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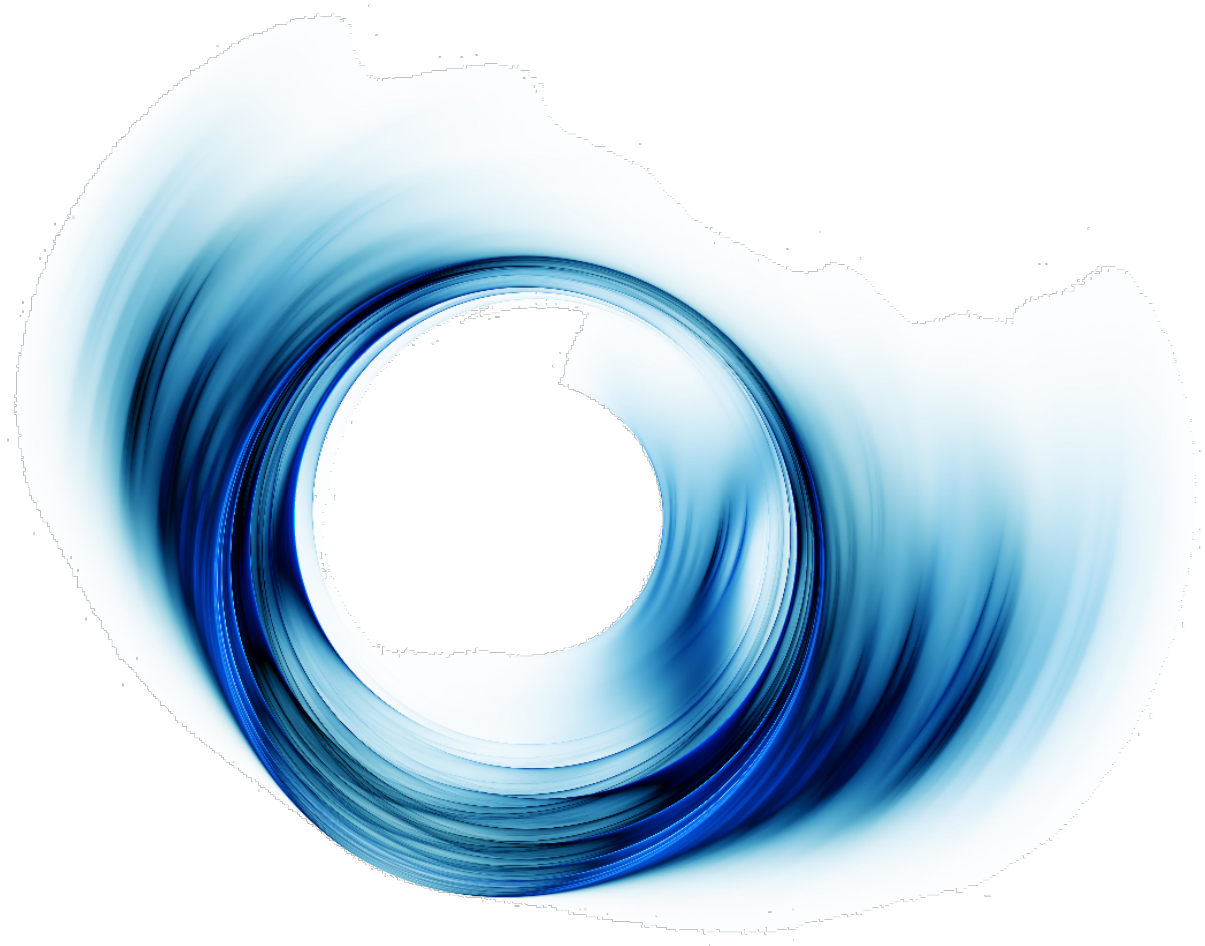
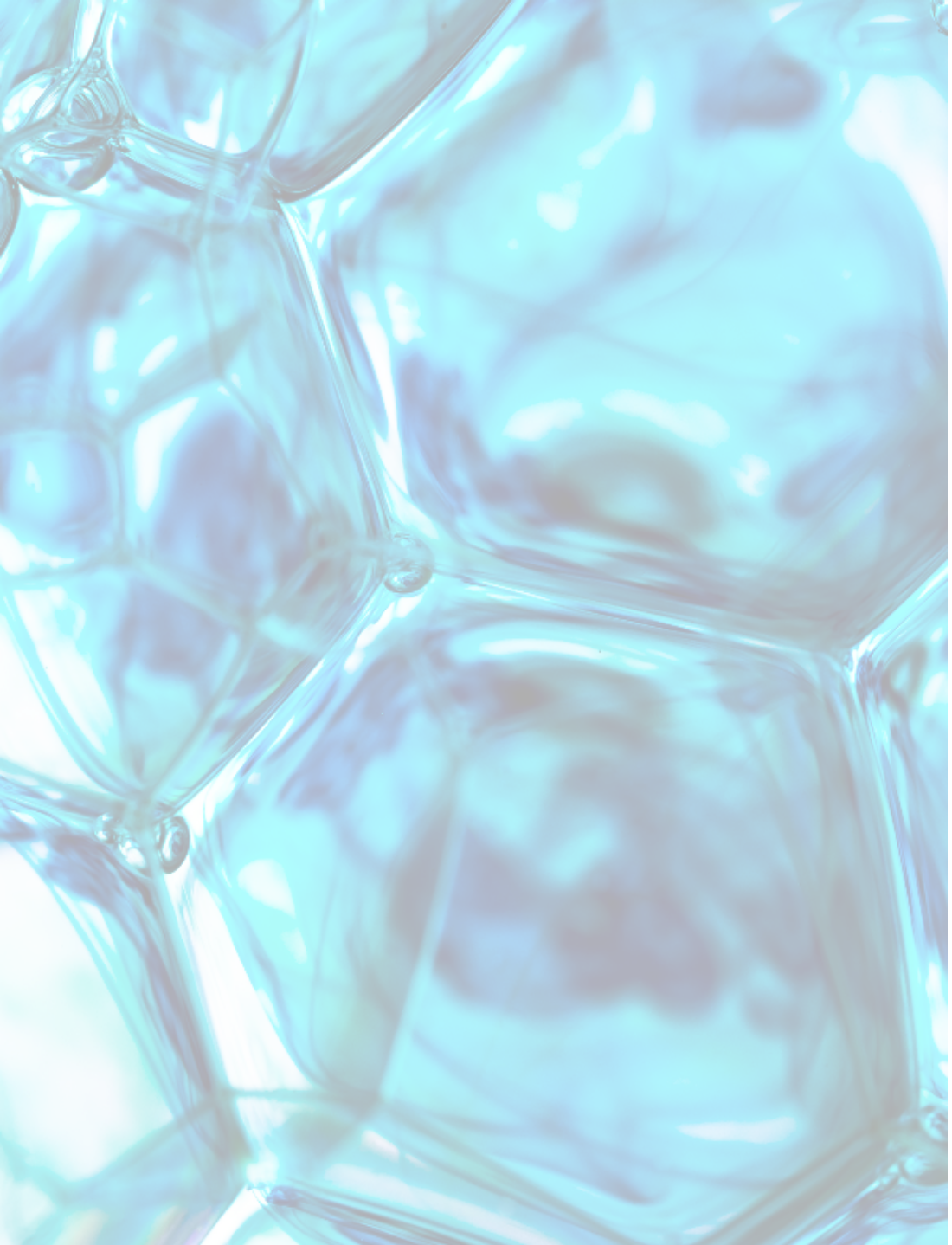


