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INFORMATION SYSTEMS AND DISTRIBUTION TECHNOLOGY, AN ANALYSIS OF DIGITIZATION OF ELECTRIC GRID FROM AN ENTERPRISE ARCHITECTURE PERSPECTIVE WITH IMPLICATIONS FOR BUSINESS MODELS

FEDERICO MARIA BRIGNOLI

Work project carried out under the supervision of:

Professor Paulo Faroleiro

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Abstract

This inquiry delves into the effects of ICT and data advancements on distribution, and the implications for consumption and production actors. Situated in the Information System and Design Research disciplines, it scrutinizes the relationship between business models, digitized assets, and distribution, analyzing reports and strategic plans of two significant European companies. Employing Business Model Canvas as meta-models, we explore the impact of IT on business models and the ensuing metamorphoses in the electricity industry.

Keywords: business models, information systems, enterprise architecture, distribution

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Introduction

Information has become an historical agent operating on a global interconnected system. With the diminishing marginal costs of communication and data processing, the acquisition, analysis, and deployment of information has become a fundamental issue for organizational design (Simon, 2002). The pervasive digitization of assets at every level of society, enabled by powerful and ever-growing IT computational capabilities, has brought about significant shifts in our economic and cultural landscape. Thus, it is essential to comprehend how the novel phenomena of digital and digitalized artifacts are affecting the production of technologies, economies, and cultures. The communication and computation meta infrastructure that underpins current value chains demands new organisational architectures (Bratton, 2015) to ensure we do not apply outdated patterns and models to the new dynamics, constraints, and relationships that govern our economic systems.

However, with IT acceleration comes the risk of leveraging higher computational power on the wrong learning and action curves, resulting in unexpected and negative externalities at both individual and collective levels. To make sense of this complex ecological transformation, we must raise our general understanding to the level of complexity of these systems. We need to engage in a process of rethinking the way we organize our society and create value in light of these transformative developments.

As we enter a new era of technological advancement, we find ourselves capable of distributing actions and recombining them into purposes at an unprecedented pace through global networks (Latour, 2010). This distribution of tasks has become a central factor in the creation of value and has had a transformative effect on economic activities. In this context, the evolution of the energy sector, and more specifically the electricity industry, has played a critical role in shaping the course of human development.

We might reasonably argue that mechanical energy has been the key to human development. As humans started harnessing water to mechanize labour and used heat to work materials, we have witnessed substantial improvement in human capabilities. Over the last century the energy sector has become the cornerstone of human development, with the spread in use of electricity and fossil fuels. However, the electricity industry has undergone a radical shift, moving from being primarily generators and distributors of electricity to coordinators of energy production and enablers of services. This shift was made possible by the embedding of IT capabilities in the industry's core infrastructure, the electric grid. By tracking the evolution of electricity companies' activities and business model, it became evident that digitization and the deployment of ICT have transformed distribution activities and the roles of actors in consumption and production (Frishammar & Parida, 2019). In a nutshell, energy companies moved from being mainly generators and distributors of electricity to coordinators of energy production and enablers of services. Such shift was made possible by the embedding of IT capabilities in their core infrastructure: the electric grid.

The thesis aims to explore the impact of digitalization on the electricity industry's distribution activities and the roles of actors in consumption and production. By analyzing the connections between business models, assets digitization, and distribution in this industry, we provide insights into the implications for organizational design and the development of sustainable business models.

Information Systems, Design Science Research, and Metamodels

Definitions and literature review

To investigate the impact of digitization and IT capabilities on the electricity industry and develop abstract models that can be applied to other industries and sectors, this research draws on the fields of Information Systems and Design Science Research. Information Systems (IS) is an interdisciplinary field that sits at the confluence of people, organizations, and technology and is built on behavioural and design-science paradigms (Hevner et al., 2004) and is concerned with the study of how information technology can be managed and utilized in organizations. IS research is rooted in both behavioural and design-science paradigms and provides a flexible tool for understanding and developing socio-technical systems that involve information flows. Design science research (DSR) is a research approach that focuses on the creation and evaluation of designs, artifacts, and systems that contribute to the improvement of society and the advancement of knowledge. DSR aims to solve problems and create solutions by designing, building, and evaluating prototypes or models of new or improved systems, processes, or artifacts.

