ACHIEVING DATA INNOVATION FOR SUSTAINABLE ENERGY SOLUTIONS

Barbro Renland Haugjord  
*University of Oslo*, barbrn@ifi.uio.no

Alexander Moltubakk Kempton  
*University of Oslo*, alexansk@ifi.uio.no

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ACHIEVING DATA INNOVATION FOR SUSTAINABLE ENERGY SOLUTIONS

Research Paper

Barbro Renland Haugjord, Department of Informatics, University of Oslo, Norway, barbrn@ifi.uio.no
Alexander Moltubakk Kempton, Department of Informatics and HISP Centre, University of Oslo, Norway, alexansk@ifi.uio.no

Abstract

Data innovation – the combining and processing of data in novel ways to create value – is emerging as a salient topic for Information Systems research. It is an important phenomenon across empirical domains, including efforts to provide more sustainable energy production and consumption. Practically, we want to know how processes of data innovation can be used to transform the residential energy market in a sustainable direction. In this paper, we therefore ask: How is data innovation achieved to provide sustainable solutions within the residential energy domain? We investigate this question through a qualitative longitudinal case study of a born digital energy platform company that has transformed the household energy scene in Norway in the latter years. Through this study, we contribute with knowledge on data innovation, the processes that enable it, and more specifically, how data innovation can enable sustainable solutions contributing to achieving the UN SDGs.

Keywords: Data innovation, data recombination, datafication, data infrastructure, energy sector, sustainability, UN SDGs

1 Introduction

Data innovation – the combining, processing and structuring of data in novel ways to create value – is emerging as a salient topic for Information Systems (IS) theory and practice (Aaltonen and Penttinen 2021). From healthcare (Crowley et al. 2021) to human resources (Margherita 2021), there is a push to leverage data to deliver new products, services, and insights. In the context of our research project, sustainable energy, a potential value of data innovation is also that it can contribute towards achieving the United Nation’s (UN) Sustainable Development Goals (SDGs). For example, to provide affordable and clean energy to all (UN 2021a), the UN has identified how big data and analytics can allow utility companies to adjust the flow of electricity to reduce waste and avoid overload at peak periods by ensuring adequate supply (UN 2017). Understanding how data innovation can be achieved is, therefore, an important knowledge pursuit.

Current IS literature offers a rich landscape of knowledge relevant to understanding data innovation across domains. As related to digital innovation, data innovation entails novelty emerging from combining and recombining digital artifacts (Nambisan et al. 2017, Henfridsson et al. 2018). This also entails that data innovation is seldomly done from scratch; rather, it involves dependencies to ecosystems of actors and digital infrastructures that make it possible to combine data from them (Wang 2021, Tilson et al. 2010). Data innovation, however, also differs from the generic features of digital innovation. Data is a specific form of digital artifact that brings value by conveying information and contextual facts in a structure that can both be technologically processed or meaningfully interpreted (Alaimo et al. 2020; Aaltonen and Penttinen 2021; Tempini 2017). As such, understanding data
innovation requires an understanding of how the specificities of data impinge on its production, recombination, and consumption, as well as the contexts these activities are embedded in.

With this paper, we are following two intertwined knowledge interests. Theoretically, we aim to contribute to research with an understanding of the processes involved in data innovation. This entails building on existent work to empirically study how data innovation is achieved. Practically, we want to contribute with knowledge on how processes of data innovation more specifically can be used to transform the residential energy market in a sustainable direction. Utilizing digital innovation to achieve sustainable societal development is one of the most pressing issues IS scholarship can address today. Yet there is still a lack of extensive research on the topic (Gholami et al. 2016; Pan and Nielsen 2021). As others have argued before us (Corbett et al. 2018; Hopf et al. 2018; Watson 2020; Watson et al. 2020, 2021), data innovation is one ingredient that can enable sustainable development in the energy sector.

With sustainable development, we refer to actions that promote prosperity for all while protecting the planet, which are the core of the UN Sustainable Development Goals (UN SDGs). There are a total of 17 goals, where each goal integrates the economic, social, and environmental dimensions (Griggs et al., 2014). All three dimensions must be met to provide a sustainable development where the present needs are met without compromising the ability of future generations to meet their needs (Brundtland Commission, 1987). As mentioned, UN has provided an overview of how it can contribute to achieving the UN SDGs and the example for SDG #7 Affordable and Clean Energy is “Smart metering allows utility companies to increase or restrict the flow of electricity, gas or water to reduce waste and ensure adequate supply at peak periods” (UN 2021b). The processing of digital data provides a foundation for both more renewables and for energy efficiency, two central elements of reaching the goals of SDG #7.

Based on this insight, we claim that the energy sector provides a salient context to investigate how data is recombined to produce important value. To follow our two interests, we ask the following research question: How is data innovation achieved to provide sustainable solutions within the residential energy domain? To investigate this question, we have performed a case study of a firm operating in the energy market that has an explicit strategy of making residential energy consumption and production more sustainable. The firm originates from Sweden and Norway and is a born digital energy platform company that has transformed the household energy scene in the latter years.