Challenges and opportunities

Powering the Future: Integrating Clean Hydrogen into the Power System

March 18, 2025



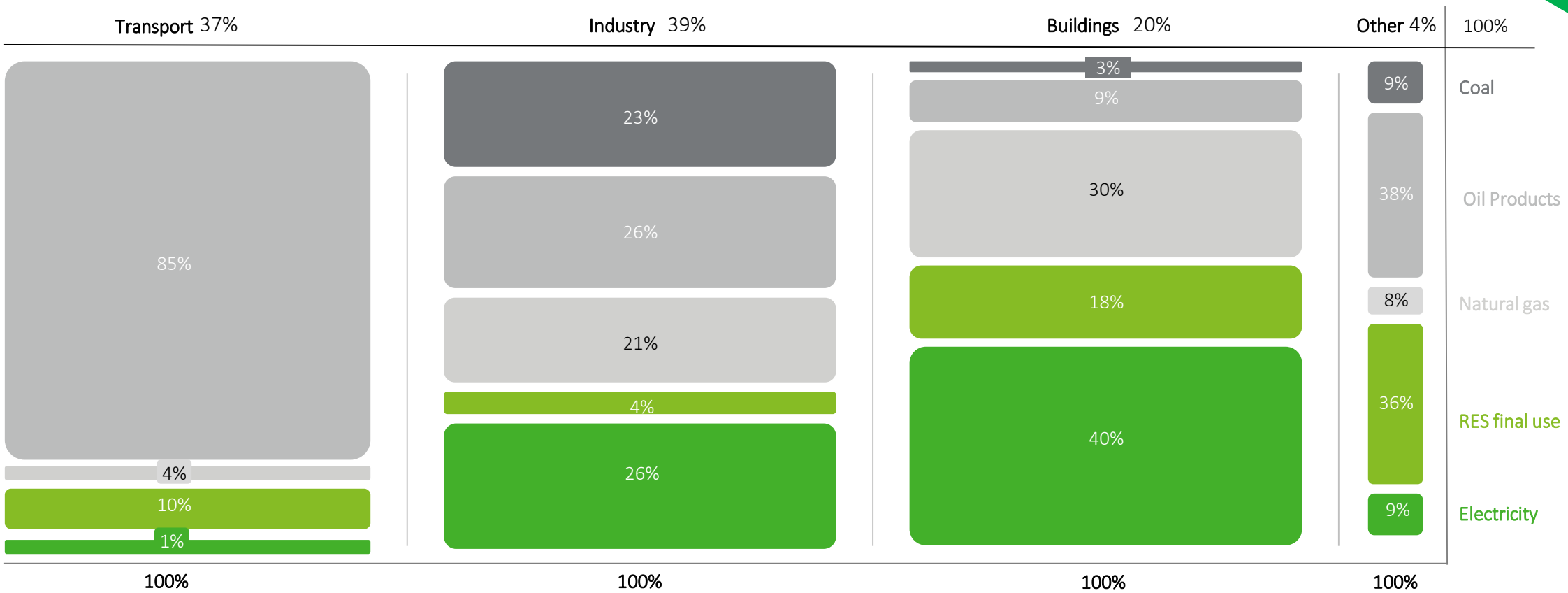
The Importance of Green Hydrogen

Powering the Future: Integrating Clean Hydrogen into the Power System

01 | The importance of Green Hydrogen

The potential **uses of hydrogen are concentrated** in sectors **heavily dependents on fossil fuels,** where fewer low-carbon alternatives are currently available

Global Final Energy Consumption



Hydrogen will be essential for decarbonizing applications that currently lack viable low-emissions solutions

Note: information updated in 2019

Source: IEA; Deloitte analysis

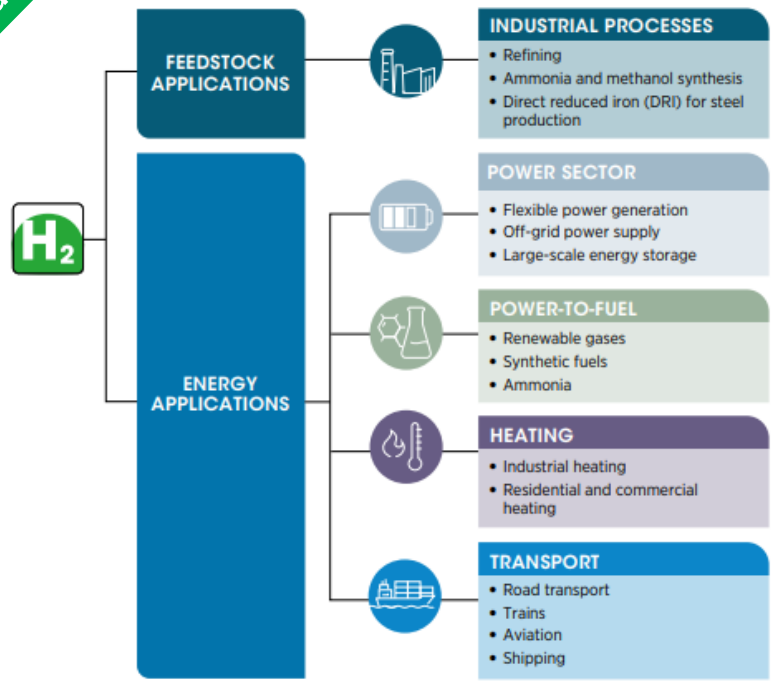
Powering the Future: Integrating Clean Hydrogen into the Power System

