Saint Petersburg State University

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MASTER THESIS

Organisational and Institutional Barriers for Diffusion of Smart Grid Solutions in the Emerging Economies

Submitted by: 2nd year student

of Master in Management Program

Pavel I. VINOGRADOV

Submitted to:

Dr. Yulia N. ARAY PhD

Associate Professor

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Abstract

Master Student's Name	Pavel Vinogradov
Academic Advisor’s Name	Dr. Yulia Aray
Master Thesis Title	Organisational and Institutional Barriers for Diffusion of Smart Grid Solutions in the Emerging Economies
Description of the goal, tasks and main results the research	The purpose of this research is to look at the organisational and institutional barriers that are hindering the widespread adoption of Smart Grid solutions in Emerging Economies, with a particular focus on the Russian Federation. The study's goal is to identify the challenges to the effective adoption and commercialisation of Smart Grid solutions in Emerging Economies and to give insights regarding tackling these constraints. The paper achieves its goal of identifying the significant organisational and institutional barriers and problems encountered in the adoption of Smart Grid solutions by conducting a thorough examination of the Russian Federation's setting by conducting semi-structured interviews and further thematic analysis. The findings constitute not only the list of the barriers identified, but tailored recommendations, which provide a pathway for power grid companies and governments to resolve these constraints and design specialised Smart Grid adoption plans in Emerging Economies.
Keywords	Smart Grid, Power Grid Innovations, TOE Framework, Technology Adoption, Emerging Economies, Power Sector, Institutional Theory, Disruptive Innovation, Sustainable Innovations

Автор	Павел Игоревич Виноградов
Научный руководитель	Юлия Николаевна Арай
Название ВКР	Организационные и институциональные барьеры внедрения решений Smart Grid на развивающихся рынках
Описание цели, задач и основных результатов исследования	Данное исследование посвящено организационным и институциональным барьерам, препятствующим широкому внедрению решений Smart Grid в странах с развивающейся экономикой, уделяя особое внимание Российской Федерации. Цель исследования - выявить проблемы, препятствующие эффективному внедрению и коммерциализации решений Smart Grid в странах с развивающейся экономикой, и дать рекомендации по устранению этих препятствий. Диссертация решает поставленную цель - выявить значительные организационные и институциональные барьеры и проблемы, возникающие при внедрении решений Smart Grid, путем тщательного изучения ситуации в Российской Федерации посредством проведения полуструктурированных интервью и дальнейшего тематического анализа. Результаты исследования представляют собой не только список выявленных барьеров, но и рекомендации, которые стремятся проложить дорожную карту для электросетевых компаний и государственных органов для решения этих проблем и разработки специализированных планов внедрения Smart Grid в странах с развивающейся экономикой.
Ключевые слова	Умные Сети, Инновации в Энергосистемах, Концепция TOE, Внедрение Технологий, Страны с Развивающейся Экономикой, Электроэнергетический Сектор, Институциональная Теория, Подрывные Инновации, Устойчивые Инновации

Preface

This master thesis is the concluding work of my Master in Management studies. This thesis was written during my final year at the Graduate School of Management of St. Petersburg State University.

I would like to thank Dr. Yulia Aray for supervising my work, and assisting with enthusiasm as well as expertise. She has been a great support during plenty of meetings. I am sincerely grateful for the opportunity to work with and your contributions!

I would also like to thank Dr. Robert J. Reinhardt, Consultant at the United Nations Environment Programme and external reviewer of this research.

Finally I would like to extend my gratitude to all the experts, who I interviewed during my work and who were kind enough to take the time to be interviewed and to share their knowledge.

St. Petersburg, June 2023

(Pavel Vinogradov)

"For me dreaming is simply being pragmatic"

[Shimon Peres, 8th Prime Minister & 9th President of the State of Israel]

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Abbreviations

1. **SG** Smart Grid
2. **EV** Electric Vehicle
3. **V2G** Vehicle to Grid
4. **DER** Distributed Energy Resources
5. **NILM** Non-Intrusive Load Monitoring
6. **AMI** Advanced Metering Infrastructure
7. **TOE** Technology - Organisation - Environment
8. **DOI** Diffusion of Innovation
9. **IEA** International Energy Agency
10. **ISGAN** International Smart Grid Action Network

Introduction

With a rapid development of new technological solutions for safe and efficient power distribution, it has become evident that there is a clear need in rethinking current and shaping new business models and implementation tools, which will help both incumbents and newcomers of the power grid industry to commercialise new technological solutions in order to provide value for both shareholders and every other stakeholder of the industry.

Specifically, digital technologies are penetrating every sphere of the energy industry and power grid industry as a part of it. Successful diffusion of ICT (information and communication technologies) to the electrical grid has potential to improve the quality, reliability and efficiency of electricity supply and to manage demand and reduce stress on the system [1].

This is particularly important, as nowadays, we witness a sharply increasing demand for power, which is accompanied with a seemingly contradictory trend: depletion of the fossil fuels, still widely used for electricity production [2] [3].

Producers in the traditional grid rely heavily on fossil fuels for power generation, thus providing society with unsustainable energy. Traditional centralised systems of power generation and obsolete technology drive power delivery costs rise, also burdening the network with inflexibility, which makes the grid unable to handle increased variation of energy sources and new consumption patterns among consumers. Moreover, in the traditional centralised systems installation, transmission, and distribution of power are exceedingly expensive in distant areas, making an economic incentive for a change. As a result, development of alternative ways for power generation and transmission is necessary to resolve aforementioned complex issues. [4]

Partly, Smart Grid appears to be the solution that could resolve some of the problems mentioned, however, the technology adoption has been troubling incumbent power grid companies for years. Technological solutions encompassed in Smart Grid concept increase complexity and interconnectedness of the network, thus, assuming renovated approaches to management of the grid.

Moreover, for successful implementation the technology creates a brand new dynamic in the value chain, thus implying rethinking utility firm business models, so the company can create additional value for its customers.

Smart Grid is widely considered to be a disruptive innovation for the energy sector, which has a potential to revolutionise the industry [5]. However, there are severe difficulties in integration and diffusion of the Smart Grid technologies into power grid companies' value chain. Mainly, they transform to organisational challenges involving issues about investment, operations and pricing, which also hinge heavily on policy and regulations.

Another aspect that is going to be addressed in this thesis is that as some elements of the Smart Grid are evolving and actively researched in OECD countries and other developed economies, Emerging Economies might lack access to the relevant innovation, expertise, investment and regulatory incentives to drive the technology forward and renovate existing power grid infrastructure.

Moreover, Emerging Economies possess unique institutional specifics, which directly influences the conditions for Smart Grid effective deployment. This issue also dictates the necessity of a continued research, as there is a significant lack of studies investigating barriers and constraints to Smart Grid adoption in Emerging Economies in a holistic manner, employing different institutional and organisational frameworks.

Thus, this thesis conducts a comprehensive study of the main challenges and barriers, constraining adoption and development of Smart Grids technology by power grid companies with the focus on the Emerging Economies, providing an in-depth understanding of the issue.

Goal and Objectives

The goal of this thesis is to identify barriers at organisational and institutional level for successful implementation and ultimate commercialisation of Smart Grid solutions in the Emerging Economies on the example of the Russian Federation.

The objectives of this paper are to identify main barriers for effective Smart Grid implementation in the Emerging Economies in a comprehensive and holistic manner utilising relevant theory, to conduct thorough analysis of these barriers, and to propose recommendations in order to successfully adopt Smart Grid solutions.

The thesis builds on the assumption that Smart Grid is a hi tech, which tends to be a game-changer within the industry at large, and has great opportunities to unlock large values by improving current power distribution frameworks.

This study is based on the relevant theoretical concepts, such as the Technology - Organisation - Environment (TOE) Framework, Disruptive Innovation Theory and Institutional Theory.

To achieve the goal of this thesis, research questions were formulated as follows:

RQ1: What are the barriers constraining the ability of utility companies to adopt Smart Grid solutions in the Emerging Economies?

RQ2: Which institutional factors hurdle successful diffusion of Smart Grid solutions in the Emerging Economies?

RQ3: Which organisational factors hurdle successful diffusion of Smart Grid solutions in the Emerging Economies?

This qualitative study answers the research questions by analysing literature and public reports and documentation and then utilising a semi-structured interview framework, measuring the state of the main barriers identified in the literature review and possibly identifying new ones.

Due to the underdeveloped character of the theoretic field related to the topic, grounded theory approach was utilised in order to constantly seek new data from the semi-structured interviews and contribute to the theory.

This methodology aims to estimate both barriers identified in the previous research and to secure new insights from various stakeholders, including both practitioners and academics.

There are a few limitations to the research, as accessibility of the data becomes the main of them, as power grid companies have commercial secret constraints, making potential assessment of introducing Smart Grid into the business model. However, these constraints were largely overcome with robust interview results and extensive secondary data analysis.

Thesis Structure

The structure of this thesis is organised in a way to ensure a comprehensive understanding and convenient reading. The paper starts with a general introduction of the thesis, explaining the essence of the Smart Grid technology and the issues regarding its adoption by utility companies. Then, in Chapter 1 comprehensive and relevant literature review is conducted. Chapter 2 presents from itself a theoretical review, showing the theoretical concepts used in this research. Chapter 3 is largely dedicated to the methodology: research strategy, design and constraints. Following Chapter 4 analyses relevant insights from the semi-structured interviews. Each with relevant theory, analysis, and discussion, respectively. Furthermore, Chapter 4 includes the theoretical contribution of the paper and practical recommendations for state-owned power grid companies in order to overcome the relevant barriers. The paper ends with the conclusion, limitations and future directions to the research.

Chapter 1

Literature Review

To establish the body of literature a systematic content analysis approach was used. The main result of examining literature is the notion that this research has made significant progress in the past.

Nevertheless, it has been also established that the research field is defined by low degree of novelty, practically no investment in theory building and a lack of unified research design and measurement options.

Concepts definitions

Smart Grid

Smart Grid solutions are a complex construct, definitions of which vary across both the energy industry and academia. For the sake of clarity, this study will use the definition proposed by the International Energy Agency: "Smart Grid is an electricity network that uses digital and other advanced technologies to monitor and manage the transport of electricity from all generation sources to meet the varying electricity demands of end users. Smart grids coordinate the needs and capabilities of all generators, grid operators, end users and electricity market stakeholders to operate all parts of the system as efficiently as possible, minimising costs and environmental impacts while maximising system reliability, resilience, flexibility and stability" [6].

According to Blackridge Research and Consulting, premier market research and consulting firm covering exclusively global energy transformation, Smart Grid, as a macro concept may include the following technological solutions [7]:

- Advanced Demand Forecasting
- Advanced Metering Infrastructure
- Big Data
- Distributed Energy Sources (DERs)

- Non-Intrusive Load Monitoring
- V2G (vehicle to grid)

As we see, Smart Grids rely heavily on digital technology, so it is important to underline that Smart Grid as a concept has started its swift development aligned with improvements in the ICT technologies, more specifically the bilateral communications, which now constitute a milestone for Smart Grids technology [8].

Blackridge Research and Consulting has also outlined the main differences between centralised (traditional) grid and Smart Grid in the table below.

Key Differences Between a Traditional Electricity Grid and a Smart Grid

Traditional Electricity Grid	Smart Grid
• Electromechanical system	• Digital smart grid system
• Unidirectional information/power flow (one-way communication)	• Bidirectional information/power flow (two-way communication)
• Centralized power generation	• Distributed power generation
• Radial grid topology	• Network grid topology
• Manual monitoring (no real-time monitoring)	• Comprehensive real-time monitoring
• Manual restoration during outage recovery	• Self-reconfiguration (self-healing) during outage recovery
• A utility company has total control.	• Customer participation is better and more.
• There is a higher risk of blackouts and failures.	• Lower risk of power outages due to the adaptive and islanding properties.
• Absence of energy storage	• Good scope for energy storage
• Slow response time	• Quick response time
• Low sensor deployment	• High sensor deployment (full grid sensor layout)
• Low energy efficiency	• High energy efficiency
• Minimal RER (renewable energy resource) integration	• Large-scale RER integration
• Less environmentally friendly	• More environmentally friendly
• Few user options	• More user options

Source: Blackridge Research & Consulting

(Figure 1. Key Differences Between Traditional Electricity Grid and Smart Grid)

For better comprehension of this study, the author would like to point out that technical specificities and complexities are out of scope of this research. However, it was considered useful to outline the contrast between two grid formation approaches.

This study underlines that Smart Grid is a macro concept, which entails different technological elements, working patterns and various stakeholders, starting with power grid companies, EV manufacturers, state authorities & regulators, technology providers, banking institutions and others.

As a result, Smart Grids development and overall raised acknowledgement of innovative power systems boosted interdisciplinary research within the field.

1.1.Business Case for Smart Grid Technology: Consumption Patterns & Integration of Power Sources

In the last decade there has been extensive research conducted regarding such aspects as Smart Grid diffusion into company's business model and overall aspects of commercialising Smart Grid through effective embedding it into company's business model.

In various cases incumbents are losing profits not due to immaturity or complexity of technology, but due to inability to adopt their business models and create new ones to extract maximum value out of hi-tech.

Importantly, existing research highlighted the importance of systemic approach in order to fully diffuse Smart Grid technology into cohesive systems creating a clear business case for it, also ensuring governmental policy goals [9].

As information technology and interconnectedness of grid participants affects the formation of a potential business model, new value creation structures typical of a more customer-oriented economy may be created [10]. Specifically, the multi-sided platform (MSP): a business model, which is exceedingly relevant as emerging digital technologies increase interactions among different consumer groups [11].

Existing research underlines the importance of the business model innovation approach in terms of successfully adopting Smart Grid technology and creating a clear business case for it, multi-sided platform just being one of the ways of designing a new type of the business model.

However, one of the main issues with the business model innovation approach is that in practice power grid companies still plan to commercialise Smart Grid technology with their existing business model assuming that the entire value chain remains the same.

For all that, the Smart Grid implies *brand new power consumption patterns, and paths of integration of power sources,* which implies a highly dynamic flexible value chain and thus demands creation of a new kind of tailored business model, creating new value for customers and demonstrating a clear business case for the technology [12].

Regarding the new consumption patterns, it is important to notice that the new approach to power transmission and distribution has the potential to reconfigure the utility system business models with a focus on the customer side. Meaning consumers are becoming increasingly interested in power-related services, rather than in electricity itself. Power grid digitalisation promotes merging of tailored services and electricity as a commodity, which possibly disrupts the traditional consumption-driven paradigm of the electricity sector and differentiates customers [13].

Generally, electricity is perceived as a homogeneous commodity and, thus, considered to be a low-involvement issue for consumers [14]. Thus, existing research underlines shifting from supplying power as a commodity to providing smart energy services [15] [16] [17]. Shifting market environment made the transition to smart energy services not only lucrative but also necessary for businesses in order to profit from market development and to remain competitive [18].

Jörg Becker and Ute Paukstadt of University of Münster conducted a comprehensive morphological analysis of Smart Energy services and provided existing research with a classification of services, which may possibly substitute electricity as a commodity. Services have been clustered into major groups, implying their main purpose in the smart energy system [19].

Authors underline *co-creation in energy management* concept, implying that in the Smart Grid systems customer engagement is widely practised, which frequently leads to co-creation of value together with the utilities, making energy management a multilateral process through the following tools:

- efficient energy use (this function implies services enabling consumption reduction (e.g., energy monitoring, control options, profound energy data and control) [20]
- flexibility management (ability of customers to contribute in order to provide different forms of flexibility, e.g. through demand response)

- self-production & storage (e.g. EV charging can be considered as the co-creation of self-production & storage, since the process of power consumption and storage are temporally separated)
- energy trading (purchase and sale of power produced by customers to their peers or energy providers through feed-in of customers-produced energy or more sophisticated P2P energy marketplaces) [21]

Another concept is *aggregation*, which stands for the notion of “smart energy services co-creation of value by forming a network of customers and aggregating their energy resources” [22]. Demand response services can be considered as aggregation services, where utility company enables power aggregation, storage and generation units for households [23]. Aggregation services also can be also be embedded as:

- V2G
- Microgrids
- Virtual power plants

Importantly, Jörg Becker and Ute Paukstadt also define the so-called “key energy-related value” concept, which tends to be crucial for a comprehension of potential renovated power transmission and distribution systems. According to Osterwalder and Pigneur, “customer value describes the value provided through bundles of products and services that are offered to a specific customer segment”. Thus, according to existing research, the exact customer value can be valid only if it has direct customer benefit. As an example, environmental impact can be considered. The value can be marked as valid only in case of the service's immediate environmental benefit. E.g green energy tariff as an example of the environment as a key value.

Another concept is the *offering* category may consist of various digital services such as smartphone apps for energy monitoring and other services including cloud technology and part-human involvement.

As an example of the latter, predictive maintenance service for a microgeneration unit can be described. Human related part of service potentially involves a technical grid specialist, who, after being duly notified of the repair necessity by the system [24].

These elements of Smart Energy services classification were considered important for this research as they briefly present potential alterings of utilities business models to more customer centred, service related approaches in order to demonstrate altering power consumption patterns and overall business case for Smart Grid technology.

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As mentioned earlier, reshuffle of power grid companies' business models involves not only *different power consumption patterns,* mentioned earlier, but changing *paths of integration of power sources.*

Regarding the form of integration of power sources, existing research perceives Smart Grid as a part of *centralised vs decentralised power systems discourse.*

As key differences between centralised vs decentralised power grids have already been mentioned in the Concepts Definition section, we may directly proceed to existing research concerning Smart Grid technology as an evolving part of a decentralised power system or distributed energy resources (DERs).

According to Ernst & Young, DERs and Smart Grids are crucial parts to achieving security of energy supplies and finding a way for net zero by 2050.

Also the company provided a well structured definition of the concept: decentralised energy evolves in different applications, including microgrids, small-scale renewables, and combined heat and power (CHP) installations, as well as distributed energy storehouse and controllable loads. In discrepancy to conventional power generation installations connected to a centralised grid with power frequently transmitted over long distances — decentralised energy is generally distributed locally [25].

Overall, well-designed DES can lead the energy sector towards smarter and further flexible grids with an advanced share of renewable sources. An optimal DES design is grounded on an intertwined planning approach and considers all affected stakeholders, specialised feasibility and effectiveness [26].

Smart Grids deployment could be considered as a crucial progress in the transition towards higher degree of decentralisation and grid resilience. The technology allows bidirectional power flows, two-way data communication and control capabilities, which is a milestone in industry's efforts to optimise energy flow within a network and promote immediate responses to demand alterations [27].

Grid formation reshuffle towards decentralised structure offers new opportunities for power grid firms, as power market gets more complex, involves more actors and creates outings for new products/services creation.

Generally, within the renovated market design, power grid companies' role significantly differs from their traditional one. While traditionally the main function of power grid companies was overall planning, connection and disconnection of power sources, network maintenance, power outages prevention and mitigation and electricity billing, new market structure requires new functions of power grid companies, which include wider cooperation with other stakeholders in order to ensure proper functioning of smart power network and an efficient market, customers engagement and empowerment and efficient integration of distributed and renewable power sources.

Thus, power grid companies tend to play a more dynamic role within renovated market structure, mainly due to the fact that decentralisation of power networks requires utilities to take a more proactive position as the market diversifies and involves more stakeholders.

In this section, two main directions of business model innovation to successfully diffuse Smart Grid technology were identified: a service-oriented approach of value generation and decentralised energy resources as a new grid architecture. The importance of this section lies not only in a holistic understanding of the major trends within which Smart Grid adoption takes place, but also in illustrating the transformation of *how* utility companies can create value in a new innovative environment.

