Hydrogen Delivery Council

Transport & Storage Market Framework Sub-group

Report on Hydrogen Market Frameworks for Initial Hydrogen Networks

August 2025

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1) Introduction and context

This section lays out the context to this Report including its purpose, use and how it was developed. We also highlight what was included and excluded from the brief, which hydrogen networks it is designed for and the market context in which it was written.

The purpose of this report is to:

Develop a model market framework, or frameworks, best suited to supporting the operation of initial hydrogen networks; with a primary focus on system balancing

The target use of this report is:

To act as a source of information for officials at the Department of Energy Security and Net Zero (DESNZ) as they work towards developing a regulatory framework for hydrogen pipeline networks. It will also be a valuable reference for industry; including parties in the hydrogen value chain (producers, asset owners, storage operators), and those who may be seeking to buy hydrogen in the future (offtakers).

The report was compiled by:

A Market Framework Sub-Group of the HDC Transport & Storage Infrastructure Sub-Group (henceforth referred to as “the Market Framework Sub-Group” or “the Sub-Group”. The Sub-Group’s membership comprised industry representatives from across the hydrogen value chain, from hydrogen production through to hydrogen consumption. There was an expectation that members should represent the views of their particular sector, and that wider stakeholder views should be channelled this way.

The Sub-Group held a series of meetings between March and July 2025 to develop the contents of this report.

The role of DESNZ, Ofgem and NESO:

Representatives from DESNZ, Ofgem and NESO attended meetings of the Sub-Group, and DESNZ also provided secretariat support. However, this report represents the views of Sub-Group industry members only, and not that of DESNZ, Ofgem and NESO

Hydrogen market framework definition

The hydrogen market framework should clarify how the day to day physical and commercial characteristics of a large-scale hydrogen network (multiple producers and offtakers, storage and transportation) will operate, what are the roles and responsibilities of each party and how safety and balancing decisions will be made.

The report includes:

- Clarity on the roles and responsibilities required for development of networks
- Market model options which could be utilised for initial networks
- Detail on the operational factors relevant to initial networks, including balancing tools, information flows and the facilitation of transportation
- A high-level assessment of the potential legislative and business model changes that may be required with the leading model

- A list of next level analysis and questions to be answered in a subsequent phase of work to this report

The report excludes:

- A fully developed market model which is ready to be executed
- Detailed operational considerations
- Decisions on or development of required legislation or changes to legislation, licenses or network codes; or detailed analysis on how the market model could be integrated into the existing Gas Act
- A long-term roadmap for market framework evolution beyond the initial hydrogen networks, although a no-regrets approach has been taken where possible, in order to minimise contradictory and/or wasted work on the initial versus mature market development
- Views or proposals for:
    - charge setting and revenue recovery
    - the applicability of a capacity market to a hydrogen network
    - ongoing new connection (network access regime)
    - physical/technical parameters for the network(s) (e.g. gas quality tolerances, network pressures, metering arrangements etc)

Glossary / Key terms

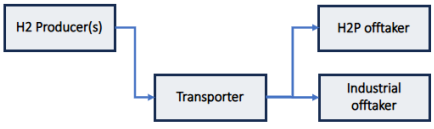
A Glossary of key terms is set out in Appendix 2. Where possible we have retained the meaning of key roles and responsibilities to align with the natural gas market for simplicity. We highlight where the meaning is intended to be different.

Network archetypes

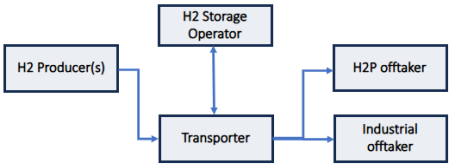
By the early 2030's the Sub-Group saw there being the potential for three archetypes of hydrogen networks in Great Britain:

1. 1:1 or Behind the Meter networks
    - 1 hydrogen producer and few offtakers
    - Pipeline network limited to a few kms

2. No storage networks
    - Multiple hydrogen producers and offtakers
    - No geological or man-made storage, only pipeline transportation and its linepack
    - Pipeline networks likely 50km+
    - Examples: West Wales, East Coast Hydrogen



3. Networks with storage
    - Multiple hydrogen producers and offtakers
    - Geological or man-made storage
    - Pipeline networks likely 50km+
    - Examples: HyNet Hydrogen Pipeline, Humber Hydrogen Pipeline



Definition of initial hydrogen networks

The focus of the Sub-Group has been to assess the *initial hydrogen networks* which are expected to be built once the Hydrogen Transport and Storage Business Models (HTBM/HSBM) have been finalised and allocation rounds progressed.

We define “initial hydrogen networks” as:

- The first built hydrogen networks which are third party accessible and contain at least a hydrogen pipeline transportation system between multiple producers and several offtakers (Archetype 2)
- We expect at least some of these networks to also have a large-scale hydrogen storage capability connected to the transportation system (Archetype 3)
- For the avoidance of doubt, we are not focused on 1:1 networks (Archetype 1), as they are typically managed privately by the hydrogen producer and have no third-party access
- These networks are expected to be completed and commissioned in the early 2030s
- We have developed the market model to:
    - Work effectively for Archetypes 2 and 3, noting that Archetype 3 creates more complexities and therefore required more of our focus
    - Be applicable to the early years of these networks as we are cognisant that there will be a period of ramp up of these networks as they become operational, particularly those with storage assets which typically take time to develop and may start up subsequent to the transportation system
    - Consider how the trajectory of market evolution should be integrated into the model

Why do hydrogen networks require a market framework?

These initial networks will be critical to catalysing a wider UK hydrogen economy. With multiple hydrogen producers and offtakers utilising several different networks, a common framework for managing the relationship between hydrogen transportation networks and their users will ensure greater consistency and equality in the deployment of hydrogen production and off-take projects and facilitate growth and future integration of the regional networks.

The preferred market framework arrangements may require changes in primary and secondary legislation, development of licenses or adoption of licenses from the natural gas network. The framework, which could take the form of a hydrogen network code which will:

1. govern the use of each network
2. clarify the roles and responsibilities on the network
3. clarify how risks are shared between network users and the network operator, and
4. define the specific networks’ constraints and operational limits.

We expect that roles, responsibilities and obligations will be consistent across networks but accept that some deviations may be required between networks.

Network characteristics

During development of this report the Sub-Group have been conscious that all initial hydrogen networks in Great Britain will have differences that are created by a number of factors:

1. Availability and scale of storage
2. Storage inflow/outflow max rates
3. Composition of production (how much and type)
4. Offtakers (share of H2P and industry, flexibility requirements)
5. Asset ownership (any consistency within the value chain)
6. Potential for connection to NTS for blending
7. Potential for connection to other H2 networks (and in what timeframe)

It is the view of the Sub-Group that network characteristics should not change the overall proposed UK hydrogen market model / framework. Instead, for simplicity, consistency should be sought where possible, with any network specific elements being factored into the Annexures of the hydrogen network code or special licence conditions. This is similar to how the CO2 network code has managed the differences between the Track 1 industrial clusters.

Learnings on which this report is built

This report is built upon the learnings developed from the previous HDC Sub-Group on Market Frameworks which developed a report, submitted to DESNZ, in August 2024. That report focused on credible hydrogen market framework models, but with a more specific view on the 'end state' of a competitive market., whereas this report's focus is on 'initial networks' being cognisant of current hydrogen market nascency and business model constraints.

This report does not require or presume that its readers have read the previous HDC Sub-Group report. It can be read and understood on a standalone basis.

This report has also taken learnings from the recent development of the CO2 market framework and associated CO2 network code developed by DESNZ and industry to manage the Carbon Capture and Storage (CCS) Transportation & Storage (T&S) networks being funded and built in the Track 1 and 2 industrial clusters.

Key learnings from the CO2 network code development include the need to start development of the required licenses and codes early to ensure all relevant industry parties are involved early, and to target a minimum viable product to support T&S final investment decisions.

Hydrogen market context in July 2025

This report has been written in a UK hydrogen market context where:

- A hydrogen production business model (HPBM) exists, and several have been allocated as well as >30 being in negotiation
    - HPBM's do not currently allow the following Qualifying Offtake uses:
        i. the use of blending of hydrogen into the natural gas network
        ii. the sale of hydrogen to Risk Taking Intermediaries (RTIs)
        iii. the export of hydrogen

    iv. the purchase of hydrogen for operational use by a hydrogen network operator or storage operators (this is not explicitly called out in the HPBM, but is implied based on ii)
- Hydrogen transport / storage (HTBM and HSBM) and Hydrogen to Power Business Models (H2PBM) are in varying stages of development and none have yet been allocated
- No hydrogen networks yet exist which are Archetype 2 or 3
- Recent hydrogen announcements
    - The recent Comprehensive Spending Review as of 11 June 2025 has confirmed continued funding for CCS clusters
    - A 13 June 2025 announcement confirmed £500m of funding for the first regional hydrogen transport and storage network, HMG aims to launch the allocation round for HTBM/HSBM in 2026
    - Additional HAR rounds are expected in 2026 and 2028

2) Executive Summary

Overall, the Sub-Group is of the view that this report meets the objectives set by the HDC and has materially developed the understanding of the requirements for a functioning market framework for the initial deployment of a large-scale hydrogen network. There is broad support within the Sub-Group for a 'decentralised' approach for the market framework (explained below). However, we recognise that there is a significant amount of further work required to develop the high-level market framework proposals into a workable (code) and there is more divergence in opinions regarding implementation and issues which were outside the scope of this work (e.g. new connections arrangements).

Key conclusions:

- The nascency of the initial hydrogen networks means that operational balancing activities will focus on physical actions over market-based actions, given the limited connectivity and lower levels of linepack and storage available
- Therefore, a key responsibility of the hydrogen market frameworks will be system balancing[1]
    1. System balancing ahead of the 'hydrogen day'[2] will be the responsibility of hydrogen producers[3]. They will ensure that ahead of the 'hydrogen day', demand and supply are balanced
    2. The proposed market models focus on how balancing will be carried out within the 'hydrogen day'. The 'hydrogen day' will be made up of more granular "balancing periods" which require further analysis and definition

Models assessed

- Two market model options (for system balancing) have been proposed and assessed by the Sub-Group:
    1. A Centralised balancing model
    2. A De-centralised balancing model

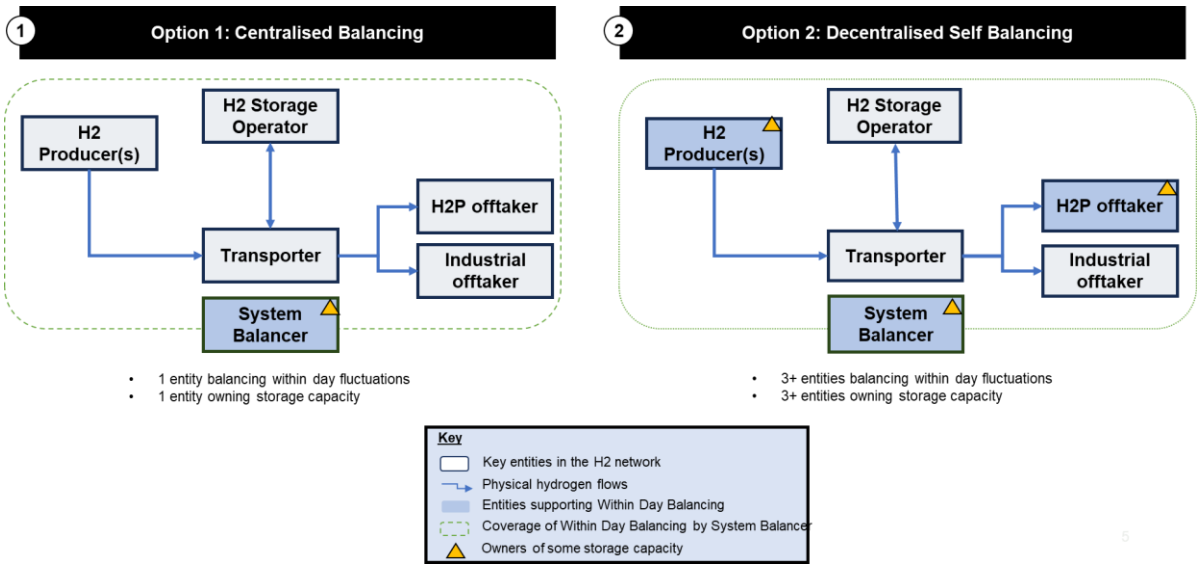
- A Centralised balancing model has only one entity obligated by its licence to be responsible for balancing (both primary and residual); the System Balancer. It acts as a centralised hydrogen aggregator to take ownership of all hydrogen entering the network within the hydrogen day and uses a range of tools to balance the system and outflows to offtakers. This option would be similar to the early natural gas networks, pre-privatisation, where a single entity owned and operated all aspects of the gas delivery chain.

- A de-centralised balancing model puts the primary balancing onto several existing parties (hydrogen producers and H2P offtakers) with a System Balancer providing a similar service to the Residual Balancing role undertaken by National Gas for the natural

[1] The System Operator has a range of physical and commercial tools available to ensure that where gas into the system doesn't exactly equal gas out of the system, linepack integrity and network safety and resilience is maintained. More details are available in the National Gas: End to End Balancing Guide
[2] Hydrogen equivalent to a Gas Day, defined in the glossary
[3] Agreement between Producers and Offtakers will be required to align commercial flows; then nominations will be passed to Shippers. Storage Operator and System Balancer also important facilitators

gas National Transmission System (NTS). This option is closer to the way the current natural gas operates, where Shippers act as Primary Balancers.

Figure 1 – Market models for system balancing



- Other permutations of these options were considered but were not pursued as they did not change the overall model structure

Preferred model

- Most Sub-Group members expressed a preference for Option 2 – De-centralised balancing to be implemented
- The De-centralised balancing model was preferred for 3 reasons:
  1. It places the responsibilities for balancing with the parties best able to manage them, allows commercial optimisation decisions to be made; and requires less potential changes to current and developing business models
  2. It is more likely to deliver more efficient use of T&S infrastructure as connectees will have a better understanding of how much storage capacity is required to manage their commercial and operational needs
  3. It may be more likely to facilitate market growth and development as it is more transparent given the need for multiple parties to take balancing actions. This may support earlier pricing, volume and investment signals for hydrogen market evolution
- The Centralised balancing model was less preferred for 3 reasons:
  1. A single entity would be required to take on significant financial (working capital and price) risk to enable management of all hydrogen entering and exiting the network and therefore may require a government backed entity
  2. This model may lead to concerns over transparency and equity as a single party has control over the entirety of the hydrogen network
  3. A lack of transparency would also make it almost impossible for the network to optimise either the infrastructure or commercial decisions within the hydrogen market; this would then lead to a longer or more limited potential for hydrogen market evolution

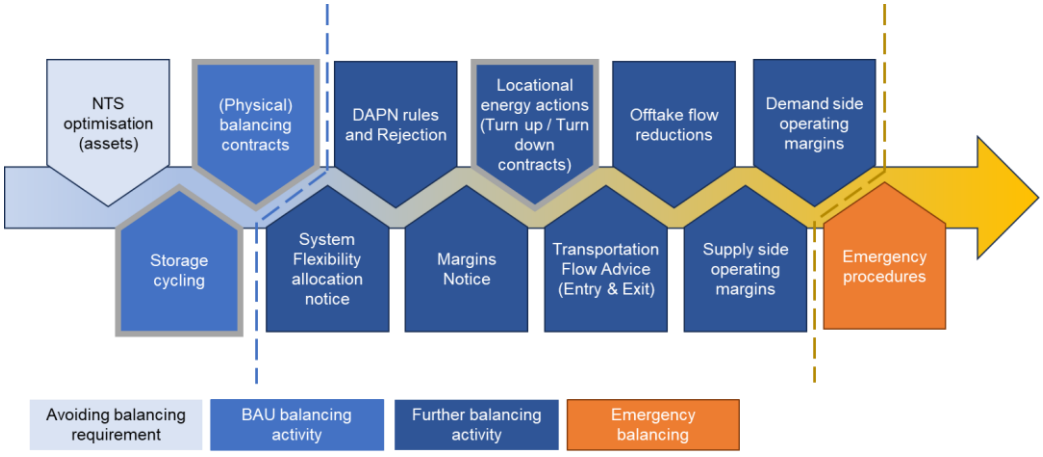
Wider roles in the hydrogen market framework

- While the market model focus was on system balancing within the hydrogen day, many other important roles need to be accounted for
- Key roles discussed include Shipper, Supplier and System Operator – all discussed in detail in Section 6
- The following other critical roles are discussed further in Section 6, the Sub-Group's expectation would be:
    1. Ofgem as the Hydrogen Regulator
    2. DESNZ to develop the Hydrogen Network Code up to the point of a financial investment decision the transportation system being taken[4], support long term planning and grant business models
    3. NESO to support long term planning

System Balancer / System Operator

- The System Operator role is likely to be undertaken by the Asset Owner, who will take on the role of Transporter and will be responsible for the safety of the network
- The System Operator will likely take on the System Balancer role
- The System Balancer will perform the residual balancing role using a range of tools to enable safe operations including the network emergency management role
- It is expected that commercial tools would have a limited role to play in a nascent hydrogen market, and physical actions, such as linepack optimisation, storage cycling and flow advice, where connectees are instructed to alter their flow in line with network safety requirements, will be used more frequently. Fewer tools will be available in networks without storage
- A centralised hydrogen data hub will be required to ensure transparency and collate information flows to provide balancing parties with a holistic network view

Figure 2 – Hydrogen system balancer toolkit



Please see Section 7 for more detail.