The company was founded in 2016, at a time when energy grid companies across Europe were in the process of altering their electricity infrastructures through the introduction of smart meters in customers’ homes. The grid operators have matured digitally the last ten years and both pilot projects and discussions on digital possibilities have proliferated. In addition, IoT (Internet of Things) connected smart appliances have increased greatly. Together this enabled an innovation space in the smart home market. The founding occurred shortly after the Paris Agreement to limit global warming and the launch of the UN SDGs both in 2015. To reach these global goals there is a need to attain more renewable energy production and increase energy and power efficiency. Our focus is on how the innovator operates given these conditions. The digital platform developed by the company answers this specific call for a sustainable societal change in energy production and consumption.

We proceed with a theoretical overview of data innovation. Next, we present our study of how the born-digital startup created sustainable solutions in the energy sector through data innovation. Three phases are explored, which together lead up to data-based energy service able to change energy consumption in a sustainable direction.

2 Conceptual background

With the term data innovation (Aaltonen and Penttinen 2021), we seek to conceptualize the distinctive characteristics of how value – provided through novel products and services – is created by utilizing the characteristics of digital data and the possibilities afforded by digital technology to combine, process and structure them. To elaborate on the concept, we draw on literature on digital innovation (e.g., Henfridsson et al. 2018), datafication (Lycett 2013), and data-based value creation (e.g., Tempini 2017; Alaimo and Kallinikos 2020).
Digital innovation is understood both as a process and as outcomes of such processes (Nambisan et al. 2017); as combining and recombining digital artifacts, resources and functionalities that provide novel products and services (Yoo et al. 2010). Researchers have characterized digital artifacts as editable, reprogrammable, and distributed (Kallinikos et al. 2013). Together with the modular and layered architecture that organize the relations between them, the characteristics of digital artifacts enable them to be combined and recombined into open-ended innovations (Yoo et al. 2010; Kallinikos et al. 2013). To put it in simple terms, digital artifacts are all made of the same “stuff”, they are malleable, and they are organized into modules that can be connected to each other across modules and layers of such modules. This provides a potential for an almost endless set of combinations of connections that brings different forms of value (Henfridsson et al. 2018). While this potential often requires substantial work to be actualized in practice, it is key to understand how digital innovation is achieved to bring new value.

The open-ended and recombinatorial affordances of digital artifacts enable digital innovation processes that differ substantially from other forms of innovation, as they enable more distributed and open ways of creating novel products and services (Nambisan et al. 2017; Nambisan et al. 2020). While physical product innovation is dependent on “the ability to specify the complete product ahead of time”, in digital innovation the product is perceived as continuously evolving (Hylving and Schultz 2020, p. 20). This has consequences for how innovation processes are structured and blurs the boundaries between organizations, as digital innovation often involves the recombination of artifacts from across an ecosystem of different actors (Wang 2021). Consequently, the recombinatorial affordance of digital artifacts are formed by the existence of digital infrastructures that connect the artifacts of these actors together and widen the scope of possible modules that can be recombined (Henfridsson and Bygstad 2013).

Digital data is a form of digital artifact that afford recombinations; they can be combined, processed and structured with other data. Nevertheless, the concept of data innovation emphasizes that digital data and the way digital technology process them have distinct characteristics that impinge on innovation processes and their outcomes. While digital data in themselves are tokens processable by digital technology, they become valuable when they convey information that can be interpreted by humans or further processed by technology (McKinney and Yoos 2019). This means that data brings value through recombinations producing data objects that represent contextual facts (Aaltonen and Penttinen 2021, Alaimo and Kallinikos 2022). To exemplify, the data object “{dustbin: full}” has no value as a set of tokens in isolation. But in the context of a robot vacuum cleaner, it can be rendered into meaningful information to a user, be algorithmically processed as input to the robot’s own behavioral logic or be aggregated into new data objects that inform the future design of such robots. Therefore, as Aaltonen and Penttinen articulates it, data innovation denotes “new ways to structure data for a particular context [that] can unlock new ways to create value through data” (Aaltonen and Penttinen 2021, p. 5923).

When investigating our research question on how data innovation is achieved, we need to consider how the recombinatorial affordances of digital artifacts are enabled and utilized in conjunction with the specific ways data becomes contextually valuable. On the one hand, any data can in theory be combined, processed, and structured together with any other data to form new data objects. The production of data objects is characterized by content-agnosticism - digital technologies are agnostic to the contextual aspects of the data they process as tokens - and homogenization – traditional boundaries between contexts do constrain the combinations of data from across these boundaries (Alaimo and Kallinikos 2022). Enabling homogenized and content-agnostic data recombination is then a question of portability and interoperability (Günther et al. 2017; Hodapp and Hanelt 2022); establishing and consolidating data infrastructures that technically enable data from across contexts to come together in a way that is open for recombinatorial activity (Swanson 2021).

