Milford Haven : Energy Kingdom – System Architecture Report – Appendix C, Needs Captured during stakeholder workshops

Milford Haven : Energy Kingdom, A Prospering from the Energy Revolution project

Energy Systems Catapult

July 2021

Document control

ESC programme name	Milford Haven : Energy Kingdom
ESC project number	ESC00399
Version*	1.0
Status	Draft: Contains preliminary information only. Approved: Contains reviewed and approved content. (delete as appropriate)
Restrictions*	Open / Confidential / Internal use only (delete as appropriate)
Release date	13th August 2021
External release ID	(if project release process requires it)

* Refer to the Information Classification Policy

Review and approval

	Name	Position
Author	Susanna Elks	Markets, Policy and Regulation
	Marie Szczepanski	Data Systems Architect
	Daniel Mee	Project technical lead / Energy systems Architect
	Pokuwa Ageyman-Buahin	Systems Engineering Consultant
Reviewer(s)	Frank Bridge	Project manager
	Daniel Mee	Project technical lead / Energy systems Architect
	Sarah Keay-Bright	Policy and Regulation Senior Advisor
Approver	Emma Harrison	Head of Systems Integration

Revision history

Date	Version	Comments
29th July 2021	Draft	First draft for review
	Issue 1	First Issue to Project

Contents

Appendix C – Needs captured during stakeholder workshops

Physical Needs Analysis and Assessment

Ref	Comment	Org.	Element	Use Case (if specific)	Diagram Modified	Category	Response	Hydrogen Energy Architecture, Properties and Interactions	National Hydrogen Market, Policy and Regulation	Local Hydrogen Market and Commercial Interactions	MH:EK
1	AT: Contaminants (Characteristic change) acquired during transport	**Arup**	**Transport**		**Yes**	**Property**	**Quality** added to transport (to include other gas and water) as a top level property (applied to each stage) to identify hydrogen quality at the end of each stage. **Losses / Efficiency** added to transport and storage to capture hydrogen losses and contamination.	Yes	No	No	No
2	TJ: My understanding of hydrogen pipelines is that they cannot currently go across public land, so either needs regulatory changes or pipelines need to be kept short & across private land	**RWE**	**Transport**		**No**	**Market**	Have you got reference to this regulation? This comment will be passed to the Policy and Regulation work package.	No	Yes	Yes	Yes
3	UU: Compression of H2 from low pressure bulk storage to higher pressures for transportation to remote applications	**0**	**Transport**	**Prepare H2 for Transport**	**No**	**Property**	This is part of the properties to be allocated for each different scenario/design. Example noted.	Yes	No	No	No

Ref	Comment	Org.	Element	Use Case (if specific)	Diagram Modified	Category	Response	Hydrogen Energy Architecture, Properties and Interactions	National Hydrogen Market, Policy and Regulation	Local Hydrogen Market and Commercial Interactions	MH:EK
4	RS: Preparation and further purification of H2 at point of usage for grid transported H2	**Fuel Cell Systems Ltd**	**Transport**	**Prepare H2 for Transport**	**Yes**	**Property Scenario**	"**Prepare H2"** includes purification as a property. Scenario transport / preparation / use	Yes	No	Yes	No
5	KK: Road tankers can distribute h2 to remote locations at liquid organic hydrogen carrier, LOHC. Coastal tankers can be used to carry LOHC between ports	**ERM**	**Transport**		**No**	**Example**	The architecture will support both options. Road tankers and coastal tankers added to examples of transport	Yes	No	No	No
6	TJ: RWE has access to bulk water procurement	**RWE**	**Produce**	**Procure Feedstock**	**No**	**Example**	Great example of integrated stakeholder role.	Yes	No	Yes	Yes
7	KC: Local production (eg.- ITM Power solar to hydrogen container located for road grade, produced at the service station)	**CREAS**	**Transport**		**No**	**Example**	Great example of integrated standalone production / storage / end use (colocation)	Yes	No	No	No
8	TJ: May want to distinguish between direct connected renewables & grid connected - very different infrastructure requirements	**RWE**	**Produce**	**Procure Feedstock**	**No**	**Example**	The difference at this operational level is made through the properties. Further design diagrams can be developed to compare these differences.	Yes	No	Yes	No
9	TJ: RWE can provide renewable power & manage power trading positions	**RWE**	**Produce**	**Procure Feedstock**	**No**	**Control**	Noted for both physical and commercial architectures.	Yes	No	Yes	Yes
10	NP: Option to transport as amonnia	**RWE**	**Transport**		**No**	**Example**	"Prepare H2" includes H2 form for transport. One example is ammonia.	Yes	No	No	No

Ref	Comment	Org.	Element	Use Case (if specific)	Diagram Modified	Category	Response	Hydrogen Energy Architecture, Properties and Interactions	National Hydrogen Market, Policy and Regulation	Local Hydrogen Market and Commercial Interactions	MH:EK
11	Ek: role for planning?	**Welsh Government**	**Transport**		**No**	**Planning**	This is the operational architecture for the system. The role of local and national planning institutions will be developed in the market and design work packages.	No	Yes	Yes	Yes
12	KC: Feels like major industrial consumers would be South of Haven? Re-use of cross have pipelines	**CREAS**	**Transport**		**No**	**Example**	Good design point. Comment passed to the project.	No	No	No	Yes
13	UU: Limitations of the water system and purity of the water for the electrolysed	**0**	**Produce**	**Procure Feedstock**	**No**	**Example**	Water procurement and preparation will appear in the physical and commercial properties of producing H2	Yes	No	No	Yes
14	EK: local generate and use could need different transport requirements	**Welsh Government**	**Transport**		**No**	**Example**	Absolutely, the architecture will allow comparison and assessment of different options/scenarios.	No	No	Yes	Yes
15	IS: Should we use PPA's with renewable energy producers?	**Sea Wind Technology**	**Produce**	**Procure Feedstock**	**No**	**Market**	PPA: Power-Purchase Agreements See comment 17 from TJ	No	Yes	Yes	Yes
16	AT: Stakeholder: Primary energy provider.	**Arup**	**Produce**		**Yes**	**Stakeholders**	Stakeholders added: Utility Providers including Energy Providers (Electricity, CH4, H2) and Water and Waste provider.	Yes	Yes	Yes	No
17	TJ: PPAs are not yet a route for green hydogen under the RTFO, so this would require regulations change	**RWE**	**Produce**	**Procure Feedstock**	**No**	**Example Market**	PPA: Power-Purchase Agreements RTFO: Renewable Transport Fuel Obligation This comment will be passed to the Policy and Regulation work package.	No	Yes	Yes	No

Ref	Comment	Org.	Element	Use Case (if specific)	Diagram Modified	Category	Response	Hydrogen Energy Architecture, Properties and Interactions	National Hydrogen Market, Policy and Regulation	Local Hydrogen Market and Commercial Interactions	MH:EK
18	IS: Securing green/blue energy to supply the plant...connection and network limitations	**Sea Wind Technology**	**Produce**	**Procure Feedstock**	**No**	**Property**	These factors all have to be considered at design phase. The physical aspects are considered within the properties.	No	Yes	Yes	No
19	AT: Are hydrogen truck manufactures a stakeholder, at least in the formative stages?	**Arup**	**Transport**		**No**	**Supply chain**	Truck manufacturers are stakeholders playing a part in the future of the hydrogen economy but not directly in the physical operation. I have added them to the stakeholder role list for other use cases.	No	No	No	No
20	SB: Hydrogen embrittlement issues in pipelines	**Insite Technical**	**Transport**		**No**	**Property**	Max **H2 Pressure and Quality** added to pipeline properties. Maintenance aspect noted but not part of this level of operational physical architecture.	Yes	No	No	No
21	KC: As gas, liquid gas, or as something else (ammonia, methanol, LOHC, ...)	**CREAS**	**Transport**		**No**	**Property**	LOHC: Liquid organic hydrogen carriers **"H2 form"** added as a property for each element. Added to the description of H2 form - used in "Prepare H2"	Yes	No	No	No
22	AT: Concurrent use of infrastructure - NG pipelines also may be needed for H2 distribution.	**Arup**	**Transport**	**Pipeline Transport**	**No**	**Example**	NG: Natural Gas Moved from **"Produce H2"** to **"Transport H2"** diagram. Absolutely, pipeline can be used for methane, hythene and hydrogen. The transition is part of the design.	No	Yes	Yes	Yes

Ref	Comment	Org.	Element	Use Case (if specific)	Diagram Modified	Category	Response	Hydrogen Energy Architecture, Properties and Interactions	National Hydrogen Market, Policy and Regulation	Local Hydrogen Market and Commercial Interactions	MH:EK
23	SK: Moving H is the primary consideration here but also consider locating H production adjacent to transport / use / injection hubs	**Pembrokeshire County Council**	**Transport**		**No**	**Example**	Absolutely, none of the element has a value on its own and has to be integrated within the system. Transport can be minimal or integrated in a collocated production / storage / end use design. The option of including transport can be valuable depending on the scenario.	Yes	No	No	No
24	EK: Couldn't these roles be the same?	**Welsh Government**	**Transport**		**No**	**Stakeholders**	The roles are distinct but can be fulfilled by one organisation depending of the system level (local/national). **System operator**: controls the physical operation of the whole system (interoperability between production/transport/storage to provide H2 to the consumers) **Network operator**: manages the physical hydrogen flow through the pipe network.	Yes	No	No	Yes
25	KS - "colour" of hydrogen - i.e. is it green or blue hydrogen	**Arup**	**Produce**		**Yes**	**Property**	The colour of hydrogen is defined by the embodied carbon in feedstock and process (environmental property).	Yes	No	No	No

Ref	Comment	Org.	Element	Use Case (if specific)	Diagram Modified	Category	Response	Hydrogen Energy Architecture, Properties and Interactions	National Hydrogen Market, Policy and Regulation	Local Hydrogen Market and Commercial Interactions	MH:EK
26	KC: Exploit waste water from existing facilities with minimal cleanup	**CREAS**	**Produce**		**No**	**Example**	Wastewater is an example of water procurement (as well as sea water, grid water). It is defined by the produce H2 properties (physical - **"Capacity"** environmental - **"Embodied carbon"** and commercial - **"Cost"**)	No	No	Yes	Yes
27	AT: Carbon footprint of the electricity will be relevant - Any carbon content will be 'concentrated' by the electrolysis	**Arup**	**Produce**		**Yes**	**Property**	Environmental property "Embodied Carbon". However, this can be difficult to calculate for grid electricity.	Yes	Yes	Yes	Yes
28	AT: Renewables Certificate of Origin	**Arup**	**Produce**		**No**	**Market**	Renewable Energy Guarantees of Origin (REGO) will guarantee the proportion of electricity sourced from renewable energy. Impact on market and policy.	No	Yes	Yes	Yes
29	KC: Re-use of the cross haven pipelines from generation in the LNG terminals, for use at Valero or the power station. JG: Five pipelines connect Valero to the VPOT/Dragon site -most are unused. One pipeline connects RWE to Valero, another connects RWE to VPOT/Dragon, these latter two are unused. TJ: RWE has two private natural gas pipelines - one going under the Haven (for the power station) & one that supplies Valero	**CREAS**	**Transport**		**No**	**Example**	Great examples passed to the project and used as examples	Yes	No	Yes	Yes

Ref	Comment	Org.	Element	Use Case (if specific)	Diagram Modified	Category	Response	Hydrogen Energy Architecture, Properties and Interactions	National Hydrogen Market, Policy and Regulation	Local Hydrogen Market and Commercial Interactions	MH:EK
30	JG: Gasification can use various waste materials as feedstock rather than methane. Waste plastic, municipal waste, forest waste etc.	**Insite Technical**	**Produce**		**Yes**	**Example**	"Waste" added as feedstock for H2 production with associated examples	Yes	Yes	No	Yes
31	KS: agree with above point, there may be opportunities for hydrogen use as a fuel onsite	**Arup**	**Transport**		**No**	**Example**	In relation to comment 23. Transport can be minimal or integrated in a collocated production / storage / end use design. The option of including transport can be valuable depending on the scenario.	Yes	No	No	Yes
32	SK: Shipping too	**Pembrokeshire County Council**	**Transport**		**No**	**Stakeholders**	In relation to comment 19: Shipping manufacturers are stakeholders playing a part in the future of the hydrogen economy but not directly in the physical operation. I have added them to the stakeholder role list for other use cases.	No	No	No	No
33	DW: Develop the Haven for Green H2 global import/export	**OREC**	**Transport**		**No**	**Import / Export**	Discuss	Yes	Yes	No	Yes
34	EK what about waste	**Welsh Government**	**Produce**		**Yes**	**Element**	See note 30	Yes	Yes	No	No

Ref	Comment	Org.	Element	Use Case (if specific)	Diagram Modified	Category	Response	Hydrogen Energy Architecture, Properties and Interactions	National Hydrogen Market, Policy and Regulation	Local Hydrogen Market and Commercial Interactions	MH:EK
35	KK: Green hydrogen from Dolphyn project can be converted to LOHC which can be stored in conventional oil storage facilities and transported by road tanker or exported by ship tanker. Benefit is that it can be stored at atmospheric pressure and ambient temperature	**ERM**	**Transport**		**Yes**	**Property**	LOHC: Liquid organic hydrogen carriers. All these properties have been captured. Benefits captured for transport and storage	Yes	No	No	Yes
36	KS - Welsh Water = key stakeholder here + Environment agency	**Arup**	**Produce**		**Yes**	**Stakeholders**	Use water and produce water (notes 36 and 88): Environment agency and Welsh Water added to our stakeholder list - contact to be identified	Yes	No	No	Yes
37	KC: Organic liquid hydrogen carrier changes hydrogen (gas) to liquid phase(easier for sshipping) or smaller parcels by road, rail. Gaseous hydrogen by these routes is problematic Creas does technology evaluations like this.	**CREAS**	**Transport**		**Yes**	**Property**	LOHC: Liquid organic hydrogen carriers. All these properties have been captured. Benefits captured for transport and storage	Yes	No	No	Yes
38	JG: Largest producer of H2 in Wales is in Pembrokeshire. Valero produce about 20tpd of high purity hydrogen. Might be useful source of hydrogen for downstream systems in early stages of the project (i.e. before dedicated hydrogen production is available).	**Insite Technical**	**Produce**		**No**	**Example**	Existing assets are of paramount importance for the development of projects.	Yes	Yes	Yes	Yes
39	KS - pipe diameter	**Arup**	**Transport**		**Yes**	**Property**	Pipe diameter is defined by the pipeline **Capacity.**	Yes	No	No	No

Ref	Comment	Org.	Element	Use Case (if specific)	Diagram Modified	Category	Response	Hydrogen Energy Architecture, Properties and Interactions	National Hydrogen Market, Policy and Regulation	Local Hydrogen Market and Commercial Interactions	MH:EK
40	KS - max hydrogen % within pipeline	**Arup**	**Transport**		**Yes**	**Property**	Hydrogen Form, Quality and Pressure properties will define the characteristics of the pipeline	Yes	No	No	No
41	JG: Carbon footprint calculation of the source electricity needs to consider the incremental electricity generation, not the average. i.e. when the electrolyser turns on, the wind doesn't blow harder, it's gas-fired generation that makes up the difference.	**Insite Technical**	**Produce**		**Yes**	**Property**	"Embodied emission" added as an environmental property. The way to guarantee and calculate these will develop over time.	Yes	No	No	Yes
42	KS - scope 1 - 3 carbon (e.g. what is the associated carbon due to embodied carbon in plant?)	**Arup**	**Produce**		**Yes**	**Property**	"Embodied emission" added as an environmental property. The way to guarantee and calculate these will develop over time.	Yes	No	No	Yes
43	KK: Green hydrogen from ERM Dolphyn project is imported to beach via pipeline. A buffer store will be located at shore location and pipeline offtakes can be provided to refinery,refuelling station or blended into gas grid.l	**ERM**	**Transport**		**No**	**Example Property**	Great example of integration and multiple usages. Using the physical architecture, this can be viewed as production/transport/storage/transport/usage(multiple).	Yes	No	No	Yes
44	RS: Provision of tube trailer / containerised low or high pressure solutions	**Fuel Cell Systems Ltd**	**Transport**		**No**	**Property**	**Capacity** and **Pressure** are some of the properties of transport.	Yes	No	No	No