[4] Under the network code approach used for CCS, Government led the development of the initial code. However, post FID of the CCS networks, responsibility for managing the network codes passed over to industry.

Shipper role

- Given the Sub-Group's preference to seek to align the market framework with existing legislation where possible (primarily the Gas Act), the role of a Shipper was introduced to contract with the Transporter for transportation of hydrogen between Entry Point and Exit Point
- In the mature natural gas market, a Shipper can provide many valuable functions including aggregating and disaggregating demand, market making and secondary trading
- Given the restrictions placed on intermediaries by the HPBM, the Sub-Group was of the view that a Shipper role for the initial hydrogen networks is valuable (to support future market development), but will initially only focus on facilitating transportation onto the network
- Shipper roles will be taken on by existing parties initially as only Producers or Offtakers (most likely H2P) can take title to the hydrogen under the HPBM
- The Storage Operator may also need to be a Shipper to allow for replenishment of hydrogen used in the course of daily activities (Own Use Hydrogen) and shinkage.
- Shippers will notify the System Balancer of network entry / exit flows at entry/exit points, ensuring that each are balanced across relevant balancing periods and (for the de-centralised model), adjusted within hydrogen day where required
- The timing of when Commercial Title is transferred from Producer to Offtaker is linked to, and dependent on, who takes on the Shipper role
    1. If the Producer is the Shipper, Commercial Title could be transferred on exit to Offtaker
    2. If Offtaker is the Shipper, Commercial Title could be transferred upon entry to the system from Producer
    3. Other permutations may exist for Commercial Title transfer from Producer's storage

Supplier role

- Given the existence of licensed Suppliers in the natural gas market, the relevance and value of Suppliers in initial hydrogen networks was assessed
- The Sub-Group's view was that there was not a strong need for licensed Suppliers in initial networks given the focus on larger industrial / power offtakers rather than smaller offtakers or domestic consumers. It was deemed that introducing Supplier licenses may add complication to initial networks without significant benefit
- Sub-Group members expressed a range of ideas from requesting an exemption for hydrogen, to changing the threshold, to retaining the role given the need to protect industrial / power hydrogen offtakers
- The Sub-Group's view was that final decision on whether a Supplier role was required and/or whether changes to a Supplier license, threshold or exemption were relevant for initial hydrogen networks should be determined by Ofgem

Connections / Capacity

- Connections to the network will require a Connections Agreement, the principles of which will be drawn from the Hydrogen Network Code and Hydrogen Gas Quality guidelines

- The Sub-Group did not come to a consensus on the need for a Capacity Regime in initial networks, but it may be possible to start networks without one and add in once they become more mature
- The Sub-Group had concerns about the allocation of finite storage capacity; particularly transparency, equity and access for future connectees to the network. Further work is required.

Legislative and business model changes required

- The Sub-Group concluded that it may be possible to structure a hydrogen market model within the existing legislative framework, including the Gas Act, and with similar types of legislative licenses and codes as in the GB natural gas market.
    1. The Sub-Group had assumed that compliance with the Gas Act and some consistency with existing licences and codes would speed up execution of the hydrogen market framework
    2. Further work is required by DESNZ and Ofgem to reach conclusions and make recommendations about the degree to which the Market Framework is required to be compliant within the existing legislative environment, or the degree to which flexibility (in the form of legislative change) is available
- Changes to the existing HPBM will be required to allow the System Balancer (and storage operators) to take title to hydrogen and support the cost of storage capacity for producers who are providing system resilience to offtakers[5]
- DESNZ will need to ensure consistency between the market framework for hydrogen transportation with the other hydrogen business models they are currently developing – i.e. transport, storage and hydrogen to power

Future proofing

- The De-centralised balancing model is considered to be sufficiently adaptable to provide a future proofed / no regrets pathway for hydrogen market evolution
- This is because limited changes are expected to be required to manage the addition of further network users and increases in network size (most likely short-term evolutions) and the introduction of RTIs taking on the Shipper role once they are permitted under the HPBM

Recommended next steps

Balancing is step one of the Market Frameworks, and while the Sub-Group and the report provide a proposed outline for system balancing, and some of the wider roles required in the initial hydrogen networks, the commercial balancing arrangements also need to be developed. Many operational areas require further development noting that the targeting of risk needs to be advanced before the market framework is sufficiently developed to allow network operators or network users to take FID – for example, network charging arrangements, dispute settlement etc.

[5] Other changes to the HPBM may also be required to ensure consistency with a large scale hydrogen network, detailed consideration of other business models was outside the scope of work for this Sub-Group.

To ensure that the Hydrogen Market Framework does not become the critical path for the development of initial hydrogen networks, DESNZ and Ofgem should:

1) **Roadmap** – Develop a roadmap for how the hydrogen market frameworks, licenses and Hydrogen Network code will be developed by end 2026 at the latest, and define accountable parties and key consultations required
2) **Legislation -** Determine if any changes to legislation or licensing is required and whether the preference is to limit legislative changes
3) **Business Models**
    a. Assess HTBM/HSBM/H2PBM impact on proposed market model
    b. Finalise the HTBM / HSBM designs and allocation rounds to clarify any impacts on the market model / framework designs
4) **Elements of Hydrogen Network Code -** With speed, progress development of the following:
    - Types of System Balancer tools needed
    - Assess the need for a Hydrogen Capacity Regime. This is the route to network access and the right to flow gas on the methane network, but may not be appropriate for the nascent hydrogen networks.
    -
    - The structure of a Charging regime: the method by which approved network costs are recovered from users
    - The expected Connections Process: the process which governs access to the network
    - Gas quality requirements: the standards which ensure gas input to the network is of the required specification to enable consistent and safe operation of the network
    - Evaluate the requirements of the Hydrogen Data Hub Requirements:
5) **Licenses -** Develop and allocate licenses for the licensed roles - System Balancer / System Operator and Shippers
6) **Code development -** Determine which parties will develop the Hydrogen Network Code, who is accountable and in what timeframe it will be developed ahead of the initial networks Final Investment Decisions and an ongoing process to facilitate changes to the Code

We note that the current expectation of Final Investment Decisions in 2027/2028 for the initial funded hydrogen network does not leave much time to spare given the complexity of the task at hand.

Therefore, it is imperative that the momentum from this report is not lost, and DESNZ rapidly develops a roadmap to cover the above points and others and ensure a Hydrogen Network Code is developed by end of 2026.

Matters for further development:

This Report provides the basis for developing a market framework, which is based on views drawn from across the hydrogen value chain. However as set out previously there is significant further analysis required and issues associated with legislation and regulatory approach which require direction from the government and market regulator.

A non-exhaustive list of key questions that need to be addressed in the next stage of the market framework's development are highlighted at the end of each section with the collated list provided in Appendix 1, section 5.

3) H2 market framework principles

The Market Framework and associated models were developed whilst being cognisant of the differences between the anticipated initial hydrogen networks and existing natural gas market frameworks, legislation licenses and codes. The models were developed to ensure they worked primarily for the hydrogen market in Great Britain today.

The hydrogen market today is in its infancy which leads to:

1. **Limited scale and a focus on physical delivery** – Day 1 hydrogen volumes in networks will only be a tiny fraction of volumes delivered in natural gas networks – with fewer supply and demand points. They will also have much more limited linepack and storage. Therefore, these will be much more physically controlled networks, when compared with the more commercially driven natural gas network, and will require different models and updated balancing tools
2. **A regional focus** – Large scale production is focused on a handful of geographic areas, which will not initially be interconnected, therefore multiple initial networks with different characteristics will be created
3. **Very limited liquidity** – With a limited number of producers and offtakers as well as RTIs not being permitted under the current HPBM – rudimentary physical and financial incentives to manage demand and supply imbalances t will be required.

The hydrogen market is supported by four business models at different levels of development. These business models will all affect how the market framework operates, and its similarities/differences to the existing natural gas market framework.

Specifically:

- **HPBM** – creates some constraints, e.g. on sale of hydrogen only to Qualifying Offtakers, incentive to produce max volumes and no RTIs
- **HT/HS/H2PBM** – may create incentives and constraints for connectees which need to be taken into account, this may require adjustments to either the market framework or the relevant business models to ensure efficient operation across the value chain
- The leading element of system design in the natural gas market is demand; for hydrogen it will initially be supply driven due to the support of the HPBM
- The key implication of the above is that the initial hydrogen market and networks will be:
    - Very physical networks, with limited linepack
    - Limited options for system balancing; this is the primary challenge the Sub-Group has sought to resolve
    - A need for network management tools to change over time as the BM’s and the hydrogen market evolves

Key market framework principles

We have developed the market models with an aim to meet 6 market principles:

Figure 3 - Key market framework principles

Principle	Explanation
Minimum Viable Product	… for Day 1 H2 networks in Great Britain, that works for "many to many" networks, i.e. multiple producer and multiple offtakers, both with and without storage
General alignment with Hydrogen Business Models	… to work in alignment with existing or planned hydrogen business models where possible, and avoid significant structural changes which would complicate market development and hinder the development of initial hydrogen networks
Potential to align with Gas Act and natural gas licenses / licensable roles	... to make execution and implementation of a hydrogen market framework as simple and quick as possible; supporting future market evolution through introduction of roles
Simple for Offtakers	… to understand and buy into, giving comfort on safety and resilience
An acceptable level of risk is taken on by all parties	… ones which they can best control and manage
Flexibility across networks	… a market model will need to ensure flexibility to work across all potential networks in GB, regardless of size, location, connectees or storage. Some elements could be network specific as part of the Annexes of a network code or as special licence conditions

The Sub-Group believes it has developed models that largely meet these principles, and that this will:

- Speed up delivery of the hydrogen market framework
- Ensure the hydrogen network code is relevant to the initial networks
- Require the least number of changes to legislation, licenses and business models possible to build a workable solution; given current market nascency and business model constraints
-

Assumptions

A number of assumptions were made when developing the market model, these are defined in the Appendix, Section 1.

4) Key roles in the market framework

Ahead of defining the market model options developed by the Sub-Group, this section seeks to highlight the key roles that are expected to be required for an initial hydrogen network and draw comparisons with the natural gas network.

It will also highlight the existing parties in a network, known as the connectees, and other parties who will be required to design, manage, operate and regulate the initial hydrogen networks

Roles

The H2 market framework will need to ensure multiple roles can be fulfilled. As a starting point we have highlighted the key roles expected to be required here:

Figure 4: Key roles required in the hydrogen market

Key roles	Example Roles
Network regulation	Responsible for regulation of the networks / market
Planning / Network constraints	Long/mid term planning (1-4, 4+ yr) to ensure supply = demand
	Short term planning (less than 1 yr) to ensure supply = demand
	Network Constraints
Granting of business models	Granting HP/HT/HS/H2P Business Models to build out infrastructure
Asset protection and emergencies	Pipeline asset protection – all aspects incl. pressures and proximity
	Emergency Coordination
	Network security of supply design standard
Purchase and sale	Purchase Gas at Entry
	Sell gas at exit
	Ultimate end customer
Provision of Storage	Contracts with storage
Connections	New Entry Connections Agreement
	New Offtake Connection Agreement
Transportation	Facilitation of transportation of molecules
	Transportation of molecules
Balancing (primary and residual)	Ahead of balancing period planning to ensure supply = demand
	Within balancing period actions to ensure supply = demand
	Within balancing period actions to profile supply and demand across the day
Data service provider	Provides data services to the network
Network code administrator	efficiently administer governance of the processes for modifying the commercial regime

Note: Payment, billing, metering and settlement have been excluded from the list for simplicity and because further analysis is required to assess how this should work in the hydrogen market.

The mature GB natural gas network has a series of legislations, licenses and codes which define the parties who take on these roles. These are summarised in Figure 5 below to orient readers of this Report.

The aim of the Sub-Group is not primarily to duplicate the roles from the natural gas network into hydrogen, but to identify if there were any commonalities and where differences were required given the different levels of maturity and physicality of the natural gas vs hydrogen networks

Figure 5: Parties responsible for key roles in natural gas network

Key roles	Example Roles	Who takes on these roles in natural gas networks
Network regulation	Responsible for regulation of the networks / market	Ofgem
Planning / Network constraints	Long/mid term planning (1-4, 4+ yr) to ensure supply = demand	Gas transporters, producers, importers and other Shippers with NESO and Government strategic oversight
	Short term planning (less than 1 yr) to ensure supply = demand	Shippers with NESO oversight
	Network Constraints	Gas Transporter and System Operator
Granting of business models	Granting HP/HT/HS/H2P Business Models to build out infrastructure	Not applicable
Asset protection and emergencies	Pipeline asset protection – all aspects incl. pressures and proximity	Gas Transporter and System Operator
	Emergency Coordination	Gas System Operator (National Gas)
	Network security of supply design standard	Legislation and Regulation
Purchase and sale	Purchase Gas at Entry	Shipper
	Sell gas at exit	Shipper to Supplier
	Ultimate end customer	Domestic and industrial or power users
Storage	Contracts with storage	Shipper
Connections	New Entry Connections Agreement	Gas Transporter
	New Offtake Connection Agreement	Gas Transporter
Transportation	Facilitation of transportation of molecules	Shipper
	Transportation of molecules	Gas Transporter and System Operator
Balancing (primary and residual)	Ahead of balancing period planning to ensure supply = demand	Shipper
	Within balancing period actions to ensure supply = demand	Shipper with Gas System Operator if required
	Within balancing period actions to profile supply and demand across the day	Gas System Operator (National Gas)
Data service provider	Provides data services to the network	Xoserve
Network code administrator	Administer governance of the processes for modifying the commercial regime	Joint Office of Gas Transporters

Key parties in the hydrogen market

There are a number of existing key parties in the hydrogen market who should be considered to fill the required roles. These include:

1) H2 producers – as the supply of hydrogen
2) H2 offtakers – as the buyers of hydrogen
3) Transporter – as the Asset Owner and System Operator of the pipeline
4) Storage Operator – as the owners / operators of the storage
5) DESNZ – as the decision makers for granting of business models for production and storage, as well as the transportation licences expected to be required
6) NESO – to support long term system planning
7) Ofgem – as the regulators of the hydrogen market

Critical roles for hydrogen market

In addition, the roles of System Balancer and Shipper have been identified by the Sub-Group as particularly key for the initial hydrogen networks, with parties who will take on these roles requiring identification through the market model assessment.

The report will discuss these roles in further detail in Sections 5, 6 and 7.

5) Market model options

This section lays out the market model options considered and assessed by the Sub-Group. In particular, it explains what the market model focuses on – system balancing, the key entities and roles in each option, their pros and cons and the option preferred by the Sub-Group for initial hydrogen networks.

Needs of the parties who will make use of initial networks

To design a market model which works for the initial hydrogen networks, the Sub-Group needed to not only be conscious of the differences for the hydrogen network, but also the needs of the parties who will make up the initial networks. The market framework needs to be designed in a way which works for all participants and places risk with those parties best able to bear and mitigate it – one of the market framework principles.

The following notes are the views expressed by those in the Sub-Group to summarise the key needs of each party:

- **H2 producers:** Need to be able to get clarity on production levels as early as possible and ensure ability to produce in line with HPBM incentives. Need to ensure that it sells as much of the hydrogen produced within day to offtakers, as it will only get paid once commercial title passes to offtakers. Incentivised to support building system resilience, to attract new industrial offtakers and be able to limit its own liabilities if it goes into unplanned maintenance.
- **Industrial offtakers:** Need to be able to maintain operations with energy security, whilst not significantly expanding the role and actions required vs those required to utilise natural gas today. They put a high value on system resilience but have less ability to monitor and manage energy use in real time. Typically, would not seek own storage capacity and would seek to minimise cost of not meeting nominations within the balancing period through the simplest method possible. Looking for firm or guaranteed supply of hydrogen, or the ability to fuel switch in the event of supply shortages.
- **H2P offtakers:** Need to able to access storage capacity to be able to manage the mismatch between hydrogen production andH2P operating profiles. Further there is a need to achieve high hydrogen ramp rates which correspond to the 30-minute electricity market dispatch notices which is unlikely to be able to be met solely by production. Require the ability to change nominations within the balancing period, as actual requirements within balancing period typically not known ahead of day. Would require certainty of hydrogen supply, particularly from storage, as its hydrogen demand will generally exceed the volumes that the producer can directly deliver.
- **Storage operator:** Need to get clarity on the users and uses of storage to be able to develop long term commercial storage products, as expected to be required under HSBM design. Need to ensure operational margins for storage are not exceeded – ie safe storage pressures are maintained.
- **Transporter:** Need to ensure safe operations of the network and ensure asset protection. This will require a level of control on system balancing to ensure residual, and if required, emergency actions can be taken. Also need to understand operational margins for network – including linepack, storage and ability of H2 producers and offtakers to flex up and down. The System Operator will need to fully understand the characteristics of the pipeline system and its users to clarify balancing options and

arrangements – some elements of this would be set out in the network specific annexes of the Hydrogen Network Code.

Timing of system balancing

Given the physicality of the initial hydrogen networks a priority focus was given to balancing within the hydrogen day.

Balancing the initial networks ahead of the hydrogen day was determined to best be managed by the H2 Producers who will have bilateral agreements with offtakers.

H2 Producers can ensure that ahead of the hydrogen day, profiles are submitted, forecasting each balancing period within the hydrogen day, ensuring that expected supply equals expected demand (inclusive of flows in and out of storage facilities) by flexing either production or offtaker requirements.

Additional information about balancing periods is addressed in Section 7.

Ahead of the hydrogen day

The Sub-Group discussed which party or parties) should be responsible for balancing ahead of the hydrogen day (i.e. ensuring supply = demand). It was determined that initial contractual discussions would be required between H2 Producers and Offtakers to ensure supply and demand could be balanced. Once agreed this information would be cascaded to their related Shipper licence holding entity/subsidiary to place nominations into the network.

