# A Framework for Exploring and Explaining the Ecosystem of Energy efficiency and Flexibility

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#### Abstract

In this paper we present a framework that aims at exploring and explaining how an energy efficiency and flexibility ecosystem emerges. The framework builds on two theories, namely information ecology theory and architectural theory of digital innovation. The framework is used in an initial test by using descriptive data from an organization working as an aggregator in the energy market. From the combination of the theories and the initial test using descriptions from the aggregator case and its products and services in the context of energy efficiency and flexibility the potential of the framework is shown. It can be concluded that the framework has a potential to explore and explain the ecosystem of an aggregator regarding energy efficiency and flexibility and by highlighting the four integration tasks; sharing, combining, standardizing, and multi-homing it can guide future development of a platform ecosystem.

#### **Keywords**

Smart grid, ecosystem, aggregator, energy efficiency, flexibility

## 1. Introduction

The energy sector and particularly the electric power industry are facing many changes due to utilization of different digital technologies and emergence of new services for different parts of power grid system [1]. A major challenge is to consider the increase of electricity demand due to growing electrification and urbanization and at the same time, dealing with limitations in electricity network capacity to transmit and distribute electricity. This challenge has motivated providing services related to energy flexibility [2]. Particularly, as stated by Karnung and Ramkvist [3], upgrading and renovating the electricity transmission network is a considerably time-consuming process in comparison to solving congestion problem in local network.

Energy flexibility is a service which leads to changes in the pattern of electricity consumption due to the price-based inventive [4] or/and as a response to the peak load of electricity in the grid [5]. From the challenges it can be claimed that there is a demand for new business models in the electric power industry. The advent of new business models implies a growing number of actors and even new actors such as aggregators [6] resulting in increasing complexities in service, product and business ecosystems. Since flexibility service can potentially be undertaken by the aggregators, additional to the importance of them, it can be an incentive to investigate how these services actually could be beneficial. It is also a question how to actually research this combination of service and product in order to further develop both understanding and contribution from what could be labeled as an energy efficiency and flexibility ecosystem. This could be related to development of business models, and one consequence of business model emergence is the creation of new platforms through which services can be provided [7-9]. Due to various challenges in studying platforms such as conceptual, scoping and methodological issues, platforms have become a complex topic to investigate [10]. In this paper we present a framework that aims at being useful in exploring and explaining the emergence and understanding of an energy efficiency and flexibility ecosystem. The practical usefulness of the developed framework is that it could in the next step be used as input for future development of services and products in relation to an ecosystem dealing with efficiency and <sup>1</sup>Proceedings EGOV-CeDEM-ePart, September 05–07, 2023, Budapest, Hungary

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Use permitted under Creative Commons License Attribution 4.0 International (CC BY 4.0). CEUR Workshop Proceedings (CEUR-WS.org) flexibilities challenges in the energy system. In this study, the ecosystem is delimited to the components that are exclusively required for the service provision, and these are provided by energy sector-related actors.

The framework presented builds on two theories: Information ecology theory and architectural theory of digital innovation and we show how these two theories can be combined. Information ecology theory by Wang [11], elaborates on relationships between part and whole in ecosystems. The architectural theory of digital innovation by Yoo, Henfridsson [12], on the other hand, deals with the layered modular architecture of digital technologies, and paves the way to have an architectural perspective when exploring and explaining an energy efficiency and flexibility ecosystem. This paper will be proceeded with background information followed by presenting findings from an initial test of the framework and then concluding remarks and future research related to the framework

# 2. Background

# 2.1. Power grid transformation and platform

Over time, power grids have transformed from a centralized generation and transmission model to a smart grid structure that includes complementary services such as auditing, maintenance, and energy efficiency [1]. This transformation has been driven by the implementation of smart meters [13], an increase in distributed energy resources [14], and market liberalization in some parts of the world [2].

