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# Integrated Risk Analysis of Aggregators: Policy Implications for the Development of the Competitive Aggregator Industry

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**Abstract:** One of the important goals of the EU is to ensure a secure, sustainable, and competitive energy system that is less dependent on external energy supply. Greater independence is planned to be achieved by diversifying energy sources, as well as investing in renewables and energy efficiency. One of the mechanisms is the demand response (DR) that provides a high level of energy independence for the consumer. In this paper, we explore perspectives of the development of DR with a mediating effect of the independent aggregators from an EU member state standpoint. We use a hybrid research methodology that combines instruments of strategic analysis, i.e., PESTLE framework and SWOT analysis, along with the integrated risk management framework in order to identify, evaluate and rank prominent risks to which this initiative is exposed. Interdependencies between the identified risk factors are also included and efficient mitigation measures are proposed. The findings of this exploratory research are aimed at developing the policies and strategies for the aggregators' development in the medium term. The most emphasized risks detected in analysis are the investment risk, the legal risk, the risk of substitute technologies, the consumer behavior risk, the risk of opportunistic behavior and the risk of entry barriers.

**Keywords:** demand response; aggregators; distributed energy resources; PESTLE; SWOT; integrated risk analysis



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## 1. Introduction

Challenges in obtaining the ambitious goals of the European Energy Union related to achieving balance, security, sustainability and efficiency of the electric power system are increasing due to the integration of renewable energy sources (RESs) and electric vehicles (EVs), along with the trend of increasing electricity consumption. Therefore, a new paradigm of improving power system flexibility is emerging [1]. For this purpose, a new market player in the form of aggregator is necessary, tasked with a role of pooling de-centralized resources [2]. Aggregators can provide supply side flexibility by operating flexible decentralized generators as virtual power plants or demand-side flexibility by aggregating demand response (DR) resources and energy storage units [3]. Sometimes, distributed power generation is owned by consumers, transforming them from traditional consumers into prosumers. Thus, aggregators operate by optimizing a portfolio of dispersed and flexible distributed energy resources (DERs) to provide different services to the power system. In this process, they may either sell or buy aggregated energy precisely when needed or rely on flexibility products by acting as retailers or intermediaries between flexibility providers and flexibility procurers [2]. Flexibility on the demand side is commonly regarded as crucial, especially considering that higher energy consumption is related to peaks in demand and possible grid congestions, which could warrant investments in grid infrastructure [4]. Therefore, in this paper, we focus on the demand-side flexibility and the mediating role of the aggregators with the objective to assess the barriers and benefits of aggregator industry development from an EU member state perspective. The main research question is: What risks need to be mitigated to encourage the development of the aggregator industry? The objective, against which risks are identified, is measured as the ability to establish a higher number of independent aggregators with a successful business model in the next five years. The objective is aligned with the regulatory recommendations related to development of the DR activity in the European Union.

The future development of aggregator-based DR is influenced by various factors that have their roots in different political, economic, social, technological, legal and environmental (PESTLE) factors that may support or hinder this initiative. In the existing literature, these issues are covered partially in the form of SWOT (Strengths, Weaknesses, Opportunities and Threats) [5,6] and PEST(LE) analyses [5,7]. Taking a different approach, Lu et al. [8] give an overview of existing aggregator business models and present a list of challenges these aggregators face, while Wang et al. [9] consider the negative impacts of aggregators' opportunistic behavior. From the presented literature, it can be concluded that the research is mainly focused on a specific aspect of the problem and does not offer a holistic long-term solution. To overcome the literature gap, we apply the Delphi–SWOT hybrid approach proposed by Capuder et al. [10], Mikulić et al. [11] and Tavana et al. [12] to identify and discuss different factors that influence the development of aggregators as mediators in DR. The results of these studies have enabled us to establish a strategic perspective related to the future development of aggregators and their role in DR. Thus, we propose a multi-disciplinary approach to the topic of aggregators as mediators in DR, borrowing techniques and research methods from the Strategic Management and Risk Management disciplines.

In this sense, our paper contributes to the existing literature in multiple ways. By employing a multi-disciplinary research method, the problem is holistically explored and studied, resulting in a comprehensive and rigorous literature review filling the literature gaps and providing an up-to-date overview of the existing research. Research results related to the identification and assessment of risk factors influencing the development of competitive aggregator industry provide valuable inputs for further studies, which can help ensure the maximization of the aggregator-based DR benefits. Conditions under which aggregators could operate as monopolists are also considered. Furthermore, our research findings propose mitigation measures related to the key identified risks providing important implications for policymakers. Specifically, the risks affecting investment in DERs and related to substitute technologies, legal risks, risk of opportunistic behavior of aggregators, consumer behavior and acceptance risks are highlighted along with their corresponding mitigation measures.

The paper has the following structure. The second section presents an exploratory research methodology based on the Delphi–SWOT hybrid approach combined with the integrated risk management model. The third section presents a critical review of the literature that summarizes the most relevant factors of PESTLE analysis. The results of the literature research are the basis for identifying strengths, weaknesses, opportunities and threats using SWOT analysis, as well as for integrated risk assessment related to the successful establishment of independent aggregators, which is presented in the fourth section. The fifth section discusses the policy implications and strategies for the aggregator's development to mitigate the identified risks. In the sixth section, the conclusions of the paper are presented.

## 2. Methodology

In this paper, we conducted exploratory research based on the Delphi method. We used a hybrid methodology borrowed from the Strategic Management and Risk Management disciplines that combined PESTLE, SWOT and Integrated Risk Management (IRM) analyses. The Delphi method, firstly introduced at the RAND Corporation in the 1950s, is the qualitative method of forecasting based on the estimations and consensus of the group of experts obtained through several rounds of anonymous surveys. The main criterion of selecting the group of experts is the knowledge about the topic that is the object of the research, so that they can forecast the potential outcomes and scenarios, predict their likelihoods and reach the group consensus. However, it is desirable that respondents have somewhat different backgrounds to encourage different perspectives of the research problem [13]. As for the number of panelists, Rowe and Wright [14] suggest 7–10 people as the optimal number because multiple members do not contribute to the accuracy of estimates. After a few Delphi rounds, convergence in answers can be expected, which is obtained through the group opinion building process and better forecasting accuracy of the experts. In the event of a significant difference in the opinions of experts, another round of discussion is held, with each expert clarifying his or her point of view and helping others to reconsider and revise their opinion. Therefore, knowledge-based brainstorming is used to support the Delphi method, and consensus is usually achieved after three to four rounds of discussion [15]. The final group assessment is calculated as the mean or median of the individual answers, while the standard deviation is decreased from round to round, which is one of the main advantages of the Delphi method in comparison to the simple one-round surveys. It also offers the benefits of group thinking by mitigating potential teamwork issues, such as dominant team members who may not be the best experts in the field of analysis [13].

The panel of experts brought together nine members from academia and the corporate sector. Following the recommendation of Rowe and Wright [14] on the optimal number of experts in the panel, in addition to the authors of this paper, four more people were selected. The key criteria for selecting experts in the panel were their knowledge and experience, taking into account somewhat different backgrounds in order to encourage different perspectives on the research problem according to the recommendations of Kauko and Palmroos [13]. Thus, 7 out of 9 experts each have over 15 years of experience in the field of power system engineering, energy economics, strategic management, risk management and business analysis. Senior experts have gained experience through leading or participating in professional and scientific projects, research work and business management. It should be noted that one of the members of the expert group is among the 2% of the world's most influential scientists, while the other is a senior industry expert with over 20 years of experience in top management positions. The two younger members of the panel are doctoral students with a background in power system engineering, mathematics and business economics. Both are collaborators on the project from which this research was funded and are deeply involved in the topic of demand response and aggregators.

