The Hamburg Hydrogen Hub

Experience and Lessons Learned for Cluster Development around Ports

May 15th 2023

Agenda

1) Introduction – Aim of the webinar
2) Approaches to Hydrogen Hubs/Valleys
   - Organizational Set-up
   - Framework Conditions
3) Summary of the Hamburg Model
   - Public perspective
   - Private perspective
4) Next steps
   - Governance - Holistic view
   - Logistics Concepts/Business Plans – Project based
5) Open Discussion

TOP 1:
Introduction/Aim of the webinar

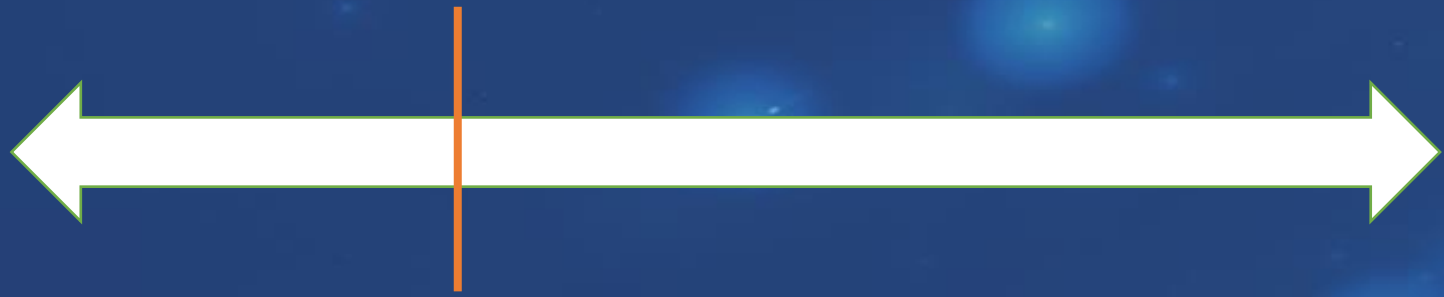
Hamburg-Kerala Hydrogen Webinar

- **Aim:**
  - Provide an overview of hydrogen activities in Hamburg
  - Explain the roles of different stakeholders, their goals and how they are interlinked in Hamburg
  - Present an outlook on other forms of hub organization
  - Introduce success factors and challenges for the development of a hydrogen hub
  - Open space for discussion on tangible next steps

- **Not part of this webinar:**
  - Technical details of different development projects
  - Phased roadmap for hub development in Kerala

TOP 2:
Approaches to Hydrogen Hubs

Governance of Hydrogen Hubs



Decentralized/
Market-driven

Central/
Govern-mental driven

Driven by community of partners

Hamburg Hydrogen Hub

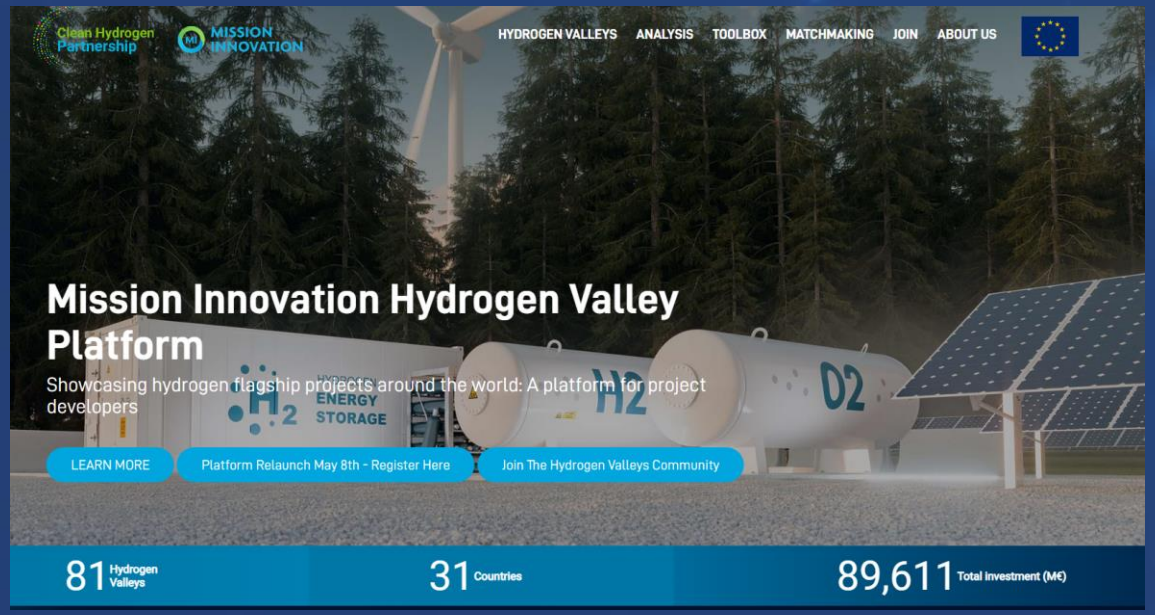
Driven by single institution "Hydrogen Hub Authority"

