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# Feasibility of a joint agricultural data space operated by established service providers: a Bavarian perspective

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In Germany's federal state Bavaria a network of advisory and service providers, called "Verbundberatung", offers various agricultural services to arable and livestock farmers. The network has great success and is jointly responsible for the high value-adding agricultural sector in this region. However, improved cooperation regarding data exchange would further strengthen the services. Based on the existing organizational and technical structures of the partners, the opportunities and risks of a self-initiated "Bavarian Agricultural Data Space (ADR.BY)" are elaborated within the frame of a participatory feasibility study. The aim of the study was to develop a foundation for information and decision-making that supports a common architecture. This architecture serves as a potential blueprint for the holistic integration of processes, applications, knowledge, data, and IT infrastructure and prepares for data exchange with stakeholders from the economy, society, and administration. Our work reveals that farmers and their partners are generally open-minded to new data management strategies. Nonetheless, adopting new approaches requires fundamental standardization based on emerging concepts.

**Keywords**
Data space, agricultural extension services, standardization, semantic data model

Market access and value creation in agribusiness are increasingly based on data and information, which is why effective and efficient data exchange is the groundwork for a forward-looking agricultural economy. Interoperability is of paramount importance for data exchange, and it must address the stakeholders' needs of all organizational levels, including the farm itself and its close partners. The specific situation in Bavaria, which is outlined in the following, demands this state-level study.

Bavaria, with its 3.3 million hectares of arable land (Destatis 2025a), has a highly mechanized and intensive agriculture with a production value of USD 14.7 billion [1 USD = 0.95 EUR] (StMELF 2025a). Nevertheless, Bavaria's agriculture is characterized by family-owned farms and thus mostly small-and medium-sized farms with an average size of 38 hectares (Destatis 2025b). The sector is supported by the "Verbundberatung" (StMELF 2025b), a voluntary network of non-governmental service providers and farmers' associations that process data from various branches of production and offer related services. Depending on the farm structure, around 90% of the farmers in Bavaria are members of at least one of these entities. These network partners enjoy a high reputation among farmers regarding the trustworthy handling of data (Gabriel and Gandorfer 2020). Because of this fact, the partners are potential operators of a pertinent data space. Due to the unique structure of the Bavarian advisory services, the partners fathom the current possibilities and opportunities in a

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region-specific feasibility study. In this exploratory study (Luckhardt et al. 2022), the authors present results from a literature study, structured expert interviews, and expert workshops on the vision, expected benefits, and salient stakeholders of a future Bavarian Agricultural Data Space (ADR.BY).

## Related work

The development of digital ecosystems for agricultural data faces a persistent gap between conceptual foundations and practical implementations. While initial work (Fraunhofer IESE 2019) has laid the groundwork, full maturity has not yet been achieved. A key obstacle is the difficulty in scaling general data space deployments beyond specific use cases, as highlighted by Bacco et al. (2024). Additionally, challenges such as insufficiently defined objectives, a lack of service descriptions, inadequate prioritization, and limited stakeholder consultation further hinder progress, as noted by Treiber (2023).

To address these issues, various initiatives have emerged at different levels. International efforts (AgGateway 2025, AEF 2025, IDSA 2024) focus on standardizing data exchange on a broad scale. European projects (AgriDataSpace 2024, Agri-Gaia 2025) complement these efforts with regionally tailored approaches, while national programs (GovData 2024) work on country-specific implementations. These initiatives aim to harmonize the fragmented landscape of agricultural data, but their effectiveness depends on successful coordination and adoption. Industry-driven solutions also play a crucial role in shaping the agricultural data spaces. The Agricultural Interoperability Network (AgIN) of the Agricultural Industry Electronics Foundation (AEF) follows a business-oriented model (AEF 2025), inviting companies to participate for a fee, with the goal of launching a viable solution by 2026. Meanwhile, the International Data Space Association (IDSA) has released the Dataspace Protocol (DSP) to establish an international standard for interoperability, and Eclipse Dataspace Components (EDC) provides a framework aligned with this standard (EDC 2025). While AEF focuses on fostering private-sector collaboration, IDSA and EDC emphasize open technical frameworks to ensure seamless system integration.

