

LOW CARBON HYDROGEN



THE CHALLENGE

Demand for hydrogen has tripled since 1975 and continues to rise.

Supplied almost entirely from fossil fuels, the production of hydrogen is responsible for approximately 900 million tons of CO₂ emissions per year. That is equivalent to the CO₂ emissions of the United Kingdom and Indonesia combined.

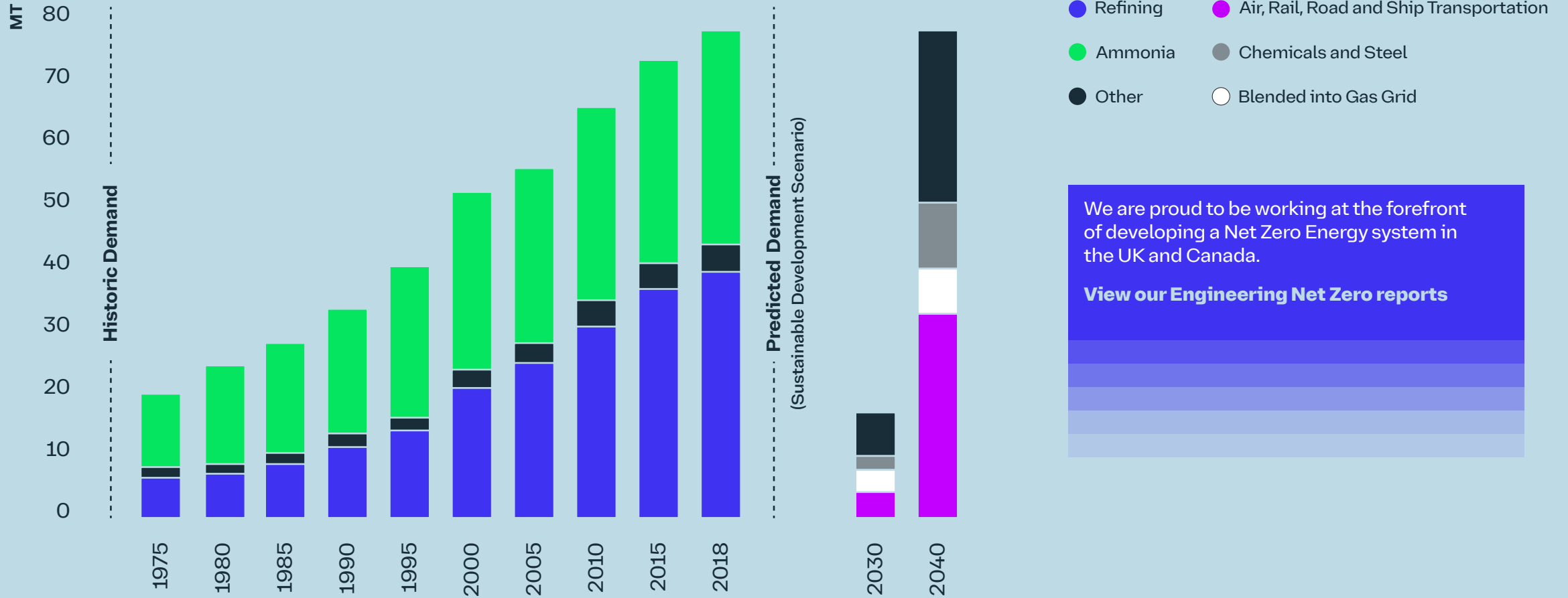
Eliminating the emissions from current demand is critical to reaching Net Zero globally. Beyond current demand, the additional industrial applications for hydrogen are developing quickly with significant economic and technological uncertainty.

With our deep understanding of hydrogen from production to end use, we can reduce economic and technological risk.

USES OF HYDROGEN:

- **Industry:** Hydrogen use today is dominated by the industry, namely oil refining, ammonia production, methanol production and steel production.
- **Transport:** The challenge with implementing hydrogen fuel cell vehicles are the current fuel cell costs and the availability of infrastructure to deliver hydrogen. For road vehicles, hydrogen is best suited for larger vehicles, including heavy goods vehicles and buses. Shipping and aviation have limited low-carbon fuel options and represent an opportunity for sustainable fuels produced from hydrogen including ammonia, methanol and kerosene.
- **Power generation:** Hydrogen is one of the options for long duration storage of renewable energy. Hydrogen, or a derivative such as ammonia, can be used in fuel cells or gas turbines to increase grid flexibility.





We are proud to be working at the forefront of developing a Net Zero Energy system in the UK and Canada.

View our Engineering Net Zero reports

FIGURE 1 GLOBAL HYDROGEN DEMAND ^{1,2}

Note: 2030 and 2040 predicted global demand for hydrogen from electrolysis and fossil fuels with carbon capture usage and storage.

¹ The Future of Hydrogen, IEA

² Global demand for hydrogen from electrolysis and fossil fuels with ccus by scenario, 2030 and 2040, IEA