Further development of this literature review implies narrowing down from major trends to exploring drivers and barriers to Smart Grid adoption.

1.2 Drivers and Barriers to Adoption of Smart Grid into Utility Business Model

As it was mentioned earlier, the power industry, largely based on traditional centralised grids, won't be acceptable in the future in terms of its effectiveness and terrain benevolence. With new challenges arising, primarily growing consumer demand, climate change, integration of renewable energy sources, the power distribution industry is subject to a rapid change, they provide the industry a brilliant opportunity for the adoption of Smart Grid solutions. [28] [29] However, deployment of Smart Grid solutions is subject to both drivers and significant barriers.

Both drivers and barriers have been covered in existing research, providing a core part for this paper's literature review.

For the moment, several key drivers for Smart Grid technology successful diffusion were identified. Firstly, it is important to mention *increasing power demand.*

With the overall advancement in hi-tech, a sharp increase in power demand takes place, which becomes a challenge not only for power production, but also for transmission and distribution. Rising electricity demand increases the complexity of power grids due to requirements of enhanced levels of security, sustainability, efficiency and overall reliability [30]. According to S&P, global energy demand will grow by almost 50% by 2050, putting extra pressure on current energy systems [31].

Adding up to the issue, the International Energy Agency claims that the current global energy crisis largely triggered by the conflict in Ukraine is reconfiguring already well-established demand trends. Both residential and commercial power consumers are adjusting their energy utilisation patterns due to sharp price growth. Moreover, major policy responses imply determination to enhance clean energy investment, which means an even stronger incentive for renewables in the power sector and faster electrification of the commercial sector, heating and transportation [32].

Moreover, Smart Grid solutions tend to promote the electrification of energy demand, taking into account that electricity is a very efficient and eco-friendly form of energy.

The rising importance of renewable energy sources underlines the necessity to approach it as a separate driver of Smart Grid technology adoption: *integration of renewable energy generation systems and overall sustainability concerns.*

Renewable energy sources are receiving vast support and their shares in electricity generation is on the rise, despite the fact that increasing renewable power generation in an inflexible power network is the major challenge for the power industry, so Smart Grid technologies with their decentralised vector can be considered as a natural boost for renewable energy sources into the power generation mix. [33]. Specifically, existing research outlines issues associated with renewables disposal within traditional power networks. The issues may imply the intermittency of power generation using renewable energy sources and the lack of innovative distribution capabilities [34]. As Smart Grid provides electricity using digital technology through continuous monitoring, optimization of distribution systems and control automation, it could provide flexibility necessary for integration of variable power generation implied by renewable resources such as wind or solar (photovoltaics).

Regarding sustainability within the utility industry, there is a robust discussion in place about its decarbonisation and overall climate change issues.

For example, McKinsey&Co outlines several environmental benefits of Smart Grid technologies [35]:

- strengthening power grid could offset the effects of violent weather conditions
- reduction of CO2 emissions and enhancing greater electrification of the national economy
- embracing residential battery storage

Further on, an important driver for Smart Grid technologies adoption is the *need for boosting efficiency and losses reduction.*

As it has been highlighted in the previous parts of this paper, Smart Grid enhances efficiency within the power network using advanced metering infrastructure, non-intrusive load monitoring and other applications. Smart Grid also enables better network functioning during peak load hours and reduces overall network load, thus potentially reducing utility companies OPEX (by delaying otherwise-necessary infrastructure impairment)[36]. Moreover, Smart

Grid allows for easy and rapid outages diagnostics and operative problem solving, which lowers utilities OPEX through less time and manpower used per outage, thus increasing revenues through reduction of SAIDI and increased sale of power [37].

Thus, from the point of view of energy efficiency, Smart cities and SGs will provide important services to society, mainly focused on saving energy, which will greatly reduce CO_2 emissions to the environment.

Using different types of consumer response, Smart Grid also allows peak demand shifting, and as a result lowering current power-acquisition costs by removing the most-expensive generation sources from the mix during peak demand, enhancing overall energy management efficiency and enhance the possibility of strategising and managing consumption, interconnect on manageable loads in an intelligent and autonomous way.

Smart Grid technologies are also aiming at reduction of power losses, which still constitutes an issue for utility companies. Across the whole utility value chain (generation, transmission, distribution and usage of electricity) great amounts of losses still occur. For example, according to the U.S. Energy Information Administration (EIA) estimates annual power transmission and distribution losses average approximately 5% of all power transmitted and distributed within the country in 2017 through 2021 [38].

Power losses constitute a much bigger issue for nations with emerging economies, especially densely populated like India due to mismanagement and less voltage profile. Distribution losses in some of the emerging economies are as high as 30% due to such factors as: prominence of electrical theft, low levels of integration of renewable energy sources and highly regulated environment [39]. These losses could be appropriately addressed with Smart Grid applications, involving continuous monitoring in order to stop energy mismanagement.

Existing research also tends to focus on *customer focus and new business opportunities* as potent drivers of Smart Grid adoption.

In traditional power networks, customers are relatively passive about their electricity consumption. However, with evolution of the Smart Grid technology, customer roles will progress accordingly, as more active participation of customers will take place also balancing the electricity network. Potentially, Smart Grid enhances more informed decisions by the customers regarding their energy use, including quantity and timing of power consumption [40].

The technology gives consumers a visibility into real-time pricing and provides an opportunity to minimise the total amount of their bills by smartly choosing the volume and price of consumption that best suits their needs. While enhancing customer satisfaction, Smart Grid implementation may provide new business opportunities in the field of manufacturing of innovative products, processes and services [41].

As it has already been mentioned, customers tend to opt for power-related services, rather than for power per se, amid electricity market digitalisation trends, which could potentially revolutionise the traditional consumption-driven paradigm of the electricity sector.

Another crucial development serving as a driver of Smart Grid growth, which needs to be outlined is *electric vehicles efficient development.*

The Smart Grid has capabilities to accommodate EV charging, while bringing all elements of the electricity system closer together and improving overall system operation for the benefit of consumers and the environment.

Moreover, Smart Grid technologies possess the necessary infrastructure in order to enhance efficient use of electric vehicles. Adding, EV can be considered as a green technology, as it has a potential to reduce global dependence on fossil fuels, and overall carbon neutrality in case of running on fully electric modes [42].

Despite the fact that Smart Grid enables EVs integration by itself, Smart Grid technologies can be considered as a solution to charging infrastructure issues. It is now clear that EVs batteries charging will enlarge power usage, which will eventually create additional pressure on grids. Smart Grid's applications, such as comprehensive real time monitoring and high sensor deployment, allow utility companies to better control the electricity network and face new challenges within the grid [43].

Aforementioned drivers of Smart Grid development seem to be the most prominent within the context of existing research. However, this list is not exhaustive, as both technology and the overall electricity market develop rapidly, creating new circumstances for technology adoption and commercialisation.

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Along with drivers for Smart Grid adoption there are considerable barriers identified by existing research. Potential benefits of the Smart Grid technologies seem encouraging, however, the pace of smart grid technologies adoption is still slow, as utilities (and, ultimately, consumers) bear the costs, and the full potential of the IT layer has not been realised [44].

Existing research identified a few significant barriers for Smart Grid technology successful adoption.

High levels of investment and regulations

Firstly, it is crucial to discuss the *high levels of investment and regulations,* as one of the key barriers to Smart Grid technologies adoption.

Existing research underlines that Smart Grid development requires significant investment and overall financial reserves for the technology transfer, adequate infrastructure development, adoption of bilateral communication systems, human resource expenses both in management, engineering and others), extensive research and development and integration of renewables into the value chain. Importantly, with high levels of initial investment, the payback period for Smart Grid deployment initiatives is relatively long [45].

Moreover, the financial framework for Smart Grid investments hinges on the regulatory systems. While regulatory systems differ around the globe, universally companies still make ultimate investment decisions, in case NPV of the project is positive, implying that companies try to magnify the expected NPV of cash flows or market value [46].

In the power industry, the overall formula is influenced by the regulatory framework through the allowable rate of return, revenues, the valuation of the rate base on which returns to capital are allowable, and the incentives that the regulatory structure creates toward investment decisions. Thus, a regulatory framework has to be set in a way that utility companies cover incurred costs and gain their own net benefits while making investments into major infrastructure overhaul [47].

For Smart Grid technology's successful implementation, regulatory stability is essential, as long-period investment grids produce benefits both for utility companies and for society. In addition to regulatory stability, policymakers should ensure fair distribution of costs between operators and customers who must benefit from the development of technologies [48].

Most certainly, Smart Grid investment does incur major uncertainties, including uncertainty about future revenues volumes and costs, which may take the form of controversial and sometimes negative results from cost benefit analysis and of overall uncertainties related to power costs) [49].

Although Smart Grid adoption incur high levels of initial investment and complicated regulatory frames, existing research underlines that the potential impact of the Smart Grid technologies tends to outweigh the initial costs. However, the key concern still stands as follows: whether the investors and market will allow companies to move towards a smarter electrical system [50].

Market uncertainty

This point leads to another potential barrier which may affect Smart Grid deployment decision making - *market uncertainty.* As the electricity market is slowly drifting from monopolised rigid framework towards a more decentralised complex structure, several market uncertainties evolve for the utility industry [51].

In a more decentralised environment market pricing mechanisms are built on market forces, implying real-time demand-supply conditions, thus, prices become more volatile in nature, as cannot be established in advance. As a result, all parties involved in an electricity market face major uncertainty of power prices [52].

Importantly, uncertain wholesale power prices have to receive increased consideration during new investment decision-making on energy markets (including Smart Grid deployment) or if current power technologies are deployed on different power markets [53].

Literature suggests other side effects of market uncertainty, mostly coming from *market imperfections*. For example, a substantial blind spot for Smart Grid deployment is *poor definition of property rights.* Inter alia this may imply incomplete financial adjustment between customers, producers, power aggregators and balance responsible parties. *Information asymmetry* also plays its role in uncertainties of the electricity market, as market parties do not have access to all available information. Another market characteristic potentially influencing Smart Grid systems adoption is *imperfect competition*. Despite an overall trend for liberalisation and decentralisation of the electricity market, frequently there is still only one or a few market participants yielding and exercising market power. For example, an occurring lack of intermediaries at aggregator level may result in an oligopoly of aggregators) [54].

In such a turbulent environment different power sector participants have to do operational and economic planning considering underlying uncertainties.

Efficiency dilemma

As market uncertainty being one of the major barriers for Smart Grid adoption identified by existing research, this study considers it important to underline the *efficiency dilemma* as a separate issue due to its core nature to the market.

It has already been noticed that Smart Grid technologies promote more efficient power usage, which is beneficial for utilities through shifts in peak demand, reduction in numbers of power outages etc. Despite these positive aspects of Smart Grid solutions efficiency, utility companies may deal with the notion identified by this study as an efficiency dilemma.

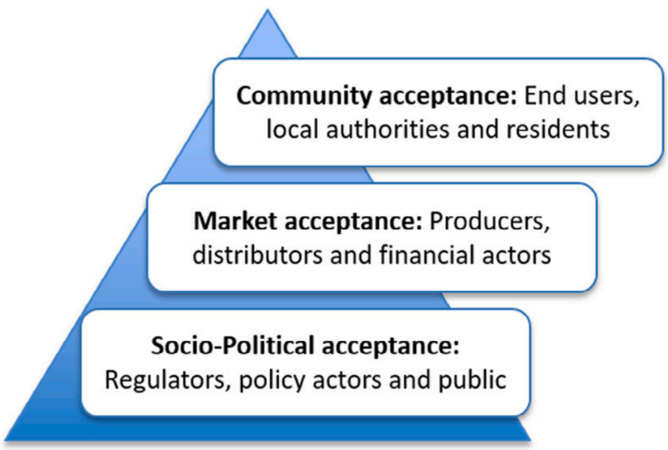
Smart Grid technologies tend to reduce overall power demand through efficiency measures, peak-load demand reductions, and the integration of alternative supplies (e.g. household solar, PV, and wind), which allow customers shift their status from consumer to prosumer, thus producing their own portion of power [55].

Aforementioned measures directly affect revenue streams, as declining demand results in dwindling revenues, which leaves less operating capital for reinvestment activities, e.g. into R&D. As alternative distributed technologies (e.g renewable energy sources) costs hinge on the level of technological development, the technologies become more attractive, and, as they are adopted, power demand tends to decline even more rapidly. A potentially reduced number of customers translates into average fixed costs growth for each, therefore transforming into higher average electric bills for the majority of consumers. Specifically these developments resulted into a profound discussion within the industry, naming Smart Grid technologies as a cause of the so-called "death spiral" for utility companies [56].

Social acceptance issues

Existing research has identified *social acceptance issues* as an extensive part of the barriers for Smart Grid solutions deployment discourse. It has been underlined that social acceptance may come in different forms. For example, market acceptance (process of technology acceptance and investment by market participants, amid appropriate policies and regulations), socio-political acceptance (regulatory framework setup conducted by policymakers in the form of legislation and executive orders stimulating adoption of innovative technological solutions) and community acceptance, which implies high levels of persuasion of local residents. Importantly, social acceptance in a community hinges on members identity, consumer behaviour, levels of involvement [57]. This model was outlined in Wolsink's study for Smart Microgrids, however it could be generalised for Smart Grid solutions.

The model graphically represented as follows:



(Figure 2. Wolsink's model for Smart Microgrids acceptance [58])

Nevertheless, there are certain criticisms in place for this model due to lack of explanations of the different levels interrelation. More specifically, it cannot explain acceptance at the global, country and local scale [59]. Also the model neglects intermediaries' role in the technology's acceptance, despite the fact that intermediaries can influence the acceptance of Smart Grid solutions by transferring acceptances to actors at all levels of governance using their agencies and capacities [60].

The model also omits communication vitality. Knowledge exchange about key innovations like Smart Grid solutions is crucial for successful technology implementation, which is backed by diffusion of innovation theory, where it is clearly articulated that a new idea or technology is developed and revealed by communication among actors [61].

While there are flaws within the model, it could work as a basis for more in-depth understanding of technology social acceptance issues.

As market and socio-political criteria have already been highlighted within this literature review, we tend to focus on the criteria of community acceptance. Within the issue community the concept of community energy is widely used in order to describe energy related communities acceptance of innovation.

Community energy can be defined as follows [62]:

- “community as stakeholders, which refers to significant stakeholders in decisions and the implementation of energy initiatives”
- “community as a space or place, which relates to space where collective action happens”
- “community as a shared interest or vision, which is about groups of people with shared interests and vision”

As a community has a certain set of values, contradiction of those can become a considerate threat to Smart Grid technologies diffusion. While retrospectively the central values in the power sector were efficiency and reliability, right now there is also a growing trend for sustainability [63].

Smart Grid solutions enable monitoring and controlling functions, which might cause contradiction between such values as security and reliability on the one hand, and privacy on the other [64].

Moreover, geography also affects how community members interpret values that are relevant to Smart Grids. Customers' self-reflection may differ within the context of various social norms, income level, overall eagerness to use innovations and, in some cases, invest in these innovations, and other factors [65].

The notion of identity is directly connected with behavioural challenges specifics, which is frequently mitigated with technologies of demand response. Usually consumers are hesitant to adapt their behavioural patterns even in those cases when benefits from the technology are clear and the call for technology adoption is evident [66].

Reluctance to change

Existing research also underlines *reluctance to change* as an extensive part of the Smart Grid solutions deployment discourse. As a part of a broader environment, institutions play a crucial part in innovation adoption.

While this literature review has already identified in existing research such issues as regulatory framework, market conditions and some other parts of the external environment, we would like to separately underline issues regarding change-management from the institutional context.

For successful Smart Grids solutions adoption power grid companies need to focus on institutional conditions and rules, which implies management of energy flows through involvement, interaction and coordination between industry’s stakeholders. By doing so, companies can ensure proper change management and innovation integration processes. However, in practice, these measures are frequently ignored [67].

Moreover, within the institutional context, literature suggests that within the power industry there is a common inertia to change the structure of the power system. Even taking in account that current power system organisational structures limit flexibility, enhance complexity of renewable power integration, sustain high power costs and social inequalities [68].

Opportunities provided by Smart Grid solutions could largely be nullified by rigid in nature established market participants and regulators resistant to change, as they fear the technology's negative impact on the companies revenues and overall financial position [70].

Data Privacy & Security

Such issues as *data privacy and security* could become a significant barrier in case power providers do not ensure proper data handling and storage as customers will not support system transformation, if these issues are neglected. While Smart Grid implies accumulation of a great amount of data through smart metres and other applications, unresolved issues of treating power-related data privacy and ensuring security pose a serious threat for the technology's continuous development.

Virtual systems could be subject to various threats from the outside: viruses, worms, denial-of-service attacks, malware, fishing, and user errors that compromise integrity and availability of the system [70]. Specifically, Smart Grid, primarily through smart metering infrastructure, is subject to delays and inefficiency due to the fact that extensive volumes of acquired data could be stolen, compromising the safety of the customers and of the grid [71].

With further development of Smart Grids, the probability of cyber-attackers getting access to the underlying virtual infrastructure is growing, which potentially results in privacy breaches. Privacy breach within the energy system can be described as manipulation of energy usage data aimed at seeking private and sensitive data regarding power consumers. While data privacy of a consumer hinges on authentication and authorisation processes, it is vital for power providers to enable secure data collection through smart metering, especially in the course of aggregation of data regarding billing operations [72].

According to existing research, data analytics is now gaining new level of importance within power network due to development of customer-oriented services, which aggregate new kind of unstructured data, such as social media messages, digital images and video/voice recordings, sensor data and bundle it together with more traditional structured data from the grid [73].

In order to prevent data security issues being a barrier to Smart Grid technologies adoption, well-tailored solutions must be put in place. These include new state-of-the-art hybrid approaches operating according to legal guidelines within regulatory framework, considering a number of different interconnected stakeholders. So, for Smart Grid effective adoption it is crucial to execute safe metering using advanced metering infrastructure (AMI), preserving customers privacy with authorised and secured aggregation procedures [74].

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Hereby we highlighted numerous key drivers and challenges to Smart Grid solutions adoption. However, it is crucial to take into account that this list is not complete or exhaustive, as the area of study is very dynamic and ever-changing.

It is crucial to consider the rapid growth of technology, which has resulted in the emergence of novel business approaches. Furthermore, there are several technical details involved with Smart Grid systems that may serve as impediments to their implementation. For instance, the complexity of technology and the requirement for tailored skills may add considerable difficulties for some companies adopting the innovation.

Regarding the academic point of view, it is important to notice that a large share of the existing research focuses on the specific cases of Smart Grid solutions adoption in particular countries and with difficulties associated with it, lacking in holistic and comprehensive studies.

Despite these obstacles, it is critical to continue developing Smart Grid technologies and investigating strategies to overcome adoption hurdles.

1.3 Adoption of Smart Grid in the Emerging Economies: Challenges and Opportunities

As this study focuses on Smart Grid in the Emerging Markets, it is important to give a comprehensive understanding of the notion.

It is important to point out that there is no official definition of Emerging Markets or Emerging Market Economies. However, in its definition of Emerging Markets this study will rely on the International Monetary Fund (IMF) methodology of world economies of classification.

According to the IMF World Economic Outlook there are 39 “developed” or “advanced” economies, based on: high per capita income, exports of diversified goods and services, and greater integration into the global financial system. Others are marked as “emerging market and developing” economies, with 40 considered as “emerging market and middle-income” economies based on higher incomes [75].

