

Establishing a regional hydrogen economy

Accelerating the carbon transition in South Yorkshire, UK



FOREWORD

Encouraging the growth of hydrogen in South Yorkshire

The Sheffield City Region is built on a strong heritage of excellence in innovation. Our passion for revolution and commitment to excellence began during the Industrial Revolution, when our rail, coal and steel industries were renowned across the world.

Now we are fuelling the future at the forefront of the North's Clean Energy Revolution.

The Sheffield City Region is already home to England's most northern hydrogen refuelling station and the world's largest electrolyser factory by ITM Power opening near Meadowhall. But there's more to be done.

Our region has many of the ingredients needed for a hydrogen economy, extensive road and rail connectivity, a legacy of industry and ingenuity to be proud of, and a skills base that is exported globally. We have two excellent universities and a track record of creating successful partnerships between academia and business to make our region more prosperous.

The world is in the midst of a climate emergency, but we have the opportunity to take climate action in our region. We can do this by putting ourselves at the forefront of hydrogen innovation and capitalising on the opportunities brought about by hydrogen technology in the transport, heating and industrial sectors, which are highlighted in this report.

In the Sheffield City Region we put people and our environment at the heart of what we do. We're building a region where public investment unlocks social good, alongside productivity gains.

This report highlights the opportunities created within the hydrogen industry for our region, but we must work together to reap the rewards and lead our region into a cleaner, greener new era.



James Muir, Chair of Sheffield City Region LEP

Introduction

The establishment of a strong hydrogen economy nationally and locally is a very real opportunity and one that is rapidly becoming within reach. This report presents a vision for the role that hydrogen could play in South Yorkshire, to help meet carbon reduction targets and contribute to the health and economic prosperity of the region.

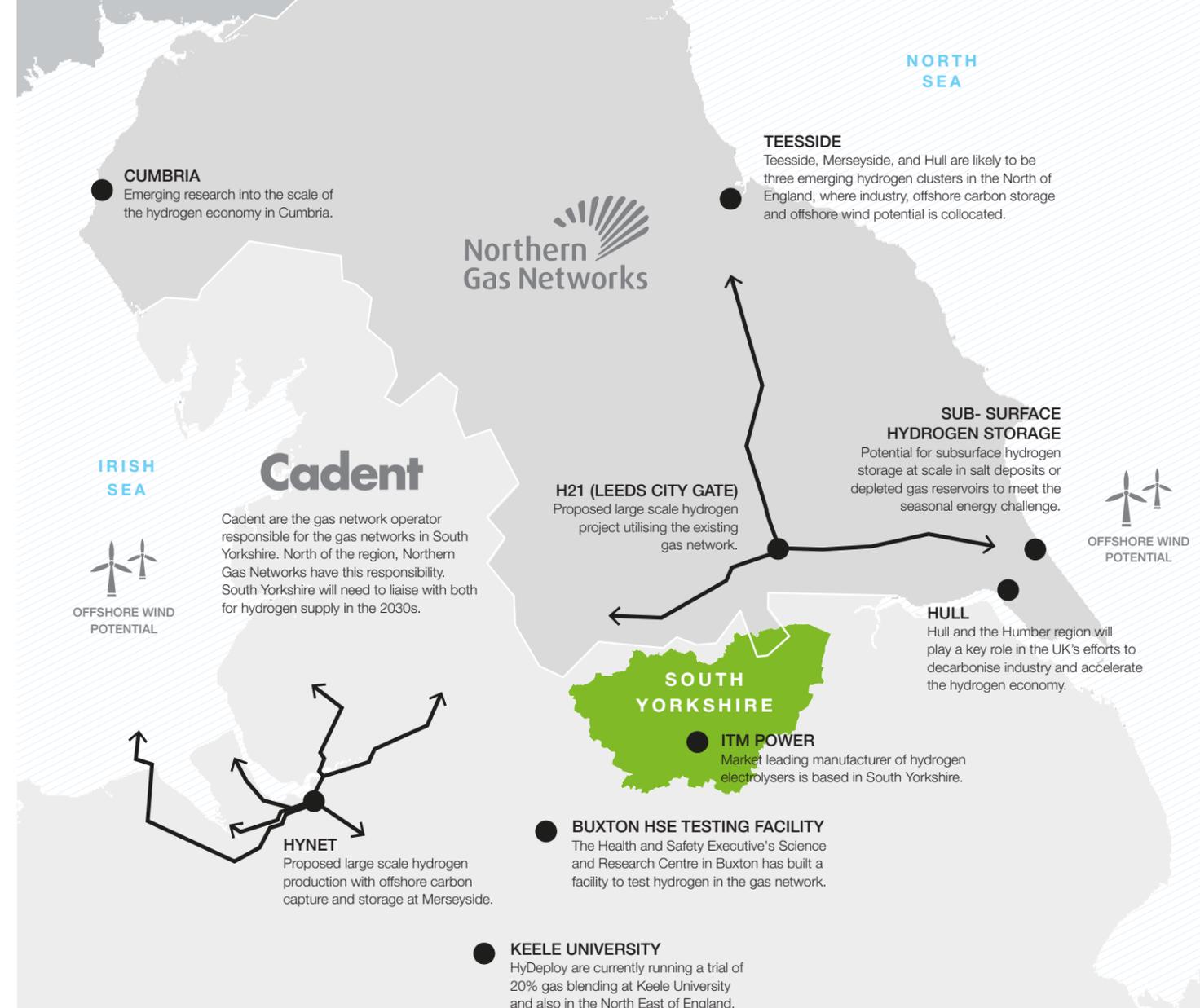
To investigate the potential for developing hydrogen projects in the region, Arup convened a series of workshops with South Yorkshire's local authorities, utilities, transport bodies, housing providers and businesses.

