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# sbh4 hydrogen and CCUS training courses and public speaking

Virtual and on-site training, seminars and events
for decarbonisation, the emerging hydrogen economy and
the energy transition

# Stephen B. Harrison: coach, trainer and public speaker for seminars and events

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**Stephen B. Harrison** is the founder and managing director at sbh4 GmbH in Germany. His work focuses on decarbonisation and greenhouse gas emissions reduction. Hydrogen and Carbon capture, transportation, utilisation and storage (CCTUS) are fundamental pillars of his consulting practice. He has also served as the international hydrogen and CCTUS expert for multiple ADB projects in Pakistan, Palau and Viet Nam.

In 2021 Stephen specified more than 2GW of electrolysers for projects in Asia. Stephen has intimate knowledge of the full hydrogen value chain from commercial, technical, operational and safety perspectives.

Stephen is a chartered chemical engineer with a master's degree from Imperial College, London. His background is in industrial and specialty gases, including 27 years at BOC Gases, The BOC Group and Linde Gas. For 14 years, he was a global business leader in these FTSE100 and DAX30 companies and spearheaded geographic expansion in China and other Asian countries.

Stephen has extensive buy-side and sell-side M&A due diligence and investment advisory experience in the clean-tech sector. His regular clients include private equity firms, investment fund managers and hydrogen start-ups.

As a member of the H2 View and **gas**world editorial advisory boards, Stephen advises the direction for the leading hydrogen-focused international publications. He is also on the Technical Committee for the Green Hydrogen Summit in Oman in December 2022 and served on the Advisory Board of the International Power Summit in Munich in September 2022.

# Expertise in many technologies across the full hydrogen value chain

## Hydrogen production

- Electrolysis for green hydrogen
- Steam methane reforming
- Methane pyrolysis for turquoise hydrogen
- Gasification for hydrogen and syngas
- Hydrogen liquefaction to enable distribution
- Conversion of hydrogen to ammonia
- Air separation: oxygen for gasification and nitrogen for ammonia
- CCS: carbon capture and storage for blue hydrogen

## Hydrogen distribution

- Hydrogen pipelines
- Hydrogen pipeline compression
- Hydrogen gas tube trailer filling
- Liquid hydrogen tanker distribution
- Liquid hydrogen shipping
- Liquid ammonia shipping
- LOHC hydrogen shipping

## Hydrogen storage

- Underground hydrogen storage
- Compressed hydrogen
- Liquid hydrogen
- Liquid ammonia terminals
- LOHC hydrogen terminals

## Hydrogen utilisation in new and established applications

- Hydrogenation of edible oils to fats
- Biofuels hydrogenation
- Synthetic aviation fuels
- Hydrogen for backup power generation on fuel cells
- Hydrogen fired gas turbines for power generation
- Hydrogen conversion to ammonia
- Hydrogen for direct reduction of iron
- Hydrogen blending into gas pipelines
- Hydrogen for float glass making
- Fossil fuel desulphurisation and hydrotreating
- Hydrogen refuelling stations
- Hydrogen mobility
- Hydrogen fired burners
- Hydrogen conversion to methanol
- Methanation
- Annealing metals

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# Training and seminar speaker: delivery formats

# Virtual sessions via Zoom or Teams

**Virtual training** can be provided using Zoom or Teams. Benefits of this format include:

- Increased convenience and flexibility
- Increased virtual collaboration
- Accessibility for a diverse international team
- Affordability

# On-site format

- **On-site training** can be also provided. Benefits of this include format:
- More interaction with the trainer
- Active collaboration.
- **Customised courses** can be discussed, for example: half of one course combined with half of another course within a 3-hour slot, or a full day combining two 3-hour courses.

# Seminar speaker for your customer events



- Aside from being an expert in the hydrogen and CCUS fields, Stephen has a vast experience delivering in-person seminars and online webinars on the growth potential, technologies and challenges within the world of hydrogen and broader decarbonisation topics.
- With his 30 years of experience in this industry, skills in public speaking, many years operating at C-level, and fluency in both English and German, Stephen is an exceptional speaker for those interested in the emerging hydrogen economy, decarbonisation and the energy transition.

