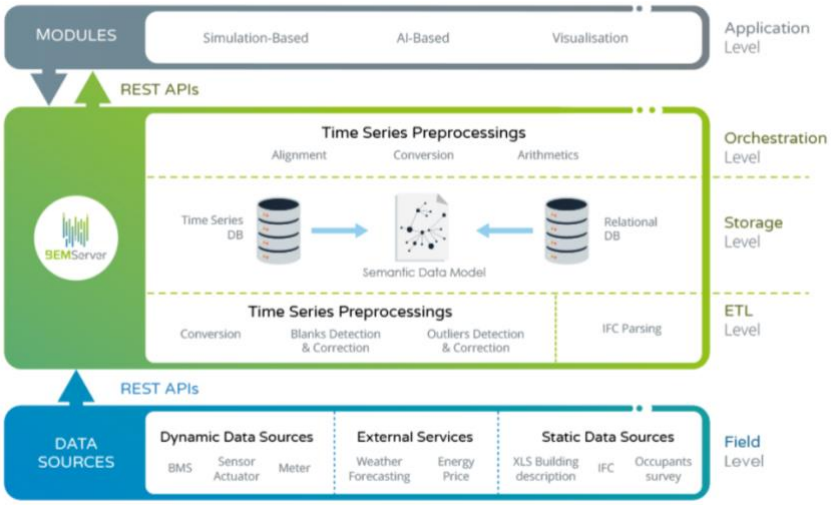

Figure 8: BEMserver platform architecture. Source: BEMserver website[29]

The BEMserver platform was developed to target three categories of actors. The main target was end users, like facility managers or building owners, who can install the open source platform to gather all the data in a central system and plug in possible application modules of their interest. In addition, the platform allows module developers to interconnect their own applications, and contributors, namely IT software experts, to further contribute to the development of functionalities of the platform.

The middleware of the platform is composed of a set of software components to perform basic cleansing operation such as detection of missing data and removal of outliers, time series resampling or measurement unit conversion. The data storage solutions are SQLLite to store events, HDF5 to store time series data and Apache Jena to store the metadata. The data models used within the platform for the data harmonization are based on the IFC and Haystack standards. The available data are then exposed to the upper layer applications via documented REST APIs.

3.2.3 Analytics for the Built Environment and their technologies

This section focuses on potential analytics that could be of use in the whole context of MATRYCS. Thus, the following subsections will cover, respectively, energy management and optimization, building and related infrastructure refurbishment and design, policy making, investments de-risking and the support of a big data vision through geo-clustering.

3.2.3.1 Analytics for Energy Performance – Indoor Condition Evaluation and Intelligent Energy Management

MATRYCS-PERFORMANCE layer consists of services and business models based on the operational stage of buildings. The services that will be deployed will aim at monitoring and improving the energy performance of buildings, incorporate predictive capabilities related to comfort evaluation, energy demand, consumption, generation as well as other building capabilities. Their scope will be to improve building energy performance, infrastructure, optimize comfort-enhanced building energy efficiency,

29 https://www.bemserver.org/

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among others. These services are Energy Prediction, BAC Services, KPIs Calculations, TBM Services, Optimization for network operations.

An extensive literature review was conducted to identify Machine Learning and Deep Learning applications aiming to increase performance at buildings. A big number of studies and proposals were identified that use building related data and Artificial Intelligence methodologies. Below an overview of these services and methods is presented with the scope to incorporate almost all the MATRYCS possible identified cases. These applications and the models will be the start point and benchmark of the MATRYCS-PERFORMANCE services that will be deployed.

Table 19: Overview of energy performance services

Reference	Service	Features	Used algorithms
Xuemei L. et al.[30]	**HVAC system operation improvement**	Date, daily average temperature, daily lowest temperature, daily highest temperature	SVM (RBF) PCA-SVM KPCA-SVM
Xuemei L. et al.[31]	**HVAC system optimization**	Dry-bulb temperature, relative humidity, solar radiation	LS-SVM (RBF) ANN (BPNN)
Solomon DM et al.[32]	**HVAC system efficiency improvement**	Temperature, dew point temperature, pressure, wind direction, wind speed, humidity, precipitation	SVM (RBF)
Dagnely P. et al.[33]	**Green electricity production management**	Occupancy, recency, temperature, irradiance, time	OLS SVM (RBF)
Massana J. et al.[34]	**Daily Power system operation and control**	Temperature, relative humidity, solar radiation, indoor temperature, indoor light level, occupancy, date	MLR ANN (MLP) SVM (PUK)
Zhao H. et al.[35]	**Energy conservation**	Holiday day, weather, zone mean air temperature, infiltration volume, heat gain through window, heat gain through lights, zone internal total heat gain	SVM (RBF)

30 Xuemei L, Lixing D, Jinhu L, Gang X, Jibin L. A Novel Hybrid Approach of KPCA and SVM for Building Cooling Load Prediction. 2010 Third Int Conf Knowl Discov Data Min 2010:1. http://dx.doi.org/10.1109/WKDD.2010.137/

31 Xuemei L, Jin-hu L, Lixing D, Gang X, Jibin L. Building cooling load forecasting model based on LS-SVM. 2009 Asia-Pac Conf Inf Process 2009;1:55–8. http://dx.doi.org/10.1109/APCIP.2009.22/

32 Solomon DM, Winter RL, Boulanger AG, Anderson RN, Wu LL. Forecasting energy demand in large commercial buildings using support vector machine regression. Department of Computer Science, Columbia University; 2011, [Tech. Rep. CUCS-040-11, September 2011]

33 Dagnely P, Ruette T, Tourwé T, Tsiporkova E, Verhelst C. Predicting hourly energy consumption. Can you beat an autoregressive model. Proceeding 24th Annu. Mach. Learn. Conference Belgium Netherlands, Benelearn, Delft, Netherlands, vol. 19; 2015.

34 Massana J, Pous C, Burgas L, Melendez J, Colomer J. Short-term load forecasting in a non-residential building contrasting models and attributes. Energy Build 2015;92:322–30. http://dx.doi.org/10.1016/j.enbuild.2015.02.007/

35 Zhao H, Magoulès F. Parallel support vector machines applied to the prediction of multiple buildings energy consumption. J Algorithm Comput Technol 2010;4:231–49

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Reference	Service	Features	Used algorithms
Liu D. et al.[36]	**Abnormal energy usage identification**	Occupancy, solar radiation	SVM (RBF)
Mena R. et al.[37]	**Energy demand management**	Date, outdoor temperature, outdoor humidity, , solar radiation, outdoor wind speed, outdoor wind direction, state of pumps, state of boilers, state of absorption machine, state of cooling tower, state of heat	ANN (NAR)
Yang J. et al.[38]	**Building daily operation**	On/off status of compressors, temperature of water entering ice tank/evaporator, outdoor relative humidity, outdoor temperature, chilled water, date, electric current in chiller, percentage of chilled water	Building daily operation
Lam JC. et al.[39]	**Heating Load Management**	Outside temperature, solar radiation, workday, occupancy profiles, operational power level characteristics, transitional characteristics	ANN (MLP)
Farzana S. et al.[40]	**Energy Supply side management**	Locale, population, people per household, electrification rate, type of devices, type of lighting bulbs, lighting energy fuel, fuel type, space heating and cooling energy use of fuel	ANN (BPNN)
Jovanović RŽ et al.[41]	**Above normal energy consumption detection**	Heating consumption of previous day, mean daily outside temperature, date	ANN (FFNN) ANN (RBFN) ANN (ANFIS)
Kwok SSK et al.[42]	**Energy auditing**	Outdoor temperature, relative humidity, rainfall wind speed, bright sunshine duration, solar radiation, occupancy area, occupancy rate	ANN (MLP)

36 Liu D, Chen Q. Prediction of building lighting energy consumption based on support vector regression. 2013 9th Asian Control Conf; 2013: p. 1–5. doi:10.1109/ ASCC.2013.6606376

37 Mena R, Rodríguez F, Castilla M, Arahal MR. A prediction model based on neural networks for the energy consumption of a bioclimatic building. Energy Build 2014;82:142–55. http://dx.doi.org/10.1016/j.enbuild.2014.06.052/

38 Yang J, Rivard H, Zmeureanu R. On-line building energy prediction using adaptive artificial neural networks. Energy Build 2005;37:1250–9. http://dx.doi.org/10.1016/j.enbuild.2005.02.005/

39 Lam JC, Wan KKW, Wong SL, Lam TNT. Principal component analysis and longterm building energy simulation correlation. Energy Convers Manag 2010;51:135–9. http://dx.doi.org/10.1016/j.enconman.2009.09.004/

40 Farzana S, Liu M, Baldwin A, Hossain MU. Multi-model prediction and simulation of residential building energy in urban areas of Chongqing, South West China. Energy Build 2014;81:161–9. http://dx.doi.org/10.1016/j.enbuild.2014.06.007/

41 Jovanović RŽ, Sretenović AA, Živković BD. Ensemble of various neural networks for prediction of heating energy consumption. Energy Build 2015;94:189–99. http://dx.doi.org/10.1016/j.enbuild.2015.02.052/

42 Kwok SSK, Yuen RKK, Lee EWM. An intelligent approach to assessing the effect of building occupancy on building cooling load prediction. Build Environ 2011;46:1681–90. http://dx.doi.org/10.1016/j.buildenv.2011.02.008/

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Reference	Service	Features	Used algorithms
Nunzio C. et al.[43]	**Chiller soft detection**	Outdoor air temperature, Electrical power input to CH-2, Supply chilled water temperature, Return chilled water temperature, Supply condenser water temperature, Cooling tower fan VFD signal, Supply cooling tower water temperature	PCA

OPTIMUS EU project will be capitalised as significant expertise has been gained regarding methodologies and tools for prediction models using ML techniques in several applications. Based on real-time data monitored (weather conditions, buildings' energy profiles, occupants' feedback, energy prices and energy production) and predicted data produced by the prediction models, OPTIMUS DSS[44] (Decision Support System), generates Action Plans for the energy managers based on a series of inference rules. In the table below, selected applications[45] are presented that were implemented and tested in OPTIMUS project and can be used under MATRYCS scope too.

Table 20: OPTIMUS implemented energy performance services to be used for MATRYCS purposes

Service	Features	Used algorithms
Photovoltaic (PV) production	Temperature, Humidity, Pressure, Wind Direction Degrees, Solar Radiation, Dew point, Wind Speed, Date	MLR
Energy Consumption	Outdoor Temperature, Indoor temperature, Degree Days – Heating or Cooling, Humidity, Pressure, Wind Direction Degrees, Solar Radiation, Dew point, Wind Speed, Date, Working/Non-Working Day, Envelope Characteristics, Occupancy profile	MLR
Indoor Air Temperature	Outdoor Temperature, Indoor Temperature, Month, Day, Hour, Working/Non-Working Daty, On/off of the heating system scheduling	MLR
Thermal Comfort Validator[46]	Temperature, Air velocity Lighting, Clothing, Activity	Decision Support System

43 Nunzio Cotrufo, Radu Zmeureanu, PCA-based method of soft fault detection and identification for the ongoing commissioning of chillers, Energy and Buildings, Volume 130, 2016, Pages 443-452, ISSN 0378-7788, https://doi.org/10.1016/j.enbuild.2016.08.083/

44 Vangelis Marinakis, Haris Doukas, John Tsapelas, Spyros Mouzakitis, Álvaro Sicilia, Leandro Madrazo, Sgouris Sgouridis, From big data to smart energy services: An application for intelligent energy management, Future Generation Computer Systems, Volume 110, 2020, Pages 572-586,
ISSN 0167-739X

45 Marinakis, V. Big Data for Energy Management and Energy-Efficient Buildings. *Energies* **2020**, *13*, 1555. https://doi.org/10.3390/en13071555

46 Marinakis, Doukas, Spiliotis,Papastamatiou, Decision Support for Intelligent Energy Management in Buildings Using the Thermal Comfort Model, International Journal of Computational Intelligence Systems, 2017, https://doi.org/10.2991/ijcis.2017.10.1.59/

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3.2.3.2 Analytics for Building and Related Infrastructure design and refurbishment

In the communication *A Renovation Wave for Europe*[47], the European Commission sets the objective of doubling the annual energy renovation rate of the building stock by 2030. This document identifies barriers but also proposes areas of intervention and lead actions to enable a step-change in the renovations. One of these actions reflects on how sustainability criteria could support the adoption of more sustainable construction products and encourage the adoption of the latest technologies.

In this regard, data analysis allows that in the design, refurbishment and development of buildings and their related infrastructure, phenomena that are traditionally considered subjective, complex or unpredictable are taken into account, supporting the different actors on decision-making. Thus, the standardised catalogues and ECM-based scenarios evaluation that will be used in this service will offer appropriate retrofitting solutions to the specific typology of analysed building and related infrastructure according to their current state.

Evaluating the correct application of an ECM in the energy efficiency of buildings is an increasingly popular topic in construction. Several instruments are on the market. Within the eCentral project, an analysis of these tools was carried out, categorising them according to required input data, calculation methodology, database behind, calculated outputs, design and usability factors. Some other general pieces of information have been required, such as: the availability, the target groups, the tool platform, the cost of the tool, tool language.

The Table 21 and Table 22 available in the deliverable D.T1.2.1 of eCentral project, provides a quick overview about all tools and their way of calculating refurbishment measures. Also, it shows how the different tools are gathering data about the building.

Table 21: Analysis of ECM tools (1/2)

Tool	CERPLAN	EnergOpt	Winwatt
Target Group	Experts/ official institutions	Experts/official institutions	Experts/official institutions
Cost	Chargeable	Free	Chargeable
Language	English/ Italian	English/ Hungarian	English/Hungarian

47 European Commission (2020): A Renovation Wave for Europe – greening our buildings, creating jobs, improving lives. COM(2020) 662 final, Brussels (Belgium).

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Tool	CERPLAN	EnergOpt	Winwatt
The tool has the ability to	**Define**: 〉 Heating Demand 〉 Primary Energy Demand 〉 CO_2-Emissions (e.g. from energy pass, performance cert., etc.) 〉 base shapes 〉 usage types 〉 walls, windows (layers, u-value or other) **Enter**: 〉 Max. investment costs obtained offers **Calculate**: 〉 cooling demand 〉 Refurbishment cost 〉 Generate most cost-effective alternatives	**Define**: 〉 Usage type 〉 Wall and window area 〉 Wall mounting (layer by layer from a library) 〉 Windows by u-value, dimensions, etc. Ventilation and cooling strategy and efficiency **Enter**: 〉 Type of heating distribution 〉 heating source 〉 mechanical ventilation performance percentage of renewables **Calculate**: 〉 Heating demand CO_2-emissions 〉 Share of renewables	**Define**: 〉 Usage type 〉 Wall and window area 〉 Wall mounting layer by layer 〉 Windows by u-value, dimensions, etc. 〉 Ventilation and cooling preferences 〉 Heating distribution system 〉 Enter positive energy impacts (PV-production) **Enter**: 〉 Heating distribution heating source ventilation performance share of renewables obtained offers **Calculate**: 〉 Heating, cooling and ventilation demand

Table 22: Analysis of ECM tools (2/2)

Tool	EnconCalc 3.0	ECOCITIES	PRoCasaClima
Target Group	Experts/official institutions	Experts/official institutions	Experts/official institutions
Cost	Free	Chargeable	Free
Language	German	English/German	Italian/German

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Tool	EnconCalc 3.0	ECOCITIES	PRoCasaClima
The tool has the ability to	**Define**: 〉 Enter positive energy impacts (e.g. PV-production) **Enter**: 〉 Energy demand (e.g. from energy performance certificate) Heating demand 〉 Cooling demand 〉 Ventilation demand 〉 heating source 〉 total area of walls 〉 primary energy factors CO_2-factors **Calculate**: 〉 Most cost-effective measures (financially)	**Define**: 〉 Building type (by usage) 〉 Priorities of the refurbishment 〉 Wall and window area 〉 Wall mounting (layer by layer from a library) 〉 Windows by u-value, 〉 Heating distribution system 〉 Enter positive energy impacts (e.g. PV-production) **Enter**: 〉 Energy demand (e.g. EPC) 〉 Energy demand for ventilation and cooling 〉 Enter heating source **Calculate**: 〉 Alternatives for refurbishment 〉 Shows costs and future savings for each refurbishment measures	**Define**: 〉 Walls, windows (layers, u-value, ...) 〉 Usage types **Enter**: 〉 Ventilation preferences for mechanical ventilation systems 〉 Cooling preferences for the cooling system (if existing) **Calculate**: 〉 Primary energy demand, 〉 CO_2-Emissions 〉 Heating demand 〉 Cooling demand

Some other tools are available at the National level such as URSA from Slovenia, EnCert-HR from Croatia, KI Expert Plus from Croatia. All of them require data of Building, information regarding building refurbishment, refurbishment costs and Usability.

On the international level the National Renewble Energy Laboratory (NREL) of the US Department of Energy developed a tool to prioritize the Energy Efficiency Investments. The tool uses established methodologies to evaluate the energy savings and cost of those savings of these investment opportunities. To reach this aim, the NREL identified over 770 energy efficiency measures through literature review and expert interviews each of which was supported by peer-reviewed publication, laboratory testing, in-situ (i.e., "pilot") testing, engineering-macroeconomic analysis (e.g., through the technical support documents of BTP's Equipment and Appliance Standards Program), building-energy use modelling, or verified savings through mass adoption (e.g., utility or other energy efficiency programs)[48].

3.2.3.3 Analytics for Policy Making and Policy Impact Assessment

This section aims at providing a description of the innovative services, applications, technologies or analytics that could constitute either competitors or foundations of the ones developed in the context of the project related to the Analytics for Policy Making and Policy Impact Assessment context. To this

48 https://www.nrel.gov/docs/fy12osti/54799.pdf/

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end, the section considers the following topics: (1) Energy Performance Certificates and (2) policy making and support of SECAPs.

Energy Performance Certificates: harmonisation and other analytics

Energy Performance Certificates schemes (EPCs) are a good method to evaluate the capability of improvement of energy efficiency for dwellings and buildings. Although the EPCs for the different member states come from the implementation of the same European directive (EPBD), EPCs datasets are very heterogeneous for different countries and regions of the EU (because the directive is implemented for each regional with certain level of freedom) and then their comparison is very challenging. The availability of harmonised EPC datasets across Europe would be beneficial firstly at EU level, allowing the comparison of EPCs datasets from different regions and countries and secondly for Regional Energy Agencies, as a valuable support to energy efficiency policies.

In the ELISE Energy & Location Applications Action[49], a series of use cases aimed to show how location data can support different types of stakeholders engaged in energy policies' cycle at different geographical scales, from local up to EU level. The objective of one of the use cased, named "INSPIRE Harmonisation of Energy Performance Certificates of buildings datasets in Spain" was to demonstrate the advantages of harmonising EPC datasets across EU countries and regions. In this case study, the objective was the harmonization of the EPC for two different regions form Europe following an INSPIRE-based methodology. The importance of working with powerful data processing tools, such as ETL and/or big data tools was highlighted during the work. In this specific use case *hale studio*[50] tool from *wetransform* was used, an INSPIRE compliant ETL tool.

Adding to the use of ETL tools for the harmonization, the application of big data tools would allow the user extract the information contained in the data in a structured and more useful way, providing valuable post processed knowledge that could be used for assessing a region's building stock in energy efficiency terms or for evaluating new EPCs, for example.

Besides, the use of open data and digital building/city twins could help to the automatic creation of data models that can be used as basis for feeding energy performance certification tools.

Energy Performance Certificates are a rating scheme to summarize the energy efficiency of buildings in the European Union. Data that are contained in an EPC can be used to create several services regarding energy performance. The main difficulty identified is that across EU EPCs is that they are not consistent in terms of data that they are made of. In this respect, a literature review was conducted to explore applications that use explicitly data from EPCs. As expected, there is limited material referring to applications that use state-of-the-art Machine Learning and Deep Learning methods and algorithms for EPCs. The findings are presented below:

49 https://joinup.ec.europa.eu/collection/elise-european-location-interoperability-solutions-e-government/energy-location-applications/

50 https://www.wetransform.to/products/halestudio/

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Table 23: Overview of EPCs AI-relevant studies

Reference	Service	Features	Learning Algorithm
Khayatian et al.[51]	Energy performance	Degree days, net volume, net floor area, dispersant surface, opaque to glazed ratio, year of construction, thermal conductivity (walls, windows, roof, basement), average floor height, opaque surface area, glazed surface area, construction period, non-linear features.	ANN
Hardy et al.[52]	Error Analysis of EPCs	Energy efficiency rating, inspection date, lodgment date, property type, built form, floor description, walls description, roof description, total floor area	Random forest, Linear Regression
Garcia-Nieto et al.[53]	Thermal Power Efficiency	Useful surface, thermal power, CO2 emissions, primary energy consumption. Opaque enclosures, holes and skylights	Gaussian process regression
Cozza et al.[54]	Energy consumption prediction analysis from EPC	Building type, construction year, ERA, envelope factor, energy label, mechanical ventilation, heating system construction year, U-value ground, U-value roof/ceiling, U-value external walls, U-value windows, construction type	Lasso regression

Supporting Policy making impact assessment and SECAPs implementation

State-of—the-art methods and applications relating SECAPs decision making and policy evaluation has been gathered for the purposes of this section. A literature review was performed, in order to investigate what kind of applications and methodologies in relation with Big Data and Machine Learning applications have been already been used. The findings are separated in two tables, the first one includes studies that analyses mainly textual information; an horizontal approach in policy making, and the second one with a more vertical approach in climate change relating issues that affects policy-makers. At first glance the findings may not be directly applicable to MATRYCS solution. However, these applications and their approach are recorded in the following table as they may be useful in latter stage and provide added value on a national or European scale.

51 Fazel Khayatian, Luca Sarto, Giuliano Dall'O', Application of neural networks for evaluating energy performance certificates of residential buildings, Energy and Buildings, Volume 125, 2016, Pages 45-54, ISSN 0378-7788, https://doi.org/10.1016/j.enbuild.2016.04.067/

52 A. Hardy, D. Glew, An analysis of errors in the Energy Performance certificate database, Energy Policy, Volume 129, 2019, Pages 1168-1178, ISSN 0301-4215, https://doi.org/10.1016/j.enpol.2019.03.022/

53 García-Nieto, P.J., García-Gonzalo, E., Paredes-Sánchez, J.P. et al. A new hybrid model to foretell thermal power efficiency from energy performance certificates at residential dwellings applying a Gaussian process regression. Neural Comput & Applic (2020). https://doi.org/10.1007/s00521-020-05427-z/

54 Stefano Cozza, Jonathan Chambers, Chirag Deb, Jean-Louis Scartezzini, Arno Schlüter, Martin K. Patel, Do energy performance certificates allow reliable predictions of actual energy consumption and savings? Learning from the Swiss national database, Energy and Buildings, Volume 224, 2020, 110235, ISSN 0378-7788, https://doi.org/10.1016/j.enbuild.2020.110235/

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Table 24: Overview of Policy Making AI-relevant studies

Reference	Purpose of the Study/ Expected Results	Method/ Technique	Learning Algorithm
Lesnikowski et al.[55]	Identifying adaption policies regarding climate issues (water treatment, sustainable growth etc)	Topic modelling	Latent Dirichlet Analysis
Lesnikowski et al. [21]	Identifying environmental issues in Canada's local governments.	Topic modelling	Robust Latent Dirichlet Analysis
Rana and Miller[56]	Proving that Machine Learning approaches can help understanding natural resource policy and predicting socio-economic effects of them.	Socio-Economic Systems and econometrics methods	Causal Tree (CT) and Causal Forest (CF) decision-tree algorithms
Biesbroek et al.[57]	Mapping actions regarding climate change adaptation by from policy texts and identifying high confidence blocks of adaptation.	Sorting and topic modelling	ANN
Debnath et al.[58]	Deep-narrative analysis in energy politics	Topic modelling, grounded theory	Latent Dirichlet Analysis
Hanchen et al.[59]	Identifying patterns and trends regarding hydro energy research and contributing towards strategy planning for hydro production growth.	Topic modelling	Latent Dirichlet Analysis
Tavana et al.[60]	Identifying key issues in energy sector and the techniques that policy makers use for risk assessment.	Text clustering, topic modelling	k-means clustering
Boussanis and Coan[61]	Introducing methodology to identify and record key issues regarding policy issues and climate change topics.	Text-analysis	Latent Dirichlet Analysis

55Lesnikowski A, Belfer E, Rodman E, et al. Frontiers in data analytics for adaptation research: Topic modeling. WIREs Clim Change. 2019;10:e576

56 Pushpendra Rana and Daniel C Miller: Machine learning to analyze the social-ecological impacts of natural resource policy: insights from community forest management in the Indian Himalaya, 2019 Environ. Res. Lett. 14 024008

57 Biesbroek, R., Badloe, S., & Athanasiadis, I. N. (2020). Machine learning for research on climate change adaptation policy integration: an exploratory UK case study. Regional Environmental Change, 20(3), [85]. https://doi.org/10.1007/s10113-020-01677-8/

58 Debnath R, Darby S, Bardhan R, Mohaddes K, Sunikka-Blank M. Grounded reality meets machine learning: A deep-narrative analysis framework for energy policy research. Energy Res Soc Sci. 2020 Nov;69:101704. doi: 10.1016/j.erss.2020.101704. PMID: 33145178; PMCID: PMC7563684.

59 Hanchen Jiang, Maoshan Qiang, Peng Lin, A topic modeling based bibliometric exploration of hydropower research, Renewable and Sustainable Energy Reviews, Volume 57, 2016, Pages 226-237, ISSN 1364-0321, https://doi.org/10.1016/j.rser.2015.12.194/

60 Madjid Tavana, Akram Shaabani, Francisco Javier Santos-Arteaga & Iman Raeesi Vanani: A Review of Uncertain Decision-Making Methods in Energy Management Using Text Mining and Data Analytics, Energies 2020, 13, 3947; doi: 10.3390/en13153947

61 Constantine Boussalis, Travis G. Coan, Text-mining the signals of climate change doubt, Global Environmental Change, Volume 36, 2016, Pages 89-100, ISSN 0959-3780, https://doi.org/10.1016/j.gloenvcha.2015.12.001/

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Reference	Purpose of the Study/ Expected Results	Method/ Technique	Learning Algorithm
Kreif and Diaz Ordaz.[62]	To provide an overview and an illustration of machine learning methods for causal inference, with a view to answer typical causal questions in policy evaluation	Overview	Several ML methods that may be applicable in policy evaluation

Table 25: Overview of ML/DL applications in Policy Making

Reference	Purpose of the Study/Expected Results	Features	Learning Algorithm
Magazzino et al.[63]	Examining CO_2 emissions, renewable energies, coal consumption and economic growth relation.	Solar energy generation, Wind energy generation, coal consumption, economic growth (GDP) and environmental pollution	D2C causality model
Mardani et al.[64]	Developing an efficient multi-stage methodology to predict carbon dioxide emissions	Energy Consumption, GDP, CO_2 emissions	Hybrid of ML techniques (SOM, SVD, ANFIS, ANN)
Mason et al.[65]	To predict future energy demand, wind generation and carbon dioxide emissions in one country (Ireland)	Historical time series of: Energy demand, Wind Power generations, CO_2 intensity levels	CMA – ES, PSO, DE, BP, MA, RWF, LR
Nam et al.[66]	Forecasting electricity demand and renewable energy generation and renewable energy scenarios suggestions to guide energy policy	Electricity demand, electricity supply, wind power generation, photovoltaic power generation	GRU, LSTM, DNN, SARIMA, MLR

62 https://arxiv.org/abs/1903.00402 [stat.ML]

63 Cosimo Magazzino, Marco Mele, Nicolas Schneider, A machine learning approach on the relationship among solar and wind energy production, coal consumption, GDP, and CO2 emissions, Renewable Energy, Volume 167, 2021, Pages 99-115, ISSN 0960-1481, https://doi.org/10.1016/j.renene.2020.11.050/

64 Abbas Mardani, Huchang Liao, Mehrbakhsh Nilashi, Melfi Alrasheedi, Fausto Cavallaro, A multi-stage method to predict carbon dioxide emissions using dimensionality reduction, clustering, and machine learning techniques, Journal of Cleaner Production, Volume 275,2020, 122942, ISSN 0959-6526, https://doi.org/10.1016/j.jclepro.2020.122942/

65 Karl Mason, Jim Duggan, Enda Howley, Forecasting energy demand, wind generation and carbon dioxide emissions in Ireland using evolutionary neural networks, Energy, Volume 155, 2018, Pages 705-720, ISSN 0360-5442, https://doi.org/10.1016/j.energy.2018.04.192/

66 KiJeon Nam, Soonho Hwangbo, ChangKyoo Yoo, A deep learning-based forecasting model for renewable energy scenarios to guide sustainable energy policy: A case study of Korea, Renewable and Sustainable Energy Reviews, Volume 122, 2020, 109725, ISSN 1364-0321, https://doi.org/10.1016/j.rser.2020.109725/

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Reference	Purpose of the Study/Expected Results	Features	Learning Algorithm
Acheampong and Boateng[67]	Predicting carbon emissions for five countries and identify significant contributory variables	Carbon emissions intensity, Energy Consumption, Financial Development index, Foreign Direct Investment, Economic Growth. Industrialisation, R&D(Total Trademark Applications), Population, Trade Openness, Urbanisation	ANN
Abrell et al.[68]	To analyse climate policy effects by providing an ex-post evaluation of a real-world policy experiment of carbon pricing: the UK carbon tax, also known as the Carbon Price Support.	Fossil-fuel power plant output, Fuel Prices, Carbon Prices, Emissions factors and plant-specific heat efficiencies, Plant Capacity, Demand, Temperature	Causal Inference

3.2.3.4 Analytics for De-risking Investments in Energy Efficiency

This section aims at providing a description of the innovative services, applications and technologies that could constitute either competitors or foundations of the ones developed in the context of the project related to the Analytics for De-risking Investments in Energy Efficiency context.