The proposed approach in this paper builds on the Delphi–SWOT hybrid method used by Capuder et al. [10], Mikulić et al. [11] and Tavana et al. [12]. Section 3 presents a detailed analysis of the prerequisites as well as constraints of DR development with the mediating role of independent aggregators by implementing the PESTLE approach. The results of this analysis enabled us to use a strategic instrument known as the SWOT matrix [16] and identify the strengths, weaknesses, opportunities and threats, as well as to identify the risks that may adversely affect the establishment and successful operation of independent aggregators. Based on the developed SWOT matrix, a group of experts identified different types of risks and assessed them according to the probability of occurrence and the significance of the impact on the objectives, after which the risks were positioned on the risk map. The risk map is a strategic instrument that ensures the visualization of the overall risk portfolio, which enables better decision making. The risk map provides a clear insight into the prioritization of risk management activities and identification of risks that should be mitigated, monitored or transferred [10]. In our research, we used scales for evaluating probabilities and significance of certain risk events, as in most cases, the answers in surveys where the Delphi method is used are numeric estimates, ratings on a scale, or yes/no. However, experts are encouraged to write their opinions on the issues raised in the questionnaire [13]. IRM or Enterprise Risk Management (ERM), sometimes also called

Strategic Risk Management, is a fundamental part of the effective corporate governance system that enables an organization to identify, assess, manage, control and monitor exposure to different types of risks. IRM (ERM) is a relatively young discipline, so a comprehensive theory still does not exist [17]. IRM systems are implemented in many ways that differ in maturity and scope; however, several frameworks developed by semi-regulatory bodies do exist, encouraging a broader implementation of IRM concepts. The best known and widely used framework is the COSO ERM 2004 [18] (see Figure 1), which presents eight dimensions of the ERM process. COSO defines the effectiveness of ERM based on the assessment of whether the eight dimensions are present in the process and whether they function in a coordinated manner, whereby the proper implementation of the eight dimensions becomes a criterion for an effective and mature risk management system [19]. This research aims to introduce an IRM process established to encourage development and successful performance of independent aggregators as market players, which should support the demand response activity. Monitoring and continuous improvement of the whole process are necessary steps, which is achieved by constant management activities, separate evaluations or a combination thereof. The effectiveness of the implemented risk management measures must be monitored so that the changes in business conditions do not alter the priorities. If certain measures prove ineffective, new measures that yield better results need to be adopted and implemented. Once the risk register and risk map have been developed, they are a sufficient basis for the risk management process only in the short term. For successful long-term risk management, it is necessary to monitor changes in the external and internal environment and modify risk management strategies in accordance with the changes and new risks that may arise.


**Figure 1.** Enterprise risk management process dimensions.

## 3. The Context and Challenges of Aggregator Industry Development

### *3.1. Political Drivers*

For the last 10 years, the European Union has positioned itself as a leader in environmental protection, with a focus on certain areas, such as climate and energy. The ultimate goal of such strategic action is to achieve zero net greenhouse gas emissions by 2050 [20]. A strategic document defining the activities aiming to "transform the EU into a decarbonized, resource efficient, green and socially fair continent" is set by the EU policy called the European Green Deal [21]. The European Commission (EC) is committed to dealing with climate and environmental issues, which makes the Green Deal the centerpiece of a new growth paradigm [20]. EU member states are independent in choosing their own energy path to reach the EU-wide targets and objectives through the National Energy and Climate Plans (NECPs), which are assessed by the EC [20]. The NECP requires EU countries to define a long-term strategy for the next 30 years [1]. However, some member states do not share the same vision in the context of implementing green agenda domestically and remain relatively inactive [21]. Many non-EU countries do not share the same vision as the EU in terms of achieving zero net $CO_2$ emissions by 2050, which poses an additional risk of not obtaining this goal [20].

The establishment of the EU Energy Union aims to provide a secure, sustainable and competitive energy system that is less dependent on external energy supplies by using strategy of diversification, as well as investing in RES and energy efficiency [1]. In that context, the moderation of energy demand is an important dimension of the Energy Union Strategy, under which consumers have a central position in a renewed EU energy system. This system should generate more flexibility and protection to consumers and provide independence in producing, storing, selling and sharing their own energy [1]. By considering the global trend of increasing electricity consumption, EV integration and variable RES production, the introduction of new auxiliary mechanisms that will improve system balancing and security of supply is of utmost importance. The most emphasized advantage of introducing a DR service is its greater economic profitability, compared to the construction of new power plants or strengthening the network infrastructure. The EC recognizes cross-border transmission capacity increase as one of the enablers of the Green Deal agenda. The ENTSO-E's Ten-Year Network Development Plan [22] reports that, by 2025, 35 GW of new cross-border lines will already be in a mature state of development, and projects additional needs of 50 GW by 2030 and 43 GW in the 2030–2040 period. The intended investments should help decrease RES curtailment and increase market integration, leading to the decrease in production costs and price convergence between states. However, even in the case of unlimited transmission capacity, RES curtailment can still occur in the cases when RES and loads reach peaks at different times, confirming the importance of DR and energy storage technologies [22].

According to [23], "the EC should ensure that energy efficiency and DR compete on equal terms with generation capacity", which is supported by the policy document: "Clean Energy for All Europeans" [1]. The document suggests the minimization of investment in the energy sector while increasing the flexibility of energy systems through flexible consumption that can be traded and managed. The mentioned strategy should result in a cost reduction by decreasing investments in additional power plants [3]. In this renewed EU energy system, citizens are empowered by way of better information, transparent energy bills and understandable contracts [1]. Therefore, to evoke a change in behavior and attitudes, it is important to increase awareness among customers regarding DR opportunities, as well as the implicit and explicit advantages of acting as DERs.

In support of the European Green Deal, the EC started an initiative for digitalizing the energy sector in July 2021 [24]. The aims of this initiative are to enable smoother integration of the prosumers in the power system and to ensure interoperability of all involved technologies. This will be achieved by developing a competitive digital energy services market and a cyber-secure, efficient and sustainable digital energy infrastructure.

### *3.2. Economic Factors of Aggregator Business Models*

Volatility driven by the rising share of RES is leading to the inability of electricity production to accommodate its consumption [2,4,25]. According to Campos do Prado et al. [26], considerable investments aimed at efficiency and affordability have been made worldwide fostering higher acceptance rates of RES technologies, even though RES are not the most cost-effective power source from a power system perspective. To cope with the variability of electricity generation and uncertainty in RES generation forecasting, flexibility is introduced through aggregators [27].

However, the benefits of aggregators extend beyond the RES integration challenges and can be grouped into services related to: operating the power system, investments in the power system infrastructure and decreasing the marginal cost of power. Balancing the system that helps integrate RES, deferring investments in the distribution and transmission of grid infrastructure, avoiding investments in peak generation capacity and reduction in the cost of power by load reduction or replacing peak power by other generation or storage technologies can be pointed out as the most important benefits in each category [3]. A comprehensive overview of the services that an aggregator can provide is presented in [8]. Scrutinizing the issue further, Burger et al. [28] referred to the above-mentioned benefits as fundamental or intrinsic values of aggregation, which do not depend on the specifics of a power system and should not fade over time. They identify the main drivers of these values as: economies of scale (related to the size of a market player) and scope (related to multiple revenue streams) as well as risk management.