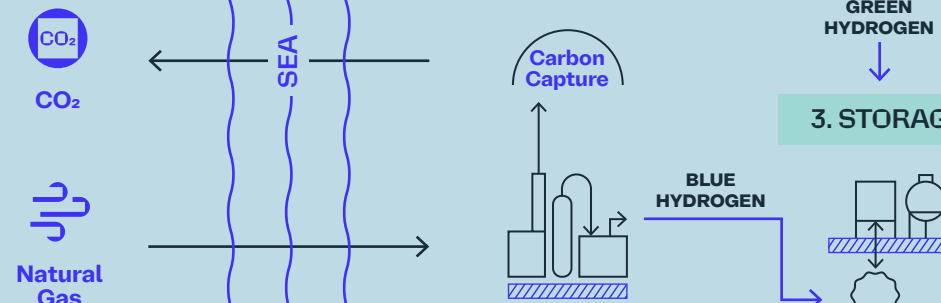
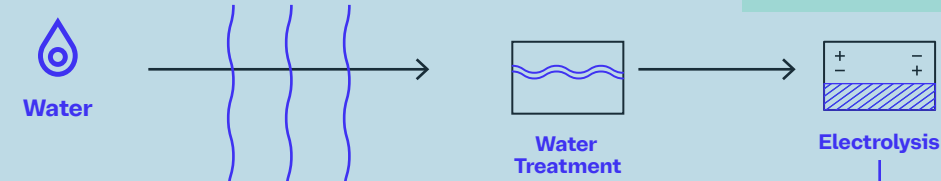


OUR SERVICES

1. POWER GENERATION



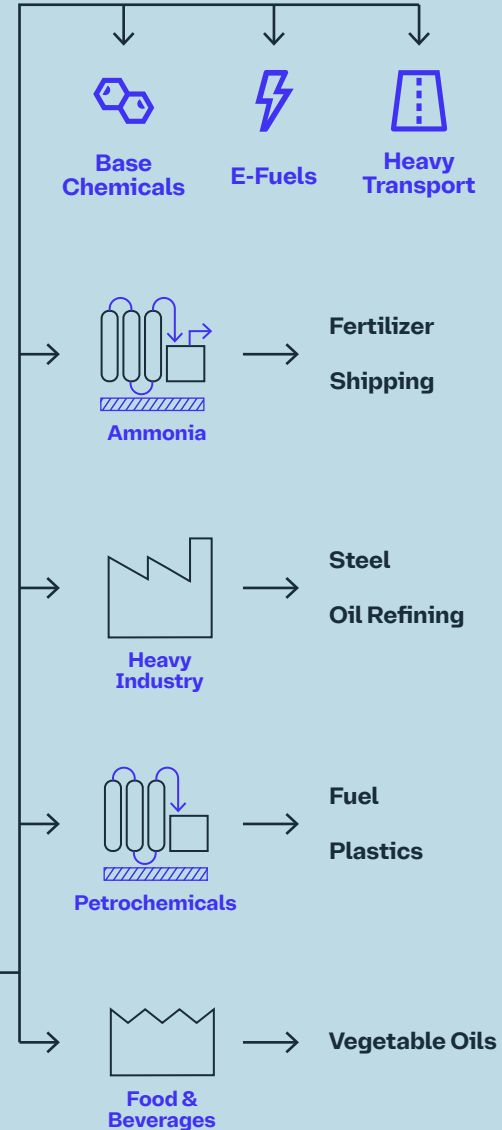
2. PRODUCTION



3. STORAGE

4. DISTRIBUTION

05 UTILIZATION



Studies

- Optioneering
- Feasibility Studies
- Siting Studies
- Market Assessment
- Technology Scouting
- Architecture and Planning
- Business Case Development
- Environment Assessment and Consulting

Design and Engineering

- Concept
- Pre-FEED
- FEED
- Detailed Design
- Demonstrator Plant
- Design and Project Management
- Commissioning

Regulatory Advice

Project Management Services

Project Controls

H₂ Storage

- Studies
- Design
- Delivery

Operations

- Operations support
- Maintenance
- Troubleshooting

FIGURE 2 HYDROGEN LIFE CYCLE



OUR EXPERIENCE AND CAPABILITIES

Delivered by our dedicated, in-house, low carbon technology specialists, our project and technical staff support our clients throughout the project lifecycle in the development, engineering, design, construction and commissioning of hydrogen facilities.

TAQA GREEN HYDROGEN AND DERIVATIVE FUELS

As technical advisor to Abu Dhabi National Energy Company (TAQA) for the development of large scale green hydrogen and derivatives plants in the United Arab Emirates, our support includes the pre-feasibility, conceptual design and development phases for several projects.

PRE-FEASIBILITY

- Develop an electrolyzer vendor database, comparing technical and commercial aspects between manufacturers and products.
- Undertake Engineer Procure Construct (EPC) contractor qualification.
- Conduct an energy and mass balance assessment to determine the optimum plant configuration that provides the lowest levelized cost of hydrogen, considering different electrolysis technologies, power sources, batteries and hydrogen storage techniques.
- Develop plant interface and utility schedules.
- Develop plot plan layouts.

CONCEPTUAL DESIGN

- Full techno-economic assessment of the hydrogen and derivative fuel production chains.
- Prepare EPC technical tender documents.

DEVELOPMENT

- Prepare qualification requests for proposal, bid management, evaluation and selection of EPC contractors.
- Provide support in negotiations through to financial investment decision by TAQA.

SERVICES PROVIDED

- **Feasibility Studies**
- **Market Assessment**
- **Technology Scouting**
- **Concept Phase - Design and Engineering**





WORLD'S LARGEST HYDROGEN FUEL BLENDING DEMONSTRATION, MITSUBISHI POWER

Blending hydrogen and natural gas to help accelerate decarbonization goals and reduce greenhouse gas emissions.

The demonstration project tested and validated blending 20% hydrogen to produce electricity by using an advanced class gas turbine. The first and largest demonstration of its kind to date resulted in a 7% reduction in carbon emissions. Hydrogen and natural gas differ significantly in their properties, so the case wasn't as simple as replacing one with the other. Hydrogen is about 14 times lighter than air, so containment was a challenge.

This also required a comprehensive examination of factors, such as evaluating the pipeline systems, considering pressure, temperature, stress, flow and pipeline age, to make sure the system remained reliable and safe with no issues or interruptions.