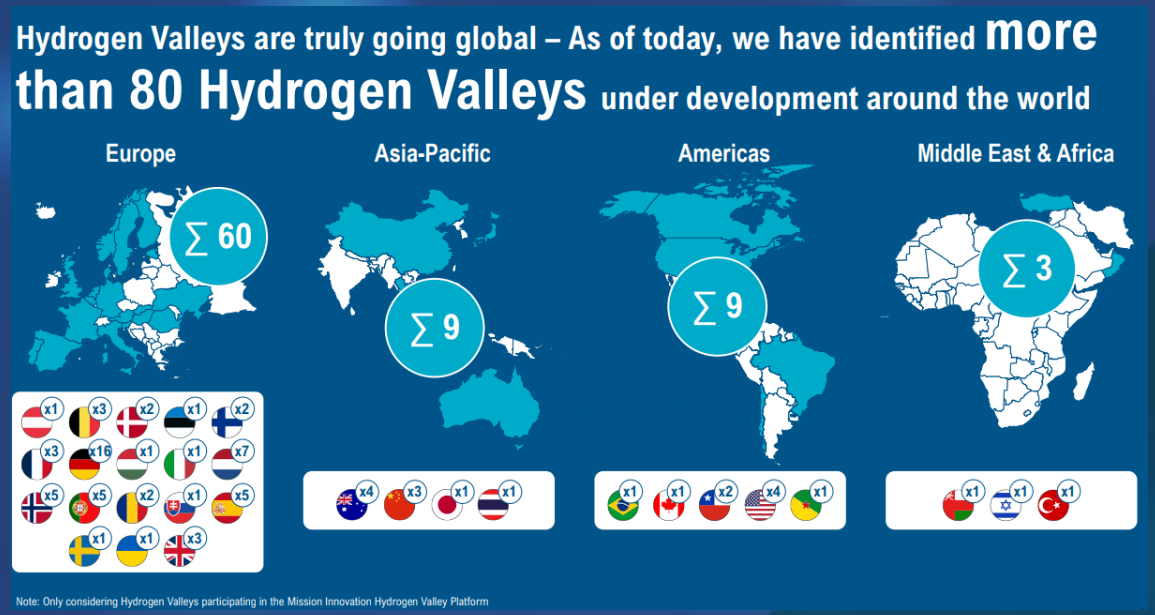
Reducing risk by partnering

Coalition of the willing

Mapping the funding opportunities both private and public

Hydrogen Hubs or H2 Valleys



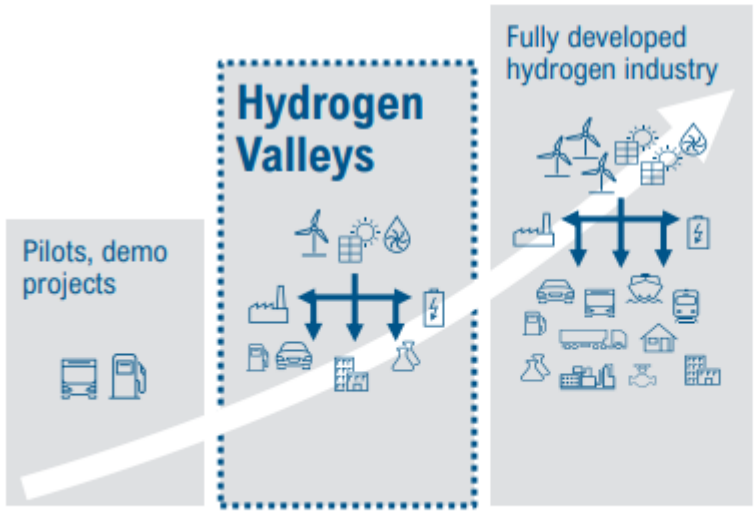


Source: https ://h2v.eu/ H2Valleys | Mission Innovation Hydrogen Valley Platform

Hydrogen Hubs or H2 Valleys

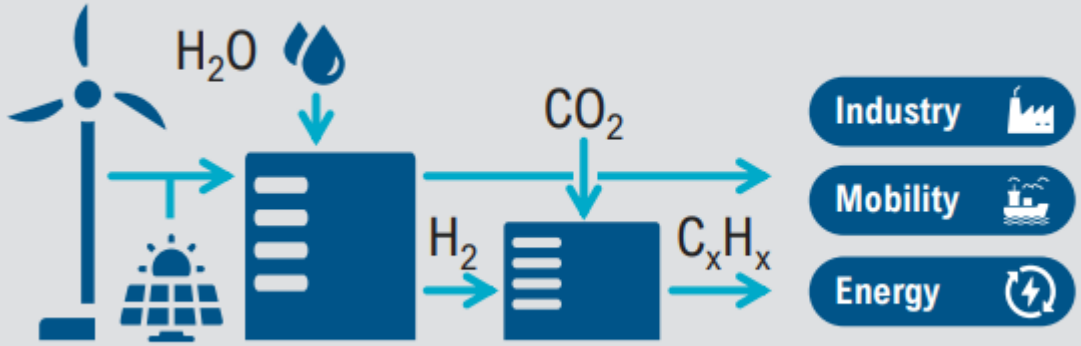
Hydrogen Valleys …

- Next-generation H2 market development
- Integrated (and larger-scale) projects covering more and more of the value chain – "mini hydrogen economies"



… and what they're made of

- **Large-scale joint investment** (> EUR 10 m and up to multi-bn EUR)
- **Full hydrogen value chain coverage**
  - Centralized clean hydrogen production (*de facto* mostly green H2)
  - Shared infrastructure (e.g., pipelines, refueling stations)
  - Multiple end-uses (e.g., steel industry, fuel cell trucks)
- **Clear regional scope** (e.g., around a major port)



Source: https ://h2v.eu/ H2Valleys | Mission Innovation Hydrogen Valley Platform Roland Berger

H2 Valleys - Archetypes

Archetype 1: Small-scale

local mobility-centred H2 valleys (typically 1–10+ MW of local electrolyser capacity):

- combination of decarbonisation of regional mobility fleets (hydrogen fuel cell trucks, buses, trains, etc.).
- matching combined demand with built out of jointly used hydrogen refuelling stations and centralised clean hydrogen production

Archetype 2: Medium-scale

H2 valleys focusing on industrial decarbonisation (typically 10-300+ MW of local electrolyser capacity):

- based on local or regional hydrogen production (usually green hydrogen) at the site of industrial consumers (refineries or fertiliser production plants (i.e., converters from grey to clean hydrogen).
- Around anchor load, mobility off-takers are added (fleets, hydrogen refuelling stations, storage and distribution)
- mostly led by anchor off-takers, which might involve energy companies as partners

Archetype 3: Large-scale

export-oriented H2 valleys (typically 250-1,000+ MW of local electrolyser capacity):

- focusing on low-cost production of clean hydrogen for local off-take, but ultimately mainly regional and international export
- typically co-located with dedicated additional renewables capacities (e.g., PV, on-shore wind, offshore wind)
- "gigaprojects" mostly led by energy majors or sovereign developers. First projects approach Final Investment Decisions, especially in Middle East and Australia.