On the other hand, data becomes valuable by being structured in a particular context for a contextual purpose (Alaimo and Kallinikos 2020). As illustrated by the robot vacuum cleaner example, this purpose can be further technological processing. But the purpose can also be to provide meaningful information to groups of human users, as the way data is combined, processed, and structured into data objects enables new forms of sensemaking (Lycett 2013). The value of data only emerges when taken into use,
and this is dependent on how the structured recombination of data fits with an existing or emergent context of technologies and users (Tempini 2017). This means that data innovation requires attending to both data infrastructure and data context. To investigate how this is achieved in practice, we turn to our case study.

3 Method

SmartEnergyCo’s (a pseudonym) role in doing data innovation in the energy sector and its impact on creating sustainable energy solutions has been the subject of our empirical case study. The choice of case was in the observed effects of the company. By 2021, they were providing consumers in several European countries with renewable energy, control and overview of consumption through an app with a store for purchasing smart home IoTs from the companies’ ecosystem of partners. While SmartEnergyCo now operates within several European markets, we constrain our case study to how the company functions in Norway.

Since our aim was to identify how the qualities of a digital innovation process can lead to transformative outcomes, we followed Markus and Nan’s suggestion to use methodological approaches developed to identify causal processes through case studies (2020). We therefore chose an inductive pathway, did within-case process-tracing methodology, which guided us through our data collection and analysis (Beach and Pedersen 2016;2019) with a temporal bracketing strategy to search for multidirectional causality (Langley 1999).

3.1 Data collection

Our aim was to understand the conditions for enabling sector and societal transformation, and we regard SmartEnergyCo as a success case (Yin 2018). With a goal of understanding why the start-up were able to push the transformation for sustainability we explored the complex socio-technical phenomenon in-depth through a process-tracing case study. This type of case study involves collecting evidence of what happened in the case over time to understand its causal dynamics (Beach and Pedersen 2016).

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Table 1. Overview of empirical material covering SmartEnergyCo
The data material was gathered with a focus on effects in provision of services, how they differed from the established services and how the start-up was able to perform these changes. An overview of the data material is presented in table 1. The empirical material for the digital frontrunner represents the period from 2016 till 2021.

The first author has worked in various parts of the energy sector from 2008 till 2020, amongst others with solar energy, energy efficiency and smart metering. This experience has been a substantial source of pre-understanding (Alvesson and Sandberg 2021) in the form of information and critical investigation of correlations and opportunities.

3.2 Data analysis

Beach and Pedersen suggest different analytical strategies dependent on what pre-understanding the researcher has of the case under study and what analytical goals she has (Beach and Pedersen 2016; 2019). For example, if the researcher knows the outcomes of the case and has a hypothesis of the causal conditions for this outcome, she can investigate the detailed causal processes linking conditions to outcome. In our case, we followed an inductive path, starting with discussions on the energy sector and the case in question, followed by a more focused data gathering. We focused on collecting data on the building blocks of the innovation processes in the case. This involved iterative analysis where we continuously coded process data forming our analysis until it provided the “best possible explanation” of the outcomes based on what we observed (Beach and Pedersen 2016; 2019).

Following the guidelines for process-tracing (Beach and Pedersen 2016; 2019), we iteratively developed a narrative of events from the empirical material. This final iteration of the narrative is presented in the findings. Throughout these iterations, we probed the narrative to find clues that could shed light on why things had happened as they did, before combining and contrasting them to identify probable conditions and processes (Beach and Pedersen 2019). When our probing made us look for more information in the empirical material, we updated the narrative to make it more complete in relation to the processes we were identifying.

Given the complexity of any social phenomenon, Beach and Pedersen suggest a bounded search of how a process is conditioned (2019). As such, the goal is not to develop insight on the complete landscape of conditions and processes in a case, but to shed light on how a bounded set of them empirically links to a bounded set of outcomes. Existing theory can be utilized to guide the setting of these boundary conditions. Building on existing research related to data innovation, our analysis was bounded by looking at conditions and events related to the recombination and contextualizing of digital data. The data material was coded with a focus on data innovation and what were identified as contributions enabling the firm to perform this innovation. We then used a temporal bracketing strategy (Langley 1999) to make sense of the multidirectional causality we believed shaped the phenomenon. The phases identified are divided by central elements being established before the next phase could be initiated. The phases are as such not mutually exclusive, but rather building blocks on top of each other and later phases include a new element and a wider transformation than the previous.