Methodologies for De-Risking Investments on EU projects and reports

The EEnvest project is a H2020 collaborative research project, which is currently going, focusing on a mainstreaming energy efficiency financing in the building renovation sector.

The aim of the EEnvest is a creation of a tool (we-based search and match platform) which investors can use to evaluate the risk of investment in energy efficiency for buildings.

This service will be a web platform that will act as a marketplace and bridge the gap between building owners, interested in upgrading their buildings for reducing energy consumption, and investors that are willing to provide the capital investment that generates profits through savings and energy efficiency. In parallel, the platform will promote investing in energy efficiency in buildings by making the initial investment risk analysis simple and attractive for the potential investors. The focus is on commercial office buildings, while the solution will be scalable to be applicable to large databases and other building types globally. Finally, a blockchain validation mechanism will ensure the validity of the data in the platform, allowing the investors to trust that there's no reliance on a 3rd party or there's no data tampering on the platform.

67 Alex O. Acheampong, Emmanuel B. Boateng, Modelling carbon emission intensity: Application of artificial neural network, Journal of Cleaner Production, Volume 225, 2019, Pages 833-856, ISSN 0959-6526, https://doi.org/10.1016/j.jclepro.2019.03.352/

68 Abrell, Jan and Kosch, Mirjam and Rausch, Sebastian, How Effective Was the UK Carbon Tax? - A Machine Learning Approach to Policy Evaluation (April 15, 2019). CER-ETH – Center of Economic Research at ETH Zurich Working Paper 19/317, Available at SSRN: https://ssrn.com/abstract=3372388/ or http://dx.doi.org/10.2139/ssrn.3372388/

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In the context of the Triple-A project [69], the Deep platform's data are analysed for constructing some predefined performance classes about Energy Efficiency projects. Following, the inspected Energy Efficiency projects are benchmarked, based to which class their predicted performance belong. Therefore, investors and bankers acquire solid knowledge about the candidate Energy Efficiency projects, recognizing the ones of good properties and with low risk. Accordingly, in the context of the SPEEDIER project [70] the patterns and trends of the building' data (e.g., user's behaviour, energy consuming equipment on site, building fabric characteristics) are analysed to find potential areas for implementing energy saving retrofits. In case of shortage, the data of similar buildings are extrapolated. In the context of CityInvest [71], the data of the Energy Efficiency projects that have been implemented through the project are analysed, in conjunction with the data of the local authorities in pilot regions, to recognize the key success factors of energy efficiency retrofits. This feedback is then integrated in future cases. EEnvest [72] and Industrial Energy Accelerator (IEA) [73] projects analyse the data of the inspected EE projects (e.g., experience and capability of the technical stuff, model used for baseline estimation) to quantify their risk of failing to achieve their predicted performance. By this way, they de-risk Energy Efficiency projects, enabling their financing. Launch project [74] follows the same approach, while also, analyses the macroeconomic data of the country that the investment takes pace like the energy prices trajectory, for calculating the risk of an Energy Efficiency project.

Paper on 'Do energy efficiency investments deliver?'[75] conducts an experimental evaluation of the Weatherization Assistance Program conducted on a sample of approximately 30,000 households in Michigan. He uses experimental and quasi experimental variation to identify the returns to these investments. The findings suggest that the upfront investment costs are about twice the actual energy savings, while also the model-projected savings are more than three times the actual savings. By this way Energy Efficiency projects of the programs are consulted to revise their estimations about the potential energy efficiency savings. R2A Project [76] creates a database that contains big data, both real records and modelled data, about buildings household's energy efficiency measures and their performance across 8 countries. Moreover, a web-oriented application that enables the handling and exploitation of these data is available. Based on these data, homeowners are consulted by banks and financiers on how to co-finance energy efficiency measures with the savings and issue loans, while also the available financial products for implementing energy efficiency measures are shown at the website.

In the context of the Energy and Environmental Policy Analysis (EEPA) Project [77], a technology-based methodology for controlling the EE project's performance is implemented. The first step comprises the benchmarking of the building's energy demand and saving without any risk event (e.g., such as the change of weather conditions) by using the EnergyPlus simulation tool. Following, the risk scenarios

69 https://aaa-h2020.eu/

70 https://speedierproject.eu/

71 http://citynvest.eu/

72 http://www.eenvest.eu/

73 https://www.industrialenergyaccelerator.org/

74 https://www.launch2020.eu/

75 Fowlie, M. 2018. Do energy efficiency investments deliver? Evidence from the weatherization assistance program. The Quarterly Journal of Economics.

76 https://www.eceee.org/library/conference_proceedings/eceee_Summer_Studies/2017/8-monitoring-and-evaluation-building-confidence-and-enhancing-practices/can-big-data-drive-the-market-for-residential-energy-efficiency/

77 Byrne et al. 2018. Investor risk mitigation in energy efficiency retrofit projects using automated monitoring and verification techniques

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with and without M&V automated Controls are simulated through a probabilistic change in input variables of EnergyPlus (Monte Carlo analysis). The results arisen are subsequently evaluated by a financial model in terms of cost savings. To perform the simulations the Amazon Web Services (AWS) are used due to the increased computing demand created by the many scenarios needed to be simulated. This approach assists in the creation of an investor-ready energy efficiency finance structure that includes automated M&V for specific energy conservation measures. In the same context, [78] performs a case study on building energy efficiency retrofits, mining operational data of the building. Decision tree, clustering analysis, and association rule mining are used for analysing the data. He finds that well designed M&V processes such as the on-site measurement of U-values, can contribute towards developing strategies for improving building energy efficiency.

Paper on 'Data drive process for the energy assessment of building envelope retrofits' [79] performs a case study on a building in Spain. Two data sources are used for monitoring the building's energy consumption and comfort conditions. The one is the radiators' energy use and the other a weather station on the roof of the Building, for capturing the climate conditions. The data gathered over 2015-2019 are separated into pre-retrofit and post-retrofit one. He proves the need of deploying well designed & executed M&V processes within building energy retrofit such as on-site measurement of U-values it is proved. [80] presents a Gaussian modelling framework to determine energy savings and uncertainty levels in measurement and verification (M&V) practices. Existing M&V guidelines usually based on linear regression techniques, which unless adjusted, they are not in place for capturing nonlinear behaviours arisen from complex multivariable interactions such as ambient conditions, occupancy levels, and building operating conditions. He performs two case studies, where at the one of them applies a regression error analysis of a control system with different explanatory variables, and at the second one applies a Gaussian approach. He finds that Gaussian modelling can better capture nonlinear trends and different sources of uncertainty compared to non-linear regression, leading to significantly less expensive M&V practices. [81] employs a novel and computationally efficient feature selection algorithm, as well as powerful machine learning regression algorithms to maximise the effectiveness of available data. He performs a case study in a large biomedical manufacturing facility, while gathering the data by climatic meters located across the facility. The baseline energy consumption is modelled by training the available data with artificial neural networks, support vector machines, k-nearest neighbours, and multiple ordinary least squares regression. He demonstrates the ability of the methodology to perform M&V to an acceptable standard in challenging circumstances, thus increasing the applicability of M&V.

IMPVP protocol application for the measurement and verification of energy savings

To recognize and increase the potential of energy efficiency it is of vital importance that the verification of savings is properly reported. Energy users need to have robust methods to verify the achievement of their energy objectives, potential and actual purchasers of energy efficiency products or services want to know that their purchases have been proven through recognized methods and

78 Fan C, Fu X. 2017. Mining big building operational data for improving building energy efficiency: A case study. Building Services Engineering Research and Technology, pp 117-128

79 Garay R. et al. 2020 Data driven process for the energy assessment of building envelope retrofits. In E3S Web of Conferences. EDP Sciences

80 Heo Y.. & Zavala V. M. Gaussian process modeling for measurement and verification of building energy savings. Energy and Buildings. Vol. 53.pp 7-18

81 Gallagher C. et al. Development and application of a machine learning supported methodology for measurement and verification (M&V) 2.0. Energy & Buildings. Vol.167. pp 8-22

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need feedback on the effectiveness of their purchases, governments and utilities need to know that savings reported from energy efficiency programs are grounded in actual field-measured results following a widely accepted protocol. Basically, the knowledge that energy savings can be transparently reported is vital to the acceptance of energy efficiency proposals.

The International Performance Measurement and Verification Protocol (IMPVP) is the leading international protocol for measurement and verification and represents a structured presentation of common principles and terms that are basic to any good Measurement and Verification (M&V) process. Each M&V project must be individually designed to suit the objectives and desired accuracy of energy savings efforts.

The IPMVP presents a framework and four measurement and verification (M&V) options for transparently, reliably and consistently reporting project's savings. When adhering to IPMVP's recommendations, these M&V activities can produce verifiable savings reports.

3.2.3.5 Geo-clustering service as support to the BD Vision

Nowadays the importance of GIS is increasing: there are more data sources and also there are more processes and workflows to work with these data in order to offer added value. Multiple companies are taking into account GIS data and workflow in order to improve the services they are offering.

Clustering technologies take advantages of different data sources, and process that in order to group the different elements in sets with similarities, that can provide very valuable information. Geo-clustering applications use also the geographical information available in order to include the geographical component in the algorithms, providing results that take into account the location of the elements. Geo-clustered data are extremely valuable to highlight trans-national similarities and provide useful information to policy makers and legislative bodies for more tailored policy decisions.

On the geo-cluster definition related to building and energy domain, the framework of the project GE20 is leading the field. The objective of the project is the creation of geo-clusters that define similarities across EU regions by combining various parameters such as Climate, building typology, socio-36 economic, regulation, financial incentive. *Calvert et al.* created mapping through geographically explicit 37 indicators such as environmental, technical and social constraint and potential benefits for the implementation of 38 renewable energy sources. *Fatiguso et al.* applies geo-cluster using climatic data, simulation of solar radiation and 39 wind exposure, mapping of typologies, materials, construction techniques and historic-architectural values for a 40 simple site retrofitting. *Kuster et al.* define geo-clusters based on heterogeneous parameters related to energy consumption 42 and production. Building typologies, environmental conditions and economic considerations will thus be used for the 43 creation of sub-continental regions in Europe reflecting strong similarities of localised systems behaviour.

The geo-cluster tool developed in the Exceed project, guides user in understanding which innovative solutions have led to operational building performance in line with expectations. In this project, using the geo-cluster tool, the user can compare performances in a building stock aiming to have a better understanding of building operational behaviour both in terms of energy and IEQ (Indoor Environmental Quality). Such enhanced knowledge and awareness generate a better management and consequent energy and cost savings as well as improve the indoor environmental quality. Definition of Key Performance Indicators (KPIs) is central to this tool. Indeed, they provide easily accessible and useful information about buildings helping the understanding of their real performance.

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Table 26: Overview of ML/DL applications in Geo-clustering

Reference	Service	Features	Learning Algorithm
C. Kuster et al.[82]	**Geo-mapping methodology**	Definition of 116 clusters using 16 parameters on building domain	Not defined: Use Matlab + Excel and "some criteria to select cluster" not specified
M. M. Sesana et al.[83]	**Geo-cluster mapping tool**	Geo-cluster concept is based on the possibility to locate similarities across enlarged EU by correlating single or multiple parameters and indicators organized in homogeneous layers and sub-layers. The different layers can be analysed using a single descriptor, to identify for instance geographical areas which share similarities in climatic conditions or financial incentives, or they can be analysed based on several layers and their corresponding descriptors for more complex investigation	Correlation and cross-correlation between variables.
Exceed Project.[84]	**Geo-cluster tool**	Geo-clustering of building performances both on energy and comfort aspects through the identification of specific KPIs. Classification of buildings by filtering them with building metadata. Benchmarking of building using specific indicators.	K-means algorithm
F. Fatiguso et al.[85]	**Building geo-cluster**	Collection of geographic and climatic data, simulation of solar radiation and wind exposure, mapping of typologies, materials, construction techniques and historic-architectural values of all the buildings. All the data, also from onsite experimental measurements and analytical simulations, are acquired according to specific protocols, including informative databases, checklists and platforms – e.g., ArcGIS – in order to enable the cross-elaboration of information from different sources and cases.	ArcGIS mapping cluster toolset (not specified what)

82 C. Kuster, J.L. Hippolyte, Y. Rezqui, M. Mourshed "A simplified geo-cluster definition for energy system planning in the Europe" Energy procedia, August 2018.

83 M. M. Sesana, B. Cuca, G. Iannaccone, R. Brumana, D. Caccavelli, and C. Gay, "Geomapping methodology 191 for the GeoCluster Mapping Tool to assess deployment potential of technologies for energy efficiency in 192 buildings," Sustain. Cities Soc., vol. 17, no. May 2013, pp. 22–34, 2015

84 European Commission, "Projects and Results : Geo-clustering to deploy the potential of Energy efficient 194 Buildings across EU," 2013

85 Fatiguso, M. De Fino, E. Cantatore, A. Scioti, and G. De Tommasi, "Energy models towards retrofitting of the historic built heritage," no. October, pp. 159–170, 2015.

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3.2.4 Digital tools for data & knowledge management

This section presents two examples of digital tools for data and knowledge management.

Electronical Monitoring System (EMSI) created by LEIF

The EMSI (electronical monitoring system) system has been created with the aim to provide an opportunity for the Beneficiaries to electronically prepare and submit monitoring (post-evaluation) reports on completed LEIF funded projects. Financial beneficiaries will submit data in EMSI system regarding their building energy consumption monthly. The submitted data will be compared with the historical data before any energy efficiency measures were taken, so beneficiaries can compare what is saved energy difference between old data and new-real time data (after measures).

The main benefits of EMSI system are:

- Simplified electronic input of monitoring data,
- Automatic data adjustment accordingly degree days,
- Report ready to print and sign (electronic submission),
- All data regarding building in one place,
- Simplified review of reports

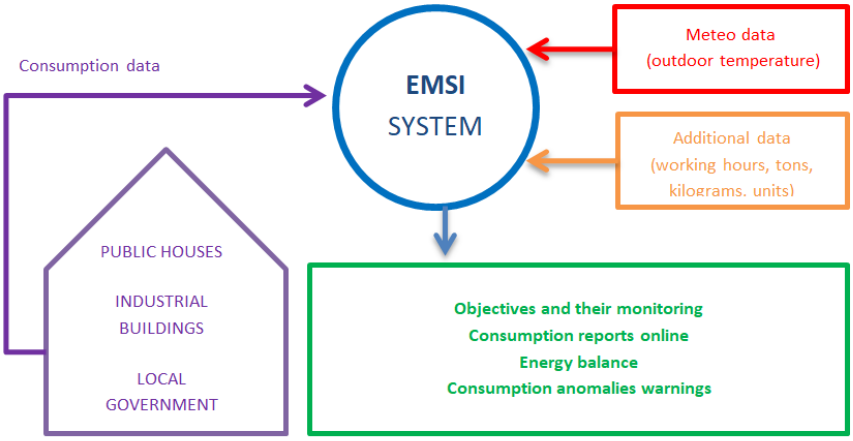

Figure 9: EMSI (electronical monitoring system)

Energy Monitoring Platform (EMP) created by Ekodoma

EKODOMA is an independent engineering-advisory company, with a long history and valuable experience gained in Latvia and other European and Eurasian countries in which we operate within both international projects and framework of private orders. To facilitate the accounting of energy consumption data by municipalities and to ensure their systematic input, processing and analysis, Ekodoma has developed and set up an energy monitoring platform.

The energy monitoring platform is a user-friendly system accessible via the Internet, which allows the municipality, as well as the energy manager, to create energy consumption accounting for three main sectors - municipal buildings, street lighting, municipal car fleet and / or public transport. EMP works on the same principles as EMSI system (LEIF) - the responsible person must enter the energy consumption data into the system on a monthly basis. Data is monitored in these areas:

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- Buildings - Heat consumption (MWh), Electricity consumption (kWh), Cold water consumption (m3),
- Transport - Fuel consumption, Mileage, Number of passengers (buses),
- For street lighting - Electricity consumption, Number of operating hours.

Other private sector energy monitoring systems

There are also private companies on the market that offer energy data monitoring digital tools, which mostly works on the same operating principles – collecting and analysing data from smart meters and loggers, for public and private persons.

Intellify system is one of them. In their monitoring system it is possible to integrate meters that communicate in Mbus, Modbus, pulse, Bacnet communication protocols. Wireless sensor data is integrated into the system using the MQTT protocol, but building management and automation system data are integrated using the Bacnet protocol.

The modular structure of the system allows the user to choose in which charts and other visualization tools the data will be displayed, or it is possible to hire an Intellify specialist who will create the data visualization.

The system has the ability to specify parameter thresholds, above which the system will display an alert, which will be automatically sent to the user's e-mail. Mathematical models integrated into the Intellify system automatically detect energy and resource consumption anomalies and provide an assessment of building management efficiency. Intellify monitoring system analysis tools and alerts received help the energy manager make smart decisions on how to change the operating parameters of engineering systems to reduce energy consumption and ensure a favourable indoor climate.

3.2.5 (Cyber) Security: Governance models for secure data and information delivery across lifecycle and supply chains

Data is the most valuable resource of digital economy, enabling participants to leverage the potential of business ecosystem. Information, as a set of data that is pre-processed in a meaningful way to possess purpose and requirement, and its exchange among participants and systems to achieve synergies represent the added value that can be achieved in a certain business context. In this context, the power of data to drive business transformation is well recognized and necessitates proper data governance. That means defining the processes involved in managing data's access, availability, usability and security in line with the respective internal policies and relevant regulation. In an ecosystem involving the exchange of data among distinct entities of a value chain or even considering the instantiation of data marketplaces, the foundations of governance must be defined and agreed upfront in terms of: (1) rules for inputting, accessing and using the data, (2) enforcement of authentication, authorization and auditing rules, and (3) management of data and respective rules over the lifecycle.

Companies are increasingly accruing massive amounts of raw data and adopting environments for its storage. However, to prevent the data assets from becoming data liabilities, this process must be complemented with governance framework to establish the baseline of data understanding and ensure integrity, usability and value creation. According to the European commission proposal on

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European data governance[86] following are the needs for the realization of digital economy potential:

- Create mechanism for re-using certain categories of protected public sector data, while ensuring the technical capability to preserve data protection, privacy and confidentiality.
- Increase trust in sharing personal and non-personal data for specific purpose and lower transaction costs linked to B2B and C2B data sharing by creating a notification regime for data sharing providers.
- Designate competent authority to monitor compliance with rules and requirements.
- Facilitate data altruism (i.e. data voluntarily made available by individuals or companies for the common good) and establish mechanisms to engage organization, lower the cost of collecting consent, and support data portability.

Availability of data and governance framework must be complemented with technical standards and tools that support individuals to exercise their rights and allow for cyber secure data exchanges.

3.2.5.1 Big data security

Big data security is a collective term for the measures and tools used to guard both, the collected data and applied analytics processes, from attacks, thefts or other malicious activities that could harm the systems and processes. Much like for other forms of cybersecurity, the big data variant is concerned with attacks that originate from either the online or offline sphere. What makes it fundamentally challenging is that data collection and analytics services are instantiated across escalating distributed and disparate IP-equipped endpoints[87]. According to Cloud Security Alliance[88], the main big data security challenges are associated with:

- Secure computations in distributed programming frameworks, utilizing parallelism in computation and storage to process massive amounts of data.
- Secure infrastructure of non-relational data stores, allowing stringent authentication and authorization mechanisms and secure communication among compute nodes (e.g. provided by middleware).
- Logging of data storage and transactions to support to support data confidentiality and integrity.
- Granular auditing of usage, pricing and billing to observe conformance, detect attacks and monitor regulatory compliance.
- Data provenance to keep track of ownership and dependencies.
- End-point validation/filtering to prevent malicious data from being introduced.
- Real-time security monitoring to monitor events of fraudulent activity and prevent from anomalous retrieval of confidential/personal information.

86 https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020PC0767/

87 Tian, Y. (2017). Towards the Development of Best Data Security for Big Data. Communications and Network, 9, 291-301. https://doi.org/10.4236/cn.2017.94020

88 https://cloudsecurityalliance.org/

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- Cryptographically enforced access control and secure communication to ensure private data is securely (encrypted) exchanged end-to-end and only accessible to the authorized entities.
- Granular access control to allow for restrictive data categorization and exchange according to individual privileges level.
- Scalable and composable privacy preserving data mining and analytics going well beyond user anonymization, such as preventing unintended data leakage or untrusted party data processing.

To establish secure data supply chains, it is critical to establish and manage trust among the parties exchanging and sharing data. According to International Data Spaces[89] architecture, this means to provide means for parties' identification, protection of communication lines and data during transactions, and control of data usage for specific purpose. Besides providing means for secure communication to protect data during transaction from modification or disclosure and the adoption of Authentication, Authorization, Accounting (AAA) framework to mediate the access and use of network and computation resources, this means to introduce concepts for (1) identity and trust management and (2) data access and use control. *Identity management* refers to ability of making access control decisions based on reliable party identities and properties, typically facilitated using digital certificates. *Trust management* refers to the certification authority issuing and managing security credentials (e.g. based on Public Key Infrastructure (PKI)), and participants to authenticate and dynamically access the resource/service. *Data access control* regulates the request to endpoints. In this respect, several models can be applied to allow for granular permissions control, with Role-Based Access Control (RBAC) and Attribute-Based Access Control (ABAC) being among the most frequent approaches. *Data usage control* extends this with the means for the enforcement of restrictions regulating what may or may not be performed with a specific data asset. That means supporting policies regulating the processing of data at the level of data flows.

3.2.5.2 Edge computing security

The growth of buildings embedding technologies to monitor the internal environment with respect to energy consumption, occupancy, comfort and the environment have an immense potential. Combining the building automation systems, such as for lighting, HVAC and access control, with analytics services based on acquired, modelled and environmental data allows for further improvement of comfort, energy efficiency and synergies with the greater environment[90]. Cloud computing is able to respond to large volumes of data and supports scalability for on demand processing, however the buildings can also profit form edge computing collocated with other control systems. This may allow for faster processing, reduced network cost, advanced data preparation and user-centred privacy management[91].

To enable such hybrid cloud-edge infrastructure instantiations, the Trusted Computing Group[92] proposed the application of Trusted Platform Module (TPM) 2.0 specifications to assure data exchanged between edge and the cloud is protected and credential authentications are authorized.

89 https://internationaldataspaces.org/

90 https://www.sciencedirect.com/science/article/pii/S1877050920304506/

91 https://ieeexplore.ieee.org/abstract/document/9377918/

92 https://trustedcomputinggroup.org/

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The cloud servers and edge computing gateway towards IoT devices and building automation system are connected over the public Internet using an OpenSSL connection that supports Transport Layer Security (TLS) and Secure Sockets Layer (SSL) protocols. TPM protects credentials and provides solutions for unique device identification in Public Key Infrastructure (PKI).

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4 Building related DATA SETs and repositories

Available public open dataset and also some private datasets valuable for MATRYCS context have been identified and are shown in the following subsections. They are classified based on the level that the reported information refers to, as well as according to their public or private nature. Thus, datasets from EU repositories (4.1), datasets existing in national repositories of the member states (4.2), some dataset identified at regional level (4.2) and finally private datasets (4.4) are presented. These identified datasets are not only datasets containing building information, but also datasets that are related to the energy performance of the buildings, districts and regions. The majority of the datasets that report information at an EU level, also contain information about each individual member state. All of them could be potentially used by MATRYCS tools and services. To conclude, section 4.5 includes already identified datasets that will be used in the MATRYCS project.

It is important to highlight that the open data are very valuable for most of the services to be developed in MATRYCS. Open data is a term that comes from 1942, with the idea of sharing scientific results, and it has been really enhance at the beginning of the 21st century. Open data are data freely available to everyone without restriction to achieve transparency. The characteristics of this type of data are the availability, the possibility of reuse the data and their redistribution and the universal participation in the redistribution and use of the data. It is also important the interoperability of this type of data in order to link datasets from different sources. Because of this, open and reusable formats are much appreciated. The final aim is cooperatively to provide knowledge from this data, creating add value datasets and also service around them.

Nevertheless, despite the existence of plenty repositories that contain data at an energy-system level or sectoral one, there is a lack of datasets that contain information at a project scale level. Some exceptions are the "Deep" platform and "MURE" database, which report information about the performance of energy efficiency measures implementation at a project level. Moreover, there is a plethora of datasets like Eurostat, World Bank, OECD, "Statistical review of world energy" and "United Nations Energy Statistics" that contain information about macroeconomic and energy-related variables of member states, thus are mostly related to the "Policy" service of MATRYCS. In general, the majority of datasets refer to the policy and performance services, while for the fund service only one relevant dataset has been identified ("Climate Fund Inventory"), providing information on the number and types of climate funds that are available.

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4.1 Public EU repositories

This section provides a list of relevant existing public EU repositories.