However, due to growing electrification and urbanization, challenges remain in the form of limited capacity of the grid network and the long process of renovating and upgrading this part [3]. This has led to the emergence of new business models and platforms that offer energy efficiency, flexibility, and trading services [2]. These platforms are defined in various ways, depending on the context or application of the studies. For example, Ardolino, Saccani [15] defined service platforms as seeking to create a mixture of products and services for efficiency improvement and cost reduction. Similarly, Idries, Krogstie [7] drew on different definitions and introduced service platform as a "modular structure that contains both tangible and intangible resources that ease and facilitate the interaction between actors and resources (p.4)." Menzel and Teubner [9] defined a green energy platform as "the study of digital platform markets that either facilitate the trading of energy from renewable sources or enable the integration of renewable energy into the energy system" (p. 457).

#### Table1.

summarizing the platform definitions in energy sector

Authors	Context or application	Components of platform		
Ardolino, Saccani [15]	Service	Service and product		
Idries, Krogstie [7]	Service	Business actors, service and product		
Menzel and Teubner [9]	Green energy, marketplace	Product and service		
Kloppenburg and Boekelo [8]	Communication	Business actors, service and product		

Kloppenburg and Boekelo [8] adopted a sociotechnical perspective and defined platforms as "digital spaces where users can communicate and interact with each other and get (temporary or permanent) access to products, services, or more broadly 'resources' provided by peers or organizations" (p.68). Ma, Clausen [16] emphasized the ecosystem aspect of a platform when studying a specific type of business model in power grids in the digitalization era. As shown in table 1, the constructive components of these platform definitions include service and product, business

actors, or a combination of these three, implying that although platforms create their ecosystem, this ecosystem can exist at different levels (e.g., service and product level, business level).

Adopting different perspectives could shed light on different angles regarding platforms and platformization in the energy sector. However, as shown by different research [e.g., 7, 16], issues with the ecosystem surrounding the platforms in the energy sector and the integration of components of platforms into ecosystems needs to be investigated. In other words, it is not clear how a combination of different components encompassing products and services provided by different actors which create a platform led to emergence of a business ecosystem.

Therefore, to facilitate the understanding of the ecosystem emergence, we aim to suggest a framework to explore and explain how the energy efficiency and flexibility ecosystem emerges from the components of its platform in the product and service level. Having this in mind, the background will proceed with an elaboration on the suggested theories that build up the framework.

# 2.2. Information ecology theory

Wang [11] employs the information ecology theory to explain how the relationships among actors involved in digital innovation mirror ecological ecosystems. Information ecology theory aims to explain the part-whole imbalance and specify the role of digital technology in an ecosystem. Part-whole imbalance means focusing on actors and their actions and relationships and forgetting the ecosystem as a whole. This imbalance undermines the interaction between parts and the whole ecosystem.

According to Wang [11] the digital innovation ecosystem is comprised of loosely connected actors, including individuals and organizations, working together to develop and implement innovations using digital technologies. The holon concept [17] is used to describe the dual nature of the elements of an ecosystem, which can act as both parts and wholes simultaneously. To explain the emergence of a business ecosystem from its subordinates, Wang [11] proposes four tasks: sharing, combining, standardizing, and multi-homing. Sharing refers to intra and inter circulation of data, knowledge, information or any other required sources essential for the survival of the ecosystem among the actors. Combining implies the process in which different elements of actors mix with one another. Standardizing refers to standards followed by the actors, de facto or de jure [11]. Multi-homing is observed when an actor is present in more than one ecosystem [18]. For example, the presence of software developers in iOS and Android ecosystem [19] shows that actors do not necessarily provide services to only one ecosystem. This study assumes the components in the service and product level as parts and the case organization ecosystem for energy efficiency and flexibility as a whole. Utilizing this theory and the incorporated tasks help to understand the ecosystem emergence from the components in the service and product level.