Ref	Comment	Org.	Element	Use Case (if specific)	Diagram Modified	Category	Response	Hydrogen Energy Architecture, Properties and Interactions	National Hydrogen Market, Policy and Regulation	Local Hydrogen Market and Commercial Interactions	MH:EK
45	KC: Conversion to green ammonia for easier export. CREAS does techno-economic evaluations of potential for ammonia manufacturer. JG: round trip efficiency H2->NH3->H2 is about 40%.	**CREAS**	**Transport**		**No**	**Property**	Great example. This scenario uses the different parameters of the architecture. This comment will be passed to the commercial work packages for the economic context.	Yes	Yes	Yes	No
46	KS - pressure	**Arup**	**Transport**		**Yes**	**Property**	H2 Pressure and Form (gas / liquid gas / mix etc) are top level properties that applies to all use cases.	Yes	No	No	No
47	TJ: Need to "future proof" pipelines by looking at potential future end users to ensure pipeline is at the correct pressure spec	**RWE**	**Transport**	**Pipeline**	**Yes**	**Property**	This is noted. ENA (Energy Network Association) are running a pipe replacement program to have H2 ready pipes installed as well as a call for H2 ready boilers. Pressure is a top level property in the H2 system architecture and user "profile" and "security of supply" will impact the pipeline transport design spec.	Yes	Yes	Yes	Yes
48	AT: Purity segregation - Dont necessarilary mix high purity with lower purity H2	**Arup**	**Transport**		**No**	**Property**	The architecture shows the possible routes for H2 through the system. It may not be technologically nor commercially recommended to mix different purity hydrogen. This has to be analysed for each scenario.	Yes	No	Yes	Yes

Ref	Comment	Org.	Element	Use Case (if specific)	Diagram Modified	Category	Response	Hydrogen Energy Architecture, Properties and Interactions	National Hydrogen Market, Policy and Regulation	Local Hydrogen Market and Commercial Interactions	MH:EK
49	TJ: RWE can operate electrolyser plant	**RWE**	**Produce**		**No**	**Example**	Great example of integrated stakeholder role.	No	No	No	Yes
50	RS: Containerised delivery via road or rail freight: Regulations will need to be addressed as a priority	**Fuel Cell Systems Ltd**	**Transport**		**No**	**Market**	The impact of regulations will be discussed in another work package.	No	Yes	No	Yes
51	eK: Regulator integration key to understanding balance between different vectors	**Welsh Government**	**Produce**		**No**	**Stakeholders**	Absolutely. This will affect the properties of the physical architecture and reported on with the national market piece. This comment will be passed to the Policy and Regulation work package.	No	Yes	No	Yes
52	IS Skills: training the operators in the future	**Sea Wind Technology**	**Produce**		**No**	**Supply chain**	Where do we capture/report this? Out of scope?	No	No	No	No
53	NP :Need to consider process safety	**RWE**	**Produce**		**No**	**Safety**	Safety case to be developed. Not part of this diagram.	No	No	No	No
54	IS/: Inclusion of STEM/WISE in the programme	**Sea Wind Technology**	**Produce**		**No**	**Influence**	STEM: Science, Technology, Engineering, and Mathematics WISE: Women Into Science and Engineering Where do we capture this? Incentive Programs stakeholder role	No	No	No	Yes

Ref	Comment	Org.	Element	Use Case (if specific)	Diagram Modified	Category	Response	Hydrogen Energy Architecture, Properties and Interactions	National Hydrogen Market, Policy and Regulation	Local Hydrogen Market and Commercial Interactions	MH:EK
55	KC: Guarantee of green origin using digital blockchain certificates enables comingled sources of H2 and end user can determine the GHG emissions CREAS has a blockchain platform VerifHy for this purpose	**CREAS**	**Transport**		**Yes**	**Property**	"Embodied emission" added as an environmental property. The way to guarantee and calculate these will develop over time. Blockchain is one option captured in the digital section	Yes	No	No	Yes
56	RS: Control systems for integration into downline functions and response to capacity demand	**Fuel Cell Systems Ltd**	**Produce**		**Yes**	**Control**	The system architecture report will present a section on control and interoperability	Yes	No	No	No
57	AT: Bio-hydrogen ?	**Arup**	**Produce**		**Yes**	**Example**	"Use Waste" including Biomass added as a source for H2 production with associated examples (plastic/municipal/forest) - see note 30	Yes	Yes	No	Yes
58	SB: High pressures required to transport H2 as lower energy density - poses potential safety issues as H2 particularly flammable/explosive compared to hydrocarbons (wide LEL 4-75%, lower O2 requirement and lower spark (ignition) energy.	**Insite Technical**	**Transport**		**No**	**Safety**	Safety case to be developed. Not directly part of this diagram. However, "pressure" and "form" will capture these constraints in the transport use case.	No	No	No	No
59	SK: Local authorities as host for renewable generation/electrolysed H production. Pension fund investment in LA backed projects for renewable elec/green H production. Production adjacent to gas grid injection point or transport nodes.	**Pembrokeshire County Council**	**Produce**		**No**	**Example**	This example can fit within the architecture. This comment will be passed to the local hydrogen market work package.	No	No	Yes	Yes

Ref	Comment	Org.	Element	Use Case (if specific)	Diagram Modified	Category	Response	Hydrogen Energy Architecture, Properties and Interactions	National Hydrogen Market, Policy and Regulation	Local Hydrogen Market and Commercial Interactions	MH:EK
60	KC: Digital hydrogen network management control system - production versus offtake - especially with variable sources of electricity (like renewables)	**CREAS**	**Transport**		**No**	**Control Digital**	Part of the control / digital sections	Yes	No	Yes	Yes
61	SB - excess nuclear power can be used to generate H2 through electrolyzes	**Insite Technical**	**Produce**		**Yes**	**Example**	Source of electricity is characterised through its properties (emission/embodied carbon/cost etc).	Yes	No	No	No
62	JG: Purity of production needs to be established. High purity required for FCEVs, but high production purity is less efficient. PSA used to get to this purity, but hydrogen is wasted in the process. Methanator purification wastes less H2 but resulting purity is lower.	**Insite Technical**	**Produce**		**No**	**Example**	**"Quality"** and **"Efficiency"** are properties of production to be taken into account for each scenario/design. End use will answer questions to suitability of production options.	Yes	No	Yes	No
63	KC: H2 production at LNG import facilities	**CREAS**	**Produce**		**No**	**Example**	Reuse of existing facilities of the Haven is of paramount importance.	Yes	No	No	Yes
64	EK: define different types of h2 as could have different uses as result	**Welsh Government**	**Produce**	**Produce H2**	**No**	**Property**	**"Form"** and **"Quality"** are properties at each stage to be taken into account for each scenario/design. End use will answer questions to suitability of storage/transport/production options.	Yes	No	No	No

Ref	Comment	Org.	Element	Use Case (if specific)	Diagram Modified	Category	Response	Hydrogen Energy Architecture, Properties and Interactions	National Hydrogen Market, Policy and Regulation	Local Hydrogen Market and Commercial Interactions	MH:EK
65	NP: If using an existing pipeline need to consider requirements for additional volume and pressure also leakage and enbrittlement	**RWE**	**Transport**		**Yes**	**Property**	"**Quantity**" (volume), **"Pressure", "Efficiency"** (leakage) and **"Quality"** (embrittlement) are all properties of pipelines (new and existing) Maintenance aspect (due to embrittlement) noted but not part of this level of operational physical architecture.	Yes	No	No	Yes
66	SB: If blending into existing gas network need to ensure existing equipment e.g. valves, compressors are correctly specified for hydrogen service - depends on % blended in (physical properties of H2 much different to natural gas)	**Insite Technical**	**Transport**		**Yes**	**Example Property**	Reuse of existing assets Captured in **"Form"** and **"Quality"**	Yes	No	No	Yes
67	JG: Existing LNG facilities have access to large quantities of gas, access to the high-pressure gas network and the expertise to handle large quantities of hazardous materials.	**Insite Technical**	**Transport**		**No**	**Example**	Reuse of existing facilities of the Haven is of paramount importance.	Yes	Yes	Yes	Yes
68	KK: ERM Dolyphn developing H2 generation from floating turbines;	**ERM**	**Produce**	**Procure Feedstock**	**No**	**Example**	Floating wind turbines noted as an example of renewable electricity source.	Yes	No	No	Yes
69	DW: Simply Blue Energy developing floating OSW projects in Celtic Sea	**OREC**	**Produce**		**No**	**Example**	OSW: OffShore Wind Floating wind turbines noted as an example of renewable electricity source.	Yes	No	No	Yes

Ref	Comment	Org.	Element	Use Case (if specific)	Diagram Modified	Category	Response	Hydrogen Energy Architecture, Properties and Interactions	National Hydrogen Market, Policy and Regulation	Local Hydrogen Market and Commercial Interactions	MH:EK
70	KC: Early H2 demand volumes need to target big industrial consumers for scale - road vollumes will be small for many years	**CREAS**	**Transport**		**No**	**Example**	Or a combination of both. The architecture should support every scenario.	Yes	No	Yes	Yes
71	KC: Valero has existing SMR. JG: No, they produce it by reforming naphtha - but still a useful source of high-purity hydrogen at large scale.	**CREAS**	**Produce**		**No**	**Example**	Examples and stakeholders captured.	Yes	No	No	Yes
72	RS: provide electrolyser and purification plant and low pressure storage in preparation for transport	**Fuel Cell Systems Ltd**	**Produce**		**No**	**Element Property**	**"Prepare H2"** contain the changes in property between production and transport such as **"Pressure"**, **"Quality"** (Purity)	Yes	No	No	No
73	AT: System energy usage during transport - Auxiliary systems such a heating	**Arup**	**Transport**		**Yes**	**Property**	"Embodied emission" added as an environmental property. The way to guarantee and calculate these will develop over time. This can also be capture in the associated cost.	Yes	No	No	No
74	EK: ammonia could alter transport properties	**Welsh Government**	**Transport**		**Yes**	**Property**	Agree. The "Prepare for Transport" will highlight the properties necessary for transport and their impact on the transport option for each scenario.	Yes	No	No	No
75	KC: CREAS carries out indepdent technology evaluations for clients: "Turquoise" hydrogen produces solid carbon as graphene	**CREAS**	**Produce**		**Yes**	**Property**	Noted as "Produce Carbon Black" by product	Yes	No	No	Yes
76	EK: produce system balancer opportunities	**Welsh Government**	**Produce**		**No**	**Control**	Balancing the system is developed in the Control and Interoperability section	Yes	No	No	No

Ref	Comment	Org.	Element	Use Case (if specific)	Diagram Modified	Category	Response	Hydrogen Energy Architecture, Properties and Interactions	National Hydrogen Market, Policy and Regulation	Local Hydrogen Market and Commercial Interactions	MH:EK
77	BS: FLOW and Marine energy being developed off the Pembrokeshire coast. Would be interested in developing sustainable system like the surf n turf project up in Orkney. Are you learning lessons from other projects like this?	**Marine Energy Test Area (META)**	**Produce**		**No**	**Example**	The ESC is involved in the ReFlex project looking at the integration of the energy system design including hydrogen. The findings in Orkney are supporting the development of the general hydrogen architecture. https://es.catapult.org.uk/impact/projects/reflex-orkney/	Yes	No	Yes	Yes
78	JG: Hydrogen content limited by the slowest part of the national network to transition to burning hydrogen. Also, peak energy transfer capacity would reduce as H2 content increases.	**Insite Technical**	**Transport**		**Yes**	**Property**	This will be taken into account for each scenario	Yes	No	No	No
79	TJ: Deblending is expensive, so should only blend if end use is as a blend	**RWE**	**Transport**		**No**	**Property**	Deblending is a possible physical H2 preparation and is therefore considered in this architecture. The price and technicality of the process may discard it as a viable option in all scenarios.	Yes	No	Yes	No
80	EK: produce chemicals of use in industry and agriculture	**Welsh Government**	**Produce**	**Produce By-Products**	**Yes**	**Element Example**	All by-products have physical and environmental associated properties as well as associated expenditure (carbon tax, waste) or revenue (used in agriculture/industry).	Yes	No	No	Yes
81	JG: Allows transport of high purity hydrogen, but to a limited geographical area. Useful during early stages of transition - conversion of consumers is more managable.	**Insite Technical**	**Transport**		**No**	**Property**	All these factors are captured in the properties to compare options.	Yes	No	Yes	Yes

Ref	Comment	Org.	Element	Use Case (if specific)	Diagram Modified	Category	Response	Hydrogen Energy Architecture, Properties and Interactions	National Hydrogen Market, Policy and Regulation	Local Hydrogen Market and Commercial Interactions	MH:EK
82	JG: Reusing the old gas grid for dedicated hydrogen may not be feasible - larger diameter and / or pressure would be required to move the same amount of energy.	**Insite Technical**	**Transport**		**No**	**Property**	This use case considers reusing existing gas grid infrastructure or new/replaced/relined gas pipes. Feasibility (physical and commercial) will be analysed for each scenario.	Yes	Yes	Yes	Yes
83	RS: Control systems to allow production systems to respond to bulk storage shortfall and initiate production at low energy cost time periods	**Fuel Cell Systems Ltd**	**Produce**		**No**	**Control**	This is developed in the different control options.	Yes	No	No	No
84	EK: produce construction opportunities but probab for commercial sketch	**Welsh Government**	**Produce**		**No**	**Example**	Correct. The comment will be passed to the national and local market work packages.	No	No	Yes	No
85	KC: H2 as an enabler for CCU (eg.- green methanol). CREAS explores green methanol use cases/volumes and production technology assessments	**CREAS**	**Produce**		**No**	**Property**	CCU is captured within the environmental property (**"Emission"**) with the associated cost for the hydrogen production element.	Yes	No	Yes	Yes
86	SB - cost of retrofitting CCS to existing SMR	**Insite Technical**	**Produce**		**No**	**Market**	The comment will be passed to the national and local market work packages.	No	Yes	Yes	No
87	RS Low pressure bulk storage	**Fuel Cell Systems Ltd**	**Produce**	**Prepare H2**	**No**	**Property**	Pressure change is one of the aspects of **"Prepare H2"**	Yes	No	No	No
88	KS - Welsh Water = key stakeholder here + Environment agency	**Arup**	**Produce**		**Yes**	**Stakeholders**	Use water and produce water (notes 36 and 88): Environment agency and Welsh Water added to our stakeholder list - contact to be identified	Yes	No	No	Yes

Ref	Comment	Org.	Element	Use Case (if specific)	Diagram Modified	Category	Response	Hydrogen Energy Architecture, Properties and Interactions	National Hydrogen Market, Policy and Regulation	Local Hydrogen Market and Commercial Interactions	MH:EK
89	SB - high demand for high purity O2 for medical applications in current circumstances	**Insite Technical**	**Produce**	**Produce By-Products**	**No**	**Example**	O2 sale will be captured in the commercial property of the by-product.	Yes	No	Yes	Yes
90	KC: Oxygen offtake for enriched combustion applicaitions to improve energy efficiency	**CREAS**	**Produce**	**Produce By-Products**	**No**	**Example**	O2 sale will be captured in the commercial property of the by-product.	Yes	No	Yes	Yes
91	UU: Simply Blue are developing floating OSW	**0**	**Produce**		**No**	**Example**	OSW: OffShore Wind Great example of renewable source for H2 production	Yes	No	No	Yes
92	RS: Downstream medical applications	**Fuel Cell Systems Ltd**	**Produce**	**Produce By-Products**	**No**	**Example**	O2 sale will be captured in the commercial property of the by-product.	Yes	No	No	Yes
93	KK: LOHC can enable H2 to be stored in conventional opil terminal storage tanks and loaded/unloaded using conventional oil jetty as available at Milford Haven Oil Terminald	**ERM**	**Transport**		**Yes**	**Example**	LOHC: Liquid organic hydrogen carriers Benefits captured for transport and storage	Yes	No	Yes	Yes
94	KS - Sale of heat (e.g. for district heating) or heat recycled within system	**Arup**	**Produce**		**No**	**Property**	If produced Heat is sold, this will be recorded in the commercial property. If the heat is recycled within the system, this will impact the physical and commercial properties of the Produce H2 process itself.	Yes	No	Yes	Yes

