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SUSTAINABLE DEVELOPMENT AND GREEN INNOVATION

MANAGING RISK THROUGH INTERDISCIPLINARY APPROACHES AND POLICY STRATEGIES

ADALAT MURADOV • FARIZ AHMADOV
NARGIZ HAJIYEVA • KIRAN SOOD • SIMON GRIMA

Sustainable Development and Green Innovation

EMERALD STUDIES IN FINANCE, INSURANCE, AND RISK MANAGEMENT

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Sustainable Development and Green Innovation: Managing Risk Through Interdisciplinary Approaches and Policy Strategies

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Foreword

One of the most significant transformative challenges of the new millennium is sustainable development and the green innovations leading to it. Pursuing sustainable development and green innovation has become a key agenda for policymakers, businesses, and researchers alike. Integrating interdisciplinary approaches and policy strategies has become increasingly prominent in the face of environmental challenges and the identification of effective solutions. In particular, the role of specific stakeholders, such as the state and municipalities, the role of corporate green strategies, and the contribution of funding institutions in the sustainability transition are all important.

This book, *Sustainable Development and Green Innovation: Managing Risk Through Interdisciplinary Approaches and Policy Strategies*, is part of the highly esteemed ESFIRM (Emerald Studies in Finance, Insurance, and Risk Management) series and aims to comprehensively explore the dynamic intersections of sustainability, finance, risk management, and policy making. This book explores the sustainability transition and related policy strategy from an interdisciplinary perspective. The book's guiding principle is that specific sectors can be drivers (or even barriers) to sustainable development, such as the financial sector, tourism, education, and energy, among others. The book's chapters provide a comprehensive overview of the background of technological, social, and policy innovations.

Good green governance is best understood through case studies. The book presents several sectoral and regional examples of policies that promote sustainability and can contribute to knowledge transfer on green issues.

From the strategic ambitions and constraints of Swiss energy companies to the complex role of stakeholder engagement in green innovation policy in Nigeria, the contributions reflect the global and multifaceted nature of sustainable development. The bibliometric review of green finance and banking literature also provides an in-depth synthesis of existing knowledge, helping to identify emerging trends and research gaps. Technology has an undeniable role to play in the transition to a green economy, and several chapters in the volume address the implications of artificial intelligence and machine learning for sustainable finance. These technological developments are shaping the future of financial markets and driving the emergence of innovative green solutions. In addition, case studies on sustainability practices in tourism and rural entrepreneurship highlight the need for targeted policy interventions that consider specific socio-economic and environmental contexts. This volume provides valuable insights into the effectiveness of

different policy measures, such as those implemented in Georgia and the Visegrad region, to promote environmentally sustainable economic growth.

One of the book's conclusions is that the sustainability transition is decided in the minds and hearts of the people. Policy instruments and institutional solutions depend on people and their communities. Another important finding is that the multidimensional nature of sustainable development requires a holistic approach, considering economic and non-economic drivers. This book seeks to bridge the gap between theory and practice by presenting empirical studies and conceptual frameworks that can guide policymakers and practitioners in achieving sustainability goals. The authors make valuable recommendations emphasising the need for collaboration across sectors and disciplines to make meaningful progress. I am confident that this volume will inspire further research and help inform policy measures to facilitate the transition to a more sustainable and resilient future.

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Preface

In an era increasingly defined by climate change, technological upheaval, and socio-economic transformation, the pursuit of sustainable development has moved from the margins to the centre of global discourse. The world stands at an inflection point, where the convergence of environmental imperatives, financial innovation, and technological advancements demands new frameworks, strategies, and a new vision of growth. This volume, *Sustainable Development and Green Innovation: Managing Risk Through Interdisciplinary Approaches and Policy Strategies*, finds its purpose and relevance within this evolving context.

