Østfold University College

Repowering the EU with Clean Hydrogen Solutions towards Green Energy Transition

Role of AI and IoT in Green Hydrogen

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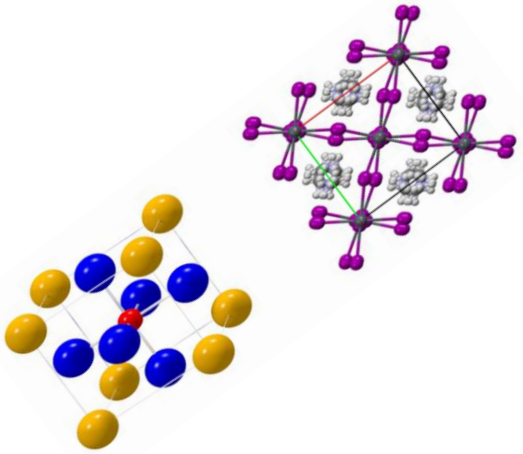


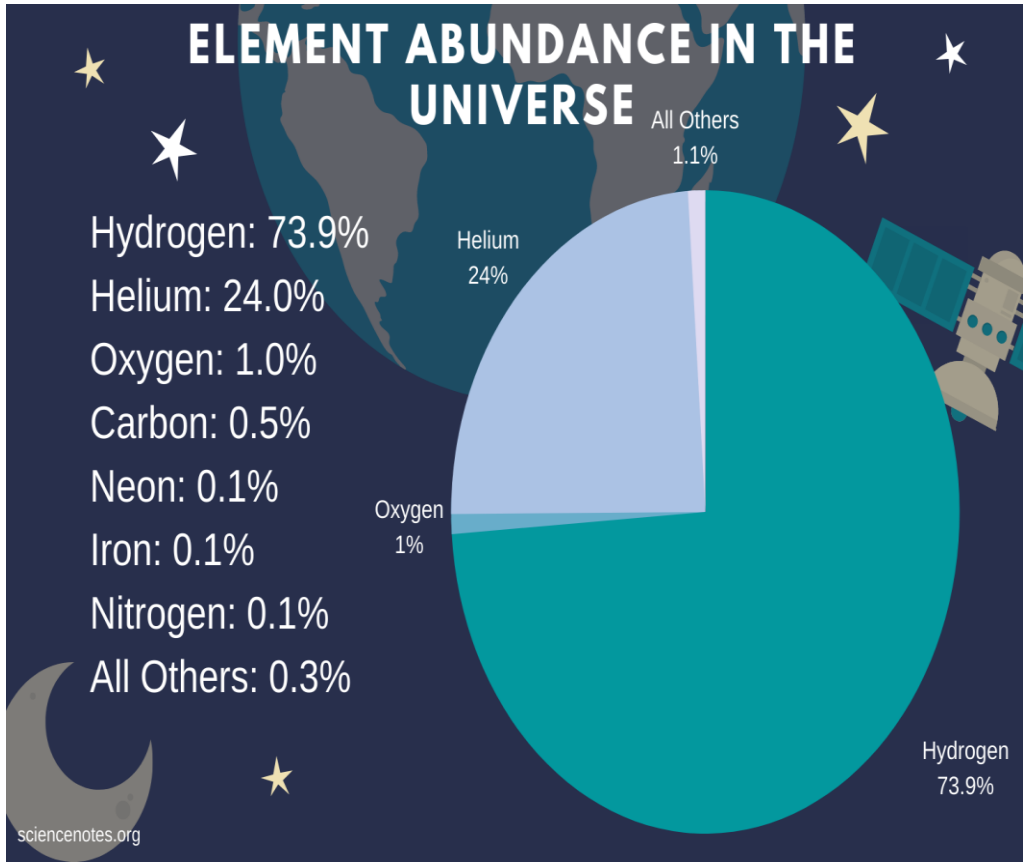
Scope and Objectives of the Presentation

- Green hydrogen
- Production methods & Comparative analysis
- Seawater Hydrogen Production
- IoT in Seawater Hydrogen plants
- AI in Seawater Hydrogen plants
- Grid Stabilization and energy management
- Benefits and Challenges
- Future Directions

Overview

Hydrogen Energy Overview

- **Hydrogen:** simplest and most abundant molecule in the universe.
- **High energy content per unit weight**, approximately three times higher than fossil fuels.
- Produces water vapor when combusted, **emitting no greenhouse gases**.
- Can be used **in fuel cells for electricity** or **directly as fuel** for heat and transportation.
- **A kg of hydrogen** has energy equivalent to **7-8 kg of coal** equivalent without associated carbon of coal and **3 kg of natural gas** or 42 NM3 CNG.



