JSL
JINDAL STAINLESS

STAINLESS STEEL SOLUTIONS FOR
THE HYDROGEN ECONOMY

EFFICIENT

SAFER

LONGER LIFE

A STAINLESS LEGACY

India's leading stainless steel manufacturer, Jindal Stainless, achieved a consolidated annual turnover of INR 38,562 crore (USD 4.7 billion) in FY24. The company is expanding its facilities to reach 4.2 million tonnes of annual melt capacity by 2026. Jindal Stainless operates 16 manufacturing and processing facilities across India, Spain, and Indonesia, with a global network of 12 locations as of March 2024.

Committed to a greener future, Jindal Stainless Steel scrap in electric arc furnaces, reducing greenhouse gas emissions and ensuring high recyclability without quality loss. The company targets a 50% reduction in carbon emission intensity before FY35 and aims for Net Zero by 2050.

HYDROGEN IS NO LONGER A FUTURE FUEL. IT IS TODAY'S IMPERATIVE.

With over 100 countries committing to net-zero emissions, hydrogen has emerged as a critical enabler in the clean energy transition. Its promise lies in versatility: from powering transport and industry to storing and distributing renewable energy, hydrogen offers a zero-emissions solution whose only byproduct is water vapor.

Yet realising its true potential depends on solving complex materials challenges. Global investments in hydrogen infrastructure are accelerating, with green hydrogen production projected to reach **500 million tons annually by 2050**

At the center of this shift stands a material built to endure: Stainless Steel.

KEY HYDROGEN MARKET DRIVERS

GLOBAL NET-ZERO MANDATES:
Driving demand for green hydrogen in energy-intensive sectors

ELECTRIFICATION OF INDUSTRIES:
Electrolyser installations expected to grow 500% by 2030

HYDROGEN MOBILITY:
Fuel cell vehicles, hydrogen refuelling stations, and rail/aviation pilots expanding globally

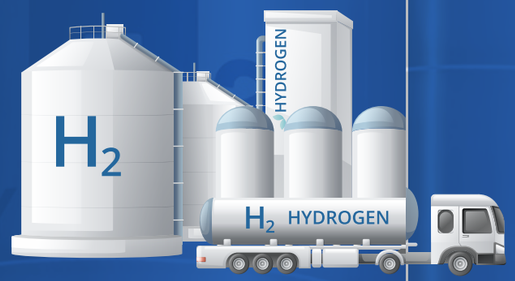
ENERGY STORAGE AND BALANCING:
Hydrogen as a long-duration, grid-scale solution

HYDROGEN FUEL PRODUCTION AND USES

RENEWABLE POWER GENERATION

WATER ELECTROLYSIS

STORAGE AND TRANSPORTATION



GAS STATION

USE OF H_2 IN MOBILITY AND VARIOUS INDUSTRIES

MATERIAL DEMANDS OF THE HYDROGEN ECONOMY

Hydrogen is an exceptionally small, diffusive molecule that poses unique engineering hurdles across its lifecycle, production, storage, transport, and end use.

Challenge	Material Demand
Cryogenic temperatures (down to -253°C)	Thermal stability and low-temperature ductility
Hydrogen embrittlement	High fracture resistance and microstructural stability
Corrosive environments (electrolyte exposure)	Superior corrosion resistance
Long-cycle fatigue and pressure	High strength-to-weight ratio and formability

These conditions call for materials engineered not just to withstand, but to perform reliably over time.

THE ROLE OF STAINLESS STEEL IN THE HYDROGEN ECONOMY

Austenitic stainless steels especially those tailored for hydrogen applications offer a compelling combination of:

- **Corrosion Resistance**
- **Mechanical Resilience**
- **Gas Impermeability**
- **Formability**

They are ideally suited for applications across the hydrogen value chain from bipolar plates in electrolysers to high-pressure pipelines and cryogenic tanks.

CUSTOMISED SOLUTIONS FOR HYDROGEN VALUE CHAIN

At Jindal Stainless, we've developed and validated a portfolio of advanced stainless steel grades designed for hydrogen infrastructure.