One way to approach IS research is through the use of metamodels. A metamodel is a model that describes the structure and behavior of another model. It is a way of creating a conceptual framework that allows researchers to study the properties of different types of models and how they interact with one another. Metamodels can be used to develop a deep understanding of the relationships between different elements of an IS, such as people, processes, and technology. To develop an IS research project, researchers can choose from several metatheoretical groundings (Bostrom et al., 2009), such as variance, network process, or co-evolution frameworks (Niederman & March, 2019). While variance frameworks define the properties of entities and their interrelationships in a static correlational manner, network process frameworks embed time and transitions in a chain of events and actions, leading to a better ex-post explanatory capability. Co-evolution meta-theories capture the interrelation and mutual interdependencies of entities within an environment as they co-evolve. As (Star & Ruhleder, 1994) point out, co-evolution meta-theory is the foundation of the development of collaboration “infrastructure” systems as an emergent process where technologies and agents’ needs create a unique and evolving hybrid.

The creation of successful artifacts in the Information Systems field, that is IT artifacts intended to solve specific organizational problems, is grounded in design science research methodology, articulated in six phases (Peffers et al., 2007): (1) identify problem and transform it in systems’ meta-requirements ; (2) define feasible objectives for a solution; (3) design and develop constructs, models, methods, or instantiations; (4) demonstrate how the artifact solves the problem, (5) find empirical evidence or logical proof of how the artifact supports the solution; (6) communicate the problem and its importance, as well as the artifact and its effectiveness.

To design an IS, researchers often use metamodels to abstractly represent and analyze the system's components and relationships, leading to the development of suitable abstract models that can potentially be applied to other industries or sectors.

Relevance within the Business Context

A socio-technical system is a combination of people, technology, and organizational structures that interact with each other to achieve a desired outcome, emphasizing the interconnectedness of people and technology in optimizing system performance. The use of Information Systems in organizations is becoming increasingly important, as more and more processes and activities become dependent on technology. As a result, understanding IS is crucial for anyone interested in managing or designing organizations.

For companies and organizations is useful to have a reference metamodel that describes the constituting elements of their organization and their relations, as they can be used to downstream to guide projects deducted from an architecture (Greefhorst & Proper, 2011). One of such metamodels is the Business Model Canvas (Osterwalder & Pigneur, 2010).

The same authors (Osterwalder & Pigneur, 2013) outline the link between Information Science and business model design. Contribution of IS in understanding and designing business models is articulated in three areas. Through modelling, Information Systems provides formalization of concepts and shared language in the discovery of objects relevant to the design of strategies, the explicit specification of these conceptual objects, and their subsequent validation. Furthermore, IS can support strategic business thinking by outlining how design epistemic framework might contribute to improving the design of answers and alternatives to strategic business questions. The third area addresses the research in computer-aided design assisting the process of making tangible otherwise abstract strategic management objects such as business models.

Design techniques and tools employed by IS are grounded in the research on artificial systems (Simon, 1996). The epistemic framework is the one of designers and engineers, concerned with how things ought to be in order to attain goals and to function. By factoring an adaptive system into goals, inner environment (substance and organization of the artifact itself) and outer environment (surroundings in which it operates) and considering artifacts as an interface between the latter, it's possible to unearth important characteristics of systems, such as separability, homeostasis, and quasi-decomposability, and most important it is possible to predict behavior from knowledge of the system's goals and its outer environment, with only minimal assumption about the inner environment.

Furthermore, it is relevant to underline that design science research paradigm has the capability of being proactive with respect to technology, and thus being able to deploy utility before truth is unearthed (Hevner et al., 2004).

The Business Models of Electricity Companies and their Key Infrastructure

Definition and Literature Review

As briefly anticipated earlier, business models are references that describe how a company is structured, creates and capture value. The Business Model Canvas are a metamodel that can be used to map, design, and innovate business models. The role of business model and business model of electricity companies has been subject of extensive research.

Bidmon & Knab (2018) investigate the interplay between societal transition and business models from a sustainability and transition perspective. In this setting, business model acts on systemic changes in three ways: as part of sociotechnical regime, that is the dynamically stable dominant cognitive, regulatory, and normative structure that emerged around a technology, business models act as industry recipe and as such determine patterns of production distribution and consumption, thus making them tools to reproduce the regime's dominant rules and resource structures.

Sociotechnical regimes interplay with technological niches, the unstable, micro-level in the multi-level perspective: this relationship is mediated by business model in such a way that they become devices to commercialize technological innovation and support the stabilization of rules and structure around the technological niche. And finally, the third way in which business model act as a factor in sociotechnical transition is as a non-technological niche innovation itself: innovative business models emerge independently from dominant designs and challenge generally accepted logics to create higher level of stability for niche innovation and emergent technologies.

Bidmon and Knab (2018) further develop their inquiry on business models in societal transitions by looking at the recent developments of "*Energiewelde*" (Krause et al., 1980), the German plan for energy policy calling for the overcome of petroleum and uranium as sources of energy, the shift of policy focus from a demand and centralized generation framework to a supply and distributed generation one. They underline the relevance of new operators operating innovative business model in reducing pain of starting and owning a photovoltaic implant as a key determinant to success of distributed generation systems.