- Hydrogen has the **highest carbon free energy**
- 33.2 kWhr (**30,000 Kcal/kg**) energy compared to any other energy resource.

Green Hydrogen

Green Hydrogen in Sustainable Energy

- Produced using **renewable energy sources**, unlike gray or blue hydrogen.
- **Zero emissions** through electrolysis powered by wind, solar, or hydroelectric power.
- Significant role in **decarbonizing heavy industry and long-haul transportation**.
- **Green Hydrogen** means the cleanest form of hydrogen production, utilizing renewable electricity to split water through electrolysis process.

Hydrogen Production

Green Hydrogen Production Methods

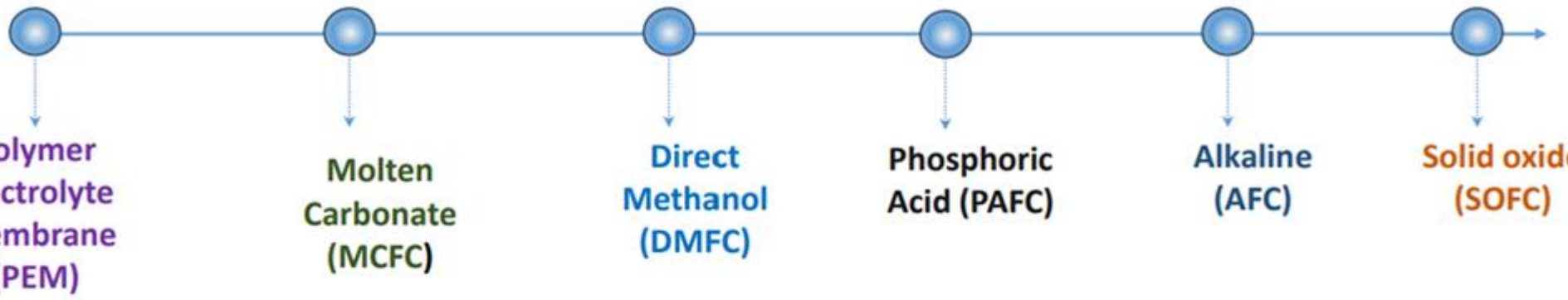
- **Water Electrolysis:** Decomposition of water into hydrogen and oxygen using electricity from renewable sources.
- **Alkaline Electrolysis:** Uses a solution of water and a strong electrolyte, facilitated by metal electrodes.
- **Proton Exchange Membrane (PEM) Electrolysis:** Uses a solid polymer as an electrolyte, operates at high current densities.
- **Solid Oxide Electrolysis:** Uses a solid ceramic material as an electrolyte, works at high temperatures and efficiencies.
- **Biological Methods:** Includes photosynthetic water splitting, enzymatic hydrogen production, and microbial electrolysis.

Cost and Efficiency Analysis of Hydrogen Production

- **High costs** due to electrolysis equipment and energy requirements.
- **Efficiency varies**: Alkaline (70-80%), PEM (60-70%), Solid Oxide (over 80% under certain conditions).
- **Technological advancements and economies of scale** expected to reduce costs, making green hydrogen competitive.

	Alkaline	PEM	SOE	AEM
Electrolyte	Aqueous potassium hydroxide	PFSA membranes (e.g., Nafion)	Yttria Stabilises Zirconia (YSZ)	Anion exchange ionomer
Cathode	Nickel, Nickel - Molybdenum alloy	Platinum, Platinum - Palladium alloy	Nickel/YSZ	Nickel and Nickel alloys
Anode	Nickel, Nickel - Cobalt alloys	Ruthenium oxide, Iridium oxide	YSZ	Nickel, Ferrous, Cobalt oxides
Operating Temperature (°C)	60-80	50-80	500-850	50-60
Operating Pressure (Bar)	30	70	1-25	1-30
Stack Lifetime (h)	60-100k	20-60k	<10k	-
Technology Readiness	Matured	Commercialised	Demonstration	Large prototype
Cost	USD 500-1400/kW	USD 1100-1800/kW	USD 2800-5600/kW	

Suitability Analysis of Hydrogen Production



	Polymer Electrolyte Membrane (PEM)	Molten Carbonate (MCFC)	Direct Methanol (DMFC)	Phosphoric Acid (PAFC)	Alkaline (AFC)	Solid oxide (SOFC)
Electrolyte	Polymer membrane	Molten Carbonate	Methanol	Phosphoric salt	KOH	Yttria-Stabilized Zirconia (YSZ
Type	Solid/liquid	Solid	liquid	Liquid	Liquid	solid
Anode	Platinum	Ceramic	Metal	Platinum	Carbon	Steel/ Nickel
Suitable for	Mobility	Mobility	Potable device	Buildings	Mobility	Power plant

Seawater Hydrogen Production with AI and IoT Integration

Seawater Hydrogen Production in Renewable Energy

Seawater hydrogen becomes a competitive alternative to traditional energy sources.