## 2.3. Architectural theory of digital innovation

Although in the previous section, four tasks for the emergence of an ecosystem [11] were explained, the way these tasks can be performed among the actors is not fully answered. To do so, we suggest adopting the layered modular architecture of digital innovation theory [12]. We do so in order to more clearly explore and explain how different integration tasks are carried out. Moreover, this theory is compatible with architectural definition of platform since platforms are considered as the instantiation of layered modular architecture [20]. In other words, digital platforms possess layered and modular technology architectures, which operate within an ecosystem [21]. These platforms have the ability to orchestrate technological components to promote co-innovation and collaborate among various ecosystem actors [21]. Therefore, our framework is able to explain integration tasks through the interaction of product and service components in the ecosystem. Yoo, Henfridsson [12] synthesized the layered architecture of digital technology [22] and the modular architecture of physical products [23] to propose a new organizing logic of digital innovation. The proposed architectural theory comprises four layers: device, network, service, and content. The device layer contains machinery and logical capabilities, the network layer refers to communication components of digital technologies, the service layer deals with application functionality, and the content layer

includes various data and graphical elements for users. Modularity is the degree to which a product is decomposed into its constructive entities [23]. The combination of layering and modularity replaces the top-down design logic of a product with a bottom-up logic [24, 25]. The bottom layer of the stack (i.e., device layer) is a relatively stable core that is not easily changeable, while the upper layers of the stack (i.e., service and content) are the periphery layers that developers can frequently change through data manipulation [26]. This architecture allows a separation between hardware and software, enabling digital and physical components to be mixed in different ways [27]. Our framework suggests exploring and explaining energy efficiency and flexibility ecosystem by adopting a sociotechnical definition [10]. It describes a platform as technical elements including software and hardware distributed in different layers of platform architecture and associated organizational processes and standards. It does so among ecosystem actors in the business level of holarchy that enable the provision of energy efficiency and flexibility. In this definition, hardware and software make up the architecture of platform [12] which are present on the service and product level of holarchy. Organizational processes and standards respectively reflect the business actors in the business level of holarchy [11]. Thus, Information ecology comprises the social and architectural theory of digital innovation elucidates the technical part of the definition.

### 3. Method

The aim of this paper is to present a framework that could be used to explore and explain an energy efficiency and flexibility ecosystem. This study started with the reviewing of the literature of digital platform in energy sector and the ecosystem of energy flexibility. As shown in the literature, due to high modularity of energy flexibility and defining the platform in different level of analysis including product, service and business levels, two theories were selected to serve this study as a lens for data collection and analysis. These two theories are information ecology theory and architectural theory of digital innovation. The Information ecology theory provided us with the following four tasks: sharing, combining, standardizing and multi-homing. While the architectural theory of digital innovation provided us with the perspective of layering (layered artefacts) and modularity.

To execute a first test, different companies related to the context of the research were identified. The initial selection of companies was delimited to the energy efficiency and flexibility services directly and indirectly associated with the single households. For finding an initial case which suit the ambition of this study, two resources were used: Färegård and Miletic [4] by introducing the actors (aggregators) and their role in energy efficiency and flexibility and Crunchbase.com by providing the search and filtration options for searching organizations. One specific company in Sweden emerged as a suitable candidate for this study among several potential aggregators. This company was chosen because it offers a diverse range of services and products (as presented in table 2), which aligns well with our research framework. Additionally, compared to similar companies, this organization had a higher level of data accessibility. Finally, considering the feasibility of establishing communication and the potential for ongoing collaboration, we decided to select this company as our case organization. Due to privacy concerns regarding the next stages of our research with the case organization, the name of the company is anonymized. Therefore, we will refer to this company as Alfa throughout this paper.

Upon selection of the case organization, the necessary data was collected to test the proposed framework. This data comprised of the company's webpage and related documents, which detailed the implementation of services and products to facilitate efficiency and flexibility. Additionally, 20 documents from Svenskakraftnät [28] (TSO) webpage were collected to supplement the data, providing insight into the structure of the Swedish flexibility market and the ecosystem actors involved in providing flexibility services. To analyze the data, this study employed document qualitative analysis approach [29] to identify the actors involved and their respective products and services, thus shaping the service and product level of the holarchy as presented in Figure 2. Subsequently, each component at the service and product level was analyzed against the layered modular architecture framework to identify the constructive elements of the energy efficiency and flexibility platform (Figure 1).

