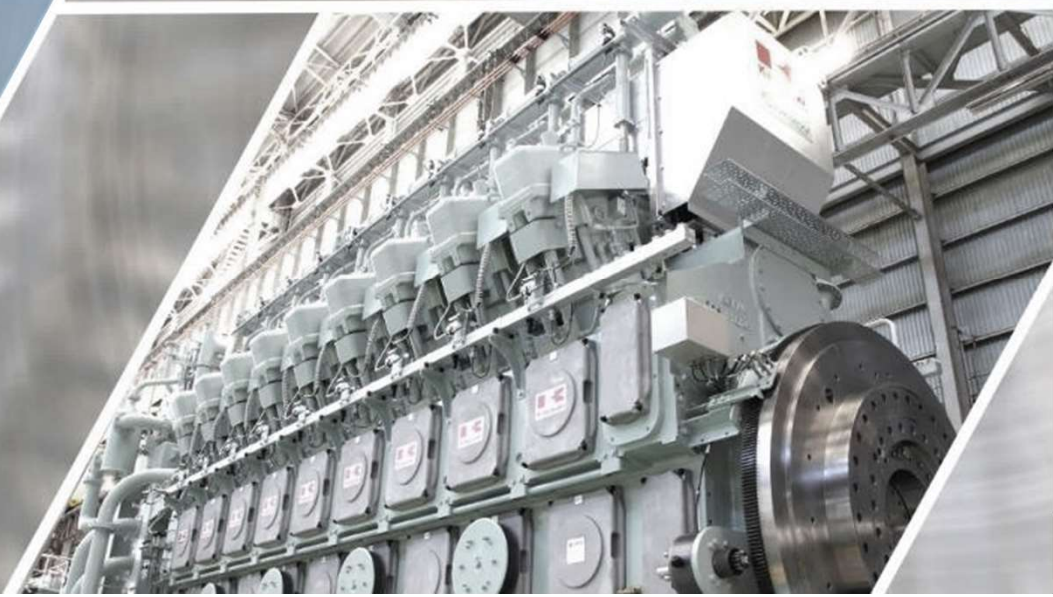
Kawasaki Gas Turbine Europe GmbH

CHP and Combined Cycle-Plants

Hydrogen in the Decarbonization of Industry

KAWASAKI HYDROGEN ROAD

Development of Innovative Hydrogen Technologies
for Future Hydrogen Society



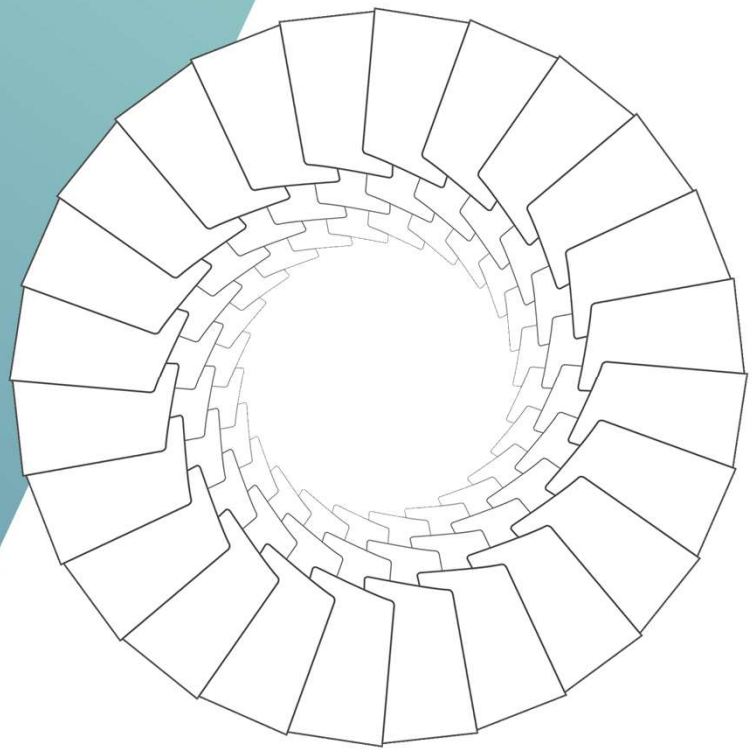
GENERA 2024- Madrid
06th February 2024

Kawasaki

I Kawasaki - Introduction

II Kawasaki Hydrogen Road

III Future H_2-Market



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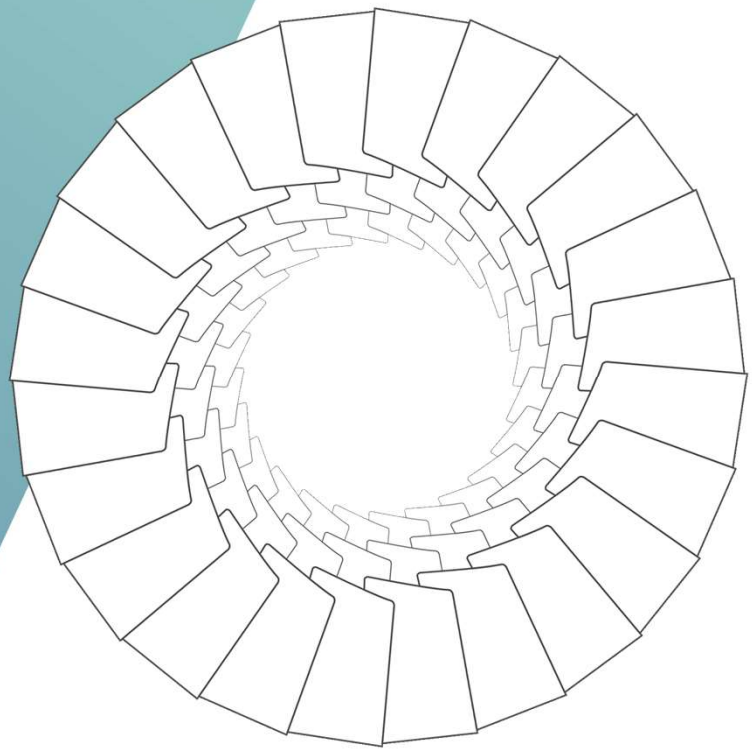


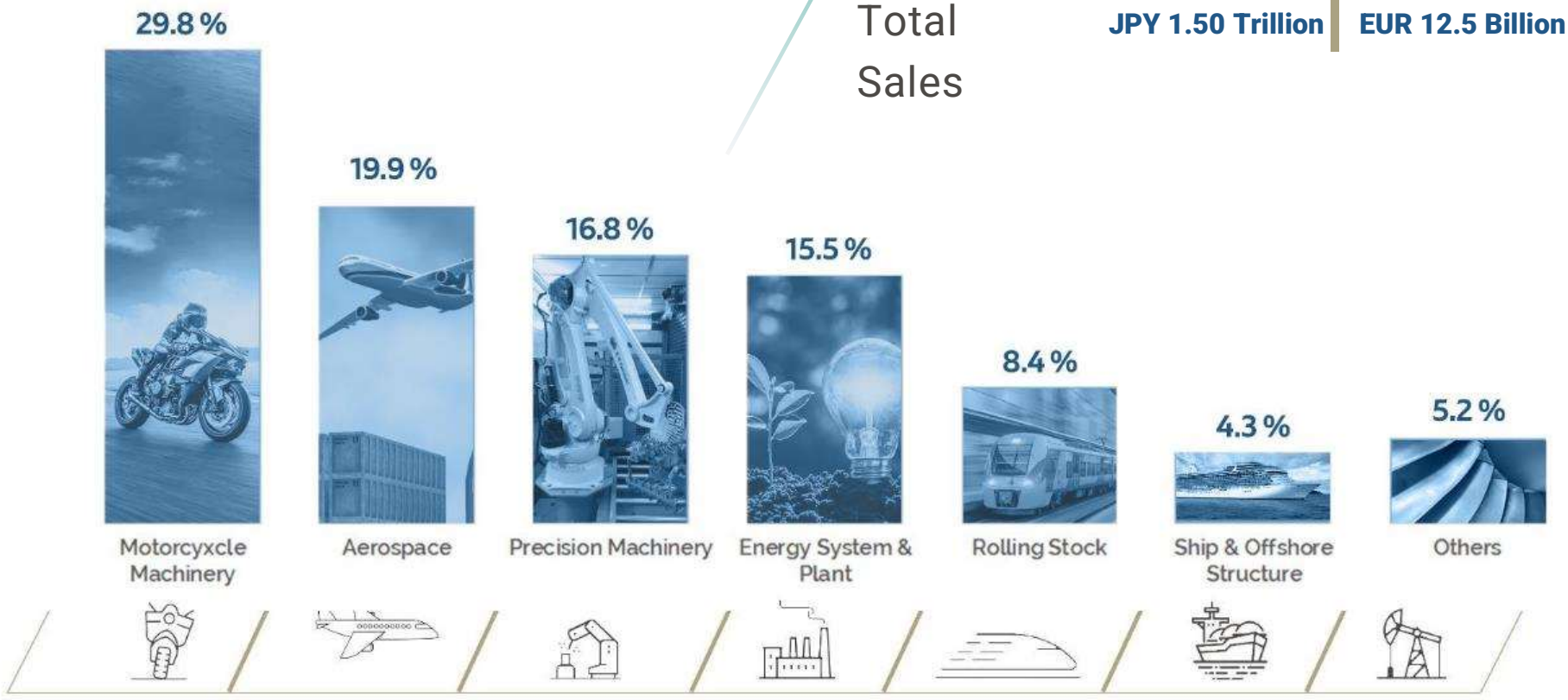
Kawasaki Heavy Industries (KHI)

