Report Summary

RP1.4-02

Future fuel use in Type B and industrial equipment

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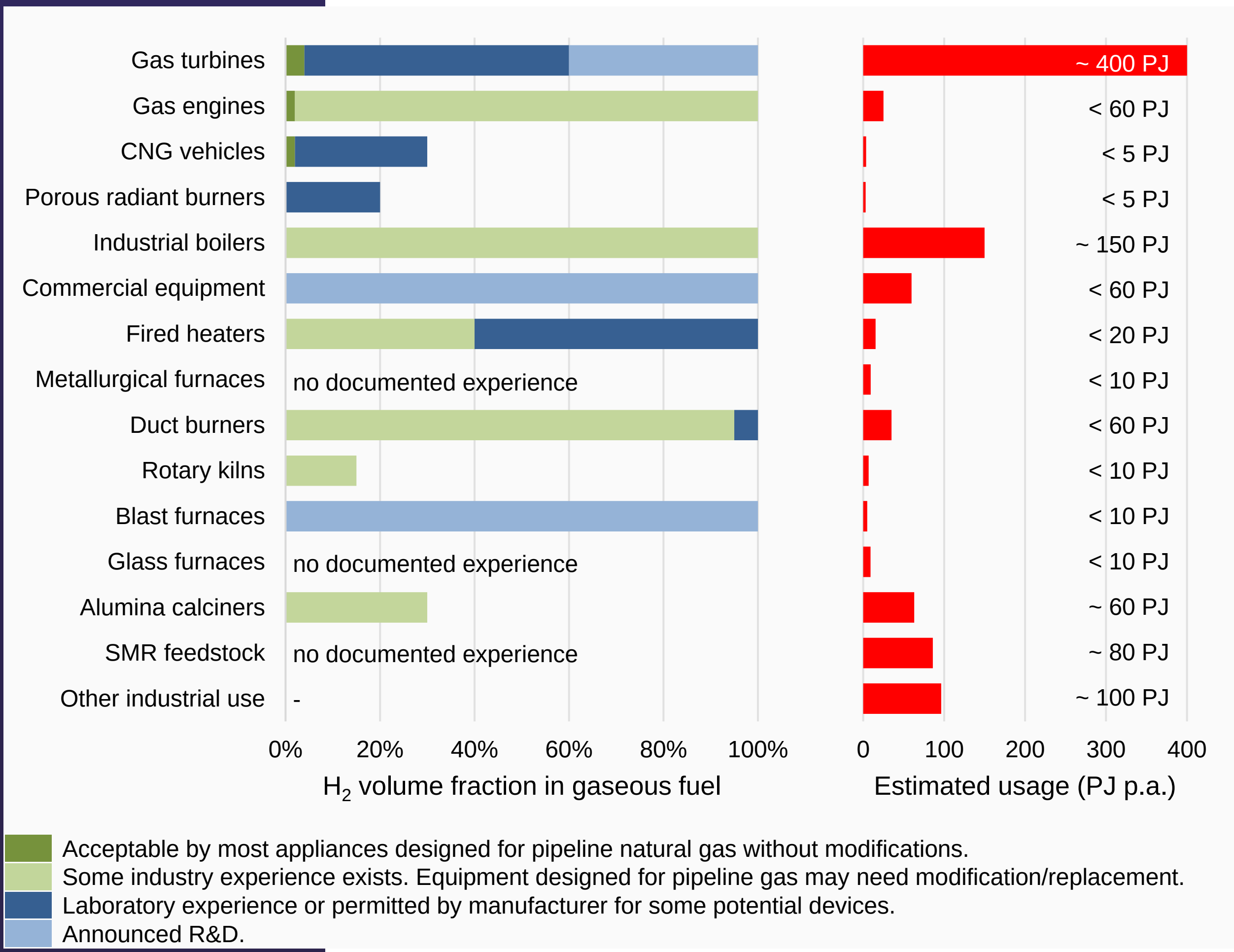
Using existing natural gas networks for storage and transport of hydrogen is being considered as a possible pathway towards decarbonisation of energy systems in both Australia and other countries. A critical part of this concept is the compatibility of end-use equipment with hydrogen and blends of hydrogen and natural gas. The different characteristics of hydrogen, when compared to natural gas, impact end-use equipment performance, emissions, life and safety. Focusing on natural gas fired Type B and industrial equipment in Australia, this project summarises research and industry experience with hydrogen to date and assesses the main knowledge gaps that could impede the adoption of hydrogen in the future. Further research is then proposed based on this assessment.