Five themes have been highlighted as levers of growth:

- Production, Storage and Transfer
- Transport
- Industry
- Heating
- Jobs, Skills and Research

This report also explores potential actions and collaborations, as well as a list of ambitions for future hydrogen projects.

WHERE DOES SOUTH YORKSHIRE FIT IN THE WIDER HYDROGEN ECONOMY?



Why hydrogen?

Since the United Kingdom government's net zero 2050 target was enshrined in law, hydrogen has risen from an option to being seen as a critical enabler in all scenarios.

Ensuring access to affordable, reliable and sustainable energy is an essential outcome in the transition to a low carbon future. This requires us to make major changes in how we produce, manage and consume energy.

One emerging energy vector is hydrogen which is applicable across multiple sectors including transport, industry and heating. It is of particular interest in those sectors that are proving difficult to decarbonise. In fact, alongside electrification it is now hard to envisage the UK meeting its net zero ambitions without a prominent role for hydrogen.

Hydrogen can be produced in many ways which are often categorised in the three ways:

Brown hydrogen: Through reformation of methane without carbon capture storage.

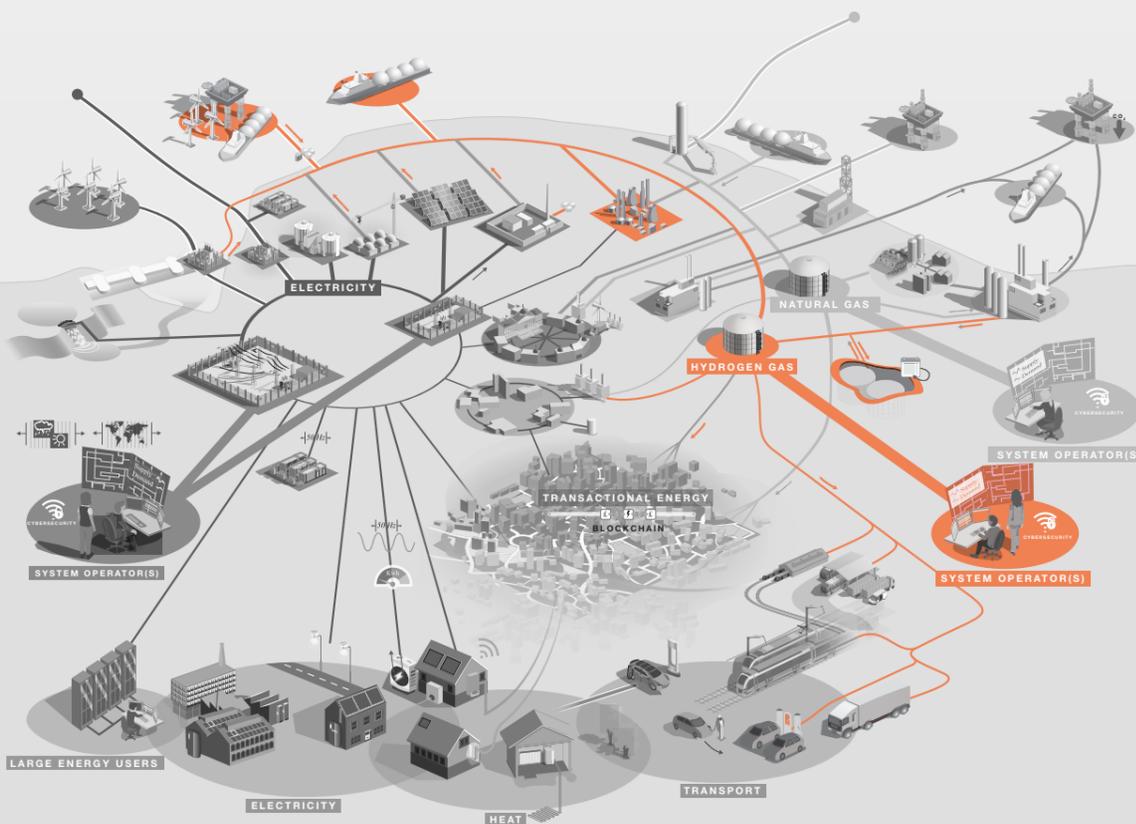
Blue hydrogen: Through reformation of methane using carbon capture storage.

