Net Zero by 2050

The need for net zero demonstration projects

International Energy Agency

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Global technology demonstration funding of at least USD 90 billion by 2026: an essential springboard to net zero emissions

In its landmark report last year, Net Zero by 2050: A Roadmap for the Global Energy Sector, the IEA stated that "international programmes to fund demonstration projects, especially in sectors where technologies are large and complex, would accelerate the innovation process". The IEA estimates that **at least USD 90 billion of public funding needs to be raised by 2026 to complete a portfolio of demonstration projects** for technologies that could be commercially ready by 2030 and contribute to achieving net zero emissions by mid-century. This note explains the key considerations and technological fundamentals underpinning such analysis.

Without a major acceleration in clean energy innovation, reaching net zero emissions by 2050 will not be possible.

Technologies that are available on the market today are able to provide nearly all of the emissions reductions required by 2030 in the Net Zero Emissions by 2050 scenario (NZE), but going all the way to net zero will require the widespread use after 2030 of technologies that are still under development today. By 2050, almost 50% of CO_2 emissions avoided in the NZE require technologies that are not yet past the demonstration stage, a share that is even higher in sectors such as heavy industry and long-distance transport. Major efforts are vital this decade for these technologies to reach markets at large scale as soon as possible.

Innovation cycles for early-stage clean energy technologies need to be more rapid for the NZE than what has typically been achieved historically. Bringing clean energy technologies under development to market by 2030 requires going from first prototype to market 20% faster on average than the quickest energy technology developments in the past, and around 40% faster than was the case for solar PV. Technologies at the demonstration stage, such as carbon capture utilisation and storage (CCUS) in cement production, are brought into the market by 2024 in the NZE. Hydrogen-based steel production, direct air capture and other technologies at the large prototype stage reach commercial scale by 2026 at the latest, with most technologies at small prototype stage – such as solid-state refrigerant-free cooling or solid-state batteries – doing so by 2030.

The IEA monitors **the development of over 400 individual technology designs and components across the whole energy system** that contribute to reaching net-zero emissions in **IEA's ETP Clean Energy Technology Guide**. For each of these technologies, the *Guide* includes information on the level of maturity and a compilation of development and deployment plans, as well as cost and performance improvement targets and leading players in the field.

Large-scale demonstration projects are most needed in a few key technology areas

The innovation process involves successive demonstrations of scientific concepts, working prototypes, and consumer demand. A "demonstration project", according to common usage in the energy sector, is typically one of the first few examples of a new technology being introduced onto a given market at the size of a single full-scale commercial unit. It involves far more time, cost and risk than a prototype, and significantly reduces investor risk for subsequent installations. Demonstration projects are usually loss-making investments when considered in isolation, with their combination of capital requirement and risk placing them squarely within what is often referred to as the "valley of death'', a stage when technologies can fail to progress commercially even if they have high market potential.

Demonstration projects in sectors where economies of scale favour large installations are generally the hardest to fund without public support. Even where the additional cost of production is modest compared to what consumers are used to paying, the sheer size of the capital being put at risk – which can easily surpass USD 1 billion in some sectors – makes the business case for demonstration projects challenging. This differs from mass-manufactured equipment or digital consumer products, where the cost of experimentation at full commercial scale is usually much lower. These other technologies need a different mix of targeted policies in their early-stages, as well as large coordinated field trials as they scale up (for example, to test the effectiveness of widespread demand response or how electric vehicles can interact with a smart power grid). Clean energy supply chains, including manufacturing and critical minerals supply, would also benefit from targeted policy support that is complementary to large-scale demonstration projects.

There are three main purposes of demonstration projects: to show customers that the technology is effective at scale; to reduce the perception of risk for financiers and insurers; and to inform regulators about costs and market deployment needs. For technologies that confer environmental and social benefits, like those in the NZE, the case for government funding support is strengthened by the ability of demonstration projects to reduce costs and narrow the knowledge gap between the public and private sectors.