Worldwide, extensive experience has been accumulated with hydrogen-rich fuels such as coke oven gas and refinery fuel gas, especially in the steel and petrochemical industries. This experience relates mainly to fired heaters, industrial boilers, gas turbines and reciprocating gas engines. In other applications the experience is limited, and less data is available to determine the maximum fraction of hydrogen in natural gas that could be used in existing installations or the extent of the necessary modifications.

The figure below summarises available information on the hydrogen compatibility of selected equipment. Significant advances have been achieved in recent years in the fuel flexibility of gas turbines. New industrial gas turbine burner designs have enabled up to 60 vol% hydrogen fuelling. Hydrogen-enriched compressed natural gas has also been trialled extensively in automotive CNG engines. Some stationary gas engines have been adapted to 100% hydrogen, with benefits in terms of efficiency and emissions, but at the cost of a reduced output.



Outside of power generation and transport, equipment used primarily for convective heating poses comparatively fewer technical challenges in conversion. Existing burner designs or operation can be adapted, or new designs suitable for hydrogen can be developed, with associated costs. For high fractions of hydrogen, premixed burners may have to be replaced with non-premixed designs, which may increase nitrogen oxide emissions and therefore potentially require additional exhaust treatment. Changes in air and flue gas flow rates will impact fans, ductwork and heat transfer in recuperators. Processes that rely on radiative heating may prove more difficult to adapt. Here, conversion to 100% hydrogen may not be possible in some cases, although hydrogen could be co-fired with other fuels to increase flame radiation.

Implications and recommendations for industry

Standing back from the above, the ultimate concerns of the sector are the full costs and technical complexities of the use of hydrogen along the entire gaseous fuel supply chain. However, whilst the costs and complexities of the retrofit and replacement of Type B and industrial equipment will be significant, they are at present poorly understood. Ignoring or underestimating such matters can compromise the usefulness of any planning or operational study of the gas system's evolution in a low emission future.

This project identifies key technical considerations for large gas users, but stops short of estimating the costs of retrofit and replacement. The following future work is therefore proposed:

1. *Desk-based study on total costs of retrofit and replacement.*

   Further work is needed to estimate total costs of retrofit and replacement by plant type. In addition to burner hardware, these costs include changes to gas pipework, valve trains, compressors, process units, heat transfer equipment and other systems, the costs involved in safety assessment, certification and commissioning as well as the impact on operating and maintenance costs. Although the technical uncertainties identified above for several different burner types will remain, a desk-based study should make significant progress towards obtaining a reasonably comprehensive estimate of these costs as well as identifying those users most likely to benefit from the use of hydrogen. Results of similar efforts in other countries should be leveraged where possible, and international partnerships should be developed.

2. *Establishment of test and development capability for smaller Type B appliances.*

   Since uncertainties in the performance of many burners can only be resolved experimentally, establishment of a test and development capability for the assessment of smaller Type B appliances, say up to 1 MW thermal, is also proposed. This will enable assessment of the impact of different hydrogen fractions on device performance, emissions and safety, and should include the study of control methods for accommodating variable fuel composition. This work can be performed at a hydrogen pilot plant or an industrial site.

3. *Bespoke and careful consideration of larger industrial plant is required.*

   Given their relatively small number and scale, larger industrial plant present more bespoke problems that should be solved by individual owners and plant manufacturers. Equipment manufacturers and suppliers in the glass, metal processing and cement industries are interested in detailed technical and economic assessments, including experimental studies. Further opportunities may be present in the alumina and ammonia industries. Retrofit or replacement of gas turbines and large reciprocating engines should primarily be the concern of their manufacturers and/or servicing companies.

4. *Studies of fundamental aspects of hydrogen/natural gas combustion are also required.*

   Uncertainty in fundamental aspects of hydrogen/natural gas combustion also remain, and this has significant implications for new and retrofitted device design, control and safety. Such uncertainties concern premixed and diffusion combustors, ambient and pressurized conditions, as well as the use of exhaust gas recirculation. Canonical studies which first enable measurement of at present poorly characterized quantities related to flame propagation, quenching, autoignition, pollutant formation and radiant heat emission could first be undertaken. Numerical modelling that is validated using this data would then enable the development of better tools for the design and/or diagnosis of many of the appliances discussed above.

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