Green hydrogen: Through electrolysis of water using renewable energy produced either on site or via the grid.

Given the urgency to take action on climate issues, this report advocates the second and particularly the third way of producing hydrogen. We do need to overcome challenges before hydrogen's full potential can be realised. We need to increase demand without which production will not happen, we need investment in new supply infrastructure, and we need a national and local policy landscape that helps it to excel.

If the UK can capitalise on best practice from home and overseas, and take coordinated action now on the steps needed to build a hydrogen economy, then it can begin to reap the benefits – not only decarbonisation but also the development of new skills and jobs.

Hydrogen will play an increasing role in future energy systems as government policy is enacted. Arup has produced a road map to establishing a hydrogen economy for the UK up to the year 2035, providing both existing and recommended processes and policy measures. www.arup.com/hydrogen2035



About South Yorkshire Potential

The geographic area of South Yorkshire is made up of Barnsley, Doncaster, Rotherham and Sheffield and is represented by the Sheffield City Region (SCR) Local Enterprise Partnership (LEP). The four South Yorkshire local authorities are also 'constituent members' of the Mayoral Combined Authority (MCA).

The region is diverse, containing both urban areas, a significant rural economy as well as a world-famous industrial sector. Decarbonisation needs to happen in the context of the region's urban and rural areas, and its existing energy and transport infrastructure legacy.

The specific characteristics of South Yorkshire relevant to the development of a robust hydrogen economy include:

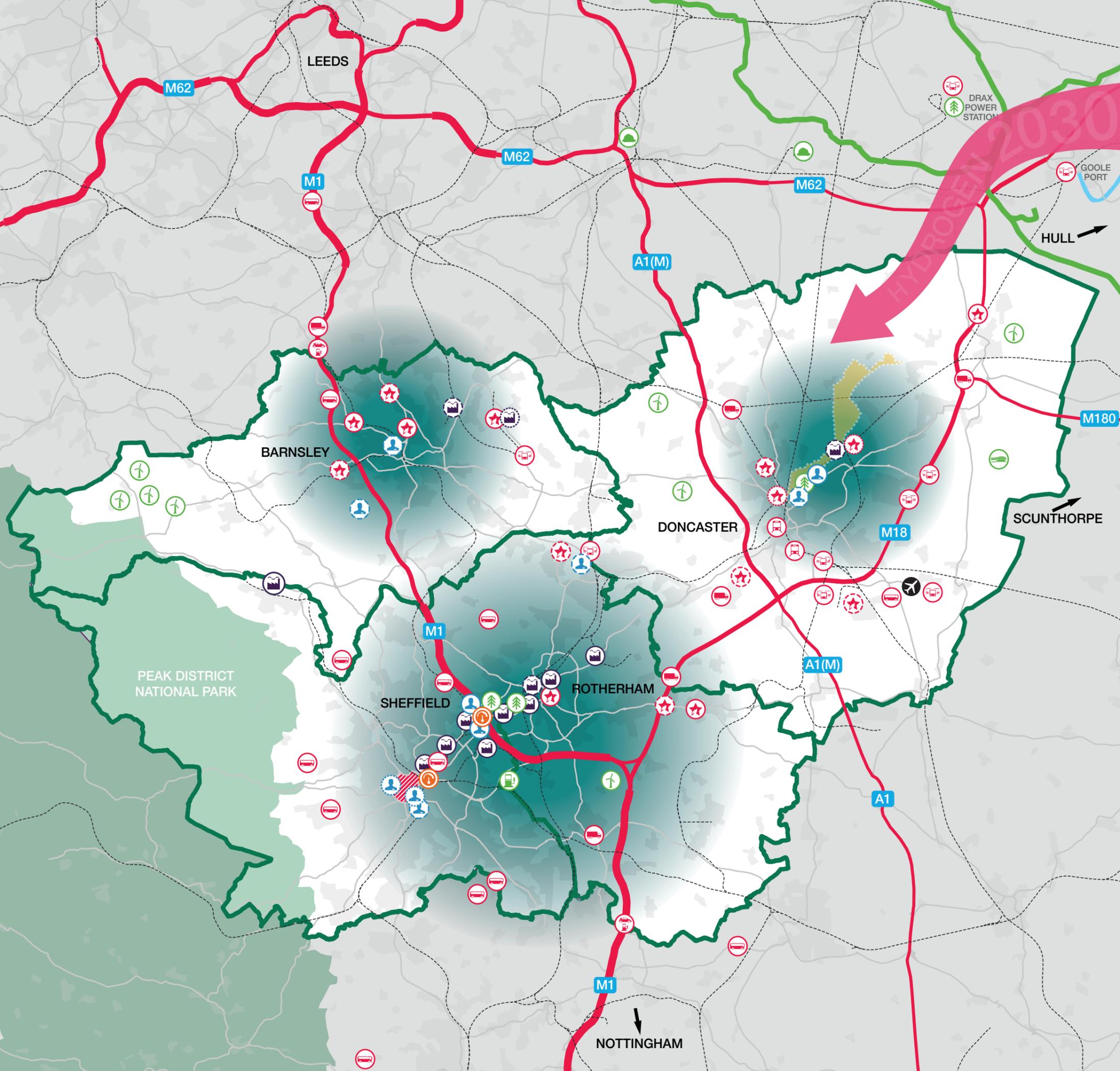
- The world's largest electrolyser factory near Meadowhall, Rotherham. Other components of the hydrogen supply chain including hydrogen storage cylinders are also manufactured nearby.
- Rotherham is home to England's most northerly hydrogen refueling station, within the Advanced Manufacturing Park.
- The region has an onshore wind sector with the potential to expand, given both land price and planning support.
- Central location in UK with good transport connections including four motorways (M1, M18, M180 and A1) and East Coast, Midland and TransPennine railway lines.

- Doncaster is a key logistics hub in the UK for both road and rail; has an adjacent airport and one of the largest inland logistical bases under development at the 'iPort'.
- The ECO Stars Fleet Recognition Scheme which began in Barnsley has been widely adopted across the UK. The scheme targets commercial fleet vehicles with the aim of assisting and encouraging emission reductions. South Yorkshire has a total of 155 members with 12,200 vehicles assessed and awarded a star rating.
- Sheffield has an industrial heritage in high quality steel and boasts two universities and a number of excellent skilled apprenticeship courses.
- Sheffield has two major district heat networks: one in the city centre and one at Blackburn Meadows.
- South Yorkshire has an elected Mayor and strong local commitments made on carbon reduction.

As a landlocked region, South Yorkshire is not bound by the need to wait for large scale hydrogen imports or production projects on the coast, though these will be necessary as demand picks up in the 2030s. Instead, a decentralised deployment of green hydrogen could provide a more flexible and responsive approach and hence improve resilience in the transition from fossil fuels.

A vision for the hydrogen economy in South Yorkshire

This map explores the potential for hydrogen in South Yorkshire. The likely growth centres of hydrogen in the 2020s and 2030s is highlighted. Five growth areas and their geographic locations have been plotted, each is explained further on the following pages.



