Energy Transition Network


# Maturity Assessment of Infrastructure for Net Zero Energy

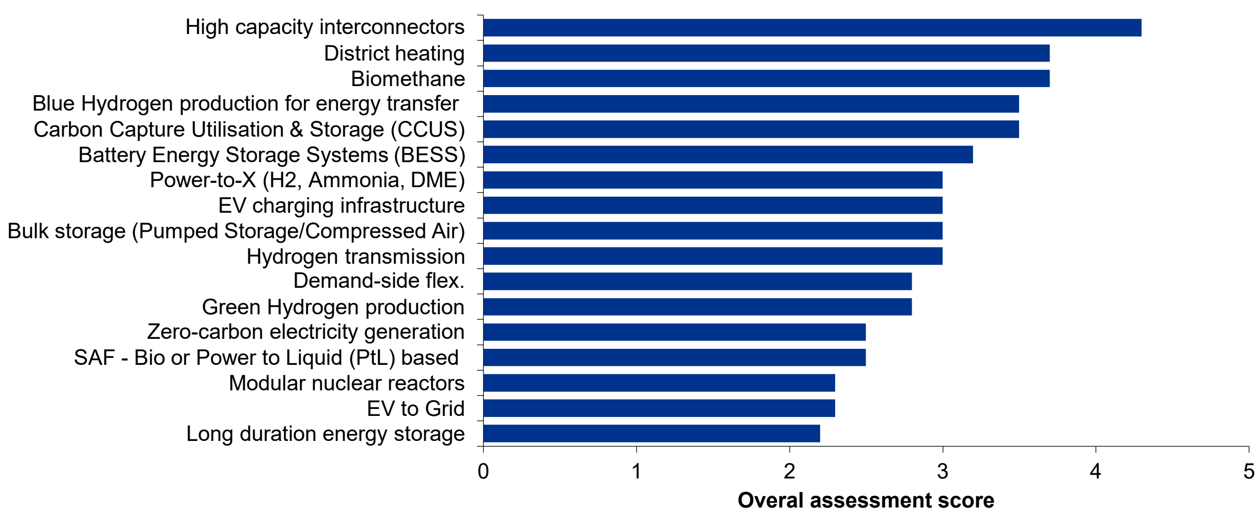
**IPFA ENERGY TRANSITION SPECIAL INTEREST GROUP (SIG) REPORT**

# Executive Summary

The transition to a net-zero carbon economy requires a multifaceted approach, leveraging a range of emerging technologies that are at varying stages of maturity. This report evaluates these technologies from an infrastructure project development perspective, focusing on their technological risks, financeability, and scalability. The scope excludes technologies already in widespread use, such as traditional energy transfer infrastructure and mature renewable sources like onshore wind, solar PV, and offshore wind. Instead, the assessment highlights less-established but crucial technologies such as biomethane, demand-side flexibility, power-to-X, small modular reactors, and blue hydrogen, all of which are essential to achieving global decarbonization goals.

Net-zero targets are ambitious, with significant reductions needed by 2030 through renewables, energy efficiency, and electrification of final demand. Beyond this, emerging technologies are critical to closing the gap to 2050. The technologies assessed show encouraging progress, with many advancing from pilot phases to late-stage development and commercial deployment. However, the pace of investment must accelerate to meet these goals, requiring clearer market signals, stronger policy frameworks, and expanded government support to bridge viability gaps.

**Overall Technology Score**




The assessment highlights that many net-zero technologies, such as biomethane and blue hydrogen, are progressing from pilot phases to commercial deployment, demonstrating increasing maturity, while others, like power-to-X and demand-side flexibility, face challenges in scaling and integration. Financeability remains a critical barrier due to high initial costs, uncertain returns, and limited offtake agreements, requiring stronger policy support and clear market signals. Scalability varies significantly, with technologies like hydrogen production benefiting from modular design, while others face constraints related to feedstock availability, infrastructure, and renewable energy access. Overall, the pace of investment must accelerate, supported by targeted government incentives, supply chain enhancements, and cross-sector collaboration to achieve net-zero goals by 2050. The results of the maturity assessment are shown in the graph below.

The results suggest that the pace of investment in emerging net zero technologies must accelerate. A lot of progress has been made in deployment of renewable energy technologies in recent years but more diversity in energy transition investment is needed. Over 95% of energy transition infrastructure investment has been channeled to wind and solar PV in 2023. There are signs that net zero technologies are maturing. However, stronger market signals are needed along with clarity on energy pathways to drive investor confidence. Many emerging technologies are currently at early manufacturing and production stages which limits investor confidence and the likelihood of raising non-recourse project finance. Private investors assessing risk vs return on such emerging technologies are not seeing the required levels of deployments with many projects to date supported only by government led research and development investments including partnerships with technology developers.

The energy transition requires an unprecedented acceleration in the pace and diversity of investments. While technologies such as biomethane, blue hydrogen, and small modular reactors show strong potential, achieving net-zero goals by 2050 will demand targeted efforts to scale these solutions alongside continued innovation. Governments, investors, and industry stakeholders must collaborate to address policy, financial, and supply chain barriers, ensuring the deployment of a balanced mix of technologies that can collectively decarbonize key sectors.

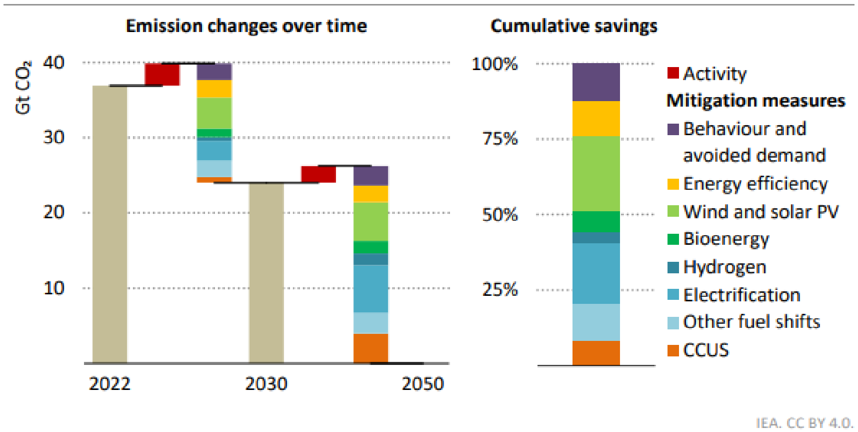
The findings underscore the urgency of investment in emerging technologies and the need for clear market signals to build confidence among investors and accelerate the global transition to a sustainable energy future.

# Contents

# 1.0 Scope of assessment

Achieving net zero ambitions relies on a range of emerging technologies with varying levels of maturity against key project development criteria. Various scenario-based studies of the global energy system identify a range of emerging technologies that are key to achieving the goal of net zero emissions by 2050. Global trends indicate that renewables such as wind and solar PV, energy efficiency and electrification of final use demand are already contributing significantly to 2030. However, more clean energy technologies are required to achieve NetZero. The International Energy Agencies (IEA) net zero roadmap study quantifies the emissions reductions expected from several technologies that are currently in early development stages in many countries as shown in the graph below. Our SIG sought to investigate the maturity of such infrastructure technologies as part of a multi criteria assessment. The scope of the assessment covered the current maturity of these technologies from an infrastructure project development point of view in terms of technological risk, financeability and investability and scalability. We did not assess energy transition technologies that are already in widespread use such as traditional energy transfer infra., onshore wind, solar PV and offshore wind.

**Figure 2.5 ▷** **$CO_2$ emissions reductions by mitigation measure in the NZE Scenario, 2022-2050**




**Source: IEA NetZero Roadmap**

*Expansion of solar PV, wind and other renewables, energy intensity improvements and direct electrification of end-uses combined contribute 80% of emission reductions by 2030*

# 2.0 Methodology

Our Special Interest Group (SIG) used a collaborative approach leveraging diverse backgrounds, skills and knowledge. The assessment followed a four-step process as described below.

**1. Scoping**
- Confirm scope of assessment
- Select technologies scoring criteria
- Assign technical leads
- Produce work plan

**2. Scoring framework**
- Set up scoring framework for each of the selected criteria
- Agree framework

**3. Assesment**
- Perform assessment for each technology
- Conduct workshop to validate initial scores
- Calibrate scores

**4. Reporting**
- Collate details of assessment in SIG paper
- Present to wider ET group
- Perform peer review
- Finalise paper

# 3.0 Scoring framework

A scoring framework was developed to ensure consistency and to limit biases in the assessment of maturity across three criteria, technology risk, financeability and scalability. This framework is informed by a literature review and was tested by each of the Special Interest Group (SIG) members as part of collaborative approach. The application of the scoring framework assisted in ensuring assessment results are objective and determined systematically against a five-point scale. The table below outlines the scoring framework applied.

| Score | Technology Risk | Financeability/Investibility | Scalability |
|---|---|---|---|
| **1** | Immature technology, still in R&D phase.<br>Tech Readiness Levels (TRL) 1, 2, & 3 | High financial risk, no clear revenue model, no demonstrated interest from investors, high costs with uncertain returns. No contracted revenue. | Limited scalability, significant barriers, requires major redesign to support larger scale,<br>high dependency on specialised resources/infra, limited ability to adapt. |
| **2** | Emerging technology with some pilot projects.<br>TRL 4 and 5 | High financial risk, unproven revenue model, high initial costs with unclear returns. Little or no contracted revenue. | Some scalability, major challenges, requires considerable effort and resources to scale, moderate dependency on specialised resources/ infra. |
| **3** | Late development stage, several<br>successful implementations.<br>TRL 6 and 7 | Moderate financial risk, some interest from investors or institutions but not widespread, Multiple funding options, moderate initial costs. Some contracted revenue/(or supports) to cover fixed costs. | Moderate scalability, some obstacles, requires some adjustments or enhancements to scale effectively, balanced dependency on specialised and general resources. |
| **4** | Proven technology, widespread adoption, still evolving.<br>TRL 8 | Low financial risk, proven revenue model with clear evidence of profitability, manageable initial costs with reliable ROI projections, multiple funding<br>options. Significant contracted revenue to cover costs. | High scalability, minor challenges, minimal adjustments to support larger scale, low dependency on specialised resources,<br>high flexibility to adapt to different markets. |
| **5** | Mature, tried, trusted, and proven technology in widespread use. | Very low financial risk established revenue model, strong interest among investors, low initial costs with high predictable ROI, strong market demand. Significant contracted revenue to cover costs. | Very high scalability, easily expandable, ready to support large scale with little to no adjustments, highly versatile, excellent adaptability to<br>various markets. |

**TRL : **GAO-20-48G, Technology Readiness Assessment Guide: Best Practices for Evaluating the Readiness of Technology for Use in Acquisition Programs and Projects***

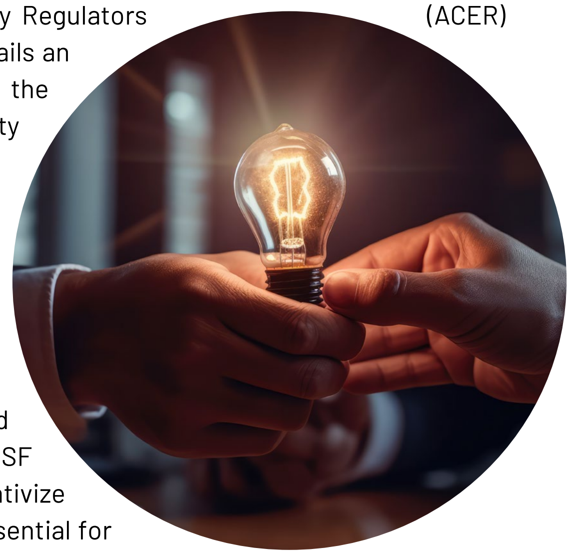
# 4.0 Detailed Assessments & Narratives

This section describes the detailed narrative supporting the assessment scores determined for each infrastructure technology across each of the criteria.

