Supported by L.E.K. Consulting

Advanced Energy Solutions Industry Vision

FEBRUARY 2024

WORLD ECONOMIC FORUM

Context

Various studies affirm the central role of energy storage, carbon management, small modular reactors, clean hydrogen and sustainable aviation fuels in the global endeavour to reduce carbon emissions and achieve a net-zero future.

The net-zero emissions path in 2030 will need carbon capture and storage (CCS) to scale to 20 times the current capacity, energy storage to 35 times, clean hydrogen production 70 times and sustainable aviation fuels (SAF) 190 times. Additionally, mass deployment of new advanced nuclear reactors will be needed. Such unprecedented capacity growth will need investment, which must grow to more than $500 billion per year by 2030.

However, while progress is being made, it is significantly lagging behind. Publicly announced plans currently cover only a fraction of the estimated investment needs. The deployment of these advanced energy solutions needs increased speed and scale.

To this end, the World Economic Forum's Advanced Energy Solutions community aims to accelerate, from decades to years, the deployment at industrial scale of advanced solutions such as clean fuels, hydrogen, advanced nuclear power, battery storage and carbon management.

This document proposes a vision for the advanced energy solutions industry and the key factors that will ensure success in achieving the required levels of deployment in coming years. It aims to enhance understanding and support collaboration within industry and across stakeholder groups, inform decision-making and foster best practice-sharing.

The vision was shaped by the World Economic Forum, supported by L.E.K. Consulting, through meetings of the Advanced Energy Solutions CEO community, interviews with senior executives and in-depth research and analysis.

TABLE 1. **Capacity, investment and growth rates**

Solution	Current capacity	Capacity required in 2030 to get on track for net zero	Annual investment required in 2030 (US$ billions)	Annual growth rate required by 2030 (CAGR %)
Battery storage	28 gigawatts (GW)	970 GW	150	66
Clean hydrogen	1 million tonnes (Mt)	69 Mt	130	83
CCS	50 Mt	1,024 Mt	100	54
SAF	0.24 Mt	45 Mt	80	111
Advanced nuclear	~0 GW*	~0 GW	75**	n/a

Source: IEA World Energy Outlook 2023, BNEF, Global Data, Hydrogen Council.

* China operates 200 MW high-temperature gas-cooled pebble-bed modular (HTR-PM) reactors. Both are for demonstration only. Russia's Akademik Lomonosov floating plant uses two 35 MW small modular reactors (SMRs).

** Investment comes before capacity. Based on achieving 25% SMR capacity by 2043. ~$4.5 billion is allocated for fusion development.

Not a technology readiness challenge

While technology development must continue to drive down cost curves and bring new innovations to market, the primary challenge in deploying advanced energy solutions over the next decade does not lie in their technological feasibility. Rather, it lies in confidence in these solutions. Many stakeholders recognize the need for these solutions and the opportunities they offer, but are not confident enough to move at the speed and scale required.

The challenge can be broken down into technological confidence, demand confidence, business case confidence and public confidence. In essence, large energy companies, energy users, financial institutions, policy-makers and the general public need to be confident that technologies are proven, safe and able to deliver the most affordable path to net-zero emissions by 2030.

Technological confidence

The increasing number of projects and plants that exist and are being commissioned in energy storage, clean hydrogen, SAF and CCS demonstrate that technology is up to the task. Advanced nuclear solutions are often seen as less mature, even though technologies behind small modular reactors, for instance, have been around for decades. Misconceptions over the technological readiness of many of these solutions continue to linger.

Business case confidence

At the same time, all advanced energy solutions are going through intense innovation to drive down costs. Innovation combined with increasing scale and industrialization is expected to substantially lower costs by 2030, as has happened with wind and solar power.