FUTURE HYDROGEN

- 2020s - GROWTH OF HYDROGEN DEMAND IN URBAN CENTERS
- 2030s - SUPPLY OF HYDROGEN AT SCALE FROM THE HUMBER REGION

1 - PRODUCTION, STORAGE AND TRANSFER

- WIND FARM
- COAL FIRED ELECTRICITY (TO CLOSE BY 2025)
- HIGH PRESSURE GAS MAINS
- AREA OF SEARCH FOR WIND ENERGY DEVELOPMENT (DONCASTER DRAFT LOCAL PLAN)
- GEOLOGICAL GAS STORAGE (HATFIELD MOOR)
- OTHER (BIOMASS / ANEROBIC)
- HYDROGEN FILLING STATION (ROTHERHAM)

2 - TRANSPORT

- RAIL NETWORK
 - RAIL REFUELLING IN DONCASTER
 - TRUCK PARKS
 - SHEFFIELD PLANNED CLEAN AIR ZONE
 - MOTORWAY SERVICE STATIONS
 - BUS DEPOTS
 - LOGISTIC HUBS
- MOTORWAYS TRUCK COUNT (PER DAY, BOTH WAYS)
- <45,000
 - 45,000 - 90,000
 - >90,000
- TRUCK FLEETS (ECOSTAR)
- 11 - 30
 - 30 - 60
 - 60 - 101

3 - INDUSTRY

- STEEL
- GLASS
- OTHER

4 - HEATING

- DISTRICT HEAT NETWORK

5 - SKILLS, JOBS AND RESEARCH

- JOBS LOCATION (EXISTING EMPLOYERS IN H2 SECTOR)
- SKILLS LOCATION (EXISTING COLLEGES)
- RESEARCH LOCATION (EXISTING UNIVERSITIES)



Production, Storage and Transfer

The landlocked nature of South Yorkshire means that the primary production method of hydrogen in the region is likely to be green hydrogen using increasing proportions of low carbon electricity.

As demand for hydrogen grows in the 2030s, South Yorkshire is likely to see hydrogen being imported from coastal sites, such as the Humber region, where it will be produced from offshore wind, methane with carbon capture, or imported by ship.

Hydrogen shipping is gaining traction with a number of countries considering export markets. Production from methane requires carbon capture and storage which is gaining political and financial consensus in the UK.

However, South Yorkshire does not need to wait for these major energy developments in the 2030s to start to decarbonise its energy systems.

Hydrogen can be produced through electrolysis using renewable energy either on site or via the electricity grid. Rapid response electrolyzers can provide valuable grid balancing services for frequency control, and can facilitate high penetration of renewable energy on the grid by enabling large scale energy storage. With a supportive planning environment, buy in local stakeholders, and considered site selection, site selection, significant expansion of renewable energy with green hydrogen supply and demand could be seen in the very near future.

OPPORTUNITIES

Emerging opportunities for hydrogen production, storage and transfer include:

- Excess electricity from renewable generation in the region (e.g. from periods of high wind or sunshine), could lead be used to create green hydrogen. In the region there is already 121MW of existing onshore wind capacity, the largest being Tween Bridge Windfarm 44MW north east of Doncaster. Doncaster's draft local plan has identified a large area for potential expansion. Dedicated hydrogen production from new renewables may also prove an attractive proposition to developers.
- Injecting (or blending) green hydrogen into the gas network displaces fossil fuel methane. It also can help to balance variation in demand and supply facilitating the construction of hydrogen production facilities. Blending is being demonstrated in the HyDeploy trials by both Cadent and Northern Gas Networks with equipment from ITM power. Up to 20% hydrogen can be blended with methane with little or no requirement to change downstream appliances. Feasibility study is recommended to examine the locations where this could occur in South Yorkshire in relation to existing or potential renewable energy sites.

- In the early 2030s, parts of the UK's gas grid could be converted to 100% hydrogen. The region could then receive hydrogen via the gas network in large quantities from production or import sites on the coast. This could include green hydrogen production from offshore wind, blue hydrogen production at Drax power station or green hydrogen shipped to the Humber estuary ports or Goole, the UK's most inland port.
- Hydrogen can be transported by tanker or train to locations where the gas network doesn't currently extend to. This may be a temporary option to accelerate hydrogen adoption, prior to the conversion of the gas network from methane to hydrogen.
- Storage of energy to meet seasonal heat demand can occur on small or industrial scales. Being able to store intermittent energy from renewable generation projects increases their viability. However, developing over ground gas tanks both large and small has numerous planning challenges. In South Yorkshire there is an existing underground storage facility at Hatfield Moor and Hatfield West which stores 116 million m³ of methane in a depleted gas reservoir. Locations such as this could be used as a hydrogen store, further geological research is required.