4 Findings: Phases in achieving data innovation

Analyzing the empirical material to investigate our research question, we discovered two things: First, there were a set of conditions in place when SmartEnergyCo was founded in 2016 that enabled the firm to do data innovation in the electricity sector. We therefore start the section on findings with an overview of these relevant conditions. Second, we saw three phases in the process of leveraging digital data to create sustainable solutions for the residential energy domain. First, establishing a digital platform, second, integrating an ecosystem of IoTs, and third, utilizing these complementarities to deliver data innovation in data-based services to the energy grid. After describing the existing conditions, we therefore present these three phases.
4.1 Setting the stage: Digitization of the grid and societal context

SmartEnergyCo’s innovative efforts cannot be understood without a grasp of the relevant conditions at the time of and following its founding in 2016, on a societal level in Norway but also more specifically within the electricity sector. These conditions led to a context favoring innovative activity as well as the establishment of data infrastructures necessary for data innovation. In addition to the development of data infrastructures, the grid operators took on the responsibility to explore the new digital solutions. Several energy industry initiatives around digitization enabled flow of information on pilot projects and joined forces to agree on information models to increase digital interaction. As such the whole ecosystem of actors in the energy sector has matured into a vital scaffold for the processes unfolding as described in this paper.

The electrical grid in Norway is characterized by an almost completely renewable production generated mainly through hydropower. The grid is nationally interconnected with international connections, and there is a longstanding experience in balancing the higher levels of the transmission grid through demand and supply of large bulk sources of power (like tuning up or down hydropowered generators or on or off industry). The value chain has for most parts been stable since a deregulation of the energy markets in the 1990s. However, the energy sector has gone through large scale digitalization in the last decade. This includes the installment of smart metering at points of consumption, transmission, and production of electricity together with associated system to collect and process data. Before smart meters were installed, meter status in residential housing was estimated on size of the building, divided between months of high use (winter) and low use (summer) and adjusted with a metering status reported manually by the consumer on an annual basis. Through the use of digital smart meters, residential electricity consumption is now measured and billed by the hour, mirroring the electricity markets pricing system. This makes it possible to correlate price and consumption, but this information has been challenging to attain and use for consumers.

This digitalization of the sector had by 2016 opened new opportunities for integrations between digital technologies. The plans for roll out of smart metering were established by 2015 and by 2019 there was a 97% coverage. This were accompanied by an increased consumer use of smart home appliances and electrical vehicles with smart chargers. This last point is crucial, as Norwegian roads are characterized by a large proportion of electrical vehicles. From 2001 electrical vehicles (EV) have been exempted from VAT, creating a massive advantage for electrical vehicles compared to fossil fueled vehicles. This exemption has considerably fueled the growth of EVs in Norway especially since 2010 (NOU 2019:11), and by 2020, Norway had a sales share of over 50% for new electric cars. This increased scope of combined digitalization and smart electrification was a salient condition by 2016 and opened up the sector for new firms and created possibilities for scalable digital solutions.

4.2 Phase 1 (From 2016): Creating a digital platform to procure energy and supply consumers

SmartEnergyCo was started in 2016 by founders with extensive knowledge from both the energy sector and the ICT sector. One of the founders had previously started a successful IT company, while the other founders had experience from working in incumbent energy firms. The founders met when they worked for a software supply company providing services to the energy sector. In retrospect, the CEO of SmartEnergyCo stated their vision as follows:

“Me and my co-founder of the company, we live like everyone else. We live in houses and have bought stuff we believe are good for our comfort and our lives. We have an Apple TV and we have an electric car. We did not have an electric car at that time, but we saw that we were going to get it. We had heat pumps and things like that. Everything was online and could be controlled via apps and so on. But everything that had to do with power was as anti-digital as possible. So, what we saw was that someone had to come in and make sure that I as a consumer can control..."
all this here and experience services on a par with Netflix or Spotify and so on.” CEO, SmartEnergyCo, February 2021

Company representatives describe the time they entered the market as characterized by some major societal trends providing disruptive changes to the energy sector. They termed these trends as decarbonization, decentralization, democratization, and digitalization (Homepage SmartEnergyCo, January 2020, and CEO, September 2020). Early on, the company was part of a public pitch contest where they presented the vision behind the company was to make people’s homes smarter and more environmentally sustainable by offering “a self-learning assistant built on machine learning, which helps the home to procure energy automatically and reducing the energy consumption through smart thermostats and other connected devices in the home” (Newspaper article on SmartEnergyCo, October 2016).

“It is now exactly one and a half years since we launched SmartEnergyCo. An app, which we believe can replace power companies, an app that trades power in a completely digital and new way, but much cooler than that, it can control power. And those are the two things we really want to achieve. That is what the message has to do with it: There is no planet b, there is no plan b. Because that has been our perception for a long time. Either you choose the cheapest thing, or you choose the environment. We believe that the best is when you get a combination of the two worlds. And you get it by using technology in the right way. Reduce consumption and we all, both the wallet and the planet, get better.” (CEO, SmartEnergyCo, October 2018)

In the first phase, SmartEnergyCo developed a digital platform for the residential market that gave customers insight into their own consumption easily accessed on their smartphones, built on a business model around energy efficient solutions. The company used machine learning technology on different data sources such as energy prices, energy consumption, and weather data to procure the cheapest energy in the market for the customers. Better predictions of consumption and production through machine learning gave the company an advantage as energy suppliers must buy the exact amount of energy their consumers use – no more, no less. This energy is sold in the market at different prices, and the closer until the time of consumption, the pricier the energy.

