MODULE 4:

HYDROGEN LOGISTICS AND SUPPLY CHAIN ADMINISTRATION

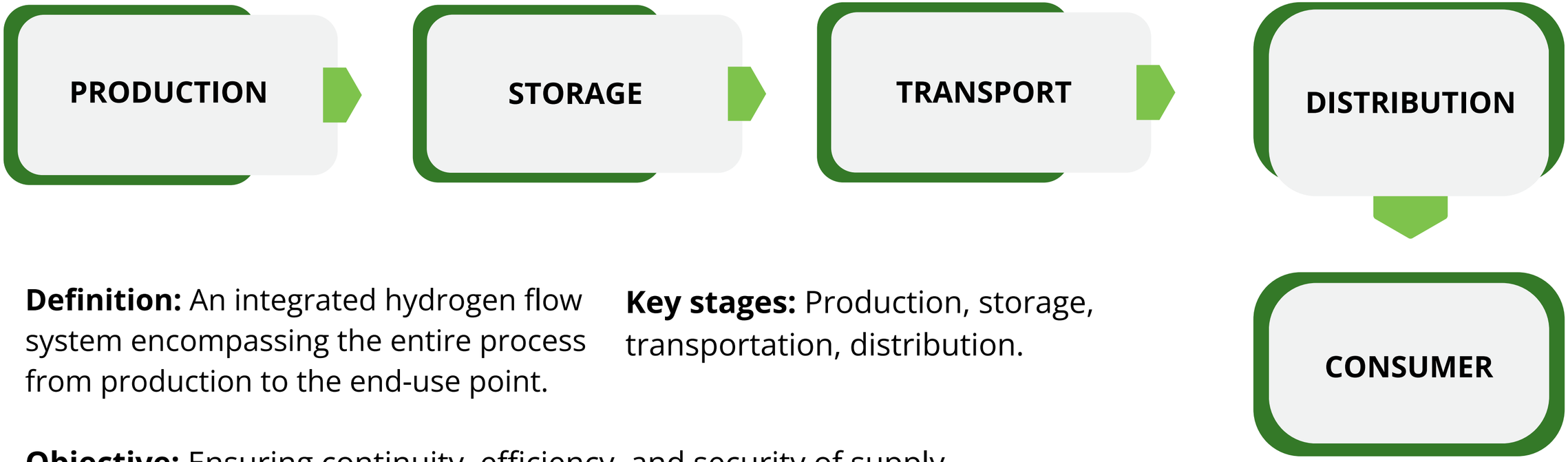
PRESENTATION

Co-funded by the European Union

The singular entity:
Mastering the Instruments for the Hydrogen Sector

- Comprehending the intricacies of the hydrogen supply chain.
- Comprehending essential operational and regulatory challenges.
- Mastering logistics planning and optimization techniques.
- Acquaintance with hydrogen storage management.
- Understanding the significance of process efficiency (Lean, Six Sigma).
- Overview of digital tools facilitating hydrogen logistics.

Hydrogen Supply Chain:
From Production to Consumer



Definition: An integrated hydrogen flow system encompassing the entire process from production to the end-use point.

Key stages: Production, storage, transportation, distribution.

Objective: Ensuring continuity, efficiency, and security of supply.

Hydrogen Generation:
Sources and Methodologies

“Gray” hydrogen

From natural gas reforming (SMR), accompanied by CO2 emissions.

“Blue” hydrogen

From natural gas reforming with carbon dioxide capture and storage (CCS).

“Green” hydrogen

From water electrolysis utilizing renewable energy sources such as wind and solar power.

Alternative approaches

Methane pyrolysis, biomass electrolysis.

Hydrogen Storage:
Forms and Challenges

Compressed hydrogen (CGH2): Stored in high-pressure tanks (200-700 bar). The most widely utilized form.

Liquid hydrogen (LH2): Stored in cryogenic tanks at -253°C. It possesses a high volumetric energy density; however, it is associated with significant costs and evaporation losses.

Hydrogen in carriers:

- **Chemical:** Ammonia (NH3), methanol, liquid organic hydrogen carriers (LOHC).
- **Physical:** Metallic hydrides, porous substances.

Hydrogen Transportation:
Diversity of Methods

- **Road transport:** Tankers for compressed or liquefied hydrogen (most popular for short to medium distances).
- **Rail transport:** Specialized tank cars, increased capacities.
- **Pipelines:** Most efficient for substantial volumes and established connections (dedicated or modified from natural gas).
- **Maritime transport:** Vessels for the transportation of LH2 or hydrogen carriers (e.g., ammonia).