## 4.1 Electricity Demand Side Flexibility

**Introduction:**

- Demand side flexibility (DSF) is the ability of electricity customers to change their behaviours based on external signals. Flexibility of energy systems is vital to achieving net zero goals and to maximize the use of intermittent renewable energy sources. Many countries have set targets in relation to demand side flexibility. In December 2022, the European Union Agency for the Cooperation of Energy Regulators (ACER) published a Framework Guideline on Demand Response which details an approach for the development of demand response markets in the European Union pursuant to Article 59(1)(e) of the Electricity Regulation.



**Technology risk:**

- DSF relies on networks of technologies integrated together. Standardization and interoperability of technical solutions at customer premises is a key challenge which must be overcome. Technology providers also require standardization across markets/jurisdiction affecting product viability and issues around prequalification. Customers must be clear on the range of DSF products that they can use, and the price signals must incentivize behavioral change. Data exchange and timely access to data is essential for market participants.
- Significant work is required in this area to streamline sharing protocols while ensuring GDPR is protected. Overall, there is significant work required to address a technology risk for DSF including ensuring that market designs address issues regarding standardization, interoperability, and data sharing.
- Technology Score: 2.5

**Financeability / Investability:**

- There are market-based dependencies including design of flexibility markets and congestion-based products. Investment in DSF to date has been mostly public led or system operator/owner led in enabling technologies such as metering assets. However, growth in private investments is increasing in countries with established DSF market designs. Participants can monetize their demand flexibility depending on the local market design. Market designs vary depending on the locations with some participant bidding into day ahead markets and other responded to signals from DSO or TSO managed platforms. Increasing private led investment relies on a mitigation to a range of barriers including consistent market design, standardization of energy management systems / smart meter platforms, data sharing and interoperability protocols.
- Financeability Score: 2

**Scalability:**

- The potential for scaling of DSF is high notwithstanding the barriers described above. Consistent market designs across jurisdiction may allow the scaling of DSF products to occur more quickly. Energy consumers must understand the products that are available, and the financial incentives associated with their use before DSF can be deployed at the scale required to achieve climate and energy policy targets.
- Scalability: 4

**Conclusions:**

- DSF will play a significant role in the energy transition helping to make better of intermittent renewable energy sources and avoiding demand driven investment. However, there are many barriers that must be overcome to integrate technology-based solutions in a standardized and interoperable way. Investment in the overall DSF systems will only increase once the key market design building blocks are in place. The potential for scaling of DSF is high assuming consistent in design and uptake across different locations / countries.

**In France, the largest DSO, ENEDIS, has implemented market-based mechanisms to utilise demand flexibility. ENEDIS accepts tenders from producers, battery storage, electric vehicles, and demand response participants, with active or reactive power for voltage congestions.**

**GOPACS was established in the Netherlands in 2016 and is a cooperation between the Dutch TSO, TenneT, and the regional DSOs to manage congestion on the electricity system. GOPACS enables large and small market participants to monetise their available flexibility to alleviate system stress by bidding in their demand reduction or flexible generation.**

## 4.2 EV To Grid

**Introduction:**

- EV to Grid technologies provide support to the electricity grid by discharging energy when it is favorable to do so and in response to market-based system. Similar in many ways to the demand side flexibility covered earlier, but with the inclusion of smart charging technologies that are integrated with metering technologies at the residential and/or commercial connection points.

**Technology risk:**

- Consistency and interoperability of vehicle and charger technologies present a significant technological risk for EV to Grid. Standardization both within and across jurisdictions is critical to enable market integration. Secure data exchange is critical to protect the consumer. Battery cycling is a key consideration and ensuring resilience to cycling is incorporated into system designs with EV to Grid in mind. A critical technology risk relates to grid congestion and whether Low and Medium voltage distribution systems can accommodate significant levels of battery exports from a fleet of connected EVs.
- There are good examples of trials in different geographies.
- Technology Score: 2

**Financeability / Investability:**

- Similar in many respects to DSF there are market-based dependencies including design of flexibility markets and congestion-based products. In the case of EV to Grid this is more complex given the need to integrate the EV charger technology into the wider flexibility system. Given the added complexity investment in EV to Grid technology lags DSF and therefore scores lower from a finaceability and investability perspective.
- Increasing private led investment in EV to Grid relies on a similar mitigation as those referenced in DSF section with focus on interoperability and common design of charger technologies.
- Financeability Score: 2

**Scalability:**

- Scalability is limited by the volumes of EVs in use, availability of charging technologies with the necessary capabilities and electricity flexibility market designs. Scaling also relies on tariff designs and financial incentives for consumers to participate.
- Scalability Score: 3

**Conclusions:**

- EV to grid is expected to play an important role in the energy transition. However, there has been lower than expected uptake of EVs in many counties and design and implementation of the required flexibility markets has limited to levels of investments. Trials to date have been mostly funded in by government innovation and research agencies in partnership with EV manufacturers, system operators, charge point operators and electricity retailers. More certainty relating to market design, interoperability of charging technologies and better understood commercial models are required to accelerate investment.

**EDF led the Vehicle to Grid Oxford (V2GO) initiative which successfully demonstrate the value of Vehicle to Grid (V2G) to fleet operators. The project was funded by Innovate UK.**

**The REVS project was co-funded by the Australian Renewable Energy Agency (ARENA) and the ACT Government and led by ActewAGL Retail in partnership with Evoenergy, Nissan, Jetcharge, SG Fleet, the Australian National University and Accenture.**

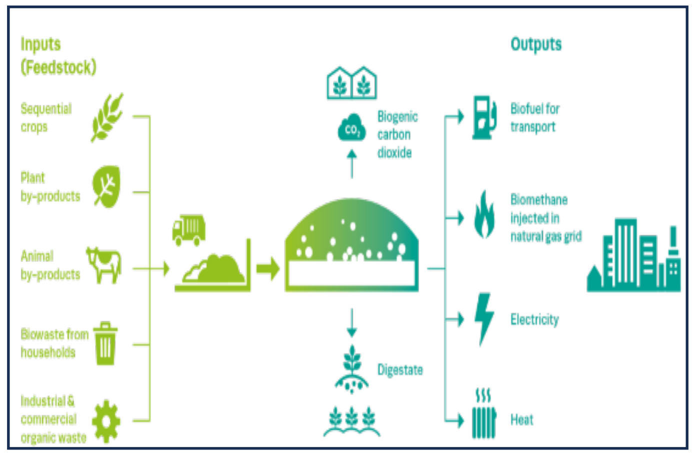
# 4.3 Biomethane

**Introduction:**

- Biomethane plays a critical role in the energy transition as a renewable and lower-carbon alternative to natural gas. It can be easily integrated into existing gas infrastructure, is versatile in its uses, and supports circular economy practices, making it an attractive alternative fuel in hard-to-abate sectors such as freight or industry.

**Technology risk:**

- The technology risks associated with biomethane, and anaerobic digestion (AD) plants, are relatively low, as they are a well proven and widespread technology that are in use today. Biomethane's use is likely to see significant growth in the coming years. The REPowerEU plan intends to increase biomethane production in Europe tenfold from 3.5 billion cubic metres (bcm) to 35 bcm by 2030. Denmark has experienced significant growth in biomethane production using AD plants, with 30% of gas demand currently met from biomethane. Ireland has a nascent biomethane industry at present but has set a target of 10% biomethane penetration in the natural gas grid by 2030.




- Technology Score: 5

**Financeability / Investability:**

- The financeability and investability of AD plants have improved significantly in recent years due to increased demand for alternative fuels. Favorable policies are also paramount to the viability of biomethane plants – no nation has developed a successful biomethane industry without some form of government support.
- Feed-in-tariffs were initially the primary OpEx instrument of governments to support biomethane industry development, but in recent years European countries have moved towards contracts for difference, feed-in-premiums, and demand-side initiatives such as Ireland's Renewable Transport Fuel Obligation (RTFO) or tax incentives and exemptions, many countries also offer capital grants to help build AD plants.
- Feedstock availability and category can impact the funding model of the AD plant. Projects using abundant waste feedstocks such as food wastes and agricultural residues are likely to have reduced costs and feedstock supply disruptions. Expensive or less reliable feedstocks would introduce uncertainty and potentially increase operating costs.
- Financeability Score: 4

**Scalability**

- Sourcing a sustainable feedstock is the number one constraint for biomethane production currently. Some countries use energy-dense feedstocks such as grass silage or energy crops, which produce a lot of biomethane but can also lead to increased emissions through land-use change or fertilizer use. Landfill gas and waste-to-energy (WtE) share significant overlap with biomethane. Landfill gas is also produced from decomposing organic matter but is not as pure as biomethane nor its production as efficient. WtE technologies involve the combustion of municipal solid waste (MSW) to generate heat and electricity. WtE is not as sustainable as AD, as incineration can emit pollutants, but both technologies have a role to play in reducing reliance on fossil fuels and promoting circular economy practices.

- Scalability Score: 2

**Conclusions:**

- Biomethane is emerging as a key player in the energy transition, offering a potentially carbon neutral alternative to fossil fuels while supporting the circular economy. Biomethane's role in the energy transition could be maximized by the introduction of targeted supports for biomethane use in hard-to-abate sectors, enhancing feedstock supply chains, tax incentives, and allowing for easier integration into the natural gas grid.


**ReFood's AD plant in London processes over 160,000 tonnes of food waste per year, producing over 14 million $m^3$ of biomethane.**

**Nature Energy has 15 AD plants across Europe, the largest of which processes over 700,000 tonnes of waste per year, producing 22 million $m^3$ of biomethane.**

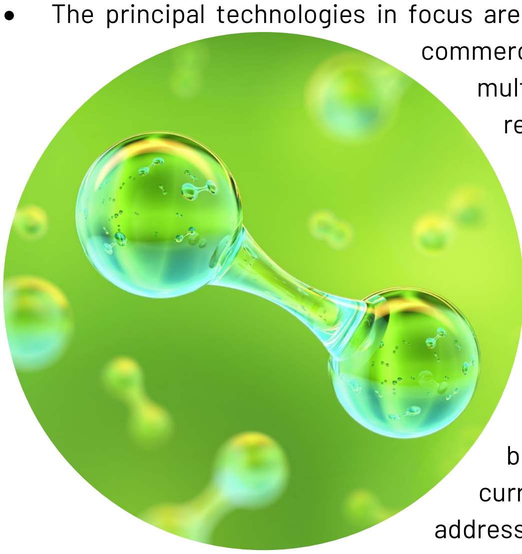
# 4.4 Green Hydrogen Production

**Introduction:**

- Green Hydrogen is hydrogen obtained from electrolysis of water using decarbonized electricity from renewables.
- In a power system largely based on variable renewable sources, hydrogen could be produced at times of low electricity demand providing additional flexibility. If needed in large quantities, hydrogen could also be produced by nuclear electricity or even might be imported from regions with potentially low-cost renewable energy production.
- Hydrogen can gradually take the role of an energy vector beyond its potential role as a chemical storage of electricity. It could replace natural gas as an energy fuel per se (albeit often with energy efficiency losses) for heating purposes or in transport (used with fuel cells) and as feedstock for industrial applications (e.g steel industry, refineries, fertilizers).
- In Europe, the Clean Hydrogen Alliance pipeline includes over 446 hydrogen production projects and 163 projects focused on transmission and distribution.