# Example training and presentation material

# Graphics and images to enrich the content with tangible examples and cases

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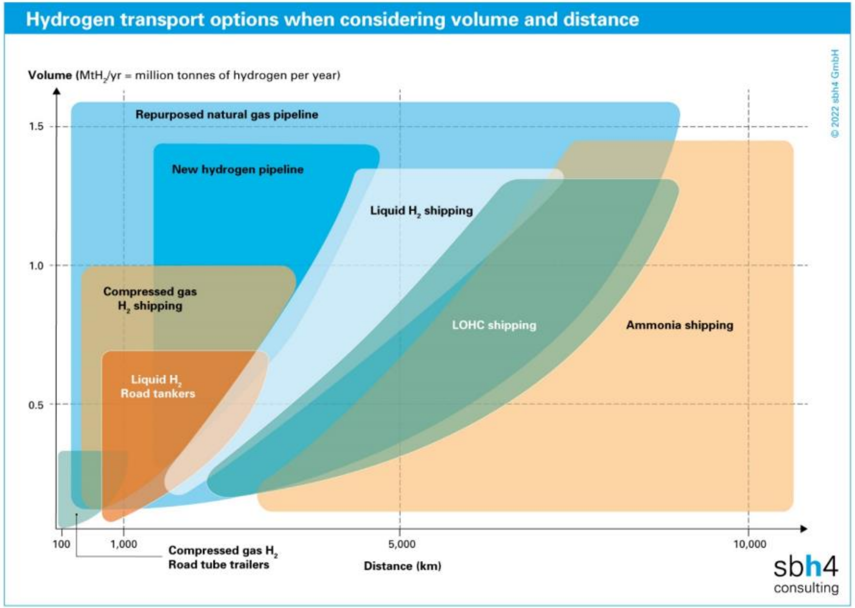
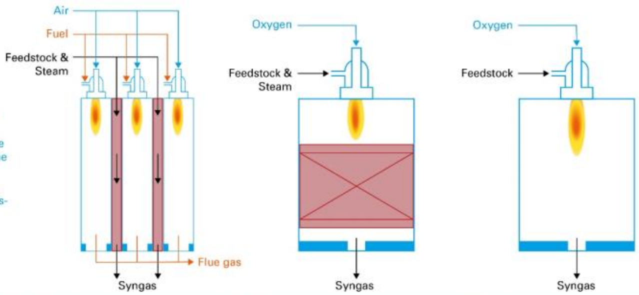


# Comparative cases to support technology evaluation and selection

## SMR, ATR and POX processes for syngas production

**Notes:**
- In the SMR the air/fuel combustion reaction takes place in a separate part of the process to the reforming reaction
- SMR may alternatively be side-fired or upwards-fired
- Shaded area denotes catalyst bed



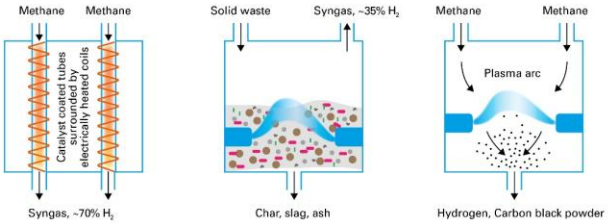



| Process | Steam Methane Reforming – SMR | Auto Thermal Reforming – ATR (Oxidative Steam Reforming) | Partial Oxidation – POX (Gasification) |
|---|---|---|---|
| Carbon feedstock | Natural gas, refinery gas or naphtha | Natural gas or light gaseous hydrocarbons | Gaseous, liquid or solid hydrocarbons |
| Oxygen feedstock | Air for fuel combustion to heat the process (not used for hydrogen generation in the SMR reactor tubes) | Oxygen from ASU fed with controlled stoichiometry to limit $CO_2$ generation | Oxygen from ASU fed with controlled stoichiometry to limit $CO_2$ generation |
| Steam feedstock | Yes | Yes, often from combined SMR | No |
| Catalyst required | Yes, Nickel | Yes, Nickel, Cobalt and others | Not for thermal POX |
| Target chemical reactions | $CH4 + H_2O \rightarrow CO + 3H_2$ | $CH_4 + H_2O \rightarrow CO + 3H_2$<br>$2CH_4 + O_2 \rightarrow 2CO + 4H_2$ | $2CH_4 + O_2 \rightarrow 2CO + 4H_2$ |
| Additional side reactions | $CO + H_2O \rightarrow CO_2 + H_2$ | $CH_4 + O_2 \rightarrow CO_2 + 2H_2$ | $CH_4 + O_2 \rightarrow CO_2 + 2H_2$ |
| Energy required/released | Endothermic, requires heat input | Balance of endothermic and exothermic | Exothermic, releases heat for steam |
| Hydrogen content in syngas | ~70% | ~65% | ~60% |
| Syngas pressure | 15 to 40 bar | 30 to 50 bar | 40 to 80 bar |
| Syngas temperature | 850 °C | 1000 °C | 1400 °C |

## Electrically powered syngas and hydrogen production from hydrocarbons



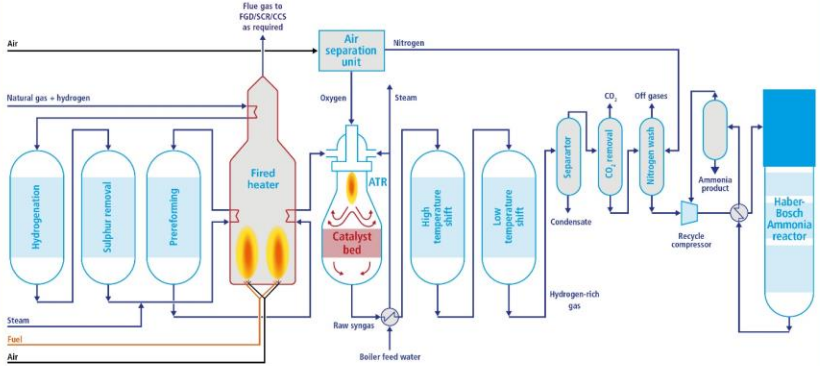
**Notes:**
- Combustion-heated SMR is an alternative to electrical heating
- Thermal or catalytic methane pyrolysis are alternatives to plasma
- Steam may be added to the waste gasifier to increase hydrogen yield, if waste is very dry
- For the plasma gasification reaction stoichiometry shown, methane is used as an example hydrocarbon
- Electrolysis is an alternative electrically powered pathway to produce hydrogen from water (AEC, PEM, SOE) or syngas from steam and carbon dioxide (SOE)