According to Rupa Duttagupta and Ceyla Pazaebasioglu, in order to identify an emerging market, IMF looked at the following markers:

- Country’s economy overall size (through nominal GDP), its share in global trade and overall population
- Share of a country’s external debt in global external debt, plus level of inclusion in global investment indices and frequency and amount of international bonds issued
- Citizens Income level: calculated through GDP per capita in nominal USD.

IMF put a score for each country not considered economically advanced according to the criteria mentioned above, using the following weighted variables:

- 0.40×nominal GDP+
- 0.15×population+
- 0.15 ×GDP per capita+
- 0.15×share of world trade+
- 0.15×share of world external debt

According to this methodology there are the following states considered as Emerging Market Economies: Argentina, Brazil, Chile, China, Colombia, Egypt, Hungary, India, Indonesia, Iran, Malaysia, Mexico, the Philippines, Poland, Russia, Saudi Arabia, South Africa, Thailand, Turkey, and the United Arab Emirates [76].

***

Smart Grid is a vital component of energy infrastructure for Emerging Economies, especially as they increasingly integrate renewable energy sources into their energy mix.

Despite the fact that decentralisation and renewables introduction is a global trend, there are geographical differences in its implementation. For example, while the centralised grid is mostly incorporated into power networks of developed economies, Emerging Economies networks tend to focus on alternative means of accessing electricity, given the historical deficit of access to power [77]. This in turn provides them with additional benefits in Smart Grid solutions adoption.

Developed countries have already invested in Smart Grid technology and have conducted extensive research on the topic. However, it is important to note that certain factors need to be considered in the context of Emerging Economies in order to implement smart grid solutions successfully.

For instance, a research study conducted by the Indian Center for Study of Science Technology and Policy (CSTEP) identified five key factors that are crucial for making power grids in Emerging Economies “smarter” [78].

The first factor is the quality and reliability of power. In some Emerging Economies, the quality of grid connection is poor, resulting in frequent blackouts and power outages. Smart grid solutions are capable of addressing this issue through demand balancing and distribution automation, which ensure that power is available continuously. This is especially important for industries that rely heavily on electricity [79].

Another factor to consider is the cost-effectiveness of Smart Grid investments. Emerging Economies like China require cost-effective solutions to meet their rapidly increasing energy demand. Smart Grid solutions can help to optimise the energy supply, which can lead to a positive return on investment.

In developing countries, like Tanzania, the power grid may not be fully built out. In such cases, it may be more advantageous to build a Smart Grid instead of a conventional one. This approach can help to provide electricity access to a larger portion of the population, as well as enable the integration of renewable energy sources into the grid.

Lastly, renewable energy sources can be added to the Smart Grid and managed effectively. Distributed generation by renewable energy sources can be a key part of the smart grid, but it requires careful management due to the intermittency of such energy sources. By addressing these factors, Emerging Economies can successfully implement smart grid technology and reap the benefits of a more efficient and reliable energy infrastructure [80].

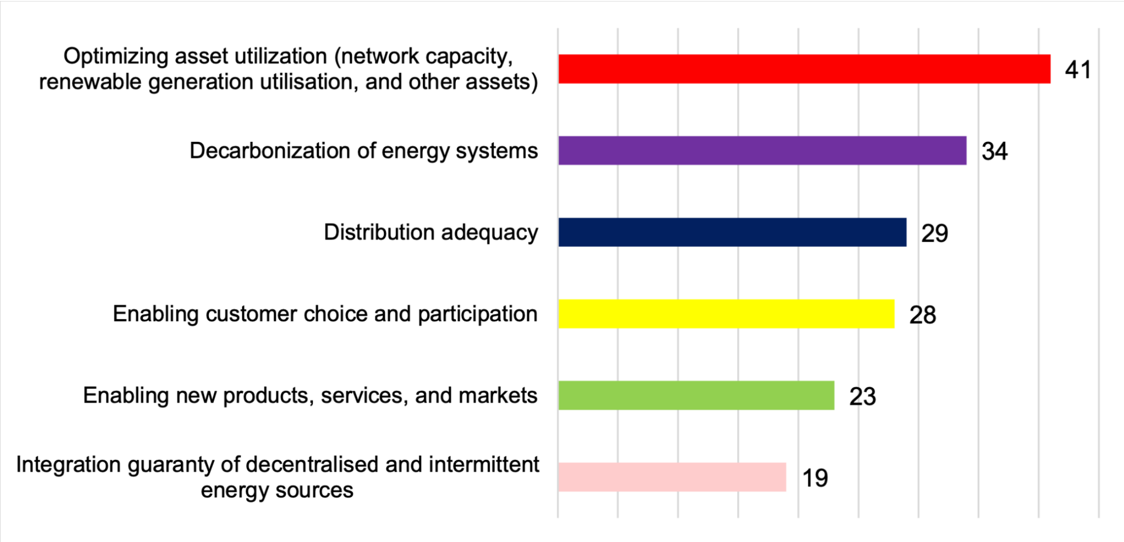
Existing research identifies several key factors that are critical for the successful implementation and operation of a smart grid according to the needs of emerging economies.

These factors include the *design of transmission and substation systems*, which can help to reduce losses for long transmission lines. Additionally, the design of distribution systems should incorporate intelligent control mechanisms that incorporate smart sensors and flexible switches. Another important consideration is the *use of smart distributed generation*, which can help maintain power quality against fluctuating generation using smart components. Moreover, *load side management* is also a crucial factor in managing demand by load control switches to reduce load-shedding. *Local charging stations* can be established to supply electricity for the basic needs of rural communities. *Billing services* can also be implemented via mobile phone, making it easier for consumers to pay their bills. Furthermore, the *information system architecture* is an important consideration when it comes to applying intelligent control by data management tools for two-way flow of information in a Smart Grid. Lastly, *financing* is a critical component, as the utilisation of Smart Grid requires a high level of investment by the government [81].

Additionally, International Smart Grid Action Network (ISGAN), a technology collaboration programme run by International Energy Agency (IEA), conducted a comprehensive study regarding major specifics of Smart Grid solutions adoption in emerging economies.

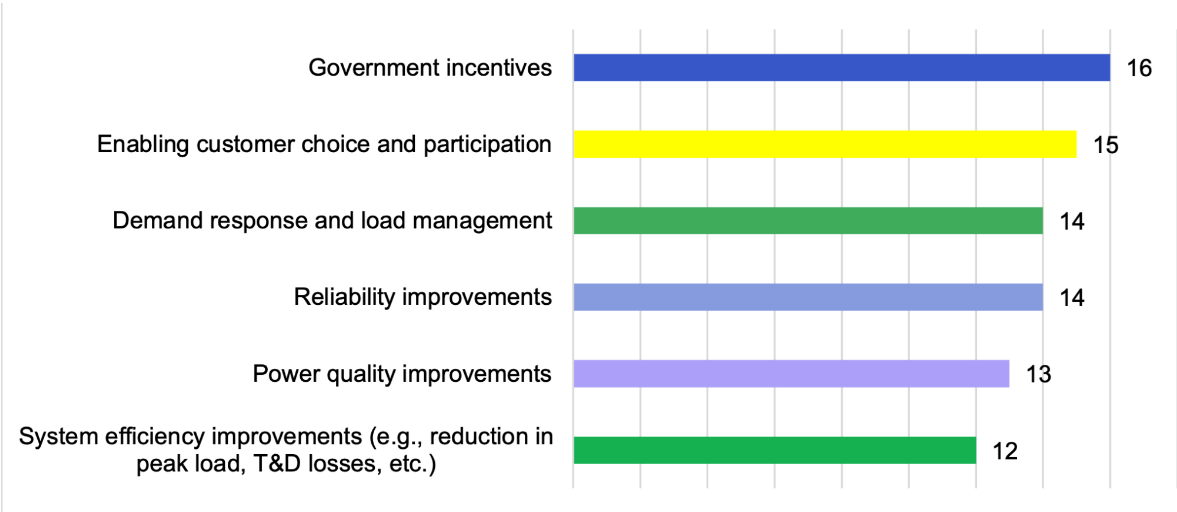
Moreover, it presents insightful findings on the top motivating drivers and technologies in both developed and emerging economies, which were analysed through the use of clustering methods based on multinational results [82].

Hereby, graphically presented analysis results for *Advanced Economies:*



(Figure 3: Top-6 Ranked Motivating Drivers from Clustering Analysis by Advanced Economies)

Hereby, graphically presented analysis results for *Emerging Economies*:



(Figure 4: Top-6 Ranked Motivating Drivers from Clustering Analysis by Emerging Economies)

The results of ISGAN analysis indicate that the major drivers of Smart Grids adoption differ between emerging and advanced economies. While developed economies tend to prioritise optimisation of asset utilisation, energy systems decarbonisation, prosumers and overall customer engagement, value creation through introduction of new products and services plus general network decentralisation and renewables introduction, emerging economies tend to emphasise government support, stability of the grid, enhancement of electricity quality, and managing decentralised resources due to emerging economies frequently limited power generation sources [83].

Literature also suggests key economic criteria that a country with an emerging economy needs to meet in order to successfully integrate Smart Grid solutions into its power network.

Recent studies have laid out several key criteria that determine the adoption of Smart Grid technologies in Emerging Economies. These criteria include [84]:

- *Access to high-quality education and job training programs.* Countries that have a well-educated and skilled workforce will be better positioned to develop and implement advanced Smart Grid systems.
- *The ability for companies and individuals to afford the costs associated with Smart Grid development and use.* The technology and infrastructure required for Smart Grids can be quite expensive, so economies must have enough financial resources to fund these projects.
- *The proximity of renewable energy sources to areas of high energy demand.* It is most efficient and cost-effective to locate Smart Grid infrastructure near the sources that will power them, such as solar and wind farms.
- *The amount of government spending on infrastructure and technology as well as the political stability of the country.* Governments that actively invest in innovation and have a stable policy environment will be more appealing locations for Smart Grid projects.

The degree to which an emerging economy exhibits these characteristics will largely determine how readily they are able to adopt Smart Grid technologies. Countries that possess high levels of development across all four criteria will likely become hubs of Smart Grids adoption, while others may face more significant challenges.

There are certainly opportunities for emerging economies at all levels, but they must evaluate where they stand with regards to these key factors before pursuing Smart Grid implementation. With proper planning and investments in infrastructure, education, and policy, even economies that are currently lagging in these areas can work to build a foundation for future Smart Grid growth.

To summarise, it is essential to recognize that the utility sector is vital for countries with emerging economies. Furthermore, in order to maintain stable economic growth, emerging economies must increase their existing installed capacity by twice as much. Within this vision, Smart Grid solutions and ageing infrastructure require substantial financial investments in the industry, which tends to be a major hurdle for emerging economy authorities. However, the aforementioned developments can be seen as a historic opportunity for Emerging Economies to boost innovation in value creation and attract private capital into the power sector [85].

In particular, the power grid industry provides the necessary infrastructure to enable emerging economies to grow their industrial and commercial sectors, which are crucial drivers of economic development and job creation. Moreover, the demand for affordable and reliable electricity will only continue to rise as populations grow and living standards improve in Emerging Economies [86]. By seizing the opportunities presented by developments in the utility sector, authorities in Emerging Economies can take a major step toward securing the energy future of their nations and facilitating continued economic growth and prosperity.

In conclusion, while the utility industry presents substantial challenges for emerging economies, it also offers significant opportunities for innovation, value creation, and private investment that can benefit both developed and Emerging Economies alike.

1.4 Conclusion

To summarise, it should be noted that the notion of Smart Grids drivers and barriers has enjoyed significant attention in the existing research, the bottomline of which is understanding that despite the fact that Smart Grid technologies offer significant benefits, there are also substantial barriers preventing their widespread adoption. Emerging Economies in particular face major challenges in funding, workforce skills, and policy support that pose significant barriers and threaten to limit Smart Grid progress. With investments in infrastructure, education and training, and government incentives, countries at all levels of development can work to overcome these barriers and transition their power grids to smarter, more sustainable systems. For emerging economies, Smart Grid solutions promise significant benefits, including increased energy access, efficiency, and integration of renewable energy sources.

Countries that make the necessary investments in their energy infrastructure and policy environments will be well-positioned to benefit from increased energy access, efficiency, and integration of renewable energy sources. Smart Grid technologies have the potential to transform Emerging Economies, and with hard work and determination they can achieve this goal.

From the academic point of view, it should be noted that, while the research has made significant progress in the last years, there is still a lack of comprehensive studies dedicated to emerging economies specifics, which includes specific barriers, in addressing Smart Grid adoption issues.

As it has already been mentioned, the majority of research focuses on concrete cases of Smart Grid solutions diffusion in particular states and with difficulties associated with it.

Thus, taking into account Smart Grid technologies practical implications, and the lack of a well-developed theoretical base of a discussion of its adoption into utilities value creation mechanisms, there is a need for research that addresses the barriers to Smart Grid adoption by utility companies in emerging economies. Focus on Emerging Economies is justified by the fact that Smart Grid solutions adoption pace has been severely imbalanced based on criteria of a countries' stage of economic development and, despite global positive development of the Smart Grid, application of the technology in emerging economies is still lagging behind as compared to the advanced ones.

This study aims to ambitiously work to address this significant gap in the literature, proposing a holistic approach for analysing barriers, with the focus on organisational and institutional ones, that are hindering the adoption of Smart Grid technologies in Emerging Economies.

Overall, the study has the potential to meaningfully inform policymakers, industry leaders, and researchers working to overcome key barriers to Smart Grid progress in the world's fast-growing economies.

Chapter 2

Theory

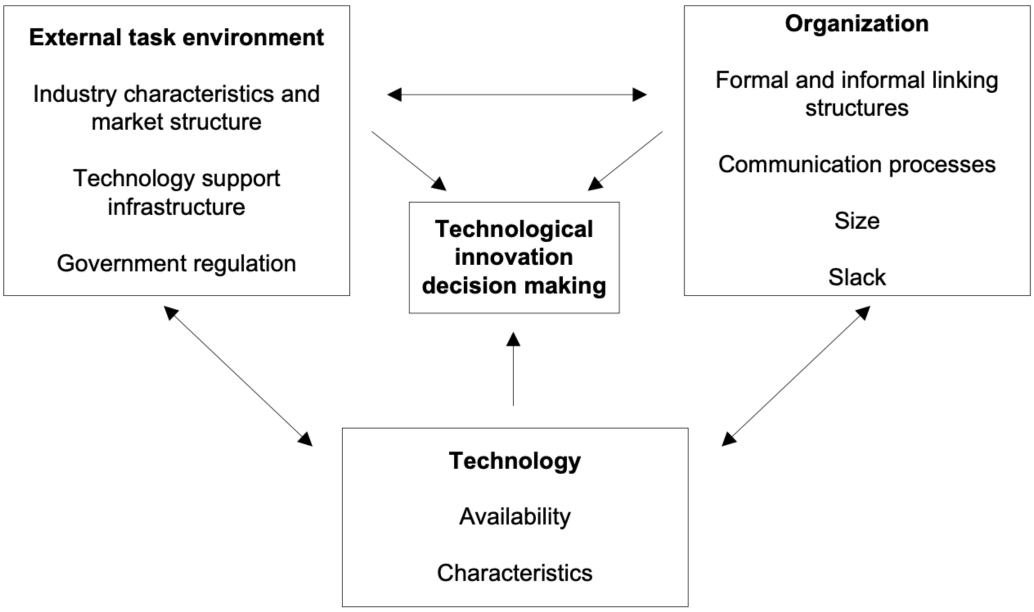
2.1 Technology Adoption within the TOE Framework

Theoretical lens for this paper is based on the technology-organisation-environment framework (TOE framework). Developed by Louis G. Tornatzky and Mitchell Fleischer in 1990, appears as a theoretical concept which explains potential technology adoption within organisations, providing a full-scale picture technological, organisational and environmental context of implementing technological innovations [87].

Specifically, technological context implies both the internal and external technologies relevant to the firm, which include both ongoing practices and equipment of the company and available technologies outside of the company. Factors like compatibility with existing infrastructure and systems, complexity and learnability, relative advantage and perceived benefits of the new technology, trialability or ability to experiment with the technology, and observability or visibility of the technology's results and impacts determine its adoption. If a technology is compatible with existing systems, easy to use, provides clear benefits, and allows for testing and visibility of results, it is more likely to be adopted. [88] [89] [90].

Organisational context implies company analysis according to its main characteristics such as scope, size, and managerial structure. Strong leadership support, sufficient IT skills, and a culture of innovation will facilitate adoption.

The environmental context refers to the arena in which an organisation operates. Things like industry standards, regulations, competitors' actions, technology trends in the industry, and relationships with trading partners and stakeholders can strongly drive an organisation to adopt new information systems to gain competitive advantage, achieve compliance, or collaborate more effectively. The need to keep up with competitors, meet industry regulations, and enhance stakeholder relationships will pressure organisations to implement new systems.[91].



(Figure 5. Tornatzky and Fleischer TOE Framework)

The TOE Framework can be considered a logical development of the discourse launched by Rogers in 1995 namely with the diffusion of innovation (DOI) theory. The theory underlines individual (both internal and external) characteristics of the company, seeing them as potential drivers of organisation’s ability to accept and diffuse innovations. [92]

These implications are ideologically close to the technology and organisation pillars of the TOE framework, but the latter introduces the third pillar - environment, which tends to be crucial for full comprehension of innovation diffusion by the organisation.

The framework also includes a wide range of contingent applications, as there are various empirical studies in place, which demonstrated that all three pillars substantially impact volumes of innovations adoption, c-suite engagement and overall value creation.

Despite the framework's various advantages, such as flexibility and, thus, ability to be applied to different types of technologies and contexts, making it useful for a wide range of research studies and its holistic nature, as it enables a holistic understanding of the complex interplay between different factors that can impact technology adoption and use in organisations, existing research has shown that the original TOE framework tend to omit the "interrelationships between the antecedents, whilst behavioural intentions rely on different characteristics of each innovation and its development in each country" [93].

Moreover, due to the fact that the TOE framework is highly dynamic based on different contexts, types of technologies and organisations [94]. Thus, various contextual factors have to be acknowledged and infused into the TOE, which would increase the validity of the interpretation of the findings.

Overall, the TOE framework is a useful tool for understanding the factors that influence technology adoption and use in organisations. However, its limitations should be considered when applying the framework in practice.

2.2 Disruptive Innovation Theory

While acknowledging the classical definition of disruptive innovation proposed by Clayton Christensen in 1995, this study underlines recent developments within theoretical field and practical limitations. Christensen insisted that disruptive innovation is "the process in which a smaller company, usually with fewer resources, is able to challenge an established business (often called an "incumbent") by entering at the bottom of the market and continuing to move up-market" [95].

However, later this definition was further modified by the author, implying that the disruptive innovation theory may also account for disruption through business models [96].

It is vital to acknowledge that the majority of innovations are not disruptive in their nature. More specifically they imply a brand new business model to deliver the breakthrough to market and make it work.

Disruptive innovation is not the same as sustaining innovation, which refers to incremental improvements to existing products or services. Disruptive innovations often create new markets and value networks, and as a result, they pose a challenge to established businesses that may not be able to adapt quickly enough to compete.

Disruptive business models become vectors for change. Nevertheless, traditional business models also may disrupt the market, when a novel product is innovated, while it often takes a long time from invention to widespread adoption.

Generally, disruptive technologies offer significant impact for both consumers and producers in the markets and society during the diffusion process [97] [98]. Additionally, existing research underlines that another factor bolstering companies' success is disruptive innovation pace, which is crucial for creating and sustaining firms' competitive advantage amid a constantly altering external environment.