**Technology risk:**

- Alkaline water electrolysis (AWE) and proton exchange membrane (PEM) technologies are well established with commercial applications and operational is experience increasing. Plant capacity is often driven by individual module output and consequently there is often a drive for unit scale up. Both AWE and PEM have specific dependencies including for AWE high purity water supply and for PEM rare metals for use as a catalyst. The availability of these materials in required qualities are also expected to be a factor in technology selection.
- Solid oxide electrolysis (SOE) technology is in the early commercial phase and anionic exchange membrane (AEM) technology is still in pilot/early commercial phase.
- The principal technologies in focus are AWE and PEM – these are commercially proven and have multiple commercial plants worldwide. The selection of technology will be based on multiple factors including: efficiency, current density, gas purity requirements and availability of rare metals. For further reference the IEA publishes a database with the status of Hydrogen projects.
- Technology Score: 3.5



**Financeability / Investability:**

- Global interest is increasing with growing interest in hydrogen economy and potential for large scale energy storage and transport. Cost is high due to infrastructure needs.
- Barriers exist for the development of a cost-effective, cross-border hydrogen infrastructure and competitive hydrogen market. The current regulatory framework for gaseous energy carriers does not address the deployment of hydrogen as an independent energy carrier via dedicated hydrogen networks. Development of rules at EU level on tariff-based investments in networks, or on the ownership and operation of dedicated hydrogen networks as well as harmonized rules on (pure) hydrogen quality will support further investment.
- Currently, there is an upfront financing gap for the European Hydrogen Backbone with a gap between tariff and off-taker willingness to pay. There is reliance on support to fill the gap, however there is investor interest.
- Financability Score: 3

**Scalability:**

- Green Hydrogen capacity is normally designed on a modularized basis – lending itself to flexible expansion.
- Dependent on low-cost renewable power source. Currently at least in part due to investment, cost of production is high compared to grey or blue hydrogen alternatives. It is expected that government incentives will make investment more attractive.
- Nevertheless, it is expected that future hydrogen production will be supported by multiple processing routes.
- Scalability Score: 2

**Conclusions:**

- Most of the hydrogen is currently produced from natural gas, however as part of the energy transition this is expected to shift to greener means of production including green hydrogen production. It is expected that the global demand for hydrogen will increase by a factor of between two and sixfold by 2050, with growth coming from a wide range of sectors, led by power generation, aviation, and heavy industry.
- Hydrogen is a versatile energy carrier that has the potential to play a significant role in decarbonizing the energy system. Hydrogen-based technologies and fuels can provide low-carbon alternatives across sectors. However, as of now, there is still a wide range of possible hydrogen pathways up to 2050 both in terms of hydrogen demand and supply, leading to uncertainty for organizations looking to enter the hydrogen market or to scale their operations.
- Regulatory developments in the EU include the introduction of a common threshold for low-carbon hydrogen and certification schemes. It also includes sub-targets for renewable hydrogen in industry and transport, coordinated planning of hydrogen infrastructure, support for the roll-out of hydrogen refueling stations, as well as carbon contracts for difference under the ETS for steel and chemicals.

**<u>Case studies</u>: H2Deal Project, Avilés (Spain) The world's largest renewable hydrogen giga-project (currently in development) - The initiative will supply renewable hydrogen for the production of green steel (ArcelorMittal), low carbon ammonia, low carbon fertilisers (Fertiberia) and other low-carbon industrial products.**

# 4.5 Blue Hydrogen Production for Energy Transfer

**Introduction:**

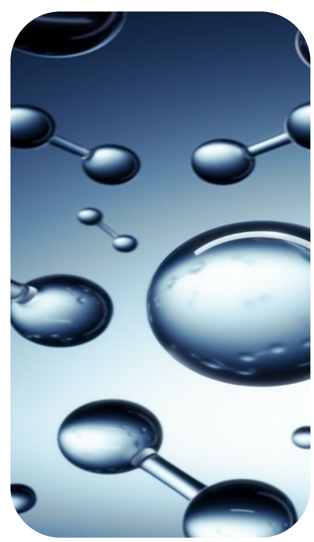
- "Blue" hydrogen is largely obtained from steam reforming or auto thermal reforming (SMR/ATR) of natural gas with by-product carbon dioxide, captured and stored or utilized. Steam and autothermal reforming and carbon capture technologies, whilst currently not commonly combined are each considered well established. Newer technologies include the Shell SGP process that integrates technologies allowing the capture of up to 99% of carbon dioxide emissions generated during production.
- Some advantages of blue hydrogen production are summarized as follows, mature technology, economic efficiency, electrical efficiency, and compatibility with existing infrastructures.

**Technology risk:**

- The front end of production is normally based on the grey production route producing hydrogen largely via the steam methane reforming (SMR) or autothermal reforming (ATR) processes that converts natural gas into hydrogen, however while SMR is a highly efficient and cost-effective means of large-scale production, it is suboptimal for low carbon hydrogen production. Low carbon hydrogen production, autothermal reforming (ATR) and ATR coupled with gas heated reforming offer more efficient and cost-effective solutions that are proven to scale.
- The main difference between blue and grey hydrogen production is the capture of carbon dioxide using carbon capture and storage/utilization technology. Carbon capture technologies are considered proven although the combination of the two technologies is growing with limited plants operational but with multiple projects in progress.
- The IEA maintains a database that supports the status of projects.
- Technology Score: 3.5

**Financeability / Investability:**

- Financeability/Investability - Without low-carbon hydrogen, decarbonizing heavy industry to achieve international net-zero ambitions will be challenging. Hydrogen production currently is carbon intensive. Green hydrogen is likely to be a long-term solution but may not be able to compete on cost with "blue" hydrogen, at least for the short to mid-term.
- Blue hydrogen is dependent on a reliable natural gas supply that while readily available at relatively low cost in certain countries, this varies globally. This can have a direct bearing on the viability of this production option. The process also requires carbon capture and storage infrastructure that require appreciable investment and in support of meeting net zero target there are growing numbers of CCS plants in operation. The pace of adoption of CCS is likely to be an important factor in the growth of blue hydrogen projects.
- Financeability Score: 3



**Scalability:**

- SMR/ATR technology is proven in operating refineries and plant capacities are expected to increase based on economies of scale.
- CCUS capacities may be relevant to meet upstream hydrogen processing capacities and will need to be in place to meet decarbonization targets.

- A distinct advantage is that plant can be supported by existing infrastructure.
- Scalability Score: 4

**Conclusions:**

- Hydrogen production is not new to industry, however, is now of growing importance in the substitution of fossil fuels in the fields of energy supply, mobility, and industry to meet decarbonization targets.
- While aiming for a maximum of renewable hydrogen from 2030 onwards, in the short- and medium-term other forms of low-carbon gases in particular low-carbon hydrogen can play a role, provided the inherent constraints of CCS are lifted. It would rapidly reduce emissions from existing hydrogen production and support the parallel and future uptake of renewable hydrogen.
- Government and private sector support is projected to heavily affect hydrogen uptake.
- Globally, production capacity of blue hydrogen is expected to grow significantly over the next decade, dramatically outpacing planned capacity for green hydrogen, which is its more costly alternative.

**There are multiple projects in progress although there are few that are currently operational. Project completion will further support construction, commissioning and handover experience.**

# 4.6 Hydrogen Transmission

**Introduction:**

- Hydrogen transmission is the effective means of transfer of hydrogen or associated compounds from generation to storage or to the final customer. Small scale production can be transferred by pipeline, however for large production site hydrogen can be converted to carrier compounds (ammonia, methanol etc.) for shipment. On the basis of announced projects, more than 100 new hydrogen and ammonia terminals and port infrastructure projects could be realized by the end of the decade, on multiple continents.

**Technology risk:**


- Hydrogen transmission infrastructure includes pipelines, storage and transfer and has been used for many years including the US in support of the oil and gas industries and are considered well proven. Pipelines normally operate at high pressures and consequently ensuring mechanical integrity is of particularly high importance. There are notable hydrogen damage mechanisms that should be carefully considered at an early design stage including in the selection of metallurgy. To expedite completion and reduce project cost – existing assets can often be repurposed - this is particularly the case for pipelines – so the validation of the condition of existing plant is critical. Hydrogen has to date been stored above ground in storage tanks and clearly plant control in case of potential release is an important consideration. Geological storage technologies (salt caverns and depleted hydrocarbon fields) have the potential to provide long-term, high-capacity hydrogen storage and appropriately designed has the potential to offer appreciable strategic storage.
- Technology Score: 4

**Financeability / Investability:**

- Current challenges include the security of supply and demand, network planning, access to existing gas infrastructure and markets.
- Network planning schemes and practices are deficient as there are discrepancies between the EU-wide ten-year network development plan and national network development plans.
- Abolishing costs for cross-border trade of hydrogen and facilitating connection of production facilities will also improve the business case.
- Differences in the volume of hydrogen blended in the natural gas system can affect the design of gas infrastructure, end-user applications and cross-border system interoperability, thus risk fragmenting the internal market.
- The new EU internal market rules for hydrogen introduce measures to cover the financial risk of hydrogen network operators such as state guarantees. It also provides for tariff discounts and incentives, to facilitate their market and system integration. A voluntary mechanism will also be set up to support the hydrogen market for five years.

- It also prioritizes connection requests at transmission and distribution level for renewable gas production over connection requests to produce natural gas and low-carbon gas.
- Financeability Score: 2

**Scalability:**

- Transmission networks will be required to meet customer supply – and are expected to be developed and or expanded to be in place prior to commence of supply commitments based on establishment of long term strategic and customer commitments. The conversion of hydrogen to carrier compounds will be critical to meet large-scale long-distance shipment. The development of infrastructure for ammonia, methanol and DME production storage, transfer and downstream conversion will be critical to allow bulk transfer of clean fuel products.
- With the growth of the clean fuel economy and drive to meet Net Zero targets – hydrogen distribution networks are likely to operate at least in the short term in parallel with other less carbon free distribution networks until the supply and distribution networks are mature and the cost differential with alternatives reduces and or government incentives are in place.
- Scalability Score: 3

**Conclusions:**

- Hydrogen transmission pipelines have been used for many years in the US and other parts of the world and technology is well understood.
- It will be critical for investment in hydrogen that transmission networks are completed at least in parallel to meet supply commitments. Additional investment in distribution infrastructure is required to meet current Net Zero targets.

**Gaseous hydrogen can be transported through pipelines much the way natural gas is today. Approximately 1,600 miles of hydrogen pipelines are currently operating in the United States. Owned by merchant hydrogen producers, these pipelines are located where large hydrogen users, such as petroleum refineries and chemical plants. The European hydrogen back bone is an initiative being led by a group of 33 infrastructure operators with the aim to accelerate Europe's decarbonization journey by defining the critical role of hydrogen infrastructure. The Capital Hydrogen programme aims to develop hydrogen networks for London, East and Southeast of England.**

## 4.7 HVDC Systems

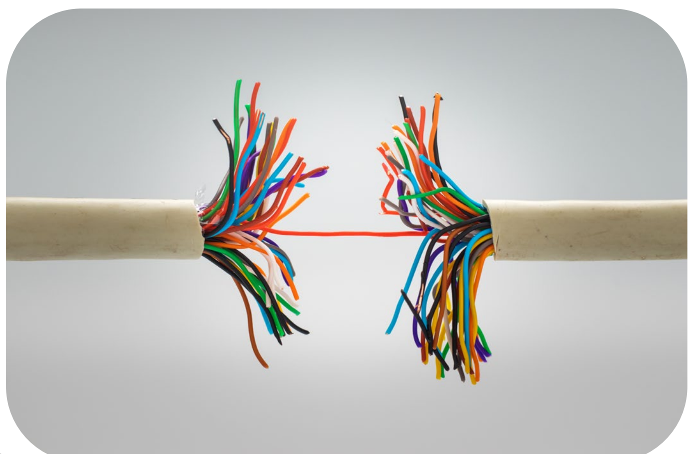
**Introduction:**

- High Voltage Direct Current (HVDC) systems are advanced power transmission technologies used to efficiently transfer large amounts of electricity over long distances. Unlike traditional AC (alternating current) systems, HVDC transmits power using direct current, offering higher efficiency, reduced energy losses, and the ability to interconnect asynchronous power grids. HVDC systems are particularly useful for transmitting electricity from remote renewable energy sources, such as offshore wind farms, to urban centers, minimizing transmission losses. HVDC is also critical for integrating renewable energy into the grid, stabilizing voltage, and enhancing grid reliability.