Erlinghagen and Markard (2012) also investigate sociotechnical transition and focus on the role of IT firms in the electricity sector. Referring, just like Bidmon and Knab, to the Multi-Level Perspective on Sociotechnical Transitions as described by Geels (2002, 2005), a framework that individuate exogenous landscape pressure, non-path-dependent niche innovation, and extra sectorial technological developments as main catalyst for sectoral transformation, they frame the smart grid as an emerging field of research and action that functionally belongs to the electricity sector but whose knowledge and technology come from the ICT sector.

Leveraging EU-level databases and market research, they mapped incumbent, ICT firms, and startups involved in smart grid related projects in Europe between 2000 and 2011.

They highlight a "massive" involvement of startups and ICT firms starting from 2008, while pre-2004 activity was negligible. In this regard, ICT firms often take a prominent role as systems integrators and enterprise software supplier.

The actor analysis showed that adjacent ICT firms operating in smart grid projects are important drivers of transformation as they bring variety to the table and can better adapt to the mutating competitive landscape thanks to their strength to withstand selective pressure.

While the focus of the present work is on incumbent, former monopolist electricity firms, Chasin et al., (2020) explore business model innovation in the electricity field and develop a taxonomy of emerging patterns, often in niche segment of the so-called "smart energy" domain. Beyond traditional utilities, they map eight "smart energy" business model archetypes and four transitional path for business model innovation. Interestingly, they business model in this field can be innovated either by preservation and termination, outsourced extension, revision, or outright creation.

As Paukstadt and Becker (2021) point out, data and connectivity technologies have spurred the development of new business models in the energy sector: demand response BM that enable flexible usage services for customers, balance supply and demand and lower costs for energy companies; peer-to-peer marketplaces that create energy communities; energy consumption data management and analytics platforms. They highlight a specific "smart grid infrastructure" archetype BM whose value proposition is centred on installation and integration services concerning sensors, control devices, outage management, and automation systems.

In the following, we intend "smart grid" as a three-layered architecture for the electricity distribution articulated in hardware, communication, and application/software. Data from the hardware layer (transmission and distribution hardware, endpoints, and various sensors) can be collected and signals can be broadcasted in a two-way communication layer. Aggregation and analysis of such data lay the foundation for the third software layer that has the potential to improve the grid itself, create new products and services, and integrate new forms of energy production and consumption.

EDP and Enel, Business Model Archetypes and the Evolution of Generation and Distribution.

Methodology

This study follows a hybrid data analysis approach that combined content analysis and process analysis. We rely on secondary data extracted from reports and strategic guidance issued by listed companies to model Business Model archetypes and try to uncover the dynamics that caused the transition.

We collect annual reports, sustainability reports, and other strategic documents of Enel S.p.A. and EDP S.A. published between 1999 and 2000 and between 2019 and 2021. This gives us the opportunity to investigate transformation in the business models of these two companies over a 20-year time span. We design a Business Model Canvas for each of the period object of analysis, collecting relevant, shared elements from both companies. While several factors are certainly at play over such a long time interval, we consciously map the elements connected to the key resources section of the business model. For the BMC modelling we followed Osterwalder & Pigneur (2010).

We aim to explore the following research questions:

- How have business models employed by incumbent energy firms transitioned with the deployment of IT capabilities in their infrastructure, with reference to the digitalisation of the grid and the creation of digital twins of the grid itself?
- Are the dynamics created by the digitalisation of a key asset (distribution grid) in an electric utility applicable to other distribution activities in other sectors?

Analysis

The business model of electricity companies at the end of the last century was heavily influenced by the fascination for the "new economy" paradigm and the need to find new growth and revenue opportunities. Liberalization pushed by regulators at that time forced both companies to reduce their quota of production in the national market and moved on to spin-off or sell portion of their business to third parties. In 1998 Enel underwent substantial corporate restructuring into distinct divisions that would result in the unbundling of generation, transmission, and distribution operation, while EDP formally unbundled in 1994 already. Distribution and network management activity once fragmented, EDP for instance had four regional distribution entities (Electricidade de Portugal S.A., 2001), were grouped and sold. For further analysis on the liberalization of the sector in Italy and Portugal, that eventually opened the market to new players in the generation and distribution phases of the supply chain see Fotouhi Ghazvini et al., 2019; Jamasb & Pollitt, 2005; Stagnaro et al., 2020.

