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Requirements of an Energy Data Ecosystem

ANNE IMMONEN AND JARMO KALAOJA
VTT Technical Research Centre of Finland, FIN-90571 Oulu, Finland

Corresponding author: Anne Immonen (anne.immonen@vtt.fi)

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ABSTRACT Digitalization is strongly entering new application domains around the world, thus also entering people's everyday lives. Digitalization enables creating new kinds of businesses, but it also changes the way services, applications and data are provided and consumed. We carried out interviews with company representatives acting in the energy domain to receive up-to-date information about the companies' awareness of digitalization, and the required changes they have identified in their future business scenarios. The interviewed companies were aware of the change pressure caused by digitalization, and especially the data exchange with other domain actors, predictions using data, new data-based services and data-based decision making were identified as key issues. However, currently there is a lack of digital infrastructure enabling the actors in the energy domain to perform data-based co-operation. The purpose of this paper is to identify the requirements for an energy data ecosystem that enables the companies in the energy domain to reach their business goals and to co-operate in data-based business. The initial goal is to identify the future tasks and goals of energy domain actors and define the type of co-operation environment, including knowledge management models and supporting services, required to support them. The research was implemented with industry actors in the energy domain that represent several different roles in energy markets, and the results of the research were also validated among the industry.

INDEX TERMS Data ecosystem, data-based business, knowledge management models, energy domain, requirements specification.

I. INTRODUCTION

Today, businesses and private lives are to a great extent transitioning to a digital format. Media, banking and telecom are the pioneers in producing digital content and services, and people have already adopted digital services in their everyday routines though the Internet and smart phones. This kind of network-based digitalization [1] is the driving force today, pushing companies to change their business, and people to adapt their consumption behavior. Digitalization can currently be seen as a global megatrend that is fundamentally changing businesses through mobile applications, big data, machine-to-machine, Internet-of-Things, Industrial Internet and Industry 4.0 [2]. Digital transformation is a result of digitalization, concerning the global process of technical adaptation by individuals, businesses, societies and nations [2]–[4]. This change caused by digitalization is naturally the smoothest in those business and industries where the business is mostly based on digitized assets, data and services. The new patterns of innovation using data, such as augmenting products to generate data, digitizing assets, combining data within and across industries, trading data and codifying a distinctive service capability [5], boost the transformation of business models and the innovation of new business possibilities.

Recently, the digital transformation is also entering the energy domain, forcing energy markets to evolve. The term 'energy markets' concerns all the markets in which energy is the object of trading (e.g. electricity and heating); however, in this work we concentrate only on electricity. Digitalization in the energy markets is expected to introduce both new opportunities and risks to the businesses already in the field, but, above all, it forces the actors to innovate new means of utilization for the gathered and existing energy-related data. The roles of existing market players will change and there are possibilities for new market players. There's a need to adapt market rules to promote an efficient use of common infrastructure, but according to the Report on the State of the

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Energy Union by the European Union [6], bottlenecks exist throughout Europe, especially due to missing infrastructure. Furthermore, in Finland, the smart grid vision 2025 published by the Ministry of Public Affairs and Employment [7] identifies several needs for a change in energy markets, such as clarifying actor roles and market rules, and increasing cooperation across different sectors in industry, which in turn also cause the need for new kinds of solutions for market actors.

Digitalization and the pressures to adapt business are forcing actors in the energy domain to strengthen their forces and to co-innovate new possibilities to sustain businesses. The strengths of ecosystems have been generally noticed, as they enable dynamic co-operation, value-co-creation and trustworthy business relations. A business ecosystem is a dynamic structure of organizations that work together in a specific primary technological platform or core business [8]. Data ecosystems consist of organizations and individuals, that generate, share and process related datasets mainly within their natural boundaries [9]. Thus, a data-based business ecosystem is formed by organizations that each have their own parts and know-how in the data-based business. Data is exchanged and traded between the different ecosystem actors, and utilized in different actions, such as in analyses, predictions, device controls, service innovations and decision making. However, currently, a collaboration environment that enables this kind of data exchange and utilization is missing. The research question of this paper can be stated as: What are the requirements for a collaboration environment that enables the actors in the energy domain to reach their business goals in data-based business?

The purpose of this paper is to identify the new data-based activities in energy markets that reflect the business goals of the different energy domain actors, and to define the required support for these activities in the form of a co-operation environment. This environment defines a digital framework in the form of the elements required for the different actors to implement new activities and find new business opportunities in co-operation. This paper is structured according to the following: Section 2 introduces the background for the work, defining the basics of data ecosystems and introducing some existing energy data ecosystems. Section 3 describes the research method used in this work, introducing the different phases and their rationale. The results of this work are described in Section 4, culminating with the concept of an energy data ecosystem. The requirements were identified with the help of the industry interviews of the companies that operate in the energy domain, and they were also validated by industry representatives. Section 5 provides discussions related to the issues rising from the research results. Finally, Section 6 concludes the work.

II. BACKGROUND

One of the key ideas of an ecosystem is to enable co-operation by sharing common assets and knowledge. The next sub-section describes the main characteristics of data ecosystems, after which some existing data ecosystems in energy domain are introduced.

A. CHARACTERISTICS OF DATA ECOSYSTEMS

Generally, a data ecosystem consists of the following entities [10]–[13]:

1) MEMBERS

Ecosystem members include the actors that act in their domain-specific roles in an ecosystem. The actors aim at the co-innovation and co-creation of value within the dynamic value networks, while utilizing the existing assets of the ecosystem that assists in achieving the business goals.

2) CAPABILITY MODEL

Capability model defines the purpose of the ecosystem, its ability to perform actions and the rules of how to operate in the ecosystem. In addition, the capabilities define the governance and regulations for directing, monitoring and managing the ecosystem. The capability model thus describes the enabled actions of the ecosystem (clustered according to the stakeholders' activities) and how, when and by who these actions are implemented. For example, in [13] the ecosystem actions include open data certification and digital service development related activities.

3) ECOSYSTEM SUPPORT SERVICES

Support services assist ecosystem members in carrying out the tasks defined as activities. These services can be provided by a third-party service provider. For example, the taxonomy of ecosystem support services represented in [13] defines an evolving set of services for the common use for actors in data-based business and in data-based service development in the ecosystem context.

4) KNOWLEDGE MANAGEMENT MODEL (KMM)

KMM provides common knowledge (e.g. common models and transformation rules) that can be utilized by the ecosystem members. The most important is the ecosystem policy that is a description of the principles, strategies, tactics and guidelines of the ecosystem common to all ecosystem members. Ecosystem policy defines a set of governance services that are common for all ecosystem members, and rules outlining how to configure and monitor these services.

5) INFRASTRUCTURE

The ecosystem infrastructure implements ecosystem capabilities, supporting the utilization of core competencies and core assets, flexible business networking, and efficient business decision making. It also provides the required services and tools for collaboration and co-operation of ecosystem members. For example, the Digital Services Hub framework[1] is used in [13] as a core of the ecosystem to register and monitor data and services.

[1] https://www.digitalserviceshub.com/registry/

6) DATA
The key in a data ecosystem is data that is understood as symbols and can be raw or processed. Raw data is produced by observing, monitoring, using questionnaires, etc., but is not yet processed for any specific purpose. Processed data is edited, cleaned or modified from raw data. Information is data that is processed to be useful, providing answers to the questions who, what, where and when [14]. Thus, refinement and processing of data analyses aligns and aggregates data from different physical and digital sources, increasing the understanding of the data, and thereby producing information from the data.

The relationships of these elements are described in Figure 1. The capability model is implemented by the support services and knowledge management models, which are provided by the infrastructure. The capabilities are implemented as activities that utilize the data that is provided in the ecosystem.

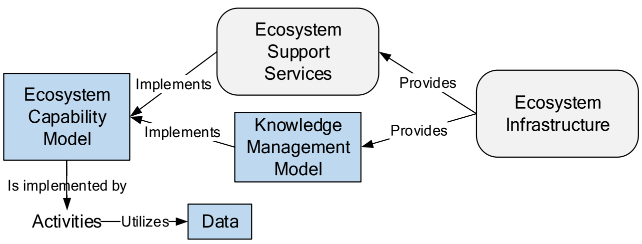

FIGURE 1. Relationships of the elements of a data ecosystem.