“Traditionally, these processes were done manually in the large power supply corporations. We have built an advanced self-learning system that handles it for us. Each and every day this system learns more. [...] That makes it possible for us to buy energy smarter and drives the cost per kilowatt-hour down.” CPO, SmartEnergyCo, May 2018

Based on their ability to buy electricity at the lowest cost possible, the company offered a membership-based energy deal priced at the equivalent of four euros a month. This provided customers with electricity at procurement cost. This membership-based energy deal is different than the established way of selling energy with a provision per kilowatt-hour. This business model made it possible for the company to be on the energy efficient consumers side, since, in contrast to other firms in the same market, they did not make more money the more energy the consumer used.

All the energy SmartEnergyCo offers their consumers are guaranteed renewable through either guarantees of origin or bilateral agreements with renewable energy producers. The certificates guarantee that the exact amount of renewable energy is produced, but the buyer of the certificate does not have to buy the electricity from the same location. The actual sourcing of energy can be through a different source – in this instance a spot market for electricity.

The consumers can compare their energy use to others and as such create a competition for becoming more energy efficient. By creating a technology that enabled easy overview of consumption in an app, the consumers were taken the first step down the road to become empowered to lower their consumption. This was enabled by the prior digitization of the grid infrastructure, as SmartEnergyCo utilized the smart meters that were installed in consumers’ homes to provide exact readings of consumption. SmartEnergyCo could build on this to collect data in the digital platform and develop their app-based power deal.
4.3 Phase 2 (From 2017): Integrating an ecosystem of energy related IoTs

Not long after launching, the first IoT solutions were integrated into the platform ecosystem. Since then, the company carried out a process of covering a wide array of smart home production or consumption home devices to become the preferred hub for consumers. In this phase, data innovation was achieved through ecosystem integrations providing the consumer with a way of controlling energy consumed by household appliances or energy produced by solar cells. The firm did not offer a multitude of offerings within each segment but focused on a few that fulfilled their requirements for sustainable products. In other words, they would not offer integrations to all smart home technology, but to selected products within specific segments like smart heating.

The leaders of SmartEnergyCo saw their role as different than other actors in the sector; not complying with the established value chain of the energy sector, but instead creating a platform ecosystem. They wanted to be:

“The one that is the spider of the web, the one that builds the system for the home […] We have a strong belief that one actor can take the perspective of the local customer, take their smart home appliances, connect them, build smart algorithms, build the mathematics and tackle the whole chain for as many as possible.” CPO, SmartEnergyCo, May 2018

The segments they integrated were heating, smart home, smart charger and electrical vehicles, inverters (for solar panels) and lights. This was a gradual development from one-to-many smart appliances integrated. They built down silos by focusing on the combination of digital and energy; the products integrated are digitally controlled smart appliances that all consume electricity, that are selected because they can have substantial effects on aggregated consumption levels.

Given that they have a business model aligning their interest with the energy efficient consumer, SmartEnergyCo can provide efficient nudging of smart energy use:

“My simple idea of what a house really is in terms of energy is that it is a battery. But the way we use energy in our house it is, at least here in the Nordic countries and in Northern Europe, not the most effective. We waste 20 to 30% of that energy. […] The reason for this is that much of the consumption is hidden behind heating. Heating is invisible. […] Our grandparents were actually extremely good at managing energy consumption. They turned on and off and adjusted up and down all the time. (…) [Today this] simply must be solved with the help of technology.”
CEO, SmartEnergyCo, February 2018

Previously adjusting heating was either done by installing a crude system to lower for night and reheat for daytime or to manually adjust temperatures on electrical heaters. Although this also will provide a lowered electricity bill today, the pricing system has become more complex with the advent of a digitized electricity system. The prices in the electricity markets have for a long time been settled by the hour, but this variation in hourly prices is now directly transferred to the consumer.

The timing of this development was central to SmartEnergyCo’s success. The founders had a vision of enabling the consumer to take control of their consumption through integrating the different smart household appliances of a smart home, but this could not have been achieved at the time of founding. Reflecting on the development of smart home and integrations of IoT-devices the CEO looks back five years down the lane, from isolated smart appliances to a holistic control of the customer’s smart home:

“Timing is extremely important when you introduce a new product. And for our case then, had we entered the market say four years before we did, then I think the company would not have existed today. For it had been too early. Both in relation to the digital megatrends, but also with regards to conscious consumption and renewable energy and the green shift and so on. So, timing has extremely much to say. […] I think we must honestly admit the development on the smartness side, of the electric vehicles and all appliances you can buy in the consumer
electronics retail shop with wi-fi and controlled through the mobile.” CEO, SmartEnergyCo, February 2021

This shows that timing was crucial to the firm and the services it delivered. By taking the customer viewpoint and creating an ecosystem of IoT platforms, SmartEnergyCo positioned themselves as “the spider of the web” and created the basis for their innovative data-based energy service. The data recombinations in this phase is of energy related IoTs, controllable by the consumer, to the digital platform that provides electricity to the consumer. This recombination gives the consumer overview of and control over the IoTs in the app and provided SmartEnergyCo with more details to their predictions.