As a response, the companies invested the resulting capital in acquiring minority but significant shares in emergent UMTS telecom operators (Electricidade de Portugal S.A., 2000, 2001; Enel S.p.A., 2000, 2001), a sector undergoing similar liberalizing processes. At the time, the operators in the telco sector were deemed to be positioned to fully exploit the value creation opportunities of the internet and the digital revolution thanks to their ownership of the telecommunication infrastructure. To pursue new growth and revenue avenues, electricity companies shaped their business model as the multi-utility, chiefly integrating telecom and gas supply in a horizontal integration. In Figure 1 we display our Business Model Canvas of the two electricity companies at the beginning of the XXI century. Here we can outline some characteristics of a "traditional" utility business model that would to a good extent remain the same in the following business model architecture. Residential households and companies were largely treated as similar customer segments with the main differences being the energy voltage provided and, while industrial clients might have enjoyed more close relationship and negotiation, most of the contracts were standardized and managed in a direct manner. It’s only at the end of the 90s’ that both EDP and Enel started developing ways to connect remotely with consumers, such as contact centres and digital channels, via their newly established commercial distribution branches (Electricidade de Portugal S.A., 2000; Enel S.p.A., 2000).

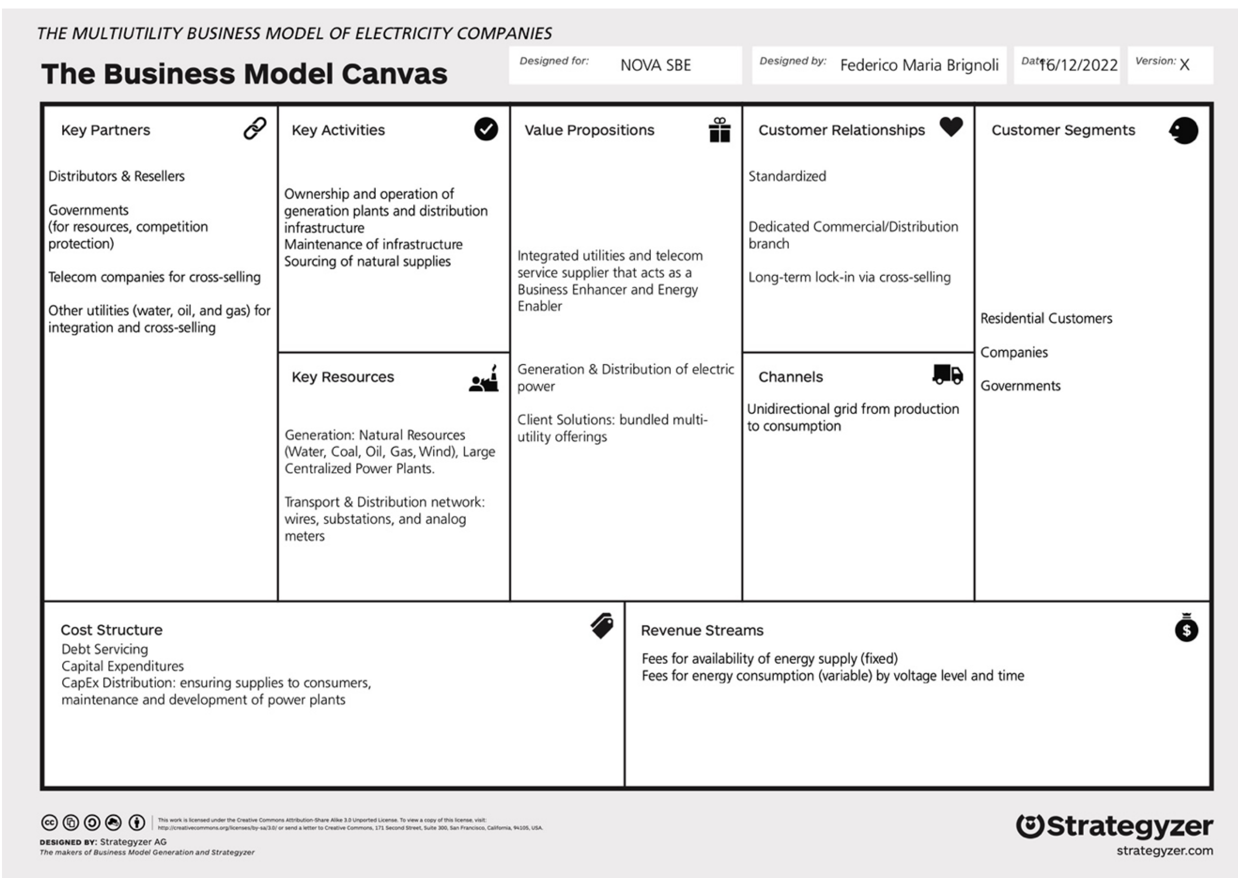

Figure 1 - The Multi-utility Business Model (1999-2001)

Electrical energy was delivered through a unidirectional grid that would connect power plants to consumer via a network of station and substation that would turn high voltage current to medium and low voltage electricity that can serve civil purposes.

