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PUBLIC TECHNICAL REPORT

INTEGRATED FIBRE-BASED BEVERAGE SERVICE SYSTEMS

A Systems Framework for Component Reduction, Operational Efficiency and End-of-Life Compatibility

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ORCID 0009-0001-1836-0296 **DOI** 10.5281/zenodo.21627597

Ekoroll Technical Report | EKR-TR-2026-01 | Version 1.0 | 27 July 2026

PUBLICATION INFORMATION

Report identity and use conditions

Report title	Integrated Fibre-Based Beverage Service Systems: A Systems Framework for Component Reduction, Operational Efficiency and End-of-Life Compatibility
Report number	EKR-TR-2026-01
Version	1.0
Publication date	27 July 2026
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Publisher	Ekoroll Packaging Solutions
DOI	10.5281/zenodo.21627597
R&D page	https://ekoroll.com/en/rd
Licence	Creative Commons Attribution 4.0 International (CC BY 4.0)

Preferred citation

Sadough, M. (2026). Integrated Fibre-Based Beverage Service Systems: A Systems Framework for Component Reduction, Operational Efficiency and End-of-Life Compatibility. Ekoroll Technical Report EKR-TR-2026-01. Ekoroll Packaging Solutions. https://doi.org/10.5281/zenodo.21627597

Public disclosure notice

This report is a public, non-confidential technical communication. It describes the systems rationale, development pathway and public technical position of Ekoroll's integrated lid-free hot-cup system. It is not a product certificate, laboratory test report, life-cycle assessment, regulatory opinion or disclosure of proprietary manufacturing know-how.

The product image included in this report is a commercial reference image. Product markings visible in the image should be interpreted together with the corresponding product specification and certification documents; this report does not independently reproduce those dossiers.

Intellectual-property boundary

No proprietary dielines, dimensional tolerances, forming sequences, tooling specifications, barrier formulations, supplier identities or confidential performance datasets are disclosed. Publication of this report should not be interpreted as a waiver of any present or future intellectual-property rights.

AT A GLANCE

Contents and executive summary

Executive summary

Conventional beverage-service packaging generally treats the cup and closure as separate products. This architecture is familiar and widely supported, but it also creates an external interface that must be manufactured, specified, transported, inventoried, matched, attached and disposed of as part of every service event. At high volumes, component and interface count become system variables affecting reliability, workflow, logistics, compliance and end-of-life behaviour.

This report introduces Integrated Fiber Systems (IFS), a systems-oriented R&D framework developed by Ekoroll Packaging Solutions. IFS treats material composition, structural geometry, barrier function, manufacturing process, distribution environment, operation/use environment and end-of-life pathway as coupled design domains. The integrated lid-free hot cup is presented as the first public product-level embodiment of this approach.

The first physical prototype was developed in 2022. The system subsequently progressed through iterative structural and material refinement, functional and application-specific validation, and commercial deployment. The report documents that development status without disclosing confidential test protocols, production geometry or proprietary process parameters.

CENTRAL PUBLIC CLAIM

The contribution is architectural: selected closure functions are incorporated into the fibre-based cup structure, reducing reliance on a separately handled lid while preserving a practical beverage-service format. Quantified environmental or operational superiority is not claimed without matched comparative evidence.

SECTION 01

Introduction and scope

Packaging is increasingly governed by interacting constraints rather than by a single material choice. A beverage-service article must satisfy containment, hygiene, mechanical integrity, barrier performance, manufacturing feasibility, logistics, user interaction and an end-of-life pathway. These requirements can conflict: improved barrier performance may affect forming or fibre recovery, lightweighting may affect stiffness, and component substitution may preserve the same interface and supply-chain dependencies as the incumbent design.

The Future Packaging Systems Initiative (FPSI) frames this as a systems-engineering problem. Its research proposal identifies seven coupled domains and argues that packaging architecture, interfaces, manufacture, logistics and end of life must be treated as one system rather than as sequential component problems [1]. The proposal is prepared by Ekoroll Packaging Solutions and establishes Integrated Fibre Systems as the programme's engineering direction. [1]

The present report is narrower and more applied. It explains how that systems rationale relates to Ekoroll's integrated lid-free hot-cup system, which was first physically prototyped in 2022 and has since reached commercial deployment. It is intended to provide a citable, public description of the design direction and its non-confidential development status.