Source: https ://h2v.eu/ H2Valleys | Mission Innovation Hydrogen Valley Platform

H2 Valleys – Hydrogen Valley Innovation Cluster

MISSION INNOVATION

Department of Science and Technology
Ministry of Science and Technology
Government of India

आज़ादी का अमृत महोत्सव

GUIDELINES FOR

HYDROGEN VALLEY INNOVATION CLUSTER

Revised document for "Call for proposals on Hydrogen Valley Platform in India"

Last Date for submission of EoIs – 14th May 2023

सत्यमेव जयते

Government of India
Ministry of Science & Technology
Department of Science & Technology
Technology Mission Division (Energy Technology Cell)
Technology Bhawan, New Mehrauli Road
New Delhi – 110016
Website: https://dst.gov.in/

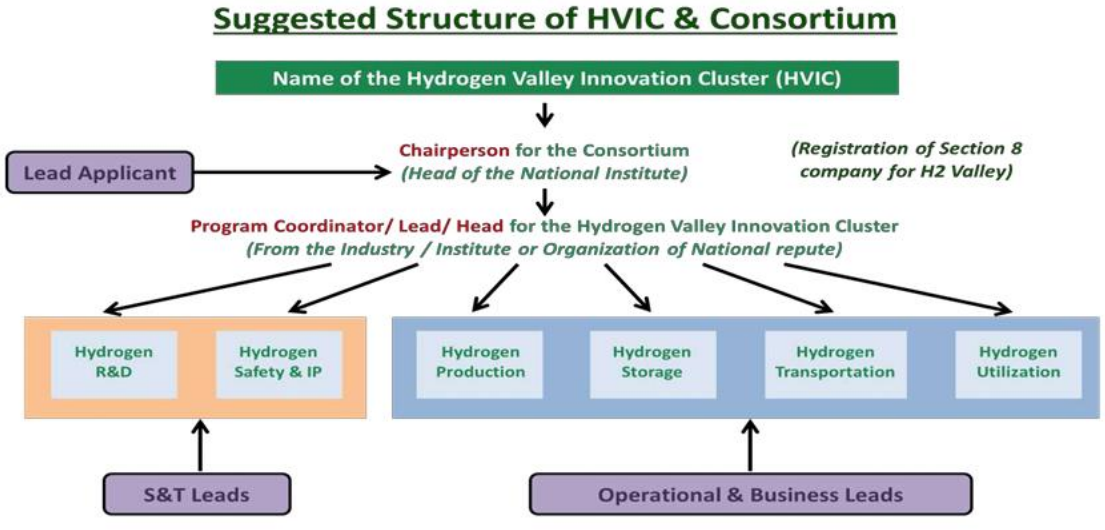


Figure 3: Suggested Structure of HVIC & its Consortium

Source: Guidelines for Hydrogen Valley Innocation Cluster.pdf (dst.gov.in)