**Technology risk:**

- The primary technology risks associated with HVDC systems include the complexity of the converter stations required to switch between AC and DC power, which are expensive and involve intricate designs. Although the technology is mature, the failure of these converters can disrupt power transmission and pose challenges in maintenance.
- Additionally, HVDC systems involve advanced control systems that must be highly reliable to manage power flow across long distances. As HVDC grids grow in scale, the integration with existing AC grids presents technical challenges, particularly in terms of system stability and fault management, which need to be carefully managed to mitigate risk.
- Technology Score: 5

**Financeability / Investability:**



- HVDC systems are capital-intensive projects due to the high cost of converter stations, cables, and other infrastructure. However, their long-term benefits, such as reduced energy losses and lower operational costs, make them attractive to investors.
- Financeability is enhanced in regions with strong regulatory support for renewable energy integration, carbon reduction goals, and grid modernization initiatives. Government subsidies, grants, and regulatory incentives often play a crucial role in making HVDC projects viable. Private investment is increasingly attracted to HVDC due to the growing need for efficient long-distance power transmission, particularly in markets with ambitious renewable energy targets. Long-term contracts with utilities and transmission operators can provide predictable revenue streams, further enhancing the investability of HVDC projects.
- Financeability Score: 5

**Scalability:**

- HVDC systems are highly scalable and can transmit large amounts of power over thousands of kilometers, making them suitable for long-distance and intercontinental energy transmission projects.
- The scalability of HVDC is evident in its application in major international transmission projects and the increasing demand for offshore wind farm interconnections.

- However, expanding HVDC networks on a large scale requires significant coordination between national grids and regulatory bodies. Additionally, integrating HVDC systems with existing AC infrastructure poses technical and operational challenges, such as managing power flow and ensuring grid stability. Despite these challenges, advancements in technology and regulatory frameworks will support the scaling of HVDC systems as global energy demand and renewable energy deployment increase.
- Scalability Score: 3

**Conclusions:**

- HVDC systems are a key enabler of efficient long-distance electricity transmission and play a crucial role in integrating renewable energy into the grid. While the technology is well-established, challenges remain in terms of high upfront costs, converter station reliability, and the integration with existing AC grids. However, with strong regulatory support, investor interest, and ongoing technological advancements, HVDC systems have the potential to significantly scale up, helping to meet the growing demand for sustainable and efficient power transmission in the global energy transition.

**The NeuConnect Interconnector is a groundbreaking EUR 2.8 billion HVDC project that will link the UK and Germany via a 725 km underwater cable, entirely financed by private investors without government subsidies. Set to be operational by 2028, it will enhance energy resilience by enabling the transfer of 1.4GW of electricity in either direction, enough to power 1.5 million homes, while integrating renewable energy and reducing CO2 emissions by over 13 MtCO2 in 25 years. The project's commercial model leverages regulatory frameworks in both countries and serves as a pioneering example for future privately funded HVDC interconnectors, like the upcoming Greenlink**

## 4.8 Bulk Storage (Compressed Air/Hydro Storage)

**Introduction:**

- Bulk storage of compressed air and pumped hydro plays a vital role in the energy transition by providing large-scale, long-duration energy storage solutions. These technologies enable the integration of intermittent renewable energy sources like wind and solar by storing excess electricity during periods of low demand and releasing it when demand is high. As reliable and scalable forms of energy storage, they are crucial for grid stability and supporting decarbonization efforts in energy systems worldwide.

**Technology risk:**

- The technology risks associated with both compressed air energy storage (CAES) and pumped hydro energy storage (PHES) are relatively low, as they are proven and mature technologies. Pumped hydro, in particular, is the most established form of large-scale energy storage globally, accounting for over 90% of installed capacity in this sector. CAES, while less widespread, has been in operation for decades demonstrating its reliability.
- Both technologies are expected to see further deployment, driven by the growing need for renewable energy integration and grid balancing solutions. However, specific risks such as geological suitability for CAES and site availability for PHES could pose localized challenges.
- Technology Score: 4

**Financeability / Investability:**

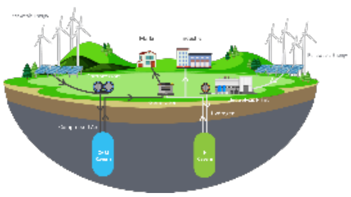
- The financeability of CAES and PHES has improved in recent years, particularly as the demand for energy storage grows alongside the expansion of renewable energy capacity. Government policies play a crucial role in making these projects viable, with many countries offering incentives such as low-interest loans, tax credits, and direct subsidies for large-scale energy storage projects. Moreover, both CAES and PHES projects benefit from financial models that are typically robust when supported by favorable regulatory frameworks and long-term grid service contracts.
- For PHES, the main constraint lies in finding suitable locations with the required geographical features, such as elevation differences between two water reservoirs, to create the necessary potential energy. Environmental and land-use considerations can also impact the feasibility of projects. CAES requires underground caverns, aquifers, or salt domes for air storage, and its deployment is dependent on the availability of such geological formations. Energy storage duration and efficiency are key operational factors, with PHES offering high round-trip efficiencies (70-85%), while CAES can vary depending on the specific technology used.
- Financeability Score: 2

**Scalability:**

- Both CAES and PHES are highly scalable, with the potential to store vast amounts of energy. PHES is well-suited for large-scale applications due to its ability to provide grid-scale storage and long discharge durations, making it ideal for seasonal energy shifts. However, the environmental impact and geographical limitations of PHES can restrict its scalability in some regions. CAES is considered more flexible in terms of site selection but can face limitations based on the availability of suitable underground formations. Advances in compressed air storage methods, including adiabatic systems that eliminate the need for natural gas, are making CAES more attractive for wider deployment.
- Scalability Score: 3

**Conclusions:**

- Both compressed air and pumped hydro energy storage are essential technologies in the transition to a low-carbon energy system. By providing reliable, long-duration storage, they enable the integration of renewable energy sources while enhancing grid stability. Continued government support, along with technological advancements that address site-specific challenges, will be critical to unlocking the full potential of these storage systems.



**Although not financed with debt two German utility providers (Eneco & Corre Energy ) joint forces to develop a CAES plant with a 220 MW capacity proving the technology.**

## 4.9 Zero Carbon Electricity Generation

**Introduction:**

- Many jurisdictions are exploring the use of zero carbon electricity generation as a means of achieving net zero ambitions. Many power systems around the world rely on fossil fuel fired generators to achieve generation adequacy so that demand for electricity is always met irrespective of consumer behaviors or weather conditions. Systems without access to nuclear energy or hydro-electric schemes will require a zero-carbon solution to generation adequacy. Many have set strategies to use hydrogen or ammonia fired generation technology to achieve this.

**Technology risk:**

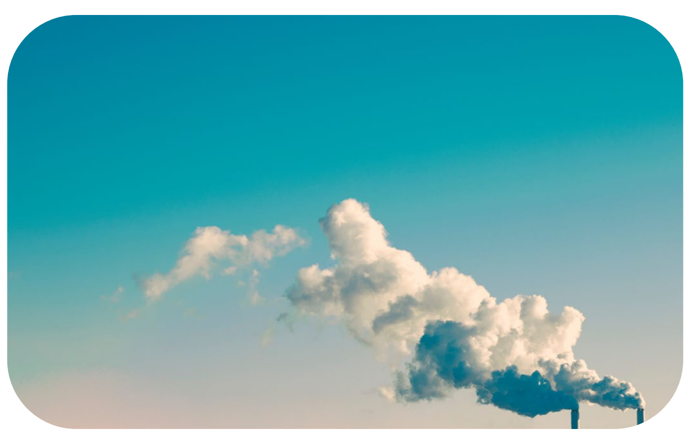
- Many OEMs are currently developing technologies required for zero carbon generation. It is expected that blending at grid scale will begin by 2027. There are projects currently in development at scales of approx. 200MW which is similar to current Open-Cycle Gas Turbines (OCGT). The technology is still largely at an emerging stage of development with few contracts in place to build at large scale with the market observing pilot schemes closely.
- Technology Score: 2.5

**Financeability / Investability:**

- Significant risks exist in relation to cost recovery of units that are expected to have low-capacity factors or running hours due to the growth of zero marginal cost technologies such as solar PV and wind. There are inefficiencies associated with H2 production due to losses in its conversion from renewable electricity followed by further losses during reconversion to electricity. If gas grid connections are needed to enable a project, this can increase capital costs significantly. There is a reliance on security of hydrogen / ammonia supplies including both production and transfer.
- These technologies require substantial supports to compete with existing conventional technologies such as OCGT and Combined Cycle Gas Turbines (CCGT) as part of traditional capacity markets and auction-based contracts. Viability will also depend on high carbon prices. High financial risks driven by high capital costs and lack of clarity in relation to support schemes place a limit on the level of interest from investors to date.
- Financeability Score: 2

**Scalability:**

- Deploying at scale relies on reliable supply of green hydrogen produced using renewable electricity sources. However, the pace of delivery of green hydrogen developments has been slow to date and lack of clarity on whether green hydrogen produced will be used in other sectors primarily. OEMs have signalled intentions to build large scale units which will require significant levels of hydrogen supplies to compete with OCGT and CCGT technologies. Storage facilities are required to ensure adequate reserves are in place given the reliance on intermittent renewables for green hydrogen production.
- Scalability Score: 3



**Conclusions:**

- Although many OEMs are developing technologies to support zero carbon electricity technologies efforts are required to address the viability gap compared to OCGT and CCGT technologies which has placed a limit on levels of investor interest to date. Policy direction in some jurisdictions suggests hydrogen will be prioritised for use in other sectors which also has a chilling effect on investor confidence. Further, there is competition from other technologies such CCUS which adds additional uncertainty.

**The Whyalla Hydrogen Power Facility in South Australia, part of the state's $593 million Hydrogen Jobs Plan, aims to produce and store green hydrogen at scale. Featuring a 250 MW electrolyser, a 200 MW hydrogen-fueled power plant, and hydrogen storage infrastructure, the facility will use surplus renewable energy to generate hydrogen through electrolysis, storing it for electricity generation to stabilize the grid. Scheduled for operation in 2026, the facility supports the decarbonization of Whyalla Steelworks by providing green hydrogen for industrial processes, advancing the production of green steel. Despite challenges like pipeline capacity constraints, the project underscores South Australia's leadership in renewable hydrogen and net-zero manufacturing innovation.**
**Whyalla hydrogen power facility | Office of Hydrogen Power South Australia**

## 4.10 Small Modular Nuclear Reactors

**Introduction:**

- Small Modular Nuclear Reactors (SMRs) are next-generation nuclear technologies with capacities ranging from 10 to 300 MW, significantly smaller than traditional reactors. Designed for modular construction, SMRs can be fabricated in factories, reducing on-site construction time and costs.
- Their smaller size and enhanced safety features make them suitable for integration into hybrid energy systems, remote areas, or countries with limited infrastructure. SMRs are emerging as a cornerstone of future low-carbon energy strategies, with over 70 designs in various stages of development globally. Key designs include water-cooled reactors, advanced gas reactors, and molten salt reactors.