B. EXISTING ENERGY DATA ECOSYSTEMS
Currently, widely adopted standard data ecosystems are still missing in the energy domain. However, examples of emerging trends in the domain are the tendencies to improve collaboration between stakeholders and to bring out more consumer-centric approaches. Identified examples of these trends are discussed below.

1) PROMOTING PROSUMER ENERGY AWARENESS AND THIRD-PARTY DATA EXCHANGE
A number of European Union (EU) member states are working to enable services consumption data to be downloaded by the customer or shared with third parties approved by the customer. Smart Grid Task Force EG1 ad hoc group on "My Energy Data" [15] provides an overview of some of the existing initiatives on data access and data management in the field of energy distribution at the EU level. In Denmark, a DataHub is already in operation, where it handles the interaction between the players in the electricity market through uniform communication and standardized processes. It is owned and operated by Energinet.dk, the Danish Transmission System Operator (TSO). By 2020 a similar DataHub will be operational in Finland and will be operated by a subsidiary of Finnish TSO, Fingrid Oy.

2) CONSUMER TAKING ACTION
Green Button Alliance[2] provides an initiative that is a USA-based industry-led effort to provide electricity consumers energy awareness with easy access to their energy consumption data. It enables consumers to take action to reduce energy consumption or save money where time-of-use pricing provides incentives for off-peak switching of energy consumption. The initiative fosters the development, compliance, and adoption of the industry standard Green Button energy and water data access and sharing protocol. OpenADR Alliance[3] provides an open, highly secure, two-way information exchange model and Smart Grid standard, OpenADR. The Alliance tends to standardize, automate, and simplify Demand Response (DR) and Distributed Energy Resources (DER) to enable utilities and aggregators to cost-effectively manage growing energy demand and decentralized energy production, and customers to control their energy in the future. A different type of approach is to guide customer investments to more active technologies by labelling products as "Smart Grid Ready" based on certain criteria, such as those for the "SG Ready-label" defined by BWP (Bundesverband Wärmepumpe)[4] in Germany for smart heat pumps that can adapt their behavior based on the network state.

3) PROSUMERS
The Digital Energy Ecosystem Framework (pDEEF) introduced in [16] promotes increasing comprehension of the prosumer role in the future energy ecosystem. The pDEEF framework is based on deducting theoretical premises for the systemic nature of the energy ecosystem. The framework exemplifies the needed multidisciplinary research for combining innovation ecosystems, end-user role, complex industry transitions and new technology platforms.

4) STAKEHOLDER COLLABORATION
QUEST[5] is a collaborative network of stakeholders that work to design, develop and apply Integrated Community Energy Solutions (ICES) in Canada. They aim to find new ways to integrate and use energy data (e.g. end use, demand, storage and production from DER), for both internal and external applications. Utilities need to ensure that they have a robust model of their grid, network connectivity, and characteristics of energy end use and production enabled by DER, and this includes bringing together these data elements in geographic information systems (GIS). As part of the "Sharing Cities" EU project, the E015 open API digital ecosystem [17], [18] enables data sharing that can be applied to different sectors relevant to the urban context, e.g., energy and transportation, in order to create innovative solutions for energy monitoring, citizen engagement, and evaluation and monitoring at district

[2]https://www.greenbuttonalliance.org/
[3]https://www.openadr.org/
[4]https://www.waermepumpe.de/sg-ready/
[5]https://questcanada.org/

and city levels. Ecosystem participants can describe and publish their Web services (i.e., APIs) in terms of both functionalities and usage policies, in order to share their data assets through standard Web service interfaces. Other participants can then discover such services and leverage them for building new value-added services or new integrated applications for the end-users, thus contributing to the overall growth of the ecosystem. In addition to the previous, various organizations promote collaboration between energy network parties, such as EBIX[6] that is a European forum for energy Business Information eXchange in the European energy industry, and ENTSO-E (European Network of Transmission System Operators for Electricity)[7] focuses on collaboration between European transmission network operators.

These trends in recent suggestions can be seen as continuous phases incorporating consumers as active participants of energy systems (see Figure 2). The key, and the driver in the way of thinking is the consumers' increased energy awareness and the opening of energy consumption data. After that, consumers have become more active, as they may, for example, change their consumption when necessary or otherwise found to the reasonable. Furthermore, consumers have shown interest in producing energy themselves, becoming energy prosumers. The most recent trend is the aggregation of the energy resources and therefore the collaboration between the stakeholders in the energy domain.

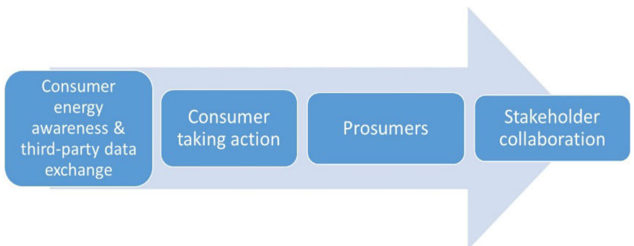

FIGURE 2. **Phases from consumer's energy awareness to energy stakeholders' collaboration.**

III. RESEARCH METHOD

As a solution to the research problem, the purpose was to identify requirements for the energy data ecosystem that support the future activities of energy domain actors. Case study [19] was selected as a research method, as it is useful when investigating the phenomenon within its real-life context, also relying on multiple sources of evidence. The research was implemented in a national research project, EDES[8] (Energy Data Ecosystem and Services), during the autumn of 2017 and summer of 2018. The research group consisted of nine research scientists, of which five had long-time energy domain experience. In addition, the project included nine Finnish companies from the energy domain, such as energy sellers, consumers, distribution system operators (DSOs), transmission system operator, technology providers and service providers.

The research was started as theoretical research that was implemented as a literature review, investigating the existing theories, elements, concepts and definitions related to the problem area. The results of the literature research were used as a starting point for the empirical part of the research that was implemented among actors in the energy domain. The data was collected directly from the companies with the help of in-depth interviews that are an optimal method for collecting data on individuals' perspectives and experiences. The results of the interviews were analyzed in several iterative phases. New concepts were developed based on the analysis results, and the results were evaluated and validated in each phase with the energy domain actors. The research included several internal workshops, where the results were validated by the researchers and energy domain experts, and five external workshops, where the results were validated by the company representatives together with representatives of the research group.

All the companies involved in the project participated in the interviews. The companies differed according to their roles, company sizes and viewpoints on energy data (see Table 1). The size of the companies is defined according to [20]: micro-enterprise $<$10, small enterprise $<$50, medium-size enterprise $<$250 and large enterprise $>$250 employees.

A. THEORETICAL RESEARCH: IDENTIFICATION OF THE DRIVERS FOR CHANGE AND NEW POSSIBILITIES

The theoretical part of the research consisted of research on the variables that affect the energy markets. The main source for the research was Finland's smart grid vision 2025 published by the Ministry of Public Affairs and Employment (https://tem.fi/), which identifies the changes in the operation environment, and outlines the issues affecting future energy markets. Furthermore, the development trends in Finland, such as MyData,[9] DataHub[10] and the National Service Architecture of Finland,[11] were also taken into account. In addition, the domain experts had visions about the direction of energy markets based on their knowledge and experiences. The purpose of the theoretical research was to identify the critical drivers that force the actors in the energy market to change or adapt their operations. These drivers also revealed the possibilities of the actors to change their roles, and furthermore, they enabled the emergence of new roles in energy markets to practice new kinds of business. The work was implemented in several internal workshops, where the drivers for change were iteratively outlined and discussed. Finally, the drivers were discussed in an external workshop with companies, allowing the company experts to comment on and modify them. The results of that phase included the identified drivers

[6] https://www.ebix.com/
[7] https://www.entsoe.eu/
[8] https://www.vtt.fi/sites/EDES/en
[9] https://mydatafi.wordpress.com/
[10] http://www.fingrid.fi/en/customers/datahub/
[11] http://vm.fi/palveluarkkitehtuuri

of a change, and the refined and new actor roles in the energy market.