Ref	Comment	Org.	Element	Use Case (if specific)	Diagram Modified	Category	Response	Hydrogen Energy Architecture, Properties and Interactions	National Hydrogen Market, Policy and Regulation	Local Hydrogen Market and Commercial Interactions	MH:EK
95	EK: participate in national and local energy markets in creating a new hydrogen market	**Welsh Government**	**Produce**	**Sell H2**	**No**	**Element**	Absolutely, that is the reason for this placeholder. The comment will be passed to the national and local market work packages.	No	Yes	Yes	Yes
96	KK: Green H2 from ERM Dolphyn field could be imported and stored as LOHC at Oil Terminal. This can be exported by ship from Milford Haven to other locations e.g. Port Talbot or used by refinery for developing synthetic fuels	**ERM**	**Produce**		**Yes**	**Property Import / Export**	LOHC: Liquid organic hydrogen carriers Discuss Import/Export	Yes	No	Yes	Yes
97	KC: H2 as an enabler of remote electricity generation - HFC	**CREAS**	**Produce**		**No**	**Example**	HFC: Hydrogen Fuel Cell Hydrogen Fuel Cell Generator for off grid applications is an example captured.	Yes	No	No	Yes
98	TJ: RWE can manage the sale of hydrogen when a market is created	**RWE**	**Produce**	**Sell H2**	**No**	**Market**	Stakeholder recorded. The comment will be passed to the national and local market work packages.	No	Yes	Yes	Yes
99	KC: Or as another subtance - eg. LOHC, ammonia, methanol	**CREAS**	**Prepare**		**Yes**	**Property**	LOHC: Liquid organic hydrogen carriers Added to the description of H2 **"Form".** This property is applicable to all elements.	Yes	No	No	No

Ref	Comment	Org.	Element	Use Case (if specific)	Diagram Modified	Category	Response	Hydrogen Energy Architecture, Properties and Interactions	National Hydrogen Market, Policy and Regulation	Local Hydrogen Market and Commercial Interactions	MH:EK
100	AT: Non-volumetric metering - Capture for later diagrams.	**Arup**	**Use**		**Yes**	**Property**	**"Measure H2 Usage"** added to diagram. Added to Commercial Diagram What are we selling?	No	No	No	No
101	KS - level of flexibility or required supply security for end user	**Arup**	**Use**		**Yes**	**Property**	Thank you. Added to the properties **"Security of Supply"**	Yes	Yes	Yes	No
102	KK: A single 10MW floating Dolphyn unit can produce 2.5 Tonnes of H2 per day. A 4GW capacity Dolphyn field in Celtic Sea can produce 360,000 Te's per year making Miford Haven a major green hydrogen port	**ERM**	**Use**	**Volume Forecast**	**No**	**Control**	Thank you. Great production example. This will be used in the Control section	No	No	No	Yes
103	KC: What form the hydrogen is stored in	**CREAS**	**Store**		**Yes**	**Property**	**"Form"** property is applicable to all elements.	Yes	No	No	No
104	SK: 99.9% purity needed for FCEV's. What purity is required for boilers and other applications?	**Pembrokeshire County Council**	**Use**		**No**	**Property**	The functions have properties that needed to differentiate between the different applications for each scenario/design. These values will also change with time (regulations/technology…)	Yes	No	No	No
105	KS - intended seasonality of storage	**Arup**	**Store**		**No**	**Property**	Seasonality of storage identified in storage **"Duration"** property	Yes	No	No	No

Ref	Comment	Org.	Element	Use Case (if specific)	Diagram Modified	Category	Response	Hydrogen Energy Architecture, Properties and Interactions	National Hydrogen Market, Policy and Regulation	Local Hydrogen Market and Commercial Interactions	MH:EK
106	AT: Manufacturing of H2 products - Fuelcell based personal power supplies etc. https://www.amazon.co.uk/Brunton-Hydrogen-Reactor/dp/B00HU5GE6W	**Arup**	**Use**		**Yes**	**Example**	**Produce Electricity** (at different scales) Comment collected as impact: H2 generators to replace diesel generator at local level Portable H2 reactor	Yes	No	No	No
107	KC: Green ammonia for eco-fertilisers. Supply local fertiliser demand	**CREAS**	**Use**		**No**	**Property**	Green ammonia noted as an example. Green ammonia is an hydrogen "**Form**" with associated embodied carbon.	Yes	No	No	Yes
108	AT: Suggest Commercial, Residential, Industrial, Transport as separate stakeholders. Also note that C&I might be confused for 'Control & Instrumentation'	**Arup**	**Use**		**Yes**	**Stakeholders**	C&I replaced with Commercial and Industrial For the high level architecture, we will not differentiate between the different types of consumers	No	No	No	No
109	KC: Green methanol as a carbon capture and reuse case . Then to aviation, marine, chemical feedstock, drop-in to petrol cars.	**CREAS**	**Use**		**No**	**Property**	"Form" property updated for green methanol	Yes	No	No	Yes
110	KC: Green methanol or MCH or DME as chemical feedstocks	**CREAS**	**Use**		**No**	**Property**	MCH: Methylcyclohexane DME: DiMethyl Ether Noted as examples of chemical industry use	Yes	No	No	No

Ref	Comment	Org.	Element	Use Case (if specific)	Diagram Modified	Category	Response	Hydrogen Energy Architecture, Properties and Interactions	National Hydrogen Market, Policy and Regulation	Local Hydrogen Market and Commercial Interactions	MH:EK
111	KS safety	**Arup**	**Store**		**No**	**Safety**	Safety case to be developed. Not part of this diagram.	No	No	No	No
112	KC: Link to Ellesmere Port H2 network - shipped from MH as a supplement	**CREAS**	**Use**		**No**	**Control**	Connection between local/regional hydrogen systems	Yes	No	No	No
113	AT: Reuse/repurposing of existing hydrocarbon storage assets - May influence	**Arup**	**Store**		**No**	**Element**	Absolutely. Benefit of existing infrastructure noted. Not part of the physical operational architecture.	No	Yes	Yes	Yes
114	KS - hydrogen for power	**Arup**	**Use**		**Yes**	**Element**	Thank you. **"Produce Electricity"** use case added	Yes	No	No	Yes
115	IS: Public Relations Campaign: Bring the public with you on this journey. Define programme KPI's to let people know iwhat success looks like	**Sea Wind Technology**	**Use**		**No**	**Stakeholders**	This architecture represents the physical system. Consumer engagement is paramount to the design project led by ARUP.	No	No	Yes	Yes
116	KK: H2 from Dolphyn can be converted to LOHC and exported to other ports (e.g. Port Talbot for Steel works usage) or exported to European Ports	**ERM**	**Use**		**Yes**	**Property Import / Export**	LOHC: Liquid organic hydrogen carriers Discuss Import/Export	Yes	No	Yes	Yes
117	NP: What about power generation?	**RWE**	**Use**		**Yes**	**Element**	Thank you. **"Produce Electricity"** use case added	Yes	No	No	No

Ref	Comment	Org.	Element	Use Case (if specific)	Diagram Modified	Category	Response	Hydrogen Energy Architecture, Properties and Interactions	National Hydrogen Market, Policy and Regulation	Local Hydrogen Market and Commercial Interactions	MH:EK
118	SK: Stored H for power generation/grid balancing to assist with intermittancy of renewables	**Pembrokeshire County Council**	**Use**		**Yes**	**Control Element**	Thank you. **"Produce Electricity"** use case added	Yes	No	No	Yes
119	SB: Green ammonia production - fertilizer demand set to increase in line with population increase.	**Insite Technical**	**Use**		**No**	**Property**	Absolutely. The **"Form"** and **"Quantity"** (volume, weight) parameter will be different for each application and will be used in conjunction with production.	Yes	No	No	No
120	RS: Smaller businesses and operations with remote locations and smaller hydrogen demands may require mobility solutions to deliver refueling solutions. FCS are expert at delivery of solutions in a mobile / transportable manner.	**Fuel Cell Systems Ltd**	**Use**		**No**	**Example**	Great examples integrating storage and transport.	Yes	Yes	Yes	Yes
121	JG: H2 for power makes sense for blue hydrogen, but makes no sense for green hydrogen - significant losses going from power to hydrogen to power.	**Insite Technical**	**Use**		**No**	**Example**	The architecture allows for each scenario to be analysed. Electricity production could make sense for excess hydrogen and balancing. The different properties (physical and commercial) will support the business case.	No	No	No	No

Ref	Comment	Org.	Element	Use Case (if specific)	Diagram Modified	Category	Response	Hydrogen Energy Architecture, Properties and Interactions	National Hydrogen Market, Policy and Regulation	Local Hydrogen Market and Commercial Interactions	MH:EK
122	KK: Pipeline Offtake from the Dolphyn buffer store can go to harbour for marine operations or to refuelling station for transport applications (buses, trucks, potential train) or direct to refinery for synthetic fuel production	**ERM**	**Store**		**No**	**Example**	Examples captured	Yes	No	No	Yes
123	KK: Green hydrogen from Dolphyn can also be blended directly into the gas distribution network via blending unit at local pressure reduction station	**ERM**	**Store**		**No**	**Example**	Example of production to use (blend scenario)	Yes	No	Yes	Yes
124	AT: Storage release process, particularly if hydrogen is not readily extracted (Physical or chemical absorbtion)	**Arup**	**Store**		**No**	**Property**	This is included in the **"Prepare H2"** process and storage properties.	Yes	No	No	No
125	KK: Green hydrogen from Dolphyn can be blended into local gas distribution netork for heating of homes and commercial premises. When legislation allows, h2 can also be blended into the national transmission system (NTS)	**ERM**	**Use**		**No**	**Example** **Property**	Local and National example Blend is a form of hydrogen.	Yes	Yes	Yes	Yes
126	KK: Hydrogen from Dolphyn will have a buffer store at shoreline location. This will typically contain 5Te of hydrogen at 40 bar stored in large storage bullets (compressed H2 gas)	**ERM**	**Store**		**No**	**Example**	Greta example captured in Storage use case.	No	No	No	Yes
127	NP: Yes was considering the transitional period as a user for blue hydrogen, before other more high value users are availble	**RWE**	**Use**		**No**	**Example**	Response to Note 121. H2 for power can be used as a buffer during transition periods.	No	No	No	No

Ref	Comment	Org.	Element	Use Case (if specific)	Diagram Modified	Category	Response	Hydrogen Energy Architecture, Properties and Interactions	National Hydrogen Market, Policy and Regulation	Local Hydrogen Market and Commercial Interactions	MH:EK
128	JG: High-pressure storage should include energy recovery from depressurisation - i.e. demand from the storage is supplied via a let-down turbine which generates electricity.	**Insite Technical**	**Store**		**Yes**	**Element Example**	"Produce By-products" added to "Prepare H2" and example noted.	Yes	No	No	No
129	SK: Green H for district heating/Fuel Cells/CHP localsied networks/new developments	**Pembrokeshire County Council**	**Use**		**No**	**Example**	Thank you. Examples noted	No	No	No	Yes
130	KC: MH:EK to participate in major European markets for H2/related prodducts (eg.- Germany -who will be looking for supply in the 2040s)	**CREAS**	**Use**		**No**	**Market Import / Export**	This comment will be passed to the Policy and Regulation work package.	No	Yes	No	no
131	KK: LOHC enable same ammount og H2 to be stored per M3 as liquid hydrogen but at atmospheric pressure and temperature. Technology is at early stage but developing quickly. Regular transport of LOHC now taking place between Brunei and Japan.	**ERM**	**Store**		**No**	**Example**	LOHC: Liquid organic hydrogen carriers Benefits captured for **Transport, Storage** elements and **Form** property	Yes	No	No	No
132	JG: Safety issues with piping H2 into homes need to be considered. Towns gas explosions were spectacular, but don't need repeating.	**Insite Technical**	**Use**		**No**	**Safety**	Safety case to be developed. Not part of this diagram.	No	No	No	No

Ref	Comment	Org.	Element	Use Case (if specific)	Diagram Modified	Category	Response	Hydrogen Energy Architecture, Properties and Interactions	National Hydrogen Market, Policy and Regulation	Local Hydrogen Market and Commercial Interactions	MH:EK
133	RS: Scale should expect to be increased over time. Important to deliver lower cost solutions that can scale with demand to ensure that initial capex does not destroy the project in the early stages. Price to the consumer early on will be very important to speed of uptake and eventual success.	**Fuel Cell Systems Ltd**	**Use**		**No**	**Market**	Agree. The comment will be passed to the national and local market work packages. Incentive and investment will play a major part.	No	Yes	Yes	No
134	RS: FCS has produced refuelling equipment that has successfully supported m/c car, van, truck, bus, train and aircraft refuelling. Very important to ensure refueling protocols are kept common across all industries to preclude regulatory woes and additional industry costs	**Fuel Cell Systems Ltd**	**Use**		**No**	**Market**	Great remark. Regulatory impact and refuelling protocol alignment will have an impact on the values for the transport properties. Note added in the **"Use H2 for Mobility"** use case and comment passed to the market work packages.	Yes	Yes	Yes	Yes
135	KC: Salt cavern storage of H2 is being studied in Germany TJ: I am not aware of any salt caverns in the MH:EK area? There are some disused salt caverns in Teesside & potential in the Merseyside area.	**CREAS**	**Store**		**No**	**Example**	The physical architecture should support MH:EK local and any other local/national hydrogen energy system. Salt caverns have been identified as an example of large, inter seasonal storage.	No	No	No	No
136	KK: Green hydrogen from Dolphyn project can be stored as LOHC at local oil terminal. From here it can be transported to a variety of end users (refuelling , industry, etc) or exported to other ports or even to Europe.	**ERM**	**Store**		**No**	**Example**	LOHC: Liquid organic hydrogen carriers Benefits captured.	No	No	No	No

Ref	Comment	Org.	Element	Use Case (if specific)	Diagram Modified	Category	Response	Hydrogen Energy Architecture, Properties and Interactions	National Hydrogen Market, Policy and Regulation	Local Hydrogen Market and Commercial Interactions	MH:EK
137	KC: Use of LOHC to enable H2 storage as liquid using existing tankage facilities in the Haven region	**CREAS**	**Store**		**No**	**Example**	LOHC: Liquid organic hydrogen carriers Benefits captured.	Yes	No	Yes	Yes
138	TJ: Government commissioned work: https://www.hy4heat.info/	**RWE**	**Use**		**No**	**Example**	Great example encompassing physical, quality, certification, safety context.	Yes	Yes	Yes	Yes
139	KC: Use existing infrastructure at LNG terminals and oil refinery for export of LH2 or related (LOHC, ...)	**CREAS**	**Use**		**No**	**Import / Export**	LOHC: Liquid organic hydrogen carriers Discuss Import/Export	Yes	Yes	Yes	Yes
140	KC: If blue hydrogen, also need consider storage of CO2 is CCU is adopted (eg.- methanol) JG: ...or local use of CO2. Carbon captured at Pernis is used in large-scale local greenhouses to improve crop yields.	**CREAS**	**Store**		**No**	**Example**	CO2 is identified as a hydrogen by-product with physical and commercial properties. These will vary widely depending on end storage of usage	No	No	Yes	Yes
141	KC: Use of hydrogen fuel cells to enable H-to-power switching as a load shed option	**CREAS**	**Store**		**Yes**	**Example**	Electricity load shed added as an example	Yes	No	Yes	Yes
142	KC: Any advantage in terms of ease of certification of storing liquid H2 at existing LNG plants	**CREAS**	**Store**		**No**	**Example**	This is a possible application and consideration to be accounted for. Certification comment passed to Market Analysis and Project	Yes	No	Yes	Yes
143	KC: Would it be possible to change offgrade oil heating for offgrid hydrogen heating with road supply	**CREAS**	**Use**		**No**	**Example**	Yes, absolutely. Example added in benefits of H2 for heating off grid buildings	No	No	No	No