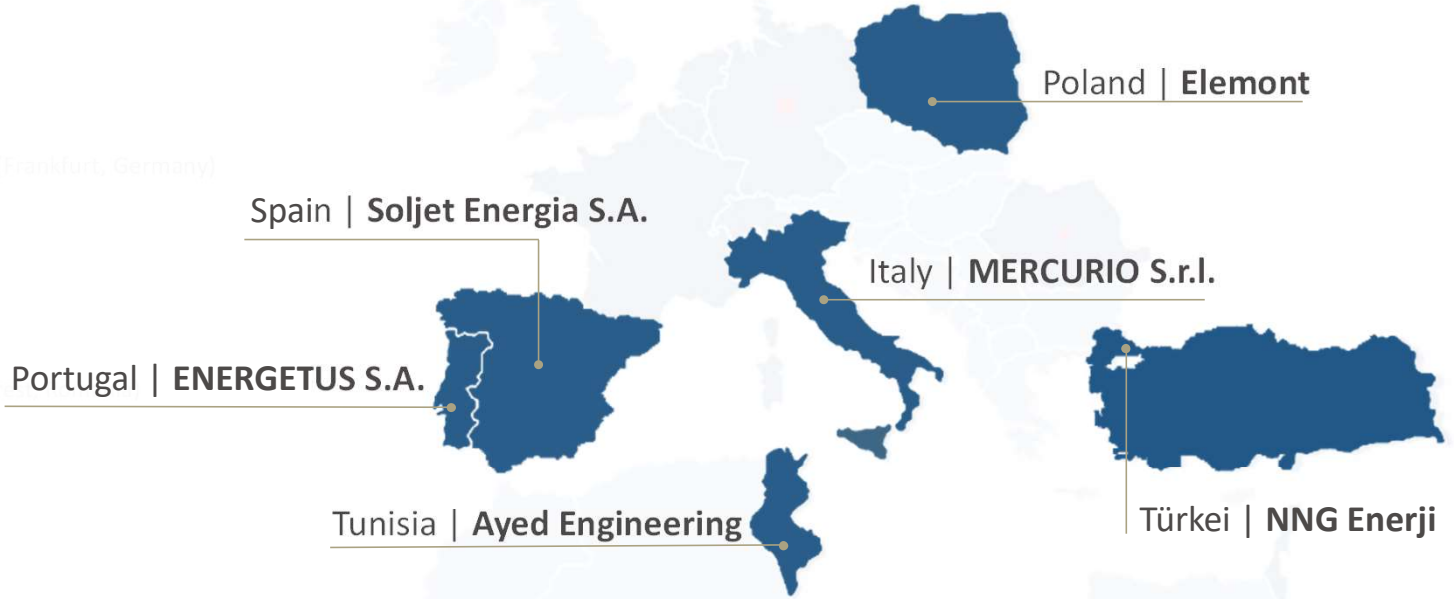
FY2022

Business year starts from April 1, 2021 and ends on March 31, 2022

Total Sales

JPY 1.50 Trillion | **EUR 12.5 Billion**





● KGE agents

Products

Gas Turbine Generator Sets

GPB17D	GPB50D	GPB80D	GPB180D	GPB300D
1,800 kWel	4,700 kWel	7,800 kWel	18,500 kWel	34,300 kWel
η = 28.1 %	η = 32.6 %	η = 33.6 %	η = 34.3 %	η = 40.3 %

Gas Engines

KG12	KG18	KG18-V
5,200 kWel	7,800 kWel	7,800 kWel
η = 49.0 %	η = 49.0 %	η = 49.5 %

@ ISO-conditions

Services

Engineering

Preliminary Engineering
Detailed Engineering

Implementation

Project Planning
Customized Packaging
Erection Commissioning

Maintenance

Scheduled Maintenance
Trouble Shooting
Spare Parts, Consumables
General Overhaul
Remote Monitoring

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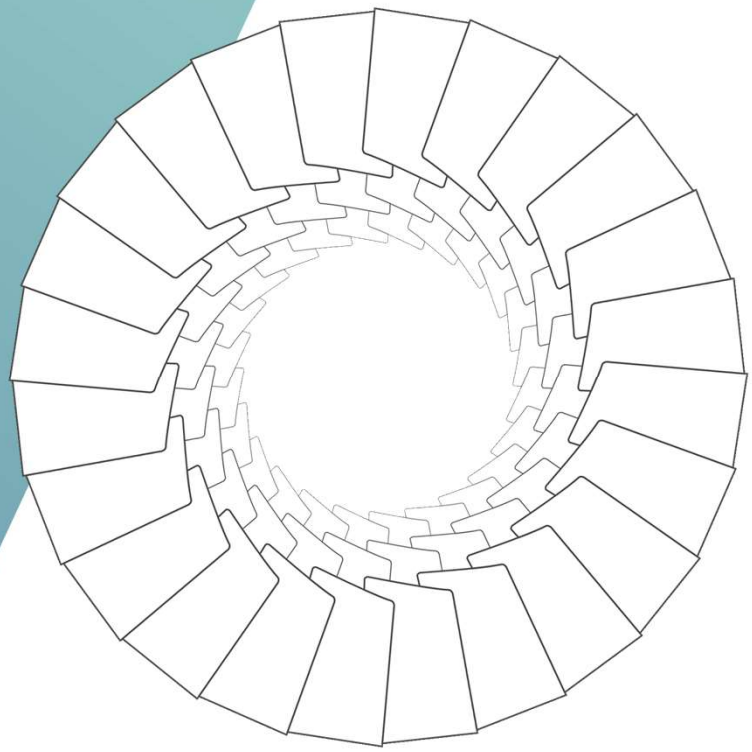