B. EMPIRICAL RESEARCH: ACHIEVING COMPANY VIEWPOINT

The empirical part of the research was implemented with company interviews. The purpose was to discuss the drivers of change, enabling the companies to innovate and outline their new possible business functionalities through them. In addition, the purpose was to outline the new kind of business model in the future energy ecosystem, and thereby identify requirements for an energy data ecosystem. Semi-structured interviews [21] were selected, because they enable variability in conversations, in this case due to the different background and status of the companies. Each company was interviewed separately, including one to three company representatives and three to five interviewers. The interviews were performed in Oulu, Helsinki/Espoo and Jyväskylä (face-to-face or in Skype meeting) between October 2017 and January 2018. The interviewees, for example the product managers, development managers and managing directors, were selected based on their knowledge of the business viewpoint of their company. Each interviewee was asked to select a role that represents his/her company's role in the future ecosystem. The roles were defined based on the analysis of the literature survey. The collected data was meant to assist in understanding the different actor viewpoints in the context of energy data-based business and to identify the major obstacles and shortcomings. The interviews consisted of some main themes:

1. The current status and motives for a change: What is the current role of the company in energy data utilization, and what are the main motives of the company for the future energy ecosystem?
2. The future operation in the energy data ecosystem: What functionalities does the company wish to perform in the ecosystem?
3. Data-related requirements: What are the requirements of the company considering energy data and data management?
4. The risks and challenges: What are the biggest disadvantages or problems that the companies see in acting in an ecosystem?

C. ANALYSIS OF THE CAPTURED DATA

The results of the literature review and the company interviews resulted in the requirements of the energy data ecosystem through several iterative analysis phases. These phases included the following analyses and activities.

1) PHASE 1: SPECIFYING USER REQUIREMENTS

The responses from the interviews were analyzed and reported using the content analysis method [22], in which the data can be presented in words and themes, enabling conclusions to be drawn from the results. This kind of analysis made it possible to identify the common characteristics among the responses, and then interpret them to the requirements of the energy data ecosystem from the viewpoints of different actors. The result of the analysis was the definition of actor-specific results, which were then combined role-specifically, enabling reaching the common requirements of each actor group. The analysis results were evaluated and refined in several internal workshops, after which they were made available for the company representatives through SharePoint, a Web-based co-operation environment, allowing the members to modify and produce content for the shared documents. At the end of the phase, an external workshop was organized with the purpose to collect feedback, comments and improvement suggestions face-to-face from the company representatives. After minor modifications, the user requirements specification was completed.

2) PHASE 2: DEFINITION OF USER STORIES

After specification of user requirements, user stories were defined iteratively in internal workshops. User stories assist in defining the high-level context of a system by shifting the focus from requirements to capturing motivations behind them. The purpose was to outline how the roles of different actors will differ and change in new, future energy ecosystems. Initial stakeholder role-specific user stories were collected during interviews and refined more formally by the domain experts. This was implemented by sketching the motivations as goals and actions to reach the goals as tasks of each stakeholder group in the context of main change scenarios. The following template assisted in the definition of the user stories: "*As a < type of user >, in order to < achieve some goal >, I need to < perform some task >*". The initial user stories were filled mainly by domain experts in order to better understand the overall picture of how goals set by business processes must be taken into account in the change scenarios. The stories were then modified and discussed in several internal workshops.

3) PHASE 3: IDENTIFICATION OF MAIN SCENARIOS AND REFERENCE USE CASE

Based on the results of the previous phases, two main scenarios were identified to represent the main actions that the future energy ecosystem should enable. The scenarios were identified iteratively in several internal workshops. Seven reference use cases were derived from the scenarios with the help of company interviews, user stories and the insights of domain experts. A reference use case describes a typical approach to adopt new technologies or business processes in the two selected main scenarios. The reference use cases were analyzed using PESTLE (Political, Economic, Social, Technological, Legal and Environmental) analysis,[12] which is a well-known method for analyzing the environment from different viewpoints. The analyses were made iteratively by three to four domain experts in several internal workshops.

[12](http://pestleanalysis.com/)

TABLE 1. The companies involved in industry interviews.

Company	Current role(s)	Size	Viewpoint on energy data
Company A	Energy seller and DSO	Medium	Data collector, data utilizer
Company B	Energy seller and DSO	Large	Data collector, data utilizer
Company C	Energy seller and DSO	Large	Data collector, data utilizer
Company D	Technology provider	Small	Data enabler
Company E	Service provider	Medium	Data utilizer
Company F	Technology provider	Large	Data enabler
Company G	Energy consumer	Large	Data collector, data utilizer
Company H	TSO	Large	Data utilizer
Company I	Energy consumer	Large	Data collector

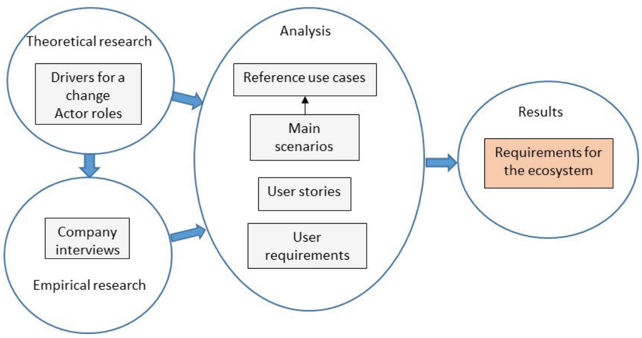

FIGURE 3. Description of the requirements engineering process.

The use cases were also presented to company representatives regularly to enable them to comment on and modify them. After the PESTLE analysis, an external workshop was organized, where the company representatives were asked to comment on and refine the use cases. These comments resulted in the refinements of the use cases.

4) PHASE 4: REQUIREMENTS SPECIFICATION

After the completion of the user requirements, user stories, main scenarios and reference use cases, the requirements for the energy data ecosystem were specified with the help of these source materials (see Figure 3). The purpose was to recognize what the ecosystem must provide to support these activities. The content analysis method was utilized again to identify the common characteristics. The main elements of the ecosystem; members, knowledge management models, support services and data, guided the data analysis. The results of this phase were the requirements of the energy data ecosystem. The requirements went through several iterations in internal workshops, after which an external workshop was organized with the company representatives, allowing them to comment on and modify the requirements.

The final requirements were classified into categories according to their content, after which they were abstracted to the required support from the ecosystem. The results are described in the following section.

IV. RESULTS OF THE RESEARCH

A. IDENTIFIED DRIVERS FOR A CHANGE

Currently, several global trends exist that simultaneously affect energy markets. According to Finland's smart grid vision 2025 published by the Ministry of Public Affairs and Employment (https://tem.fi/), five significant, interlinked global development drivers can be identified, of which even one of them changes the electricity markets substantially [7]:

- **Renewable energy**: Renewable energy was long ago identified as one of the most important solutions to current environmental problems [23]. New challenges emerge in the balancing of the load and the production in the case of renewable energy.
- **Electrification of traffic:** Electrification among traffic is very fast. Electric traffic is considered to be clean, efficient and cost-effective. The increased demand for electricity and batteries operating as energy storage presents new challenges.
- **Battery energy storage:** Batteries as energy storage are already economically profitable, and will be more so in the future, as their usage will increase.
- **Internet-of-Energy (IoE):** IoT enables real-time control of distributed energy resources (loads, storages, distributed generation). This considers all our surroundings, such as living rooms, cars and workplaces.
- **COP21 (Paris climate agreement)**[13]**:** Europe's greenhouse gas emissions are required to be reduced to zero by the 2050's, which is a very powerful driver. The agreement will increase the role of electricity in the whole world.

Several other drivers and trends can be detected from the literature or directly by following the energy markets:

1) NEED FOR FLEXIBILITY INCREASES

The amount of renewable, intermittent generation of energy is increasing. Flexibility needs to be added to the system, since these cannot be controlled in the same way as the traditional fossil-fuel power stations. The flexibility can be provided by any type of resource (load, generator, storage unit) and the

[13]https://www.gouvernement.fr/en/cop21

utilized resource should be selected based on costs. Also, small-scale resources can be utilized. The operational principles of the system must be revised.

