Module: MI6228[A] — Analytics Live (2023-24)

IDES – ENERGY DATA SPACES IN RENEWABLE ENERGY COMMUNITIES IN IRELAND

Customer: Energy Data Space - IDES

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Declaration: I hereby declare that the content presented in this report has been created by me and none of the writing has been directly taken from the sources (or) was presented by other students.

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Abstract

In the year 2020, the European Commission approved a European data strategy to establish a single data market to guarantee Europe's data sovereignty and global competitiveness. While retaining control over the data, common European data spaces will guarantee that more data is made available for use in society, the economy, and research. Data space is the Digital Transformation strategy and the Action plan for digitalizing the energy sector. The study preliminary focuses on the stages of creating a common energy data space in Europe. The data spaces introduce a new era of sustainability, dependability, and efficiency in essential electrical energy systems. Data spaces solve technical issues and create new business opportunities. The need for intelligent and interconnected systems is becoming more and more apparent as the energy landscape changes dramatically, marked by the integration of renewable sources, the electrification of various sectors, and an increasing emphasis on decarbonization.

Through expediting the deployment of sophisticated automation solutions, data spaces enable responsive and adaptive grids that can quickly adapt to shifting supply and demand conditions for energy. Moreover, the interconnectedness of data spaces encourages cooperation between different stakeholders, such as consumers, technology providers, utilities, and regulators. This cooperative setting guarantees a more inclusive and participatory approach to the energy transition while also encouraging innovation and accelerating the development of smart technologies. Thus, data spaces can become active drivers of the digital transformation of electrical energy systems, providing a holistic and integrated framework for handling the intricacies of contemporary energy environments.

Introduction

The objective of studying IDES-Data Spaces [Energy dataspaces] is to conceptualize the comprehensive energy data space. This document researches the existing energy data spaces and their stakeholders. It will also provide more information about the value creation for stakeholders and how they can access data spaces to examine the trends, and inefficiencies and promote energy generation and usage (Monti et al., 2023). It encourages new customers to use the energy data paces and how it can be used in various energy sectors.

To create the European energy data space, a wide range of energy companies, academic institutions, and technological partners have joined GAIA-X. The group is made up of individuals from all over Europe and represents every link in the energy value chain. European stakeholders anticipate that the GAIA-X ecosystem enables mutually beneficial business outcomes. Its active support is directed towards the emergence of federated services and data platforms that generate opportunities and value for all businesses, ultimately benefiting the citizens of Europe.

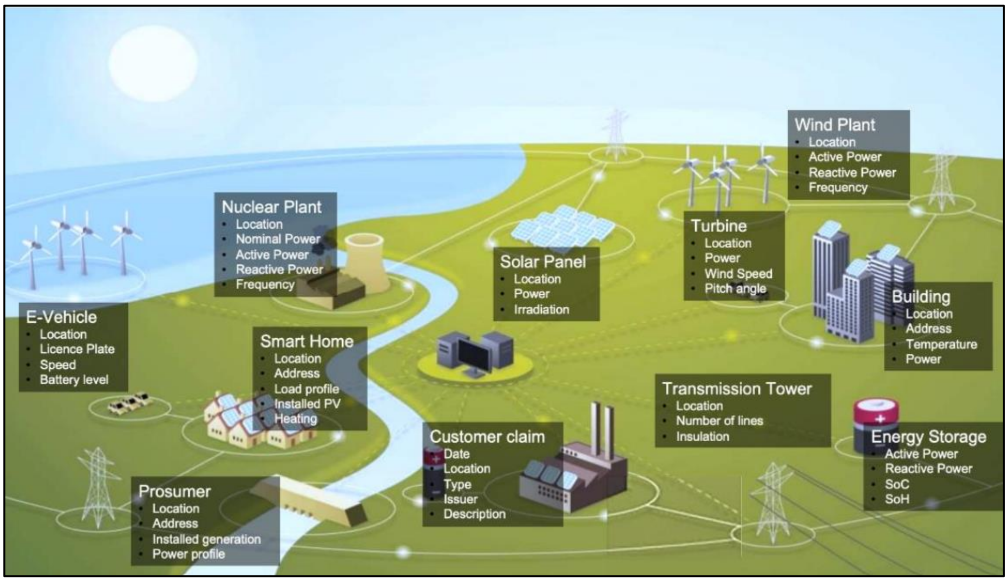


Figure 1: Entities of energy data space (Source: Data Spaces for Energy, Home and Mobility, 2022)

There is a practical as well as close forward path through the GAIA-X initiative to create new products/services and support new business models that are compliant "by design" with European regulations and values, as well as to easily build, assemble, and use trusted and value-creating cloud services. This means that, in addition to the data, there is also the chance to construct a robust European digital system layer on top of the current energy system layer, which ought to be seamlessly coupled.

This paper examines the benefits, challenges, and practical applications of an Energy Data Space in the context of a Renewable Energy Community. In-depth review of data space infrastructure for sharing data that is made up of several systems of participants who have decided to work together within a predetermined framework (Dognini et al., 2022). Additionally, both interoperability and governance structures should be considered to ensure the protection of sensitive data. Moreover, it should ensure that the relevant parties have better access to the data for developing innovative energy services. To facilitate data exchanges that achieve shared objectives, data spaces should also be interoperable. Each data space can be customized to meet the needs of its members. However, what are its limitations and constraints to necessary action and what are some possible solutions to be analyzed?

GAIA-X System

GAIA-X is one reference at the European level. Its architecture uses information technology and digital processes to make it easier for everyone involved in the European digital economy to connect.

The architecture represents the entire GAIA-X ecosystem, which is divided into two: (i) the data ecosystem and (ii) the infrastructure ecosystem. In contrast to data ecosystems, where the primary asset is provided by the data model and data information, activity in the infrastructure ecosystem is concentrated on producing or consuming infrastructure services.

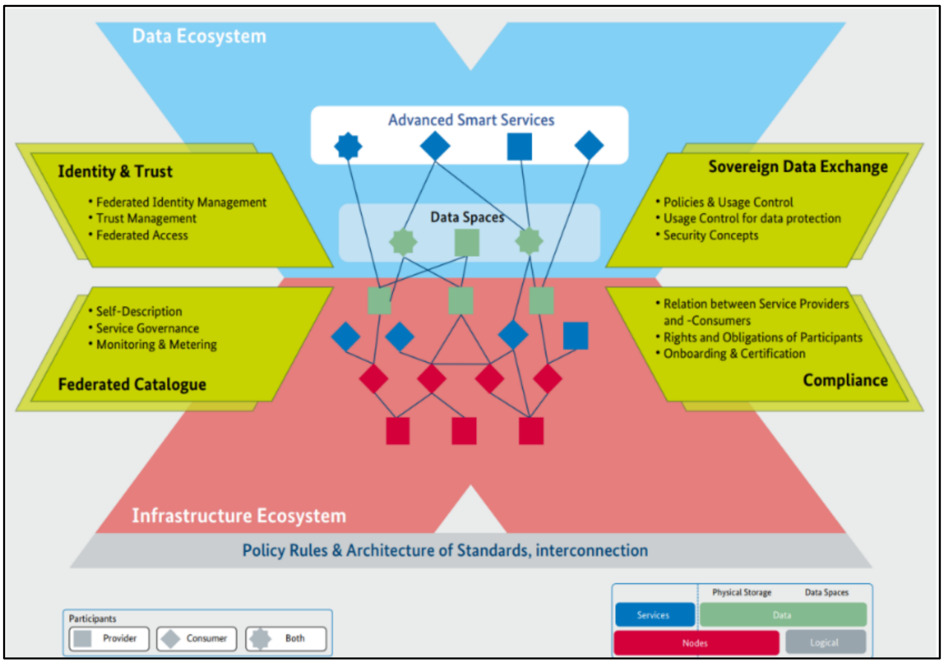


Figure 2: Ecosystem (Source: EDDIE - European distributed data infrastructure for energy, 2024)

Literature Review

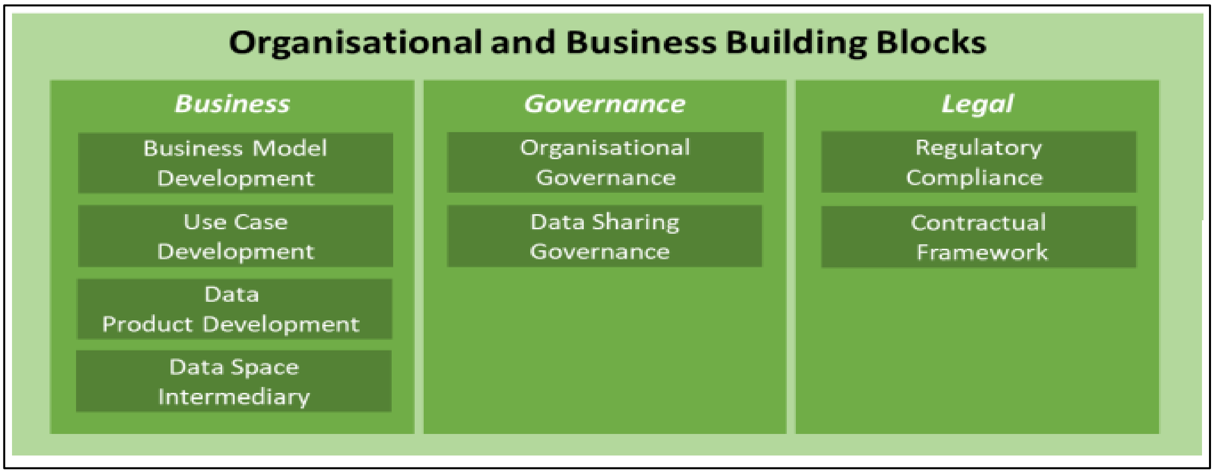
The world's energy needs are constantly rising. The environment is seriously threatened by conventional methods due to the increasing energy production. The creation of energy has direct effects on daily life through CO2 emissions and other byproducts. As a result, we must comprehend and raise both producer and consumer energy efficiency.

To measure energy consumption and reduce environmental impact, data space which stores data from smart energy grids and sensors, are being used worldwide. These smart objects generate large volumes of data, generated by various devices and in various formats, thereby embodying the concept of Gartner's 'Big Data 3Vs' [3] - volume, velocity, and variety.

Users are crucial to administer the data space. Since human insight contributes to the data space’s gradual development, users of data space can become data providers. Data consumers include public authorities, communities of interest, citizens as well as other users like research labs and schools.

Building Blocks of Energy Data Space

Data spaces involve collaboration between various components with varying expectations, interests, and capabilities in addition to technical aspects. Future solutions should be: 1) End user-supported, meaning they should enable fair use of personal data and a functional connection to personal data spaces; 2) business-supported, meaning they should facilitate data-sharing ecosystems with distinct and transparent goals; and 3) policy-supported, meaning they should facilitate cross-sectoral local, regional, and European policies with social goals and missions. The goal of the common European mobility data space is to establish a network that allows pertinent, albeit occasionally closed, access to a variety of pre-existing data sources.