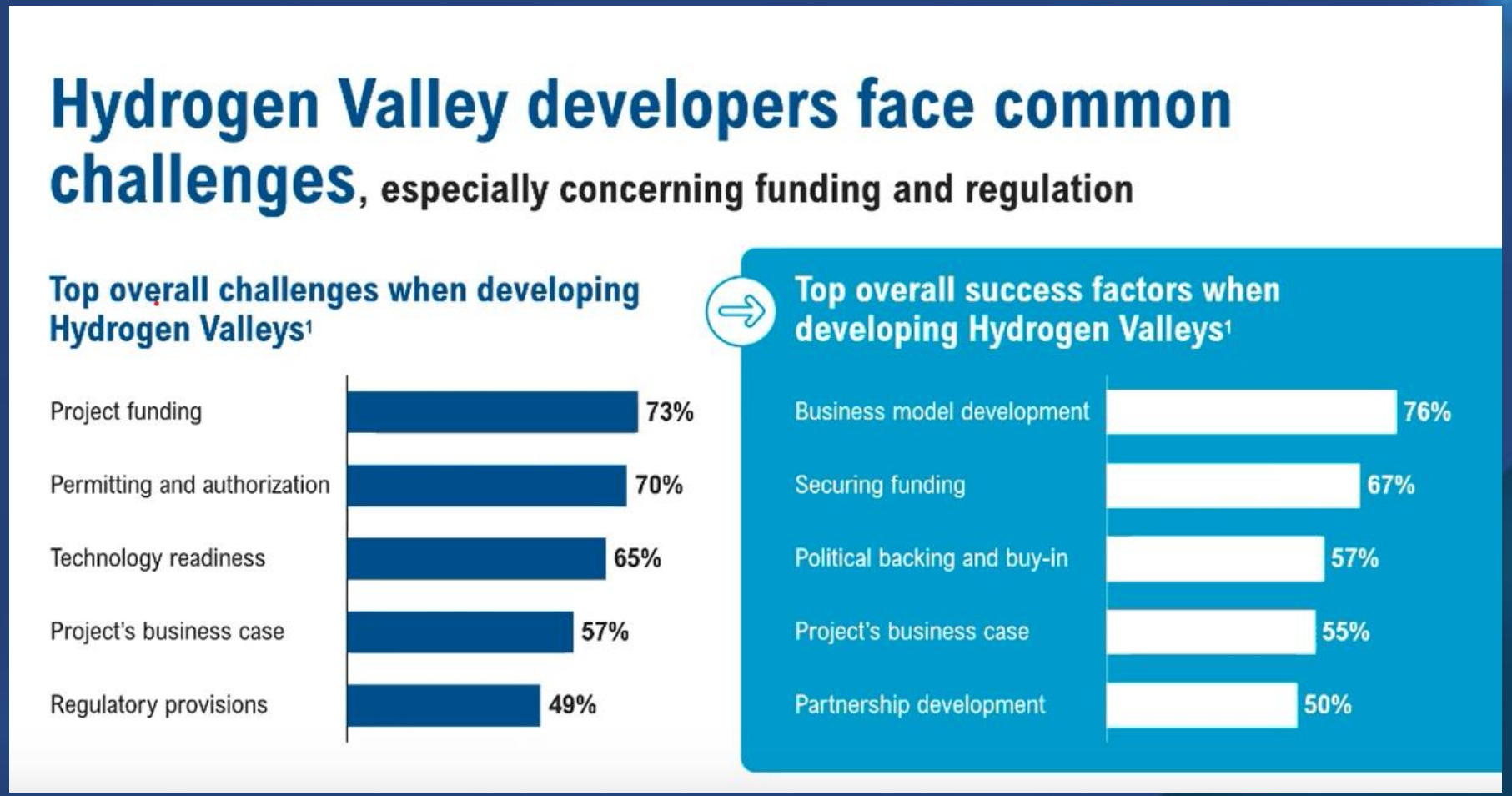
Five key factors for success

Five factors are the most important during the preparation phase:

01	A convincing project concept that covers the value chain and includes technology that leverages local assets and addresses local needs.
02	A viable commercial structure and business case for project developers.
03	Public-private financing from multiple sources, including enough public funding to close initial gaps to commerciality.
04	Partnering and stakeholder cooperation that covers the entire project scope and ensures continuous commitment from all parties.
05	Political backing and public buy-in.

Source: www.rolandberger.com

H2 Valleys - Challenges



Source: https ://h2v.eu/ H2Valleys | Mission Innovation Hydrogen Valley Platform Roland Berger

Five critical factors for hydrogen projects

01	**public funding support** flexible and tailored project scopes to match public funding requirements is important
02	**offtake commitments** Credible investment plans and discussions with as many potential off-takers as possible contribute to successful de-risking.
03	**private investment** Hydrogen Valleys and Hubs need to pursue a structured development approach, involve off-takers and equity partners to de-risk the project and obtain early feedback from the lending community Involving local private investors may help locally anchored projects
04	**technology readiness** Projects must remain flexible and consider adding further applications to their portfolio Efficient operation and maintenance services are crucial.
05	**regulatory provisions** Policymakers must have a **clear vision of a region or country's future** hydrogen economy and create the necessary regulatory environment to realize this vision Barriers exist around enabling a level playing field for green hydrogen as well as permitting and standardization.

Source: www.rolandberger.com

Public bodies provide funds for H2 terminal investments

Public funds rather focus on setting up the infrastructure and production facilities

National Funds

To develop national ports, to implement policy goals, to reduce CO2 emission, to develop national sustainable energy supply

Co-financing:

Necessary infrastructure for production, storage and pipelines to enable H2 terminals by

- Green Hydrogen Sector Fund (Uruguay)
- Roadmap of Green Hydrogen (Morocco)
- National Hydrogen Program, PNH2 (Brazil)
- The Norwegian Government's Hydrogen Strategy

European Commission

EU Hydrogen Strategy: to decarbonise hydrogen production and expand its use in sectors where it can replace fossil fuels to reach CO2 goals until 2030/ 2050

Co-financing:

- EU IPCEI H2, €10.6 billion public funding in 2022
- EU Recovery and Resilience Plan, EUR 9.3 billion allocated to H2 projects
- **Global** Gateway, €300 billion, also for sustainable transport hubs
- **Global** European Hydrogen Facility/ European Hydrogen Bank (€3 billion)

Int. Development Institution

Supporting governments of developing countries to produce and transport H2 (or derivatives) by TA, networking but also by loans:

- World Bank: Hydrogen for Development Partnership (H4D), catalyse significant financing for hydrogen investments
- African Development Bank: Sustainable Energy Fund for Africa by AFD
- EIB Global (Green Hydrogen Fund)
- Asian Development Bank

Private companies may provide funds for H2 terminal investments

Private investors rather focus on attractive business cases

Motivation

- Profitability, profitability, profitability
- Sustainability as a corporate identity

Private maritime companies

- Terminal investors (e.g. APM Capital)
- Shipping lines

Private non-maritime companies

- International pension funds, insurance companies, venture capital firms, asset management firms

Exemplary:

APM Capital

محطة بوابة البحر الأحمر
RED SEA GATEWAY TERMINAL

Hapag-Lloyd

صندوق الاستثمارات العامة 1971
Public Investment Fund

DZ BANK

J.P.Morgan

BLACKROCK

UNIVERSAL INVESTMENT

TOP 3:
Summary of Hamburg Hydrogen Activities

Hamburg Port Authority

Role and Tasks in the Hydrogen Activities

1. Landlord:
   - Strategic long term port development concerning mega trends (climate neutrality, hydrogen, renewable energy)
   - Master planning of port areas, ensuring balanced and sustainable port development, industrial location

2. Provision of infrastructure: waterways, quays, etc.

3. Point of contact: Aggregate interests of different parties to leverage synergies

4. Support/Preparation for bunkering of alternative fuels (regulatory enabler)
   - Increase Port Readiness Level

<u>(In Hamburg) not:</u>

- Owner (or operator) of gas grid (common pipeline infrastructure)
  ➔ Gasnetz Hamburg (also 100% subsidiary of City of Hamburg)