This volume combines an interdisciplinary collection of scholarly contributions examining the multifaceted green and sustainable development dimensions. From the empirical evaluation of green bond exchange-traded funds (ETFs) to the bibliometric mapping of green banking research, from the exploration of artificial intelligence and machine learning in sustainable finance to the role of social marketing in rural entrepreneurship, the chapters presented herein address the complex, interconnected challenges of promoting a green economy across diverse regional and sectoral landscapes.

Some contributions centre on the financial mechanisms catalysing green transformation. Green finance, encompassing green bonds, banking, and ESG (environmental, social, and governance)-focussed investment vehicles, is scrutinised through quantitative bibliometric reviews and empirical analysis. Studying green bond ETFs offers new empirical insights into the debated 'green premium', revealing the complexities of market dynamics, investor expectations, and certification processes. Concurrently, bibliometric analyses of green finance and banking literature reveal critical gaps, emerging trends, and global research collaborations, providing a structured roadmap for future academic inquiry.

Technology's transformative potential is a recurring theme throughout the volume. Chapters dedicated to the intersection of emerging technologies and sustainable finance illuminate the critical roles played by artificial intelligence, machine learning, and distributed ledger technologies (DLTs). These technologies offer powerful tools for enhancing transparency, improving risk assessment, optimising resource allocation, and embedding ESG principles into financial decision-making. Through systematic reviews and qualitative interviews, contributors explore how digital innovation can be harnessed to support the transition to a green economy while highlighting the ethical, regulatory, and implementation challenges accompanying technological adoption.

Policy frameworks and governance structures are another critical pillar of this volume. Regional analyses, particularly focussed on the Visegrad countries, demonstrate the nuanced and often uneven progress towards green growth within the European Union. By employing rigorous econometric techniques such as panel Fully Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Squares (DOLS) models, the studies herein provide robust empirical evidence regarding the impact of policy stringency, carbon taxes, green finance, and technological innovation on greenhouse gas emissions, renewable energy adoption, and material productivity. These findings have significant implications for policymakers balancing economic growth, environmental sustainability, and social equity.

Socio-economic and educational dimensions of sustainability are also robustly addressed. The role of social marketing in promoting rural entrepreneurship is critically examined, emphasising the necessity of integrating social goals with business innovation to achieve inclusive and sustainable development. Stakeholder engagement strategies in education systems are analysed as vital for cultivating green innovation mindsets and fostering a new generation of sustainability champions. These chapters underscore that technological and financial innovation, while necessary, are insufficient without the active participation and empowerment of communities.

This volume is distinctive in its methodological diversity. Bibliometric analyses using Bibliophagy and VOSviewer provide quantitative mapping of research landscapes, thematic structures, and intellectual linkages across green finance and green banking domains. Qualitative methodologies, including case studies and interviews, enrich the analysis of technology adoption and social innovation. Econometric modelling enhances the empirical rigour of policy evaluations. The multi-method approach adopted by the contributors not only improves the validity and reliability of findings but also reflects the inherently interdisciplinary nature of sustainability science.

Several common threads weave through the diverse contributions. First, there is a need for systemic approaches that integrate financial innovation, technological advancement, social engagement, and policy reform. Second, recognising that regional, cultural, and institutional contexts profoundly shape the pathways and outcomes of green transitions. Third, there is an urgency to foster global collaboration, as no single nation or sector can address the magnitude of environmental challenges in isolation.

Importantly, the chapters in this volume do not shy away from identifying persistent barriers to sustainable development. Issues such as regulatory fragmentation, the 'greenwashing' of financial products, technological inequalities, limited access to green financing in developing economies, and the socio-political inertia resisting environmental reforms are critically examined. These challenges highlight the necessity for continued research, innovation, and dialogue.

This work also contributes significantly to filling gaps in the existing literature. The bibliometric reviews offer fresh insights into under-researched areas such as green credit policies, rural entrepreneurship in the context of social marketing, and the emerging intersections of AI and sustainable finance. Empirical analyses

of green bond ETFs, an area previously underexplored relative to traditional green bonds, provide important evidence for investors and policymakers navigating the evolving landscape of sustainable finance.