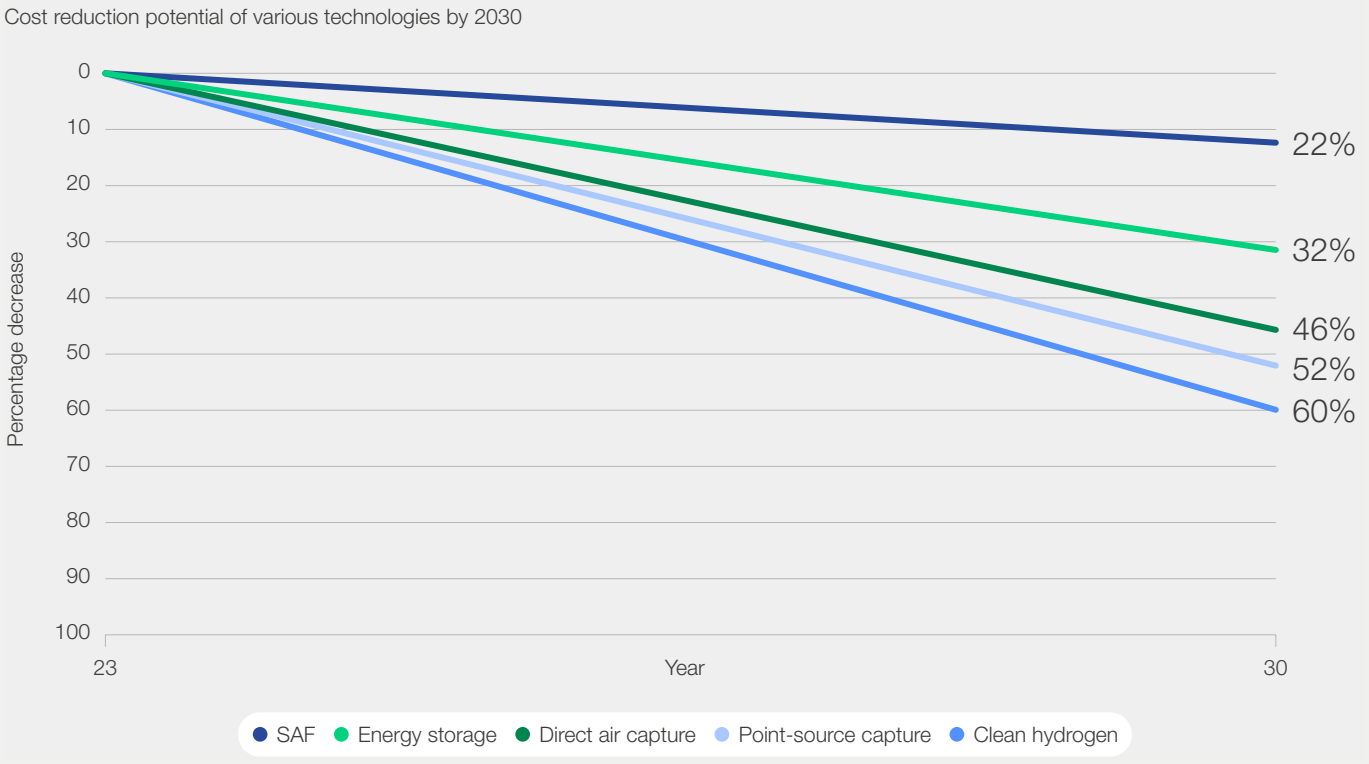
However, despite these gains, a “green premium” will persist over the next decade and beyond when comparing various options solely on cost basis. Understanding the value of emissions and pollution reduction, better public health, improved industrial competitiveness and energy security will be instrumental to increase confidence in the business case.

For example, SAF is likely to remain 2-3 times more costly than kerosene by 2030 and, according to L.E.K. Consulting [1] absorbing this cost would increase the passenger price by 18% to reduce approximately 50% of flight emissions. Another study[2] suggests that decarbonizing Europe’s power grid by 90-95% would cause bills to rise roughly by €14 per month for a typical household in the European Union.

To scale, every solution needs a viable business case. For advanced energy solutions, any business case must include clear mechanisms to cover green premiums. It needs to be established how additional cost will be met and distributed through a range of options from government subsidies, consumers paying more to philanthropic capital.

One such practical approach can be observed in California in the United States. The state has launched a plan[3] for carbon neutrality by 2045, including $48.3 billion from state funds additional to the Inflation Reduction Act.[4] The cost has been justified by redefining the value of clean solutions. In addition to neutralizing carbon, the plan factors in 71% reduction in air pollution, 4 million new jobs and $200 billion of savings in health costs.

FIGURE 1: **Ability of advanced energy solutions to reduce costs**



Demand confidence

Market studies and forecasts project exponential growth of advanced energy solutions. However, despite such robust market outlook, confidence in actual demand from industries and individuals remains low. Demand confidence is necessary to justify investments in supply.