Ref	Comment	Org.	Element	Use Case (if specific)	Diagram Modified	Category	Response	Hydrogen Energy Architecture, Properties and Interactions	National Hydrogen Market, Policy and Regulation	Local Hydrogen Market and Commercial Interactions	MH:EK
144	JG: Fertiliser industry consumes hydrogen. Try to involve a fertiliser company in the project?	**Insite Technical**	**Use**		**No**	**Example**	Comment passed to the project team	No	No	No	Yes
145	RS: Transport applications do not necessarily require national distribution networks. Centralised, back to base operations can can easily reach a scale to make hub storage, production and fueling viable	**Fuel Cell Systems Ltd**	**Use**		**No**	**Example**	Agree. The architecture presented should cover both national and local applications. Noted in the **"Use H2 for Mobility"** section	No	No	Yes	Yes
146	SB: Existing domestic boilers may need to be converted to use H2 - what timescale and cost is associated with this?	**Insite Technical**	**Use**		**No**	**Example**	The comment will be passed to the national and local market work packages.	No	Yes	Yes	Yes
147	JG: Vale's nickel refinery in Clydach consumes hydrogen.	**Insite Technical**	**Use**		**No**	**Example**	Thank you for the example	No	No	No	No
148	RS: Variable levels of storage capacity via modular solutions to enable capacity to be relocated as demand levels alter	**Fuel Cell Systems Ltd**	**Store**		**Yes**	**Property**	Storage "capacity" and "modularity" are properties.	Yes	No	Yes	Yes
149	SB: Dow silicones plant in Barry uses H2 for specific processes (already have SMR on site but demand could increase in future capacity expansions).	**Insite Technical**	**Use**		**No**	**Example**	Great example to be using the architecture to develop.	No	No	No	No
150	RS: High purity, high volume usage applications may require distributed production of H2 to reduce transportation impact	**Fuel Cell Systems Ltd**	**Use**		**No**	**Integration**	Agree. Different scenarios can use the architecture with different parameters. Barriers to hydrogen transport detailed in the project.	No	No	Yes	Yes

Ref	Comment	Org.	Element	Use Case (if specific)	Diagram Modified	Category	Response	Hydrogen Energy Architecture, Properties and Interactions	National Hydrogen Market, Policy and Regulation	Local Hydrogen Market and Commercial Interactions	MH:EK
151	JG: If the largest scale use of hydrogen is for heat, it may be more efficient to store heat than store hydrogen. Companies like Energy Nest are developing high-temperature heat storage.	**Insite Technical**	**Store**		**No**	**Example**	This is a possible scenario. In the architecture, final use would be "Heating" with the relevant profile for stored heat. This can be compared with stored H2 followed by use H2 for heating with a peakier profile.	Yes	Yes	Yes	Yes
152	RS: Provision of very high pressure H2 storage for fast fill delivery to transport and other industrial Fuel Cell application	**Fuel Cell Systems Ltd**	**Store**		**No**	**Example**	This can be defined as either storage or end use (mobility or industry). **Pressure** and **Use Profile** are properties depending on the scenario.	No	No	No	Yes
153	SK: Council bin lorry fleet, buses, high mileage vehicles	**Pembrokeshire County Council**	**Use**		**No**	**Example**	Examples noted	No	No	Yes	Yes
154	JG: Natural gas storage has switched from gasometers to peak-shave LNG to line-packing the high-pressure grid. In a future with a high-pressure H2 grid, line-packing the grid may be the best option if sufficient pressure margin is included in the design.	**Insite Technical**	**Store**		**No**	**Example**	All options can be considered with the different properties (**Pressure**, **Quantity**) of each use case to analyse the most efficient, secure and cost effective design.	Yes	Yes	Yes	No
155	KC: Logistics facilities for various transport mechanisms (bottling plant, road tanker, vessels). Anything already existing at LNG plants or at Valero that can be adopted/re-used?	**CREAS**	**Store**		**No**	**Example**	Design question passed to the project.	Yes	No	Yes	Yes

Ref	Comment	Org.	Element	Use Case (if specific)	Diagram Modified	Category	Response	Hydrogen Energy Architecture, Properties and Interactions	National Hydrogen Market, Policy and Regulation	Local Hydrogen Market and Commercial Interactions	MH:EK
156	TJ: Hydrogen storage is expensive, so should only be used to manage intermittent hydrogen production / to ensure security of supply	**RWE**	**Store**		**No**	**Example**	This is the physical architecture. This aspect will be considered in the control and interoperability section.	No	Yes	Yes	No
157	KK: Green hydrogen offtake from the Dolphyn onshore buffer store can supply Pembroke /Milford Haven Por for marine applications (hydrogen tugs/ferries)	**ERM**	**Use**		**No**	**Example**	Noted: Marine applications are part of "Use H2 for Transport"	No	No	Yes	Yes
158	TJ: Need to ensure involvement from South Wales Industrial Cluster (some potential large producers / consumers involved)	**RWE**	**Use**		**No**	**Market**	Absolutely. Stakeholder analysis is key. The comment will be passed to the national and local market work packages.	No	No	Yes	Yes
159	SB: H2 very light - easy to leak through containers so need to think carefully about materials of construction and H2 recovery systems to avoid wastage.	**Insite Technical**	**Store**		**No**	**Safety**	Maintenance and safety aspects are noted but not part at this level of the physical architecture. These considerations will indeed influence the design of storage within the hydrogen system.	No	No	No	No
160	KK: H2 from Dolphyn can be used by Pembroke refinery for producing synthetic green fuels (e.g. for aviation fuel)	**ERM**	**Use**		**No**	**Example**	Depending on the scenario, this can be part of **"Use H2 for Industry"** to create syngas (for whichever application) or **"Use H2 for Mobility"**.	No	No	Yes	Yes
161	KC: As transport fuels decline, Valero need for hydrogen for fuel hydrotreating will reduce - an opportunity to export H2 and use the SMR capability; as well as an opportunity for hydrogen to road fuel switching	**CREAS**	**Use**		**No**	**Example**	Great example of impact between H2 and fuel use.	Yes	No	No	Yes

Ref	Comment	Org.	Element	Use Case (if specific)	Diagram Modified	Category	Response	Hydrogen Energy Architecture, Properties and Interactions	National Hydrogen Market, Policy and Regulation	Local Hydrogen Market and Commercial Interactions	MH:EK
162	KC: Moving hydrogen to main chemical/industrial consumers in South Eastern Wales (eg.- green steel...)	**CREAS**	**Use**		**No**	**Example**	Chemical use added as an example of industrial use.	No	No	Yes	Yes
163	RS: Storage of multiple day predicted usage capacity at medium pressures to cater for varying levels of demand and high capacity compressors to keep high pressure, delivery storage to optimum pressures.	**Fuel Cell Systems Ltd**	**Store**		**No**	**Example**	This is identified in the different properties of storage (duration, pressure, efficiency...)	Yes	No	No	No
164	AT: HRS (Hydrogen Refueling Station) - Another Block?	**Arup**	**Use**		**No**	**Example**	HRS can be part of container storage or transport usage depending on the context. Added in the notes for both.	No	No	No	No
165	JG: About time Pembrokeshire joined the space race?	**Insite Technical**	**Use**		**No**	**Example**	I haven't added Space as a mobility example but if you insist...	No	No	No	No
166	KC: Vaporisation and/or recompression	**CREAS**	**Store**	**Prepare H2**	**Yes**	**Example**	"Prepare H2" includes H2 form and pressure change both prior and post storage.	Yes	No	No	No
167	KK: Green h2 from ERM Dolphyn project canbe used directly for transport due to high purity. Uses include local buses, trucks and potentially a hydrogen train	**ERM**	**Use**		**No**	**Example**	Example and purity constraints for fuel cells noted	No	No	No	Yes

Ref	Comment	Org.	Element	Use Case (if specific)	Diagram Modified	Category	Response	Hydrogen Energy Architecture, Properties and Interactions	National Hydrogen Market, Policy and Regulation	Local Hydrogen Market and Commercial Interactions	MH:EK
168	AT: Cooling/heatiog during storage process	**Arup**	**Store**	**Prepare H2**	**Yes**	**Property**	Passive Cooling/Heating during storage can be identified in losses / efficiency / quality. Active Cooling/Heating is a property of "Prepare H2". Heat is also identified as a by-product of Prepare H2 if used	Yes	No	No	No
169	AT: Contested use case for storage assets, particularly geological, but also hydrocarbon assest like tanks etc.	**Arup**	**Store**		**No**	**Example**	Storage types added - underground and containers because they are likely to be managed differently	Yes	No	No	Yes
170	AT: Possibly better to define end use, not end user (Stakeholder) - Space heating, process heating, feedstock, logistics	**Arup**	**Use**		**No**	**Element**	Changed Use elements to: Heating (space heating and domestic appliances), Mobility, Industry and Electricity generation.	No	No	No	No
171	SK: localised district heat / power networks and storage	**Pembrokeshire County Council**	**Store**		**Yes**	**Example Element**	Localised district heat / power networks are included in the "Use H2" use case.	Yes	No	No	Yes
172	KC: Green methanol to marine for IMO2030/2050 compliance	**CREAS**	**Use**		**No**	**Example**	Interesting example: Depending on the scenario, this can be seen either as: - hydrogen for mobility for the green production as methanol as a fuel for marine applications. - or hydrogen for industry as a feedstock to produce methanol for marine and other applications.	No	No	No	No

Ref	Comment	Org.	Element	Use Case (if specific)	Diagram Modified	Category	Response	Hydrogen Energy Architecture, Properties and Interactions	National Hydrogen Market, Policy and Regulation	Local Hydrogen Market and Commercial Interactions	MH:EK
173	SK: The ideal scenario for transport has to be green hydrogen production, storage & use at the transport nodes/hubs -road, rail, shipping	**Pembrokeshire County Council**	**Use**		**No**	**Example**	The architecture should fit any scenario to find a pathway to the ideal one for the application.	No	No	No	Yes
174	BS: use H2 to decarbonise Pembroke Port. I understand the svitzer jetty doesn't have an electric line and so uses a diesel generator for auxillary electric.	**Marine Energy Test Area (META)**	**Use**		**Yes**	**Example**	**Produce Electricity** H2 generators to replace diesel generator at local level Portable H2 reactor	Yes	No	Yes	Yes
175	KC: Seasonal variation of storage volumes - supply and demand	**CREAS**	**Store**	**Balance H2 System**	**No**	**Example**	"Balance H2 System" will be part of the Control H2 System use case. One scenario can be balancing the system (national to local) for seasonal supply/demand variations depending on H2 end use.	Yes	Yes	Yes	Yes
176	KC: Overall digital system to control production, storage considering offtake forecasts (and seasonality of renewable power generation). Use of AI to support management and demand forecasting. See Imubit.com	**CREAS**	**Store**	**Balance H2 System**	**No**	**Information Control**	"Balance H2 System" will be part of the Control H2 System use case. Information flows will be detailed.	Yes	No	Yes	Yes
177	AT: Usage of marine vessels as storage during import phase.	**Arup**	**Store**		**No**	**Import / Export**	Discuss	Yes	Yes	Yes	Yes

Ref	Comment	Org.	Element	Use Case (if specific)	Diagram Modified	Category	Response	Hydrogen Energy Architecture, Properties and Interactions	National Hydrogen Market, Policy and Regulation	Local Hydrogen Market and Commercial Interactions	MH:EK
178	AT: Potential green and blue CfD (Contracts for Difference) in upcoming Energy White Paper?	**Arup**	**Use**	**Pay for H2 Usage**	**No**	**Market**	CfD will play an important role in the development of the H2 market. The comment will be passed to the national and local market work packages.	No	Yes	Yes	Yes
179	AT: Lead time from dispatch request to physical dispatch	**Arup**	**Store**	**Request Dispatch**	**No**	**Control**	Property added to all request functions: Lead time	Yes	No	No	No
180	TJ: Viable business models need to be in place to realise hydrogen projects	**RWE**	**Use**	**Pay for H2 Usage**	**No**	**Market**	Absolutely, the market analysis will support the development of business models. The comment will be passed to the national and local market work packages.	No	Yes	Yes	Yes

National Market Analysis

Question Number	Question	Comment	Reference (see cross analysis table)	Response
1	How could the operation and retail arrangements of a pure hydrogen system differ from that of the gas system? • Production • Transport • Storage • Use	KC: Using blockchain to differentiate hydrogen sources (green, blue, etc). CREAS has already developed a blockchain certificate of green origin application VerifHy	1	X
1		KC: Regulatory limitations regarding maximum hydrogen content, CV, Wobbe Index need to be reformulated to enable higher hydrogen consumption	2	X
1		BD: Regulation to control quality across different H sources & storage	3	X
1		JG: How pure is 'pure'? Some end users (e.g. FCEV market) will push for 99.9% PSA hydrogen. Some producers may argue that methanator rather than PSA is less wasteful, but purity would be lower.	4	X
1		KC: Applicability/conversion of domestic heating systems to enable pure hydrogen usage	5	X
1		DW: Useful to look at analogies in today's global crude oil market, as the global green H2 market might resemble that, more than the global NG/LNG market	6	X
1		EK: production - shift in local vs central sources. transport - multiple options pipes, tubes, rail complicates vs just pipes at moment. Storage - more difficulty for h2 rather than natural gas plus added CUS issues. Use - more options available than natural gas so potential for growth of market and new entrants	7	X
1		TB: Opportunity to prioritise different 'types' of hydrogen and also the location it is produced. For example, we can design markets that favour local production as opposed to international production	8	X

Question Number	Question	Comment	Reference (see cross analysis table)	Response
1		RC It is likely the users on a grid will be larger business users at least for the forseeable future so direct retail to consumers with point of sale distribution and transactions will not be required. This would allow a transition phase where consumers are controlled by contracts and H2 transefer and end use can be more easily controlled.	9	X
1		JG: ...and process safety issues of putting hydrogen in people's homes.	10	X
1		TB: Tax implications of hydrogen and amonia shipping internationally and the role of freeports in reducing tax exposure for processing	11	X
1		TJ: Big question for blending into the Gas Network is "Who's pays?" - needs careful consideration as not to overburden end-consumer	12	X
1		KC: Hydrogen may be shipped in different forms (liquid, gas, LOHC) or as another compound (eg.- ammonia) depending on distribution vectors and relative costs	13	X
1		TJ: As hydrogen is a high energy density but low volume density gas, the current volumetric metering is an issue	14	X
1		RS: Transport: ADR regulations severely impact the costs of high pressure transport solutions that will only be negated when significant scale is achieved	15	X
1		RS: Generation preferable at point of demand to reduce transportation needs.	16	X
1		NP: Need to consider how costs of new dedicated infrastructure is covered, is this a roll for central government instead of cost being passed on to end users?	17	X
1		SK: Localised production and or national/inernational H storage hubs adjacent to national gas grid injection points so Milford Haven and Baglan both fit with this	18	X
2	What specific commercial and operational consideration are there for a blended hydrogen grid? • Production • Transport • Storage • Use	DM: What does this mean for siting storage? The implication is that you need bespoke H2 pipes for this so colocation is key, but the best storage sites aren't necessarily near the best production / import sites	19	X

Question Number	Question	Comment	Reference (see cross analysis table)	Response
2		RC H2 Direct end users as chemically pure are limited in number so the production and storage could potentially be co-located.	20	X
2		TJ: Storage is a commercial opportunity (buy low, sell high) therefore Trading opportunities should be facilitated (i.e. either private owned storage or storage auctioned off to trading companies)	21	X
2		TJ: Hydrogen should be stored pure (not as a blend) as it can then have direct use off-takers	22	X
2		NP: H2 producers could monitor composition of blend local to them and regulate production based on difference from target blend and flow rates.	23	X
2		TJ: Hydrogen is best blended at LNG Import Terminals (large volumes, entry point), which makes MH:EK as ideal place for blending with 2 LNG Terminals & good location for green hydrogen (from offshore floating wind) & blue hydrogen (linked into to the South wales Industrial Cluster CCS)	24	X
2		TJ: Hydrogen should be able to be traded across the network (even if physical delivery isn't possible) in the same way as biomethane is, this can be done e.g. through Guarantee of Origin Certificates	25	X
2		KC: How to track hydrogen content in "real time" to enable end users to account for GHG emissions or to adjust heat content?	26	X
2		KC: Potential conversion of existing LNG import and storage facilities to LH2 as a means for hydrogen content control in the blended grid	27	X
2		TJ: Daniel - I acknowledge the point. Hydrogen storage is expensive (whether salt cavern or otherwise) & if you look at the salt caverns in the UK, they are actually very small if you are looking to (e.g.) time-shift green hydrogen when there is over-production. Therefore storage is going to be a premium & whereas you can schedule imported natural gas when it is required, you want to produce green hydrogen when it is cheap (over-supply of renewable power) & use it when required (high gas demand times). Therefore using salt caverns to store natural gas is an "economic waste" & should be reserved for hydrogen. It is unfortunate that there isn't any storage around MH:EK...	28	X
2		NP: Could work similar to frequency response in power generation. Producers will be dispatched to produce a certain amount of H2, which would then be modulated if there is an excess or deficit in their area. Users will be compensated for providing the service.	29	X