By bringing together perspectives from Europe, South Asia, and Eastern Europe, including case studies from countries such as Kosovo, Georgia, Ukraine, India, and the Visegrad group, the volume offers a genuinely global view of sustainable development challenges and strategies. This international scope reinforces that while sustainability challenges are universal, solutions must be sensitive to local contexts.

The intended audience for this volume is broad. Academics and researchers will find rich empirical data, methodological innovations, and extensive literature mappings to support further inquiry. Policymakers and regulatory bodies will discover actionable insights into designing and implementing green finance mechanisms and technological regulations. Industry practitioners, particularly in the banking, finance, and technology sectors, will gain strategic perspectives on aligning business practices with sustainability imperatives. Students and educators will find the volume a valuable resource for understanding the complex interrelationships that define the field of sustainable development today.

Overall, this volume affirms that sustainable development is not a distant aspiration but an immediate necessity. Achieving it requires the collaborative efforts of diverse stakeholders operating across multiple scales and sectors. Financial markets must realign incentives towards long-term environmental stewardship. Technologies must be harnessed ethically and inclusively. Policies must be ambitious, coherent, and adaptive. Communities must be empowered to drive bottom-up change.

The editors and contributors hope that *Sustainable Development and Green Innovation: Managing Risk Through Interdisciplinary Approaches and Policy Strategies* will serve as both a scholarly reference and a catalyst for further research, dialogue, and action towards a greener, fairer and more resilient world.

Chapter 1, 'Swiss Energy Companies and Energy Transition: Between Strategic Ambitions and Internal and External Constraints', analyses the strategic management of Swiss energy companies facing the renewable transition, revealing how internal capabilities and external pressures shape energy strategies.

Chapter 2, 'Stakeholder Engagement as Policy Instrument for Green Innovation and Development: A Study of Nigeria's Government Engagement with Educators', examines how stakeholder engagement between government and educators in Nigeria acts as a catalyst for green innovation and sustainable entrepreneurship development.

Chapter 3, 'Green Finance and Sustainable Development: A Bibliometric Review', presents a bibliometric analysis of global green finance research trends, highlighting emerging themes, intellectual networks, and research gaps critical for sustainable development.

Chapter 4, 'The Role of Technology, AI, ML and DLT in Sustainable Finance and a Green Economy', explores how artificial intelligence, machine learning, and distributed ledger technologies drive transformation in sustainable finance and green economic systems.

Chapter 5, 'Greening the Future: A Comprehensive Approach to Sustainable Development', provides a holistic framework for addressing global environmental and socio-economic challenges through sustainable development policies, with an emphasis on innovation and risk management.

Chapter 6, 'Imperatives of Social Marketing in the Context of Rural Entrepreneurship', highlights how social marketing strategies can promote rural entrepreneurship, improve social welfare, and support sustainable economic development, particularly in transitional economies.

Chapter 7 'Sustainability of Tourism and Regional Airports Based on Good and Less Good Practices', investigates sustainability practices at regional airports, comparing successful and less effective initiatives to promote environmentally responsible tourism and aviation.

Chapter 8, 'Policy Strategies for Sustainable Development and Green Innovation', analyses policy mechanisms and strategies governments can employ to accelerate green innovation and ensure the successful transition towards sustainable economic models.

Chapter 9, 'Policy Instruments for Promoting Green Innovation in Economic Development: The Case of Georgia', focusses on the Georgian experience and assesses how specific policy instruments foster green innovation and contribute to environmentally sustainable economic development.

Chapter 10, 'Corruption Perception in the Light of Green Transition Indicators', examines the interplay between corruption perceptions and green transition efforts, emphasising how governance quality directly impacts environmental and sustainability outcomes.

