Cleaner energies

BCG hello tomorrow

Report 3

Cleaner energies

The latest IPCC 6th Assessment Report underscores fossil fuel emission cuts as an urgent requirement in our climate change mitigation efforts. Although low-carbon electricity generation and storage technologies were rapidly deployed in the last decade, fossil fuels still represent ~80% of the world's energy consumption [(1)]. This is highly alarming and inconsistent with the COP 21 Paris Agreement and IEA's net-zero roadmap, which project a need to reduce emissions to 20% by 2050 [(2)].

To effectively address our fossil fuel usage and emission impact, we must take active steps toward an energy transition. This transition to the energy infrastructure of the future will require substantial investment and new technological developments. These factors are required to scale mass electrification and energy storage, and establish a sufficiently diverse energy mix from alternative sources. Currently, economical and geopolitical uncertainties, such as the ongoing war in Ukraine, challenge these efforts and pull attention toward short-term policies and solutions for energy security. Additionally, it is not enough to only tackle the fossil fuel emission problem from an energy angle. We must also create and implement solutions in how we manufacture and build the energy infrastructures of the future. For example, we can properly dispose and repurpose the composite materials found in wind turbines, materials from solar panels and batteries to secure long-term environmental impacts.

Today's deep tech entrepreneurs focus their work on the following topics:

3.1 Scaling low-carbon electricity production & storage

Moving away from fossil fuels requires massive electricity usage. Scaling electrification demands innovative and low carbon energy harvesting and storage solutions. These solutions are specifically curated for each use case. Additionally, establishing a material recycling infrastructure is key for completing this resilient energy supply chain cycle. Deep tech companies are driving the solutions we need to develop this resilient and sustainable energy supply chain. These start-ups are developing large scale recycling technologies for the battery industry, cleaner storage solutions adapted to low power electronics, and nonintermittent renewable electricity production.

3.2 Accelerating clean energy production capacity

Some heavy polluting industries, such as steel production, cannot be electrified and therefore rely on other decarbonized solutions. Hydrogen holds immense potential for these more complicated sectors but requires massive infrastructure and R&D investment to rapidly meet the demands and gains in energy efficiency. Deep tech companies are developing solutions to create cheaper and more efficient electrolyzers, new H_2 production processes and infrastructure transformations.

In the meantime, deep tech startups are making efforts to develop innovative technologies that recover waste heat from industrial processes and buildings, and convert waste streams into biofuels with synthetic biology processes.

Cleaner energies

Why it matters

To continue life on Earth, we must significantly reduce greenhouse gas (GHG) emissions. Even if we were to achieve net-zero tomorrow, the cumulative emissions already in our atmosphere would invariably increase temperatures over the next twenty years [3]. A 1.5C° increase alone will shrink glaciers and ice caps, and increase sea levels, severe weather and ocean water acidity. However, there is hope. According to the United Nations, **we can still curb the increase in the average global temperature to 2°C above pre-industrial levels** [3], by implementing a broad range of technological measures and changing some of our behaviors. Without these efforts, developing countries will face increasingly limited access to food, water, health, and energy security. Today, 70% [5] of global GHG emissions come from energy production and consumption. The immediacy of this climate crisis only underscores the urgency with which the energy industry must consider this reality, and implement scaled sustainable solutions now.

Why is it important to play the ecosystem game?

Fossil fuels will inevitably become an energy source of the past; however, increasing the number of renewables to meet the resulting energy demand gap will require the energy industry to undertake broad scale development and adopt use-case specific energy harvesting and storage solutions. Valued at **$151.96 billion in 2019, the global market for advanced battery storage systems is expected to achieve a 5.5% growth rate from 2020 to 2027** [6]. Additionally, by relying on greener H_2 production models, large industries can scale decarbonization through electrification. With sustained investments and a maturing hydrogen value chain, the market for hydrogen-related machinery, equipment, and components can reach up to $200B annually, with projected increases leading into 2050 [7]. Deep tech startups are now outpacing established industry actors, adding some healthy competition to the established selection of energy solutions. However, the entire energy industry, inclusive of corporations, startups, private and public investors, will need to join forces to invest, develop, and deploy these new solutions, at an unparalleled level of coordination and collaboration if we are to meet our net-zero goals in time.