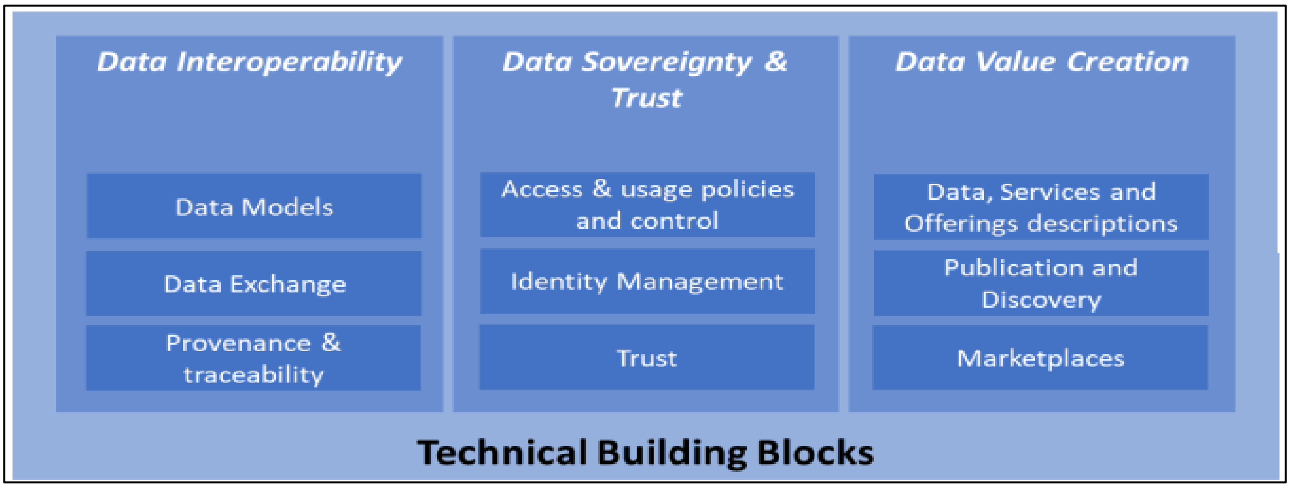


Figure 3: Building Blocks (Source: Jiménez et al., 2023)

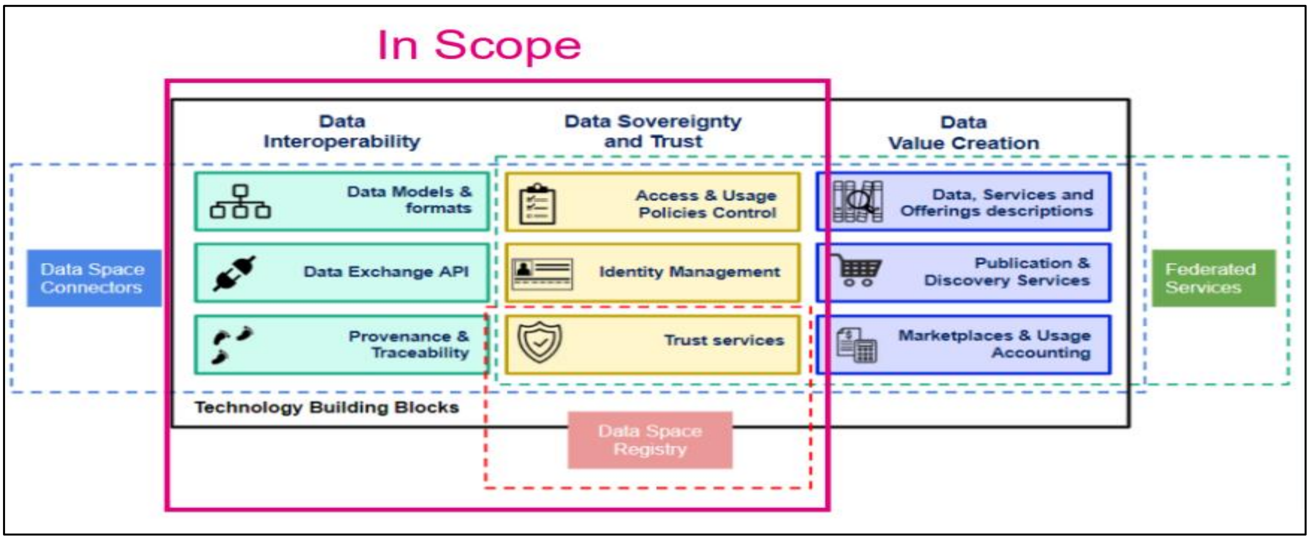


Figure 4: Blueprint of Energy Dataspace (Source: Jiménez et al., 2023)

An overview of the background and current state of the art is provided, which discusses innovative projects on the subject and the emergence of the new "Energy of Things," characterized by diverse big data sets.

Dataspace Governance

Governance is crucial in dataspaces as the dataspaces contain various stakeholders' confidential data. Micheli et al., 2020 defined governance as ‘the power relations between all the actors affected by or affecting on, the way data is accessed, controlled, shared, and used, the various socio-technical arrangements set in place to generate value from data, and how much value is redistributed between actors’. In dataspaces, governance needs to be implemented to control the data access to the users and provide proper responsibilities to the roles of the participants.

DS4SSC created a multi-stakeholder governance framework that can be implemented for dataspaces. Figure 5 illustrates the possible structure of the Data Governance framework (DS4SSC).

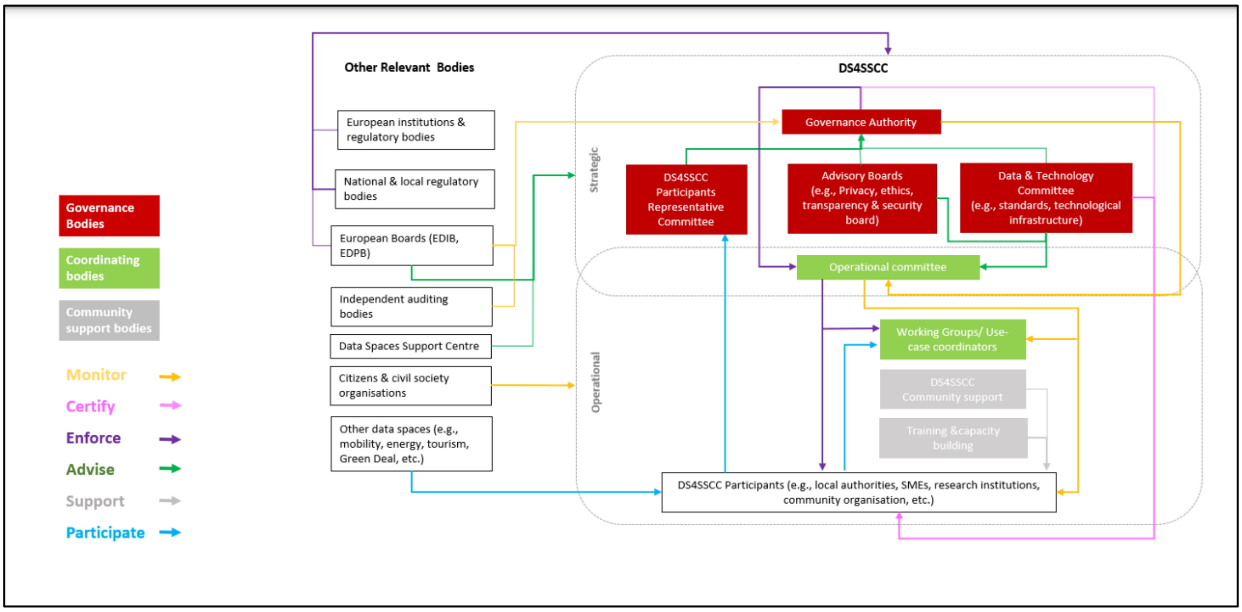


Figure 5: Data Governance framework (DS4SSC)

Roles and Responsibilities

Data Governance can be successfully implemented only with appropriately defined roles and responsibilities. Table 1 describes the roles and responsibilities of the Dataspace Governance block. The roles are divided into three categories based on the involvement in the dataspaces. They are Participatory roles, Intermediary roles, and Governing roles.

Participatory roles:

The stakeholders who are sharing the data, receiving the data, and holding the data come under this category. All the data-related transactions are authorized and organized by these roles. Data providers, Data users, and Data holders can be the names of the roles. Further, the use-case stakeholders can also be a part of this section, but it still depends on the circumstances and the use-case objectives.

Intermediary Roles:

Intermediary category roles facilitate the data exchange transactions and enable the functioning of the Dataspaces. To perform operations under this category, the organization can be registered and DGA-compliant as per Article 10 of the Data Governance Act. Data intermediaries can also provide services such as identity management, vocabulary providers, authorization management, consent management, and clearing houses.

Governing Roles:

Governing roles related to the development, implementation, enforcement, and facilitation of rules of engagement and the governance framework of the Dataspaces. Governance bodies such as advisory boards and Governance authorities, Orchestrators, and Support teams are the roles that can be assigned in this category. Table 1 illustrates roles and responsibilities for the respective roles identified.

Roles	Responsibilities
Participatory Roles	
Data Holder	- Provide and Retract Consent - Are informed and agreed about the purposes for which and how data is processed
Data provider	- Define reference datasets - Define Dataset terms and conditions of use (including clear data licences (open, restricted, private, etc.) - Anonymisation of data Maintain/ check availability of datasets - Ensure data quality and report when data is no longer available/ up to date - Provide sampling of data for better understanding of value of data and possibility of reuse - Make methods of processing data open & transparent - Make available and keep updated metadata & relevant documentation for data reuse - Publish clear and transparent data catalogue and quality standards
Data User	- Be transparent about data usage - Be aware of the quality/limitations of data used - Share insights/ documentation on the added value of the used data - Provide feedback for all (data providers, right holders)
Use Case Participants	- Share insights/ documentation on the added value of use-cases - Demonstration public value of use-case

Intermediary Roles	
Data intermediaries/ enabling services	- Maintain technical infrastructure/ services they provide - Provide technical assistance/ support to data space participants - Enable connections with other data spaces - Disclose content plugging/processes - Monitor services and inform users if deterioration/discontinuity - Publishing clear documentation on data product possibilities
Governance Roles	
Governance bodies	- Monitor compliance to DS4SSCC processes (constitutive/ contractual processes) - Request providers to correct/add relevant metadata - Ensure & monitor responsible and fair use of data - Make decisions in a transparent manner - Advise on technology and data standards for data space - Ensure convergence of solutions - Define strategic direction of DS - Resolve conflicts - Manage change and continuity of data space (e.g., decide new rules/ edit rules) - Checks and certifies data agreements according to DS4SSCC principles
Orchestrator/ coordinating entity	- Take care of onboarding new participants - Inform all actors about the guidelines/rules/negotiations. Find new stakeholders & connect participants working on similar use-cases - Maintain a common catalogue - Manage communication channels - Organise working group meetings, events, etc to increase awareness in the ecosystem and interactions frequency. - Manage change and continuity of data space

Community support bodies	- Provide support to users to onboard and comply with DS technical and governance standards - Provide training & capacity building - Organise Knowledge exchange activities - Help stakeholders work together on projects or initiatives - Provide technical and governance support negotiation collaborations/ contracts

Table 1: Description of Roles and Responsibilities (DS4SSC)

Governance Agreements

Data Space Support Center (DSSC) has proposed a Governance agreement design process in their Starter kit for all the participants in Dataspaces. The design process is explained in below steps:

- Onboarding: building trust among the participants in the design process.
- Exploration: what is already known about the governance topics and what is in and out of scope.
- Design: find answers to the many topics included in governance.
- Evaluation/Experimentation: find additional answers to open parts.
- Finalization: approval from stakeholders.
- Formalization: The governance can be formalized in agreements.

The Governance Agreements mentioned in the formalization step include the legal and Data terms of use conditions. These pre-defined agreements can be utilized by all the dataspaces irrespective of the sectors. The list of the governance agreements is mentioned below:

- Contractual Framework Key Legal Questions
- Description of the Data Network
- Code of Conduct
- Terms and Conditions
- Constitutive Agreement.
- Accession Agreement.
- Governance Model.
- Dataset Terms of Use

In the following sections, existing use cases of Renewable Energy Communities, key architectural features and modelling difficulties associated with Energy Data Space in Ireland are discussed. These factors contributed to the creation of a case study on a REC in Ireland which uses Energy Data Space.

Use Case 1: HOMER – Benevento

Ceglia et al. (2022) propose a case study on renewable energy communities (REC) whose main goal is to reduce consumption by installing photovoltaics in a social housing district in Benevento (Italy) where there are residential buildings and restaurants.

This project aligns with EU Directives 96/92/EC and 2006/32/CE, facilitating energy system efficiency in energy conversion systems through the System of Efficient Users (SEU). SEU consists of a group of consumers, producers, and a power plant where the last individual who uses the energy will be the one to provide it in the next energy procurement cycle. Moreover, the energy-sharing stakeholders have upgraded the SEU systems into RECs where both the private companies, SMEs and local authorities can participate and better promote the project.

A part of the creation of new jobs for the maintenance of renewable energy plants, a greater benefit is the influence that a REC can have on the residents' lifestyle. By the creation of a REC in Benevento, the residents will learn common energy-saving behaviors and therefore be highly aware of topics related to the transition to a sustainable energy system.

The REC is simulated with HOMER software environment where meteorological data, thermal and electric loads, economic scenarios, and plant components are externally provided or extracted from the database of HOMER. Subsequently, the data is analyzed to supply the required energy to the photovoltaics of the residential buildings and restaurants in the district. Below is a figure that explains how SEUs and REC function.

