NTT DATA

Hydrogen: The New Commodity Powering a Greener Economy

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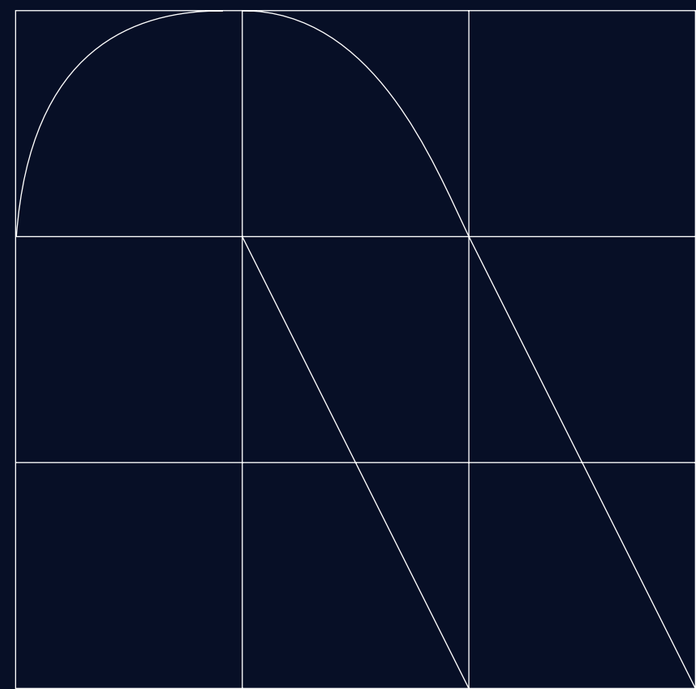