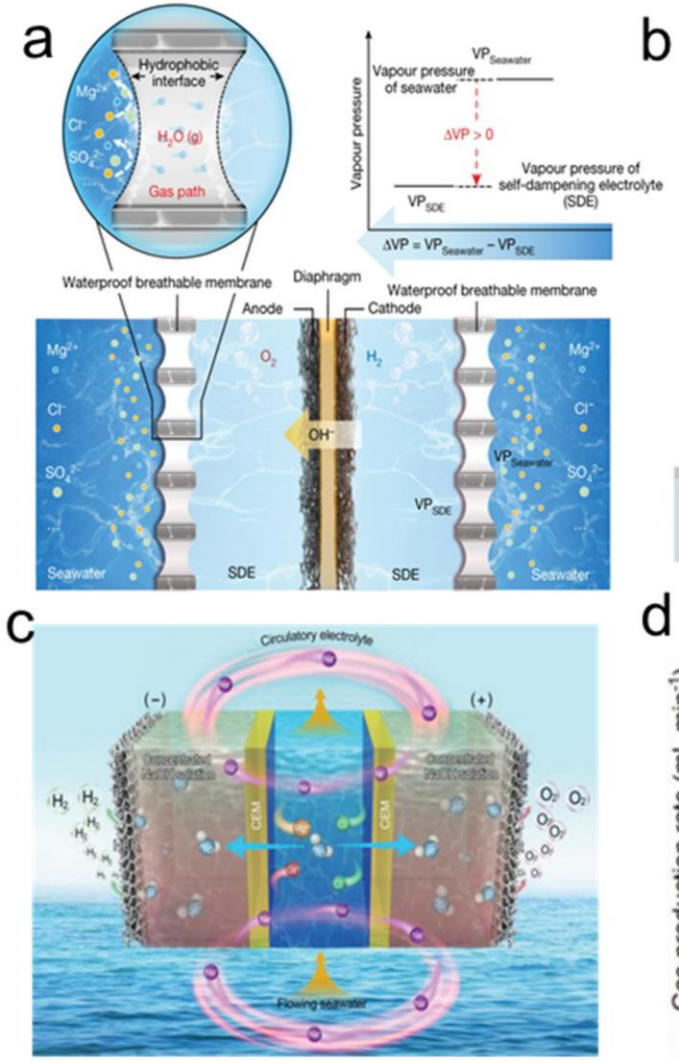
- Plays a critical role in the renewable energy sector.
- AI and IoT reshape plant operations for enhanced efficiency, cost reduction, and reliability.
  -

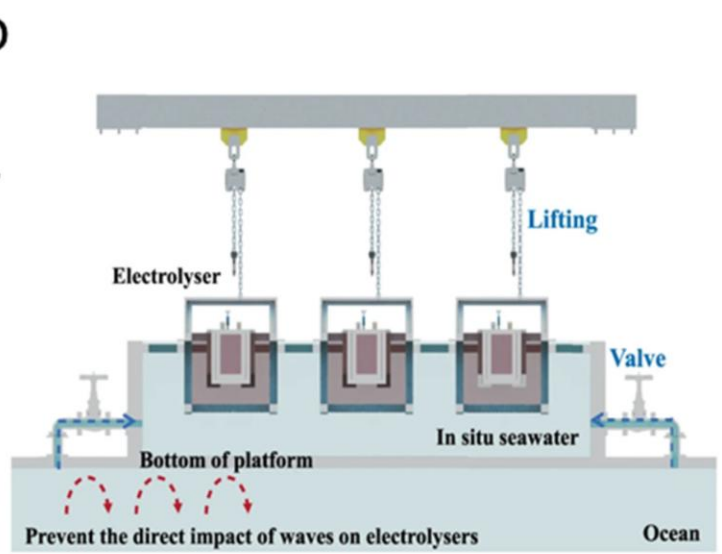
IoT in Seawater Hydrogen Plants

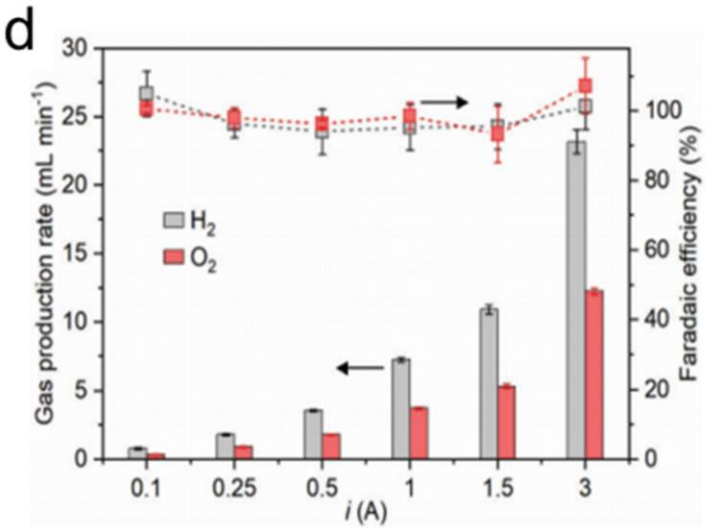
Real-Time Data Collection:

- IoT sensors track electrolyzer performance, seawater salinity, temperature, equipment health, and renewable energy fluctuations.