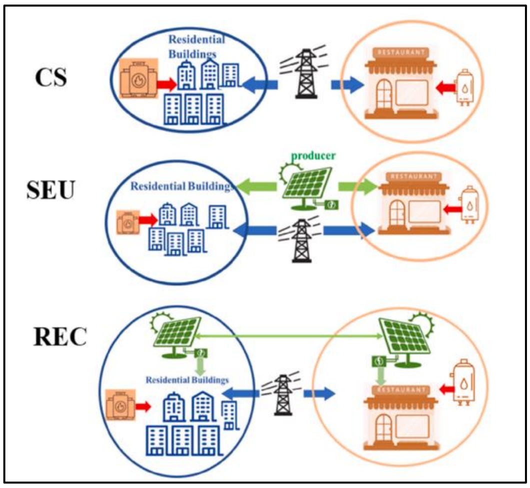


Figure 6: Schematic diagram of CS SEC & REC Ceglia et al. (2022)

Findings

The energy produced through PVs is dependent on the climate. Weather conditions and seasonal changes will affect the excess energy generated by the PVs and potentially create technical issues or malfunctions that could disrupt the energy supply to the community. To avoid this, the project should consider other renewable sources or technologies.

Implementing Renewable Energy Communities (RECs) is not a simple task and involves overcoming several challenges, as pointed out by Ceglia et al. (2022). Some of these challenges include scepticism towards the installation of plants, lack of financial resources, and the absence of community support for voluntary work, which is necessary for the project to succeed.

Additionally, the lack of financial aid makes it difficult to invest in the required equipment. To ensure the success of a REC project, innovation should be the driving force, which should start from individuals who can become "prosumers" by transitioning from energy consumers to energy producers.

Use Case 2: Renewable Energy Community in Carinthia (Austria)

Cosic et al. (2021) proposed, in their paper, a case study on a small-scale REC in Carinthia (Austria) where the energy is shared at a local level among a local authority, a bank, a fire authority, a residential building and 3 single-family households. The excess power provided by existing photovoltaics (PV) is sold to a utility and this project aims to transform the community into a REC where the excess energy is transferred to the members of the community (defined as nodes) at a lower price, cutting the costs of outsourcing electricity.

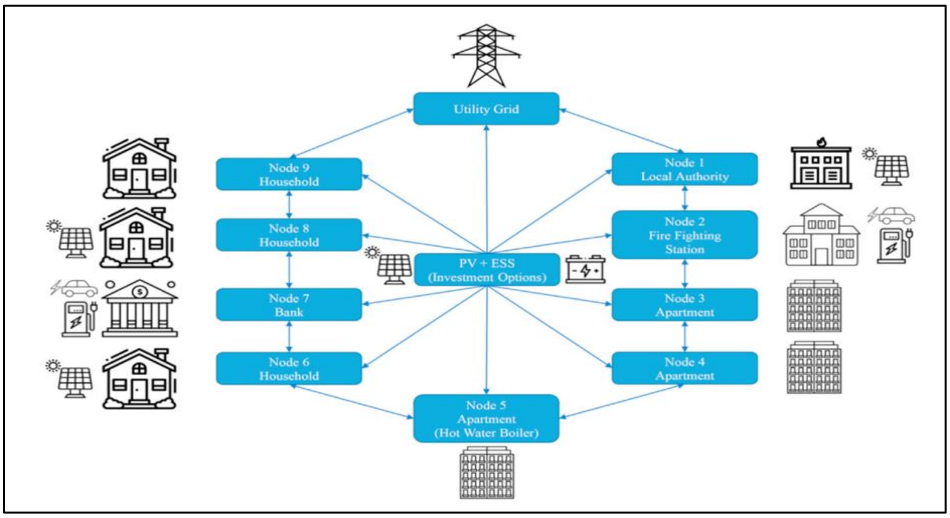


Figure 7: The network topology of the REC testbed at a village in Carinthia (Austria) with central investment options and other existing technologies Cosic et al. (2021)

An optimization model is used to minimize the energy costs and the total annual CO_2 emissions. Two scenarios are compared in this case study: the reference case and the optimization case.

The reference case depicts the current state of the community, considering technical and economic aspects such as the Energy Storage System's (ESS) charging efficiency, maximum charge and discharge rates, and associated costs for the three existing PV systems. The utility purchase is based on a tariff scenario that doesn't consider demand rates, hence named RC-Without DR-PV. Moreover, the PV surplus is injected into the grid at a fixed feed-in rate.

The optimization scenario associated, also without demand rate (OC-Without-DR-PV), specifies the maximum amount of PV self-consumption that the REC can achieve. In this scenario, the existing tariff, which allows for the transfer of renewable energy between participants, has the potential to cut overall annual energy prices and CO_2 emissions.

Findings

In the first scenario, the existing PV produced a surplus of energy that can be recycled in the grid of the REC, increasing the use of the existing PV, and decreasing the costs of energy outsourcing. The usage of PV energy can be increased from 26.5% to 65.2%. This increase is due to the new option of transferring renewable electricity between different nodes (community members). This means each participant's electricity demand can be met with the surplus renewable electricity from the PV source, contemporarily reducing the cost by 8.73% and the annual CO_2 emissions by 14.7%.

In the second scenario, the total energy cost will decrease by 15.3% while the CO_2 will see a decrease of 34.06%. Thus, the optimization case will be much more profitable in terms of the decarbonisation of the regional sector.

Use case 3: SYNERGIES - Reference Energy Data Space Implementation

The SYNERGIES project funded by the European Commission seeks to implement a reference energy data space in three demonstration sites in Greece, Spain, and Denmark. The project runs from 2022 to 2026 and the purpose is to support data-driven innovation, the shift to green energy, and information sharing throughout the energy data value chain to all stakeholders. The main aim of the project is to enable data-driven innovative energy services that will benefit all involved fields. It is done by integrating and sharing data from multiple sources, including buildings, mobility, energy networks, and consumers. Hence the stakeholders will find it simpler to share information and insights. Furthermore, the project offers data-driven energy services to support users, network operators, and the transition to a sustainable, equitable, and inclusive green energy source (Cordis, 2022).

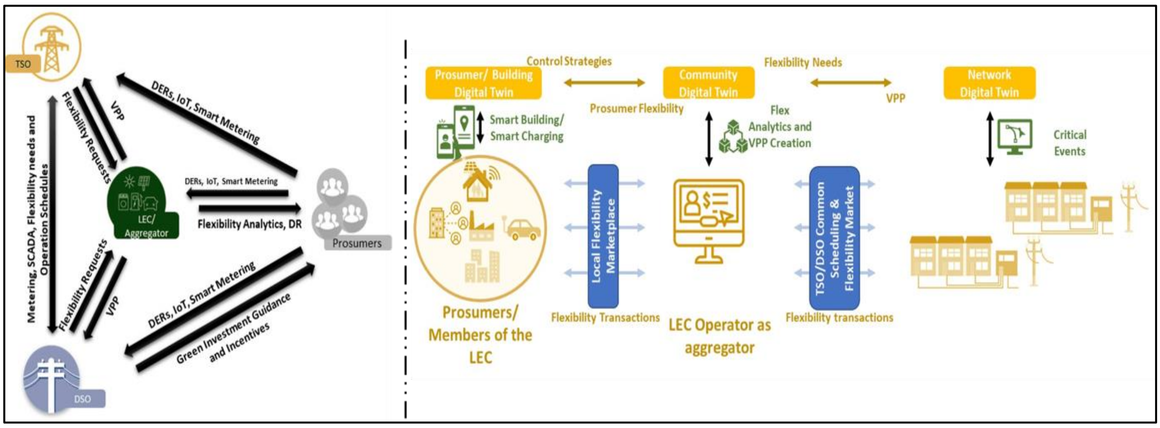


Figure 8: Flow of Energy data space implementation (Cordis, 2022).

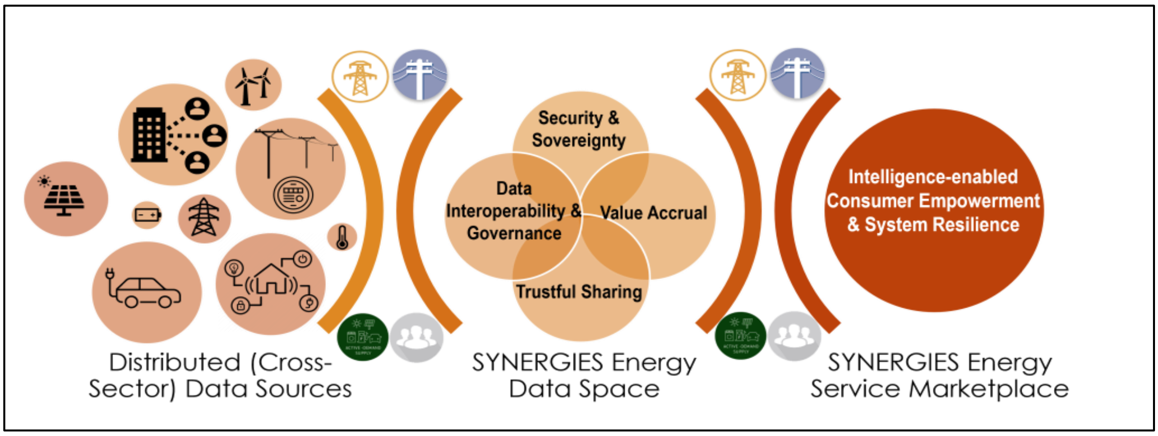


Figure 9: Components of Energy data space implementation (Cordis, 2022).

Expected Outcomes

A model implementation of an Energy Data Space will be created to facilitate data interoperability, security, and sovereignty among various energy stakeholders. As a result, various energy sector actors including producers, consumers, prosumers, network operators, service providers, and regulators will be able to share data more easily with greater security and sovereignty. Also, for the energy transition, data-driven innovation and value creation will be made possible by the Energy Data Space.

To empower customers and assist in decarbonizing the energy system, a suite of digital solutions and energy services powered by data-driven intelligence are provided. This also includes digital twins, data analytics, peer-to-peer trading, and energy management. These are implemented to enhance the energy system's dependability, efficiency, and sustainability. A new business model will also be created for prosumers, energy producers and consumers that enables their open participation in a data-sharing-driven ecosystem where they can supply and obtain data for value creation (Anon, 2022).

Use Case 4: Smart energy cities in a 100% renewable energy context - Denmark

The paper offers a national approach to designing Smart Energy Cities with 100% renewable energy. When it comes to resources, industry, and transportation, cities and municipalities should respond locally to meet local demands while also considering the larger national and international context. Using the example of converting the municipality of Aalborg to a smart energy system that is entirely renewable, the method is applied in the framework of the Danish and European energy systems. The case study illustrates the feasibility of implementing a Smart Energy City strategy that aligns with Denmark's and Europe's 100% renewable energy framework. The suggested method is also applied to other cases worldwide.

Findings

The case study is about creating a sustainable energy solution for the Aalborg Municipality in Denmark. The paper identifies sustainability, innovation, and citizen engagement as the primary factors. The strategy is based on the idea that focuses on local participation switching to renewable energy sources. It focuses on the energy requirements and available resources of various industries, including home heating, industry, transportation, and electricity. It also proposes a transition plan that optimizes the mix of variable renewable energy sources (VRES), shifts from fuel to electricity, increases the use of electric vehicles and decreases the use of biomass.

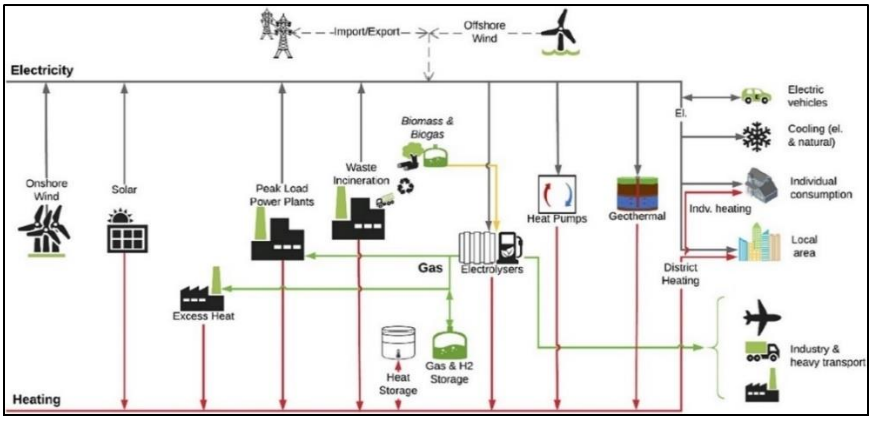


Figure 10: principle of how the different technologies work together in a system (Thellufsen et al., 2020).

In conclusion, the most practical solutions are to use steam storage and overcapacity in electrolysers. These suggested solutions can provide social and economic benefits in addition to achieving carbon neutrality by 2050 (Thellufsen et al., 2020).