Chapter 11, 'Financial Market Contribution to Sustainable Development: Two Approaches to Green Bonds ETF's Analysis', provides empirical analysis of green bond ETFs, testing the existence of a 'green premium' and evaluating their contribution to financing global sustainability initiatives.

Chapter 12, 'Green Growth Policy in Visegrad: Key Drivers from an Economic and Non-Economic Perspective', evaluates how policy instruments, economic factors, and EU environmental standards drive or constrain the green transition in the Visegrad Group countries.

Chapter 13, 'A Bibliometric Review on the Literature of Green Banking: Using Scopus Database (1997–2022)', conducts a bibliometric review of green banking literature, identifying major research areas, trends, influential authors, and outlining future directions for sustainable finance research.

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Chapter 1

Swiss Energy Companies and Energy Transition: Between Strategic Ambitions and Internal and External Constraints

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Abstract

Purpose: If the Swiss political environment is generally rather favourable to the production of considerably more renewable energy (RE), the implementation of concrete projects by energy companies is influenced by various internal and external constraints. This chapter aims to describe, illustrate and analyse strategies and the nature of constraints, as well as their impact on the energy transition from energy enterprises' perspective.

Need for the study: The Swiss landscape of energy enterprises is highly diversified. Yet, it is unclear to what extent this diversity has an impact on the companies' strategies and constraints regarding the production of RE and, thereby, on green growth within Switzerland.

Methodology: This study is based on a mixed method consisting of qualitative interviews with CEOs from six Swiss energy enterprises and two experts as well as quantitative data generated on the basis of annual reports of most Swiss energy-producing enterprises (n = 105).

Findings: To varying extents, all company strategies seek to develop RE. The number of RE types produced or envisaged by public companies is generally higher than for private companies. Companies are influenced by external factors, such as legal opposition, regulations and customer and citizen behaviour, as well as internal factors, such as risk management capacities, human resources availability and innovation capacity.

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Practical implications: Each energy enterprise must choose its RE projects by considering its specific external and internal constraints in order to maximise its benefits and contribution to the national energy transition strategy.

Keywords: Energy companies; Switzerland; constraints; obstacles; energy transition; size; legal status

JEL codes: H12; L25; L33; P18; Q42

Introduction

Given the long tradition of hydropower in Swiss energy production (Tabi & Wüstenhagen, 2017), it can be considered that the topic of RE is not new in Switzerland. Nevertheless, attention to RE suddenly and greatly increased across all political parties with the Fukushima accident. In this context and due to growing awareness of the climate crisis, the Swiss federal government and parliament reformulated their energy strategy towards successive replacement of nuclear and fossil energy with RE (Díaz et al., 2017). Several federal laws were adapted in order to promote the production of RE. These legal changes were clearly confirmed by the votes of the Swiss population in 2017 and 2024. Simultaneously, Switzerland faces another major problem, namely, a high dependency from imports. In fact, 70% of Switzerland's energy supply depends on foreign fossil and nuclear fuels.[1] Since negotiations on an electricity agreement between Switzerland and the European Union (EU) were suspended in 2018, Switzerland has been increasingly isolated from the advancing EU market integration and mechanisms which are crucial for grid security (IEA, 2023). Consequently, Switzerland finds itself in a typical situation of the 'impossible energy trinity', which means to be a state 'which cannot simultaneously achieve energy security, sustainability, and sovereignty' (Thaler & Hofmann, 2022, p. 1). Given these circumstances of successive renouncement of nuclear energy and the uncertain relationship with the EU, the pressure to develop RE is high.

Despite the broad political support for the development of RE, the implementation of concrete projects often meets opposition, especially at the local level. Legal opposition, for instance, regarding the enlargement of hydropower plants or the installation of wind power plants, may block the implementation of projects for a long time, sometimes even several decades (IEA, 2023). Indeed, civil society organisations or individual citizens oppose RE projects, often with the argument that they want to preserve the landscape for functions such as nutrition, aesthetics, heritage or habitat (Kienast et al., 2017).