Concerning installation of distributed energy resources, both Italian and Portuguese consumers benefited from an accommodating regulatory framework offering generous feed-in tariffs to households investing in photovoltaic systems between 2000 and 2015 (Antonelli & Desideri, 2014; Behrens et al., 2016). Table 1 shows the financial incentives from the Italian government for photovoltaic generation systems ramping up significantly from 2010 and remaining above €6 B per year from 2012 until 2021.

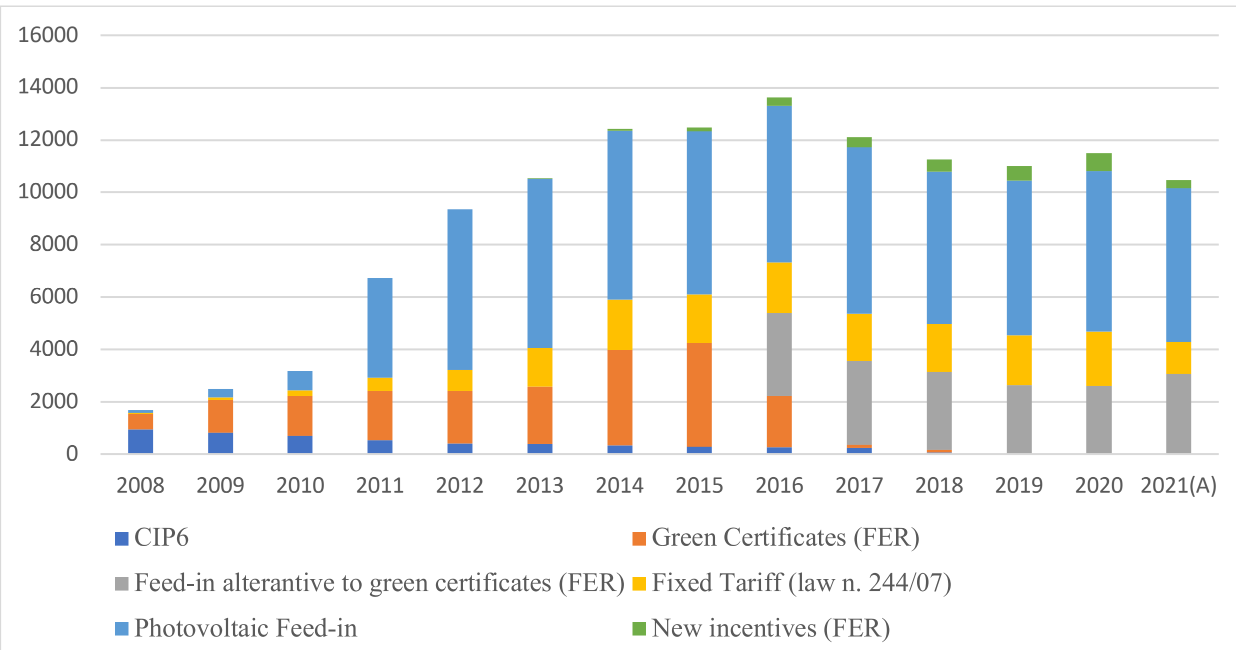

Table 1 – Financial incentives for photovoltaic energy generation (source: Autorità di Regolazione per Energia Reti e Ambiente, 2022*)*

That was a decisive factor in the transition from the multi-utility business model to the current business model, displayed in Figure 2.

There are elements in electricity companies' business models that have broadly remained the same over the last twenty years. Customer segments are still households, companies, and governments. On a side note, we can mention that with the retail customer segment, with the broader electrification of services, there is a novel subcategory: the users of electric mobility services. The core value proposition of supplying energy is left untouched, but it's now paired with a more elaborated value proposition connected with a new type of customer relationship based on co-creation. Notably, startups have taken a significant role among the key partners.