4.4 Phase 3 (From 2018): Innovative data-based energy services

In the last phase, SmartEnergyCo built on their digital platform and ecosystem to provide data-based energy services in the form of automated balancing of the grid and energy efficiency measures for customers. With the scope and scale of data they now integrated from different sources, they could influence both production and consumption, and they could recombine data from these sides for the benefit of both the consumer and grid. We describe two examples from this phase, both involving setting the infrastructure that was integrated in the previous phase in play.

The first example is balancing the grid through non-consumption. The flow of electricity needs to be in balance to avoid problems for its provision. This balancing is increasingly important as countries are moving towards green energy sources like wind and solar, prone to variable power generation. The alternative to achieving balance through adjusting consumption or production are costly grid updates. The search for alternatives to investments in the grid have led to several pilot projects led by grid operators from 2018 onwards. The experiences from these are shared in communities discussing data centered solutions formed by the industry itself in cooperation with national authorities. An electrified future with more variable renewable energy requires a shorter activation time and more frequent use of these services to provide uninterrupted energy (ENTSO-E, 2020). Grid operators at different levels and flexibility market providers in the Nordics participate in several pilot projects to push the different grid levels to have the necessary amount, response and duration time required for the decarbonized future. The demands for the response time will in the future be ranging from a complete activation of the resource within 30 seconds to slower reserves and with different duration (ENTSO-E, 2021), placing great demands on precise automation of consumer flexibility for SmartEnergyCo.

SmartEnergyCo partake in many pilot projects in the Nordics on aggregation and consumer flexibility. Consumer flexibility opens up the resource landscape of the energy flow and provides the consumer with a more active role in the energy balance. Previously, the energy flow has gone from a central consumption site towards the consumer, but with consumer flexibility the landscape becomes much more complicated providing several solutions for attaining the necessary balance of the grid. SmartEnergyCo took an active role in contributing to the projects that solved the different parts of the automated flexibility puzzle on both local, regional, and national grid levels. They showed through their participation that balancing could be done through aggregation of residential energy, and not just as it had been in the past from large facilities of hydropower plants.

“We don't see many other aggregators yet, so I think our role is being like this tip of the spear trying to push a little bit the boundaries. And we have made the TSO [Transmission System Operators - highest grid level] rethink what their products look like. [...] Our entrance have made them realize that someone else wants to do something different and maybe they should think about this again.” (Project leader, SmartEnergyCo, June 2021)

The way they perform this consumer flexibility is by combining many items into one product. Instead of seeing charging of electrical vehicles as only energy consumption, data related to it is made into a possible non-consumption and aggregation of this turns into a substantial amount of energy. Depending on location for balance demand, the response can be tailored to that geographical area, whether it is a
large regional area or a sub-substation in a residential area. This is performed by choosing consumers within the area and grouping them into populations able to jointly deliver a service.

“But when it comes to delivering services to the grid. Then we need to look at them as a group, so we call them populations. This is basically a group of devices and this group of devices needs to act in tandem you could say [...] and then comes the beauty of the controller. They need to look at all of them together and make them work like one. Like yeah, because basically they represent a generator or it’s like a turbine of a hydro producer. They do exactly the same, but they are cars, and they are like tiny pieces of this turbine. So, we need them to act in tandem to for the for the grid companies to see it like if it was a generator. That’s what we show them. So, when we when we make a bid in the flexibility market, we basically input one number, one megawatt and this is our price. And if they buy it, they buy the number one megawatt. But for us its four hundred vehicles.” (Project leader, SmartEnergyCo, June 2021)

The data-based energy services are built step by step through the foregoing phases and pilot project making the foundation for a larger societal roll-out of the services. SmartEnergyCo drove this innovation effort by being an active partner in these projects delivering proof of concept and early phase adjustment and learning points. As such the firm not only leveraged the opportunity through their recombination, but they form the very timing opportunity that they themselves leverage.

The second example we emphasize from this phase, is that from 2018 SmartEnergyCo has provided the customers with smart charging which automatically charges the car at the time when it costs the least. In 2021 they enhanced this option by incorporating one element from their own ecosystem, solar production, and one new element, local grid fees. This enabled the consumer to take charge of their own energy consumption in a new way by either choosing to max out self-consumption of solar energy in charging or keep to optimization of cost. This anticipates the expected change in grid tariffs mirroring the capacity challenges in the grid. The tariffs will have ladders for simultaneous use of capacity of power and/or energy. The challenge is that this is difficult to manually intervene by running around and switching on or off appliances. Charging of electrical vehicles is a power consuming affair and the changes SmartEnergyCo makes in their service anticipates this grid tariff change for the best for their customers.