- Enables informed, real-time decision-making for plant operators.







IoT in Seawater Hydrogen Plants

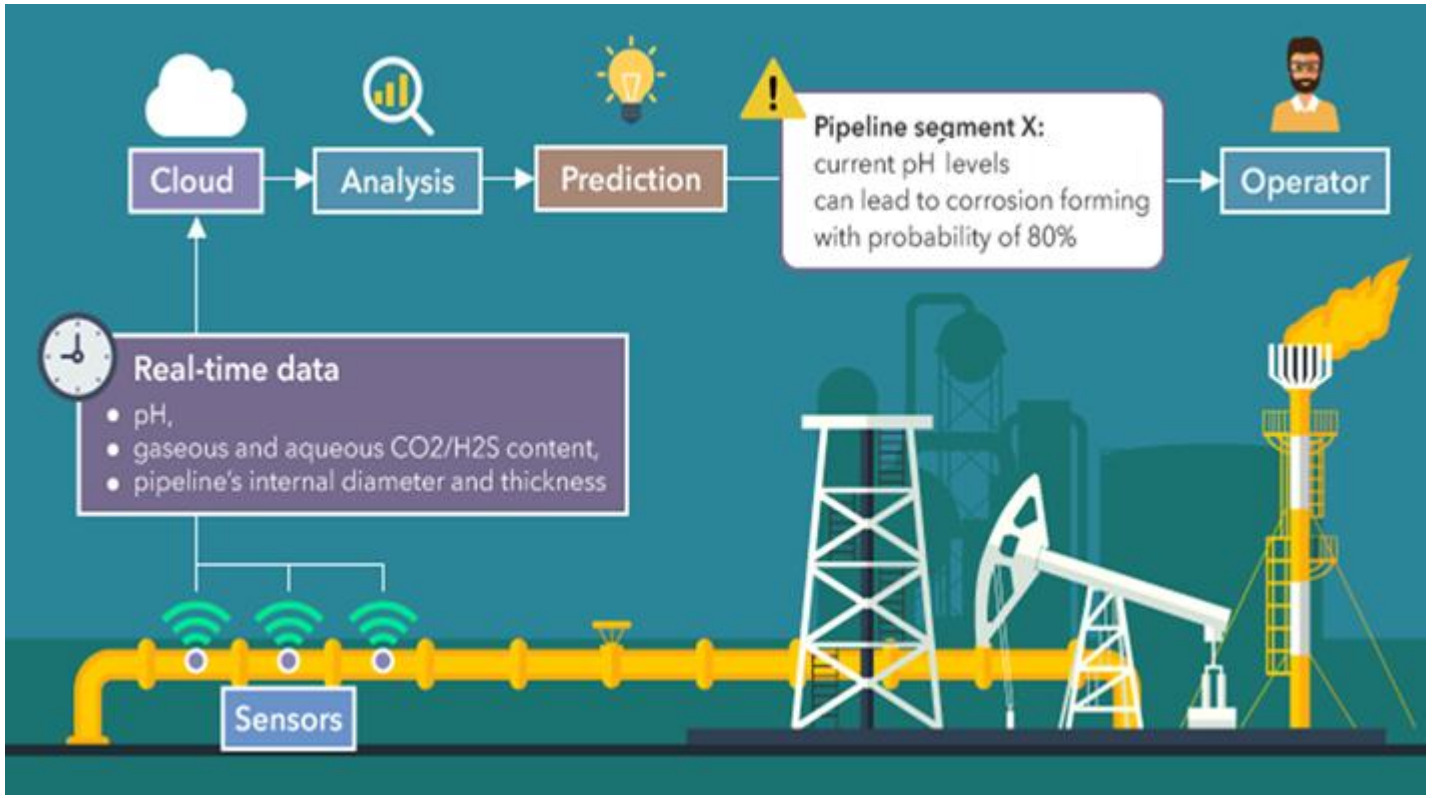
Predictive Maintenance:

• AI analyzes sensor data to predict equipment failure or servicing needs.