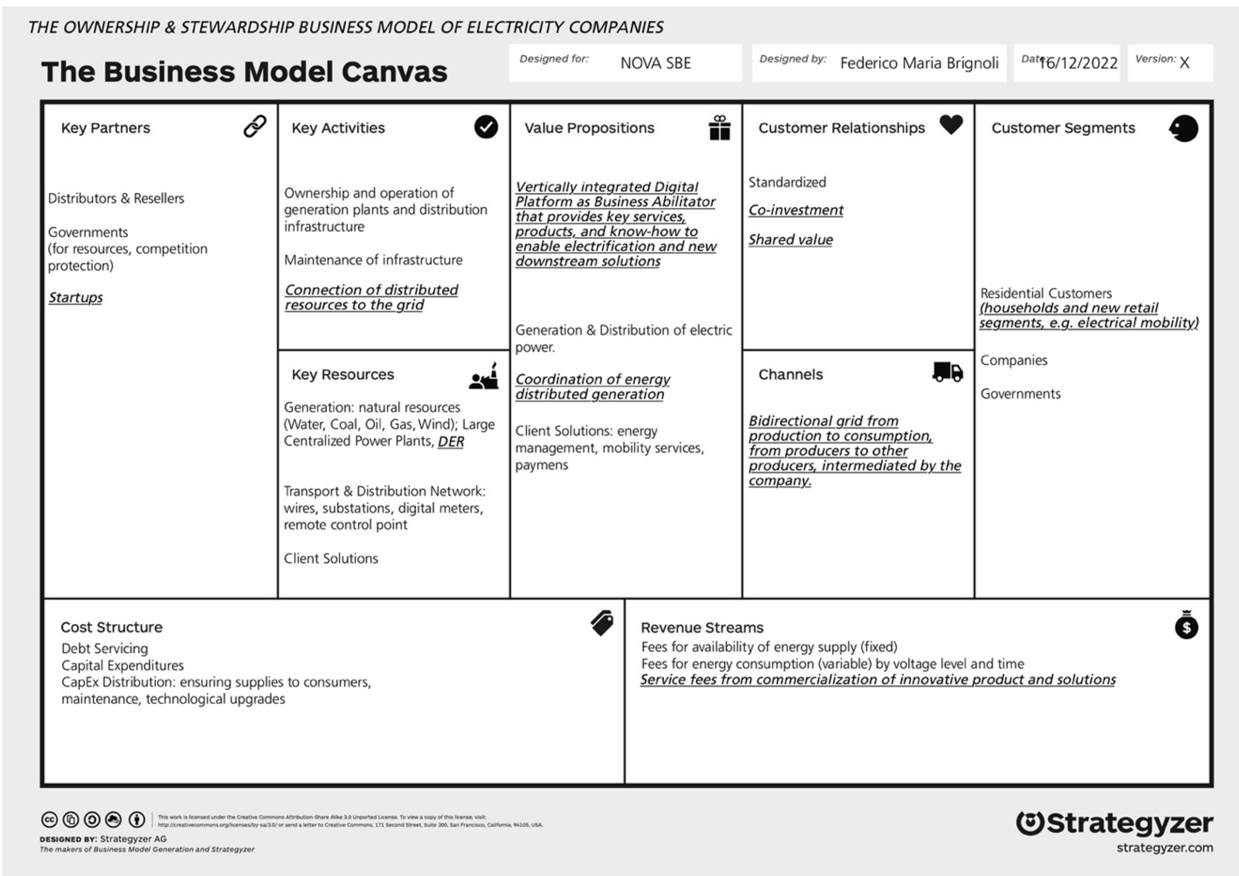

Figure 2 - The Ownership & Stewardship Business Model (2019-2021)

Access to natural resources was and still is a critical element. As the limited pilot projects of nuclear energy generation begin a gradual phase out in Italy at the beginning of the XXI century already, EDP and Enel take two different ways in diversifying their natural energy sources. EDP is getting closer to a complete shut-down of coal power plants and has established a strong leadership in wind energy production, both onshore and offshore. Enel still capitalizes on his know-how in hydroelectric generation that dates back to the beginning of the last century, still maintains a substantial geothermal production, albeit strongly concentrated in Tuscany, and has found in photovoltaic generation the technology that drove its renewables developments.

Both companies object of analysis underline the crucial role of their electricity grids in enabling energy transition and business model evolution. The electric grid is nowadays characterized by decentralization of extraction and feed-in points, real time data collection, remote control systems, and networked redundancy (alternative possible routes of end-to-end distribution) (Electricidade de Portugal S.A., 2019; Enel S.p.A., 2019). The grid is further enhanced by digital artifacts, such as the digital twin, and physical artifacts such as storage solutions, both at company and customer level.

In the case of electricity companies, the digital twin is a digital platform that creates a virtual replica of the infrastructure of physical power supply, of its components and of system dynamics. It is based on the use of technologies such as 3D modeling for the examination of grid components, sensors for monitoring the infrastructure, artificial intelligence for data analysis and augmented and virtual reality solutions. These combined applications support the functioning of the system, grid design, integration of distributed energy resources, management of the workforce, the improvement of field operations, and real time data management.

The renovated and digitalized grid allows for risk prevention models based on probabilistic assessment (Enel S.p.A., 2020a) that make it easier to predict and manage service interruptions thanks to remote isolation of portions of the grid and targeted upgrades in risk sensitive segments. Smart grids operate on an Advanced Metering communication network, an infrastructure that is built on smart meters, and data management systems that enables two-way communications (Rashed Mohassel et al., 2014). Smart Meter Data Management System is an essential example of application solution enabled by the smart grid.