Question Number	Question	Comment	Reference (see cross analysis table)	Response
2		KC: How to avoid the price of hydrogen blended into a mixed gas network falling to the gas price	30	X
2		EK: production: uncertainty of what blending might be affecting production opportunities. Transport - issues over gap of compartor to existing vehicles and chicken and egg for demand and supply. Storage: how fits in business model depending on blended mix. Use: blending may not have wide ranging uses if not suitable for fuels for transport	31	X
2		JG: Accounting for calorific value differences as hydrogen content increases.	32	X
2		TB: End user application must be carefully considered which is tricky as this is likely to be an interim measure on road to pure hydrogen.	33	X
2		TJ: some sensitive end-users (e.g. power stations) need to be considered when upper blend limits are set (deblending is expensive)	34	X
2		NP: Need to consider the fiscal metering of blends based on composition (H2%) to ensure end users are correctly billed.	35	X
2		TJ: Blend limits need to be carefully managed to ensure end-user / pipeline system compatibiity	36	X
2		JG: Short-term changes in composition would need to be managed. e.g. if a large hydrogen producer trips unexpectedly, the gas quality will change suddenly. Systems will need to be in place to ensure consumers (industrial and domestic) can cope with this.	37	X
2		JG: Increasing H2 content will increase NOx emissions from combustion in existing equipment. Trade-off between local and global environmental concerns.	38	X
2		JG: It won't be possible to move the same amount of energy through the existing pipeline network as the hydrogen content increases.	39	X
2		EK: Gov need to introduce ability for counterfactual to equivalent renewable source rather than natural gas?	40	X
2		JG: Rate of increase in hydrogen content will be limited by the slowest adapting consumer. Could one consumer with particular transition issues halt progress?	41	X
2		RS: Consider purification at point of demand for hydrogen delivered through the grid, to reduce road/other transport of high purity hydrogen	42	X

Question Number	Question	Comment	Reference (see cross analysis table)	Response
2		TB: Is there any opportunity for very local blending. Even at a business or homeowner level? A bit like we have LPG tanks for domestic heating, could we have incentives for end users to buy in bottled hydrogen and blend on site? This also fits with the push by the likes of Enaptor for local small scale electrolysis which could be at community or business estate scale.	43	X
2		It should be considered how to notify customers that the fuel they are using is partially sourced from low/zero carbon technologies.	44	X
2		RC H2 grid will have to be a national operator in the model of National Grid to control infrastructure safety and act as the gateway to grid connection	45	X
2		DM how would dispatch of h2 sources work?	46	X
2		KS: Important to consider the calorific value of the blended gas so that customer pays a fair amount, prices may need to vary as the hydrogen content in the blended gas varuies	47	X
2		TJ: Grid equipment (e.g. valves, compressors) need to be taken into consideration	48	X
2		KB: Do we know who may be reluctant to adapt/adopt? I am aware of issues with glass production, for example, as H2 blend can affect manufacturing processes that have been refined over tens of years	49	X
2		DM what physical issue limits the pressure first?	50	x
2		DM: How might this work commercially? I want to sell as much as possible, if I'm last in the chain I might never get to put my H2 onto the system	51	x
2		RC I think the input would have to be metered and tariff determined by purity. Output would be the same.	52	X
2		SK: Completely agree with this comment by TJ	53	ignored as will be caputred with whichever comment SK agreed with

Question Number	Question	Comment	Reference (see cross analysis table)	Response
3	During the transition to hydrogen, how could these arrangements develop? What would they need to consider? (i.e. some local markets on pure H2, others on gas and some possibly being decommissioned)	KC: Ability to segregate the national/local gas networks into no H2 / blended H2 systems. How to manage this commercially without disadvantaging certain consumers on price	54	x
3		KC: Industrial consumers onsite hydrogen storage and supply of LH2 (or other form of hydrogen) by road	55	x
3		KC: Supply of LH2 by road to remote locations to displace diesel heating	56	x
3		RS: Transport usage: With regards the dispensing of hydrogen to private and commercial transport users there are plenty of issues surrounding H&S and co-location of solutions at traditional transport refueling locations. Current sites may not be deemed suitable for hydrogen dispensation and newly acquired sites may be required, adding to up-front costs	57	x
3		TJ: Sensitive end-users need to be carefully considered, as if they cannot take the hydrogen/natural gas blend in the grid then they will have to deblend & this is expensive & will effect the cost of production of their end product (this is particularly important when considering companies who operate on a world market)	58	x
3		DW: Nailing the question of whether the NTS pipes can go to 100% H2 is critical and urgent.	59	x
3		EK: studies and trials to help with learning and understanding implications. Look at design and concepts of place-based hydrogen hubs and how integrate within the mix. Issues over blue versus green continues with no clear answers	60	trials - not a deliverable blue versus green captured in ref3
3		EK: new entrants coming into the market so need to capture their thoughts and opportunities	61	procedural issue rather than architecture
3		KS: hydrogen islands to act as a testing ground for regulation and market control before stepping up to national scale	62	x
3		TB: Acknowledge that end user choice on available fuel might be limited to their location. Some market arrangements or subsidies to support higher cost arrangements to level the playing field.	63	x

Question Number	Question	Comment	Reference (see cross analysis table)	Response
3		A review of what infrastructure updates will be necessary e.g. Do boilers have to be replaced	64	procedural issue rather than architecture
3		KB: Do we know who these end users are?	65	procedural issue rather than architecture
3		RS: Transport sector: Hydrogen management and dispensation regulations are still evolving in the road transport sector. Rail and Aviation sectors have yet to be tackled and are likely to be more onerous. Work needs to start now to ensure these sectors are ready to go and that wherever possible a consistency of regulatory standards are maintained across the various sectors	66	x
3		NP: During transition likely to see increasing proportion of H2 in the NTS, sensitive users will need to deblend or close, compensation arrangements may be needed for these users.	67	x
3		SK: Pembrokeshire gas network is 80% hydrogen ready in terms of the distribution system. Oliver Lancaster at WWU can confirm. So as a transition this is a great place to start!	68	x
4	How can investment come forwards as the hydrogen economy develops? • What is needed from Gov? • What is needed from industry? • How can projects evolve to be suited to investment.	DW: Interim/transitional business models, e.g. road transport of pure H2, prior to a pipeline switchover, should be able to attract funding. The energy markets have many examples of failed bets based on short time horizons, but the investors keep turning up.	69	x
4		TJ: The BEIS work on Hydrogen Production Business Models is progressing well but there is still a lot of work required (the devil is in the detail!). Demand side also needs incentivising - even current grey hydrogen users need to see the benefit (so companies are not yet on the "we need to decarbonise to survive page" yet.	70	note - not requirement
4		KC: Carbon emissions limitations for large scale consumers should drive decarbonisation and boost hydorgen demand	71	x
4		KC: Standards for home building in terms of thermal efficiency and heating systems	72	x
4		KC: Carbon pricing policy needed to incentivise the growth of hydrogen economy	73	x
4		EK: In Wales we're developing a hydrogen pathway via the Welsh Hydrogen Reference Group and happy to share - covers opportunities for demand, production and cross fertilisation actions	74	comment - not requirement

Question Number	Question	Comment	Reference (see cross analysis table)	Response
4		JG: Classic chicken and egg problem. Who would invest in production if there are no consumers? Why would a consumer invest in conversion while there is no production? Who would invest in storage while there is no production or demand? Co-ordinating all this will be difficult with a complex system. Would it be easier to get going with a single producer / single consumer model and develop from there?	75	procedural issue rather than architecture
4		KS: need UK hydrogen roadmap, incentives for small scale projects, bulding up scale. Financial incentivisation is key either through enabling grants / loans and a carbon price that truely reflects the need for clean energy	76	x
4		RC - Gov need to mandate to create demand, this will be based on carbon price and legislation would need to be put in place to prevent carbon offshoring of emissions, possibly by a tax on embedded carbon for imported products. This could work but would put UK at a competivive disadvantage as the whole system would work as an overhead drag, unfortunately requiring international co-operation and legislative alignment.	77	x
4		RC - as long as emissions permits are given away for large emitters, the incentive for using hydrogen to displace natural gas for heating will not exist. If permits are not given away then the large industrial sites may close and move to low permit cost areas leading to large numbers out of work, which is politically unacceptable.	78	x
4		EK: Investment needs to see the way to commercial market to invest. Helped with surety of gov strategic direction, potential commitment of demand, orders showing demand and general emerging of market and potential trading opportunities	79	procedural issue rather than architecture
4		RS: Transport/high purity: Significant govt or private investment in high volume production plants is required. There are plenty of private equity firms sniffing around this sector but few business models that deliver returns within a 10 year period, if it assumed that low/competitive price at the pump is critical to generate the customer demand	80	x
4		EK: help with differentials of costs to bring forward transport solutions to create demand	81	x

Question Number	Question	Comment	Reference (see cross analysis table)	Response
4		EK: Industry seem willing to come in on supply side if can guarantee demand as business models then can stack up	82	comment - not requirement
4		JG: Government needs to incentivise hydrogen rather than penalise fossil fuels. Otherwise we will offshore our emissions rather than eliminate them.	83	x
4		JG: Is there an analogy with long-term strike prices offered to nuclear and renewables? i.e. guaranteed minimum hydrogen price to incentivise investment in production.	84	x
4		TB: Community ownership of H2 production can be linked to demand creating energy clubs	85	x
4		TJ: Initial business models will be through bilateral contrasts (i.e. off-taker contracts with producer in relatively long term contract) until low carbon hydrogen markets & distribution networks are created. Companies will create projects Gov. incentives are in place.	86	x
4		TJ: the initial markets to be incentivised should be the sectors where the incumbent fuel is as comparable in terms of cost (both to produce & cost of conversion / new technology required) to hydrogen as possible, e.g. road transport (but mainly due to tax!), industry where hydrogen is a premium input	87	procedural issue rather than architecture
4		TJ: this is the imitial recommendations to Gov., see: https://www.gov.uk/government/publications/business-models-for-low-carbon-hydrogen-production	88	comment - not requirement
4		SK: UK Govt hydrogen strategy needed asap to give investor confidence and market stimulation. This is imminent in early 2021	89	procedural issue rather than architecture
5	Where should market arrangements consider carbon intensity?	EK: important for any decision to ensure comparator across renewables in carbon calculations to avoid apples and pears occurring. For instance EV infrastructure calculations may not take account of impact on electricity network costs whereas for hydrogen you may include all refuelling costs and in doing so impact on decision makers adversely. Also standards. likely to have higher standards for hydrogen than electric and therefore more costly but again need to be comparator introduced in assumption and calculations across the baord	90	(Core feature of a functioning market for sure) comment - not requirement

Question Number	Question	Comment	Reference (see cross analysis table)	Response
5		KC: Blockchain certificate generators attached to export meters at hydrogen generation facilities will enable 'system' wide tracking of hydrogen content. Should be possible to calculate hydrogen content within the system (whole network, or segregated part of the network) in real-time. Supplement by hydrogen content measurements at key sample points across the system to facilitate reconciliation	91	x
5		DW: Retail-level green H2 certificates, similar to green electricity, would coordinate the market from end-use to production. Other countries are likely to go down that route, because of simplicity for policy makers and public.	92	x
5		RS: Current RTFO/RTFC incentives are convoluted and make little sense. Incentive is provided at the pump for usage of cleaner source hydrogen rather than at point of production. The industry would benefit enormously from shifting the financial incentives to production and would deliver a mechanism that would be much easier to regulate.	93	comment - not requirement
5		KC: National carbon price applied should reflect the cost/type of hydrogen production at each location	94	x
5		TJ: Guarantees of Origin Certificates allow companies to "green" their gas (in the same way as green electricity) without direct connection to the physical source and are therefore essential if you want to create a low carbon hydrogen market in early deployment phases	95	x
5		KS: carbon intensity should be as real time as possible so that the consumer has a true understanding of energy use. This is key when using hydrogen as energy vector due to variability of source, potential to mix, etc. Agree with above, blockchain could well be the answer to this	96	x
5		TJ: RS - I agree but also needs demand side incentives too - what is in place to incentivise HGV s fleet operators to convert to hydrogen?	97	x
5		JG: Carbon accounting needs to consider the real overall impact. i.e. turning on an electrolyser doesn't make the wind blow harder - the incremental electricity production will be burning gas, at least for the medium term.	98	x
6	Are the current roles in the energy industry codes sufficient? Where will there need to be changes?	H2 trading?	99	x

Question Number	Question	Comment	Reference (see cross analysis table)	Response
6		H2 system operator?	100	x
6		H2 retailers?	101	x
6		DW: Combine regulated gas and electricity entities, into regulated energy service entities. Big Bang change! We've done it before.	102	x
6		EK: not sure of impact as current retailers more financial rather than physical interactions.	103	comment - not requirement
6		KC: Impact on water demand and regulations in the event of large scale electrolysis facilities - esp assurance of the right volumes and quality of water for the electrolysis to run	104	x
6		NP: When green H2 from renewables predominates, what happens on low wind days, shortfall on electricity, H2 production goes down, gas peaking plants ramp up, more demand on gas grid, who is responsible for balancing the blend? Will we need a capacity market for blue H2?	105	x
6		EK: hydrogen help balancing needs so gas and electric regulations need to combine for hydrogen	106	procedural issue rather than architecture
6		KS: cross vector regulations on costs - price per kWh regulated regardless as to if this has been sold as electricity, hydrogen or heat	107	x
6		EK: As with financial markets need set up national and local trading markets so that local and national sources of hydrogen can be considered e.g. SMR likely to be national whereas electrolysis more likely to be local. Similar FTSE and AIM markets allowing new entrants with less rigidity	108	procedural issue rather than architecture
6		KS: potentially further roles around system safety	109	x
6		EK: Might be new role for hydrogen system operator abridging gas/electric operations	110	x
7	How could the development of the UK system interact with the international system?	KC: Link to growing hydrogen economy in Germany - they will be short of hydrogen so are looking to Morocco for green hydrogen. Maybe MH offshore wind-derivedexport hydrogen (or ammonia) could be more cost effective logistically. MH has a strong heritage in the international markets as an energy hub (plus deep water port enables larger cargoes)	111	x
7		DM: Carbon pricing and links to international markets so we don't disadvantage UK	112	x
7		TB:Domestic H2 production could be basis of supply of CO2 to international customers/ or those with storage facilities!	113	x

Question Number	Question	Comment	Reference (see cross analysis table)	Response
7		KS; potential for international load balancing, MH imports from Morocco when resource is low exports elsewhere when high. considered as an internal "energy island" but also a node as part of a bigger picture	114	procedural issue rather than architecture
7		KC: Difficult to tap into the Asian growing markets from logistics cost standpoint and lower cost green hydrogen producers neaer (eg. Australia), so international export markets are more likely to be Europe	115	comment - not requirement
7		RC - The electrical interconnectors could conceivably be used as a porxy to transfer renewable hydrogen as electricity to and from europe.	116	x
7		KC: Tokyo Gas are already importing ammonia to displace coal fired power gen - tested at up to 20% ammonia in one station, planning to refit to 20% across all coal fired plants and then expand to 50%. If they achieve this, they will need to buy all the freely traded ammonia globally, so ammonia production (green and blue) could be a major opportunity for the UK on a global basis - and logistics facilities, safety issues are well known, and vessels already exist.	117	x
7		RC - There is a vital role in activism and popular opinion to facilite the development of an H2 economy to force politicians to the table to agree these critical international arrangements, so advocacy and education may prove to be as important as technical capability and access to finance.	118	comment - not requirement
7		JG: UK exports natural gas through pipelines to Ireland, Belgium, Holland, IoM. Adding H2 to our existing gas grid will affect these markets too.	119	x
7		TJ: Hydrogen is relatively expensive to transport, so initially supply will be local then national. Eventually, hydrogen will be produced in the cheapest possible place (i.e. areas of high renewable availability) but there is quite a way to go yet... With the UK's potential for offshore wind, it makes most sense for us to produce hydrogen domestically & that gives us a security of supply for hydrogen.	120	x
7		TB: Production of blue hydrogen in run up to all green hydrogen future ensures future for LNG shipping and therefore medium term dependancy on international markets	121	comment - not requirement
		FROM LEM workshop1 Export		