The importance of economies of scale arises from the ability of aggregation to include small players in electricity markets to which they would otherwise not have access to due to their size, costs or technical requirements [29]. Therefore, smaller residential and commercial customers could encounter more obstacles in their efforts to access markets, while at the same time, it is sometimes stated that industrial customers are being able to sell their flexibility more easily [2]. On the other hand, Barbero et al. report that aggregators mostly deal with large industrial consumers [4]. Nevertheless, according to [29], the vast majority of flexibility is provided through aggregation, which involves individual residential houses, tertiary buildings, while also including large industrial sites.

Furthermore, market participants may differ in their level of risk aversion and capability to hedge against risk. Aggregators can provide hedging solutions to smaller market players, i.e., stabilized prices to retail customers. In some markets, the same goal was achieved through vertical integration, which can create barriers to entry reducing competition [28]. In this sense, it is worth noting that photovoltaic (PV) systems are currently the second most-used RES worldwide, behind hydropower capacity [26]. Therefore, independent aggregators may encounter difficulties when attempting to attract consumers and participate in wholesale markets due to barriers to entry and market development, which are present in the case of traditionally hydropower-related vertically integrated monopolies [30]. Moreover, Staffell and Rustomji [31] noted that storage devices could provide better service in the ancillary service market than conventional market players, but no financial premium is available to them and that energy storages are not subsidized as RES. They also reported that fixed premia incentives for RES do not apply to dispatchable facilities, and that policy development is centered on large-scale storage, while the role of small-scale storage ought to be emphasized due to the future integration of heat and transport electrification [31].

The economies of scale and scope and risk management as the underlying factors of the fundamental value of aggregators regrettably encourage lower market competition. Therefore, Burger et al. [28] advocated competition as an additional driver of fundamental value in order to foster desired and economically viable innovation leading to competitive prices, customized products and consumer engagement. However, a profitable industry is a necessary precondition for attracting competition. Unfortunately, poor results regarding economic viability are reported, even in the case of industrial plants with multiple revenue streams and when models heavily rely on battery storage. As pointed out by Okur et al. [27], if capacity reservation is modeled properly, battery storage can enable multiple business models. Suitability to provide frequency containment reserves (FCRs) in the reserves market is highlighted in [4], while the profitability of providing FCR and peak shaving is emphasized in [32]. Nevertheless, regardless of superiority in the mentioned respects to other DER technologies, Braeuer et al. [32] showed that, in the German market, even in perfect foresight conditions and relying on multiple revenue streams, the positive net present value (NPV) of investment is realized in the case of roughly half of the companies analyzed in their sample and assuming a discount rate of only 2%. Moreover, they found that relying solely on arbitrage trading in the day-ahead market, peak shaving or providing FCR did not yield positive NPVs for any of the companies, dismissing economic viability.

The findings stress high sensitivity to the battery price and lifetime and the importance of economies of scale in the case of peak shaving. Additionally, the lack of profitability from arbitrage in the day-ahead market is attributed to low battery usage providing earnings relative to its price. The market price spreads should be large enough given the battery price in order to yield a viable investment [32]. However, Staffell and Rustomji [31] pointed out that the peak demand for electricity in Germany seems to coincide with RES power generation, unlike in the UK, reducing the base-peak price spread and subsequently the profitability of arbitrage trading. Čović et al. [33] found that economic viability can be achieved, even when conducting out-of-sample forecasting in multiple markets (Denmark, Germany and Croatia). Nevertheless, a discount rate of only 3% was used while PV and intraday trading were added, compared to the revenue streams mentioned in the research above. Generally, battery storage is commonly used in both industrial and residential systems with installed PVs, since the price of energy injections is usually lower than the price that the consumer pays for withdrawing electricity from the grid [34].

Irrespective of the vast industrial DR potential, applications in residential and tertiary buildings also attracted a lot of research attention since they account for approximately 40% of worldwide energy consumption, with 50% of the amount being related to heating, ventilation and air conditioning (HVAC), which makes HVAC systems one of the most substantial sources of DR in buildings [35,36]. However, recent research examining the economic viability of a cluster of household heat pumps and HVAC systems in public buildings reported even poorer results than in the case of industrial sites, as the researchers hardly detected any profits [4,25]. Nevertheless, Barbero et al. [4] found that adding batteries and self-consuming power generation in the form of PV to the system increases profitability, corroborating the results obtained for industrial sites.

It should be mentioned that, according to [37], in 2020, 139 GW of new PVs were installed, resulting in an estimated 760 GW at the global level. Worldwide, module prices decreased by 8% on average in the 2019–2020 period, which marks a ten-year-long trend of decline in PV prices for commercial and residential use [26,37]. Regarding batteries, the production capacity for Li-ion batteries in 2017 was estimated to be 100 GWh annually with estimates for 2020 surpassing 250 GWh, while the costs of the Li-ion battery storage of various technologies in the 2016–2030 period are expected to decrease between 54% and 61% [38]. According to Jaeger-Waldau [34], in the 2010–2018 period, battery prices fell by nearly 85%. Such an increasing trend in production accompanied by a decreasing trend in prices is important because lower investments increase the profitability of operating the resources and make them more affordable, which can potentially increase the number of small- and medium-sized DERs that the aggregators hope to engage.

When considering the consumers' savings, it is important to note the difference between the DR and energy efficiency. As stressed by BEUC [30], the DR is related to the "optimal use of energy from a system perspective" and does not imply energy savings associated with energy efficiency. Therefore, low energy-saving possibilities imply low chances for bill reduction for consumers, as energy consumption might only be postponed (instead of reduced). The full benefits of DR in the EU in 2016 were, however, estimated at EUR 1.6 billion [30]. Moreover, poor information, weak price signals due to the high share of taxes, fees and network charges in the electric price complicate the issue, further hindering consumer engagement [2]. It should also be noted that Ghose et al. [39] reported that the volatility of prices reduces when market players take on more risk. Therefore, by enhancing the efficiency, the risk-taking players may face losses instead of profitability [39]. Such considerations place even more emphasis on the multiple revenue streams of aggregators. In turn, however, they add to the complexity of their business model in terms of the optimal operation of each unit the aggregators control, but even more in terms of the advanced demand and supply forecasting the optimization of DER dispatching [3]. Dealing with complexity along with enabling agent engagement via automation and filling the information gaps was observed by Burger et al. [28] as a transitory value of aggregators that will fade over time, but is nevertheless an important step in the transition of the power system.

Lastly, issues regarding regulation and market imperfections need to be addressed. These were classified by Burger et al. [28] as an opportunistic value of aggregation which is seen as undesirable since it stems from regulatory flaws. It therefore leads to private benefits and should be avoided, which is further discussed in Section 3.5, regarding legal and regulatory framework. Here, it should only be pointed out that a microgrid with a point of common coupling is presented as a viable solution for the aggregation of different consumers to overcome some of the regulatory issues. Microgrid aggregators as a reliable, secure, efficient and economically viable solution are also advocated by Ghose et al. [39] and Vatanparvar et al. [40].

### 3.3. Social Acceptance and Consumer Engagement

The widespread use of DR depends largely on the acceptance and engagement of users [41]. The growing interest of consumers to act as DERs may increase the number of aggregators. One of the key social factors for consumer involvement in DERs is a self-awareness of own energy consumption. While consumers usually know how much money they spend on the electricity bill, they do not know how much electricity their household consumes. The installation of a graphical user interface allows the consumer to monitor electricity consumption in detail, and in this way, electricity is no longer invisible [42]. The consumer can easily analyze own load profiles and can compare them to others.

