NEXT IAS

DAILY EDITORIAL ANALYSIS

TOPIC

HYDROGEN TRAINS IN INDIA: A GREEN TRANSITION OR A TECHNOLOGICAL EXPERIMENT

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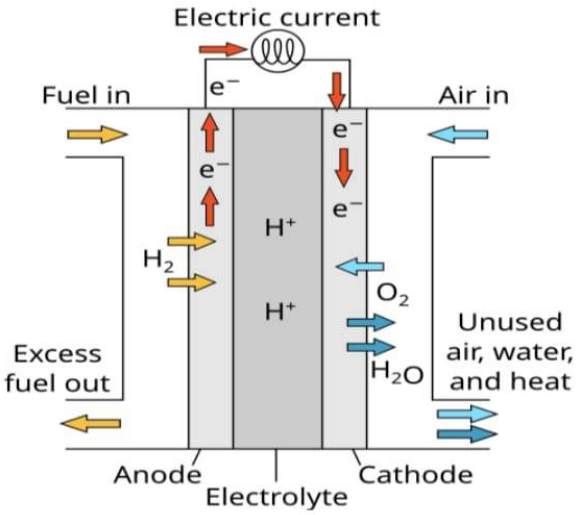
Context

- **India's first hydrogen train** was recently flagged off by the Prime Minister of India at the Jind railway station in Haryana, making **India the third country in the world after Germany and China** to roll out hydrogen trains in commercial passenger service.

About Hydrogen Train

- Hydrogen trains use fuel cells to **combine hydrogen with oxygen** to produce electricity, with the **only direct emission being water vapour.**



- Electricity generated in the **fuel-cell stack** drives electric traction motors, and batteries support acceleration and regenerative braking.
  - **Hydrogen is an energy carrier, not a primary fuel.**
  - The fuel-cell stack of India's prototype is imported.
  - Propulsion systems, control systems and train integration have been developed indigenously, showing India's engineering capability.
- It is consistent with the **National Green Hydrogen Mission** to promote clean hydrogen technologies.

Global Experience with Hydrogen Rail

- Across the world, hydrogen trains are mainly for **regional lines without electrification** where electrification is not economically feasible.
- **Germany** led the way with commercial hydrogen rail (Alstom Coradia iLint, 2022).
  - But many operators have since moved to **battery-electric trains** because of fuel-cell degradation, maintenance difficulties, hydrogen supply issues and operational costs.
- **China** has introduced hydrogen trains on selected routes.
- Countries such as **Japan, South Korea, Sweden, Switzerland and the United States** continue to operate mostly pilot or demonstration projects while assessing long-term viability.

India's First Hydrogen Train Project

- Indian Railways is set to launch hydrogen-powered trains as part of its **decarbonisation strategy.**
- The first prototype is being trialled on the **Jind-Sonipat section** of the Northern Railway.
- India has announced plans to build **35 'Hydrogen for Heritage'** trains for **eight narrow-gauge and metre-gauge heritage routes**, where conventional electrification may be environmentally undesirable.
- The project aims to build expertise in hydrogen propulsion, safety, storage and maintenance, while supporting the objectives of the **National Green Hydrogen Mission.**

Significance of Hydrogen Trains

- **Environmental Benefits:** At the point of use, fuel cells emit only water vapour, reducing local air pollution and dependence on diesel.
- **Technological Capability:** Indigenous development of propulsion and control systems strengthens India's railway manufacturing eco-system and supports the Atmanirbhar Bharat initiative.
- **Energy Diversification:** Hydrogen offers a different clean-energy route for transport, cutting long-term reliance on fossil fuels.
- **Strategic Learning**: Operational experience from the prototype will help Indian Railways build expertise in hydrogen storage, safety procedures, maintenance and system integration.

Issues & Concerns

- **Questionable Route Selection:** India is one of the few countries testing hydrogen passenger trains on a **fully electrified railway corridor**, whereas globally hydrogen trains are intended to replace diesel on non-electrified routes.
- **Infrastructure Challenges:** Substantial investment and complex logistics would be needed to develop the necessary hydrogen production, storage and refuelling facilities for geographically dispersed heritage routes.
- **Low Energy Efficiency:** Hydrogen requires multiple energy intensive stages, including production, compression/liquefaction, transport, storage and reconversion into electricity, making it **less energy efficient than battery electric systems.**
- **Green Hydrogen Limitations:** More than 9**5% of the world's hydrogen** is currently derived from natural gas, which produces carbon emissions.
  - Electrolysis using renewable energy is still much more expensive, as is green hydrogen.
- **Limited Progress:** Despite an allocation of **around ₹2,800 crore** for hydrogen train development, there has been relatively little visible progress on heritage train deployment.

Is Hydrogen the Best Green Fuel for Railways?

- Hydrogen is **not always the best solution for rail transport** especially where railway electrification is already in place.
- Indian Railways has electrified **more than 99% of its routes**, which reduces the need for hydrogen on main line corridors.
- **Battery-electric trains** are more energy efficient, have lower operating costs and simpler infrastructure for short and medium-distance routes.
- However, hydrogen still holds promise for use in applications where batteries are not practical, such as **steel and fertilizer production, long-distance shipping and possibly aviation.**
- Therefore, hydrogen should be seen as a **complementary technology** and not as a universal replacement for railway electrification.

Way Forward

- The use of hydrogen trains should be focused on **non-electrified or heritage routes** where electrification is not environmentally or economically suitable.
- Increase **green hydrogen** production with renewable energy to enhance its environmental benefits.
- Conduct detailed **cost-benefit and lifecycle analyses** prior to large-scale deployment.
- At the same time, whenever possible, promotion of **battery-electric trains** should be made for regional services.
- Develop indigenous capabilities in fuel cell technology, hydrogen storage and safety standards and learn from global operational experience.
- Take an **evidence-based approach**, using the Jind-Sonipat prototype as a technology demonstrator before scaling up.

Conclusion

- India's hydrogen train is an important technological milestone and augments domestic engineering capabilities.
  - International experience suggests, however, that hydrogen is not a universal solution for railways.
- Future expansion should be based on operational evidence and economic viability and sustainability rather than on technological enthusiasm alone.
- Indian Railways is exploring the deployment of hydrogen technology on heritage railways, including the **Kalka–Shimla route,** by leveraging the experience gained through the Jind–Sonipat Hydrogen Train project.

Daily Mains Practice Question

[Q] Critically evaluate whether hydrogen-powered trains are the most suitable solution for achieving net-zero emissions in Indian Railways.

Source: BL

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