Question Number	Question	Comment	Reference (see cross analysis table)	Response
		SK: UK Govt should invest in national infrastructure projects to alleviate elec grid constraints that exisit in Pembs and also for switch to Hydroigen ready gas grid; Local public bodies to invest in H fuelled transport via localised green H production and fleet upgrades - pending proof of business case; If Government mandate H ready boilers /hybrid systems this will drive all new and retrofit projects to install the kit	122	
		HD - Investment must be pump primed by Gov at the outset in conjunction with the private sector. Models could include product innovation support, calls for implementation at scale, CFD / revenue support, alignment with industrial decarb support, eg BEIS Industrial Energy Transformation Fund etc etc		
		IS: investment will be dependant on which element is being funded. For example the electrolysers could be funded (almost) tomorrow (dependant on RoI, clients etc). Generic Infrastructure is a different issue and will need a PPP approach I suggest. THerefore, I would segment the proposed strategy and develop individual investment plans to suit.		
		EK: gas network blend up to 20% beyond that apparently only 100%?		
		EK: Also European storage prospects		
		AT: Need to consider different phases of maturity, including the pathway to a fuller market. Initially trucking LH2, but later piping GH2 for example. Think of 'energy chain' from primary energy to end use - some links work (green), others need support/incentive (red).		
		Bw: is storage being considered for daily profiles, seasonal and / or security of supply?		
		PC - Storage is v expensive, How can MHEK create cost-effective storage?		
		AT: Is the market structure future proof or does it just work for the current relatively modest level of trading. Is it 'scale-ready'.		
		Helen D - great potential to consider waste heat within the Haven		
		KS converse to fuel poverty point is also true, new energy vector and associated higher p/kWh could be seen as unfair to those struggling to afford to heat their homes, mechanisms to support those in need and to regulate heat costs required to overcome this barrier		

Question Number	Question	Comment	Reference (see cross analysis table)	Response
		SC: Different hydrogen standards - e.g. Fuel cell purity can have price premium		
		SC - fuel cell standard is very stringent, this level of purity is not required for e.g. boilers. Higher cost to meet purity standard (easier from electrolysis) https://www.npl.co.uk/products-services/environmental/hydrogen-purity-for-fuel-cell-vehicles		
		AT: consideration of potential CfD for blue / green hydrogen		
		BD: Proxy also for wider benefits e.g. tackling fuel poverty or air quality.		
		AT - Need to establish proxies for non-monetised value - security of supply, resilience, decarbonisation etc which are not currently reflected.		
		NP: Need to consider if local distribution fixed infrastructure is to be developed how this will be funded and who will operate it?		
		KS - UKCCC report highlights poor CCS potential in SW, need to consider transporting CO2 waste		
		BD: Water - need to consider commercial / regulatory / technical infrastructure (input & output)		
		HD - investment in infrastructure is required		
		AT: To what extent is there a 'transmission' level market and a 'distribution' market or 'Local market' - Does the scale of one over the other impact segregation of the two?		
		Helen D - definitely export opportunities to Ireland aligned to offshore renewable energy deployment		
		SK: It would be advantageous if the area can get some sort of rapid consenting regime from NRW/Crown Estate for offshore renewables		
		BW: is security of supply and liabilities for it considered here? I.e who carries out residual balancing and manages imbalances / supply emergencies in the event commercial mechanisms fail		
		AT: Think about origin certification - How green is your hydrogen.		
		SK: large public sector organsiations will consider zero emissions Power/Heat Purchase Agreements's very readily given that all public sector in Wales are bound by WGs 2030 net zero carbon target. The public secor (along with the fossil fuel sector) is the dominant employer in the region.		

Question Number	Question	Comment	Reference (see cross analysis table)	Response
		AT: Need to consider system costs (eg: storage for security), also competing vector situation (eg: green taxation/levy on natural gas as well as electricity.		
		AT: Need certainty of supply underwritten. Contracted oblications need to be underwritten/assured. Particularly important if hydrogen is the only vector. into an end user.		
		SK: Bluesky - I'd like to be able to buy my renewable energy needs just like I can buy anything else online. I'll have 14,000 kWh's of hydrogen backed heat and 3500 kWH of electricity from offshore wind at the press of a button.		
		BW: Potential products: exit and entry capacity to a network (access to customers), hydrogen - secure supply versus flexible services / offerings, heat, storage services,		
		BW: operating signals include: max / min requirements (long term), planned usage (shorter term),		
		Consideration for interactions between system operation functions versus a whole system operator		
		KS - need thought as to how storage losses impact costs to the end user - who pays for this?		

National Market Cross Analysis

Ref	Function	Sub-function	Notes	Reference from focus groups
1	Production	Identification of source (including for trading)	Blockchain? Certificates of origin	1, 25, 91, 92, 95
2	Production	Aspects of production - how to value different properties	including local 'vs' national	8, 16
3	Production	type	green / Blue etc	7, 60
4	Production	co-location near demand	transport cost minimisation?	18, 20
5	Blending	%age limits	limits on rate of change too (e.g. if a producer trips)	2, 37
6	Blending	quality / purity control		3, 4
7	Blending	who adds how much?		23
8	Blending	How decentralised is blending?		24, 43
9	Blending	%age measurement	e.g. for tracking carbon intensity (marginal not average)	26, 36, 44, 96, 98
10	Usage	General	moves at the pace of slowest to convert	41
11	Usage	Deblending		58
12	Usage	Cleaning / preparing / purification		42
13	Usage	Domestic (combustion)	replacing heating diesel at remote sites (link to transport decarbonisation)	5, 31, 56
14	Usage	Domestic (fuel cells)		31
15	Usage	Industrial (combustion)		34
16	Usage	Industrial (chemical feedstock)	sensitive production e.g. glass	34, 49
17	Usage	Industrial (fuel cells)		34
18	Usage	Synthetic fuels		
19	Usage	Safety		10, 57, 66
20	Distribution	Pressurising		
21	Distribution	depressurising		

Ref	Function	Sub-function	Notes	Reference from focus groups
22	Distribution	Pipes (dedicated vs blend)		9, 68
23	Distribution	Containerised / limits to pressure		9, 15
24	Distribution	LHOC / ammonia / H2 (gas or liquid) - what form?		13, 117
25	Distribution	density by volume challenges		39
26	Distribution	NTS 100% H2 capability		59
27	Distribution	impact on exports through connections to Europe etc.		119
28	Storage	Blend 'vs' H2	note: unneccessary expense to store natural gas	19, 22, 28
29	Storage	Purity		3
30	Storage	Business models	(national infrastructure or commercial opportunities?	21
31	Storage	short vs long term	e.g. salt caverns	28
32	Storage	local vs centralised		55
33	Operation	Billing / Metering		14, 32, 35, 47, 52
34	Operation	Dispatch of electrolysers to compliment electricity system		31
35	Operation	Supporting electricity peaking plant		
36	Operation	control access of gas onto system	system operator?	45, 46, 51
37	Operation	Limits on pressure / flow speed		50
38	Finance	Value of flexibility		
39	Finance	What model for trading? E.g. like the crude oil market?		6
40	Finance	taxation / fuel duty (As it is derived from electricity)		11
41	Finance	freeports		11
42	Finance	H2 is less valuable but more expensive to the consumer - who should pay?		12

Ref	Function	Sub-function	Notes	Reference from focus groups
43	Finance	Who pays for infrastructure such as networks and generation	capacity market?	17
44	Finance	repurposing existing infrastructure to avoid stranded assets		29
45	Finance	how to trade H2 in gas pipes, not at the gas price	could all kWh be equal	30, 107
46	Finance	carbon tax / emissions permits on natural gas?		40, 78
47	Finance	socialising costs to supply remote areas		63
48	Finance	socialisng costs of replacement equipment?		64
49	Finance	Compensation requirements for those who can't adapt?		67
50	Finance	Incentives / disincentives to industrial players		71, 76, 80
51	Finance	demand side incentives	closing the differential between other energy vectors	77, 81, 97
52	Finance	Carbon pricing policy needed	incentivise H2 rather than penalise gas to avoid offshoring	73, 83, 94, 112
53	Finance	CfDs for H2?	like offshore and nuclear	84
54	Finance	what can happen with respect to community financing?	does this need to be separate from any other investor?	85
55	Finance	exports?		111
56	Timing	Important to note that the first solutions may not be the final ones e.g. start with direct sales using tankers and then progress to pipes		33, 69, 86, 120
57	Timing	Geographical segregation to tranistion some areas at a time		54, 62
58	Consequences	NOx increases in blending without nozzle modifications		38

Ref	Function	Sub-function	Notes	Reference from focus groups
59	Consequences	cost to make available might not be the same in all areas		
60	Consequences	improved insulation to reduce energy demand		72
61	Consequences	water usage		104
62	Consequences	Captured CO2 impact?		113
63	Roles	trading organisations?		99
64	Roles	systems operator		100, 110
65	Roles	how my retail work?	integration of energy companies rather than separate gas/elec	101, 102
66	Roles	balancing	low wind days means less elec/h2 and more demand for peaking plant (burning H2)	103
67	Roles	safety	regulation?	109
68	physical system	all control and conditioning equipment		48
69	physical system	links with electricity		116

Local Markets Needs and Analysis

Question Number	Question	Comment	Organisation	Reference	Physical, Control and Interop	Local Energy Market	LEM included	National Energy Market, Policy and Regulation	Need?	Comments
1, 2, 3	Questions (please add comments on the relevant part of the diagram): 1. Are there any other elements which are missing? 2. What assets/companies in the local area do you think could evolve into these elements? Which elements do you think would require new assets/companies and how can you imagine them fitting into the local system? 3. How could investment come forwards for these different elements?	SK: UK Govt should invest in national infrastructure projects to alleviate elec grid constraints that exisit in Pembs and also for switch to Hydroigen ready gas grid; Local public bodies to invest in H fuelled transport via localised green H production and fleet upgrades - pending proof of business case; If Government mandate H ready boilers /hybrid systems this will drive all new and retrofit projects to install the kit	Pembrokeshire County Council	1	Y	Y	x	Y	Y	Potential needs for all three areas covering: Provide system assets Support infrastructure investment
1, 2, 3		AW - Pembrokeshire College - Investment - As mentioned in the presentation (training), there is a need to invest in building the workforce of the future. There is a need to ensure existing training across the region gives young people (local to the area) the necessary skills and knowledge to work in any of the emerging energy sectors (Oil, Gas, Wind, Tidal, Hydrogen etc). This would ideally be across all the levels, craft level courses through to university degrees.	Pembrokeshire County Council	2	Y	N	x	N	N	Training is an Enabling System to provide the 1..* "Person" with the necessary "Competency" to fulful a defined "Stakeholder Role". Should probably add to to a SoS-level SIV diagram
1, 2, 3		HD - Investment must be pump primed by Gov at the outset in conjunction with the private sector. Models could include product innovation support, calls for implementation at scale, CFD / revenue support, alignment with industrial decarb support, eg BEIS Industrial Energy Transformation Fund etc etc	Regional Development Wales	3	N	Y	x	Y	Y	Potential needs for investment types listed

Question Number	Question	Comment	Organisation	Reference	Physical, Control and Interop	Local Energy Market	LEM included	National Energy Market, Policy and Regulation	Need?	Comments
1, 2, 3		IS: investment will be dependant on which element is being funded. For example the electrolysers could be funded (almost) tomorrow (dependant on RoI, clients etc). Generic Infrastructure is a different issue and will need a PPP approach I suggest. THerefore, I would segment the proposed strategy and develop individual investment plans to suit.	Sea Wind Technology	4	N	Y	x	Y	Y	Potential need for individual investment strategies depending on asset type
1, 2, 3		EK: gas network blend up to 20% beyond that apparently only 100%?	Welsh Government	5	Y	Y	x	Y	Y	Potential needs for supporting/enabling blends of hydrogen at defined percentages (1-99%)
1, 2, 3		EK: Also European storage prospects	Welsh Government	6	Y	N		Y	Y	Potential need for interoperability with EU electricity/gas/hydrogen networks/markets?
1, 2, 3		AT: Need to consider different phases of maturity, including the pathway to a fuller market. Initially trucking LH2, but later piping GH2 for example. Think of 'energy chain' from primary energy to end use - some links work (green), others need support/incentive (red).	Arup	7	Y	Y	x	Y	N	Maturity/implementation scenarios/pathways need to be considered to ensure completeness in the LES/market design
1, 2, 3		BW: I attended a national grid future markets session yesterday and they were asking what other projects were looking at hydrogen markets, I've mentioned this one so they may be in touch. Are you involved in the national grid one already?	Wales and West Utilities	8	N	N		N	N	Information only
1, 2, 3		KS - Arup is involved in both MH:EK and NG2050 and can act as an interlink between these projects	Arup	9	N	N		N	N	Information only
1, 2, 3		KK - Benefits of converting green hydrogen to LOHC are that it can be transported at ambient pressure and temperature by ship or road tanker to industrial users or refuelling stations. This is particularly advantageous if industry has conventional oil storage facilities and if they have waste heat available to unlock the h2 from the LOHC. This could enable Milford Haven to be a hydrogen hub tha can export H2 to the rest of wales and the uk i	ERM	10	Y	N		N	Y	Potential need for LES to connect to local LOHC system and process LOHC

Question Number	Question	Comment	Organisation	Reference	Physical, Control and Interop	Local Energy Market	LEM included	National Energy Market, Policy and Regulation	Need?	Comments
1, 2, 3		Bw: is storage being considered for daily profiles, seasonal and / or security of supply?	Wales and West Utilities	11	Y	Y	x	Y	Y	Potential needs for different types of storage and/or their business models/market arrangements
1, 2, 3		AT: SMR, ATR, ATR+GHR, POx all have different characteristics and by-products eg: Nitrogen from ASU. Some exopthermic, some endothermic.	Arup	12	Y	Y	x	N	Y	Potential needs for H2 production types; plus handling/processing/trading/uses of by-products
1, 2, 3		Kev Ball - This relates to another comment under use: building/heat. Maybe an opportunity there?	ESC	13	N	N		N	N	Comment only
1, 2, 3		PC - Storage is v expensive, How can MHEK create cost-effective storage?	RWE	14	N	Y	x	Y	Y	Potential need for enabling storage
1, 2, 3		EK: Bus model likely to need whole system benefits	Welsh Government	15	N	N		N	N	Comment only
1, 2, 3		KK - Green hydrogen produced from offshore wind (using ERM Dolphyn) will have high purity and will be brought directly ashore via a hydrogen pipeline. This can therefore be used directly for transport applications (i.e. hydrogen buses, trucks, trains and marine vessels). If converted to LOHC can be trasported to hydrogen vehicle refuelling stations outside of Milford Haven	ERM	16	Y	Y	specific application	N	Y	Potential needs for physical connections and local trading
1, 2, 3		DM - in a FC CHP isn't that called heat - why is it waste? IS there some fundamental reason not to capture that?	ESC	17	Y	Y	x	N	Y	Potential needs for use of and/or commoditising heat
1, 2, 3		SC - Hydrogen usage in Fuel Cell CHP would generate waste heat	University of South Wales	18	Y	N		N	Y	Potential needs for properties and transfer of heat from assets
1, 2, 3		AT: Is the market structure future proof or does it just work for the current relatively modest level of trading. Is it 'scale-ready'.	Arup	19	N	Y	x	Y	Y	Potential need for market scalability
1, 2, 3		SC - True - maybe waste heat is the wrong term here. But an opportunity for further heat source.	University of South Wales	20	N	N		N	N	Comment only
1, 2, 3		KS - strong poential to use waste heat for district heating e.g. around Milford Haven marina and can be combined with other technologies	Arup	21	Y	Y	x	N	Y	Potential needs for use of and/or commoditising heat
1, 2, 3		AT: Need to be aware that geological storage will be contested buy other hydrogen projects as well as other things such as CAES etc. Also network constraints routing to/from storage.	Arup	22	Y	Y	x	N	Y	Potential needs for new storage type and network capacity; and how this is valued/traded