The Aalborg Municipality relied heavily on fossil fuels before implementing the smart city solution, particularly for transportation and industry, and only accounted for a small portion of its electricity supply from renewable energy sources.

The municipality has also faced issues like oversupply of electricity, grid outages, and the environmental effects of using biomass. With a greater proportion of renewable energy sources (VRES), reduced carbon emissions, and improved integration with both domestic and global energy networks, Aalborg Municipality will have a better sustainable energy system after the adoption of smart city solutions. The municipality would also become more resilient, competitive, and liveable as a smart city.

Gaps

After conducting a literature review, it was discovered that involving stakeholders from both private and public sectors was an effective way to raise individual awareness of climate change and renewable energy communities. The case studies also revealed that software and prediction models could accurately calculate energy sourcing and tracking. However, none of the studies reviewed provided a simulation of implementing Renewable Energy Communities (RECs) in Ireland using data spaces. With the implementation of data spaces in the energy sector, all the single models can be unified in a unique digital infrastructure reducing operational costs and making the prediction model more reliable (Gaia-X, 2021).

Therefore, our case study aims to fill this gap. Establishing RECs that use data spaces in Ireland will bring about cost savings and improve efficiency in data exchange. Additionally, it will help the country comply with the interconnectedness that the EU aims to achieve through the creation of a common data space.

Author	Findings
Ceglia et al. (2022)	- Individuals' scepticism towards RECs building. - Lack of financial support. - Absence of data spaces use for energy data management.
Cosic et al. (2021)	- Recycle of surplus energy produced by photovoltaics reduces energy outsourcing costs and notably decreases CO2 emissions. - Absence of data spaces use for energy data management.

Cordis (2022)	- Synergies Project: model implementation of an Energy Data Space. - Integrating and sharing data from multiple sources. - Empowering Customers.
Thellufsen et al., (2020)	- Smart Energy cities by 2050. - Shift to renewable energy sources. - Improved integration with domestic and global energy networks.

Table 2: Case findings

Renewable Energy Communities in Ireland - Case Study

In December 2018, the EU Renewable Energy Directive (RED II) entered into force allowing individuals to consume, store and sell renewable energies generated on their premises and it aims to decentralize energy management and set the consumer at the heart of the energy market (Lowitzsch et al., 2020).

As mentioned earlier, data spaces can help to exchange energy-related data. In this context, it can be beneficial for local users to calculate the energy produced, consumed, and transferable. In the following session, we will analyse the findings of some use cases to identify gaps that our case study can fill.

Communities focused on renewable energy which are neighborhood-based projects that make investments in "clean energy" to satisfy environmental objectives and consumption demands, which frequently promotes the use of renewable energy sources (Bresnihan et al., 2021). It is shown how Ireland communities based on renewable energy support energy system transitions as social niches using available technological innovations.

(Source: Harmon (2023), council.ie)

RES communities in Ireland are associations of individuals and these are working together with local government agencies, small and medium-sized businesses, and other stakeholders to address renewable energy sources. Communities using renewable energy sources (RES) in Ireland generate, supply, distribute, share, and consume energy through collectively chosen rules and decisions. Mapping the different specific cases of RES communities is made possible by two fundamental dimensions: the geographic area in which they operate and the overarching goal that inspires group action. While the second can be relational or economic, the first can be local or dispersed.

RES communities in Ireland are currently evolving and they primarily consider municipal and residential electrical loads; they ignore the possible advantages that could arise from taking into account various end users, as well as a cross-coupling with the thermal loads and the transportation sector. There are possibilities for a potential way for future development of the approach that will enable assessment of the potential benefits arising from the incorporation of new players (SMEs, for example) into the energy community and the electrification of energy end uses (heating, cooling, and transportation), which will pave the way for new and expanded uses of the REC. In the following section, the proposed case study will be discussed to align energy dataspaces with REC in Ireland.

The Compatibility of Intelligent Buildings and Smart Grids

Improving the efficiency of homes and buildings, which account for a sizeable portion of total energy consumption, is essential for the successful implementation of the energy transition. Household equipment that depends on electricity is essential for coordinating the operation of the electrical distribution system and maximizing energy efficiency. To accomplish this, the smart building devices need to connect to the smart grids in a methodical manner using an effective data exchange system.

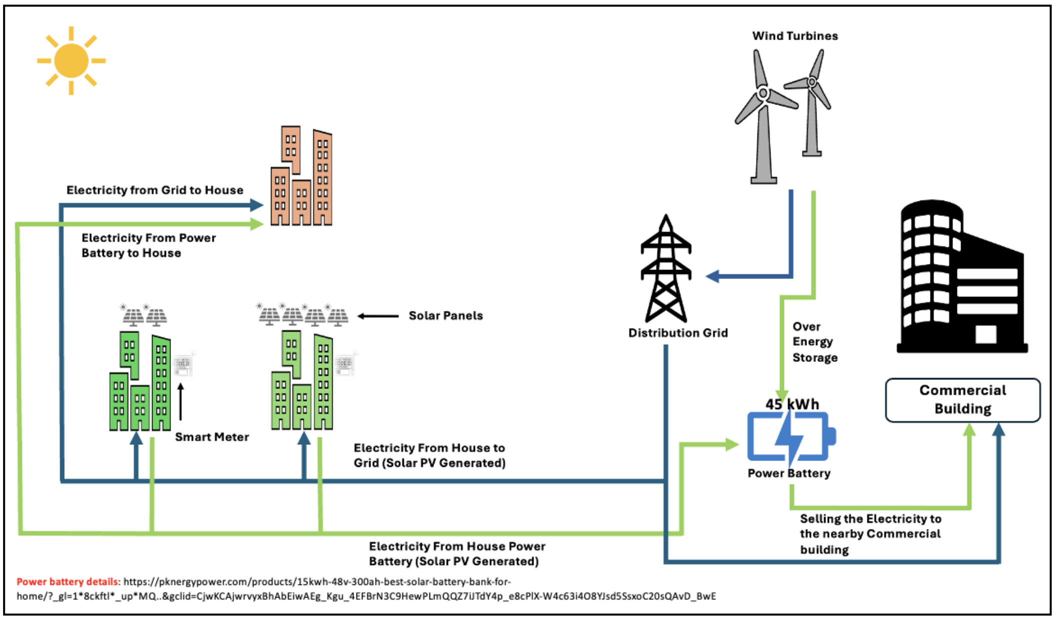


Figure 11 - Prototype of Renewable Energy Community

Figure 11 explains the energy generated through renewable sources from houses with solar panels will be utilized for self and the excess power (or) unutilized electricity will be stored in batteries and upon the consumer's request, it will be shared with the commercial or residential buildings. Whereas, for the power generated from the wind turbines, the distribution Grid will be a hub for power supply and transfer the excess power from grid to the buildings through power batteries.

It is possible that the energy data space will quicken the process of digitizing risk prevention plans' life cycle, which is necessary to meet state requirements for work authorization, risk reduction, and risk evaluation. Digital canals that were accessible from both the contractor's and the industry's offices, allowing each to access a subset of the data, were used to share data between the two parties and occasionally with the State (Ntafalias et. al 2024). Processing and sharing of sensitive, commercial, and personal data via various communication channels will be ensured by the data space. Along with an easy-to-use user interface for small businesses, it will provide integration capabilities with industrial IT systems. The architecture of the energy data space in the community has three phases: i) Finding a data provider, ii) Query data and iii) log transaction details as shown in Appendix 1.

Integration of Data Space in Proposed REC

The success of the Energy Transition depends on energy (RE). When owners of RE installations become consumers. They can turn into prosumers, producing a portion of the energy they consume. This enables them to lower their total energy costs while also gaining an additional revenue stream from the sale of overproduction. An increase in consumers is anticipated to rise in energy communities with a wide range of participants.

An innovative approach rewarding private metering will be used to facilitate the people of the data space, with importance on simple onboarding and interaction. This will ensure seamless integration with other energy data spaces and provide stakeholders with tools and services to further develop their activities.

According to the prototype (Figure 12), the new smart grid and energy system solutions built on more effective renewable energy sources are expected to have an impact that makes the energy supply more competitive, secure, clean, and efficient. In terms of data access, an open source, distributed, decentralized data space will be accessible to the stakeholders (or) people of communities. In the initial phase, Ireland's interconnected data hub is to be set, so there will be a single API access into Ireland, allowing an energy service provider, with the consent of the customer. This would help to access smart meters in communities across the nation, which is the fundamental component. Subsequently, the existing meter will be replaced with a dedicated measurement device by a sub-meter. Optimizing the use of data generated by low-carbon technology users is one of the main objectives.

In the coming days, there could be a possibility to create infrastructure that, in accordance with the Data Act, will enable users to manage energy and flexibility data. This would allow individuals to choose who they wish to share the data within order to take advantage of the best retail offer or the best flexibility offer.

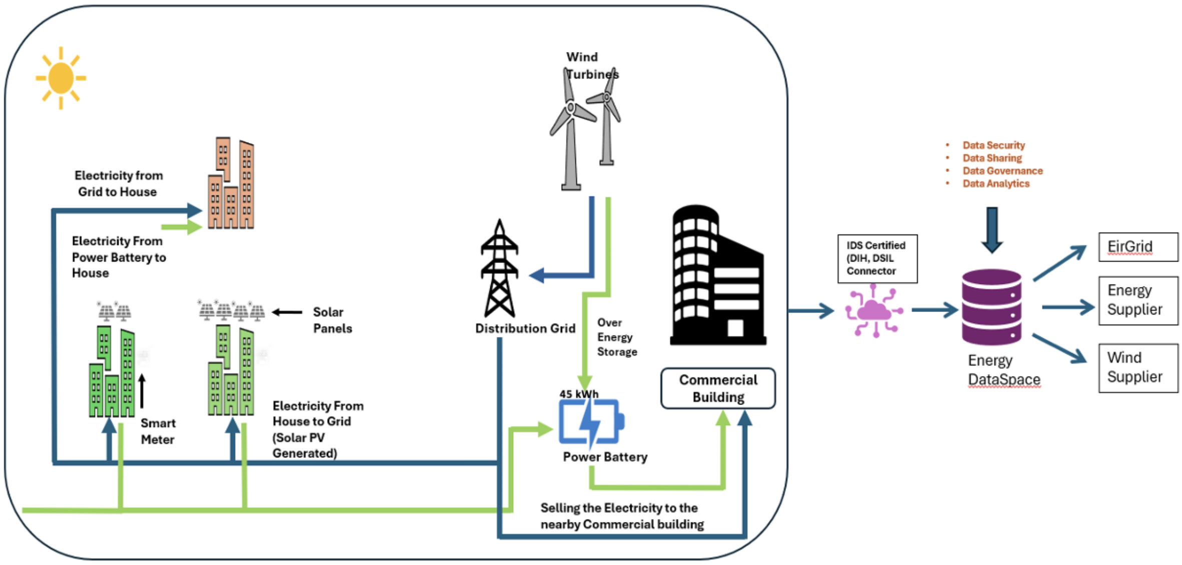


Figure 12: Integration of Dataspace in the REC

A limitation on the amount of the excess energy sold can be imposed by policymakers or the one in charge of dataspace management. A data asset (raw data or computations on data in the form of analysis results, reports, or visualizations) is shared between two or more data value chain stakeholders (Dognini et al., 2024). There needs to be an agreement through contract to enable this.

Data governance for the REC

According to Curry et al., (2022), Data Governance is defined as the maintenance of data assets and the guidelines during the data-sharing process. The data-sharing process includes data rights, data privacy, and data security with defined policies and guidelines. These guidelines can be established within an organization, for a group of organizations and at national and international levels. In the case of RECs, data governance must be integrated at all levels.

The existing Data Governance policies and regulations of RECs and their implementation process of Data Governance are explained in this section.

REC Energy sharing Policies within the community

European Commission established a set of guidelines for RECs regarding the sharing of energy among the communities. The Renewable Energy Directive (RED) was first proposed in December 2018 as a part of the 'Clean Energy for all European package' ((Renewable Energy Directive, n.d.)). However, RED was revised and re-published on December 2023 (Revised

Directive EU/2023/2413). Articles 18 and 22 from RED proposed the Information sharing and Renewable energy communities' policies and guidelines listed in Table 1.