Beyond these technical and organizational efforts, structured blueprints for agricultural data spaces are beginning to emerge. Initial reference architectures, as outlined by Falcão et al. (2023), provide a foundational structure for future developments, while insights from completed projects (Urdu 2024) offer valuable recommendations and emphasize the need for cross-sectoral integration. However, despite these advancements, the key challenge remains how to create concrete value for stakeholders, particularly in Bavaria. The success of these data ecosystems will ultimately depend on their ability to provide practical benefits to farmers, agribusinesses, and policymakers, ensuring not only technical feasibility but also economic and strategic viability.

## Methodology and method

The innovative idea of the “Verbundberatung” to initiate a common data space and the associated technological knowledge transfer required several preparatory meetings and workshop sessions. In this preparatory phase each partner delegated a decision maker and, depending on the topic, a subject-matter expert. The core of the group was composed of at least one representative from each organization. This steering group had ten sessions within half a year.

This feasibility study follows a structured methodological approach combining Design Science Research (DSR), Participatory Action Research (PAR), and Case Study Benchmarking to assess the implementation of a shared data space for stakeholders in Bavarian agriculture. Grounded in DSR,

the study identifies the challenges of agricultural data integration, designs a conceptual IT architecture, and iteratively refines it through stakeholder engagement and empirical evaluation. Workshops played a crucial role in the PAR approach, facilitating knowledge co-creation with stakeholders from the Verbundberatung through interactive discussions on IT infrastructure, data processing, and interoperability. The iterative refinement of findings ensured that practical insights and stakeholder needs were continuously incorporated into the study's development. Additionally, Case Study Benchmarking was employed to analyze similar initiatives, drawing lessons from established best practices and adapting proven methodologies for system design. By integrating these three methodological perspectives, the study delivers a feasibility assessment that is both theoretically grounded and practically applicable, ensuring a scalable, interoperable, and stakeholder-driven data space.

The feasibility study for the introduction of a common data space for various stakeholders in Bavarian agriculture followed a structured and iterative method that integrated stakeholder participation, data collection, and critical evaluation (Figure 1).

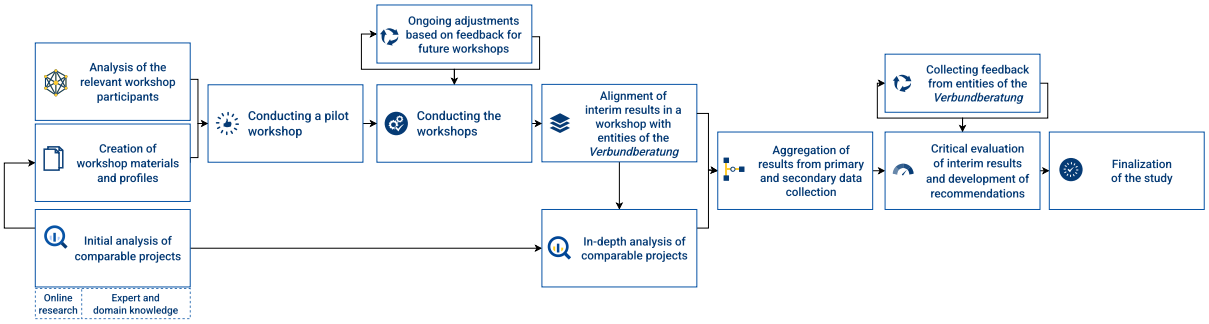


Figure 1: Overview of the methodological approach of the feasibility study (LUCKHARDT et al. 2022)

To begin with, a primary and secondary collection of information and data were carried out to establish a foundational understanding of the project requirements and constraints. The process started with an analysis of relevant workshop participants to ensure the inclusion of key stakeholders. In parallel, workshop materials and participant profiles were created to facilitate effective discussions. An initial analysis of comparable projects was conducted through online research and expert domain knowledge to gather insights from similar initiatives.

A pilot workshop was then carried out to test the approach and gather early feedback. In preparation for the workshops, profiles containing key information (e.g., number of employees, existing IT infrastructure, business partners) were requested from the organizations. Subsequently, between four and eight people of different ages and genders from the respective organization took part in the workshop, lasting around seven hours. The participants were mainly managing directors and department heads, as well as specialists from the relevant fields.