For industrial corporate clients the digital grid has enabled the demand response, a flexibility service that leverage optimization algorithms to remodulate energy consumption according to eventual supply and demand imbalances in the grid. Corporate clients with available backup energy sources can participate in Demand Response programs by joining a so-called Qualified Virtual Units whose energy needs are monitored and adjusted by a Balancing Service Provider (Enel S.p.A., 2021). Companies receive remuneration for their flexibility. Similarly, capacity market mechanism allows owners of energy production and storage units to enter term contracts to sell energy to utility companies.

For residential customers, the opportunity of becoming co-producer of electricity with the installation of distributed energy sources, such as photovoltaic units, benefit from more flexible energy pricing, smart home services, more and more end uses are transformed and electrified. EDP has taken a multi-pronged approach to consumer distributed generation. On the international markets where it operates, EDP has acquired several startups, for instance C2 Omega in the USA and Sunseap in Singapore. EDP installs residential photovoltaic systems either with a transactional model, a tailored installation service, or with an “as-a-service” model according to which the company co-invests and operates the system over a contracted period.

Conclusions

Organizations adopted new, agile and flexible business models and transitioned from traditional industrial operator dedicated to the transformation of inputs (natural resources) and distribution of outputs (electrical energy) to Distributed System Operators that require ad-hoc service-oriented architectures (Bass & Mabry, 2004). The companies analyzed are no longer closed systems, but rather open systems that generate value through interaction with the environment and the communities in which they operate, and towards which they are accountable. The grid act as the digital lever to transform operating models and integrating "platform" business models. The creation of digital, multi-layered platform that connects data and solutions put utility companies "at the vertex of increasingly complex systems, which will include a growing number of distributed generation assets, with an increasingly active role of end customers" (Enel S.p.A., 2020b). Metering infrastructure is the fundamental physical subsystem that feeds into the other subsystems of the smart grid (Rashed Mohassel et al., 2014), as time-stamped system information generated at the grid layer is fed into distribution and transmission operations systems, and ultimately to asset management.

The shift is sufficiently profound that electricity companies are required to rethink their human resources apparatus and to recruit people with new experience and professional skills.

The emergence of distributed energy resources is an opportunity for electricity companies, as it opens the possibility of selling new products and services, but carries potential threats as well, such as reduction of margins for traditional generation, a reduction in cost of system's contribution from self-generation consumers that would require an increase in tariffs, and unpredictable alteration of energy flows and consumption patterns in the grid (Electricidade de Portugal S.A., 2021).