Our solutions are purpose-built for:

- **Electrolysers**
- **Balance-of-Plant Equipment**
- **Storage & Distribution Systems**

Backed by in-house R&D, rigorous testing, and deep materials science expertise, our offerings ensure long-term durability and operational reliability even in the harshest hydrogen environments.

Application	Jindal Stainless Steel Grades	Benefits
Bipolar Plates (Electrolysers)	304 L (Hi Ni), 316 L	Corrosion Resistance
Fuel Cell Interconnects	441, 446	Mechanical Resilience
Storage Tanks & Vessels	304 L (Hi Ni), 316 L	Formability
Pipes & Fittings	304 L (Hi Ni), 316 L	Gas Impermeability
Balance of Plant	304 L (Hi Ni), 316 L	Cost-Efficiency, Durability

INSIDE THE HYDROGEN PLANT ELECTROLYSERS & BIPOLAR PLATES

Electrolysers sit at the heart of green hydrogen production.

Key components like bipolar plates must deliver:

- **Resistance to Hydrogen Embrittlement**
- **Acid/alkaline Corrosion Resistance**
- **Thermal Regulation**

JSL stainless steel grades meet these needs, enabling high-volume, cost-effective manufacturing for leading electrolyser technologies:

Electrolyser Type	Our Material Role
Alkaline Water Electrolysis (AWE)	Durable, corrosion-resistant plates and components
Proton Exchange Membrane (PEM)	Formable, high-purity steels for compact designs
Solid Oxide Electrolysis Cells (SOEC/SOFC)	Heat-resistant materials for extreme operating temperatures

- Typical JSL Grades : **Austenitic: 304L(Hi Ni), 316L**

KEY MATERIAL CHALLENGES IN ELECTROLYSER MANUFACTURING

1. **Hydrogen Embrittlement**
   Exposure to hydrogen can cause certain metals leading to fracture, **leading to potential failures**
2. **Extreme Operating Environment**
   Highly acidic or alkaline environments **accelerate corrosion** and require **high strength materials**
3. **Nickel Plating Degradation**
   Nickel Coatings can **chip or peel over time**, compromising corrosion protection & leading to potential system failures
4. **Various Forms of Corrosion**
   Materials used in electrolyzers are vulnerable **to various corrosion types**
5. **Efficiency Issues**
   Electrolyte contamination & stack fabrication (flatness & tolerance) leads to lower efficiency
6. **Leakage & Safety**
   Hydrogen's flammability & small molecular size make leakage a significant safety concern, requiring robust containment strategies
7. **Prolonged Service Life**
   Stack lifespans of **80,000+ hours** demand material durability over time
8. **High Cost of Exotic Metals**
   Platinum, Iridium, Titanium & Nickel alloys **drive up stack costs**

STAINLESS STEEL SOLUTIONS FOR BOP SYSTEMS

BALANCE OF PLANT: THE BACKBONE OF HYDROGEN INFRASTRUCTURE

The Balance of Plant (BoP) includes a range of critical sub-systems that support the hydrogen generation process, maintaining system pressure, regulating gas flow, managing temperature, and filtering impurities.

These components operate in highly corrosive and mechanically demanding environments, where material failure is not an option.

Jindal Stainless has developed both standard and customised stainless steel grades designed to deliver:

- **Corrosion Resistance** Long-term corrosion resistance in acidic and alkaline media
- **Seamless Formability** for complex BoP geometries
- **High Mechanical Strength and Fatigue Resistance**
- **Cost-effective lifecycle performance**

- Typical JSL Grades : **Austenitic: 304L(Hi Ni), 316L**

Our Stainless Steel support OEM flexibility while ensuring regulatory compliance & system safety.