Buildings with installed RES and DR-enabling technologies are more attractive in the real estate market. In addition, such technology installed on the building acts as an indicator of social status. According to Kowalski and Matusiak [42], the results of a study aimed at analyzing attitudes about the use of energy management systems showed that the ability to own and use attractive technological devices and the ability to impress families and neighbors are significant motivating factors, because one of these two factors has been noted by 23% of respondents in Portugal, 17% in Poland and 12% in the Netherlands.

The decisions to operate DERs can be a cognitive burden for the user. The solution to this problem lies in the automation of the energy management process. According to Wissner [43], subsequent changes to the automatic control settings by the user lead to a reduction in energy savings. Difficulties with the implementation of automatic load control have been highlighted for industrial consumers because they want to retain the ability to interfere with automatic settings [44].

The DR system should be easy to use so that people with limited ICT knowledge can successfully overcome the usage issues [45]. In addition, consumers expect that the installation of a DR system should lead to an increase, and not a decrease, in comfort. For example, reducing the peak load by turning off the air conditioner requires a thorough analysis of energy needs. Installing an energy storage increases the possibility of demand flexibility while maintaining consumer comfort.

According to Rathnayaka et al. [46], in terms of energy sharing, consumers can be represented as "single entities" or "groups". The aggregation of consumers in terms of community-based initiatives can reinforce a positive change in social norms regarding environmental/energy efficiency behavior and allow the sharing of good practices [47].

Although financial incentives are the most important factors for customers to participate in DR, environmental concerns are often reported as a driving factorm as well as the opportunity to enhance one's knowledge [42,48]. Most of the consumers emphasize the desire to contribute to the preservation of the environment as an important incentive. According to Kowalski and Matusiak [42], environmental benefit would be an incentive to incorporate DERs for more than a quarter of the surveyed consumers in Portugal, Netherlands and Poland. For industrial consumers, the desire to brand a company as a "green company" is based on several benefits they can achieve, namely, the mediating role of aggregators can be easily put in the context of supporting SRI (socially responsible investing) and ESG (environmental, social and governance) investing. The Paris Climate Agreement, the UN's Responsible Banking initiative, the Global Ethical Finance Initiative and many other initiatives emphasize the significance of sustainability factors for security investors when creating investment portfolios. The survey results indicate a continuous growth in interest for the integration of an SRI/ESG component into the investment decisions, suggesting favorable access to finance and financing conditions for companies adhering to the above-mentioned criteria [49,50]. Stolowy and Paugam [51] also reported a dramatic increase in non-financial reporting by companies through corporate social responsibility reports for the US and European markets in the 2002–2015 period.

### 3.4. Technological Challenges

A crucial technical prerequisite towards power system DRs and the introduction of aggregators is the existence of controllable load and supply assets (storage capacities, EVs, PVs, etc.), implementation of smart meters and development of aggregation software solutions and two-way communication protocols [3]. Moreover, one should take safety and security into account.

First, it should be noted that processes in which heat, materials or final products can be stored are regarded as having the DR potential. Technical constraints, process requirements and the availability of unutilized machines can be limiting factors for the implementation of load shifting in the industry [52]. If most of the energy in the industry is used in a single process (e.g., electrolysis), only load reduction can be applied, whereas energy-intensive industries with multiple processes (e.g., chemical industry and food processing) can provide both load shifting and reduction. In the household sector, flexible appliances with DR potential are typically HVAC and washing equipment [52].

Adding energy storage increases system flexibility by providing an additional potential to reduce peak load or valley filling [53]. The most significant influences on the choice of appropriate energy storage technology include power and energy capacity, the period during which energy should be available, the space required for installation, life cycles, efficiency and cost. Additionally, by implementing controllable load and supply assets, aggregators might contribute to the overall power system flexibility by providing virtual inertia [54].

According to Das et al. [55], technologies that are commercialized and available for integration in the power system are electrical (capacitors), mechanical (pumped hydro storage, compressed air energy storage, flywheel energy storage), electrochemical (batteries) and chemical (fuel cell). Capacitors and flywheels can smooth out sudden transients; however, they have a smaller capacity than other energy tanks. Pumped hydro storage and compressed air energy storage are mature technologies with a large available capacity, but the dependence on the geological formation of the environment and very high investment costs are crucial aggravating factors for the implementation of these technologies [56,57]. A hydrogen storage system contains an electrolyzer to produce hydrogen using electricity. The stored hydrogen can then be used in fuel cells that directly convert electrochemical energy into electricity. The average efficiency of such a system is estimated at about 25–58% [55], which is not acceptable when compared to batteries. Batteries are proven options for energy storage applications for residential and commercial use. The authors in [58] presented the comparison of battery technologies and concluded that lithium-ion is currently the most widely used technology, highly suitable for various purposes due to high specific power and energy, high power and energy density, high cell voltage and efficiency between 75% and 97%. The main disadvantage of lithium-ion battery technology is its high price in comparison to other battery technologies [58].

In addition to the technologies explored in the previous paragraph, thermal storage can also play a significant role in DR. The thermal mass of a building can be used to store heat/cool energy and HVAC is scheduled to reduce power consumption during peak periods. However, the disadvantage of HVAC used in public institutions may be its unavailability for demand-response during non-working hours [4]. Additionally, an additional limiting physical factor is a minimum operating time of 30 min to prevent a reduction in the life of heat pumps [25]. Additionally, using HVAC as a DR could cause thermal discomfort to the residents of the building. To overcome this problem, Vedullapalli et al. in [59] suggested the co-optimization of the HVAC set-points and battery energy storage system, which resulted in 22% annual savings in the annual electricity bill.

Regarding the implementation of smart meters, the Third Energy Package requires EU member states to ensure their implementation with a target of rolling out at least 80% by 2020 [60]. As of 2019, smart meter implementation in Europe and North America is estimated at 30–40% of all utility customers [61]. However, the implementation score is not homogenous between EU member states and there are considerable variations in terms of both the realized level of implementation and willingness to adopt smart electricity meter solutions. Energy management companies predict a continuing global electricity smart meter market growth rate of 2% annually until 2023, thus achieving a 63% level of roll out in Europe [62].

An aggregation software solution is the key to connecting DERs and aggregators and represents a fundamental competitive advantage and differentiation of the companies that will own it. Advanced models for a better prediction of supply and demand are important for the implementation of optimization algorithms [3]. The examples of software models for planning market aggregator strategies and scheduling DR including uncertain market prices and demand can be found in [63,64].

The connection possibilities are very diverse: cellular, mesh network, powerline communications, fiber optics, etc. [61]. EC required the standardization process to ensure the interoperability of technologies and applications [65]. Regarding the two-way communication protocols, in March 2009, the EC issued a mandate, M/441, for the standardization of smart metering functionalities and communication. At the moment, the Open Smart Grid Protocol (OSGP) is a dominant European network standard used for smart meters and smart grid infrastructure communications [66].

Lastly, the safety of a system is defined as the absence of catastrophic errors, while the security deals with the unauthorized access or sharing of confidential information [67]. Cyber security represents one of the main barriers for consumers to implement DR. This is especially important for industrial consumers because electricity consumption data can reveal confidential business operations to competitors. In addition, data on consumer load patterns can be used to plan criminal activities [44]. It is necessary to maintain a balance between the privacy of the user and his or her willingness to "monetize" data on load patterns [45].