We provided detailed design and modeling of the hydrogen fuel delivery system, ensuring that the piping system kept the hydrogen and natural gas combination well-mixed when it reached the combustion turbine.

In addition, we provided subject matter expertise and advised on code compliance, safety provisions and material selection. A natural gas and hydrogen blending skid was built to mix the two fuels before delivery to the combustion turbine. We provided design modifications to alter the existing infrastructure to blend hydrogen into the natural gas line.

SERVICES PROVIDED:

- **Design and Engineering**
- **Regulatory Advice**





SSE THERMAL ALDBROUGH HYDROGEN PATHFINDER

We supported SSE thermal's end-to-end, fully integrated hydrogen production, storage, and power generation project, named the Aldbrough Hydrogen Pathfinder.

Located at SSE Thermal and Equinor's existing Aldbrough Gas Storage facility, the project will demonstrate the integration, scale-up and operation of the technology to inform the development and execution of other large projects that would require similar infrastructure.

Our involvement has been in the development of the feasibility and concept design of an electrolyser system, underground hydrogen storage solution and a hydrogen fired Open Cycle Gas Turbine (OCGT) at the East Yorkshire site. The project will produce hydrogen using renewable energy in a 35-megawatt electrolyser which will be stored in an underground salt cavern. The stored hydrogen will then be used to fire a OCGT which can export power to the grid when demand is high.

We completed a series of high-level optioneering exercises and considered the limiting factors associated with integration of the project within an existing operating asset and development alongside the Aldbrough Hydrogen Storage (AHS) project.

We produced a basis of design along with key deliverables that supported and inputted into the client's application to Department for Energy Security and Net Zero (DESNZ).

This multidisciplinary project has been delivered in exceptionally short timescales to achieve the DESNZ Net Zero Hydrogen Fund deadline.

Sally O'Brien, Project Manager at SSE Thermal said: "The Aldbrough Hydrogen Pathfinder is a hugely exciting and ambitious project that aims to bring together hydrogen production, storage, and power generation in one location by the middle of the decade, and has real potential to showcase how important hydrogen may be as an enabler of net zero. It was fantastic to be able to incorporate the expertise of the AtkinsRéalis team in the feasibility phase of this project."

SERVICES PROVIDED:

- **Feasibility Studies**
- **Concept Phase - Design and Engineering**





ALDBROUGH HYDROGEN STORAGE, EQUINOR

Equinor's Aldbrough Hydrogen Storage (AHS) project is a joint venture with SSE to develop a first of a kind, major hydrogen storage plant.

The facility will be located adjacent to the existing Aldbrough Gas Storage site. With a planned capacity of at least 320GWh, Aldbrough Hydrogen Storage would be significantly larger than any hydrogen storage facility in operation in the world today. The Aldbrough site is located to store the low-carbon hydrogen set to be produced and used in the Humber region and will be a key part of the East Coast Industrial Cluster developments.

SSE Thermal and Equinor's partnership in the Humber marks the UK's first end-to-end hydrogen proposal, connecting production, storage and demand projects in the region.

While the Aldbrough facility would initially store the hydrogen produced for the Keadby Hydrogen Power Station, the benefit of this large scale hydrogen storage extends well beyond power generation. The facility would enable growing hydrogen ambitions across the region.

AtkinsRéalis have collaborated with Equinor, SSE, and environmental consultants ERM, to assess the feasibility of the project and to develop the concept design for the surface and subsurface infrastructure.

Our international experience in the development, engineering and execution of major subsurface energy storage projects, coupled with our knowledge of the location, means we were able to develop an optimum solution for the project, tailored to Equinor's storage needs.

SERVICES PROVIDED:

- **Feasibility Studies**
- **Concept Phase - Design and Engineering**





ISLANDMAGEE ENERGY: POWER-TO-X, DESNZ

We developed the engineering design of new hydrogen storage facilities on the islandmagee energy site in Northern Ireland.

We are provided concept design and frontend engineering design (FEED) services for the proposed hydrogen storage at Islandmagee as part of the first-of-its kind Ballylumford Power-to-X Project. The project is part of the UK Government Long Duration Energy Storage Demonstration innovation competition, run by Department for Energy Security and Net Zero (DESNZ).

We provided concept design and FEED services to support Islandmagee Energy's vision for Large Scale Hydrogen Storage at the Islandmagee site, utilizing proposed salt caverns to store hydrogen.

SERVICES PROVIDED:

- **Concept Phase - Design and Engineering**
- **FEED Phase - Design and Engineering**





BLUE HYDROGEN AND AMMONIA PROJECT, CONFIDENTIAL CLIENT

Confidential project in the US to develop a blue hydrogen and ammonia plant using proprietary technology with cryogenic CO₂ capture.

As owners engineer, we are providing services in the project's development prior to financial close, including the product development process (PDP), front-end engineering design (FEED) studies and engineering, procurement and construction (EPC) contracts. A thorough understanding of the technology and the constraints is critical to make sure the performance benefits are fully realized.

Our subject matter experts are providing assessments and developing the specific engineering required for the project, including reviewing the interconnection agreements, codes and standards, contractor's quality assurance and design procedures and environmental requirements.

Project consists of two phases, with development and EPC FEED oversight in Phase 1 and construction and quality assurance oversight in Phase 2.

SERVICES PROVIDED:

- **Owners Engineer**
- **Regulatory Advice**
- **Environmental Assessment and Consulting**





HYDROGEN TO HEYSHAM: EDF HYNAMICS

Hydrogen to Heysham (H2H) was a project run by EDF Energy with support from the Department for Energy Security and Net Zero (DESNZ).