Hydrogen Road

H2-Production and Liquefaction

H2-Storage Tanks

H2-Oversea Transportation

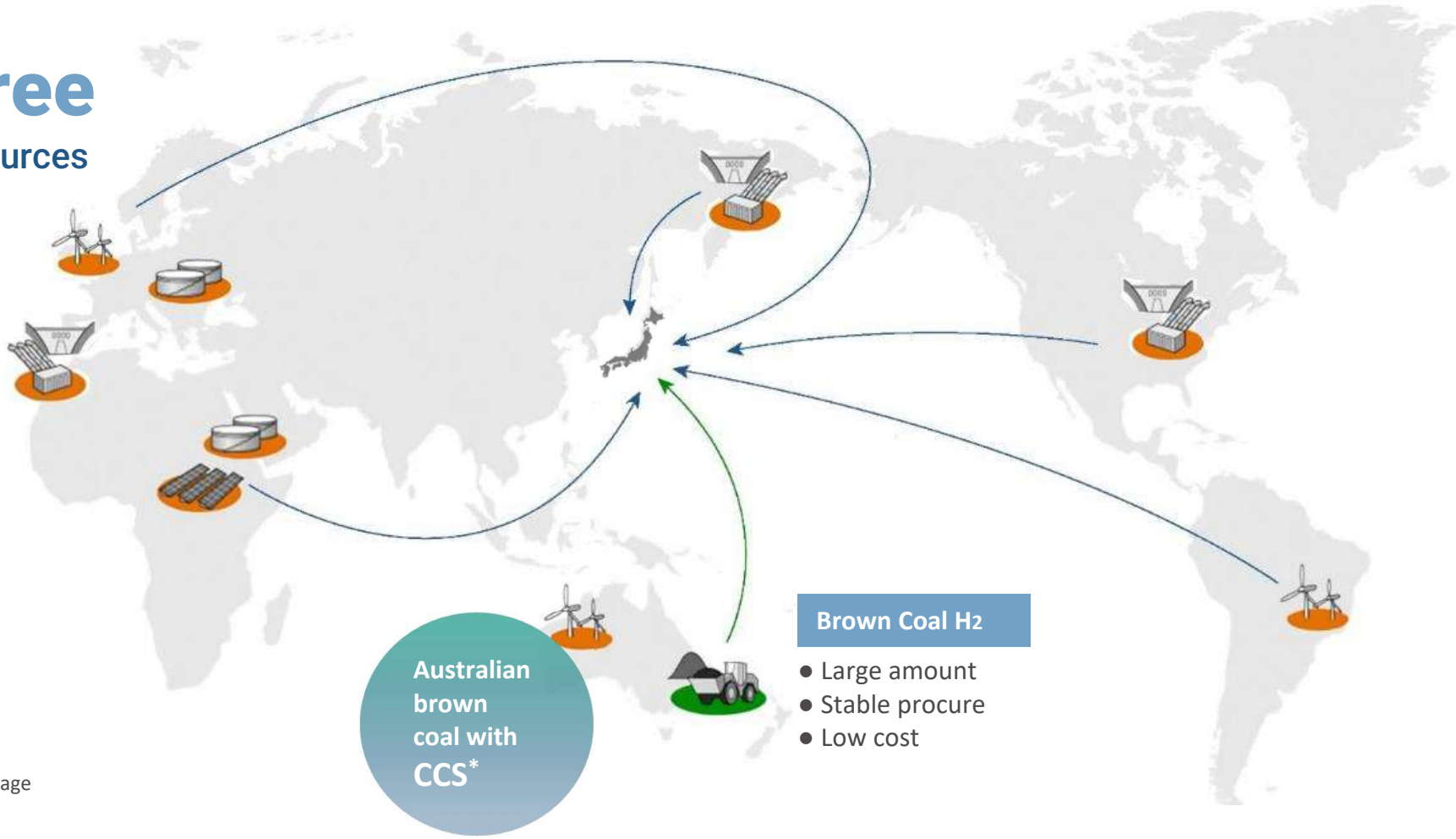
H2-Land Transportation

H2-Gas Turbines
H2-Compressors

Hydrogen Road of Kawasaki Heavy Industries (KHI)

CO2-Free

Hydrogen Resources in the World



- Natural Gas H2
- Solar Power H2
- Hydro Power H2
- Wind power H2

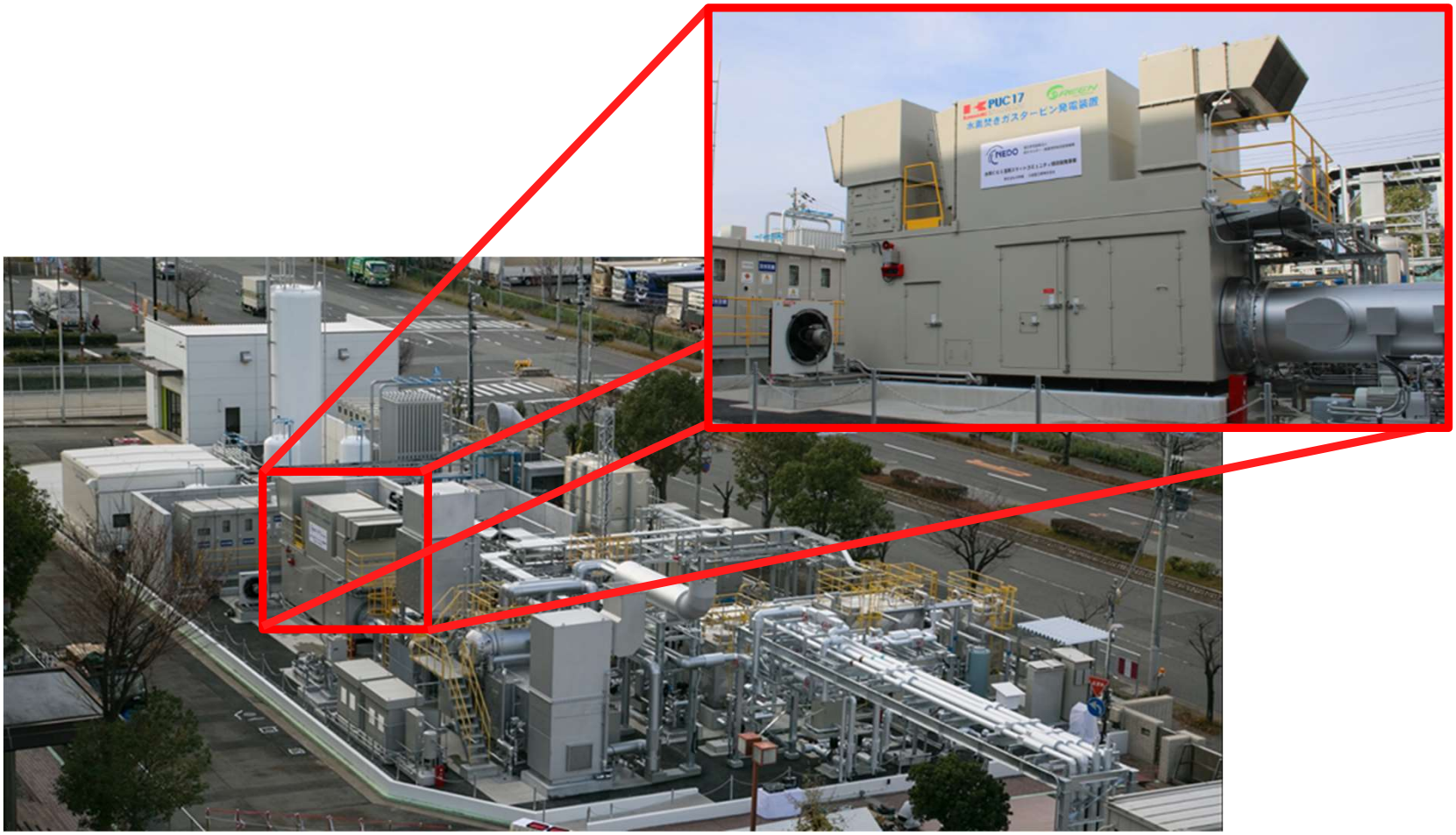
* CCS: CO2 Capture and Storage

Australian brown coal with CCS*

Brown Coal H2

- Large amount
- Stable procure
- Low cost

Heat & Power Supply With World‘s First 100% H2-CHP Plant at Kobe Port – Since 2018



Project Summary with hydrogen retrofit

GPB17D-H2 / Chevron Phillips Chemicals (BE)

Challenges

- highest efficiency needed
- full flexible 0 - 30vol% Hydrogen capability
- 15 ppm NOx
- chemical plant ambient