| Process | Electrical Steam Methane Reforming (eSMR) | Plasma Gasification of Solid Hydrocarbons, eg waste | Plasma Pyrolysis of Methane (Methane Cracking, Methane Splitting) |
|---|---|---|---|
| Carbon feedstock | Natural gas, refinery gas or naphtha | Municipal solid waste, dried waste water treatment sludge, biomass, waste paper, tyres, etc | Methane from natural gas |
| Target chemical reactions | $CH_4 + H_2O \rightarrow CO + 3H_2$ | Hydrocarbon + $O_2 \rightarrow 2CO + 4H_2$<br>Hydrocarbon + $H_2O \rightarrow CO + 3H_2$ | $CH_4 \rightarrow C + 2H_2$ |
| Additional side reactions | $CO + H_2O \rightarrow CO_2 + H_2$ | Hydrocarbon + $2O_2 \rightarrow CO_2 + 2H_2O$ | $2CH_4 \rightarrow C_2H_2 + 3H_2$ |
| Carbon produced as | CO and $CO_2$ | CO, $CO_2$, char, slag and ash | Carbon black powder |
| Product gas pressure | 15 to 40 bar | Close to atmospheric pressure | Close to atmospheric pressure |
| Product gas temperature | ~850 °C | ~1000 °C | 1500 to 2000 °C |

# Ammonia, methanol and carbon capture technologies to support decarbonisation

## ATR for Ammonia production

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## DAC technologies for direct air capture of carbon dioxide

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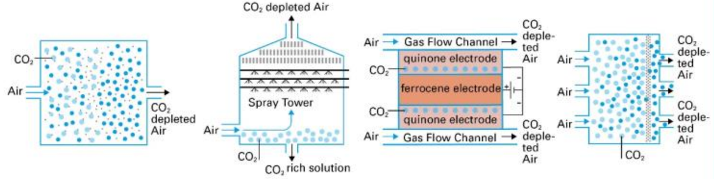
**Notes:**
Only the $CO_2$ separation aspect of each DAC process has been shown






| | Climeworks | Carbon Engineering | Verdox | Carbyon |
|---|---|---|---|---|
| System type | Solid Sorbent | Liquid Absorbant | Solid Sorbent | Solid Sorbent |
| Technology | Amine-functionalised | Potassium Hydroxide solution/ Calcium Carbonation | quinone-carbon nanotube composite | Thin film coated amine- and/or bicarbonate-based porous membrane |
| Regeneration | Temperature / Vacuum | Temperature | Electro-Swing | Temperature |
| Specific Energy Demand | Heat: 2,000 kWh / $t_{CO2}$ Electricity: 650 kWh/ $t_{CO2}$ | NG: 2,777 kWh/$t_{CO2}$ or Electricity: 1,500 kWh/$t_{CO2}$ | Electricity (only cell, w/o BoP in particular ventilation): 568 kWh/$t_{CO2}$ | TBD |
| Operating Temperature | 80-100°C | 900°C | Ambient | 60-85°C |
| Technology maturity level | Commercial | Pilot | Laboratory | Theoretical |

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# Training course themes

Each of the courses presented here is approximately 3-hours duration and suitable for a half-day training session.

Two courses can be combined for a more diverse full-day session, examples of potential course combinations are given.

Each course is designed to give an impactful overview suitable for investors, senior managers, operators, executives and policy makers.

The courses are ideal for experienced professionals looking to leverage their functional expertise into the hydrogen economy.

# 1. Electrolysis for green hydrogen
## Circa 3-hours duration
## Combines well with Technologies for HRS

Green hydrogen is becoming synonymous with electrolysis of water with renewable power. And, accordingly, the scale and breadth of electrolyser technologies is in an exponential phase of growth. Salt-water electrolysis may be the answer for offshore hydrogen generation on floating wind turbines and arid coastal regions with ideal wind and solar conditions. There are numerous additional examples of application niches and innovative electrolyser solutions.

This course will provide tangible examples of technologies for green hydrogen generation from electrolysis pathways. Many of the electrolysis technologies covered in this course have the potential to become mainstream green hydrogen production routes in future decades and will challenge established equipment and well-known electrolyser industry names. If you are investing in the hydrogen economy or considering technologies to implement for your projects, thinking through the best fit solution and likely winners and losers will be fundamental to your analysis. This course will provide some insights support that process.