1.1 Purpose

- Define the public systems rationale for integrating cup and closure functions.
- Position the hot cup as a practical demonstrator of the Integrated Fiber Systems framework.
- Document the development pathway from prototype to commercial deployment.
- Clarify the boundaries of validated knowledge, commercial claims and confidential information.
- Establish a foundation for future academic, industrial and standards-oriented collaboration.

1.2 Scope limitations

This report does not attempt to compare all available cup-and-lid formats, calculate a carbon footprint, establish universal recyclability or compostability, publish a migration dossier, or provide a complete design-for-manufacture specification. Such conclusions require a defined construction, market-specific infrastructure, matched functional units and reproducible test methods [5,10].

SECTION 02

The multi-component packaging problem

A conventional hot-beverage service unit commonly comprises a cup and a separately manufactured closure, often accompanied by sleeves, stirrers or other accessories. Although each item can be optimised individually, the service system operates as an assembly. The cup and lid must be dimensionally compatible, available at the same point, matched to the same size, stored separately and attached reliably under actual service conditions.

This is more than a procurement detail. Every discrete element adds a physical interface and usually a tolerance chain, supplier relationship, inventory stream, compliance document set and disposal decision. The FPSI analysis identifies component and interface count as first-order variables affecting operational reliability, manufacturability, logistics and recovery behaviour [1].

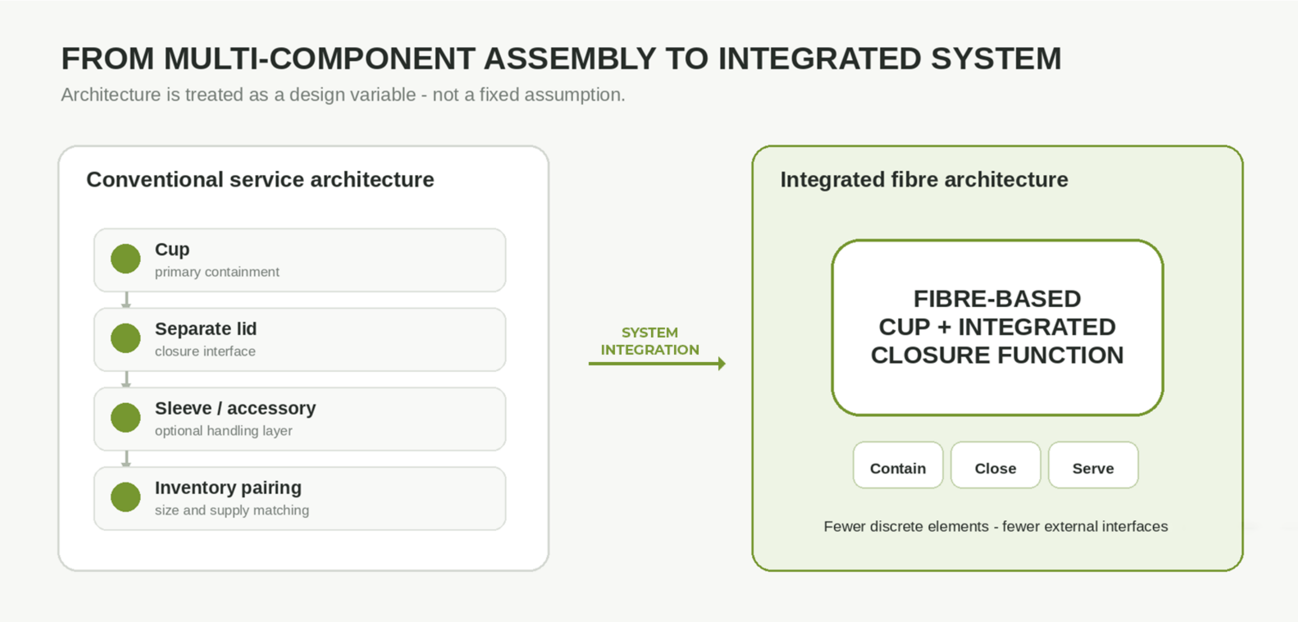

Figure 1. Conceptual comparison between a conventional multi-component service architecture and an integrated fibre architecture. The diagram is functional and does not disclose proprietary geometry.