- *Opportunities:* New and existing actors can participate in different markets by controlling aggregated small-scale resources. TSOs and DSOs will have access to new controllable resources that can be utilized for different purposes (e.g. frequency control on the transmission system level or overvoltage mitigation on the distribution system level).
- *Challenges:* Current ICT systems and market structures do not enable large-scale utilization of small resources, and no applicable (generally accepted) standards exist. Several solutions are required for solving the conflicting interests of different actors, verifying cost-effectively the executed adjustment, and evaluating and forecasting the controllable capacity.

2) NEW MARKET STRUCTURES AND STAKEHOLDERS

The existing energy markets will evolve, allowing also the smaller actors to participate. New flexibility markets will emerge that enable the utilization of smaller resources. New stakeholders, such as aggregators and service providers will emerge, and the roles of the existing stakeholders will change.

- *Opportunities:* The new markets and actors enable the utilization of all types of resources in system control, leading to decrease of total costs. New local markets (e.g. peer-to-peer) could increase customer engagement and awareness.
- *Challenges:* The system will be more complex, may lead to sub-optimal solutions taking into account only the needs of some actors. There might be a need to change policies and regulations to realize new types of market structures.

3) INCREASING DATA ANALYTICS

Data analytics will become one of the key assets in business decision making. When integrating and analyzing one's own data, collaborators' data and open data, more accurate business decisions can be made. The analyzed data can be thought of as a data service that can also be provided to customers.

- *Opportunities:* Analyzed data can be used in several decision-making points; e.g. to predict the demand, observe consumer behavior, innovate new data-based services, etc. Data analytics itself can be provided as a service, enabling opportunities for several (new) actors. Lowering cost of cloud farms enabling sharing of raw input data for analysis with data oceans provides technologies for efficient development of those services.
- *Challenges:* The trust making and identification of business benefits between actors in an ecosystem; what the mutual benefit is when sharing one's own data with collaborators. Quality of data; how to ensure that the data is reliable, accurate, complete, comprehensive and valid. The quality of data will be emphasized, especially when the data analytics will be more automatized. Metadata: What information is needed concerning the data when using it in business? Data transfer: How is it possible to reliably transfer data between organizations?

4) OPENING OF ENERGY DATA

The collected energy data from the consumers will be opened and provided as an asset (i.e. data service) to different ecosystem actors. The data can be provided roughly in two ways: 1) The privacy information is removed from data and the anonymous data is provided to the actors, or 2) The data is the MyData type (personal data that is provided in an exploitable format), provided through an application directly to the data owner.

- *Opportunities:* Enables new business potential for data providers that manage the data. Enables new business potential for several (new) actors that provide applications and services on data; the customers can be either large energy actors that can make decisions based on data or consumers that can observe or control their own consumption.
- *Challenges:* Privacy of data; how is it possible to ensure that the private user cannot be recognized? Further challenges are set by European GDPR legislation.[14] Motivations of consumers; what are the motivations of the consumers to enable the usage of their data? Data reliability: How can the quality of data be ensured?

B. IDENTIFIED ROLES

The roles of the actors in the energy markets were first defined based on the literature survey, and then refined according to the industry interviews. The roles are identified in Table 2. However, it is notable that one actor can take several roles in the ecosystem; for example, an energy seller can act according to its current role, but also act as an aggregator and as a service provider.

C. RESULTS OF THE COMPANY INTERVIEWS

The company interviews managed to reach the viewpoint of six different roles. Very often, one actor answered from the viewpoint of more than one role. The identified roles included energy seller, consumer/prosumer, technology provider, service provider, distribution system operator and transmission system operator. The role of the DSO in the future ecosystem was discussed specifically; the future business goals for DSO could not be identified, most likely because the pressure for change does not consider the role of a DSO as much as other roles. Due to this, the following tables do not include the viewpoint of the DSO.

Table 3 describes the interests of different actor groups towards an energy domain ecosystem, identifying the new business opportunities or targets of the domain actors, and the goals the actors have for acting in the energy data ecosystem.

[14] https://eugdpr.org/

TABLE 2. Identified actor roles in energy data ecosystem.

Role	Role description
Consumer	An owner of a small property that pays for energy used at a consumption site. Can control several consumption sites.
Prosumer	Pays for energy used at a consumption site, and also produces energy.
Building owner	Owns the building which contains several apartments or offices.
Tenant	A consumer that does not own the house where he/she lives or works, but pays for the energy consumed.
Flexibility service provider	Provides consumer site flexibility services offering the flexibility either directly to energy markets or an aggregator.
Data-based service provider	Provides data-based services to customers. Customers can be large companies or a single energy consumer.
Aggregator	Offers flexibility to energy markets by aggregating it from smaller flexibility resources provided by consumers or independent aggregators.
Sub-aggregator	An aggregator that does not operate in markets but controls the home devices.
Energy seller	Sells energy (here, electricity) to consumers.
Technology provider	Provides technologies that enable energy flexibility or automation system for flexibility aggregation (virtual power plants) to consumers or building owners.
DSO	Distributes electricity to consumers using their own distribution network.
TSO	Delivers energy to distribution networks. Provides flexibility markets.
Ecosystem provider	Initializes the ecosystem and maintains its functionalities and operation, also managing its evolvability and sustainability.

TABLE 3. The interests and goals of the companies towards an energy data ecosystem.

Actor/role	Interests in energy ecosystem	Goals
Energy seller	*New business models *Data content, data chain *Customer orientation *Consumption flexibility	*Consumer services *Flexibility: bringing loads to TSO markets *Acting as an aggregator
Consumer/ prosumer	*Improving energy efficiency *Flexibility markets	*Reducing costs; no peaks in energy consumption *Storing and potentially selling energy
Technology provider	*Small houses, real properties and heat pumps as flexibility resources *Possibilities for consumers to monitor and control consumption *Digitalization and open interfaces	*Enabling bringing virtual power plants to markets *Acting as a sub-aggregator *Integration of various parts of home automation *Verification of implemented flexibility
Service provider	*Future market mechanisms, rules and standards *Productization and services	*Enabling new market models *Comprehensive solution, and its possible linkage to heating
TSO	*Flexibility management *Common markets to all actors in transmission and distribution network	*Enabling flexibility for different actors *Real-time markets with public prices

The company interviews revealed that the companies have clear interest towards co-operation with other actors in the domain. Table 4 describes the identified requirement of different actor groups for co-operation, and the foreseen challenges for the operation.

Energy data is the key element in an energy data ecosystem. The interviewed companies had a lot of data and they were also aware of the value of the data and the possibilities that the data provides in business. The identified data-related requirements are described in Table 5.

As a result of the analysis of the company interviews, two main interests could be identified. One of them was consumer-centric business and consumer services, when the service provider implements and provides the services for consumers as agreed, including the measurement, monitoring and controlling of home devices. This consumer orientation, productization, and services emerged from the viewpoints of the energy seller, technology provider and service provider. Especially, the energy sellers will no longer provide energy services but more like ‘comfort services’, such as

TABLE 4. Identified requirements for co-operation and issues that complicate the operation.

Actor/role	Requirements for the co-operation	Constraints/challenges/threats
Energy seller	*Integration of the roles of energy seller and aggregator *Common and clear rules *Energy price in real-time on-line *Knowledge about the tendency of regulation in an early phase	*Regulation, and the slow process in making new regulations *Electric cars; real challenge both for distribution network and for seller's pricing *The monopoly of large sub-aggregator
Consumer/ prosumer	*Optimization of the value chain so that each actor receives benefits according to the role in the chain *Customer-centricity: the customer receives financial benefits from flexibility	*The reaction of energy sellers to consumer's own production and adjustment
Technology provider	*The interfaces for aggregators for controlling energy resources though the technology provider's cloud services *Utilization of location data	*Ensuring the conditions during flexibility and verifying the flexibility *Implementing a virtual power plant *Taking locality into account
Service provider	*Equality of actors to discover the market needs *Common rules and clear roles for everyone *Transparency: a market mechanism or regulation is required to allow balancing. *Platform that takes care of data collection and management, interfaces for purchasing data *TSO enables the supply of flexible markets	*Not enough demand for flexibility *Micro balance responsibility is required for smaller actors *Regulation; regulation should support different business models
TSO	*Common rules for flexibility *A regulatory model that favors local adjustment in the distribution network	*Market changes (European flexibility markets) *Transparency of the network disappears

TABLE 5. The identified data-related considerations.