Lessons learned and level playing field of Port Authorities

1. Early engagement of critical stakeholders (water police, fire brigade, permitting local authorities)
2. PA can facilitate and structure the transformation process by conducting groundwork for feasibility studies for knowledge building (nautical restrictions, safety distances)
3. Realization of a holistic hydrogen value change concept: Green transport needs to be considered and therefore refuelling infrastructure for climate neutral fuels needs to be part of a comprehensive import concept
4. Building on existing expertise and permission can speed up transformation process

Renewable Energy Hamburg Cluster Activity

Role and Tasks in the Hydrogen Activities

Target

- Platform to meet and connect
- Point of contact
- Coupling of players in renewable energies and hydrogen sector
- Regular direct exchange of stakeholders/networking
- Initiation of projects to promote the practical implementation of innovations
- Representing the hydrogen and energy industry of Hamburg area

Organization

- Forum Management & Project Management R&I (Cluster-EEHH) are responsible for topics to be discussed, selection of speakers and other organization

Hydrogen Alliance Hamburg

Covering the entire hydrogen value chain

Production of green hydrogen

Infrastructure to connect supply and demand (Storage & Distribution)

End uses / Application of green hydrogen in **Industry**, **Logistics** and **Mobility**

- 100 MW centralized electrolyser (conversion of existing coal power plant)
- Additional small-scale production for in-house use (decentralized “prosumer”, 5-20 MW, e.g. refinery)

- Public H2 grid
- Green energy import terminals, including storage facilities (starting with ammonia and e-fuels)

<u>Industrial Offtake:</u>

- Steel production (phased increase of H2 use in existing reduction plant)
- Metal production (e.g. copper)

<u>Heat integration</u>

<u>Mobility:</u>

- Trucks (incl. HRS)
- Terminal equipment (innovation cluster)
- Ships (starting with ferries and push boats)
- Shunting locomotives
- Green aviation

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Green Ammonia Import Terminal

Import

Storage and Distribution

- Plans for Germany's first large-scale, green energy import terminal in the Port of Hamburg
- Joint development agreement between terminal operator and hydrogen producer signed in November 2022 (MoU already in February 2022)
- Targeted to provide hydrogen to Germany **in 2026**
- Planned import terminal will be located at existing tank terminal in the port: **partial conversion of infrastructure**
- Significant investments to deploy energy infrastructure capabilities and expertise to accelerate the energy transition in Hamburg as the key import gateway for Germany
- Import from large-scale production facilities around the world, conversion of ammonia to green hydrogen via Air Products' facilities in Hamburg, before distributing it to buyers locally and across northern Germany