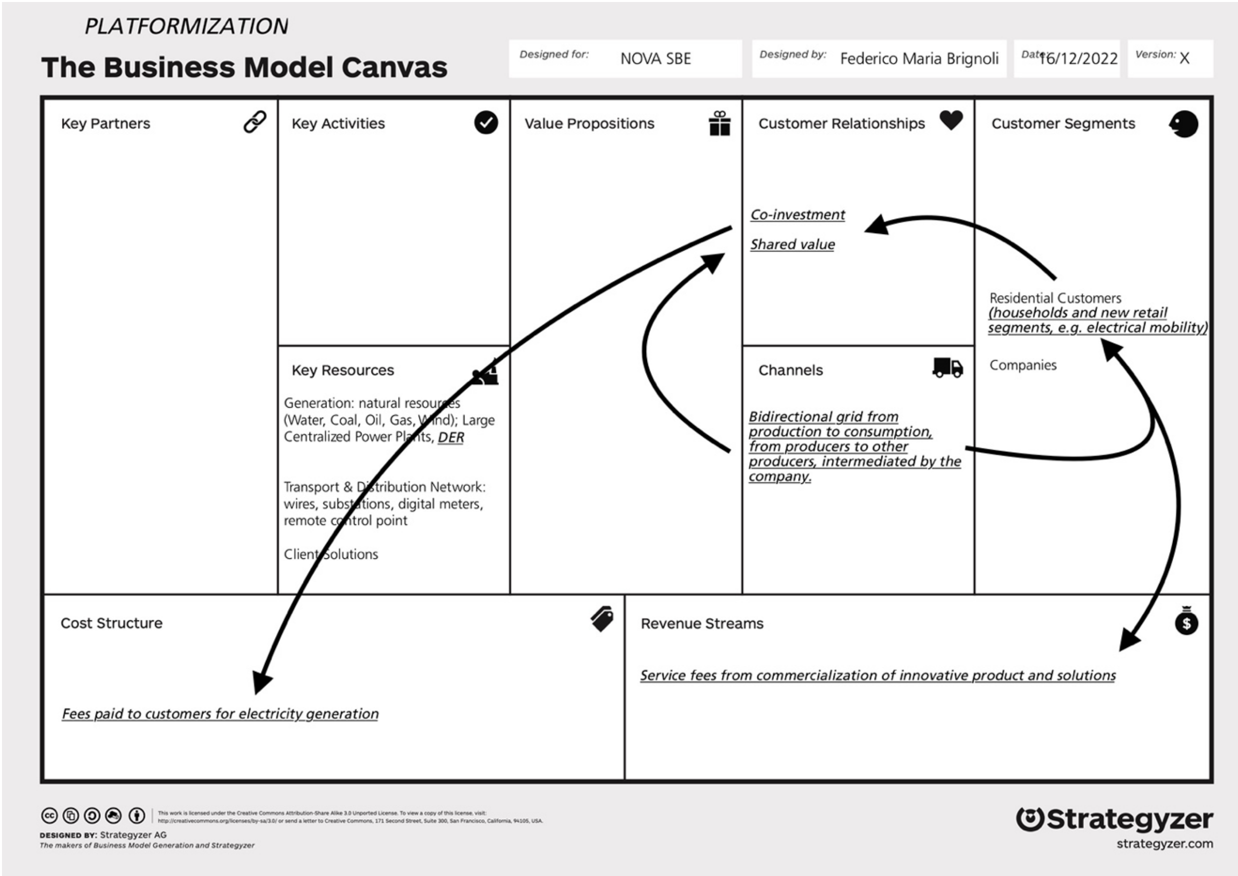

Figure 3 - Platform and loops in the new business model

In the case of major electricity companies in Europe, the digitalization of a key resource has created the necessary infrastructure to operate a more complex business model, with a substantially renovated value proposition orientated towards the co-creation of value that ultimately reverted a horizontal diversification trend in favor of a more decisive vertical integration bringing back the focus on electric energy supply and creating innovative product and services for consumers.

While we cannot deny the relevance of other external agents, such as political, monetary institution and other cultural shifts, such as the awareness for sustainable energy consumption, it appears clear that there exist a causal relationship between the emergence of new technologies and the development of new business design paradigms.

The objective of this work project was to enhance the theoretical understanding of business model transition from the perspective of BM theory, Information Systems, and Enterprise Architecture, following the indications of several authors (for instance Osterwalder & Pigneur, (2013), Peffers et al., (2007)) who complained about the limited IS and EA research on the topic. This work can also help guide other organization in formulating novel strategies in face of technological advancements and bridge this strategy to the design of its own implementation, as well as presenting grid digitization as a relevant property of a novel architecture.

The digitalized grid creates several positive reinforcing feedback loops that could be useful for other distribution activities. The most interesting one being the information collection of points of failure, a fine-grained understanding of consumers' behaviors, a more direct engagement of consumers that could result in higher awareness in production and consumption.

The utility company acting as a steward in a distributed energy market comprised of co-producer seems to be forming a strong, void center with nested centers arrange in a recursive hierarchy. The emptiness created from the progressive scale-back of generation activities, more and more located at the outer boundaries of the system, creates a void that balances and gives strength to the outer centers by removing clutter.

Actors conducting distribution operations must equip themselves to operate a more complex business model. While traditional operations are likely to continue with variations from the as-is status, multiple platforms are likely to emerge on top of the underlying activities.

Limitations and Direction of Future Research

The companies analyzed publish extensive reports since they are listed on public stock exchanges and national governments still own significant shares; yet the reliance on secondary data constituted a strong limitation to the work hereby presented. In addition, the qualitative analysis conducted might have resulted in biased or subjective judgements.

Further research might be orientated towards field research in utility companies, adjacent or uncorrelated organizations similarly involved in distribution activities. Proceeding on this path, it could be possible to further articulate the structure we have uncovered here from a pattern-oriented perspective (Alexander et al., 1977; Op ’t Land et al., 2009) and understand whether it can play an informative or instructive role (Greefhorst & Proper, 2011) in defining a more comprehensive architecture.

Further exploration and validation of business model archetypes can be conducted during workshops with industry experts.

While our work focused on electricity companies, the fundamental intention was to lay the foundation for more comprehensive research on how distribution mechanisms and network of agents work in a present characterized by deep IT-driven transformations, especially when these agents take a more nuanced role that is not just the one of the “passive” consumers. Ultimately, our goal would be to identify a business model pattern that can be applied on distribution activities to guide transitions towards complex business architectures.

Moreover, it would be interesting to model agent behaviour following the framework for semiotic agents by Rocha, (see Joslyn & Rocha, 2000; Rocha, 1996, 1998), and the meta-theoretical information systems approach employed by Leonardi (2011) that explores changes in behaviour of agents in response to changes in technology and vice-versa.

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