**Technology risk:**

- Despite leveraging proven nuclear technologies, SMRs face several developmental and operational risks:
  - Regulatory Hurdles: New designs require extensive safety and licensing reviews, with approval timelines varying significantly by country.
  - Supply Chain Readiness: Limited manufacturing capacity for key reactor components may delay deployment.
  - Public Perception: Historical concerns about nuclear safety and waste disposal persist, potentially hampering adoption.
  - Waste Management: Long-term solutions for handling and storing spent fuel remain critical.
- Early-stage deployment risks are mitigated by pilot projects in countries like the U.S., Canada, and the U.K., which aim to validate designs and demonstrate commercial feasibility.
- Technology Score: 2

**Financeability / Investability:**

- SMRs face significant financial barriers, including high capital costs, extended development periods, and competition from cheaper renewables.
- Investment risks can be mitigated through:
  - Government Support: Many countries provide subsidies, loan guarantees, and direct investment in SMR development (e.g., U.S. Department of Energy's Advanced Reactor Demonstration Program).
  - Private Sector Partnerships: Collaborative funding models between utilities, technology developers, and private investors are essential to share risks.
  - Global Harmonization: International collaboration on standardizing SMR designs and safety protocols can reduce costs and accelerate deployment.
- Financeability Score: 2

**Scalability:**

- SMRs' modular nature offers significant scalability advantages, including shorter build times and potential mass production.

- Key applications include powering remote locations, islands, and areas with limited grid infrastructure, as well as serving as backup capacity for renewables in hybrid systems.
- Scalability hinges on achieving standardized designs, reducing costs through factory manufacturing, and ensuring robust supply chains.
- International projects, such as the Canadian SMR Roadmap and collaborations through the International Atomic Energy Agency (IAEA), are fostering knowledge sharing and global scalability.
- Scalability Score: 3

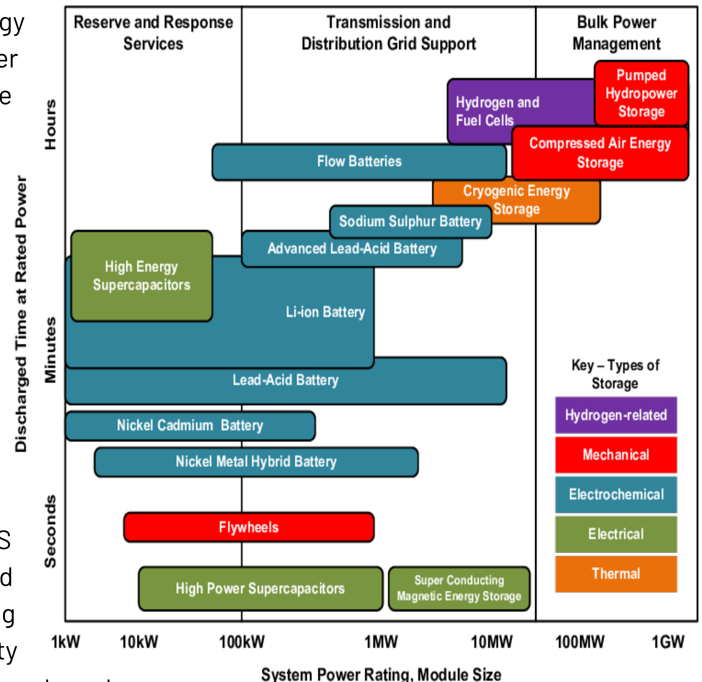
**Conclusions:**

- SMRs offer transformative potential for clean, reliable energy but require overcoming challenges in regulatory approval, cost competitiveness, and public trust. With supportive policies, strong investment frameworks, and global collaboration, SMRs can play a pivotal role in achieving net-zero targets by providing a stable, low-carbon energy source for decades to come.

**Case Study: NuScale Power, headquartered in Portland, Oregon, is a leader in Small Modular Reactor (SMR) technology, providing scalable, efficient, and safe nuclear energy solutions. Its VOYGR power plants utilize modular configurations (4, 6, or 12 reactors), each based on NuScale's flagship 77 MW Power Module, which features passive cooling systems for enhanced safety, requiring no external power or water for operation. In 2023, NuScale became the first company to receive U.S. Nuclear Regulatory Commission certification for its 50 MW design and has since submitted the upgraded 77 MW design for approval. Internationally, NuScale is advancing major projects, including a 924 MW plant in Poland (targeted for 2029) and an SMR deployment in Ghana, while also serving industries like data centers. With reduced construction times, factory-built components, and economic flexibility, NuScale's SMRs are poised to transform the energy landscape by replacing coal plants, complementing renewables, and addressing the growing global need for clean, reliable**

# 4.11 Long Duration Energy Storage

**Introduction:**




- Long Duration Storage (LDS) encompasses energy storage solutions that can discharge electricity over extended periods, ranging from several hours to multiple days or weeks. LDS enables the reliable integration of variable renewable energy sources like wind and solar into the grid, providing grid resilience and bridging the gap between supply and demand during prolonged low-generation periods.
- Common LDS technologies include pumped hydro storage, flow batteries (vanadium, zinc-bromine), compressed air energy storage (CAES), thermal energy storage (TES) (molten salts or phase change materials), and hydrogen-based storage. Increasing global focus on decarbonization has accelerated LDS development. For purposes of this assessment CAES and pumped hydro are considered bulk storage and discussed in a separate section of this report. According to industry projections, global installed storage capacity could grow tenfold by 2040, driven by ambitious net-zero targets and renewable energy adoption.

**Technology risk:**

- Emerging LDS solutions, such as flow batteries and hydrogen-based systems, face technical and commercial hurdles, including:
  - Cost-efficiency: Many systems remain expensive, particularly in terms of capital expenditure and energy conversion losses.
  - Durability: For example, battery degradation over repeated cycles limits lifespan and reliability.
  - Energy Density and Efficiency: Hydrogen-based LDS is promising but faces challenges in round-trip efficiency due to energy losses in electrolysis and reconversion.
  - Safety Risks: Hydrogen and other advanced storage methods require strict safety protocols due to risks such as leaks, explosions, or thermal runaway (batteries).
- Technology Score: 2.5

**Financeability / Investability:**

- Financial risks arise from high upfront costs, uncertain long-term revenues, and policy gaps in providing clear economic incentives for energy storage deployment.
- Emerging business models like energy-as-a-service, revenue stacking, and ancillary grid services (e.g., frequency regulation and capacity markets) are evolving but require further maturation to attract private investment.

- Government policies and subsidies, such as tax credits for energy storage and renewable portfolio standards, can improve investability. For example, the U.S. Inflation Reduction Act and EU Green Deal emphasize grid-scale storage funding.
- Financeability Score: 2

**Scalability:**

- LDS scalability is closely linked to its ability to support a growing share of renewables in the energy mix.
- Batteries and hydrogen offer more deployment flexibility. However, batteries require significant land take and are therefore exposed to location based and site suitability constraints. Hydrogen storage at scale is reliant on the availability of suitable geographical sites such as depleted gas fields presenting challenges in terms of site selection.
- Large-scale deployment requires significant economies of scale, supply chain advancements, and continued cost declines, particularly in materials like vanadium, lithium, and membranes for flow batteries.
- Regulatory harmonization and international collaboration will play a critical role in expanding LDS to serve both developed and emerging markets.
- Scalability Score: 2

**Conclusions:**

- LDS technologies are essential for achieving a low-carbon grid and integrating renewable energy at scale. While mature technologies provide stability, innovations in advanced batteries and hydrogen systems will drive future growth. Strategic investments and robust policy frameworks are critical to unlock LDS's full potential as a backbone for renewable energy systems.

**Case Study: EDF UK, supported by £2 million from the UK government's Net Zero Innovation Portfolio, is advancing four groundbreaking long-duration energy storage (LDES) projects to enhance renewable energy integration and grid resilience. These include hydrogen storage using depleted uranium hydride, a large-scale vanadium flow battery, zinc-based storage solutions, and compressed air energy storage (CAES) leveraging existing gas storage facilities. Each project explores innovative methods for cost-effective, durable energy storage to address intermittency challenges, aiming to provide backup power over extended periods. These initiatives support the UK's net-zero targets by enabling sustainable, scalable energy solutions.GW by 2030, advancing grid resilience and the clean energy transition.**

# 4.12 Battery Energy Storage Systems (BESS)

**Introduction:**

- Battery Energy Storage Systems (BESS) are playing an increasingly vital role in the energy transition by enabling the integration of renewable energy sources such as solar and wind into the grid. By storing energy and releasing it when demand peaks or renewable generation drops, BESS helps stabilize power grids, reduce reliance on fossil fuels, and supports decarbonization efforts across sectors. Their versatility in applications—from grid stabilization to load shifting—makes BESS a key technology in supporting renewable energy expansion and enhancing energy security.

**Technology risk:**

- The technology risks associated with BESS are moderate but decreasing as advancements in battery technology, particularly lithium-ion batteries, continue to improve efficiency, lifespan, and safety. BESS is a proven technology, with deployments rapidly expanding worldwide. In regions with growing renewable energy portfolios, such as the EU, the U.S., and parts of Asia, BESS deployment is accelerating to meet energy storage needs. Additionally, countries like Australia and the U.S. are scaling up BESS projects to support grid resilience and maximize renewable energy use.
- Technology Score: 3.5

**Financeability / Investability:**

- The financeability and investability of BESS projects have improved significantly due to the decreasing costs of battery technology and the increasing demand for renewable energy integration. Favorable regulatory frameworks, along with energy storage mandates and incentives, are key to enhancing the viability of BESS projects. In several regions, governments are offering capital subsidies, tax incentives, and market mechanisms to support energy storage deployment. Furthermore, revenue streams can be generated through participation in ancillary services markets, grid services, or demand-side management, enhancing the business case for BESS.
- Financeability Score: 4

**Scalability:**

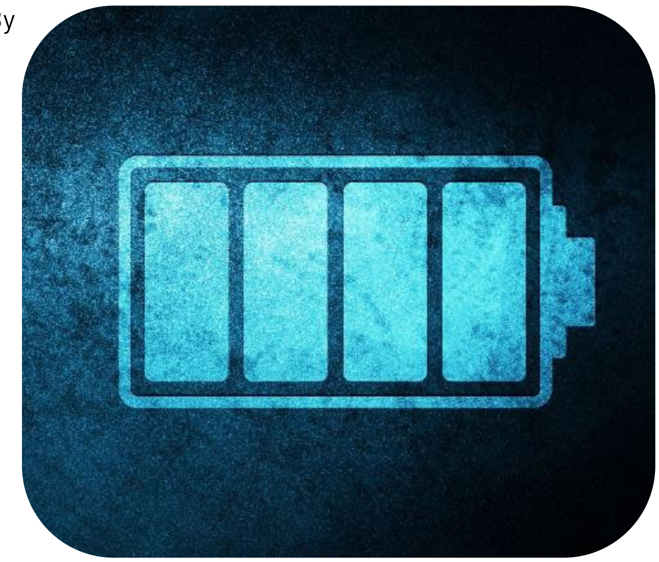
- The scalability of BESS is primarily dependent on advances in battery technology, raw material availability (such as lithium, cobalt, and nickel), and supply chain resilience. Lithium-ion technology currently dominates the BESS market due to its high energy density and declining costs. However, innovations in alternative technologies, such as solid-state batteries and flow batteries, may offer improved scalability and longer durations in the future.
- The ability to recycle batteries and reduce the reliance on critical raw materials will also be key to scaling BESS while maintaining sustainability. Additionally, large-scale BESS projects, such as grid-scale storage facilities,

are being deployed to balance renewable energy fluctuations, making the technology increasingly viable for widespread adoption.

- Scalability Score: 2

**Conclusions:**

- Battery Energy Storage Systems (BESS) are emerging as a critical enabler of the energy transition, helping to integrate variable renewable energy sources while enhancing grid stability and reliability. The future of BESS will depend on continued innovation in battery technologies, supportive policies, and the development of efficient recycling and material management systems. By addressing these factors, BESS can support decarbonization across industries, increase renewable energy use, and contribute to a more resilient and sustainable energy system.



