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Transitioning from natural gas to hydrogen: H_2-ready infrastructure

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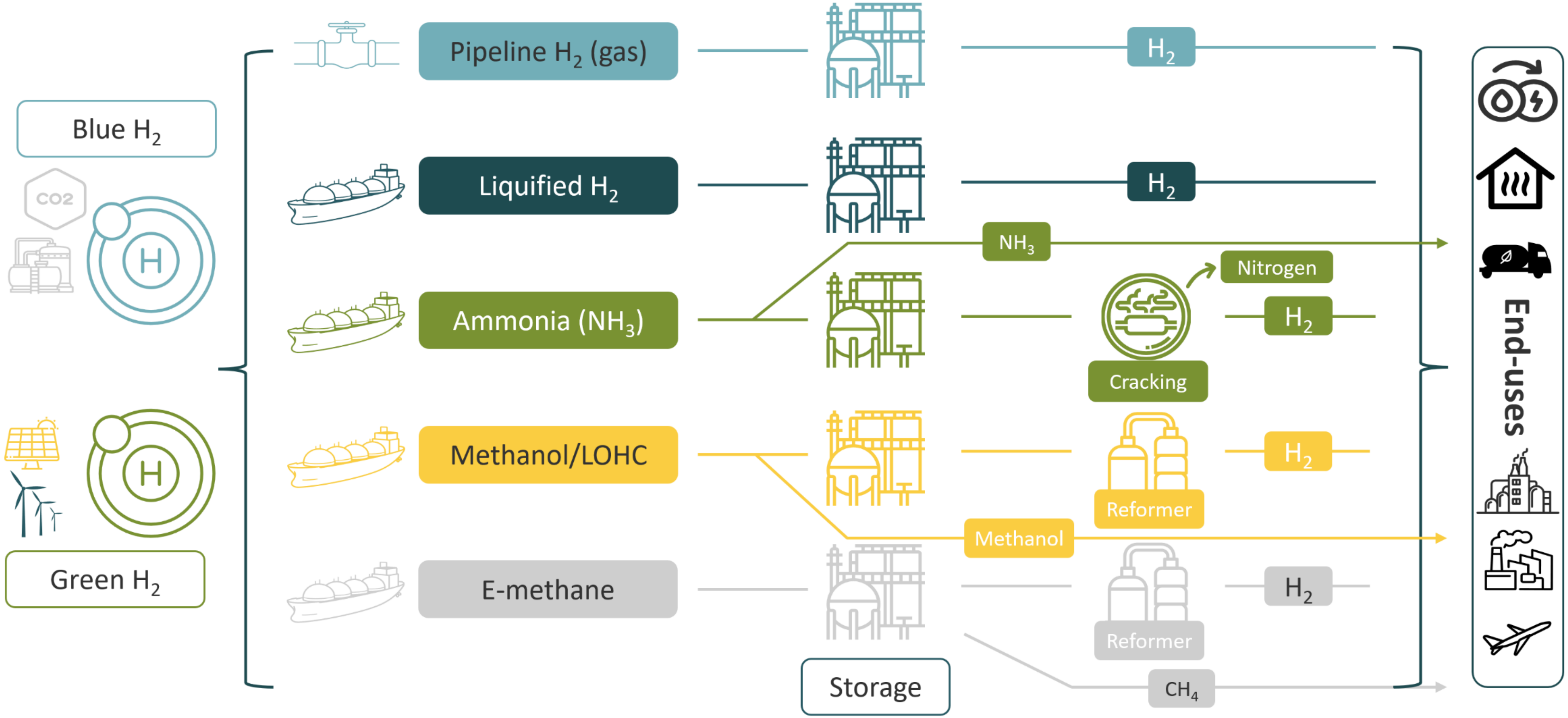
Agenda

1. **Import of gases**
2. **Refurbishing distribution infrastructure**
3. **Gas-fired power plants**

"Hydrogen-ready" has become a widely used term that describes the ability of today's natural gas infrastructure to also handle hydrogen in the future



Main issue: EU still builds large amounts of gas infrastructure that will have to be repurposed or become stranded assets before the end of their lifetime if climate ambitions are to be met