Table 27: Public EU repositories

Repository	Description	Website
EU Building Stock Observatory	The EU Building Stock Observatory monitors the energy performance of buildings across Europe. Among the features under supervision, the energy efficiency levels in buildings (EU countries /EU as a whole), certification schemes, financing aspects and levels of energy poverty throughout the EU can be mentioned	https://ec.europa.eu/energy/eu-buildings-database_en
EU Energy Poverty Observatory (EPOV)	The EPOV is an initiative by the European Commission to help Member States combat energy poverty. The approach is to use a set of indicators that individually capture a slightly different aspect of the phenomenon. Together, they can bring a snapshot of energy poverty issues.	https://www.energypoverty.eu/indicators-data
EUROSTAT	The Statistical Office of the EU is responsible for publishing high-quality statistics and indicators at the European level that allow comparisons between countries and regions.	https://ec.europa.eu/eurostat/web/energy/data
Statistical Review of World Energy	This report analyses data on world energy markets from the prior year. The review has been provided timely, comprehensive and objective data to the energy community since 1952.	https://www.bp.com/
TABULA EPISCOPE	The general objective of the EPISCOPE project was to make the energy renovation processes in the EU housing sector transparent and efficient. As main outcome, a concerted set of energy performance indicators are given. It is focused on residential building typologies. It contains data about buildings' energy needs, costs, demand, emissions etc. per climate zone, construction year classes and buildings' characteristics	http://webtool.building-typology.eu/
ENTRANZE	ENTRANZE is a project funded by the Intelligent Energy Europe programme. Its main objective is to actively support policy making by providing the required data, analysis and guidelines to achieve a fast and strong penetration of nZEB and RES-H/C within the existing national building stock.	https://entranze.enerdata.net/

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Repository	Description	Website
ODYSSEE – Full database	Odyssee, the European Energy Efficiency data base, has collected for the last two decades valuable and detailed energy efficiency and CO_2 emissions indicators. It provides a review and benchmark of EU members' progress in the energy efficiency target. It contains energy and macroeconomic data at an economy-wide level, and environmental indicators at an economy-wide and sectoral level (Industry, Transport, Residential, Services & Agriculture) over 2000-2018.	https://www.odyssee-mure.eu/
ODYSSEE – Key indicator tool	The Key indicator tool contains saving rates and consumption data at an economy wide and sectoral level and offers the results geo-located. The user can check the results in a map and graph, and the info can be downloaded in excel format or as an image (for the map)	https://www.indicators.odyssee-mure.eu/online-indicators.html
ODYSSEE – Decomposition tool	This online-web tool decomposes the energy use into various explanatory effects. The user can make the consults online and download the results in excel format	https://www.indicators.odyssee-mure.eu/decomposition.html
ODYSSEE – Market diffusion tool	The Market diffusion tool reports indicators reflecting the market diffusion of various energy efficient technologies. The results can be also downloaded in excel format or as an image	https://www.indicators.odyssee-mure.eu/market-diffusion.html
ODYSSEE – Comparison tool	This tool enables the comparison of two countries in terms of their energy efficiency performance, at an economy wide and sectoral scale	https://www.indicators.odyssee-mure.eu/benchmarking.html
ODYSSEE – Energy saving tool	The Energy saving tool displays the trends and targets for the primary and final energy consumption, and energy savings at a national level.	https://www.indicators.odyssee-mure.eu/energy-saving.html
ODYSSEE – EU energy efficiency scoreboard	This tool scores EU countries on a) the energy efficiency level, b) the energy efficiency progress, c) the energy efficiency policies and a combination of all these criteria. The user can make the consults online and download the results in excel format	https://www.odyssee-mure.eu/data-tools/scoring-efficiency-countries.html
MURE database	MURE database (Mesures d'Utilisation Rationnelle de l'Energie) provides information on energy efficiency policies and measures that have been carried out in the Member States of the EU (including Norway, Switzerland and Serbia as well). The implemented measures can be filtered by country, type and targeted end-use. It also evaluates them in terms of cumulative annual savings. The user can make the consults online and download the results in excel format	https://www.measures.odyssee-mure.eu/energy-efficiency-policies-database.html#/

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Repository	Description	Website
EnergyPlus Weather Data	EnergyPlus is an open-source whole-building energy-modelling engine. Weather data for more than 2100 locations are available in its weather format, which are arranged by World Meteorological Organization region and Country. It contains weather data at a city level.	https://www.energyplus.net/weather
Climatic Research Unit (CRU)	The objective of the CRU is to improve the scientific understanding of the climate system and its interactions with society. Its research attempts to explain how and why the climate changes, and how to reduce and improve associate uncertainty in information. It contains weather data, monthly and annually	https://sites.uea.ac.uk/cru/data
European Environment Agency (EEA)	The EEA is the agency of Europe that focus on providing data related to environmental policies and other topics related to environment taking advantage of its extensive network. The main objective of the EEA is to provide information and integrate environment issues in policies. The user can make the consults online and download the results in different formats (pdf, csv, excel…)	https://www.eea.europa.eu/data-and-maps
Our World in Data	It contains information about macroeconomic and energy-related variables. The user can make the consults online and download some of the results in csv format	https://ourworldindata.org/
European Open Data Portal	The EU Open Data portal represents the access point to data institutions, agencies and other bodies of the European Union.	https://data.europa.eu/euodp/en/home
European Data Portal	The European Data Portal collects the metadata of the public sector information available on the public data portals of EU countries.	https://www.europeandataportal.eu/en
World Bank	It contains information about the majority of macroeconomic and energy related variables	https://data.worldbank.org/
Organization for Economic Co-operation and Development (OECD data)	The OECD is an international organization that works to shape policies that foster equality, opportunity, prosperity and well-being for all. Its website contains information about the majority of macroeconomic and energy related variables. The datasets can be downloaded in multiple formats	https://data.oecd.org/
Covenant of Mayors	The Covenant of Mayors represents the world's largest movement for local climate and energy actions. Its website contains information about the climate mitigation measures and targets set per municipality, and the estimated impacts in terms of estimated greenhouse gas emissions reduction per sector	https://www.covenantofmayors.eu/plans-and-actions/action-plans.html

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Repository	Description	Website
The shift data portal	The shift project is behind this initiative. It is a non-profit organization committed to serving the general interest through scientific objectivity, and dedicated to informing and influencing the debate on energy transition in Europe. Its website contains information about national macroeconomic and energy statistics	https://www.theshiftdataportal.org/energy
United Nations Statistics Division website (UNSD)	The UNSD mission in the area of energy statistics is to strengthen national statistical systems to provide high quality energy statistics and balances. UNSD collects annual and monthly energy statistics and disseminates them on data publications. Its website contains information about national macroeconomic and energy statistics	https://unstats.un.org/unsd/energystats/
Ember	Ember is a not-for-profit company that has a commitment to making as much of their data and research as open as possible. Its website offers interactive tools that report statistics about energy systems	https://ember-climate.org/data/
Climate Fund Inventory Database	The Climate Fund Inventory database (CFI) is a qualitative database of bilateral and multilateral public climate funds. It supports recipient countries, least developed ones in particular, by providing consolidated information on the number and types of climate funds that are available.	https://qdd.oecd.org/subject.aspx?subject=climatefundinventory
The carbon Center	The carbon Center was created to support transparency, accountability and credibility. It aims to support cities, towns and regions tackling climate change (CDP and ICLEI are partnering to present one unified process for subnational climate action reporting). This site contains information about cities' climate mitigation measures, climate targets and performance in terms of carbon emissions	https://carbonn.org/
Open Street Map (OSM)	OSM is a collaborative project to create a free editable map of the world. The data generated by the project is considered its main output. Maps are created using geographic information captured with mobile GPS devices, orthophotos and other free sources.	www.openstreetmap.org
Copernicus data	Copernicus is the European system for Earth monitoring. It offers information services based on Earth Observation and "in situ" data covering six thematic areas: atmosphere monitoring, marine environment monitoring, land monitoring, climate change, emergency management and security.	https://www.copernicus.eu

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Repository	Description	Website
HotMaps	A Horizon 2020 project that completes building stock analysis for the EU27+UK. Values related to final energy consumption and useful energy demand for space hearing, space cooling and domestic hot water, construction materials and methodologies, technologies used and building stock data/information can be found both for the residential and the non-residential sectors per building types and construction vintages.	https://gitlab.com/hotmaps/building-stock/-/tree/master/data
ZEBRA	A Horizon 2020 project which gathers building stock data including data for energy efficiency trends in buildings as well as data for net zero energy buildings. The project focused on the newly built buildings and on the creation of an observatory for monitoring the market uptake of nZEBs across Europe. It contains information related to energy performance certificates, materials employed for the buildings, energy performance and final energy consumption among others.	https://zebra-monitoring.enerdata.net/
CommONEnergy	FP7 project on building stock data including building sector data and final energy demand data for non-residential buildings, especially focusing on the trade sector.	https://eeg.tuwien.ac.at/commonenergy/
JRC IDEES 2015	The JRC IDEES (Integrated Database of the European Energy System) is focused on the incorporation in a single database of all necessary information for a better understanding of the off the European energy system dynamics. In this way it provides a way to better analyse both the past and to create the best possible basis for future policy assessments. JRC IDEES offers a set of disaggregated energy-environment-economy data, compliant with the EUROSTAT energy balances, as well as widely acknowledged data on existing technologies. It also contains a plausible decomposition of final energy consumption.	https://data.jrc.ec.europa.eu/dataset/jrc-10110-10001/resource/f590b6f1-60e5-49a6-a972-60bc2b2e34b3
SET-Nav - Strategic Energy Roadmap	The project intends to support strategic decision making in Europe's energy sector, enhancing innovation towards a clean, secure and efficient energy system.	http://www.set-nav.eu/
ExcEED	H2020 project (European Energy Efficient building district Database) takes the pulse of the actual energy consumed by last generation of buildings. The project answers the need for transparency and comparability of energy performance calculations. The scope of ExcEED is to create a European database for measured and qualitative data on beyond the state-of-the-art buildings and districts.	http://www.exceedproject.eu/

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Repository	Description	Website
iNSPiRe	FP7 project on building stock analysis and data gathering exercise focusing its attention on published literature and other sources, aiming to extrapolate information about the current residential and office building stock.	https://zenodo.org/record/3256270#.XwayHqSnIU
ZENSUS 2011	This dataset contains disaggregated data concerning a building stock analysis for Germany, information about the occupancy of the buildings and socio/economic related data. Information concerning the type of heating systems used are reported too. The goal of the 2011 Census is to provide the most accurate snapshot possible of basic data on the country's population and the employment and housing conditions.	https://ergebnisse.zensus2011.de/#
Towards a sustainable Northern European housing stock – Sustainable Urban Areas 22	This report contains complete data for a building stock analysis with data varying from State to State between 2000 and 2006. Data concerning material used and (heating, ventilation and cooling) systems installed are reported too. Construction/Demolition rates (1980-2004) have been added to the report.	https://www.arct.cam.ac.uk/Downloads/towards-a-sustainable-northern-european-housing.pdf
DEEP – De-risking Energy Efficiency Platform	The De-risking Energy Efficiency Platform (DEEP) is an open source database for energy efficiency investments performance monitoring and benchmarking. The platform provides an exhaustive analysis on the performance of energy efficiency investments in order to support the assessment of the related benefits and financial risks. More in the detail it could be possible to extrapolate data concerning the energy savings per renovation type or per building type.	https://deep.eefig.eu/overview
Energy consumption and efficiency technology measures in European non-residential buildings	This paper provides an overview on the results of the data collected by the Green Building Programme (GBP) and its main results from the launch in 2006 up to its completion in 2014. The paper focuses on building characteristics, energy performance, efficiency measures and energy savings. The paper categorises the main technological measures related to envelope, appliances and systems.	https://www.sciencedirect.com/science/article/abs/pii/S037877881730676X
National Housing Census: European statistical System	This dataset contains a variety of data collected in relation to the national census performed in 2011 by EU27+UK member states. More specifically it is possible to find data concerning households such as the number of components of single households at a granularity till NUTS3 level.	https://ec.europa.eu/CensusHub2/query.do?step=selectHyperCube&qhc=false

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Repository	Description	Website
EDGAR (Emissions Database for Global Atmospheric Research) CO2 Emissions	Carbon Dioxide (CO_2) emissions by country and sector (Buildings, Transport, Other industrial combustion, Power Industry and other sectors) have been collected for the years between 1970 and 2018 and are reported expressed in $MtCO_2$/year.	https://github.com/openclimatedata/edgar-co2-emissions
CORDEX - Regional climate model data on single levels for Europe	Climatic data for Europe expressed in daily, monthly and seasonal mean values as well as 3 or 6 hours resolution. Data for air temperature at 2 m, wind speed, atmospheric pressure and humidity can be found.	https://cds.climate.copernicus.eu/cdsapp#!/dataset/projections-cordex-single-levels?tab=overview
PVGIS - Photovoltaic Geographical Information System	This GIS dataset contains data related to the solar radiation. It takes into account both day and night-time periods expressing the solar radiation raster map in W/m2.	https://ec.europa.eu/jrc/en/PVGIS/downloads/CMSAF

4.2 Public EU member

This section aims at identifying existing public national repositories. Sample countries are selected according to the location of the pilots.

Table 28: Public EU national repositories

Country	Repository	Description	Website
Italy	**Open Data Hub Italia**	The Open Data Hub provides the most complete catalogue of Italian open data.	https://sciamlab.com/opendatahub/dataset
	EPC cadastre of Lombardia Region	Cadastre of Energy Certificate for Lombardia Region. This database provides information related to: Energy verification, Primary Energy Demand, Transmittance (U-value) of façade elements, Thermal production systems and emission systems. Photovoltaic and Solar panel	http://www.cened.it/statistiche_cened
	Statistica Office	Italian statistical office provides statistical data on national level in different fields. I.E for buildings: http://dati.istat.it/Index.aspx?QueryId=22794&lang=en	https://www.istat.it/en/
	GreenDataset	GREEND dataset, containing detailed power usage information obtained through a measurement campaign in households in Austria and Italy (it can be downloaded size: 1.9 GB)	https://sourceforge.net/projects/greend/
Slovenia	**Portal energetika**	National portal where data on energy efficiency, RES production, energy certificates of buildings, energy management, etc. are collected	https://www.energetika-portal.si/

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Country	Repository	Description	Website
	Statistical Office	The Statistical Office of the Republic of Slovenia (SURS) is the main producer and coordinator of national statistics in Slovenia.	https://www.stat.si/StatWeb/en
	OPSI	The OPSI national open data portal of Slovenia OPSI is a single national website for the publication of open data for the entire public sector.	https://podatki.gov.si/
Poland	**Geoportal**	Data (cloud point) from Airborne Laser Scanning for Poland (ALS), land development, land-developments plans, cadastral data, English version available.	https://www.geoportal.gov.pl/o-geoportalu/aktualnosci
	EPC register	Energy performance certificates are mandatory for buildings and premises sold or for rent, or for office buildings over 250m2, but there are no restrictions or penalties for their absence. This database covers only public office buildings	https://rejestrcheb.mrpit.gov.pl/rejestr-budynkow
Spain	**Spanish Cadastre data**	The Cadastre makes the cadastral data of the territory under its jurisdiction available to citizens (almost the entire national territory). Information about properties' cadastral information is organized by municipality and it is INSPIRE complaint.	https://www.sedecatastro.gob.es/Accesos/SECAccDescargaDatos.aspx
	AEMET OpenData	The AEMET OpenData is the System for the dissemination and reuse of AEMET information. The State Meteorological Agency of Spain is a state agency whose objective is the provision of meteorological services, which are the responsibility of the State.	https://opendata.aemet.es/
	INE Open data	The National Statistics Institute has created the Open data space in order to include the public information resources generated in it.	https://www.ine.es/uc/qLXuzTM8
	CNIG Download Center	This website provides digital geographic information produced by the National Center of Geographic Information.	http://centrodedescargas.cnig.es/CentroDescargas/index.jsp
	BIM Document Library	This site contains a dashboard with different reference documents published by the main actors, as guides, manuals, standards, reports, etc. in different countries.	https://www.buildingsmart.es/observatorio-bim/biblioteca-bim/
Greece	**ELSTAT**	It provides information regarding the national macroeconomic accounts, energy sector's statistics and other sectors' statistics	https://www.statistics.gr/

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Country	Repository	Description	Website
	Hellenic Ministry of Energy and Climate	This website provides national energy statistics in Greece.	https://ypen.gov.gr/
	Greece National Data Portal	It included datasets for central government, local authorities and public bodies.	https://data.gov.gr/
	Open Data Greece	Geoadata.gov.gr is providing open geospatial data and services for Greece, serving as a national open data catalogue, an INSPIRE-conformant Spatial Data Infrastructure, as well as a powerful foundation for enabling value added services from open data.	http://geodata.gov.gr/
	Hellenic Statistical Authority	It provides information regarding the national macroeconomic accounts, energy sector's statistics and other sectors' statistics	https://www.statistics.gr/en/home/
	EnergyHUBfor ALL	Statistical data about EPC, building stock, energy demand, energy efficiency potential etc.	http://www.cres.gr/energyhubforall/
Portugal	**National Statistical Inst.**	The INE is the official Portuguese body responsible for the production and dissemination of official statistics, as well as the coordination, development and dissemination of national statistical activity	https://ine.pt/xportal/xmain?xpgid=ine_main&xpid=INE
	Open data Portal	Dados.gov is the Portuguese Public Administration's open data portal. Its function is to aggregate, reference and store open data from different Public Administration's bodies and sectors, therefore creating the central catalogue of open data in Portugal	Dados.gov.pt
Germany	**Bauwerksdaten bank**	Physical constitution of the built environment – Database of Buildings and Infrastructure	http://ioer-bdat.de/en/
	Literaturdatenbanken des Deutschen Instituts für Urbanistik	Literature database of the German Institute for Urban Studies	https://repository.difu.de/jspui/simple-search
Latvia	**Latvia's Open Data portal**	The aim of this Data portal is to gather and circulate Government institution and organization collected data in one place for public use.	https://data.gov.lv/eng
	Database of official statistics	Database mainly with indicators published within the official statistical program	https://csb.gov.lv/lv/statistika/db

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Country	Repository	Description	Website
Belgium	**Belgium Government Open data**	This website is related to the Belgian Open Data Initiative.	https://data.gov.be/en
Czech Republic	**ENEX**	Czech national database of energy audits and EP certificates	https://www.mpo-enex.cz
	Energo 2015	Czech Statistical Office provides information on energy consumption of households, available for year 2015	https://www.czso.cz/csu/czso/energo-2015
United Kingdom	**Live tables on Energy Performance of Buildings Certificates**	These tables show data from certificates lodged on the Energy Performance of Buildings Registers since 2008 (non-domestic and domestic properties), including average energy efficiency ratings, energy use, carbon dioxide emissions, fuel costs, average floor area sizes and numbers of certificates recorded. All tables now include data by regions.	https://www.gov.uk/government/statistical-data-sets/live-tables-on-energy-performance-of-buildings-certificates

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4.3 Public Regional/ local

This section includes examples of existing public regional and local repositories. The list will be complemented in the future within the project.

Table 29: Regional and local public repositories

Country	Region	Repository	Description	Website
Italy	**Umbria**	**Open data Umbria**	This website provides the data of the Umbrian Public Administration available to citizens.	http://dati.umbria.it/
Spain	**Castilla y León**	**Energy DataHub**	The portal aims to increase transparency, making available to the public aggregated information on energy data of the energy supplies of the Administration of Castilla y León	https://analisis.datosabiertos.jcyl.es/pages/eren/?flg=es
		EPC Register	Energy Efficiency Certificates registered in the Registry of Energy Efficiency Certificates of Castilla León.	https://datosabiertos.jcyl.es/web/jcyl/set/es/energia/certificados-eficiencia/1284543386412
		Open Data Portal	The Open Data Portal implements the Open Government Model of Castilla y León Administration for the transparency information and the space for citizen participation among other actions.	https://datosabiertos.jcyl.es/web/es/datos-abiertos-castilla-leon.html
	Catalunya	**Open Data Portal – Generalitat de Catalunya**	The information in the Open Data portal comes from various agencies of the Government of Catalonia. The intention is to open any public data that citizens can now apply for.	http://governobert.gencat.cat/es/dades_obertes/index.html
		Open Data BCN	Open Data BCN represents the Ajuntament de Barcelona's open data service.	https://opendata-ajuntament.barcelona.cat/

4.4 Other Private data sources

This section identifies existing private data sources that could provide useful information, to be potentially analysed in the context of MATRYCS. The list will be complemented in the future within the project, if necessary.

It should be highlighted that "Enerdata" contains many datasets in the development of which has participated, related to national energy statistics (e.g., energy demand, CO2 emissions). A free trial with restricted use is provided, while the full use of datasets requires a subscription with fess. IEA contains

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information about most energy-related variables (e.g., energy consumption, energy intensity, energy prices) at a national and EU level. However, only a part of them can be freely accessed and downloaded in an excel file, such as the countries' energy balances, while the rest of data can be acquired on demand (fees).

Table 30: Other Private data sources

Repository	Description	Website
Enerdata	Enerdata is an energy intelligence and consulting company. It publishes a free online application that provides up-to-date energy statistics, visual maps and graphs on an online platform. Its website contains many datasets in the development of which has participated, related to national energy statistics (e.g., energy demand, CO2 emissions).	https://www.enerdata.net/
International Energy Agency (IEA)	The IEA main objective is to "shape a secure and sustainable energy future for all". This agency provides analysis, data, policy recommendations and solutions in relation to energy sustainability. The energy categories that are covered are coal, electricity, natural gas, oils, renewables and waste.	https://www.iea.org/subscribe-to-data-services/
APES	Czech association of ESCOs operates database of Czech EPC projects	https://www.apes.cz/en/mapa-projektu.php

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4.5 Building related Dataset and repositories to be potentially used by MATRYCS

This section provides further description for datasets and repositories that at this stage of the project will be potentially used in MATRYCS. This is an initial approach to the data gathered so far, but it will be a living document to be continuously expanded during the project.

Table 31: Building related Dataset and repositories to be potentially used by MATRYCS

Repository	Type of information	Starting date	Ending date	# Variables used	Communication interfaces	Interface documentation	Storage format	Ownership
EU Building Stock Observatory	Characteristics of buildings for residential and non-residential, in different countries of the EU	2015	03/2020	TBD	Download via web application	https://ec.europa.eu/energy/eu-buildings-database_en	CSV	European Commission
EU Energy Poverty Observatory (EPOV)	Set of energy indicators, focused on residential building typologies.	2004	2019	TBD	Download via web application	https://www.energypoverty.eu/observatory-documents/methodology-guidebook	SVG, PNG, CSV	European Commission
TABULA EPISCOPE	Characteristics of buildings for different typologies for residential, in different countries of the EU	2012	2016	TBD	Download via web application	https://episcope.eu/building-typology/webtool/	XLSX	TABULA EPISCOPE project
Open Street Map (OSM)	Geographic information	2014	-	TBD	Directly from website, API	https://wiki.openstreetmap.org/wiki/Overpass_API	osm	Collaborative project
AEMET OpenData	Meteorological services	Depends on data	-	TBD	API	https://opendata.aemet.es/dist/index.html	JSON	Spanish Government

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Repository	Type of information	Starting date	Ending date	# Variables used	Communication interfaces	Interface documentation	Storage format	Ownership
Spanish Cadastre data	Cadastral data of buildings	-	-	BU: 13 BU part: 13	ATOM Service (sml) and individual conexion to cadastre (https)	http://www.catastro.minhap.es/webinspire/index.html http://www.catastro.minhap.es/webinspire/documentos/inspire-ATOM.pdf	GeoJSON and GML	Spanish Government
Energy DataHub from Castilla y León	Aggregated energy data information	2017	-	TBD	API	https://analisis.datosabiertos.jcyl.es/api/v1/console/datasets/1.0/search/	EXCEL, CSV, JSON	Regional Administration
DEEP	Risk and benefits of energy efficiency measures.	2016	-	TBD	API	https://deep.eefig.eu/static/pdf/DEEPUserGuideV1.pdf	CSV,JSON	European Commission
ENERGYPLUS	Weather data (>2100 locations)	-	-	TBD	Software application	https://energyplus.net/sites/all/modules/custom/nrel_custom/pdfs/pdfs_v9.4.0/InterfaceDeveloper.pdf	CSV, XML, HTML	ENERGYPLUS
EUROSTAT	High-quality statistics and indicators at EU level	-	-	TBD	Download via web	https://ec.europa.eu/eurostat/web/main/data/database/information	XLSX, CSV	European Commission
ODYSSEE	Energy efficiency and CO_2 emissions indicators.	2013	-	TBD	Download via web	https://www.indicators.odyssee-mure.eu/energy-efficiency-database.html	XLSX, CSV	ODYSSEE-MURE Project

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Repository	Type of information	Starting date	Ending date	# Variables used	Communication interfaces	Interface documentation	Storage format	Ownership
MURE	Energy efficiency policies and measures in member states of the EU	2013	-	TBD	Download via web	https://www.measures.odyssee-mure.eu/energy-efficiency-policies-database.html#/	XLSX, CSV	ODYSSEE-MURE Project
Covenant of Mayors	Climate mitigation measures and targets and impacts per municipality.	2008	-	TBD	Download via web	https://www.covenantofmayors.eu/plans-and-actions/action-plans.html	PDF	Covenant of Mayors

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5 User Stories and Use Cases

This chapter is related to the task T2.2 User Stories and Requirements Analysis. The content covers the main parts according to the Grant Agreement: Activities related to the main user requirements generation process and use cases creation and finally results. The use case generation process was divided into three phases, as it will be later explained (section 5.1). Results and final use cases are described in detail in sections 5.2 and 5.3. In addition, Annexes VI and VII are provided, where examples of test cards, personas, user stories and use cases are provided, and the meetings and the work done are presented.

5.1 Description of the process

The process of user requirements search was designed in detail by CARTIF and commented by SEVEn and RWTH. The user requirements were derived from pilot partners using set of Test Cards, Personas and User Scenarios which led pilots to typical User Stories describing the typical user needs and operations. The complex array of input data was reviewed and Usage Scenarios were generated. Usage Scenarios consist of very detailed user stories and matrix of specific information and concerned services' needs.

The process continued in finding similar or same patterns in defined usage scenarios which could be deployed by project's services. The user requirements resulted from defined common usage scenarios.

The process of user requirements search and generation was divided into three stages described below:

- **Phase I:** Test Cards and Personas generation + user stories,
- **Phase II:** creation of usage scenarios,
- **Phase III:** the final use cases matching with requirements specification.

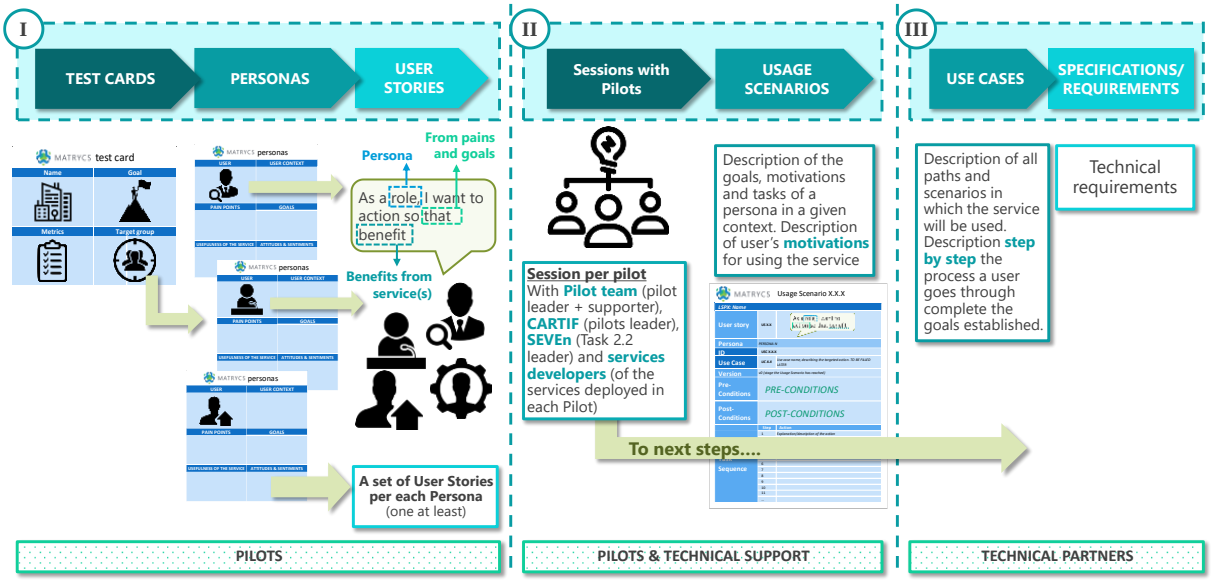

Figure 10: The user stories generation process overview

The use cases and user requirements generation process were based on extraction needs and

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possibilities of 11 pilot partners (aka large scale pilots, LSP). The overview of the process can be seen on the next picture.

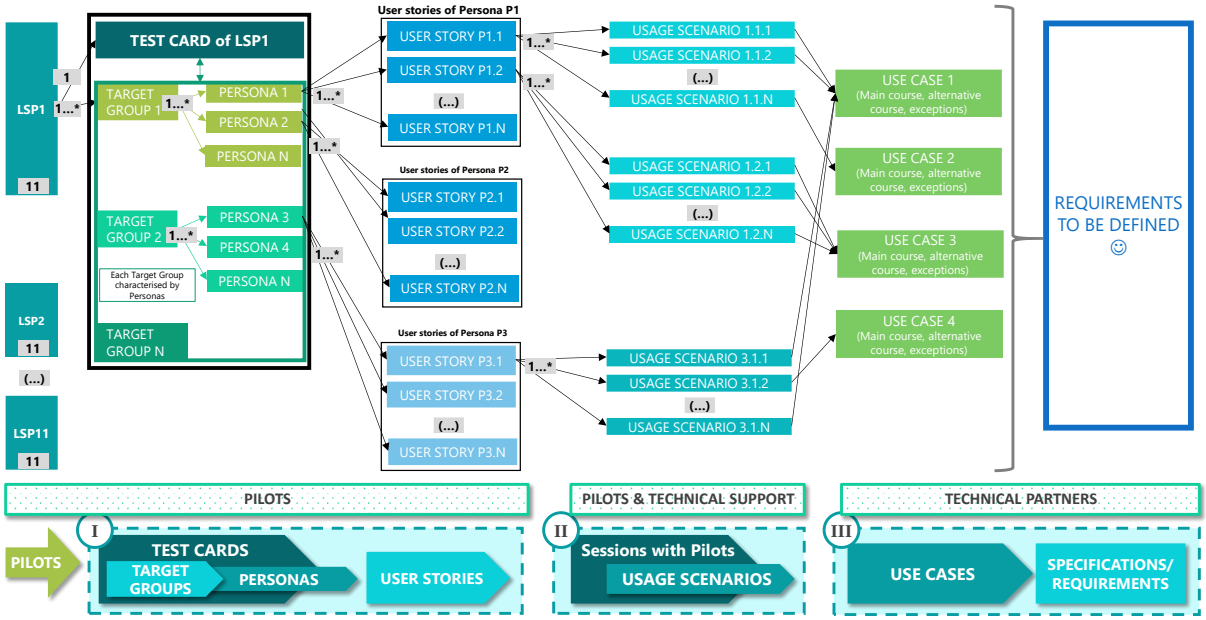

Figure 11: The complete picture of use cases and user requirements process generation and matching

5.1.1 Phase I

The goal of the first phase was to draft main user types, characters or roles, called *personas*, and their typical needs or operations, called *user stories*.