• Prevents costly downtime and extends the lifespan of components like electrolyzers prone to saltwater corrosion.

Monitoring Marine Challenges:

IoT sensors helps in addressing issues like salt corrosion and maintaining system integrity.



AI in Seawater Hydrogen Plants

AI in Energy Optimization:

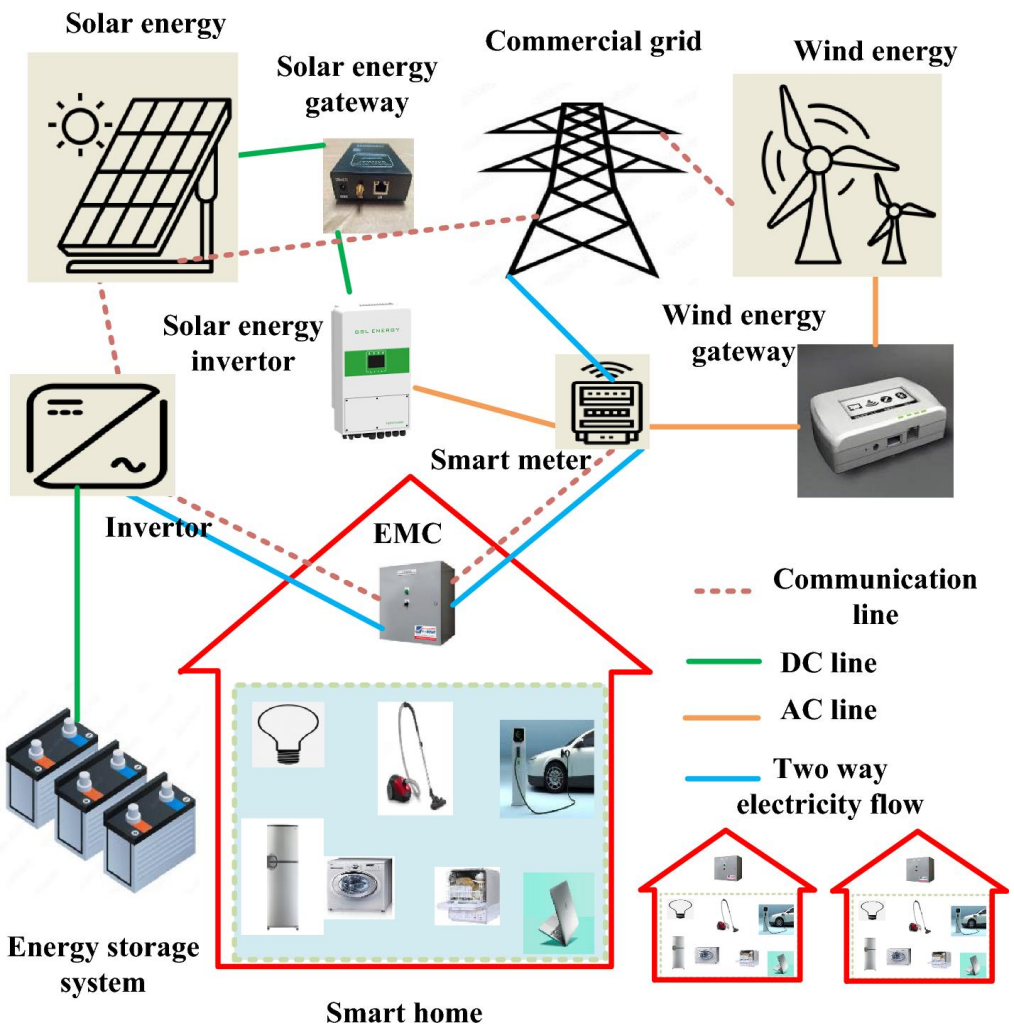
- Aligns hydrogen production with renewable energy availability (e.g., solar and wind peaks).

- Dynamically manages energy inputs to maximize efficiency and reduce costs.

AI in Chlorine Suppression:

- AI minimizes chlorine byproduct formation during electrolysis.

- Ensures safer and more environmentally friendly operations.



AI in Seawater Hydrogen Plants

Catalyst Performance Management:

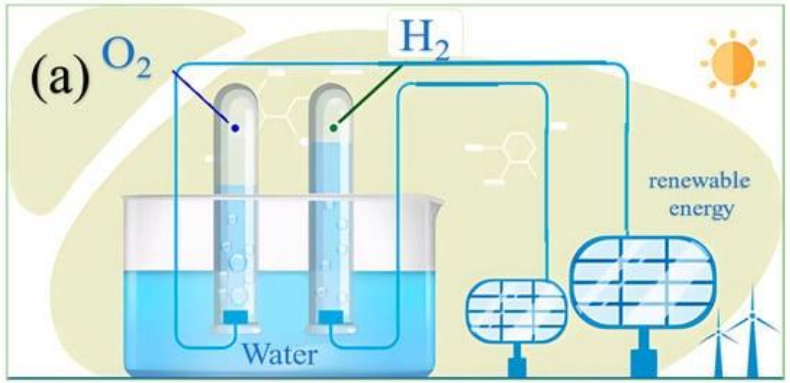
- Machine learning predicts catalyst wear and optimizes replacements or upgrades.