**Agenda**

- Wind, solar and hydro renewable power pull for different electrolyser technologies
- The impact of electrolyser capex & utilisation on green hydrogen project economics
- Alkaline and PEM technologies, the established solutions
- SEOC and AEM technologies, rising to challenge
- Containerised, standardised products vs engineer to order solutions
- Disruptive technologies that could steal the lion’s share of the market in coming decades
- Supply chain de-bottlenecking and achieving GW scale production capacity

# 2. Utilities and Feedstocks for Electrolysis
## Circa 3-hours duration
## Combines well with Electrolysis for Green Hydrogen

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Green hydrogen is produced through the electrolysis of water. The purity of the water is critical to ensure longevity of the electrolyser. Often, the best location for renewable power generation is in arid locations where pure water is scarce. However, desalination of the sea water is a viable route to ensure plentiful water supply for electrolysis without stressing local freshwater systems.

The other ‘hidden’ utilities for electrolysis are the Lye, or electrolyte solution and nitrogen which is essential for safe operation of the electrolyser. Local production and access to these utilities is essential. This course will look at the technologies and processes required to produce, purify, store, and use these essential utilities and feedstocks. Safety considerations when handling these materials will also be presented.

**Agenda**

- Electrolysis technologies overview
- The problems with impurities
- Water purity, desalination, and purification
- Lye sourcing, storage, and electrolyte maintenance
- Nitrogen for daily operations and shut-down purging
- Nitrogen production or sourcing
- Safety implications of these utilities and feedstocks

# 3. Biomass to Green Hydrogen
## Circa 3-hours duration
## Combines well with Technologies for Waste to Hydrogen

Green hydrogen is becoming synonymous with electrolysis of water with renewable power. But the definition also covers other renewable pathways to hydrogen such as thermolysis of biomass or reforming of biomethane.

This course will provide tangible examples of technologies for green hydrogen generation from non-electrolysis pathways. Some of the processes are used at scale today; others are plans or pipedreams for the future. Many of the technologies covered in this course have the potential to become mainstream low-carbon hydrogen production routes in future decades.

If you are investing in the hydrogen economy or considering technologies to implement for your projects, thinking through the likely winners and losers will be fundamental to your analysis. This course will provide some insights support that process.

**Agenda**

- Biomass-rich municipal solid waste as a feedstock
- Woody biomass and agricultural wastes as feedstock
- Thermolysis technologies for biomass to hydrogen and other coproducts
- Wastewater / animal waste to biomethane to hydrogen with reforming
- Carbon-negative pathways

# 4. Technologies for Waste to hydrogen
## Circa 3-hours duration
## Combines well with Biomass to Green Hydrogen

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Hydrogen enables 'sector-coupling'. Simply put, we can 'couple' the unrelated sectors of garbage collection and operation of a zero-emission bus fleet though the use of hydrogen to join the links in this value chain.

This course will provide tangible examples of chemcycling and waste to hydrogen pathways. Many of the technologies covered in this course are in use today and some will emerge to become mainstream clean energy generation routes in future decades.

If you are investing in the hydrogen economy or considering technologies to implement for your projects, thinking through the likely winners and losers will be fundamental to your analysis. This course will provide some insights support that process.

**Agenda**

- Chemcycling and its role in the waste management hierarchy
- Thermolysis of municipal solid waste and industrial wastes
- Review of commercialised technologies and others in development
- Hydrogen and other coproducts of thermolysis processes
- Waste incineration for power to hydrogen with electrolysis

# 5. Technologies for Turquoise Hydrogen
## Circa 3-hours duration
## Combines well with Technologies for HRS

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Hydrogen production will scale up by several orders of magnitude in the coming decades and the range of low-carbon production technologies will diversify. Grey hydrogen today means small modular reactors (SMRs). Blue hydrogen for tomorrow will integrate those with carbon capture and storage (CCS) and see autothermal reforming (ATRs) become popular. Green and pink hydrogen produced on electrolysers from renewable and nuclear power will play a growing role. All of those are on the radar for the 2020s.

In addition, turquoise hydrogen will also become a mainstream low greenhouse gas emission hydrogen production technology. Turquoise hydrogen is made from methane using pyrolysis (also known as splitting, or cracking). When the process is fed with renewable electricity and biogas it has the potential to be carbon negative.

This course will introduce the main technologies for producing turquoise hydrogen and identify the companies leading their development and commercialisation. The course will also explore current and emerging high scale applications for the solid carbon and graphite that are produced through these processes.

**Agenda**

- Defining methane pyrolysis and turquoise hydrogen
- Plasma, catalytic and thermal technologies for methane pyrolysis
- Carbon allotropes and applications for the solid carbon co-products
- Carbon negative and carbon neutral pathways

# 6. Technologies for HRS

## Circa 3-hours duration, Combines well with Technologies for Turquoise Hydrogen, or Electrolysis Technologies

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Hydrogen mobility is one of the best-known aspects of the hydrogen economy. However, the low volumetric energy density of hydrogen can make storage of hydrogen challenging. Therefore, high pressure gas or liquid hydrogen are required. Hydrogen refuelling stations (HRS) compress and store gaseous hydrogen or store and pump liquid hydrogen. The technologies behind the refuelling stations are complex diverse.