Parties are supported to manage this by the Storage Operator and System Balancer who will receive a Daily Profile Notice, broken down into shorter balancing periods.

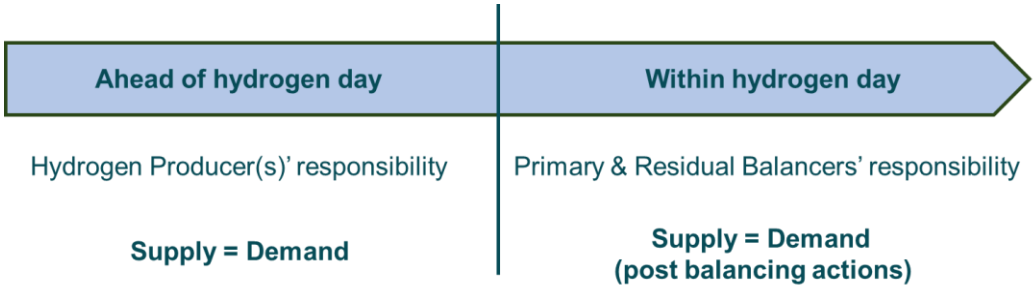
Further work will be required to ensure clarity over the method and information required when passing / cascading of information from H2 Producer Shippers or Offtaker Shippers to the central hydrogen data hub.

Within the hydrogen day

- Dependent on the market model, different entities may take on either:
    - Primary balancing responsibilities
    - Residual balancing responsibilities

Across these balancing responsibilities, the initial hydrogen networks would be expected to be in balance within each balancing period (length to be determined) and across the hydrogen day.

Figure 6 – Ahead and within hydrogen day balancing



Please note that the Sub-Group did not undertake sufficient modelling to determine what the most appropriate balancing period should be, but it has noted that:

1) Balancing periods may be as short as 20/30 minutes to support the electricity system's dispatch notice periods
2) Balancing periods may be longer within larger networks as they may have additional linepack and storage capabilities
3) It will be more critical in the initial hydrogen networks for network users to match their flow as closely as possible to the daily profile notice submitted to advise the System Balancer of their flow nomination
4) The requirement to balance ahead of the hydrogen day may not be as granular as individual within day balancing periods, but should result in an overall within day balance as a minimum. Ie ahead of the hydrogen day an overall demand and supply balancing requirement on the producer may be required at within say 6/8 hour intervals (to be determined by further work), but the primary balancers within day may be required to stay balanced to smaller intervals (say 2-3 hours)
5) Work will be needed to refine the requirements

Further detail is discussed in Section 7 – Operational Considerations.

Market Model Options

The Sub-Group had proposed two market model options, focused on system balancing arrangements within the balancing period. These were developed and iterated over the course of the Sub-Group. No further different models were proposed but permutations of these models were discussed.

The options proposed can be viewed as bookends; representing the two extremes of how system balancing for initial hydrogen networks could work.

Model focus

Please note that these models focus only on the entities in the initial networks who are supporting balancing within the balancing period. Section 6: Responsibilities, will highlight entities who will take on other important roles in the initial hydrogen market, including Shipper roles.

The two market models are:

1) **A Centralised balancing model**
2) **A De-centralised balancing model**

At the highest level the difference between the two models is how many entities are responsible for balancing and who these entities are.

- A **Centralised balancing model** has only one entity responsible for balancing (primary and residual), the System Balancer, who is a licensed entity. They act as a centralised hydrogen aggregator to take ownership of all incoming hydrogen within the balancing period, and use a range of tools to balance the system and outflows to offtakers within the balancing period

- A **De-centralised balancing model** puts the responsibility for primary balancing onto certain network connectees (expected to be hydrogen producers and/or offtakers with greater demand volatility such as H2P offtakers) with a System Balancer providing a similar service to the Residual Balancing role. This is aligned with the gas National Transmission System (NTS) where National Gas as the system operator uses a range of tools to balance the system after shippers have exhausted their tools

These are likely the extremis options, with a full spectrum of variants between them to be discussed, but there is some consistency within the options presented:

- Network users submit entry/exit flow nominations, ahead of the hydrogen day, to the hydrogen data hub
- The Hydrogen Day will be divided into Balancing Periods, expected to be shorter than the 24-hour day and for simplicity will likely be a factor of 24, i.e. ¼, ½, 1, 2, 3, 4, 6 or 8 hours
- Network users will be able and expected to renominate for future balancing periods within the hydrogen day based on their latest forecast data
- Network Users will be expected to use best endeavours to balance entry and exit volumes
- The System Balancer will validate incoming entry and exit nominations, both ahead of and within day, to ensure they are in balance within an agreed tolerance
- Charges maybe raised against network users who exceed those agreed tolerances even if they are not the obligated balancing party

Figure 7 – Market Model Options

Elements	Option 1 – Centralised Balancing	Option 2 – Decentralised Balancing
What is the model?	• A centralised system using 1 entity to ensure the system balances within the hydrogen day	• A decentralised system using multiple entities to ensure the system balances within the hydrogen day (multiple primary balancers), with parties managing their own risks and commercial optimisation potential
Entities involved in within day balancing	• Only 1 centralised entity who is both primary and residual balancer • A regulated, licensed System Balancer (SB) • SB takes title to all hydrogen within day – and then manages the balance / flows; they essentially act within day as a monopoly supplier; taking all hydrogen production and matching with requests for hydrogen offtake	• Multiple entities (Producer, H2P, SB) who each have storage capacity and manage their own hydrogen imbalances within the hydrogen day • Includes a regulated, licensed System Balancer (SB) entity, who only takes title to hydrogen it expects to use for system balancing if other parties cannot (ie residual balancer)
Balancing actions	• SB contracts for all storage capacity required to manage balancing • SB takes all balancing actions using storage capacity or turning production or offtakers up / down to manage the system • SB responds to: planned / unplanned production outages, demand fluctuations, H2P demand variations from dispatch	• Each party manages their own imbalances (primary balancers) • If they cannot, the SB steps in to manage imbalances • If the system works well, the SB's role may be small and be focused on balancing across peak hours within day • Both network users and the SB may hold storage capacity
Implications for the SB	• SB takes title to all hydrogen within the hydrogen day to balance the system • SB takes very significant Working Capital risk • A charging framework and support mechanism is needed	• SB takes title to hydrogen required to balance the system after other entities have exhausted their ability to balance
Implications for connectees	• Direct network charges likely to be higher than decentralised model due to the SB having to hold more risk and storage capacity • Greater likelihood that the average charge across users will not reflect the impact they have on maintaining balance on the system • Less control over day to day operations as the SB will have more discretion as to how imbalances within the day are managed	• Producer and/or H2P will take responsibility for holding storage capacity or managing within day operations to maintain balance • Overall average network charges lower, as SB taking less risk and holding less storage • Connectees will have to incur direct costs for the tools they use to maintain their ability to stay in balance

Option 1 – Centralised Balancing Model

Option 1 aims to simplify the operational considerations of the initial hydrogen networks by placing all balancing responsibility within the hydrogen day on one centralised, licensed entity, the System Balancer.

The complexity of Option 1 comes from the wider remit of the System Balancer within the hydrogen day. They also take on the role of aggregator of all hydrogen entering the network within the hydrogen day. This means that the System Balancer not only has to manage daily fluctuations but also match hydrogen production with hydrogen offtake.

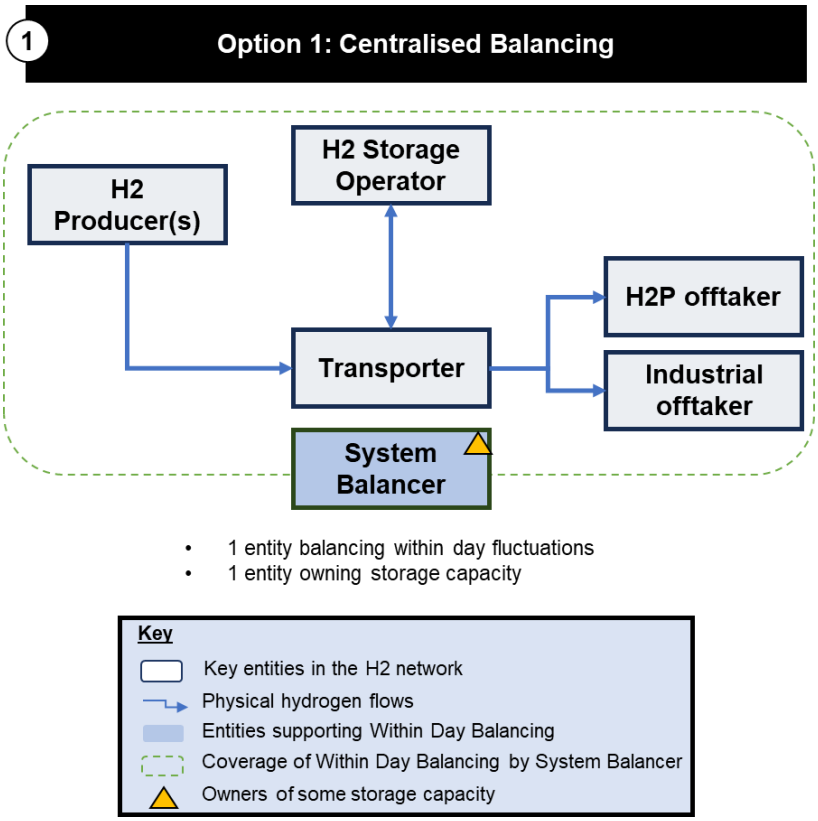
The key implications here are:

- The need to take title to all hydrogen entering the network
- The need to have access to all storage capacity in the network aside from that required by the Storage Operator to manage their facility
- Network connectees may be required to take actions within the hydrogen day or a specific balancing period, which do not best optimise their commercial positions

Some Sub-Group members pointed out that this model essentially creates a monopoly role where the System Balancer takes on elements of a Shipper and a Supplier role. This might not be tenable given the complexity and risk taken on by one entity and the intention of the hydrogen market to evolve in the future – which would require a level of transparency that may not be possible in this construct.

The figure below is a simple graphical representation on system balancing in Option 1.

Figure 8 – Option 1 roles and responsibilities



There are a number of other issues which the Sub-Group considered would require further consideration if Option 1 were to be progressed:

- **No storage networks:** In a network without storage, the market framework may more naturally revert to this option, given that the balancing tools available are limited and likely to be controlled primarily by the System Balancer
- **Charging mechanism:** If this option was developed, the System Balancer's charging mechanism would need to be clearly laid out with transparency for all system connectees and a focus on fair allocation of charges across system connectees based on their use of system balancing tools. A system user who does not accurately nominate or uses a significant share of storage will incur a higher cost.
- **Working Capital / Remit:** Some Sub-Group members were particularly concerned with the potential scale of Working Capital the System Balancer would require. If this System Balancer was a licensed entity, perhaps a government entity, that may lead to it becoming the absolute single point of failure in a network.

Option 2 – De-Centralised Balancing Model

Option 2 aims to put the balancing operations within the hydrogen day into the hands of those parties with the greatest incentive to optimise their operations and capacity to manage imbalances. This means that multiple parties will perform primary balancing actions within the hydrogen day. These are expected to be primarily Hydrogen producers and H2P offtakers, although they could also be industrial offtakers. A System Balancer role is retained, albeit with a much smaller mandate than in Option 1 – to perform any residual balancing roles as required. Under this model, it is expected that the network connectees responsible for primary balancing will also have procured storage capacity.

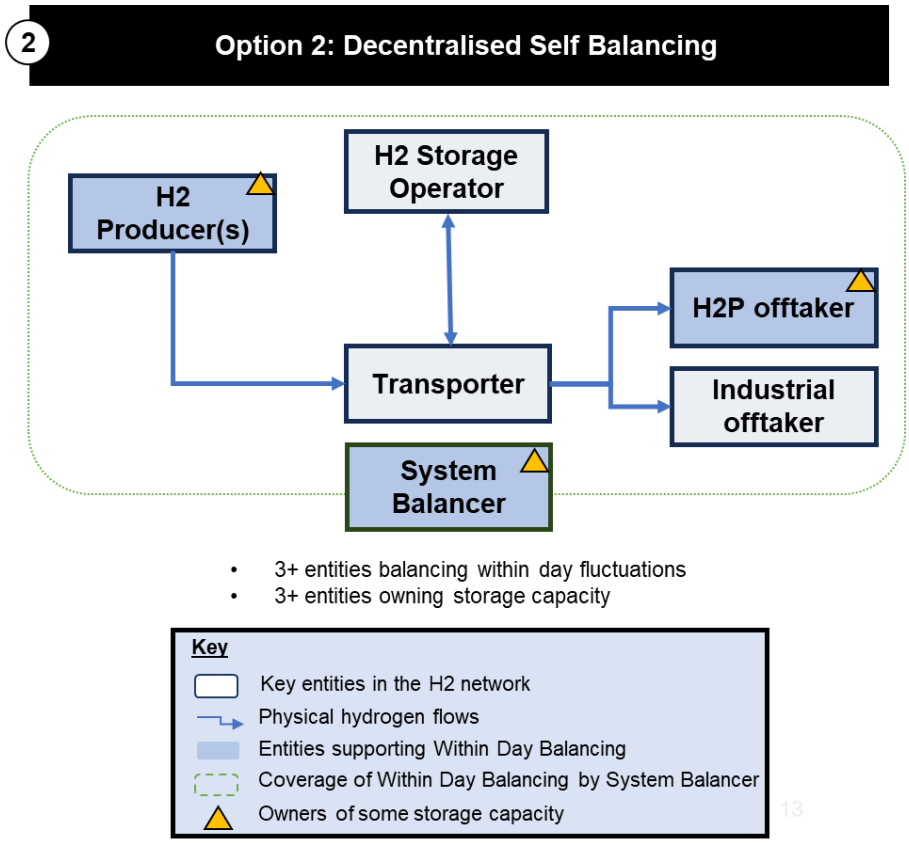
There will be a greater requirement for transparency and data sharing in Option 2 to ensure system imbalances are known and actions to be taken are clear. Therefore, the System Balancer here will have much more of an oversight role and will only take title to limited quantities of hydrogen and storage capacity it considers necessary to maintain system balance where primary balancing actions (from primary balancing entities) have been insufficient.

This is expected to bring infrastructure and commercial optimisation opportunities and a potential for faster market evolution.

The key implications here are:

- **Primary balancing -** H2 producers will take on the role of balancing for any of their offtakers who don't retain their own storage capacity (expected to be largely industrial offtakers)
- **Residual balancing -** System balancer role is limited, but they will still be required to take title to volumes of hydrogen and storage capacity required for residual balancing actions
- **H2P -** H2P Offtakers or other offtakers with own storage capacity will manage their own imbalances; and will therefore need to take title to the hydrogen at entry into the network
- **Storage -** The Storage Operator will design commercial storage products to optimise the use of the storage by customer type / requirement, multiple customers in storage may allow early opportunities for a market to develop

Figure 9 – Option 2 roles and responsibilities



Option 2 considerations:

- **Electricity market driving storage:** A key driver of hydrogen storage usage will be electricity market signals for two reasons:
  1. Electrolytic hydrogen producers will (based on current LCHA/LCHS design) be operating when there is excess, low-cost electricity available and will be off when there is limited electricity. Therefore, they will seek to store spare hydrogen to be used when required.
  2. H2P offtakers will use storage in the opposite way, placing blue hydrogen into storage at a consistent rate, then withdrawing hydrogen to support the electricity grid when they receive the appropriate signals. H2P offtakers will therefore be a mirror to the usage of storage from electrolytic producers
- **Storage use signals:** The signals for the use of storage in initial hydrogen networks will come from the network connectees. Under this model, connectees are more likely to make decisions on how to use storage based on optimising their commercial and operational needs which will be influenced by signals from the electricity market. Use of storage capacity should be more efficient under the decentralised model, but this will be impacted by HSBM design and potential change to HPBM to account for cost of storage – particularly during the early market development period
- **Incentives:** Primary balancers (H2 producers and Offtakers) should be incentivised to take responsibility for balancing through the network code, with the System Balancer only being utilised as a backstop. This would reduce the requirement for the System Balancer to retain a high volume of hydrogen in its storage allocation

- **Hydrogen network code:** The Sub-Group were conscious that the hydrogen network code under Option 2 may be more easily adaptable to changes in hydrogen business models. (See Section 9 and 10 for further details)
- **Permutations -** Some other permutations of Option 2 were considered and discarded. This was primarily because they were deemed to be more appropriate to potential market evolutions rather than Day 1 networks, and introduced roles that could already be filled by existing network parties

Pros / cons

The Sub-Group identified a number of pros and cons across the two market models which are summarised in Figure 10. The table captures various areas of pros vs. cons, with relevant colour coding.