SmartEnergyCo provides such balancing services in the form of data-based services. These data-based services are provided in the form of automated control of the smart home IoTs, for instance smart electrical vehicle chargers or smart heaters, which were integrated in phase 2 to the digital platform developed in phase 1. With this control they can aggregate “non-consumption” to offer flexible resources to the grid operator.

5 Discussion

In the introduction, we asked the following research question: How is data innovation achieved to provide sustainable solutions within the residential energy domain? From the conceptual background we saw that achieving data innovation requires both data recombination – the combining, processing, and structuring data into new data objects – and forming connections to context and infrastructure. Empirically we have seen how these three aspects of data innovation – recombination, context, infrastructure - plays out in the case (as summarized in table 2), with the outcome of sustainable solutions for residential energy consumption and production. Studying the empirical phases illuminates how data innovation is achieved over time. Data innovation in our case works through a process of data recombination that both draws on and influences existing contexts and infrastructures. As this forms a pattern across the phases, we have developed a process model to illustrate it (Figure 1).
Table 2. Elements of data innovation

Data innovation conceptualizes how novel services and products are created by recombining data in a way that provides value in a context. While data as a form of digital artifact have an almost endless potential for recombination through being combined, processed, and structured as tokens (Henfridsson et al. 2018), it must be contextualized to become data objects that bring value in a context (Aaltoenen et al. 2021). In the model, we conceptualize this through the arrow labeled contextualizing. The model, therefore, captures that although recombination of data as tokens is theoretically open-ended (as argued by for example Monteiro and Parmiggiani 2019), it must in practice be related to a purpose or function in specific contexts to be valuable. An example of this from the case is the way SmartEnergyCo structured data from smart devices into data objects that are used with the purpose of influencing energy consumption in the home. In turn, this data innovation impacted the context – as captured by the arrow label impacting – as increased numbers of smart home customers provided a basis for performing balancing services to the grid, as described in the third phase.

Before SmartEnergyCo’s recombined data generated by them, smart home products and energy supply were typically separate entities. Their data were as such not homogenized (Aalimo and Kallinikos 2022) and had no network of data provisioning that made them portable (Gunther et al. 2017) and open for recombinatorial activity (Swanson 2021). SmartEnergyCo consolidated these data sources by first connecting energy consumption to energy supply on their digital platform. The digital platform established a data infrastructure which technically enables data from across contexts to come together and be treated as part of the same context. The next step in data infrastructuring was to onboard the

<table>
<thead>
<tr>
<th>Phase</th>
<th>Infrastructure: enabling and infrastructuring</th>
<th>Data Recombination</th>
<th>Context: contextualizing and impacting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Setting the stage Digitization of the grid and societal context</td>
<td>Digital electricity market and smart metering was in place.</td>
<td>Combining electricity supply data with data on weather, customer, and consumption. Structuring it into data objects able to predict future energy demands and inform consumers.</td>
<td>UN SDGs and Paris agreement (2015) made sustainable energy solutions increasingly salient.</td>
</tr>
<tr>
<td>Phase 1 from 2016 Creates a digital platform for the residential energy scene</td>
<td>Platform architecture is implemented to combine data sources and connecting hourly supply with same hour consumption. Start roll-out of automatic metering of all residential consumption.</td>
<td>IoTs at the smart home scene are made into data energy objects able to afford detailed overview and control for the customer.</td>
<td>Modern access to energy (app-based deal) on the customers’ side. Enables energy efficient behavior by nudging, consumption overview and comparing with “neighbors”.</td>
</tr>
<tr>
<td>Recombinatory phase 2 from 2017 Integrating ecosystem of energy related IoTs</td>
<td>Previously detached devices attached to the platform. IoT providers from central smart home devices are integrated in the ecosystem.</td>
<td>Energy related IoTs in the data ecosystem are structured into groups and recombined to offer local, regional or national balancing services.</td>
<td>Consumers gains easy control through the app of their smart home. IoTs only admitted into ecosystem after tests of durability and reliability.</td>
</tr>
<tr>
<td>Recombinatory phase 3 from 2018 Innovative data-based energy service</td>
<td>Incorporating different signals for grid capacity and balancing needs. Flexibility markets for decentralized balancing services arise.</td>
<td>Residential energy aggregation in tests and pilots enables grid companies to rely on these new sources of balance.</td>
<td></td>
</tr>
</tbody>
</table>
different IoT-segments representing different areas of smart home consumption. As such, the company incrementally broke traditional boundaries siloing data and rendered them open for recombinatory activities across these boundaries. This dynamic, of how data recombination is enabled by data infrastructures but also require the infrastructuring of previously separate networks of data, is captured by the arrows labeled enabling and infrastructuring in the model.