02 | The importance of Green Hydrogen

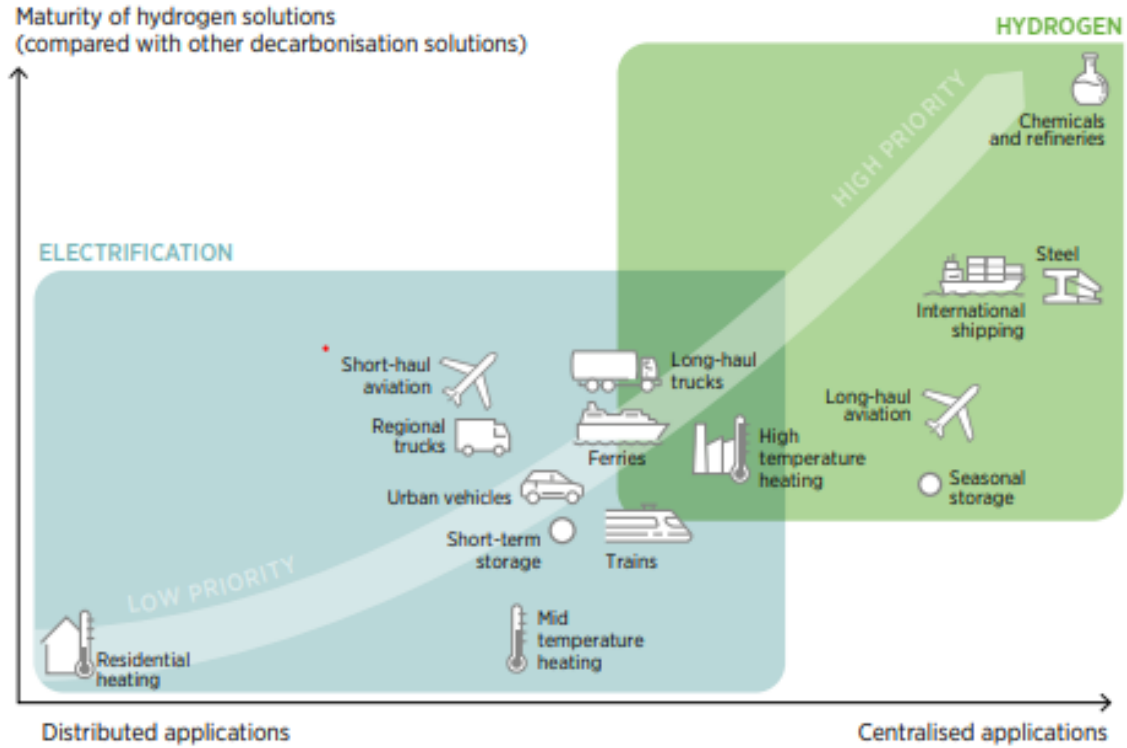
Hydrogen has **applications in almost every sectors.** However, in some of them, more efficient or more mature electrified alternatives exist

Illustrative

Main Applications of H2



Priority Applications for H2 Compared to Electrified Alternatives



- Hydrogen is a highly versatile energy carrier that **can be used in a wide range of applications** and end-uses
- However, **not all of them are the most efficient option**, as more advanced and cost-effective electricity-based solutions are available

Source: IRENA; Monitor Deloitte

Powering the Future: Integrating Clean Hydrogen into the Power System

03 | The importance of Green Hydrogen

Key factors

1 **Decarbonization of Industrial Processes**

Green hydrogen enables the decarbonization of **strategic sectors** that cannot feasible adopt other renewable technologies.

Construction *Steel* *Petro-chemical*

2 **Production of Sustainable Products**

Green hydrogen also serves as feedstock in producing **low-carbon-footprint goods.**

Advanced fuels *Fertilizer* *Bio-gas*

3 **Energy Storage**

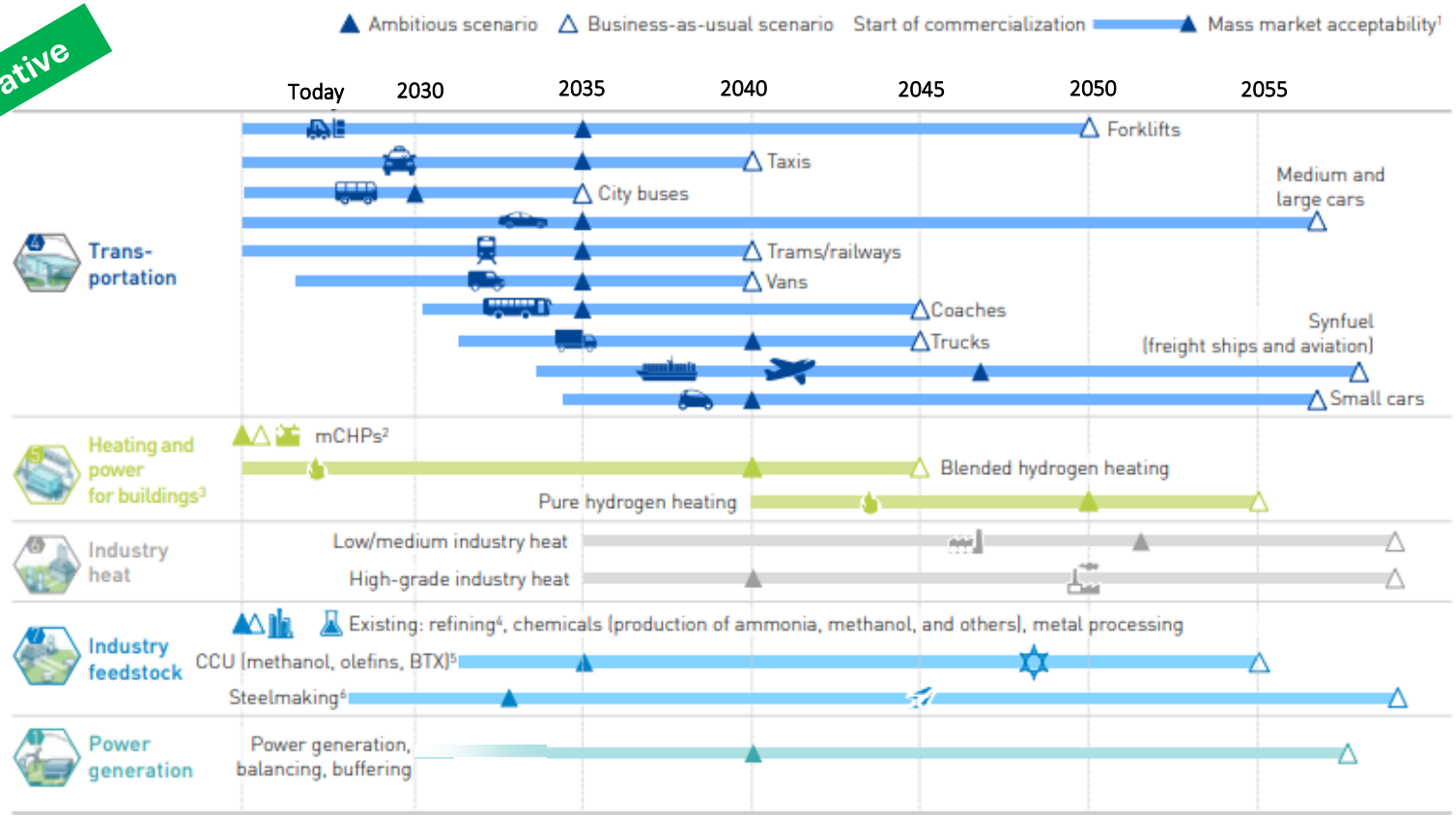
In the long term, hydrogen has the **potential** to be used as an energy storage system.