Pace of disruptive innovation is affected by several factors and conditions. For example, a major condition is an appropriate environment, characterised by intensive competition, overall high market and technological dynamics and less restrictive regulatory frames. Other factors are majorly related to the company's strategic-orientation and organisational capabilities [99].

Powerful strategic leadership plays a crucial role within the context of the innovation process as it inspires the company's management and staff with progressive vision and incentivises personnel to perform and achieve KPIs in a highly intensive external environment [100]. Development of disruptive innovation also hinges on the ability of an organisation to learn and to adapt, as these characteristics allow an enterprise to develop and sustain competitive advantage [101].

Current theoretical base implies that diffusion of disruptive innovation can be described from the point of two macro concepts – “technological push” and “markets pull” [102].

"Technology push" stands for disruptions implied by unexpected technological developments within the spheres previously considered unattractive and improbable to have major technological breakthroughs. "Market pull" stands for disruptions provoked by major market forces, leading to quicker innovation diffusion or bolstering of innovative progress in order to meet major market needs. For example, renewable energy integration to the power system [103].

With a proper combination of two perspectives, firms can achieve and sustain their competitive position, as a disruptive technology adoption may allow a company either to conduct different business initiatives than its competitors or perform the same operations at a lower cost [104].

2.2.1 Smart Grid as a Disruptive Innovation

In a relatively regulated utility industry, the innovation process can be described as investing in new innovative technologies with two main reasons: to decrease OPEX or to increase customers' demand for already adopted or brand new services. Decision making of utility companies include decisions both in terms of the quantity and timing of Smart Grid technological advancements in distribution networks, as they are up to significant risk due to overall investment costs and future benefits offered by such innovations [105].

Smart Grid is often considered a disruptive innovation because it has the potential to fundamentally change the way we generate, distribute, and consume electricity.

Smart Grid solutions open up new business opportunities for power grid companies and third-party service providers. For example, power distributors can offer demand response programs to customers that incentivize them to reduce electricity use during peak periods, thereby reducing the need for expensive and polluting fossil fuel power plants. Third-party providers can offer services such as energy management and home automation systems that help consumers save money and reduce their carbon footprint.

Here are some specific ways that the Smart Grid can be considered a disruptive innovation [106]:

1. Decentralised Power Generation: The smart grid enables a shift away from a centralised electricity system to a more decentralised one. With the increasing adoption of DPRs like rooftop solar panels, energy can be generated at or near the point of consumption, reducing the need for large, centralised power plants. This could disrupt the traditional business model of power grid companies that rely on centralised power generation.
2. Real-Time Data and Control: The smart grid provides real-time data on energy supply and demand, enabling utilities to optimise the grid and reduce waste. This could disrupt the traditional approach of relying on fixed generation and transmission capacity that is overbuilt to handle peak loads.
3. Customer Empowerment: Smart Grid enables customers to actively participate in managing their energy use through demand response programs and home automation systems. This could disrupt the traditional approach of treating customers as passive consumers of energy.
4. New Business Models: Smart Grid creates new business opportunities for power grid companies and third-party service providers, such as offering energy management and home automation services. This could disrupt the traditional business model that relies on selling electricity as their main revenue stream.
5. Integration of Renewable Energy: Smart Grid enables the integration of renewable energy sources like wind and solar, which are variable in nature. This could disrupt the traditional approach of relying on fossil fuel power plants that provide constant and predictable power output.

Overall, the Smart Grid can be considered disruptive because it challenges the traditional approaches to electricity generation, distribution, and consumption, and opens up new possibilities for innovation and change.

2.3 Institutional Theory & Application to Technology Diffusion

Institutional theory is a prominent theoretical framework that emphasises the importance of institutional environments in shaping organisational structure and actions [107].

According to this theory, organisational decisions are not solely driven by rational goals of efficiency, but also by social and cultural factors, as well as concerns for legitimacy. Institutions are shaped by cultures, structures, and routines, and operate at multiple levels. They are a set of rules and regulations that govern the behaviours and actions of organisations, as well as individuals within them. They act as a social glue that holds together the fabric of society and provides a sense of stability and predictability to organisational actions [108].

The theory suggests that firms become more similar due to pressures for isomorphism and pressures for legitimacy. This means that firms in the same industry tend to become similar over time, as competitive and customer pressures motivate them to imitate industry leaders. For instance, firms are likely to adopt and use e-commerce due to external isomorphic pressures from competitors, trading partners, customers, and government rather than making a purely internally-driven decision to do so [109].

Moreover, institutional theory argues that institutional environments provide a sense of legitimacy to organisational actions. Organisations seek legitimacy as it enhances their reputation and credibility in the eyes of stakeholders, such as customers, investors, and regulators. Institutional environments provide a set of norms and values that organisations must follow to gain legitimacy. For example, environmental regulations provide a set of norms and values that organisations must follow to gain legitimacy in the eyes of environmental stakeholders [110].

Importantly, the institutional theory suggests that adoption decisions are influenced by more than just rational considerations. According to this theory, organisations are expressions of social values and operate as a distinct type of social system. They are guided by internal and external institutional logics [111].

The organisation's external environment includes a range of actors such as suppliers, consumers, regulatory agencies, and partner organisations, all operating within a recognized institutional field [112]. Internally, corporate doctrines, positions, schemes, and procedures are influenced by governmental laws, public opinion, education systems, or other institutions, and are put into effect by managers with the intention of improving organisational efficiency and/or legitimacy [113].

Other theories, such as TAMs and diffusion of innovation, also recognize the influence of social norms as a factor in adoption decisions [114] [115].

However, these theories view social norms as perceived rather than objective, and do not indicate who creates them. Meanwhile, the TOE framework only considers environmental factors from the viewpoint of the focal organisation. On the other hand, innovation decisions from an institutional theory perspective typically conform to the rules and values imposed by the broader institutional environment, and are mainly driven by the need for legitimacy within this context [116].

Existing research identifies three kinds of institutional pressures that affect technology adoption: mimetic, coercive, and normative. Institutional theory suggests that organisations in the same institutional environment become more similar due to experiencing similar pressures. Isomorphism can also emerge from regulation that requires certain levels of technology adoption or gives legitimization and possibly preferential treatment to organisations that respond to such coercive pressures and adopt certain innovations. The state is one of the largest originators of coercive pressures, referring to government (public sector) institutions such as destination marketing organisations, government departments and agencies, and regulatory bodies. The third type of institutional pressure results from the need to legitimise the organisation with respect to norms established by trade associations, educational institutions, or certification programs [117].

In conclusion, institutional theory provides a comprehensive understanding of how institutional environments shape organisational structure and actions. It highlights the importance of understanding the social and cultural factors that influence organisational decisions, as well as the role of institutions in providing a sense of stability, predictability, and legitimacy to organisational actions.

Chapter 3

Methodology

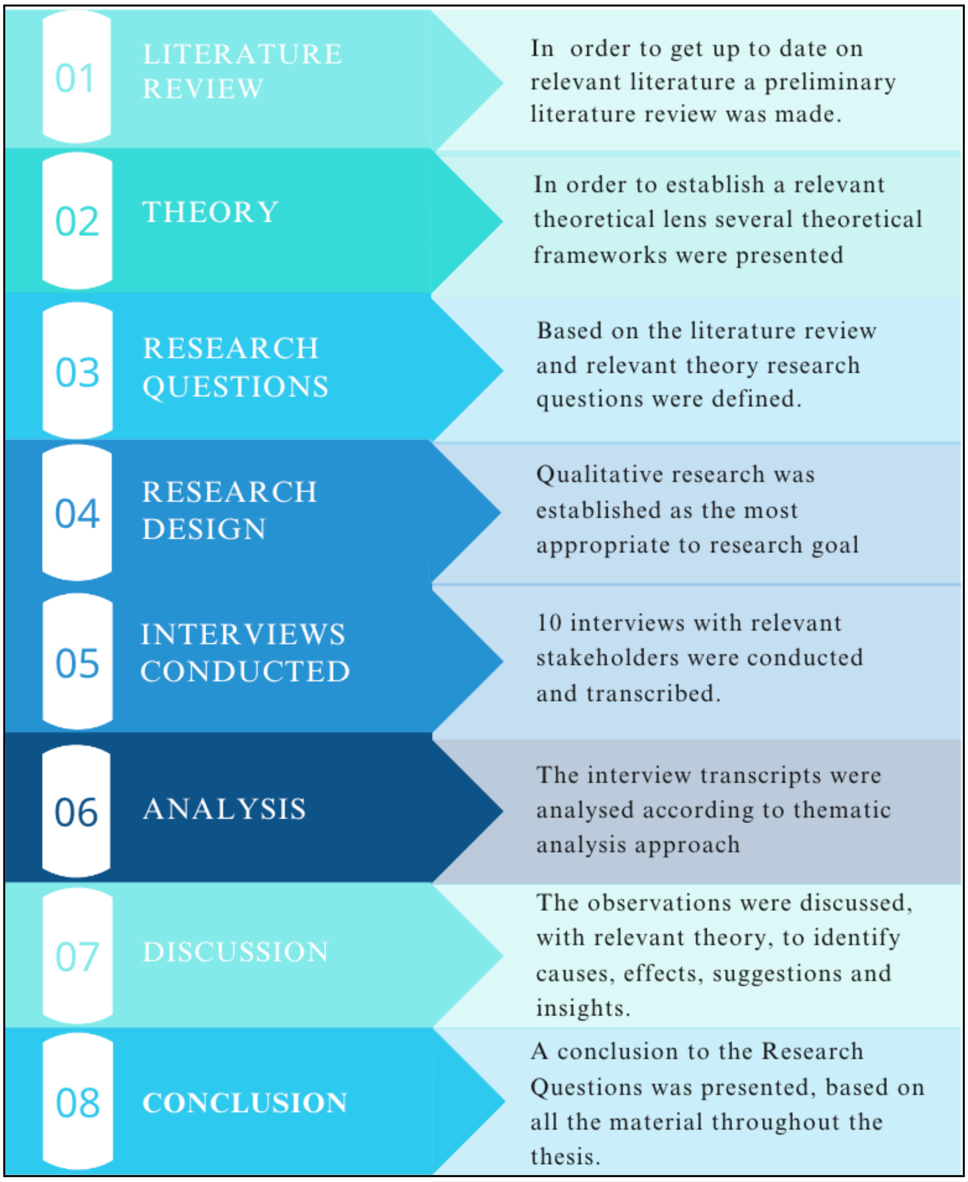
Methodology refers to the systematic and theoretical analysis of research methods. It is a crucial aspect of research that outlines the general research strategy for conducting a study. It is not only a method but also provides a justification for using a particular method. This thesis focuses on examining the overall research strategy, research design, and research method to define methodology.

3.1 Research Process

The research process is graphically outlined in Figure 6. In order to explore barriers to Smart Grid solutions adoption in the Emerging Economies, firstly, comprehensive literature review was conducted. Taking into account the interdisciplinary character of research, articles have been screened according to “Business & Management” and “Economics and Social Science” criteria. Moreover, corporate materials, consulting presentations and various think tanks data was analysed to track rapid changes in the business environment and detect root causes of barriers to Smart Grid adoption.

Following completion of literature review, the research questions were identified, accompanied by development of further research design and method in order to initiate the interview process.

Interviews with relevant stakeholders were conducted and transcribed. After transcription data was analysed. The findings were then discussed in order to identify relevant insights, root causes, effects, and suggestions for the respective research. Finally, thematic analysis was conducted in order to answer the research questions.



(Figure 6. The research process illustrated, step-by-step, chronologically.)

3.2 Selection of Literature

The literature was collected from the scientific databases: Google Scholar [118], Scopus [119], Emerald [120], Taylor & Francis [121] and JSTOR [122]. Most of the literature analysed was scientific articles, conference papers, book chapters, which helped to establish challenges to Smart Grid adoption in Emerging Economies identified by existing research.

The databases' choice was mainly based on their high reliability, integrity and high quality content. Articles provided by the databases were insightful not only from a business perspective, but also technologically, which helped to form a more comprehensive picture of the topic. The information cited is consistently based on the highest integrity source.

3.3 Selection of Research Method

To establish a research method, it is important to recognise that the research method is a systematic process that seeks to gain knowledge, often through the collection of pertinent information or data. This data can be measured either numerically or non-numerically, leading to two main research methods: quantitative and qualitative. In this study, it is essential to clarify the concept of qualitative research, which aims to gather non-numerical data on subjective meanings and experiences, and emphasises the analysis of words rather than numbers.

In this study, the aim was to comprehensively understand the various barriers that hinder the adoption of Smart Grid technology. To achieve this objective, it was crucial to choose an appropriate research method that could capture the underlying nuances and complexities of the subject matter. After careful consideration, it was determined that a qualitative research method would be best suited for this purpose.

Qualitative research is a scientific approach that seeks to gather non-numerical data about subjective meanings and experiences, emphasising the analysis of words over numbers. This method was chosen because it is particularly useful when dealing with complex and multifaceted topics, such as the barriers to Smart Grid adoption. It allows for an in-depth exploration of the subject matter, capturing the rich and diverse experiences of those involved [123].

The primary data collection method chosen for this study was semi-constructed interviews. This method was selected because it allows for flexibility and adaptability, ensuring that the interviewees are able to provide their unique perspectives on the subject matter. Through these interviews, it was possible to gather rich and meaningful insights into the various barriers to Smart Grid adoption, and to understand the factors that contribute to these barriers.

Grounded theory strategy was utilised within the qualitative method of the research due to the underdeveloped state of the theoretic field related to Smart Grid adoption in Emerging Economies. This strategy allowed the author to constantly gather new data from the semi-structured interviews and contribute to the existing theory.

Overall, the use of a qualitative research method and semi-constructed interviews as the primary data collection method has resulted in a comprehensive and nuanced understanding of the barriers to Smart Grid adoption. The findings of this study have important implications for policymakers, industry practitioners, and researchers who are interested in promoting the adoption of Smart Grid solutions.

3.4 Research Design

The main object of this thesis is the knowledge presented by relevant stakeholders regarding the implementation of Smart Grid solutions in Emerging Economies, with a focus on identifying the barriers to adoption. The study seeks to understand the perspectives of various stakeholders on the challenges and opportunities of Smart Grid technology in Emerging Economies.

To ensure that the interview process was conducted in a safe and confidential environment, all interviews were conducted anonymously. This approach was taken to encourage interviewees to express their opinions freely and honestly without fear of retribution. No sensitive information or identifying data was used in this thesis to protect the anonymity of the interviewees.

To provide context for the analysis, interviewees were assigned a randomised number and a general role description. This was done to enable the easy separation and identification of their statements during the data analysis process.

Hereby presented the relevant information regarding interviewees for this research:

Interviewee Number	Location & Date	Relevance (Position)	Company/ Entity	Industry	Country	Time
1	Google Meet 19.03.23	Head of Department	RusHydro PSJC (ex-Rosseti)	Renewable Energy	Russia	1 hour 50 min
2	Google Meet 29.03.23	Deputy CEO	Power System Group LLC	Power Systems Manufacturer	Russia	1 hour
3	Google Meet 1.04.23	Senior Consultant	ARB PRO Consulting	Consultancy	Russia	1 hour
4	Google Meet 27.03.23	Consultant UN Environment Programme	United Nations	Intergovernmental organisations (IGOs)	Germany	1 hour
5	Google Meet 22.03.23	Associate Professor	GSOM SPbU	Education	Russia	40 min
6	Google Meet 03.04.23	Business Development Manager	Origin E-Mobility	E-Mobility	UAE	40 min
7	Google Meet 14.03.23	Researcher	Institute for Environmental Economics Research (IÖW)	Research	Germany	45 min
8	Google Meet 17.03.23	Associate Professor	MGIMO (ex-Rosseti, Rosatom)	Education	Russia	1 hour 55 min
9	Google Meet 22.03.23	Member of the Board	T Plus	Utility Company	Russia	1 hour
10	Google Meet 28.03.23	VP	RosEnergoAtom	Power Company	Russia	30 min

3.5 Selection of Interview Objects

The methodology employed in this research was specifically designed to estimate the barriers that were previously identified, as well as to gain new insights from both practitioners and academics. To achieve this objective, interviewees were selected from a diverse range of fields, including experts in various technological applications of the Smart Grid, economics, and policy. Although the sampling process was to certain extent convenient due to time and resource limitations, each interviewee was carefully chosen based on their hands-on experience with various aspects related to Smart Grids.

During the interviews, the author carefully documented the insights provided by each interviewee. The discussions were wide-ranging and covered topics such as the challenges of implementing Smart Grids with focus on hurdles that need to be overcome.

The author expresses deep appreciation for the diverse and distinguished interviewees who generously made time to participate in this study. Without their contributions, the study would not have been possible.

3.6 Data Collection

As it has already been noted, the primary source of data and information used in this thesis has been the semi-structured interviews with a diverse set of participants, including industry experts, academics, and practitioners, to gain a well-rounded understanding of the topic. The interviews provided rich qualitative data, allowing for an in-depth analysis of the research questions.

In addition to the interviews, information consulting firms, statistical bureaus, and public information such as annual sustainability reports from power grid companies have been consulted to supplement the data collection. This additional data enabled a more comprehensive review of the topic, as it provided a broader perspective on the key issues.

By combining these sources, the data collected is both comprehensive and reliable. Furthermore, the use of multiple sources helped to mitigate potential biases that may have arisen from relying on a single source of data.

Overall, the data collection process was robust and thorough, providing a solid foundation for the analysis and conclusions presented in this thesis.

Semi-Structured Interviews

Using a semi-structured allowed the interviewer to delve deeper into experiences of the interviewees and extract more detailed information.

Additionally, it facilitated more open and candid discussion, as the interviewees had more freedom to express their thoughts and feelings without feeling constrained by a rigid question-and-answer format that prompts short answers. This approach also has a higher likelihood of subjective responses, which can provide valuable insights into the interviewee's perspective and experiences.

Using a semi-structured interview technique enables the interviewer to ask open-ended and ambiguous questions, which can then be followed up with more specific questions if necessary. This is particularly helpful in trying to obtain a deeper understanding of a topic or issue. By allowing the interviewee to speak more freely, it is possible to gain insights into areas that may not have been considered before. This trait is especially useful when trying to understand complex or multifaceted issues, such as Smart Grid.

In summary, a semi-structured interview technique is a valuable tool for gathering detailed and nuanced information from interviewees. By using open-ended and ambiguous questions, longer questions the interviewer can gain insights into areas that may have been overlooked or not previously considered, and obtain a more complete and accurate understanding of the topic being discussed.

3.7 Conclusion

Overall, research methodology served as a valuable canvas for investigating the complexities and nuances surrounding barriers to Smart Grid adoption in Emerging Economies. Qualitative nature of the research, enhanced by the employment of grounded theory strategy allowed the author to delve into nuanced aspects of the insights provided by interviewed experts.

In addition, the grounded theory strategy assisted in identifying major patterns and trends in the data. The active data collecting and analysis procedure allows for the development of new insights as well as the refining of old ones. This method guaranteed that the studies conclusions were found in the data itself, boosting the research's validity and reliability.

Semi-structured interviews made discussions wide-ranging, however, systemic, with each interviewee contributing greatly to the field of the research. The qualitative data gathered through the process of interviews provided rich and detailed insights that could not have been captured through other methods, such as quantitative research.

Chapter 4

Research Findings

4.1 Analysis of the Research Results

In order to gain rich insight from the data collected, the thematic analysis tool was utilised. Thematic analysis is a widely used method in qualitative research for analysing and interpreting data. It involves identifying and analysing patterns or themes within the data collected from interviews, focus groups, observations, or other sources [124].