The workshops were designed to be highly interactive, with a focus on collaborative participation. Active moderation, a minute-taker, and a clear and consistent structure supported by brown papers guaranteed a common thread, reliable documentation, and enabled a systematic comparison of the results from the different workshops. The workshop sections focused on the a) vision of the ADR. BY, b) implementation of the vision, c) stakeholder expectations, d) prospective use cases, e) IT infrastructure and data formats, and f) sequence of use cases with associated data flow. Following this, a series of workshops was conducted with each organization of the Verbundberatung individually.

These workshops involved iterative refinement of findings, particularly regarding technologies used, existing data, and data processing approaches of the partners. A key aspect of this phase was the identification and description of relevant use cases, which were schematically positioned within a rough IT architecture.

In addition to the seven workshops conducted with the partners of the Verbundberatung, an additional workshop with the Bavarian State Research Center for Agriculture (LfL) was held. This workshop served to deepen the use case of farm nutrient management with a focus on implementing the nutrient-flow balance, as most partners were involved in this use case. The joint work between the study partners and the Department of Fertilization of the LfL was equally well documented and opened the exchange for further processing of the use case. Moreover, additional discussions on intermediate and final outcomes took place online and in person. In addition, the results of the study were presented and discussed at the Bavarian State Ministry of Food, Agriculture and Forestry. The event was attended by various experts from the ministry and highlighted the need for further discussion on the development and establishment of ADR.BY and cooperation between the institutions involved.

As interim results emerged, they were aligned in a dedicated workshop with entities of the Verbundberatung to validate the exploratory findings (e.g., synergies among partners, common goals, overlapping competences) and gather additional insights. At the same time, a more in-depth analysis of comparable projects was conducted to refine the study further. The results from primary and secondary data collection were then aggregated, forming the basis for a critical evaluation of the interim findings and the development of concrete recommendations. To ensure the robustness of the study, additional feedback was collected from entities of the Verbundberatung, enabling further refinement. Finally, all insights and recommendations were consolidated into a comprehensive final report. The outcome was a feasibility study that contributed technologically to specifying the data architecture of the Verbundberatung and presented use cases alongside a scalable implementation strategy. This strategy complied with established principles such as the FAIR guiding principles for scientific data management and stewardship, fostering Findability, Accessibility, Interoperability, and Reuse of digital data (Go Fair Initiative, www.go-fair.org).

For system design, an already proven approach was adapted, envisioning the integration of heterogeneous data sources – ranging from natural language manuals and relational databases to expert knowledge – using semantic technologies. These included the Resource Description Framework (RDF) and the Web Ontology Language (OWL) from the Semantic Web stack (Weckesser et al. 2022, Kessler et al. 2021). This structured methodology ensured a participatory and evidence-based evaluation of the feasibility of a shared data space, incorporating stakeholder perspectives, empirical findings, and state-of-the-art technological considerations.

## Results and Discussion

### Common vision

Getting started with the workshops, the partners developed individual perspectives and elaborated the questions “What exactly is the ADR.BY?”, “Why is an ADR.BY needed?”, “How should the ADR.BY be realized?”, and “Who are the actors in the ADR.BY?”. Subsequently, the individual ideas were combined into a common vision for an ADR.BY. The common answer to “Why is an ADR.BY needed?” is that the Bavarian agricultural ecosystem should be strengthened and value creation enhanced. Considering how these goals could be supported by ADR.BY – above all through the benefits of syn-

ergies, the complementary bundling of competencies, the linking of business processes, and the improvement of time and cost structures. What should an appropriate tool do to achieve the how and to fulfill the why? Potential options include an agreement on an entirely common infrastructure, a joint coordination of the technology stack, and a data linking portal.

In the context of developing the ADR.BY vision, the partners were asked to identify the needs, challenges, tasks, and benefits they foresee for other stakeholders (partners of the Verbundberatung, public authorities, farmers) to capture a multi-actor perspective. Obviously, the stakeholders from livestock-focused associations, and those from arable farming-focused associations differ in their opinions on this matter. Furthermore, this is influenced by the individual vision and the selected use cases. Nevertheless, there is a significant overlap.

