Written Evidence Submitted by Dr Martin Hanton, TÜV SÜD National Engineering Laboratory (part of the UK's National Measurement System)
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Introduction to person/organisation and reason for submitting evidence

As an industrial chemist by background I have 14-years of extensive first-hand experience in the use of hydrogen in various petrochemical and refining processes (at Sasol), therefore have a deep level of technical knowledge. In my role as Technical Director at the UK's DI for flow and density measurement, I have spent much of the last 3 years leading the expansion of the organisation into the hydrogen space. This time has been spent engaging with the 'hydrogen community' UK and EU wide to understand the role hydrogen can play in a decarbonised economy, and what the role of measurement, standards and regulation should be. As such I have good knowledge related to standards and regulations, and the gaps and challenges related to these. I have an excellent understanding of all aspects of the hydrogen value chain and sectors to which it applies.

TÜV SÜD National Engineering Laboratory, as the UK's Designated Institute for Flow and Density as part of the UK's National Measurement System funded by BEIS, is involved with hydrogen throughout the entire value chain, and has an ongoing interest as we will provide the UK's flow measurement traceability for all hydrogen uses. We have an extensive track record over the last three decades of development of Documentary Standards and working to inform regulation; and have already turned our attention in this regard to hydrogen.

More verbosely, we are interested in the whole hydrogen value chain as a flow measurement will generally take place between each link in the chain, because a financial or fiscal transaction will be based directly upon that flow-meter reading. Hence, we are interested in production, to transport of hydrogen and storage, to end use for mobility, heat or by industry. As custodians of the UK's Physical Primary Standards for flow and density, we provide the underpinning measurement traceability for this area, as it essential that all flow measurements used for fiscal and financial transactions are both accurate and traceable to Physical Primary Standards (as they are for O&G today for example).

For flow, the Physical Primary Standards are a suite of facilities covering different applications, and we are currently expanding that suite to cover hydrogen. We recently completed the construction of a facility for domestic gas metering of hydrogen, and have just started construction of a portable Primary Standard that will be used to test Hydrogen Refuelling Stations for dispensed quantity of fuel (this will be finished by mid-2021). We will be expanding the suite of facilities for hydrogen further as the industry sector develops, so that we provide the measurement traceability needed for all applications and all scales.

It will further be noted that we are actively engaged in R&D related to hydrogen flow measurement, to ensure the necessary measurements can be made in an economical, reliable and sufficiently accurate way, and we work closely with industry in this regard. Additionally, as part of the TÜV SÜD group were offer TIC (testing, inspection and certification) services for the entire hydrogen value chain (https://www.tuvsud.com/en-gb/industries/energy/hydrogen).

Evidence

1. The suitability of the Government's announced plans for "Driving the Growth of Low Carbon Hydrogen", including:

The scale and timescale of the ambition of "5 GW of low carbon hydrogen production by 2030" is equally proportionate with our national size and the ambitions of others (*e.g.* EU overall targets 40 GW, Germany 5 GW and Netherlands 3-4 GW of green hydrogen production by 2030). However, the focus of the UK's target is "low carbon hydrogen" which includes green and blue, whereas these targets of the EU and most other EU nations is on green hydrogen specifically. Hence, the UK has a broader focus. Given that most people recognise the preference for green hydrogen (only a small, indirect CO_2 by-product to be dealt with vs a large and direct CO_2 by-product for blue hydrogen), and the UK's privileged position of abundant renewable energy potential, then the focus of the UK's target should be tightened to 5 GW of green hydrogen specifically. Furthermore, the recently released Scottish Hydrogen Policy statement sets an intention for Scotland alone to provide "5 GW of *renewable* and low carbon hydrogen production by 2030". Hence, an overall UK target of somewhere in the region of "7-10 GW of low carbon hydrogen production, of which at least 5 GW should be green, by 2030" would seem more suitable, and show the appropriate level of policy support from the Government about to host COP26. Whilst formally out-of-scope for this consultation, it should be noted that as per point 3 of the "10-point plan", nuclear energy will be an essential element in providing stable baseload electricity and most probably a contribution towards low-carbon hydrogen production. A final point on 'focus' is that that the 10-point plan, was heavily focused on hydrogen for heat, where in practice it should be balanced between heat and mobility, with also an aspect of industry (I will return to this point later in the evidence).