Article	Guidelines and Policies
Article 18	1. Member States must share support measure information to relevant stakeholders, including consumers and industry professionals. 2. Information on the benefits, costs, and efficiency of renewable energy systems must be provided by suppliers or competent authorities. 3. Certification schemes for installers of various renewable energy systems must be established and recognized across Member States. 4. Information on certification schemes must be made public, including lists of qualified installers. 5. Guidance must be provided to planners and architects for optimal integration of renewable energy and high-efficiency technologies in building projects. 6. Member States should develop informational sharing programs to educate citizens about the importance of energy communities and their rights as energy consumers and the benefits of renewable energy usage, including self-consumption and community initiatives.
Article 22	1. Member States must ensure that household customers can participate in renewable energy communities without unfair conditions, except for primary commercial or professional activities. 2. Renewable energy communities have rights to produce, consume, store, and sell renewable energy, share energy within the community, and access energy markets without discrimination. 3. Member States must assess existing barriers and potential for developing renewable energy communities.

	4. Member States must create a supportive framework for renewable energy community development, removing barriers, ensuring fair treatment, facilitating energy transfers, and providing financial and regulatory support. 5. Elements of this framework must be included in Member States' energy and climate plans. 6. Member States can allow cross-border participation in renewable energy communities. 7. Support schemes must consider the specific needs of renewable energy communities to ensure fair competition with other market participants.

Table 3: Renewable Energy Communities Data Sharing and Establishment Policies and Guidelines (RED)

Data Governance and Data Policies

As Energy Dataspaces are still in the development phase, no specific policies have been defined. However, the European Commission established a set of guidelines to increase the flexibility and ease of data sharing among the European Countries. These proposed guidelines are applicable across all the data domains (European Commission, 2020). The Data Policies are explained in Table 2.

Data Policy	
Data Management	• Policies focus on creating, collecting, and acquiring data assets only once to avoid duplication. • Emphasizes exploring existing data before creating new data assets. • Data assets should be reported only once to prevent redundancy. • New inventories should consider existing ones to ensure comprehensive coverage.
Data Interoperability and Standards	• Policies aim to ensure data can be shared and used across different systems. • Establish standards and protocols for data exchange to promote compatibility. • Enhance collaboration and data sharing among different entities within the organization.

Data Quality	• Policies set standards for data accuracy, completeness, consistency, and reliability. • Define criteria for assessing and monitoring data quality to support decision-making. • Improve the reliability and trustworthiness of data assets.
Data Protection and Information Security	• Policies focus on safeguarding data from unauthorized access, use, or disclosure. • Address compliance with data protection regulations. • Establish measures to protect data confidentiality and integrity. • Mitigate risks related to data breaches, cyber threats, and data loss.

Table 4: Data Policies Established by European Commission

Key Takeaways from REC Data Spaces

Ireland is leading the way in renewable energy and is at the frontline of the green revolution. Businesses and the Irish communities are moving toward more environmentally friendly energy solutions because of a focus on sustainability. This change is an important step in the fight against climate change and the promotion of environmental stewardship. There are considerable benefits from the Data space communities, some of which are mentioned below.

- Decreased use of the electrical grid.
- Rise of renewable energy sources usage.
- Availability of sustainable local energy sources and transportation services.
- Financial savings for the end consumer.
- Prospects for investments for local businesses and citizens.
- Opportunity to earn money that remains within the local community.
- Development of community businesses.
- Transparency in the Energy Sector.

Renewable energy data spaces value for stakeholders

Renewable Energy Data space has a liable relationship between parties that store and exchange data according to the same strict guidelines. They are a quickly developing answer to the problems posed by the data economy and data sharing. Currently, the EU is making significant investments in the development of best practices and data space solutions for several business sectors (European Commission, 2023). In the upcoming years, millions of euros will be invested to strengthen the European data economy (European Commission, 2023).

From the learnings of this case study, the following stakeholders can benefit from Energy Data Spaces: individual households, commercial buildings, Wind Turbine manufacturers and Solar Panel manufacturers.

The above stakeholders can add value to their business if they digitalize their operations by using data spaces. They can improve their flexible marketplace functionality by monitoring energy flows and reporting changes in energy supply and demand (Flexibility markets, n.d); they can benefit from economies of scale to enrich their service capability (BDV, 2024)and shared marketing costs (Dognini, 2024).

Some of the existing stakeholders and their description is mentioned below.

The proposed REC can utilize Energy Data Space to understand and manage energy production and consumption throughout a certain period. This provides a flexible energy-sharing system which provides monetary benefits to the individuals living in the REC. The Energy Data Space can also be utilized to integrate multiple energy sources for constant energy supply.

SolEctric is a manufacturer of solar panels in Ireland that leverages its connection to ESB (Electricity Supply Board) to provide consumption analysis to its clients (Solar Panels Ireland, Expert Advice | Solectric.ie, n.d.). With the collected data, SolEctric provides a detailed solar performance to identify yearly paybacks and return on investments. By integrating with Energy Data Spaces, SolEctric can utilize the dashboards available in the data spaces and identify the opportunities in the RECs to expand its business and maximize its profits. SolEctric can share its data to Energy Data Spaces which can be utilized by other stakeholders.

Heverin-Wind Turbines are manufactured by 'Heverin Renewable Energies' which offers services of installation to homes, farms, and industries (Irish Wind Turbines - Heverin Renewable Energies, n.d.). The company aims to provide affordable wind turbine systems that can help reduce or eliminate electricity costs, sell electricity to the grid, and in general, reduce the individual carbon footprint (Irish Wind Turbines - Heverin Renewable Energies, n.d.). By incorporating Energy Data Spaces, Heverin can increase its market visibility, understand customer needs, and identify their location to propose a wind turbine installation in REC.

Methodology

Multiple Linear Regression with Python was used to perform the prediction of the energy consumption of three sample houses in the Renewable Energy Community (REC) of this case study, as in Figure 8. The historical data on solar energy consumption was acquired from reliable secondary sources such as SEAI.ie, data.gov.ie and the European Commission. To facilitate the analysis, the data was cleaned and pre-processed for the forecasting of energy consumption.

Multiple Linear Regression (MLR) is one of the most common Machine Learning techniques used to predict energy-related data (Bennett et al., 2020; Matos et al., 2024). According to Maulud and Abdulazeez (2020), it "is a statistical technique to predict the result of an answer variable, using a number of explanatory variables. The object of (MLR) is to model the linear relationship between the independent variables x and dependent variable y that will be analyzed".

For instance, in the REC of this case study, the answer variable (dependent variable y) is the energy consumption, while the explanatory variables (independent variables x) are the sun radiation and number of solar panels:

$$log_{(EC)} = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \varepsilon$$

Where $log_{(EC)}$, β_0, $\beta_1 X_1$, $\beta_2 X_2$, ε are the energy consumption to be predicted, the estimated intercept, the slope of global active power, the slope of global intensity, the sub-metering of each house's room, and the error term.

The electricity consumption of the House Without PV was estimated considering the data from the Central Statistics Office of Ireland and the average monthly electricity per hour was calculated.

The resulting output is the monthly average electricity consumption and the total yearly electricity consumption for each of the houses.

In this process, to train the model the samples of three houses were taken and their average electricity consumption for the three houses was computed. For the model only two key factors were considered: the sun's radiation and the number of solar panels for each house.

For the wind turbine energy generation, historical data was used to perform the analysis. As the wind flow is inconsistent, with variable trends in different seasons, the prediction with ML models was not accurate. However, wind speed, temperature and air density were considered to calculate the power output generated by the wind turbine with the below formula:

$$P = \frac{0.5 * C_p * \rho * \Pi * R^2 * \gamma^3}{1000}$$

P = output (in kilowatts)

0.5 = Betz Limit Coefficient

C_p= Wind Turbine Efficiency Factor (of 40%)

ρ = air density (in kg/m^3) = $\frac{Sea\ Level\ Pressure\ (pascals)}{Gas\ Constant\ (287.05) * Temperature\ (Kelvin)}$

Π = 3.14

R = blade length (in meters)

γ = wind speed (meters/second)

The resulting forecast was utilized to predict the energy flow within the community.

Discussion

The dataset used to predict solar energy consumption was retrieved from the UCI Machine Learning Repository which contains 1037630 instances with a sampling rate of 1 minute for 2 years (Damodaran et al., 2015 – include the website).

For the prediction, the MLR model was applied. The dependent variables considered were the global active power, the global intensity, the sub-metering of each house's room, and the error term with kWp unit.

Global active power is the power that can be consumed by the electrical appliances in a house, while global intensity is the amount of electricity consumed per unit of economic output of a country (in this case, Ireland). Three rooms are considered to calculate the sub-metered data. The details are as follows:

- Sub_metering_1: It corresponds to the kitchen, containing mainly a dishwasher, an oven, and a microwave (hot plates are not electric but gas-powered).
- Sub_metering_2: It corresponds to the laundry room, containing a washing machine, a tumble drier, a refrigerator, and a light.
- Sub_metering_3: It corresponds to an electric water heater and an air-conditioner.

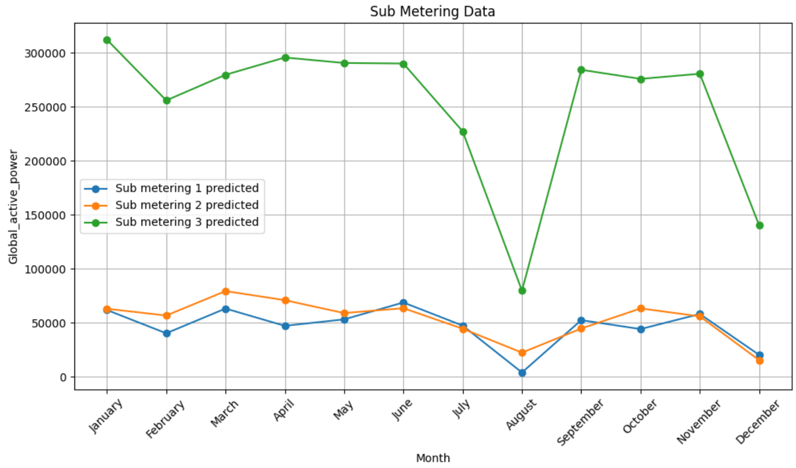


Figure 13: Predicted sub-metering data

Figure 13 demonstrates the prediction of energy consumption of each room in a house for the third year using the 2-year data. The model predicted the consumption of Sub-metering 1 as the highest consumption because it's a kitchen containing daily used appliances. However, the consumption drops from July to August and increases again by September. Sub-metering 2 and 3 have similar cadences with a notable decrease in August. The energy consumption in August is lower in Sub-meter 3 due to less water heater usage in the summer season.

The prediction performed for solar energy consumption is reliable as the accuracy of the model is explained by a MAPE of 3.63, an MAE of 3.34, and an MSE of 3.74.

Energy Data Spaces Analytics Sample

Below are some of the samples of analysis images that can be shown in the Energy Data Spaces platform that stakeholders can utilize.

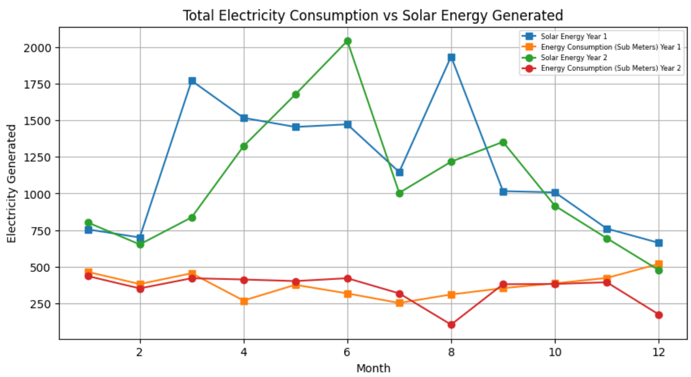


Figure 14: Total Electricity Consumption vs. Solar Energy Generated

According to the analysis, there's a vast difference between the solar energy produced and the electricity consumed by a house, which is evident in Figure 14. The difference will be considered as the transferable energy to the community's power battery, as in Figure 15.