The aim of the project was to develop a hydrogen production and distribution facility that would produce hydrogen and oxygen from water electrolysis using pre-grid electric power generated by Heysham's nuclear power stations.

The hydrogen produced could then be used for various applications including powering vehicles, supplying industrial processes and even injecting it into the UK gas network.

The self-sufficient design integrated two designs of electrolyzer into a facility capable of adapting capacity to suit demand. A key objective was to ensure the novel technological concept could be delivered with off-the-shelf technology and safely sited adjacent to an operating nuclear power station.

The feasibility study assessed the technical and commercial viability of building a demonstration plant at Heysham and then the potential for replicating bulk hydrogen generation from low-carbon electricity across the UK.

We provided the following:

- Full multidisciplinary concept design
- Hazard identification study (HAZID).
- Guidance on compliance with relevant codes of practice (BCGA CP33).
- 3D visualization of design in-situ for presentation of bid documents.
- A process flow diagram and piping and instrumentation diagram for the integrated process with limited data, produced by our process engineering team.

SERVICES PROVIDED:

- **Feasibility Studies**
- **Concept Phase- Design and Engineering**
- **Regulatory Advice**





ACORN HYDROGEN PROJECT: PALE BLUE DOT ENERGY (PBDE)

Project Acorn is a carbon capture and storage (CCS) and hydrogen project at St Fergus Terminal, Peterhead, UK.

Through this project, natural gas produced in the North Sea will be reformed to clean hydrogen with CO₂ mitigation infrastructure. The hydrogen created would be used in transport applications and in the gas grid to decarbonize heating in our homes and industries.

The project is supported by the Department for Energy Security and Net Zero (DESNZ). Innovation Funding through the Low Carbon Hydrogen Supply Competition.

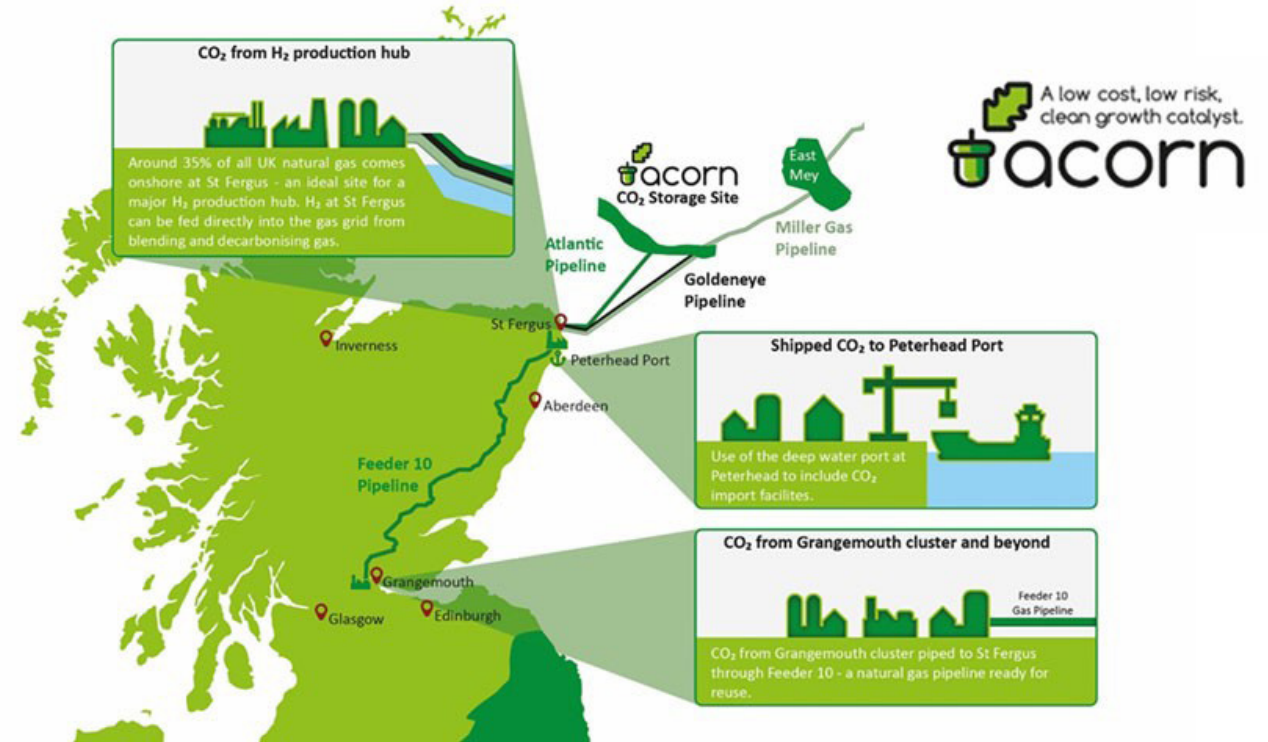
We carried out an optioneering study for PBDE, assessing different hydrogen storage technologies. Various types of storage we explored included salt caverns, depleted oil and gas reservoirs, surface storage (vessels), conversion of hydrogen to ammonia and novel technologies (including solid state and liquid carrier).

We delivered a report describing and evaluating the options, along with recommendations and cost estimates.

The outcome of the hydrogen storage optioneering assessment and report was a proof of concept in demonstrating how the decarbonization targets legislated by the Scottish and UK Governments could be met through a low-carbon energy source.

SERVICES PROVIDED:

- **Optioneering Studies**





SSE HYDROGEN STORAGE

As a long-term partner to SSE Gas Storage, we provide a range of engineering and project services to the salt cavern storage sites at Aldbrough and Atwick in the UK.