2.1 Typical system dependencies

- Dimensional compatibility between separately produced components.
- Coordinated production quantities, packing formats and replenishment schedules.
- A repeated selection and attachment step for every beverage served.
- Additional storage positions and separate handling at the point of service.
- Material and documentation compatibility across the finished assembly.
- End-of-life behaviour determined by the complete article, not the preferred material of one part.

2.2 Integration as a design question

Component reduction is not achieved by deleting a part while ignoring its functions. A closure can contribute spill restriction, carrying stability, a drinking interface, airflow and user confidence. Integration is therefore a functional allocation problem: the design must decide which functions can be carried by structural geometry, which depend on the substrate or barrier, and which should remain separate. Systems engineering provides the vocabulary of requirements, interfaces and architecture for making that decision explicit [11].

SECTION 03

Integrated Fiber Systems framework

Integrated Fiber Systems (IFS) is Ekoroll's systems-oriented framework for fibre-based packaging development. It shifts the primary design question from "how can each component be improved?" to "what architecture should satisfy the whole set of requirements?" The method treats functions, components and interfaces as design variables rather than inherited assumptions.

3.1 The seven-domain model

Domain	Primary design question	Example coupling
Material composition	What substrate and surface system can carry the required functions?	Moisture changes stiffness and dimensional behaviour.
Structural geometry	How are containment, closure, drinking and handling functions allocated?	Creases and forming strain may affect barrier integrity.
Barrier function	Where and to what duty level is resistance required?	Barrier selection affects forming, sealing and recovery.
Manufacturing process	Can the architecture be produced consistently at target speed and yield?	Geometry determines tooling, tolerances and process windows.
Distribution environment	What loads, climate and nesting conditions occur before use?	Humidity and compression affect shape and closure behaviour.
Operation/use environment	How is the article filled, closed, carried, opened and consumed?	Workflow and user interaction determine practical success.
End-of-life pathway	How does the complete construction behave in available systems?	The least-compatible element can govern the assembly outcome.

3.2 Four methodological requirements

1. Use the full system, rather than a single component, as the unit of design and verification.
2. Treat component count and interface count as explicit architectural variables.
3. Evaluate trade-offs across coupled domains during design, not only after a design is complete.
4. Create architectures robust enough to accommodate material, operational and regulatory evolution.
5.

HYPOTHESIS BOUNDARY

Integration can offer system advantages, but it can also concentrate functional demands into fewer elements. The correct scientific position is comparative and testable: integrated architectures must meet the complete requirement set and should not be assumed superior in every domain [1].

SECTION 04

Development pathway and product status

The integrated lid-free beverage cup system was developed by Ekoroll Packaging Solutions. The first physical prototype was produced in 2022. Development proceeded through repeated structural refinement, material and barrier consideration, functional review under intended use conditions, and application-specific validation.