Test cards

The phase I was based on so called *Test Cards*. A Test Card allows to create a high-level description of the Pilot service(s) and it contains 4 easy steps. It served as first approach to the rest of the steps of the methodology, by defining the basic characteristics of the pilot and its objectives when following the four steps/questions in the card:

- **Name**: of the pilot
- **Goals**: of the pilot that will allow the potential users to get things done
- **Metrics**: are used to determine if the pilot service(s) delivers on the user's goals
- **Target group**: these are the potential users (beneficiaries) of the pilot service(s), it can be expanded by expressing the traits, intentions and needs of the users through the development of ***personas*** (characters).

The *Target Group* is the group of stakeholders or other kind of users/beneficiaries from the service. Target groups were categorised in order to have a common classification and naming:

- Researchers (research organizations and universities)
- Facility Managers (manager in charge of the correct functioning of their facilities)
- ESCOs (energy services companies)

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- Real estate developers (developers and managers of real estate)
- Utilities (public and private utilities and aggregators)
- Institutions (relevant national and European institutions or departments)
- Investors (industry and investors related to the real estate management and development)
- Policy makers (policy authorities and policy makers (local to European level), e.g. urban planning department)
- Designers (architects and engineers in charge of the design, retrofitting or decommissioning of buildings)
- Constructors (construction companies and consulting firms)
- Citizens and Owners (citizens and individual owners)
- SMEs, Companies and entities (Small and Medium enterprises, related and not related to construction)
- Others

The example of the test card is below.

MATRYCS test card

Name *Pilot name*	**Goal** *Overarching pilot goals*
LSP2: BUILDING REFURBISHMENT Sustainable building assessment and optimitisation of refurbishment options [*FASADA*]	▶ **Holistic and reliable analysis:** that allows select the optimum renovation scenario depending on the building status and the actual building conditions ▶ **Cost-effective assessment:** that contributes to the selection of the better refurbishment options for a certain building ▶ **Reduce human errors** in the selection of the most optimum renovation solution
Metrics *The measures to determine if the pilot achieves the goals*	**Target group** *The users and stakeholders benefited by the pilot service/development. Development of*
▶ **Evaluation of refurbishment solutions** containing **passive measures** ▶ Assessment of **economic costs** of applied measures ▶ Reduced **error rates**	***Target group*** / ***Personas***
	Investors – ● Informed investor ● Cost-conscious investor
	Citizens and Owners – ● Sensitive owner ● Informed owner ● Reluctant owner
	Constructors – ● Cost-cutting constructors ● Sustainability-supporting constructors ● Traditional constructors ● High-tech constructors
	Add more :)

Figure 12: Test card example

Personas

Personas, expanded from target groups, are fictional characters created to represent the needs, wants and behaviors of the target groups to ensure that we are thinking from their perspective. Each persona captures a different point of view of each target group. Thus, for each target group several personas or

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characters can exist.

For instance, for the target group "Citizens and Owners", there can be different personas/characters: the careless owner (who doesn't care about energy consumption and doesn't pay attention to their bill), the technology-aware owner (who is fully aware of what technology can offer in terms of comfort in their homes and has the latest gadgets installed), the technology-hater owner (opposite to technology-aware inhabitant and isn't prone to using technology), the bill-aware owner (who is mostly worried about the economic aspects of their energy consumption), etc.

The *personas* characters were extracted from the pilots as the next steps after test cards. The personas were elaborated through person card examining details of the role. The details examined were:

- **Persona** name and appropriate **target group**
- **User context** – description of the Persona, for example work he/she deploys, where, their main tasks, involvements
- **Pain points** – the main pain points the Persona has and wants from the Pilot services to be solved
- **Goals** – how the Pilot services help this Persona to achieve the goals (solving him/her pains)
- **Usefulness of the service** – how the Pilot services are incorporated into his/her work or life
- **Attitudes and sentiments** – emotions that the Pilot services will create, for example calm and security because of solving the pain

The personas were numbered within each LSP. An example of the personas card is below.

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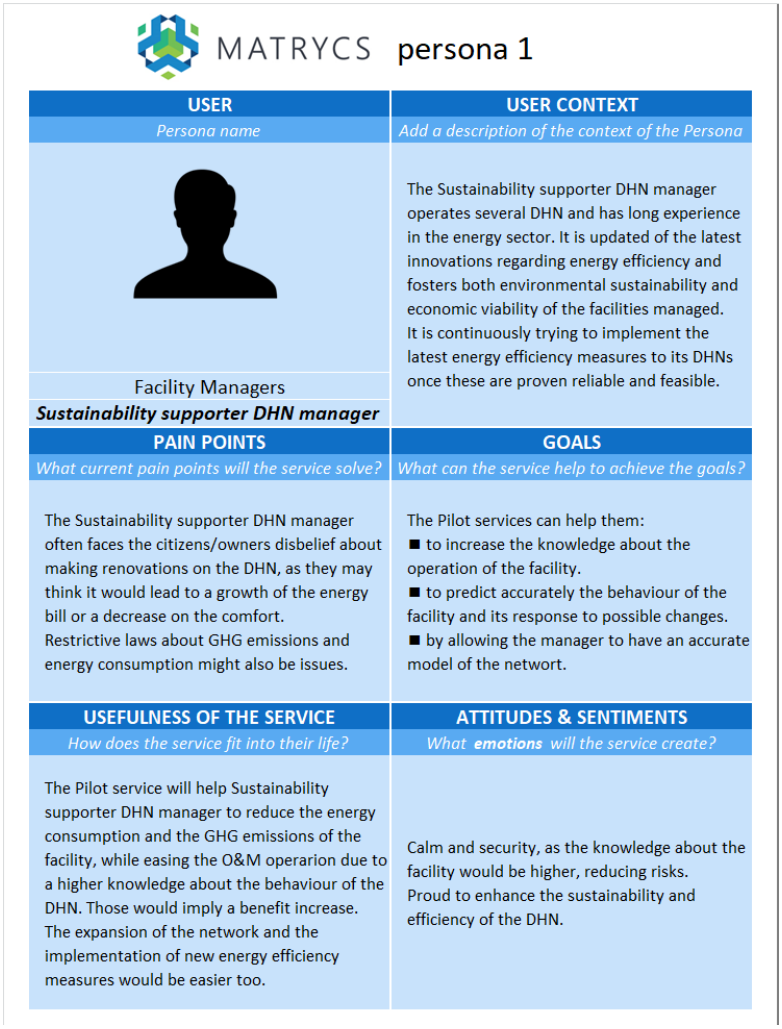

MATRYCS persona 1

USER	USER CONTEXT
Persona name	*Add a description of the context of the Persona*
Facility Managers ***Sustainability supporter DHN manager***	The Sustainability supporter DHN manager operates several DHN and has long experience in the energy sector. It is updated of the latest innovations regarding energy efficiency and fosters both environmental sustainability and economic viability of the facilities managed. It is continuously trying to implement the latest energy efficiency measures to its DHNs once these are proven reliable and feasible.
PAIN POINTS	**GOALS**
What current pain points will the service solve?	*What can the service help to achieve the goals?*
The Sustainability supporter DHN manager often faces the citizens/owners disbelief about making renovations on the DHN, as they may think it would lead to a growth of the energy bill or a decrease on the comfort. Restrictive laws about GHG emissions and energy consumption might also be issues.	The Pilot services can help them: ■ to increase the knowledge about the operation of the facility. ■ to predict accurately the behaviour of the facility and its response to possible changes. ■ by allowing the manager to have an accurate model of the networt.
USEFULNESS OF THE SERVICE	**ATTITUDES & SENTIMENTS**
How does the service fit into their life?	*What **emotions** will the service create?*
The Pilot service will help Sustainability supporter DHN manager to reduce the energy consumption and the GHG emissions of the facility, while easing the O&M operarion due to a higher knowledge about the behaviour of the DHN. Those would imply a benefit increase. The expansion of the network and the implementation of new energy efficiency measures would be easier too.	Calm and security, as the knowledge about the facility would be higher, reducing risks. Proud to enhance the sustainability and efficiency of the DHN.

Figure 13: Persona card example

User Stories

The persona expansion leads to *User Stories* as the last part of the phase I. The user story is a method used to capture a description of a service feature from the user's perspective. User stories are written in a natural language and are placed at the center of the user experience. A User story should capture the essential elements of a requirement:

- **Who** it is for?
- **What** it expects from the system?
- **Why** it is important?

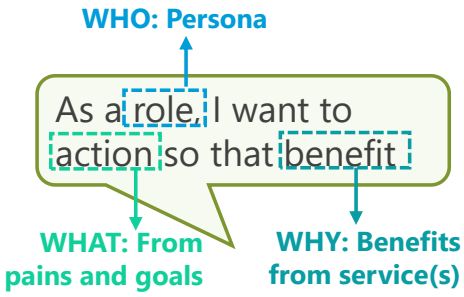

Figure 14: User Story scheme structure

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The structure of the User Story is: "As a **XXX** (persona name/brief description), I want to **XXX** (Action/Task extracted from goals and pains) so that **XXX** (benefit from pilot service(s), desired result)."

There are usually several user stories for each persona. The user stories were numbered X.Y where X is persona number and Y is the user stories number. User stories were prepared by pilot partners.

The example of user story for persona "informed investor" is as follows:

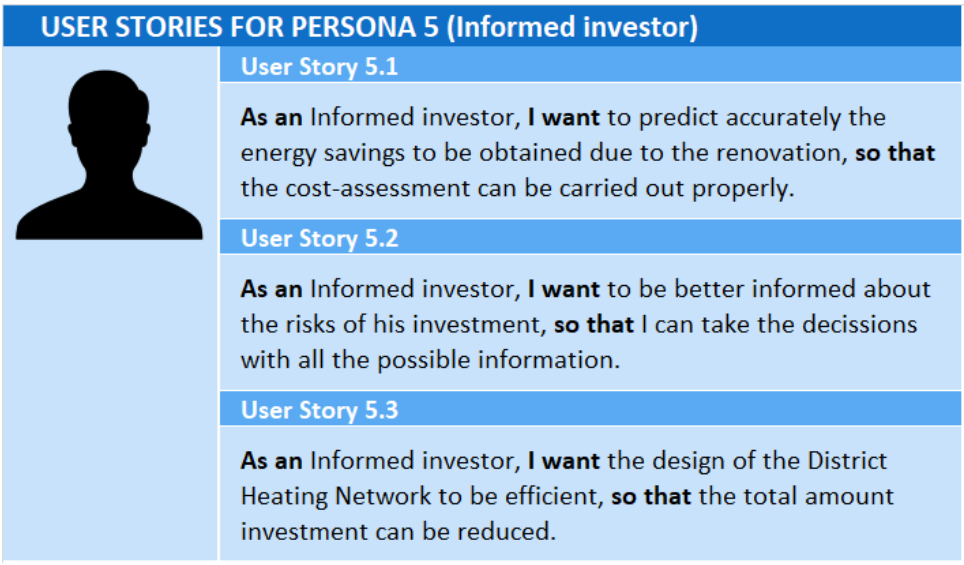

Figure 15: User story example

5.1.2 Phase II

Sessions with pilots

The phase II started with series of individual sessions with pilots. There were 11 mostly two hour sessions. The main points of sessions:

- Test Cards, Personas and User Stories presentation and clarification,
- data availability and formats, data gathering process, data examples,
- service matching to set user stories,
- Usage Scenarios presentation, and start the Usage Scenario generation.

The sessions with pilots were attended usually by:

- pilot leader,
- pilot supporter,
- T2.2 leaders (SEVEn),
- pilot coordinator (Cartif)
- appropriate services leaders
- WP5 leader (EURAC).

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Usage scenarios

The usage scenarios are detailed versions of user stories. It covers the involved persona, specific preconditions and post-conditions. The usage scenario contains series of steps/actions needed for accomplishment of usage scenario. The actions are service related.

MATRYCS Usage Scenario 1.4.2

LSP3: ESCO SUPPORT SERVICES		
Related User story	US 1.4	As an Advanced ESCO, I want to make the energy savings verification procedure easier, so that the increase of the owners can increase.
Involved Persona	PERSONA 1 (Advanced ESCO)	
Usage Scenario ID	USC 1.4.2	
Version	v0 [EXAMPLE]	
Preconditions	Environmental conditions: ■ Energy Efficiency Measures (ECMs) are going to be deployed on a Building ■ Existing monitoring devices to meassure the most significant parameter of the ECM or they are going to be installed (Option A of the IPMVP) ■ Energy Savings have been estimated	
Post-Conditions	■ Report on energy savings ■ Report on money savings	
Main Task Sequence Course	Step	Action
	1. Model Creation	
	1	Creation of a new IPMVP
	2	User defines the ECMs are going to be installed
	3	Definition of the most significant parameter and its monitoring plan before ECM installation
	4	Estimation of the rest of parameters
	5	Calculation/estimation of energy consumption, before the installation of the ECM
	6	Definition of the reporting period (during some time, one year, two, etc. depends on the ESCO's contract duration, continuous, punctually frequency of measurements)
	2. Assesment and Reporting (iterative)	
	7	User provides data of the most significant parameter of the ECM after renovation every time defined on the reporting period (measurements of the monitoring device, and energy price)
	8	Generation of the energy and money saving reports

Figure 16: Usage scenario example

The usage scenarios were reviewed then and appropriate services added and assessed. The process was called service mapping. Service providers were contacted and asked to review the initial service mapping.

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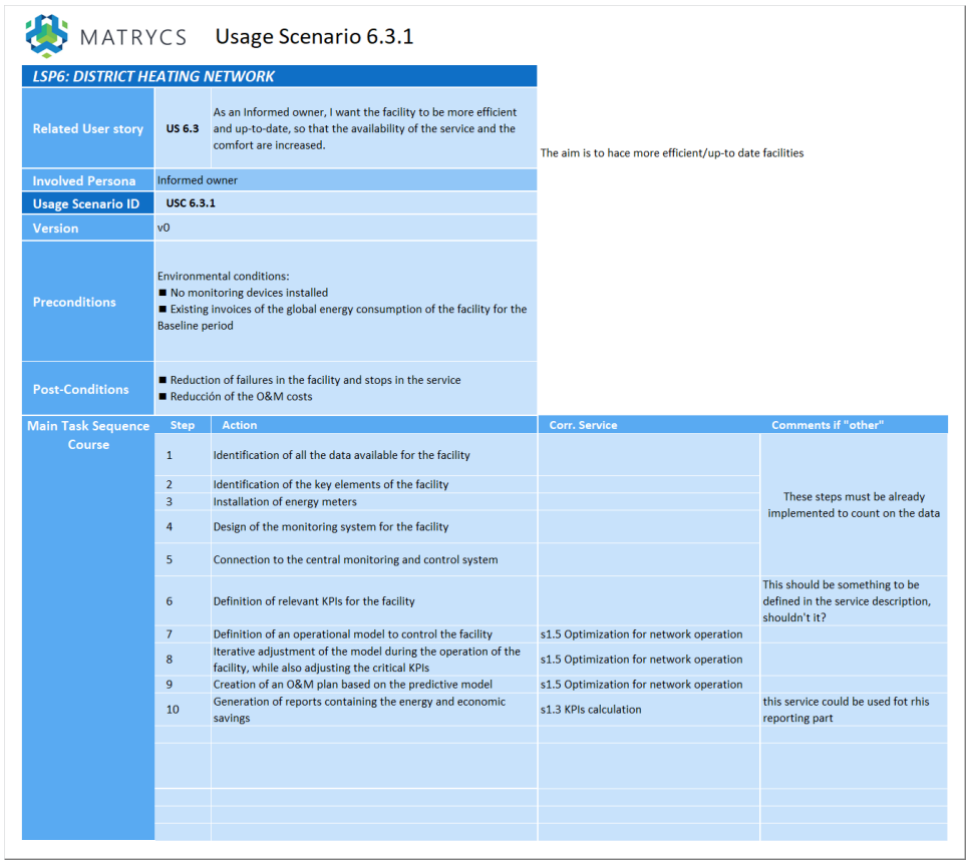

MATRYCS Usage Scenario 6.3.1

LSP6: DISTRICT HEATING NETWORK				
Related User story	US 6.3	As an Informed owner, I want the facility to be more efficient and up-to-date, so that the availability of the service and the comfort are increased.	The aim is to hace more efficient/up-to date facilities	
Involved Persona	Informed owner			
Usage Scenario ID	USC 6.3.1			
Version	v0			
Preconditions	Environmental conditions: ■ No monitoring devices installed ■ Existing invoices of the global energy consumption of the facility for the Baseline period			
Post-Conditions	■ Reduction of failures in the facility and stops in the service ■ Reducción of the O&M costs			
Main Task Sequence Course	Step	Action	Corr. Service	Comments if "other"
	1	Identification of all the data available for the facility		These steps must be already implemented to count on the data
	2	Identification of the key elements of the facility		
	3	Installation of energy meters		
	4	Design of the monitoring system for the facility		
	5	Connection to the central monitoring and control system		
	6	Definition of relevant KPIs for the facility		This should be something to be defined in the service description, shouldn't it?
	7	Definition of an operational model to control the facility	s1.5 Optimization for network operation	
	8	Iterative adjustment of the model during the operation of the facility, while also adjusting the critical KPIs	s1.5 Optimization for network operation	
	9	Creation of an O&M plan based on the predictive model	s1.5 Optimization for network operation	
	10	Generation of reports containing the energy and economic savings	s1.3 KPIs calculation	this service could be used fot rhis reporting part

Figure 17: Usage scenario example with appropriate services added

5.1.3 Phase III

The final phase III includes usage scenarios review process (internally in WP2 team and by service providers) and final steps needed for final requirements.

Usage scenarios review

The usage scenarios were reviewed by internal WP2 team and by service providers. This led to several comments on specific usage scenarios. This step includes check on available data. Service providers were approving the basic concept of usage scenario steps. This results in preliminary usage scenarios approval and several uncertainties and several usage scenarios eliminations. Uncertainties were discussed among appropriate partners.

The preliminary usage scenarios were inserted in one review sheet with necessary data (see example below).

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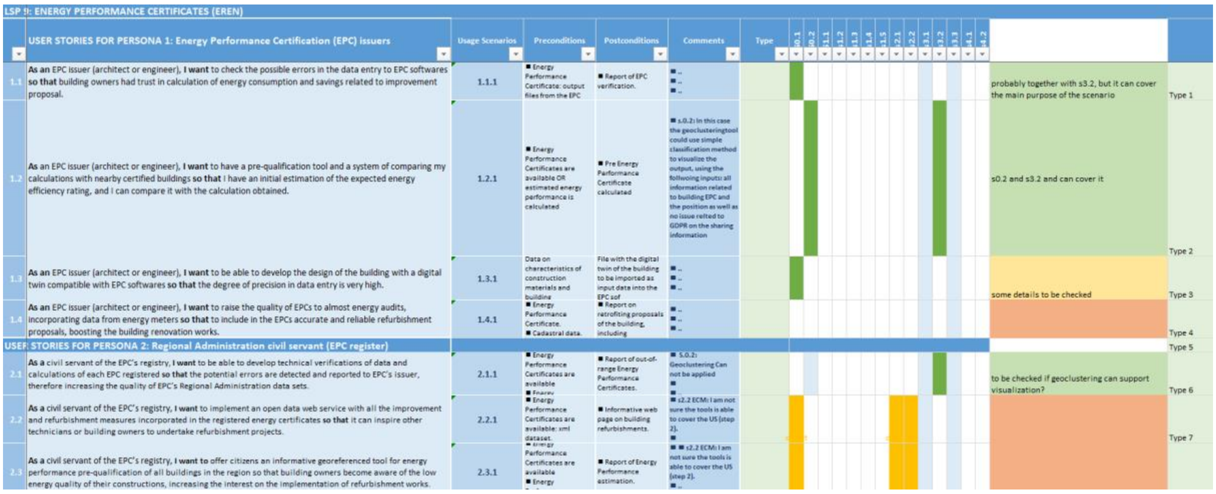

LSP 9: ENERGY PERFORMANCE CERTIFICATES (EREN)																						
	USER STORIES FOR PERSONA 1: Energy Performance Certification (EPC) issuers	Usage Scenarios	Preconditions	Postconditions	Comments	Type	s0.1	s0.2	s1.1	s1.2	s1.3	s1.4	s1.5	s2.1	s2.2	s3.1	s3.2	s3.3	s4.1	s4.2		
1.1	**As an** EPC issuer (architect or engineer), **I want** to check the possible errors in the data entry to EPC softwares **so that** building owners had trust in calculation of energy consumption and savings related to improvement proposal.	1.1.1	■ Energy Performance Certificate: output files from the EPC	■ Report of EPC verification.	■ .. ■ .. ■ ..																probably together with s3.2, but it can cover the main purpose of the scenario	Type 1
1.2	**As** an EPC issuer (architect or engineer), **I want** to have a pre-qualification tool and a system of comparing my calculations with nearby certified buildings **so that** I have an initial estimation of the expected energy efficiency rating, and I can compare it with the calculation obtained.	1.2.1	■ Energy Performance Certificates are available OR estimated energy performance is calculated	■ Pre Energy Performance Certificate calculated	■ s.0.2: In this case the geoclusteringtool could use simple classification method to visualize the output, using the follwoing inputs: all information related to building EPC and the position as well as no issue relted to GDPR on the sharing information																s0.2 and s3.2 and can cover it	Type 2
1.3	**As an** EPC issuer (architect or engineer), **I want** to be able to develop the design of the building with a digital twin compatible with EPC softwares **so that** the degree of precision in data entry is very high.	1.3.1	Data on characteristics of construction materials and building	File with the digital twin of the building to be imported as input data into the EPC sof	■ .. ■ .. ■ ..																some details to be checked	Type 3
1.4	**As an** EPC issuer (architect or engineer), **I want** to raise the quality of EPCs to almost energy audits, incorporating data from energy meters **so that** to include in the EPCs accurate and reliable refurbishment proposals, boosting the building renovation works.	1.4.1	■ Energy Performance Certificate. ■ Cadastral data.	■ Report on retrofiting proposals of the building, including	■ .. ■ .. ■ ..																	Type 4
USER STORIES FOR PERSONA 2: Regional Administration civil servant (EPC register)																						Type 5
2.1	**As a** civil servant of the EPC's registry, **I want** to be able to develop technical verifications of data and calculations of each EPC registered **so that** the potential errors are detected and reported to EPC's issuer, therefore increasing the quality of EPC's Regional Administration data sets.	2.1.1	■ Energy Performance Certificates are available ■ Energy	■ Report of out-of-range Energy Performance Certificates.	■ S.0.2: Geoclustering Can not be applied ■ ■																to be checked if geoclustering can support visualization?	Type 6
2.2	**As a** civil servant of the EPC's registry, **I want** to implement an open data web service with all the improvement and refurbishment measures incorporated in the registered energy certificates **so that** it can inspire other technicians or building owners to undertake refurbishment projects.	2.2.1	■ Energy Performance Certificates are available: xml dataset.	■ Informative web page on building refurbishments.	■ s2.2 ECM: I am not sure the tools is able to cover the US (step 2). ■																	Type 7
2.3	**As a** civil servant of the EPC's registry, **I want to** offer citizens an informative georeferenced tool for energy performance pre-qualification of all buildings in the region so that building owners become aware of the low energy quality of their constructions, increasing the interest on the implementation of refurbishment works.	2.3.1	■ Energy Performance Certificates are available ■ Energy	■ Report of Energy Performance estimation.	■ ■ s2.2 ECM: I am not sure the tools is able to cover the US (step 2). ■ ..																	

Figure 18: Example of usage scenarios overview sheet

The overview sheet underwent extensive two sessions review by WP2 T2.2 internal team and service providers. Each user story and each usage scenario were discussed. The matrix results of each usage scenario and each service provider became:

- yes (green) – the service is suitable for service without any objections;
- doubt (yellow) – the suitability of service should be verified;
- no (grey) – the service is finally not suitable.
- Each usage scenario were marked according to the final relation to services:
- green – the usage scenario is finalised, verified and suitable for appropriate service providers;
- yellow – some details should be clarified or checked (specified in the comment);
- orange/red – the usage scenario is not suitable for any of specified service providers or there is no suitable service provider at all; in some cases the usage scenario should be rephrased;
- comment – the overall commend for usage scenario;
- type – the usage scenarios were clustered in several types combining similar approach and similar types of usage scenarios; the types were numbered (1-10).

The array of usage scenarios was listed in specific sheet and different cases were identified. The cases are described in the figure below.

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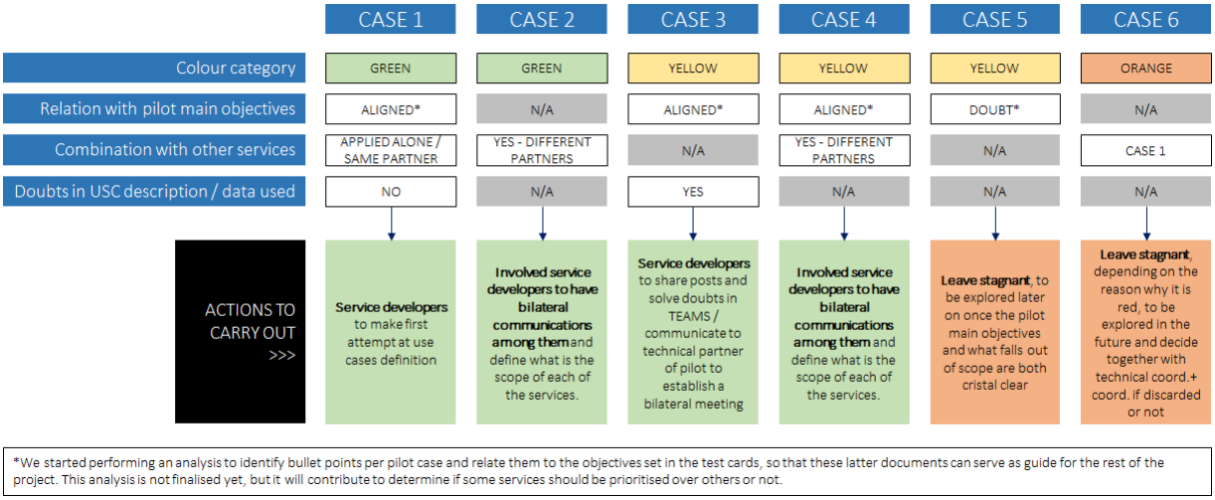

Figure 19: Different cases of usage scenarios in relation to the usability to the service providers

Description of each cases identified for usage scenarios:

- case 1 (green) – the usage scenario covers only one service provider and service providers are ready to proceed;
- case 2 (green) – the usage scenario covers two or more service providers (other than pilot main objectives) and communication among tackled parties is needed;
- case 3 (yellow) – the usage scenario covers only one service provider but service provider must solve doubts or any other objections;
- case 4 (yellow) – the usage scenario covers two or more service providers, involved service providers have to overcome some doubts and solve the scope of the services;
- case 5 (yellow) – there are doubts on scope and objective, this usage scenarios will be explored later;
- case 6 (orange) – serious doubts leading to postpone the usage scenario to the future, there could be various reasons for this situation; the usage scenario will be explored and discarded or modified.

The usage scenarios generated by all pilots (see Figure 18) with appropriate case classification (see Figure 19) was listed in a summarizing table, see example below.