Overview of trends

Deep tech startups are actively supporting the electrification scaling effort by developing new solutions, such as harvesting tidal wave energy, designing paper-enzyme batteries for low-power devices, and creating new processes for efficiently recovering raw materials from used batteries (see page 09).

They are also leveraging deep tech to accelerate greener H_2 production and curb infrastructure costs by using anion-exchange electrolyzers (see page 15). Additionally, deep tech startups are introducing new materials that recover heat waste to warm office buildings, and engineering microorganisms to scale biomethanation from organic waste and flue gases. (see page 16).

These forerunners are helping the entire energy industry transition into a more sustainable model.

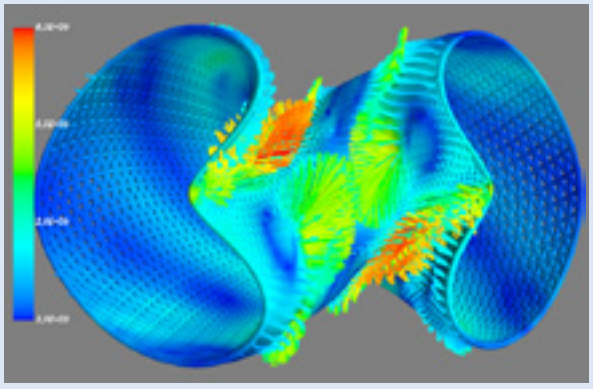
What's next to watch?

After closely reviewing over 150 deep tech startups, selected through the Hello Tomorrow Global Challenge in 2021, we have identified two trends that will have long-term inpacts on the energy market:

1. The emergence of carbon-negative biofuels derived from new sources, such as plastic wastes or wastewater streams, an evolution from today's agro and organic waste valorisation technologies;

2. The development of new nuclear reactor designs and technological bricks to accelerate fusion energy development, the most promising energy production technology leveraging nuclear power with abundant and safe elements, and without harmful radioactive emissions and wastes.

AlgBio » This startup from Turkey produces carbon-negative biofuels from microalgae by treating wastewater and flue gas.



Renaissance Fusion » A startup bringing a unique fusion power solution onto the grid by building on a proven, new design for magnetic-based fusion technologies.

Trends' expected time to market [8]