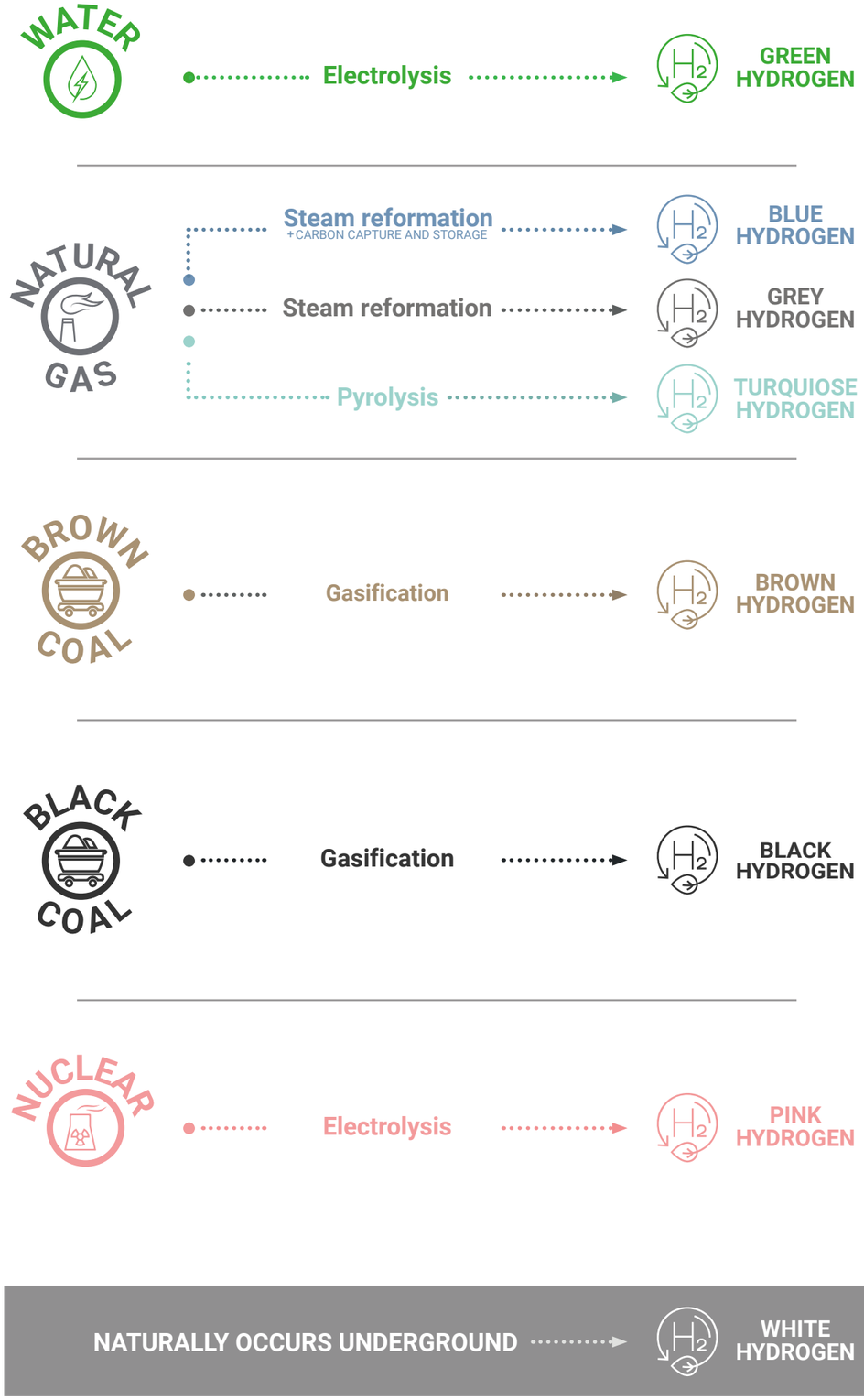
Introduction

The commercial market for hydrogen has been evolving over time, but a turning point occurred in the early 2000s when hydrogen started to gain momentum as a fuel source and industry and governments began to take the new fuel more seriously for the role it could potentially play in decarbonizing economies.

A key milestone was the launch of the first commercial hydrogen fuel cell-powered vehicle, the Toyota Mirai, in 2014. Since then, the market for hydrogen has continued to grow, with increased demand from various sectors such as transportation, industry, and power generation. According to a report by the Hydrogen Council, the global hydrogen market size is expected to reach $2.5 trillion by 2050.

Before going further, it is important to realize that hydrogen is not always a “greener” choice over other fuels, as its carbon footprint depends on the source of energy used to produce it. Hydrogen is classified using a colour-based system – see Figure 1 - depending on the source of energy and only hydrogen produced from renewable sources such as solar, wind or hydropower can strictly be classified as true green hydrogen.

Figure 1 The Hydrogen Color Spectrum



The new commodity

Industrial processes that require hydrogen mostly produce it from fossil fuels, as transporting hydrogen is challenging because of its low density. For this reason hydrogen has typically not been seen as a commodity but more as an intermediate material.

But recent years have see a change in mindset, with hydrogen now considered a valuable material that can be traded - a new commodity.