Actor/role	Data related requirements and challenges
Energy seller	*Important: data reliability, security, real-time data, location-specific data *Control of demand flexibility required *Increasing data collection and analytics *Interaction between different actors *Data integration, selection, making forecasts *Offering and selling data *Unclear data management
Consumer/ prosumer	*A lack of information on how to receive knowledge about technology *Challenge in forwarding the right information
Technology provider	*Data is in its own cloud, allowed to connect to data through interfaces *Two-way communication
Service provider	*Common measurements of data *Increasing data analytics: forecasting demand *Transparency of information for ecosystem members *Smart decisions based on data
TSO	*Management requires a real-time, scalable solution *Demand for data between all actors *Security, real-time and price are important *Data needs: view of the whole network and the market

heat-as-a-service. Another important goal was identified as consumption flexibility, when different actors operate in flexibility markets providing their aggregated loads as flexibility potential. The interviewed companies were very aware of the possibilities that the flexibility markets provide, but also recognized the risks and challenges that this involves. The biggest concern was that the markets are not ready; there is not enough demand for flexibility. In addition, the slow process in making new regulations was seen as an obstacle, as well as the fear that a large aggregator/sub-aggregator will obtain a monopoly position in the markets.

Common rules were defined as one of the most important requirements; the new operations require agreed upon rules. Also, the actor roles, responsibilities, rights and distribution of profits must be strictly defined. Transparency is required among all actors; the required data and information must be available for everyone. In addition, the transparency and reliability of data is important, as the data analytics will increase and the data is used increasingly for prediction and for reliable decision making. A real-time and scalable system is required for data collection and management. That kind of system enables smart, data-based decision-making. Currently, there are data needs among all actors, but no one knows what data needs to be transferred. It is unclear what level of information should be exchanged, whose interest the information exchange serves, and who collects the information and arranges the measurement. Regulation was identified as one of the most significant challenges, since it does not usually follow the development in a domain and is therefore often slowly changing. Thus, it is important to know the direction of regulations in their early phases.

D. IDENTIFIED USER STORIES

The effect of change scenarios on the different actor roles according to analysis of company interview results is presented in Table 6 in the form of user stories. The user stories describe the goals of each role, as well as the outlined tasks each actor predicts to implement in the future.

E. MAIN SCENARIOS AND ASSOCIATED USE CASES IN FUTURE ENERGY MARKETS

Two main issues or scenarios were identified as a result of the analysis of the company interviews and user stories.

1) SCENARIO 1: BRINGING SMALL LOADS TO CURRENT FLEXIBILITY MARKETS

The aggregator controls several smart homes and/or properties, whose combination of flexible potentials creates a total package of the aggregator's flexibility potential that the aggregator utilizes in energy and reserve markets. The aggregator can control the resources directly or with the help of a sub-aggregator. A sub-aggregator can be, for example, a home automation system company or electric car charging operator, who does not operate in energy markets. The consumer in a smart home/property has granted consent for the collection of energy data and made a contract with the sub-aggregator that controls the property as agreed. The sub-aggregator measures, monitors and estimates the consumptions and capacity of the devices of the property, including the smart devices and the regular devices, and makes analysis and predictions about the energy consumptions and thereafter the flexibility potential. The aggregator provides the flexibility to the different markets and is responsible for the validation of the flexibility. Table 7 describes the reference use cases that were derived from Scenario 1. The use cases concentrate on the operation of the flexibility markets and the co-operation of actors.

2) SCENARIO 2: ACTING IN NEW FLEXIBILITY MARKETS

Flexibility can be offered to the markets in the form of a virtual power plant that aggregates several energy resources into one controllable unit. The plant is usually controlled by a large actor such as an aggregator. Also, small resources could participate in the markets directly if the structure of the markets were changed. In this way, there is no need for an aggregator, but the small actors (e.g. households) could be market actors and provide the flexibility by themselves. New service providers would emerge that would be responsible for the functionalities between the households and the markets. There must be common rules on the markets; how to operate, make contracts, validate flexibility and so on. The legislation and the possible restrictions must be taken into account. One possibility to implement the markets could be the automation of trading with bots that are already familiar from money exchanges. The operation of bots should be highly regulated in order to guarantee the reliability of the electricity grid. Bots should be available only for certified actors that fulfill the security and reliability requirements. Table 8 describes the reference use cases that were derived from Scenario 2. These concentrate mainly on providing flexibility to the markets in the form of a virtual power plant and operating in new markets.

F. THE ECOSYSTEM CONCEPT

All in all, 70 requirements could be identified with the help of iterative analysis of company interviews, user stories and the main scenarios with the reference use cases. The requirements were classified into three main categories. Ecosystem-related requirements define the ecosystem concept, including the required support services and knowledge models that the ecosystem must provide in order for the different actors to implement the desired activities. Architecture-related requirements define the reference architecture that takes care of energy data management in the ecosystem. Data-related requirements define the required properties of the data, the required data itself and data management in the ecosystem. These include the knowledge, information and data that is required for the ecosystem to operate. The actual content of the data is determined by the ecosystem, whereas the structure and data models are determined by the reference architecture.

The identified requirements enabled identification of different levels in the operation of the ecosystem actors. The next sub-sections describe these levels together with the required support from the ecosystem.

1) OPERATION LEVELS

Figure 4 describes the identified levels in an ecosystem operation based on the actors' goals and foreseen future tasks in energy markets.

TABLE 6. Viewpoints of different roles to the change scenarios.

Role	Goal	Task(s)
Consumer	*Achieving economic benefits and making ecological choices when adjusting consumption based on network needs. *Free competition that provides savings.	*Offering flexibility by registering to new flexibility markets. *Is able to change aggregator, i.e. virtual power plant provider.
Building owner	*Achieving benefits from total energy infrastructure of owned properties. Is interested in customer satisfaction.	*Making investments and solutions at construction time may enable new types of flexibility offerings.
Tenant	*Good living comfort	*Setting preferences related to living comfort
Aggregator	*Monetary benefits when able to provide aggregation solutions. *Aggregating flexibility from several sites. *Bringing local and non-local market strategies together better on its owned consumption sites.	*Providing flexibility to appropriate energy markets. *Providing (local) flexibility as an aggregator by registering in non-local markets. *Can analyze and optimize cost benefits of different flexibility (local/non-local) choices.
Sub-aggregator	*Wants to concentrate on continuous customer relations.	*Hands market role over to the selected aggregator.
Technology provider	*Offering customers new types of technical flexibility solutions cost-effectively. *Offering technology solutions to small property owners that enable aggregation of small loads to energy markets.	*Offers technical solutions and secure interfaces so that customers can participate in new types of flexibility markets. *Offers solutions and secure interfaces for virtual power plants for aggregation.
DSO	*Wants to minimize overall costs and improve the utilization of network. *Regulation changes and other change scenarios cause need to utilize flexibility. *Ensures that TSO market flexibility does not disturb DSO network.	*Diminishes power fluctuation in network by utilizing consumer-provided flexibility. *Is able to save investing costs by using flexibility instead of improving throughput of network. Can buy flexibility from markets. *Wants to see the events in TSO markets.
TSO	*Network functionality and division of responsibility of network to other parties. *Motivation of balance responsible parties to provide better forecasts. *Prevention of balancing conflicts between different marketplaces. *Ensuring the accuracy and dependability of forecasts related to balancing.	*Offers new and differing levels of flexibility markets and buys smaller flexibility services provided by aggregators. *Sets more sanctions for balancing errors. *In the future: real-time data transfer to communicate the flexibility agreement, and real-time markets with shorter time-window (e.g. 15 min balance responsibility).

TABLE 7. The reference use cases of Scenario 1.