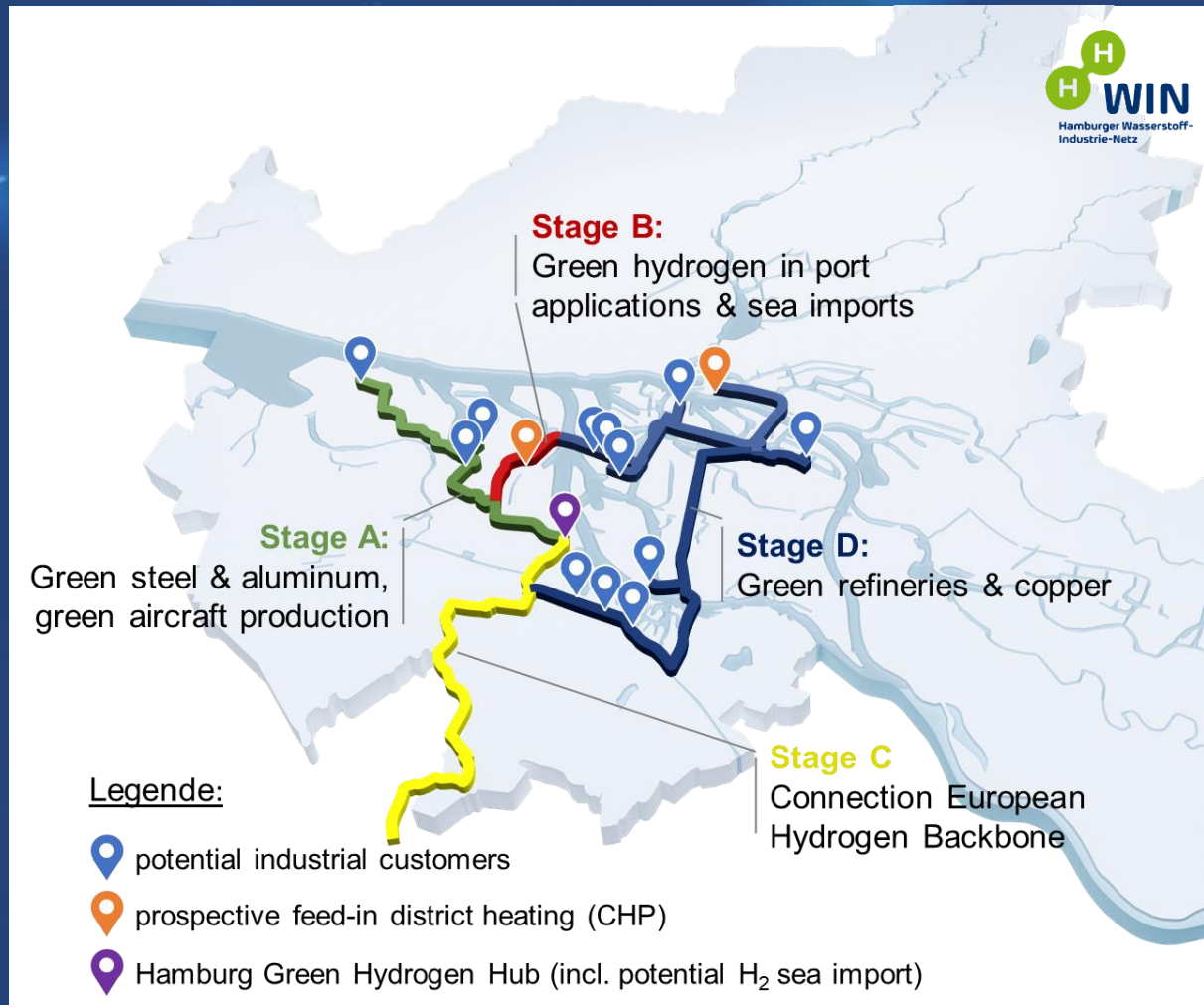
Hamburg Hydrogen Industry Grid

Distribution

Expansion Stages A to D

- A **hydrogen grid** for **industry** and **commerce** in the south of Hamburg (>200 RLM customers with 7.6 TWh)
- With **60 km hydrogen pipeline** around one third of Hamburg's natural gas consumption can be replaced, i.e. **570 million m³ natural gas p.a.** (6.4 TWh at 14 industrial sites)
- **Annual CO2 savings potential**
  ≈ 1.2 million metric tons of CO_2
  14 industrial sites
  > 1.4 million metric tons of CO_2
  all >200 RLM customers

Non-discriminatory grid infrastructure enables the **ramp-up** of a real, flexible **hydrogen market**



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GASNETZ HAMBURG

Port of Hamburg as a blueprint for hydrogen and fuel cell applications in European logistics hubs

Mobility Offtake

Refuelling infrastructure

Hydrogen applications

Trucks

HHLA

DAIMLER

MAN

Shunters

HPA Hamburg Port Authority

ALSTOM

evb

Ships

Pilot ship & Future launch

HPA Hamburg Port Authority

GREENPLUG

Push boat

Passenger ferry

HADAG

Terminal equipment

HHLA

HYSTER-YALE

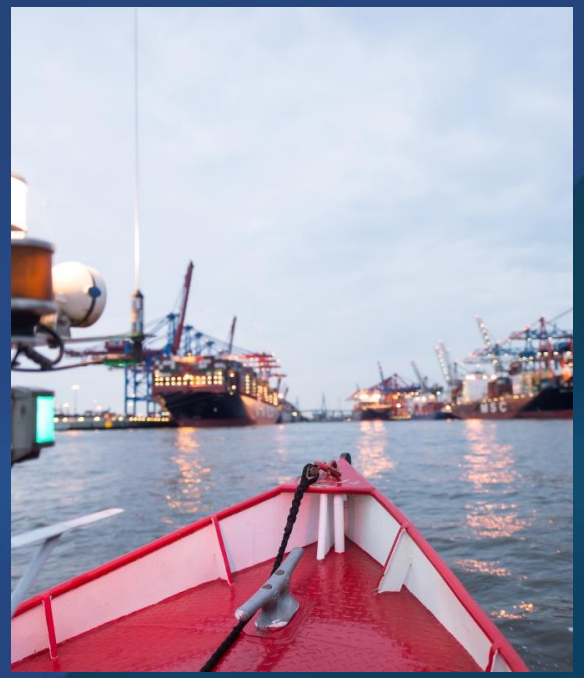
KONECRANES

KALMAR

Example Hamburg

Application: Bunkering

- Hamburg Port Authority key duties:
  - Maintaining the waterside and landside infrastructure
  - Ensuring safe and efficient navigation
  - Managing the port property
- Role in alternative fuels bunkering:
  - Preparer - pro actively (network, nautical safety, approval process, bunker options)
  - Offtaker – Fleet
  - Nautical safety – Harbour Master
- Challenges:
  - Creating growth despite limited land resources
  - The port – an industrial area in the heart of the city of Hamburg



Example Port of Hamburg

Application: Bunkering

Fuel producer	Role: Producer Involvement: low
Fuel supplier	Role: Seller Involvement: low
Bunkering company	Role: Seller Key stakeholder for approval process Involvement: high Tasks: technical & process information
Shipping company	Role: Consumer Key stakeholder for approval process Involvement: high Tasks: technical & process information
Local authorities	Role: approving authorities Critical stakeholder for approval process (fire brigade, water police & environmental authority) Involvement: high Tasks: safety standard information, licensing, incentIves

Fuel type	Ship type	Expected in	Shipping Company
Ammonia	Tanker	2026	Import
	RoRo		
Methanol	Tanker	2026	Import
	Container vessels	2024	Maersk, CMA CGM, MOL
	Cruise vessels		
Hydrogen	Cruise vessels	2023	SilverSea

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Lessons learned

- **Industry alliances reduce investment risks**
  - Secure market demand
  - Enable cost sharing
  - Back-up business cases
  - Highlight lack in legislation and need for action
  - Facilitates proposition for standardization of procedures
- **Coordination of timelines enables ramp-up**
  - Production depends on distribution depends on off-take
  - Simultaneous market ramp-up
  - Parallel development required for financially viable hydrogen economy
- **Dynamically adjust national/regional strategy based on project development**

TOP 4:
Next steps

Next steps to establish a successful hydrogen economy

Governance-Structure

- Role of state
  - Creating a vision, what aims to be established in 2030/2040
  - Assessment of regulatory readiness
  - Location of companies and scientific institutions
  - Raise public awareness
- Benchmark governance options from similar hydrogen endeavors

- Build up processes and systems that define interactions amongst various stakeholders
- Allocate roles and responsibilities between private operators, research institutions and public actors
  - Common activities to raise technical readiness level
  - Off-taker agreements
- Define role and function of port authority: facilitating role; active involvement?
  - Just landlord or investor?