2028

pages 12 - 16

Accelerating clean energy production capacity

Spark Cleantech » Sustainable H_2 production through cold plasma

Energo » large-scale biomethane supply

Accenta » Building heating decarbonization through thermal energy

pages 08 - 11

2026

Scaling low-carbon electricity production & storage

Alchemr » Cost-effective electrolyzers

Eco Wave Power » 24/7 energy harvesting from sea waves

BeFC » Paper and enzymes-based battery

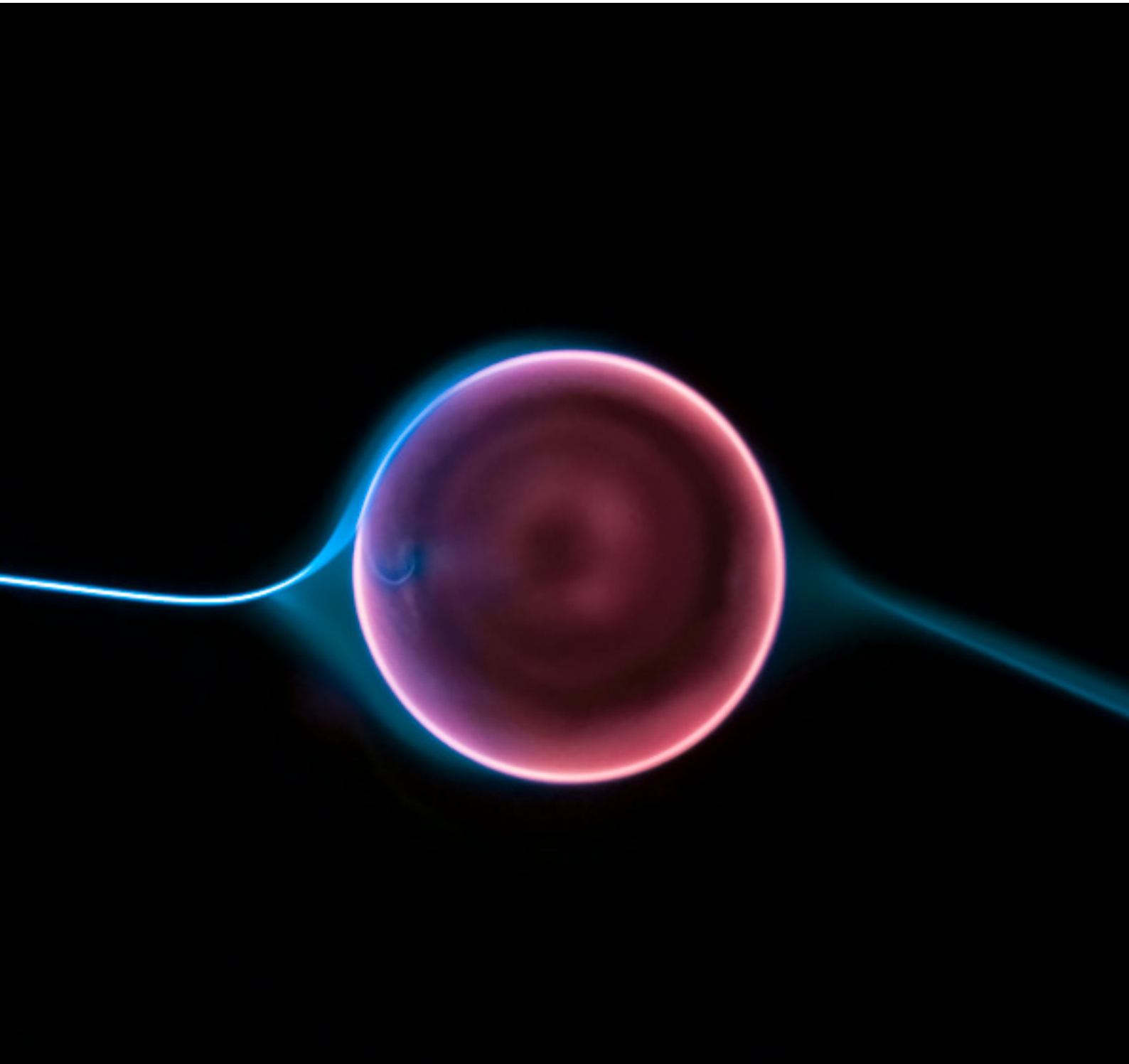
Noon Energy » Low-cost and long duration CO_2-based battery

NEU Battery Materials » Full lithium-ion battery recycling

2024

2022

3.1 Scaling low-carbon electricity production and storage



3.1 Scaling low-carbon electricity production and storage

Context

Counteracting climate change and building a sustainable society will require a transition from a fossil fuel to renewable energy based industry. Central to this transition is the energy sector, which produces around 70% of global GHG emissions [9]. Yet renewables only account for 15% of global energy production.

Today, numerous challenges including energy harvesting capacity, production intermittence, development time, materials availability and territorial non-adaptation, limit industry ability to meet global energy demands with renewable sources. Therefore, developments in electricity storage technology are key for supporting this renewable energy transition.