04 | The importance of Green Hydrogen

Today, **some of these alternatives already have market penetration**. However, it will take decades to reach maturity and development in some applications and end-uses

Time Horizon for Green Hydrogen Adoption

Illustrative



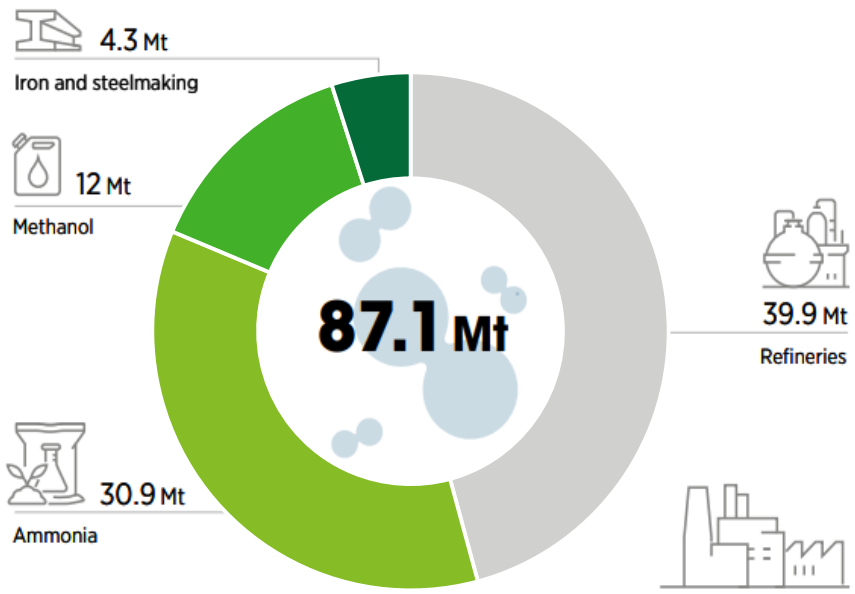
- **Replacing grey hydrogen with green hydrogen** as a feedstock in petrochemical process is the first steep.
- **Among the new uses of hydrogen,** transportation currently shows the greatest performance.

Powering the Future: Integrating Clean Hydrogen into the Power System

05 | The importance of Green Hydrogen

The **main source of hydrogen demand** today is **oil refining**, followed by **ammonia and methanol** production

Current Uses of Hydrogen



Note: information updated in 2020

Source: Deloitte Analysis

Main Uses of Hydrogen as a Feedstock in Refinery Processes

(and expected performance in the coming years)

Hydro-cracking	• **Decompose** medium and heavy distillates into **lighter and higher-quality fuels** (E.g. jet kerosene, gasoline, etc.) • **Demand for aviation jet fuel** but, in the long-term, **could be displaced by biofuels. and synthetics**
Hydrotreatments	• **Removes sulphur** and other impurities, **improving fuel quality** • **Usage could decline due to lower demand for petroleum products** and refinery developments
Biofuels	• Production of **renewable fuels** from **biomass pyrolysis and plastics.** • **Expected to grow in line with European targets** of penetration in transport consumption.
Comb. Synthetic	• **Renewable fuels, combining CO2 and H2,** for Internal Consume Fuels (ICE) vehicles. • **Lower H2 costs would boost the competitiveness of synthetics** compared to fossil fuels (H2 accounts around the 70-75% of production cost). Projections suggest **~30% cost reduction between 2020-2030 and 25% between 2030-2050**

The Impact of Green Hydrogen on Power Grids

The challenge is to balance the growth of unmanaged electricity supply and demand with the capacity of electricity grids and their regulatory framework

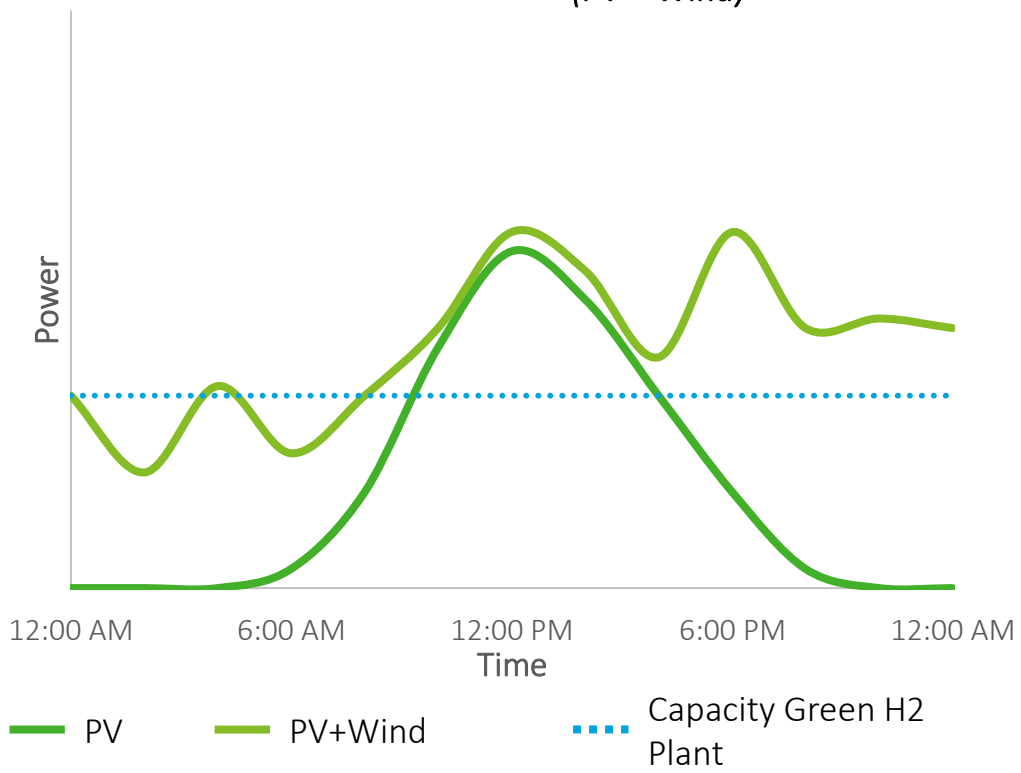
There are 2 primary pathways to produce hydrogen