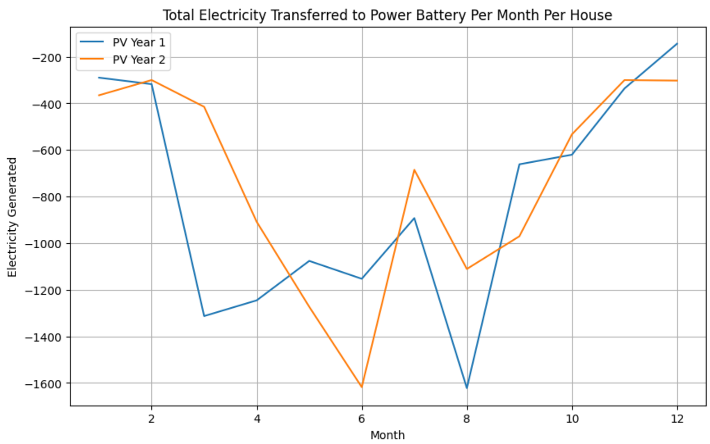


Figure 15: Monthly Total Electricity of One House Transferred to Power Battery

Month	Solar Radiation (kWh / m^2 / day)	AC Energy (kWh)
January	1.02	470
February	1.77	759
March	2.72	1,280
April	3.74	1,684
May	4.75	2,173
June	4.98	2,171
July	4.64	2,078
August	4.16	1,886
September	3.02	1,340
October	2.21	1,036
November	1.24	553
December	0.83	374
Annual	2.92	15,804

Month	Sun Radiation	Solar Energy
January	2.970968	802.16129
February	2.417857	652.821429
March	3.1	837
April	4.896667	1322.1
May	6.206452	1675.741936
June	7.556667	2040.3
July	3.719355	1004.225807
August	4.506452	1216.741936
September	5.006667	1351.8
October	3.393548	916.258064
November	2.573333	694.8
December	1.770968	478.16129
Annual	4.009911167	12992.11175

Figure 16: Comparison of solar energy (NREL data vs. calculated data)

In Figure 16, a comparison between the National Renewable Energy Laboratory (NREL) data and the calculated solar energy for this case study is done to check the accuracy of the analysis.

The results show that the calculated solar energy by NREL is similar to the one calculated for this case study. However, there is a difference of circa 3000 kWh per annum. This is because, for this case study, the efficiency considered was 20% and the peak power by solar panels was 3 kWp.

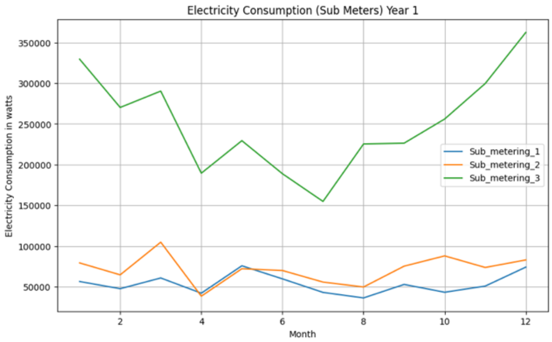


Figure 17: Electricity Consumption of Sub Meters in Year 1

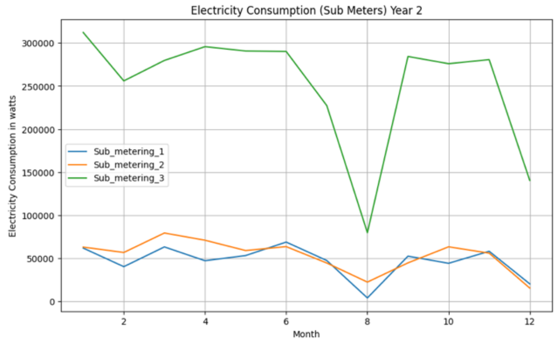


Figure 18: Electricity Consumption of Sub Meters in Year 2

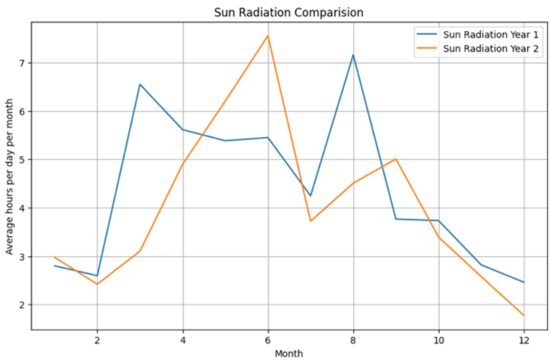


Figure 19: Sun Radiation Comparison in Years 1 and 2

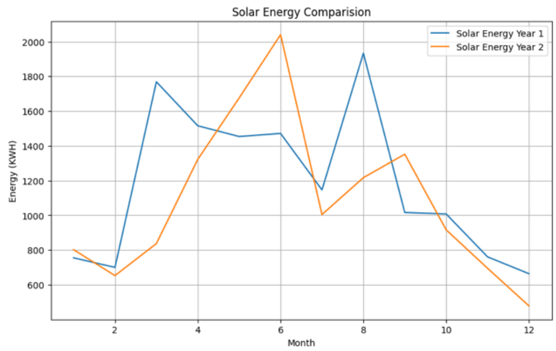


Figure 20: Solar Energy Comparison in Years 1 and 2

The figures above demonstrate the solar energy generation and consumption of each room per house, with a comparison of the last 2 years. These analyses can aid the stakeholders in their decision-making processes. For example, they can check the amount of energy preserved that can be transferred within the community at a low cost.

Challenges in Implementation of Energy Data Spaces in Ireland

A detailed analysis of current Research and Innovation initiatives in Ireland has produced many significant obstacles to overcome to implement the energy data spaces, that will be widely deployed throughout Europe. This study specifically analyzed Expert Groups and laws, such as the EU Smart Grids Task Force, in addition to being based on a specific questionnaire that addressed pertinent stakeholders and the activity carried out with the cluster of preparatory actions for energy data spaces.

The challenges are grouped and categorized based on various classifications. Generally, the technical and regulatory aspects can be handled jointly. Significant issues may surface when regulatory and technical challenges are taken into separate consideration. The primary obstacle would be the complete evaluation of Ireland's energy market and industry business procedures. To operate in the new decentralized digital energy infrastructure, sector coupling, and end users will be crucial to grid control balancing. The design of data spaces must consider how traditional market roles must change.

- Data models, ontologies, and architectures must be synchronized: Currently, the development of new standards and data models is not always necessary to achieve interoperable solutions (apart from new technologies); rather, most of the time, it depends on the mapping between various standards and data models. In particular, the impending new business models related to the data spaces will support the interconnection of various sectors (such as transportation, heating and cooling, and cities in conjunction with electrical grids, at the regional and national levels), as well as operational functionalities requiring data model interoperability among recently connected applications.
- Data accessibility: With specific measuring devices and smart meters and the successful implementation of flexibility mechanisms within data spaces is contingent upon the seamless and effective sharing of data among all data space participants. Currently, there are restrictions on access to smart meter data, which is necessary for the successful implementation of all main Advanced Metering Infrastructures (AMI) concepts. As such, concrete measures addressing this issue are needed. Furthermore, requirements for the resolution and quality of shared data for distributed energy resources need to be strengthened.
- Functionality of metadata: In addition to electrical measurements and power system quantities, different categories of metadata are necessary for advanced grid services, such as demand response and flexibility, which are made possible by data exchanged within the ecosystem. Even though data models for electrical grid data have already reached a high level of maturity, there are still gaps in the formalized processes for adding metadata, which calls for more work.
- Business models: Across sectoral and national levels, acknowledged soft infrastructures of data spaces incorporate roles for intermediaries positioned between the data owner and the data user. One of the challenges in developing energy data spaces is that business models for intermediaries need to be thoroughly analyzed and validated.
- Long-term data space maintenance: Risks and solutions to potential problems must be considered during the design stage and incorporated into the governance guidelines.

For instance, to maintain the ecosystem's integrity, trust, and security, the required intermediaries' (such as clearinghouses, governance bodies, or service providers) withdrawal from the data space must be addressed. Furthermore, the implications of emerging technologies like artificial intelligence will call for a dynamic regulatory approach in the context of data spaces, involving the use of regulatory sandboxes.

Conclusion

Energy efficiency and sustainability have become crucial. Current business models (Table 2) are shown to be inefficient and replacing them can be very expensive. Growing interest has been seen in using contemporary computing techniques to optimize energy consumption and lower costs in buildings using an automated system.

The approach used in this study was centred on locality with an organized platform. The establishment of a common information model (Energy data spaces) has been one of the keystones, supporting the integration and data flow across the system. It predicts and assists stakeholders with energy sharing. With this analysis, the creation of innovative solutions like the demand for flexibility service, which has been effectively applied to drastically lower energy costs, can be generated.

This paper describes the technology components developed for the energy use cases. The approach is modern and scalable. It can be demonstrated that the suggested architecture is effective at managing resources and responding quickly to changes in user demand.

It is suggested to use novel ML algorithms to predict day-ahead electricity prices and energy consumption loads, which can lead to reduced energy costs in buildings with legacy equipment.

Findings from different projects in Ireland have demonstrated that energy consumption can be greatly decreased, particularly during peak hours. Additionally, the outcomes demonstrated that the solution might be a useful instrument for lowering building energy expenses. Promising features that might be advantageous for building occupants include the platform's capacity to effectively control energy demand during peak hours, optimize energy use for appliances, and control energy consumption during high-demand periods. To confirm the findings of these pilot studies in a larger and more varied sample of buildings, more investigation is required. Studies indicate that Renewable Energy Data Space can also hold promise for lowering energy expenses in multipurpose smart buildings.

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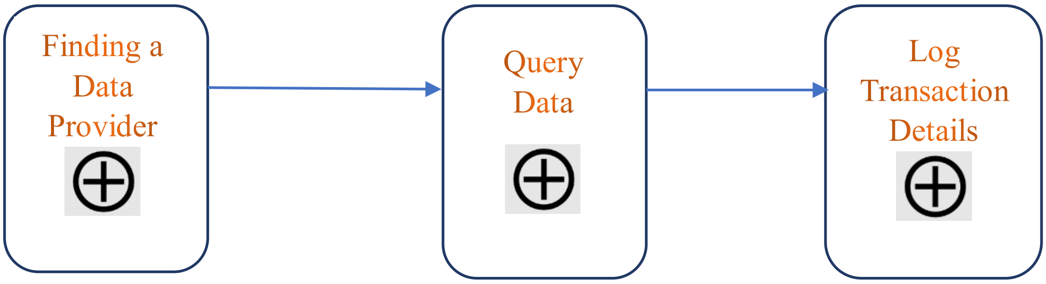
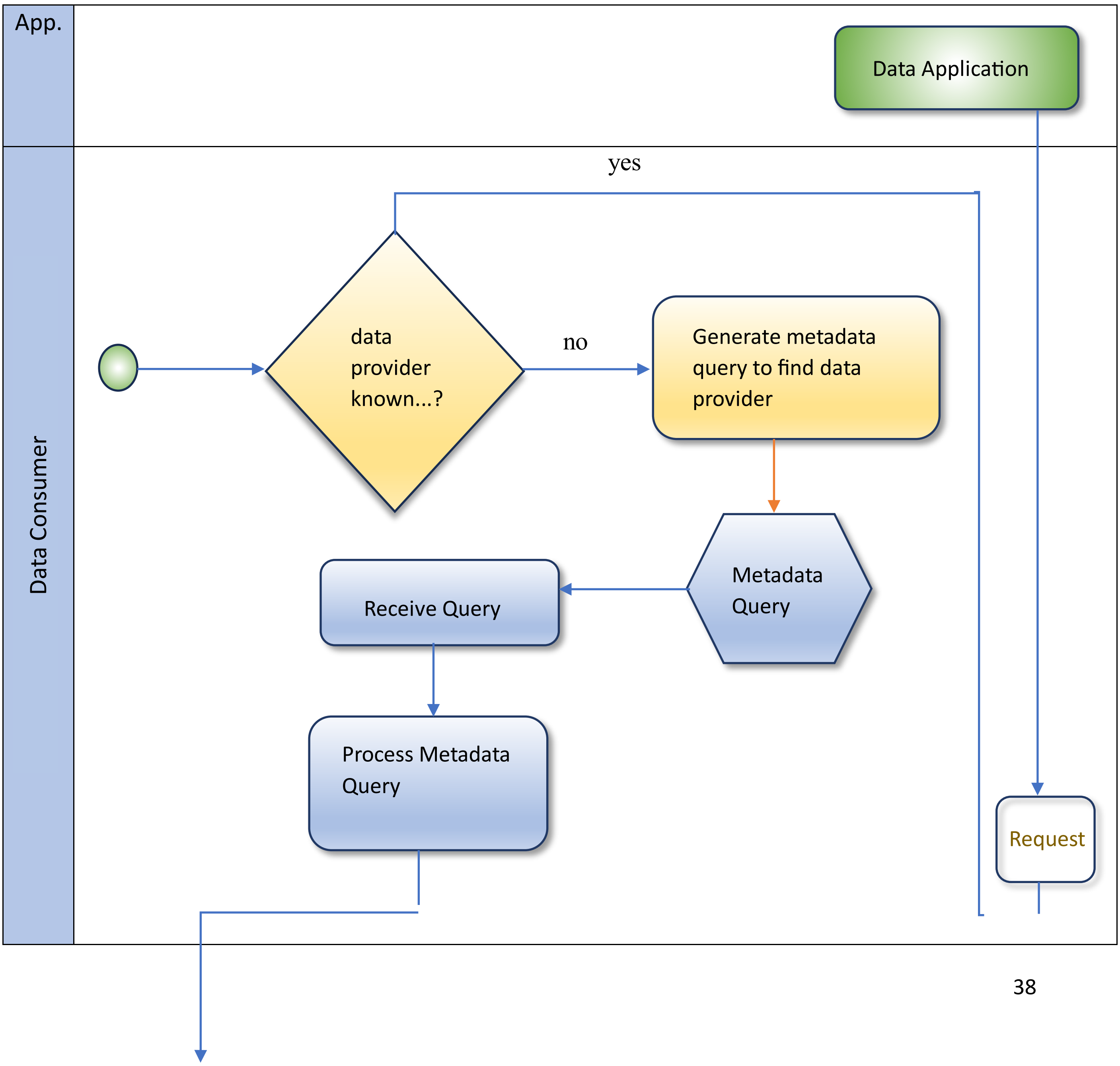
Appendices