This course will provide examples of hydrogen refuelling station configurations and the equipment that is required to make them work. On-board hydrogen storage on fuel-cell electric vehicles will also be covered.

If you are involved in hydrogen mobility or hydrogen fuelling infrastructure development, this course will provide some insights into the technologies that are enabling this value chain.


**Agenda**

- The status of HRS infrastructure development and hydrogen mobility
- Hydrogen storage on board the fuel cell electric vehicles (FCEV)
- Gas and liquid supply modes to the refuelling station
- Technologies for hydrogen compression and pumping at the HRS
- High pressure gaseous hydrogen storage at the HRS
- Hythane and compressed natural gas (CNG) - hydrogen and natural gas

# 7. Hydrogen and derivatives as heavy transportation fuels
# Circa 3-hours duration
# Combines well with Technologies for HRS

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Green hydrogen can be converted to green ammonia, e-methanol, or synthetic e-fuels to enable long distance transportation. Aviation, railways, long distance trucking, shipping, and mining operations all require high powered engines and extended operating times. Selecting the most appropriate fuel for the use case is dependent on multiple factors beyond the cost of the fuel. Asset availability, fuel availability, refuelling times and range are all key to the overall business model.

If you are investing in the production, storage, distribution, or use of e-fuels then an appreciation of the alternatives is required. Understanding the market drivers and most likely use cases is essential. Furthermore, consideration of the transition requirements from fossil fuels and future operating cost implications will be beneficial. This course will provide insights support all these processes.


**Agenda**

- Transport sector decarbonisation
- Properties of an ideal clean heavy-duty transportation fuel
- Clean fuels for aviation
- Clean maritime fuels
- Clean fuels for mining vehicles
- Clean fuels for trains, trucks, and buses
- Hydrogen refuelling stations
- Safety precautions

# 8. CCTUS (Carbon capture, transportation, utilisation & storage)

## Circa 3-hours duration

## Combines well with Blue Energy Islands or Low-carbon Hydrogen

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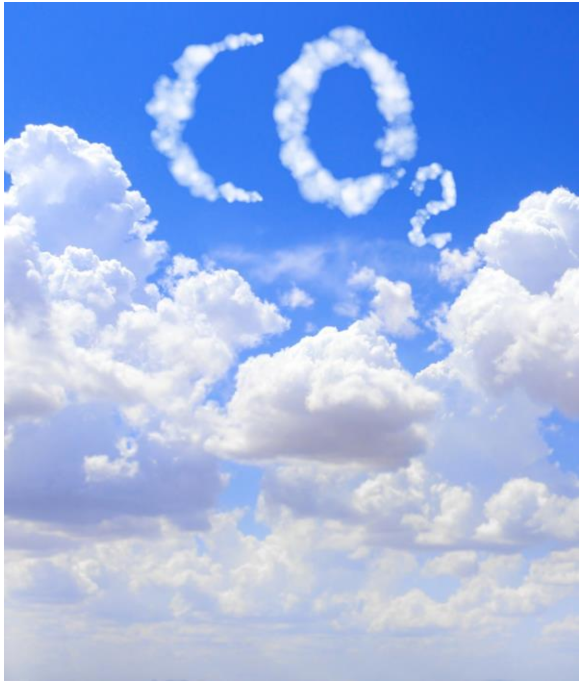
CCTUS is one of the most powerful tools for decarbonisation of existing assets. Furthermore many chemical, biological and mineral processing applications liberate CO2 from within the process, so decarbonisation using hydrogen or electrification is not possible: CCTUS can help to solve the issues. However, underground CO2 storage is also a controversial topic - are there viable alternatives?

This course will provide tangible examples of technologies for carbon capture from flue gases and the ambient air. Pipeline transmission, liquefaction, terminals, and shipping infrastructure will also be covered. Drivers of the carbon capture and storage (CCTUS) business cases such as $CO_2$ emissions taxation and climate pledges will also be covered.

If you are investing in CCTUS, considering technologies for your projects, and thinking through the best fit solutions will be fundamental to your analysis. This course will provide insights support that process.




**Agenda**

- Mature and emerging $CO_2$ capture technologies for flue gas emissions
- Flue gas $CO_2$ pressure and concentration – the implications for carbon capture
- Direct air capture of $CO_2$
- Supercritical $CO_2$ compression and transmission in pipelines
- $CO_2$ liquefaction and liquid $CO_2$ shipping on purpose-built tankers
- Permanent underground $CO_2$ storage
- Mineralisation of $CO_2$

# 9. Pathways to Low-carbon Hydrogen
## Circa 3-hours duration
## Combines well with Blue Energy Islands or CCTUS

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Hydrogen production will scale up by several orders of magnitude in the coming decades. Electrolysers are currently operating at 10 to 20MW and already we have plans for GW schemes. Similar scaleup leaps are proposed for thermal hydrogen production processes.