Layered architecture	Heating system	Layered architecture	Advanced metering infrastructure	Layered architecture	Service type 1	Layered architecture	Service type 2	Layered architecture	Service type 5	Layered architecture	Electricity provision and billing
Content	Functional indicators of the heat pump (e.g., temperature)	Content	Record and transmitting Consumption data	Content	Consumers interface visible on their cellphones (mobile app), cloud service app, and website Turning the gathered data to functions and applications (e.g., consumption	Content		Content	-		Depends on the service (e.g., spot price indicators)
							Connecting to the main phone app as an add on	Service	to load balance of the grid for DSO and	Content	
	Decreasing and		Electricity provision						suppliers.	Service	Delivering electricity and billing based on contract type. Complementary services related to energy market (e.g., spot price comparison)
Service	increasing the heat according to the information of control box	Service	role and Enabling the supplier for complementary services (e.g.,	Service		Service	Showing the consumption history		Including the grid congestion into electricity consumption optimization and		
Network	Communication with	with d the e the Dnse Network	Transmitting		Circulating the data Network between the depositor, gateway and cloud		Sending the	ending the Network			
	control box (send the data and receive the respective response from the centrol how)		consumption data to supplier and tracker box	Network		information to the mobile app		communication between consumer facilities and	Network	Transmission of consumption data from	
Device	Heat numns	Device	Smart meters	Device	Depositor, Control box,	Device	the smart meter	Device	suppliers	Device	-

**Figure 1.** analyzing product and service level components against the layers of platform architecture

After establishing the roles of each service and product component in integration tasks, this study further explained each task by utilizing different layers of the layered modular architecture of digital technology.

# 3.1. Case organization

Alfa is a Swedish-based company which is a developer, manufacturer and seller of products (hardware and software) and services for energy efficiency and flexibility. The service and product scope of the company is shown in table 2. The service and products vary from diverse types of electricity consumers including single family houses (service type 1, service type 2), villas and apartments (service type 3, service type 4) to different power grid actors including electricity suppliers, distribution system operators (DSO), transmission system operators (TSO), balance responsibility parties (BRP) and district heating network owners (service type 4, service type 5).

#### Table 2

Type of service	Customer segment	Functions
service type 1	Single family house	Electricity consumption optimization
service type 2	Single family house	Electricity consumption tracker
service type 3	Condominium associations, Property owners	Electricity consumption distribution via individual metering and billing
service type 4	Condominium associations, Property owners, district heating companies	Control and optimization of properties' heating system
service type 5	District heating companies, electricity suppliers, electricity network companies (e.g., DSOs),	Power load control and optimization of district heating network

product and service portfolio of Alfa

This company shifts consumers' consumption by providing smart thermostats for controlling the heating system of buildings based on the consumers' preferences (ideal internal temperature), building energy efficiency, and electricity prices. The demand peak in the grid is not considered in the energy optimization' equation as long as the related services (e.g., service type 5) to the energy companies are not provided and required agreements are not made with DSOs. Therefore, by controlling the heat

pumps' thermostats, Alfa provides the cheapest electricity for households and simultaneously helps grid actors to reduce the potential congestion in the power grid by controlling the households' consumptions on demand.

# 4. Preliminary findings

This study, in line with holon and holarchy-components, shows a dual behavior as a part and a whole [17] and delineates that the components in the product and service level, despite having their individuality, are parts of the Alfa business ecosystem as a whole. As shown in Figure 2, each of the actors at the business ecosystem level has different ecosystems for specific purposes. The Alfa ecosystem is only one of the ecosystems constituted by a collaboration of different actors for the purpose of energy efficiency and flexibility provision. Each part of the product and service level, depicted by the layered modular architecture framework, shows how these pieces together create the foundation for the Alfa energy efficiency and flexibility ecosystem. Every integration task comprises different elements of the modular architecture framework.



