HySchool 2026

TA4: Application
From Supply to Demand

Understanding the Hydrogen Supply Chain from Electrolysis to Steel

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What Are We All Working On?

Across HySchool 2026 PhD submitted topics in Section TA4: Application, complementary research addresses every step of the hydrogen chain

Advanced Materials & Hydrogen Chemistry

- **Oxyhydrides & MOFs** — Novel materials for hydrogen storage and selective separation
- **Catalytic CO_2 hydrogenation** — Converting captured carbon to methanol fuel

→ Enabling hydrogen production, storage, and conversion

Combustion & Fuel Behavior

- **Ammonia-hydrogen mixtures** — Understanding combustion dynamics for clean fuels
- **Marine engine applications** — Powering shipping with hydrogen-based fuels

→ Making hydrogen usable in real energy systems

Industrial Transformation

- **Glass & aluminum** — High-temperature processes transitioning to hydrogen
- **Ferroalloys & steel** — Reduction processes redesigned around clean hydrogen

→ Translating hydrogen into large-scale industrial demand

Systems, Monitoring & Optimization

- **Real-time analytics** — Data-driven optimization of hydrogen system performance
- **Smart operation** — AI-enhanced control for energy system efficiency

→ Improving efficiency and reliability of hydrogen systems

What is striking is that almost every step of the hydrogen chain is already being addressed here

Mapping Our Work into the Hydrogen Application

Production → Storage → Transport → Conversion → End-use

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Production & Materials

- Catalysis research
- Hydrogen generation
- Advanced materials

Conversion & Energy Use

- Combustion systems
- Fuel cell technology
- Marine applications

Industrial Demand

- Steel production
- Glass manufacturing
- Aluminum & ferroalloys

System Performance

- Real-time monitoring
- System optimization
- Digital tools

Each project solves a critical part — while these parts are still loosely connected if you want to work together

From Components to Chains

The critical shift from individual technologies to integrated deployment

Current Focus

Most research focuses on **individual components** — optimizing electrolysers, improving storage materials, or enhancing combustion efficiency.

- Component-level optimization
- Technology performance metrics
- Laboratory validation

Deployment Reality

But real-world deployment depends on **system integration** — how technologies connect, where they're located, and how they scale together.

- → How components **connect**
- → Where they are **located**
- → How they scale **together**

Key Insight

How to integrate them

Component Research → **System Integration** → Real Deployment

Why Hydrogen?

Understanding hydrogen's role in the decarbonization challenge

Not a Universal Solution

Hydrogen is **not suitable for all applications**. Direct electrification is more efficient where possible.

Better alternatives exist for:

- Light-duty vehicles (EVs)
- Building heating (heat pumps)
- Low-temperature industry

Critical For

Steel Production

High-temperature reduction processes

Chemicals

Ammonia, methanol synthesis

Shipping

Long-distance maritime transport

Core Principle

Hydrogen is essential **where electrification is difficult or impossible** — these are the hard-to-abate sectors that cannot be decarbonized through direct electricity use.

Hydrogen Supply Chain

Electricity → Hydrogen → Transport → Storage → Demand

Electricity
Renewable sources

→

Hydrogen
Electrolysis production

→

Transport
Pipelines, shipping

→

Storage
Tanks, caverns

→

Demand
Industrial use

Geographic Separation

Supply and demand are **geographically separated** — renewable resources and industrial centers rarely coincide.

Infrastructure Critical

Infrastructure **determines feasibility** — without transport and storage, hydrogen cannot reach demand centers.

Geography Matters

Location determines outcomes — where production, infrastructure, and demand are situated shapes the entire system.

Hydrogen is not just a fuel — without clear downstream markets, production cannot scale in an uncertain world.