We have served as the subsurface technical authority since 2013 and owner's engineer since 2017.

Our services included:

- Optimization of the storage assets.
- Management, planning, engineering and design of major CAPEX projects.
- Management, planning, engineering and supervision of major subsurface operations.
- Design of major modifications to existing plant.
- Strategic advice on the future development of the assets.

We supported SSE in the development of a hydrogen salt cavern storage concept to determine whether the current surface and subsurface assets, as well as any potential new assets, could function within a wider hydrogen economy.

A multidisciplinary team with previous knowledge and experience with hydrogen projects were deployed to review the potential for conversion of the existing facilities.

We performed a technical feasibility study to assess the cost, duration and potential benefit of converting the existing assets versus a new build. This study helped convey to the SSE board of directors that the existing assets could function within a wider hydrogen economy.

SERVICES PROVIDED:

- **Feasibility Studies**
- **Owners Engineer**
- **Concept Phase - Design and Engineering**





THE ENERGY TECHNOLOGIES INSTITUTE (ETI) HYDROGEN STORAGE APPRAISAL

The ETI commissioned us to undertake an appraisal of salt cavern behavior when operated in a hydrogen storage scenario to meet peak electrical demands, up to 1GWe.

This two-year feasibility study included a review of UK salt storage sites and available gas turbine technologies to burn up to 100% hydrogen.

We examined caverns in Cheshire, Teesside and East Yorkshire and worked closely with some of the UK's leading cavern storage operators, including Storengy, SSE Gas Storage and SABIC, to base our research on real cavern data.

Our work advanced the understanding of the potential use of salt caverns to provide hydrogen storage in a low-carbon economy.

During this feasibility project, our services included:

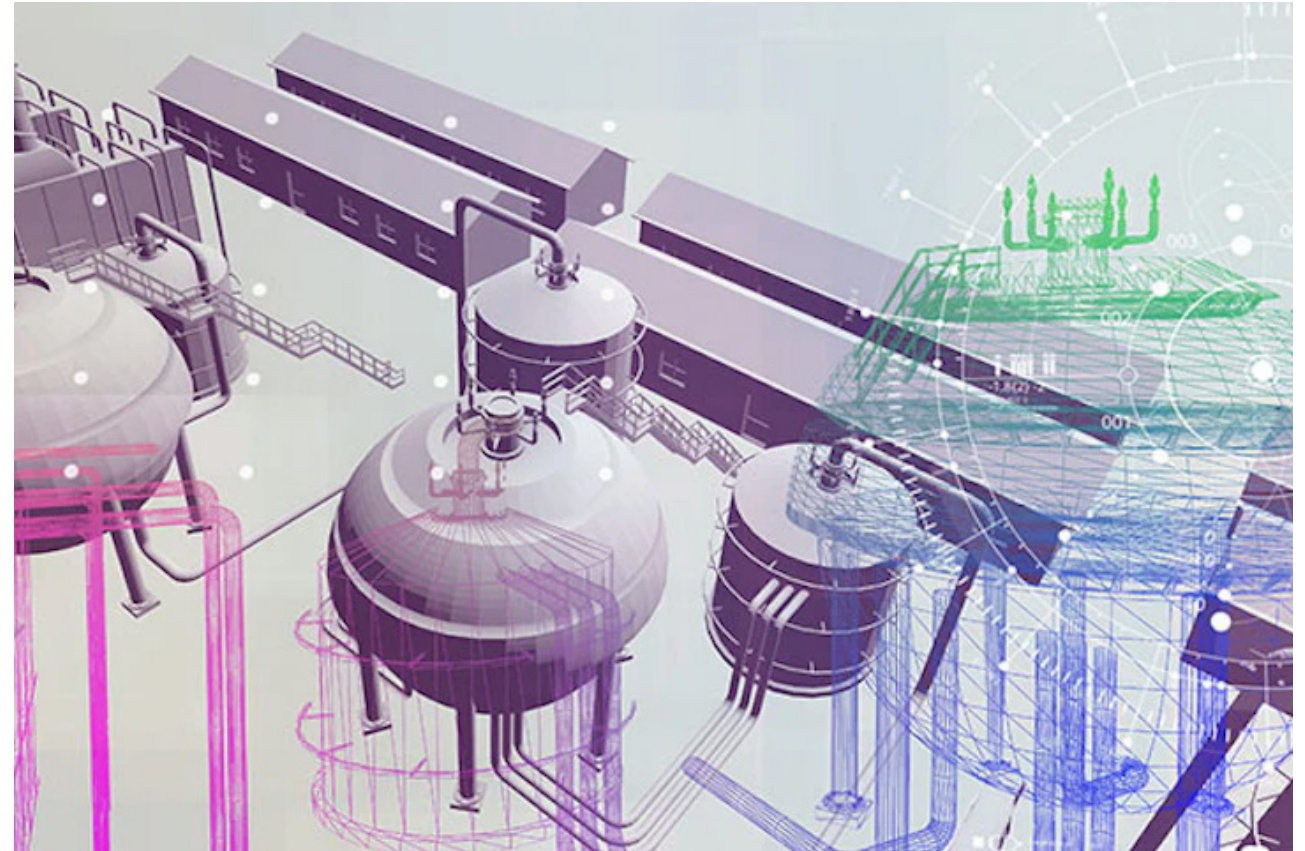
- Health safety and environmental (HSE) regulatory and compliance guidance.
- Full-chain cost model, including capital expenditure, operational expenditure to AACE International Level 5.
- Project planning, management and systems integration.

