Novonanmek

EXECUTIVE STRATEGY & ARCHITECTURE PROPOSAL

Are You Planning a Regional Multi-Stakeholder CCUS or Hydrogen Infrastructure?

Start with System Architecture.

Novonanmek Material Sciences Pvt. Ltd. | System Architecture & Lifecycle Stewardship

Define the system before developing the infrastructure. Preserve its architectural integrity throughout its lifecycle.

Novonanmek helps you establish the system architecture that should guide technical and financial analysis, infrastructure development, and long-term lifecycle oversight.

1. The Proposition

Regional Carbon Capture, Utilisation and Storage (CCUS) networks and hydrogen logistics systems are more than collections of individual infrastructure projects. They are interconnected systems expected to accommodate multiple participants, infrastructure assets, development phases and future investment decisions.

The way these systems are structured can influence their scalability, utilisation, interoperability, capital efficiency and long-term value.

Yet infrastructure development can begin with individual facilities, supply arrangements, transport routes or investment opportunities before the architecture of the overall regional system has been adequately defined. As projects accumulate, their interfaces, dependencies and development pathways may not form the coherent system originally intended.

Novonanmek Material Sciences Pvt. Ltd. addresses this challenge through two system-architecture standards:

- **HOPT-AS®** — Hub-Only Pipeline Topology Architecture Standard, for regional CCUS infrastructure.
- **HLAS®** — Hydrogen Logistics Architecture Standard, for regional hydrogen logistics infrastructure.

These standards provide a defined architectural structure around which regional infrastructure can be organised and developed.

Novonanmek also provides Dynamic Compliance, a lifecycle service intended to help preserve the defining characteristics of an adopted architecture as the infrastructure progresses through assessment, design, procurement, implementation, operation and subsequent expansion or modification.

The proposition is straightforward:

Define the architecture. Develop the infrastructure around it. Preserve the architectural characteristics that mitigate risk throughout the lifecycle.

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2. Why System Architecture Must Come First

When a region decides to establish a CCUS network or a hydrogen logistics system, the first step is to define the architecture of the system it intends to develop.

This step must follow the formation of intent and precede the detailed technical, engineering and financial analyses of the proposed infrastructure. It is at this point that the fundamental structure of the regional system must be established: how it is organised, how its components relate to one another, how participants engage with it, where its boundaries lie, and how the system is intended to develop over time.

System architecture must be defined before the principal analyses of the infrastructure are undertaken, because those analyses need a defined system within which to operate.

Analysis Requires an Architectural Context

Technical and financial analyses are indispensable to infrastructure development. They assess matters such as engineering requirements, capacity, performance, cost, financing, utilisation and commercial viability. But they do not, by themselves, establish how the regional infrastructure system should be organised.

Consider a regional network involving multiple producers or emitters, transport infrastructure, hubs, users and storage or export destinations. Before its individual elements can be meaningfully assessed as parts of a regional system, decisions are needed about how those elements are intended to connect, which infrastructure is shared, how participants are accommodated, and how the network can expand.

These are questions of system architecture.

The architecture establishes the structural context within which subsequent technical and financial analyses are conducted. It defines the system being evaluated and the relationships that the constituent projects are expected to form. The analyses can then assess the technical, economic and financial implications of developing that system, identify constraints, compare options and inform decisions about its implementation.

The distinction is fundamental:

- **System architecture** defines the intended system.
- **Technical and engineering analyses** assess the system and its constituent infrastructure within that architectural context.
- **Financial and commercial analyses** evaluate the costs, funding requirements, economics and commercial conditions associated with the proposed development.

These activities inform one another, and their findings may require aspects of a proposed architecture to be reviewed. But they serve different purposes. Analysis of a proposed system is not a substitute for defining the system in the first place.

Why Architecture Should Not Be Deferred Until Later

If system architecture is addressed only after substantial technical or financial analysis has been completed, important decisions may already have been made around individual facilities, transport arrangements, capacity assumptions, interfaces and investment configurations.