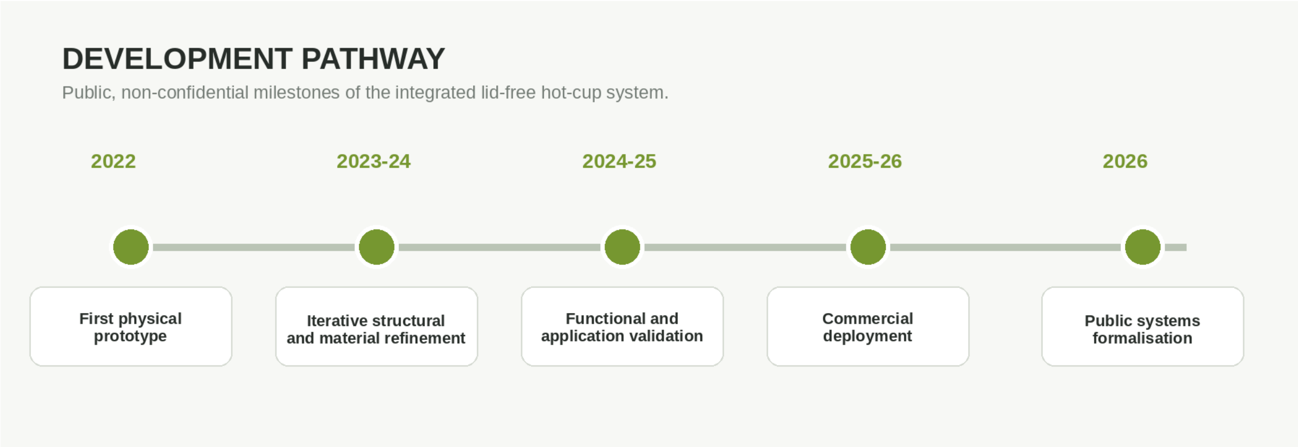

Figure 3. Public development pathway from the first physical prototype in 2022 to commercial deployment and formalisation of the systems framework.

4.1 Public development statement

DEVELOPMENT STATUS

The first physical prototype was developed in 2022. Following iterative design refinement and functional validation, the system progressed beyond the prototype stage to commercial deployment.

The phrase “commercial deployment” is used here to distinguish the current status from an early laboratory concept. It does not disclose customers, production volumes or commercial agreements. Detailed protocols, datasets, thresholds and proprietary failure-mode analyses remain outside the scope of this public report.

4.2 Product configuration

Figure 4. Commercial hot-cup configuration of Ekoroll's integrated lid-free beverage cup system. The image is provided for public technical reference and does not disclose proprietary production geometry or manufacturing parameters.

The demonstrated configuration incorporates closure functionality into the fibre-based cup body. The public image shows the overall service format while intentionally leaving manufacturing geometry, dimensions, forming sequence and material construction outside the report.

SECTION 05

System architecture and operational logic

The integrated hot cup is best understood as a service architecture rather than as a cup with an unusual top. Its design intent is to coordinate containment, closure preparation, carrying and drinking within one primary article. That coordination changes both the physical architecture and the workflow around it.

5.1 Functional allocation

Containment	The cup body retains the beverage under the defined service conditions.
Closure preparation	Structural regions are prepared and engaged without selecting a separately stocked lid.
Carrying support	The closed configuration is intended to restrict uncontrolled liquid movement during normal handling.
Drinking interface	A defined access geometry supports consumption while the integrated structure remains part of the cup.
Airflow	The architecture must permit appropriate air movement to avoid irregular flow during drinking.
Post-use state	The closure function remains part of the primary article rather than becoming a separate discarded component.

5.2 Operational implications

In a conventional workflow, the operator retrieves a cup, fills it, identifies a compatible lid, retrieves the lid, aligns it and attaches it. In an integrated workflow, the closure operation is performed using features already present in the cup. The operational question is therefore not simply whether one item disappears, but whether the revised sequence is reliable, learnable and compatible with service speed, storage and user expectations.

- Component availability is consolidated into one primary stock-keeping unit for the service body.
- Size matching between cup and separately supplied lid is reduced as an operational dependency.
- Closure preparation becomes part of the cup-handling sequence.
- The complete article can be evaluated as one coordinated body during use and disposal.
- The architecture can be adapted for different service conditions only after application-specific validation.

5.3 Demanding use environments

Airline and transport-service applications are particularly relevant because they combine constrained storage, high service repetition, movement, limited working space and a strong need for predictable handling. Hospitality, events, institutional catering and high-throughput takeaway operations present related but not identical requirement sets. IFS therefore treats application context as a design domain rather than assuming one configuration is universally transferable.

SECTION 06

Materials, barrier and food-contact considerations

Fibre-based beverage packaging depends on the interaction between substrate, geometry and surface system. Cellulosic materials are moisture-sensitive and inherently permeable; practical performance therefore requires an application-specific barrier and converting process [3]. The important systems question is not only whether a barrier performs on a flat specimen, but whether it remains effective after printing, creasing, forming, closure preparation, filling and use.