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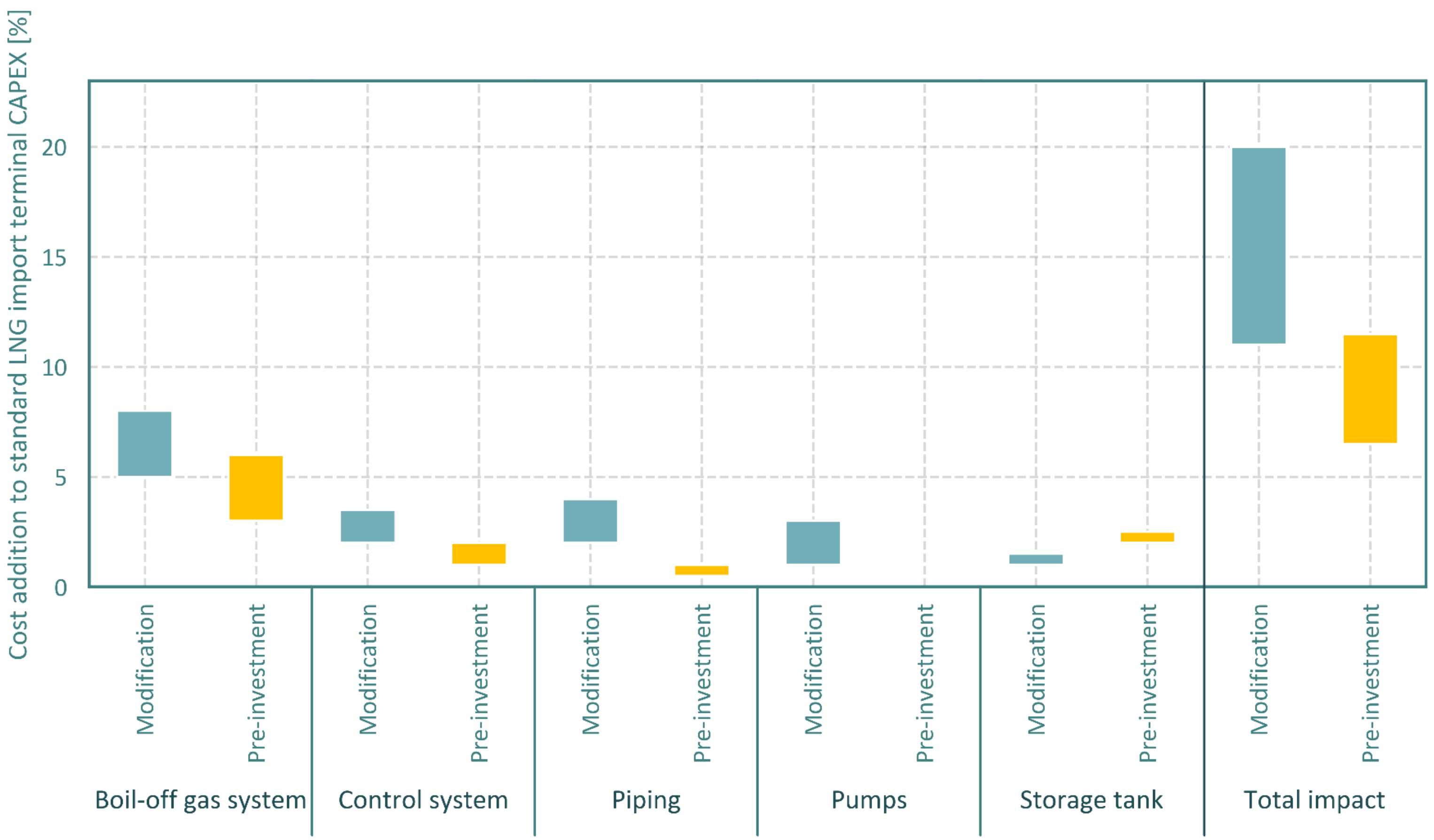
Hydrogen-ready import terminals about 10 % more expensive than standard, still significantly cheaper compared to later modification

Expected cost difference resulting from planned H2-readiness vs. later adaptation