Figure 10 – Pros and Cons of each market model

Area	Option 1 - Centralised Balancing model	Option 2 - Decentralised Balancing model
Simplicity	May be simpler as only 1 balancing entity; may be more easily understood by new network connectees	May be more complex as multiple parties self-balancing. May take longer to make decisions on balancing
System costs	System balancing costs may be higher if infrastructure optimisation is more limited. Greater system costs to spread across connectees with to-be-defined charging regime	System costs may be minimised as individual balancing actions should support a minimum cost associated with commercial opportunities. Fewer system costs to spread across connectees by System Balancer
Commercial risk management	Commercial risks within day difficult for parties to manage as they have no control and limited visibility	Puts control of commercial risk on those parties best able to handle it, therefore risk management likely to be better
Optimisation	More limited optimisation potential, as system connectees cannot optimise positions within the balancing period as they have limited ability to act without storage capacity. Also more difficult to optimise physical infrastructure use as storage is aggregated into one 'pot'	More optimisation potential – both of infrastructure and commercial opportunities as connectees who can benefit have storage capacity
Information flow	Less transparent information flows across all network users, as managed by one entity – the System Balancer who has no requirement to flow information the back to system connectees	Potentially more transparent information flows – as a requirement that all system connectees are aware of the need for balancing and their potential actions
Working capital	Requires a significant amount of Working Capital for System Balancer	Each party will require some Working Capital; that they can self optimise
Ability to support electrolytic producers	May be more challenging, or expensive as electrolytic producers may be unable to predict production profiles given the linkage to the electricity market; this may lead to high costs or challenges to match production and supply within day	May be easier to support electrolytic producers as the ability to manage own storage capacity ensures that producer can itself match demand and supply by using both within balancing period production and its own hydrogen in storage
Ability to support H2P Offtakers	Potentially a risk for H2P Offtakers, if System Balancer cannot guarantee their ability to take hydrogen within a balancing period, based on different uses of H2 storage	May be easier for H2P to manage own storage capacity with their H2PBM and commercial optimisation opportunities; particularly with blending options (with natural gas)

HSBM	Very difficult for storage operators to build long term storage products – as less transparency on use of storage – as all held by System Balancer	Expected to work for HSBM's incentive to build long term storage products – as transparency of use allows these to be determined
Market evolution	More difficult to see market signals on price / volume liquidity, as System Balancer has all information but not freely available to others, and they are not able to take action within day to optimise their own positions	More likely to support early development of transparent market signals due to multiple participants who are incentivised to create commercial opportunities. Early requests to borrow / lend storage capacity may be seen.System Balancer will need a mechanism to sell excess hydrogen back into the market, which could give rise to auctions over time

Proposed model

Most Sub-Group members expressed a preference for Option 2 – De-centralised balancing to be implemented, and by the end of the Sub-Group it was determined that the Centralised model was unlikely to work for the initial hydrogen networks due to its complexity to set up and its challenges with supporting market evolution and commercial optimisation decisions aligned with the business models.

The De-centralised balancing model was preferred for 3 reasons:

1. It places the responsibilities for balancing with the parties best able to manage them, allows commercial optimisation decisions to be made; and requires less potential changes to current and developing business models
2. It is more likely to deliver more efficient use of T&S infrastructure as connectees will have a better understanding of how much storage capacity is required to manage their commercial and operation needs
3. It may be more likely to facilitate market growth and development as it is more transparent given the need for multiple parties to take balancing actions. This may support earlier pricing, volume and investment signals for hydrogen market evolution

The Centralised balancing model was less preferred for 3 reasons:

1. A single entity would be required to take on significant financial (working capital and price) risk to enable management of all hydrogen entering and exiting the network and therefore may require a government backed entity
2. This model may lead to concerns over transparency and equity as a single party has control over the entirety of the hydrogen network
3. A lack of transparency would also make it almost impossible for the network to optimise either the infrastructure or commercial decisions within the hydrogen market; this would then lead to a longer or more limited potential for hydrogen market evolution and it isn't deemed to work for H2P offtakers given high flexibility requirements, but no transparency in hydrogen availability within day. It would be difficult to build a H2PBM business case off this model

Do the models meet the framework principles?

Part of the model assessment was whether they met the framework principles.

Figure 11 – Models' ability to meet framework principles

Framework Principles	1) Centralised Balancing	2) De-Centralised Balancing
Minimum Viable Product	Yes	Yes
General alignment with Hydrogen Business Models	No	Yes mostly
Potential to align with Gas Act and NG licenses / licensable roles	Partly – some complexities	Yes
Simple for Offtakers	Yes	Yes – if Producer is Shipper
Acceptable level of risk	Maybe – less clear	Yes
Flexibility across networks	Maybe – less clear	Yes

The De-centralised Balancing Model meets all six of the market framework principles. It also ensures network balance, safety of the network and supports building commercial confidence and future resilience.

The Centralised Balancing Model does not meet all six of the market framework principles. It has bigger consequences for changes required to Business Models as the System Balancer has a much larger role and there are no within balancing period actions for H2 producers and offtakers available, which may reduce their ability to work in alignment with their business models. For example, the incentive in HPBM for producers to maximise production.

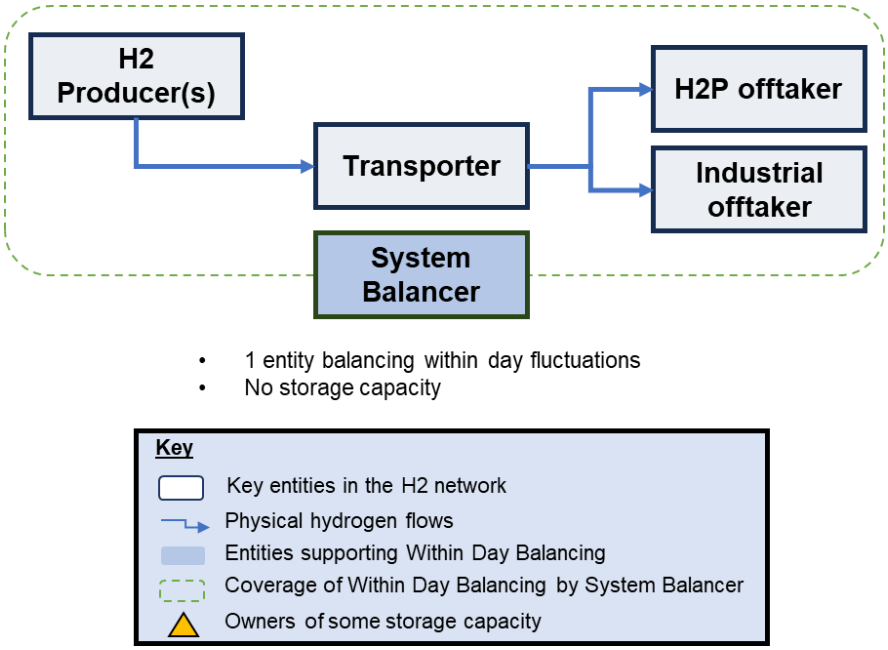
- There are potential complexities with alignment with the Gas Act and natural gas licenses given the very broad remit of the System Balancer role in Option 1
- It is also not clear whether the risks are acceptable or borne in the right way by the right parties due to a lack of transparency of decision making within the balancing period. It may also be less flexible to adapt to changes across networks. While some of this could be mitigated by the presence of a Hydrogen Network Code – there will be daily operational scenarios that cannot be perfectly forecasted or planned for in the Code.

Do these models work in a network with no storage?

Yes, the models should both work in a network which doesn't have any large-scale storage. The models would however then converge in terms of how they managed any within day imbalances.

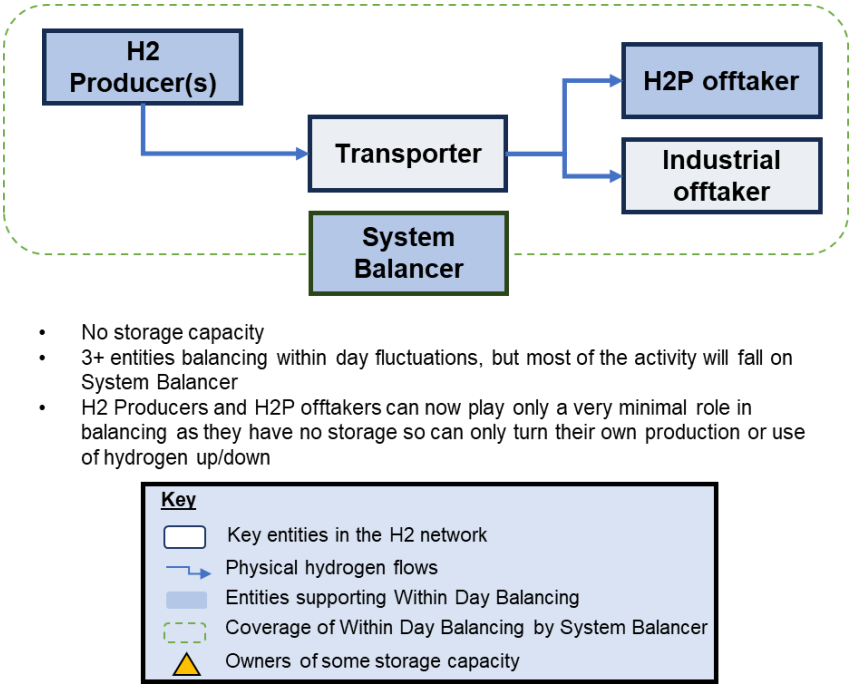
It was noted by Sub-Group members that not all networks will have storage, and even those that do may not have it on 'Day 1' given the time required to develop hydrogen storage facilities. Therefore, all networks may have a period of ramp up time where they have no access to storage.

Figure 12 - Centralised Balancing Model without storage



In the Centralised balancing model there is limited change to how system balancing operates without storage, with the System Balancer still being the key entity, but with much fewer balancing levers at its disposal

Figure 13 – De-centralised Balancing Model without storage



In the De-centralised Balancing Model with no storage, Producers and H2P Offtakers would not have storage access and therefore have very limited actions in terms of managing imbalances. These will be managed largely through production turn up or turn down with the same tools applicable to offtake dispatch unless they have access to both hydrogen and methane networks and are able to fuel switch.

The System Balancer here also has a greater role to play in early network balancing and may require system connectees to take more or less hydrogen up to their operational parameters. The use of linepack flex would also become more important, although this will likely be limited in early networks

Order of balancing tools in no storage network

We expect the following order of use of balancing tools in a no storage network:

- Linepack if available
- Offtaker / Production Contractual turn down/up
- Offtaker / Production Operational turn down/up by SO
- Emergency actions by SO

Summary of next level of questions to be answered

- Does the preferred model work within the current gas legislation and license framework?
- Are there any options not considered which would be significantly different from the two presented here?

6) Responsibilities

The purpose of this section is to broaden the discussion of responsibilities from the initial focus on within hydrogen day balancing, to the wider range of roles and responsibilities needed in initial hydrogen interactions.

System Balancing

Under Option 1 – Centralised Balancing:

- The System Balancer would take on both Primary and Residual Balancing
- System Operator, and by proxy, Transporter, would need to take on this role as the only party with sufficient expertise and operational capability to act as the Residual Balancer. The ability to purchase and take title to hydrogen and to ship on and off the network would be essential.

Under Option 2 – De-centralised Balancing:

- The H2 Producer or larger Offtakers (e.g. Hydrogen to Power) would take on a Primary Balancing role, either managing their operational profile or using storage to maintain balance.
    - Any smaller offtakers who did not want to be involved in Primary Balancing would have the Producer undertake this role on their behalf for their associated hydrogen volumes
    - Alternatively, the introduction of an agent, who can manage those activities on behalf of any party in need of support was discussed, and while not actively pursued, could be a possibility
- The Residual Balancer would be the System Operator (a role taken up by the Transporter)

The Transporter

We expect that the roles of Asset Owner and System Operator would remain as closely linked in Hydrogen as they are in the NTS today, this means the Transporter would take on both sets of licence obligations though how this is structured is still to be determined.

Other key roles under all models proposed:

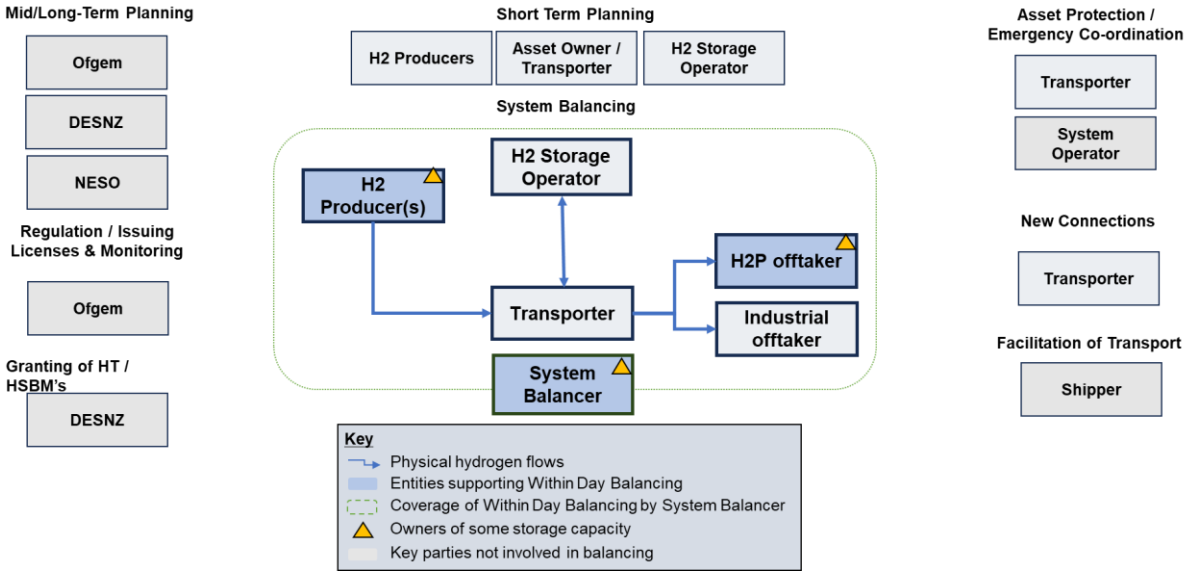
It is expected that:

- Ofgem will act as the Hydrogen Regulator, and will have a role in mid and long-term role in strategic planning through oversight of any access regime and through the issuance and monitoring of licenses
- DESNZ will be responsible for developing the initial Hydrogen Network Code, alongside supporting mid-long term hydrogen system planning stemming from choices made on HP/HT/HS/H2P business models granted and timing of these
- NESO will have a role in longer term system planning through their Centralised Strategic Network Plan and its components, as well as in developing the Future Energy Pathways

- The Network Emergency Coordinator (NEC) role currently sits within the Transporter for NTS. This role is linked to the assets and operation of a network but requires oversight from a qualified NEC[6]
- The Transporter will also be responsible for completing new connections; with process to determine new connections yet to be determined
- Shippers – *discussed in more detail below*
- Suppliers – *discussed in more detail below*
- Additional service roles may also be required to support the data management and administration of the Hydrogen Network Code, but these have not been considered in detail by the Sub-Group

Figure 14 represents a depiction of the key roles in the initial hydrogen networks. It is not intended to be exhaustive but helps to illustrate the wide range of parties and key roles and responsibilities.

Figure 14 - Key initial network roles & responsibilities



The Appendix contains a full list of roles and a comparison to the roles in the natural gas system.

Shippers

The Sub-Group had extensive discussions about whether there was a need for Shipper licensed entities in the initial hydrogen networks and what specific roles Shippers would be able to take on given constraints under the HPBM.

Shipper roles in natural gas today

In the natural gas network today, Shippers hold multiple roles and have supported the maturity and market development of the GB natural gas market.

One of the key shipper roles is facilitating the transportation of gas. Shippers act as the interface between producers, offtakers and the gas network, contracting with the Transporter

[6] Further discussion required by following working group

on behalf of the connectees to enable conveyance of volumes of gas across the network from Entry Point to Exit Point. The Gas Act states that a Shipper must be in place to enable that contractual relationship between parties.

Shippers also support the facilitation of a mature market and enable purchase and sale of natural gas. This also enables them to support within day balancing of the NTS. Finally, Shippers play a crucial role in supporting market liquidity through exchange of information, secondary trading etc.

Potential Shipper roles in initial hydrogen networks

Given that the HPBM restricts the use of Risk-Taking Intermediaries and requires that hydrogen is sold directly from the H2 Producer to Offtakers, the roles that a Shipper can take up in the initial hydrogen networks, assuming a continuation of this RTI restriction, is limited.

Our analysis below suggests that most Shipper activities in natural gas cannot be replicated in initial hydrogen networks, without a change in the RTI restriction.

Figure 15 – Shipper activities in natural gas and relevance to initial hydrogen networks

Roles	In Natural Gas	In Hydrogen	Notes
Buy gas	Shippers	Offtakers	HPBM doesn't allow RTI's – Shippers cannot play that role
Sell gas	Shippers	Producers	
Facilitate transportation	Shippers	Producers / Offtakers (with Shipper licenses)	Proposed to be existing entities, not new entities given limited role
Secondary trading	Shippers	Not allowed	No secondary trading as no RTIs
Within day balancing	Partially Shippers, + Transporter and SO	H2 Produces & Offtakers in Decentralised model	Shippers could not take title to H2, therefore could not support balancing

Despite having a much narrower role in the initial hydrogen networks, a limited Shipper role (that of contracting for conveyance of gas) is recommended for the initial hydrogen networks, particularly if the aim of the hydrogen market framework is to align to existing gas legislation and licenses where possible.

This Shipper role will primarily encompass the facilitation of transportation onto and off the network through contracting with the Transporter, on behalf of connectees, to enable hydrogen transmission from Entry Point to Exit Point.

Who takes on the Shipper role/license?

The Shipper role could only be taken on by one of two existing parties:

1) H2 Producers
2) Offtakers

This means that a H2 Producer would either have to agree to be the Shipper for its hydrogen entering and exiting the network, or its Offtakers would have to take on this role.

The Sub-Group concluded that both H2 Producers and Offtakers were likely to take on Shipper roles in the initial hydrogen networks, and the proportion of each would depend on individual discussions and network specific characteristics. It was also noted that H2P Offtakers particularly may prefer to have their own Shipper license.