The developed vision focuses on two points: Firstly, an ADR.BY should strengthen Bavarian farmers and open prospects. Above all, it aims to maintain the long-term efficiency and sovereignty of Bavarian agriculture and its Verbundberatung as strong partners, for example, by reducing individual communication and management efforts. Secondly, ADR.BY is intended to increase value creation along the entire chain through digitalization. This includes the establishment of seamless end-to-end business processes through effective networking of data, information, and knowledge. The aim is to achieve profitable data communication between the partners of the Verbundberatung, public authorities and private businesses, while retaining the successful traditional Bavarian structures – even in the digital age. With unanimous agreement, the "geographically limited" virtual ADR.BY should also be technically prepared to handle data originating outside Bavaria.

### Benefits – agricultural perspective

To implement an ADR.BY, the initial focus is on self-selected use cases that meet the current core businesses of the partners or will become more important in the future. These are:

- First cluster: farm nutrient management with the use cases: a) nutrient-flow balance, b) advisory service nutrient management 4.0 and c) cross-linked soil sampling.
- Second cluster: production of animal products with the use cases: a) advisory and certification service for products with certain quality, b) traceability and transparency of Bavarian commodities, c) animal welfare and health monitoring and d) balancing service for $CO_2$ and greenhouse gases.
- Third cluster: institutional administration with the use cases: a) collaborative member management and b) master data service.

After identifying the use cases in partner-specific workshops, the necessary data are collected to accurately represent these use cases from the stakeholders' perspective, particularly that of the farmers. Results show that there is no use case (strict system boundaries were not set) for which all needed data is already available within one individual organization. Moreover, 50% of the use cases lack data from more than three other partners to fully provide the ideal input for the related services (e.g., cluster farm nutrient management). As partners of the Verbundberatung partly offer similar services, the intersection of data is 80%, determined by self-assessment (e.g., the use case "advisory service nutrient management 4.0"). In other use cases, the intersection is lower. However, no substantial use case was identified that relies solely on data that is needed or accessed by only one partner.

Substantiating the second cluster, the digital representation of the “regional cattle (regio-cattle)”, which focuses on regional production and sustainability monitoring along the whole value chain, is shown in Figure 2. As farmers are usually supported by one or more partners of the Verbundberatung over the course of a year (e.g., advice on fodder production and milk quality testing), data is frequently collected directly by the Verbundberatung and their contractors (LKV 2023) or via other partners like hardware and software providers (Green et al. 2022). This data can be connected to the ADR.BY in the structure of an open or federated database system. In this way, farm-specific or product-specific environmental or climate-impacting data can be combined.