Transport

South Yorkshire has one of the highest density of road and rail connections in the UK, making hydrogen for transport a key opportunity.

Strong transport connectivity puts the South Yorkshire region in a strategically important position within the UK logistics and distribution sectors. This includes a major hub centred around Doncaster Sheffield Airport and the nearby iPort; one of the UK's largest logistics developments. The region is also positioned en route for freight traveling south from the Humber region's sea ports.

Hydrogen for propulsion, will play an increasing role in the decarbonising of transportation, although the infrastructure required currently lags far behind the infrastructure required for battery electric vehicles. Hydrogen is therefore likely to play a key role initially in niche markets. The use of fuel cell electric vehicles, powered by energy dense hydrogen, is ideally suited to heavier vehicle fleets with back to base journeys, that have long range requirements.

Hydrogen mobility is ideal where there are short refueling times requirements as well as limited space for charging of multiple battery electric vehicles at depots. Retrofitting of existing diesel vehicles for hydrogen combustion maybe an option for some fleets in the transition period.

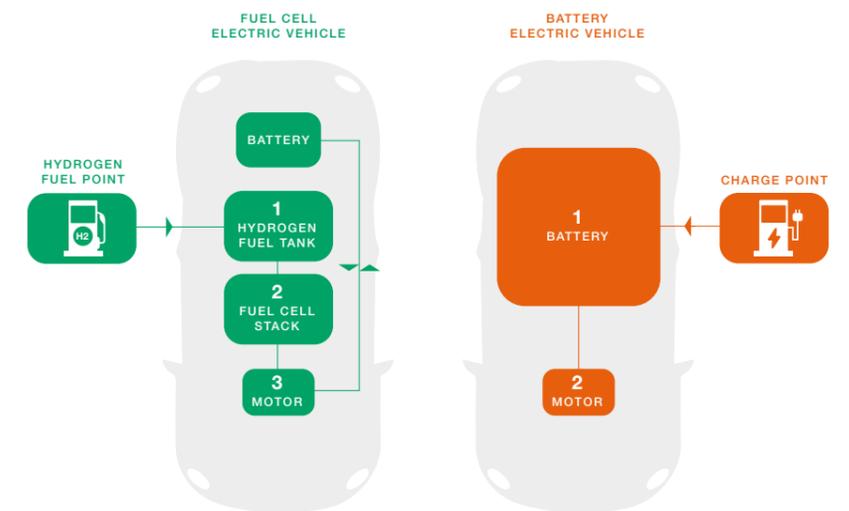
Hydrogen is being used for an increasing number of bus fleets and the first passenger train service, powered by hydrogen, is operational in Germany.

OPPORTUNITIES

A number of specific opportunities for hydrogen to fuel the transport sector include:

- The introduction of large hydrogen bus fleets on long or hilly routes between the urban centers of South Yorkshire or into adjacent rural areas. Arup recently completed a technical study on hydrogen buses for South Yorkshire, alongside a study on electric buses.
- A network of hydrogen refuelling centres designed for heavy duty vehicles around Doncaster servicing the logistics sector, retrofitting the existing truck parks.
- A large, or series of large, hydrogen refuelling stations, located at existing or proposed M1 motorway service areas, providing both a hydrogen refueling station and electric charge points.

- Establishing a significant hydrogen train service that focusing on replacing diesel on lines that are challenging to electrify is a key opportunity. Arup is currently working on the safety case for hydrogen trains for the Rail Standards and Safety Board. Trials of hydrogen-powered trains were included as a commitment by Abellio when it was awarded the East Midlands franchise in mid-2019, which includes stations in South Yorkshire.
- Transitioning airside vehicle fleets at Doncaster airport to low emission vehicles, following the trend across airports globally.



Schematic comparison of a Fuel Cell Electric Vehicle and a Battery Electric Vehicle



Industry

South Yorkshire has a long industrial heritage and continues to be a leader in specialised steel and glass manufacturing, advanced manufacturing and high-tech industries.