Use case name	Rationale
1: Buying flexibility in new flexibility markets	The most suitable flexibility offering must be selected in the flexibility markets automatically. In the markets, the flexibility provider could be represented by "a bot" that digitally negotiates with the TSO's "bot" and agrees on the contract (Bot is an acronym for robot and stands for a computer program that can work independently within the limits of its pre-defined policies).
2: Data transfer between the local markets and TSO markets	Market transactions must be approved on higher hierarchy levels, e.g. the consumption and the production in the DSO network has to be approved both by electricity retailers (i.e. balance responsible parties) and the TSO which is responsible for balancing the whole transmission network. Realized market transactions must be verifiable afterwards in order allocate costs and incentives.
3: Site-specific flexibility and consumer services	An energy service must be defined together with a consumer, as well as its implementation in an environment where there are several technology providers and different energy resources providing flexibility potential.

a: MARKET LEVEL: OPERATION IN FLEXIBILITY MARKETS

The flexibility provider (e.g. an aggregator) must be able to reach the real-time status of the energy resources that constructs the flexibility potential and updates the offered flexibility accordingly, and to monitor the market situation and adjust the price accordingly. To enable the uniform

TABLE 8. The reference use cases of Scenario 2.

Use case name	Rationale
4: Adding sites into the virtual power plant	A new site must be easily added as part of an existing virtual power plant. A site is represented by a sub-aggregator that monitors the site and collects and analyzes the data that is provided to the aggregator when adding the site to a virtual power plant.
5: Registering the virtual power plant into reserve markets	Certification service is used to verify that the virtual power plant fulfills the acceptance criteria. The criteria include, for example, the requirements for the reliability of the aggregator, the amount of provided flexibility, availability, etc. If the requirements are met, the virtual power plants is accepted as a market operator.
6: Operation of the virtual power plant in the reserve markets	The operation of a virtual power plant includes, for example, selling flexibility to energy markets, money transaction between different actors, controlling single sites and/or energy resources, analysis and prediction of the energy production, the amount of flexibility and the status of energy resources of the virtual power plant, and the optimization of the operational and financial performance of the plant.
7: Bringing small loads directly into new flexibility markets	Small actors (e.g. consumers) can bring their own loads to the flexibility market, possibly with the help of intermediate service providers. Certification service is used to verify that the actor fulfills the acceptance criteria, such as reliability/trustworthiness, availability, amount of provided flexibility, location, etc.

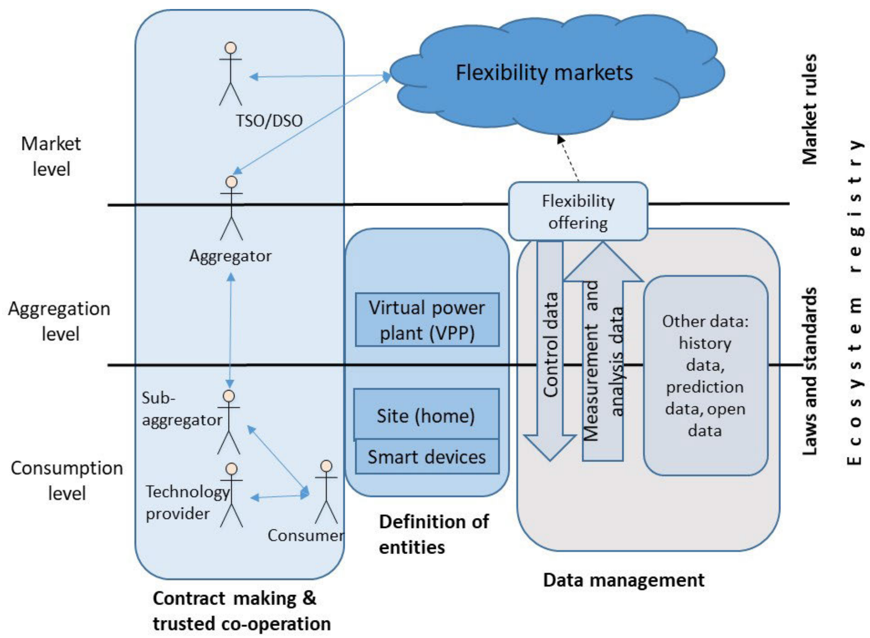

FIGURE 4. The operation levels in an ecosystem and the support from the ecosystem.

offerings, a form/template for offering the flexibility potential is necessity. The knowledge models (e.g. the offering template and measurement baselines) and support services (e.g. analysis services) from the ecosystem registry assist the aggregator in the activities. An actor that utilizes the flexibility (e.g. TSO or DSO) selects the most suitable flexibility operator and requires services and knowledge models from the registry for contract making and money transfer.

b: AGGREGATION LEVEL: AGGREGATION OF CONTROLLABLE LOAD

To be able to control several sites, the aggregator needs analysis services and knowledge models for making analyses and predictions about the energy consumptions of sites, and for combining the analyses of several sites. The energy data is measured directly or with the help of a sub-aggregator that controls single sites, and is analyzed with other data, such as history data of sites and open data (e.g. weather data). An aggregator provides the total package of flexibility potential to a market actor (or can be a market actor itself), monitors the sites that construct the potential, and gives control commands to sites/devices according to the instructions of the market actor to increase/decrease consumption. Data management services and policies have an important role for transferring data between the aggregator and sub-aggregators, analyzing data, and verifying that the control commands have implemented the agreed flexibility.

c: CONSUMPTION LEVEL: CONTROLLING HOME DEVICES

One to many technology providers provide the devices and systems to the consumer, which enable control by a third party. A sub-aggregator coordinates the devices and represents a site, providing the predicted flexibility potential of the site to an aggregator. The sub-aggregator also controls the home devices according to the commands from the aggregator. These controls must be in accordance with the contract with the consumer. The content for the agreement with the consumer must be defined. Using this, the consumer grants consent and accepts the terms of his/her data collection and usage, and the control of his/her devices. However, the consumer can define the boundaries for the control, and he/she must have rights to take control of the devices.

2) SUPPORT FROM THE ECOSYSTEM

Based on the results, the following support is required from the ecosystem to enable the goals of the different ecosystem actors (see Figiure 4).

a: CONTRACT MAKING

The ecosystem must assist in contract making (so called ''smart contracts'') between different types of actors, including the contracts between sub-aggregators & consumers, sub-aggregators & aggregators, and TSO/DSO & flexibility provider. The contract making must be flexible and automatic, and the contract must define the roles and responsibilities of each party, the achieved value, and the data that is required to be transferred between the actors.

b: TRUSTED CO-OPERATION

The ecosystem must assist in certifying different entities for the ecosystem actors for reliable co-operation, such as the actors and the virtual power plants. The certification includes the evaluation policies and verification that the entities meet the acceptance criteria. Virtual power plant evaluation policy defines when and how the virtual power plant is evaluated, and the criteria include, for example, the minimum amount of flexibility, interfaces, and availability. The criteria for actor acceptance may include, for example, reliability and trustworthiness of the actor.

c: DATA MANAGEMENT

The heterogeneous and huge amount of different types of data sources require data management policies that include all the strategies, tactics, metrics and definitions used to manage data inside the ecosystem, making the data valuable for ecosystem members. The policy contains the following parts:

- Data privacy and ownerships: The collected data is usually consumption data that enables recognizing the consumer's consumption habits. This data is private and its usage requires consent from the consumer, and the delicate means to manage it.
- Data quality: The collection of energy data and feedback data requires data filtering, processing, evaluation and validation policies and services to achieve valuable, high-quality data.
- Monitoring and measurement: Common measurements for different types of entities are required to be defined for comparative analysis and value reliability estimation. A common baseline is required to unify the measurement results, enabling them to be consistent and comparable.
- Data analysis: Data analysis is required for flexibility estimation and prediction, for balance prediction, and for future prediction of the virtual power plant. Uniform analysis policies in the ecosystem are required to define a common way to analyze the virtual power plant for optimizing and adjusting the plant operation, to analyze the site to reveal the current status and to predict the future flexibility, and to analyze collected data from an energy resource to measure and monitor the status of the resources. In addition, the baseline (i.e. comparative values) for flexibility verification must be defined to enable the objective flexibility verification.
- Controlling: Controlling the virtual power plants, sites and energy resources is implemented according to the signals from the markets (i.e. the agreed flexibility contract between the flexibility provider and the DSO/TSO). The controlling must be agreed in contracts between the virtual power plant's owner (or the aggregator), the site owner and/or the consumer. Agreed interfaces are required for different devices and systems to co-operate.