### 3.5. Legal and Regulatory Framework

Aggregators as mediators between distributed resources and wholesale energy and reserve markets are pushed forward by the EC through the Clean Energy for all Europeans legislative package. Aggregation was first mentioned in the Electricity Directive 2009/72/EC [68] and the definition of aggregators appeared in the Energy Efficiency Directive from 2012 [69]. While this prompted their early appearance in some member states, such as France, they are only recently attaining a more prominent role throughout Europe. As one of the goals of the Clean Energy package is to ensure that consumers attain a more central role in energy transition by actively participating in the power system, the aggregators are gaining more and more attention. The basis for this is the clear definition of their roles, along with an article in the Electricity Directive 2019/944 [70] dedicated solely to DR through aggregators, aimed at making it easier for aggregators to develop in less developed markets.

The Electricity Directive, through its definition, distinguishes an independent aggregator from the one affiliated to a consumer's supplier [70]. This Directive, and the Clean Energy package as a whole, provide a strong framework for the development of independent aggregators with an aim of ensuring competition between aggregation service providers. It remains, however, to be seen how fast and how thoroughly this set of provisions is implemented in the member states' national law systems. The changes proposed in the Clean Energy package are beginning to take root in the national energy laws, but there is often a web of other regulations to untangle to enable the appearance of aggregators, especially the independent ones.

There are two main roadblocks to the integration of aggregators in markets in which they are not present: regulatory barriers and a lack of legal incentives. The former are the elements of regulatory framework that complicate the establishment of aggregators, such as the lack of clear definitions and bureaucratic procedures. The latter are not directly related to aggregators, but to the technologies important for their operation, such as energy storage systems.

The regulatory framework not only sets the speed of aggregator integration in the markets, but also their relationships with other market participants. One of the main issues is the aggregators' role as balancing responsible parties, and the other is their relationship with suppliers. Six different setups were identified by Poplavskaya and de Vries [71] depending on the aggregators' relationship with suppliers and balance groups connected to the same customers. The setups range from the aggregators' complete integration within balancing responsible suppliers, to their total independence as balance group leaders who control their portfolio in full. These two extreme types are the simplest and usually the first two types to develop in countries that do not specifically address the in-between types in their regulatory framework [71]. One of the countries that did address the in-betweens is Germany, where specific rules enabled the appearance of aggregators that do not carry the balancing responsibility, but act within balancing groups [71].

To realize their potential, the aggregators need flexible resources. While they can aggregate any type of controllable device, the technology with the highest potential for balancing market participation is the battery. Lots of EU member states offer incentives for PVs and EVs, but only Austria and Italy have such programs for energy storage [72]. Building automation required by the Energy Performance in Buildings Directive [73] offers another source of flexibility for the aggregators as the thermal storage devices are another form of technology with great potential for aggregation.

### *3.6. Environmental Effects of Aggregators*

A total of 93% of EU citizens see climate change as a serious problem, and 60% count it among the most serious problems the world is facing [74]. This attitude is transferred to the governing bodies of the EU and member states. Since the EU's ratification of the Paris Agreement in 2016, the Union is continuously updating targets for drawing down greenhouse gas emissions, increasing shares of renewable energy and improving energy efficiency in all sectors. The current goals include $CO_2$ neutrality by 2050 [20], 32% renewable energy [73] and 32.5% energy efficiency by 2030. The targets are being revised under the European Green Deal agenda with an aim of raising the bar.

According to the EU's long-term climate strategy [75], the dependence on fossil fuels will fall to 20% by 2050, while the share of electricity in final energy use will reach 53%. To achieve this transition, consumers will need to play their part by investing in RES and taking an active role in the power system. It is expected that almost 50% of all households will have some kind of RES installed by 2050. This is already becoming a reality in Germany, where more and more consumers are investing in PV, many of them including energy storage. By the end of 2018, there were 120,000 combined PV and storage systems installed in households and commercial buildings in Germany [76].

Nowadays, companies are motivated to pursue sustainability targets through sustainability performance reporting. Measures of the sustainability performance for companies, such as the ecological footprint, can include indicators, such as RES share in total energy used, percentage of $CO_2$ sequestered by tree planting, etc. [77]. Ahi et al. [77] warned that the indicator lists should be assembled with a specific company in mind. The companies can therefore add their activities within DR programs to such reports as well.

A framework to facilitate public and private investments needed for transition to a climate-neutral and green economy is based on the European Green Deal Investment Plan under which the mobilization of at least EUR 1 trillion over the next decade is planned. The framework also includes rules, such as Non-financial Reporting Directive (NFRS), and institutions, such as the European Investment Bank acting as an EU climate bank. In order to attract funding, projects will be subject to thorough sustainability proofing based on EU taxonomy and specific guidelines, e.g., EC, Commission Notice on Technical Guidance on Sustainability Proofing for the Invest EU Fund.

Aggregators rely on storage-type technologies with a less-than-ideal efficiency. Depending on the technology, the efficiency of battery storage is between 50% and 97% [58], while for thermal storage these numbers range from 50% to 90% [78]. Therefore, even though the aggregation of DERs can be useful for achieving RES integration targets, its impact on energy efficiency targets may be the opposite. On the other hand, the aggregation of non-thermal household appliances and EVs without vehicle-to-grid option does not present the same issue, as load-shifting with those technologies does not impact the overall energy use.

## 4. Exploratory Risk Assessment

The SWOT–IRM framework enabled us to recognize the most prominent risks related to the development and successful performance of independent aggregators as intermediators in DR, as well as to evaluate them and propose policies and strategies for the aggregators' development in the medium term. Specifically, when assessing the impact of different identified risk factors, a panel of experts agreed that a larger number of independent aggregators is set as a desired objective, which maximizes the benefits for all stakeholders. The objective is aligned with the regulatory recommendations related to the development of DR activity in the European Union. The process of risk identification, assessment and management is consistent with the approach used by Capuder et al. [10] and Mikulić et al. [11].

Information obtained through the analysis of the environment and industry, presented in the third section of this paper, is sublimed through SWOT analysis presented in Table 1. SWOT analysis provides a comprehensive visualization of the overall profit-risk position, and is therefore a useful tool for identifying risks and opportunities in the medium term [10,79].

The conducted PESTLE and SWOT analyses, as well as industry knowledge and experience of the experts, provided an understanding of the factors influencing the independent aggregators' development and their successful operation. The panel of experts agreed on the final list of risks and their evaluation according to the importance and probability of occurrence. The initial list of risks was subsequently improved and refined by the Delphi method [13]. Scales from Capuder et al. [10] and Mikulić et al. [11] were used to assess the significance and probability of risk (Tables 2 and 3). The experts anonymously evaluated all risks and achieved an agreement on each risk's impact and probability. For the majority of risks, the experts found a consensus during the first round of anonymous evaluation, which can be explained by detailed PESTLE and SWOT analyses performed prior to the risk identification and evaluation. Only for a few risks, the experts needed a second and third round of argumentative discussion, after which consensus was achieved. Table 4 shows the results of the overall risk assessment, on the basis of which a risk map was prepared (Figure 2) where all the risks are ranked according to their importance. The risk map enables a strategic view of the risk portfolio and helps to define priorities in the implementation of risk management policies and strategies that are presented in Section 5.