Our model describes how the process of data innovation is constituted both by purposeful recombination and by being dependent on the specificities of existing contexts and infrastructures at the time of that activity. Whether data is structured by people or by machines, it is dependent on purposeful and timely recombination in a specific context and being enabled by a data infrastructure to gain value. We see this in the findings, as at the time SmartEnergyCo was founded, the energy grid was in the process of being fully digitized through smart metering and there was a push for more renewables and energy efficiency through the UN SDGs and the Paris agreement. There was, therefore, ongoing trends in the company’s societal context that favored sustainable energy and energy efficiency, and Norwegian regulations led to a rapid growth of the electrical car market. The company’s founders had a vision of how the residential energy scene could be transformed from being viewed as the end-station for energy consumption to being a more dynamic part of the energy system with an empowered consumer. Through the different phases, the company showed an ability to both build on and change existing contexts and infrastructures in their favor, for example testing out grid balancing from residential homes. The company also showed an understanding of how data can be used to nudge and automate energy consumption, empowering the consumer and at the same time putting the company in a central position to perform crucial services.

This purposeful data recombination brings us to our practical knowledge goal: investigating how data innovation can lead to sustainable solutions. There is urgency to make sustainable transformation of societies to meet the goals of the Paris Agreement and the United Nations Sustainability Development Goals. The energy sector contributes to massive emissions worldwide and both decarbonization and energy efficiency are clearly stated targets. Digital technologies have been identified as a key contributor to these transformations. Corbett et al. (2018), for example, finds positive effects of smart metering on energy efficiency, but insignificant effects for end-consumers contribution to load management. Energy efficiency and an improved load management are two main contributors to increased sustainability since they decrease total energy demand and ease the need for maintenance or new grid.

The process of making consumers more energy efficient and aggregating consumer flexibility have been discussed since the EU Smart grid vision (European Commission 2006), but it has taken time to make the vision into reality. The proof of concept developed through pilots and tests, described under phase 3, have spurred further work. SmartEnergyCo takes advantage of the recombinatorial potential that is there through existing infrastructures and at the same time creates the foundation for the next steps through performing the recombination. The empirical material shows that the company managed to
actively time their innovative activity at the best time for the desired outcome, based on knowledge of global goals for sustainability, what possibilities lie in technology and how these possibilities can be leveraged to achieve a contribution to the global goals. The constellation of conditions of infrastructure enabling and context being contextualized into a data recombination, which later impacts the evolution of both context and infrastructure is an example of timely data recombination.

It requires active and purposeful choices to achieve data innovation for a sustainable impact. Whilst the theoretical recombination potential is limitless, the desired value of sustainability must be actively pursued. This requires knowing the context and being able to incorporate it into data recombinations, and in turn, to turn these recombinations into infrastructures for further recombination. Data as sets of tokens are content-agnostic (Alaimo and Kallinikos 2022); it must therefore be contextualized with meaning and made into the data objects suitable for the sustainable outcomes. It is through such processes that data innovation affords sustainability. Data is recombined and made meaningful as a way of empowering the consumer to be more energy efficient, enable the platform to provide system services to the grid and as such avoid or delay costly investments and secure a pull for more renewable energy as part of the energy provision. All of these are connected to reaching the targets of UN SDG #7 Affordable and clean energy, which specify that by 2030, we should “increase substantially the share of renewable energy in the global energy mix” and “double the global rate of improvement in energy efficiency” (UN 2022c).

6 Conclusion

Data innovation is an emerging research area that has shown how data becomes valuable through recombinations in different contexts (Aaltonen and Penttinen 2021; Alaimo et al. 2020). With this paper, we extend and complement this growing literature. We have performed an empirical study of the processes making up data innovation and how it develops over time. We have investigated a case of data innovation leading to sustainable energy solutions within the residential energy domain. Through this example we have developed a view of the specifics of data and innovation. We complement Kallinikos and Alaimo (2022) in showing how the recombining and structuring of data into data objects is different from recombination of functions, and therefore differs from the larger phenomenon of digital innovation (theorized for example by Yoo et al. 2010 and Henfridsson et al 2018). We believe this contribution based on a synthesis of literature on digital innovation, datafication (Lycett 2013), and data-based value creation (Tempini 2017; Alaimo and Kallinikos 2020) is important to understand the characteristics of how novel products and services are created through recombinations of data.

Through the empirical case showing the making of sustainable impact by purposeful data innovation, we arrive at a process-model providing insight into the workings of data innovation. This model extends current knowledge of data innovation by bringing forward the relation between context, infrastructure, and data recombination in data innovation. With the model and emphasis on the active and purposeful choices made in data recombination, we seek to contribute to the literature by developing the understanding of data innovation as a process can contribute to the UN SDGs. It is a success case of data innovation answering to the call from Holmström (2018) for explanations which takes the complex social and material interaction involved and the specifics of digital technology into account. With this model, we also hope to inspire practitioners to seek out the recombinatorial affordance of data to achieve the UN SDGs.

There are limitations to conclusions drawn from a single-site qualitative study. The strength of going deep into an example also leaves the weakness of not being able to illuminate several cases or the larger ecosystem to full strength. Nonetheless we suggest exploring further the notion of data innovation in the recombinatory space between context and infrastructure.
7 References