**Traditionally, BESS projects have been either utility-owned, or underpinned by the existence of one or more long term offtake agreements. As one of the first fully Merchant risk BESS projects, with debt financing Enersmart solidified the bankability of such**

# 4.13 CCUS – Capture

**Introduction:**

- Carbon capture and storage facilities aim to prevent CO2 produced from industrial processes and power stations from being released into the atmosphere. Most of the carbon dioxide from burning fossil fuels is captured, transported, and then stored deep underground. Alternatively, it can be exported to customers for downstream utilization. Today, to meet global decarbonization targets by 2050 the global community is facing a requirement to ramp up execution of decarbonization projects.
- CCUS development has gained significant momentum in recent years, driven by strengthened climate targets and subsequently increased policy support for the technology around the world.

**Technology risk:**

- The main forms of carbon capture are direct air capture and process-based capture. that are both proven commercially will be discussed further below. CO2 can be captured from point sources efficiently with a capture level of over 90% using a range of different engineering approaches.
- Direct air capture (DAC) - This is based on recovering CO2 from atmospheric air. Licensors are active with the largest commercial plant recently commissioned in Iceland. Additional projects worldwide are in progress.
- Process-based capture (pre-combustion, post-combustion and oxyfuel)- capturing CO2 from waste gas streams (power stations, steel plants, cement plants etc). Licensed technologies have been developed for each technology with multiple in commercial operation.
- Further technology developments will support growth in this sector.
- Technology Score: 3.5

**Financeability / Investability:**

- In 2023, there were approx. 395 CCS projects in the pipeline worldwide, however only 43 were operational, while almost 190 were in early development (Global CCS Institute 2024).
- With appreciable capacity planned however as yet not executed – a key barrier is the capital cost of construction. According to the IEA – experience indicates that cost associated with the construction of CCUS plant should reduce in the future as the market grows, technology develops and finance cost falls.
- Financeability Score: 3

**Scalability**

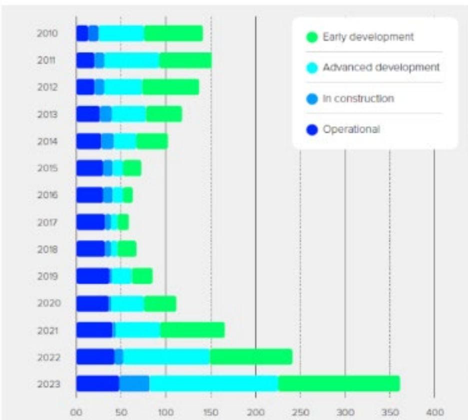
- Industry reports an unprecedented growth in the commencement of new projects with 11 facilities that were in construction in 2022 are now operational. 26 new facilities moved into construction with a capacity of 32Mtpa. However, based on current progress - we will fall far short of meeting 2050 targets. Status of projects over recent years is shown on the graph.
- An area of focus will be on plant economics with plant capacities showing appreciable increase to meet planned capacity.
- Scalability Score: 4

**Conclusions:**

- CCUS will be vital to meeting net zero targets. This will allow both CO2 storage but also importantly the use of this product for commercial value-added purposes.
- Today, the global community is facing an acceleration of decarbonization with a worldwide 5.6Gtpa target to be reached by 2050. The UK alone needs to capture and store 50 million tonnes/year (MTPA) to achieve net zero by

2050, according to official figures. However, with a global capacity of 40 MTPA in 2021 additional appreciable funding is required to meet targets.

- Increased investment is planned in the UK and in October 2024 the Government pledged £22 billion in funding for two "carbon capture clusters" in Merseyside and Teesside - to capture and store carbon emissions from energy, industry and hydrogen production from 2028. They could help to remove 8.5 MTPA of carbon emissions and support downstream value-added processing.




**Viridor's Runcorn CCS project (UK) is currently developing the world's largest carbon capture project for energy from waste.**
**Holcim**
**https://www.iea.org/data-and-statistics/data-tools/ccus-projects-explorer**

# 4.14 CCUS – Storage & Utilization

**Introduction:**

- CCUS – Storage & Utilization is the long-term storage of carbon dioxide. Storage can be both on or offshore and if shore based in reservoir or saline aquifer of depleted hydrocarbon fields.

**Technology risk:**

- Carbon Capture and Storage (CCS) requires a long-term plan for safe storage of captured carbon ($CO_2$), from injection to closure and environmental monitoring.
- Gas storage in land and sub-sea storage reservoirs/caverns is well established. Strategic storage for carbon dioxide is established and growing. Countries where this is more advanced include Norway (Sleipner Project) and examples of both reservoir and aquifer-based projects in the N Sea exist – summarized below. Development of this important sector will be critical to meet Net Zero targets and it is expected that there will be focus on government approval/incentives to allow increasing numbers of projects to commence.
- CCS and CCU are technically feasible for most large point sources (power and $CO_2$- intensive industry).
- Technology has been widely used for decades and is currently applied in several small and large-scale CCUS projects worldwide.
- As of 2023, there are 43 operational commercial CCS facilities, mainly in the US and China.
- Technology Score: 3.5

**Financeability / Investability:**

- In Europe, decarbonization through CCS is being driven by the Green Deal, EU Emissions Trading Scheme and national $CO_2$ levies. There is also a supportive climate in North America; the 45Q tax credit is available in the USA and carbon taxes are set to triple by 2030 in Canada. Across the world, CCS provides an opportunity to meet demand for low-carbon products, enabling resource holders to export blue hydrogen or blue ammonia to fuel low-carbon manufacturing industries.
- Project financing is often complex and needs to consider multiple factors including expected duration of the storage site as well as the ultimate use of the stored gas and availability of transmission systems to allow effective transfer and financial incentives.
- Several planned projects have been abandoned due to uncertain economic performance.
- Financeability Score: 3

**Scalability:**

- With expected increase in carbon capture plant capacity - this will also drive the requirement for increased gas storage. Abandoned depleted reservoirs will allow the growth of gas storage options. Multiple storage projects are currently in progress and expected to support capture plant capacities.
- Scalability Score: 4

**Conclusions:**

- Carbon storage is needed to meet permanent storage requirements, to initially provide strategic storage prior to utilization.
- Government economic incentives, motivated by international ambitions to limit global warming, are increasingly making CCS a commercially viable decarbonization route for many hard-to-abate industries.
- With 11 CCS projects under construction, 153 in development and more than 190 projects in the pipeline there are appreciable plans for expansion, however as for the capture plants these are likely to require government stimulus/incentive.
- To meet net zero targets, CCS and CCU will be necessary to compensate the emissions for the harder to abate sectors, especially in cement and chemical industries.

**Storage site based on depleted HC reservoir - Porthos, Aramis in the Netherlands, Greensand in Denmark, Hynet, Acorn, Viking, Poseidon, Orion in Norway and SVT and Morecambe Bay in the UK.**
**Storage sites based on saline aquifers Sleipner and Snohvit in Norway, Northern Lights, Trudvang, Polaris, Poseidon, Smeahera, Luna, Havsjerne in Norway and NEP and Camelot in the UK**

# 4.15 Power-To-X/E-Fuels ($H_2$, Ammonia, DME)

**Introduction:**

- Power-to-X refers to a range of technologies that convert electricity, particularly from renewable sources, into other forms of energy or products: Power-to-Heat stored in aquifers, Power-to-Hydrogen that can be stored in dedicated reservoirs and retransformed into electricity or used directly as a fuel, Power-to-Gas and Power-to-Liquid technologies or even Power-to-Ammonia that can be stored and used as a fuel in power plants or in maritime applications. These technologies enable the storage and utilization of surplus renewable energy, creating pathways to decarbonize hard-to-abate sectors like transportation, industry, and agriculture. While the underlying technologies for renewable energy generation and hydrogen extraction are well-established, scaling PtX operations to commercial levels presents challenges and opportunities. With increasing global demand for green energy solutions, PtX is poised to play a pivotal role in achieving net-zero targets.

- The conversion process is primarily driven by the production of hydrogen through electrolysis - a process in which water is split into hydrogen and oxygen using electricity. The resulting hydrogen, known as green or clean hydrogen when produced using renewable electricity, can either be used directly or serve as a base reactant to produce a variety of energy carriers and raw materials. By changing the form of renewable energy from electricity to molecules, it becomes better suited to decarbonizing industries that cannot be directly electrified fully and at scale.

**Technology risk:**

- The technologies to produce renewable energy, and extract renewable hydrogen, are already available. And each power-to-X pathway – from creating valuable gases to synthetic fuels to food products – is also technologically proven.
- However commercially this value chain is emerging and due to cost will need to be incentivized.   It is expected that plant scale will be relevant to meet expected demand.
- The technology underpinning Power-to-X systems is proven at smaller scales, but scaling up these processes introduces notable risks. While renewable hydrogen production through electrolysis and its conversion into ammonia, methane, or liquid fuels are well understood, large-scale implementation depends on the reliability of plant infrastructure and modularized units. Key risks include inefficiencies in system integration, reliability during prolonged operations, and performance at industrial scales, which require significant engineering advancements. Additionally, the ability to scale production facilities while maintaining efficiency and cost-effectiveness is critical to mitigate risks. Advances in plant modularization, robust pilot projects, and partnerships with experienced contractors will be essential to ensure reliability and manage the uncertainties associated with scaling these technologies. The industry must continuously monitor and adapt to emerging technological challenges as demand for PtX grows.
- Technology Score: 3

**Financeability / Investability:**

- Power-to-X technologies contribute to economic development by creating new industries and jobs in the renewable energy sector, driving technological innovation, and helping to reduce dependence on imported fossil fuels.
- Power-to-X is best suited to situations where renewable energy supply exceeds demand. It enables electricity generators to turn their excess renewable energy into monetizable liquid fuels or gases. However, there is also

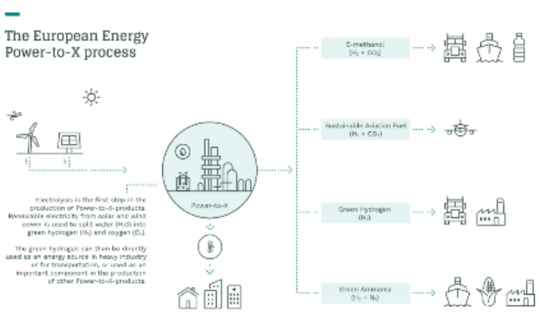
an increasing number of projects that are looking at dedicated power-to-X solutions, and some of them are not grid connected.
- Economies of scale are also likely to be a major factor with plant capacities expected to show steady growth.
- There is growing competition for electrical supplies, and this is likely to increase further, which will make renewable energy production far more important in the future.
- Revenue Models: PtX projects typically operate under contracted revenue models, often backed by full offtake agreements. However, significant risks emerge during the construction phase due to the high reliance on precise execution by project management consultants (PMCs) and contractors.
- Challenges for Financing: Turnkey EPC arrangements are uncommon, and limited warranties increase risks for project finance structures with long tenors. Investors face heightened risk during construction, making robust project execution critical for financial viability.
- Enabling Factors: Government incentives, carbon pricing mechanisms, and product pricing improvements can enhance the financial attractiveness of PtX projects. Access to low-cost renewable power, particularly in regions like the Nordics and Spain, is another critical factor for ensuring project viability. With increased commercialization and operating models – unit scale up is expected to be notable and so technology risk will need to be monitored. Speed of development will depend on multiple factors including availability of low- cost power, product pricing/government incentives.
- Financeability Score: 2

**Scalability:**
- Globally, installed power-to-X (production of low-carbon fuels gas or liquid fuels from renewable electricity) capacity stands at just over 100MW, but there are aggressive targets with the pipeline through to 2030 now exceeding 11 GW.
- It has been reported that the number of projects is growing strongly, and of note is that importantly individual projects are getting much larger. The largest operating Power-to-X project is 10MW, with a 20MW facility under construction, but recent announcements are for projects on the gigawatt scale.
- This increase in the size of individual projects is clearly a key consideration as it is estimated that over 70% of the reduction in the cost of electrolysis expected through 2025 will be from larger projects with the greatest benefits seen in scaling up to 50-100MW.
- Access to Resources: The scalability of PtX operations is closely tied to the availability of cheap, renewable electricity. Regions with abundant wind and solar resources, such as the Nordics and Spain, are well-positioned for large-scale PtX deployments.
- Modularization: PtX plants are often built using modularized units, which allow for incremental scaling to meet demand. Recent advancements in unit scaling have shown promise in reducing costs and improving operational efficiency.
- Future Growth: The speed of commercialization will depend on a combination of factors, including government support, competitive product pricing, and the availability of renewable energy infrastructure.
- Scalability Score: 4

**Conclusions:**
- PtX projects have a pivotal role in the energy transition. Innovative strategies will be critical to ensure these projects are successfully executed.
- While the foundational technologies are well-proven, scaling them to commercial levels introduces technical, financial, and operational challenges. Strategic investment, technological innovation, and supportive policies will be essential to unlocking the full potential of PtX. By addressing construction risks, ensuring access to low-

cost power, and leveraging modular designs, PtX can achieve the scalability required to meet growing global demand.

