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Our response to Consultation Questions from the Department for Energy Security and Net Zero:

# The Need and Design for a Hydrogen-to-Power Market Intervention

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## 1. Background

The authors of this response document are members of the Hydrogen Integration for Accelerated Energy Transitions (**HI-ACT**) Hub. HI-ACT objectives are threefold, which are to:

- examine the role and value of hydrogen in a net-zero transition,
- identify the contribution that hydrogen can make to energy security and resilience and
- evaluate trade-offs in a whole energy system with hydrogen.

The Hub's vision is to ensure that hydrogen is appropriately integrated into a future equitable energy system through holistic multi-disciplinary research which addresses integration challenges. To achieve this vision, the Hub fosters strong research collaborations with a consortium of 27 academics from 11 universities across England, Northern Ireland, Scotland, and Wales, as well as over 40 project partners with commercial interests in hydrogen.

Responding actively to the government's consultation call, we would like to offer our views based on the insight we obtained from our multi-year research on hydrogen integration in the UK. This response document contains the opinions of some academic members of the Hub, who are listed as the authors. Please note that these views are solely the authors' opinions and may not necessarily be those of other members and project partners.

## 2. Response to the Consultation Questions

Below is our response to every question posted in the consultation documents.

### 1. What are your views on the vision we have set out for hydrogen to power?

We concur with the government's perspective on the significance and functions of Hydrogen to Power (H2P) in the decarbonised energy system. The roles of H2P are detailed in our response to Question no 2. However, we have doubts about the statement (p.10) that presumes H2P could ensure demand certainty to facilitate the growth of the burgeoning hydrogen economy, particularly in the initial phase of hydrogen transport and storage development.

While it is true that H2P is likely to increase hydrogen demand, the volume of hydrogen for H2P will depend on many factors, such as power production cost and ancillary service costs of different low-carbon technologies, demand for ancillary services, e.g. depending on the reduction levels of physical inertia in the electricity network, hydrogen prices, and renewable energy source availability, among others. Those factors affect the dispatch of H2P and, eventually, the volume of hydrogen used for power generation. This will pose some uncertainty in hydrogen demand. This is reflected in the statement on page 20, where it was stated that H2P plants would be expected to generally be intermittent off-takers of hydrogen in response to changes in the power market.

**2. In your view, what role should hydrogen to power plants be playing in the power system? Please provide details and an explanation of your reasoning.**

Our studies[1] demonstrate that H2P have the following roles:

- As an alternative zero-carbon power generation technology that can displace traditional hydrocarbon power generation to reduce residual carbon emissions from the power sector.
- To provide firm and fully dispatchable capacity to support the system security and meet electricity demand.
- To support efficient system operation through ancillary services and flexibility. The ancillary services include frequency response, reserve, system balancing, voltage management, network congestion management, and black start.
- To enable hydrogen as a zero-carbon fuel in the electricity sector; this will broaden the scope of hydrogen applications and create stronger multi-energy vector coupling flexibility. It allows flexibility in the electricity-hydrogen system, e.g., provided by electrolysers and hydrogen storage.
- To improve energy resilience against extreme events, as hydrogen can be stored in large volumes for long duration with very low losses. Studies by Met Office[2] reveal the possibility of having Winter-time wind-drought peak demand, i.e. no or very low wind power output across large areas during very cold conditions in winter, for a few weeks. Sufficient hydrogen must be stored to support H2P operation during such conditions to secure electricity demand.
- To enable cost-effective deployment of intermittent renewable electricity technologies by reducing their system integration costs through the aforementioned multi-vector coupling flexibility.