Regarding CCS (inherent in blue hydrogen production) and "the dependency of the Government's proposed plans on carbon capture and storage, any risks associated with this and how any risks should be mitigated" then the above change in policy ambition would ensure that even without CCS being realised, 5 GW of low-carbon hydrogen would be produced, and with CCS, the more ambitious target is possible. It should be noted, that as per the Committee on Climate Change (CCC) scenarios, significant amounts of CCS are required in most futures envisaged, regardless of blue hydrogen, but just to off-set remaining fossil fuel usage. There is clearly a risk around whether CCS can be successfully monetised/incentivised given previous failures. Hence, blue hydrogen appears to be a good way to lower these risks, by providing a pathway to financially enabling CCS in the short-to-medium term, whilst providing low carbon hydrogen on these timescales; then in the longer term all hydrogen can transfer to green production methods, and the CCS capability can then be used exclusively for offsetting remaining fossil fuel usage. A further risk concerning CCS, is that whilst the cost of green hydrogen production is widely predicted to fall (due to improvements in associated technologies and falling costs with deployment at scale), the costs for blue hydrogen / CCS are predicted to remain level, and based on my extensive prior experience of large projects of this nature, will in all likelihood rise. There is also the issue/risk of who takes the very long-term responsibility for the sequestered CO_2 and ensuring that it remains sequestered; it may be necessary for Government to assume these liabilities for CCS to happen.

Regarding how measures can best be coordinated, until now there has been a lack of coordination, not least because, at present, the various parts of the energy system (electricity, gas grid, O&G production, vehicle refuelling) have few touchpoints. However, even within a single sector, such as the gas sector, coordination is only now starting to improve. Given the well-recognised ability of hydrogen to serve as an integrating vector across the energy system, not only will inter-sector coordination need to be improved, but intra-sector coordination needs to be put in place to ensure that activities to develop hydrogen are coordinated across the whole energy system. Furthermore, hydrogen is just one desperately needed aspect of decarbonisation; to ensure that the various different methods for decarbonisation (noting that the CCC makes clear we need "all the tools in the box") are deployed efficiently and where best appropriate even wider coordination again needs to be improved. The recent formation of the BEIS Hydrogen Advisory Council is a good first step in this regard, and the role of such bodies should be expanded and strengthened.

Regarding "potential business models that could attract private investment and stimulate widespread adoption of hydrogen as a Net Zero fuel", and the numerous different strands to decarbonisation, then a generic approach to pricing and incentivisation based upon energy content and emissions should be developed that can hence be applied to any energy use, to ensure that the best behaviours to achieve net-zero are encouraged. There should be an equal balance between 'carrot-and-stick' to discourage use of fossil fuels, whilst incentivising use of decarbonised energy sources.

2. The progress of recent and ongoing trials of hydrogen in the UK and abroad, and the next steps to most effectively build on this progress;

The progress of trials related to 'heat' is good, as is the roadmap of next steps. However, there needs to be an equivalent level of support and roadmap for trials related to transport. The gas sector is dominated by just a few large players who have a framework of working together already, which has made progress relatively easy. Thought should be given to how such trials can be made to work and the numerous players coordinated, in the transport sector.

3. The engineering and commercial challenges associated with using hydrogen as a fuel, including production, storage, distribution and metrology, and how the Government could best address these;

The UK has a strong science and engineering base, with well-established organisations and institutions. Little new needs to be created to address these challenges, rather targeted support for appropriate existing organisations and institutions should be strengthened, and/or funding should be focused. A good example here is the National Measurement System (NMS), of which I am a part. This organisation has seen an attenuation of funding support over the last several decades, however, it has managed to maintain a world-leading base of experts who, crucially from the Governments perspective, are probably more agnostic of sector or application, and independent of bias, as is likely to be realistically possible. There are many challenges to be overcome in realising net-zero that have an aspect of metrology in them, and it will be noted that the work they do related to metrology is much broader and far reaching than many might initially realise. The skills and knowledge they hold is not just relevant to engineering challenges but commercial challenges as well. For example, in the decarbonised energy system needed for net-zero, apart from electricity, every other use, transport or storage of energy will involve a liquid or gas (*e.g.* hydrogen, ammonia, carbon dioxide for CCS, etc). Therefore, every financial and fiscal transaction will be based upon a flow measurement and flow meters will be the cash registers of this economy (as they are for the gas networks and oil & gas industry today). At present, this point has not been recognised widely enough. My organisation has made a major realignment of focus in the last several years to support net-zero and the UK Industrial Strategy, but a great deal remains to be done, and the ongoing traceability and support for this sector will need to continue as long people use these energy vectors.

Furthermore, organisations such as the NMS are well placed to work across sectors to ensure efficiencies and no reinventing the wheel; many challenges are sector wide, but currently many different organisations are trying to tackle these independently.

For the record, and those who are not aware, the National Measurement System is a BEIS funded network of five institutions: National Physical Laboratory (NPL), Laboratory of the Government Chemist (LGC), National Engineering Laboratory (NEL), National Gears Metrology Laboratory (NGML) and National Institute for Biological Standards and Control (NIBSC).

Regarding the point above about funding being focused, the UK university sector is already extremely well-funded, however, more focusing of how that funding is delivered to drive the support for national challenges, such as net-zero, should be considered.