**Table 1.** SWOT matrix.

| Strengths | Weaknesses |
|---|---|
| • Aggregation services facilitate DR through economies of scale and scope—the establishment of aggregators provides the aggregation of small- and medium-sized DERs that are not cost-effective for independent market operation.<br>• Aggregators can provide risk management, e.g., hedging solutions to smaller market players.<br>• Flexibility service aggregators reduce the need to invest in new power plants reducing the total cost of power.<br>• Surplus electricity produced by prosumers is grouped and sold on the wholesale market by aggregators.<br>• DR reduces the energy import dependence.<br>• Early market entry of an aggregator can provide a competitive advantage.<br>• Increasing the usability and efficiency of RES by optimal utilization of battery storage.<br>• Activation of DR based on battery storage does not reduce consumer comfort.<br>• Increase in self-awareness of consumer's own energy consumption.<br>• For consumers, ability to analyze consumption profiles and compare one's own energy consumption with others.<br>• Technology as an indicator of consumer social status.<br>• Community level initiatives—strengthening the positive change in social norms related to energy-efficient behavior and enabling the exchange of good practice. | • Different motivations among EU members in the implementation of the Green Deal through their national energy strategies and climate plans.<br>• Independent aggregators could cause imbalances in the system.<br>• Cost-effectiveness depends on the type of DER (cost-effectiveness grows with the variety of DERs—battery tank in combination with photovoltaic power plant, EV, wind power plant) and whether RES generation coincides with peak demand.<br>• Unprofitability in case of too small range between peak and base energy prices.<br>• Poor profitability even with storage technologies (given current technology level and prices) and multiple revenue streams.<br>• Poor information and price incentives.<br>• Possible opportunistic action of the aggregator as a result of the establishment of a single, centralized aggregator.<br>• Extremely detailed knowledge of user behavior.<br>• Problems related to the difficulty of use that represents a cognitive burden for consumers.<br>• The installation of an energy management system can lead to a decrease in comfort. |
| **Opportunities** | **Threats** |
| • The establishment of the aggregator is in accordance with EU policy (Green Deal, Directive EU 2018/2002—decarbonized, resource-efficient, green and socially fair continent; moderation of energy demand; consumer-centered energy system; energy diversification strategy).<br>• Development of the reserve market and the possibility of active consumer participation in the market.<br>• Increasing the level of integration of RES in the power system.<br>• The trend of reducing the cost of battery tanks and DERs increases the operability and cost-effectiveness of the aggregator.<br>• The profitability of aggregators is growing as volatility and stochastics in the power system increase due to the rising share of renewable energy sources and transport electrification.<br>• The growing interest of consumers to act as DERs may increase the number of aggregators and strengthen the competition between them.<br>• The desire of consumers to contribute to the preservation of the environment.<br>• Opportunity for companies to brand themselves as "the green company".<br>• Supporting socially responsible investing (SRI) and ESG investing.<br>• The possibility of DR raises the attractiveness of the building in the real estate market.<br>• The potential of flexibility service aggregators will grow with the number of installed smart meters.<br>• The initiative for digitalization of the energy sector in Europe. | • (Under)development of the reserve energy market.<br>• Difficulties in attracting consumers due to obstacles to entering the wholesale market in which established players are already operating.<br>• Aggregator's activity could lead to even lower volatility of electricity prices.<br>• The currently high investment price of battery storage and DERs highly affect the profitability of the aggregator.<br>• Low-price incentive for consumers due to fees and taxes.<br>• High level of inertia among end customers.<br>• Industrial customers are reluctant to interfere with processes that might harm industrial output.<br>• Cyber security regarding personal data and system vulnerability.<br>• Network charges can be introduced for DERs when they sell energy back into the grid leading to reducing profitability.<br>• The network fee can rise for those who cannot be energy self-sufficient.<br>• Ability to accurately predict stochastic factors (e.g., production from wind power plants, use of EVs).<br>• Bounded rationality of the consumer.<br>• Slow process of installing smart meters.<br>• Slow process of clean energy package implementation.<br>• Interactions between various market participants can become very complicated and bureaucratic without proper legal incentives set by regulatory and legislative bodies.<br>• Increase in interconnection between states could influence profitability of the aggregator.<br>• Increase in installation of substitute technologies that can provide flexibility service (e.g., hydropower and gas power plants). |

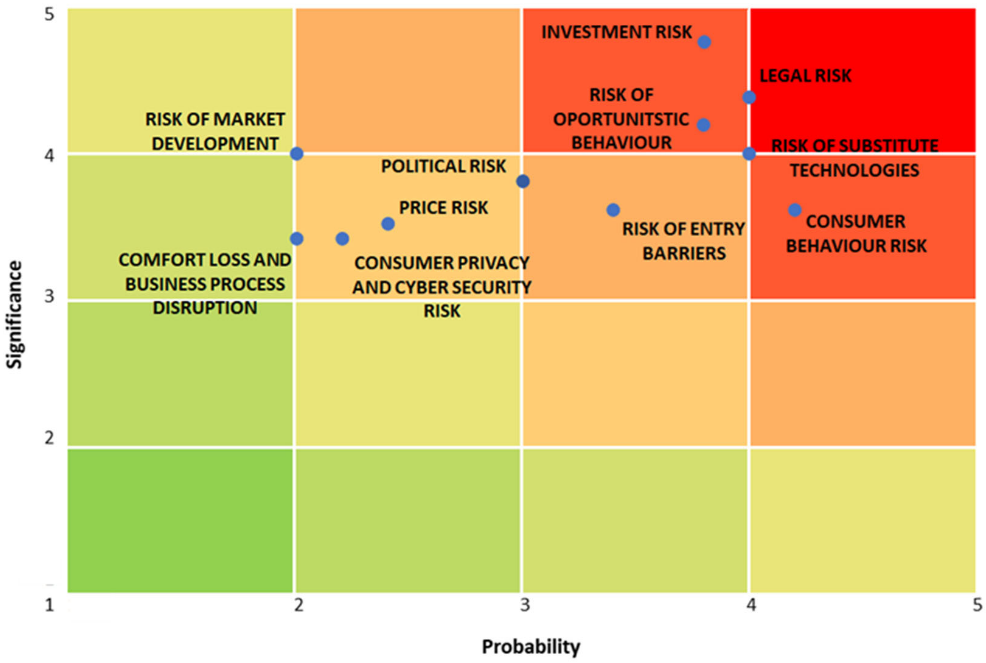


**Figure 2.** Risk map.

**Table 2.** Significance scale.

| Significance | Level |
|---|---|
| Critical | 5 |
| High | 4 |
| Medium | 3 |
| Low | 2 |
| Negligible | 1 |

**Table 3.** Probability scale.

| Probability | Level | Description |
|---|---|---|
| <5% | 1 | Rare |
| ≥5% <25% | 2 | Unlikely |
| ≥25% <65% | 3 | Possible |
| ≥65% <95% | 4 | Likely |
| >95% | 5 | Almost certain |

**Table 4.** Risk identification and evaluation.

| Type of Risk | Significance | Probability | Risk Value |
|---|---|---|---|
| Investment risk | 4.8 | 3.8 | 18.24 |
| Legal risk | 4.4 | 4 | 17.6 |
| Risk of substitute technologies | 4 | 4 | 16 |
| Risk of aggregators' opportunistic behavior | 4.2 | 3.8 | 15.96 |
| Consumer behavior risk | 3.6 | 4.2 | 15.12 |
| Risk of entry barriers | 3.6 | 3.4 | 12.24 |
| Political risk | 3.8 | 3 | 11.4 |
| Price risk | 3.5 | 2.4 | 8.4 |
| Risk of market development | 4 | 2 | 8 |
| Consumer privacy and cyber security risk | 3.4 | 2.2 | 7.48 |
| Risk of losing comfort or disrupting business process effectiveness | 3.4 | 2 | 6.8 |

## 5. Discussion of Factors Affecting Aggregators' Development and Policy Implications

After identifying, evaluating and ranking the most prominent risks to which the aggregators are exposed, the findings of this exploratory research enabled us to propose the mitigation measures and policies for the aggregators' development in the medium term, by considering the interdependencies between the identified risk factors into the IRM framework. The risks with the highest value, as shown in Table 4, are the ones with the highest priority in the context of their mitigation.