Technical subsurface specialists:

- In-depth understanding of the geology and stratigraphy of the identified salt fields.
- Determination of minimum and maximum cavern pressure.

SERVICES PROVIDED:

- **Feasibility Studies**
- **Regulatory Advice**
- **Project Management Services**





SIZEWELL C ENERGYHUB: EDF

Sizewell C (SZC) is the UK's proposed new build nuclear power plant, currently being planned by EDF as a replica of Hinkley Point C – a European pressurised reactor (EPR) from EDF design in France.

SZC will meet up to 7% of the UK's energy demand once delivered, expected in the early 2030s.

EDF aims to facilitate the construction and operation of SZC, as well as associated low-carbon projects such as Net Zero Leiston and Moorside energy hubs.

Our team is providing support with various work scopes for these projects:

- **Short Term:** Electrolyzer 'Demonstrator' Project: 2MW proton exchange membrane (PEM) electrolyzer using private supply of power from Sizewell B to decarbonize construction of SZC. Hydrogen will be used in plant and worker transport buses.

- **Medium Term:** Develop a larger hydrogen hub in East Anglia, which could be scaled up from 2MW project or be a standalone project using power from SZC in combination with offshore wind.
- **Long Term:** Use waste heat and power from SZC to produce hydrogen using solid oxide electrolysis. SZC potentially to be designed with Direct Air Carbon Capture (DACC) and district heating. Moorside Clean Energy Hub to use this project as blueprint for design with potential for other nuclear technologies to be included / trialed.

SERVICES PROVIDED:

- **Feasibility Studies**





UK ATOMIC ENERGY AUTHORITY (UKAEA) HYDROGEN TECHNOLOGY ASSESSMENT AND FEASIBILITY STUDY

The UKAEA Spherical Tokamak for Energy Production (STEP) program aims to design a commercially viable compact fusion reactor, collaborating with partners to build a UK prototype by 2040.

To improve the value proposition of the STEP reactor, UKAEA wants to consider alternative thermal to electric conversion, specifically the production of hydrogen.

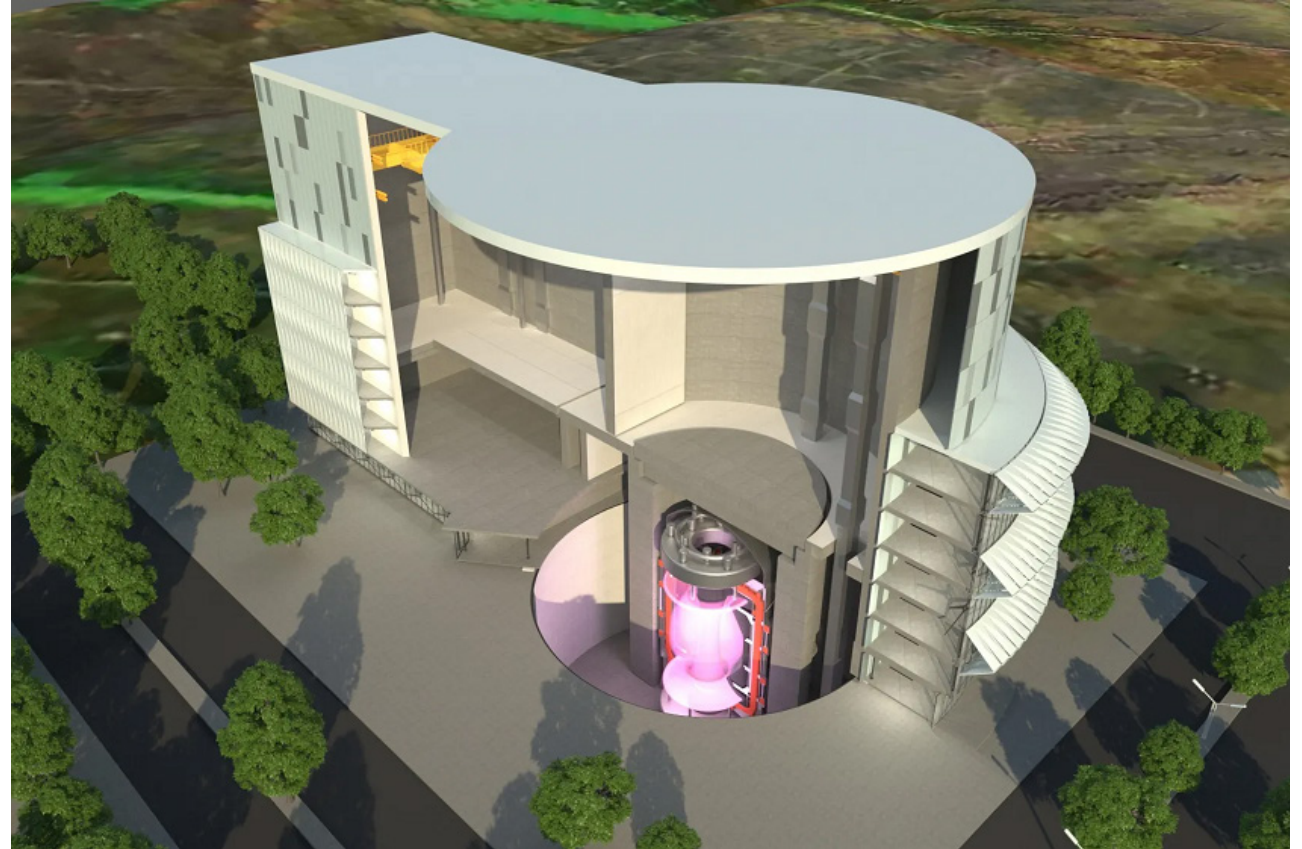
We performed technology assessments and feasibility studies for the most promising hydrogen production technologies:

- Biomass gasification
- Pyrolysis

- Sulphur-iodine cycle
- Copper-chlorine cycle
- Low-temperature electrolysis
- High-temperature electrolysis

SERVICES PROVIDED:

- **Feasibility Studies**
- **Technology Scouting**





MASDAR HYDROGEN PROJECT AND TECHNICAL ADVISORY

We are supporting Abu Dhabi Future Energy Company (Masdar) in its hydrogen for fuels program to produce green hydrogen from a solar powered electrolyzer.