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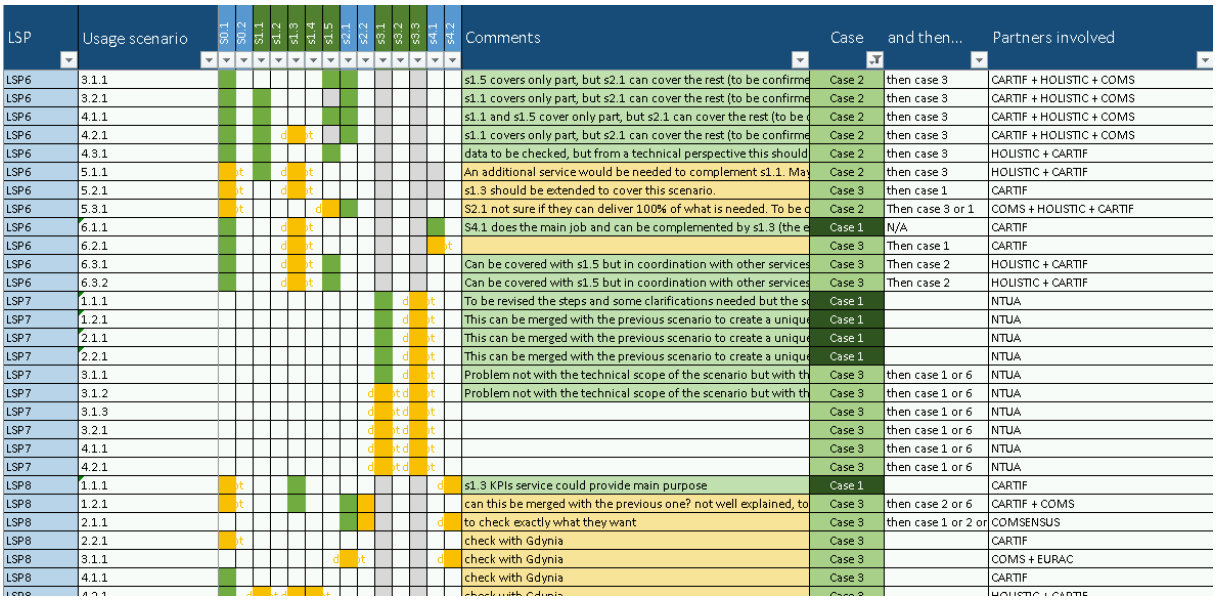

LSP	Usage scenario	s0.1	s0.2	s1.1	s1.2	s1.3	s1.4	s1.5	s2.1	s2.2	s3.1	s3.2	s3.3	s4.1	s4.2	Comments	Case	and then...	Partners involved
LSP6	3.1.1															s1.5 covers only part, but s2.1 can cover the rest (to be confirme	Case 2	then case 3	CARTIF + HOLISTIC + COMS
LSP6	3.2.1															s1.1 covers only part, but s2.1 can cover the rest (to be confirme	Case 2	then case 3	CARTIF + HOLISTIC + COMS
LSP6	4.1.1															s1.1 and s1.5 cover only part, but s2.1 can cover the rest (to be	Case 2	then case 3	CARTIF + HOLISTIC + COMS
LSP6	4.2.1															s1.1 covers only part, but s2.1 can cover the rest (to be confirme	Case 2	then case 3	CARTIF + HOLISTIC + COMS
LSP6	4.3.1															data to be checked, but from a technical perspective this should	Case 2	then case 3	HOLISTIC + CARTIF
LSP6	5.1.1															An additional service would be needed to complement s1.1. May	Case 2	then case 3	HOLISTIC + CARTIF
LSP6	5.2.1															s1.3 should be extended to cover this scenario.	Case 3	then case 1	CARTIF
LSP6	5.3.1															S2.1 not sure if they can deliver 100% of what is needed. To be c	Case 2	Then case 3 or 1	COMS + HOLISTIC + CARTIF
LSP6	6.1.1															S4.1 does the main job and can be complemented by s1.3 (the e	Case 1	N/A	CARTIF
LSP6	6.2.1																Case 3	Then case 1	CARTIF
LSP6	6.3.1															Can be covered with s1.5 but in coordination with other services	Case 3	Then case 2	HOLISTIC + CARTIF
LSP6	6.3.2															Can be covered with s1.5 but in coordination with other services	Case 3	Then case 2	HOLISTIC + CARTIF
LSP7	1.1.1															To be revised the steps and some clarifications needed but the sc	Case 1		NTUA
LSP7	1.2.1															This can be merged with the previous scenario to create a uniqu	Case 1		NTUA
LSP7	2.1.1															This can be merged with the previous scenario to create a uniqu	Case 1		NTUA
LSP7	2.2.1															This can be merged with the previous scenario to create a uniqu	Case 1		NTUA
LSP7	3.1.1															Problem not with the technical scope of the scenario but with th	Case 3	then case 1 or 6	NTUA
LSP7	3.1.2															Problem not with the technical scope of the scenario but with th	Case 3	then case 1 or 6	NTUA
LSP7	3.1.3																Case 3	then case 1 or 6	NTUA
LSP7	3.2.1																Case 3	then case 1 or 6	NTUA
LSP7	4.1.1																Case 3	then case 1 or 6	NTUA
LSP7	4.2.1																Case 3	then case 1 or 6	NTUA
LSP8	1.1.1															s1.3 KPIs service could provide main purpose	Case 1		CARTIF
LSP8	1.2.1															can this be merged with the previous one? not well explained, to	Case 3	then case 2 or 6	CARTIF + COMS
LSP8	2.1.1															to check exactly what they want	Case 3	then case 1 or 2 or	COMSENSUS
LSP8	2.2.1															check with Gdynia	Case 3		CARTIF
LSP8	3.1.1															check with Gdynia	Case 3		COMS + EURAC
LSP8	4.1.1															check with Gdynia	Case 3		CARTIF

Figure 20: Summarizing table of usage scenarios with cases classification

The summarizing table serves for the overview of usage scenarios. The table provides with ongoing steps for each usage scenario: the case classification, ongoing plan, affected service providers, comments and subsequent case classification after the solving obstacles. The table servers for filtering options for later work too.

Use Cases Generation

The final step was the use case generation.

Source data for use cases generation was usage scenarios with classification of case 1, i.e. usage scenario covering one service provider with no objectives or uncertainties. The usage scenarios were clustered and the same or similar needs were grouped into types. The same type usage scenarios led to the final use case. The use case definition table is below.

Table 32: The final use case definition template – main part – description

1 Description		
Use Case Identification		
Use Case ID	**Scale / Domain(s)**	**Name of Use Case**
Internal ID for use case identification	*Building, District, Regional, National, European* *MATRYCS-PERFORMANCE, -MATRYCS-DESIGN, MATRYCS-POLICY, MATRYCS-FUND*	***UC1** - name (Use case name, describing the targeted action).*

Version Management				
Version No.	**Date**	**Name of Author(s)**	**Changes**	**Approval status**
Stage reached	*DD-MM-YYYY*	*Name of author (s)*	*DD-MM-YYYY*	*Approved/*

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1 Description				
				Pending/ Rejected
Related LSP(s)	*LSP(s) where the use case applies*			
Scope and Objectives				
Scope	*A brief sentence that states what the user wants to be able to do and what benefit he will drive.*			
Objective(s)	*Main functionalities to offer*			
Related business case(s)	*Related business case*			
Narrative of Use Case				
Description	*A brief sentence that states what the user wants to be able to do and what benefit he will drive.*			
General Remarks				

5.2 Results and statistics

The final number of generated target groups, personas and user stories is shown in the figure below.

PILOT		Personas		User Stories
		No. Target groups	No. Personas	No.
LSP1	BTC	4	9	20
LSP2	FASADA	3	4	4
LSP3	VEOLIA	3	7	19
LSP4	ASM	3	9	25
LSP5	COOPERNICO	3	5	12
LSP6	VEOLIA	4	6	17
LSP7	ICLEI	2	4	10
LSP8	GDYNIA	3	4	9
LSP9	EREN	3	4	12
LSP10	LEIF	4	6	18
LSP11	HOUSING EUROPE	4	8	8

Figure 21: The final number of target groups, personas and user stories generated in WP2 T2.2

The final number of usage scenarios is shown in figure below. Also, the services matrix is shown. The description of each item:

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- ✓ Service included in the pilot
- ? Service proposed to be added to the pilot
- X Service included in the pilot but not communicated by service provider
- ? Service proposed to be added in the pilot but not communicated by service provider
- Service not included in the pilot
- ✓ Service included in the proposal, and proposed for addressing the User Scenarios
- ✓ Service proposed to be added after the Sessions with Pilots, proposed for addressing the User Scenarios
- X Service included in the proposal, and not proposed for addressing the User Scenarios

		Services in the Pilot (and matched with User Stories)													Usage Scenarios
PILOT		s0.1	s0.2	s1.1	s1.2	s1.5	s1.3	s1.4	s2.1	s2.2	s3.1	s3.2	s3.3	s4.1	s4.2	No.
LSP1	BTC	✓			✓		✓	✓		✓				✓	✓	20
LSP2	FASADA	✓					X		✓	✓				✓	✓	3
LSP3	VEOLIA						✓	✓						✓		19
LSP4	ASM			✓	✓	✓	?	?						✓		10
LSP5	COOPERNICO		?	✓	✓		✓	?	✓					✓		16
LSP6	VEOLIA	X	?	X		X	✓	?	X	X						18
LSP7	ICLEI		?				?				✓		X			12
LSP8	GDYNIA	X					✓			X					X	9
LSP9	EREN	✓	✓				✓		✓	✓		✓				12
LSP10	LEIF		✓				?		✓	✓			✓	✓	✓	18
LSP11	HOUSING EUROPE												✓			3

Figure 22: The final number of pilots' usage scenarios and services matrix

5.3 Final Use Case(s)

This section presents the final use cases extracted from the process. The final use cases should be considered as a basis for MATRYCS analytics and services development, which will potentially be expanded during the project's duration. It should be mentioned that in this document only basic information of the use cases is presented (scope, objective and comments). However, complete versions of these use cases are available at this stage. In particular, one example can be seen in Annex VI.

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Table 33: MATRYCS use cases identified so far

#	Use Case ID	Name	Related LSPs	Involved services	Actors
1	**UC01_01**	***Action plans for preventive maintenance***	*LSP1*	*s1.2, s1.4*	*Facility Managers*
Scope	*Definition of energy efficiency measurements and to provide support for preventive and predictive maintenance of the systems at building level.*				
Objective	*Define suitable solutions for providing decision support to improve sustainable aspects and improve thermal comfort. Additionally, to develop technical functionalities for building management, fault detection and diagnostics.*				
Comment	*Two scenarios: 1. List of action plans for preventive maintenance, 2. Support for preventive and predictive maintenance of the systems*				
2	**UC01_02**	***Action plans for performance improvements***	*LSP1, LSP4*	*s1.1, s1.2*	*Facility managers, Sustainability supporting owner, Informed owner of shops, Sensitive office employee*
Scope	*Identification of possible action plans and selection of optimal solution to provide energy savings considering sustainability aspects and thermal comfort*				
Objective	*Evaluate and report performance measurements*				
Comment	*Two scenarios: 1. Actions plans for performance improvements, 2. Actions plans for performance improvements including thermal comfort aspects*				
3	**UC02_01**	***Building evaluation of ECM / Building refurbishment***	*LSP2*	*s2.2, s4.2*	*Management staff of buildings, designers*
Scope	*Identification of list of possible renovation actions to improve energy efficiency at building level*				
Objective	*Definition of priorities for the possible refurbishment actions to enhance the energy efficiency of buildings and provision of associated economic information*				
4	**UC03_01**	***M&V plan creation***	*LSP3, LSP6*	*s4.1*	*Advanced ESCO Informed owner*
Scope	*Selection of the best mathematical model to predict energy savings.*				
Objective	*Define M&V plan based on IPMVP (Option C). Selection of the best mathematical model to predict energy savings.*				
5	**UC03_02**	***Savings report generation***	*LSP3, LSP6*	*s4.1*	*Advanced ESCO, Informed owner*
Scope	*Verification of the savings achieved after the implementation of Energy Conservation Measures (ECMs) to a building/district through a recognized measurement and verification protocol (IPMVP).*				

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Objective	*Verify and report the savings achieved after the implementation of ECMs.*				
Comment	*Two scenarios: 1. Basic savings report generation, 2. Savings report generation*				
6	**UC03_03**	***Increased knowledge and confidence of the owners of benefits of EEM application***	*LSP3, LSP6*	*s1.3*	*Advanced ESCO, EPC facilitator, Owner, Bank, investor*
Scope	*Increase user knowledge about the benefits of energy efficiency measures implementation and confidence on the Energy Performance Contracts to avoid the upfront costs of the interventions, and as an alternative way to finance the interventions reducing the financial risk perceived by the owners.*				
Objective	*The main objective of the KPI tool is to promote Energy Efficiency Measures application in buildings and districts assests and increase potential owners trust and confidence on EnPC contracts.*				
7	**UC04_01**	***Optimization of electrical distribution system operation***	*LSP4*	*s1.1, s1.5*	*Small Scale DSO Head*
Scope	*To monitor and optimise the electrical distribution system operation*				
Objective	*To understand and predict accurately the behaviour of the system operation so as to be optimised and avoid volatilities*				
8	**UC04_02**	***Action plans for performance improvements***	*LSP1, LSP4*	*s1.1, s1.2*	*Facility managers, Sustainability supporting owner, Informed owner of shops, Sensitive office employee*
Scope	*Identification of possible action plans and selection of optimal solution to provide energy savings considering sustainability aspects and thermal comfort*				
Objective	*Evaluate and report performance measurements*				
Comment	*Two scenarios: 1. Actions plans for performance improvements, 2. Actions plans for performance improvements including thermal comfort aspects*				
9	**UC05_01**	***Predictions about carbon footprint***	*LSP5*	*s1.1*	*EV owner; eco-friendly SME*
Scope	*Implementation of several energy prediction applications, depending on the input data.*				
Objective	*The final benefit is a high-quality prediction tool, based on latest techniques and applications to calculate carbon footprint.*				
10	**UC05_02**	***Identification of PV performance issues***	*LSP5*	*s1.1, s1.4*	*Prosumer*
Scope	*To identify when a PV system is not performing properly*				
Objective	*Identification of possible maintenance actions in a PV system and its overall efficiency*				
Comment	*Two scenarios: 1. Identification PV performance issues, 2. Support for monitoring and*				

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	fault detection				
11	**UC05_03**	***Optimization of self-consumption of PV system***	*LSP5*	*s1.1, s1.2*	*Prosumer*
Scope	*To maximize the value of an investment of a PV system*				
Objective	*Increase of self-consumption and reduction of surplus production of the system*				
12	***UC05_04***	***Creation of technology catalogues***	*LSP5*	*S2.1*	*Prosumer*
Scope	*Generation of standardised technologies catalogues to support the design of optimal solutions at building or district level of a community.*				
Objective	*The outcome will be a tool that provides list of potential technologies that can be applied based on building/ districts and area specific characteristics. This will allow members of a community to make better decisions, when designing renovation road maps at the local level (specific blocks of buildings/ district).*				
13	**UC06_01**	***M&V plan creation***	*LSP3, LSP6*	*s4.1*	*Advanced ESCO Informed owner*
Scope	*Selection of the best mathematical model to predict energy savings.*				
Objective	*Define M&V plan based on IPMVP (Option C). Selection of the best mathematical model to predict energy savings.*				
14	**UC06_02**	***Savings report generation***	*LSP3, LSP6*	*s4.1*	*Advanced ESCO, Informed owner*
Scope	*Verification of the savings achieved after the implementation of Energy Conservation Measures (ECMs) to a building/district through a recognized measurement and verification protocol (IPMVP).*				
Objective	*Verify and report the savings achieved after the implementation of ECMs.*				
Comment	*Two scenarios: 1. Basic savings report generation, 2. Savings report generation*				
15	**UC06_03**	***Increased knowledge and confidence of the owners of benefits of EEM application***	*LSP3, LSP6*	*s1.3*	*Advanced ESCO, EPC facilitator, Owner, Bank, investor*
Scope	*Increase user knowledge about the benefits of energy efficiency measures implementation and confidence on the Energy Performance Contracts to avoid the upfront costs of the interventions, and as an alternative way to finance the interventions reducing the financial risk perceived by the owners.*				
Objective	*The main objective of the KPI tool is to promote Energy Efficiency Measures application in buildings and districts assests and increase potential owners trust and confidence on EnPC contracts.*				
16	**UC06_04**	***Operation of DH Network***	*LSP6*	*s1.1, s1.5*	*Technical Manager*
Scope	*To effectively understand the operation of the DH Network*				

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Objective	*To predict accurately the behaviour of the facility, its response to possible changes and increase the knowledge about the operation of the facility.*				
17	**UC07_01**	***Policy-makers decision-making support***	*LSP7*	*s3.1, s3.3*	*Urban Planning Professional, Local transport department director*
Scope	*Support policy-makers regarding climate change initiatives and action plans.*				
Objective	*The outcome will be a tool that enables policy-makers to gain valuable insights and make better decisions when they plan and design action plans to tackle climate change. This tool will be enabled by visualizations, comparisons and aggregation based on existing data and possibly data that the user will provide*				
18	**UC07_02**	***Building's investment prioritization***	*LSP7*	*s3.1, s3.3*	*City council member*
Scope	*Support policymakers regarding prioritizing renovation plans of public buildings in city-level*				
Objective	*The outcome will be a tool that provides prioritization of investments based on building specifics characteristics. This will allow policy maker in local level to make better decisions, when designing climate action plans.*				
19	**UC08_01**	***Geo_municipality service***	*LSP8*	*s0.2, s1.3*	*Real state owner*
Scope	*Show information regarding the performance of public building (School building available) based on energy consumption data provided by the municipality.*				
Objective	*1) Visualize specific information about energy performance of public buildings* *2) Workers use it to compare the performance of different buildings.* *3) The KPIs can provide information about the possibility to refurbish the building .*				
20	**UC09_01**	***EPCs data error checker and validator***	*LSP9*	*s3.2*	*Energy Performance Certification (EPC) issuers*
Scope	*Support EPC issuers in detecting errors in the data entry to EPC softwares.*				
Objective	*The outcome will be a relevant tool that enables EPC issuers to offer trustful calculations on energy consumption and saving and also Regional Administration civil servant (EPC register) to verify registered EPCs detecting potential errors increasing the quality of EPC's Regional Administration data sets*				
21	**UC09_02**	***Visualization of estimated EPC***	*LSP9*	*s3.2, s1.3*	*Regional Energy Efficiency planner*
Scope	*The scope is the generation of estimated EPCs based in different approaches and providing this information in different levels of detail to different stakeholders*				
Objective	*The outcome will be a relevant tool that will allow the energy efficiency planner to obtain valuable insights from the registered buildings EPCs, for making better decisions when designing action plans and also will provide information of estimated EPCs to different actors: Energy Performance Certification (EPC) issuers, buildings buyers and sellers, landlords and tenants.*				

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Comment	*Two scenarios: 1. Visualization of estimated EPC, 2. Visualization of estimated EPC advanced*				
22	**UC10_01**	***Risk assessment of funding in energy efficiency investments***	*LSP10*	*s3.3*	*Informed policy maker*
Scope	*To assess risk evaluation of funding in energy efficiency investments.*				
Objective	*To define reliable investments, to identify opportunities and make comparisons between different energy efficiency actions and to have a better view of funding direction and proposals.*				
23	**UC11_01**	***Portfolio optimization***	*LSP11*	*s3.3, s4.2*	*National authority - policy maker*
Scope	*Support policy making, by providing optimal solutions under a ranging number of different criteria.*				
Objective	*The outcome of the service will be a graphical representation of optimal portfolios, which features a different pair of cost-risk values. For each selected action, the number the number of interventions is extracted from the optimisation process. For each intervention of the selected actions, the year of implementation is also decided from the optimisation process.*				
24	**UC00_01**	***Digital Twin creation***	*LSP1, 2, 6, 8, 9*	*s0.1*	*DT creator; Service developer*
Scope	*Analytics services and Digital Twin definition at Building, District and City/ Region scale. Compile the relevant information to be used at three different scales to support the implementation of energy services.*				
Objective	*The objective is to support the deployment of other services by providing a digital twin, which integrates all relevant information at each scale. This will allow to automatically generate models based on other data sources if they do not exist. To this purpose, s0.1 Digital Twin is involved.*				
Comment	*Three scenarios: 1. DT creation at building scale, 2. DT creation at district scale, 3. DT creation at city/ regional scale*				
25	**UC00_02**	***Services integration in Digital Twin***	*LSP1, 2, 6, 8, 9*	*s0.1*	*DT creator; Service developer*
Scope	*Analytics services integration in Digital Twin*				
Objective	*Implement in Digital Twins analytics services to feed these services with data and enrich the digital twin with the outputs generated in the services. The objective is to integrate analytics services of the same type in the Digital Twins answering the needs specified in the pilots and captured in the user stories and the specifications.* *Prepare/adapt the Digital Building Twins to the required inputs and outputs, the required predictions and behavioural analysis, as well as the features to be applied for the ML and DL definitions.*				
Comment	*Four scenarios: 1. Prediction and BAC services, 2. ECMs assessment support, 3. GIS support, 4. District network support*				

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The figure below summarises the use cases presented above and relates them to the services that are involved and the pilots where they are preliminarily to be deployed.

Pilots	s0.1	s0.2	s1.1	s1.2	s1.3	s1.4	s1.5	s2.1	s2.2	s3.1	s3.2	s3.3	s4.1	s4.2	Use case ID	Use case name	Scenarios	Use cases / pilot
LSP1				■		■									UC01_01	Action plans for preventive maintenance	2	2
	■		■	■											UC01_02	Action plans for performance improvements	2	
LSP2	■								■					■	UC02_01	Building evaluation of ECM / Building refurbishment	1	1
LSP3													■		UC03_01	M&V plan creation	1	3
													■		UC03_02	Savings report generation	2	
					■										UC03_03	Increased knowledge and confidence of the owners of benefits of EEM application	1	
LSP4			■				■								UC04_01	Optimization of electrical distribution system operation	1	2
			■	■											UC04_02	Action plans for performance improvements	1	
LSP5			■												UC05_01	Predictions about carbon footprint	1	4
			■			■									UC05_02	Identification of PV performance issues	2	
			■	■											UC05_03	Optimization of self-consumption of PV system	1	
								■							UC05_04	Creation of technology catalogues	1	
LSP6													■		UC06_01	M&V plan creation	1	4
													■		UC06_02	Savings report generation	2	
					■										UC06_03	Increased knowledge and confidence of the owners of benefits of EEM application	1	
	■		■				■								UC06_04	Operation of DH Network	1	
LSP7										■		■			UC07_01	Policy-makers decision-making support	1	2
										■		■			UC07_02	Building's investment prioritization	1	
LSP8	■		■			■									UC08_01	Geo_municipality service	1	1
LSP9	■										■				UC09_01	EPCs data error checker and validator	1	2
	■				■						■				UC09_02	Visualization of estimated EPC	2	
LSP10												■		■	UC10_01	Risk assessment of funding in energy efficiency investments	1	1
LSP11												■			UC11_01	Portfolio optimization	1	1

* DT (s0.1)		UC00_01	Digital Twin creation	3	2
		UC00_02	Services Integration in Digital Twin	4	

Figure 23: The list of use cases identified so far in compact overview table

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The final services/pilots matrix shows used services for different pilots below, as per the use cases identified so far.

Table 34: MATRYCS services / pilots matrix

		MATRYCS Large Scale Pilots										
		LSP1	LSP2	LSP3	LSP4	LSP5	LSP6	LSP7	LSP8	LSP9	LSP10	LSP11
MATRCYS SERVICES	s0.1	X	X				X		X	X		
	s0.2								X			
	s1.1	X			X	X	X					
	s1.2	X			X	X						
	s1.3			X			X		X	X		
	s1.4	X				X						
	s1.5				X		X					
	s2.1					X						
	s2.2		X									
	s3.1							X				
	s3.2									X		
	s3.3							X			X	X
	s4.1			X			X					
	s4.2		X								X	

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Annex I: EC directives and initiatives – description

This Annex I presents a short description of the EC directives and initiatives presented in section 2.4, as well as the reports and studies commissioned by the European Commission.

EC directives and initiatives

European Strategy for Data (COM(2020) 66);

The European Strategy for Data is one of the pillars of the new digital strategy of the EC. It focus on the need to put people first in developing technology, as well as on the need to defend and promote European values and rights in how we design, make and deploy technology in the real economy. The European strategy for data (COM(2020) 66) intends to: adopt legislative measures on data governance, access and reuse, for example for business-to-government data sharing for the public interest; make data more widely available by opening up high-value publicly held datasets across the EU and allowing their reuse for free; invest €2 billion in a European High Impact Project to develop data processing infrastructures, data sharing tools, architectures and governance mechanisms for thriving data sharing and to federate energy-efficient and trustworthy cloud infrastructures and related services; enable access to secure, fair and competitive cloud services by facilitating the set-up of a procurement marketplace for data processing services and creating clarity about the applicable regulatory framework on cloud framework of rules on cloud; empower users to stay in control of their data and investing in capacity building for small and medium-sized enterprises and digital skills; foster the roll out of common European data spaces in crucial sectors such as industrial manufacturing, green deal, mobility or health.

From 19 February to 31 May 2020, an open public consultation on the European strategy for data happened. Some important points were raised in the summary report, but so far only based on quantitative research. The main topics included data strategy; data governance; high-value datasets; and regulatory context of cloud computing. The summary report is available at the EC portal[93]. This online consultation is of a data initiative regarding defining a legislative framework on the common European data spaces, expected in 2020, and an implementing act on a list of high-value datasets, expected in 2021.

Proposal for a Regulation on European data governance (Data Governance Act) Nov. 2020

Proposal for a regulation of the European parliament and of the council on European data governance (Data Governance Act) is considered the first of a set of measures announced in the 2020 European strategy for data[94]. This current proposal complements the Directive (EU) 2019/1024 (Open Data Directive). The proposal has logical and coherent links with the other initiatives announced in the European strategy for data. It aims at facilitating data sharing including by reinforcing trust in data sharing intermediaries that are expected to be used in the different data spaces. The instrument addresses: 1) Making public sector data available for re-use, in situations where such data is subject to rights of others; 2) Sharing of data among businesses, against remuneration in any form; 3) Allowing personal data to be used with the help of a 'personal data-sharing intermediary', designed to help

93 https://ec.europa.eu/newsroom/dae/document.cfm?doc_id=68611/

94 COM (2020) 66 final: https://ec.europa.eu/info/sites/info/files/communication-european-strategy-data-19feb2020_en.pdf

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individuals exercise their rights under the General Data Protection Regulation (GDPR); 4) Allowing data use on altruistic grounds.

White Paper on Artificial Intelligence (COM(2020) 65);

The White Paper on Artificial Intelligence (COM(2020) 65) sets out the Commission's proposals to promote the development of AI in Europe whilst ensuring respect of fundamental rights. AI is developing fast, which is why Europe needs to maintain and increase its level of investment. At the same time, AI entails a number of potential risks that need to be addressed. The White Paper sets out options to maximize the benefits and address the challenges of AI, and invites comments on these options by stakeholders. To achieve an ecosystem of trust, the Commission presented options on creating a legal framework addressing the risks for fundamental rights and safety. A legal framework should be principles-based and focus on high-risk AI systems in order to avoid unnecessary burden for companies to innovate. Aiming to promote the uptake of artificial intelligence (AI) while at the same time, addressing the risks associated with its use, the European Commission has proposed a White Paper with policy and regulatory options towards an ecosystem for excellence and trust. This document was published in February 2020. The White Paper proposes two main points: measures that will streamline research, foster collaboration between Member States and increase investment into AI development and deployment; and policy options for a future EU regulatory framework that would determine the types of legal requirements that would apply to relevant actors, with a particular focus on high-risk applications. After its publication, the White Paper underwent an open, public consultation process. From 19 February to 14 June 2020, all European citizens, Member States and relevant stakeholders (including civil society, industry and academics) provided their views on the upcoming policy and regulatory steps on artificial intelligence. The online survey focused on three distinct topics: (1) Specific actions for the support, development and uptake of AI across the EU economy and public administration; (2) Options for a future regulatory framework on AI; (3) Safety and liability aspects on AI. The full Summary Report on the open public consultation on the White Paper on Artificial Intelligence can be accessed via the EC portal[95]. This online consultation is part of a broader stakeholder consultation. The analysis of the consultation results will serve as a base for presenting a regulatory proposal.

Report on the safety and liability implications of Artificial Intelligence, the Internet of Things and robotics (COM(2020) 64) EU;

In the Report on the safety and liability implications of Artificial Intelligence, the Internet of Things and robotics (COM(2020) 64 EU) - published in February 2020. The European Commission recognized the importance and potential of Artificial Intelligence, the Internet of Things (IoT) and robotics as potential creators of new opportunities and benefits for the society in general, as well as the need for significant investment in these areas. In order to make Europe a world-leader in AI, IoT and robotics, a clear and predictable legal framework addressing the technological challenges is discussed.

Ethics Guidelines for Trustworthy Artificial Intelligence;

The final Ethics Guidelines for Trustworthy Artificial Intelligence, published on 8 April 2019, includes seven key requirements that AI systems should meet in order to be trustworthy are presented: human agency and oversight; technical robustness and safety; privacy and data governance; transparency; diversity, non-discrimination and fairness; societal and environmental well-being; and accountability.