The *investment risk* is related to the high investment cost of battery storage, which adversely affects the aggregator's profitability. Additionally, high investment cost reduces the affordability of storage, thus reducing the number of small and medium DERs available for aggregation, which could prove to be especially detrimental to heat and transport electrification. The battery storage seems to be best suited for various types of aggregated DR services. However, given the current state of technology in terms of energy densities and prices per capacity, the profitability levels reported are still inadequate, unless (self-consuming) power generation is introduced. Therefore, as a mitigation measure, it can be proposed to combine battery storage and a PV power source in order to substantially increase battery storage profitability. Moreover, the production increase in the near future should result in battery storage production cost decrease due to economies of scale, while technological advancement is expected to increase battery efficiency and energy density. Mauler et al. [80] indicated that all authors in the reviewed studies expect a continuously declining battery cost. In case the mitigation measures fail, the aggregator industry might not be able to produce an independent and competitive aggregator service, at least not based on the battery storage technology.

The *legal risk* stems from the changes in the legislative systems of the European countries driven by the EU legislative framework and the political wills in each state. Energy regulatory bodies play a large role in market development as well. A lack of legal incentives set by regulatory and legislative bodies can make interactions between market participants very complicated and hinder market development. The negative consequences of the inertness of governing and regulatory bodies can be mitigated by lobbying activities of various interest groups, such as environmentalists, energy industry, tech start-ups, etc. By pushing forward the idea of the development of the flexibility service markets, the interest groups can pressure governing bodies to set up the necessary legal framework, which is highlighted by Mlecnik et al. [7], who proposed allowing different tariff models in the market so that electricity prices can reflect the market price, and removing or lowering taxes.

The *risk of substitute technologies* is related to two aspects. The first one refers to the existing substitute technologies (e.g., hydropower) and development of new ones (e.g., hydrogen), which can be used to provide flexibility services instead of the aggregators. The ability of aggregators to differentiate their services both in range and quality from other market players should enable significant mitigation of this risk, which, as argued by Burger et al. [28], should be facilitated by competitive forces in the market if market competition can be established and maintained. Interconnection lines and cross-border trade between countries can also be a source of substitute technologies risk as they play an important role in providing flexibility services. Although this can be viewed as a source of risk, foreign markets' participation at the same time provides an opportunity for additional earnings. However, this implies optimization routines and/or that power sources are in place, which will support competition in those markets.

The *opportunistic behavior of aggregators* is related to private benefits that should not exist in the market. Therefore, the materialization of this risk increases the risk of establishing a single, centralized aggregator, which will act as a monopoly. This would greatly jeopardize the development of the independent and competitive market for aggregation services. In the case of the inappropriate allocation of balancing costs and their socialization, there is a strong incentive for the existing supplier acting as a balance responsible party (BRP) assuming the role of central aggregator. This risk grows in the case of a small number of suppliers. As noted by Poplavskaya and de Vries [71], in such cases, a conflict of interest is avoided and greater consumer engagement is achieved, however, at the expense of market competition. Therefore, the legislative framework should allow for the establishment of different aggregator models and create measures to support the establishment and operation of independent aggregators on the market. For instance, Wang et al. [9] proposed a tariff scheme under which the system operator can apply penalty charges to aggregators that are then used to compensate other market participants in the case of a negative impact of aggregators on the system's performance. Kapassa et al. [6] suggested the introduction of mechanisms aimed at imposing a price cap on services provided by the distribution system operator (DSO) as a BRP. Regulations ensuring that information between aggregators and DSOs is securely shared were also proposed.

The *consumer behavior risk* captures the lack of information about the benefits of aggregation, which provides incentives to consumers to act as DERs as well as consumers' inertia and cognitive barriers to understand models of aggregators. This risk is attributed to high probability because consumer inertia and cognitive barriers have been proven in the example of choosing an electricity supplier where consumers are willing to pay a higher price, despite the potential gains from switching the supplier. To mitigate the risk, aggregators can primarily focus on large- and medium-sized business customers. Then, at the market level, consumer behavior risk can be reduced by knowledge dissemination, customer educations and promotional campaigns that emphasize the benefits of participation in DRs. Espe et al. [81] also suggested that consumer resistance can be managed through communication strategies to uphold public awareness of the consumer benefits.

The wholesale energy and reserve markets are dominated by traditional market players, such as electricity suppliers and generators, which in some markets form vertically integrated monopolies. This creates *barriers to entry* and can adversely affect the development of the aggregator industry, as independent aggregators find it difficult to engage with consumers and access some wholesale markets. In order to manage the risk of entry barriers, an independent aggregator could seek ways to obtain synergies or build the business model around close cooperation with the established market players within the existing balancing group, namely, as advocated by Poplavskaya and de Vries [71], aggregators with flexible DERs can help optimize the BRP's portfolio and provide hedging options regarding their imbalance costs. However, acknowledging independent aggregators by explicitly allowing setups independent of existing suppliers with or without BRP requirement should allow the exploitation of the aggregation flexibility potential in full. Setups without BRP requirements lead to increased cooperation with other market participants, while including the requirement can facilitate competition with existing suppliers. Under the current EU law, aggregators are independent from other market actors. However, it is up to each member state to define specific interactions between them, for instance, if aggregators should compensate the BRPs for imbalances [71]. Additionally, the early market entry of an aggregator could also be used to form such a cooperation and increase profitability.

One of the main causes of political risk is the relatively slow adoption of the Green Plan and clean energy package through the National Energy and Climate Plans of EU member states, because some member states do not share the same vision and ambition in the context of implementing an ambitious green agenda. Therefore, it can be expected that they will remain relatively inactive or that the progress towards set goals will be slower than planned, as argued by Munta in [21]. A group of experts has evaluated this risk as intermediate according to significance and probability of occurrence. To manage this risk, lobbying activities of interest groups, such as environmentalists, energy industry, tech start-ups and ESG-rated companies, are recommended to foster a faster implementation of EU regulations on the local market.

The research on economic viability shows that predefined *market price spreads* in the day-ahead market should exist given the battery price. Another important factor in this respect is whether peak demand for electricity coincides with RES power generation. This implies that a small range between the peak and base energy price could impose even further restrictions regarding the price of future storage technologies. Moreover, the concerns about market saturation regarding more lucrative sources of revenue in the form of ancillary services were reported along with evidence that a more risk-taking activity could lead to a lower volatility of electricity prices. Lu et al. [8] further point out the problem of customer load forecasting with the growing proliferation of RES (such as PV for instance), since this is expected to increase the volatility of the demand. Furthermore, they refer to a rise in electricity consumption after a demand response event as a challenge, which is, however, in contrast to the arguments presented in [30] stating that the overall consumption should remain the same, regardless of the differences in time allocation. Price risk mitigation measures are related to the diversification of sources of revenue, namely, the participation in foreign power markets, adding power generation (e.g., from a PV power source) and peak shaving to the aggregation services. Economies of scale also play a role; therefore, orientation towards large-sized business customers and residential customers participating in micro grids should help to manage the risk.