[1]Swiss Confederation – International energy policy (admin.ch); consulted in June 2024.

Swiss energy companies are situated at the centre of this field of tension between pressure for and opposition to the development of RE. In fact, they are the organisations which should plan and implement concrete RE development projects. Yet, there is a research gap concerning their strategies for the development of RE and the external and internal constraints they face. Such knowledge is a crucial source of information for public policies on RE. The case of Switzerland is particularly interesting because of its highly diversified energy companies. Indeed, they consist of approximately 600 firms, which vary greatly regarding variables such as size, energy production, legal status, and so on. This chapter examines to what extent the variables of size and legal status have an impact on the companies' strategies, which are based on the analysis of their annual activity reports, and the constraints they face, and these are based on semi-structured interviews with CEOs from six varying energy enterprises and two experts.

This introduction is followed by a literature review focussing on obstacles met for the development of RE in Switzerland and a description of the Swiss landscape of energy companies. The methodological section specifies the data used and the analysis performed, followed by a presentation and discussion of the results obtained.

Literature Review

Obstacles for the Development of Renewable Energies

The development of RE meets various kinds of obstacles. As reported by several studies, these obstacles concern the *human resources*, *social*, *technical*, *political*, *legal* and *economic* dimensions. A first study dedicated to the development of wind energy in China makes it clear that even if some conditions are met, such as the availability of a high production capacity, others, such as the shortage of professional talent in wind power technology, may slow down further development. Indeed, in the case of RE production, there needs to be a wide range of qualified labour in a wide range of professions: R&D professionals, senior management personnel, manufacturing professionals, senior technicians, as well as wind plant and turbine operations and maintenance personnel (Zhao et al., 2014). The nature of these obstacles impedes further development of RE and varies according to the type of RE. This becomes clear when comparing the results of the previous study with another Chinese study concerning hydrogen. Thus, a shortage of manufacturers, incomplete supporting facilities and hydrogen fuel safety issues are identified as being the main obstacles. In addition, the political and technical dimensions constitute another important hurdle (Wu et al., 2021). Paradoxically, the lack of stable legal regulations precisely constitutes another obstacle, as argued by a study on Polish biogas plants. Indeed, changing regulations have a negative impact on investment according to the employees of a biogas-producing firm (Bednarek et al., 2023).

RE sources do not only represent interesting opportunities for large energy enterprises, but also smaller, decentralised RE systems, which are situated at the local level. Apart from energy provision, there also seem to be promising routes for local economic development. A study on Scottish wind farmers demonstrates

that RE can constitute a means to diversify and future-proof the farmers' business. However, in some cases, farmers fear the obstacles of economic risk and transaction costs and, therefore, compensate this by reducing the turbine size and renting land to developers. Thereby, these opportunities would be 'at risk of being co-opted by large-scale energy companies, which are better able to negotiate the growing complexities and risks of turbine development' (Sutherland & Holstead, 2014, p. 102). Economic and further obstacles related to size are also mentioned in a Finnish study on various kinds of RE: insufficient information and availability of professional services, lacking profitability of small-scale energy sales and the cost of production systems (Varho et al., 2016). An American case study on an on-farm biogas production explained this shutdown by the underestimation of technical problems and operating costs, overestimation of financial returns and low RE credit price (Wang et al., 2021). Finally, the obstacles of two case studies in South Africa on smaller-scale solar energy concern several of the previously mentioned dimensions, such as issues with battery management systems, an incoherent business model imposed by a large energy company, bureaucratic obstacles, and growing pains concerning cohesion within the concerned community (Bloem et al., 2021).

Thus, existing literature points to a series of obstacles for the development of RE, among which there is the political dimension. Since this is generally specific regarding a given territory, the following section develops the Swiss political context in more detail.