Source: Fraunhofer ISI (2022). Conversion of LNG Terminals for liquid hydrogen or ammonia

H_2 readiness helps decreasing costs but comes with a risk

- Germany's hydrogen imports could reach between 129 and 422 TWh in 2045
- Hydrogen-readiness prescribed by government for the new LNG terminals: New materials, compression, storage technologies and specialised safety and control systems needed for H_2 handling
- Costs for anticipatory investments lower than later adaptation

BUT:

- Hydrogen can be imported as different derivatives: Liquid H2, ammonia, LOHC
- Choice of hydrogen carrier needs to be made prior to construction and thus poses a significant investment risk and potential technology lock.

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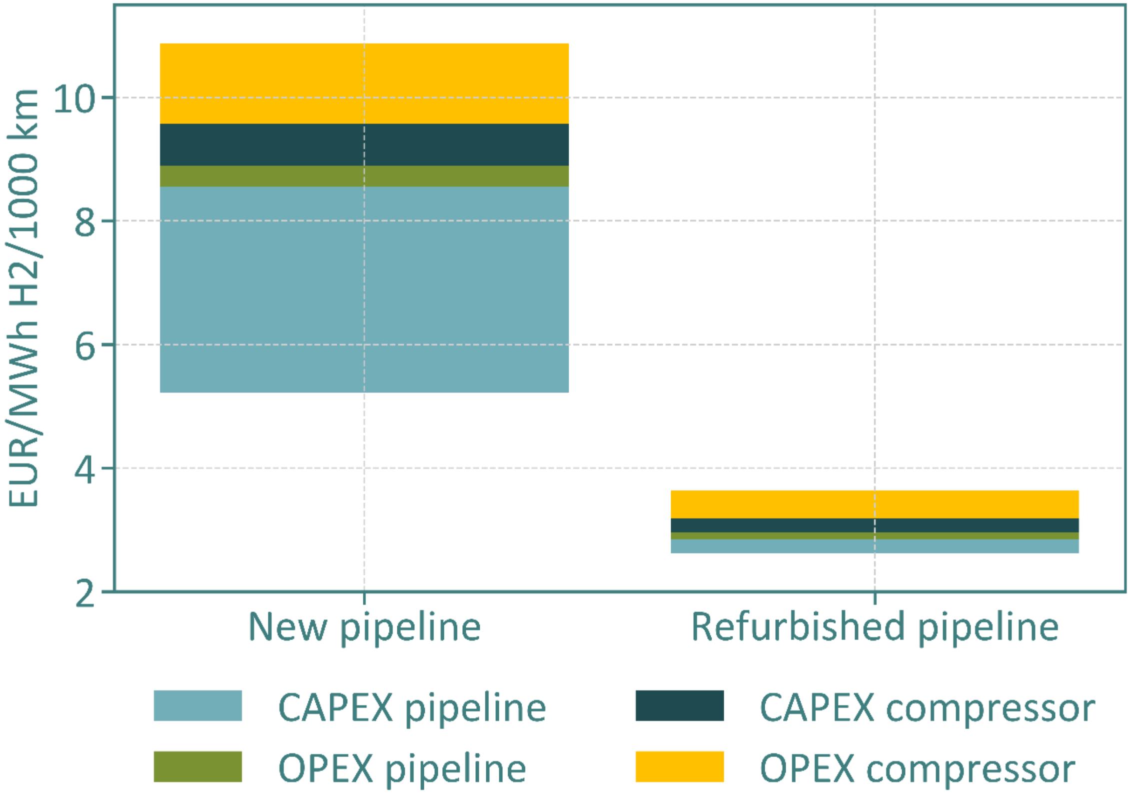
Re-purposing old gas pipelines has a lower capital investment cost per kilometre than constructing new ones

Levelized cost comparison of new and repurposed H_2-pipelines



Source: Guidehouse - Gas for climate: A path to 2050 (2022)

Conversion feasibility strongly depends on the condition of the specific pipeline as well as consumer quality requirements