Project key data

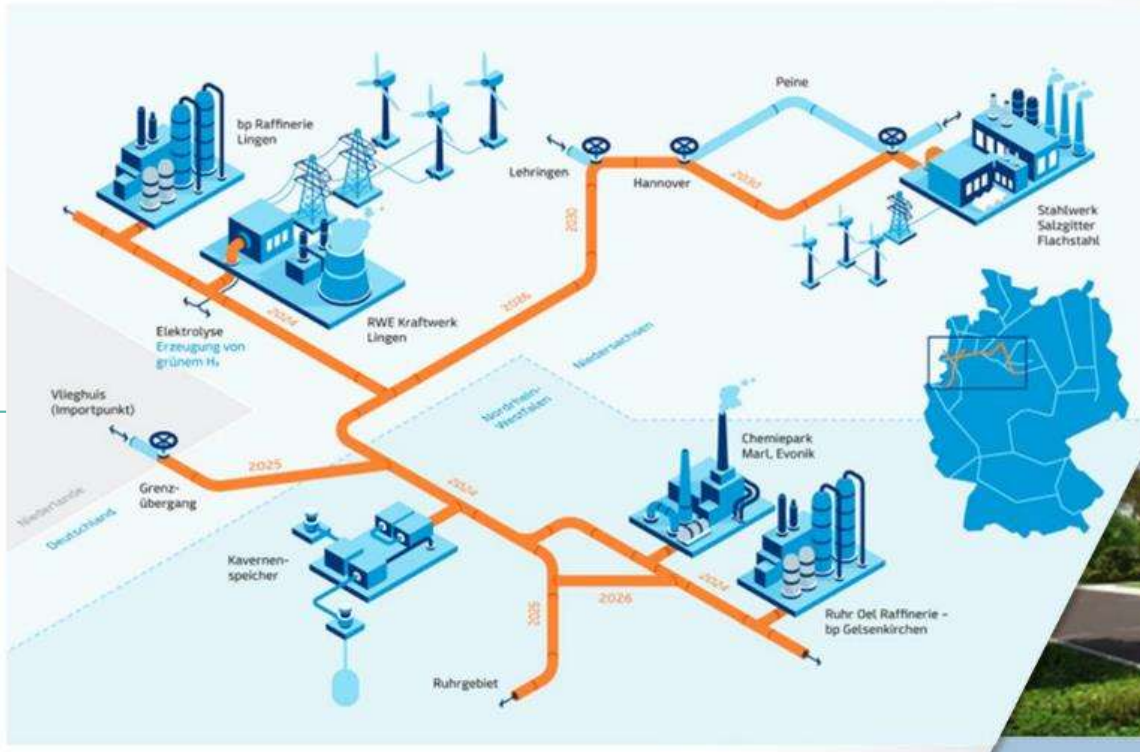
Commissioning	August 2021
Hydrogen retrofit	September 2023
Electrical Output (ISO)	1.8 MW
Electrical Efficiency (ISO)	28.1 %

Project background:

Supplementation of Steam Generator by one GTGS with usage of Hydrogen

Joint undertaking of Kawasaki & RWE

RWE and Kawasaki plan to install a 100% hydrogen-capable industrial-size gas turbine in Lingen, Germany



- From 2024 onwards 34-megawatt plant could reconvert green hydrogen to power
- In future, H2-fuelled power plants will contribute significantly to green security of supply

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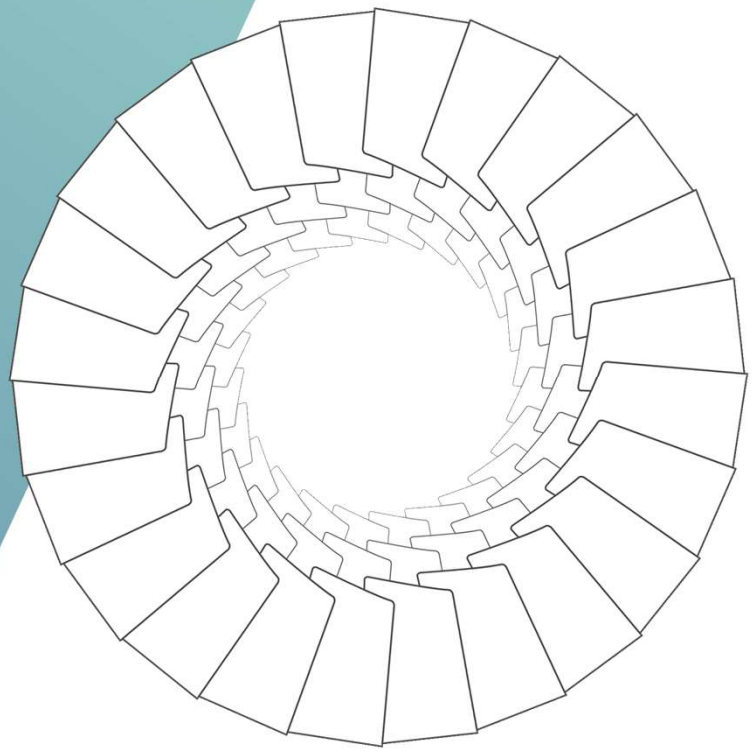


Market dynamics based on the number of projects

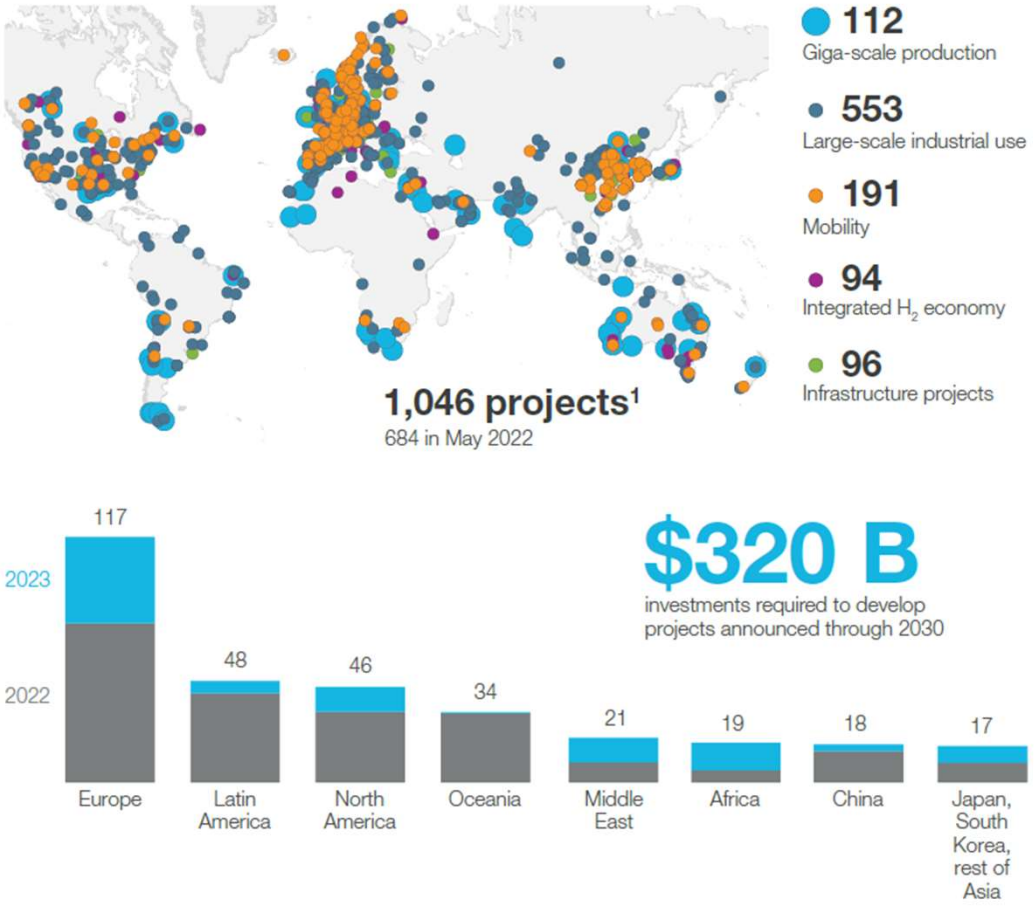
Hydrogen momentum is strong: more than 1,000 project proposals have been announced globally

Globally, the industry has announced more than 1,000 large-scale project proposals as of the end of January 2023. Since the previous publication,[2] more than 350 new proposals have been announced. Of the total, 795 aim to be fully or partially commissioned through 2030 and represent total investments of USD 320 billion of direct investments into hydrogen value chains through 2030 (up from USD 240 billion).

Europe remains the global leader in hydrogen project proposals, with the highest total investments (USD 117 billion, 35% of global investments) and highest absolute growth (USD 40 billion). Latin America and North America follow Europe, each representing about 15% of announced investments. Growth in North America increased following the announcement of the IRA (see Section 03 of this publication).

Giga-scale project proposals (over 1 GW of electrolysis for renewable hydrogen supply or more than 200,000 kt p.a. of low-carbon hydrogen) account for 112 project proposals (requiring about USD 150 billion investment until 2030), nearly doubling from 61 eight months ago. Of these 112 proposals, 91 are renewable and 21 are low-carbon hydrogen.