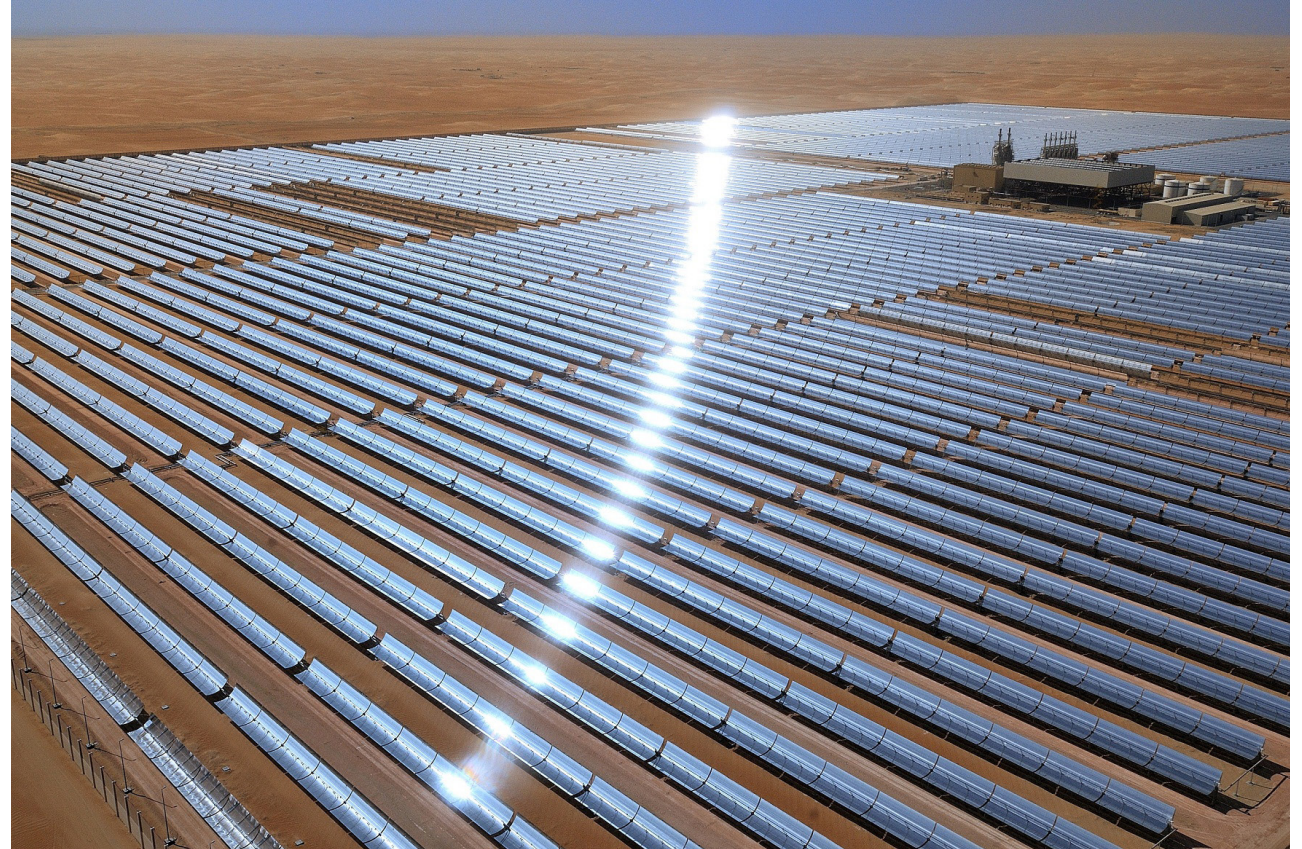
The green hydrogen can then be used as a fuel for ground mobility, such as cars and buses, and fuel cell maritime vessels. The green hydrogen can be further processed to produce synthetic kerosene, a sustainable aviation fuel.

We play a key role in the project management organization (PMO) in the coordination of activities between various working groups and the development and management of a cost model for the integrated system.

Our technical role includes coordination of activities including demand identification of ground mobility users, selection and installation of the ground mobility refueling infrastructure, assessment and selection of hydrogen-to-sustainable aviation fuel pathways and technologies.

SERVICES PROVIDED:

- **Project Management Services**
- **Market Assessment**
- **Technology Scouting**





GULF COAST CARBON CAPTURE AND STORAGE (CCS) AND HYDROGEN PRODUCTION, BP AND LINDE

Advancing decarbonization efforts across the Texas Gulf Coast, the Gulf Coast project is a joint venture between bp and Linde that will enable low carbon hydrogen production.

Located in the Greater Houston area, the project will capture and store CO₂ from Linde's hydrogen production facilities to produce low carbon hydrogen for the region.

The low carbon hydrogen will be sold to customers along Linde's hydrogen pipeline network under long-term contracts to enable production of low carbon chemicals and fuels. Appointed by bp to deliver project control services, we are currently embedded within the client team providing daily support at their Houston location.