Supply, Infrastructure & Demand

The three pillars of the hydrogen system

Supply

Green Hydrogen

Produced via electrolysis using renewable electricity

Renewable Electricity
Wind, solar, hydro power

Water
Pure water for electrolysis

Land
Space for installations

Uneven distribution: Nordics, Iberia have advantages

Infrastructure

Transport Methods

- Pipelines (most efficient)
- Shipping (long distance)
- Ammonia carriers

Storage Solutions

- High-pressure tanks
- Underground salt caverns
- Liquid hydrogen

Key bottleneck: Infrastructure limits deployment speed

Demand

Industry Dominates

- Steel production
- Chemicals & refining
- Shipping & aviation

Demand Characteristics

- **Concentrated:** Large industrial hubs
- **Location-specific:** Tied to existing infrastructure

Scale: Massive volumes needed for decarbonization

Why Steel? The Industrial Driver

Steel as the critical demand center for hydrogen systems

Climate Impact

7-8% of global CO_2

Steel production accounts for **7-8% of global CO_2 emissions** — one of the largest industrial sources.

Hard-to-abate sector: Cannot be easily electrified

Policy Priority

Central to EU decarbonization strategy — steel is a key sector in European Green Deal.

CBAM (Carbon Border Adjustment)

Massive investment: Billions allocated to green steel

Why Steel Drives Hydrogen Demand

Steel production is being **redesigned around hydrogen at massive scale.** Traditional blast furnaces using coal are being replaced by hydrogen-based direct reduction.

Massive	Proven	Applied
Scale of demand	Technology pathway	Policy support

Case: Hydrogen use at Scale

Real-world projects demonstrating hydrogen system deployment

Case 1: HYBRIT (Sweden)

Operational

World's first hydrogen-based steel production facility — a partnership between SSAB, LKAB, and Vattenfall.

~15	~10%	2021
TWh/year electricity	Sweden's CO_2 reduction	First delivery

Source: hybritdevelopment.se, IEA

Case 2: H2 Green Steel (Sweden)

Under Construction

New large-scale hydrogen-based steel plant in Boden, Sweden — one of Europe's largest industrial investments.

~5 Mt	70-100k	12-15
Steel/year capacity	Tonnes H_2/year	TWh electricity

Source: h2greensteel.com

Case 3: European Hydrogen Backbone

Planning

Pan-European hydrogen infrastructure network connecting supply and demand across the continent.

28-40k	60-70%	€80-140B
km pipelines by 2040	Repurposed gas pipes	Investment needed

Source: ehb.eu

Matching Supply and Demand

The core challenge of hydrogen system deployment

Supply Location

Renewable-Rich Regions

- Nordics (wind, hydro)
- Iberia (solar, wind)
- North Sea (offshore wind)

Advantage: Low-cost renewable electricity

Demand Location

Industrial Hubs

- Ruhr region (Germany)
- Northern Italy
- Benelux corridor

Challenge: Limited renewable resources

The Fundamental Question

Option A

Move **hydrogen to industry** via pipelines and shipping?