Illustrative

01 New Dedicated Renewable Generation

1,200 – 2,000 hours (PV)

3,000 – 4,000 hours (PV + Wind)

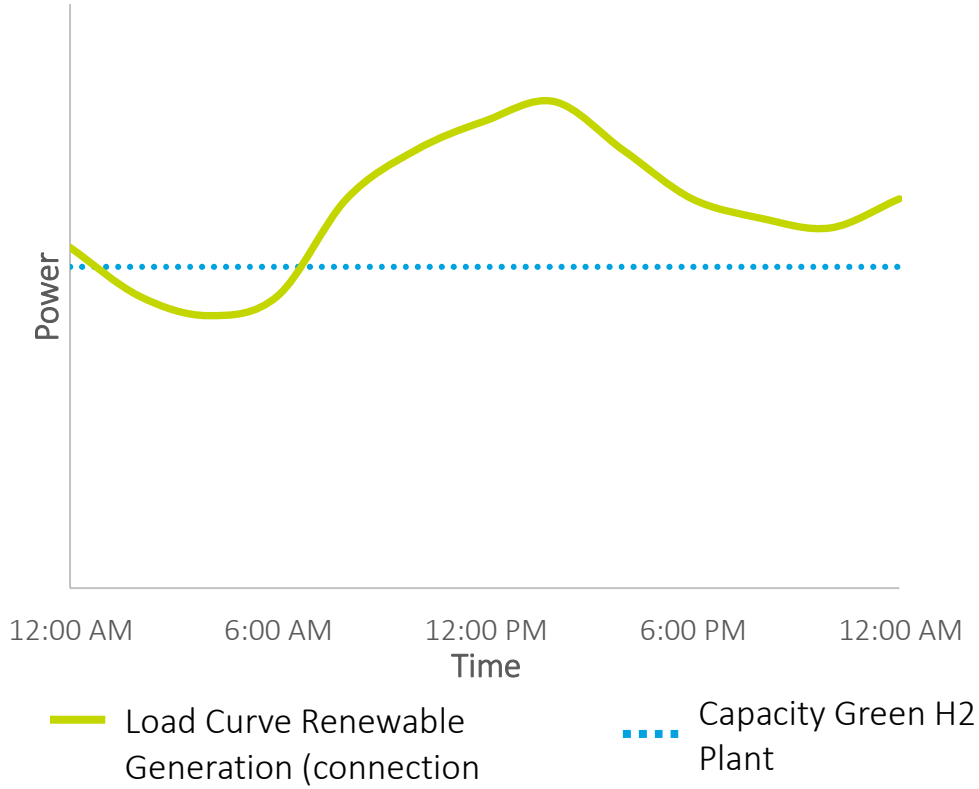


02 Connected to the Electricity Grid

(New Dedicated Renewable Generation + Grid Connection)

- Considering system restrictions and power generation mix -

4,500 – 8,000 hours



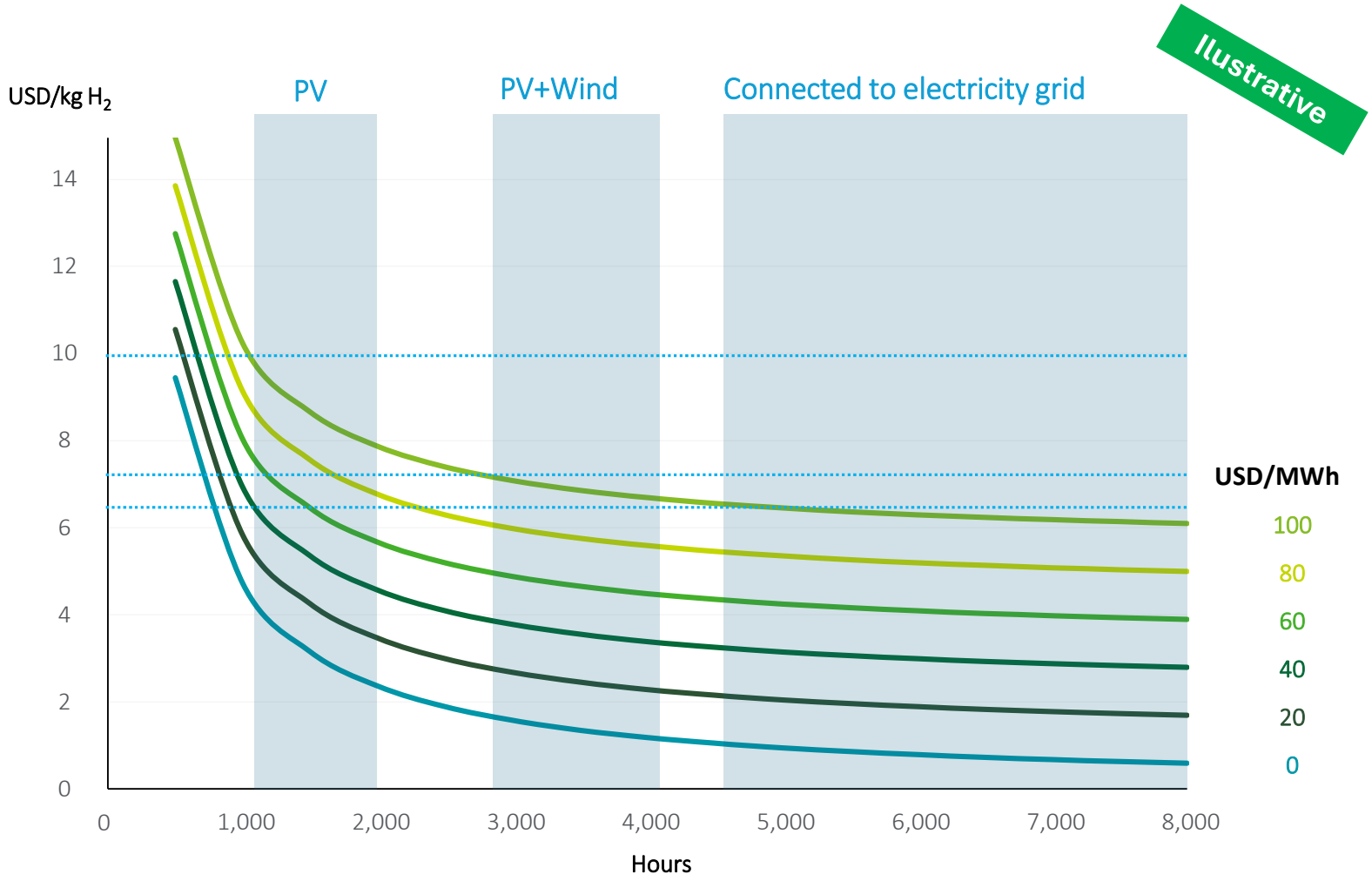
Source: Institute for Local Resilience, Deloitte analysis

Powering the Future: Integrating Clean Hydrogen into the Power System

07 | Green Hydrogen Production and the Power System

- As the number of **plant load hours increases**, its LCOH decrease more rapidly.