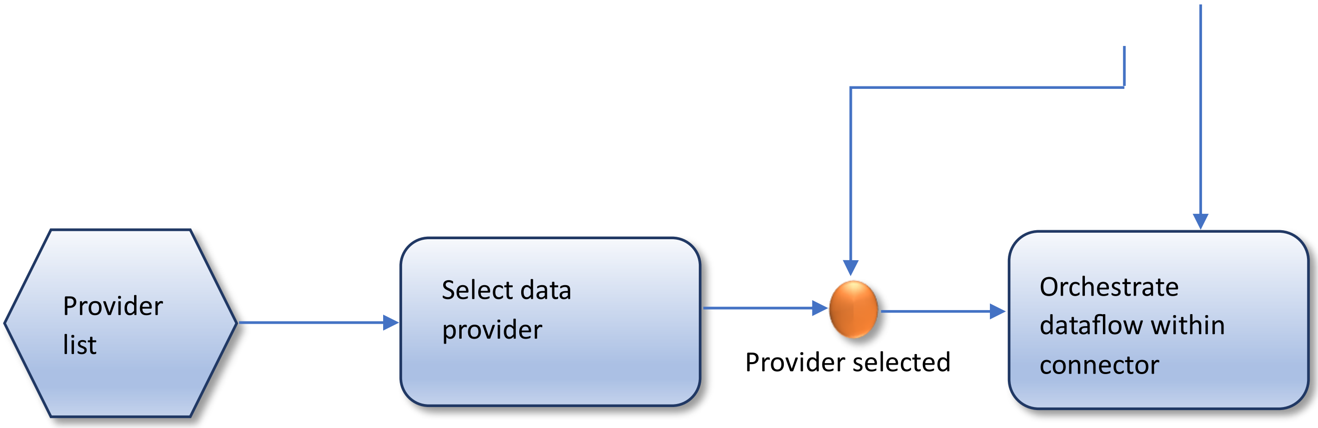
Appendix 1: Energy Dataspace Architecture/Data Flow



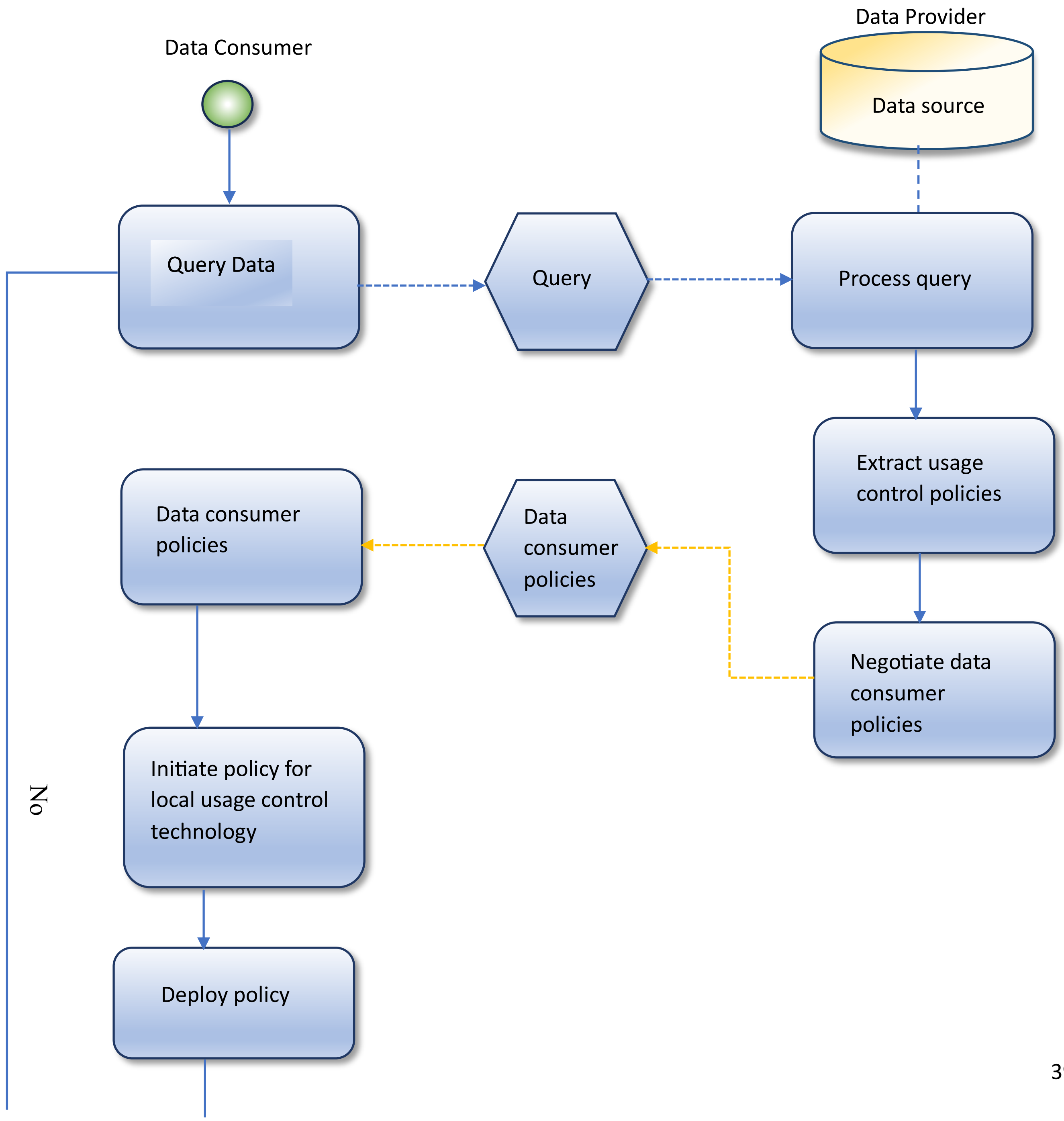
3 phases (or) sub-process of data exchange