It was also noted by two Working Group members that the Storage Operator may also need to be a Shipper to allow for replenishment of hydrogen used in the course of daily activities (Own Use Hydrogen) and shinkage.

The Sub-Group raised a concern that small H2 Producers or those with small projects may find it challenging to take on a Shipper License. However, there is no obvious solution to this other than having their Offtaker(s) be the Shipper, or ask another H2 Producer to be their Shipper, but without taking Commercial Title to the hydrogen.

Shipper role and market evolution
The introduction of this Shipper role will allow for potential future market evolution when RTI's are allowed. Shippers are expected to be able to support the growth of the market by taking risk away from H2 Producers and Offtakers, building secondary trading markets and supporting optimisation across the hydrogen networks. They will also be able to create optimisation potential across the network, in addition to individual H2 Producers' portfolios.

Commercial Title
Commercial title is an important concept which is linked to the Shipper role discussion and is an important concept in the hydrogen market due to constraints created by the HPBM.

It is important to note that commercial title is not directly defined in the LCHA. Instead, it is a concept named to highlight the requirement for hydrogen to pass directly from the H2 Producer to the Qualifying Offtaker.

This is not the same as legal or custodial title which is required by the Transporter and Storage Operator to ensure they have the ability to act on emergency measures if required within the network or storage.

The HPBM restricts the H2 Producer from selling hydrogen to any party that isn't a Qualifying Offtaker (if the H2 Producer wants to avail itself of the negotiated CfD). This means that the commercial title of the hydrogen once produced must pass directly to the H2 Offtakers. So, at any point, only H2 Producers or H2 Offtakers may hold commercial title. In addition, the change of commercial title is required for H2 Producers to be paid the CfD under the HPBM.

This creates two requirements:

- H2 Producers cannot sell to Offtakers through an intermediary
- H2 Producers are incentivised to pass on commercial title as quickly as possible to Offtakers, to get paid the CfD under the HPBM

Timing of commercial title being passed on

We highlight where commercial title passes in the following Shipper scenarios:

1) If the H2 Producer is the Shipper; Commercial Title passes from the H2 Producer to the Offtaker at the Exit Point
2) If the Offtaker is the Shipper; Commercial Title passes from the H2 Producer to the Offtaker at the Entry Point

When the commercial title passes from H2 Producer to Offtaker also has implications for who bears the risk of within hydrogen day imbalances.

- If the Offtaker is the Shipper, then they take on the risk of within day imbalances in their own usage; which they would need to manage via operational changes (increasing or decreasing demand, or seeking that the producer changes supply rate) or through the use of their storage capacity
- However, if the H2 Producer is the Shipper, the H2 Producer takes on the risk of within day imbalances in their Offtakers usage. Physically they could manage this with their storage capacity, but it would have a commercial implication as the hydrogen has not passed to the Offtaker and so the H2 Producer has not been paid for the hydrogen or the CfD
    - This could introduce two risks: Working Capital risk and price risk
        - A price spread between the cost of producing hydrogen and the price finally paid for it, if hydrogen remains in storage for some time
    - Given this, it is likely that H2 Producer Shippers will seek to pass through or share some of the liabilities associated with bearing this risk with its Offtaker(s)

Suppliers

The Sub-Group also spent time discussing whether a Supplier role in the initial hydrogen networks was relevant and needed.

In the natural gas market, the Gas Act requires that piped supply of gas to any premises must be carried out under a Supplier License. The Supplier's license requires levels of protection for customers; primarily domestic customers.

The Gas Act has an exemption to this licensing requirement for supply to large customers (Schedule 2A(5) of Gas Act), with a threshold set at 2,000,000 therms a year. This is approximately equivalent to a constant rate of supply of 6.7MW of hydrogen.

It is expected that the vast majority of hydrogen customers in initial networks will be above this threshold, and therefore a Supplier license may not be a requirement. However, we are aware of some cases of smaller offtakers, particularly those focused on R&D, who may fall under this threshold.

Figure 16 – Supplier License exemption

	Supplier license required	Supplier license not required
Therms / yr		2,000,000
MWh / yr		58,614
MW equ.		~6.7

A range of views were expressed on the need for a Supplier role in initial hydrogen networks, these are summarised below.
Expressed views included:

- Whether an exemption for Supplier Licenses across the hydrogen networks could be sought from the Secretary of State given the focus on hydrogen for industrial and commercial uses, not domestic uses
- Whether an exemption for Supplier Licenses across the hydrogen networks should be sought to reduce complexity and uncertainty for Producers who may need to become Suppliers if any of their smaller industrial offtakers fell under the current 'limit' – which would create implementation complexity and a need to work with Ofgem for limited customer protection benefit
- Some Sub-Group members noted that the role of a Supplier could provide offtaker protection – a role which is not held anywhere else. But it was noted that the decision if this was required was an Ofgem decision
- It was also noted that the need for a Supplier in later hydrogen networks was not ruled out, but that there appeared to be limited additional value in adding another role to the initial hydrogen networks
- If Centralised Balancing Model was taken forward the System Balancer would need to be the Shipper and the Supplier

The final view from the Sub-Group was that a determination from Ofgem would be required on whether a Supplier role was required, whether changes to a Supplier license were required and whether a threshold or exemption was relevant for initial hydrogen networks.

Other roles in the initial hydrogen networks

Code governance
In addition to these key roles, Governance of The Code is the responsibility of Transporters but is dispensed to a Code Administrator in natural gas. Whether that remains the same, or the Code Administrator is replaced with a Code Manager is yet to be decided, but an entity will be required to perform that role.

As we have seen with the implementation of the CCS Network Code, there may need to be amendments to the agreed code prior to it coming in to force, and so a body in position to manage those changes is essential to ensuring that on Day 1 the code can be modified to ensure that it is still appropriate to the networks to which it applies.

Data services provider

Responsibility for management of the data service currently sits with the System Operator in the natural gas market. The SO dispenses this obligation to the Central Data Service Provider, who operate the Gemini platform. It is yet to be decided whether this relationship will be replicated, but it is expected that a similar service will be required, and so a tender process run under the governance of the regulator, to find a suitable provider may be required.

Please see Appendix Section 6 for further information.

Commercial agreements

The Sub-Group found it helpful to consider the key commercial agreements between the various parties in the market framework. These are largely the same between the two models, except for the parties who need to sign the network code and the Shipper role

Please note these are not intended to be exhaustive and further work is required on the Connection / Capacity Agreements by a following Sub-Group.

Figure 17 – Key commercial agreements (Option 2 depiction)

Agreement	For what	Party A	Party B
Hydrogen Offtake Agreement	Sale / purchase of H2	H2 Producer	H2P or Industrial Offtaker (SO and storage operator for operational needs)
Storage Capacity Agreement	Access to storage capacity	Storage Operator	H2 Producer / H2P / SBOLR
Operating Volumes Offtake Agreement	Sale / purchase of H2 required to maintain reasonable operating margins	H2 Producer	Storage Operator / SBOLR
Connection Agreement	Agreement for connection to network and max flow based on capability	H2 Producer / Offtaker / Storage Operator	Asset Owner / Transporter
HPBM / HTBM / HSBM / H2PBM	Agreement toenable invest in the development of relevant H2 infra assets and government support	DESNZ or designated counterparties such as LCCC	Relevant parties
H2 network code	Agreement to abide by network code rules and related charging mechanisms; includes confirmation of process and cost for transportation of hydrogen	Hydrogen network code administrator / SO	Shippers, SO, Storage
SO / SBOLR license	License to allow SO/SBOLR for network	OfGem	SO / SBOLR
Shipper license	License to allow Shippers to transport H2	OfGem	Shippers

Data system agreement	Agreement to develop and support H2 data hub	Hydrogen network code administrator	3rd party data provider

Focus of report from here

Given the Sub-Group's strong preference was for Option 2, the De-centralised balancing model, the report from here onwards will primarily focus on the use of this option.

Summary of next level of questions to be answered

- Ofgem decision on whether Supplier role / license is required in initial hydrogen networks and/or whether an exemption will be granted
- An assessment of the full suite of commercial agreements required to operate initial hydrogen networks; particularly with regard to the Network Code
- Are different conditions required for small HAR producers who may not want to take on a shipper license?
- Is a Supplier exemption the best solution?

7) Operational factors

The initial hydrogen networks are expected to encounter operational challenges that will require management of physical flows. Day 1 of any network is expected to have low resilience, minimal linepack availability and potentially no storage as infrastructure assets ramp up.

Initial fill of linepack and cushion gas for storage will require management as well as ongoing linepack assessment.

To ensure that each network functions in the most resilient and efficient way several operational parameters will need to be determined:

- Nomination periods
- Balancing periods

In addition, processes and systems will need to be put in place. These include:

- A network modelling and forecasting system in medium and long term
- A data hub to manage information flows
- Nomination and re-nomination processes
- Balancing tools – use and link to operating margins
- Clarity on management of SO 'excess' hydrogen sale[7]

Nomination Periods

Nomination and balancing periods were discussed by the Sub-Group as part of the operational factors to be considered. However, the Sub-Group was not able make final conclusions on the nomination periods to be utilised as these will be influenced by the hydrogen Business Model designs, the network specific considerations and decisions during the development of the Hydrogen Network Code.

Flow nominations will be provided Day Ahead and we expect will provide a breakdown of expected supply for Entry Points, and for demand for Exit Points, across the hydrogen day. These nominations will be provided by the Primary Balancers, the H2 Producers and Offtakers, with validation from the Storage Operator and System Balancer. They will be ultimately confirmed by the Shippers.

Offtakers who historically have not submitted the Offtake Profile Notices (typically hourly) used for larger NTS Exit Points, expressed a preference not to have to take on a role in the balancing regime. Instead, they would defer their demand profiling to the Producer with whom they have contracted.

Balancing Periods

Similarly, the Sub-Group did not come to a firm conclusion on the period lengths for balancing or whether nominations day ahead had to be balanced on the same period as within day.

[7] May potentially be the case if SO has had to residually balance excess hydrogen by placing it into its store. When this excess hydrogen in the SO's storage reaches a critical level (to be defined by network), then it should seek to sell the excess hydrogen (process to be defined by Hydrogen Code).

The Sub-Group did acknowledge that hydrogen networks will be far smaller in scale than existing natural gas networks and as a consequence there will be very little linepack available to support cushioning of imbalances between supply and demand.

Therefore, it was expected that balancing periods would be shorter than in natural gas. Some provisional estimates provided by the Sub-Group based on initial network modelling suggested that setting the period as low as 20 minutes may be required in some scenarios, primarily where a connection to the electricity network is involved and 30-minute dispatch notices are received.

It was noted that balancing periods may be longer within larger networks as they may have additional linepack and storage capabilities.

The balancing periods set will need to cater to all networks, and so there may need to be some flexibility in the way the Hydrogen Network Code is drafted, but it is expected that the Daily Profile Notices, provided on a day ahead basis, would need to specify flows in increments (likely in minutes or a few hours). How networks then balance supply and demand within day will be dependent on network capability, availability of linepack and storage etc.

Incentives and penalties

Incentives and penalties will need to be developed that provide the right level of motivation for Primary Balancers to appropriately forecast and manage their flows throughout the day to help balance the network and minimise the need for intervention by the Residual Balancer.

Hydrogen to power users in particular are expected to struggle with accurate forecasting due to the nature of their role in supporting the electricity networks and the need for rapid ramp up to respond to dispatch notices. Because of this, hydrogen to power exit points will frequently be out of balance vs the day ahead expected position

Electrolytic hydrogen producers may also have challenges in producing as forecasted day ahead given the connection to renewable generation. This would result in significant imbalances and mismatches against their Daily Profile Notices.

The Sub-Group also noted that incentives and penalties in bilateral hydrogen supply agreements may also interplay here – particularly where the Producer takes the risk of within day imbalances.

This makes the development of a simple incentive regime unsuitable for many connectees and in some cases, discriminatory. Further development of a flexible incentives structure may be required.

Forecasting system

Each network would need to have an annual forecasting system to support mid to long-term planning. This may be led by the System Operator, in conjunction with DESNZ and NESO. It would define the expected overall network balance across supply and demand, and expected future changes.

This system could then be used by the System Operator to manage new connections and continue to assess operating margin requirements as the network use and user base changes.

Data hub

The Sub-Group was aligned in the need for a centralised data hub to ensure transparency and to provide balancing parties with the ability to view the network holistically.

The hub would be intended to act as an interface between all parties, allowing non-balancers (likely industrial Off-takers in this example) the ability to input details which enable their balancing partner, the Producer, to submit profile notices to the System Balancer.

It will give the System Balancer a holistic view of the expected supply and demand and allow them to pro-actively flag issues and the potential for network constraint ahead of time.

Over time this platform could evolve alongside the network, with additional functionality being brought online as required, potentially allowing for the matching of additional production with demand and eventually developing into a full trading platform.

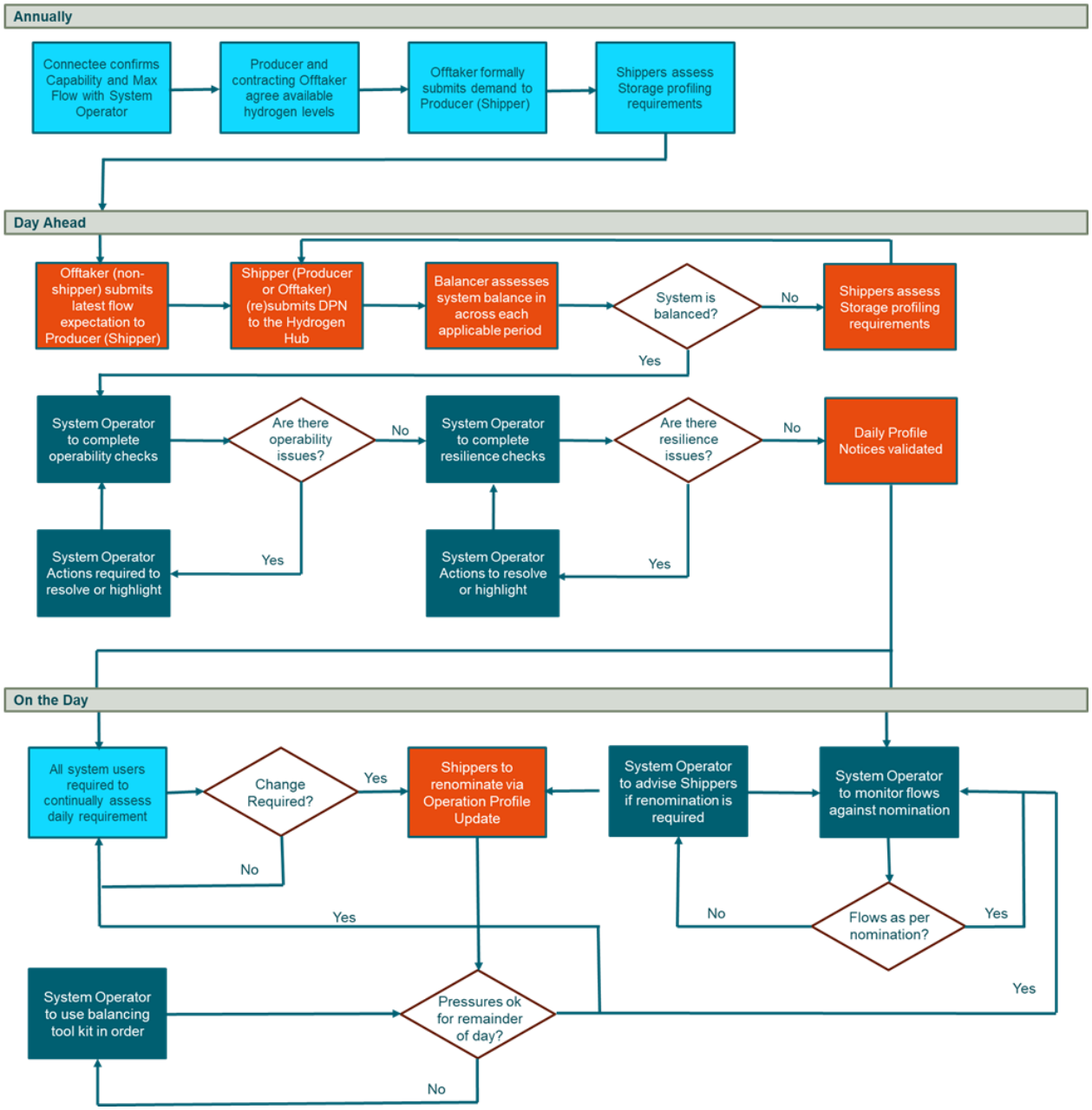
Further work will be required to assess the right provider for such a tool, and to fully develop the system to fulfil the requirements of the network. It is expected that at a minimum the hub will accept and validate day ahead flow profile notifications against network capability, ensuring entry and exit are balanced, with alerts produced to relevant parties, including the Balancer, where a mismatch is identified.

Information flows

Flow nominations would be sent using a Daily Profile Notice, to be processed in the central hydrogen data hub where supply and demand will be validated and the profile notices confirmed if all is in alignment.

The Sub-Group spent a little time discussing information flows and have documented some principles which require further development. These are summarised in the Appendix.