Component	Stressors	Material Needs
Separator tanks / Bubblers / Dryers	Moisture, gas pressure	Structural integrity, weldability
Heat Exchangers	Thermal cycling, chemical exposure	Thermal conductivity, corrosion resistance
Pumps & Pipes	Long-cycle fatigue, pressure drops	Mechanical strength, hydrogen tightness

CRYOGENIC STORAGE & HYDROGEN HANDLING

Hydrogen storage and transport involve some of the most extreme conditions in engineering especially when stored as a liquid at cryogenic temperatures (~–253°C). At these temperatures, even minute design flaws or brittle materials can lead to catastrophic failure.

The Material Science of Cold Containment Cryogenic Stressors

- **Hydrogen Embrittlement**
- **High-pressure Containment Risks**
- **Material Brittleness and Stress Cracking**
- **Thermal Contraction & Expansion Cycle**

Jindal Stainless austenitic grades especially high-nickel variants are engineered for exceptional performance under cryogenic loads.

Featured Grades

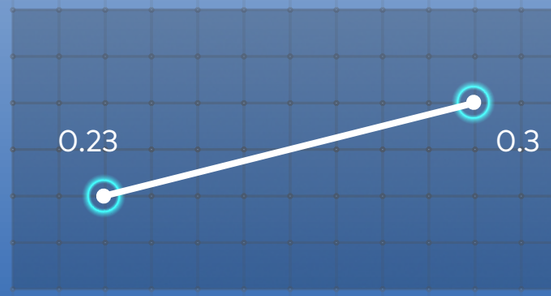
- **304L (Hi Ni)**
- **316L**

STAINLESS STEEL IN LIQUID HYDROGEN

Austenitic Stainless Steel Grades 316L & 304L (Hi Ni)
find suitability due to:

- **Greater resistance to hydrogen embrittlement**
- **High strength at cryogenic temperatures**
- **Greater phase stability at cryogenic temperatures**
- **Higher Impact toughness & ductility at cryogenic temperatures**

YS/UTS Ratio at (-) 196° C



Grade	YS (MPa)	UTS (MPa)
304L (Hi Ni)	248	1058
316L	352	1181

IMPACT ENERGY AT (-) 196 DEGREE CELSIUS

	Parent 304L{Ni}	Parent 316L	HAZ 304{Ni}	HAZ 316L	Weld 304{Ni}	Weld 316L
Avg impact energy (J)	132	157	110	114	32	44
Specific impact energy (J/cm2)	165	196	138	143	40	55