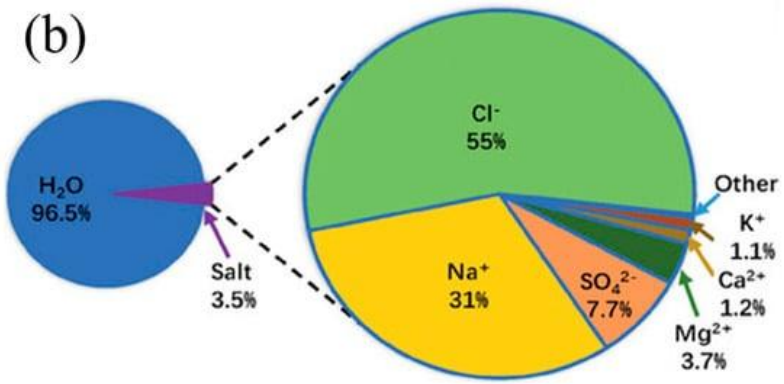
- Advances catalyst design for improved durability and efficiency.

Integration with Renewable Energy Systems:

- Hydrogen plants act as both energy consumers and storage solutions.

- Certainly, IoT and AI enable seamless integration into smart grids.





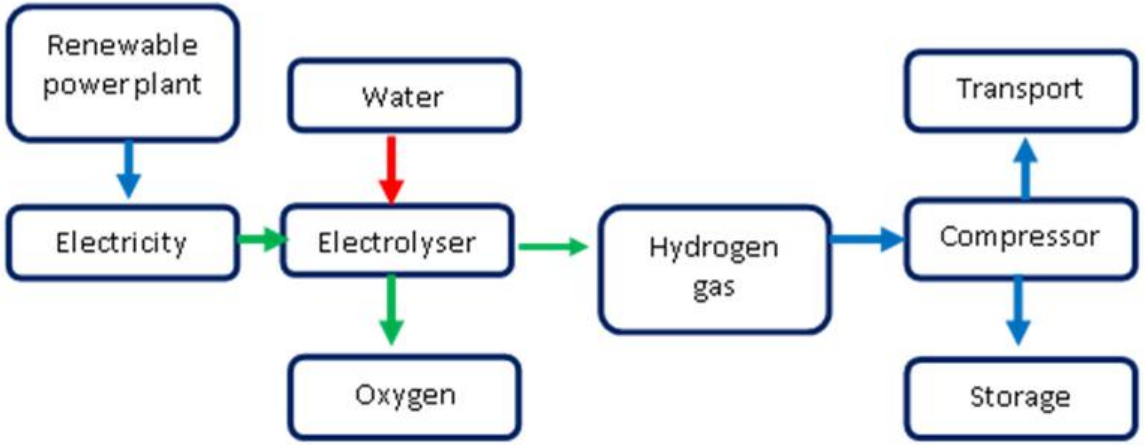
Grid Stabilization and Renewable Energy Utilization

in Seawater Hydrogen Plants

- **AI-driven** systems align supply and demand (dynamic automated response).

- Surplus renewable energy during low demand periods can be stored as hydrogen, stabilizing the grid and ensuring efficient energy use.

- IoT sensors monitor grid conditions in real-time, enabling dynamic adjustments in hydrogen production rates.