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Those decisions can create dependencies that influence subsequent development. Once projects have been designed, evaluated, contracted or partially implemented, changing their relationships to accommodate a coherent regional architecture may require redesign, renegotiation, additional expenditure or the reconsideration of earlier investment decisions.

There is also a more fundamental concern. Individual projects may each appear technically feasible or financially attractive when considered separately, while their combined configuration may be poorly suited to the needs of the regional network. The system may develop with duplicated infrastructure, incompatible interfaces, concentrated dependencies, constrained expansion pathways or insufficient coordination between supply, transport and demand.

A later architectural exercise may identify these problems, but by then the available choices may be more constrained and the cost of changing direction may be greater.

The purpose of placing architecture first is to address the structure of the system before individual project decisions and capital commitments begin to lock in that structure by default.

This does not mean that all technical or financial work must wait until every architectural question is permanently settled. Preliminary studies may be useful in informing the initial architectural choices, and subsequent analysis may reveal the need for refinement. The principle is that detailed assessment and development should proceed within an explicitly defined architectural framework, rather than allowing the architecture to emerge inadvertently from a succession of independent project decisions.

Architecture Establishes the Basis for Capital Allocation

For a regional infrastructure system, capital is not committed only to individual facilities. It is also committed, in effect, to the configuration of the wider system in which those facilities must operate.

The architecture influences how infrastructure is shared, how participation is organised, how assets can be integrated, how expansion may occur and what future investment pathways remain available. These characteristics can affect capital efficiency, utilisation, adaptability and exposure to stranded-asset or fragmentation risk.

Defining the architecture before detailed project development therefore provides investors, lenders, sponsors and infrastructure owners with a clearer structural basis on which to evaluate the proposed system. It allows technical, financial and commercial assessments to examine not only individual projects, but also their relationship to the intended regional network.

Architecture does not establish financial viability, guarantee demand or replace independent due diligence. It establishes the system-level framework against which those matters can be assessed.

The Point at Which Novonanmek's Standards Enter

HOPT-AS and HLAS are intended to be applied at this formative stage—immediately after the intent to establish a regional CCUS or hydrogen logistics system has emerged, and before detailed technical and financial assessment and project development establish potentially restrictive assumptions.

HOPT-AS defines the hub-only pipeline topology architecture for regional CCUS networks. HLAS defines the architecture for regional hydrogen logistics. Each provides a structured response to fundamental questions about the organisation, relationships, boundaries and development of the relevant infrastructure system.

Their role is to give the regional infrastructure initiative a defined architectural starting point.

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This creates the basis for subsequent engineering, technical, financial and commercial work to proceed in the context of an identified system architecture, with individual projects assessed in relation to the network they are intended to form.

The intended sequence is:

Regional Intent → System Architecture → Technical, Engineering, Financial & Commercial Analysis → Detailed Project Development & Implementation → Lifecycle Oversight

The architecture is therefore neither a late-stage review nor a substitute for feasibility analysis. It is the foundational step that defines what is to be assessed and provides the structural reference for how the resulting infrastructure is developed.

That is why Novonanmek positions system architecture at the beginning of regional infrastructure development—and why HOPT-AS and HLAS are intended to be adopted before the development of individual projects proceeds in detail.

3. The Two Architecture Standards

HOPT-AS® — Regional CCUS Infrastructure

HOPT-AS establishes the Hub-Only Pipeline Topology for regional CCUS networks. The HOPT-AS framework decouples emitters from pipelines, making implementation feasible for emitters.

Its defining principle is that emitters participate through solid-carbon logistics rather than through direct pipeline connections from individual emitters. The handling and pipeline transportation of gaseous CO_2 are concentrated at designated hubs.

This hub-centred configuration provides a structural basis for organising multiple emitters, regeneration hubs, CO_2 pipelines and storage or utilisation interfaces into a coherent regional system.