d: LAWS, STANDARDS AND MARKET RULES

The relevant international and national laws and standards must be taken into account in the ecosystem. Several efforts already exist for the different parts of the Smart Grid, most of them collected by the International Electrotechnical Commission (http://smartgridstandardsmap.com/). In addition, the markets have their own controlling rules that must be followed.

e: DEFINITION OF ENTITIES

All the entities that are accepted to the ecosystem must be described with the metadata that describe their properties. The entities include energy resources (e.g. refrigerator, battery, and energy storage), the sites (e.g. apartments, houses, offices, and factories), virtual power plants, the ecosystem actors, data sources, data sets, smart energy services and flexibility offering. The definition of smart energy service must include the content of the service, involved actors (i.e. the service consumer and provider) and the value it provides to the involved actors. The flexibility offering must include the data at least about the location, the amount (and the predicted amount) of the flexibility, the duration of the flexibility, and the price.

f: MAINTAINING A REGISTRY

The ecosystem must maintain a registry of several types of data, including accepted actors and virtual power plants (incl.

the sites and the energy resources of which they consist), current and past contracts between the ecosystem actors, current and past flexibility offerings, and the implemented flexibility, consents from consumers for data collection and device adjustment and feedback data. In addition, the registry manages the available support services (e.g. analysis services, visualization services, evaluation and certification services) and knowledge models (e.g. evaluation policies, acceptance criteria, definitions) for the different actions of the ecosystem. Furthermore, the registry manages the energy data that is available for the utilization of the different ecosystem actors according to the contract.

V. DISCUSSION

A. DESCRIPTION OF ELEMENTS OF AN ENERGY DATA ECOSYSTEM

The main elements of the ecosystem (see Figure 1) and their content are here discussed from the viewpoint of the results of this research.

1) CAPABILITY MODEL

The management and actions form the capability model of the ecosystem, i.e. its capability to perform actions, describing when, how and by who these actions are implemented.

- **Management:** The energy data ecosystem requires an actor, an ecosystem provider, who takes care of the management, support, marketing and maintenance of the ecosystem. Usually a large actor or the one that gathers the different actors together can take this role. In the energy domain, this would be an apparent role for a TSO that could provide the future flexibility markets, and possible manage flexibility with common rules and a regulatory model. However, also a large DSO, a large energy seller or even a large technology provider could establish an ecosystem with the help of collaborators.
- **Actions:** Two main scenarios were identified that were seen to describe the main actions in the ecosystem: bringing small loads to current flexibility markets, thereby controlling consumers' smart devices and enabling the provision of new consumer services, and acting in new markets where different actors, even small actors, can provide their capacity directly to new flexibility markets. The scenarios were refined into seven smaller activities that were seen as the reference use cases of the ecosystem. These activities can be refined further into two categories. *Ecosystem governance and management related activities* include all the activities related to offering flexibility and in operating in flexibility markets, assisting in co-operation, certifying different entities for the ecosystem, and description of the principles, strategies, tactics and guidelines of the ecosystem that is common to all ecosystem members. *Activities related to data* include the activities related to data management support, such as assisting in data analysis and prediction on different levels, managing data visualization and access to data, description of data entities, description of criteria and evaluation practices for different ecosystem elements, and defining the data content in data transfer between different ecosystem actors.

2) DATA

Data is the key asset in the ecosystem, and the energy data ecosystem must manage different kinds of data. One type of data is the data required to manage the ecosystem itself, such as evaluation and acceptance criteria, definition of entities and elements, and the registry of support services, knowledge management models, and the registry of accepted entities. These kinds of data assets are managed through the ecosystem data management models and data policies. Another type of data is the energy data itself that is managed usually with the help of data management architecture. The energy data typically include energy consumption data, but new smart devices and technology also enable real-time collection of energy consumption data from each device. Data management actions must be carefully defined in an ecosystem, including the phases in the data life cycle (i.e. data production, collection, aggregation, processing, storing, integration, analysis, transfer and utilization). Data management and trading requires a managed registry used to search the applicable data, verifying the properties of data (including quality) and purchasing the data or the data license. The data itself can be located somewhere else.

3) ACTORS

Each actor acts in one or several roles in the ecosystem. To enable smooth co-operation in an ecosystem, the actor's rights, responsibilities and obligations must be defined, when each actor has its share of profits and there will be no conflicts. Several actor roles could be identified, of which some of them considered the existing roles in the energy domain but the role descriptions were refined, and also several new roles could be identified, such as different types of consumers, aggregators and sub-aggregators, energy data-based service providers and flexibility providers. Especially providing flexibility and operation of virtual power plants bring new challenges to the role descriptions (rights, responsibilities) of different actors. Also, the actor 'energy consumer' is challenging, since the consumer can act in different roles.

4) SUPPORT SERVICES

Support services assists in implementation of the activities in the ecosystem. These services are usually provided by third-party service providers that receive a fee for the service usage. The support services identified in this research could be categorized into the following groups: market services, co-operation services, visualization services, data management services, analysis services, monitoring services, controlling services, certification services and tool services. The market services, co-operation service and partly the certification services represent the services for ecosystem governance

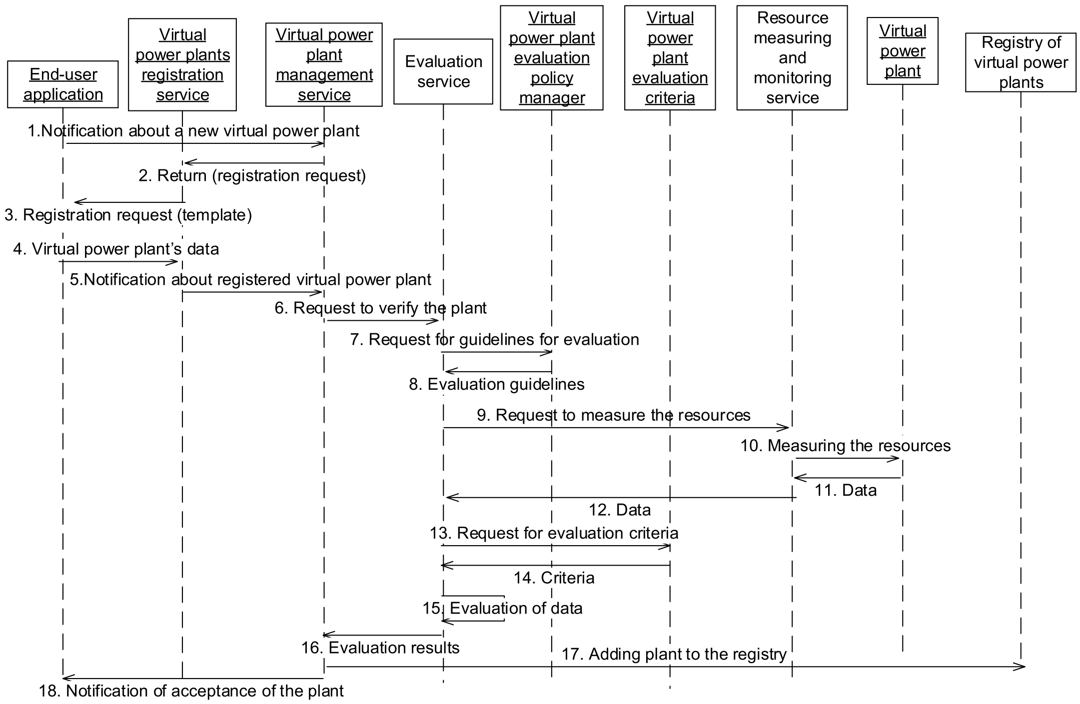

FIGURE 5. **Implementation of a use case with the help of ecosystem support services and knowledge models.**

and regulation, whereas the rest represent the data-based activities. The services of these categories are needed to implement the two main scenarios and seven referenced use cases. New services are especially needed when acting in new flexibility markets. Currently, several actors in the ecosystem already have their own analysis and device control services. However, if these services were provided by the ecosystem (by a trusted actor in an ecosystem), it would be easier for the smaller actors to enter the energy markets.