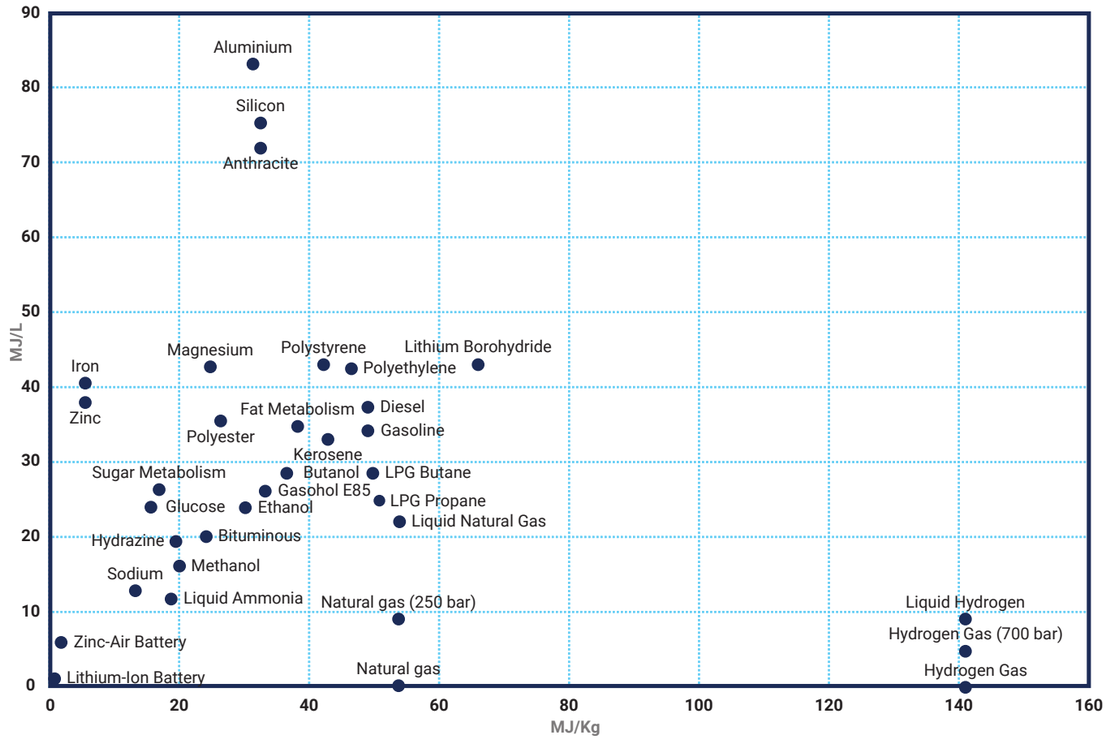
The LNG experience provides a model to help understand how to accelerate the adoption of hydrogen as an intermediate material and a fuel for heavy industry and transport. The two products share the following similarities:

- Both use a similar supply chain based on pipelines, trucks and vessels.
- Both face technical challenges for cryogenic transport and storage, although these are more significant for hydrogen.
- There is rapid demand growth both from existing industries and new markets and uses.

However, hydrogen production also involves some additional challenges that need to be considered:

- **Low energy density:** Hydrogen has the highest energy content per unit of weight of common fuels, but because its density is so low, the volumetric energy density of hydrogen is third that of LNG. This can significantly increase transport costs.

Figure 2 Energy Densities of Selected Energy Sources



- **Transport losses:** As the hydrogen molecule is the smallest that exists, it can more easily leak from any closed container. An average loss of between 5-10% can be expected for long-term storage and long-range travel.

- **Greenhouse effect:** We need to take into account the greenhouse gas emissions across the full lifecycle of the product, including the source energy for its production, transportation, losses and final usage. Estimates for the Global-Warming Potential (GWP) of hydrogen between 3 and 11.

Due to the significant issues associated with the transportation and logistics of moving hydrogen, a first step for the hydrogen market development has been to reduce the distance between production and consumption. As a result, electrolyzers are being installed alongside renewable power plants and close to final usage facilities.

As H2 liquefaction is not profitable, the industry is looking for a more suitable vector to simplify the supply chain for long distances.

The main options are:

- **Methanol** is an established fuel with a simplified conversion method and is a liquid at atmospheric conditions, but it produces CO2 when burnt.

- **Ammonia** is also a liquid at atmospheric conditions and established transport and storage technologies already exist (reusing current LPG carriers). However, its vapours are toxic and spillages can damage the environment. It also produces NOx emissions when burnt.

- **Pure hydrogen** is dangerous because of its great flammability and can be unstable during burning. If used in a fuel cell, NOx emissions are avoided.

- **LOCH:** Liquid Organic Carriers are molecules in liquid state at room conditions in which H2 can be transported by first hydrogenating them and then dehydrogenating them at the destination point.