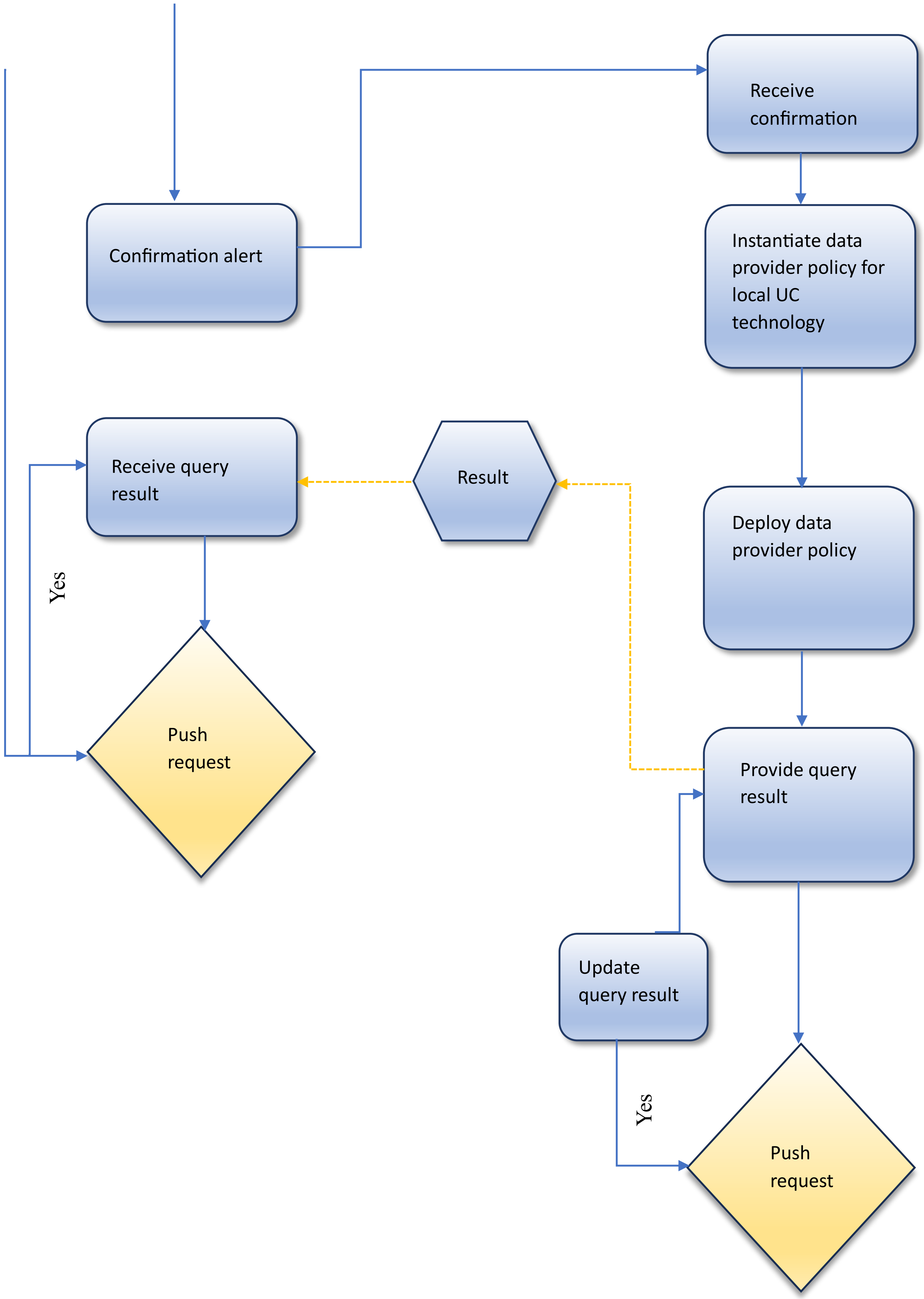
<u>Finding a Data Provider</u>





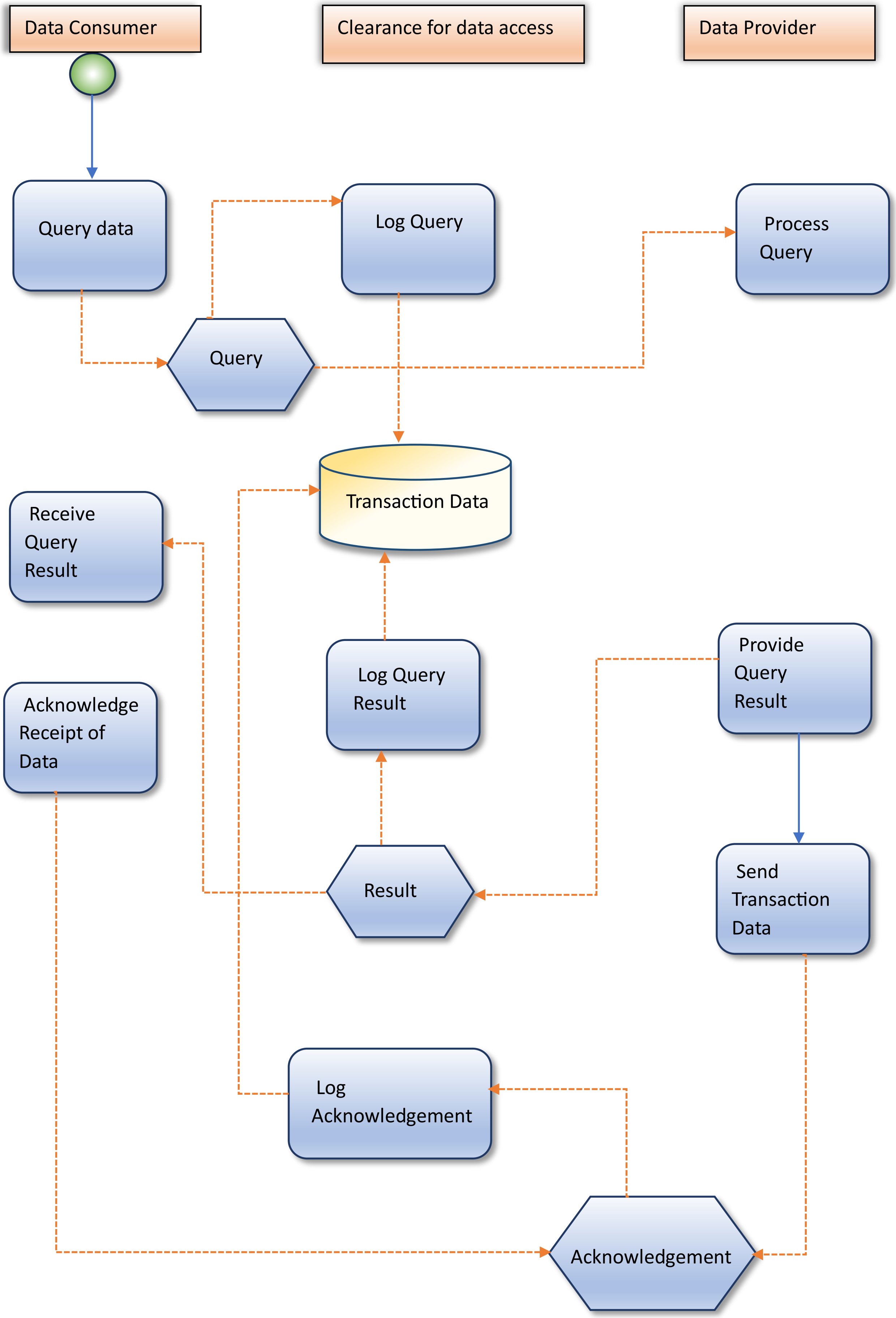
Query Data sub-process





Receive confirmation
Confirmation alert
Instantiate data provider policy for local UC technology
Receive query result
Result
Deploy data provider policy
Yes
Push request
Provide query result
Update query result
Yes
Push request

Log Transaction Details



Appendix 2:

Solar Energy Prediction using MLR model

1) Input from the User

```
Enter the number of houses: 
```

2) User will be prompted to enter number of solar panels (Considering one solar panels as 2.5 mts)for each house

```
Enter the number of houses:   3
House 1:
Enter the number of solar panels for House 1:  3
House 2:
Enter the number of solar panels for House 2:  4

House 3:
Enter the number of solar panels for House 3:  0
```

3) Based on the User's inputs, the monthly average electricity consumption will be calculated. Here, only factors are considered. 1) Sun radiation 2) Number of Solar panels

Output: The output will be monthly average electricity consumption and Sum of yearly electricity consumption.

```
House 1:
Enter the number of solar panels for House 1:  3

Predicted energy consumption for each month:
January: -406.54
February: -428.94
March: -796.46
April: -1036.68
May: -1271.04
June: -1018.36
July: -781.47
August: -828.40
September: -729.69
October: -645.50
November: -415.88
December: -344.20
House 2:
Enter the number of solar panels for House 2:  4
```

```
Predicted energy consumption for each month:
January: -555.49
February: -585.69
March: -1074.51
April: -1393.38
May: -1705.29
June: -1368.56
July: -1052.42
August: -1115.40
September: -984.04
October: -872.20
November: -567.23
December: -472.05
House 3:
Enter the number of solar panels for House 3:  0
Predicted energy consumption for each month:
January: 40.31
February: 41.31
March: 37.69
April: 33.42
May: 31.71
June: 32.24
July: 31.38
August: 32.60
September: 33.36
October: 34.60
November: 38.17
December: 39.35

Total energy consumption for each month:
January: -921.73
February: -973.32
March: -1833.28
April: -2396.63
May: -2944.62
June: -2354.68
July: -1802.50
August: -1911.19
September: -1680.37
October: -1483.10
November: -944.95
December: -776.91

Total energy consumption for each house:
House 1: -8703.16
House 2: -11746.26
House 3: 426.14
```

The negative numbers indicate the excess energy that can be shared or sold.

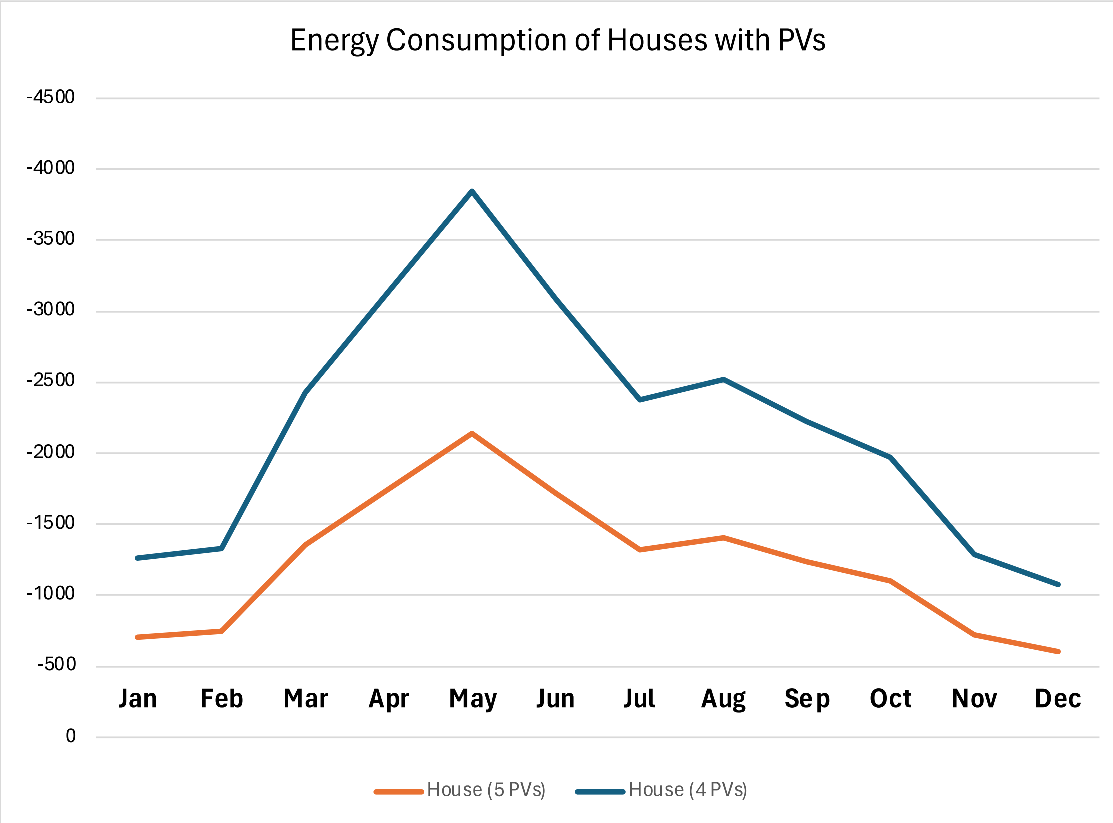
Formula: The formula used for calculating energy generated by solar panels is explained below:

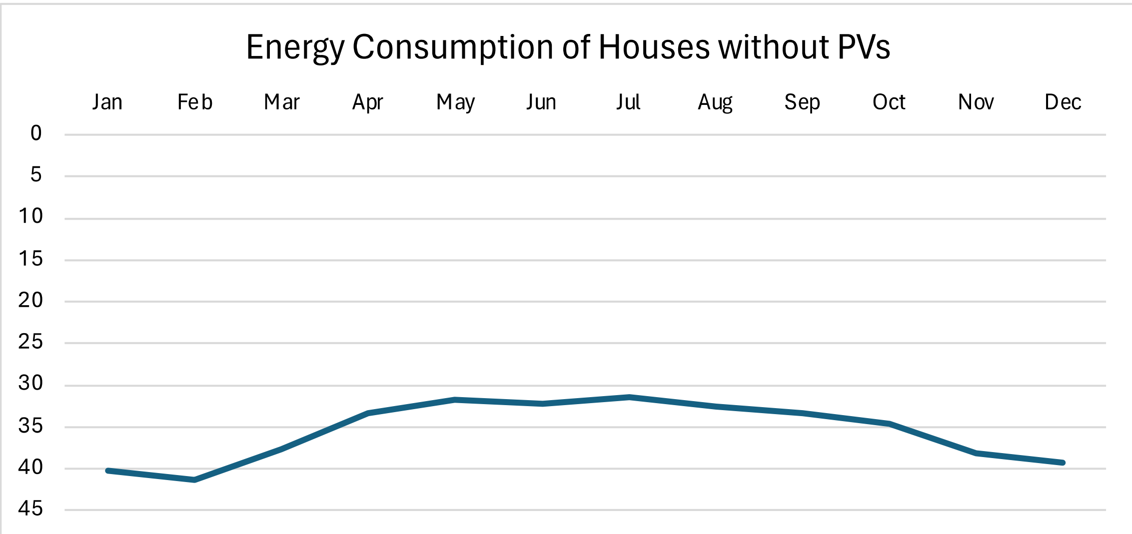
Electricity Consumption for a House with Solar panels (Per Month per Hour) = Electricity consumption for a House without Solar panels – (Sun radiation at Hour of the Day X Length of solar panels X Efficiency)

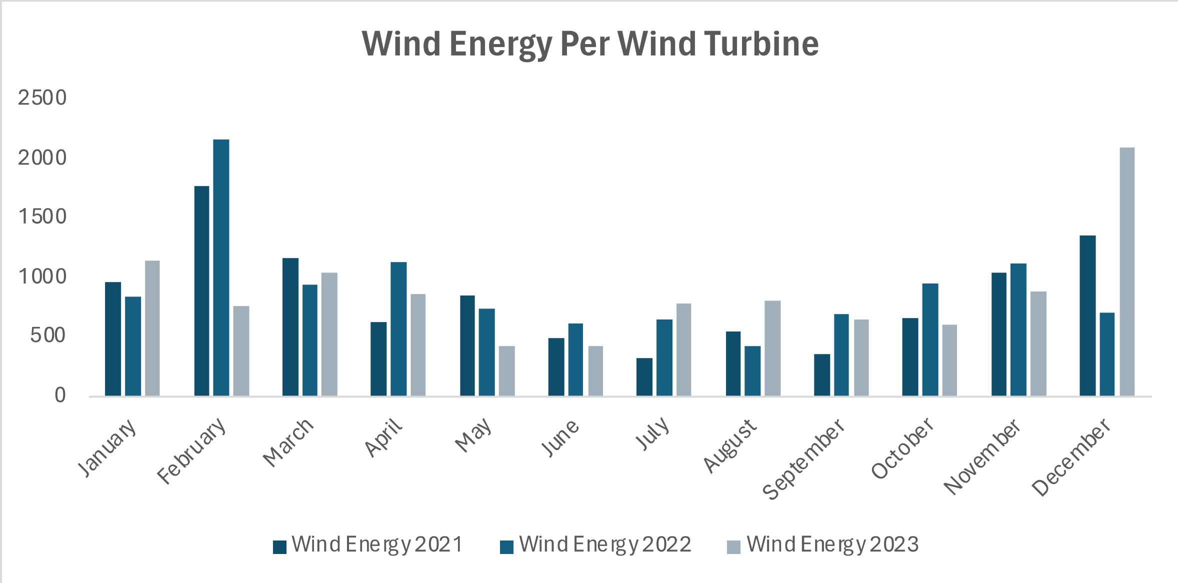
Sun radiation = Data taken from Meteor Ireland

Efficiency = Considered as 20 percent

Electricity consumption for a House Without Solar panels = Considering data from the Electricity website of Ireland and calculated average monthly electricity per hour.






Wind Energy Per Wind Turbine
2500
2000
1500
1000
500
0
January
February
March
April
May
June
July
August
September
October
November
December
Wind Energy 2021
Wind Energy 2022
Wind Energy 2023