The architecture is designed to support:

- **Shared infrastructure:** multiple emitters can participate through a common hub-based system.
- **Reduced duplication:** centralised hub infrastructure can reduce the need to replicate processing and transport arrangements at individual emitter sites.
- **Flexible participation:** emitters can be added, withdrawn or reassigned through solids logistics, subject to the applicable architecture and continued compliance.
- **Phased development:** the system can progress from simpler hub configurations towards larger multi-hub networks.
- **Multiple destinations:** the architecture provides for relationships with storage and utilisation infrastructure.
- **Long-term integration:** topology rules, boundaries and architectural controls provide a common basis for incorporating future infrastructure.

HOPT-AS is a system-architecture and assurance standard, not a carbon-capture technology or detailed engineering specification. Its role is to define the network structure within which technical design, safety assessments, capacity studies, financial evaluation and regulatory processes can be undertaken.

Download HOPT-AS

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HLAS® — Regional Hydrogen Logistics Infrastructure

HLAS establishes the system architecture for hydrogen logistics across production, aggregation, transportation, storage, distribution, utilisation and export.

Rather than treating each production facility, transport corridor or customer as an isolated project, HLAS provides a framework for organising these elements as parts of a wider regional logistics system.

The standard establishes Architecture Classes, architectural principles, building blocks, topology rules, system boundaries and stakeholder responsibilities.

Its architecture addresses:

- **Demand aggregation and diversification:** providing a structural basis for serving multiple users rather than relying exclusively on individual customers.
- **Shared logistics infrastructure:** organising production hubs, aggregation hubs, corridors, backbone pipelines and supporting infrastructure.
- **Interoperability:** providing common architectural rules to help independently developed projects integrate into a coherent network.
- **Supply and pathway flexibility:** accommodating multiple producers, users, storage arrangements and market pathways.
- **Phased deployment:** allowing infrastructure to expand through defined architectural building blocks.
- **Demand-aligned development:** addressing the relationship between infrastructure development and aggregated or demonstrable demand.
- **Lifecycle integrity:** providing a framework for evaluating changes against the defining characteristics of the adopted architecture.

HLAS is an architecture standard, not a hydrogen production technology specification or detailed engineering design. It defines the intended system structure within which project-specific technical, safety, commercial, financial and regulatory assessments take place.

Download HLAS

4. The Infrastructure Risks Addressed

The standards use system architecture to address recognised infrastructure and investment risks. They do not introduce a new category of financial risk; they seek to reduce established sources of uncertainty arising from how infrastructure systems are organised and developed.

The specific contribution of each provision depends on the architecture adopted and its application to the proposed system. Architectural measures do not eliminate all infrastructure, market, execution or financial risks. They provide a structured means of addressing risks that originate, in whole or in part, in system configuration and development.

Risk Category	Architectural Contribution & Impact
Stranded asset risk	A defined system structure, shared infrastructure and flexible participation can reduce dependence on a narrow or inflexible configuration.
Under-utilisation risk	Shared infrastructure and diversified participation can broaden the potential user or emitter base.

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Risk Category	Architectural Contribution & Impact
Infrastructure duplication	Hub-based arrangements and shared corridors can reduce unnecessary replication of infrastructure.
Fragmentation and incompatibility	Common architecture classes, topology rules, boundaries and interfaces provide a basis for integration.
Scalability and expansion risk	Defined building blocks and expansion pathways help organise progressive development.
Counterparty and supply concentration	HLAS provides a structural basis for diversified producers, users and logistics pathways.
Premature infrastructure development	HLAS addresses the relationship between infrastructure development and aggregated or demonstrable demand.
Governance and architectural drift	Dynamic Compliance helps assess whether development and operational changes preserve the adopted architecture's defining characteristics.

5. From Intent to Infrastructure: The Development Pathway

The development of regional CCUS and hydrogen infrastructure can be understood as a connected progression from regional intent to an operating infrastructure system:

1. Intent → 2. System Architecture → 3. Licensed Project Initiator → 4. Build → 5. Operate

Each stage serves a distinct purpose, while contributing to the development of an integrated regional infrastructure system.