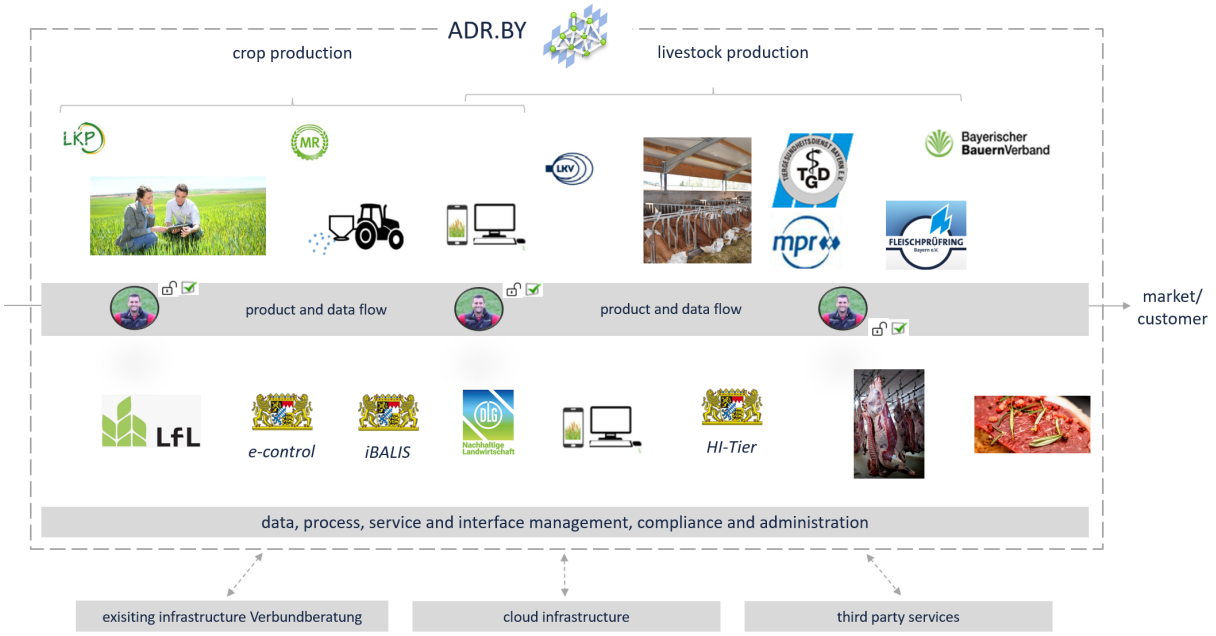


Figure 2: Joined data of the value chain “regio-cattle” through the virtual ADR.BY showing the partners of the Verbundberatung with its data sections in the product cycle; data sovereignty, vertical and horizontal data routing, and management, lie with the farmer or contracted service partner; the architecture of ADR.BY provides internal and external interfaces

Via the ADR.BY, the collected farm data and special achievements (e.g., reduction of the greenhouse gas emissions of a dairy product) can be transferred, communicated, or monetized with the support of the Verbundberatung. Meanwhile, the first industrial offerings provide nutrient monitoring and $CO_2$ foot printing (MSC, www.milksustainabilitycenter.com). However, farmers must agree to transaction-related data exchange with the ADR.BY; data will only flow if consent is given. Furthermore, there is a need for the farm to exchange data with third parties and public institutions. Depending on the functionality and design of the services (governance model, dashboard, roles and usage rights), the farmer can assign rights and proactively manage data flows, for example to merge production parameters for certification or transfer data to different trading partners or partners of the Verbundberatung itself. This improves the availability and quality of farm-related advisory services across production branches (e.g., optimization of the nutrient cycle of the whole farm).

Interfaces to existing systems and data registers (e.g., Bavarian Integrated Administration and Control System “iBALIS”, member administration) need to be implemented and a description of future interfaces should be developed. This includes the definition of a holistic technological basis (e.g.,

semantic notation, open data cataloging, access controls, open API standards), which should ensure the future development and adaptation of interfaces across applications. In this way, third-party data can be processed for applications of all partners. This means that service and app providers can refer to specifications on this basis in the future, aiming to maintain a strong market position for the Verbundberatung and agricultural businesses in Bavaria. Existing services should be accessible via interfaces so that integrated and complementary offers can be developed and reach customers via agricultural advisors or a technical solution, e.g., a web application. The ADR.BY itself represents the transparent infrastructure in the backend.

### Benefits – technical and organizational perspective

Innovative data networking offers clear advantages for partners in the network. Added value for agricultural ecosystems can be generated from the overarching data and its linkage, which is supported by the bundling of interests and the resulting synergy and allocation effects. Existing structures need to be considered, and new developments should align with both the existing structures (ensuring integration with reasonable effort or a transitional approach) and the potential for new, inter-organizational data exchange.

The concept of ADR.BY, a semantic data metamodel, links existing products of the partners and authorities as services and provides means for integration into a knowledge model. In detail, it needs to be assessed to which extent the currently used technology stack can be integrated (different database technologies, legacy systems, and programming languages). Therefore, introducing best-practice principles, standards, and a common systematic requirements-engineering approach can be used to reduce complexity and consolidate efforts. Where applicable, it is necessary to implement matching mechanisms and develop appropriate connectors. Above all, data must be consistently aligned and semantically integrated, e.g., using ontologies. On this basis, processes are interlinked, redundant (manual) data entry is avoided, knowledge can be reused and shared across disciplines, data becomes interoperable, and applications are better tailored to user needs – while considering organizational and regulatory requirements such as data safety, data security, and access control. Notably, legislation has since established a stabilizing framework for these challenging questions through the adoption of the EU Data Act (11/2023), although other issues remain unresolved (Doerr et al. 2022).

Three facets to institutionalize ADR.BY were identified, namely: a) a holistic common infrastructure, b) a joint coordination of the technology stack used, and c) a centralized registry-based data-linking portal. The extent to which each aspect needs to be incorporated into the ADR.BY is yet to be defined, as strategies of the organizations of the Verbundberatung varied and did not result in a unified approach at the time of our research. Once this extent is defined, the economic impact and the return on investment can be estimated based on feasible assumptions and real economic data.