**3. Do you agree with our assessment that less CAPEX-intensive plants and/or plants with ready access to low-carbon hydrogen fuel could deploy in the short term without bespoke support? Please provide an explanation of your reasoning.**

We do not see the evidence supporting that assessment. We are concerned that even less CAPEX-intensive H2P will still require support. Our reasons are as follows:

Less CAPEX-intensive plants, such as open-cycle gas/hydrogen turbines (OCGT/OCHT), are typically less efficient and have higher operating costs. Their capacity factor is usually low and runs only to relieve

[1] D. Pudjianto, H. Ameli, and G. Strbac, "A Holistic Approach to Empower Hydrogen Supporting Net-Zero | Energy Proceedings," Energy Proceedings. Accessed: Jan. 10, 2024. [Online]. Available: https://www.energy-proceedings.org/a-holistic-approach-to-empower-hydrogen-supporting-net-zero/

[2] Source: Met Office (Tom Butcher and Laura Dawkins, et al.), "Adverse Weather Scenarios for Renewable Energy System Testing: Discovery Phase", June 2021

the system constraints or meet the peak demand. Their revenue will come from different sources, such as capacity, ancillary services, and energy markets.

When analysing the need for bespoke market support for a particular technology like H2P, we consider whether the technology in question faces an unequal level of playing field due to its technology maturity level, economies of scale, present market design imperfection causing some value of the technology cannot be remunerated, level of financing costs compared with competing technologies, among others. These are, in some cases, barriers to entry. Some are barriers to operation after entering the market, particularly where market frameworks or access to finance change over time. H2P technology is likely to face all those challenges. Therefore, to support the deployment and further development of this technology, market intervention will be needed to derisk the investment and enable feasible commercial project development. For example, OCHT will face competition from traditional gas OCGT. The operating and capital costs of OCHT are likely to be higher than those of OCGT.

If carbon prices are not set at appropriate levels, OCHT may struggle to compete with OCGT. Additionally, the first type of H2P technology will eventually face competition from the more efficient Nth type of H2P. This means that the initial projects may not be able to recover their costs without tailored support.

**4. What are your views on our proposal to enable hydrogen to power plants to compete in the Capacity Market as soon as practical?**

We support the view that H2P can compete in the Capacity Market as soon as practical. Our studies demonstrate that H2P can provide firm capacity, contribute to system security, and ensure the capability to meet peak demand.

**5. Are there any additional changes to existing markets which could support the deployment of hydrogen to power? Please provide details and an explanation of your reasoning.**

First, the H2P technologies should be able to access all markets and allow competition with other technologies on a level playing field.

Second, the cost of offsetting carbon emissions from power plants should be reflected in carbon prices. The market design should recognise the system integration costs of power generation technologies, including the costs associated with their carbon footprints.

Third, hydrogen markets should be developed to provide signals which enable appropriate H2P, and that are compatible to electricity markets.

**6. Do you agree with the risks and barriers to hydrogen to power deployment that we have identified? Please provide an explanation of your reasoning.**

We agree that the current electricity market arrangements cannot capture the value of low-carbon flexible technologies, like H2P, that support electricity decarbonisation and provide flexibility and capacity to meet energy security requirements. It is worth considering that current electricity security requirements might require review and amendment to consider the impact of H2P and other low-

carbon electricity generation technologies, as well as supply-side flexibility and its contribution to security. We also agree that there is a significant financial hurdle for being a First of a Kind (FOAK) technology due to uncertainty and high investment risk. This challenge is even greater because hydrogen production, transport, and storage systems must be developed simultaneously, creating "cross-chain risks". We also agree that other non-financial barriers exist, such as clear H2P policy, technology readiness, engineering and safety standards, etc.

**7. In your view, what should industry's role be in addressing the barriers that we have identified? Please provide details and an explanation of your reasoning.**

The industry should work together with the government to:

- Agree and set a clear policy roadmap and financing framework on how the hydrogen ecosystem and supply chain can be built sustainably and economically to support the future energy system requirements.
- Review the current energy (electricity and gas, including hydrogen) and ancillary service markets and recommend changes to accommodate H2P technologies.
- Provide more demonstration projects to understand the integration of H2P technologies better.
- Develop engineering and safety standards for H2P technologies.