- An appreciable advantage of power-to-X technology is its flexibility. Power-to-hydrogen, power-to-ammonia, and power-to-methane enable electrical suppliers to store excess renewable energy for subsequent use in other industries. Or the stored energy can help to provide electricity for the power grid when conditions don't suit renewable energy production.
- By reducing project costs and timelines, the synergistic deployment of key levers will not only significantly enhance returns for project developers but also support the much-needed acceleration of the energy transition.
- By providing carbon-neutral alternatives to fossil fuels, Power-to-X offers a viable pathway to significantly lower carbon emissions in carbon-intensive sectors that are difficult to electrify and account for around 30% of global emissions.
- Power-to-X technologies are a key enabler of the energy transition as they help to decarbonize various sectors where it would otherwise be difficult to lower carbon emissions. As we continue to innovate and optimize these technologies, they will play an increasingly crucial role in our path towards a sustainable and carbon-neutral future.




**Whilst hydrogen and ammonia plants have been commissioned – downstream synthetic chemical projects are still in progress.**

**<u>Case Study</u>: European Energy and Petrobras have signed a Heads of Agreement to develop a commercial-scale green methanol production facility in Pernambuco, Brazil. This collaboration builds upon a Memorandum of Understanding from November 2023, aiming to leverage European Energy's expertise from Denmark's first large-scale e-methanol plant, which is set to produce 32,000 tons annually starting in 2024. The partnership aligns with Petrobras' Strategic Plan 2050, focusing on emission reductions and sustainable product expansion. European Energy, active in Brazil since 2016, has secured a 25-year land lease at the Port of Suape for the facility, reinforcing its commitment to**

# 4.16 Sustainable Aviation Fuels (SAF)

**Introduction**

- Sustainable aviation fuel (SAF) is an alternative fuel to fossil-based jet fuel that can help to reduce emissions by up to 80% compared to conventional jet fuel. Current production is principally from the biofuel production route.
- With the industry expected to double to over 8 billion passengers by 2050 it is a critical milestone in meeting International Civil Aviation Organization's (ICAO) net-zero carbon 2050 goal.

**Technology risk:**

- Processing technologies include two main groups; Bio-SAF and e-SAF, which are discussed below.
- Bio-SAF: This type is more proven and currently more widely used. The majority of production is based on the hydrotreating of esters and fatty acids. The max blend ratio of this fuel type is 50%. Airlines have successfully integrated Bio-SAF into their operations, demonstrating its viability and effectiveness.
- e-SAF: Although still emerging, e-SAF has significant potential due to its reliance on renewable energy sources. However, it faces challenges related to cost, scalability, and the need for technological advancements.
- Other types of SAF processing routes are synthesized iso-paraffin, alcohol to jet and catalytic hydro-thermolysis. With appreciable processing flexibility, an important design consideration is that plant metallurgy should consider the range of feedstocks anticipated.
- The flexibility of SAF production based on processing of multiple feedstocks will be critical for the aviation industry's goal of achieving net-zero carbon emissions by 2050.
- Technology Score: 2.5

**Financeability / Investability:**

- The European Union's RefuelEU legislation is expected to play a major role in driving the growth of the SAF industry.
- One of the main challenges in adopting SAF is its cost, as SAF is currently more expensive than fossil kerosene, which makes incentivizing the use of this fuel particularly important. With production capacity currently limited, current supplies are only sufficient to replace a small fraction of total jet fuel consumption.
- Bio-SAF is fairly well established with commercially operational plants worldwide. For E-SAF whilst each section is established - this is emerging commercially.
- Whilst technology is proven in these areas some important factors currently are the availability of feedstocks and utilities and associated plant design as well as cost of production.
- Financeability Score: 2

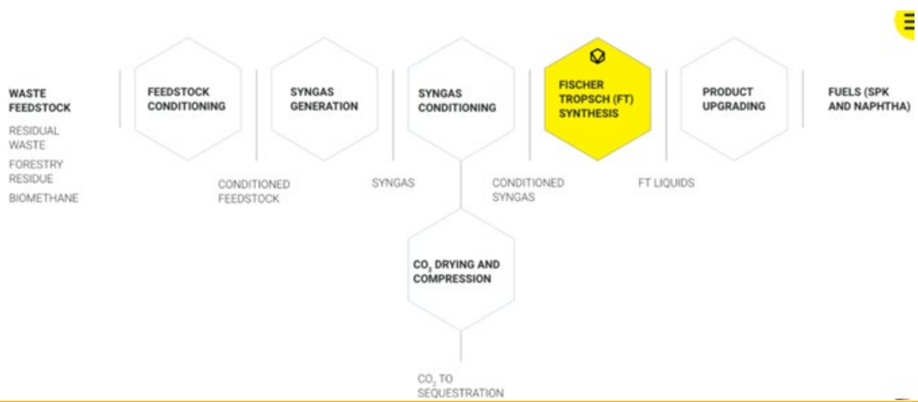
**Scalability:**

- Based on the ReFuel Aviation Regulation, the UK SAF Mandate will be enacted via the Renewable Transport Fuel Obligations that is expected to come into force on Jan. 1, 2025. The main obligation starts in 2025 at 2% and increases annually to 10% in 2030 and 23% in 2040. The PtL obligation begins in 2028 at 0.2%, rising to 4% in 2040.
- Meeting these targets will require an appreciable increase in available supply. Bio SAF plants have shown increase in capacity although plant economics including that associated with cost of feedstocks, production and market conditions are currently providing some resistance to expansion.
- Government incentives in promotion of decarbonization are expected to be required to promote the increase in Power to Liquid SAF capacity and it is likely that future supplies will be based on bio and PtL based SAF.
- The development and scaling up of these fuels are essential steps toward a more sustainable future for air travel.

- Scalability Score: 3

**Conclusions:**

- Sustainable Aviation Fuel (SAF) is transforming the aviation industry by providing a cleaner alternative to conventional jet fuel, with increasing adoption mandated by regulations requiring SAF blends. Currently, most SAF is produced via hydro-processing of waste products, but emerging technologies, including Power-to-Liquid (PtL) pathways, enable production from diverse feedstocks to meet growing demand. While international regulations drive market growth, challenges like feedstock availability, scalability, engine compatibility, and cost competitiveness persist. Innovations in processing, strategic partnerships, and consumer education are crucial to addressing these hurdles and ensuring SAF's role in the industry's sustainable future.




**Airbus is actively advancing the adoption of Sustainable Aviation Fuels (SAF) to reduce the aviation sector's carbon footprint. All Airbus aircraft are currently certified to operate with up to a 50% blend of SAF and conventional jet fuel, with plans to achieve 100% SAF compatibility by 2030. In collaboration with industry partners, Airbus conducted the ECLIF3 study, the world's first in-flight assessment of a commercial aircraft using 100% SAF in both engines. The study demonstrated significant reductions in soot particle emissions and contrail formation, indicating SAF's potential to mitigate aviation's non-$CO_2$ climate impacts. These initiatives underscore Airbus's commitment to integrating SAF into aviation, aiming to enhance environmental sustainability and**

## 4.17 District Heating

**Introduction:**

- Decentralized heating and cooling solutions such as heat pumps have significant decarbonizations potential. Heat pumps are emerging as an alternative to traditional district heating due to regulatory changes, reduced electricity consumption and rising district heating prices. Although the share of renewable fuels in district heating is growing, a significant portion still comprises of fossil fuels, resulting in substantial CO2 emissions. Heat pumps can reach high levels of efficiency (300% to 400% according to MIT Technology Review) and can support the achievement of ambitious energy efficiency targets, set by governments.

**Technology risk:**

- There are several different heat pump technologies such as air-to-air, air-to-water, exhaust air and ground source heat pumps. They extract heat from a source such as the surrounding air or geothermal energy stored in the ground and then transfer the heat, resulting in a more efficient method than boilers or electric heaters. Heat pumps are considered proven and mature technologies. Ground source heat pumps benefit from the advancement of deep drilling technologies in high density areas. The integration of smart technologies and energy storage solutions will further improve the decentralized local energy ecosystem.
- Technology Score: 4

**Financeability / Investability:**

- Regulatory changes such as energy efficiency directives enhance the attractiveness of decentralized heating and cooling solutions compared to traditional district heating. The financing of these solutions by electricity-as-a-service (EaaS) business model is gaining popularity with capital constrained companies and organizations. The model allows 15+ years of contracted cash flows and makes heat pumps financeable by long-term private equity and debt capital. Subsidies and grants for heat pumps exist in over 30 countries according to a 2022 report by the International Energy Agency.
- Financeability Score: 5

**Scalability:**

- The penetration of decentralized heating and cooling solutions is steadily increasing but still relatively low. It involves a significant upfront capital cost which has risen recently due to the higher cost of financing and volatile electricity prices. The rate of uptake depends on the building type and floor area and is closely correlated with construction activity. For example, the installation of ground source heat pumps is growing in non-residential new builds and residential retrofits in areas with expensive or unavailable district heating. Project timelines can stretch due to the availability and cost of essential components, the number of sufficiently trained heat pump installers and the state of the existing electricity infrastructure.

- Scalability Score: 2

**Conclusions:**

- Demand for sustainable heating and cooling solutions is on the rise, but it requires a larger scale and faster penetration. The success of heat pumps depends on their competitiveness with alternative systems both in terms of cost and carbon-reduction benefits. Predictable government policies and long-term market incentives are essential as are innovative financing solutions that attract lower-cost capital.

**The U.K. government has a target of installing 600,000 heat pumps every year by 2028 and 1.6 million pumps by 2035. The Department for Energy Security and Net Zero funds the Heat Pump Ready Programme to overcome roadblocks to heat pump deployment. The Programme has found that the market requires a range of financing products to suit different circumstances such as low-cost loans or financing against the property rather than the individual.**

## 4.18 EV Charging Infrastructure

**Introduction:**

- Electric vehicle (EV) charging infrastructure is an enabler of the transition to zero-emissions transport and logistics. While private home chargers are most widespread, public charging infrastructure is needed to allow more equitable and convenient access to electric vehicles. Therefore, several governments maintained the subsidies for public and private charging installations even after withdrawing the financial incentives for the purchase of electric vehicles.