Question Number	Question	Comment	Organisation	Reference	Physical, Control and Interop	Local Energy Market	LEM included	National Energy Market, Policy and Regulation	Need?	Comments
1, 2, 3		IS: may also be of interest to waste water if they have thermal processes at site	Sea Wind Technology	23	Y	N		N	Y	Potential need for use of heat from waste water
1, 2, 3		Kev Ball - big challenge! We've talked about 'fitted for but not with' to try and build in scalable, flexible and growth potential. But not easy	ESC	24	N	N		N	N	Comment only
1, 2, 3		Helen D - great potential to consider waste heat within the Haven	Welsh Government	25	Y	Y	x	Y	Y	Potential needs for access/using open water for heat, and how it is commoditised; plus regulated, etc.
1, 2, 3		Helen D - i think adding in redundancy is key at the start of the project to ensure that we future proof and not cause headaches in the future	Welsh Government	26	Y	Y	x	N	Y	Potential needs for redundancy (or scalability and/or availability)
1, 2, 3		KS - dependent on process used, SMR is endothermic	Arup	27	Y	N		N	Y	Potential need for heat input into SMR assets/processes
1, 2, 3		KK - Use can be made of existing oil infrastructure (jetties, pipeline, storage tanks) if h2 is converted to LOHC. Waste heat produced can be utilised locally (district heat network) and large volume of h2 stored and exported	ERM	28	Y	Y	x	N	Y	Potential needs for LOHC conversion, storage/transport and heat transfers; plus market/trading arrangements
1, 2, 3		KS converse to fuel poverty point is also true, new energy vector and associated higher p/kWh could be seen as unfair to those struggling to afford to heat their homes, mechanisms to support those in need and to regulate heat costs required to overcome this barrier	Arup	29	N	Y	x	Y	Y	Potental needs for managing fuel poverty and/or pricing for those fuel poor
1, 2, 3		SC: Different hydrogen standards - e.g. Fuel cell purity can have price premium	University of South Wales	30	Y	Y	x	Y	Y	Potential needs for accommodating different hydrogen standards and purities; plus markets and values associated with different purities
1, 2, 3		SC - fuel cell standard is very stringent, this level of purity is not required for e.g. boilers. Higher cost to meet purity standard (easier from electrolysis) https://www.npl.co.uk/products-services/environmental/hydrogen-purity-for-fuel-cell-vehicles	University of South Wales	31	Y	Y	x	Y	Y	Potential needs for accommodating different hydrogen standards and purities; plus markets and values associated with different purities

Question Number	Question	Comment	Organisation	Reference	Physical, Control and Interop	Local Energy Market	LEM included	National Energy Market, Policy and Regulation	Need?	Comments
1, 2, 3		Kev Ball - great point - playing devils advocate, redundancy could also be considered waste, if it's not needed immediately (and it may never be needed). Any examples of where such extra investment has been realised for future proofing?	ESC	32	N	N		N	N	Comment only
1, 2, 3		SK: Ambition to create a zero carbon area at Milford Waterfront. H storage for elec gen to balance intermittancy of exisiting on site solar PV; potential for heat network etc	Pembrokeshire County Council	33	Y	Y	x	N	Y	Potential needs for H2 storage for elec gene for local network balancing; and heat network integration
1, 2, 3		KK Milford Haven can be major hydrogen hub for Wales and UK and import green hydrogen at scale from offshore wind. Potential to use for pembroke refinery, local transport or blend into gas network. Also potential to convert to LOHC and store in conventional oil assets at local oil terminal.ERM Dolphyn project currently looking at feasibility of early project.	ERM	34	Y	Y	x	N	Y	Potential needs for offshore wind integration; and uses of H2 for refinery, transport and blending; plus conversion to LOHC and storage
1, 2, 3		KS - need to consider if there are any salt caverns within the local area	Arup	35	Y	N		N	N	Potential need for natural storage type/properties
1, 2, 3		AT: consideration of potential CfD for blue / green hydrogen	Arup	36	N	N		Y	Y	Potential need for CfD/policy/network for H2 production
1, 2, 3		FW - Which is better? Using waste heat for DH in homes, or using hydrogen produced directly to heat homes? Need some sort of hierarchy for best uses of hydrogen vs. waste heat depending on quality/ value etc...	Edinburgh University	37	Y	N		N	Y	Potential need to accommodate different use cases for heating homes from different sources
1, 2, 3		BD: Proxy also for wider benefits e.g. tackling fuel poverty or air quality.	Arup	38	N	Y	x	Y	Y	Potential needs for value-streams for non-monetised benefits e.g. air quality, fuel poverty
1, 2, 3		Helen D - how many grids are considered optimal within a regional system?	Welsh Government	39	N	N		N	N	Comment only
1, 2, 3		PC - How can hydrogen/ blends come to MHEK for security of supply?	RWE	40	N	Y	x	N	Y	Potential need for security of supply
1, 2, 3		PC - creating a liquid market for hydrogen is key to reducing producer risk, ie local demand could come and go	RWE	41	N	Y	x	N	Y	Potential need for liquid market
1, 2, 3		EK: Ammonia?	Welsh Government	42	Y	Y	x	N	Y	Potential needs for ammonia conversion, storage/transport

Question Number	Question	Comment	Organisation	Reference	Physical, Control and Interop	Local Energy Market	LEM included	National Energy Market, Policy and Regulation	Need?	Comments
										and heat transfers; plus market/trading arrangements
1, 2, 3		AT - Need to establish proxies for non-monetised value - security of supply, resilience, decarbonisation etc which are not currently reflected.	Arup	43	Y	Y	x	Y	Y	Potential needs for value-streams for non-monetised benefits e.g. security of supply, resilience, decarbonisation
1, 2, 3		AT: Need to consider Temporal, System and Spatial context - Location timing and connectivity are necessary, otherwise the trade is notional only, not physical.	Arup	44	Y	Y	x	N	Y	Potential needs for location and timing constraints on trading arrangements
1, 2, 3		KK - Potential to supply green hydrogen to local Pembroke refinery for production of synthetic fuels for aviation, syn diesel, etc	ERM	45	Y	Y	specific application speak with ARUP	N	Y	Potential needs for transfer and use of H2 for refining of biofuelsl; plus trading arrangements to make this happen
1, 2, 3		SK: excellent 'local' gas grid injection points exist in Pembrokeshire obviously currently serving the LNG industry	Pembrokeshire County Council	46	Y	N		N	Y	Potential need to integrate with existing LNG assets (now or in the future)
1, 2, 3		DM - please can you elaborate? Do you mean electricity? Can you define what you meant by "grids" please?	ESC	47	N	N		N	N	Comment only
1, 2, 3		NP: Need to consider if local distribution fixed infrastructure is to be developed how this will be funded and who will operate it?	RWE	48	N	Y	x	Y	Y	Potential need to incentivise investment in local infrastructure; including operating models
1, 2, 3		BW: is a review of different customer types in the region been carried out, are there any blockers to adding hydrogen to the general,distribution network?	Wales and West Utilities	49	Y	N		N	Y	Potential need to accommodate different stakeholders and use cases for blended H2/natural gas in GDN
1, 2, 3		JG: Captured CO2 could be used in local agriculture if a greenhouse industry were established. Pernis in the Netherlands is an example.	Insite Technical	50	Y	Y	x	N	Y	Potential needs for local agriculture integration and CO2 transport; plus local trading arrangements
1, 2, 3		KS - UKCCC report highlights poor CCS potential in SW, need to consider transporting CO2 waste	Arup	51	Y	Y	x	Y	Y	Potential needs for CO2 transport away from local area and local/national trading arrangements
1, 2, 3		KK - Green hydrogen produced from offshore wind can be blended into local gas distribution network (up to 20%) at local pressure reduction station	ERM	52	Y	N		N	Y	Potential need to integrate with local pressure reduction stations for green H2 injection into GDN

Question Number	Question	Comment	Organisation	Reference	Physical, Control and Interop	Local Energy Market	LEM included	National Energy Market, Policy and Regulation	Need?	Comments
1, 2, 3		Helen D - there is no natural storage site off S Wales, so it is likely that a transport option should be considered	Welsh Government	53	Y	N		N	N	Potential need for CO2 transport away from local area
1, 2, 3		Helen D - innovation required re capture and reuse within the local system	Welsh Government	54	Y	Y	x	N	Y	Potential needs for CO2 localuse and trading arrangements
1, 2, 3		BD: Water - need to consider commercial / regulatory / technical infrastructure (input & output)	Arup	55	Y	Y	x	Y	Y	Potential needs for access/using water for electrolysis, and how it is commoditised; plus regulated, etc.
1, 2, 3		SK: PCC fleet depot - works vans, school buses, bin lorries, pool cars;NHS ambulance fleet. PoMH fleet and port vehicles; National Park fleet vans/cars; community car shares	Pembrokeshire County Council	56	Y	Y	x	N	Y	Potential needs for fleet integration/use with H2 inftrastructure and local trading arrangements
1, 2, 3		NP: CH4/H2 bend from the NTS should also be considered as an input	RWE	57	Y	N		N	Y	Potential need to integrate with blends of natural has from NTS
1, 2, 3		Helen D - both local electrical and hydrogen micro grids. Are we looking to service local domestic and retail micro grids?	Welsh Government	58	Y	Y	x	N	Y	Potential needs for integration with local domestic/retain elec/H2 microgrids
1, 2, 3		SK: Significant PCC managed council housing still exists in Milford, Pembroke, Pembroke Dock and around the Waterway. Opportunities for heat/power/cooking via Hydrogen either on local networks or blended into national gas grid; PCC could 'control' for example the roll out of Hydrogen ready boilers/hybrid systems	Pembrokeshire County Council	59	Y	Y	x	N	Y	Potential needs to integrate with council housing/PCC; and local H2 or blend of gas use/trading; and H2 infrastructure installation
1, 2, 3		SK: local production of green H via electrolysis to serve Milford Waterfront ZCA heat, transport, storage for smart grid balancing; localised production of green H at transport nodes/hubs - eg PCC have funds for revamp of Milford Haven railway station	Pembrokeshire County Council	60	Y	Y	x	N	Y	Potential needs to integrate green H2 production with heat, transport, storage, and grid balancing; plus produce green H2 at transport nodes/hubs e.g MH railway station
1, 2, 3		HD - investment in infrastructure is required	Regional Development Wales	61	N	Y	x	Y	Y	Potential need to incentivise investment in local infrastructure; including for retail and domestic consumers

Question Number	Question	Comment	Organisation	Reference	Physical, Control and Interop	Local Energy Market	LEM included	National Energy Market, Policy and Regulation	Need?	Comments
1, 2, 3		KK- H2 can be stored as LOHC at local oil terminal and from there can be exported by ship to industrial users such as Steel at Port Talbot or Baglan Power Station. Producing LOHC at oil terminal would produce waste heat which could supply local distric heat network	ERM	62	Y	Y	x	N	Y	Potential needs for LOHC conversion, storage/transport and heat transfers; plus market/trading arrangements
1, 2, 3		KK - ERM would be interested in performing a feasibility study for using Dolphyn offshore wind technology in Celtic Sea to bring green hydrogen into Milford Haven. Funding from Welsh Gov for this would kick start the process.	ERM	63	N	N		N	N	Comment only
1, 2, 3		SC - Are fuel cells being considered as CHP devices? Potential to produce efficient heat and electricity	University of South Wales	64	Y	N		N	Y	Potential need to use FC as CHP
1, 2, 3		KS - longterm, there are also immature tech which might develop to allow hydrogen to be produced from wastewater / biomass	Arup	65	Y	N		N	Y	Potential need to integrate with waste water and biomass supplies
1, 2, 3		SB: need to consider water usage as water feed to electrolyzes needs to be pre-treated - approx. 20 tons of impure water for 1 ton of H2 produced (when taking account of efficiency losses). Treating requires energy. Also transportation costs. Offshore renewables helps with this but will always be more costly and pose other challenges than onshore alternatives.	Insite Technical	66	Y	N		N	Y	Potential need to integrate with water supplies for electrolysis
1, 2, 3		helen d - offshore renewables offer great potential here in the medium to long term	Welsh Government	67	Y	N		N	Y	Potential need to integrate with offshore renewables producing both electricity and H2
1, 2, 3		Helen D - infrastructure needs to be able to flexible in terms of transport refilling and serving local micro grids, eg local retail and domestic requirements	Welsh Government	68	Y	Y	x	N	Y	Potential needs for integration with local domestic/retain elec/H2 microgrids
1, 2, 3		JG: Alternative uses for oxygen would be medical gases (small quantities), or oxygen enrichment for sulphur recovery unit at Valero (large quantities).	Insite Technical	69	Y	Y	x	N	Y	Potential needs to integrate with and exploit local O2 use cases
1, 2, 3		KS - oyygen can be used in waste water treatment works - there is a DCWW site within the boundary	Arup	70	Y	Y	x	N	Y	Potential needs to integrate with and exploit local O2 use cases

Question Number	Question	Comment	Organisation	Reference	Physical, Control and Interop	Local Energy Market	LEM included	National Energy Market, Policy and Regulation	Need?	Comments
1, 2, 3		IS: I'd check what the major industrial gas suppliers do and emulate their strategy. keep it simple	Sea Wind Technology	71	N	N		N	N	Comment only
1, 2, 3		BD: Market / trading platform will need to consider priority of 'dispatch' for different usage based on demand / commercial / efficiency.	Arup	72	N	Y	x	N	Y	Potential need to consider dispatch priority of enegy depending on demand/commercial/efficiency
1, 2, 3		BD - Question back - are you envisaging potential in terms of mainly H production, or electricity (requiring grid upgrades)? Or maybe just highlighting potential for OW generally?	Arup	73	N	N		N	N	Comment only
1, 2, 3		AT: To what extent is there a 'transmission' level market and a 'distribution' market or 'Local market' - Does the scale of one over the other impact segregation of the two?	Arup	74	N	Y	x	Y	Y	Potential need to define market boundaries and interoperability arrangements
1, 2, 3		DM: Could you elaborate please? This seems like an excellent direction in a containerised setting - but could the same work in large scale piped applications? Would love to hear more of your thoughts...!	ESC	75	N	N		N	N	Comment only
1, 2, 3		Helen D - companies are initially focussing on electricity production but are particularly interested in exploring hydrogen production alongside their projects	Welsh Government	76	N	N		N	N	Comment only
1, 2, 3		IS: I'm not an expert in this area. Just a point that we will be competing (dependant on the grade of O2) with industrial gas suppliers, So worth having a look at their sales strategy	Sea Wind Technology	77	N	N		N	N	Comment only
1, 2, 3		JG: InSite Technical Services would consider hosting demonstration facilities on our site in Pembroke Dock. We have space for an electrolyser, space for limited number of solar panels, good electrical connections. We could switch one of our LPG boilers to hydrogen, good location adjacent to A477 for FCEV refuelling point, experienced technical workforce to take care of all of the above.	Insite Technical	78	N	N		N	N	Comment only
1, 2, 3		Helen D - what consideration has been given to new assets coming on stream, eg floating offshore wind?	Welsh Government	79	Y	N		N	Y	Potential need to integrate new generators as they come on line in the future

Question Number	Question	Comment	Organisation	Reference	Physical, Control and Interop	Local Energy Market	LEM included	National Energy Market, Policy and Regulation	Need?	Comments
1, 2, 3		Helen D - we are working with a number of developers looking at investing in the Celtic Sea. Our enquiry pipeline is over 2GW. One in the public domain is Blue Gem Wind's 96MW floating offshore wind project. These projects will be delivered from 2027 onwards	Welsh Government	80	N	N		N	N	Comment only
1, 2, 3		Response: Jake thanks for proposing this, very interesting - one of your team reached out to me after last week's workshop & I'll set up a call to discuss further (BD).	Arup	81	N	N		N	N	Comment only
1, 2, 3		Response to above: Arup are mapping the current system at both a geospatial & schematic level and then running scenarios out to 2050 as part of our parallel workstream. This will include offshore/floating wind potential. Into both High Electric & High Hydrogen scenarios. (BD)	Arup	82	N	N		N	N	Comment only
4	For discussion: 4. Why would Milford Haven win investment for different elements? USP?	Helen D - definitely export opportunities to Ireland aligned to offshore renewable energy deployment	Welsh Government	83	Y	N		Y	Y	Potential need for international integration to nearby countries e.g. Ireland
4		SK: It would be advantageous if the area can get some sort of rapid consenting regime from NRW/Crown Estate for offshore renewables	Pembrokeshire County Council	84	N	N		Y	Y	Potential need for new, faster approvals scheme for NRW/Crown Estate developments
4		SK: The skills, supply chain and infrastructure are already here allied to ideal natural geography/geology: Pembrokeshire has the Atlantic on 3 sides of the County	Pembrokeshire County Council	85	N	N		N	N	Comment only
4		SK: Projects such as Pembroke Dock Marine (City Deal), SWIC and MH:EK demonstrate strong private and public sector support for investment in renewables/hydrogen	Pembrokeshire County Council	86	N	N		N	N	Comment only
4		Helen D - alignment with SWIC and industrial diversification and decarbonisation opportunities	Welsh Government	87	N	N		N	N	Comment only