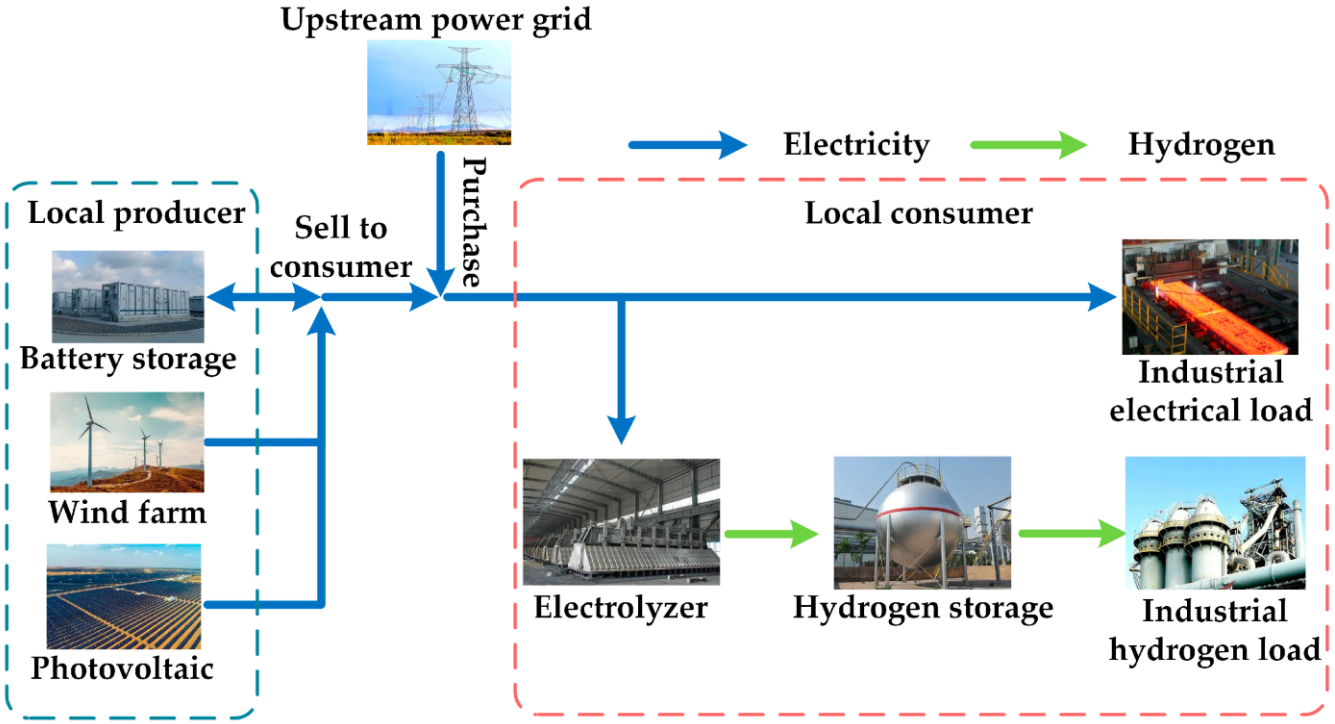
Optimal capacity planning of green energy – Multi-Energy system

Flexible Energy Management

in Seawater Hydrogen Plants

- Hydrogen plants act as flexible loads, absorbing excess electricity during overgeneration and converting stored hydrogen back into electricity **during shortages.**

- This capability balances supply and demand, making hydrogen plants integral to modern energy systems.



Optimal capacity planning of green energy – Multi-Energy system

AI Integration with Renewable Energy Systems:

in Seawater Hydrogen Plants

Real-World Applications:

- **Australia:** AI-driven systems that optimize hydrogen production based on real-time solar and wind output.
- **Singapore:** IoT-enabled compact electrolyzers provide to urban needs, monitoring metrics and adjusting operations efficiently.
- **Norway:** IoT monitors coastal hydrogen plants, tracking ocean conditions and optimizing electrolyzer performance to reduce maintenance costs.

1. Langstranda – Bodø, 2. Sandnessjøen, 3. Slagentangen – Tønsberg,4. Vestbase – Kristiansund, 5. Årdalsfjorden

https://greenh.no/en/projects/

Efficiency and Sustainability Benefits

- AI and IoT increase efficiency of the production plant by optimizing energy use, reducing waste, and maximizing hydrogen output.

- Predictive maintenance extends component lifespan, minimizes downtime, and **reduces operational costs**.