- Large-scale deployment of clean hydrogen in Europe will require an effective transmission and storage system that connects domestic production hubs, import terminals and pipelines to demand centres
- A future large-scale hydrogen transmission network will most likely consist of both new and retro-fitted gas pipelines
- Significantly lower costs and shorter lead times for retro-fitting
- This translates to lower grid tariffs for consumers, improving the cost-competitiveness of low emission hydrogen

However, important challenges remain:

- Different gas properties of hydrogen and methane lead to different flow behaviours in a pipeline. Higher operating pressure is needed
- Pipeline material's hydrogen feasibility must be evaluated, as hydrogen may cause embrittlement and enhance crack propagation
- Chemical substances may desorb from the walls and blend with the hydrogen, affecting the gas' quality

Need to standardise hydrogen blending thresholds across Europe and improve collaboration across TSOs

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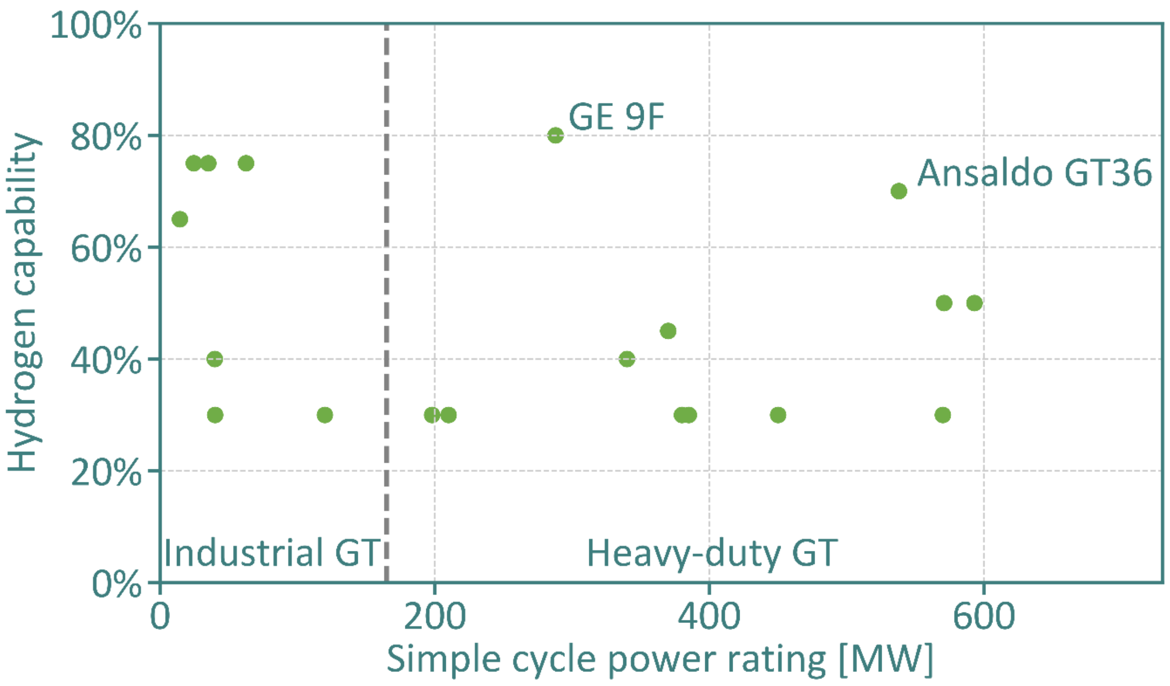
100% hydrogen-ready gas turbines can be expected by the end of the decade

Some of today's turbine models can process up to 80% H2-blend

Overview of the hydrogen tolerance of different turbine models from four selected major turbine manufacturers



100% H2-ready gas turbines are not on the market today but expected by 2025 - 2030

Challenges:

- Heavy-duty gas turbines are a product of decades of engineering efforts to secure reliable, efficient and low-emission operation
- Higher flame temperatures cause challenges in the combustion process, e.g. increased potential of NOx emissions
- Higher flame speed and lower auto-ignition energy create challenges
- Power plant piping system including the valves has to be adjusted in order to account for the fugitive nature and the lower energy density
- Appropriate leakage detectors have to be installed and security schemes to be revised
- Suitable storage containers have to be installed and sufficient space must be available for later additions