As already mentioned, the wholesale energy and reserve markets are dominated by traditional market players that can not only create entry barriers, but also hinder *market development*. Specifically, the risk of the underdevelopment of the reserve energy market is stressed here as established players, such as large hydro-power plants, may be well suited to participate in one segment of the reserve market with rules tailored to their participation, as highlighted in Mlecnik et al. [7]. However, developing more market segments introducing a regulation on unbalanced costs and generally allowing stronger competition in each of them would help to develop a more stable and efficient power system. The presented problem can be overcome by lobbying activities focused on harmonization across different EU member states in order to foster better business models [7]. Furthermore, aggregators should, as previously mentioned, try to diversify their revenue streams by providing aggregation and peak shaving services and arbitrage in the day-ahead and intraday markets. Additionally, adding the production from a PV power source significantly increases their profitability and mitigates the aforementioned risk.

*Consumer privacy and cyber security risk* is attributed to medium significance and low probability. The data on electricity load patterns can present detailed knowledge of user behavior, which can support criminal actions. Additionally, the competitors can obtain confidential business information. To minimize this risk, the strong legal protection of consumers' data should be enforced through laws and regulations. This can be found in the General Data Protection Regulation (GDPR) that ensures the protection of natural persons with regard to the processing of their personal data and guarantees the free movement of such data, provided that the appropriate safeguards are applied. A review of the existing works highlighting the importance of energy consumption as valuable personal data and its main challenges from a legal viewpoint is presented in [82]. In addition, aggregators must protect their business processes from external cyber attacks by implementing efficient IT security controls, as discussed for instance by Lu et al. [8].

By implementing an energy management system for DRs, residential customers are concerned about a *loss of comfort*. Likewise, industrial customers are reluctant to *interfere with processes* that might harm industrial output. These concerns pose a risk of losing comfort or disrupting business process effectiveness that is valued with the lowest probability and significance of all considered risks. As previously mentioned, the inclusion of the battery storage in the contract (sell or lease agreement) with the consumers is an effective measure for managing this risk. In addition, the implementation of the accurate automatic load control considering all consumer energy requirements may contribute to risk mitigation. An example of automated load control in the home energy system under dynamic pricing and power and comfort constraints can be found in [83]. The proposed automated load control aims to reduce the consumer's electricity bill below a desired level, whilst increasing their comfort.

By reviewing the mitigation measures proposed above for the identified risk factors, it can be noted that they can be classified into three broad categories since they can be mitigated by policy interventions and market or technological developments. The legal risk, political risk, the risk of opportunistic behavior of aggregators and the risk of market development can be mitigated by policy interventions. The investment risk and the risk of loss of comfort and business process disruption fall into the category of risks that can be mitigated by technological development, while the risk of barriers to entry and market price spreads can be mitigated by market development. The consumer behavior risk requires both policy interventions and market development, whereas consumer privacy and cyber security risk require policy interventions and technological developments. Lastly, given the two aspects of the risk of substitute technologies, market development is related to mitigating existing and future substitute technology threats, while cross-border trades relying on interconnection lines are related to technological development. The findings highlight the importance of regulators and economic and fiscal policy decision-makers, since four of the identified risks can be directly influenced by the policy interventions alone with another two being affected by policy interventions and other mitigation measures. Thus, in total, for more than half (6 out of 11) of risk factors' mitigation, measures are related to policy interventions that range from necessary changes to regulatory framework in order to foster market development and prevent the opportunistic behavior of aggregators to the introduction of new tariff models reflecting market prices and lowering or removing taxes.

Regarding market and technological development mitigation measures, it should be noted that many possible concrete solutions exist, which can be specific to strategies pursued in different aggregators' business models' setups. For instance, strategy leveraging improvement in battery technology will reduce investment risks and focus on possible profitability gains, whereas a strategy relying on the flexibility that the aggregators offer is likely to target cooperation with established market players and aims at market access, therefore increasing and diversifying sources of revenue. Future research should assess the specific different approaches based on the focus of the research. This paper provided the necessary foundation for many possible research avenues by expanding the PESTLE and SWOT analysis methodological framework and integrating the findings in the risk identification and evaluation process.

## 6. Conclusions

The findings of this exploratory research could help in developing the policies and strategies for the aggregators' development in the next few years. Taking everything into account, the research findings show that the most salient risks jeopardizing the development of independent aggregators can be traced to investment and consumer behavior risks on one side and legal and substitute technology risks (further related to the entry barriers and market development risks) on the other side of the spectrum. In between the two lies the risk of the opportunistic behavior of aggregators, the occurrence of which could lead to the inappropriate allocation of balancing costs and their socialization, which could in turn provide a strong incentive for a simple but second-best solution—the existing supplier acting as a balance responsible party (BRP) assuming the role of the central aggregator. The documented profitability issues and existing legal and technological barriers to entry and market development could only further support this line of development, should the proposed mitigation measures fail. The conducted analysis resulted in the classification of identified risk factors into three groups based on the proposed mitigation measures, since it was found that mitigation measures fall into policy interventions, market development and technological development categories. Therefore, the findings of the research complement and support the findings of other similar papers on the topic, but also contribute to the existing literature by providing a foundation for future research and focusing on the most relevant issues. The analyzed aggregators' business models in the future should be set up by taking into account the strategies that reflect the identified risk factors and their classifications. Regulators and economic and fiscal policy decision-makers should take note of the findings that suggest that more than half of the identified risk factors can be mitigated by policy interventions.

This paper was based on a critical analysis of a number of relevant studies processed by qualitative research methods using the Delphi–SWOT–IRM hybrid paradigm. The fundamental limitation of the applied methodology lies in the possible biased views of the experts, but a higher level of objectivity was achieved by the careful selection of experienced and knowledgeable panel members that ensured the grounding of individuals' views in the research results, relevant policies and best business practice. The results of the research were further objectified by applying the Delphi method, which ensured the consensus of experts and the uniformity of their views through an intensive debate on individual risk factors and mitigation measures. Other limitations include the EU focus of the paper and medium-term-oriented analysis.

Our findings support further research both in the qualitative and quantitative domains, especially in the context of the current energy market conditions and possibility of recurring periods of increased price volatility in the future. Qualitative research should focus on the legal incentives for market development and reduction in entry barriers, while also providing additional insight into consumer behavior fostering consumer engagement. Thorough the examination of the profitability of operating various types of DERs, especially battery storage technology paired with RES, systems should remain the primary focus of the quantitative research on economic viability. The estimation of optimal investment regarding the power and capacity of the analyzed system and sensitivity of profitability to investment costs should be considered under different market conditions in order to provide a clearer risk and return profile of the industry.

As further research, the authors aim to use the current analysis to develop specific and feasible business models of multiple independent aggregators taking into consideration current real-life conditions and expectations, thereby anticipating that independent aggregators make a power system more efficient and are economically viable. Additionally, the final goal is to identify the risk-return characteristics of the independent aggregator in the long run from the investors' point of view. Additionally, if the concept of independent aggregators turns out to be economically unaccepted, the authors plan to evaluate the role and importance of aggregators within vertically integrated electric utilities.

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