Finally, much of the Government support provided through various schemes to support the UK Industrial Strategy, net-zero and hydrogen, is focused on the building of large projects. Whilst this is good, only a very small portion of support is targeted elsewhere, and this should be increased. For example, what about the development of the documentary standards and regulations needed to enable net-zero, the metrology, and a better understanding of human behavioural aspects that will be needed to achieve net-zero (noting that behavioural aspects are likely to be harder to address than technological ones).

4. The infrastructure that hydrogen as a Net Zero fuel will require in the short- and longer-term, and any associated risks and opportunities;

Coming back to the above point about coordination, this is an area that the BEIS appointed Hydrogen Advisory Council should consider in a holistic way. The gas sector is well advanced in thinking regarding the evolution of the gas grid to hydrogen, for their purposes. However, more thought needs to be given to the role of the gas grid as a potential hydrogen transport system for purposes other than just heat.

Where the UK is particularly lacking is in regard to the infrastructure for hydrogen vehicle refuelling. Depending on your source of information, the UK currently has around 10 functioning hydrogen refuelling stations (HRS) compared to nearly 100 for Germany (who has also set out clear milestones to increase this significantly further). In order to achieve net-zero a good portion of vehicles will need to be hydrogen powered (either hydrogen fuel cell EV, HFCEV, or direct combustion in the intermediate term), but we currently have a chicken and egg scenario that need to be broken; people will not buy these vehicles until the ability to use and refuel them is present. The major risk here is that hydrogen vehicles lag too far behind BEV's and the consequences of excessive BEV's become realised, and/or people can not give up their fossil-fuelled power vehicles in time to meet the Government targets for no new petrol or diesel cars from 2030. In short, lack of infrastructure is a major risk to the Governments own target on vehicles.

5. Cost-benefit analysis of using hydrogen to meet Net Zero as well as the potential environmental impact of technologies required for its widespread use; and

Such analyses are already extensive and will continue to be so. The good work should continue but no additional support or focus is required aside from my point above that "a generic approach to pricing and incentivisation based upon energy content and emissions should be developed".

6. The relative advantages and disadvantages of hydrogen compared to other low-carbon options (such as electrification or heat networks), the applications for which hydrogen should be prioritised and why, and how any uncertainty in the optimal technology should be managed.

The uncertainty in the optimal technology choices should be managed by the well established 'learning by doing' approach, hence why further trials and scaling up in all applications is required rapidly, so we can learn fast.

It is clear that renewable electricity is the maximally decarbonised primary energy source and should be used wherever possible and optimal, for reasons of overall system energy efficiency. However, there are many application where electricity in not optimal, electricity is hard to store for anything other than short periods, and the most overlooked challenge in decarbonisation is consumer/human behaviour where hydrogen can sometimes provide more acceptable solutions. To give some examples:

Electricity driven heat-pumps can provide base-load heat with an attractive energy multiplier, but what about water heating? Here hydrogen-fired boilers are a much better choice, and equally, for peak-load heating. The 'line-packing' of the gas-grid is well documented and its ability to meet the rapid and enormous ramp in energy demand that occurs every morning. Equally, heat-pumps become a less preferable solution as the population density of an area increases. Hence, full decarbonisation of heat will also require hydrogen boilers.

A broad consideration is that currently approximately one-fifth of UK energy needs are met by electricity, and the National Electricity Grid is at capacity. Hence, to provide all energy need via direct electrification would require a five-fold reinforcement of the electricity grid, which would be both costly and disruptive. Clearly, some extensive grid reinforcement will be needed for net-zero, but not five-fold.

Approximately 1.5 times as much energy is currently used for mobility/transport in the UK as the electricity grid currently provides, hence this leads to battery electric vehicle (BEV) charging considerations. If we all switch to BEV's, then without major localised renewable energy generation on every household to supply their own vehicle, there will be a major need to upgrade the grid. Hydrogen can help eliminate this problem. Regarding transport more generally, then as we have petrol and diesel today, in future we will need BEV and HFCEV, the only choices are which are best for which applications. BEV's are great for small vehicles on short journey's and relatively infrequent use. For HGV's and buses, and many off-road vehicles, only hydrogen can provide the range and power required.

For fleet vehicles where time in motion is a key metric, then again HFCEV are preferable due to short refuelling times, and back-to-base refuelling also aids deployment. However, consumer behavioural aspects will also be crucial in acceptance (and again I say these aspects should not be downplayed), HFCEV provide a consumer experience no different to petrol/diesel cars, whereas BEV's require a major change in behaviour.

In short, it is too early to prioritise, we need more learning by doing. Hydrogen for heat is advancing well, but we need an increased focus of providing a critical nation-wide hydrogen refuelling infrastructure so that HFCEV's can be deployed and the 'learning by doing' can occur. Ideally, an HRS infrastructure on major roads that allowed nation-wide movement, but selected regions to have an increased density of HRS, to allow consumers and businesses to experience both BEV and HFCEV, and so that at a higher/Governmental level an informed assessment of pros and cons of each in practice can be made.

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