Question Number	Question	Comment	Organisation	Reference	Physical, Control and Interop	Local Energy Market	LEM included	National Energy Market, Policy and Regulation	Need?	Comments
4		KS - high renewable potential within SW and potential limits within the elec grid makes a strong case for this as an ideal place to begin to incentivise road to commercialization fo hydrogen	Arup	88	N	N		N	N	Comment only
4		SC - Location at end of South Wales "Hydrogen Corridor" and integration with projects such as SWIC	University of South Wales	89	N	N		N	N	Comment only
4		EK: Potential storage for Europe and corridor across from Ireland for heavy goods	Welsh Government	90	N	N		N	N	Comment only
4		DM - where else could you bring tankers the size that would be required to imprt / export H2 - what are the other options and why is MH a better answer?	ESC	91	N	N		N	N	Comment only
4		KS - import / export infrastructure in MH makes it ideal location for MH has as UK hydrogen trading hub	Arup	92	N	N		N	N	Comment only
5	5. How would people want a local energy market to work (i.e. What commercial relationships may you want? What would you want to buy? How would you want to buy a commodity/service? What operational signals may be required between assets?)	KS - agree with this point Steve, consumers also need to be aware that if they move from gas boilers to ASHPs they will then not be able to connect into a hydrogen network if it becomes available in the future, need support for collective community choices and making informed decisions at the right point in time	Arup	93	N	N		N	N	Comment only
5		SC - Individual consumer choices - e.g. heat pumps make a lot of sense, but not for all homes and not without significant investment. Hydrogen boilers closer to current operation. How can people make informed choices, and who pays for investment?	University of South Wales	94	N	N		N	N	Comment only
5		BW: is security of supply and liabilities for it considered here? I.e who carries out residual balancing and manages imbalances / supply emergencies in the event commercial mechanisms fail	Wales and West Utilities	95	Y	Y	x	Y	Y	Potential needs to ensure security of supply outside of commercial arrangements; and manage residual balancing
5		DM: Great point, there is lots of work in this area we could discuss. But I would extend this to consider installers too. Feels like the transition to hydrogen boilers would retain a lot of the gas fitters, not sure if that is true of heat pump installations and how much retraining that would require,,,,	ESC	96	N	N		N	N	Comment only

Question Number	Question	Comment	Organisation	Reference	Physical, Control and Interop	Local Energy Market	LEM included	National Energy Market, Policy and Regulation	Need?	Comments
5		BD: Great comment!	Arup	97	N	N		N	N	Comment only
5		AT: Need confidence in counterparty ability to deliver.	Arup	98	N	N		N	N	Comment only
5		DM: Indeed - or should this be national as with electricity. Whatever the answer needs to work commercially AND physically (can't trade nationally and balance locally I suspect)	ESC	99	N	N		N	N	N
5		AT: Think about origin certification - How green is your hydrogen.	Arup	100	N	Y	x	Y	Y	Potential need for H2 origin certification i.e. "greenness" of supply
5		KS - different orgs might undertake this role as transition from MH;EK to larger / more national scale	Arup	101	N	N		N	N	Comment only
5		SK: large public sector organsiations will consider zero emissions Power/Heat Purchase Agreements's very readily given that all public sector in Wales are bound by WGs 2030 net zero carbon target. The public secor (along with the fossil fuel sector) is the dominant employer in the region.	Pembrokeshire County Council	102	N	Y	x	Y	Y	Potential need for zero emission power/heat purchase agreements, given Welsh Government 2030 net zero target
5		DM - if hybrid solutions are deployed - e.g. hydrogen/electric heating then how does a consumer get control over which vector is used to heat their homes - and should this be the cheaper or the lower carbon (if different)? - discuss please	ESC	103	Y	Y	x	N	Y	Potential need for consumer choice in hybrid heating options
5		DM - Can heat / energy as a service make the transition to hydrogen easier for consumers? - discuss please	ESC	104	Y	Y	x	N	Y	Potential need for X as a service business models that are attractive to consumers to deliver low carbon infrastructure change
5		AT: Need to consider system costs (eg: storage for security), also competing vector situation (eg: green taxation/levy on natural gas as well as electricity.	Arup	105	N	Y	x	Y	Y	Potential need for non-financial incentives for storage e.g. security of supply
5		DM: For really early work could we just rely on bilateral / retail type trades. e.g. company A makes hydrogen, sells to company B and sends a tanker around to deliver/ What additional "local market" points could improve on this? Discuss please	ESC	106	N	N		N	N	Comment only

Question Number	Question	Comment	Organisation	Reference	Physical, Control and Interop	Local Energy Market	LEM included	National Energy Market, Policy and Regulation	Need?	Comments
5		AT: Lessons from LPG market in the first instance	Arup	107	N	N		N	N	Comment only
5		AT: Need certainty of supply underwritten. Contracted oblications need to be underwritten/assured. Particularly important if hydrogen is the only vector. into an end user.	Arup	108	N	Y	x	Y	Y	Potential need for supply to be underwritten/assured
5		BD: Heat as a service model?	Arup	109	N	N		N	N	Comment only
5		BD: Transport as a service model	Arup	110	N	N		N	N	Comment only
5		AT: Consideration of spot and forward market for hydrogen or hydrogen derived commodity cf: electricity trading Not just local P2P spot trading	Arup	111	N	Y	x	N	Y	Potential need for both "spot" and "forward" trading options, beyond local P2P trading c.f. electricity market and lessons from LPG market
5		IS: Should also 'try' to forecast when these things come into place, regulatory changes etc	Sea Wind Technology	112	N	N		N	N	Comment only
5		BD: IS - thanks for suggestion, we have a variety of in-house models & modelling work from H100. W will also be using Plexos on the project to model diff future scenarios, in terms of supply dispatch & carbon price.	Arup	113	N	N		N	N	Comment only
5		SK: Bluesky - I'd like to be able to buy my renewable energy needs just like I can buy anything else online. I'll have 14,000 kWh's of hydrogen backed heat and 3500 kWH of electricity from offshore wind at the press of a button.	Pembrokeshire County Council	114	N	Y	x	Y	Y	Potential need for bulk energy orders with defined origins e.g. hydrogen-sourced heating, offshore wind-sourced electricity, etc.
5		SE: I would hope there would be different consumer propositions so that a consumer can choose which they would prefer (i.e. low cost or low CO2 and possibly a more intelligent option of low carbon but not higher than price x)	ESC	115	Y	Y	x	N	Y	Potential need for consumer choice in hybrid heating options
5		IS: Good point. Not sure if Arups have a trading model in development? Wood Group have one on Carbon which could be adapted. Happy to link them in to this project. They are also involved in one of the Scottish 100% H2 projects	Sea Wind Technology	116	N	N		N	N	Comment only

Question Number	Question	Comment	Organisation	Reference	Physical, Control and Interop	Local Energy Market	LEM included	National Energy Market, Policy and Regulation	Need?	Comments
5		SK: Smart systems and automation will be key. E.g. controls for hybrid heating systems, PV solar, battery strorage, V2G etc. that can use, buy and trade energy at optimium times with minimum user intervention. Individuals have the potential to benefit from energy trading. For many though this will need to be optimised and automated.	Pembrokeshire County Council	117	Y	Y	x	N	Y	Potential need for smart systems to trade energy automatically to benefit individuals
5		BW: Potential products: exit and entry capacity to a network (access to customers), hydrogen - secure supply versus flexible services / offerings, heat, storage services,	Wales and West Utilities	118	N	Y	x	Y	Y	Potential need for trading energy services e.g. secure hydrogen (guaranteed delivery) vs flexible hydrogen (when available)
5		BW: operating signals include: max / min requirements (long term), planned usage (shorter term),	Wales and West Utilities	119	Y	Y	x	Y	Y	Potential need for market/trading operating signals e.g. max/min requirements; planned usage, etc
5		Consideration for interactions between system operation functions versus a whole system operator	Wales and West Utilities	120	Y	Y	x	Y	Y	Potential need for system operator functions/trading
5		KS - need thought as to how storage losses impact costs to the end user - who pays for this?	Arup	121	N	Y		Y	Y	Potential need for storage cost recovery or financial reward for including
5		DM - how can the "system" be controlled to manage the interface between electrical and hydrogen systems - particularly around electrolysis when there is excess renewables and peaking plant operation - discuss please	ESC	122	N	N		N	N	Comment only
5		SC impact of self driving technologies on ownership models and impact on refuelling behaviour	University of South Wales	123	N	N		N	N	Comment only
5		SC - future car ownership options - c.f. riversimple model.	University of South Wales	124	N	N		N	N	Comment only
5		SK: completely agree; Riversimple 'Mobility as a Service' (MaaS) model is key. Consumers simply make one monthly payment for mobility and Riversimple provide the car, insurance, servicing and fuel etc.	Pembrokeshire County Council	125	N	N		N	N	Comment only
5		KS - can H2 trade prices vary in real-time depending on demand. Can test this on a local scale (e.g. through MH:EK) to then create national and international trading markets	Arup	126	Y	Y		N	Y	Potential need to trade H2 in real time with prices varying on demand

Question Number	Question	Comment	Organisation	Reference	Physical, Control and Interop	Local Energy Market	LEM included	National Energy Market, Policy and Regulation	Need?	Comments
6	6. As these local projects will be first movers, with likely little comparable infrastructure around the UK, how do you think this may change the needs of the projects?	BD: Hydrogen clusters expected to develop at very local level in short-term. With supporting mechanisms whether CfD or other.	Arup	127	N	N		N	N	Comment only

Local Market Cross Analysis

Ref	Function	Sub-function		Notes	Reference from focus groups
1	Production	cobenefits of production technologies		different forms of production have different co-benefits e.g. heat, oxygen, solid carbon, responsiveness to signals	12, 17, 69
2	Production	redundancy required		to ensure secuirty of production?	26
3	Production	colour		green / blue	60
4	Production	certificate of origins			95
5	Blending	level of blending		are there levels between 20% and 100%	5
6	Blending	secuirty of supply through varying quantities			40
7	Usage	reuse of existing infrastrcture		e.g. jetties for input, pipelines, storage etc.	28
8	Usage	used to balance electrical system	Balancing electrical system methods		33
9	Usage	transport (private and fleet)			34, 56
10	Usage	heat		including hybrids	34, 103
11	Usage	LOHC for storage / transporting			34, 62
12	Usage	agriculture			50

Ref	Function	Sub-function		Notes	Reference from focus groups
13	Usage	micro grids			58, 68
14	Usage	by products - oxygen			70
15	Usage	by products - carbon			70
16	Usage	public sector PPAs			100
17	Distribution	containers versus piping			7
18	Distribution	required for moving H2 to and from storage			22
19	Distribution	as what vector? Ammonia, LHOC?			42
20	Distribution	funding for bespoke infrastructure			48, 61
21	Storage	short term		daily?	
22	Storage	long term		interseasonal / security of supply	11
23	Storage	cost of storage is high - how could we reduce need for storage			
24	Storage	market for storage (attributable value)		geological features contested for other uses e.g. compressed air storage	22
25	Storage	location is important		SW is not blessed with storage facilities	51
26	Operation	scalability of market solutions			19
27	Operation	utilisation of by-products		e.g. heat, carbon, o2	21

Ref	Function	Sub-function		Notes	Reference from focus groups
28	Operation	spatial and timings of operations are important to ensure trades are real and not just notional	Definiton of trade operations - spatial & timing	H2 produced by "x" is consumed by "y" rather than trading certificates	44
29	Operation	integration with electricity			58
30	Operation	trading links to dispatch			72
31	Operation	link with national systems			74
32	Operation	integrated smart devices and controls			117
33	Finance	targetted investment required			1, 2
34	Finance	private AND public investment needed			3
35	Finance	somethings are private driven (electrolysers say) whereas infrastructure is publicly funded			4
36	Finance	support mechanism for fuel poverty			29
37	Finance	H2 is less valuable (by volume) but is anticipated to be more expensive - how can value of decarbonisation be included?	Demonstration of hydrogen value in terms of decarbonisation		new
38	Finance	price of purity?			30, 31

Ref	Function	Sub-function		Notes	Reference from focus groups
39	Finance	value of co-benefits			38
40	Finance	market liquidity required over broader geography not just local			41
41	Finance	proxies for non-monetised benefits (security of supply, resilience, decarbonisation etc.)			43
42	Finance	desire for circular economy			54
43	Finance	taxes levys on H2 or alternatives			105
44	Finance	certainty of supply	Is this not under operation?	and demand - in case a colocated / p2p trading arrangement goes under	108
45	Finance	spot and forward trading			111
46	Finance	trading online as easily as buying from amazon	Online trading opportunities		114
47	Finance	different propositions for different customers			115
48	Finance	entry and exit pricing			118
49	Finance	who pays for storage losses?	Storage loss responsibility		121
50	Finance	real time trading?			126
51	Consequences	waste heat generated		should try to use	25
52	Consequences	requirement for water			55

Ref	Function	Sub-function		Notes	Reference from focus groups
53	Roles	system operator			95, 120
54	Roles	retailer - retailing what		HaaS, H2???	104
55	Roles	planning and control signals			119

LICENCE/DISCLAIMER

Energy Systems Catapult (ESC) Limited Licence for [Milford Haven : Energy Kingdom – System Architecture Report]

ESC is making this report available under the following conditions. This is intended to make the Information contained in this report available on a similar basis as under the Open Government Licence, but it is not Crown Copyright: it is owned by ESC. Under such licence, ESC is able to make the Information available under the terms of this licence. You are encouraged to Use and re-Use the Information that is available under this ESC licence freely and flexibly, with only a few conditions.

Using information under this ESC licence

Use by You of the Information indicates your acceptance of the terms and conditions below. ESC grants You a licence to Use the Information subject to the conditions below. You are free to:

- copy, publish, distribute and transmit the Information;
- adapt the Information;
- exploit the Information commercially and non-commercially, for example, by combining it with other information, or by including it in your own product or application.

You must, where You do any of the above:

- acknowledge the source of the Information by including the following acknowledgement:
- "Information taken from [REPORT NAME], by Energy Systems Catapult";
- provide a copy of or a link to this licence;
- state that the Information contains copyright information licensed under this ESC Licence.
- acquire and maintain all necessary licences from any third party needed to Use the Information.

These are important conditions of this licence and if You fail to comply with them the rights granted to You under this licence, or any similar licence granted by ESC, will end automatically.

Exemptions

This licence only covers the Information and does not cover:

- personal data in the Information;
- trademarks of ESC; and
- any other intellectual property rights, including patents, trademarks, and design rights.

Non-endorsement

This licence does not grant You any right to Use the Information in a way that suggests any official status or that ESC endorses You or your Use of the Information.

Non-warranty and liability

The Information is made available for Use without charge. In downloading the Information, You accept the basis on which ESC makes it available. The Information is licensed 'as is' and ESC excludes all representations, warranties, obligations and liabilities in relation to the Information to the maximum extent permitted by law.

ESC is not liable for any errors or omissions in the Information and shall not be liable for any loss, injury or damage of any kind caused by its Use. This exclusion of liability includes, but is not limited to, any direct, indirect, special, incidental, consequential, punitive, or exemplary damages in each case such as loss of revenue, data, anticipated profits, and lost business. ESC does not guarantee the continued supply of the Information.

Governing law

This licence and any dispute or claim arising out of or in connection with it (including any noncontractual claims or disputes) shall be governed by and construed in accordance with the laws of England and Wales and the parties irrevocably submit to the non-exclusive jurisdiction of the English courts.

Definitions

In this licence, the terms below have the following meanings: 'Information' means information protected by copyright or by database right (for example, literary and artistic works, content, data and source code) offered for Use under the terms of this licence. 'ESC' means Energy Systems Catapult Limited, a company incorporated and registered in England and Wales with company number 8705784 whose registered office is at Cannon House, 7th Floor, The Priory Queensway, Birmingham, B4 6BS. 'Use' means doing any act which is restricted by copyright or database right, whether in the original medium or in any other medium, and includes without limitation distributing, copying, adapting, modifying as may be technically necessary to use it in a different mode or format. 'You' means the natural or legal person, or body of persons corporate or incorporate, acquiring rights under this licence.

Energy Systems Catapult supports innovators in unleashing opportunities from the transition to a clean, intelligent energy system.

Energy Systems Catapult
7th Floor, Cannon House
18 Priory Queensway
Birmingham
B4 6BS

es.catapult.org.uk
info@es.catapult.org.uk
+44 (0)121 203 3700