3.1.1 Why does it matter now?

Our selected deep tech startups are leading the charge towards global electrification, by creating next-generation energy harvesting and storage solutions. Thus, these start-ups are steering an industry heavily reliant on Lithium ion (Li-ion) storage technology, toward more cost-efficient and sustainable technologies. Additionally, the limited number of companies and geographies that can extract and purify Li-ion at a large scale restrict the industry's supply. As a result, Li shortages could appear as soon as 2025 leaving a large gap in the growing energy demand [8]. Deep tech startups are working to secure the future of batteries, by developing new solutions to address battery efficiency and sustainability ahead of the projected Li shortage, and by building infrastructures that recover and recycle end-of-life batteries.

3.1.2 Market potential & applications

Li-ion technology dominates the current battery and energy storage market. The Li-ion battery market is expected to grow from $41.1 billion in 2021 to $116.6 billion by 2030 [11]. However, the limited availability of vital materials, quick performance decreases, and the non-recyclability of Li-ion batteries threaten the industry's continued reliance on this technology. Additionally, this dependence on Li-ion batteries has severe environmental impacts, compromise the energy transition to renewables, and accelerate geopoltical instability.

Improving and going beyond Li-ion

While the global battery market is projected to reach at least $360 billion by 2030 [12], Li-ion technology cannot accommodate a market of this size. To meet this market demand, we must optimize battery performance, production scalability, and long term reliability. Already, a new generation of batteries is emerging to address these concerns, boasting innovative designs, materials, and performance.

New energies and storage systems

In additional to battery market innovations, developments in energy harvesting and delivery systems are driving global electrification in parallel. These new systems are capable of adapting to climate, geographic and demographic specificities. Solutions include flexible solar panels, plants harvesting energy from tidal and oceanic currents, and technologies that store renewable energy surplus by compressing gas, leveraging gravity or chemical bonding.

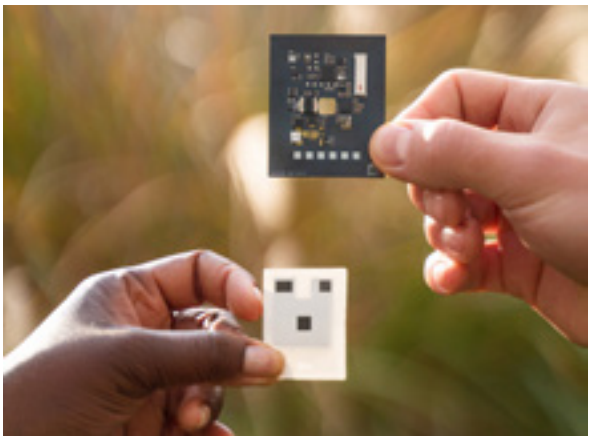
3.1.3 Key roadblocks to overcome

While progress is underway, the road towards global electrification is still fraught with challenges. One roadblock is the discovery and introduction of new, innovative systems that provide non-intermittent renewable energy and large-scale electricity storage solutions. There is also a need for more energy efficient and sustainable batteries, which are recyclable and made with cleaner materials and processes. Additionally, global electrification efforts must meet growing demands from a diverse range of energy requirements, including Industry 4.0, Internet of Things (IoT), consumer electronics, transportations, cities, etc.

There is also a need for batteries that are more energy-efficient and sustainable, meaning made using cleaner materials and processes, and recyclable.

3.1.4 Use cases

Eco Wave Power » Today's renewable energies are subject to intermittence and, as such, only account for 15% of the global energy mix[13]. However, there are alternative energy sources that continually generate electricity. **Eco Wave Power** taps into one of these alternative energy sources: ocean waves. Using a patented technology, this deep tech startup harvests the mechanical energy naturally generated by waves, 24/7. The result is a climate change resistant source of sustainable electricity, which can power remote locations, islands and coastal communities.



BeFC » As of 2020, IoT counted 20 billion connected devices worldwide,and is expected to reach 30 billion devices by 2025[14]. Many of these products, such as smart consumer goods, microchips for packaging, urban sensors, small drones, and wearables, run on low-power electronic devices. Because they are low-consumption, they won't require high-performance batteries. **BeFC** is committed to providing low cost and low environmental impact electronics. Their paper-based biofuel cell uses enzymes to convert glucose and oxygen into electricity. Combined with flexible electronic platforms, featuring highly-optimized hardware and firmware, BeFC provides data opportunities without the negative environmental impact of battery disposal.