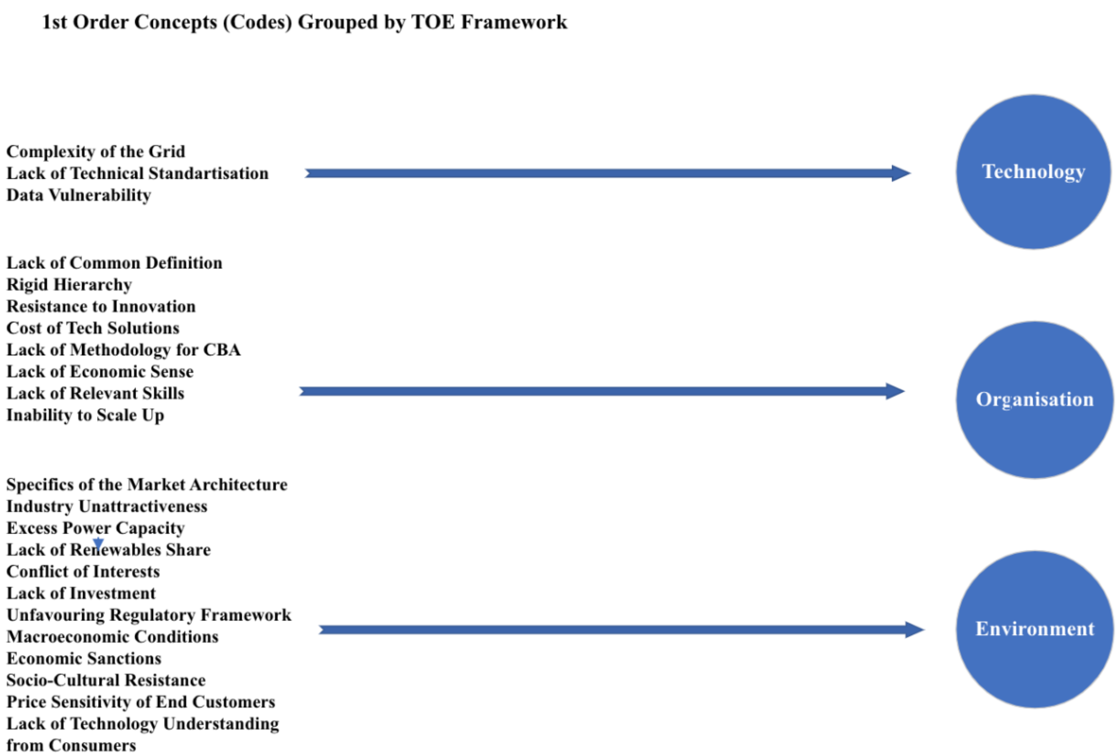
The process of conducting thematic analysis involved several steps:

- **Familiarisation with the data:** screening the data to gain a deep understanding of its content.
- **Establishing themes:** theoretical construct (the TOE Framework) provides future classification of potential codes.
- **Generating initial codes:** identifying meaningful units within the data and assigning them a label or code to capture their essence.
- **Reviewing codes:** reviewing and refining the codes to ensure they accurately reflect the data.
- **Grouping codes into the themes:** ensuring every code reflects a certain part of a theoretical construct (theme).
- **Finalising analysis:** writing up the results of the thematic analysis, including quotes from the data to illustrate the themes.

Thematic analysis is a highly flexible method that proved to be extremely useful in this study. By analysing the data within the context of barriers to Smart Grid adoption, we were able to uncover patterns and insights that would have been impossible to identify otherwise. This method allowed us to approach the data with an open mind, without imposing any preconceived notions or assumptions. In doing so, we were able to perform a thorough analysis that took into account all of the complexities and nuances of the data [125]. Overall, the use of thematic analysis greatly enhanced the quality and validity of our study.

Using the techniques mentioned earlier and guided by theory, we created analytical constructs to further analyse the data. We iterated between theoretical concepts, our data transcripts, and analytical constructs using pattern matching and explanation building techniques. Explanation building is often used in conjunction with pattern matching to uncover causal links and explain why or how a particular event or outcome occurred. Through this iterative, sense-making process, we progressed from our initial observations to enhancing current theory. Lastly, we shared and discussed the findings of our analysis with our respondents. As we based our research on the TOE Framework, we organised interview questions accordingly. Thus, we also grouped and analysed final codes and themes within the framework. We transcribed the interviews and used a combination of open and axial coding to identify key themes and sub-themes based on the TOE framework.

Hereby, we present the visualisation of thematic analysis results, where the TOE Framework pillars "technology", "organisation" and "environment" serve as main themes set for classification of codes.



(Figure 7: Thematic Analysis Results)

Technological Barriers

Complexity of the Grid

Issues regarding complexity of grid infrastructure and difficulties in integrating Smart Grid solutions into it have been labelled as a prominent narrative in interviewees responses.

"The adoption of Smart Grid technology in emerging economies can be hindered by significant barriers related to the technological complexities associated with its implementation and integration. These complexities can include issues related to compatibility of existing complex grid with innovative Smart Grid infrastructure"

"In other words, how can this play out with all the technologies that we might already have in place? How can they be better connected? So the question of integration of Smart Grid solutions into the current network. We might have all the technologies in place, but their integration in the network is an issue."

"Generally speaking, in countries with developing economies, and in Russia in particular, the problem of Smart Grid integration into the current grid definitely exists."

"Smart Grids have a technical peculiarity - there are a lot of complicated elements that interact with each other, and you have to deal with them."

"Technical challenges include the functionality and reliability of the equipment used, solving problems with the placement of equipment at existing facilities and ensuring its power supply in case of emergency outages"

"If you imagine a substation right now, it's a huge complex."

The responses all focus around the issue of grid complexity as a key impediment to Smart Grid solutions adoption, particularly in Emerging Economies. The technological challenges connected with the development and implementation of Smart Grid equipment might be substantial, impeding its adoption.

The interoperability of existing sophisticated grid infrastructure with cutting-edge Smart Grid architecture is one of the issues highlighted. The old grid may include all of the required technologies, but their integration into the Smart Grid network may be a challenge. As a result, integrating Smart Grid technologies into the existing network is a considerable issue.

Emerging Economies confront unique obstacles in incorporating Smart Grid technologies onto existing grids, as the problem of Smart Grid integration into the current grid exists in these countries. Smart Grids have technical peculiarities, and there are a lot of complicated elements that interact with each other, which can be challenging to manage.

The technical challenges associated with Smart Grids include ensuring the functionality and reliability of the equipment used, solving problems with the placement of equipment at existing facilities, and ensuring its power supply in case of emergency outages. The substation, for instance, is a huge complex, and managing its operations can be a challenge.

Lack of Technical Standardisation

Another problem arising from technical complexity of the grid is lack of technical standardisation on the level of procedures. While every stakeholder/interviewee approached this topic differently, the clear pattern of it being a real issue prevailed.

"Realising that the automation solution, such as Smart Grid, that may work at the sensor factory, where it is produced, may not always be fully capable of being implemented at the substation. Because technologically the process is different. Requirements to accuracy, reliability of operation of sensors, and speed of information exchange between them are objectively different and they need to be unified."

"Traditionally, the crew is being sent out to check whether everything is de-energized and then to switch the grid over. That is a major setback in all development, because the grid company now has to ask itself who will be responsible if something does not go according to plan. Because the current procedures say that someone has to go and make sure that the facility is actually de-energized. In Smart Grid, that happens automatically. So you need new standardised procedures."

"There are a lot of issues associated with the restructuring of technical standards, regulations, and norms"

"There were such long-term plans for the introduction of new standards, data transmission, and so on. They were not about architecture, but about solving technical issues. But the progress has been very limited."

The quotes emphasise the difficulties connected with the introduction of automation systems such as Smart Grid due to a lack of technological standards. Due to variations in technical processes, reliability and precision criteria, and the velocity of information flow between sensors, automation solutions created within one setting may not always be entirely capable of being applied in another. This lack of standardisation can cause considerable delays in the development of automation systems, as well as difficulties in assuring its safe and effective deployment.

There are various challenges with the rearrangement of technical standards, laws, and standards, and progress has been slow. The development and introduction of new standards, data transmission, and other technical issues require long-term planning and effort. However, the lack of standardisation and cooperation between different stakeholders can hinder progress and make it challenging to implement new solutions.

Data Vulnerability & Privacy Issues

Regarding the issue of data vulnerability and privacy concerns, this research faced significant challenges in reconciling different views on the topic. The narrative of interviewees has been inconsistent, adding various perspectives to the context of digital innovations adoption.

Part of the expert pool provided valuable insights and concerns about Data Vulnerability & Privacy Issues could be a real barrier for Smart Grid adoption within Emerging Economies.

"Data privacy is a critical issue that should be taken seriously by organisations, especially in emerging economies. These economies may have less developed regulatory frameworks and policies, making it challenging to ensure data privacy."

"I mean let's think of the worst-case scenario. Imagine you have a very well-advanced hacker group. They could, if they want, shut down the entire country. With the Smart Grid that could be possible."

"I think data privacy and more broad information security could be a massive barrier from Smart Grid adoption. We most certainly must take this risk into account. I think we're all aware about ongoing cyber-attacks that we are experiencing everywhere at the moment. And it's not only with regards to the energy industry, but I think also elsewhere again looking at this whole interconnectedness that we're seeing in the energy industry."

"Another point is that if, of course, through hacker attacks, it is possible to get access to the controlling effects of the power generation, then these things should, of course, be secured as much as possible."

"When implementing the Smart Grid, information security is of great importance. This is a broader concept than data privacy and includes the prevention of unauthorised access to the network in order to create emergencies, make changes to network settings or introduce virus programs. Prevention of these situations is solved by manufacturers by encrypting data exchange at the level of field devices, access to the settings of field devices is possible only by password from an authorised device with a set certificate. Thus, information security in Smart Grid technology is provided by solutions similar to those of the banking sector, but its reliability depends on its compliance by the operating personnel. Of course there are always certain risks."

However, another part of the interviewees considered the problem to be far fetched and exaggerated.

"Well, again, I think this is all highly exaggerated. Well, let's say there's a leak. Data leaked about how much electricity was delivered from the "Timiryazevka" substation to the "Olkhovka" substation. What is the value of this information?"

"Look, it seems to me that if we're talking about the end consumer data, to be honest, I don't see any big problems. On the whole, it seems to me that this is a very far-fetched problem."

While acknowledging this notion, this research still underlines the importance of Data Vulnerability & Privacy as a potential barrier for Smart Grid. Nevertheless, it is important to point out that the scale of importance of this issue in Developed Economies and Emerging Economies differ, with the latter prioritising different issues. Experts interviewed for this research attributed this difference to a perception divide.

"There is a perception divide between emerging and developed economies. Both within the implementing personnel and customers."

While perception of data security-related issues is a crucial point for the development of such an innovative and digitalised solution as Smart Grid and it is worth noticing, as a separate phenomena it lyes out of scope of this study.

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Overall, technological barriers are being considered as not a major issue with the adoption of the Smart Grid solutions. Moreover, it is not the main focus of this study. The main goal of this part was to focus on some major concerns to get a better understanding of a technological context of further development of organisational and environmental barriers to Smart Grid adoption.

Organisational Barriers

Lack of Common Definition

During the process of interview collection, lack of common definition of Smart Grid notion has been frequently pointed out by various stakeholders.

"I think we're lacking in studies. I think we're lacking robust consensus at the global scale of holistic studies. I mean we could even start by saying what's the definition of a Smart Grid. If you ask someone from Africa versus someone from Peru, I'm pretty sure they will come up with a different definition of what the Smart Grid means to them…"

"It is true that all the manufacturers put into the concept of Smart Grid somewhat different functional requirements…"

"The whole question is what we mean by the Smart Grid. This is a very important point, because, in fact, what we mean by that is like saying an umbrella. Different understandings, completely different ideas, can be gathered under it…"

"Smart Grids are understood in different countries as very different things…"

The comments illustrate a fundamental obstacle to Smart Grid adoption: the absence of a clear and widely understood connotation of precisely what a Smart Grid is. Because there is no common definition, it is difficult for diverse stakeholders to coordinate their objectives, priorities, and expenditures, resulting in confusion and ambiguity.

As stated in the quotes, various areas, nations, and businesses have varied ideas about what a Smart Grid actually is. In a specific country, a Smart Grid may be viewed as a tool to promote the integration of renewable energy and improve grid resiliency, whilst in another, it may be viewed as a means to reduce peak demand and improve consumer engagement.

Similarly, manufacturers' of Smart Grid equipment may prioritise various features and functions, resulting in a lack of interconnection and interoperability. This lack of definition and standardisation could hinder Smart Grid solutions rollout and scalability by creating hurdles to interaction, coordination, and collaboration among stakeholders. It can also result in unsatisfactory results since various parties may pursue conflicting or duplicate endeavours.

Rigid Hierarchy

Interviews highlight the idea that rigid hierarchy and traditional thinking patterns can pose a significant challenge for the implementation of smart grid technologies in the energy industry.

"I think they have to overcome some thinking patterns. Okay, because like in the energy system you always have a paradigm of "the bigger the better" and affection for a centralised system. And that's a paradigm which needs to be shifted…"

"Let's say there's a chief engineer, underneath him there's a service. Even the word "service," right? Not the company, but the service. So there's even a kind of militarization. The subordination is harsher in the power industry…"

Well, it seems to me that this is really a problem in the utilities industry, because power supply organisations, especially here and in other emerging markets, historically have a very rigid hierarchy…"

Rigid hierarchy can be a significant barrier to the adoption of Smart Grid technologies. In the energy sector, traditional ways of thinking, such as the belief that bigger is better and the preference for centralised systems, have been ingrained for a long time. This type of thinking can make it challenging to adopt new, more decentralised approaches like those required for Smart Grids. In addition to traditional ways of thinking, the language used in the power industry can also create a militarised approach to managing power systems. Terms like "service" and ideas of subordination can create a rigid hierarchy that may impede innovation and the adoption of new technologies. In some emerging markets, power supply organisations may have a history of strict hierarchies and centralised decision-making, which can make it difficult for innovative ideas to be introduced and adopted.

Resistance to Innovation

Following the discourse of rigid hierarchy as a barrier for Smart Grid diffusion, interviews point out significant levels of resistance to innovation both on organisational and individual level.

"These barriers can include a lack of awareness and understanding of the potential benefits of Smart Grid technologies, as well as a reluctance to change established practices."

"Organisational culture and management practices can present significant barriers to Smart Grid implementation, especially in emerging economies where there may not be established procedures for implementing new technologies…"

"…no willingness to change…"

"I think there would be huge amounts of reluctance to adopt a new kind of business model…"

"When we, as innovators, try to tell these people, again, professionals, that the consumers themselves will do some manipulations on the grid, it creates a very strong rejection on a cultural level…"

"All the attempts to talk about smart grids themselves, about two-way flows, control, metering, customer-centricity, tariff choices were strong, big innovations provokes resistance…"

"Power grid companies are very reluctant to change their internal network management regulations, and without changing them, the effect of implementing Smart Grid is reduced to zero…"

"We often encounter the situation where the CEO says that he wants to make the most modern, observable, controllable system. And when he goes to talk to engineers it all turns into an ordinary network, because they are afraid of the super fancy stuff…"

"There are opponents of all this at a high level of management…"

"In fact, quite a few problems. The first is the resistance of the staff, at all levels. It does exist because people are partly afraid for their employment, there are people who are afraid of the new and innovations in general."

"…general inertia of the institution. We are used to the way it works, and okay. Resistance to change in other words."

Resistance to changing established procedures, which can be linked to organisational culture and leadership practices, can be substantial obstacles to Smart Grid deployment.

In Emerging Economies, there could exist a reluctance to modify established business models, especially if the present models have proven to be effective in the past. This can be attributed to fears about the possible impact on jobs, in addition to an overall apprehension of the unknown and aversion to change. Furthermore, there may be cultural resistance to innovations and modifications, especially if they imply a shift in the way people work or live.

Resistance to Smart Grid implementation may additionally be observed at the power grid company level. Power grid companies, for example, may be hesitant to modify their own internal network management statutes, which can have a substantial influence on the efficacy of Smart Grid solutions. High-level management may also be resistant to the adoption of new technology due to worries about expenses, complexities, and possible influence on established business models.

Cost of Tech Solutions

Narrative of Smart Grid being a costly technological solution has been prominent and consistent throughout discussions. Thus, we have to specifically point it out.

“Obviously, any serious transformation of infrastructure, and Smart Grid is a component of infrastructure, is a serious investment…”

“Because these are very expensive solutions and they only exist in certain economic realities when you can, for example, raise power grid rates and things like that…”

“Plus Smart Grid is quite a big investment, the initial ones, you have to get it from somewhere…”

The quotes highlight the cost considerations associated with the implementation of Smart Grid technology in emerging economies. While the Smart Grid is a complex system that requires significant investments in infrastructure, such as sensors, communication networks, and control systems, any country that wishes to adopt this technology must have the financial means to support the initial capital investment.

Implementing Smart Grid technology is not a one-time expense, but a long-term commitment that requires continuous funding to maintain and upgrade the system. The cost of infrastructure is often one of the biggest barriers to adopting new technologies, and Smart Grid is no exception. Raising power grid rates is one way to finance the implementation of Smart Grid technology, but this is only feasible in countries with a stable and developed economy. Emerging Economies may not afford serious rate enlargement, as for these states electricity is often considered to be a social obligation, rather than commodity, which was also frequently mentioned within the process of the interviews.

Lack of Economic Sense

One of the most pressing issues about Smart Grid solutions diffusion in the countries with Emerging Economies appears to be the cost of Smart Grid technologies and struggles of power grid companies to commercialise them.

"We have approached this many times in Russia. In particular, when I worked at RAO UES, we tried it, but it did not work economically….

"Because when you are integrating these Smart Grid solutions it is not like one or two years , it's many many years to meet the return on investment and that's a pressing issue...:"

"I think that the problem is that the return on investment is very long…"

"There was an experiment in Italy conducted by Enel. They installed virtual metres and all the fancy smart grid infrastructure everywhere. How much money, including public money, was spent, but what did it yield? It's unclear…"

"The electricity supplier must not only invest in the metre, but also pay for the electricity itself and other costs, right down to the paper for the bills. And how do you achieve return on investment for this metre? This means that any smart, innovative technology in the Smart Grid concept must be properly adjusted. Any technology must either have a direct economic effect or indirect social and economic effect..."

"The second point is that it's quite difficult to prove a clear return on investment, because in my opinion, the Smart Grid is primarily about improving the reliability and quality of power transmission. Here, it's hard to calculate the economic feasibility of this…"

"Smart Grid does not give rise to any additional qualitative economic effects…"

According to the quotes, a fundamental barrier to the widespread implementation of Smart Grid solutions in Emerging Economies is a lack of perceived economic sense. The interviewees emphasised that the payback period for Smart Grid projects is long and challenging to demonstrate. For example, the setting up of Smart Metres may incur significant upfront costs, but the advantages and returns may not be realised for many years. Furthermore, the speakers stressed that any Smart Grid solution must have an either direct or indirect social and economic impact in order to be successful. Therefore, it means that any Smart Grid investment must demonstrate obvious economic or social advantages, which may be difficult to deliver in the immediate future.

Another key hurdle is demonstrating an undeniable return on investment. Smart Grid's major goal is to increase the reliability and quality of electricity transmission, which may not result in a direct economic advantage. As a result, convincing stakeholders as well as investors of the long-term advantages of Smart Grid innovations may be problematic.

Inability to Scale Up

Another aspect of economic viability within the organisational barriers is inability of power grid companies to scale up Smart Grid solutions from the status of pilot projects to a full scale working infrastructure.