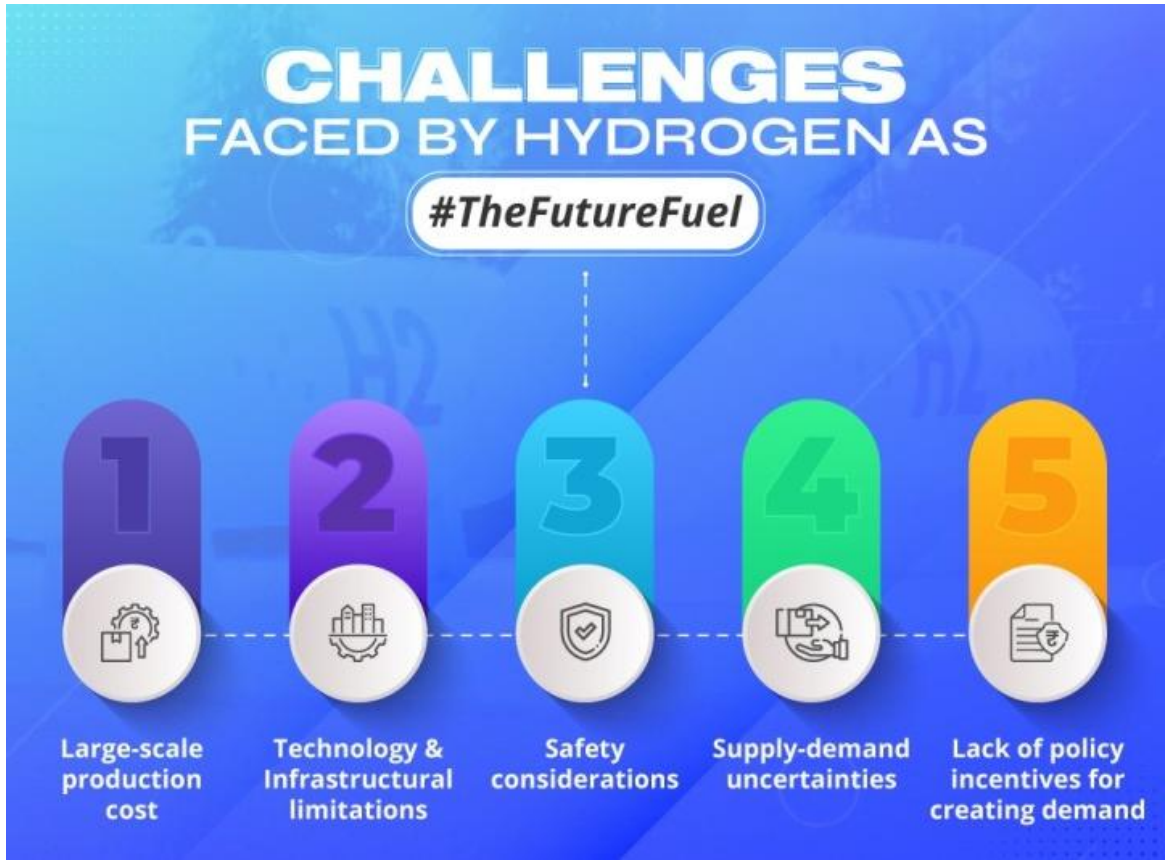
- Enhanced chlorine suppression and integration with renewables improve the environmental sustainability of hydrogen production.

Challenges in Implementation

- **High Initial Costs:** May discourage adoption, especially in developing regions.

- **Data Security:** Interconnected systems are vulnerable to cyber threats.

- **Integration Issues:** Requires advanced expertise and robust networks for compatibility with existing infrastructure.

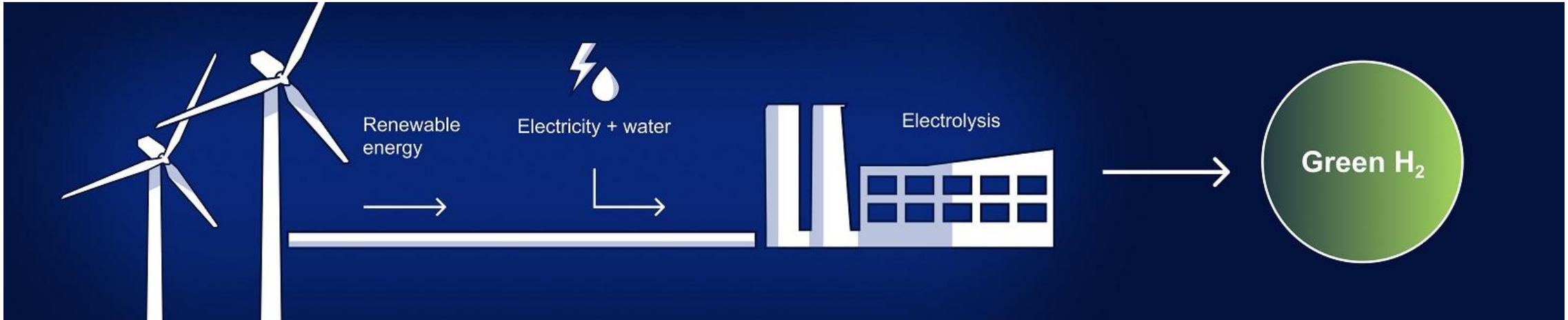


Future directions

• Advances in machine learning and sensor technology will further enhance optimization and cost-effectiveness.

• Increased integration into smart grids will stabilize energy systems and reduce emissions.

• Ongoing and **upcoming research works** and innovation will make seawater hydrogen plants more viable and scalable, **revolutionizing the energy industry**.



Summary

- AI and IoT are transforming seawater hydrogen plants into scalable solutions for clean energy production.

- Real-time monitoring, predictive maintenance, and smart grid integration: these technologies unlock **the potential of seawater** as **a sustainable resource**.

- As pilot projects evolve, AI and IoT will drive efficiency, sustainability, and innovation **in the renewable energy sector**.

Thank You !