South Yorkshire, in collaboration with the neighbouring Humber Region, is well placed to fulfill the challenge¹ set out by the government's Industrial Strategy to create net zero industrial clusters. The Humber clean Growth Local White Paper sets out a routemap to rise to the challenge. This white paper² on clean growth in the Humber region sets out a route map to rise to the challenge. For industry in both South Yorkshire and the Humber it's clear that hydrogen energy systems will play an increasingly significant role.

Approximately 1.7m tonnes of steel are processed in South Yorkshire each year. There are no blast furnaces in the region, (electric arc furnaces are used to recycle scrap steel), but significant quantities of natural gas are used by the steel industry in South Yorkshire for reheating steel stock to form steel products. Reheating steel requires high grade heat, and blending with green hydrogen should be investigated as a route to decarbonisation. Similarly, South Yorkshire has a significant glass manufacturing industry. Glass processing is reliant on high temperature process which requires decarbonisation.

As large energy users are a core part of the regional economy, it is essential that a balance between transitioning from fossil fuels and retaining jobs in industry are found. Advocating for legislation for the year on year tightening of the allowed embodied carbon emissions in high energy products that are used by the construction industry such as steel, glass, brick and cement is one key way to achieve this balance.

OPPORTUNITIES

Hydrogen poses an opportunity to decarbonise heavy, medium and light industries. Though more work is needed to understand the individual opportunities for specific sites and businesses, the general industry opportunities include:

- Combustion for furnaces or reheating process – either blended with natural gas or through 100% conversion to hydrogen.
- Using the by products of hydrogen production in industry: oxygen from green hydrogen or carbon dioxide from gas reformation.

- Hydrogen fuelled freight transport, road and rail (see previous Transport section). Co-locating green hydrogen production, which has pure oxygen as a by product, with industry that requires oxygen is a synergy that can be further investigated..
- Using waste heat from industrial processes to pre-heat methane in the gas reformation process, which is one method to produce hydrogen (see section on Why Hydrogen?).



Continuous reheating of steel ingots in Sheffield

1 - https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/803086/industrial-clusters-mission-infographic-2019.pdf

2 - <https://www.humberlep.org/wp-content/uploads/2019/11/Humber-Clean-Growth-White-Paper.pdf>



Heating

Hydrogen could have a significant role in decarbonising our heat in both the commercial and domestic sectors.

In the short term, there is the potential to blend hydrogen up to 20% in the gas network without the need to alter household appliances, providing an opportunity to partially decarbonise the gas grid. Longer term, 100% hydrogen within the gas network is being explored which will necessitate the change of domestic appliances such as cookers and boilers, and a larger scale of hydrogen supply than it may be possible to produce in the region.

Nationally, there are projects underway to investigate and trial both the 20% and 100% cases, the results of which can be taken forward in the region. Arup is involved in several projects investigating the 100% case including the government's Hy4Heat program³.

The region already has a number of heat networks and there are plans to extend these and develop new ones in densely built areas. Electric heating may be the preferred option for new build, commercial and off-gas grid properties. However, there is an opportunity for hydrogen to play a key role for medium-density housing and areas in which heat networks or electric heating solutions will not be technically or financially viable.

Ground or air source heat pumps often require an upgrade to central heating systems. Domestic hydrogen boilers generate higher temperatures so only the boiler requires replacement, not the whole central heating system.

OPPORTUNITIES

The region should position itself at the forefront of national initiatives to use hydrogen in the commercial and domestic sectors, including:

- Considering the conversion of large campus estates to hydrogen: the universities, hospitals, schools, colleges and local authorities who currently consume a large proportion of their energy in the form of heat from natural gas could generate their own hydrogen from renewables either onsite or road tanker it in from more rural areas. This could be blended to supply existing gas-fired boilers and CHPs, or through full conversion of private gas networks to hydrogen.
- Choosing a mix of dense urban and sub-urban population to trial a mix of different small, medium and large hydrogen heating systems. There are plans to build approximately 4,000-5,000 new homes per year in the region. There is also an imperative to decarbonise the existing housing stock. For a proportion of both the new and existing house stock, heating by hydrogen may be the solution.

- Explore road tankering of hydrogen to locations of demand, as a precursor to the conversion of the gas grid from methane to hydrogen or to locations that are off grid.
- Hydrogen combustion could be used as an effective way to further decarbonise and add capacity to Sheffield's high-temperature district heat networks. The Sheffield District Energy Network, operated by Veolia, is heated primarily by energy from waste but is reliant on backup gas boilers. Similarly, the E.On heat network from Blackburn Meadows biomass power station has backup boilers which run on methane.
- There is potential to investigate hydrogen fuelled generation for current and proposed gas fuelled heat networks in the region.
- Early adoption of hydrogen ready appliances when available on the market, particularly in new build dwellings.