"But there are no economic prerequisites for scaling at the moment…"

"It is clear that when trying to scale these technologies, there will be growing resistance from the operating staff…"

"Smart Grid is a very "boutique" thing, which is hard to scale…"

According to the responses, there are various problems that must be solved while ramping up Smart Grid systems. One of the most serious obstacles is a lack of economic conditions, which may prohibit critical investment and finance from being readily available. It may be difficult to apply these innovations on a wide scale without appropriate expenditure. Another issue that may arise is opposition from the staff who are accustomed to working with traditional grid infrastructure. Implementing new technology may need considerable modifications to existing procedures and structures, which could cause opposition from operational personnel. Addressing this difficulty may necessitate extensive educational and training initiatives to guarantee that personnel have the abilities and expertise required to run these new technologies.

Smart Grid solutions are highly sophisticated and exclusive, which may make scaling difficult. Implementing such innovations necessitates a high level of skill and specialised expertise, which could be difficult to recreate on a large scale. To guarantee that these technologies can be applied effectively, addressing this problem may need the establishment of novel educational initiatives and the nurturing of a trained workforce.

Lack of Necessary Skills

As it was already mentioned, Smart Grid technologies may require significant expertise and specialised knowledge. Within the process of the interviews, experts have underlined that lack of necessary skills and knowledge appear to be a significant hindrance for Smart Grid solutions adoption.

"We need to actually start to transform or upgrade or do more training for our workforce to adapt to new reality and to digital innovations…"

"That is why the moments related to education and the level of competence have immense importance in order to successfully integrate complex systems with different dimensions and impacts, such as the Smart Grid…"

"...So what if you're a techie and you know how to code. That said, there's a lack of understanding of the market and strategy as well as marketing and other things. Interdisciplinarity is required, which is more even on the side of the creators of all these solutions, I guess…"

"It seems to me that we have, well, not a problem, but there is a deficit of personnel on this side…"

"This is a problem on the side of the operating personnel. That is, new technologies require a corresponding increase in the qualifications of people. Yes, that is, already complex equipment, electrical equipment is in the service of people who often, especially in the regions, may not always have the appropriate skill level…"

"There is also a point in terms of service personnel. Relatively cheap personnel, who are the classics, who arrived, looked at the iron and left, will be in less demand. More people are needed who service these advanced electronics and so on. Those people are few in number, and they cost more…"

Smart Grid solutions demand a competent workforce that is flexible to the new realities of digital technologies. The workforce's lack of necessary abilities can be a significant barrier to properly incorporating complex systems with multiple dimensions and implications, such as the Smart Grid. Technical employees must have more than just coding abilities; they must also grasp the business, strategy, and marketing elements of Smart Grid technologies. Even among the manufacturers who develop Smart Grid solutions, cross-disciplinary collaboration is necessary to assure their effectiveness and success.

Insufficient education and training might result in a shortage of individuals who are qualified to deal with emerging technology. Service employees also have to be able to handle complex equipment, which means they might be rather expensive to recruit.

Furthermore, the conventional paradigm of relatively inexpensive staff doing simple duties such as inspecting and moving on may no longer be applicable, and more experienced personnel are required to maintain the complex equipment required by the Smart Grid. Upgrading staff skills and expertise is thus critical for the successful deployment of Smart Grid technologies.

Environmental (Institutional) Barriers

Specifics of Market Architecture

Market configuration, which encompasses numerous aspects including the monopolistic or oligopolistic market structure and stakeholder relations, has been outlined in the interviews as one of the dominant hindering forces of Smart Grid adoption in Emerging Economies, including the Russian Federation.

"Plus, you see, of course, all this is slowed down by a very high share of the state sector. The attitude to such things in the private sector is completely different as compared to the public sector companies…"

"But yes, I think monopolies kind of hinder innovation…"

"I am also looking at developing countries and the first question for me is monopolies. To what extent would current companies who are leading the market would be willing to make the transformation happening…"

"The grid sector is heavily burdened by tariff regulation, just because of the natural state of monopolisation of this process…"

"The electric power industry was initially like this, very strongly vertically oriented…"

"Market structure dominated by state monopolies hinders innovations such as Smart Grid…"

"Monopolies and big players, of course, are not interested in any risks related to innovation adoption..."

"In Emerging Economies the power market is frequently dominated by big super monopolies, which is not the best climate for innovations…"

The quotes mentioned above highlight the role of market architecture as a barrier to the adoption of Smart Grid solutions. In Emerging Economies, many markets are dominated by the state sector, which leads to slow and inefficient decision-making processes that impede innovation. Moreover, monopolies and large companies have little incentive to invest in innovative technologies that could disrupt their market dominance, resulting in a lack of competition and innovation in the sector.

Historically, the electric power industry has been vertically oriented, frequently dominated by a few large players. This is also the case in emerging economies, where super monopolies dominate the power market. These monopolies have little incentive to invest in new technologies that could potentially disrupt their market position, leading to a lack of innovation in the sector.

Excess Power Capacity

Whether we could consider this issue to be a part of a broader concept of Market Architecture, due to the significance of this factor on the Russian power market, we have decided to address it separately, as the importance of the issue was highlighted by interviewees.

"…There is a big surplus. In recent years, we have made good progress in generation and grids. We are not threatened by a deficit under any circumstances; we don't see it on the horizon. Right now we have the largest capacity surplus in the history of the Soviet and Russian energy sector…"

"...But in Russia there is not much interest in efficiency. We have excess generating capacity..."

"We have excess capacity and no economic growth…"

According to the quotes, there is currently an excess of generating capacity in the Russian power sector, which may be hindering the adoption of Smart Grid solutions in the country. This excess capacity means that energy companies have little or no incentive to invest in new technologies that could improve efficiency and reduce costs.

However, it is important to note that this may not be the only factor contributing to the slow adoption of Smart Grid solutions. Additionally, the lack of interest in improving efficiency within the sector implies there may be a reluctance to implement Smart Grid solutions that could optimise the use of existing infrastructure and reduce losses.

Lack of Renewables on the Market

An overarching majority of respondents considered RES to be a trigger for development of Smart Grid solutions, as they tend to mitigate intermittent nature of such sources as e.g. solar or wind. Thus, insignificant share of renewables in the energy market potentially may hinder the adoption of Smart Grid.

"Since we have a very small share of renewable energy, and it is still not even close to one percent, it can be considered a barrier, as the Smart Grid is driven by intermittent energy supply…"

"…It is perfect to balance intermittent generation, which dictates a clear need for innovation. But the share is too low right now and it seems to be a barrier for Smart Grid adoption…"

"…If there are a lot of decentralised RES, then it becomes very difficult to manage it. And it is precisely the Smart Grid that will allow us to manage all of this to some extent. That's partially why Smart Grid is needed in general. But the share in Russia is very low…"

"So, in general, solar and wind are the triggers of the Smart Grid in Russia, but the volume is critically low and I do not think it is going to be higher any time soon…"

The quotes highlight the lack of renewable energy in Russia and how it can act as a barrier to the adoption of Smart Grid technologies. The low share of renewable energy, which is still not even close to one percent, does not create additional massive incentive for Smart Grid diffusion.

Smart Grid technologies are designed to balance intermittent generation, which is precisely what is required to integrate more renewable energy sources into the grid. However, with the low share of renewables in Russia, there is less motivation to invest in Smart Grid technologies.

Lack of Investment

During the interviews, the participants almost unanimously agreed that lack of funding is considered to be a major obstacle in the implementation of Smart Grid solutions in the Emerging Economies.

"When we look at other technologies or other areas, there's just a lot of reluctance there from big organisations to go and invest…"

"...But billions are still needed to make these projects really work…"

"Another obstacle to the implementation of Smart Grid technology is securing financing and calculating the payback…"

"We live in the old regime, where the situation in the power grid complex is not very profitable. It can't be profitable, sometimes because of competition, sometimes it's price regulation. Basically, it's a bad business for investment. That is why it has not been invested in it for a long time…"

"And the need for investment remains high, because. There really needs to change a lot of things in order for it to be modern and meet all requirements, including economic ones…"

"Over the past few years, investments have been growing, but at an insufficient rate…"

The following quotes suggest that lack of investment tends to be a significant barrier to the adoption of Smart Grid solutions. Essentially, this means that companies are reluctant to invest capital in new technologies, while substantial funding is required to make Smart Grid projects work effectively.

Securing financing and calculating the payback for Smart Grid investments might present a significant challenge. Partly it is explained by the issues raised in the *Lack of Economic Sense* part of this research. While it is not easy to determine the expected return on investment for such projects, the costs involved can be substantial. This is particularly true given the current regulatory environment for the power grid sector, which can make it unprofitable for investment.

Unfavouring Regulatory Framework

Role of policies and regulations in the innovation adoption has been outlined as one of the primary topics within the discussions.

"I think that if you push this whole thing from the regulator's point of view, it can easily be done. But right now it's not."

"I think the most important barrier is the regulatory framework…"

"It is not possible to create a business model, when the regulatory framework is not in place to support it…"

"Smart Grid is being hindered from the regulation perspective…"

"On the whole, as for investments, it seems to me that the first question is how to set up mechanisms to stimulate the owners of grid assets to improve these assets themselves. In other words, some incentive measures on the part of the authorities…"

"Since there are currently no approved tariffs for the implementation of Smart Grid technology, companies are forced to remove additional functionality from projects in order for the estimate to be approved…"

"Regulatory framework in Russia seems to slow down innovation adoption rather than to facilitate it. Because first of all, almost all grid companies are state-owned. They all have to comply with all regulatory budgetary approvals and so on…"

Interviewees emphasised that diffusion of the Smart Grid technology in Emerging Economies is frequently hindered by the absence of supportive regulatory frameworks. The current regulatory environment fails to incentivise the implementation of Smart Grid solutions, leading to insufficient investment in modernising existing power grid infrastructure.

As a result, companies struggle to develop viable business models for Smart Grid technology adoption. Furthermore, the absence of established tariffs for Smart Grid implementation makes it challenging for companies to accurately estimate the costs and benefits of investing in this technology. Without approved tariffs, enterprises may have to remove additional digital innovative functionality from new grid development projects to ensure they meet budgetary approvals. In addition, power grid infrastructure in many Emerging Economies is owned and operated by state-owned companies, which has already been discussed. These companies are subject to numerous regulatory budgetary approvals, which can delay the adoption of new solutions like Smart Grid.

Macroeconomic Conditions & Sanctions

While factors of economic turmoil and uncertainty regarding international trade and finance might be considered specific to the case of Russia, certain conditions also may be faced by other Emerging Economies, thus can be extrapolated.

"As for Russia, I think that investments in the electric power sector in Russia will be zero for the next couple of years…"

"Any investment is possible only when there is sustainable economic growth and an increase in electricity consumption…"

"Let's see where the current geopolitical situation will lead us in some time. Maybe there will be more certainty. Including macroeconomics and geopolitics. But now all of this hinders Smart Grid adoption…"

"And right now, I think there's quite a bit of uncertainty. And on the one hand, there is a low-carbon trend and there is a strategy. But on the other hand, now it could be postponed a little bit. Not in first place. And the priority is shifted, although everyone understands that it is important, but not now…"

"...And then again in the current economic context, this is all quite complicated, expensive and just not a priority…"

According to the data collected, the Russian Federation faces various challenges when it comes to Smart Grid diffusion, within the context of macroeconomic conditions and sanctions, which are among the factors that hinder the development of innovative solutions in the power industry. The experts underline that investments in the utility sector are usually tied to sustainable economic growth and increasing electricity consumption. However, uncertainty in the geopolitical and macroeconomic environment could lead to a redirection of financial flows, which directly affects the perspective of Smart Grid technology diffusion on the market. Economic sanctions and political instability can also have a negative impact on the development of the electric power sector, making it difficult to establish a clear business case for innovative technologies and provide necessary equipment.

The high costs associated with implementing Smart Grid technology can also make it less of a priority in the current economic context. Despite the importance of Smart Grid technology for energy efficiency and sustainability, it is clearly not a top priority for governments and businesses facing economic challenges.

Socio-Cultural Specifics of the Market

Social and cultural aspects of the electricity market burden heavily on innovators across the industry, which has been frequently outlined within the discussions.

"In brief, socio-culturally, the population has an understanding that electricity, by virtue of historical features, should always be available and free…"

"That is why this social aspect of the industry makes it difficult to introduce mechanisms for recouping investments in smart infrastructure…"

"The moment of historical background is also important here, that it is possible to avoid paying for resources. In the Soviet Union, the consumer was kind of subsidised, too. In terms of resources, the population lived almost at no cost. But now, when a slight increase in the tariff becomes apparent, there is rejection… And how then the company should pay for innovation, if it cannot increase bills?..."

"In terms of socio-cultural elements, people simply do not understand really complex sector nuances…"

"In other words, electricity is a socially important commodity. So technically it is much more difficult to apply a technology that has worked brilliantly elsewhere, for example, in the contractual format between suppliers…"

"In Russia, these processes of innovation are treated, let's say, quite sceptically…"

The socio-cultural context of a market might have a significant impact on the adoption of such innovations as Smart Grid. Specifically, the historical understanding that power should always be available and free is a significant barrier to its adoption in some emerging economies, such as Russia. Thus, this mindset that resources should be free or heavily subsidised is rooted in the socialist economic context, making it challenging to introduce mechanisms for recouping investments in smart infrastructure. As a result, any increase in tariffs is met with resistance from the public.

Additionally, the social importance of electricity as a commodity makes it technically challenging to apply technologies that have worked elsewhere, such as the contractual format between suppliers. Plus, processes of innovation are often treated sceptically, making it challenging for companies to invest in new technologies.

While the socio-cultural conditions of a market can vary significantly from one Emerging Economy to another, there might be some similar patterns in place. For example, historical precedent of subsidising basic resources like electricity, is common for various Emerging Economies. Plus, as it has already been mentioned, in some cases, there may also be scepticism towards innovation, particularly if it is not seen as a priority or if there are concerns about the reliability or security of the new technology.

Price Sensitivity of the Customers

Within the narrative of socio-cultural specifics of the power market, this research considered important to underline such factor as price sensitivity of the end consumer, which has also been prominent.

"I think it's at the end it's about the price, that's really the barrier that I'm seeing…"

"Another point, in addition to the reluctance of the client to pay for the company's investment, is actually a question of "why do I need all this tricky stuff?"…"

"It's hard for people to explain the necessity of any costs…"

"The population is not ready to bear the burden of the company's investments. We certainly have these problems in our country, and I suspect that in many other emerging economies, there is a certain sensitivity of the base, the electorate, too…"

"It is difficult to implement innovations here, because people are simply not ready to pay for them…"

"I think in developing countries with low per capita income this [innovation adoption] is significantly limited. All Emerging Economies, they're very price sensitive…"

Aforementioned quotes highlight the importance of price sensitivity as a barrier to Smart Grid adoption in Emerging Economies. Customers in these markets are often unwilling or unable to bear the burden of the cost of company's investment required for the implementation of Smart Grid solutions. The population's reluctance to pay for the company's investment, coupled with a lack of understanding of the necessity of these costs, creates challenges for utilities and regulators looking to modernise and digitalise the grid.

The challenge of overcoming price sensitivity in emerging economies is frequently tied to a larger socio-economic context. The cost of electricity is seen as an important factor in the economic well-being of the population, and increases in tariffs are often met with resistance. Additionally, the lack of understanding of the benefits of Smart Grid technology creates a perception that the cost of Smart Grid solutions is not worth the investment, which also hinders the adoption.

Lack of Technology Understanding

To conclude the notion of social and cultural aspects of Smart Grids adoption, it is important to outline the topic of lack of technology understanding by the end consumers, as it has also been prominent within the discussions.

"[There is] no knowledge of what Smart Grids are, how they can benefit them, awareness on what does all that mean to them…"

"Frequently people simply do not understand Smart Grid…"

"Another point, in addition to the reluctance of the client to pay for the company's investment, is actually a question of why I need all this tricky stuff?"

"In any case, it should be marketing departments to develop campaigns to popularise innovations and explain the benefits of these innovations to the population…"

"Our population is price-sensitive. If innovation helps save money, why not? It's just necessary to convey the arguments of the wallet to the consumer…"

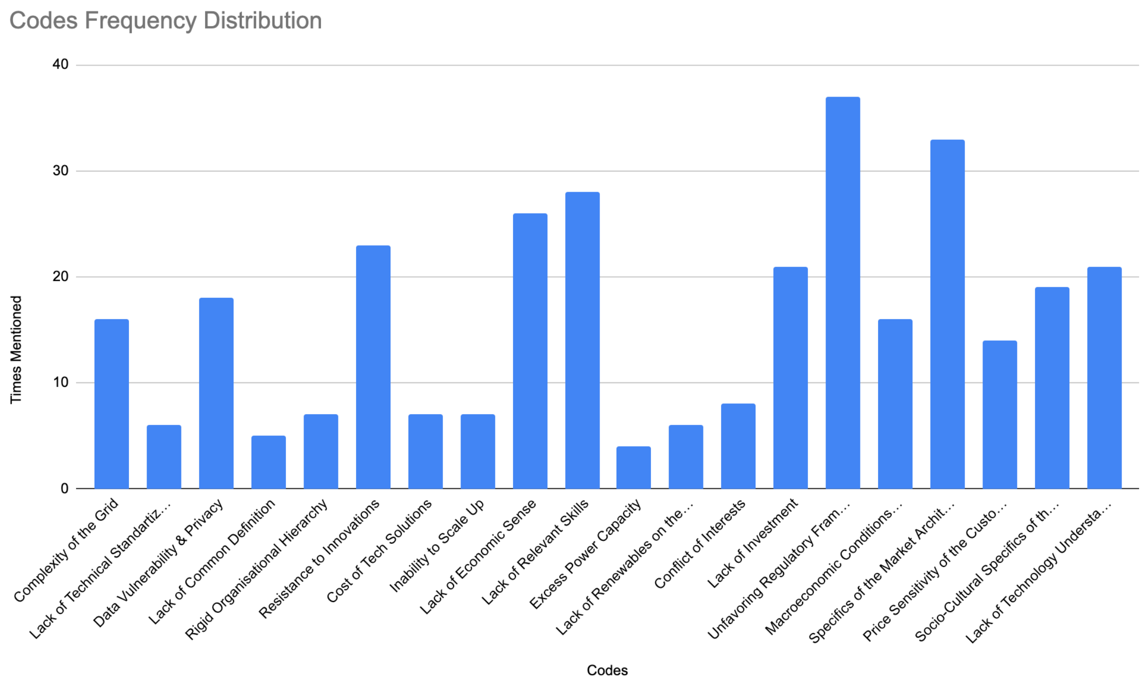
"…You have to have consumers understand what's going on in general. It's an extension of everyone's knowledge in general, really. This has to be done, so that you don't have new Luddites chopping up these metres…"

"Again, here again there is a significant issue of education and communication with society, because when you plan to introduce innovations, you must explain it to society why you are doing all this…"

The quotes suggest that a lack of understanding of Smart Grid technology is a significant barrier to its adoption in emerging economies. This issue is further compounded by the lack of knowledge and awareness of the benefits of Smart Grid technology, making it difficult for consumers to understand why they should indirectly invest in it. As a result, there is often a reluctance on the part of consumers to "pay" for investments made by energy companies, which they do not understand or do not see the benefits of.

However, while the lack of understanding and awareness of Smart Grid technology poses a significant challenge to its adoption in emerging economies, there are efforts being made to address this issue. By increasing consumer education and highlighting the potential long-term benefits of Smart Grid technology, we can encourage more consumers to support its adoption and help pave the way for a more sustainable energy future.