Next steps to establish a successful hydrogen economy

Stakeholder Management & Project Administration

- General project administration (including reporting, organizing of meetings, administrative duties)
- Identify relevant stakeholders
- Develop stakeholder strategy
- Organize and prepare stakeholder workshops
- Collect stakeholder´s needs and requirements

Next steps to establish a successful hydrogen economy

Logistics Concept

Integration of a hydrogen hub into an international supply chain

- Definition of options for transporting green hydrogen overseas?
  - Assessment of most promising hydrogen state of aggregation for transport
  - Assessment of transport routes / Definition of a hydrogen transport circle
  - Assessment of type of carrier and implications on infrastructure
  - Elaboration of handling / operations / safety concepts
  - Assessment of permit requirements
- Depending on import relations / market studies, what would be the preferred transport scenarios? (e.g. centralized, de-centralized)?
- How would transport facilities look like for the different options of transporting hydrogen? (e.g. site analyses, transport scenarios, development roadmaps)

Business Plan

Can a hydrogen hub be financially viable for a private investor?

Review of potential for generating sufficient revenues to justify the investments

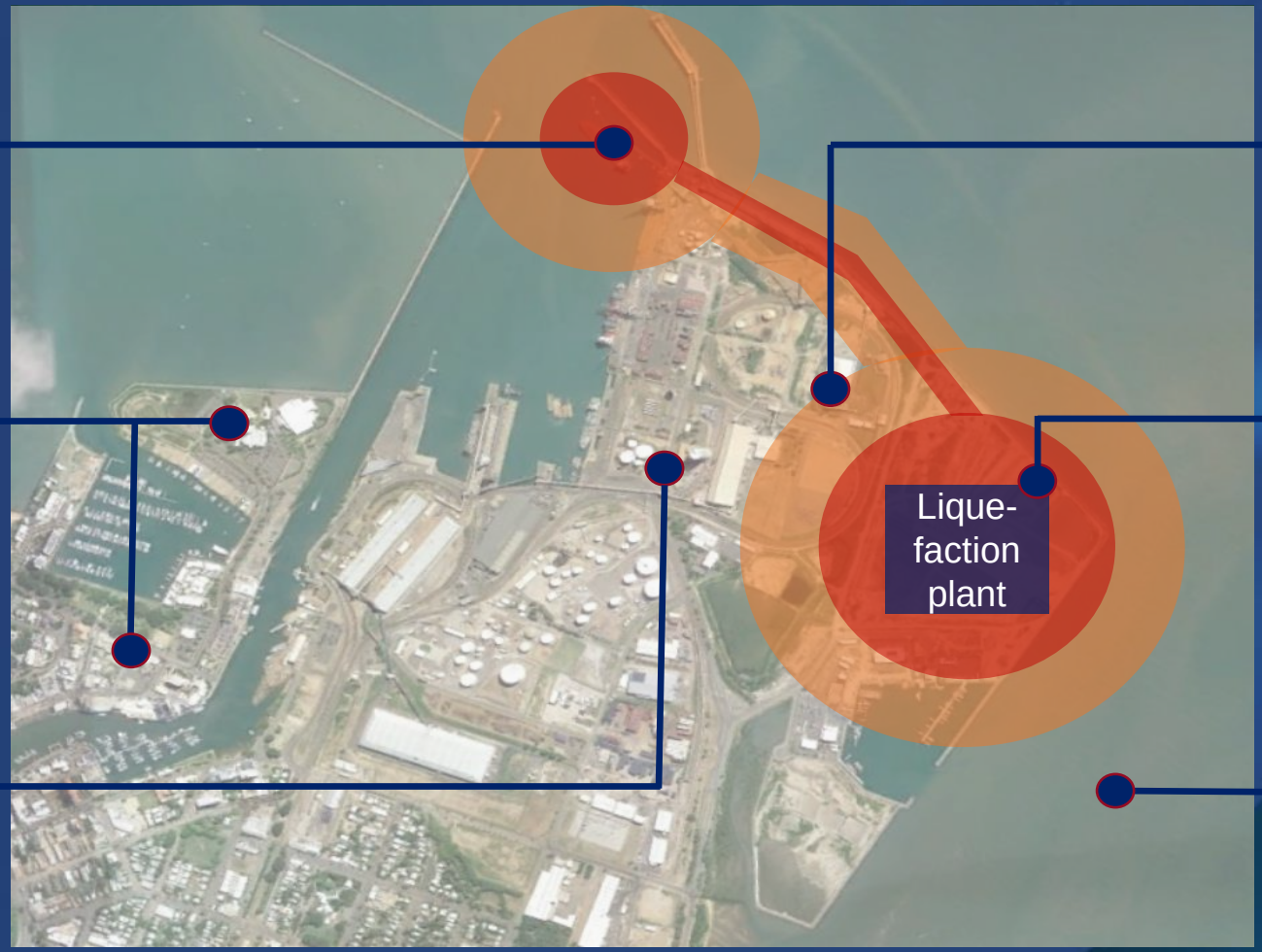
- Which income streams can be determined and how do they develop?
- Which are required operations expenses (labour, maintenance & repair, energy, and administration cost) over time?
- What is the volume and schedule for capital expenditures for infrastructures and superstructures?
- Is the investment commercially viable from the investor's point of view (under consideration of financing options)?
- Can the investment demonstrate benefits for the society (based on an analysis of cost and benefits)?

Hydrogen in ports causes challenges based on the innovative nature of the product and its specifics, lack of experience and resulting integration and compatibility

Challenge	Impact	Action/Resolution
No national legislation for hydrogen operation / handling in place	Juristical grey zones cause uncertainties	Elaborate risks and chances based on grey-zone situation as long as no governmental restrictions are graved into stone.
International benchmarks/best practices for liquefied hydrogen operation/port integration not available	Unclear situation impedes evaluation and decision-making process and results in reservations towards integration	Study impacts and drive consensus towards integration setting a new national standard
Lack of experience	Overly cautious/restrictive requirements imposed on port and plant by regulators	Engage in coordination and develop best practice proactively
Highly flammable and explosive (small amount of energy required for ignition)	Dangerous commodity requires highest safety standards and community acceptance	High level of engineering knowledge required. Necessitates special handling to prevent the inadvertent mixing of hydrogen with air and buffer zones to ensure safety requirements