This course will explain the current and proposed low-carbon Giga-scale hydrogen production technologies such as ATR, POX, pyrolysis, and utility scale electrolysis. The best-fit criteria to apply each of these technologies will be discussed.

Spotting the right technologies early can mean the difference between a good and an excellent project. If you are investing in the hydrogen economy or considering technologies to implement, thinking through the pros and cons of various options will be fundamental to your decision making. This course will provide some insights support that process.


**Agenda**

- Methane splitting (pyrolysis / cracking) – turquoise hydrogen
- Autothermal reforming (ATR) and partial oxidation (POX) for natural gas conversion to hydrogen
- Coal, vacres and petcoke gasification
- Combining thermolysis pathways with carbon capture and storage (CCS) to produce low-carbon hydrogen
- Utility scale electrolysis from renewable power

# 10. On-purpose blue hydrogen production

## Circa 3-hours duration
## Combines well with CCTUS or Blue Energy Islands

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Hydrogen production will scale up by several orders of magnitude in the coming decades. Blue hydrogen will be produced using carbon capture and storage (CCS) integrated into new on-purpose hydrogen production facilities.

This course will explain how thermochemical hydrogen production technologies such as steam methane reforming (SMR), autothermal reforming (ATR) and partial oxidation (POX) fit with integrated carbon capture. The optimum solution for on-purpose blue hydrogen production is very different to the optimum solutions that have been implemented in the past for grey hydrogen production. Project case studies will be used to provide real life examples.

Using the right technologies can mean the difference between a good and an excellent project –profit margins, energy efficiency and return on capital are at stake. If you are investing in a greenfield site blue hydrogen facility, thinking through the technology options will be fundamental to your decision making. This course will provide some insights support that process.

**Agenda**

- Integration of SMR/ATR/POX plus CCS
- Carbon Capture technologies
- CO2 transportation from the capture site to the sink
- Hydrogen vs syngas product requirements and their implication on technology selection
- Hydrogen and CO2 pipeline pressure implications for technology selection
- GW-scale green hydrogen as an alternative to blue

# 11. Blue Energy Islands

## Circa 3-hours duration
## Combines well with Giga-scale Low-carbon Hydrogen or CCTUS

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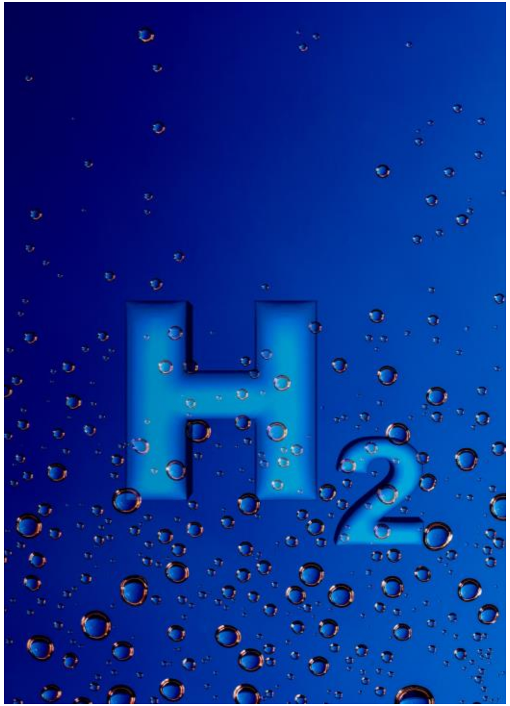
Hydrogen production will scale up by several orders of magnitude in the coming decades. Blue hydrogen will be produced using carbon capture and storage (CCS) retrofits to existing steam methane reformers. And to generate the additional hydrogen capacity, new on-purpose blue hydrogen plants will be built.

This course will explain how thermochemical hydrogen production technologies such as steam methane reforming (SMR), autothermal reforming (ATR) and partial oxidation (POX) fit with integrated carbon capture. The optimum solution for on-purpose blue hydrogen production is very different to the optimum solutions that have been implemented in the past for grey hydrogen production. Value stacking to profitably utilise all the available process streams is also key to competitive success in the international energy market. Up to date project case studies will be used to provide real life examples.

Using the right technologies can mean the difference between a good and an excellent project –profit margins, energy efficiency and return on capital are at stake. If you are investing in the hydrogen economy or considering technologies to implement, thinking through the options will be fundamental to your decision making. This course will provide some insights support that process.




**Agenda**

- Integration of SMR/ATR/POX plus CCS
- Hydrogen vs syngas product requirements and their implication on technology selection
- Hydrogen and CO2 pipeline pressure implications for technology selection
- Value stacking with Ammonia production
- Integration of low-carbon power generation and energy storage

# 12. Shipping Hydrogen & Derivatives

## Circa 3-hours duration

## Combines well with Green Ammonia and Green Methanol

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Green ammonia is emerging as the preferred international distribution mode for green hydrogen from GW-scale renewable power and electrolysis projects. Methanol is another hydrogen derivative that will enable sustainable energy exports. Liquid organic hydrogen carriers, liquid hydrogen and compressed gaseous hydrogen shipping are also likely to become mainstream.