**Technology risk:**

- Electric vehicle charging infrastructure is a mature technology but evolving towards super-fast-charging capabilities. There are emerging and innovative charging alternatives such as wireless charging, battery swapping and electric road systems. On the legislative front, a key focus is on developing standards that allow interoperability of the charging infrastructure. This will allow any supplier or manufacturer to use the connector.
- Technology Score: 2

**Financeability / Investability:**

- There are many business models to finance EV charging infrastructure and the revenues of some models are entirely exposed to volume risk. If the usage rate remains low, these businesses struggle to make a profit. Charging-as-a-service benefits from longer-dated contracts and stickier customers and is becoming more widespread in high-powered (trucks and commercial vans) charging. Infrastructure investors seek asset-heavy charging along strategic locations (a highly utilized motorway or predictable routes around ports). EV charging needs between $1.6 trillion and $2.5 trillion in cumulative investment by 2050, according to Bloomberg New Energy.
- Financeability Score: 3

**Scalability:**

- The share of electric vehicles in sales is expanding globally, but the progress varies by country and segment. Heavy-duty vehicles such as electric buses have already reached very high rates of adoption, and electric trucks experience a positive sales momentum. Policy support has slowed down as targets for the phasing out of internal combustion engines were pushed out in several European markets. The appeal of electric vehicles depends on battery costs, range, the cost premium to internal combustion vehicles and the rollout of new models. The installation of large charging stations and the servicing of heavy-duty fleets relies on grid capacity and access to electricity.
- Scalability Score: 4

**Conclusions:**

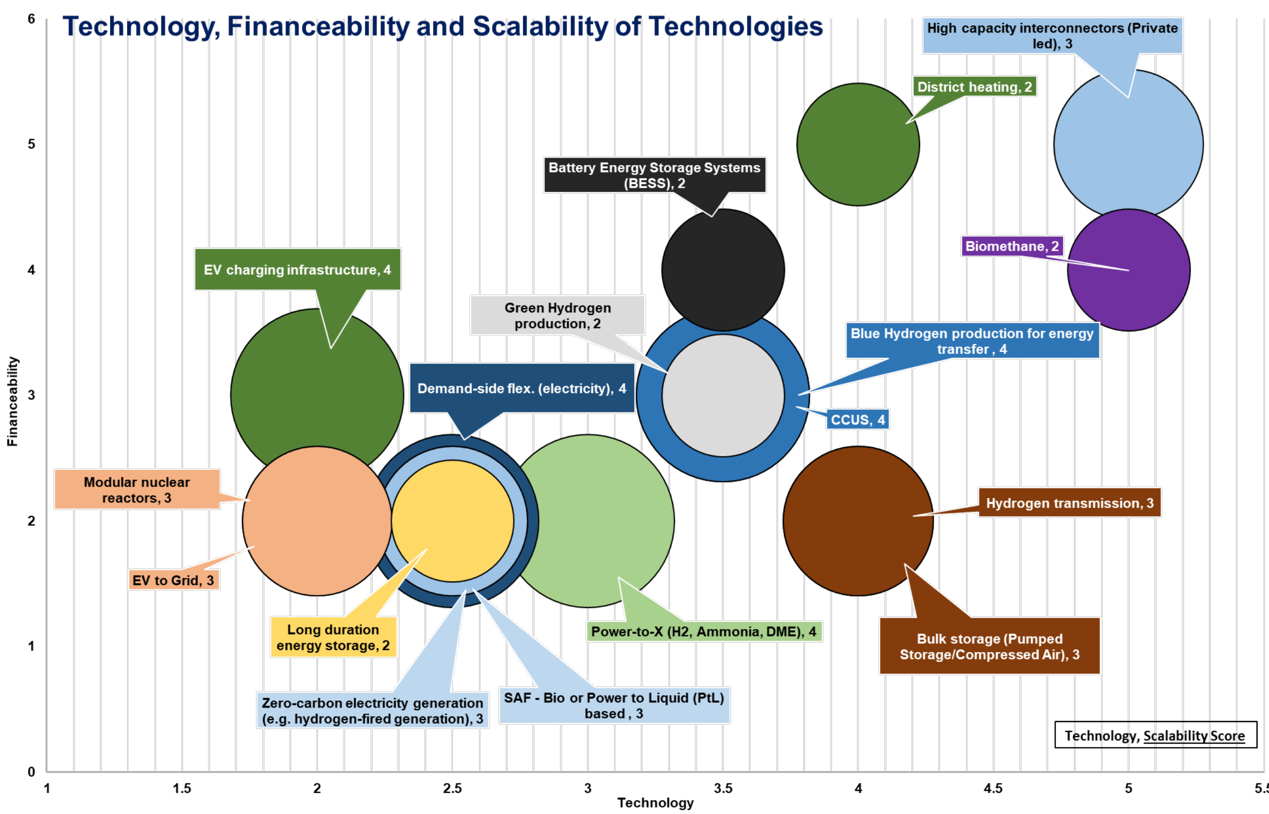
- EV charging infrastructure needs to keep pace with the usage of electric vehicles. The buildout of extensive public charging networks depends on the co-operation between many stakeholders such as fleet operators, utilities, land and infrastructure owners. Policy support is needed to set clear standards for interoperability, facilitate grid access and encourage private-sector investment.

Amazon is building an unrivalled EV charging network, having installed more than 17,000 chargers at 120 warehouses in the United States in less than two years. Getting electric infrastructure to the sites was the hardest part as it required long lead times, coordination with the local utilities, getting permits and approvals. The charging infrastructure is needed to power Amazon's increasingly electric fleet of delivery vans; the company procured 11,000 special design Rivian electric vans according to its 2023

# 5.0 Results

## 5.1 Assessment Results

Each of the technologies have been assessed using the scoring framework discussed earlier in this report. The scores were calibrated as part of a collaborative approach taken by the special interest group ensuring that overall scores and scores for each criterion were validated in relative terms. Results are illustrated in the graph below with scalability indicated by size of the bubble on the plot. We can see that some technologies, such as HVDC systems and Biomethane, demonstrate high maturity whilst others, such as SMRs and EV charging infrastructure face issues from a maturity perspective. The scores serve as a useful tool in identifying remedial actions required to accelerate technological, financing and scalability improvements for infrastructure technologies that are considered in many countries as vital to achieving net zero energy ambitions.



## 5.2 Feedback from the IPFA energy transition group

The Special Interest Group (SIG) consulted with the wider IPFA energy transition group on interim findings from the assessment as part of an interactive poll. The results below were received by the SIG and used to finesse the assessment findings and helped to determine the overall conclusions from the assessment. The feedback suggested that, in order to drive maturity in net zero technologies, focus is required in three key areas relating to investor confidence, risk management and government or policy-based supports. The feedback is presented in the table below.

| | Feedback- interim presentation | Application to technologies |
|---|---|---|
| **Investor confidence** | Innovation | This underpins the scoring criteria developed. Innovative technologies and innovations in finance and policy are all needed to progress net zero. |
| **Risk Management** | Proven technology projects | This applies across all chosen technologies where demonstrator/ pilots can boost investor confidence. Specific examples from each technology can be highlighted. |
| | Independent assurance | Examples where independent assurance has been and can be provided- this is not specifically considered in the scoring criteria. |
| | First loss capital | Not explicitly considered in scoring, but falls within the "financeability" category when assessing viability |
| | Quality offtake contracts | Contracted revenue taken to account for scoring. Emphasis on "quality" in offtake contracts further considered- specifically for nascent markets. |
| **Government support** | Targeted revenue support | Not currently in scoring criteria, but implied across all 3 scoring criteria- technology, financeability and scalability. |
| | Upskilling labour | Not currently incorporated as a specific metric into scoring criteria but falls within the "specialised resources" needed for scalability. |

# 6.0 Conclusions

## 6.1 Pace of Investment

The pace and diversity of investments in net-zero technologies needs to accelerate:

The transition to a low-carbon future can take many different pathways but two common messages stand out: the pace needs to accelerate to reach our global goals and success depends on the deployment of many carbon transition technologies. In one estimate of the investment gap, to realize the 1.5°C target by 2050 we need to invest over USD 4.5 trillion in annual terms, up from a record high of USD 1.3 trillion in 2023. While many technology choices exist, most investments were in solar PV and wind power, with 95% channeled towards them. More investment needs to flow to other energy transition technologies such as biofuels, hydropower, and geothermal energy, as well as to sectors beyond electricity that have lower shares of renewables in total final energy consumption such as heating

PATHWAY TO 1.5°C 2030

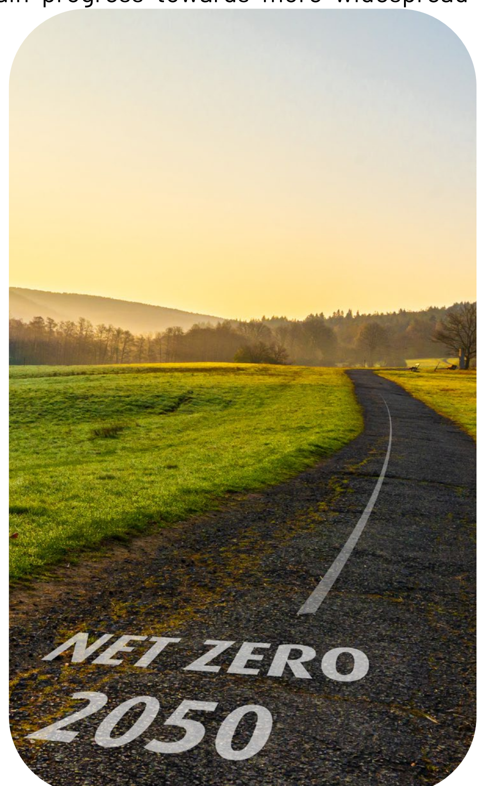
| All numbers in 2023 USD billion | | Investment in 2023 | Average annual investments required 2024-2030 |
|---|---|---|---|
| RENEWABLE POWER GENERATION CAPACITY | Total | 570 | 1 532 USD billion/yr |
| GRIDS AND FLEXIBILITY | Total | 391 | 717 USD billion/yr |
| ENERGY EFFICIENCY AND ENERGY CONSERVATION | Total | 328 | 2 250 USD billion/yr |
| | TOTAL | 1289 | 4 499 USD billion/yr |
| | | | 2024-2030 USD 31.5 trillion |

and transport.

## 6.2 Technology Maturity

Net zero technologies are maturing. However, stronger market signals are needed along with clarity on energy pathways:

The technologies assessed are showing positive signs of increasing maturity with many shifting from trials and pilot schemes into late development stages with more widespread deployment. Government supports are required to bridge viability gaps for many emerging technologies, and to maintain progress towards more widespread adoption. Research and development funding is playing a critical role in many countries and there are positive examples of multi-stakeholder partnerships driving outcomes in the form of trials and pilots' schemes.




Clarity is required in relation to optimal decarbonization pathways and certainty regarding the optimal technology mix. In the absence of this technological certainty, investment is likely to remain subdued as investors wait to see how the energy system needs evolve and the technologies that are required. There is potential that successful deployment of some technologies minimizes the needs for others which creates hesitancy for investors. Supply chain constraints are a significant barrier for emerging technologies that currently lack the economies of scale required to reduce costs. This highlights infrastructure delivery reliance on manufacturing investment and establishment of supply chain. Financing of manufacturing and supply chain is highlighted as a key dependency for many of the technologies assessed.

Lessons can be learned from other, more established, energy transition technologies such as wind and solar PV such as the transition from research and development phase into widespread use including development of supply chain, innovations and market dynamics driving reductions in levelized costs, policy and financial support frameworks, and route to markets.

# 6.3 Risk and Return

Investors are assessing the balance of risk versus return for emerging net zero technologies ensuring that:

In considering the financeability of the technologies, we have considered the likelihood of being able to raise non-recourse project finance. It should be noted that some of the technologies may be considered primarily manufacturing/production in nature rather than infrastructure, for example sustainable aviation fuel, hydrogen and power-to-x.

As we have seen with the reported suspension of the Northvolt expansion project, the financeability assessment needs to differentiate between infrastructure and manufacturing/production when considering the risks, in particular, the demand risk or robustness of offtake agreement. If not, lenders may be focusing on a projects' green credentials rather than the ratio of risk to return.

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Have a query or interested in collaborating? Get in touch.

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