Option B

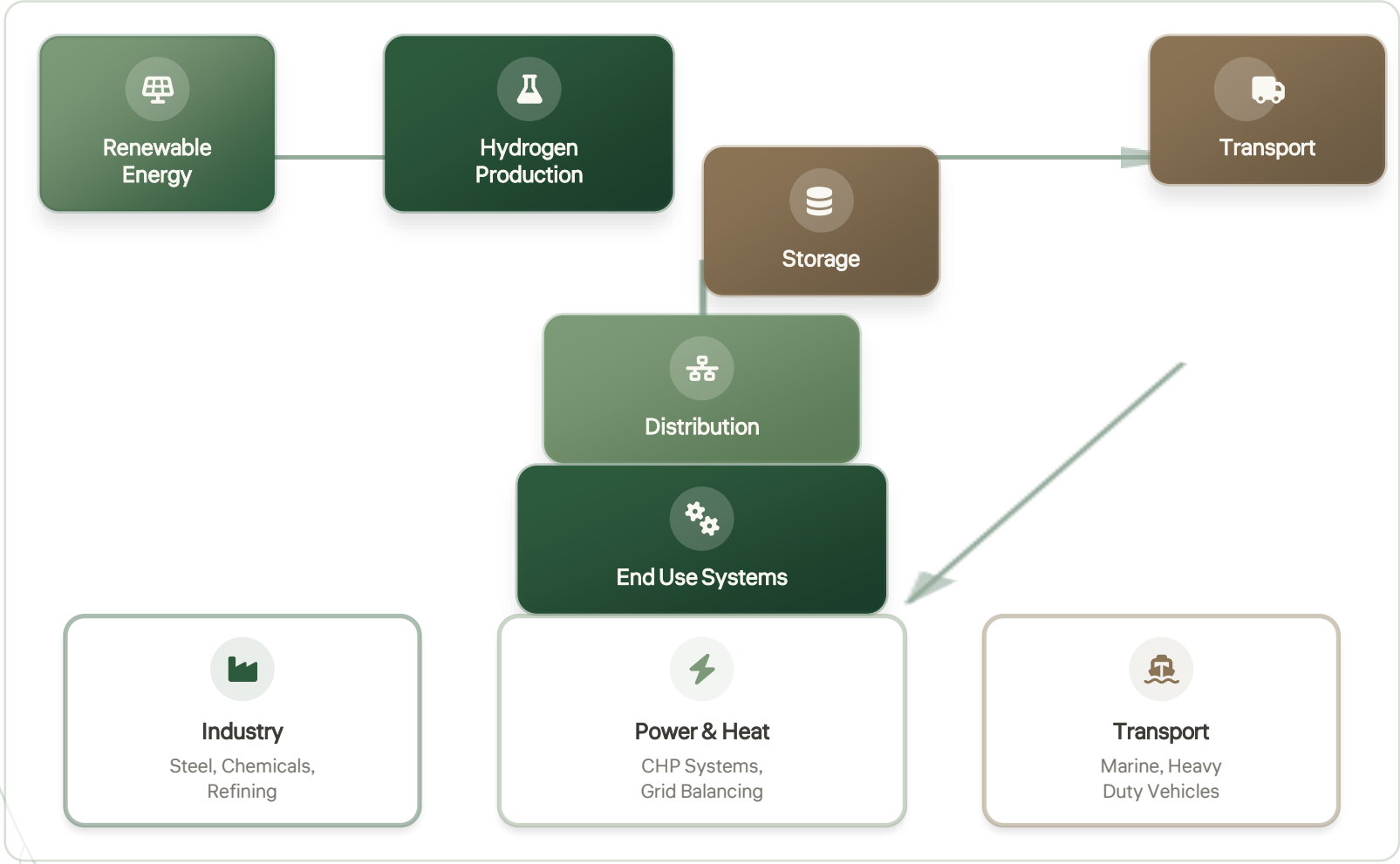
Move **industry to hydrogen** — relocate production?

System constraints: Very high electricity demand ▪ Infrastructure gaps ▪ Storage limits ▪ Cost uncertainty

Hydrogen Supply Chain & TA4 Applications

Mapping TA4 PhDs' research to the hydrogen supply chain

Hydrogen Supply Chain Flow



TA4 PhD Research Projects

PRODUCTION
MOF-based catalysts for CO_2 hydrogenation
Sahra Ahmed

PRODUCTION
Hydroxide-ion conducting MOFs
Qingqing Shao

DISTRIBUTION
Integrated hydrogen system design & digital twin operations
Giulia Fede

POWER & HEAT
Hybrid fuel cell CHP systems
Muhammad Uzair Azhar

TRANSPORT
Combustion in marine engines
David Zilles

Research Domain Legend

- Production/Materials
- Optimization
- End-Use Applications

Open Research Questions & Key Takeaways

Open Questions

1. How can hydrogen be **integrated under real constraints**?
2. What drives **industrial hydrogen demand** (e.g., steel)?
3. Where should **infrastructure be built first**?
4. How do **energy constraints** reshape deployment?

Key Takeaways

1. **Hydrogen supply chain**
   Not just a fuel — an integrated energy network
2. **Industry drives demand**
   Steel is the critical sector for hydrogen adoption
3. **Infrastructure shapes feasibility**
   Transport and storage are key bottlenecks
4. **Geography determines outcomes**
   Location of supply, infrastructure, and demand matters

The hydrogen transition is fundamentally a coordination challenge along the supply chain.

Will hydrogen be produced where to be used?

Or

Will the demand move to where hydrogen is?

TA4: Hydrogen Applications – Advancing Towards a Promising and Realistic Future

Questions & Discussion