**8. Are there any other potential risks and barriers that we should be considering? If so, which ones? Please provide details and an explanation of your reasoning.**

One of the key potential barriers is the insufficient market force that can drive high CAPEX investment in firm and flexible, emerging low-carbon technologies like H2P. The market design should allow the value of the technologies providing different system functions to be captured. Carbon prices should accurately reflect the cost of offsetting carbon to meet the carbon target. The markets should also capture the system integration costs of different technologies and have proper cost allocation mechanisms that provide economic signals to investors and system users. For example, the system integration costs of variable renewable energy sources (vRES) will be higher than those of H2P because vRES has a limited capacity value, increases ancillary service requirements, and may require additional infrastructure such as network, storage and other flexibility sources to operate efficiently.

**9. Do you agree with our assessment that bespoke hydrogen to power market intervention is required to mitigate our identified deployment barriers and accelerate the deployment of hydrogen to power plants, likely those which are more CAPEX-intensive? Please provide an explanation of your reasoning.**

Taking a whole energy systems approach (WES), our modelling work can ascertain the interactions between hydrogen demand for power, transport, industry, and domestic heat. H2P market intervention should be evaluated within the broader landscape of competing hydrogen demands and associated market interventions that may attempt to promote hydrogen end use for these other sectors.

We agree that power market intervention is required to overcome the deployment barriers and stimulate the deployment of hydrogen to power plants. We wonder if more CAPEX-intensive plants should be discriminated against lower CAPEX plants regarding the level of market support. More

CAPEX-intensive plants typically are more efficient and operate as mid-merit plants. In this context, more CAPEX-intensive plants should run more operating hours. They should be able to recover some costs through the energy and ancillary service markets as well as the capacity market. However, we know that the risk levels of different H2P technologies could differ. Various levels of support could be considered according to the level of risk faced by other technologies and the technology characteristics to stimulate the deployment of those technologies.

**10. Have we considered all credible market intervention options for hydrogen to power? Please provide details of any design options you think we may have missed and explain your reasoning.**

Another option of market intervention is to develop a support scheme that de-risks the investment in H2P to be at the same level as other traditional power plants and capture the value of flexibility provided by H2P that the present market frameworks cannot capture, for example, the value of enabling multi-energy vector flexibility and long duration energy storage that can reduce the overall system costs. The industry and government can discuss and agree on the details of this de-risking strategy. Once the emerging H2P technologies can compete on the same level of playing field, then those technologies should be integrated into the current market frameworks. In principle, the market should be designed to be technology agnostic, allowing all technologies to compete on the same level of playing field.

**11. Do you agree with our shortlisted three market intervention design options? Please provide an explanation of your reasoning.**

We agree that the shortlisted market intervention design options, namely (i) Dispatchable Power Agreement (DPA), (ii) Split CM, and (iii) Revenue Cap and Floor, will derisk the investment in H2P while retaining some risks to be managed by investors to stimulate efficient investment and operational behaviours. However, we would like to see more quantitative evidence on the performance of such design options or more detailed analyses.

**12. Have we accurately identified the benefits and risks of a DPA-style mechanism? If not, are there any further benefits and risks to consider? Please provide details and an explanation of your reasoning.**

We agree that the DPA style would be appropriate for the initial deployment of H2P, and it is consistent with the market intervention for the gas CCUS.

**13. Do you agree with government's assessment that a mechanism based on the Dispatchable Power Agreement is the most suitable option for bespoke hydrogen to power market intervention to support the accelerated deployment of hydrogen to power? Please provide an explanation of your reasoning.**

We are not in the position to endorse a specific market intervention as we do not see the evidence (such as quantitative risk analyses) provided in the document that can be used to support a specific market intervention option.

**14. What are your views on the need for a Variable Payment? Please provide details and an explanation of your reasoning.**

It is important that the market can capture the value of the technologies. In the case of H2P, the value of this technology is not only in its capacity but also in how it contributes to energy decarbonisation from power sectors (and electrification of other sectors), system flexibility, including sector coupling flexibility, and energy system resilience. Variable payment will support derisking the operational cost of the H2P technology, which is important since there is still significant risk associated with the beginning phase of hydrogen supply chain development. Variable payment may also cover the disparity due to insufficient carbon prices.