- **Connecting to the electricity grid** currently is the only way to **guarantee project viability** when the renewable dedicated generation is intermittent and unmanaged



Source: EAWE, Deloitte analysis

Powering the Future: Integrating Clean Hydrogen into the Power System

08 | An Energy System in Transformation

Establishing a robust and decarbonized electricity system is essential for developing a Hydrogen Ecosystem, to ensure:

Connect Hydrogen Production Projects to the Power System

- **Standalone renewable plants** dedicated to hydrogen production plants.
- **Ensure new capacity in the power system** to guarantee access to new renewable generation and new demand.

A Decarbonized Power System by Incorporating Additional Renewable

- **New renewable capacity** into the power grid to contribute in the decarbonization of the entire electricity system

Maintain a Reliable Power System

- **Strengthen electricity infrastructure** to improve quality and security of supply across power grids

At the same time, the Power System faces broader **decarbonization** challenges

- **Decarbonization Transport:** electric vehicles, fuel cell vehicle, synthetic fuels, renewable fuels, etc.
- **Decarbonization Industry:** CO_2 capture, electrification of industrial processes, integration of renewable gases/green hydrogen, etc.
- **Increasing Self-consumption integration in Power Grids:** which implies bi-directional power flows.
- **New Standalone Battery Energy Storage:** to enhance grid stability and facilitate the integration of intermittent renewables.
- **New Electro-Intensive Industries:** such as data centers, blockchain, artificial Intelligence, etc.

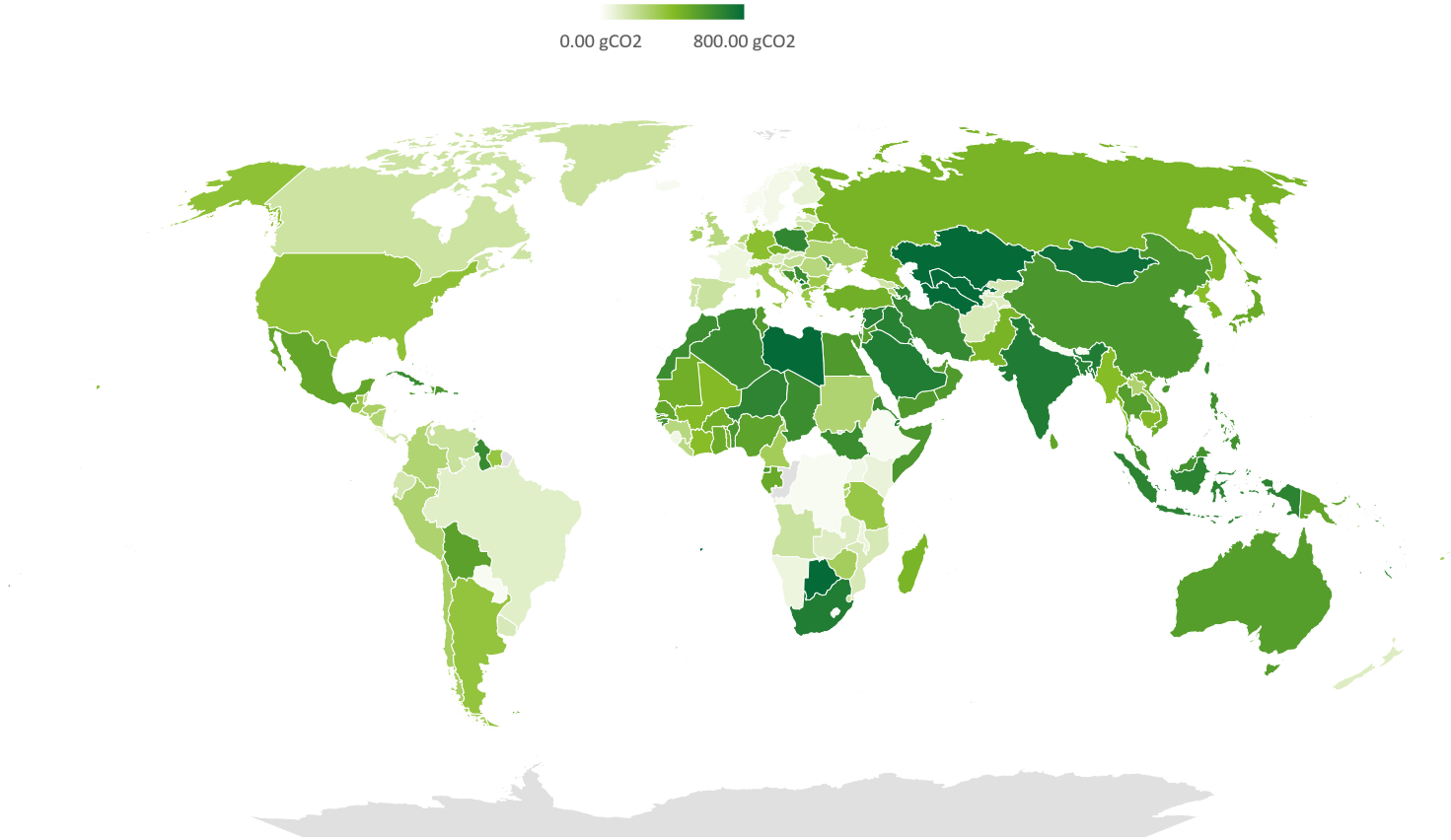
Powering the Future: Integrating Clean Hydrogen into the Power System

09 | How Prepare are Power Systems Around the World for this Challenge?