95 https://ec.europa.eu/newsroom/dae/document.cfm?doc_id=68462/

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Aiming to operationalise these requirements, guidance on each requirement's practical implementation is presented.

The **Open Data Directive (Directive (EU)** 2019/1024);

The Directive on open data and the re-use of public sector information, also known as the 'Open Data Directive' (Directive (EU) 2019/1024), provides a common legal framework for a European market for government-held data, specifically for the public sector information. It is built around two key pillars: transparency and fair competition. This Directive replaced the Public Sector Information Directive, also known as the 'PSI Directive' (Directive 2003/98/EC).

General Data Protection Regulation (GDPR) (EU) 2016/679.

The General Data Protection Regulation (GDPR) (E) 2016/679 encompasses the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC. Applying as of 25 May 2018, the Regulation has consolidated and innovated data protection rules and brought several improvements to deal with data protection violations, giving citizens more control over their personal data and allowing businesses to benefit from a level playing field.

Open source software strategy 2020-2023

The new Open Source Software Strategy 2020-2023[96] of the Commission was approved on October 2020. The internal strategy, under the theme ''Think Open'', sets out a vision for encouraging and leveraging the transformative, innovative and collaborative power of open source, its principles and development practices. It promotes the sharing and reuse of software solutions, knowledge and expertise, to deliver better European services that benefit society and lower costs to that society. The Commission commits to increasing its use of open source not only in practical areas such as IT, but also in areas where it can be strategic.

Reports and studies commissioned by the EC

EU Building Stock observatory[97] The BSO contains a database, a data mapper and factsheets for monitoring the energy performance of buildings across Europe. It covers a broad range of energy related topics and provide information on the building stock, energy consumption, building elements and technical building systems installed, energy performance certificates, nearly zero-energy buildings and renovation rates, but also areas like energy poverty and financing aspects.

EU Energy Poverty Observatory (ENPOV)[98] The observatory aims to provide a user-friendly and open-access resource that will promote public engagement on the issue of energy poverty, disseminate information and good practice, facilitate knowledge sharing among stakeholders, as well as support informed decision making at local, national and EU level.

European Data Portal[99] The European Data Portal harvests the metadata of Public Sector Information

96 Open source software strategy 2020-2023: https://ec.europa.eu/info/sites/info/files/en_ec_open_source_strategy_2020-2023.pdf

97 https://ec.europa.eu/energy/eu-buildings-database_en/

98 https://www.energypoverty.eu/

99 https://www.europeandataportal.eu/en/

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available on public data portals across European countries. Information regarding the provision of data and the benefits of re-using data is also included.

De-risking Energy Efficiency Platform ("DEEP")[100] DEEP is an open-source database for energy efficiency investments performance monitoring and benchmarking and provides an improved understanding of the real risks and benefits of energy efficiency investments by providing market evidence and investment track records.

ECEEE[101] focusing on big data for residential buildings ECEEE offers governments, industry, research institutes and citizen organisations a unique resource of evidence-based knowledge and reliable information and promotes the understanding and application of energy efficiency in society and assists its target groups – from policy makers to programme designers to practitioners – with making energy efficiency happen.

Smart Readiness Indicator for Buildings (SRI)[102] This indicator will allow for rating the smart readiness of buildings, i.e. the capability of buildings (or building units) to adapt their operation to the needs of the occupant, also optimizing energy efficiency and overall performance, and to adapt their operation in reaction to signals from the grid (energy flexibility). The smart readiness indicator should raise awareness amongst building owners and occupants of the value behind building automation and electronic monitoring of technical building systems and should give confidence to occupants about the actual savings of those new enhanced functionalities.

LEVEL(s)[103] represents the European Commission's framework for sustainable buildings, with the aim to unite the whole sector value chain around a common language that allows to assess and report on the full life-cycle of buildings. To this end, a minimum number of indicators are used to deliver sustainability and track performance across the various stages of a building project.

100 https://deep.eefig.eu/

101 https://www.eceee.org/library/conference_proceedings/eceee_Summer_Studies/2017/8-monitoring-and-evaluation-building-confidence-and-enhancing-practices/can-big-data-drive-the-market-for-residential-energy-efficiency/

102 https://smartreadinessindicator.eu/

103 https://ec.europa.eu/environment/topics/circular-economy/levels_es

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Annex II: H2020 projects contributing to MATRYCS landscape

This Annex complements section 2.5 on H2020 projects contributing to MATRYCS landscape, and it is divided into three sections: (1) EU-funded projects on data, according to the B4E-6 call objectives, (2) EU-funded projects on ICT (contribution to the development of the MATRYCS modular toolbox), (3) EU-funded projects in Energy / Building (contribution to the development of the analytics building services).

EU-funded projects on data

The following table presents EU-funded projects on data, according to the B4E-6 call objectives.

Table 35: EU-funded projects on data

Project name	Short project description	Key stakeholders
BigDataOcean (http://www.bigdataocean.eu/)	It aims to propose and validate maritime big data scenarios for EU-based companies, organisations, and scientists	Maritime-related industries
AEGIS (https://aegis-project.org/)	It aims to strengthen international dialogues on cybersecurity and privacy to facilitate the exchange of viewpoints, policies, and best practices, accelerating EU-US cooperation in cybersecurity and privacy research and innovation	EU and US experts in policy, research, academia, and the industry
PLATOON (https://platoon-project.eu/)	This project aims al deploying distributed/edge processing and data analytics technologies for optimized real-time energy system management in a simple way for the energy domain expert. The project will develop and use the PLATOON reference architecture, COSMAG-compliant, for building and deploying scalable and replicable energy management solutions that contribute to increased renewable energy consumption, smart grids management, increased energy efficiency and optimised energy asset management.	Energy Generation Companies, Energy Service Companies, Renewable Energy Companies, TSOs / DSOs, Small and Medium-Sized Companies, Energy End Users/ Building Owners, Political
MUSKETEER (https://musketeer.eu/)	It aims to create machine learning models over a variety of privacy-preserving scenarios by ensuring security and robustness against external and internal threats and ultimately to enhance data economy by boosting sharing across domains	Transport, Retail, Health & Manufacturing Sector
INFINITECH (https://www.infinitech-h2020.eu/)	It aims to lower the barriers for Big Data / IoT / AI driven innovation, boosting regulatory compliance, and stimulating additional investments.	FinTech, financial and insurance sector

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Project name	Short project description	Key stakeholders
BIGG	It focuses on facilitating the adoption of Member States' Action Plans by applying big data technologies and data analysis for more than 4000 buildings in Spain and Greece by developing big data reference architecture and analytics toolbox to support a wide range of services and new business models.	Building sector community
BEYOND	It aims to develop a reference big data management platform with AI analytics toolkit which will enable the execution of a wealth of descriptive-predictive-prescriptive analytics focusing consumer behaviour, comfort levels, flexibility profiling, energy performance, predicative maintenance, forecasting and real-time automated control in building assets.	Building sector community
BuiltHub	It aims to define a roadmap and vision for a durable data flow to characterise the EU building stock, via an organised and inclusive data collection method	Building sector community
C-TRACK 50 (https://www.c-track50.eu/node/35/)	It aims to mobilise and guide public authorities at a local and regional level, for achieving climate resilience and carbon neutrality by 2050	Regional public authorities
BD4NRG	It aims to deliver a reference architecture for Smart Energy, which aligns BDVA SRIA, IDSA and FIWARE architectures, SAREF standard and extend COSMAG specification to enable B2B multi-party data exchange, while providing full interoperability of leading-edge big data technologies with smart grid standards and operational frameworks. It also aims to evolve and upscale a number of TRL 5-6 technology enablers, as well as deliver a TRL8 open modular big data analytic toolbox as front-end for one-stop-shop analytics services development by orchestrating legacy and/or third party assets.	TSOs and DSOs power network operators, aggregators, storage/renewable assets operators, local energy communities, ESCOs, power market operators, municipalities, financial institutions and ENTSO-E.
I-NERGY	I-NERGY aims at evolving, scaling up and demonstrating innovative AI-as-a-Service (AIaaS) Energy Analytics Applications and digital twins services that will be validated along 9 pilots on energy commodities network, distributed energy resources and energy efficiency and non-energy related aspects .To this end, I-NERGY will deliver: (i) Financing support through Open Calls to third parties SMEs for new energy use cases and technology building blocks validation, as well as for developing new AI-based energy services; (b) An open modular framework for supporting AI-on-Demand in the energy sector by capitalising on state-of-the-art AI, IoT, semantics, federated learning, analytics tools, which leverage on edge-level AI-based cross-sector multi-stakeholder sovereignty and regulatory preserving interoperable data handling.	TSOs and DSOs, energy suppliers, DER operators, policy makers, off-grid data/solution provider, aggregators / energy cooperatives, ESCOs, building operators, funds, energy agencies, third parties.

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EU-funded projects on ICT

The following table presents EU-funded projects on ICT that could contribute to the development of the MATRYCS modular toolbox.

Table 36: EU-funded projects on ICT

Project name	Short project description	Key stakeholders
4RINEU (https://4rineu.eu/)	It aims to develop new tools and strategies for encouraging large scale renovation of existing buildings, fostering the use of renewable energies, and providing reliable business models to support their applications	Building sector community
BREASER (http://www.bresaer.eu/)	It aims to develop a cost-effective, adaptable, and industrialized "envelope system" for buildings refurbishment	Building sector community
CYBELE (https://www.cybele-project.eu)	It aims to generate innovation and create value in the domain of agri-food, empowering capacity building within this sector and the research community associated with this domain	Everyone involved in the agri-food value chain (research community, SMEs, entrepreneurs, etc.)
EnerGAware (http://energaware.eu)	It aims to decrease energy consumption and emissions in an affordable housing pilot and increase the affordable housing tenants' understanding and engagement in energy efficiency	Housing sector
eQuad (https://www.eu.jouleassets.com/)	It aims to facilitate innovative financing for energy efficiency and renewable projects in Europe and the UK	ESCOs, engineering firms, construction companies
ELISE Energy Location Applications (https://ec.europa.eu/isa2/actions/elise_en)	The project aims at demonstrating through a series of use cases how an integrated data approach can be established for planning, implementation, monitoring and reporting for the multiple policies and initiatives, considering energy performance of buildings, energy consumption of buildings and energy production at a local level. This is linked to the application of the INSPIRE Directive at the different scales of energy planning and the implementation of energy policies.	Policy makers, regional authorities, building sector
EXCEED (http://www.exceedproject.eu/)	It aims to cover the need for transparency and comparability of energy performance calculations, creating a database for measured and qualitative data on beyond the state-of-the-art buildings and districts	Building managers, designers, and policy makers
ICARUS (https://icarus2020.eu/)	It aims to develop integrated tools and strategies for urban impact assessment in support of air quality and climate change governance in EU Member States	Policy makers / City partners
INSITER (https://www.insiter-project.eu/)	It aims to eliminate the gaps in quality and energy-performance between design and realisation of energy-efficient buildings based on prefabricated components	Building sector community

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Project name	Short project description	Key stakeholders
IRIS (https://irissmartcities.eu)	It aims to demonstrate and replicate the cities' great potential in integrating technological solutions for contributing to the socially inclusive energy and mobility transition	Building sector community
LinDA workbench semantic component (https://linda-project.eu/)	It aims to assist SMEs and data providers in renovating public sector information, analysing, and interlinking with enterprise data by developing a linked data workbench	SMEs and Public sector
Net-UBIEP (http://www.net-ubiep.eu)	It aims to increase energy performance of buildings by wide spreading and strengthening the use of Building Information Modelling (BIM)	Public administration, Engineers and architects, Technicians and producers, Owner, tenants and facilities managers, Financial Institutions and ESCOs
OptEEmAL (https://www.opteemal-project.eu/)	It aims to design energy efficient retrofitting projects that are based on different energy conservation measures to improve the behaviour of a district	Designers, Owners, Constructors
OPTIMUS (https://www.optimus-smartcity.eu/)	It aims to design, develop, and implement a DSS addressed to city authorities, in order to assist them to optimize the energy use in their premises and reduce CO_2 emissions	City authorities
PHOENIX (https://phoenix-h2020.eu/)	It aims to improve the cyber security of the European electrical power energy systems, protecting European EPES infrastructure. It aims to offer a cyber-shield armour to European EPES infrastructure enabling cooperative detection of large scale, cyber-human security and privacy incidents and attacks, guarantee the continuity of operations and minimize cascading effects in the infrastructure itself, the environment, the citizens and the end-users at reasonable cost	EPES Management Teams/Owners, Utilities - CERTs and National Security Organizations - ICT & security technology providers - Institutional agencies for Civil Protection, EU and National-wide policy makers and regulatory bodies
Quantum (https://www.quantum-project.eu/)	It aims to close the gap between predicted and actual energy performance in European buildings	Building sector community
Shelter (https://shelter-project.com)	It aims to develop a data driven and community-based knowledge framework that will bring together the scientific community and heritage managers	Building sector community

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Project name	Short project description	Key stakeholders
SMARTEES (https://smartees.eu/)	It aims to help innovative companies digitise their businesses thanks to flexible and wearable electronics (FWE) testing, experimentation and manufacturing support	Innovative Companies
SMARTPARTICIPATE (https://www.smarticipate.eu/)	It aims to empower citizens and make the exchange of ideas between cities and the local council easier and more efficient	Citizens, entrepreneurs, city administrations
SOFIE (https://www.sofie-iot.eu/)	It aims to facilitate the creation of new IoT business platforms through secure open federation - powered by the SOFIE architecture, software framework, and reference implementation	Enterprises
THERMOS (https://www.thermos-project.eu/)	It aims to provide advanced energy system data and models in a user-friendly open-source software to make heat network planning faster, more efficient, and more cost effective	Regional public authorities
TOREADOR (http://www.toreador-project.eu/)	It aims to overcome some major hurdles that until now have prevented many European companies from reaping the full benefits of Big Data Analytics (BDA)	Companies
Triple-A (https://aaa-h2020.eu/)	It aims to assist financial institutions and project developers to increase their deployment of capital in energy efficiency, mainstreaming energy efficiency investments	project developers, financiers / investors, policy makers, researchers
TripleA-reno (https://triplea-reno.eu/)	Building upon results from a number of relevant European projects, it aims to achieve a set of specific measurable qualitative objectives: fostering new consumer and end-user centered business models, improving performances of deep renovation by enhanced quality control, provide attractive, understandable and personalized information of realized real performance, demonstrate solutions in live demonstration cases, roll out the results on a wider European scale.	Consumers, policy makers, citizens, European interest groups and associations

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EU-funded projects on Energy / Building

The following table presents EU-funded projects on Energy / Building, that could contribute to the development of the analytics building services.

Table 37: EU-funded projects on Energy/ Building

Project name	Short project description	Key stakeholders
SWIMing (www.swim-h2020.eu/)	The SWIMing project looked at over 100 EeB projects, analysing 53 in detail, and resulted in 49 case studies from 33 projects of particular relevance to BIM and interoperability. It has worked to identify shared data requirements, promote data harmonization for improved interoperability and identify where linked open data technologies can be utilized to make data more accessible and, hence, easier to exploit.	Public authorities and stakeholders
MORE-CONNECT (www.more-connect.eu/)	The MORE-CONNECT project, which ended on November 2018, has enabled a significant construction time reduction thanks to prefabricated multifunctional modular renovation elements. The positive contribution of matching the 3D scanning and BIM model has allowed for the collection of better and more precise data on the building geometry and technical conditions.	Homeowners, third party developers, concept developers and suppliers
STREAMER (www.streamer-project.eu/)	The STREAMER project aims are to reduce the energy use and carbon emissions from healthcare districts in the EU using semantics-driven design methods and interoperable tools. Since the scope of designing covers multiple dimensions, the role of the interoperability between Building Information Modelling (BIM) and Geospatial Information Systems (GIS) is crucial for a new design methodology. A design phase looking towards energy optimization needs to pay attention to the inter-connections between the architectural systems and the MEP/HVAC systems, as well as on the relation of Product Lifecycle Modelling, Building Management Systems, BIM and GIS.	Building sector community. Public administration
BIM4REN (www.bim4ren.eu/)	The BIM4REN project defines digital-ready renovation workflows adapted to the construction sector needs and elaborate an open, decentralized BIM environment as strong innovative basis for the core developments.	Building sector community
BIM-SPEED (www.bim-speed.eu/)	The BIM-SPEED project aims to enable all stakeholders to adopt BIM to reduce the time of deep renovation projects by at least 30% by providing them with: 1) an affordable BIM cloud platform, 2) a set of inter-operable BIM tools, and 3) standardised procedures for As-Built data acquisition, modelling, simulation, implementation and maintenance of renovation solutions.	Building sector community

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Project name	Short project description	Key stakeholders
ENCORE (www.encorebim.eu/)	The ENCORE project proposes the creation of a system that integrates services for data acquisition from the buildings like Static LiDAR setups, and LiDAR or photogrammetry equipment embarked in UAVs. It will also allow involving dwellers in the process by providing them with mobile tools to capture images or other in-doors information. It also provides support to architects and designers in the creation of the 3D models from the acquired data, automatically identifying and classifying the constructive elements, and allowing them to complete the model with existing BIM resources.	Building sector community, building occupants
BIM4EEB (www.bim4eeb-project.eu/)	The BIM4EEB project aims to foster the renovation industry by developing an attractive and powerful BIM-based toolset able to support designers in the design and planning phase, construction companies to efficiently carry out the work and service companies to provide attractive solutions for building retrofitting. Additionally, public and private owners will be able to use a tool that eases decision making and asset management, thanks to the exploitation of augmented reality and the use of updated digital logbooks.	Building sector community
BIMEER (www.bimerr.eu/)	The BIMEER project designs and develops a Renovation 4.0 toolkit which comprises tools to support renovation stakeholders throughout the renovation process of existing buildings, from project conception to delivery. It comprises tools for the automated creation of enhanced building information models, a renovation decision support system to aid the designer in exploring available renovation options through an accurate estimation of renovation impact on building performance as well as a process management tool that will optimize the design and on-site construction process toward optimal coordination and minimization of renovation time and cost.	Building sector community
Pro-GET-OnE (www.progetone.eu/)	The Pro-GET-OnE project integrates pre-assembled components with the highest performances in terms of energy requirements (adding new plug and-play high energy performing envelopes), safety (using appropriate steel structures to reduce horizontal loads and implementing the structural safety while supporting the new envelopes), and social sustainability (increasing the desirability of retrofit options). The production process of components in off-site factories, their supply to the construction site, and the onsite assembly procedures are optimized by a BIM-based process to maximize the workflow and project efficiency.	Building sector community

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Project name	Short project description	Key stakeholders
ASHVIN (http://www.ashvin.eu/)	ASHVIN aims at enabling the European construction industry to significantly improve its productivity, while reducing cost and ensuring absolutely safe work conditions, by providing a proposal for a European wide digital twin standard, an open source digital twin platform integrating IoT and image technologies, and a set of tools and demonstrated procedures to apply the platform and the standard proven to guarantee specified productivity, cost, and safety improvements.	Building sector community
CULTURAL-E (https://www.cultural-e.eu/)	It aims to define modular and replicable solutions for Plus Energy Buildings (PEBs), accounting for climate and cultural differences	Building sector community
E2VENT (http://www.e2vent.eu/)	It aims to develop an Energy Efficient Ventilated Facades for Optimal Adaptability and Heat Exchange, enabling low energy architectural concepts for the refurbishment of existing buildings	Building sector community
eDREAM (https://edream-h2020.eu)	It aims to transform the traditional market approaches and smart grid operations into novel decentralized and community-driven energy systems	DSOs, aggregators, prosumers
EEnvest (http://www.eenvest.eu/)	It aims to mainstream energy efficiency financing in the building renovation sector	Building sector community
ELSA (https://www.elsa-h2020.eu/)	It aims to demonstrate an environmentally friendly and effective electrical storage system that integrates second life electric car batteries and an Intelligent Energy Management System to provide innovative services in a wide range of applications	City authorities
Energy in Time (https://www.energyintime.eu/)	It aims to reduce system inefficiencies and contributing to improve building energy efficiency and comfort	Building sector community
EnergyMatching (https://www.energymatching.eu/)	It aims to maximize the RES harvesting in the built environment by developing cost-effective active building skin solutions	Building sector community
GROWSMARTER (https://grow-smarter.eu/)	It aims to bring together cities and industry to integrate and demonstrate '12 smart city solutions' in energy, infrastructure and transport, providing also other cities with valuable insights on how they work in practice and opportunities for replication	City authorities
Houseful (http://houseful.eu/)	It aims to propose an innovative paradigm shift towards a circular economy for the housing sector	Housing sector
mySMARTLife (https://www.mysmartlife.eu/mysmartlife/)	It aims to make Nantes, Hamburg and Helsinki more environmentally friendly by reducing their CO_2 emissions and increasing the use of renewable energy sources	City authorities

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Project name	Short project description	Key stakeholders
Success (https://www.success-energy.eu/)	It aims to develop an overarching approach to threat and countermeasure analysis with special focus on the vulnerabilities introduced by Smart Meters in the energy domain	Energy sector
RemoUrban (http://www.remourban.eu)	It aims to develop a holistic and replicable model of sustainable urban regeneration, exploiting the convergence between energy, mobility and ICT to improve quality of life	Building sector community
Sinfonia (http://www.sinfonia-smartcities.eu/)	It aims to deploy large-scale, integrated, and scalable energy solutions in mid-sized European cities (1 June 2014- 31 May 2019)	Buildings sector community
SmartEnCity (https://smartencity.eu/)	It aims to create Smart Zero Carbon Cities, increasing their sustainability and inclusiveness, improving citizens' quality of life, creating jobs and wealth, and offering equal growth opportunities	City authorities

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Annex III: Existing data models – description

This Annex complements section 3.2.1.1 on existing data models within the context of the digitalization of the built environment. In particular, the following existing data models are presented:

- FIWARE Smart data model
- Industry Foundation Classes (IFC)
- CityGML
- INSPIRE Directive
- SAREF
- BRICK

FIWARE Smart Data Model

FIWARE Smart Data Models[104] is an open initiative for agile data model standardization promoted by FIWARE foundation with contribution of TMForum[105], GSMA[106] and IUDX[107] and many other people and organizations contributing to the data models.

Smart Data Models have been harmonised in such a way as to enable data portability for different applications in different domains: Smart Energy, Smart Cities, Smart Agrifood, Smart Environment, Smart Sensoring, and Smart Water, among others. They are intended to be used wherever you want but with compliance to FIWARE NGSI-V2 and NGSI-LD.

They are free to use and open-licensed, and can, therefore, evolve to meet wider user needs. Smart Data Models are useful for those working in innovative projects who want to maintain their data models and get support for maintaining them. In this sense, these models should be compatible with those of other initiatives.

The Smart Data Models initiative provides a community site with detailed data models[108] available for open use across multiple domains. The community consists of relevant organisations working together to provide consistency and coherence between data models and domains, creating a method for agile standardisation of data models and their curation over time. Models are tested in real-life scenarios before being included. This provides extensive benefits to users of the FIWARE platform; in terms of more interoperability, reduced time spent to data model coding, and accumulated experience tested in real case scenarios.

FIWARE NGSI V2 DATA MODEL

The core element of NGSI v2 (see Figure 24) is the data Entity, typically a real object with a changing state. Entities have Attributes (such as “name” and “location”) and these in turn hold Metadata such as “accuracy” (e.g. the accuracy of a “location" reading). Every entity must have a type which defines the

104 https://smartdatamodels.org/
105 https://www.tmforum.org/
106 https://www.gsma.com/
107 https://iudx.org.in/
108 https://www.fiware.org/developers/data-models/

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sort of thing the entity. Relationships can be defined using NGSI v2, but only so far as giving the attribute an appropriate attribute name defined by convention (e.g. starting with ref, such as refManagedBy) and assigning the attribute type = Relationship which again is purely a naming convention with no real semantic weight.

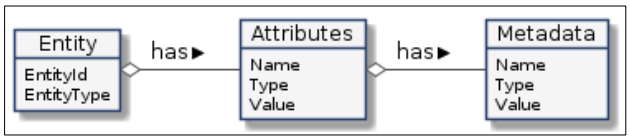

Figure 24: NGSI V2 Data Model

FIWARE NGSI LD DATA MODEL

NGSI-LD (see Figure 25) is an evolution of the NGSI v2 information model, which has been modified to improve support for linked data (entity relationships), property graphs and semantics (exploiting the capabilities offered by JSON-LD[109]). This work has been conducted under the ETSI ISG CIM initiative[110] and the updated specification has been branded as NGSI-LD.

The main constructs of NGSI-LD are: Entity, Property and Relationship. NGSI-LD Entities (instances) can be the subject of Properties or Relationships. In terms of the traditional NGSI v2 data model, Properties can be seen as the combination of an attribute and its value. Relationships allow establishing associations between instances using linked data.

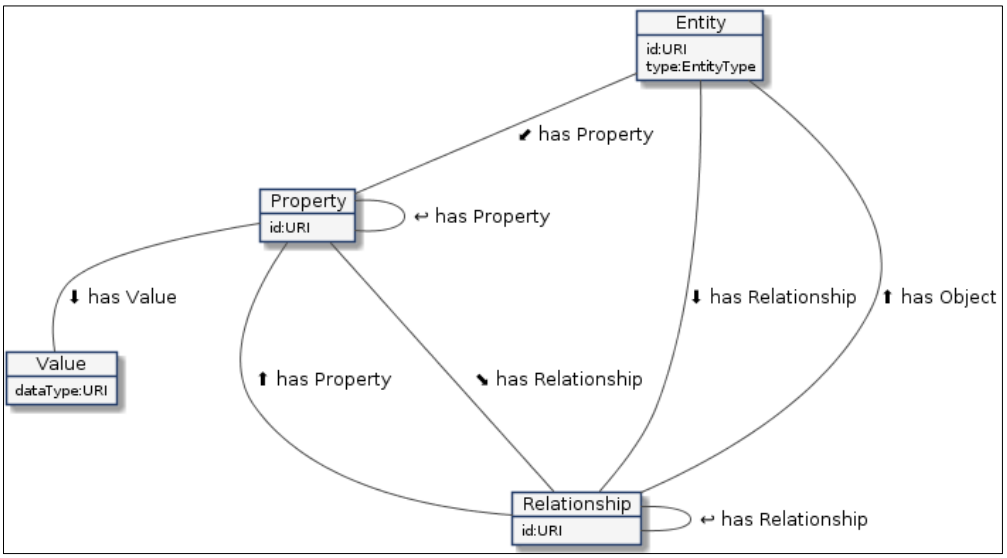

Figure 25: NGSI LD Data Model

The core element of NGSI-LD is the Entity. Every entity must use a unique id URN[111] and the type, used to define the structure of the data held, which is also a URN. This URN should correspond to a well-defined data model which can be found on the web. For example, the URN https://uri.fiware.org/ns/datamodels/Building is used to define common data model for a Building.

109 https://json-ld.org/

110 https://www.etsi.org/committee/1422-cim/

111 Uniform Resource Name – Wikipedia

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Industry Foundation Classes (IFC)

Industry Foundation Classes (IFC) is a standardised and digital definition of built environments, including buildings and civil infrastructure. It is an international open norm (ISO 16739-1:2018), aimed at being neutral with respect to the buyer, and can be deployed in ample hardware devices, software platforms and interfaces for many different use cases. The IFC schema specification is the main technical product of buildingSMART International to comply with its objective of promoting openBIM®.

The IFC scheme is a standardised data model that codifies in a logic manner:

- The identity and semantic (name, unique identifier, type of object or function)
- The characteristics or attributes (like the material, colour and thermal properties)
- The relations (including locations, connections and property)
- Abstract concepts (efficiency, cost)
- Processes (installation, operation)
- People (owners, designers, suppliers, etc).

The specification of the schema can describe how a specific installation is used, built or how it operates. IFC can define the physical components of the buildings, the manufactured products, the mechanic or electric systems, as well as more abstract structural analytical models, energy analysis models, costs specifications, work programmes and much more.

IFC can be codified in different formats and each of them has its advantages and disadvantages in terms of its scalability and legibility of the software. Given that the amount of data of this type of models can be very big, choosing the right format can have practical considerations. If the best compatibility and the lowest size to import and export files is sought, the STEP Physical File (SPF) is recommended. If it is to be used in the framework of web service communications, any of the formats is valid to be used automatically by clients and servers.

The possibility to apply IFC in a great variety of fields, leads to the data scheme being very vast and that for specific applications not all the information that is contained in the file needs to be managed.