Our experience in delivering project controls services, coupled with our knowledge of the industry and location, enables us to provide the right skillset to deliver the project's specific requirements successfully.

With a potential start-up by 2026, the project aims to store up to 15 million metric tons of CO₂ per year in multiple sites – the equivalent of removing approximately 3 million cars from the road.

SERVICES PROVIDED:

- **Project Controls**
- **Project Management Services**





BP INTEGRATED MIDWEST ENERGY HUB PROJECT

The integrated Midwest energy hub project will deliver the transition of the Whiting Refinery to a key central energy hub that provides power, hydrogen and biofuels that will meet the future needs of the region.

Located in Northwest Indiana, the project is in the early stages and targeted for completion in 2030.

Upon completion, the project aims to deliver the following:

- Provision of carbon capture and storage to neighboring steel mills and power plants.
- Production of large amounts of blue hydrogen to feed refining business, fuel buses and trucks and neighboring steel mills.
- Reduction in operational CO₂ emissions by 1.6 million tons (350,000 cars worth) annually by powering existing furnaces with cleaner hydrogen.
- Production of up to 7,000 barrels per day of sustainable aviation fuel (SAF) through new units that run on bio or waste feedstocks.

- Process up to 8,000 barrels per day of alternative feeds to existing units such as waste, waxes or other biofuels.
- Partner with other bp businesses to develop a Northwest Indiana Hydrogen Hub supported by the Department of Energy.

By being embedded within the bp Whiting site over the last 15 years, our expertise and knowledge of the site enable us to provide multiple project controls services to the various capital projects involving the maintenance, refurbishment and replacement of the existing plant.

SERVICES PROVIDED:

- **Project Controls**
- **Project Management Services**



OUR LOW CARBON TRACK RECORD

Over 100 years ago we made our mark while the energy sector was undergoing a major transformation.

Today, as a new energy paradigm emerges, our clients recognise us for our sustainable project execution and tangible contributions to improving people's lives around the world.

Our teams are based in the UK, Europe, Middle East, Canada and the United States.

Across the globe AtkinsRéalis has 36,000 engineering and project management staff with over 3,000 working on low carbon energy projects. Our experts deliver offshore wind, hydroelectric, carbon capture, hydrogen and power distribution projects.

LEADING INDUSTRY BY EXAMPLE

TRANSMISSION & DISTRIBUTION

We work with National Grid, Office of Gas and Electricity Markets (OfGEM), and Energy System Operators (ESOs) to support the transformation of the grid to support increased decentralisation of supply from renewables. We provide services in network planning and development, power system modelling, High Voltage and Low Voltage substation Front End Engineering Design and detailed design and support to utility regulation.

Boniface.Chileshe@atkinsrealis.com

CARBON CAPTURE

We delivered SaskPower's groundbreaking Integrated Carbon Capture and Utilisation initiative in Saskatchewan, Canada. We have completed feasibility, concept and FEED studies for carbon capture projects for Drax, Energy Technologies Institute, SSE, National Grid, the Department for Business Energy and Industrial Strategy (BEIS) and the International Energy Agency. AtkinsRéalis is the owner's engineer for the pioneering Whitetail Clean Energy project on Teesside in the UK.

Julie.Gilmour@atkinsrealis.com

ENERGY STORAGE

Our energy storage team specializes in the subsurface storage of hydrocarbons and clean energy products such as hydrogen and compressed air. As owner's engineer for Nord West Kavernengesellschaft (NWKG), we provided technical and project management services across NWKG's operational assets. We are a long-term delivery partner to SSE Gas Storage and have advised the Energy Technologies Institute on salt cavern behavior when operated in a hydrogen storage system.

Christopher.Mcmichael@atkinsrealis.com

INDUSTRIAL DECARBONISATION

We support energy intensive industries to develop their roadmaps to Net Zero through specialist engineering advice. We assist our clients in understanding their current energy demands and greenhouse gas emissions and utilise our in-house tools, methodologies and expertise to identify viable technology interventions to achieve targeted levels of emissions reductions.

Julie.Gilmour@atkinsrealis.com

NUCLEAR

We work alongside our clients to provide unparalleled support throughout the entirety of the nuclear lifecycle. We are working on projects to realise the benefits of nuclear generation in a low carbon energy system, including for hydrogen generation and direct air carbon capture. We are also heavily involved in the future of nuclear power developing small modular reactors (SMRs) and fusion projects.

Jason.Dreisbach@atkinsrealis.com

WIND & RENEWABLES

We carry out design, geotechnical, environmental, asset integrity and life extension work on offshore and onshore wind turbines for developers in the UK and globally. We provide transmission and distribution services for offshore wind connectivity to the grid and we integrate renewable energy with hydrogen generation projects.

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WORKING
TOGETHER
TO PROTECT
TOMORROW

DIFFERENTIATORS BRINGING VALUE TO OUR CLIENTS

FULLY INTEGRATED GLOBAL TECHNOLOGY CENTRE

Our advanced global technology centre located in India is fully integrated with our day-to-day client delivery and held to the same high-quality standards and systems across our organisation. Our focus on investing in the best tools and data processing capabilities and a team that has delivered hundreds of projects all over the world provides our clients the opportunity to achieve lower costs, and longer working hours - seamlessly.

LOCAL COMMUNITIES AND SUSTAINABLE DEVELOPMENT

We are committed to leaving behind a positive and sustainable legacy for the communities in which we work. We have a demonstrated track record of our commitment to community engagement, particularly in industrial work locations, delivering:

- Skills training and mentoring programs
- Involvement in our local community's organizations
- Traditional knowledge and community studies
- Assistance in education and health services
- Permitting and approvals

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EXCUSES.



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