This course will provide tangible examples of technologies for green ammonia and methanol generation from electrolysis and renewable power pathways. Shipping infrastructure and terminals will also be covered, as will key demand drivers such as ammonia-fired power generation and the use of hydrogen, ammonia, or methanol as a maritime fuel.

If you are investing in green ammonia, methanol, or hydrogen as clean synthetic fuels, considering the best technologies for your projects, and thinking through the best fit solutions will be fundamental to your analysis. This course will provide insights support that process.

**Agenda**

- Liquid hydrogen transportation as a shipping cargo on purpose-built tankers
- Compressed hydrogen gas shipping on purpose-built tankers
- Liquid organic hydrogen carriers for transportation of hydrogen
- Conversion of hydrogen to ammonia for transportation as a shipping cargo
- Conversion of hydrogen to methanol for transportation as a shipping cargo
- Simultaneous use of the cargo as the fuel for the tanker doing the shipping

# 13. Technologies for Green ammonia
## Circa 3-hours duration
## Combines well with Shipping Hydrogen & Derivatives

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Green hydrogen can be converted to green ammonia to enable long distance transportation. Green ammonia is emerging as the preferred international distribution mode for green hydrogen from GW-scale renewable power and electrolysis projects.

This course will provide tangible examples of technologies for green ammonia production. Shipping infrastructure and terminals will also be covered, as will key demand drivers such as ammonia-fired power generation. The potential to crack ammonia to re-convert it to hydrogen will also be reviewed.

If you are investing in green ammonia, as a clean fuels, considering the best technologies for your projects, and thinking through the best fit solutions will be fundamental to your analysis. This course will provide insights support that process.


**Agenda**

- The motivation for green ammonia
- The green ammonia value chain
- Air separation from renewable power to generate green nitrogen
- Green ammonia synthesis from green nitrogen and green hydrogen
- Green ammonia shipping in dedicated vessels and flexi-cargo CO2 / ammonia tankers
- Green ammonia terminals and cracking for reconversion to hydrogen
- Applications of green ammonia

# 14. Technologies for Power to Liquids
## Circa 3-hours duration
## Combines well with Shipping Hydrogen & Derivatives

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Green hydrogen can be converted to e-methanol and other liquid e-fuels such as e-kerosene for aviation. These e-fuels are produced using a range of ‘Power to Liquids’ or PtL technologies. This course will provide tangible examples of the key technologies required for PtL pathways including electrolysis and the downstream conversion of hydrogen, CO2, and syngas to liquid fuels. Technologies for point source CO2 capture and direct air capture (DAC) of CO2 to provide the backbone of the e-fuel hydrocarbon molecules will also be presented.

If you are investing in clean synthetic e-fuels production, considering the best technologies for your projects, and thinking through the best fit solutions will be fundamental to your analysis. This course will provide insights support those processes.

**Agenda**

- The motivation to convert green hydrogen to e-fuels
- Chemical pathways to synthetic hydrocarbons
- Alkaline electrolysis technology pathways
- Solid oxide electrolysis technology pathways
- Point source CO2 capture and distribution
- Direct air capture of CO2
- Methanol synthesis and methanol to gasoline
- Fischer Tropsch to generate syn-crude

# 15. Underground Hydrogen Storage

## Circa 3-hour duration

## Combines well with Hydrogen Transmission in Pipelines

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When hydrogen replaces natural gas for heating, the demand profile will be highly seasonal according to how warm or cold the weather is. Hydrogen production from hydroelectric power can also be highly seasonal according to how much rainfall or snowmelt is entering the river system. High-capacity storage is required to ensure cost-effective hydrogen production or utilisation in seasonal situations. Underground hydrogen storage in man-made salt caverns is one of the most cost-effective solutions, where the underground geography permits. Other high-capacity storage options exist.

This course will cover some of the high-capacity storage options and explain in which situations each may be suitable. The seasonality of some production and use-cases will also be covered to underline the importance of high-capacity hydrogen storage.

If you are investing in hydrogen value chains or considering the most appropriate technologies to implement for your projects, this course will provide insights to support your decision making. Future operators and owners of high-capacity underground hydrogen storage will also gain exposure to the technique.

**Agenda**

- The need for energy storage as variable renewable energy production scales up
- Time-shifting with seasonal hydrogen storage and seasonal hydrogen demand
- Large-scale hydro-electric power to hydrogen with seasonal energy storage
- Underground storage of hydrogen in salt caverns, depleted gas fields and aquifers
- Underground storage of natural gas and underground methanation

# 16. Hydrogen Transmission in Pipelines
## Circa 3-hour duration
## Combines well with Underground Hydrogen Storage

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Hydrogen distribution is a challenging aspect of the hydrogen economy. The low volumetric energy density of high pressure gaseous and liquid hydrogen can make distribution of large quantities of hydrogen over long distances expensive. Hydrogen transmission and distribution in pipelines is a cost-effective mode, but questions are often asked about the possibility to re-purpose existing natural gas pipelines for this purpose.