**15. Have we accurately identified the benefits and risks of a Split CM? If not, are there any further benefits and risks to consider? Please provide details and an explanation of your reasoning.**

In our view, the market design should be technology agnostic, although it must consider the technology characteristics in a transparent and measurable process. As the objective of CM is to stimulate investment in generation capacity to meet energy security requirements, having a different variant may induce more complexity, lack of transparency and competition against other technologies. We recommend speeding up the transformation of CM to support all technologies, including H2P.

**16. Do you agree with our proposal to discount the Split CM as an option for bespoke hydrogen to power market intervention to support the accelerated deployment of hydrogen to power? Please provide an explanation of your reasoning.**

We agree with the proposal to discount the Split CM as a market intervention option to support H2P. Unless other supporting mechanisms accompany it, the Split CM does not provide support in the operation of H2P, and therefore, a higher CAPEX of H2P would make it difficult to compete with a lower capex technology that can provide the same capacity value.

**17. Have we accurately identified the benefits and risks of a Revenue Cap and Floor? If not, are there any further benefits and risks to consider? Please provide details and an explanation of your reasoning.**

While there is a risk associated with the reconciliation period, it is unclear whether this issue is relatively minor and can be managed properly during the scheme. We are not convinced that this is a major issue. We also do not believe that the cap and floor model may disincentivize dispatch as this model has been used for electricity interconnectors.

**18. Do you agree with our proposal to discount the Revenue Cap and Floor as an option for bespoke hydrogen to power market intervention to support the accelerated deployment of hydrogen to power? Please provide an explanation of your reasoning.**

We disagree with the proposal to discount the Revenue Cap and Floor option. In our view, this scheme could be similar to the DPA-style mechanism but provides a cap on the revenue, which may make it less attractive and does not stimulate efficiency and innovation.

**19. What is your view on the need for price-based competitive allocation within/between bespoke business models versus moving assets straight to a technology-wide competitive market? Please provide an explanation of your reasoning.**

As mentioned earlier, at this phase, H2P technologies will not be able to compete at the same level of playing field with other mature technologies because of many reasons discussed earlier. Hence, a bespoke market intervention will be needed but with the goal that eventually, H2P will need to be integrated into the technology-wide competitive market.

**20. How should a bespoke hydrogen to power business model be evolved to promote competition between low carbon flexible technologies? Please provide details and an explanation of your reasoning.**

As mentioned earlier, the whole system value and system integration cost of H2P must be captured and considered in the market design. The same should be applied to other technologies for a level playing field competition.

**21. What are your views on the alignment of hydrogen support and policies needed to enable the deployment of hydrogen to power capacity. Please provide details and an explanation of your reasoning.**

We concur with the government's view that hydrogen support and policies must be aligned with the energy market designs and should be considered in the Review of Electricity Market arrangements.

**22. Do you have any reflections on the feasibility of hydrogen producers, or qualifying offtakers, to facilitate the volume of storage required for hydrogen to power – for example, regarding sourcing finance/capital? Please provide details.**

We are not in a position to comment on this question.

**23. What are your views on the feasibility of developing commercial arrangements between hydrogen producers, storage providers, and electricity generators that meet the Hydrogen Production Business Model (HPBM) requirements relating to Risk Taking Intermediaries (RTIs)?**

We are not in a position to comment on this question.

## 3. Final remarks

To ensure the financial feasibility of initial Hydrogen-to-power (H2P) projects, a bespoke market intervention will be needed. Our research has identified that H2P will be essential in providing energy security and flexibility while decarbonising the electricity sector. Therefore, the sooner the H2P projects are deployed, the more valuable experience we will have in the technologies, which will pave the way for more investment and development to support the transition to net zero.

To design the market intervention, we should ensure that all technologies, including H2P, will compete fairly on the same level of playing field, considering their system characteristics and integration costs. The market design should capture different technologies' whole-system value and align with the carbon agenda through appropriate carbon pricing. With proper designs, the markets should have sufficient force to drive investment in low carbon, including H2P technologies. It is important to note that the bespoke market intervention must be temporary; the goal is to integrate the H2P technologies into a technology-wide competitive market.

Members of HI-ACT can provide further support and analyses regarding the system and market integration of H2P. For further clarification on our responses, please get in touch with Prof. Sara Walker or Prof Goran Strbac to follow up.