Purchase agreements and offtake contracts are often key levers for providing demand confidence. Suppliers greatly need these demand signals to invest in production facilities, infrastructure, feedstock and materials. At the same time, purchasers are often unwilling to sign purchase agreements with "take or pay" obligations at current prices when prices are likely to fall in future.

Public confidence

For people to proactively embrace advanced technologies, the necessity, urgency and safety of advanced energy solutions need to be made clear, and misconceptions clarified. Public support can ensure rapid scale-up.

Much of the confidence in the public stems from gaining a better understanding of the value these solutions bring. Moreover, standards and certification help assure transparency and quality while facilitating market creation.

Towards 2050

While the immediate focus can be on deploying technology that is currently available, acceleration along the net-zero path beyond 2030-2040 will need the development and deployment of more frontier solutions.

For example, short duration lithium-ion battery storage is already deployed at industrial scale and needs to be further accelerated towards a net-zero path by 2030. At the same time, long duration storage needs innovation and technology maturation, as the ability to store renewable energy across weeks, months and seasons will be increasingly important on the way to 2050.

Collaboration

Exponentially scaling the advanced energy solutions industries over the next decade – by building and unlocking confidence in technology, business case and demand, while taking a people-positive approach[5] – will require unprecedented levels of collaboration. It will be essential to driving scale, creating the demand signals, unlocking investment, spreading the risk and informing policy-making.

For example, collaborations that increase demand confidence could be transformative. Initiatives such as the First Movers Coalition[6] contribute to creating strong demand signals for innovative clean technologies in industrial sectors.

Another opportunity is related to support for scaling up to $500 billion in investment per year by 2030. Even though the capital and investment appetite exist, the investment landscape is fragmented and risk is not effectively shared. Either suppliers shoulder all the risk for infrastructure investment with low demand certainty, or the risk can sit entirely on the purchasers through take or pay agreements. Increasingly, stakeholders aim to spread the risk through collaborations where various types of investors, industrial players and solution providers partner together by pooling investments, and create industrial clusters and buyers' clubs.

Policy

The role of policy remains central to unlocking various challenges to scale. For instance, permitting and supportive regulation such as financial subsidies and demand mandates can help create business cases and address green premium scenarios. Speeding up permitting shortens time needed do deploy projects and improves business case through better net present value of investment opportunities.

Public funding provided a quarter of the roughly $1 trillion that flowed in 2023 into new energy technologies and systems,[7] coming through government subsidies and tax credits such as the Inflation Reduction Act in the United States. Creating viable business cases and demand pull for massive scale up will need further public funding to multiply the inflow of capital from private sources.

Policies must create a stable environment for growth and innovation. Regulations need to keep up with the speed of technological advancement, be tailored to specific needs and challenges, and foster a level playing field for innovation.

Community

While every region, country, industry and company will decide its own approach, all stakeholders need to work in concert with each other and the existing system.

The World Economic Forum's Advanced Energy Solutions community aspires to accelerate, from decades to years, the deployment at industrial scale of advanced energy solutions. The community aims to increase public and stakeholder confidence in technology, demand and business case by enabling collaborations and informing policies.

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Endnotes

1 "Fuelling the future of aviation", L.E.K., 2023.

2 "Decarbonisation pathways: Full study results", EUElectric, 2018, https://cdn.eurelectric.org/media/3558/decarbonisation-pathways-all-slideslinks-29112018-h-4484BB0C.pdf

3 "CARB approves unprecedented climate action plan", California Air Resources Board, 15 December 2022, https://ww2.arb.ca.gov/news/carb-approves-unprecedented-climate-action-plan-shift-worlds-4th-largest-economy-fossil-fuels.

4 "Inflation Reduction Act of 2022", United States Department of Energy, 2022, https://www.energy.gov/lpo/inflation-reduction-act-2022.

5 "Better Community Engagement for a Just Energy Transition: A C-Suite Guide", World Economic Forum, 2023, https://www3.weforum.org/docs/WEF_Using_a_People_positive_Approach_to_Accelerate_the_Scale_up_of_Clean_Power_2023.pdf.

6 "First Movers Coalition", World Economic Forum, 2024, https://initiatives.weforum.org/first-movers-coalition/home.

7 "Capitalisms Green Revolution", Foreign Affairs, November 2023, https://www.foreignaffairs.com/world/capitalisms-green-revolution.