1. Intent — Establishing the Regional Opportunity

The process begins when a region, industrial cluster or group of stakeholders identifies the need or opportunity to establish a regional CCUS network or hydrogen logistics system. This intent provides the basis for considering the infrastructure requirements, potential participants and broader regional objectives.

2. System Architecture — Defining the Intended System

Once the intent has been established, the system architecture defines how the proposed regional infrastructure is to be structured. It establishes the system boundaries, topology, constituent elements, relationships, participation arrangements and potential development pathways.

HOPT-AS provides this architectural framework for regional CCUS infrastructure, while HLAS provides the corresponding framework for regional hydrogen logistics. The adopted architecture establishes the structural context within which subsequent technical, engineering, financial and commercial assessments can be undertaken.

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3. Licensed Project Initiator (LPI) — Developing the Opportunity

Under HOPT-AS, Novonanmek may designate and commercially license an independent Licensed Project Initiator (LPI) to initiate and develop the regional CCUS opportunity.

The LPI undertakes the initial opportunity-development activities, which may include stakeholder coordination, preliminary technical and commercial assessments, infrastructure opportunity structuring and engagement with prospective investors and infrastructure developers.

The LPI provides an entrepreneurial mechanism for taking the architecturally defined opportunity forward and developing it into a proposition capable of attracting infrastructure investment.

4. Build — Developing the Physical Infrastructure

As the opportunity progresses towards implementation, an appropriate project entity, such as a Special Purpose Vehicle (SPV) or infrastructure developer, may take forward the development of the physical infrastructure.

This stage encompasses detailed engineering, financing, procurement, construction, commissioning and the associated project-development activities. The infrastructure is developed in accordance with the adopted architecture and applicable project requirements.

5. Operate — Managing and Evolving the Infrastructure

Following commissioning, the infrastructure enters operation. Over time, the regional system may accommodate additional participants, new facilities, increased capacity, modifications and further investment.

The adopted architecture continues to provide the structural framework for considering these developments and maintaining the intended relationships between the constituent elements of the regional system.

> **Continuing Architecture Stewardship**
>
> Novonanmek's role as Architecture Steward extends across the entire infrastructure lifecycle. It does not end when the LPI completes its initial opportunity-development role, or when an SPV or infrastructure developer takes forward the physical project.
>
> Through Dynamic Compliance, Novonanmek administers the applicable architectural compliance and assurance arrangements as the infrastructure progresses through assessment, design, procurement, implementation, operation, expansion and modification.
>
> This provides continuity between the architecture originally adopted and the infrastructure ultimately developed and operated, helping preserve the defining characteristics of the system as its ownership, participants and physical configuration evolve.

Together, these stages provide a connected pathway from regional infrastructure intent to an architecturally defined opportunity, through infrastructure development and long-term operation, with continuing architectural stewardship throughout.

6. Dynamic Compliance: Preserving the Architecture Over Time

Defining an architecture is only the first part of the proposition.

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Regional infrastructure may evolve over several decades. New assets may be introduced, equipment and specifications may change, suppliers may propose alternatives, ownership and participation may shift, and additional investment may alter the original configuration.

These changes can be individually reasonable while collectively moving the infrastructure away from the architecture on which its original risk-mitigation rationale depended.

A network may continue to operate and individual projects may continue to be delivered even as its shared infrastructure, interfaces, expansion pathways or other defining characteristics gradually change.

> **Architectural drift is the risk that the infrastructure ultimately developed and operated no longer retains the characteristics of the architecture originally adopted.**
>
> *Novonanmek's Dynamic Compliance service is intended to address this challenge.*

Once an architecture has been adopted, Dynamic Compliance provides a means of assessing relevant decisions and changes against its applicable requirements throughout the infrastructure lifecycle. This can include:

- Technical and financial assessment, where relevant architectural assumptions are being evaluated.
- Engineering development, design and blueprint preparation.
- Procurement of equipment, systems, packages and supplier specifications.
- Construction and implementation.
- Commissioning and transition into operation.
- Operational modifications, new connections, expansions and other lifecycle changes.