In conclusion, hereby we provided a detailed account of the study's findings. The chapter interprets the collected data comprehensively and discusses the implications of the results in relation to the research questions and objectives. It highlights the key themes and patterns that have emerged from the data and identifies the factors that contribute to the research problem.



(Figure 8. Codes Frequency Distribution)

In conclusion, our discussions have highlighted the pressing issues of an Unfavourable Regulatory Framework, Specifics of the Market Architecture, Lack of Relevant Skills, and Lack of Economic Sense as crucial obstacles that need to be overcome for the growth and development of the relevant industry.

4.2 Discussion of Results

In this chapter, we discuss both theoretical and practical results of this study and the key contributions that it makes to the field of diffusion of complex innovation, such as Smart Grid itself.

Theory

In academia the technology-organisation-environment (TOE) framework is frequently used to explain the diffusion and effects of technologies like the Smart Grid. However, as has already been highlighted, the traditional TOE framework implies a number of constraints, including a limited focus on the institutional component of a larger environment and the exclusion of the disruptive potential of numerous technologies. Therefore, for the sake of this study, we suggest adding a few pertinent theoretical topics, such institutional theory and disruptive innovation, to the TOE Framework.

As it has already been mentioned, institutional theory suggests that organisations are influenced by their institutional environment, which includes norms, values, and regulations. This theory has been used to explain how companies respond to changes in their institutional environment and adapt their managerial practices accordingly. By incorporating institutional theory into the TOE framework, we can better understand the influence of the institutional environment on the adoption and implementation of new technologies.

We propose that the "Environment" component of the TOE framework can be extended by adding a component of "Institutional Context". It represents a broader concept of the external factors that shape the institutional environment in which organisations operate. These factors may include industry standards, market architecture, regulatory frameworks, socio-cultural norms, and customer perceptions. By incorporating the notion of "Institutional Context" into the TOE framework, we can better understand the influence of the institutional environment on the adoption and implementation of new technologies.

We also propose that institutional theory can be used to explore the role of legitimacy in the adoption and implementation of new technologies. Legitimacy refers to the perception that an organisation's actions are appropriate and aligned with societal norms and expectations.

New technologies may challenge established norms and practices, and their adoption and implementation may require organisations to navigate legitimacy concerns. By incorporating institutional theory into the TOE framework, we can better understand how organisations navigate legitimacy concerns in the adoption and implementation of new technologies.

While some studies have combined the TOE Framework with institutional theory [126][127] as it adds external pressures from competitors and other stakeholders of the market architecture to the environmental context of the TOE Framework, it may also be useful to incorporate disruptive innovation concept into the theoretical debate.

As it has already been said, despite the clear potential of Smart Grid as a disruptive technology that has a possibility to transform the energy sector, the application of disruptive innovation to Smart Grid has been relatively limited. Disruptive innovation concept explains how new technologies can fundamentally change the market, creating new opportunities for innovation and competition. Despite the fact that Smart Grid is often considered a disruptive technology, the theory has not been widely explored in relation to this field.

Some scholars have argued that this is because Smart Grid is still in the early stages of development, and its potential impact on the energy market is not yet fully understood. Others have pointed out that the regulatory and institutional barriers to Smart Grid adoption are too high to allow for disruptive innovation to take place.

In order to enhance a notion of organisation within the TOE Framework, this research proposes adding into it a fifth component, “Disruptive Capability” of a particular innovative technology. The “Disruptive Capability” dimension represents the extent to which a new technology has the potential to disrupt existing practices and create new opportunities for an enterprise. Importantly, “Disruptive Capability” can be influenced by factors such as the technology's ability to reduce costs, increase efficiency, or provide new functionality.

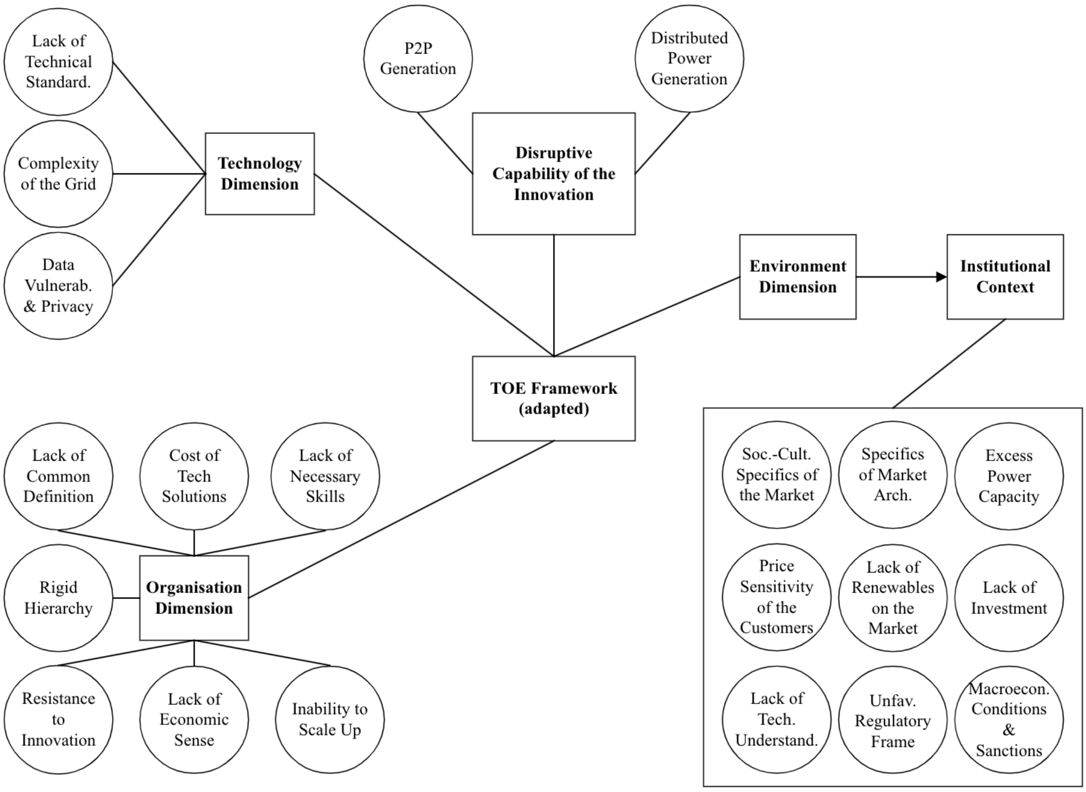
By incorporating the notion of “Disruptive Capability” into the TOE framework, we can better understand the potential for new technologies to overhaul a company's existing operations and create new opportunities.

Although the concept of disruptive innovation suggests that certain innovations can revolutionise existing market architecture and create new ones, the explanation of innovation success can be considered limited due to insufficient attention to the internal and external factors that affect companies. By incorporating the concept of disruptive innovation into the TOE framework, we could better comprehend the potential of innovations that can disrupt existing management practices and open up new opportunities.

By incorporating the framework that combines institutional theory and disruptive innovation theory, researchers can gain a more comprehensive understanding of the complex factors that influence the adoption and diffusion of Smart Grid technology.

This framework provides a holistic view of the interplay between the regulatory, social, and technological dimensions of Smart Grid, which is essential for identifying the key drivers and barriers that shape its development and impact. Institutional theory provides insights into how regulatory and normative pressures shape the behaviour of organisations and individuals, while disruptive innovation theory highlights the importance of technological innovation in transforming the energy sector.

By integrating these two theories, researchers can develop a deeper understanding of the complex dynamics of such innovations as the Smart Grid adoption and diffusion, and identify the most effective strategies for promoting its growth and impact.



(Figure 9. Adapted TOE Framework on example of Smart Grid)

With regard to this research, the Adapted TOE Framework gives a clear depiction of the barriers identified empirically with a clear focus on organisational and environmental components, expanded by our TOE Framework adaptation into "Institutional Context", also adding the notion of "Disruptive Capability".

Also, in the example of the Smart Grid adoption, experts interviewed for this research outlined that the dominant Disruptive Capability of this innovation is co-generation with sharing through P2P marketplaces and the notion of distributed power generation.

Co-generation of power requires significant shifts in the power grid company business model, due to the fact that consumers are partly employing the functions of power providers. Thus, for economically effective introduction of this feature of the Smart Grid it is crucial to establish an equilibrium between gains of this technology due to enhanced efficiency and potential revenue losses due to less power volumes delivered. Distributed power generation, in contrast with other Smart Grid solutions, such as advanced metering infrastructure, sensor infrastructure, self-healing capabilities and real-time monitoring, also requires a revolutionised business model, grid architecture and geography and economics of power generation.

Additionally, Figure №8 also suggests not only the dominance of organisational and environmental barriers, but also visualises the wide-range variety of the barriers, dictating the necessity of providing a clear theoretical solution for such a complex socio-technical phenomena as Smart Grid adoption.

Comparison of "Initial" Barriers & "Empirical" Barriers

In order to proceed to the practical part and to establish barriers specific to Emerging Economies, hereby we conduct a comparative analysis of the general barriers identified in the literature review and those identified empirically through an interview process. This method can assist in developing a more thorough grasp of the distinctive difficulties that Emerging Economies encounter and locating viable solutions that are catered to their particular requirements.

Barriers Identified in the Literature Review
High levels of investment and regulations
Market uncertainty (transition to deregulated market, market imperfections, poor definition of property rights, information asymmetry, imperfect competition)
Efficiency dilemma
Social acceptance issues
Reluctance to change
Data Privacy & Security

Barriers Identified Empirically
Complexity of the Grid
Lack of Technical Standardisation
Data Vulnerability & Privacy Issues
Lack of Common Definition
Rigid Hierarchy
Resistance to Innovation
Cost of Tech Solutions
Lack of Economic Sense
Inability to Scale Up
Lack of Necessary Skills
Specifics of Market Architecture
Excess Power Capacity
Lack of Renewables on the Market

Lack of Investment
Unfavouring Regulatory Framework
Macroeconomic Conditions & Sanctions
Socio-Cultural Specifics of the Market
Price Sensitivity of the Customers
Lack of Technology Understanding

Hereby, it is clear that this study and empirical data gathered for this research significantly enhanced an understanding of which barriers persist in the process of Smart Grid adoption in Emerging Economies. While confirming existing general barriers, applicable to the global scale, this research not only presents new specific barriers, but unfolds new dimensions in existing ones.

For example, there is a significant match in such barriers as:

- Data Privacy and Security (literature review) / Data Vulnerability and Privacy Issues (empirical)
- High Levels of Investment and Regulations (literature review) / Lack of Investment (empirical)
- Resistance to Innovation (empirical) / Reluctance to Change (literature review)
- Socio-Cultural Specifics of the Market (empirical) / Social Acceptance Issues (literature review)
- Unfavouring Regulatory Framework (empirical) / High Levels of Investment and Regulations (literature review)

Despite the fact that there is a significant resemblance in these barriers, empirical data provided crucial context, making the notion of factors hindering the adoption of Smart Grid in Emerging Economies more complex and multilateral. Remaining barriers can be considered new and also add significant value into existing research.

It's important to note that while some of overall barriers may be related, they may also be distinct in their specific manifestations or causes. Therefore, it's important to consider each barrier individually and in the context of the broader business environment in Emerging Economies.

It is also important to notice that there are few barriers specific to the Russian case, e.g. *Excess of Capacity* and *Macroeconomic Situation & Sanctions*. However, they provide future research with a general path to examine in every specific case.

Overall, the analysis of empirical data of this study can contribute greatly to the development of tailored solutions and strategies that are better suited to the specific needs and challenges of Emerging Economies, and ultimately accelerate the adoption of Smart Grid in these markets.

Recommendations for Smart Grid Adoption in Emerging Economies

Taking into account the barriers identified, in this section we aim to provide a complex of steps and recommendations for Smart Grid adoption in Emerging Economies to state-owned power grid companies.

State-owned power companies are prevalent in Emerging Economies and are considered critical business due to their significance in power supply to the population and supporting overall economic development. Thus, state-owned power companies are regarded as enterprises of substantial importance for this research.

Based on the data collected through interviews, this research acknowledges the fact that Smart Grid adoption necessity can be considered as a controversial issue. As a result, this research has developed recommendations in order to overcome the barriers associated with Smart Grid adoption in Emerging Economies, which may be implemented if there is an intent to pursue Smart Grid adoption.

The study's guidelines are based on an in-depth examination of the barriers that may potentially hinder Smart Grid deployment, as well as best practices and success factors provided by literature and the experts.

This research created a roadmap for state-owned power grid companies to successfully steer through the complicated environment of Smart Grid adoption process and maximise the technology's potential advantages.

The study also emphasises that the steps offered below are neither prescribed or ultimate, and need to be adapted to the unique environment and context of any particular state-owned power grid company. Furthermore, the suggestions are reliant on a final choice of implementing Smart Grid technology, which itself might involve additional investigation and assessment of the costs, benefits, and risks associated with the innovation.

In order to successfully overcome the barriers identified, this study considers relevant the following steps:

1) **Strategy Development On The State Level**

Due to the fact that the main stakeholder in the state-owned power grid company is the government, it is crucial to develop a clear and comprehensive roadmap on the state level (depending on the concrete country: federal, provincial, regional etc).

A comprehensive state-level plan enables the state-owned power grid company to match its actions with the state's greater energy policy objectives. This ensures that the company's financial decisions and operations are consistent with the state's general energy objectives and priorities, such as ensuring efficiency and reliability of the grid.

Furthermore, a comprehensive plan issued at government levels may support the coordination of the actions of numerous players in the energy sector, such as regulatory bodies, power generators, oil & gas companies and other entities. This could guarantee that everyone is working toward the same set of ambitions, which can eventually lead to improved effectiveness and efficiency in utilisation of resources.

Moreover, a comprehensive state-level strategy can serve as a factor, contributing to building public backing for the actions of the state-owned power grid company. By including municipalities, consumers, businesses and other stakeholders in the process of the strategy's creation, the government guarantees that its actions are in line with the requirements and priorities of the residents, which can lead to stronger societal support for adoption of Smart Grid technology.

2) Standard Connotation Development

Due to the fact that Smart Grid is an interdisciplinary, complex and multilateral concept, establishing a standard connotation is an important step in the adoption of the Smart Grid solutions both globally and in Emerging Economies.

A single connotation effectively guarantees that all stakeholders have a clear understanding and certainty about what Smart Grid actually is, about its vital elements, and its purposes. This shared understanding allows for improved interaction, cooperation, and decision-making among the numerous stakeholders participating in Smart Grid adoption, including as well as state-owned power grid firms and private power grid companies, governing bodies, and other relevant parties.

The process of creating a standard connotation implies an in-depth examination of the terminology, which is already in use by international agencies, such as e.g. IEA and ISGAN, corporations, and other appropriate stakeholders. Thus, enabling appropriate use of current expertise, consistency with internationally accepted standards while adjusting the definition to the region's circumstances.

Concise and widely recognized standard connotation constitutes a starting point for Smart Grid adoption strategy and development of policies.

3) Strategy Development On The Company Level

As an upfront innovation, Smart Grid requires a strategic action for its successful adoption into the company’s business model. In order to achieve this goal, Smart Grid should be embedded into the company’s overall corporate strategy and be aligned with the company’s strategic goals.

The complete strategy for Smart Grid adoption would include a systematic and holistic approach towards resolving the numerous constraints and problems associated with adopting Smart Grid solutions in Emerging Economies. A comprehensive strategy may take into account a variety of elements, including technological, economic, legislative, and socio-cultural considerations. It should also be adapted to the specific market's individual demands and conditions, taking into account technical conditions of local power grids, resources at hand, and market dynamics.

A complete strategy involves thorough preparation, analysis, and collaboration. The plan should be created collaboratively and iteratively, engaging stakeholders from all sectors, including government, industry, and civil society.

Hereby examples of key steps in building a comprehensive strategy are presented:

1) Defining specific aims and objectives for Smart Grid diffusion, such as enhancing grid stability and boosting energy efficiency.
2) Performing an in-depth evaluation of the existing power grid infrastructure in order to identify any technical issues or flaws that must be overcome.
3) Assessing the financial implications and advantages of Smart Grid implementation, including the cost of technological solutions, cost savings potential, and influence on power pricing.
4) Collaboration with authorities in order to determine and overcome potential regulatory hurdles or challenges to Smart Grid deployment.
5) Engaging with customers/consumers in order to grasp the market's socio-cultural characteristics and developing methods to overcome possible cultural or social impediments to Smart Grid adoption.

6) Developing explicit metrics for tracking and assessing the Smart Grid adoption strategy's success and making modifications if necessary.

Creating an extensive strategy for Smart Grid adoption in Emerging Economies involves a systematic and well-organised effort. As a result, the plan can assist in overcoming the hurdles to Smart Grid adoption and gaining access to the numerous advantages of this innovation for consumers, businesses and the national economy.

4) Addressing technical standardisation and data privacy

Technical standardisation and data privacy are critical for the successful adoption of Smart Grid solutions in Emerging Economies. The establishment of standardised protocols and requirements that enable compatibility across diverse technologies and equipment is necessary for guaranteeing that Smart Grid equipment from various manufacturers can coexist effectively, allowing future integration of cutting-edge technology into the grid.

The development of technical standards for Smart Grid adoption implies collaboration among industry participants, regulatory organisations, and other stakeholders. This process includes creating the technical requirements for interoperability-required software, hardware, and communication standards. Smart Grid infrastructure technical standards should be responsive to developments in the technological field.

Data privacy and security are also important factors for Smart Grid implementation. Smart Grid technology creates significant volumes of sensitive and personal data, such as information on power consumption and place of residence. As a result, adequate security measures need to be established to protect this data and the privacy of consumers and other stakeholders.

Another critical aspect of data security is that Smart Grid obviously implies extensive digitalization of grid infrastructure, making it more vulnerable to cyberattacks and other types of intrusion capable of causing blackouts and power shortages in strategic industries such as the military-defence complex.

Encryption, access restrictions, and anonymization techniques, along with procedures and regulations for data management and storage, might constitute examples of data protection measures. Governmental organisations may additionally have a role in maintaining data privacy by implementing new and strengthening existing security rules and regulations on the national level.

5) Managing Economic Viability

A key part of Smart Grid implementation in Emerging Economies involves tackling economic issues. While the innovation deployment is influenced by several factors (e.g. current power grid conditions, budget available for reinvestment activities etc.) it frequently implies considerable initial investment, and economic feasibility is an important factor for parties participating in decision-making.

The foundation of Smart Grid adoption is conducting a comprehensive cost-benefit analysis in order to examine the economic feasibility of Smart Grid implementation. Cost-benefit analysis must take into account both the costs associated with the initial investment and the possible long-term advantages, such as increased reliability and resilience of the grid, energy efficiency, and lower operational costs. The analysis assists stakeholders in assessing the financial effects and calculating key financial indicators, such as the return on investment (ROI).

Taking into account the economic scale, cautious gradual deployment might be a successful approach for a diffusion of such innovation as Smart Grid.

Smart Grid solutions could be adopted "step-by-step", with an emphasis on locations with the greatest economic potential and significant grid infrastructure needs. This strategy enables stakeholders to provide evidence of the economic sustainability of Smart Grid technologies on a smaller scale before moving to bigger areas.

This approach represents a positive step aside from the pilot projects approach, allowing Smart Grid solutions not only to exhibit potential benefits in demonstration mode, but to actively contribute to the particular problems of existing power grid infrastructure, avoiding part of the costs.