CityGML

The international standard CityGML[112] (City Geography Markup Language) is an open data model based on XML for the exchange and storage of spatial data of virtual models of cities in 3D. It is implemented as a application schema for the Geography Markup Language 3 (GML3), international standard from the Open Geospatial Consortium (OGC) and ISO TC211. The main objective of this standard is to provide a common definition of the geometric, topologic, semantic and appearance properties of a 3D city model.

These models can be represented in five different levels of detail (LOD), as it can be observed in

[112] http://www.opengis.net/spec/citygml/2.0

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- LOD0: region, landscape
- LOD1: city, region
- LOD2: urban districts, projects
- LOD3: buildings (exterior) and places of interest
- LOD4: buildings (interior)

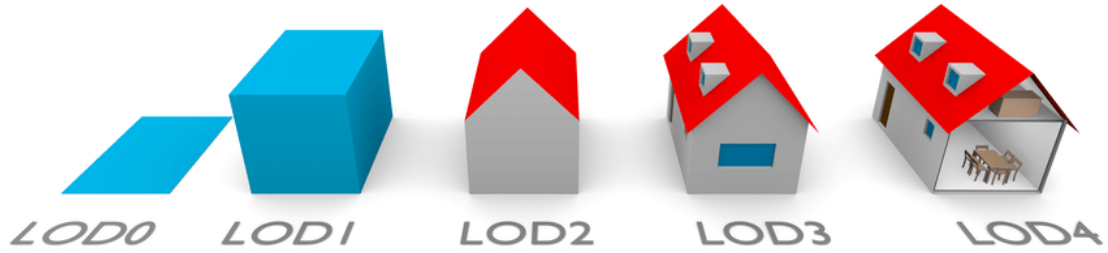

Figure 26: CityGML Levels of Detail[113]

The main characteristics of CityGML are the following:

- It allows to represent the different surfaces of the object (textures, materials).
- It allows to represent models in different levels of detail simultaneously
- It contains the following taxonomy and aggregation groups: digital terrain models, places, vegetation, waterbodies, transport, urban furniture, generic urban models, groups defined by the users.
- It allows the topology connections among objects (optional).
- There are application domain extensions (ADE) available to support specific applications[114]

INSPIRE Directive

The INSPIRE Directive (2007/2/EC)[115] establishes an infrastructure for spatial information in Europe to support Community environmental policies, and policies or activities which may have an impact on the environment.

INSPIRE is based on the infrastructures for spatial information established and operated by the Member States of the European Union. The Directive addresses 34 spatial data themes needed for environmental applications, with key components specified through technical implementing rules. This makes INSPIRE a unique example of a legislative "regional" approach.

In the Figure 27 below, the 34 spatial data themes can be observed. These have been grouped by annexes, which are linked to the INSPIRE implementation roadmap.

[113] Biljecki, Filip & Ledoux, Hugo & Stoter, Jantien. (2016). An improved LOD specification for 3D building models. Computers Environment and Urban Systems. 59. 25-37. 10.1016/j.compenvurbsys.2016.04.005.
[114] https://www.citygmlwiki.org/index.php/CityGML-ADEs
115 https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32007L0002/

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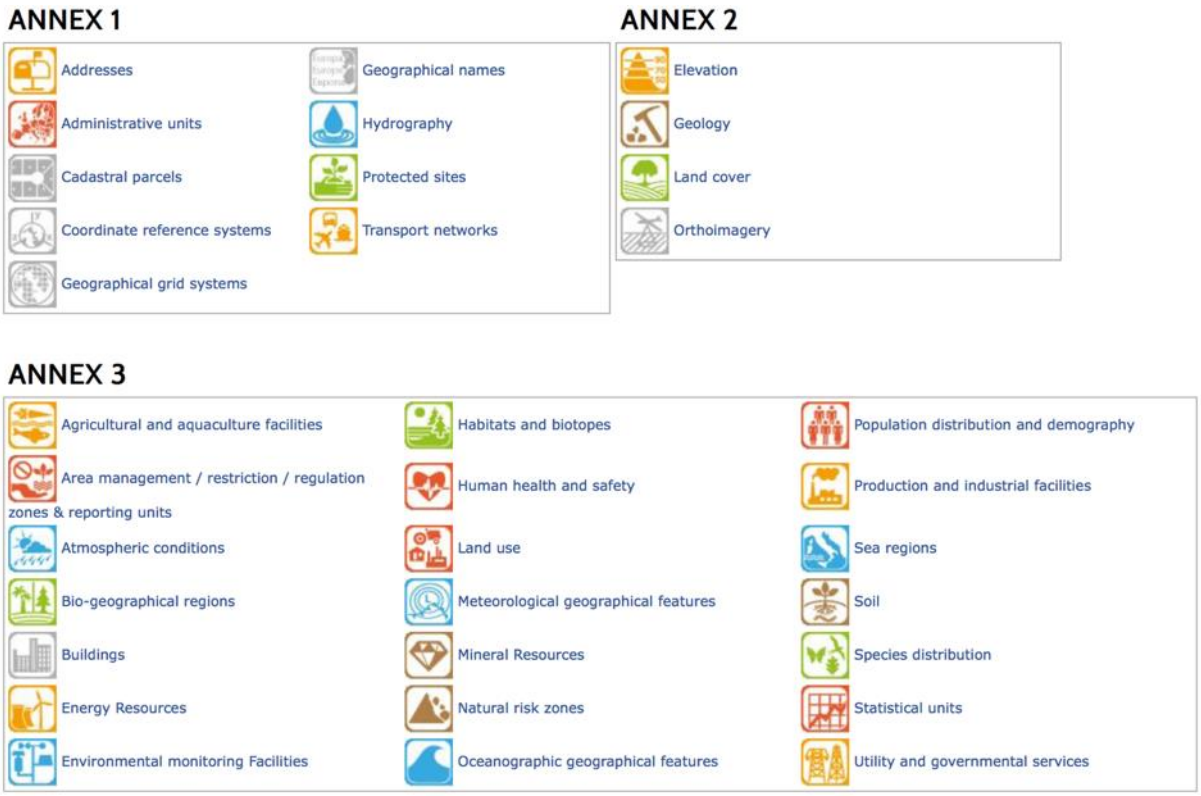

Figure 27: 34 spatial data themes contained in INSPIRE. ***Source: INSPIRE Knowledge Base***

The main objective is to ensure the compatibility and the reusability of Data in a Community context.

Directive requires that common Implementing Rules (IR) are adopted (as Commission Decisions or Regulations) in a number of specific areas:

- Metadata
- Data Specifications
- Network Services
- Data and Service Sharing Monitoring and Reporting.

These IRs are adopted as Commission Decisions or Regulations, and are binding in their entirety, as it can be seen in the following Figure 28:

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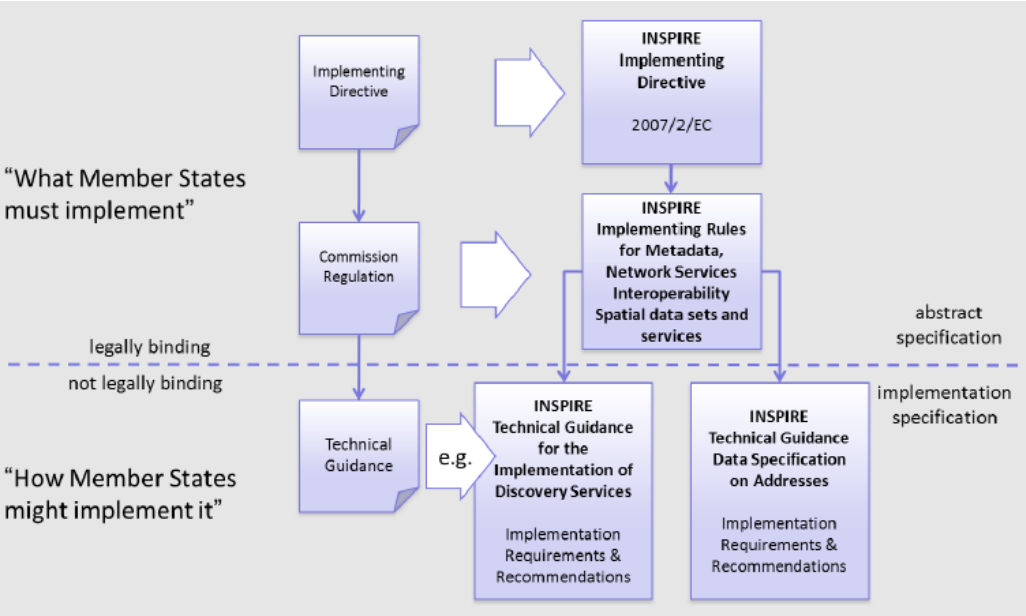

Figure 28: INSPIRE implementation: legally and non-legally bounding documents. ***Source: INSPIRE Knowledge Base***

This INSPIRE implementation follows a series of common principles:

- Data should be gathered only once and be stored where they can be maintained in the most efficient manner.
- It should be possible to combine without interruptions the geospatial information from different sources around Europe and share it with many users and applications
- It should be possible that the gathered information at one level / scale can be shared with other levels or scales (with a high granularity for specific research and general for strategic purposes)
- The necessary geographic information for ensuring good governance at all levels should be prepared and available in a transparent manner.
- Available geographic information should be easily available, as well as their conditions for use.

Last but not least the available harmonised data under this standard made available by EU member states is available in the INSPIRE geoportal[116].

SAREF

The Smart Applications REFerence (SAREF) ontology was developed by the European Commission in cooperation with the European Telecommunications Standards Institute (ETSI) to enable interoperability among solutions of different providers in the Internet of Things (IoT) domain. It is a model of consensus originally conceived to represent semantic assets and concepts in the smart building applications domain together with their relationships.

116 https://inspire-geoportal.ec.europa.eu/

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The concepts and relationships defined in SAREF build upon the previous work already done in the sector of smart appliances, which mainly derives from the domain-specific ontologies already defined by the World Wide Web Consortium (W3C). The core concept of SAREF is the device, which is used to represent any generic appliance. The devices are usually designed to perform some specific functions, which can be activated via a dedicated command. The function performed by the device leads it to have a specific state. The description of the device can be further enriched by specifying some properties, profiles, tasks, etc. The following Figure 29 shows the overall view of the main classes within the SAREF ontology as well as the relationships used to link them.

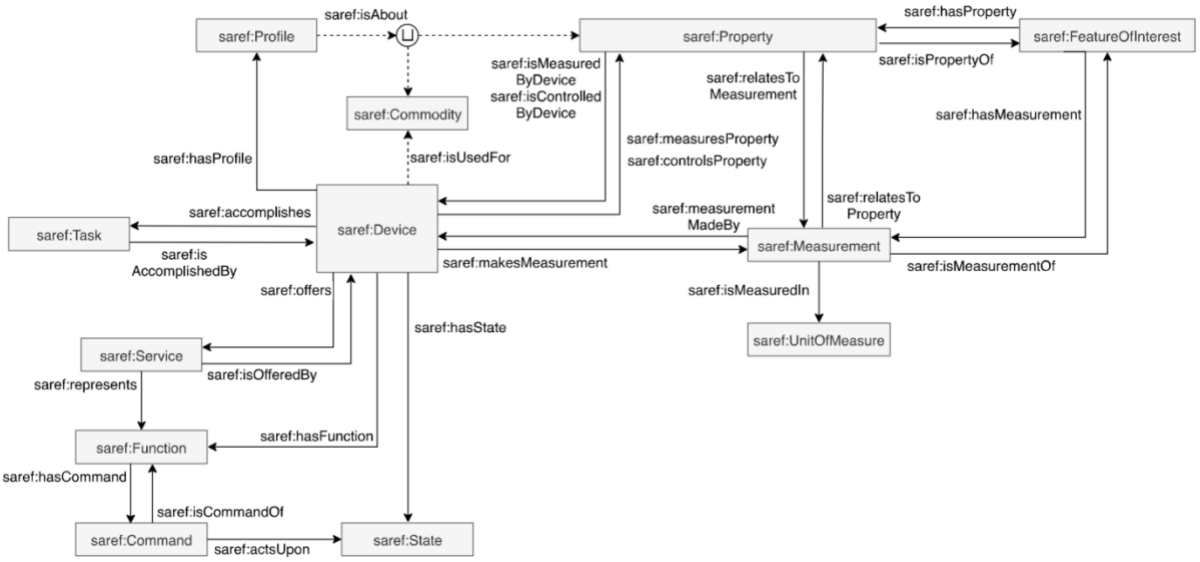

Figure 29: Overview of the main classes in SAREF together with their relationships. ***Source: SAREF website***[117]

Since SAREF deals with general smart appliances and smart applications, it is likely that appliances or applications related to a specific domain cannot be completely mapped into the general SAREF ontology. For this reason, several extensions were developed over the last years to describe more in details the ontology associated to specific domains. At the moment, ten different domain extensions are available, which include SAREF4ENER (energy domain), SAREF4BLDG (building domain), SAREF4CITY (smart cities domain), SAREF4AGRI (agriculture domain), etc.

For the purposes of this project, SAREF4BLDG is particularly relevant since it directly refers to the building domain. SAREF4BLDG was created starting from the previously mentioned Industry Foundations Classes (IFC) standard for building information (section 0). It extends SAREF by adding to it 72 classes, 179 object properties and 83 data type properties.

BRICK

BRICK is an ontology-based metadata schema that provides semantic descriptions of physical, logical and virtual assets within buildings as well as the relationships among them. BRICK consists of an extensible dictionary of terms and concepts in and around buildings, a set of relationships for linking and composing concepts together, and a flexible data model permitting seamless integration

117 https://saref.etsi.org/

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of Brick with existing tools and databases.

The core concepts within the BRICK are the following:

- Entity: is an abstraction of any physical, logical or virtual item; the actual "things" in and around a building.
- Tag: is an atomic fact or attribute of an entity. Examples of tags are sensor, set point, air, water, etc.
- Class: is a named category with intentional meaning (a definition) used for grouping entities.
- Relationship: defines the nature of a link between two related entities; in other words it expresses how entities, classes and tags interact and are associated one each other.

A BRICK model is a digital representation of a building that adheres to the BRICK schema. Entities in a BRICK model are classified according to the classes defined by BRICK, and are connected using the relationships defined by BRICK. The BRICK ontology and models specifically refers to the building domain, but it is extensible and allows for the possible integration of other higher-level ontologies, like SAREF, or ontologies associated to other domains, via the definition of new classes.

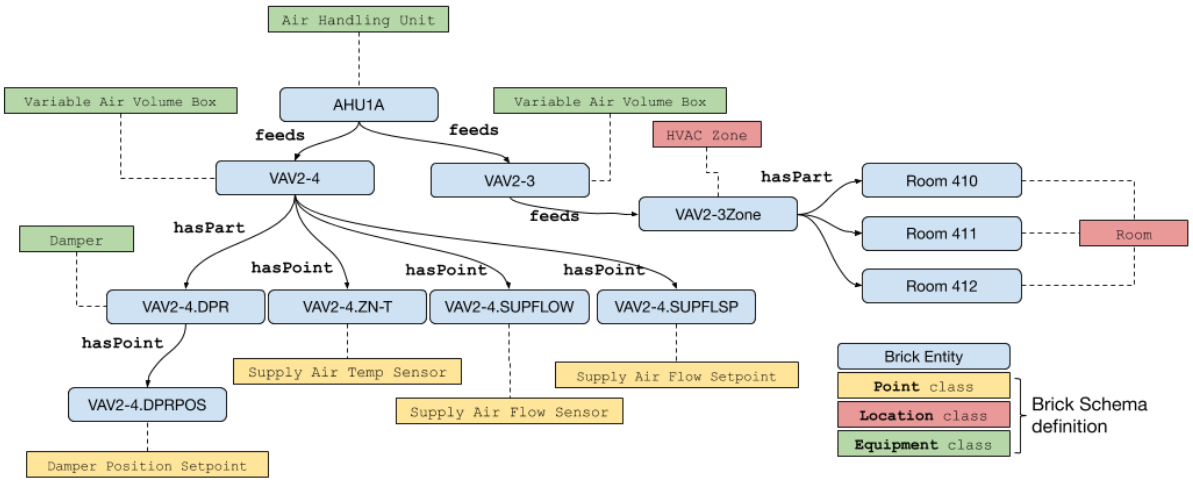

Figure 30: Example of BRICK model. ***Source: BRICK website***[118]

118 https://brickschema.org/

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Annex IV: End-to-end process digitalisation methodology example

This Annex complements section 3.2.1.5 on end-to-end process digitalisation and presents a methodology to process point clouds in order to manage and extract useful information for existing buildings in a BIM environment from point clouds. The objective is to create sets of archetypal elements as a basis to make libraries of parametric objects from point clouds since BIM platforms are not currently ready to handle huge amounts of 3D data or to represent required particular features. There are two main ways of producing a useful BIM model from point clouds:

- Using specific 3D data processing software to create parametric elements on the point clouds to be exportable to BIM environments by interoperable formats.
- Directly modelling into the selected BIM software package by means of special functionalities or complementary applications to handle point clouds.

These possibilities imply great potential for point clouds as raw material for BIM issues. However, the second possibility allows to directly operating in a BIM package without intermediate conversions in addition to using the full operational capabilities of the selected package.

Point clouds contain geometrical data, which consists of the set of the measured coordinates, which can be stored in polar or a cartesian coordinates. Most scan file types include also the reflectivity value per point. The RGB colour data can be stored within the geometry files, but more commonly the native formats used by the laser scanner manufacturers are kept separately, linked to the scan position.

The survey data from 3D image-based modelling and 3D laser scanning are of multiple natures. The raw data produced go through various pre-processing operations until the 3D point cloud model is fully completed, the data optimized and ready for export towards the processing steps of data interpretation. For the 3D laser scanning, the main operations of the pre-processing are data filtering, colouring and registration.

Once the pre-processing is completed, the standard approach is using commercial tools, mainly REVIT or ARCHICAD, to boosting the BIM modelling of the building from the point cloud data. Different commercial plug-ins for efficiently using rich as-built point cloud data are usually provided by laser scanners makers, mainly within REVIT for this purpose. This is useful for a wide range of BIM activities including retrofit design, intervention operations or lifecycle asset management of the building.

In the case of REVIT, point cloud files can be imported through a wide variety of scan formats. Raw point cloud files are converted to the RCP and RCS indexed formats. *ARCHICAD* allows importing point clouds natively, but contrary to *REVIT*, is restricted to XYZ coordinates and the E57 format. *ARCHICAD* also requires importing cloud files with at least 6 columns (X, Y, Z, R, G, B). Thus the 4-column XYZ file (X, Y, Z, L) needs an intermediate conversion. For these reasons, the open-source *CloudCompare* multi-platform software is recommended, leading to XYZ files with a controlled number of columns.

Once the point cloud has been imported into the selected BIM software, the standard approach is to use the data as a template for modelling the geometry as a basis to create libraries of parametric elements of the existing building.

A typical designing workflow for obtaining the 3D model of an existing building is presented below. The proposed scheme combines the geometry data obtained from the point cloud with non-graphical

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data obtained from third-party sources related to the case of study.

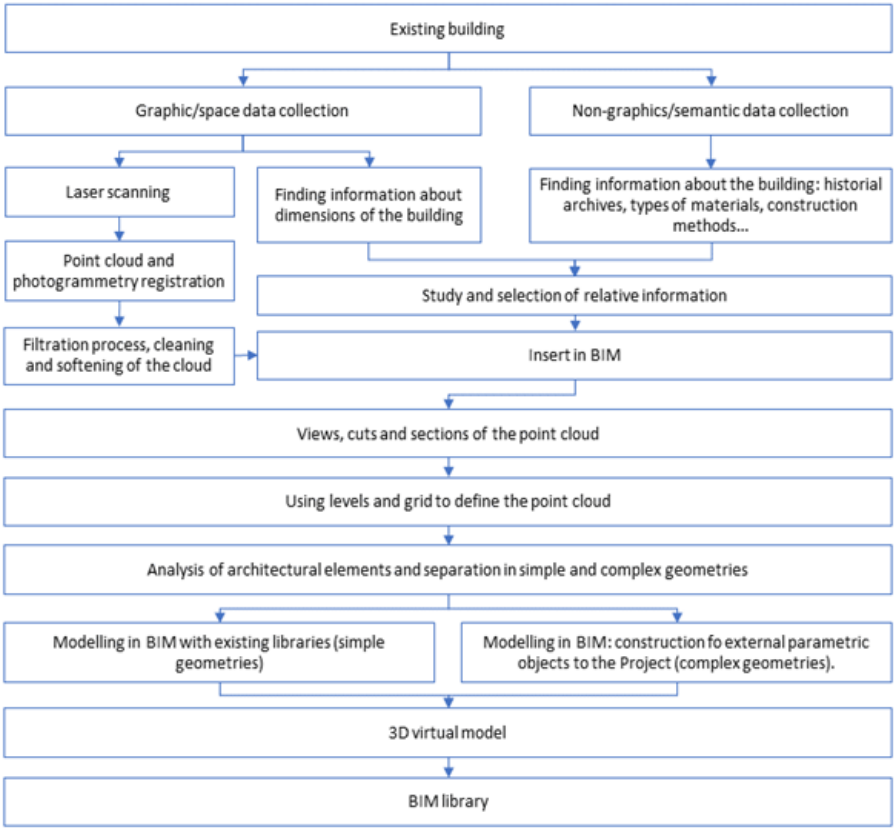

Figure 31: Typical 3D modelling workflow of existing buildings[119]

This scheme (Figure 31) can be not only a solution for 3D modelling of a wide range of buildings in the same style due to the flexibility of the modelled elements, but also the adaptation to new requirements is ensured, which widely change in shape and proportions.

119 López, F.J.; Martin Lerones, P.; Llamas, J.; Gómez-García-Bermejo, J.; Zalama, E. (2017a): "A framework for using point cloud data of heritage buildings towards geometry modeling in a BIM context: a case study on Santa Maria la Real de Mave Church". International Journal of Architectural Heritage, 11(7), p. 965-986. http://www.tandfonline.com/doi/full/10.1080/15583058.2017.1325541/

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Annex V: MATRYCS target groups and personas

This Annex complements section 2.8. In particular, it contains Table 38: MATRYCS Stakeholder approach: Target groups and Personas, which presents the final classification of target groups and the different Personas that have been assigned to them by pilot leaders. Personas from each LSP are deeply analysed by considering their context, goals and pains in the section of Pilots (Section 5.1.1), and it is the common thread also to Part II of this deliverable (user stories analysis).

Table 38: MATRYCS Stakeholder approach: Target groups and Personas

Target Group	Brief definition	Personas	
Researchers	Research organizations and universities	No persona has been assigned for the moment	TBD
Facility Managers	Manager in charge of the correct functioning of their facilities	Informed facility manager	**LSP1**
		Sustainability supporting facility manager	
		Cost-conscious facility manager	
		Sustainability supporter DHN manager	**LSP6**
		Cost-conscious DHN manager	
		Responsible managers	**LSP10**
		Careless managers	
ESCOs	Energy Services Companies	Informed ESCO	**LSP1**
		Sustainability supporting ESCO	
		Advanced ESCO	**LSP3**
		Energy Performance Contract facilitator	
		Energy Manager (Private sector)	**LSP4**
Real estate developers and managers	Developers and managers of real estate	Director of Project Development among one of the biggest housing managers	**LSP11**
		Manager of a small local housing cooperative	
Utilities	Public and private utilities and aggregators	Informed utility	**LSP1**
		DSM aware utility	
		Large scale DSO Head	**LSP4**
		Small scale DSO Head	
		Energy Manager (Public sector)	
Institutions	Relevant national and European institutions or departments	Urban planning professional	**LSP7**
		Local transport department director	
		Workers of the municipality (Gdynia) and other municipalities	**LSP8**
		Ambitious head of department	**LSP10**
		Project manager	
Investors	Industry and investors related to the real estate management and development	Benefit-oriented bank	**LSP3**
		Sustainability supporter bank	
		Informed investor	**LSP6**

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Target Group	Brief definition	Personas	
Policy makers	Policy authorities and policy makers (local to European level), e.g. urban planning department	Local authority	**LSP5**
		City Council member	**LSP7**
		European Commission staff	
		Energy Performance Certificate's Regional Registry Management Service	**LSP9**
		Regional Energy Efficiency Strategy planners	
		Informed policy makers	**LSP10**
		Member of the Parliament (Energy and Housing Committees)	**LSP11**
		Senior official in the Commission for Europeans	
Designers	Architects and engineers in charge of the design, retrofitting or decommissioning of buildings.	Designers willing to plan efficient renovation activities	**LSP2**
		Profit-oriented DHN manager	**LSP6**
		Efficiency-oriented DHN manager	
		Energy Performance Certification (EPC) issuers	**LSP9**
Constructors and contractors	Construction companies and consulting firms	Worker of a large construction company	**LSP11**
		CEO of a large manufacturer of energy systems	
Citizens, tenants and Owners	Citizens and individual owners	Informed owner	**LSP1**
		Sustainability supporting owner	
		Personnel of the kindergarten	**LSP2**
		Management staff of educational buildings in the municipality (City of Gdynia)	
		Users of the kindergarten	
		Motivated owner	**LSP3**
		Careless owner	
		Disbelieving owner	
		Sensitive office employee	**LSP4**
		Informed office employee	
		Reluctant office employee	
		Dynamic Prosumer	
		Static Prosumer	
		Prosumer	**LSP5**
		EV owner	
		Environmentally conscious citizen	
		Informed owner	**LSP6**
		Real estate owner	**LSP8**
		Building administrator and manager	
		Building buyers and sellers, landlords and tenants	**LSP9**

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Target Group	Brief definition	Personas	
		Old citizen in rented house	**LSP11**
		Student in community group to convince government and public housing provider to install solar panels in the roofs	
SMEs, Companies and entities	Small and Medium enterprises, related and not related to construction	Eco-friendly SME	**LSP5**
		Renovation contractors and auditors	**LSP8**
		Director of finance	**LSP10**

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Annex VI: Examples of test cards, personas, user stories and use cases

This chapter will show the examples of specific pilots, test cards, personas, user stories, usage scenarios and use cases.

Examples covering services s4.1 IPMVP service were chosen to demonstrate the combining needs of different personas and user stories. The service s4.1 covers pilot number 3 and 6.