The purpose is to identify potential deviations, assess their implications for the adopted architecture and support the appropriate review, decision and documentation process.

Dynamic Compliance does not mean that infrastructure must remain unchanged. Regional networks need to adapt. It means that changes are considered in relation to the adopted architecture, with deviations identified and addressed through the applicable review and authorisation arrangements rather than occurring without adequate architectural consideration.

The service is intended to help preserve the risk-mitigating characteristics of the architecture as the infrastructure develops and evolves.

7. Relevance to Lenders, Investors and Infrastructure Owners

For institutions committing capital to long-life infrastructure, the investment question extends beyond whether an individual project can be delivered.

It also concerns whether the wider system can accommodate future participation, maintain its intended relationships, support expansion and retain the characteristics on which the investment rationale depends.

An architecture helps establish these conditions at the outset. However, those conditions may change after capital has been committed.

The infrastructure ultimately built and operated may differ from the configuration assessed when an investment decision was made. If changes undermine important architectural characteristics, the original assumptions about integration, scalability, shared infrastructure or future development opportunities may need to be reconsidered.

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Dynamic Compliance provides a means of examining this relationship over time.

The architecture assessed at the outset should remain the reference throughout the life of the asset. Dynamic Compliance helps identify and manage deviations between the adopted architecture and the infrastructure ultimately developed and operated.

For lenders, investors, insurers, infrastructure owners and project sponsors, this offers a structured approach to architectural oversight alongside existing technical, commercial, financial, operational and regulatory controls.

> **Addressing a critical institutional question:**
>
> *It is not a guarantee of bankability, asset value, project performance or financing outcomes. Rather, it addresses an important question: are the architectural conditions that supported the original infrastructure rationale being preserved as the system evolves?*

8. Working with Novonanmek

Novonanmek's proposition is relevant to organisations that intend to initiate, plan, develop, finance, own or expand regional CCUS and hydrogen logistics infrastructure.

Depending on the stage and requirements of the proposed system, engagement may involve:

- **Architecture selection and adoption** — determining the relevant standard and establishing the architecture applicable to the proposed regional system.
- **Architecture definition** — establishing the system structure, boundaries, relationships and applicable architectural requirements.
- **Development alignment** — using the adopted architecture as the structural reference for subsequent assessment and project development.
- **Dynamic Compliance** — assessing relevant activities, specifications and changes against the adopted architecture.
- **Lifecycle oversight** — supporting the preservation of architectural integrity as the system operates, expands and adapts.

The precise scope, deliverables, review arrangements and assurance mechanisms would be established for the particular engagement in accordance with the applicable standard and agreed service requirements.

HOPT-AS and HLAS are proprietary standards owned by Novonanmek Material Sciences Pvt. Ltd. Any formal certification, conformity determination or other assurance outcome is subject to the relevant standard and the applicable process administered by Novonanmek or an authorised party.

9. The Central Proposition

Regional CCUS and hydrogen logistics infrastructure requires more than technically sound individual projects. It requires a defined system architecture that connects those projects into an intended coherent network.

HOPT-AS provides that architectural approach for regional CCUS infrastructure. HLAS provides it for regional hydrogen logistics infrastructure.

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Both seek to address recognised infrastructure risks by establishing a defined system structure before development proceeds. Dynamic Compliance extends that proposition across the lifecycle by helping preserve the architectural characteristics on which the intended risk mitigation depends.

The result is a connected approach to infrastructure development: architecture first, development within that architecture, and continuing attention to architectural integrity as the system evolves.

Novonanmek Material Sciences Pvt. Ltd.

Defining the architecture of regional carbon and hydrogen infrastructure—and helping preserve its integrity over time.

To discuss the application of HOPT-AS or HLAS to a proposed regional infrastructure system, please contact:
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