Momentum is strong, and the industry is planning investments into clean hydrogen, yet much more needs to be done. To be on track to net zero in 2050, more than a doubling of announced investments is needed by 2030 – and these need to be matured and deployed.



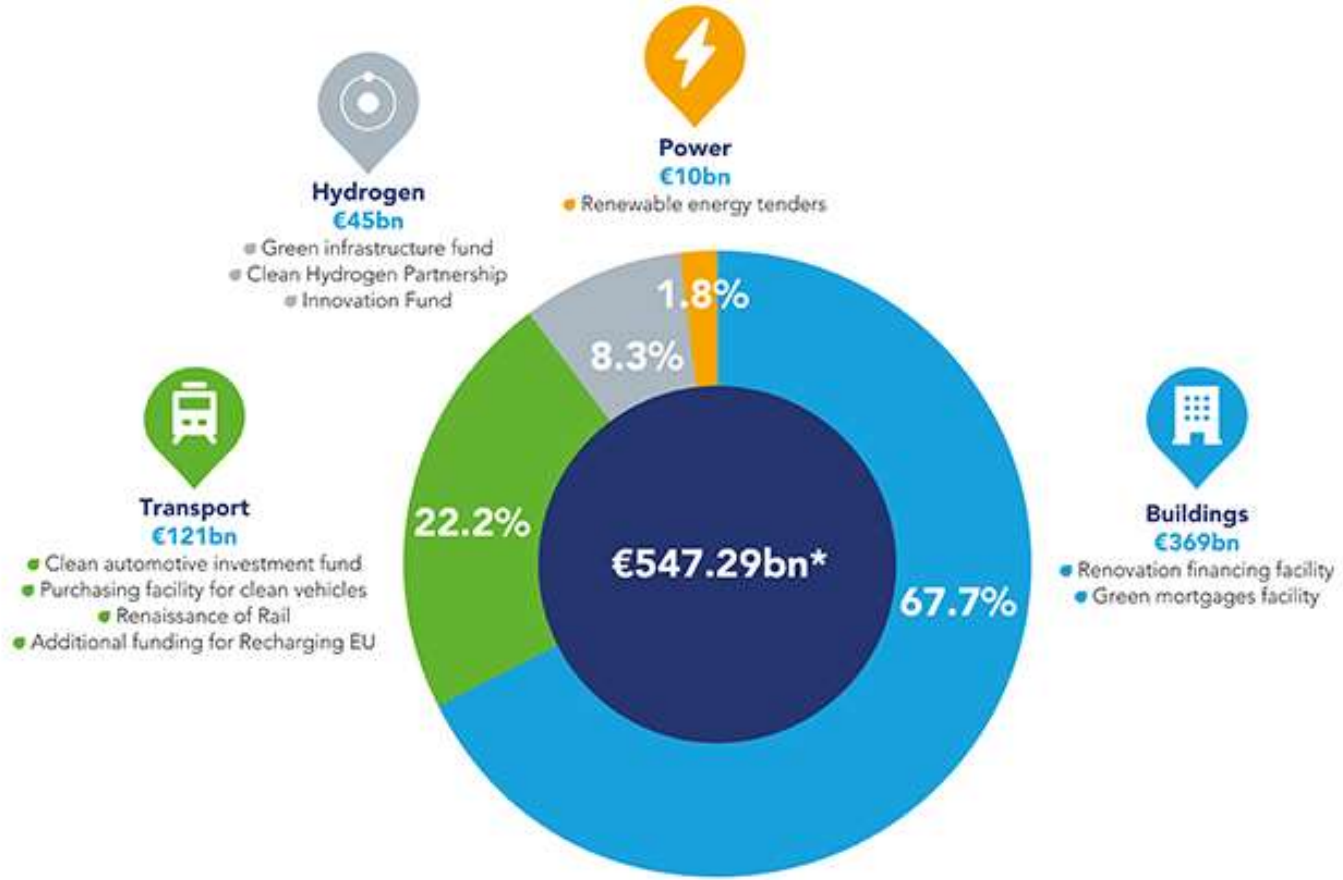
[2] Hydrogen Insights 2022 with data from May 2022; comparisons in this report are relative to this publication unless stated otherwise

1. Focus on projects of >1 MW

Source: Project & Investment tracker, as of Jan 31, 2023

Source: „Hydrogen Insights 2023:An update on the state of the global hydrogen economy, with a deep dive into North America ", Hydrogen Council and McKinsey, 05/2023

EU budget for 2021-2027



The EU Commission has committed to spending 30% of total expenditure (1,824.3 billion) on climate-related purposes.

Source: EU Infrastructure Atlas 2020

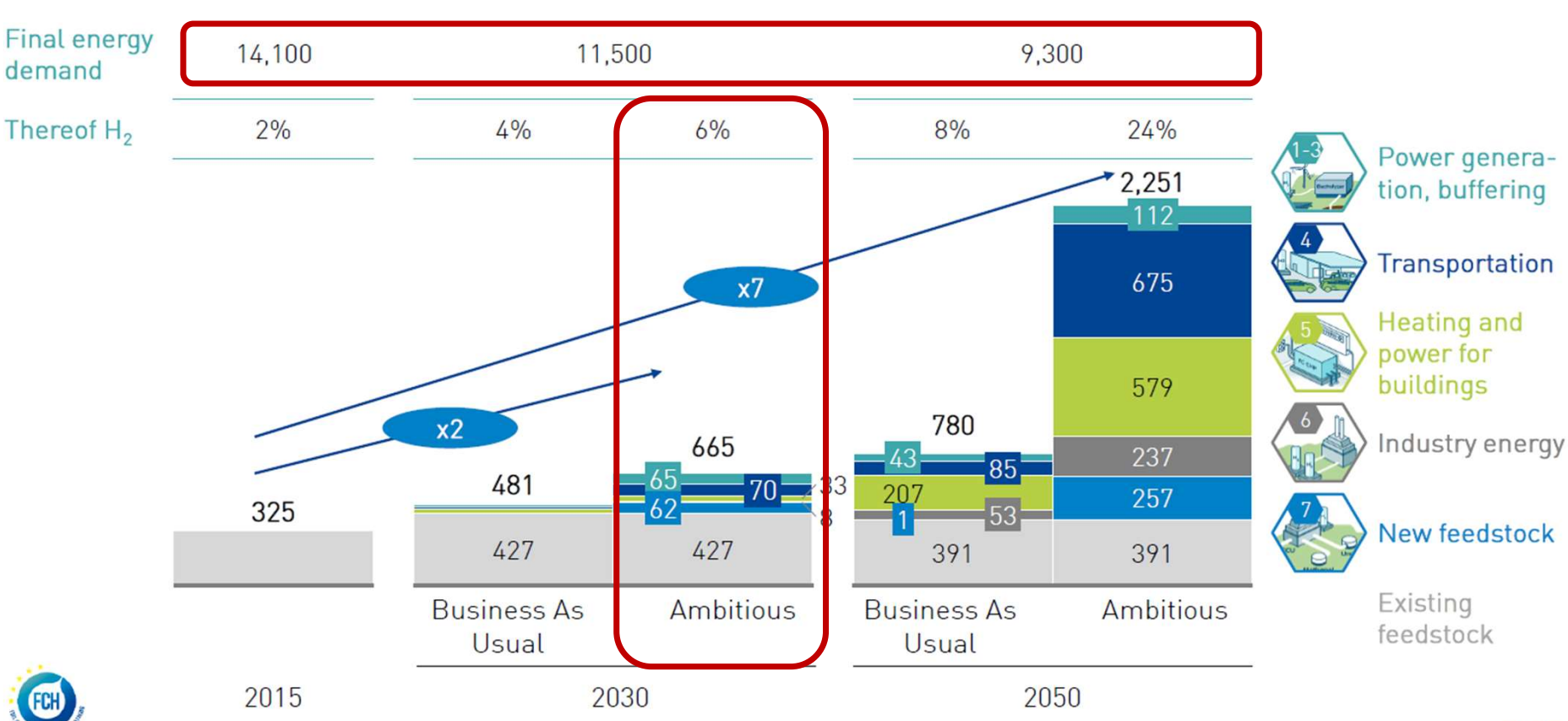
Importance of hydrogen for the decarbonization of individual sectors

