INTESA SANPAOLO
INNOVATION CENTER

INDUSTRY TRENDS REPORT
ENERGY, ENVIRONMENT AND UTILITIES

HYDROGEN AND THE FUTURE OF RENEWABLES

FROST & SULLIVAN

INTESA SANPAOLO
INNOVATION CENTER

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EXECUTIVE SUMMARY

Over the next decade, Frost & Sullivan forecasts that total global installed power generation capacity will reach 10,532 GW up from 7,180 GW in 2020. Investments in the 2020s will continue a trend that gained pace in the 2010s. The ongoing move away from carbon-intensive energy sources will gather additional momentum as environmentally-friendly alternatives become increasingly cost competitive and improvements in transmission and distribution, digital grid and energy storage solutions minimise curtailments.

Interest in **hydrogen**, in particular, has exploded in recent years with many governments recognising it as the best long term low/zero-carbon alternative to fossil fuels.

Overall, production is expected to reach 168 million tonnes by 2030 to create a global industry worth $400 billion in revenue terms. Growth will be driven by concerns over climate change and the emergence of hydrogen as a viable storage medium for fuel cells. The sector will also be shaped by the move away from polluting "grey" hydrogen to, eventually, "green" hydrogen which is generated from carbon-free sources. New production, separation, storage and transportation technologies will enable a true hydrogen revolution.

Fresh interest in **renewables** stems not only from their potential to support the hydrogen market but also from developments on the supply side. Currently, the cost of producing green hydrogen from off- and on-shore **wind** is lower than with most green energy sources but the **solar** industry is moving from first to third generation solutions. Here, perovskites, for example, offer the long-term potential to replace silicon as a material for the production of efficient and low-cost photovoltaics.

Frost & Sullivan expects investment in renewables to be supported by new business models and, over the next ten years, the emergence of an interconnected web of new systems and solutions that is collectively referred to as the **Internet of Energy**.

In the short term, **Distributed Energy Resources** will play an increasingly pivotal role in the global energy mix and support moves to decarbonise. Growth will be driven by aggregation, blockchain and as-a-service models.

Source: Frost & Sullivan

The success of DER is dependent on the presence of a smart grid which itself is enabled by the ongoing development and deployment of **smart meters**. Roll-out relies on supportive government legislation with demand for second generation solutions emerging in mature markets in Europe and the United States. Smart meters also form one of four main core components of **virtual power plants** which allow for electricity to be dispatched at times of peak demand and bring benefits to operators, prosumers and policy makers.

Storage and **mobility** makes up the final piece in the Internet of Energy jigsaw with technologies comprising of alternative and battery energy systems. From a technology perspective, lithium-ion chemistry continues to dominate the latter but the adoption of renewable energies and electric vehicles is sharpening the need for more efficient and cost effective solutions. Sodium-based technologies are gaining ground and, in the longer term, nickel-zinc and zinc-air will have applications in both grid storage and transport.

Innovation is also occurring in other areas of the energy industry.

Following their successful adoption in many sectors, unmanned vehicles are increasingly finding applications here. In particular, demand for drones is expected to grow ten-fold between 2019 and 2030 with improved analytics capabilities, autonomy and regulatory clarity allowing them to replace conventional inspection and maintenance solutions for transmission and distribution infrastructure. Unmanned ground vehicles are similarly making inroads in oil and gas, supporting sampling, drilling and surveillance activities.

Moving forwards, Artificial Photosynthesis, a synthetic alternative to the natural process, has the potential to create a range of value-added chemicals and fuels. Co-electrolysis and photo-electro catalysis are the most established AP technologies with the latter using photo electrochemical cells to make hydrogen.

This paper examines each of these areas with a focus on the way in which technology is enabling more sustainable power generation, transmission and distribution. More broadly, it provides a guide as to how innovation is impacting selected Energy markets.

Source: Frost & Sullivan

HYDROGEN

Interest in hydrogen has exploded in recent years with many governments recognising it as the best low- or zero-carbon alternative to fossil fuels

Hydrogen can help curb carbon emissions and, in turn, address climate change, by:

- Decarbonising carbon-intensive areas of the economy such as the transportation and manufacturing sectors
- Integrating more Renewable Energy Sources (RES) into the energy mix
- Providing greater resiliency and reliability to the electricity grid as a green Energy Storage System (ESS)

Although the promises associated with hydrogen as an important lever in driving the transition towards the supply of more sustainable energy are huge, its current application is largely in the industrial sector. Many of the projects across areas such as power generation and transportation are still in their pilot stages and technological and cost breakthroughs are needed for increased adoption.