Swiss Governmental Policies and Goals

Annually assessed by the Federal Office of Energy, three approaches can be identified in the Swiss context for the substitution of fossil fuels: a purely electric system with battery storage (EBS), a hydrogen-based system (HYS) and a system using synthetic hydrocarbons (HCR). The EBS is the most energy-efficient method; however, this requires seasonal electricity storage to meet year-round energy needs. Using batteries for this is currently expensive and impractical due to production limits, and expanding pumped hydropower would have significant environmental impacts. The HYS allows for underground hydrogen storage to balance seasonal demand, but it needs infrastructure development. The HCR demands the largest photovoltaic (PV) field but leverages existing infrastructure (Züttel et al., 2022). Otherwise, the heating and mobility sectors, responsible for nearly half of domestic greenhouse gas emissions, are transitioning, which is leading to increased electricity demand (Bucher et al., 2019). Relatively, Switzerland's energy policies are designed to promote sustainability and reduce dependence on fossil fuels and nuclear energy. As a matter of fact, the 'Stratégie énergétique 2050' is a pivotal framework aiming for climate neutrality by 2050.[2] Key components of this strategy include the enhancement of energy efficiency, the development of

[2]https://www.bfe.admin.ch/bfe/en/home/policy/energy-strategy-2050.html/ (retrieved on 18 June 2024).

RE sources and the gradual phasing-out of nuclear energy sources. This strategy builds upon previous initiatives, for example, Energy Perspectives 2035, which sets ambitious targets to comprehensively transform the country's energy landscape. This consists notably of incentives for RE projects, stringent regulations to curb emissions and support for technological innovations. For instance, the government offers subsidies and tax incentives to encourage the adoption of RE technologies in both residential and industrial sectors (Züttel et al., 2022).

RE Production in Switzerland

Switzerland's RE portfolio is diverse, with significant contributions from hydropower, solar, wind and biomass energy. Hydropower remains the cornerstone, providing approximately 68% of the country's electricity. This represents an important source of revenue for public bodies, in particular in the mountainous regions (Gaudard et al., 2014). This focus is due to the country's abundant water resources, which offer a reliable and sustainable energy source. In recent years, the government and private sector have heavily invested in PV systems, leading to a significant increase in solar power capacity. Solar energy not only supplements the energy mix, however, it also reduces dependency on hydropower during dry seasons. Albeit less prevalent than hydropower and solar, wind energy is gaining traction. Thus, several wind farms have been established, primarily in mountainous regions where wind conditions are more favourable. Finally, biomass energy also contributes to Switzerland's RE mix. This alludes to energy generated from organic materials such as agricultural waste, wood and biogas. Biomass energy supports both electricity generation and heating applications, thereby enhancing energy security and reducing greenhouse gas emissions (Gaudard et al., 2014).

After the nuclear accident in Fukushima and the Swiss Federal Council's and parliament's landmark decision to successively replace nuclear power by RE sources (Díaz et al., 2017), several studies examined what the 'optimal' energy mix could be for Switzerland (Dujardin et al., 2017). In 2021, domestic energy production relied on three main pillars: hydropower plants (62%), nuclear power plants (29%), and conventional power plants and renewable energies (9%). Simultaneously, the share of oil and gas of the gross energy consumption still approaches 50%.[3] These figures show that the need to develop further RE is still strong if the political goal of zero net emissions target is to be met by 2050,[4] especially with the ongoing closure of nuclear power plants. Among the RE sources with development potential, PV, wind power, hydropower, geothermal power and biofuel are the most discussed methods (Kahl et al., 2019; Kienast et al., 2017).

[3]Swiss Confederation – Energy – Facts and Figures (admin.ch); consulted in June 2024.

[4]Swiss Confederation – What is the Energy Strategy 2050? (admin.ch); consulted in June 2024.