**Figure 2.** The holarchy of energy efficiency and flexibility ecosystem emerges from a service and product components.

Each integration task - sharing, combining, standardizing and multi-homing- will be explained by the help of the dimensions of layered modular architecture as follows:

## 4.1. Sharing

Sharing in product and service level is observed in device and network of layered modular digital technologies. The most common device in this ecosystem includes smart meters, depositors, controller, gateway and heat pumps. Sharing by these devices refers to the presence of required device to enable the service provision for Alfa. The mentioned components need to be shared among the users so that they can benefit from energy optimization. However, important to state is that these devices are not provided by Alfa. Therefore, the required devices such as smear meters and heatpumps formed the infrastructure of flexibility ecosystem were constructed prior to creation of such services by other actors. In the network layer, sharing means that data should be transmitted between different technological components such as depositor, controller and gateway. For example, Alfa should be connected to the modem with a network socket (ethernet) and since the sensors (i.e., depositors) are wireless, they communicate with their own radio signals [30]. In a broader perspective, when providing the flexibility services, both suppliers and the consumers should be connected closely with each other implying that the flexibility should embody a solution that shift the consumption peak

[4] and thereby be a benefit for power grid actors and simultaneously manage to take the preference of the consumers (e.g., indoor temperature) into consideration for the electricity optimization. In this situation, communication between technological components on the consumer side (i.e., service type 1 and service type 2) and the electricity market actors (e.g., suppliers) is critical. This communication is possible only if the (near) real time information sharing task through the network layer happens.

In sharing mechanism, all ecosystem actors are involved in device and network layer. Thus, the data transferred among the technological components needs to be accessible for the actors whose function depends on that data [31].

### 4.2. Combining

Combining as defined before refers to mixing various elements from different actors together. In the product and service level, depending on the requested service, different elements should work together. Combining can be observed in all layers since this is essential if a service should be able to deliver the expected value. In the device layer, combing refers to the ability of the device to interact with each other physically. For instance, Alfa takes the physical compatibility of thermostat controller with heat pumps. It might be the case that this compatibility is not met, and providing services needs further customization. Combining the network level represents the process in which the sensorial data is aggregated and transfer to the service layer via the communication protocols [32]. These protocols are set of rules that must be followed when exchanging information between different entities [33]. Wang [11] explained how the combining task is a programming attribute of the digital technology [34, 35] due to the possibility for applying application programming interfaces (APIs) in platforms: "in order to become a platform, a software program—or a website—needs to provide an interface that allows for its (re)programming: an API" [34]. Alfa provides open APIs that enable third parties to use the sensorial data for different purposes [36] that basically make the development of various services possible [37-39].

It seems the role of APIs in developing and expanding ecosystems is prominent since they facilitate the creation of new applications [40]. Providing the APIs creates the opportunity for developers to build new services or integration of apps. APIs in this scenario connect the device layer of the platform to the service layer where other organizations, including other aggregators, can offer services to consumers through the devices provided by Alfa. Therefore, combining at the network layer is closely related to service layer. In network layer, additional to the importance of sharing the real time data, the way this data from different components combine to deliver a service needs to be noticed. In the service layer, the success of energy efficiency and flexibility will be materialized when the services both for the grid actors such as DSOs and the consumer side are appreciated. It means that implementation of only service type 1 for consumers or service type 5 for the grid side actors alone cannot result in electricity peak management and consequently flexibility services. Having inadequate number of consumers using service type 1, or the lack of grid actors' cooperation (service type 5 service) means that the services will be restricted to the consumers only for energy efficiency and cost saving purposes.

Finally, the combining task is reflected in content layer when the interface corresponding to other changes is modified. For instance, when service type 2 is purchased as an add on service for service type 1, the appearance of the mobile app changes accordingly in the user page which implies the changes of the content following the service updates. The interface is the outcome of combining all components in three mentioned layers.

It is interpreted that combing task make the ecosystem orchestration possible. In this task, the role of Alfa in the emergence of flexibility ecosystem is more than other actors since this company offer the final value to the customers.