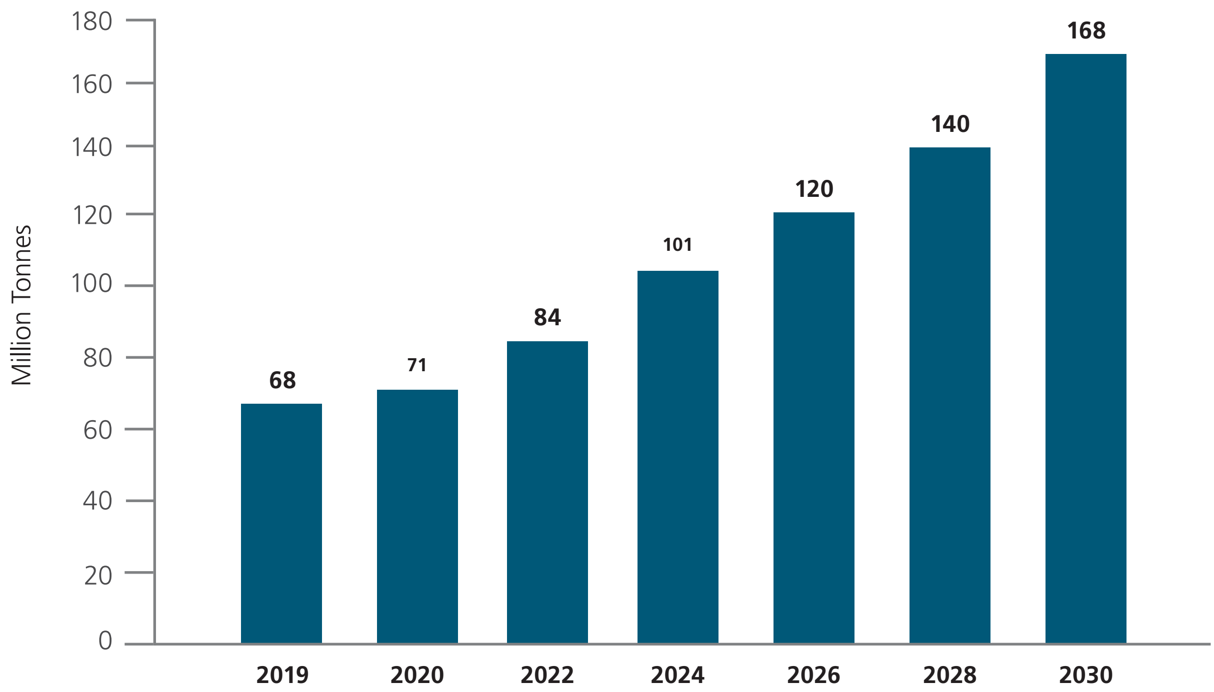
For the hydrogen economy to become a true reality, decisive government intervention and actions are required in four main areas:

- Supporting Research & Development (R&D) activities related to the production, storage, transportation and utilisation of hydrogen
- Providing incentives to companies developing hydrogen and the associated Carbon Capture and Storage (CCS) infrastructure
- Addressing the socio-economic barriers which are currently often inhibiting the development of hydrogen-enabling technologies
- Mandating policies toward decarbonisation

There is still a long road to travel but a holistic global roadmap, involving the public and private sector, needs to emerge to drive the ongoing transition.

Overall, global production is expected to increase from 68m tonnes (T) in 2019 to 168mT by 2030 to create an industry worth over $400b in revenue terms

HYDROGEN, PRODUCTION FORECAST, GLOBAL, 2019–2030



Source: Frost & Sullivan

Growth will be driven by concerns over climate change and the emergence of hydrogen as a commercially-viable storage medium for Fuel Cells (FCs)

Increasing concern over carbon emissions

Global climate change is the main reason for the consideration of hydrogen as a fuel of the future. It is increasingly seen as a key plank in international plans to transition towards cleaner energy generation when limiting global warming to 1.5 degrees Celsius will require that CO2 emissions decline by 25% by 2030. Hydrogen is now recognised as having a significant role to play in making these ambitions become a reality.

Growing demand for Fuel Cell technology

The accelerating growth in battery-powered Electric Vehicles (EVs) will add to the pressure on power grids. Hydrogen FCs offer a promising alternative to existing solutions as they do not require long charging cycles. The demand for hydrogen FCEVs is increasing with the current focus particularly on forklifts trucks and other small off-highway vehicles.

Hydrogen FCs have an energy-to-weight ratio that is ten times greater than Lithium-ion (Li-ion) batteries. However, their adoption has been restrained due largely to high production costs. Manufacturers are making progress to reduce the price of key components to make FCs competitive from a performance and a commercial standpoint.

Nonetheless, high capital costs, the regulatory environment, a lack of awareness and ongoing safety concerns continue to act as a restraint to hydrogen's use

Capital costs

The cost of producing, storing and transporting hydrogen are high when compared to Li-ion batteries and fossil fuels. For hydrogen to become a truly viable clean energy source, this differential needs to narrow and eventually reach parity.