Hydrogen Distribution:
To the Endpoint

- **Refueling stations:** Designed for hydrogen fuel cell electric vehicles (FCEV).
- **Direct deliveries:** To industrial facilities (refineries, fertilizer manufacturing, metallurgy).
- **Energy provision:** Hydrogen power facilities, energy storage systems.
- **Additional applications:** Heating, aviation, and marine fuel.

Refueling facilities

Direct shipments

Power source

Operational Challenges:
The specificity of hydrogen.

- **Low volumetric energy density:** necessitates high pressure or liquefaction, thereby elevating costs and complexity.
- **Flammability and extensive explosive range:** Necessity for rigorous safety protocols.

- **Diffusivity:** Hydrogen readily permeates materials, necessitating specialized sealing and detection measures.
- **Hydrogen embrittlement:** Impacts on structural materials, susceptibility to cracking.

Operational Challenges:
Infrastructure and Economic Factors

- **Limited infrastructure:** An inadequate pipeline network, a deficient number of refueling stations, and insufficient storage facilities.
- **High initial expenditures (CAPEX):** Investments in production, storage, and transportation.
- **Elevated operational expenses (OPEX):** Compression, condensation, cooling, energy consumption.
- **Scalability:** Challenges in rapidly expanding operations to accommodate large volumes.

Regulatory Obstacles:
Absence of Unified Regulations

- **International disparities:** Inconsistent regulations across countries and regions impede the global hydrogen trade.
- **Dynamic development:** Regulations and standards are undergoing continuous evolution and adaptation to emerging technologies.
- **Complexity:** The requirements for transport, storage, certification, and safety are frequently intricate.

Regulatory Obstacles:
Social Acceptance and Education

Risk perception: Public apprehensions regarding hydrogen safety (e.g., historical incidents, imperceptible flame).

Insufficient knowledge: Limited public awareness regarding the characteristics and safe management of hydrogen.

Education and Communication: The necessity of effective education and transparent communication to foster trust and acceptance.

Local regulations: Resistance from local communities regarding the development of hydrogen infrastructure.

Hydrogen Logistics Planning:
A Strategic Framework

Objective: To guarantee the uninterrupted supply of hydrogen (in suitable quantity, quality, timing, and location) while reducing costs and mitigating risks.

Key components:

- Supply and demand assessment.
- Selection of optimal storage and transportation technologies.
- Logistics network configuration.
- Risk management and regulatory adherence.

Demand Forecasting:
Demand Prediction

Importance: Essential for efficient production planning, transportation capacity, and inventory management.

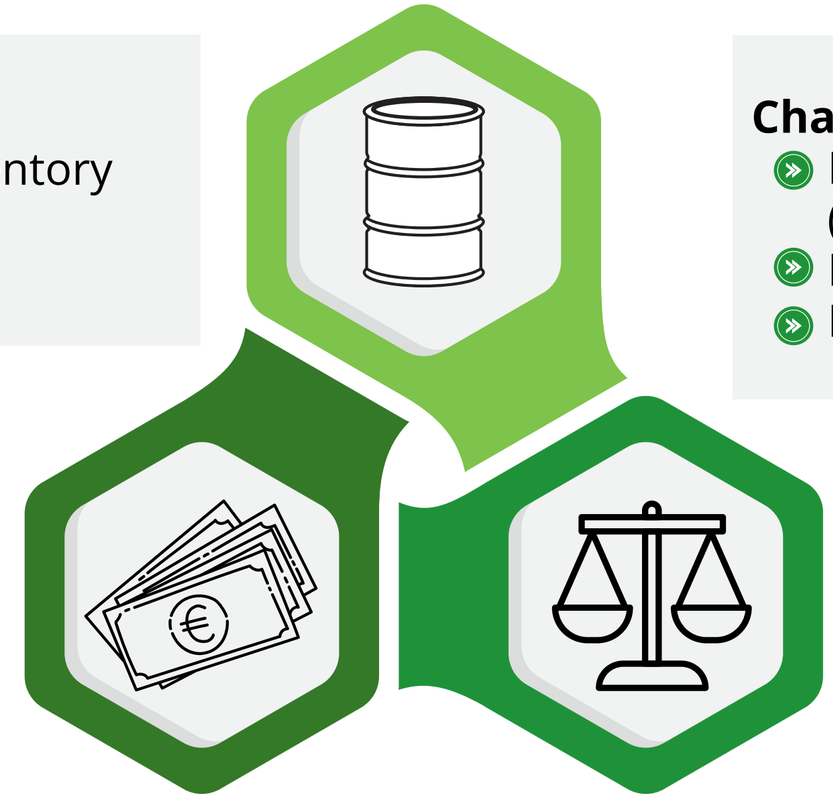
Methods:

- Analysis of historical data, if accessible.
- Market trend analysis (FCEV development, hydrogen sector).
- Predictive models (statistical and machine learning).
- Analysis of macroeconomic and political variables.

Inventory Management:
Balance of Cost and Accessibility

The singular entity:
Ensuring optimal hydrogen inventory levels across the supply chain.

Strategy:
Just-in-Time (JIT), minimal safety stocks, centralization and decentralization of warehouses.

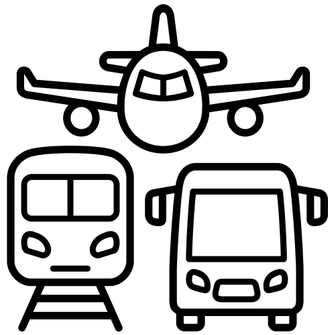


Challenges:
- Elevated storage expenses (particularly for LH2).
- Particular safety requirements.
- Risk of loss (e.g., evaporation).

Transport Optimization:
Efficiency and Safety

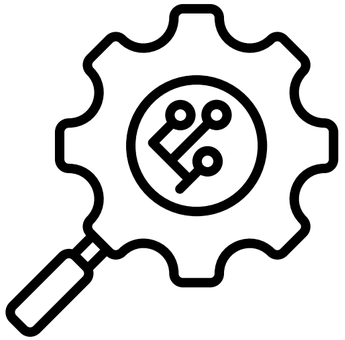
Route optimization

The utilization of algorithms and software (TMS) to ascertain the most efficient, secure, and cost-effective routes.



Selecting a mode of transportation

It depends on the distance, volume, form of hydrogen, and associated costs.



Optimization criteria

Delivery duration, fuel efficiency, toll fees, regulatory constraints (ADR), safety considerations.

Hydrogen Storage Administration:
Types and Characteristics

- **Pressure vessels:** Steel or composite materials designed for hydrogen gas (200-700 bar).
- **Cryogenic tanks:** Designed for liquid hydrogen (LH2), featuring advanced vacuum insulation.

- **Underground storage:** In salt caverns or exhausted gas fields (substantial volumes, long-term).
- **Storage in carriers:** ammonia tanks, liquid organic hydrogen carriers (LOHC), etc.

Warehouse Automation:
Safety and Efficiency

- **Monitoring systems:** Ongoing assessment of hydrogen concentration, temperature, pressure, and flow.
- **Automatic ventilation systems:** Engaged upon detection of a hazardous concentration of hydrogen.
- **Automatic shut-off systems:** Rapidly close valves and terminate the hydrogen supply in the event of an emergency.
- **Robotics and drones:** Utilized for inspection, monitoring, and maintenance in inaccessible or hazardous locations.

Standards and Safety:
The Hydrogen Storage Foundation

1. **Location:** Optimal positioning of warehouses (proximity to structures, thoroughfares).

2. **Design specifications:** Hydrogen-resistant materials, sufficient ventilation, explosion-risk areas (ATEX).

3. **Safety systems:** Hydrogen detection devices, fire suppression systems, alarm systems, emergency stop switches.

4. **Operating Procedures:** Formulate and comply with stringent operating and maintenance protocols.

Process Efficiency:
Lean Management in Hydrogen Logistics

The Lean Individual:
Identification and eradication of waste (Muda) in logistics processes.

Benefits:
Cost reduction, speed enhancement, and improvements in quality and safety.

APPLICATION ILLUSTRATIONS

Flow optimization:

Minimization of superfluous movements and transport.

Waiting Time Reduction:

Minimizing the interval between phases of the process.

Minimizing Inventory:

Retaining Only the Essentials inventory (JIT).

Quality enhancement:

Removal of errors and defects.

Process Efficiency:
Six Sigma in Hydrogen Logistics

Six Sigma Objective: Minimize variation and defects (errors) in processes to a level approaching zero (3.4 defects per million opportunities).