6.1 Barrier as part of the architecture

Within IFS, barrier function is allocated across the architecture and evaluated together with forming strain, heat exposure, edge conditions and intended end-of-life route. Water-based and other fibre-compatible barrier directions can be considered where their verified performance, food-contact status and recovery compatibility match the actual construction and market requirements.

6.2 Food-contact and regulatory status

Food-contact compliance applies to the finished article under defined conditions of use. It cannot be inferred solely from the generic identity of paper, a coating family or a supplier statement. Appropriate documentation may include material declarations, migration or compliance testing, manufacturing controls and market-specific regulatory assessment. This public report does not replace those documents.

6.3 Claims discipline

Claim area	What may be stated publicly	Evidence required for a quantified claim
Component integration	Closure functions are incorporated into the cup structure.	Architecture comparison and product specification.
Operational efficiency	The design is intended to simplify component handling.	Matched workflow study with defined task boundaries and sample size.
Waste reduction	A separate lid component is not required in the demonstrated configuration.	Mass- and system-boundary comparison against a functional reference.
Carbon reduction	No quantified claim in this report.	Comparative LCA with transparent functional unit and assumptions.
Recyclability / compostability	Must be construction- and market-specific.	Applicable standard tests, certification and infrastructure assessment.
Food-contact safety	Must be supported by the relevant compliance dossier.	Finished-article assessment for the defined conditions of use.

Comparative life-cycle studies of disposable cups show that outcomes are sensitive to system boundaries, energy mixes, disposal routes and functional assumptions; no material format is automatically superior across all impact categories [5].

SECTION 07

Functional validation and deployment status

Ekoroll reports that the system has undergone the functional and application-specific validation required for its intended deployment and has entered commercial use. The development process included iterative review of structural behaviour, closure interaction, handling, usability and application suitability. This public statement is intentionally high-level: it records maturity without publishing proprietary test methods, acceptance thresholds or datasets.

7.1 Validation classes

A defensible systems-level validation programme for an integrated beverage-service architecture should address the following classes together rather than interpreting any single test as proof of whole-system performance:

- Structural integrity before, during and after closure preparation.
- Liquid containment and resistance to leakage or uncontrolled movement under defined handling conditions.
- Thermal and moisture exposure appropriate to the intended beverage and service duration.
- Closure preparation repeatability and user interaction.
- Manufacturing consistency, process window and dimensional tolerance.
- Packing, transport, nesting and storage behaviour.
- Food-contact and hygienic requirements for the finished construction.
- End-of-life behaviour of the complete article under relevant recovery or composting conditions.

7.2 Evidence maturity

Concept	Systems rationale and intended function defined.
Physical prototype	First physical prototype produced in 2022.
Iterative development	Structure and application behaviour refined through repeated evaluation.
Functional validation	Internal and application-specific validation completed for deployment.
Commercial deployment	Product progressed beyond prototype status into commercial use.
Public research formalisation	IFS and FPSI provide the methodological framework for future transferable research.

7.3 What remains a research question

Commercial viability of one product configuration is not, by itself, proof of a general design methodology. The broader FPSI research question is whether a systems-oriented procedure can reproducibly generate, evaluate and validate integrated fibre architectures across multiple product categories and teams [1]. That transferability requirement distinguishes an engineering framework from a successful product instance.

SECTION 08

End-of-life compatibility and claim boundaries

Environmental performance emerges from the complete package interacting with actual collection and recovery infrastructure. A fibre-based body can still encounter poor outcomes if a barrier, adhesive, print system or remaining accessory is incompatible with the chosen pathway. Conversely, an integrated architecture may reduce the number of separately discarded elements without automatically proving a lower environmental impact.

8.1 Architecture matters

Multi-component and multi-material assemblies can complicate separation, sorting and material recovery [4]. Integrated design can remove an external interface, but the complete construction must still be evaluated. IFS therefore treats end-of-life as a design input and verification domain, not as a label applied at the end of development.