	Industry	Transportation	Energy supply	Building
No real alternative to H_2	• Steel industry • Chem. industry	• Long-haul flights • Shipping	• Long-term storage for seasonal generation	• High-temperature heat for district heating supply • Partial replacement of gas in unrenovated areas
Comparably better alternative to H_2	• Industries with high-temperature processes	• Heavy commercial vehicles • Short-haul air traffic • Inland navigation	• Medium-term storage	
Better alternative to H_2	• Industries with low-temperature processes	• Passenger car • Light commercial vehicles	• Short-term storage for backing up power generation	• Individual houses, local and district heating up to 90°C with the use of heat pumps

Source: Based on: Presentation by PWC: "The Hydrogen Compass", Albersmann, J. (Energy Consulting), 11.05.2023

Hydrogen Market Outlook

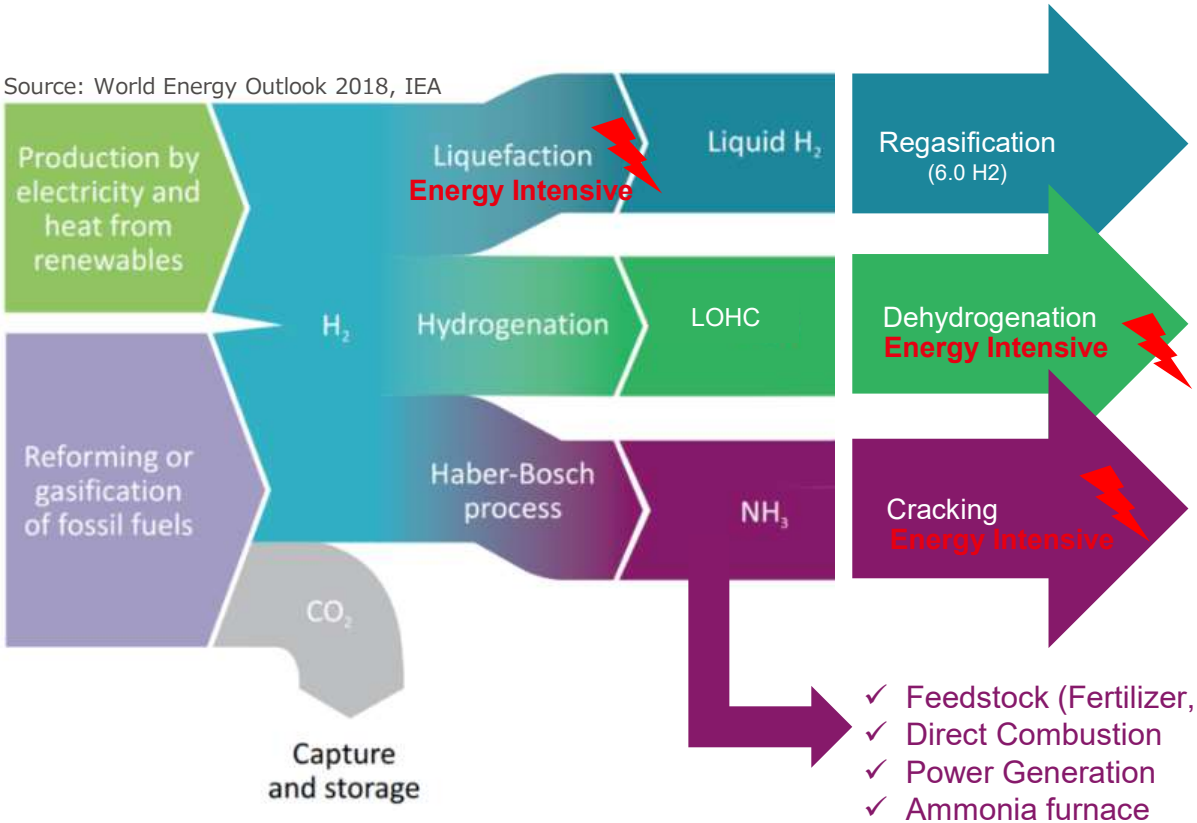
HYDROGEN COULD PROVIDE UP TO 24% OF TOTAL ENERGY DEMAND, OR UP TO ~2,250 TWH OF ENERGY IN THE EU BY 2050



SOURCE: Hydrogen Roadmap Europe team

Supply routes for low-carbon hydrogen

End-Use Application Defines The Path



Pros & Cons

+ Easy and cheap reconversion
+ Pure hydrogen (6.0) without PSA
+ Production of cold
+ Boil-Off-Gas can be used for propulsion
+ Compression in liquid phase
- Challenging technology with expensive production, transport and storage
- Energy intensive production

+ Easy and safe handling
+ Using of existing oil infrastructure
- Fluid carrier can be reused, but requires to be shipped back
- High degradation of fluid carrier, reuse is limited
- Expensive fluid carrier, 6% only is H2
- Reconversion is very energy intensive

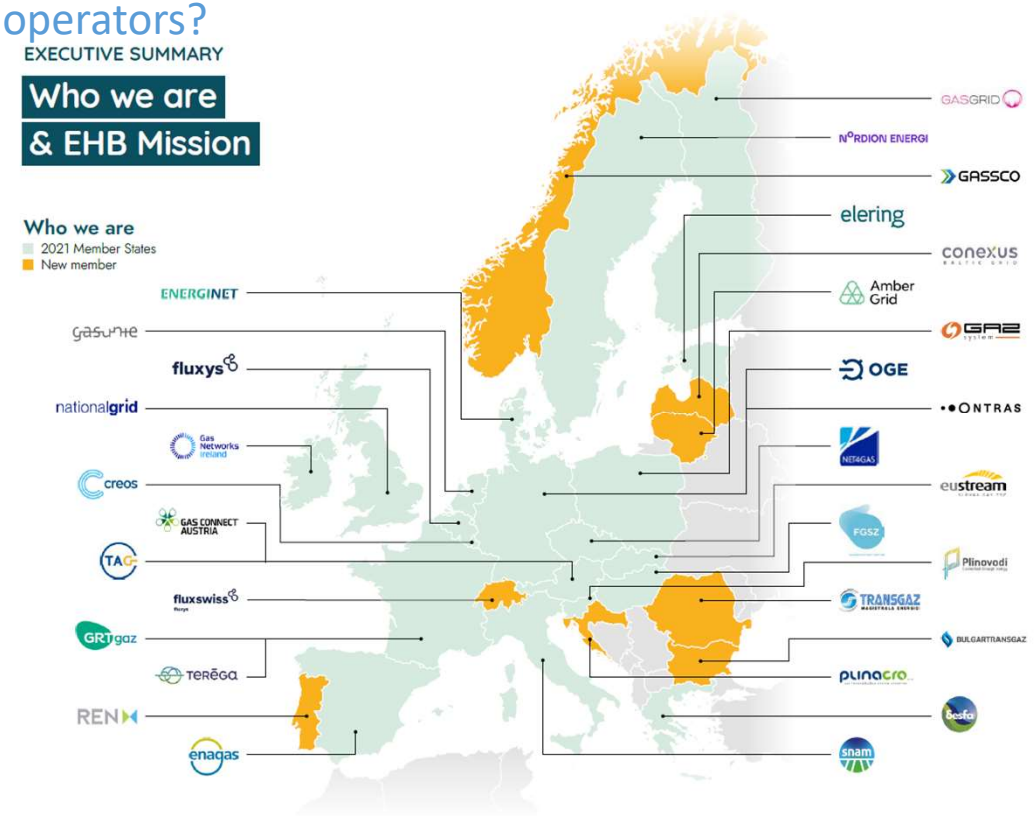
+ Production, transportation and storage is proven
+ Using of existing infrastructure (LPG, etc)
- Reconversion is energy intensive
- Immature ammonia cracker
- Toxic, handling and storing restrictions in residential areas, limited options for in-land distribution
- High NOx-Emission (Fuel Nox)

Hydrogen infrastructure of the future

What is currently happening on the part of infrastructure operators?