The lack of infrastructure exacerbates the situation. Li-ion batteries have had a significant head start over FCs with the existing electricity grid acting as a readily available network to charge and manage them. In contrast, there are currently few large-scale production facilities for hydrogen on a global basis.

Regulatory environment

Legislative frameworks for hydrogen are yet to be really established. In recent years, many countries like the United States, Canada, Germany, the Netherlands, the United Kingdom, France and Japan, via its "Strategic Roadmap for Hydrogen and Fuel Cells", have initiated pilot projects for exploring hydrogen as a potential zero-carbon energy carrier. A homogenous regulatory environment is, however, required – ideally on an international basis – to support the use of hydrogen across different segments.

Source: Frost & Sullivan

End-user awareness

The transition to the hydrogen economy is currently hindered by a lack of end-user awareness about – and acceptance of – hydrogen as a clean energy source. Commercial and private customers are concerned about the levels of investment that hydrogen requires as well as the associated safety issues.

Safety concerns

Safety concerns present a major challenge to the adoption of hydrogen across the transport and power sectors in particular. Hydrogen has a relatively low ignition temperature which means it can pose a combustion risk. However, the enabling technology has developed to a point where hydrogen has become more stable than the gasoline that is used in cars so perceptions of it as a dangerous source of fuel are slowly starting to change.

Perhaps the biggest challenge for the industry is, however, to move away from the use of "brown" or "grey" hydrogen which stem from C02-emitting fossil fuels

Although it is, in itself, a clean energy, almost all of the hydrogen used today is produced from fossil fuels with CO2 released into the atmosphere.

Based on the method of production, over 99% of hydrogen is either;

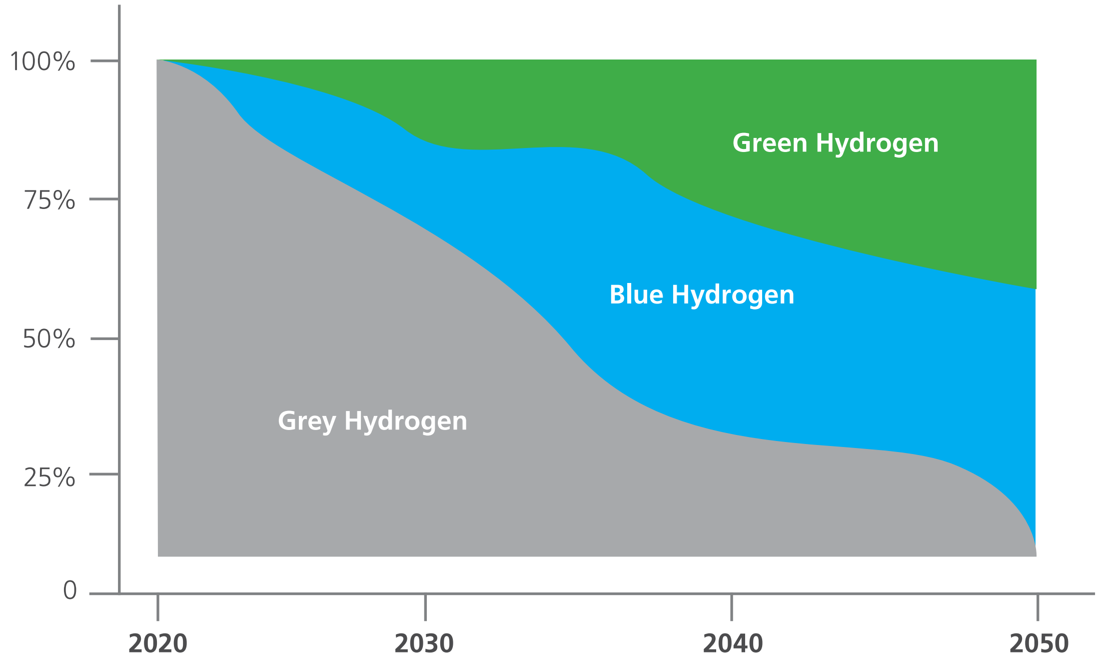
- **Brown hydrogen** which is produced from coal through a gasification process. This releases high amounts of up to 60% carbon dioxide and carbon monoxide whilst also requiring significant levels of energy consumption
- **Grey hydrogen** which is produced from natural gas and biomass. This consumes less energy than brown hydrogen however it still has a relatively high carbon monoxide and carbon dioxide production up to 55%

Grey hydrogen can be used in the short-term to meet the growing demand. However, in the long term, this method will be unsustainable and require alternative measures.