Hydrogen integration options may impact future strategic port development

Numerous uncertainties with effects on port development and area utilization



Vessel sizes

Vessel size may trigger massive capital projects (berth and channel)

Community acceptance

Harmony with community endangered due to unknown product characteristics

Future port development

Possible exclusion zones may limit port income from other commodities

Business continuity

Operational risks / disturbances for exising commodities

Site requirements

Exclusion zones limit port capacity

Environmental impact

Compromises might be required to protect environment

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Challenges and requirements for landside storage and handling

Different derivates have different handling risks and determine the location for handling in a port

- Fire and explosion (H2), toxicity (ammonia), few health risks (H2, Methan and Bio-fuel)
- Logic of protecting sensitive assets and goods and safety distances
  - 500m for cold ammonia (warm ammonia more difficult in handling)
  - 200m for H2
  - Safety concepts and incidents management need to be in place and can reduce safety distances
- Building on established procedures and technology is key (ammonia, Methanol, and bio-fuels, LOHC)
- Green energy carrier and fuels are not new to ports: E-methanol, bio-fuels and LOHC can be stored and handled in existing oil tanks
- No logistics value chain for LH2
- No safety experience for large scale crackers
- All emissions have to be managed, e.g. smell NH3

Expected vessel dimensions of sustainable energy imports

	Current dimensions	Expected prospective dimensions
LH2 hydrogen tanker	Suiso Frontier , **Volume** 1.250 m³ **Dimensions:** Length 116 m, draft 10.6 m	**Volume** 160.000 m3 (4* 40.000m³ tanks, AiP by Kawasaki) **Approx. dimensions** Length 346 m, width 57 m, draft 9.5 m
Ammonia – LPG carrier	**Volume** 75.000 m³ / 51.000 t **Approx. dimensions**: Length 205 m, width 32 m, draft 12.2 m	**Volume** 91,000 m3 (Very Large Gas Carrier (VLGC) **Approx. dimensions:** Length 230 m, width 36,60 m, draft 12.2 m
E-Methanol – product tanker	**Volume** 58.000 m³ / 46.000 t **Approx Dimensions** length 186 m, width 32 m draft ca. 12 m	Additional scaling unclear prospectively equal to NH3 vessels.
LOHC - product tanker	**First volumes in Container**	**Small to mid size product tankers**
BIO-LNG – LNG tanker	**LNG tanker dimensions**	**LNG tanker dimensions**
BIO-Fuels – product tanker	**Product tanker dimensions**	**Product tanker dimensions**

- Due to lower volumetric energy density of hydrogen derivates larger ships with large tanks or more vessels calls are expected
- Locally check, if additional measures needed (mandatory pilot, mandatory tug boat, VTS, restrictions in visibility range)
- Designated tank ship area is needed for berthing and handling – restrictions for vessels and handling
- Dedicated collision protection required

Key uncertainties are segmented in four interdependent clusters and suggested to be addressed in three workstreams

Hydrogen integration assessment - Clusters

Legal
What can be done do to encourage regulatory frameworks supporting H_2 integration in ports?

Port Planning
How to integrate H_2 in the port whilst retaining and growing current businesses and building in physical and commercial resilience

Commercial
Does it pay? And if so under which operating model?

Community / Social Licence to operate
What measures have to be taken to achieve a lasting community acceptance?

1 **Regulatory Workstream**

2 **Port Impact Workstream**

3 **Community Engagement Workstream**

Regulatory workstream designed to help facilitate the establishment of a framework for hydrogen operation in ports

Legal Framework

- Review existing legislated framework, identify current gaps in safety standards
- Assess planned legislation initiatives impacting hydrogen in ports
- International legislative framework benchmark

General Framework

- Check applicability of potentially relevant and influential codes (IGC, IMDG, etc.)
- Assess and understand impacts on port planning and operation assumptions

Environmental Framework

- Assess applicability and requirements towards environmental impact assessment (EIA) based on national standards and regulations
- Highlight indicative repercussions for the implementation and export of hydrogen and possible compromises to be made

Assessments from the regulatory workstream are assumed to assist in shaping the regulatory framework towards reasonably encouraging hydrogen handling in ports in Australia

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Port impact workstream assesses the impacts of hydrogen integration in the port considering the input variables preparing for commercial discussions

Ship Size Scenario	Regulatory „allowances“	Evaluation of Opportunities	Financial Analysis
Different ship sizes and their impact on ▪ Channel ▪ On-port facilites ▪ Production link (not! Production itself)	The dimensions of regulatory requirements towards safe handling ▪ Unconstrained ▪ Restricted buffer zone use ▪ Strict exlusion zones	Options sketching as basis for future developments, detailing ▪ Land use plan ▪ Capacities ▪ Potential need for and cost of relocating existing businesses ▪ Flexibility and resilience to market changes	▪ Port activity / responsibility related Capex & Opex ▪ Revenue ▪ Project NPV and IRR ▪ Sensitivity analysis ▪ Opportunity cost assessment

Understanding the impact of variable planning factors on terminal operations and business opportunities and facilitate factual discussion basis for pricing and ownership models

Community Engagement Workstream

Proximity to City - Community sentiments

- Identification and clustering of stakeholder groups
- Capture key concerns and reservations
- Identify drivers for hydrogen integration perception
- Development of communication action plan detailing
  - Groups
  - Participants
  - Messaging
- Seek regional and federal political support

Community engagement ownership to stay with the port to create a sense of accountability with the public

TOP 5:
Discussion

What degree of centralization (responsibilities of a specific "hub authority") do you think is necessary?

Kerala?

Decentralized/
Market-driven

Driven by community of partners

Hamburg Hydrogen Hub

Central/
Govern- mental driven

Driven by single institution "Hydrogen Hub Authority"

How to approach “Offtake-Agreements”?


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