The EHB initiative (European Hydrogen Backbone)

- Group of 32 energy infrastructure operators
- The aim is to accelerate decarbonization by:
- Definition of the role of hydrogen infrastructure based on existing and new pipelines
- Development of a Europe-wide market for renewable/low-CO_2 energy sources
- Promoting competition on the market
- Securing the supply
- Promoting cooperation between European countries



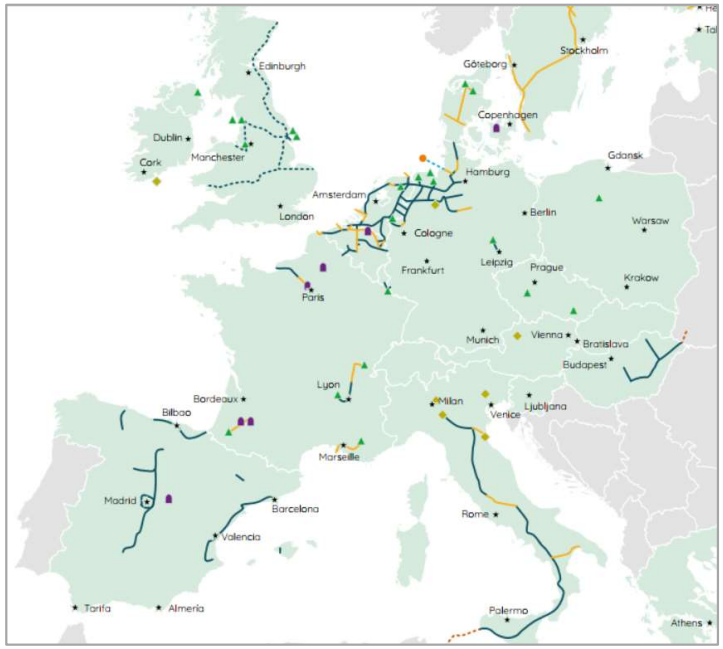
But:

➡ Risk of market concentration if these companies merge?!

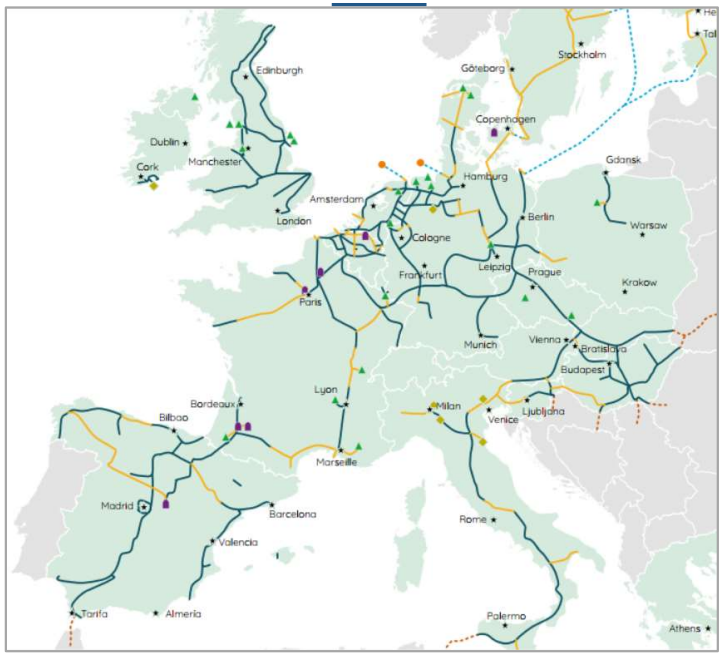
Source:
"Five hydrogen supply corridors for Europe in 2030, Executive Summary", EHB, 06.2022

European H2 network development plan according to EHB

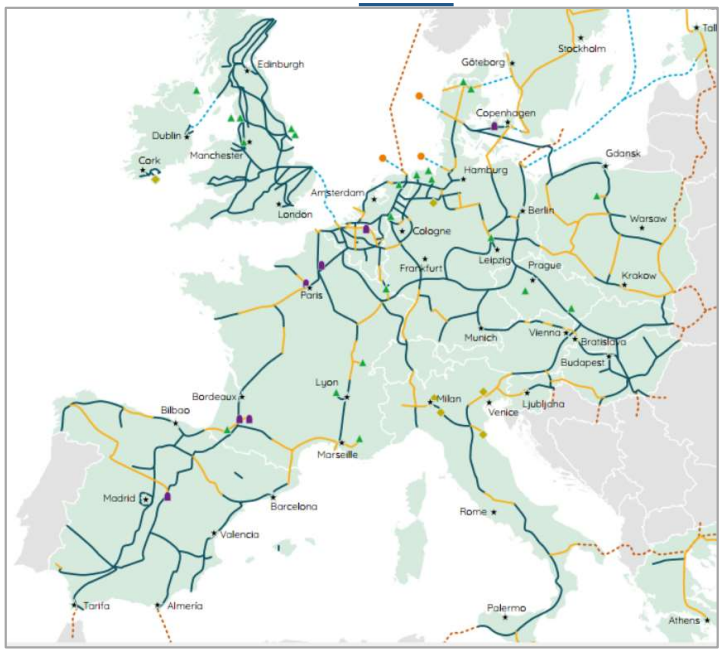
2030



2035



2040



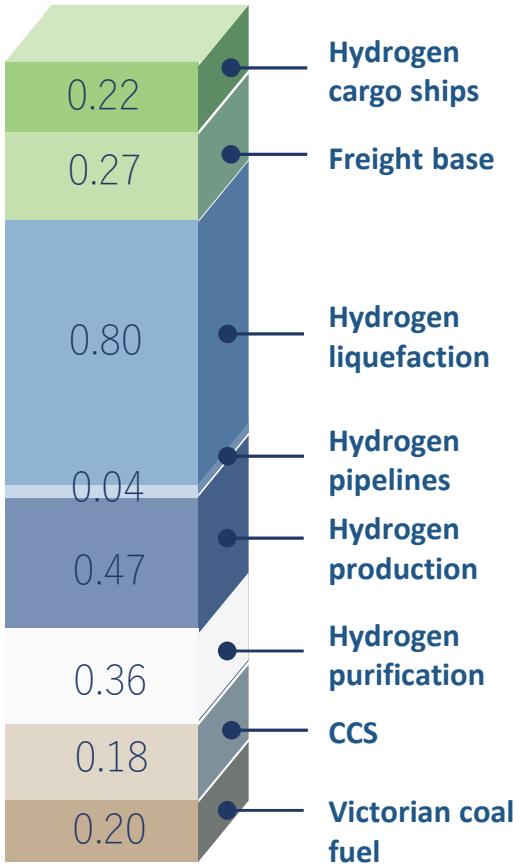
- 40,000 kilometers in 2040
- consisting of 69% reused existing infrastructure
- 31% new hydrogen pipelines

Source:
"Five hydrogen supply corridors for Europe in 2030, Executive Summary", EHB, 06.2022