Noon Energy » This deep tech startup is developing a new type of battery that provides low cost, energy dense, long duration electricity storage. Solar and wind power are now available for less than 3 cents/kWh, but require costly gas peaking power plants, because available energy storage technologies are too expensive. **Noon Energy**'s battery uses ultra low cost storage media, while providing high energy efficiency comparable to Li-ion batteries. This new technology will make grid-scale renewable electricity available 24/7, year round for 5 cents/kWh, achieving 100% carbon-free electricity.

NEU Battery Materials » By 2030, around 1.2 million tons of Li-ion batteries will need to be recycled [15]. **NEU Battery Materials**, a spin-off of the National University of Singapore, proposes a closed-loop system, that recovers reusable raw material from end-of-life batteries. Their system is over 100x less polluting and 10x more profitable than Li recycling systems currently in place. Additionally, their compact, Lego-like, stackable design is highly scalable.

3.1.5 What our startups need

Collaboration opportunities and constraints based on our deep tech pioneers' insights.

Experiment				Develop			Scale	
1	2	3	4	5	6	7	8	9
Exploration		Experimental, proof of concept		Functional proof of concept	Minimum viable product		Industrialization	Commercialization

» Providing industrial facilities to demonstrate batteries performances in field conditions

» Exploring the battery value chain to find applications where innovations can bring value

» Licensing the technology first

» Engaging in discussions about large capacity manufacturing and distribution

» Provide international visibility through customers portfolios and contacts

» Acquisition opportunities

3.2 Accelerating clean energy production capacity

3.2 Accelerating clean energy production capacity

Context

As efforts accelerate to achieve the 2050 net-zero economy objective, set by the Paris Agreement, Hydrogen (H_2) is emerging as a potential global-scale solution for decarbonizing energy, mobility, and industrial sectors. The European Green Deal has already identified hydrogen implementation as a key action area. Close to 60 million tons of H_2 are already used every year, with dominating usage in the chemical (ammonia synthesis) and oil refining industries[16]. Indeed, hard-to-abate sectors, such as steel, glass and chemical production require vast amounts of heat that cannot be provided by electricity. In the transport and mobility sectors for instance, large fleets could also benefit from hydrogen technology instead of batteries.

Deep tech startups match growing energy demands with specific solutions aligned to economical, logistical, and environmental concerns. As a result, these startups are driving a paradigm shift in the energy industry.

To secure a sustainable and resilient future, and stay aligned with the 2C trajectory, we must diversify our energy source mix. It is why the demand for energy produced through circular processes (recovering waste heat, transforming organic wastes to biofuels and biogas, etc.) is growing. These technologies will also help to face geopolitical instabilities and potential technological limitations.

3.2.1 Why does it matter now?

H_2 is set to play an important role in the future energy mix. However, around 95% of H_2 is generated from steam methane reformation, a costly process that demands significant energy levels and leads to air pollution. This current process falls out of step with the industry's environmental goals.[17]

Propelled by the geopolitical and price instabilities caused by the war in Ukraine, European countries are prioritizing energy sovereignty as a major strategical component. While fuel and gas prices are soaring, innovative technologies can help relocate energy production and consumption by using new sources, including organic and industrial waste streams. Additionally, heat efficient materials and processes can decrease fossil fuel dependency.

3.2.2 Market potential & applications

The global market for hydrogen production is currently increasing at a steady 5% CAGR. The market already reached $120 billion in 2022, due to support from government initiatives such as the EU's plan to achieve a 40-gigawatt (GW) electrolyzer by 2030[18]. In response and anticipation, the public and private sectors have turned their interests towards two forms of hydrogen: the first, known as green H_2, is mostly produced by a water electrolysis reaction and powered by renewable energies; the second, blue H_2, is produced by reforming methane while capturing CO_2 emissions in the process. While more R&D is needed to scale these technologies at the industrial level, the future of these technologies is hugely promising and optimistic.