- Some countries still need to make **significant efforts** to decarbonize their electricity system

- Countries such as **China, Morocco, Turkey, Egypt, and Australia are poised to achieve some of the most competitive hydrogen production** in the world. However, their **electricity mixes still have a high carbon intensity**

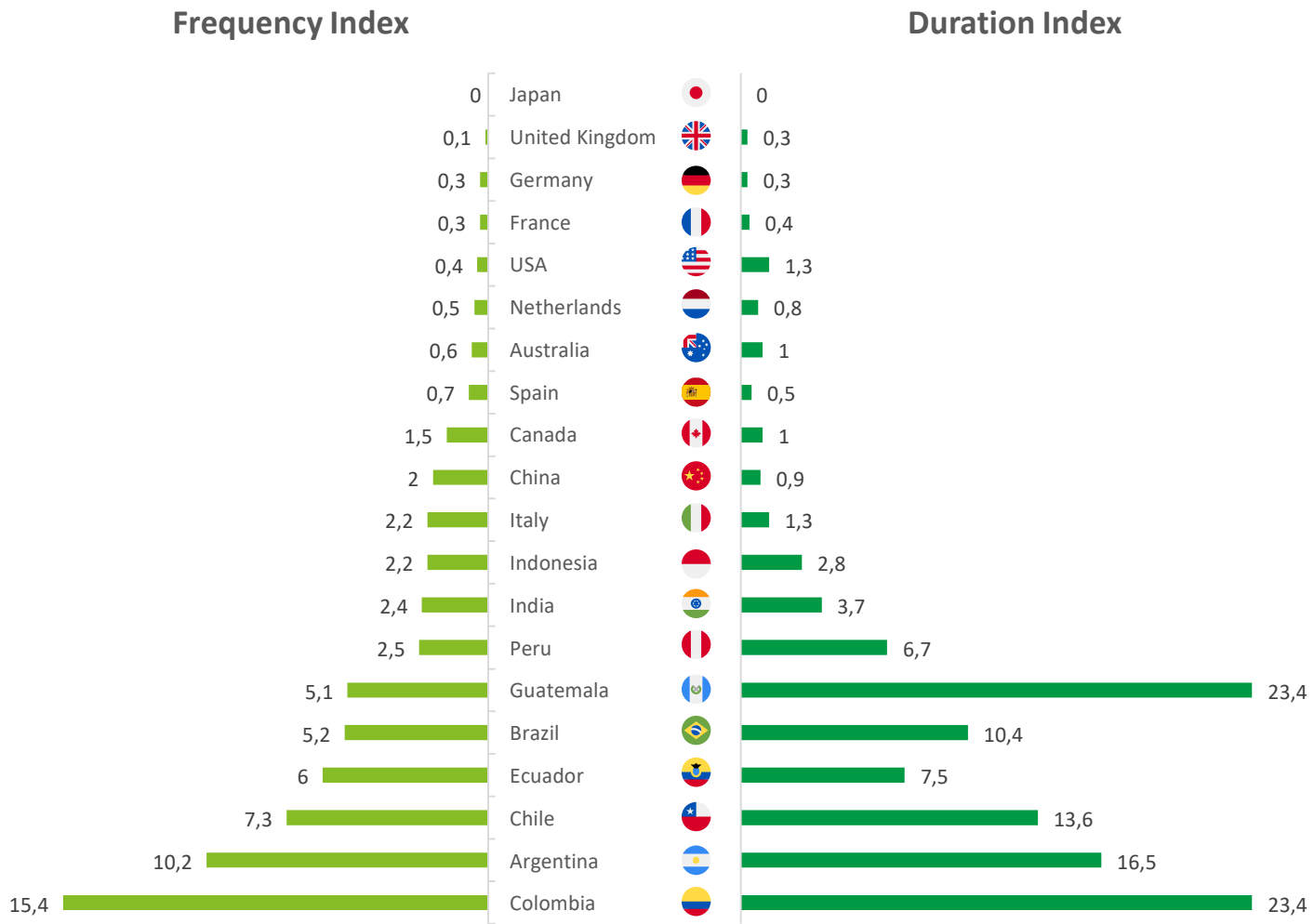
Carbon intensity of electricity (gCO_2) [2023]



Source: Ember, Energy Institute - Statistical Review of World Energy, Deloitte

10 | How Prepare are Power Systems Around the World for this Challenge?

Some **countries** are **better prepared** than others for the **increasing pressure** in the **power system.**

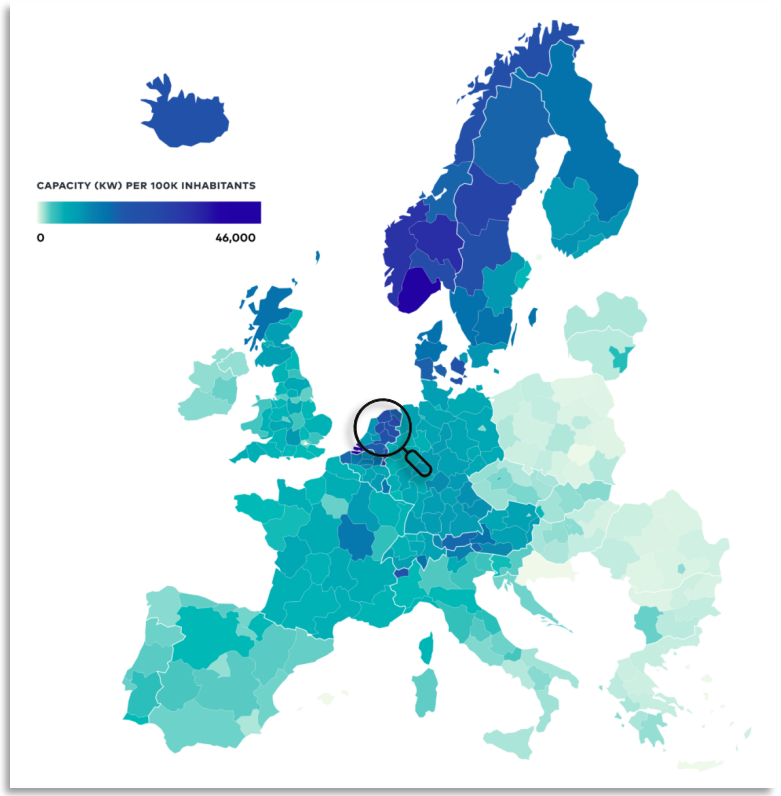


Source: Adelat, World Bank, Deloitte

11 | How Prepare are Power Systems Around the World for this Challenge?

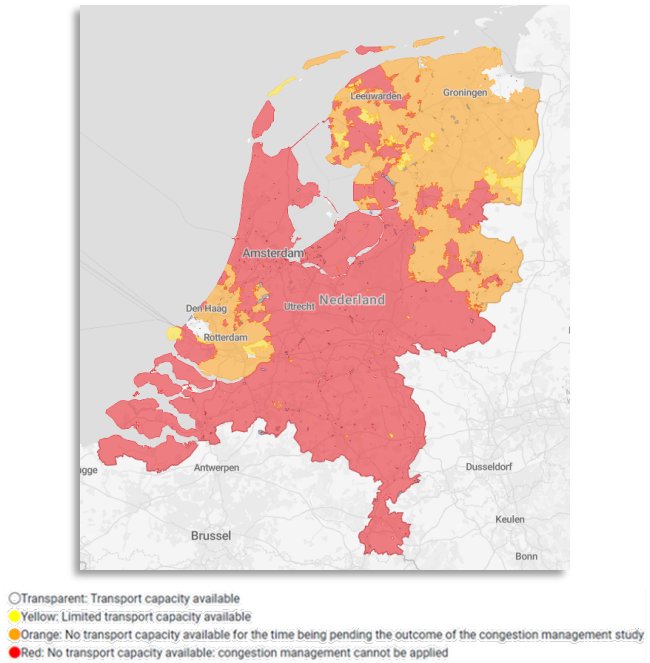
- Even in regions with a highly security of supply index, **access for new demand and generation can be significantly constrained**
- In many parts of the world, **electricity grid** access, both for demand and generation, **remains highly congested**

Capacity (kw) per 100k inhabitants



Source: Fleeteurope

Netherland grid congestion map [2025]



Source: Capaciteitskaart

Powering the Future: Integrating Clean Hydrogen into the Power System

12 | How Prepare are Power Systems Around the World for this Challenge?