Estimation of H_2 cost in 2030

2.54 €/kg

Hydrogen cost (CIF)@2030



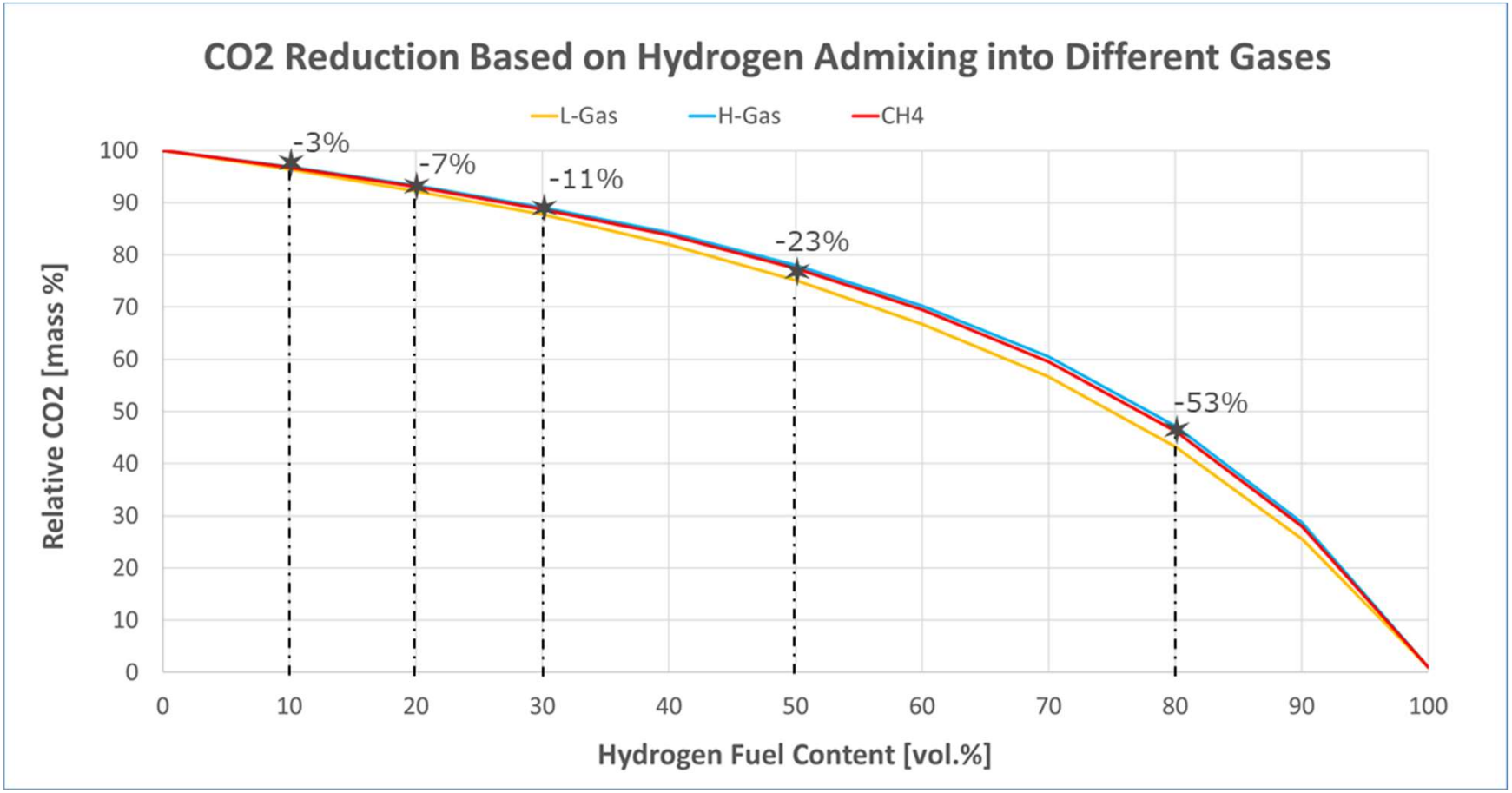
Target Scope of the Cost Analysis in Liquefied Hydrogen Supply Chain

Precondition for Hydrogen Cost Calculation in 2030

Item	Unit	FS results
Victorian Coal Consumption	Mt / y	4.74
Victorian Coal Cost	€ / t	9.5
CCS Amount	Mt / y	4.39
CCS Cost	€ / t	9.5
Hydrogen Production	t / d	770
Hydrogen import in JPN	t / y	225,540

Item	Unit	Condition
Project period	year	30
Borrowing period	year	15
Years of depreciation	year	15
Tax	%	30
Investment and debt ratio	-	50 : 50
Borrowing rate	%/y	3

Impact of Hydrogen Admixing on CO_2 Reduction



Gas Composition [vol%]			
	L-Gas	H-Gas	Methane
CH4	81.8	93.0	100
C2H6	2.8	3.0	-
C3H8	0.4	1.3	-
C4H10	0.2	0.6	-
CO2	0.8	1.0	-
N2	14.0	1.1	-

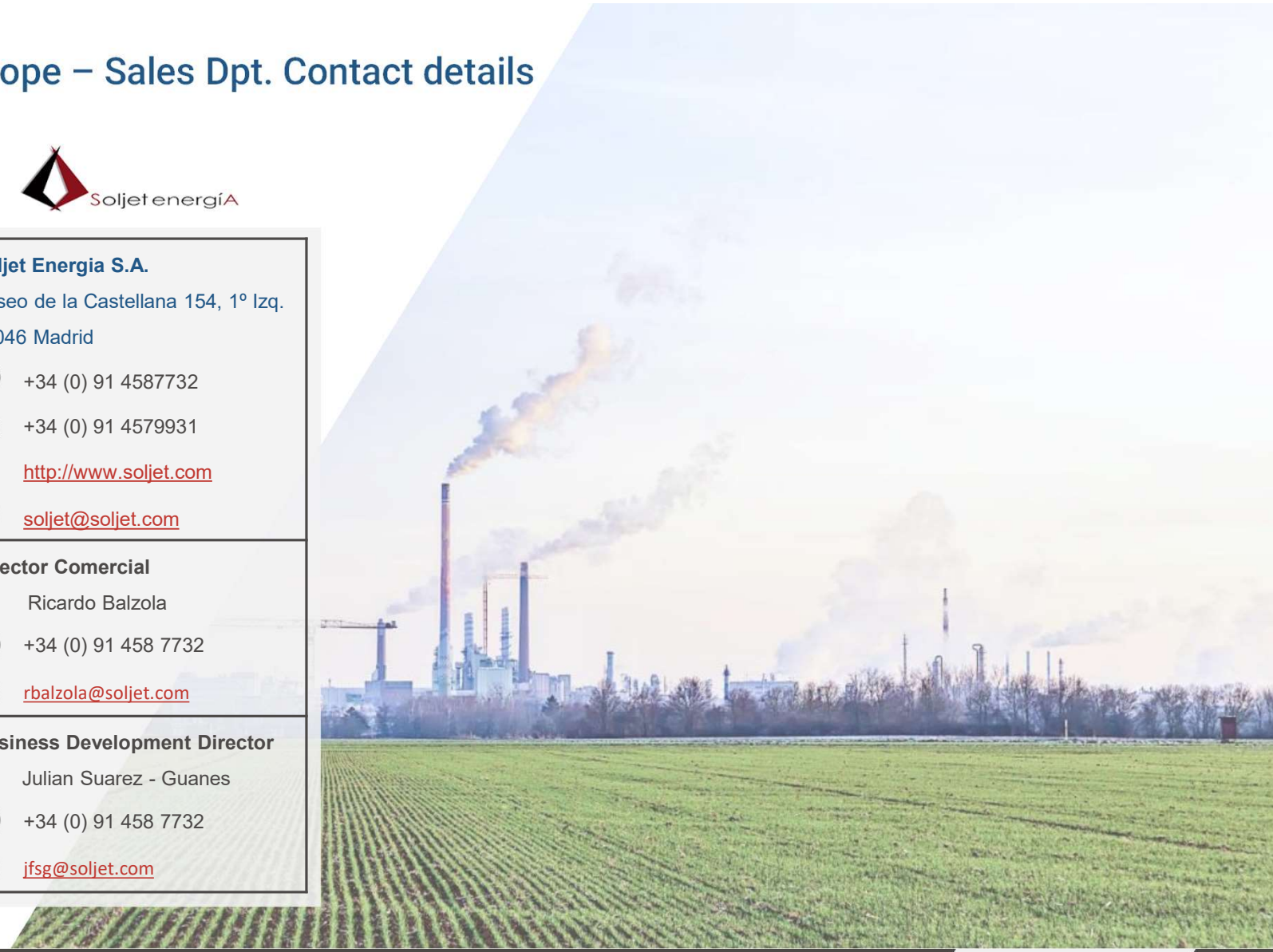
Kawasaki
Powering your potential

Kawasaki Gas Turbine Europe – Sales Dpt. Contact details

KAWASAKI Gas Turbine Europe GmbH

Soljet energíA

KAWASAKI Gas Turbine Europe Nehringstrasse, 15 D-61352 Bad Homburg, Germany +49 (0) 6172 7363 - 0 +49 (0) 6172 7363 – 55 www.kawasaki-gasturbine.de info@kge-gmbh.com	**Soljet Energia S.A.** Paseo de la Castellana 154, 1º Izq. 28046 Madrid +34 (0) 91 4587732 +34 (0) 91 4579931 http://www.soljet.com soljet@soljet.com
Head of Sales Shahrad Adjili +49 (0) 61727363 – 21 Adjili@kge-gmbh.com	**Director Comercial** Ricardo Balzola +34 (0) 91 458 7732 rbalzola@soljet.com
Sales Spain Mohsen Tavangar +49 (0) 61727363 – 27 m.tavangar@kge-gmbh.com	**Business Development Director** Julian Suarez - Guanes +34 (0) 91 458 7732 jfsg@soljet.com



“Global Kawasaki”

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Powering your potential