This course will provide examples of major schemes that have been proposed for pipeline hydrogen transmission and distribution and outline the testing work that has taken place to confirm whether hydrogen can indeed be admixed into natural gas and under what conditions existing infrastructure can be adapted for use with hydrogen.

If you are considering hydrogen distribution, understanding the safety considerations and technology will be fundamental. This course will provide some insights to support that process.

**Agenda**

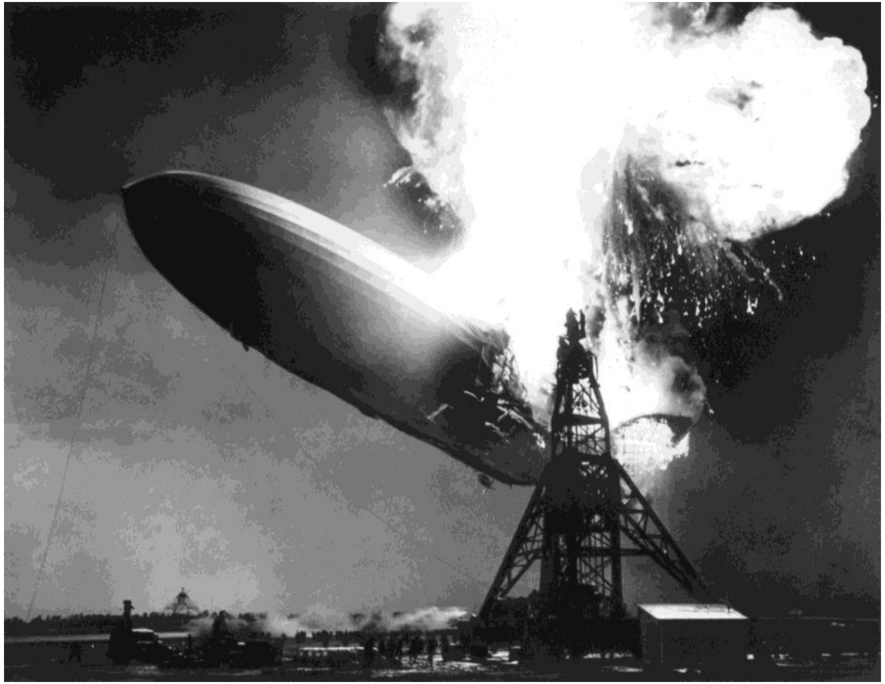
- Materials compatibility issues with hydrogen and pipeline steel
- Large-scale hydrogen transmission network proposals with integrated energy storage
- The differences between natural gas and hydrogen compression
- Special considerations for admixing hydrogen in natural gas
- Transmission versus distribution, which infrastructure is more adaptable to hydrogen
- The alternative to hydrogen transmission: decentralised hydrogen production

# 17. Ensuring safe development of the hydrogen economy
## Circa 3-hour duration
## Combines well with Hydrogen Transmission in Pipelines

sbh4 consulting

Perhaps you are financing an investment in hydrogen or will be processing this gas in the future as an operator. Or you may be curious about how the public at large will react to hydrogen hazards, based on what they have heard about the Hindenburg airship explosion.

This short course will put the risks of hydrogen into context with real facts and clear examples. You will have the chance to ask questions or raise concerns that you might have about hydrogen safety in a friendly environment.



**Agenda**

- The professional language and terminology of safety
- Overview of the main risks of hydrogen and how these compare to other fuels and gases that are in daily use
- The must-know safety aspects of compressed high-pressure hydrogen and liquefied cryogenic hydrogen
- Tools in use and precautions taken to minimise the risks of hydrogen

# 17. Hydrogen Safety Essentials
## Circa 3-hour duration
## Combines well with Hydrogen Safety Masterclass

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**Agenda**

- The psychology of safety: perception matters
- Will safety concerns stop the development of the hydrogen economy?
- Essential safety terminology
- Safety issues and precautions taken with hydrogen production
- Safety issues related to high pressure compressed gaseous hydrogen / liquid hydrogen storage and distribution
- Safety issues and precautions taken related to hydrogen mobility

# 18. Hydrogen Safety Masterclass

## Circa 3-hour duration
## Combines well with Hydrogen Safety Essentials

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This short course will put the risks of hydrogen into context with real facts and clear examples. You will have the chance to ask questions or raise concerns that you might have about hydrogen safety in a friendly environment.


**Agenda**

- Risk, hazard and incident frequency: definitions and real-life mitigation to reduce risk
- The must-know safety aspects for production, distribution, storage and use of hydrogen
- The main risks of hydrogen and how these compare to other green fuels and hydrogen-rich energy carriers such as ammonia and methanol
- Second-order environmental implications of 'green' hydrogen

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