Current and emerging use cases for hydrogen

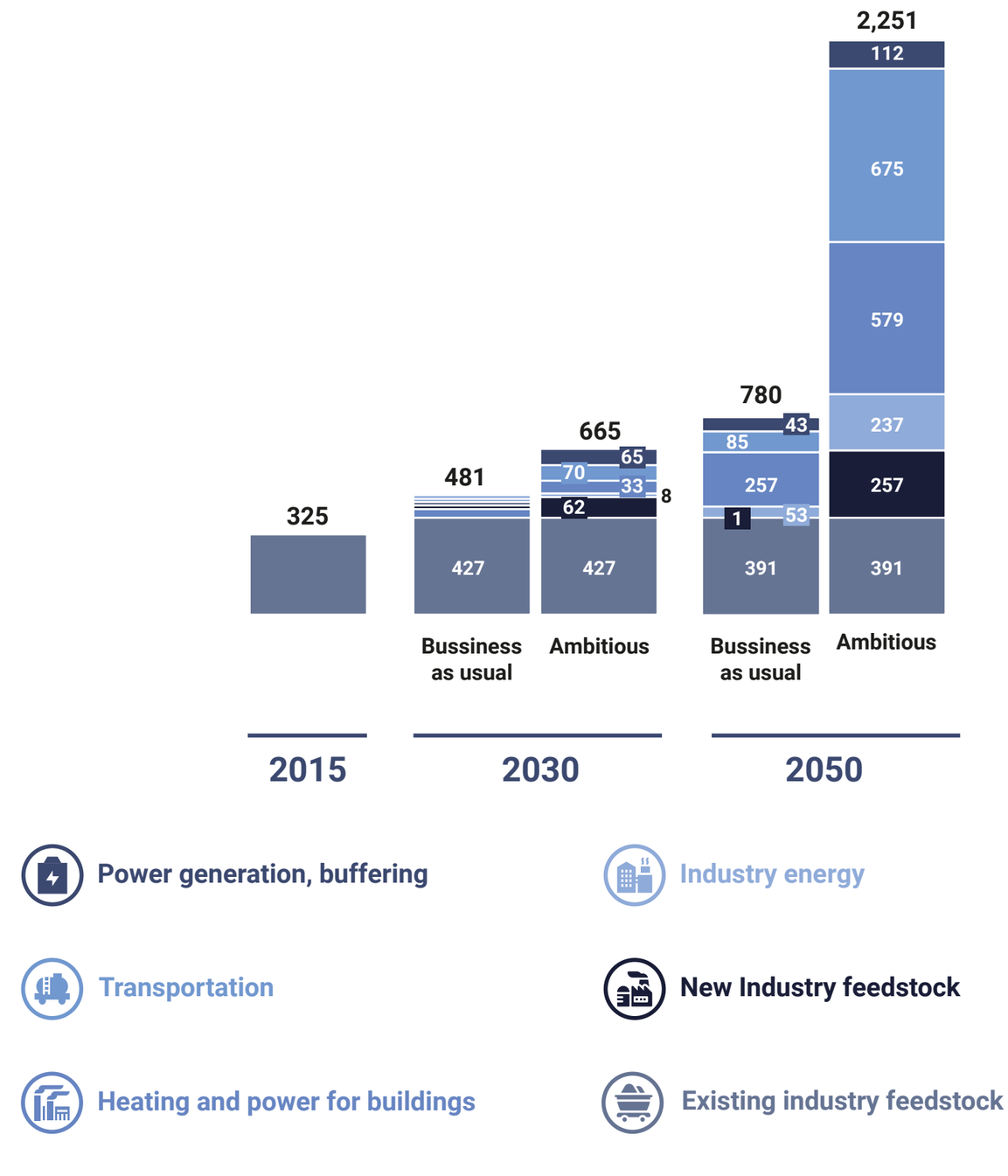
Nowadays, the primary uses of hydrogen are the following:

- **Refineries:** used for cracking and polymer manufacturing.
- **Fertilizers:** used for industrial processes.
- **Iron manufacturing:** used for both heating and industrial processing (as synthesis gas).

These are the new uses for hydrogen:

- **Power generation and storage:** renewable energy can produce H2, which can be stored for the short term as a buffer to meet power demand. Then, H2 can be converted to power using fuel cells or burning inside turbines.
- **Heavy transport:** The first hydrogen-gas turbines are being produced to provide a more efficient solution in the mid-term for aviation and shipping, and will probably run on less pure forms of hydrogen, such as methanol or ammonia.
- **Light transport:** fuel cells are already available to power cars and buses.

Figure 3 Scenarios for the Development of the Hydrogen Market in Europe



The European trade-off

Europe is considered a leader in the development of hydrogen. Stricter emissions reduction regulations have elevated hydrogen to become one of the key technologies for the energy transition and this has opened up new markets and promising business opportunities.