## Conclusions

The agricultural sector needs technical solutions to efficiently integrate data – this requirement is postulated as a consent among all stakeholders involved in this feasibility study. Moreover, the consortium of associations has concluded that standardizing data exchange for data that is required frequently and in different contexts, is one of the major advantages of a common ADR.BY. Therefore, the question of how to handle and secure data quality, which demands transparency on the origin, needs to be answered. Besides solving the problems with data heterogeneity, the partners recognize a

potential advantage in better coordinating their interests among themselves and strengthening their negotiating positions towards third parties.

To elaborate the benefits to the associations even more, the aforementioned use cases should be demonstrated using the existing technology stack. A notable example is Matar et al. (2024), who implemented the data exchange of a farm management information system (FMIS) and a data service point for soil measurements using the technology stack of sovity (sovity GmbH, Dortmund, https://sovity.de/en/) and an appropriate authentication service. The authors outline that while the underlying concepts and technologies are maturing, there are still limitations, such as restricted data sharing options and limited support for controlling data usage purposes and enforcement mechanisms (like data deletion obligations). Matar et al. (2024) relied on the current state of technology, yet shortcomings emerged during their testing in 2024. Nevertheless, building on the currently available framework would likely yield different results for the realization of an ADR.BY than in 2022, when the feasibility study was conducted. In particular, generative AI is an emerging technology that has the potential to affect the design and implementation of a common data space for agricultural data. Beyond its widely used capabilities such as code generation and interface design, it may support the harmonization of diverse data formats by synthesizing standardized schemas and metadata. This could potentially lead to a large impact, given the wide variety of agricultural data sources. Using generative AI technologies, legacy systems as well as new platforms might be more easily integrated via automated adapter creation. It further enables the efficient integration of natural language interfaces, making complex agricultural data accessible to a broader range of stakeholders, e.g., farmers and policymakers. While seemingly promising, these benefits depend on the careful management of data quality, governance, and security to ensure its trustworthy and effective use in the ADR.BY.

During the feasibility study the partners held different views on the efforts and strategies required to realize the ADR.BY, which provides several limitations to this study. Additionally, varying opinions emerged within the organizations of the Verbundberatung, as they are mostly managed in the legal form of registered associations, which require alignment across all legal bodies. This aspect is particularly unique to the Bavarian approach establishing an ADR.BY. Until further notice, the associations will continue to pursue technical connectivity and API integration for new developments. At the same time, opportunities for joint development with partners should be evaluated. Firstly, for economic reasons (e.g., amortization of product development, wider range of users). Secondly, for rational reasons and consensus to act in the interest of the user – as users, mostly farmers, are often members in several associations. Overall, assuming digital and data sovereignty, a decisive impulse, contribution, and readiness can be expected by farmers and their partners. Detailed plans for the implementation of potential realization paths including fine-grained business models, funding mechanisms, and cost structures fall out of scope of the feasibility study and must be further developed by the Verbundberatung. Nevertheless, the financial aspects are key to decision building and should be based on agricultural expertise, chosen technology stacks, and organizational structures, as these elements are highly interdependent.

The task of defining and establishing an institutional role of a data management board and coordinator is challenging. A joint approach for development and operation requires a high level of coordination, willingness to compromise, and openness to change on the part of all partners. Refinancing and a possible weakening of the core competences of individual partners are identified as potential obstacles. Further actions would be to develop operating concepts and evaluate eligible legal organ-

izational forms. There is a consensus that a shared data space offers institutions the opportunity to mature individual and joint ideas. Examples include the improvement of existing services (e.g., extending reach, increasing the quality of advice), establishment of new value-adding services (e.g., collaborative advice, holistic farm advice, digital decision support), as well as the development of new business models.

A next impulse that further engages the Verbundberatung in developing a forward-looking data strategy could be the upcoming Common European Agricultural Data Space network. This initiative aims to define national policies with an inclusive approach towards incorporating stakeholders of the domain including farmers' associations (AgriDataSpace 2024). This allows data space approaches at the federal state level while maintaining the opportunity to scale their networking activities (StMELF 2025c).

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