LSP3 and LSP6 test cards

MATRYCS test card

Name *Pilot name*	**Goal** *Overarching pilot goals*
LSP3: ESCO SUPPORT SERVICES Energy Saving Verification Service for increasing the trust on Energy Performance Contracts [*VEOLIA*]	▶ **Cost-effective assessment and new EPC simulations:** ▷ Energy savings verification service for increasing the trust on EP contracts. ▷ Improvement on the deployment of M&V Protocols (i.e. IPMVP) to generate analytics to aid in the calculation of energy savings with the aim of supporting EPCs. ▷ Identification of new savings ▶ **Energy efficient refurbishments:** Support the design of energy efficient refurbishments at EPC facilities ▶ **Advanced facility analysis:** ▷ Behavioral usage prediction ▷ Errors detection of facilities ▷ Advanced reporting ▶ **Improved ROI**

Metrics *The measures to determine if the pilot achieves the goals*	**Target group** *The users and stakeholders benefited by the pilot service/development* *Development of PERSONAS*	
	Target group	***Personas***
▶ **Reduced error rates** in facilities and following costs ▶ Better **evaluation of EPCs** ▶ Higher **customer trust** ▶ Development of further **saving measures**	**ESCOs**	● Advanced ESCO ● EPC facilitator developing new market
	Citizens and Owners	● Motivated owner ● Careless owner ● Disbelieving owner
	Investors	● Benefit-oriented bank ● Sustainability supporter bank

Figure 32: LSP3 test card

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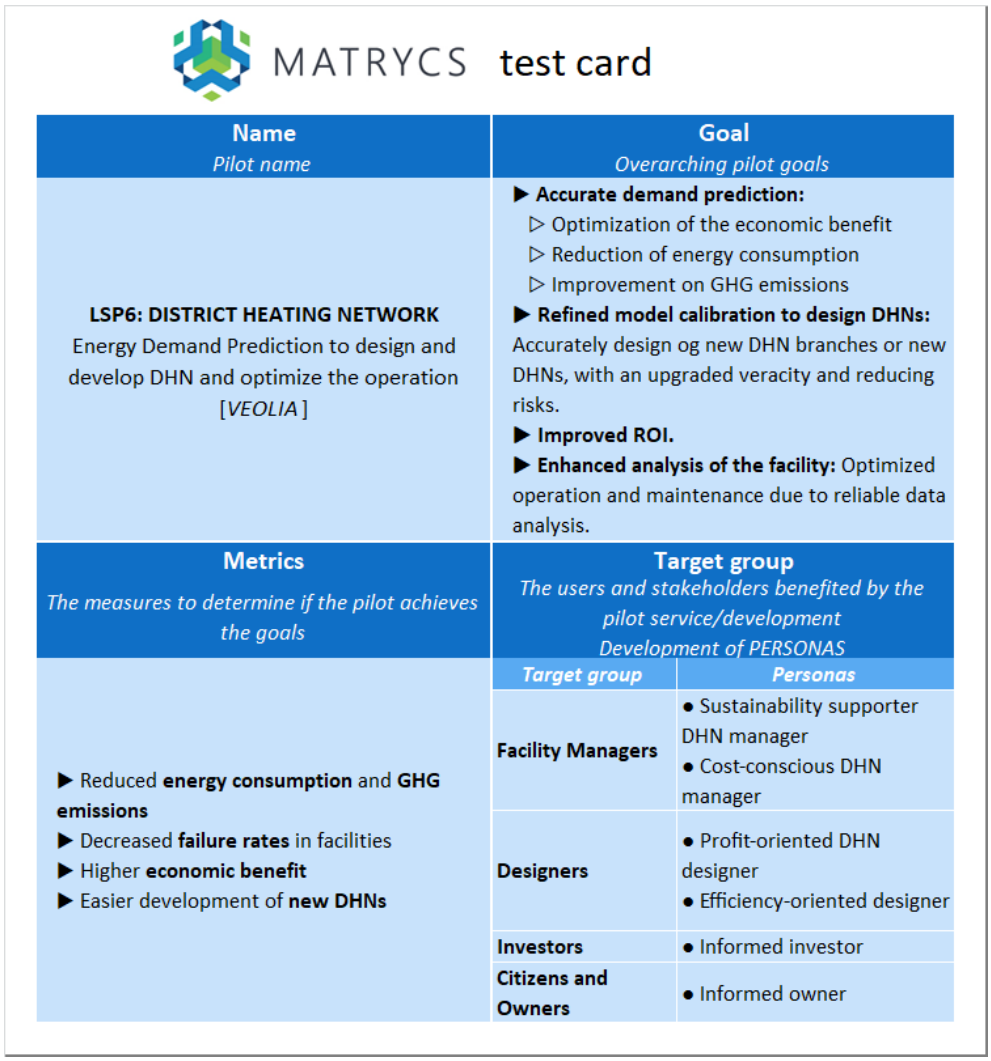

MATRYCS test card

Name *Pilot name*	Goal *Overarching pilot goals*
LSP6: DISTRICT HEATING NETWORK Energy Demand Prediction to design and develop DHN and optimize the operation [*VEOLIA*]	▶ **Accurate demand prediction:** ▷ Optimization of the economic benefit ▷ Reduction of energy consumption ▷ Improvement on GHG emissions ▶ **Refined model calibration to design DHNs:** Accurately design og new DHN branches or new DHNs, with an upgraded veracity and reducing risks. ▶ **Improved ROI.** ▶ **Enhanced analysis of the facility:** Optimized operation and maintenance due to reliable data analysis.
Metrics *The measures to determine if the pilot achieves the goals*	**Target group** *The users and stakeholders benefited by the pilot service/development* *Development of PERSONAS*

Target group	*Personas*
▶ Reduced **energy consumption** and **GHG emissions** ▶ Decreased **failure rates** in facilities ▶ Higher **economic benefit** ▶ Easier development of **new DHNs**	
Facility Managers	● Sustainability supporter DHN manager ● Cost-conscious DHN manager
Designers	● Profit-oriented DHN designer ● Efficiency-oriented designer
Investors	● Informed investor
Citizens and Owners	● Informed owner

Figure 33: LSP6 test card

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Personas examples

There were 7 personas developed in LSP3 and 6 personas in LSP6. The relevant personas examples following the s4.1 service are as follows:

- LSP3 persona 1
- LSP6 persona 6

MATRYCS persona 1

USER	USER CONTEXT
Persona name	*Add a description of the context of the Persona*
 ESCOs ***Advanced ESCO***	The Advanced ESCO is a company with high experience in the energy sector. It is aware about the benefits that the energy efficiency can provide to its business, so it fosters the implementations of energy efficiency measures in the facilities it manages. The knowledge the Advanced ESCO has about some of the facilities it manages is limited, difficulting the optimal operation of those.
PAIN POINTS	**GOALS**
What current pain points will the service solve?	*What can the service help to achieve the goals?*
The Advanced ESCO finds difficult to convince the owners of the facilities it manages about the benefits that the energy efficiency measures provide. This issue will be eased by increasing the trust of the owners in these measures. Implementing new and more efficient energy efficiency measures is also hard sometimes, due to the required initial investment and the uncertainty implied	The Pilot services can help them: ■ to implement energy efficiency measures in different facilities. ■ to make it easier to convince the owners to carry out the interventions to improve the efficiency. ■ to improve the analysis of the facilities. ■ by easing the energy savings verification procedure. ■ by helping increase the knowledge that the Advanced ESCO has about the facility it manages
USEFULNESS OF THE SERVICE	**ATTITUDES & SENTIMENTS**
How does the service fit into their life?	*What **emotions** will the service create?*
The service will help increasing the trust of the owners, making it easier for the Advanced ESCO to convince them about the benefits of the energy efficiency measures. The implementation of new and more efficient measures will also be easier to carry out, providing more benefits to the Advanced ESCO.	Motivation and security, as the service will improve the capacity of the Advanced ESCO to implement energy efficiency measures, helping the workers to carry out the work easier and better.

Figure 34: LSP3 persona 1

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MATRYCS persona 6

USER	USER CONTEXT
Persona name	*Add a description of the context of the Persona*
 Citizens and Owners ***Informed owner***	The Informed owner is owner and inhabitant of one or more dwellings in a building supplied by an old and outdated DHN, and he is interested about the benefits a renovation in the DHN can provide regarding energy consumption, GHG emissions, economic savings and availability. He is willing to carry out this renovation, pushing other owners and trying to convince them about the benefits in consumption, comfort and emissions it would provide.
PAIN POINTS	**GOALS**
What current pain points will the service solve?	*What can the service help to achieve the goals?*
Other owners of this and other building are not willing to carry out the DHN renovation. They do not believe the this renovation would imply any benefit and think it would cost a lot of money. The civil works to carry out the renovation would imply discomfort for the citizens.	The Pilot services can help them: ■ to convince other owners about the benefits of the renovation of an outdated DHN. ■ to avoid the upfront costs of the interventions by the use of Energy Performance Contracts. ■ by increasing the availability of the service and the comfort, due to the use of a more efficient facility.
USEFULNESS OF THE SERVICE	**ATTITUDES & SENTIMENTS**
How does the service fit into their life?	*What **emotions** will the service create?*
The Pilot services will help Informed owner by giving him further arguments to prove the benefits of the renovation of the DHN, helping him convince other owners of this and other buildings. The old DHN suffered from temporary breakdowns from time to time and its low efficiency meant high energy and operating costs. These issues would be solved with the renovation.	Motivation and excitement, as he will be able to foresee the benefits of the new DHN, making he foster this renovation.

Figure 35: LSP6 persona 6

User stories examples

There were developed 19 user stories for LSP3 and 17 user stories for LSP6. The user stories relevant for service s4.1 are as follows:

- User story 1.1, 1.4 (LSP3)
- User story 6.2 (LSP6)

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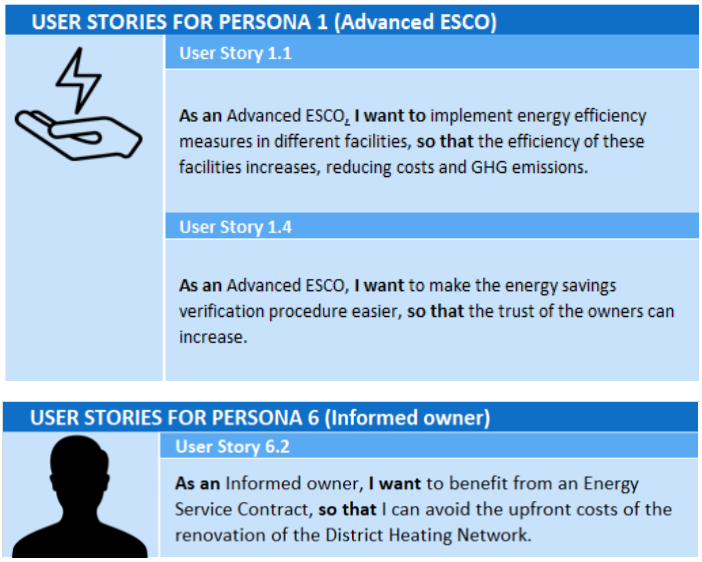

Figure 36: User stories 1.1, 1.4 (LSP3), 6.1 (LSP6)

Usage scenarios examples

There were 3 usage scenarios developed and finally related to the service s4.1:

- Usage scenario 1.1.1 (LSP3)
- Usage scenario 1.4.1 (LSP3)
- Usage scenario 6.1.1 (LSP6)

MATRYCS Usage Scenario 1.1.1

LSP3: ESCO SUPPORT SERVICES		
Related User story	**US 1.1**	As an Advanced ESCO, I want to implement energy efficiency measures in different facilities, so that the efficiency of these facilities increases, reducing costs and GHG emissions.
Involved Persona	Advanced ESCO	
Usage Scenario ID	**USC 1.1.1**	
Related Use Case	**UC X.X**	Use case name, describing the targeted action. TO BE FILLED LATER
Version	v0	
Preconditions	Environmental conditions: ■ Energy Efficiency Measures (ECMs) are going to be deployed on a Building ■ Existing invoices of the global energy consumption of the buiding for the Baseline period (Option C of the IPMVP) ■ Energy savings have been estimated ■ GHG emissions reduction has been estimated	
Post-Conditions	■ Energy consumption reduction ■ GHG emissions reduction ■ Cost reduction	

Figure 37: Usage scenario 1.1.1 (LSP3)

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MATRYCS Usage Scenario 1.4.1

LSP3: ESCO SUPPORT SERVICES		
Related User story	US 1.4	As an Advanced ESCO, I want to make the energy savings verification procedure easier, so that the trust of the owners can increase.
Involved Persona	Advanced ESCO	
Usage Scenario ID	USC 1.4.1	
Related Use Case	UC X.X	Use case name, describing the targeted action. TO BE FILLED LATER
Version	v0	
Preconditions	Environmental conditions: ■ Energy savings verification are going to be implemented in a facility ■ Existing invoices of the global energy consumption of the buiding for the Baseline period (Option C of the IPMVP) ■ Energy savings have been estimated ■ GHG emissions reduction has been estimated	
Post-Conditions	■ Energy Performance Contract signed with the owners ■ Trust from the owners	

Figure 38: Usage scenario 1.4.1 (LSP3)

MATRYCS Usage Scenario 6.1.1

LSP6: DISTRICT HEATING NETWORK		
Related User story	US 6.1	As an Informed owner, I want to be able to prove the benefits of the renovation of the District Heating Network, so that I can convince other owners to carry ot the renovation.
Involved Persona	Informed owner	
Usage Scenario ID	USC 6.1.1	
Version	v0	
Preconditions	Environmental conditions: ■ Monitoring devices already installed ■ Historical monitoring data available ■ Energy savings have been estimated ■ GHG emissions reduction has been estimated	
Post-Conditions	■ Report on energy savings ■ Report on GHG emissions	

Figure 39: Usage scenario 6.1.1 (LSP6)

Use case example

Finally, the Usage Scenarios converge in a group of use cases. In this case, there is not a single use case, because it has been considered that the process does not have to always run completely.

- The first Use case has associated the 3 usage scenarios that have been identified from the description provided by the pilots and 2 types of personas, so there is only one scenario (Scenario No. 1 - M&V plan creation)

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- The second use case has two variants, so it arises in two application scenarios: the first one related to two usage Scenarios (and type of personas, Scenario No. 1 - Basic savings report generation), and the second related to a single usage Scenario and type of personas (Scenario No. 2 - Savings report generation). These small differences between the application scenarios are a consequence of the fact that the final tool will not offer the same outputs.

Table 39: Final generated Use Case UC03_01/UC06_01 (full version)

1 Description				
Use Case Identification				
Use Case ID		**Scale / Domain(s)**	**Name of Use Case**	
UC03_01, UC06_01		*Building, District* *MATRYCS-FUND*	*M&V plan creation*	
Version Management				
Version No.	**Date**	**Name of Author(s)**	**Changes**	**Approval status**
v01	*01-03-2021*	*Javier Antolín* *Roberto Sanz*	*DD-MM-YYYY*	*Pending*
Related LSP(s)	*LSP3 and LSP6*			
Scope and Objectives				
Scope	*Selection of the best mathematical model to predict energy savings.*			
Objective(s)	*Define M&V plan based on IPMVP (Option C). Selection of the best mathematical model to predict energy savings.*			
Related business case(s)	*TBD*			
Narrative of Use Case				
Description	*In this use case, the user wants to obtain the best mathematical model to predict energy savings. To this purpose, a dedicated service is used to measure and identify potential energy and money savings after renovation/installation of energy efficiency measures in buildings, following the IPMVP (s4.1 Measurement and verification of energy services). This gives the users the possibility to demonstrate the potential savings.*			
General Remarks				

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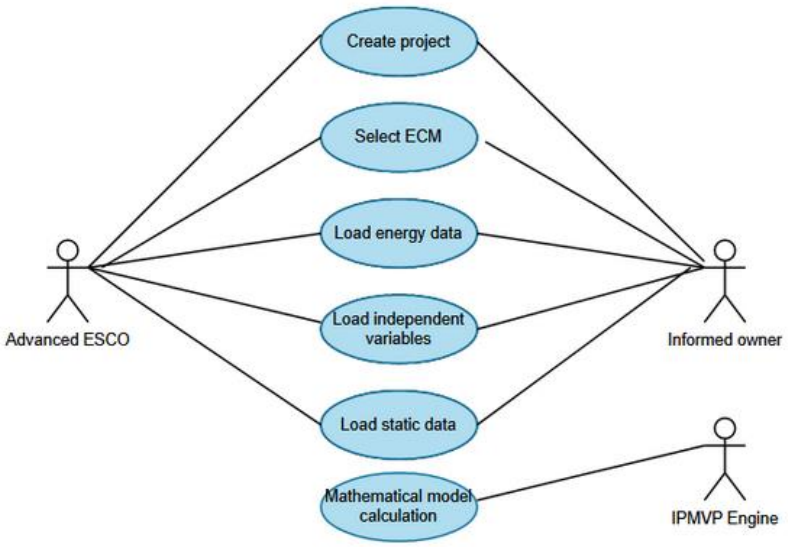
2 Diagram(s) of Use Case

Scenario 1 - M&V plan creation



3 Technical Details

Use Case Conditions			
Actor/ System/ Information/ Contract	**Triggering Event**	**Pre-conditions**	**Post-conditions**
Advanced ESCO; Informed Owner	The user needs to know which is the mathematical model that better fits with the reference data to be able to verify energy savings with higher confidence after the implementation of the ECMs	Building identified (General Project data) ECMs identified Reference period identified • Energy consumption data (Different fuels). • Independent variables (Weather conditions, occupation, etc.) • Static factors (Building use and characteristics, Equipment, etc.)	Best mathematical model selected for different fuels complying with statistics

4 Step by Step Analysis of Use Case

Scenarios			
Scenario Name	***No. 1 - M&V plan creation*** *LSP3: USC 1.1.1, USC 1.4.1* *LSP6: USC 6.1.1*	**Actors**	*Advanced ESCO/ Informed owner*

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4 Step by Step Analysis of Use Case					
Step No.	**Event**	**Description of Process/ Activity**	**Information Exchanged**	**Service**	**Req. ID**
1	*Create Project*	User creates a new project and identifies the project general data	General data to define the project through a template	s4.1	TBD [120]
2	*Select ECM*	User identifies the ECMs	List of ECMs to be implemented (from Drop down menu)	s4.1	TBD
3	*Load Energy Data*	User loads the energy consumption data for baseline period in the system	Energy consumption data files (e.g. CSV)	s4.1	TBD
4	*Load Independent Variables*	User loads the independent variables data for baseline period in the system	Independent variables data files (e.g. CSV)	s4.1	TBD
5	*Load Static Data*	User loads static data for the baseline period	Static conditions data file (e.g. CSV)	s4.1	TBD
6	*Mathematical Model Calculation*	The statistical engine generates the optimal mathematical model based on previous data (Regression model engine)	Statistical engine gives the optimal mathematical model to the user (e.g. virtual interface)	s4.1	TBD

Table 40: Final generated Use Case UC03_02, UC06_02 (full version)

1 Description				
Use Case Identification				
Use Case ID	**Scale / Domain(s)**	**Name of Use Case**		
UC03_02, UC06_02	*Building, District* *MATRYCS-FUND*	*Savings report generation*		
Version Management				
Version No.	**Date**	**Name of Author(s)**	**Changes**	**Approval status**
v01	*01-03-2021*	*Javier Antolín* *Roberto Sanz*	*DD-MM-YYYY*	*Pending*
Related LSP(s)	*LSP3 and LSP6*			

[120] The templates will need to be completed with the associated requirements, to be defined in Deliverable 2.2 "MATRYCS Technical and Security Specification"

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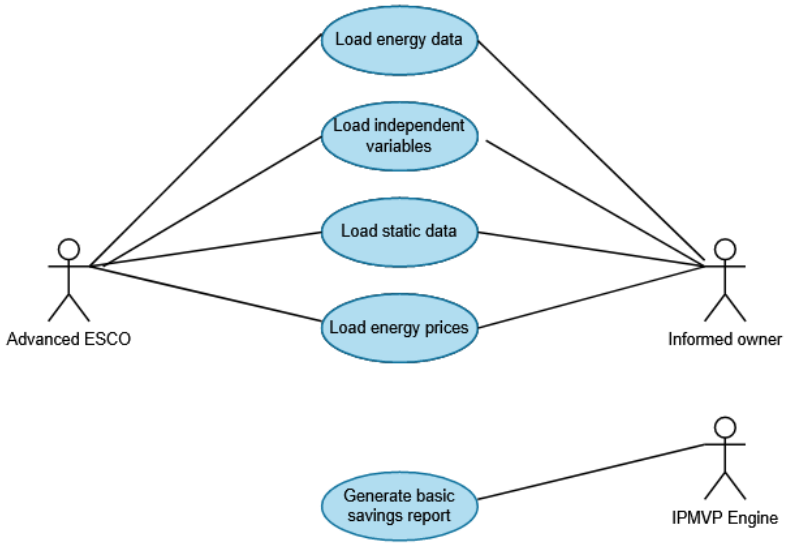
1 Description	
Scope and Objectives	
Scope	*Verification of the savings achieved after the implementation of Energy Conservation Measures (ECMs) to a building/district through a recognized measurement and verification protocol (IPMVP).*
Objective(s)	*Verify and report the savings achieved after the implementation of ECMs.*
Related business case(s)	*TBD*
Narrative of Use Case	
Description	*The user wants to verify the savings achieved after the implementation of the energy efficiency solutions. The service s4.1 Measurement and verification of energy services serves this purpose: it follows the IPMVP and establishes a workflow to measure and identify energy and money savings after renovation/ installation of energy efficiency measures in buildings, giving the possibility of demonstrating corresponding savings achieved.*
General Remarks	

2 Diagram(s) of Use Case

Scenario 1 – Basic Savings report generation



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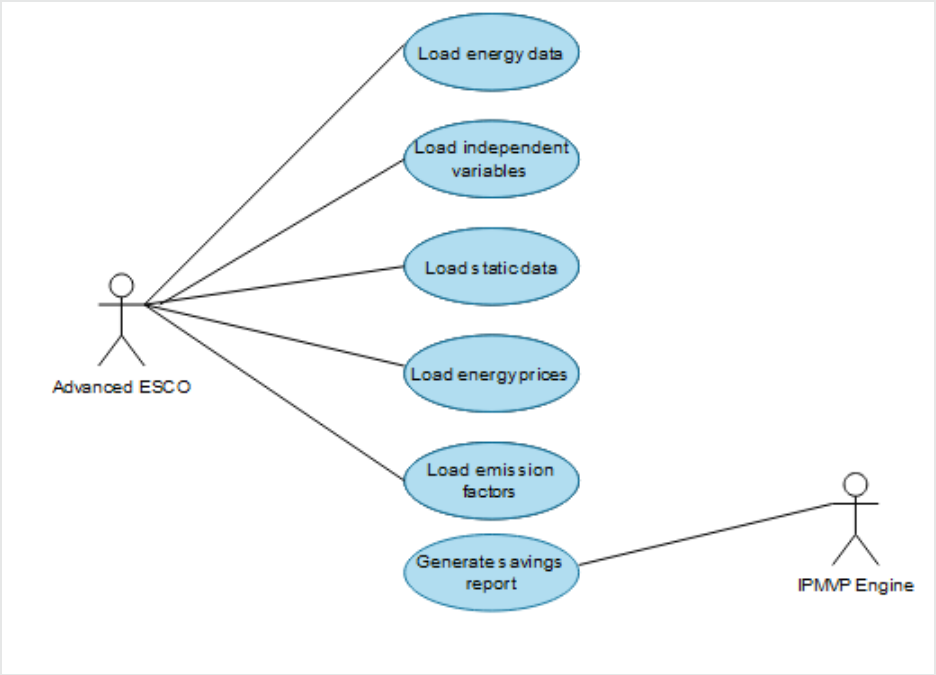
2 Diagram(s) of Use Case

Scenario 2 – Savings report generation



3 Technical Details

Use Case Conditions			
Actor/ System/ Information/ Contract	**Triggering Event**	**Pre-conditions**	**Post-conditions**
Advanced ESCO / Informed owner	ECMs have been implemented in the building/district	ECMS installed and commissioned Reporting period identified • energy consumption data • independent variables • changes in static factors • Energy prices Baseline mathematical model previously generated (*M&V plan creation* UC)	Savings report (energetic and economic) for the different fuels

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3 Technical Details			
Advanced ESCO	ECMs have been implemented in the building/district	ECMS installed and commissioned Reporting period identified • energy consumption data • independent variables • changes in static factors • Energy prices • Emission factors Baseline mathematical model previously generated (*M&V plan creation* UC)	Savings report (energetic, economic and emissions) for the different fuels

4 Step by Step Analysis of Use Case					
Scenarios					
Scenario Name		***No. 1 - Basic savings report generation*** *LSP3: USC 1.4.1* *LSP6: USC 6.1.1*	**Actors**	*Advanced ESCO/ Informed owner*	
Step No.	**Event**	**Description of Process/ Activity**	**Information Exchanged**	**Service**	**Req. ID**
1	Load Energy Data	User loads energy consumption data for Reporting period in the system	Energy consumption data files (e.g. CSV)	s4.1	TBD
2	Load Independent Variables	User loads the independent variables data for reporting period in the system	Independent variables data files (e.g. CSV)	s4.1	TBD
3	Load Static Data	User identify changes in static factors from baseline to reporting period	Static conditions data file (e.g. CSV)	s4.1	TBD
4	Load Energy Prices	User loads energy prices for reporting period	Energy prices data file (e.g. CSV)	s4.1	TBD
5	Generate Basic Savings Report	The service provides with the energy and economic savings report	Service provides the user with the savings report (e.g. PDF)	s4.1	TBD
Scenario Name		***No. 2 - Savings report generation*** *LSP3: USC 1.1.1*	**Actors**	*Advanced ESCO*	
Step No.	**Event**	**Description of Process/ Activity**	**Information Exchanged**	**Service**	**Req. ID**
1	Load Energy Data	User loads energy consumption data for	Energy consumption data files (e.g. CSV)	s4.1	TBD

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4 Step by Step Analysis of Use Case					
		Reporting period in the system			
2	Load Independent Variables	User loads the independent variables data for reporting period in the system	Independent variables data files (e.g. CSV)	s4.1	TBD
3	Load Static Data	User identify changes in static factors from baseline to reporting period	Static conditions data file (e.g. CSV)	s4.1	TBD
4	Load Energy Prices	User loads energy prices for reporting period	Energy prices data file (e.g. CSV)	s4.1	TBD
5	Load Emission Factors	User loads emission factors	Emission factors data file (e.g. CSV)	s4.1	TBD
6	Generation Savings Report	The service provides with the energy, economic and emissions savings report	Service provides the user with the savings report (e.g. PDF)	s4.1	TBD

Common Terms and Definitions	
Term	**Definition**
CSV	Comma Separated Value
ECM	Energy Conservation Measure
EEM	Energy Efficiency Measure
ESCO	Energy Service Company
IPMVP	International Performance Measurement and Verification Protocol
M&V	Measurement and Verification

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Annex VII: Meetings and work done

In this Annex, an activities' timeline as well as the meetings and work done in relation to the user stories and use cases development are presented.

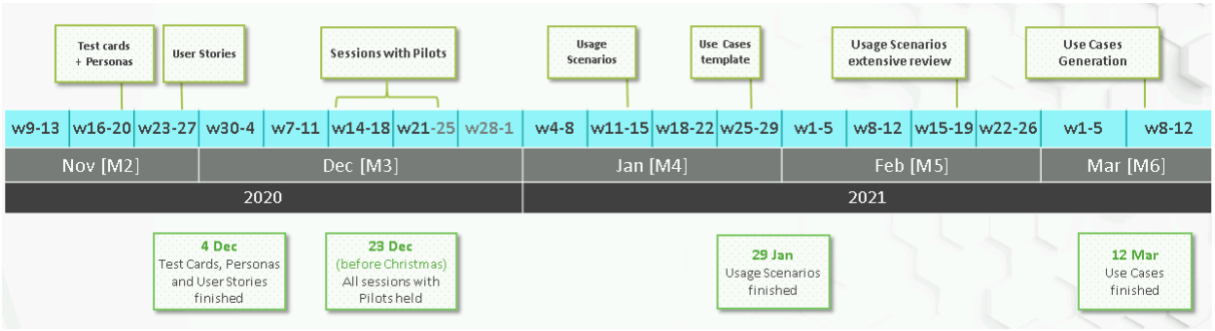

Figure 40: WP2 T2.2 Activities timeline

The table below presents the meetings carried out to develop the process presented in this deliverable (D2.1 and T2.2 related activities).

Table 41: List of D2.1/T2.2 related meetings

#	Date	Phase	Main T2.2 related points
1	13/11/2020	I	Whole process presentation and discussion
2	20/11/2020	I	Pilot leaders inclusion, start of test cards collection
3	27/11/2020	I	Test cards filled, user stories gathering presentation
4	4/12/2020	I	Feedback from pilot leaders, user stories gathering
5	11/12/2020	I/II	Presentation of next phase, usage scenarios gathering, planned pilot sessions
		II	*Sessions with pilots, see table below*
6	15/1/2021	II	Status overview, usage scenarios gathering
7	22/1/2021	II	The small WP2 group session for coordinating next steps, first usage scenarios reviews
8	29/1/2021	II	The usage scenarios generation completed, next steps coordination, service providers check (exact description of the services)
9	10/2/2021	II/III	Ongoing plan of usage scenarios reviews
10	12/2/2021	II/III	Presentation of ongoing steps, description of reviews by service providers, service providers asked to review usability of services for different scenarios
11	19/2/2021	II/III	Extensive usage scenarios review and service matching, part 1
12	22/2/2021	II/III	Extensive usage scenarios review and service matching, part 2
13	24/2/2021	III	The final steps WP2 T2.2 internal process discussion, use cases generation

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#	Date	Phase	Main T2.2 related points
14	26/2/2021	III	The final steps presentation and description of the process, use cases generation
15	5/3/2021	III	Next steps for use case definition
16	9/3/2021	III	Use cases progress, internal WP2 T2.2 discussion

Table 42: List of pilots' sessions

LSP #	Date	LSP Session + Main T2.2 related points
1	16/12/2020	LSP1 session, usage scenarios presentation
2	14/12/2020	LSP2 session, usage scenarios presentation
3	15/12/2020	LSP3 session, usage scenarios presentation
4	21/12/2020	LSP4 session, usage scenarios presentation
5	18/12/2020	LPS5 session, usage scenarios presentation
6	15/12/2020	LPS6 session, usage scenarios presentation
7	16/12/2020	LSP7 session, usage scenarios presentation
8	21/12/2020	LSP8 session, usage scenarios presentation
9	14/12/2020	LSP9 session, usage scenarios presentation
10	16/12/2020	LSP10 session, usage scenarios presentation
11	16/12/2020	LSP11 session part A
11	22/12/2020	LSP11 session part B, usage scenarios presentation

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