That, in turn, has attracted investment from specialist funds, venture capital and established energy companies.

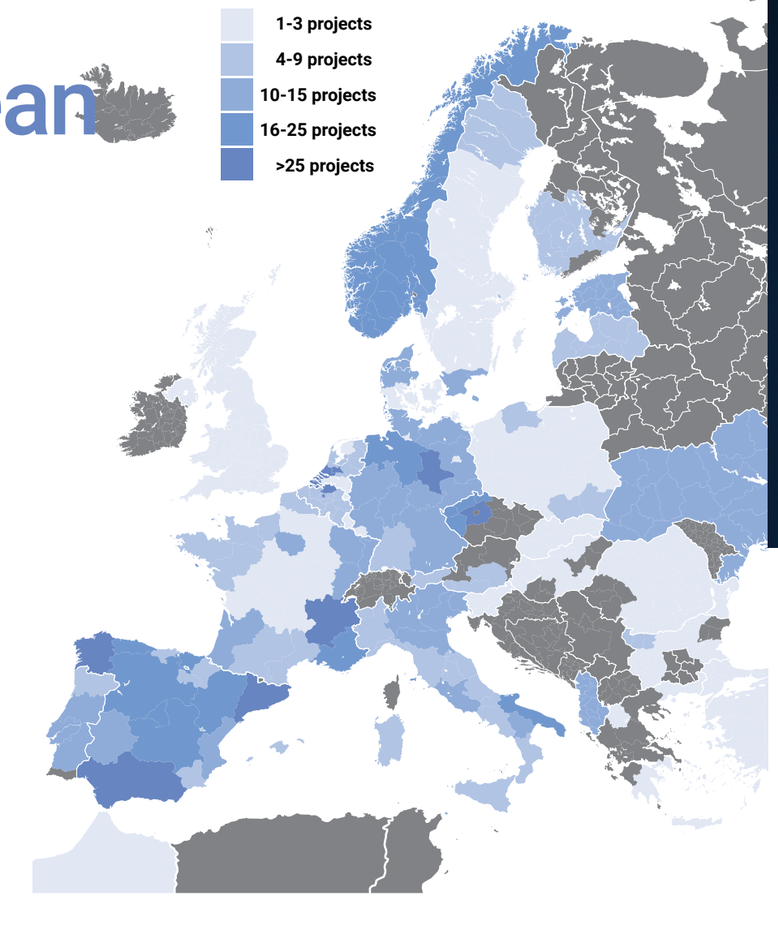


Figure 4 shows that Spain is a leading contender for hydrogen investment as it meets some of the pre-conditions for hydrogen production and transportation:

Increased development of renewable production facilities. The current installed capacity exceeds the daily demand and there is still a big potential to extend.

Good infrastructure network (ports, gas pipelines) to facilitate export. By mixing 20% hydrogen with natural gas, existing infrastructure can be used for transport with the additional benefit of a 20% reduction in carbon emissions. Pilot projects have already demonstrated the feasibility of this solution. New infrastructure will be required for pure H2 transport.

Large companies based in Spain with integrated supply chains (like Cepsa, Fertiberia or Repsol) that have their own demand for hydrogen for refineries and industrial processes. As a result, they can produce H2 very competitively.

Natural hydrogen deposits discovered closed to the Pyrenees which can provide a relatively cost-effective natural source of hydrogen.(approx. < €0.5/kg)

The growth path for a liquid hydrogen market

There are many lessons that can be learnt from the development of the LNG markets to foster the equivalent growth in the hydrogen market.: The following phases will go some way to achieving this.

Phase 1: No market

At the outset, producers and consumers need to look for tailor-made solutions, signing long-term contracts that enable a return on investments and provide finance for the projects. Taking into account the transportation challenges, production and consumption facilities must be located close to each other (<10 km) and connected to a local production power plant.

At this point, the enabler to move to the next phase will be a growth in production, based on the installation of additional renewable capacity and reduction in the manufacturing and installation of electrolyzers.