### 4.3. Standardizing

Standardizing is observed in device layer when the essential condition of interoperability is in place, and it is then possible to use Alfa services from the different components. According to the Alfa website, service type 1 and service type 2 are almost compatible with all smart meters. In fact,

the smart meters should follow minimum functional requirements defined by Swedish Energy Markets Inspectorate (Ei) when they are installed by different DSOs [13]. Thus, these requirements act as the standards for the meter and that is why Alfa can build other components and related services on meters. Another sign of standardizing can be seen in the heat pumps provided by different manufacturers. One requirement for Alfa to be able to provide services to consumers is that the heat pumps should function with an external thermostat. However, even if it seems that many of the types and the brands are compatible with Alfa service not all types are compatible at the moment. Standardizing makes the foundation for combining tasks due to reducing the customization and expediting the service provision for households.

In the network layer, the salient responsibility of standardizing in device and network is on Alfa to make the components of the ecosystem interoperable. For instance, Alfa delineates that service type 1 public API supports JSON format via HTTP. Defining the format of APIs allows developers to incorporate encoding and decoding functionality into their application code. This ensures that data is appropriately structured when transmitted and received through the API.

### 4.4. Multi-homing

Multi-homing occurs across ecosystems [11] due to the actors' strategy to be present in more than one ecosystem. In our case, multi-homing happens when Alfa makes the heat pumps a resource of flexibility provision. By doing so, heat pumps become part of the flexibility ecosystem despite the fact they were never been used in this way before Alfa. Multi-homing in this scenario is observed in the device and network layer since a physical component is added to the flexibility ecosystem, which is a tool for data transferring between different components of the flexibility ecosystem. Similarly, another example is smart meters, which originally belonged to the energy provision and billing ecosystem under the control of DSOs, TSOs, and suppliers. However, they also have applications in the flexibility ecosystem. In other words, smart meters were initially designed to transmit consumption data to grid actors, but by utilizing them to provide flexibility services, Alfa enables them to serve a new service for the new ecosystem.

### 5. Concluding remarks and future research

The preliminary findings of the initial test of the framework show that combining is one of the critical tasks that seems to be more significant when it comes to the creation of an energy efficiency and flexibility ecosystem. Although we admit that it might be too early at this stage of research to prioritize importance of the tasks, it has been observed that the involvement of all elements of platform architecture, including device, network, service, and content in combining task, can signify the importance of it. Standardizing, sharing, and multihoming together seems essential in parallel to combining as they contribute to involving all layers of platform architecture in specific ways. Additionally, the device and network layers presented in all tasks depict the importance of these two ecosystem parts that need to be considered in power grids. It means the physical components (e.g., smart meters, sensors, heat pumps) and their interaction with one another at the product and service level and, at the same time, among associated organizations at the business level, play a crucial role in the formation of energy efficiency and flexibility ecosystem. Additionally, Alfa shows a different degree of dependence and independence in different tasks. For example, in the combining task, Alfa shows more independence to orchestrate the flexibility ecosystem and connect both the demand and supply sides of the grid. In contrast, in the sharing task, more dependence on other actors, such as DSOs or heating system companies, is observed since they provide the essential infrastructure that enables Alfa to create such a platform. Understanding this interdependence in different tasks helps to design a guideline within which ecosystem actors can collaborate with each other with the least conflict of interest [41].

The study's findings suggest that Alfa's services are not solely intended for households but also target consumers and producers in the energy sector. Specifically, the flexibility services offered by Alfa aim to address grid congestion while satisfying household preferences for temperature and electricity prices. Effective implementation of such services requires collaboration between households and power grid actors with Alfa. Our study utilized case organization and its products and services to demonstrate how sharing, combining, standardizing, and multi-homing tasks facilitate the emergence of an ecosystem.

We propose future research utilizing primary data collected from interviews to further explore and explain integration tasks and their implications. Additionally, it is of interest to investigate how this platform reforms the interaction between supply and demand side of power grids and what potential conflict might be observed among ecosystem actors.

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