A high increase in the demand is causing relevant blackouts around the world

A Buenos Aires power outage leaves over 600,000 customers without electricity

A power failure in Buenos Aires has left hundreds of thousands of customers without electricity in the Argentine capital, shutting off traffic lights, stranding subway passengers and testing the electric grid for the second time in 24 hours during a si...

Source: abc News (March, 2025)

Power back on in Chile after blackout leaves millions in dark

Electricity restored to almost all affected regions as investigation under way into how outage occurred

Source: The Guardian (February, 2025)

Total blackout in Panama: A failure in a private power plant disrupts the electrical grid

An incident in a private power plant caused a nationwide blackout in Panama on Saturday night. The national power grid was severely impacted, leading to an interruption in the potable water supply. Authorities are investigating the causes of the event.

Source: energynews (march, 2025)

Cuba struggles to restore power to millions as night falls

Source: Reuters (March,2025)

More than 25,000 homes, businesses still without power as temperature hits 35 degrees

Source: 9News (March, 2025)

Power outage persists as Nigeria masks 'grid collapse'

Source: Business Day (March, 2025)

Nationwide power outage in Sri Lanka blamed on a monkey

Millions were left without power during the blackout, which began around 11am local time on Sunday.

Source: sky news (February, 2025)

Power blackout hits Montenegro, Bosnia, Albania and Croatia's Adriatic coast

Source: ekathimerini (December, 2024)

Flight Delays Warning Issued After Massive Puerto Rico Power Outage

Source: Newsweek (December, 2024)

Power Grid Failure in Ethiopia Causes Nationwide Blackout

Source: News Central (December, 2024)

Ecuador struck by power outage leaving 18 million in the dark

Power was restored on Wednesday afternoon, after the outage caused confusion on the streets of Quito as traffic lights ceased working

Source: The Guardian (June, 2024)

Egypt temporarily extends daily power cuts to three hours

Source: Reuters (June, 2024)

Blackouts spark fears of grid 'collapse' in Brazil's biggest city

Power outages in São Paulo reflect chronic underinvestment in country's infrastructure

Source: Financial Times (April, 2024)

Some blackouts published in the last year

Regulation as key driver to adapt the electricity system to new necessities

PLANNING OF THE POWER SYSTEM

Early planning of electricity systems is **essential** to **accommodate** the **increase of unmanageable generation and new electricity demand**

REGULATION MECHANISMS

The **regulatory frameworks should give sufficient flexibility** to allows the adaptation of the power system

KEY CHALLENGES IN ADAPTING ELECTRICITY GRIDS IN A REGULATED ENVIRONMENT

- Unclear bureaucratic **procedures and lack of flexibility**
- Regulatory **limitations** on the **investment** capacity
- **Insufficient** incentives and guarantees for **return** on investment

These challenges also present opportunities for innovation and regulatory adaptation

Opportunities identified

There is an opportunity to adapt the regulated electricity grid model, and to promote hydrogen through specific measures, new grid investment models, and regulatory adjustments that eliminate investment penalties.

Make **investment limits** for DSOs and TSOs **more flexible** to facilitate the **energy transition**

HOW: key practices

Speed up necesary investments

Develop a flexible and **agile plan** for grid expansion

Adopt a **cross-sector approach** to grid investments

Make **better use** of the **existing grid**

Readjust investment limits

WHERE: investment categories

- **Replacement and Renewal** – Replace assets that have reached the end of their life or facing other issues.
- **Reinforcement for Demand Growth** – Expand grid capacity to accommodate increasing demand electrification.
- **Reinforcement for Capacity** – Integrate new renewable energy sources to ensure they reach areas with high demand.
- **Smart Metering** – Implement smart meters to improve the accuracy of energy consumption measurement.
- **Automation and Digitalization** – Invest in AI, IoT, and other technologies to enhance operational flexibility.
- **Grid Resilience** – Strengthen the grid and build additional redundancy (e.g., network meshing) to improve reliability.

Ensuring a reasonable **return on grid investments**

Modern Remuneration model
Stable, flexible and guaranteed

- Recognition of anticipatory investments.
- Promoting project financing.
- Recognition of inflation effects.

The Importance of an Adequate Tariff
Key considerations

- Sends appropriate and clear signals to encourage investment in efficient and profitable assets.
- Adapt system to rising electricity demand.
- Contributes to achieve environmental goals.
- Ensure control costs for consumers.

Appropriate regulation to organize and prioritize **access to Power Grids**

Set Clear Technical and Administrative Requirements – Ensure each project meets the necessary technical standards to guarantee their feasibility and quality (e.g. business plans, technical project, etc.).

Use Alternative Systems for Prioritization – Implement improved methods to manage access and connection requests. This includes standardizing request processing, improving transparency, and using competitive bidding when needed.

Require Financial Guarantees – Stakeholders requesting connection points must provide appropriate financial guarantees to prove their commitment and project viability.

Establish Mandatory Deadlines – Define clear timelines and key milestones that projects must meet to maintain their access and connection rights (e.g. specifying when permits expire).

Provide Transparent Information on Available Capacity – Regularly publish data showing available capacity at the critical points in the distribution and transmission grids.

Conclusions

Some recommendations

1 ***Ensure Reliable Grid Access*** *improve the request process for access and connection to new renewable generation and demand*	• Implement measures to restructure and streamline grid access applications procedures • Preventing fraud and speculative congestion while prioritizing projects with proven strategic value
2 ***Advance a proactive and cross-sectoral approach to grid planning***	• Develop a flexible network planning strategy considering future demand from green hydrogen and other sectors • Enhance efficiency and adaptability to support rising electricity needs
3 ***Create attractive remuneration models*** *Encourage investment in electricity grids*	• Establish compensation frameworks aligned with grid needs • Incentivize participation in projects that reinforce energy infrastructures and contribute to decarbonization objectives
4 ***Encourage greater demand-side participation in electricity markets***	• Strength the system flexibility and stability. • Define mechanisms enabling active demand participation in electricity markets, including capacity markets.

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