Phase 2: Initial market setup

Hydrogen is recognized as a real commodity. New projects will be designed to use hydrogen as as energy source and/or input to the industrial process which should precipate demand growth. Some small-scale industry needs may appear as a result.
On the production side, the investment costs start to reduce, and economies of scale facilitate excess production which can be sold bilaterally for smaller demand requirements. The first production facilities with no preset off-taker may appear.

The enablers for moving to the next phase will be the development of a capability to transport small-scale shipments (by trucks or by train-hauled tankers) and the necessary institutional investment to build new facilities without requiring a long-term offtake agreement.

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Phase 3: Market in development

The share of production/demand with long-term bilateral contracts starts to grow. The newest developments are cheaper and more efficient, providing competitive spot prices. Production cost optimization is possible. A technical shift has occurred, with new industrial processes directly fed with hydrogen, and switching old fossil-fueled engines to hydrogen-based ones. Fuel cells will start to be affordable for small-scale applications (vehicles, buildings...).

The increment in the number and size of bilateral contracts will lead to an OTC market. Brokers will take advantage of poor price transparency and will start arranging transactions. Contracts and delivery points start to standardise.

The key to the achieving the next phase will be technological evolution in the demand side of the equation. If hydrogen starts to be more competitive than other fuels or inputs (which become less attractive due to their CO2 emissions), industry will start investing in new machinery and production lines and improve production costs. Once the shift has occurred, the supply chain will need to be uninterruptible, so a spot market will develop for balancing and the purchase of additional volumes. Manufacturers will want to keep costs under control (with no exposure to wholesale markets) and financial hedges will appear, allowing banking and trading companies to participate into this new market (not just with credit funding but also taking positions at risk).

Phase 4: Mature market

The development of hydrogen projects transitions from a period of exponential growth to one of greater maturity. It is important to supply the demand for the medium and long-term. Exchanges start to appear and gain liquidity, providing public reference prices. The transition is natural, and the switch from other commodities is tangible. Companies begin to increase the complexity of their sourcing portfolio, taking advantage of different contracts and arbitraging between markets.

	NO-MARKET	INITIAL MARKET SETUP	MARKET IN DEVELOPMENT	MATURE MARKET
PRODUCTION-DEMAND RATIO	1:1	1:1	1,1:1	>1,5:1
CONTRACT TYPE	OTC long-term off-takers	OTC mid-to short-term	Spot market	Exchange and derivatives
TRANSPORT	No	Point-to-point supply chain	Flexible supply chain	International trading
PRICE	2-3 €/kg	1-2 €/kg	0,75-1,5 €/kg	0,25-0,5 €/kg
LEVEL OF TRANSFORMATION	Heavy industrial processes	Industrial processes	Small-scale & heavy transport	Domestic & light transport

How to speed up the transition and reach maturity

The key driver to developing a mature hydrogen market is to reach a state where surplus hydrogen is available to offer. When this situation is reached, hydrogen will become more competitive and price, storage and supply chain optimization will occur. This will allow us to move from a developing market and into a utility-scale business.

Currently, there is strong financial support for the development of new infrastructures, both from private investment and public funding, as an accelerator to achieve the goals defined. An excess of supply will push prices down and will make hydrogen technologies more competitive against other solutions (e.g. fuel cell versus combustion engines). A local excess of supply will further enable international trading and bring in more investment around the optimization of storage and transport.

Improving transportation pipelines will facilitate international trading, improve liquidity and avoiding congestion will reduce the spread between adjacent market areas. The development of green hydrogen, can act as a buffer between generation and consumption of green energy, for a day-night cycle and for a summer-winter cycle.

Hydrogen and NTT DATA

Hydrogen is a key driver for energy transformation, and NTT DATA intends to be a part of this new future. Our offering includes:

- **Strategy advisory services:**
  Hydrogen roadmaps and business model creation around green hydrogen and derivatives.

- **Business development and contract execution:**
  Deal generation leading the search for the best partner for producers and off-takers.
  Due diligence support for investment rounds.

- **New business models definition:**
  Identification of opportunities, TOM design and support to go-to-market.

- **Permitting:**
  Support for the elaboration and validation of project documentation.

- **Trading:**

  Contract management, risk analysis and support to Back-office processes.

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