8.2 Market-specific pathways

- Fibre recovery depends on local collection, sorting, repulping acceptance and the behaviour of the finished construction.
- Industrial composting claims require the applicable standard, certified construction and access to appropriate facilities.
- Home-composting and biodegradation claims require their own evidence and should not be inferred from industrial compostability.
- Litter reduction and carbon reduction require separate system boundaries and cannot be inferred solely from component count.
- Design-for-recycling requirements are becoming more explicit in regulation, including the EU Packaging and Packaging Waste Regulation [8].

PUBLIC POSITION

This report claims architectural integration and commercial deployment. It does not make a universal claim that the product is recyclable, compostable, plastic-free, lower-carbon or environmentally superior in every market. Such statements must follow the exact product construction and supporting evidence.

8.3 Why the boundary is important

Clear claim boundaries strengthen rather than weaken the technical case. They separate demonstrated architecture from hypotheses that require comparative study, and they allow future publications to add evidence without rewriting the underlying product history.

SECTION 09

Future research and transfer pathway

The integrated lid-free hot cup provides a practical anchor for the broader FPSI programme, but the intended contribution extends beyond beverage cups. The programme seeks a validated methodology that can allocate functions across fibre structures, quantify interface consequences, evaluate coupled trade-offs and verify system performance at laboratory, pilot and production scales [1].

9.1 Priority research directions

1. Architecture generation: formal methods for allocating containment, closure, insulation, spill resistance, stacking and communication functions.
2. Interface modelling: quantitative relationships between component/interface count and reliability, yield, logistics and recovery behaviour.
3. Coupled evaluation: design-time methods that compare structural, barrier, manufacturing, operational and end-of-life consequences.
4. System-level validation: pre-registered test architectures capable of demonstrating simultaneous requirement satisfaction.
5. Industrial transfer: use by independent teams and application to product categories beyond the original demonstrator.

9.2 Collaboration model

Progress requires collaboration across structural engineering, fibre and paper science, barrier technology, food-contact science, manufacturing, logistics, statistical analysis and end-of-life engineering. The FPSI proposal explicitly defines this as a consortium problem because the object of research lies between disciplines rather than inside one specialist domain [1].

9.3 Public outputs

- Technical reports and peer-reviewed publications describing public methods and findings.
- Non-confidential diagrams, terminology and requirements models for integrated fibre systems.
- Comparative validation studies with explicit functional units and acceptance criteria.
- Design rules and applicability boundaries that can be transferred to other fibre-packaging categories.
- Industry and university partnerships supporting independent testing and reproducibility.

FIRST PUBLIC PROOF OF CONCEPT

The integrated lid-free hot cup is positioned as the first public product-level proof of concept for Ekoroll's Integrated Fiber Systems direction. Its role is to demonstrate that structural integration can be realised commercially and to provide a concrete domain for developing the wider methodology.

SECTION 10

Conclusion

The integrated lid-free hot cup demonstrates an architectural alternative to conventional cup-and-separate-lid service systems. Developed by Ekoroll Packaging Solutions, first physically prototyped in 2022, iteratively refined, functionally validated and commercially deployed, it provides a practical example of closure functionality being incorporated into a fibre-based primary article.

Its broader significance lies in the design method it represents. Integrated Fiber Systems treats packaging as a coupled engineering system whose performance emerges from interactions between material, structure, barrier, manufacture, distribution, operation and end of life. It makes component and interface count explicit design variables and requires claims to be evaluated at the level of the complete functional system.

This report establishes a public technical record without disclosing proprietary implementation knowledge. It does not substitute for product-specific certification, regulatory documentation, comparative LCA or detailed validation data. Instead, it creates a stable foundation for citation, collaboration and future research on transferable systems-oriented methods for fibre-based packaging.

TECHNICAL SUMMARY

One integrated service body; fewer external component dependencies; a defined public development history; and a research framework that separates demonstrated architecture from future comparative claims.

Author and organisation

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DOI: 10.5281/zenodo.21627597 **Report page:** https://ekoroll.com/en/rd