DMAIC Methodology: Define, Measure, Analyze, Enhance, Control.

Benefits: Enhanced reliability, superior quality, diminished expenses, enhanced security.

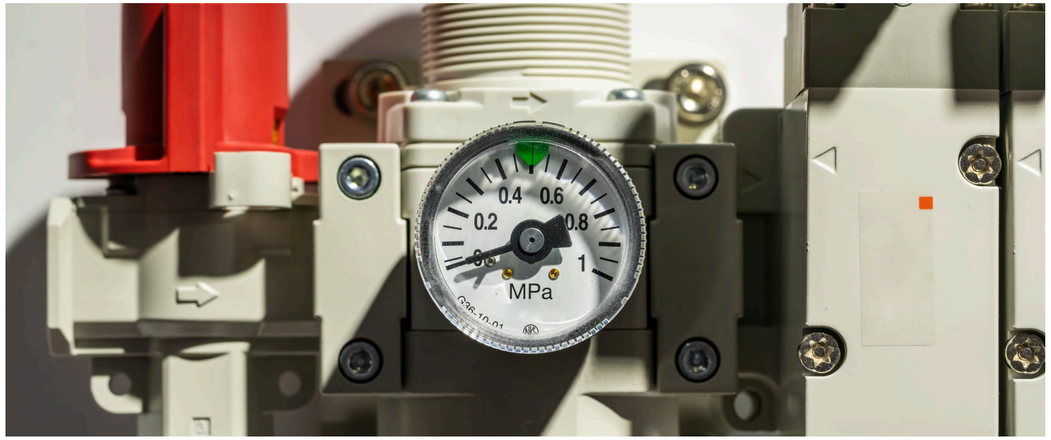
Application Illustrations:

- Enhancing the quality of hydrogen supplies (purity, pressure).
- Minimization of errors in transportation documentation.
- Optimization of energy usage in processescompression/ condensation.

Minimizing Losses:
Minimizing Leaks and Breaches

Losses: Natural hydrogen losses (e.g., LH2 evaporation, diffusion through materials).

Leaks: Uncontrolled discharge of hydrogen from facilities (malfunctions, leaks).



Minimization strategies:

- Routine leak inspections and maintenance.
- Utilization of premium materials and seals.
- Optimization of storage conditions (insulation and pressure).
- Rapid identification and response to leaks.
- Ongoing training and staff awareness initiatives.

WMS
Hydrogen Storage Administration

Functions: Monitoring hydrogen placement (tanks, batches), management of warehouse space, optimization of receipt and issuance processes, and real-time inventory oversight.

Hydrogen-specific: Integration with security systems (detectors, alarms) and management of LH2 batches (evaporation monitoring).

Benefits: Enhanced accuracy, efficiency, and safety of warehouse operations, along with a reduction in errors.

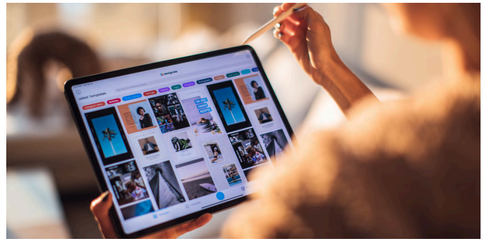
Digital Instruments:
TMS – Hydrogen Transportation Management

Functions: Route planning and optimization, real-time shipment tracking (GPS), vehicle fleet management, transportation cost optimization, documentation management.

Hydrogen specificity: Considering ADR restrictions, monitoring pressure and temperature in tanks, risk management along the route.

Benefits: Decrease in transportation expenses, enhancement of punctuality resources, enhanced security, improved oversight.

GPS-equipped truck



TMS interface display

Key Messages:
Holistic Approach

- **End-to-end supply chain:** Encompassing production to distribution, along with its distinct challenges.
- **Strategic planning:** Crucial for optimizing costs and enhancing security.
- **Innovative Warehouse Management:** Diverse Approaches storage, automation.
- **Process efficiency:** Employing Lean and Six Sigma methodologies to reduce waste and enhance quality.
- **Digital tools:** WMS and TMS as the cornerstone of contemporary logistics.
- **Safety:** The paramount concern at every phase of the supply chain.

THANK YOU FOR YOUR CONSIDERATION!
QUESTIONS?

- Prepared for the hydrogen future!
- We invite you to pose inquiries and engage in further discussion.

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