On the other hand, biogasses such as biomethane, resulting from organic waste digestion by dedicated microbes, can replace the use of fossil natural gas for residential and industrial heating applications. Biogas implementation is expected to become a large opportunity in the energy space in the coming years. In fact, the latest EU energy package set a target of 35 billion cubic meters (bcm) of annual biomethane production by 2030[19]. This would lead to a more than 10 fold increase in biomethane production, when compared to the 3 bcm currently produced.

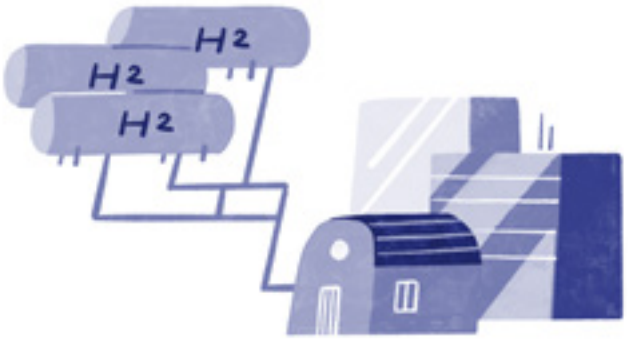
The global demand for biofuels, which mainly lies in the transport and mobility sectors, is also increasing and projected to grow by 28% between 2021 and 2026[20]. As a result, the global biofuel market is projected to reach more than $200 billion by 2030.

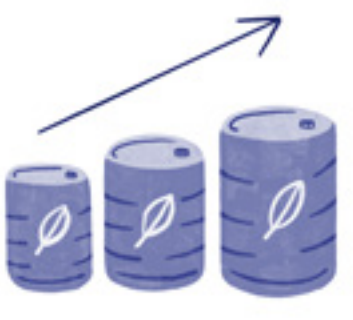
Cost-competitive green hydrogen

To satisfy the growing energy demand while meeting the industry's environmental targets, deep tech players are creating new technologies, processes, and materials that can provide low-carbon power. Deep tech startups provide new materials to produce H_2 in an environmental and cost competitive way, including energy efficient electrolyzers and low consumption methane plasmalysis.

Building the hydrogen infrastructure

The need for cost efficient H_2 distribution infrastructures become clearer as low carbon, H_2 production scales. Creating these infrastructures, in addition to up-cycling existing ones, is now the focus of several key innovative solutions.





Scaling green fuels and gas production

Waste streams that do not compete with food production, such as industrial flue gas, heat, and organic waste, innovative heat production technologies, biofuels, and biogasses are now at the industrial pilot production stage. Additionally, there is governmental support for these alternatives. However, scaling production and generating big impact on the market will require investment and industrial collaborations.

3.2.3 Key roadblocks to overcome

New innovations and developments are required to industrially scale H_2 and make the cost of green H_2, fuels, and heat waste competitive when compared to traditional processes. In response to this need, deep tech startups are now developing new base materials, along with more energy-efficient processes to rapidly scale cleaner energy production.