Apart from the issue of absolute production capacity, the annual distribution is another central issue for Switzerland. Indeed, the energy deficit is particularly important in winter. According to Kahl et al. (2019), this winter deficit could be reduced by up to 50% through the installation of PV at high altitudes, which means in the Swiss Alps. Yet, the production of renewable electricity often 'collides with provisioning, regulating and the cultural services of the landscape' (Kienast et al., 2017, p. 397). Based on a conflict assessment opposing RE sources, such as wind, PV, forest biomass, and six competing landscape services (nutrition and materials; aesthetics; physical and experiential interactions; heritage and symbolic content; water and liquid flows; lifecycle maintenance, habitat and gene pool protection), Kienast et al. (2017) consider that biomass from forests and PV placed/installed on rooftops are the least socially conflicting RE sources; however, PV on open, marginal and scrubland would be totally unfeasible. In fact, wind has a higher conflict potential.

The 'NIMBY' (not-in-my-backyard) syndrome also concerns RE in Switzerland. A study by Rudolf et al. (2014) demonstrates that Swiss people changed their attitude towards nuclear power plants after the Fukushima accident, whereas their preferences for other energies, such as RE, only changed marginally. A comparative study between Switzerland and Germany shows that the attitude towards geothermal energy is influenced by its proximity. Fearing seismicity, the public generally prefers projects situated in remote areas, although geographical proximity to consumers would increase their viability (Knoblauch et al., 2019). Similarly, a comparative study between Switzerland and Austria reveals that a majority of respondents would be willing to invest small sums in RE, among which are a large group of 'urban wind energy enthusiasts'. However, a significant part of these potential investors are reticent to nearby wind installation (Broughel & Hampl, 2018, p. 722).

Unsurprisingly for a federal state, such as Switzerland, the local context matters. First, values related to energy policy that exist at the local level differ compared to those communicated at the cantonal (regional) and national levels. At the local level, the promotion of energy production is seen as a means for local development, whereas at the cantonal level, the empowerment of the regional government in the field of energy policy implementation is emphasised. Finally, the value communicated at the federal level consists of the promotion for a national-level 'greener' environmental agenda (Díaz et al., 2017). Second, there are differences at the local level. The local context is framed by such aspects as politics and cultures, which plays a crucial role regarding acceptance of RE projects (Schumacher & Schultmann, 2017). For instance, regarding the rate of solar PV uptake, Hirt et al. (2021) identified nine clusters of municipalities, out of which solar PV uptake is greater in the case of clusters characterised by high agricultural and innovation activities, as well as higher education institution density. Furthermore, the roles played by different local actors also have an important impact. A comparative study of Switzerland, Germany and Austria reveals that citizens rate local scale opportunities related to distributed energy systems higher than the challenges; yet, they also consider that the responsibility for the energy system transition is the responsibility of the national government and large supply utilities rather than for municipalities and households (Seidl et al., 2019). Still

regarding the role played by various actors, a study on higher degrees of regional energy autarky sees an important role for administrations and civil society actors at the local level in initialising and developing projects in order to ensure their acceptance and implementation (Müller et al., 2011). Also, Hirt et al. (2021, p. 1) consider that 'different local actors, such as local authorities, energy companies, and devoted citizens, can accelerate PV uptake using various strategies based on local specificities'. Consequently, they suggest developing context-specific strategies to promote PV uptake.

The Landscape of Swiss Energy Companies

In Switzerland, energy production is shaped by governmental policies and proactive initiatives of energy companies, often in near-monopolistic positions, which drive the transition towards more sustainable and resilient system (Mühlemeier, 2019). The foundational legislative framework, which is rooted in the 1990 Energy Article of the Federal Constitution, includes the Energy Act, CO_2 Act, Climate and Innovation Act and Electricity Supply Act.[5] While challenges exist, the opportunities for innovation and growth in the RE sector are substantial. Hence, Switzerland's journey towards climate neutrality by 2050 may serve as a model for other nations aiming to balance energy needs with environmental stewardship.[6] We hereby explore the current state of Swiss energy companies, focussing on the challenges and opportunities for the industry.