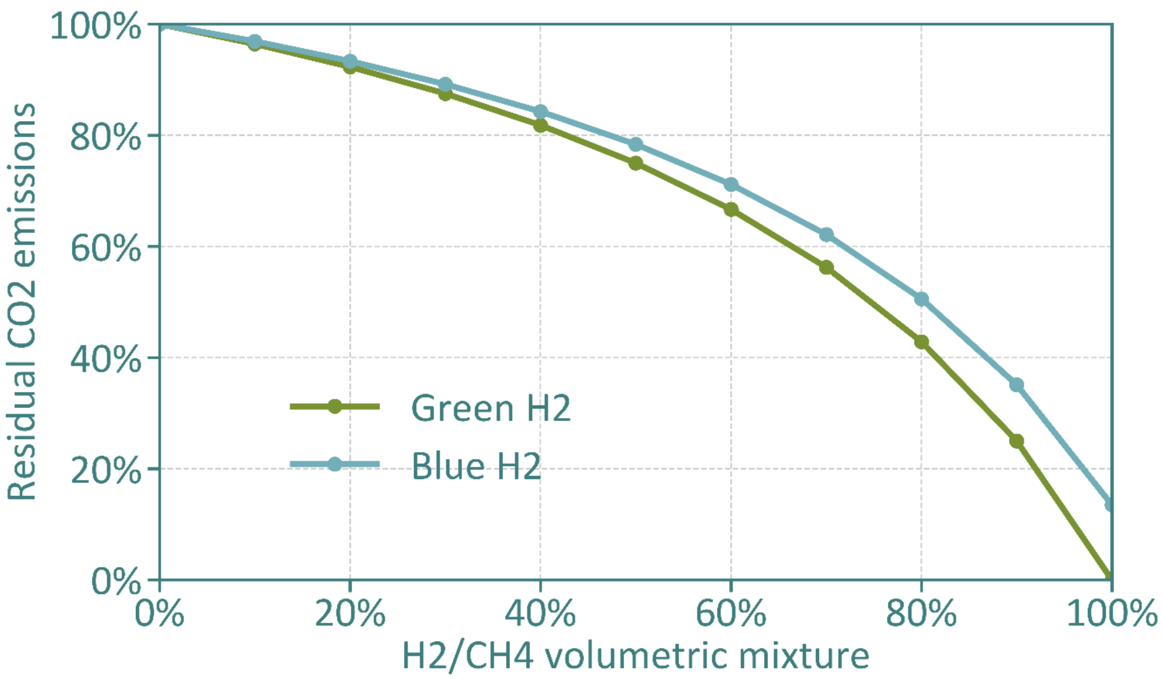
Clear aim of all major manufacturers to achieve 100 % hydrogen tolerance for their largest heavy-duty turbines by 2025 - 2030

High volumetric mixtures needed to significantly reduce total emissions per MWh

High hydrogen volumes needed for effective decarbonization

- In terms of CO_2 emission savings, 30% hydrogen admixture represents only a minor step
- Given the lower volumetric energy density of hydrogen, a significant reduction of CO_2 emissions per MWh of power produced requires high volumetric shares of hydrogen
- Assumption: 90% of the CO2 emissions from production of blue H2 can be captured by CCS

CO_2 emissions of a given H_2-CH_4 mixture for green and blue H_2



Hydrogen-ready infrastructure is underway. Standardization and regulatory support needed to reduce economic risks and unlock investments

Import terminals

- Preparing the terminals for an eventual switch to H_2 imports comes at an extra cost at roughly 10%
- BUT: Hydrogen carrier is main design determinant and needs to be decided from the start

Gas grid infrastructure

- Europe's extensive gas grid can be repurposed, leading to much lower cost than new-build
- Refurbishment will be necessary due to embrittlement and the fugitive characteristics of hydrogen

Gas turbines

- Blending already possible at lower shares, with 100% H_2-use planned by the end of the decade
- High volumetric mixtures needed to significantly reduce total emissions per MWh

What needs to be done to enable shift?

- Regulatory support
- Scale-up of the relevant technologies
- EU-wide harmonization

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