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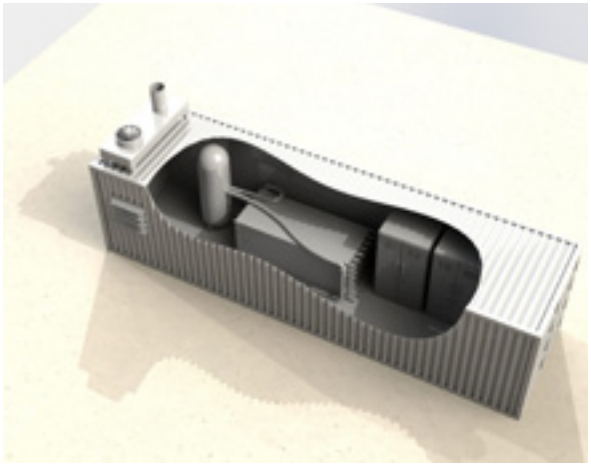
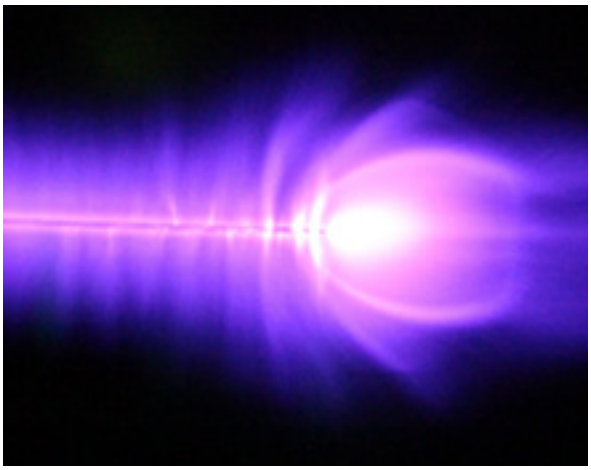
3.2.4 Use cases

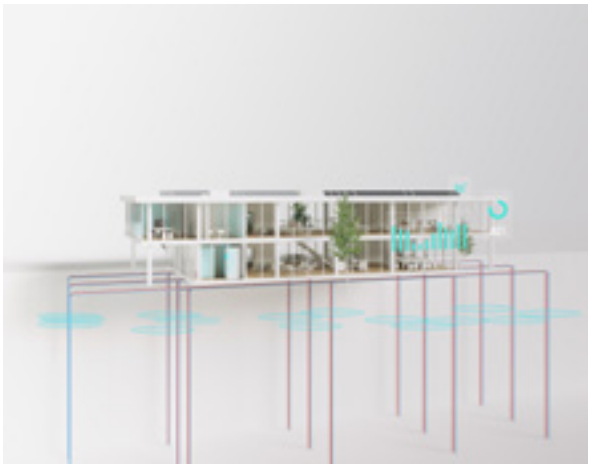


Alchemr » This startup uses anion-exchange technology to develop water electrolyzer stacks at a megawatt scale. Their solution efficiently couples with intermittent renewable power sources, and makes use of low-cost metals, such as stainless steel, to offer on-site production. Unlike other water electrolyzer options currently available, their technology does not require expensive or precious metals, or highly corrosive electrolytes. The net result is a 300% cost savings compared to existing electrolyzers, and the ability to produce green hydrogen at less than $2/kg by 2024.



Spark Cleantech » This startup proposes a new process called plasmalysis, that uses cold pulsed plasma discharges. Cold plasmas enable molecule separation while minimizing pressure and temperature increases. This decreases energy consumption and the associated footprint of methane reforming to produce H_2.

ENERGO » Shaking up the world of chemistry by developing a completely new way of converting gases into other gases, in the fastest, cheapest, and most environmentally friendly way. This technology combines two mature and robust technologies (catalysis and cold plasma), and can be applied to H_2, methanol, ammonia production and depollution. **ENERGO** offers the first, most mature renewable methane production process from wastes, at a cost 15-40% cheaper than conventional methods. As a result, this solution produces gas at prices competitive to fossil gas.



Accenta » The act of heating and cooling buildings accounts for almost 17% of global GHG emissions[21]. With the introduction of more environmental policies, the construction and building sectors are seeking new solutions to drive infrastructure energy management toward a sustainable future. With its .PILOT LowCarbon software, **Accenta** combines AI and data science to harness geothermal energy from the ground to power infrastructure heating and cooling.

3.2.5 What our startups need

Collaboration opportunities and constraints based on our deep tech pioneers' insights.

» Financing or incorporating pilot programs to demonstrate technologies

» Building long-term partnerships to carry out industrial demonstration and scale up to first commercial projects

» Activating new market opportunities on a large geographical scale

» Providing licensing opportunities

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