Figure 18 – Example representation of information flows day ahead and within day



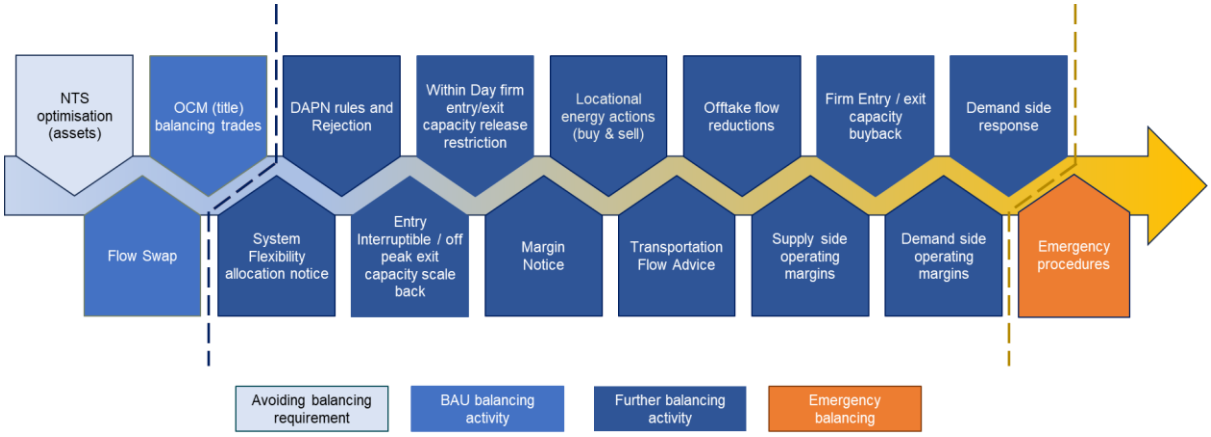
Not only will the information flows in the central data hub be key for operational management, we also expect they may have value for the LCCC and DESNZ in the future to assess how the initial hydrogen networks are being used and where further opportunities exist for market development.

Balancing Tools

Currently System Operators have a range of balancing tools available in the natural gas network. However, many of these are designed to work within the existing natural gas market framework and in a mature and liquid market. In a nascent hydrogen market, with high physicality, low initial system resilience and no liquidity, some of those levers will no longer be available. The figures below are grouped in chronological order, with Business-as-

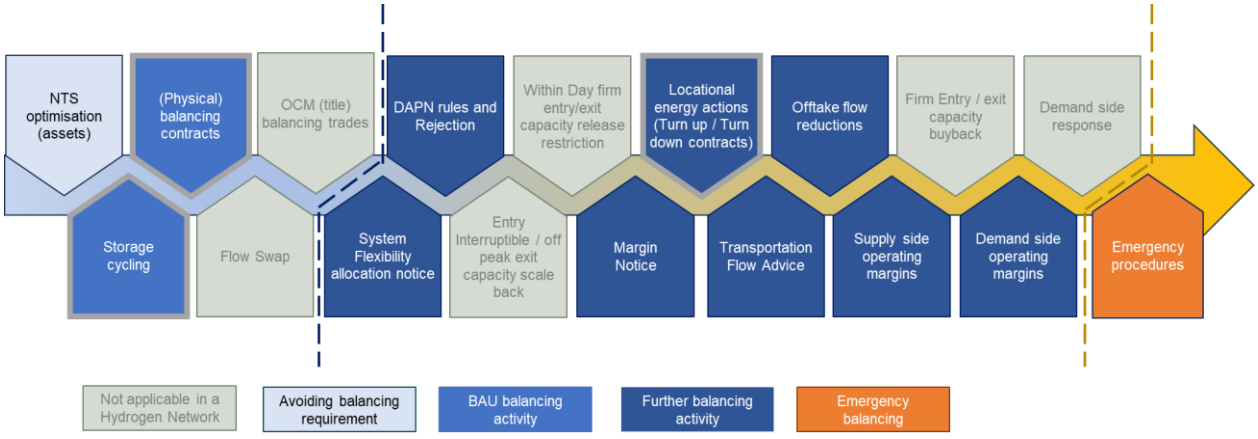
usual activities to the left of the first dividing line, pre-emergency activities in the centre, and Emergency activities to the right of the second dividing line.

Figure 19 – Balancing tools utilised by System Operator in natural gas



The expectation of the Sub-Group is that the balancing tools for the initial hydrogen networks will be operational ones, rather than commercial ones. This is primarily because the Sub-Group was not clear whether there will be a Capacity regime (i.e. users securing the right to flow a certain amount of hydrogen on/off the network at a particular time and place) for the initial hydrogen networks. Given this, it was not clear whether commercial balancing tools, such as “buying back capacity” would be suitable. Instead, it is expected that a narrower selection of physical options will be primarily used by the System Operator.

Figure 20 - Balancing tools expected to be available to System Operator in initial hydrogen networks



These tools demonstrate the list of potential options for use in an initial hydrogen network. Not all of these balancing tools would be expected to be used from Day 1, the type of tools utilised and the frequency may differ across initial networks dependent on their characteristics and on complexity. More discussion will be required to narrow down the list of available options to a shorter list of most effective tools for the initial networks

The use of tools may also depend on the network specific operating margins – and network specific commercial options – e.g. if offtakers have a greater ability to flex take up and down.

The System Operator may also be constrained in its available actions by the bilateral commercial agreements signed between the Producers and Offtakers; these agreements may refer to operating limits and tolerances. This is particularly important as many industrial Offtakers will require certainty of supply and interruptions can create significant disruption and in some cases damage equipment, notwithstanding that it is anticipated, at least in the short-term that offtakers will maintain connections to the natural gas network.

It is expected that the System Operator would have access to its own storage capacity (specifically reserved for its use), with levels to be defined by network specific models, dependent on number and type of producers and offtakers on the network and the expected operational parameters. This would be set aside for use in daily BAU, residual balancing activities.

Operations in networks with no storage
In a hydrogen network without storage, fewer balancing tools are available, and operating margins of the system become more important. A determination would also need to be made on priority of actions to be taken which has commercial consequences – e.g. if offtakers are turned up or down or producers are turned up or down.

Connections and Capacity
In Section 6 we highlighted the role of Shippers as the facilitators of transportation onto and off the network through contracting with the Transporter, on behalf of connectees, to enable hydrogen transmission from Entry Point to Exit Point.

However, there are two other elements of access to the network and ability to access hydrogen which will be important for the market framework to consider – Connections and Capacity. The Sub-Group only discussed these at a high level so do not have definitive views. We are summarising the perspectives shared for completeness, but more work will be required to define these further.

1) **Connections:** the ability for new network users, either production, offtake or storage, to connect physically to the network for access to hydrogen
    a. This would typically require a Connection Agreement between the Asset Owner and the new connectee
    b. Sub-Group members expected that a Connection Agreement would have to cross reference to the hydrogen network code, as not all users may be required to sign the network code, e.g. if offtakers are not Shippers
    c. We would expect the hydrogen network code (similar to UNC) will clarify how, when and under what conditions new connectees can be added
    d. It was noted that perhaps the Asset Owner and wider system forecasting, planning and design needs to consider paired connections – i.e. only adding demand side connections if the supply is clear. This may put a requirement on new connectees to prove they have commercial contracts to either supply or purchase the hydrogen

2) **Capacity:** the right to flow hydrogen through a connection point

a. The Sub-Group discussed whether a need for a Capacity Regime in the initial hydrogen network was required. There was no consensus
b. Some members thought that a Capacity Regime would make a simple network with few users more complicated, while others saw the potential value, particularly as the markets evolve and interconnections between networks occur
c. Given the nascency of networks we would expect initial connectees would be given a maximum flow rate based on the capability of their physical connection and the local network. We would not initially expect this to change annually, or for there to be a requirement to submit capacity bookings. However, this may change over time

Summary of next level of questions to be answered

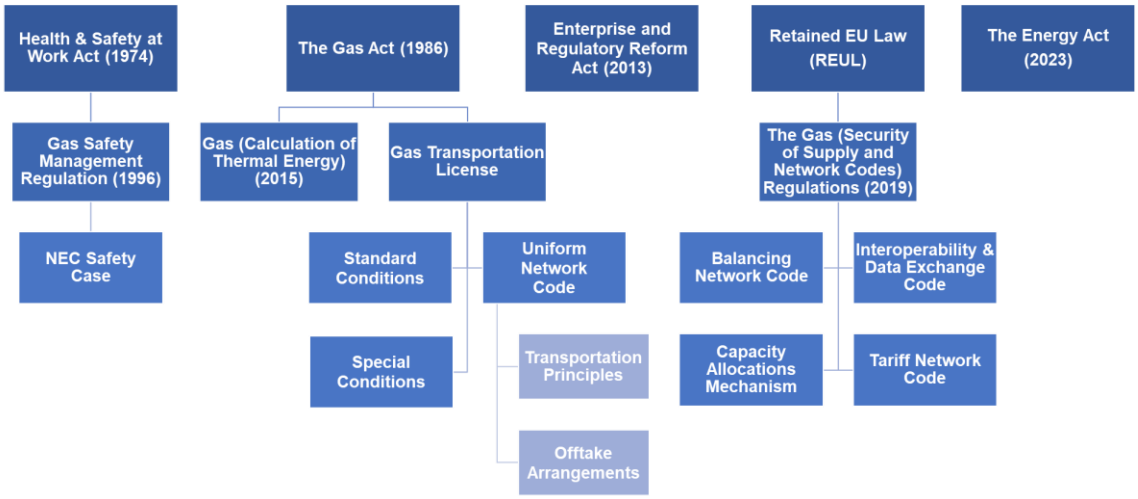
- How do we develop a set of commercial incentives around forecasting and balancing which account for the difficulties inherent in the H2P generation model?
- How do we develop a set of commercial incentives around forecasting and balancing which account differences between blue and green hydrogen production?
- What is the relevant charging regime for the system balancer? How will it be developed?
- What if the producer /shipper owns the exit capacity, and then the offtaker wants to change producer how will the transfer of the exit capacity be managed?
- Could access to H2 networks in the future come from tube trailers? How?
- What is the process for ‘sale’ of excess H2 that the System Balancer holds?
- How will new connections be managed / by whom?
- Can rights be transferred or assigned to RTI’s in the future?
- Allocation of storage – method for developing transparency / fairness
- Viability of storage lending

8) Implications for legislative framework

The current natural gas framework is complex, with many pieces of primary and secondary legislation interacting to help define the scope of the networks' obligations.

Some of these will continue to apply to a hydrogen network as they use the more generalised term, "combustible gas(es)" while others may not be directly applicable to a hydrogen network, as they only specify natural gas. Work will need to be done to understand whether the intent and principles laid out by those documents should still be adhered to in the hope that it will aid future interconnectivity between domestic and European networks.

Figure 21 – GB Natural Gas Legislative Framework



Initial conclusions

The Sub-Group recognises that The Gas Act is the key piece of legislation to be considered, and has, where possible, aimed to stay within the Gas Act to avoid changes to that primary legislation.

The Sub-Group believes it should be possible to structure a hydrogen market within the existing Gas Act and with similar types of legislative licenses and codes as used in the GB natural gas system, to retain familiarity and support speed of development for initial networks.

The most important elements of the current legislative framework to consider in relation to hydrogen are:

1) **The Gas Act** – *as the main legislative framework*
2) **The Licenses** – *as the vehicle used to set expectations and assign obligations to licenced parties (primarily Shipper & Transporter)*
3) **The Uniform Network Code** – *given the expected need for a Hydrogen Network Code*

It is a clear belief across the Sub-Group that the hydrogen market will require its own Hydrogen Network Code, even if other changes are managed under existing legislation and license frameworks.

We expect the Hydrogen Network Code to:

1. govern the use of each network
2. clarify the roles and responsibilities on the network
3. clarify how risks are shared between network users and the network operator, and
4. define the specific networks' constraints and operational limits.

It is expected that the Health and Safety Act, which supports the GS(M)R and The Safety Case will remain applicable to a hydrogen network, with the need for similar, if not even more robust safety processes to be in place to support the safe operation of hydrogen networks.

What isn't fully understand, is whether the intent of some of the surrounding legislation, should still be considered. In particular, the raft of EU legislation which was enshrined in UK Law post the Brexit Agreement. These documents reference natural gas specifically, but if we do wish to retain some familiarity with the existing natural gas framework, for example a Capacity based charging mechanism, they provide a ready-made framework for us to adapt rather than reinventing from scratch.

The Sub-Group has not undertaken a detailed assessment to assess this in detail – and these assumptions will need to be confirmed by DESNZ and Ofgem. Further investigation and legal guidance will be required to understand the full list of changes needed across different legislative and regulatory levels.

Summary of next level of questions to be answered

1. Which items of legislation are directly applicable to Hydrogen?
2. Which items of legislation or licenses may need to change to meet the preferred Option 2 Decentralised balancing model?
3. Which of those obligations which are not directly applicable should we still consider in developing a hydrogen network?
4. How closely should we align to development in future EU legislation to ensure cross border trade?

9) Requirements for Hydrogen Business Models

The Sub-Group has been cognisant of the interaction between the hydrogen market model and the existing and in-design hydrogen Business Models. The Sub-Group's aims have always been to avoid significant business model changes if possible, while recognising that in all considerations some change would be required.

Impacts the Business Model has on the hydrogen market framework

The Business Models can interact with the hydrogen market framework either by; 1) creating opportunities and constraints, or by 2) needing to be changed for the market model to work.

Figure 22 – Impacts the Business Models have on the hydrogen market framework

Business Models	Impact on hydrogen market framework
HPBM	• Limitation on qualifying offtakers limits who can buy hydrogen • Which in turn impacts to who and when commercial title passes from H2 producer to offtaker • Incentive to max produce may limit balancing tools the SO has available
HTBM	• Defines the responsibilities of the transporter / system operator • Defines network operational parameters (particularly availability) • Defines the hydrogen transportation charging mechanisms which can impact on charging mechanisms on the System Balancer
HSBM	• Potentially defines who storage capacity rights can be sold to, and therefore who can be a primary balancer • Defines how access to storage is granted and how often; giving certainty to primary balancing entities • Defines the charging arrangements and cost of storage, and (within the HSBM or other models) who bears the cost of storage capacity
H2PBM	• Connection to electricity system (alongside electrolytic producers) creates a need for shorter balancing periods, and an increased likelihood of within balancing period fluctuations

Expected Business Model changes / design considerations

Some changes to the HPBM will be required for all versions of market models - primarily focused in 2 areas:

1) The need to allow for a System Balancer to be a Qualifying Offtaker, and

2) For HPBM / H2PBM to allow for storage capacity charges to be recovered within the agreed strike price.

For HTBM, HSBM, H2PBM's which are in development stages – it will be important to consider the interactions with the market model and make changes accordingly. What will be particularly key in the initial networks is consideration of how the four defined Business Models interact, and whether their collective design works within the hydrogen Market Framework.

The Sub-Group's initial perspectives on Business Model changes are noted in Figures 23 and 24 below. These should be taken as initial suggestions or considerations which each Business Model design team should reflect on and discuss with their relevant industry stakeholders.

They will require further refinement as the detail of the Market Model gets built out and as we get more clarity on the Business Models.

Figure 23 – Hydrogen Production Business Model changes

Business Models	Changes
HPBM	- Allow the System Balancer to be a Qualifying Offtaker to allow them to take title to hydrogen to support system balancing - Allow H2 producers to purchase storage capacity - Support the cost of that storage capacity for H2 producers to provide system resilience to industrial / smaller offtakers and to compensate for the risk of taking on the within balancing period changes from these offtakers - Consider how H2 producers may be supported to reduce their Working Capital risk and/or price risk for holding hydrogen in storage for long periods of time - Ensure H2 producers can also be Shippers

Figure 24 – HTBM/HSBM/H2PBM considerations

Business Models	Potential design considerations
HTBM	- How transport costs are allocated, and interaction with some offtakers being Shippers (and so taking commercial title at entry points) and some not - To allow expansion of transporter role to potentially include System Balancer as bolt-on if granted a license
HSBM	- Allows any relevant market participant who can take title to hydrogen to purchase storage capacity (H2 producer, offtaker, System Balancer) - Allow storage operators to buy hydrogen for operational purposes – ie ensures storage is a qualifying offtaker for cushion gas and gas required for rebalancing stock due to daily over/under runs - How can capacity be best utilised as a storage develops
H2PBM	- H2P Generators are allowed to take storage capacity and retain title to hydrogen in storage - H2P generators are not prevented from being H2 shippers - H2PBM should consider supporting the cost of H2 storage to support H2P generators to manage their own resilience and commercial optimisation potential - H2PBM should be designed to allow flexibility in multiple sources of hydrogen (multiple producers) for H2P Generators

Summary of next level of questions to be answered

- How does the proposed market model interact with the final versions of HT/HS/H2PBMs?
- What is the process by which the Business Models be updated and in what timeframe?
- Could timeframes affect the T&S allocation rounds?
- How will industry stakeholders be consulted on Business Model changes?
- How will DESNZ ensure integration and alignment across Business Models and the Market Framework?
- How much additional time is expected to be required for BM changes?

10) Future Proofing

The UK hydrogen market is nascent and will evolve considerably over the next few decades. While our focus is on initial networks, we cannot discount the need for any market model to be future proof and to at least consider how market evolutions may affect the market model structure.

During the Sub-Group discussions, the models have been reviewed and have evolved to ensure they can support the development of the hydrogen market in the UK. We have reviewed the preferred decentralised balancing model against the four most likely categories of market evolution to test robustness

Market evolution categories

At the highest level we see 4 categories of hydrogen market evolution.