PRECISION STAINLESS FOR HYDROGEN VALUE CHAIN ENABLING ELECTROLYSIS ACROSS AWE, PEM, SOEC & SOFC

AWE
Alkaline Water Electrolysis

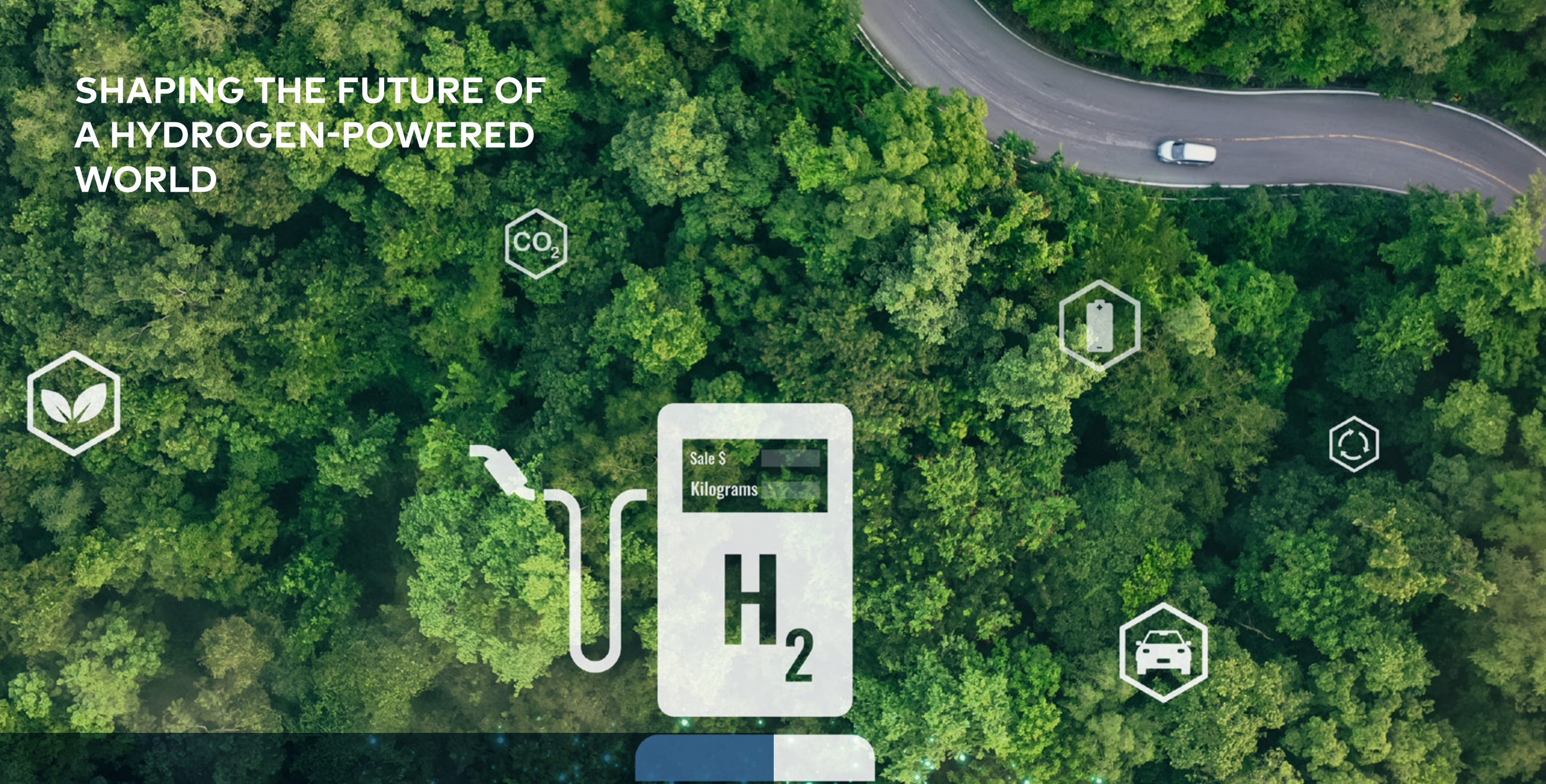
PEM
Proton Exchange Membrane

SOEC
Solid Oxide Ceramic Electrolyte

SOFC
Solid Oxide Fuel Cell

Grade	Category	YS (MPa) (min)	UTS (MPa) (min)	%El	Hardness (HRB)	%C Max	%Mn Max	%Cr	%Ni	%Mo	%Ni Max
304L (Hi Ni)	Austenitic	170	485	40	92	0.030	2.0	17.5-19.5	9.5-12	-	0.1
304L	Austenitic	170	485	40	92	0.030	2.0	17.5-19.5	8-12	-	0.1
316L	Austenitic	170	485	40	95	0.030	2.0	16-18	10-14	2.0-3.0	0.1
441	Ferritic	250	430	18	88	0.030	1.0	17.5-18.5	-	-	-
446	Ferritic	275	515	20	96	0.20	1.50	23-27	0.75	-	0.25

SHAPING THE FUTURE OF A HYDROGEN-POWERED WORLD



At Jindal Stainless, we believe that clean energy needs clean materials. Our hydrogen-ready stainless steel grades are engineered not only for performance but for a more sustainable, circular future.

We are actively collaborating with technology providers, EPCs, and policymakers to scale hydrogen solutions globally. Whether it's powering electrolysis, enabling safe storage, or fueling mobility, we are ready.

If you're building for the hydrogen economy, let's engineer the future, together.

JINDAL STAINLESS

Get in touch

For product inquiries, technical support, or partnership opportunities

Group Email ID - salesdevprocess@jindalstainless.com

Website: www.jindalstainless.com/hydrogen