In the medium term, "blue" hydrogen – produced from fossil fuels but leveraging Carbon Capture Utilisation & Storage – will play a key role in the transition

- **Blue hydrogen** is produced from fossil fuels and biomass. The process is similar to that which is used for grey hydrogen but the carbon which is emitted can be captured, stored and used for other industrial uses through the deployment of a Carbon Capture Utilisation and Storage (CCUS) system
- The process is currently at prefatory stage

HYDROGEN, PRODUCTION FORECAST, SHARE BY TYPE, GLOBAL, 2019–2050



Source: Frost & Sullivan

PRINCIPAL ABBREVIATIONS

AA	*Advanced Adiabatic*
AC	*Alternating Current*
AEM	*Anion Exchange Membrane*
AI	*Artificial Intelligence*
AMI	*Advanced Meter Infrastructure*
AMR	*Automatic Meter Reading*
AP	*Artificial Photosynthesis*
APAC	*Asia Pacific*
B	*Billion*
BESS	*Battery Energy Storage System*
BVLOS	*Beyond the Visual Line of Sight*
C&I	*Commercial & Industrial*
CAES	*Compressed Air Energy Storage*
CAGR	*Compound Average Growth Rate*
CBA	*Cost Benefit Analysis*
CCS	*Carbon Capture and Storage*
CCUS	*Carbon Capture Utilisation and Storage*
CHP	*Combined Heat and Power*
CIS	*Commonwealth of Independent States*
CO2	*Carbon Dioxide*
CSP	*Concentrated Solar Power*
DC	*Direct Current*
DER	*Distributed Energy Resource*
DG	*Distributed Generation*
DSO	*Distribution Service Operator*
DSP	*Drone Service Provider*
ESCO	*Energy Service Company*
ESS	*Energy Storage System*
EV	*Electric Vehicle*
F&B	*Food & Beverage*
FC	*Fuel Cell*
FCEV	*Fuel Cell Electric Vehicle*
FiT	*Feed-in Tariff*
GW	*Gigawatt*
HER	*Hydrogen Evolution Reaction*
IoT	*Internet of Things*
IPP	*Independent Power Producer*
KG	*Kilogramme*
KPI	*Key Performance Indicator*
LIB	*Lithium Ion Battery*

Li-ion	*Lithium Ion*
ML	*Machine Learning*
MM	*Millimetre*
MW	*Megawatt*
NDT	*Non-Destructive Testing*
O&G	*Oil & Gas*
O&M	*Operations & Maintenance*
OEM	*Original Equipment Manufacturer*
OPEX	*Operating Expense*
P2G	*Power To Gas*
P2P	*Peer To Peer*
P2X	*Power To X*
PEM	*Proton Exchange Membrane*
PEM	*Polymer Electrolyte Membrane*
PLC	*Powerline Communication*
PPM	*Part Per Million*
PSA	*Pressure Swing Absorption*
PV	*Photo Voltaic*
R&D	*Research & Development*
RES	*Renewable Energy Source*
RF	*Radio Frequency*
SCADA	*Supervisory Control and Data Acquisition*
SI	*Systems Integrator*
SMR	*Small Modular Reactor*
SMR	*Steam Methane Reforming*
SOEC	*Solid Oxide Electrolyzer Cell*
T	*Tonne*
T&D	*Transmission & Distribution*
TES	*Thermal Energy Storage*
TRL	*Technology Readiness Level*
TSO	*Transmission Service Operator*
UAV	*Unmanned Aerial Vehicle*
UGV	*Unmanned Ground Vehicle*
UK	*United Kingdom*
US	*United States*
VPP	*Virtual Power Plant*
WGS	*Water-Gas Shift*
XaaS	*Everything-as-a-Service*

Source: Frost & Sullivan

ABOUT INTESA SANPAOLO INNOVATION CENTER:

Intesa Sanpaolo Innovation Center is the company of Intesa Sanpaolo Group dedicated to innovation: it explores and learns new business and research models and acts as a stimulus and engine for the new economy in Italy. The company invests in applied research projects and high potential start-ups, to foster the competitiveness of the Group and its customers and accelerate the development of the circular economy in Italy.

Based in the Turin skyscraper designed by Renzo Piano, with its national and international network of hubs and laboratories, the Innovation Center is an enabler of relations with other stakeholders of the innovation ecosystem - such as tech companies, start-ups, incubators, research centres and universities - and a promoter of new forms of entrepreneurship in accessing venture capital. Intesa Sanpaolo Innovation Center focuses mainly on circular economy, development of the most promising start-ups, venture capital investments of the management company Neva SGR and applied research.

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businessdevelopment@intesasanpaoloinnovationcenter.com

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LIVIO VANINETTI
Director of Frost & Sullivan's Italian operations;
livio.vaninetti@frost.com

Published: April 2021