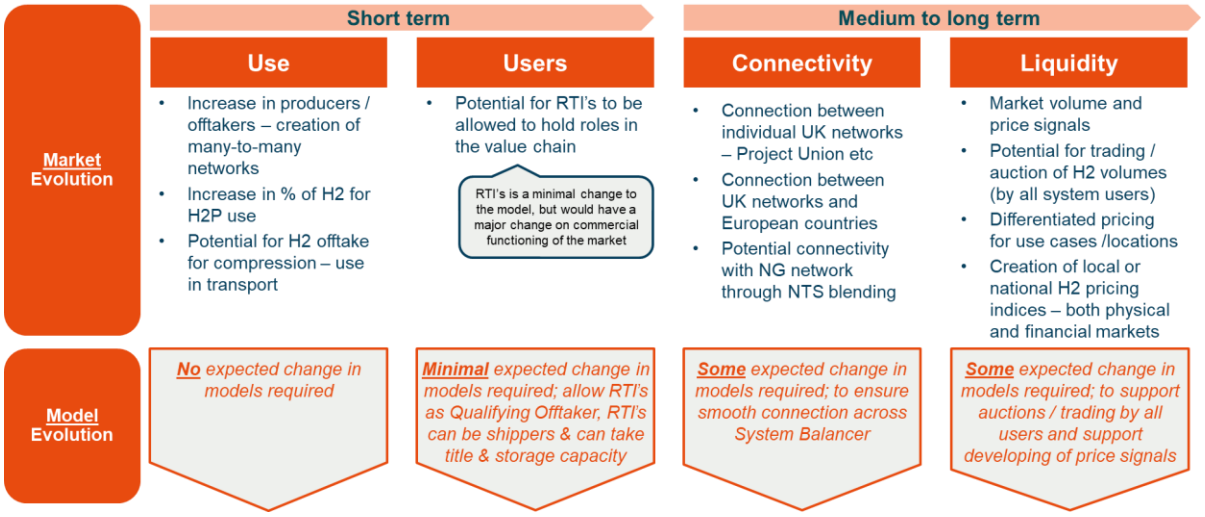
In the short term we may see a change in:

1) Use
2) Users

In the medium to long term we may see a change in:

3) Connectivity
4) Liquidity

Figure 25 – Potential market evolutions and required associated model evolution



Model changes required

A high-level assessment of these four categories of market evolution against the preferred decentralised balancing model has identified that minimal expected changes would be required in the short term.

Primarily to allow RTI's, changes to the HPBM are the key. Once this has happened then RTI's could take on existing roles and contractual agreements in the model.

Broader updates to the model would be required at the points when hydrogen networks are connecting to each other and when market liquidity begins to develop – to ensure that there are no restrictions on the free flow of information.

Does the preferred decentralised balancing model support the evolution of the UK hydrogen market? How?

The Sub-Group felt that the decentralised balancing model is the best model to support evolution of the hydrogen market. This is primarily because the model:

1) Promotes transparent flows of data
2) Encourages commercial and infrastructure optimisation
3) Allows for a Shipper role to be expanded in the future from simply facilitating transportation
4) Could create an early framework for borrowing / lending of storage capacity and/or hydrogen which could facilitate volume and price signals once RTI's are allowed to carry out market making activities

Operational Management of Networks

We can also envisage, given the highly physical nature of the initial hydrogen networks that there may be some additional demand for physical balancing and optimisation of storage. Particularly we could see the time-bound lending and borrowing of storage capacity or potentially hydrogen in storage as required or helpful to balance the network and reduce overall network costs – particularly for those with storage capacity (hydrogen producers and H2P).

Whilst not a direct evolution of the market model, we would expect the hydrogen network code when developed to allow for these physical balancing needs.

We also note that there will also need to be a mechanism for the System Operator to sell any excess hydrogen it has accumulated through its balancing actions. This hydrogen would likely be needed to be sold back to Producer(s) ahead of any RTI decision. We would expect this process to be revenue neutral and so any financial benefit or cost incurred would be returned to connectees of the network via the charging model.

Does the decentralised balancing model work if RTIs are permitted?

A common question that came up in Sub-Group discussions was; "Will the decentralised balancing model support the advent of RTI's if permitted through the HPBM?"

In addition, during the Sub-Group's time assessing the options a DESNZ questionnaire on RTI's requested responses which further brought forward the discussion as part of future proofing.

The Sub-Group were of the view that RTI's would be valuable to support medium term market development and would be even more valuable to market development once initial networks are built.

The decentralised balancing model has set up the basis of a Shipper function; which initially will only facilitate transportation, but could later play a wider role more akin to the Shipper role in the natural gas network.

The decentralised balancing model allows for both:

1) Expansion of roles for a Shipper
2) And a more systematic evolution to a traditional Shipper model

Figure 26 – Examples of RTI roles and impact on position in model

Potential RTI roles	Position in Decentralised Model	Requirements
Aggregation or disaggregation of hydrogen	Offtaker / Shipper	- Ability to buy hydrogen - Access to storage - Ability to sell to offtakers
Support H2 Producer FIDs – credit support / 15 year agreements	Offtaker	
Market maker – creating price signals and trading hydrogen within day etc (secondary trading)	Storage Capacity Owner	

Note – these are illustrative, not exhaustive

Practicalities of model evolution

Any further changes required to the market framework after they have been defined by the hydrogen network code could be dealt with under a modification panel, similar to how this works under the CO2 network code.

Changes to legislation and licenses would be required to be dealt with by relevant parties including DESNZ, Ofgem and others.

A modification panel could meet on a periodic basis to consider future changes to the (front end) network code based on:

- Changes to business models (HPBM/HTBM/HSBM/H2PBM and others)
- Changes to market liquidity
- Changes to market scale / reach – e.g. due to Project Union
- Requests from market participants for changes

The modification panel would likely be made up of a series of chosen market participants who represent a cross section of the GB hydrogen networks (existing and proposed), as well as government and regulators, although we note that there will need to be consistency with ongoing energy code reform.

Any changes would affect all UK hydrogen networks in the same way as they would be changes to the front end of the network code

Summary of next level of questions to be answered

- How does the market model need to change if there are changes to HPBM ahead of first networks being built?
- Will the relevant legislation, licenses and codes support an easy evolution of the market model?
- What needs to be put in place during drafting to ensure the potential role for Shippers could easily be expanded once RTI's are allowed?

11) Appendix 1 – Additional Detail

Sections:

1. Assumptions made during model development
2. Full list of roles and responsibilities under the two market model options
3. Scenarios to represent difference between the two market model options
4. Additional operational considerations
5. Balancing overview
6. Existing Data Services Providers
7. Full list of questions to be answered going forward

(1) Assumptions made during model development

- **Offtaker types –** Networks will have both industrial and H2P offtakers; and ensuring storage works for them will be critical
- **Flow of H2 to offtakers**
    - **H2P –** Offtakers will have H2 delivered daily/periodically into H2 storage, and when H2P needs to dispatch that will come from storage and possibly within day H2 production
    - **Industrial** - Customers will predominantly be served directly from H2 production
- **Storage capacity**
    - **Flows** (in / out) will be netted across customers / connectees
    - **Storage use:**
        - H2 producers want to use H2 storage to manage unplanned outages / intermittency in production, or to optimise production (for electrolytic)
        - H2P will want to use storage to manage their dispatch requirements to meet H2 demand profiles which cannot be matched by H2 production directly
        - Industrial offtakers are unlikely to want to manage their own H2 storage capacity, but do want resilience
        - System Balancer will want to use hydrogen storage to support operating margins of network
- **Contracts / Agreements**
    - Hydrogen is sold bilaterally between H2 producer and offtakers
    - A H2 network code will be developed and signed by relevant parties
    - Each connection (entry/exit) has a Connection Agreement with the network owner

(2) Full list of roles / responsibilities

Figure 27 - Full assumed roles and responsibilities in Option 1 & 2

Key roles	Example Roles	Option 1 – Centralised Balancing	Option 2 – De-Centralised Balancing
Network regulation	Responsible for regulation of the networks / market	Ofgem	
Planning / Network constraints	Long/mid term planning (1-4, 4+ yr) to ensure supply = demand	Gas producers, importers and other Shippers with NESO and Government strategic oversight	DESNZ through HPBM awards, NESO and Ofgem input
	Short term planning (less than 1 yr) to ensure supply = demand	System Balancer/Operator	H2 Producers / Storage Operator / System Operator
	Network Constraints	Transporter / System Balancer	Transporter / System Operator / Shippers
Granting of business models	Granting HP/HT/HS/H2P Business Models to build out infrastructure	DESNZ	DESNZ
Asset protection and emergencies	Pipeline asset protection – all aspects incl. pressures and proximity	Transporter	
	Emergency Coordination	Transporter / System Operator	
	Network security of supply design standard	Ofgem	Ofgem
Purchase and sale	Purchase Gas at Entry	System Balancer/Operator	Shippers who are Offtakers
	Sell gas at exit	System Balancer/Operator	H2 Producer (for non Shipper Offtakers)
	Ultimate end customer	Industrial / H2P Offtakers	
Storage Users	Contracts with storage	System Balancer/Operator	System Balancer / H2 Producer / H2P Offtaker
Connections	New Entry Connections Agreement	Transporter / Asset Owner	
	New Offtake Connection Agreement	Transporter / Asset Owner	
Transportation	Facilitation of transportation of molecules	System Balancer/Operator	Shippers (initially either Producers or Offtakers)
	Transportation of molecules	Transporter / System Operator	
Balancing (primary and residual)	Ahead of balancing period planning to ensure supply = demand	Producer / System Balancer	Producer / Offtaker / Shippers
	Within balancing period actions to ensure supply = demand	System Balancer	Producer / H2P Offtaker / System Balancer
	Within balancing period actions to profile supply and demand across the day	System Balancer	Producer / H2P Offtaker / System Balancer

Data service provider	Provides data services to the network	TBC – 3rd party
Network code administrator	Administer governance of the processes for modifying the commercial regime	Ofgem

(3) Scenarios to represent difference between the two options

Figure 28 – Scenario 1 – H2 Producer trips with only 30% of production vs Day Ahead Nominations

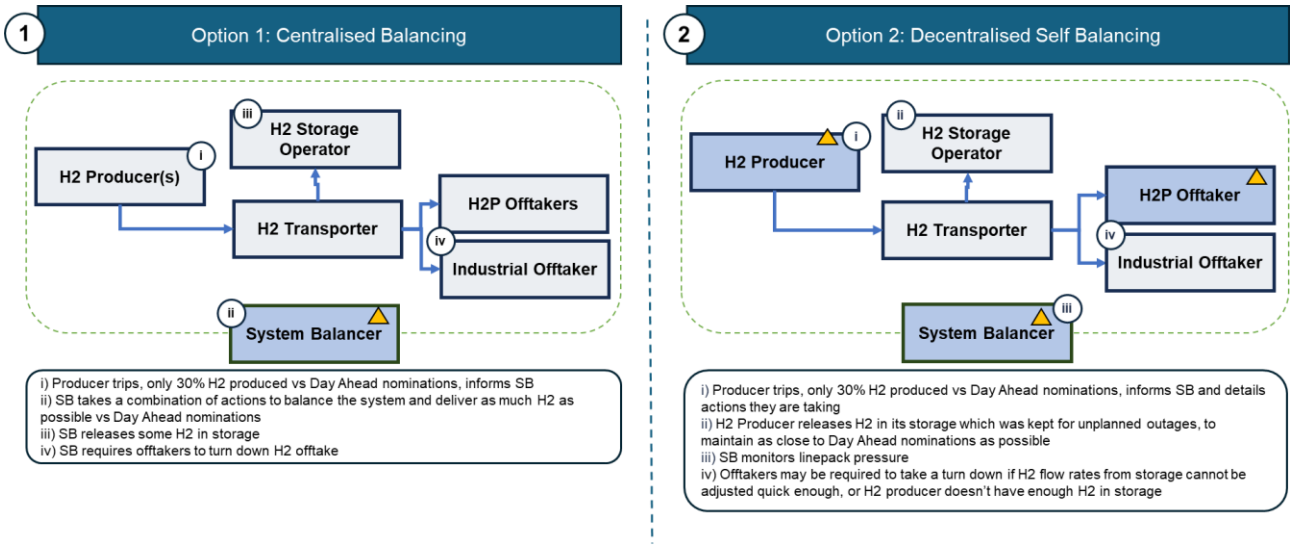


Figure 29 - Scenario 2 – Major offtaker trips and cannot take H2 vs Day Ahead Nominations

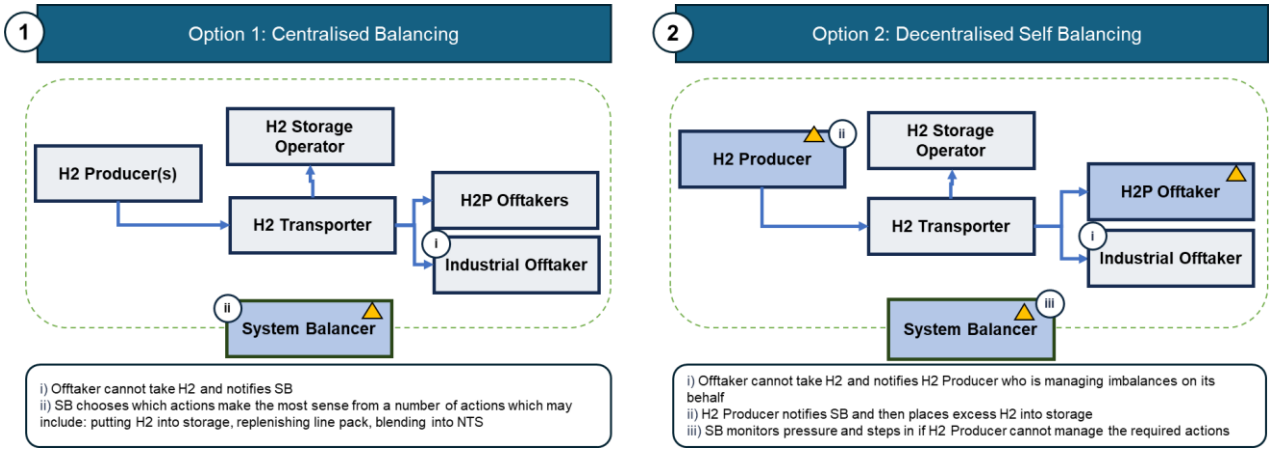
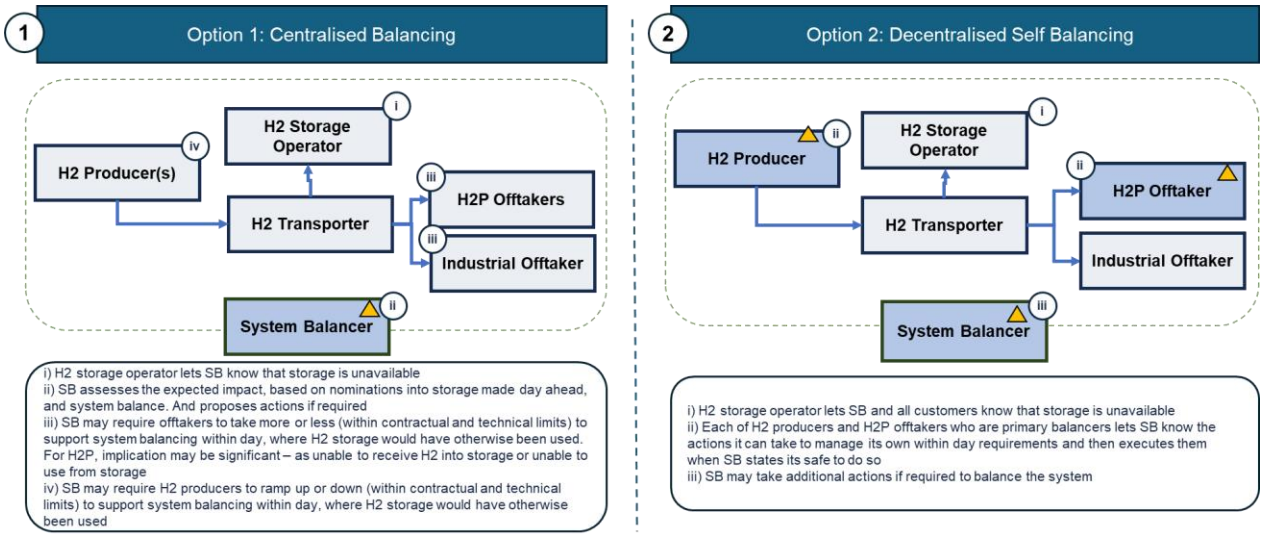


Figure 30 – Scenario 3 – H2 storage is not available



(4) Additional Operational Considerations

Principles on information flows

- Daily Profile Notice cover a 24 hour period, and include profiles for the hydrogen day
- All sites have physical limits and ramp rates agreed in a Connection Agreement
- Both the day-ahead and the within day information flows are primarily dealt with using an automated system (specific system to be decided)
    - This is similar to natural gas system today – and could be called a Hydrogen Data Hub
- Daily Profile Notice – ahead of the hydrogen day reflect nominations based on existing contracts and network operational parameters
    - Then changes within day would be ‘Operational profile updates’ or similar, which are not new nominations, but reflect operational changes to actions which were not expected day ahead
    - Both day ahead and within day nominations / updates are all required to be underpinned by the network safety case
- Network operational parameters are fed into the automated system when set up and updated periodically to reflect the min / max takes / flows and other operational or commercial parameters
- Matching of nominations is done in the automated system; as well as confirmations
- The automated system then would rapidly process changes in the network with sign off from relevant parties
- Any mismatches or calculated imbalances would trigger alert notifications to relevant balancing parties
- There would be manual oversight of decision making and actions to ensure that day ahead nominations worked and for any within day changes required
- After day settlement would ensure all actions were accounted for

Storage access and allocation principles
The Sub-Group had several discussions about the ability of network connectees to access storage and the allocation process by which this might happen. It was noted that the allocation of finite storage capacity to prospective network connectees is an important topic to address, given the pivotal role storage will play in the hydrogen economy (including being used by the System Operator as a tool in residual balancing).