6) Skills Development

Building the appropriate set of skills can be considered an essential element for the effective and successful diffusion of Smart Grid solutions in Emerging Economies. Providing personnel with the knowledge, competence, experience and abilities needed to properly adopt, operate, and sustain Smart Grid systems is a cornerstone for the grid transformation.

Developing relevant intellectual capital may involve several actions, including extensive training programmes within the corporate universities and centres of additional education, established to improve the skills and competences of the personnel participating in operations of the Smart Grid, including both deployment and maintenance.

While Smart Grid is a complex socio technical phenomena, skills development process may include cultivating STEM competencies alongside business ones. Smart Grid technology education should include a wide range of topics, including both software and hardware elements, communication protocols, data analytics, privacy and security on one side and strategic management, operational management and market analysis on the other.

Practical training seminars and simulations held on the company's facilities may also all help to ensure that knowledge is understood and used practically.

Furthermore, in order to utilise the status of the dominant force on the market and prominent employer, state-owned power grid companies may engage in a collaboration with universities and other academic institutions with focus on engineering, digital technologies and digital transformation.

Aforementioned collaboration might include launching of specialised training or more complex degree programs dealing with Smart Grid technology, energy oversight, and data security on the power grid, also involving managerial techniques of innovation adoption and hi tech business models creation.

Another crucial issue is a significant lack of specialists working in the field. According to multiple concerns raised by the experts interviewed, line technicians qualifications in Emerging Economies frequently lack up-to-date knowledge on everyday service of Smart Grid solutions.

In order to overcome lack of skills in line personnel, companies should establish special "on the field" training conducted by equipment manufacturers and design all-rounded instructions and guidelines to hedge inefficiencies and mistakes, hindering proper Smart Grid functioning.

While employing various educational efforts, leading power grid companies of Emerging Economies may build a trained workforce ready to work with Smart Grid solutions in the field.

7) Creating a Culture of Innovation

In order to truly embrace Smart Grids, it is critical to encourage innovation within the organisation. While top management in state-owned monopolies is frequently risk averse and conservative, innovation and ability to change and employ creative thinking is critical in driving the development and setting up new technologies and business models that can improve the power grid's functionality, stability, and safety.

For the start it is crucial to renovate the approach to leadership, which is critical in encouraging and cultivating an innovative culture and, consequently, adopting innovative solutions.

This can be considered as a complicated issue, due to the nature of state-owned company's position, but in order to succeed corporate leaders should encourage their personnel to take risks, recognize innovative thinking, and create a safe atmosphere for them to experiment with new ideas and technologies.

It remains critical to encourage collaboration and partnerships among many stakeholders in order to drive innovation. For example, cooperation between energy companies, technology manufacturers, academic institutions, and the government and others allows for exchange of information, pooling of resources, and sharing of skills in order to overcome hurdles and create new solutions.

As a step further, state-owned power grid companies can consider creating an ecosystem that encourages partnerships with entrepreneurs and startups, which significantly fosters innovation. Entrepreneurial environment has resources and capabilities in order to revitalise the utility monopoly’s organisational culture, infuse new ideas and approaches, exchange experience and knowledge and enhance the organisation's innovation capabilities.

8) Navigating Market Specifics

While setting up strategy for Smart Grid implementation in Emerging Economies, it is critical to consider overall market characteristics.

Firstly, it is crucial to conduct a thorough analysis of the market to evaluate its composition, size, and future prospects for Smart Grid implementation. Moreover, the company's strategy department should examine the existing power grid, including generating and distribution networks, as well as power consumption trends and determine market deficiencies, inefficiencies, or obstacles to the innovation adoption.

After market analysis the company might launch the process of tailored business model creation, which is in line with the market's particular qualities and requirements. For this to succeed, it is necessary to evaluate the cost, connectivity, and flexibility of Smart Grid solutions in an existing external environment and, moreover, tailor business models to the unique requirements of various consumer categories, including households, businesses, and industrial customers.

In order to adopt Smart Grid solutions in a customised and tailored way, taking into account market complexities, it is crucial to set grid modernisation priorities. This implies examining the major issues and trouble spots in the present power system, such as excessive distribution and transmission losses, insufficient voltage control, and poor grid stability. Taking into account these factors, the company could create strategies that address these issues while also providing actual market rewards.

This approach goes in line with the “step-by-step” strategy proposed earlier, underlining graduate introduction of Smart Grid solutions on the sites with the highest economic potential and considerable grid infrastructure demands, as contributing to economic viability of Smart Grid solutions, creating a business case for technology and recouping initial investments.

9) Managing Regulatory Framework

Managing issues related to regulatory framework constitutes one of the most significant issues in effective Smart Grid rollout in Emerging Economies. In the case of Russia, legislative specifics are clearly leaning towards “unfavourable”, thus, it is crucial for state-owned power grid companies to be able to navigate complex regulatory environment.

In order to successfully adopt innovation in a legal landscape, it is necessary to examine current regulatory frameworks to comprehend what specific challenges it poses and possibilities it opens for Smart Grid implementation.

As the progress in the field, while in some countries significant, generally has been limited, it is vital to initiate a comprehensive collaborative legislation process in order to establish a favourable framework for innovation adoption. This implies involving important industry players in the regulatory process, such as, private grid operators, technology manufacturers, consumers representatives, and industry alliances. To establish a proper regulatory framework and guarantee a weighted approach that respects the interests and priorities of all stakeholders it is essential to ensure key stakeholders participate actively in governmental consultations, parliamentary hearings, and working groups.

Furthermore, industry experts interviewed outlined that one of the most significant barriers within the unfavouring regulatory framework concerns is lack of incentives for Smart Grid adoption. Thus, it is necessary to create rewards system to stimulate investment in Smart Grid solutions, which includes financial incentives for both power grid companies and customers in the form of subsidies, grants, or tax credits. Utilities may consider adopting performance-driven regulation, which rewards power grid companies for attaining particular goals such as minimising losses on the grid, ensuring grid connectivity and digital transition.

10) Addressing socio-cultural resistance

Considering socio-cultural resistance to innovation is critical for the effective Smart Grid adoption in Emerging Economies, as cultural, sociological, and behavioural aspects seriously impact energy consumption patterns, the adoption of new technology, and participation in energy management techniques. It is necessary to learn about the key values, opinions, and norms that influence energy usage as well as views towards Smart Grid solutions implementation. For example, for countries with developed economies, a high level of concern regarding sustainability related issues is common, while Emerging Economies are still lagging behind.

Thus, for Emerging Economies sustainability agenda can be considered less relevant in decision making, as it has low or none impact on power consumption patterns and eagerness to adopt innovation.

Based on the relevant information, the company could customise communication techniques, instructional efforts and, finally, propose tailored solutions and user-friendly interfaces to accommodate diverse user requirements and preferences, which reflect local cultural specificity, lifestyles, household sizes and locations that may influence energy consumption patterns.

Another significant issue within the concept of socio-cultural resistance is lack of understanding of Smart Grid solutions by the end consumers. In order to tackle this issue, the company could engage in thorough public education campaigns to inform customers on the advantages and relevance of Smart Grid technology and to underline how Smart Grid may help with grid reliability, efficiency and cost savings.

Moreover, to connect with diverse sectors of the population and improve awareness and understanding of Smart Grid solutions, it is possible to employ multiple communication channels such as media and TV platforms, grassroots events, and seminars.

Additionally, by implementing demand-side management techniques including energy-saving initiatives, customer feedback tools, time-of-use pricing, and providing immediate data on power use will allow consumers to make knowledgeable choices and actively participate in network optimisation and demand-side management activities.

Limitations of the Research

While the barriers and recommendations outlined in this dissertation provide a path for the adoption of Smart Grid technologies, some limits and restrictions are included in this study. These constraints come from the Russian Federation's emphasis and particular features of Emerging Economies.

First of all, the conclusions and suggestions offered in this dissertation are mostly focused on the Russian Federation's setting. The financial, socio-cultural, and legal settings of Emerging Economies differ considerably. As a result, it is critical to note that the stated limitations and rules may not be uniformly relevant to all states with Emerging Economies. As each Emerging Economy might come with its own set of obstacles, options, and potential, which makes necessary development of tailored Smart Grid deployment strategies.

In addition, the constantly shifting dynamics of the power grid industry, as well as the ever-changing environment of Smart Grid solutions, dictates the necessity of ongoing research and strategy adoption.

However, it is crucial to notice that this study can be used as a roadmap for Smart Grid solutions adoption in Emerging Economies due to the utilisation of institutional theory as one of the theoretical pillars of this research. As Emerging Economies possess common traits in their institutional frameworks, this study can serve as an important starting point for generalisation to different state contexts.

In conclusion, while this thesis provides essential insights and suggestions for the adoption of Smart Grid technologies in Emerging Economies, it is critical to realise the research's contextual limits as well as the necessity for continual adaptation and cooperation.

Conclusion

In conclusion, this research has fully accomplished its objective of identifying and analysing the organisational and institutional barriers that hinder the diffusion of Smart Grid solutions in the Emerging Economies utilising the case of the Russian Federation as an example.

By conducting an in-depth examination of the challenges faced by power grid companies in adopting and commercialising Smart Grid technology, valuable insights have been obtained.

The study's findings reveal a few significant barriers to the effective adoption of Smart Grid in Emerging Economies, which include such factors as the complexity of the grid infrastructure, lack of technical standardisation, data vulnerability and privacy concerns, rigid hierarchy, resistance to innovation, high costs of technology solutions, and the lack of necessary skills and expertise. Furthermore, economic, regulatory, socio-cultural and market-specific barriers substantially affect the adoption process.

By tackling these obstacles and constraints, power grid companies in Emerging Economies may fully exploit the long-term benefits of Smart Grid and maximise on the advantages the technology provides. This involves enhancing the standards, security, and efficiency of the grid power supply, effectively managing consumer demand, and producing profit for their ownership and other utility industry stakeholder groups.

Importantly, this thesis not only adds to the current body of knowledge, but it also gives specific insights into the hurdles encountered by power grid companies in Russia alongside other Emerging Economies. The research's results and suggestions may assist power grid companies, government bodies, and stakeholders in developing strategies and regulations that will enhance Smart Grid successful adoption.

Once again, it is vital to emphasise that the outcomes and recommendations proposed by this master dissertation are not exhaustive or final. Each Emerging Economy possesses its own set of difficulties, challenges and possibilities, and the approaches proposed should be tailored to the specific environment of the power grid corporations that operate inside it.

Finally, this thesis represents a helpful tool for power grid companies, legislators, and other players in Emerging Economies, who are looking to remove hurdles and support the effective adoption of Smart Grid technologies.

Power grid companies could pave the path for a feasible, effective, and secure power grid architecture in Emerging Economies, including Russia, by overcoming the discovered organisational and institutional obstacles and implementing the proposed measures.

Directions for Future Research

It has been underlined throughout this research that Smart Grid adoption in Emerging Economies is a highly dynamic and constantly evolving field of study, offering great opportunities for future research.

Based on this study and on the Adapted TOE Framework in particular, it is possible to perform investigations of Smart Grid adoption in specific countries possessing characteristics of an Emerging Economy. Taking into account state specifics in the set of its own barriers, economic characteristics and market configuration, future research could embrace this study and develop tailored Smart Grid adoption strategies.

Another direction of future research is testing the barriers identified via quantitative techniques, providing a statistical model with a potential for generalisation. This direction would provide a broader understanding of the prevalence and impact of these barriers across different Emerging Economies, allowing for comparisons and benchmarking.

Overall, this study evolves as a good starting point for both generalisation and case-studies in the field of Smart Grid adoption, providing the guidelines both in theory and practice and being open to adaptations and utilisations by the future research.

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Appendix

Example Excerpts from Transcripts

Pavel: Good afternoon, Ivan Vladimirovich! I would like to structure our discussion around very barriers to the implementation of the Smart Grid, yes, but I would still like to start with some technological things, although they are not central to my work. Let's just say, just to have a general idea.
My first question to you.
What role do you see the technological challenges of adopting and integrating Smart Grid technology as a disruptive technology?
How do you see the, shall we say, technical difficulties as a barrier to the implementation of the technology, how significant are they?

Ivan: Let's start at the beginning. Since I have been engaged professionally in the Smart Grid for a long time, and I am in charge of economic research in this area, first of all, I would not say that this is direct disruption. Emerging, maybe, and then not right now.
The whole question is what we mean by the Smart Grid. This is a very important point, because, in fact, what we mean by that is like saying an umbrella.
Different understandings, completely different ideas, can be gathered under it.
So the first part of the Smart Grid, as a matter of fact, is the transition to a distributed energy system. And with a strong, so-called, non-fuel component.
In other words, this relates to various alternative energy sources, primarily solar and wind.
We have exhausted the technological potential to develop and increase the efficiency of wind energy.
That is, roughly speaking, we can put more wind turbines. But as if technologically you can't come up with anything else, because the rotor, respectively, the concrete tower... The maximum that can still be lightened is the wings, these blades made of composite materials. But that's all it can be. In the long term, in terms of some kind of improvement, it's the sun, because it's all about materials science.

There's good growth potential here, although nobody understands what kind and on what horizon. I was involved in these energy technologies for more than 15 years; I remember all these forecasts, but they did not come true, you know?

In terms of those predictions that were made, organic solar cells should have scaled by now, but they haven't.

Here, this story with the decentralised concept would have been disruptive, because it involves a complete restructuring of the energy system, that is, it respected Christensen's message, essentially speaking a transformed Schumpeterian about changing the market itself and the underlying technology in this market.

Everything else is essentially about the bottom line. For the most part, it is simply a modernization of the existing system in favor of increasing energy efficiency and reducing material intensity.

That is, it is, roughly speaking, a cosmetic repair of the modern energy system.

Smart Grids are understood in different countries as very different things. Oh, and by the way, energy efficiency is systemic, which is important to understand. That is, it's not just end consumption, but energy efficiency across the entire grid. From generation to consumption.

It's important to understand that the real disruption was there. This transition has not yet happened, partly because we strongly overestimated the progress in materials science regarding solar cell technology, energy storage, and so on.

Now there's hydrogen again. It has appeared about three times: in the '70s, the '80s, the early 2000s, and now it's back.

We just could not invent a good and cheap battery, while energy carriers are batteries, as a matter of fact!

So oil is a big battery that, unlike regular batteries, is much cheaper because nature made it for us.

Pavel: And if we return to the complexity of the system as an obstacle to integration?

Ivan: There is a technological aspect here, of course. And there are different opinions as to how complicated or difficult it is to integrate the elements of Smart Grids into the network.

Before the early 2010s, let's just say it was a big headache, because what did we need Smart Grids elements for, in particular?

To increase system reliability with the introduction of large amounts of intermittent generation, that is, these non-periodic, renewable sources.
Back then, there were situations, especially in California, in Denmark, when gray-haired dispatchers with shaking hands were balancing the system by hand to keep the network from collapsing.
It was really a very big challenge.
The second thing was the final energy efficiency that made it possible to achieve systemic energy efficiency through communications technology, which is probably familiar to you from the second or third generation of smart metering.
This is where automated, fully automatic metering goes all the way down to the ability to manage demand.

There were a lot of technical issues related to working out standards for the development of relatively cheap meters, and their installation. Also, everything related to solar panels and so on. At the beginning, there were simply not enough competent installers. Yes, in principle, there was such a ridiculous problem, right? But that is, how should I say, those were such local problems that, well, somewhere were overestimated, somewhere, maybe, were underestimated.

It has not been connected with that for some time, but I do not observe any direct technological problems. The main problem is different - now it all develops in the range from cosmetic repairs of the current power system. Or the introduction of what you know, we like to call a new technological base.
As someone who worked in the industry, I have a very negative attitude toward all this revolutionary terminology, but that's because, you know, it sounds beautiful in articles, but in real life everything is completely different. It takes a sober assessment of what's going on.

To say that right now we have some revolutionary technologies, I can't, I don't see them. Yes, there is work that we need, related, for example, to the transition from electromechanical machines to solid-state transformers. In other words, these are all these crystals for power electronics, which will allow us to completely get rid of transformers and other electromechanical machines, which ensure the stability and reliability of the energy system.

But as it goes, it goes. There is some kind of linear progress, but I honestly do not see any breakthroughs yet.

They have developed a new generation of these power electronic crystals instead of GBT. But this, roughly speaking, was the Pentium 1, and now the Pentium 4. In the sense that it's a big step, but it's not some crazy step.

If you imagine a substation right now, it's a huge complex. I mean, there was even a concept that in the long run, it would already be box solutions. So now you have to build substations, you have to design even digital ones. Before, you just put in a box, put in cables, and there you have a substation. Over the last few decades, the biggest problems were probably with digital substations, where a common process bus and fully optical measurement systems are used, which means that everything goes to electronics instead of, again, electromechanics and analog signals. But somehow that problem is also more or less solved there, let's say, on the correct scaling.

It's just that a substation is a pretty expensive thing. Five to seven years ago, an ordinary substation cost about 100,000,000 rubles.

But then again, there was no such disruptive technology. That is, you simply replace one piece of equipment with another, and the problem was to develop it all and standardise it. But there have been no breakthroughs or disruption here.

There was an alternative concept that we, among others, are working on: the concept of multi-agent control, which involves a gradual decrease in the level of network centralization, i.e., decentralisation, but not only through generating sources, but through decentralisation of the control system, including VPP and other technical capabilities, through various digital solutions.

We are not even necessarily talking about some powerful complexes, i.e. it is a question of using various existing systems.

But this concept did not go very well either. I occasionally see something about the West there, too. But again, there is no revolution that everyone has suddenly switched to a multi-agent system.

I do not see active implementation. There is such a quiet process, but if you look at the problem comprehensively, there have been no revolutions of this kind in recent decades.

Pavel: I see what you mean. To summarise a little bit of what you have just told me: for you, the disruption in the Smart Grid is only about, shall we say, the decentralisation of the grid. Everything else is just additive.

Ivan: Not what the extras are. Here's the thing, I've just written a few papers on the subject. It's an evolutionary transition. Yes, sure, there are major changes there, but they don't, you know, they don't change the three most important things:

1. the architecture of the marketplace.
2. the architecture of the technical network.

And they do not give rise to any additional qualitative economic effects, which, for example, could arise on the consumer side. There are no spillover effects.

Pavel: With regard to renewable sources. As far as I understand, you believe that technologically, let's say, renewable energy is still a barrier at the moment? That is, the level of technological development of renewables is a barrier to the implementation of this technology at the moment?

Ivan: Let me put it another way. We can technically supply a 100 percent renewable energy grid, but only if it is part of a larger energy system.

And only if it's a very rich state can it afford large investments, for example in an energy storage system.

So I would say it's a very boutique thing. It's a solution for a very specific system. In everything else we have, especially in developed countries, there is progress, the share is growing, the volume per share of statutory capacity is growing. The share of output is growing, the absolute output is growing, the investment is growing.

But what we expected, roughly speaking, not even us, but what was forecasted 10 years ago, has not happened.

We can take it now and say that we are stopping the use of gas, but the example of modern Europe is very indicative, even though Europe was a pioneer in these technologies for a long time.
Or take China: it has enormous capacity, and coal is still widely used. Again, everything rests on pure materials science.
First of all, because we simply do not have the material to make cheap energy storage and we do not have the material to make very cheap solar panels. There is price parity in some areas, of course, but you understand that price parity and cheap technology are not the same thing.
The fact that a kilowatt hour of solar energy, with all its complexities, costs the same as the energy generated by natural gas, for example, is often not taken into account. That doesn't mean that they are technically equivalent. Roughly speaking, this is a matter of redundancy, stability, and reliability of the grid.

You see, if this were the case, we would have already started introducing power units of other types of generation en masse, but this is not happening. So it's not like that.