5) KNOWLEDGE

Knowledge assets of the ecosystem are required for ecosystem operation and management. Ecosystem policy is common to all ecosystem members, defining actor roles, rights and responsibilities, ecosystem-enabled actions, criteria for actors, and contracts and the role of consumers. In addition, the current laws and standards must be taken into account in ecosystem operation. Data management is controlled by the data and data evaluation policies. Data policies define the allowed entities and other data assets of the ecosystem, and the policies to handle the collected energy data. Data evaluation policy defines the activities and criteria for the evaluation of the different data assets in the ecosystem. In addition, the knowledge management models of the ecosystem also include the models, practices, processes, ontologies and other artifacts for service development and evaluation, and most importantly, the domain model that defines the elements and their relationships in the energy domain.

6) CORE OF THE ECOSYSTEM

Some type of registry is required that stores the assets of the ecosystem, also assisting in managing them. These include the different items, such as support services, knowledge assets, data and flexibility offerings. For example, the Digital Services Hub as used in [13] can contain any digital entities that have a digital API; e.g. data, support services, digital services, etc.

B. IMPLEMENTATION OF ECOSYSTEM ACTIVITIES

To implement the main scenarios and related activities, several support services and knowledge models could be identified. Figure 5 describes an example of how the identified support services and knowledge models assist in implementing the reference use case 5 (Registering virtual power plant into reserve markets) at the conceptual level.

Description of the implementation:

1. An aggregator notifies (through an end-user application) the virtual power plant management service about a new virtual power plant that they wish to register to the markets.
2. The management service notifies the registration service to start the registration process.
3. The registration service enters the registration template to the aggregator.
4. The aggregator fulfills the template and returns it to the registration service.
5. The registration service notifies the virtual power plant management service about a new registration.
6. The virtual power plant management service asks the evaluation service to verify that the plant is acceptable to the ecosystem.
7. The evaluation service requests policy manager for guidelines for the evaluation of the properties of a virtual power plant.

8. The guidelines are returned to the evaluation service from the virtual power plant evaluation policy manager.
9. With the guidelines, the evaluation service asks the measurement and monitoring service to measure the properties of the plant.
10. The measurement and monitoring service measures the properties of the plant.
11. The measurement and monitoring service receives the data.
12. The measurement data is returned to the evaluation service.
13. The valuation service checks the right evaluation criteria for the virtual power plant.
14. The evaluation criteria are returned to the evaluation service.
15. The evaluation service analyses the data and performs the evaluation of the data against the evaluation criteria.
16. The evaluation service returns the evaluation results to the virtual power plant management service.
17. If the virtual power plant fulfills its criteria, the plant is accepted to the ecosystem, and the virtual power plant management service enters the data of the plant to the registry of virtual power plants.
18. The virtual power plant management service notifies the aggregator about the acceptance of the plant.

C. SUMMARY AND NEXT STEPS

As a summary, it can be detected that the digitalization and the changes it causes have been well understood among the companies, and some of the companies already had a clear vision of their future functionalities. The interviewed companies had a high degree of interest towards co-operation and data exchange. This research managed to gather the viewpoints of six major actor roles of energy markets, and several new actor roles could be identified that are apparent in future energy markets. It was apparent that each of the companies can take more than one role in a future energy ecosystem.

As a result of this research, the most interesting issue from the viewpoint of energy domain actors was identified to be flexibility markets, i.e. different actors (e.g. electricity sellers and aggregators) can offer their aggregated loads as flexibility potential, as well as a single energy consumer can offer his/her property as a flexibility unit. Several rules and policies must be defined to enable the operation of this kind of flexibility market. These include, for example, the criteria that the actors and virtual power plants must meet to be accepted to the markets, how those criteria are evaluated, the responsibilities of each actor in flexibility offering and utilization, and how to share profits for all the actors that are involved in the implemented flexibility. These cannot be defined strictly until the ecosystem is established and these are agreed by the ecosystem actors. This work managed to define the framework of the elements required to be defined when combining forces for new co-operation. The benefits of the ecosystem in the energy domain will be similar to those in any other domain: trusted relationships, certified quality of data, rights and responsibilities for activities, applicable knowledge models and support services, and reliable co-operation to create value.

Our next step is to define the data management architecture for the ecosystem. This will be provided in the form of a reference architecture that describes the elements and the structure of the system, as well as the interactions of elements in their actual environment, thus being a guideline for implementing system and application architecture. This architecture would be responsible for real-time energy data management, exchange and trading in different phases of data life cycle. The goal is to enable the interoperability, transparency and control, supporting the identified main scenarios. However, the energy data ecosystem also manages a lot of other data in addition to energy data, and the separation of this data from energy-related data is not always clear. This requires that the relationship between the energy data ecosystem concept and data management architecture must be specifically defined.

As the results of this research showed, the actors in the energy domain are highly interested in providing their aggregated loads into new flexibility markets. These flexibility markets highlight the role of the energy consumer; the consumer can make a contract and thus agree that the smart devices at his/her home are controlled by a third party that offers the load to the flexibility markets, or the consumer can possibly in the future offer his/her small loads directly to these markets. It is important to examine the viewpoint of the energy consumer to the visions of the actors of the energy domain, and to reveal the main motives and attractions for consumers to participate in this kind of new energy market. This is also one of our forthcoming research steps.

The selection of companies and interviewees have an effect on the results of this research. Thus, the identified requirements cannot be directly generalized for all companies, but more specific requirements may emerge from the viewpoints of smaller actors. This research managed to obtain the requirements for an energy data ecosystem from the viewpoint of nine Finnish companies. Thus, the results of the interviews cannot be directly globally generalized. For example, the requirements for flexibility, and amount and characteristics of available flexibility resources differ greatly in European countries, potentially resulting in different dynamics between ecosystem parties [24]. However, the demand for energy data and its management can be assumed to be current issues in other countries in Europe as well, and the resources of neighboring countries can complement each other.

VI. CONCLUSIONS

Digitalization in the energy domain causes change pressures for the actors to transform their business models and to innovate new business possibilities and functionalities in order to maintain their positions. Currently, the lack of digital infrastructure complicates co-operation and energy data exchange between different actors. To address this issue, this paper introduced requirements for an energy data ecosystem based on a literature survey and the information collected during the interviews among companies in the energy domain. This kind of ecosystem concept provides required elements, such as support services and knowledge management models that are required to act and co-operate in new energy markets. The interviews among energy company representatives revealed several new actor roles and new business possibilities for the existing actors, and several requirements considering the supporting services, knowledge management models, knowledge and the data itself.

This research identified two main scenarios that represent the main future actions in the energy domain agreed on by the interviewed companies:) bringing small loads to current flexibility markets, when smart homes and/or properties can be thought of as a flexibility potential that can be provided to the flexibility markets of TSO/DSO, and 2) acting in new flexibility markets, when the market structure is changed in a way that flexibility can be offered in the form of virtual power plants, or small consumers can participate directly in energy markets providing their own flexibility. In both cases, the participation and/or the consent of the consumer (i.e. home or property resident) is required. The smart device and system monitoring and controlling also enable the innovation of new kinds of data-based consumer services. The results of this research showed that Finnish companies are very aware of the possibilities of the flexibility markets and new market structures, but also detect risks, challenges and deficiencies that cause them to carefully consider the new scenarios.

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ANNE IMMONEN received the M.Sc. and Ph.D. degrees from the University of Oulu, Finland, in 2002 and 2018, respectively. Since 2002, she has been a Research Scientist with the VTT Technical Research Centre of Finland, and the last four years as a Senior Scientist. Her main research interests include quality-driven service engineering, digital service ecosystems, data ecosystems, and data quality evaluation. Currently, she is involved in a research project within energy domain, in which her current areas of interest are data and quality management in an energy data ecosystem, new business models, and innovation of new kind of data-based smart services.

JARMO KALAOJA received the M.Tech. degree in electrical engineering from the University of Oulu, Finland, in 1986. He has over 30 years of experience in customer and research projects in the area of software architectures and domain modeling. He is currently with the VTT Technical Research Centre of Finland, Oulu, as a Senior Research Scientist. His research interests include software architecture and data modeling, analysis and design of service-oriented architectures, semantic technologies, and linked data. He has recently been working in various European research projects in the fields of energy systems and data-driven bioeconomy.