It was noted that storage allocation principles would largely be defined by the HSBM and no conclusions could be drawn by this Sub-Group on how it should work. However, some principles were discussed which should be considered by the HSBM design team:

- Storage allocation should be transparent and fair;
- Arrangements for Storage capacity allocation should evolve over time as the market develops
- New connectees may need access to storage and this issue will need to be considered in more detail, particularly in relation to any funding allocation rounds and the short listing of new projects
- The System Operator should be allocated sufficient storage capacity to meet expected operating margins – this may change over time as the network connectees and availability of storage capacity changes
- It may be necessary to withhold some storage capacity should government want to reserve capacity for projects expected to join the network at a later date, this process should be transparent. Further, the capacity withheld from the market will need to be sufficient for the potential connectee to operate in accordance with any business model requirements
- If the cost of storage is supported through HPBM; where Producers are providing a resilience and Shipper service to Offtakers, assessment of whether a 15 year storage allocation is required should be undertaken
- There should be arrangements to allow for secondary trading of storage capacity

Further development will be required on storage allocation principles by HSBM, taking into account where the cost of storage will be paid.

Storage capacity lending / borrowing
The Sub-Group noted that it was possible that storage capacity lending and borrowing may develop relatively early on in the initial networks. This would allow different groups of connectees with storage capacity to have some flexibility to access more storage if needed. This may be particularly valuable for H2P.

The Sub-Group noted that the value of this would likely be limited to short-term borrowing and lending and was constrained by the inability to trade hydrogen given the RTI restriction.

Excess or low hydrogen levels of the System Operator / Storage Operator
It was noted by the Sub-Group that the System Operator and Storage Operator may over time accumulate more hydrogen through its residual balancing operations or require

additional hydrogen to meet residual balancing operations and storage physical over and under delivery[8].

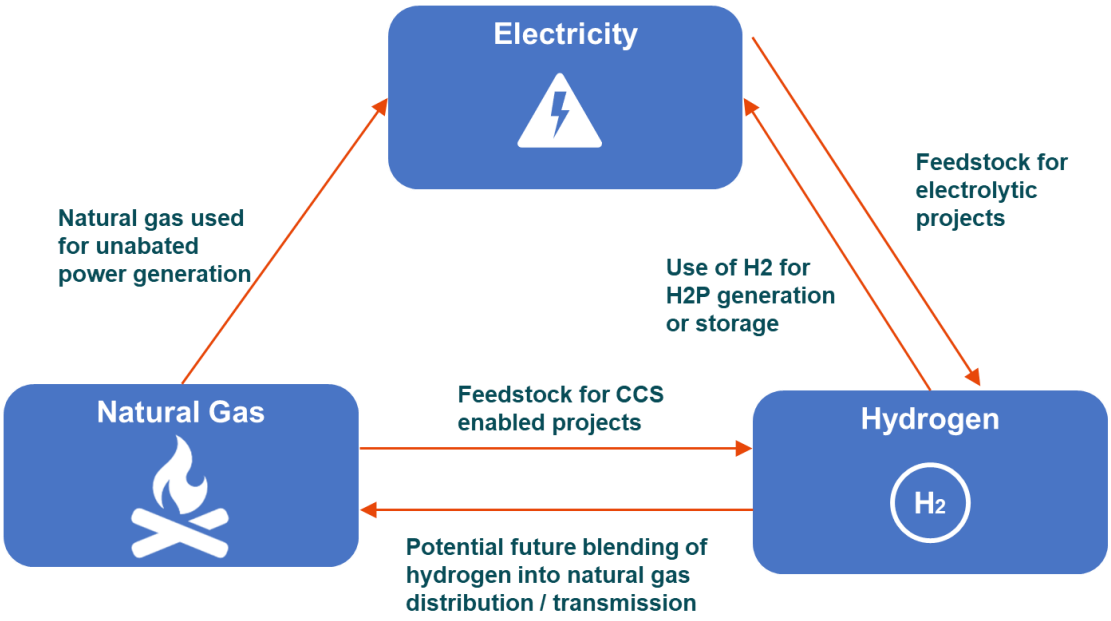
As such it was noted that a methodology would need to be devised for how this could be done and how often. The Sub-Group discussed the following principles:

- Hydrogen bought and sold by the two parties should be at the floor price (hydrogen equivalent to natural gas principle)
- Both parties should retain bilateral contract(s) with H2 Producer(s) to purchase hydrogen as required, and should have adequate ability to be prioritised for system balancing / resilience and emergencies
- A process needs to exist under the Hydrogen Network Code for the sale of excess hydrogen, via auction or direct agreement
- A neutrality arrangement should be in place to ensure that costs and benefits are socialised across connectees

Coordination across networks

The Sub-Group were also conscious of the future need to consider coordination across natural gas, hydrogen and electricity networks due to the multiple connection points.

Figure 31 – Depiction of network interactions



Further assessment should be undertaken by NESO / Ofgem and System Operators.

(5) Balancing Overview

The System Balancer's primary concern is safety. It's crucial that network gas pressures stay within safe and acceptable limits. For instance, if more gas comes in than goes out, the

[8] Storage operations are not exact so on a daily operation there may be slightly more or slightly less gas allocated to the store than expected.

pressure will increase. On the flip side, too little gas and the pressure will drop. Either of which could constitute an Emergency if left unchecked.

Gas moves slowly through the system, this means, for example, that if gas is needed in Plymouth but has been delivered in Scotland, theoretically it would take a minimum of 23 hours to reach its destination. To meet any changes in demand, compression of gas within the pipeline system to make sure that it is always available.

The amount of gas within the system at any time is known as ‘linepack’. The acceptable range over which the amount of gas in the network can vary and the ability to further compress and expand this gas is generally referred to as ‘linepack flexibility’. However, this flexibility has limits, so to maintain acceptable gas quantities and support its distribution there are other balancing tools we can use.

The GB gas market contains a number of players, such as producers that own and operate the gas production facilities, and gas suppliers that sell the gas to businesses and domestic households. In terms of gas market balancing, the major player is the gas shipper. Gas shippers buy gas from producers, trade gas and sell it onto gas suppliers. Importantly, they need to use the NTS to transport the gas between these two players: this means they have a critical role to play in its overall balance.

Shippers have incentives to balance inputs and outputs each day – what goes in should equal what comes out. Shippers are commercially exposed if their energy account is not balanced at the end of the Gas Day. NGT have incentives that encourage them to make sure that the whole NTS is balanced for each ‘Gas Day’ (5am to 5am), so that the linepack at the end of the day remains close to the level at the start of the day.

In addition to making sure that the system is safe, NGT acts as the residual balancer of the GB gas market. They monitor and assess gas supply and gas demand, making sure the NTS remains within efficient operational limits. If shippers struggle to balance the gas market, the Residual Balancer may step in and take action to influence them, to make sure linepack levels remain within acceptable limits.

Ofgem monitors those actions to make ensure they work in an efficient and cost-effective manner, minimising the effect on the gas market.

NGT publish an End-to-end Balancing Guide which provides a fuller description of the balancing process should you require further detail.

(6) Existing Data Services Providers

Standard Special Condition A15 of the National Gas Transporter licence details the obligation relating to the Central Data Service Provider.

The purpose of this condition is to provide for the continued appointment of a “central data service provider” (“CDSP”) and to set out the obligations with which the licensee must comply with respect to the ongoing operation of the CDSP. Currently Xoserve fulfils this role for Great Britain.

The licensee must, ensure that there is always in post, a person appointed as the CDSP to provide CDSP services and systems. The licensee must, ensure that the UNC sets out a

classification of CDSP Services, including those which are required to be used by Gas Transporters, gas shippers and other parties to the UNC.

Relevant Users of CDSP Services jointly control and govern the CDSP on an economic and efficient basis and are responsible for procurement of CDSP Services. They keep the CDSP Service Agreement under review to ensure it continues to comply with the relevant sections of the UNC.

The relevant users must ensure that the CDSP is: a company under the joint ownership of the licensee and of Relevant Gas Transporters; a company the purpose of which is to provide CDSP Services; a company jointly controlled and governed by the licensee and by Relevant Users of CDSP Services. Full details of the CDSP Services are available from the CDSP Service Definitions document, published on the Ofgem website.

Separately to this, a second system, operated by PRISMA, is used by the market. This platform provides similar services across the interconnectors linking Bacton with Zeebrugge in Belgium and Balgzand in the Netherlands. While this is not regulated by the licence, it must be compliant with all GB legislation to ensure its operation, and while export of hydrogen is not currently envisioned by the HPBM, it would be prudent to ensure future compatibility is not negatively impacted by any decisions made when developing the hydrogen data hub needed to support the hydrogen networks.

(7) Full list of remaining questions

Figure 32 - Full list of remaining questions to be answered

Area	Question	Responsible for answering
Market model options	- Does the preferred model work within the current gas legislation and license framework? - Are there any options not considered which would be significantly different from the two presented here?	DESNZ
Responsibilities	- Ofgem decision on whether Supplier role / license is required in initial hydrogen networks and/or whether an exemption will be granted - An assessment of the full suite of commercial agreements required to operate initial hydrogen networks and their interactions; particularly with regard to the Hydrogen Network Code	DESNZ & Ofgem
Operations	- How do we develop a set of commercial incentives around forecasting and balancing which account for the difficulties inherent in the H2P generation model? - How do we develop a set of commercial incentives around forecasting and balancing which account differences between blue and green hydrogen production? - What is the relevant charging regime for the system balancer? How will it be developed? - What if the producer /shipper owns the exit capacity, and then the offtaker wants to change	DESNZ + Entities developing Hydrogen Network Code + Ofgem

	producer how will the transfer of the exit capacity be managed? - Are different conditions required for small HAR producers who may not want to take on a shipper license? - Is a Supplier exemption the best solution? - Could access to H2 networks in the future come from tube trailers? How? - What is the process for 'sale' of excess H2 that the System Balancer holds? - How will new connections be managed / by whom? - Can rights be transferred or assigned to RTI's in the future? - Allocation of storage – method for developing transparency / fairness	
Legislation	- Which items of legislationare directly applicable to Hydrogen? - Which items of legislation or licenses may need to change to meet the preferred Option 2 Decentralised balancing model? - Which of those obligations which are not directly applicable should we still consider in developing a hydrogen network? - How closely should we align to development in future EU legislation to ensure cross border trade? - When will decisions be made on legislation – changes / exemptions etc?	DESNZ & Ofgem
Business models	- How does the proposed market model interact with the final versions of HT/HS/H2PBMs? - What is the process by which the Business Models be updated and in what timeframe? - Could timeframes affect the T&S allocation rounds? - How will industry stakeholders be consulted on Business Model changes? - How will DESNZ ensure integration and alignment across Business Models and the Market Framework? - How much additional time is expected to be required for BM changes?	DESNZ
Future proofing	- How does the market model need to change if there are changes to HPBM ahead of first networks being built? - Will the relevant legislation, licenses and codes support an easy evolution of the market model? - What needs to be put in place during drafting to ensure the potential role for Shippers could easily be expanded once RTI's are allowed?	DESNZ
Next steps	- What's the approach and timeline from here to development of a H2 network code? - How will the licensed entity be granted a license? By when? - What is the expected timeline of the first H2 networks, and their FIDs – for which the H2 network code needs to be ready for?	DESNZ

12) Appendix 2 - Glossary

Categories	Term	Definition	Variation between natural gas and hydrogen
Balancing	Day Ahead	Actions taken prior to the Gas Day	No change
	On The Day / Within Day	Actions taken within the Gas Day	No change
	Gas Day	For natural gas this is the period from 5am to 5am the following calendar day across which shippers are metered and charged	It is likely that there will be an equivalent Hydrogen Day, but not yet defined – scope that the period for hydrogen may be shorter than a 24-hour day
	Hydrogen Day	Not currently defined, but used here to give a reference point for the terms “Day Ahead” and “On-The-Day” while differentiating from the Gas Day	Not applicable to natural gas
Hydrogen flows	Flow	The gas transmitted across an Entry or Exit point	No change
	Entry Point	The point at which gas enters the hydrogen network	Used in reference to the NTS currently
	Exit Point	The point at which gas exits the hydrogen network	Used in reference to the NTS currently
	Delivery Point	The point at which risk and title in hydrogen pass from the upstream Party to Shippers, and from Shipper to the downstream Party, at an Offtake shall be the Delivery Point	Equivalent to the Point of Offtake in natural gas
Information flows	Offtake Profile Notice	Used in natural gas by large off-takers, directly connected to the NTS, to provide expected flow profile	To be replaced in hydrogen by the Daily Profile Notice which encompasses both Entry and Exit flow nominations
	Daily Profile Notice	The daily flow nomination process for applicable hydrogen Entry and Exit points	Not currently used in natural gas
	Nomination	A shipper must inform NGT via a gas flow nomination of how much gas it intends to either input or offtake at each separate entry or exit point on the system. A shipper can record its initial gas flow nominations up to 30 days in advance and can also change them at any time up to 3am on the Gas Day. Shippers cannot withdraw the nomination, although they can change them to any value (including zero).	Details to be refined in relation to Hydrogen networks, but intent would be the same.
	Capability	The peak flow to which a pipeline is constructed to manage, used in creation of the connection agreements	No change
	Capacity	A term used when booking the right to low volumes on the natural gas network. At present no plans for a Capacity regime to be included in the hydrogen networks have been discussed	No capacity regime has yet been discussed in relation to a hydrogen market. Until further Sub-Groups assess and develop, changes are unknown
System Balancing entities	Primary Balancer	The party responsible for ensuring that Flow Nominations are matched for Entry and Exit. For natural gas	It is expected that shipper licences will be issued to existing parties within the

		this is the role caried out by Shippers	framework which ensures compliance with the Gas Act obligation for a shipper to contract with a transporter for access to flow on the network. Under Option 1 this would be the System Balancer, under Option 2, a combination of parties.
	Residual Balancer	The party responsible for ensuring that any mismatch between Flow Nominations and recorded Flow is corrected to ensure line-pack integrity is retained. This role is currently fulfilled by National Gas for the NTS	It is expected that the System Balancer would fulfil this responsibility, likely within the remit of the System Operator, and therefore Transporter.
	System Balancer	Under Option 1, Centralised, this party takes on both Primary and Residual Balancing roles. Under Option 2, De-centralised, this party takes on the Residual Balancer role	This is a new role with scope yet to be defined. However, it is likely fulfilled by the hydrogen network System Operator
Title	Commercial Title	The commercial ownership of the hydrogen molecules. The concept around the requirement for hydrogen to pass directly from the H2 Producer to the Qualifying Offtaker Not defined directly in these terms in the HPBM.	Not applicable
	Legal/Custodial Title	Non-commercial title taken to the hydrogen by the Transporter while it is in the network. Done primarily to ensure critical operations can be managed and there is clarity on Transporter responsibility for physical leaks / losses	*None*
Business models	Hydrogen Production Business Model (HPBM)	The HPBM is the production support scheme – via Contract for Difference – which DESNZ grants though competitive processes to develop new low carbon hydrogen production in the UK	Not applicable
	Hydrogen Transport Business Model (HTBM)	The HTBM is the DESNZ led transport business model which supports the building of hydrogen transportation infrastructure of network scale, with third party access. It provides a RAB model to support infrastructure build out	Not applicable
	Hydrogen Storage Business Model (HSBM)	The HSBM is the DESNZ led storage business model which supports the building of hydrogen storage infrastructure of network scale, with third party access	Not applicable
	Hydrogen to Power Business Model (H2PBM)	The H2PBM is the DESNZ led power business model which supports the building of hydrogen ready power generation assets which support balancing of the grid	Not applicable
Key entities in initial hydrogen networks	Hydrogen Producer	The producer of hydrogen who has been granted a HPBM	Not applicable
	Hydrogen Offtaker	The hydrogen customer who has signed a bilateral agreement with a	Not applicable

		hydrogen producer – can be hydrogen to be used in industry, power or transport	
	Hydrogen to Power (H2P)	The owner of a Hydrogen ready power generation asset; a subset of the hydrogen offtaker	Not applicable
	Asset Owner	The owner of the physical assets used to transport gas, i.e. pipes, valves, compressors etc	No change
	System Operator	The operator of the physical assets to ensure continued safe operation and maintenance	No change
	Shipper	The licensed entity which primarily facilitates the transportation of hydrogen onto and off the hydrogen networks across entry and exit points; with the Transporter	A licensed entity who has a Shipper license with a number of available actions including buying / selling gas, facilitating transport, secondary trading etc
	Risk Taking Intermediary	An entity who is not a Qualifying Offtaker under the HPBM as they as not the end user of the hydrogen but intend to sell it on to another offtaker	No change
	Connectee	An umbrella term inclusive of all parties who connect to the network: producers, off-takers, H2P, industrial, storage etc.	No change
	Transporter	A combined role encompassing Asset Owner and System Operator	We note that the ENNOH refers to Hydrogen Transmission Network Operators (HTNOs). This is not yet the standard term but could in future be defined and used to align with European counterparts
Natural gas network terms	Network Exit Agreement (NExA)	The document detailing technical arrangements between a network Exit Point and the Transporter	It is expected that connection agreements will be required, but details have not yet been discussed
	Network Entry Agreement (NEA)	The document detailing technical arrangements between a network Entry Point and the Transporter	It is expected that connection agreements will be required, but details have not yet been discussed
	European Network of Network Operators for Hydrogen (ENNOH)	This is the hydrogen network equivalent to ENTSOG or ENTSOE, the European Network of Transmission System Operators for Gas or Electricity.	No change