3 - <https://www.arup.com/projects/hy4heat>



Skills, Jobs and Research

South Yorkshire is home to world-class academic institutions, research facilities and firms, all of whom can support the development of hydrogen in the region.

The University of Sheffield and Sheffield Hallam University are both within the region. They are supported by the Advanced Manufacturing Research Centre, where academics and industrial partners collaborate on new technologies. These research and development capabilities could provide a supply of graduates knowledgeable on hydrogen as well as a resource for industry to test ideas.

The region is also the base for world-leading organisations, such as ITM Power, manufacturing electrolysers for both home and export markets. The presence of this manufacturer, a growing employer in the region, gives a natural advantage in deploying the technology locally as well as growing the hydrogen-related skills within the workforce. The region could build on its advanced materials and manufacturing reputation and could quickly develop into a recognised global leader in the manufacture of hydrogen electrolysers and create a highly skilled work force.



University of Sheffield

OPPORTUNITIES

There are a number of opportunities for the region to contribute to the national research into hydrogen, develop local projects and grow skills:

- Align research institutions and local industries to direct research on overcoming specific technical barriers.
- Industry to work with local colleges such as the Think Low Carbon Centre at Barnsley College, The National College for Advanced Transport & Infrastructure in Doncaster, Doncaster University
- Technical College (UTC) and Sheffield UTC to include educational and training opportunities in hydrogen and its application to the built environment.
- Ensure that organisations in the region are enabled to invest in skills development through training schemes and apprenticeships.
- Support businesses and industries to export their products, skills and expertise outside of the region.



A series of workshops were convened amongst key stakeholders in South Yorkshire

Developing opportunities through collaboration

The South Yorkshire Hydrogen Network is a collaboration led by Arup bringing together a broad range of organisations, both public and private, who see an opportunity to develop hydrogen projects in the region. We are motivated by both the region's and the UK's commitment to decarbonisation, as well as the need to see a boost to skills, jobs and livelihoods locally.

We held a number of open meetings and workshops throughout 2019 to develop our understanding of the role hydrogen could play in the region's energy mix. Our intention is to accelerate the transition to net zero carbon using the disruptive opportunity posed by hydrogen as an energy vector. We believe that collaboration will be key to accelerating the carbon transition.



Site visit to the wind powered hydrogen refuelling station in Rotherham

A call to action

The South Yorkshire Hydrogen Network has developed this vision for a hydrogen economy in the region as a first step towards establishing a pipeline of projects in the region. The South Yorkshire Hydrogen Network will help the public and private sector to form working partnerships to develop concepts, form bankable projects, attract funding and deliver projects.

CURRENT POSITION

- Established the South Yorkshire Hydrogen Network in 2019, a collaborative network of local public and private organisations focused on hydrogen, and published in this document.

AMBITIONS FOR HYDROGEN IN SOUTH YORKSHIRE?

- ▶ Expansion of onshore wind and solar PV with green hydrogen production.
- ▶ A large scale hydrogen bus fleet.
- ▶ A large hydrogen refuelling hub on the M1 motorway.
- ▶ A significant hydrogen rail service.
- ▶ A net-zero carbon industrial cluster, linking with the Humber region.
- ▶ A housing district trialling 100% hydrogen for heating.

A world class research capability in the hydrogen economy.

Exceptional vocational training programmes in hydrogen related skills.

NEXT STEPS FOR THE SOUTH YORKSHIRE HYDROGEN NETWORK?

- ▶ Broaden collaboration to identify projects and develop proposals.
- ▶ Explore funding opportunities with central government and private investors.
- ▶ Develop a programme for delivery.

OUTCOMES

- ✓ Accelerated progress towards net-zero emissions.
- ✓ Improved air quality and better livelihoods.
- ✓ Inclusive growth, improved productivity, economic success.
- ✓ The region being recognised as a leader in advanced low carbon manufacturing.

With thanks to all those who have contributed to the South Yorkshire Hydrogen Network workshops and other local organisations which have enabled us to develop this report.



We shape a better world

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