In recent years, Swiss energy companies have played a critical role in the nation's energy transition. For instance, major players such as Axpo, Alpiq and BKW have been substantively involved in various segments of the energy market, from generation and distribution to innovative energy solutions. Mainly, these companies seek to invest heavily in RE projects and smart grid technologies in order to enhance efficiency and reliability. Axpo, for instance, is a leader in hydropower and wind energy. The company has expanded its operations beyond Switzerland, contributing to RE projects across Europe. Another key player, BKW, is notable for its investments in solar energy and its comprehensive approach to integrating RE into the national grid. The company's initiatives include developing decentralised energy systems and promoting electric mobility, thus aligning with Switzerland's broader energy strategy (Crettenand, 2012; Dietsche & O'Sullivan, 2021; Hettich & Kachi, 2022). Most Swiss energy companies have a regional or a local anchorage. They operate in a monopolistic regime, viewing the network within their activity zone and in a market-based regime regarding energy production and supply (Mühlemeier, 2019). Data in our possession, which was generated from the base of a publicly available list[7] concerning energy-producing

[5]https://www.uvek.admin.ch/uvek/en/home/energy/energy-policy.html (retrieved on 18 June 2024).

[6]https://www.uvek.admin.ch/uvek/en/home/energy/energy-policy.html (retrieved on 18 June 2024).

[7]https://www.strom.ch/fr (retrieved on 18 June 2024).

companies, show a predominance of private companies in the Swiss energy sector, followed by autonomous public companies and non-autonomous public companies. It is an open question as to what extent this legal status plays a role in the production of RE. The majority of companies are small and large enterprises, comprising of over two-thirds of the total. Medium enterprises also form a significant portion, while micro-enterprises represent the smallest share.

Despite significant strides made by the country, several challenges remain for energy companies. As mentioned earlier, the primordial one is the balance between energy production and environmental conservation. If one considers hydropower projects, the ecological impact on river ecosystems is always at stake. Similarly, wind farms often face opposition due to their visual impact on the landscape and the noise produced (Huber et al., 2017; Spiess et al., 2015). Another challenge dwells in the intermittency of RE sources such as solar and wind. To address this, Swiss energy companies are investing in energy storage solutions and smart grid technologies with the hope of gaining more stability and reliability in the energy supply. On average a 25% increase in seasonal storage is required for a fully renewable, balanced system (Dujardin et al., 2017). All these challenges must not obscure the numerous opportunities available for growth and innovation. In particular, advances in technology, improved power storage and efficiency, not to mention Switzerland's strong research and development sector, support continuous improvements in the energy sector. The transition to RE also offers economic opportunities, including job creation in the green energy sector and the potential for the country to become a leader in RE technology exports (Hettich & Kachi, 2022).

Data and Methodology

As mentioned in the introduction, two major questions are at the core of this research. First, what are the strategies of the Swiss energy-producing companies regarding the production of renewable energies, and to what extent do they vary according to the companies' size and legal form? In order to answer these questions, annual reports from all Swiss energy-producing and -distributing companies for the year 2022 were used. Indeed, annual reports are a useful source because they usually mention information about produced energy and future plans, thus what is considered here as strategy. Annual reports were identified based on the member list of the Swiss Association of Electricity Companies.[8] This list is constituted of 408 members (state: end of January 2024). According to the association's director, about 600 energy companies exist in Switzerland, and those who are members of the association represent more than 90% of all produced, transported, traded and sold electricity from/in Switzerland. Thus, in the first step, all 408 members were screened regarding the fact whether they produce and distribute electricity, with a result of 177 companies. Then, annual reports were looked for on the respective companies' websites. 105 annual reports were identified and

[8]Adhésion | AES (strom.ch).