Government R&D and demonstration spending needs to be increased and reprioritised. Looking across the spectrum of technologies needed globally to achieve net zero emissions by 2050, there is a clear group most in need of major demonstration projects. Most involve manipulating molecules, not just electrons, and include the transformation of sustainable biomass into affordable fuels, keeping CO_2 out of the atmosphere by capturing and storing it, and replacing fossil fuels in heavy industry and long-distance transport with low-emission alternatives, mostly involving hydrogen and related fuels. However, hydrogen, CCUS, electrification and bioenergy only represent about 25% of global public clean energy R&D and demonstration spending funding today.

The public cost of a portfolio of net zero demonstration projects is within reach

The IEA estimates that at least USD 90 billion of public funding needs to be raised by 2026 for an efficient portfolio of demonstration projects. This portfolio would directly support and leverage private investment in demonstration projects, providing the greatest chance that the range of technologies needed to avoid emissions across all sectors in line with the IEA's NZE by 2050 Roadmap could be commercialised by 2030. These technologies are all well known, and have all been proved conceptually at pilot scale, but need a final push via demonstration projects. The USD 90 billion estimate factors in the demonstration of two or more competing solutions for each emissions challenge, and also accounting for regulatory and geographical contexts. For example, demonstration projects in certain advanced biorefining technologies will need to consider a variety of biomass feedstock and climatic conditions if they are to be insurable and saleable in the key markets for scale-up. Given that past experience points to non-zero failure rates in each region, some redundancy (or amplification) is built into the estimate.

Cost estimates are based on the latest available operating projects or advanced engineering designs. The share of total costs to be covered by the public sector is around 50% while funding needs and instruments will vary between technology areas and regions. Total costs include capital costs and operational costs for a fixed period. For example, in some technologies, such as water electrolysis, capital investment may be unlocked solely by operational subsidy guarantees.

The portfolio includes:

- Container-size ships with alternative drivetrains.
- Cracking of ammonia to hydrogen and full integration of hydrogen and ammonia production.
- Hydrogen-based synthetic liquid and gaseous fuels production.
- Integrated renewable electricity and polymer electrolyte membrane and solid oxide electrolysers for hydrogen production, storage and distribution.
- Iron and steel production solely based on hydrogen, blends of hydrogen and natural gas, or with CCUS.
- Floating offshore wind in novel configurations.
- Small modular nuclear reactors.
- Bulk chemicals production from non-fossil sources.
- CCUS applied to cement manufacturing, hydrogen production and power generation (from coal, natural gas and biomass) in situations not yet demonstrated.
- Capture and storage of CO_2 from ambient air.
- Advanced biofuels from cellulosic feedstocks via enzymatic and thermochemical processing.

Global cooperation is imperative

An acceleration of this magnitude is clearly ambitious but possible. It requires technologies that are not yet available on the market to be demonstrated quickly at scale in multiple configurations and in various regional contexts. In most cases, these demonstrations are run in parallel in the NZE to meet the 2050 net zero goal. It is, however, in contrast with typical practice in technology development: learning is usually transferred across consecutive demonstration projects in different contexts to build confidence before widespread deployment commences. The nature of innovation means that project funders and investors risk failure, yet this failure can be fundamental to making progress across the global portfolio in aggregate.

The IEA estimate of portfolio cost is contingent on international cooperation. Sharing knowledge and learning between stakeholders and projects is a key requirement. Regulators will also develop more effective policies if information is exchanged between governments. Without such cooperation, the number of projects would certainly be unnecessarily larger and the portfolio more costly.

International cooperation can also ensure that demonstration projects are located in the most appropriate locations for technology scale-up. Emerging market and developing economies account for more than 40% of the world's energy investment in the NZE, more than the 30% projected under current policies. For example, around 85% of new production capacity coming online in heavy industries to 2030 is projected to be in the emerging and developing world.

Cooperation along supply chains is also critical to accelerate demonstration projects. Given the inherently challenging business case of technology demonstration, building early demand signals for goods, fuels and services delivered with substantially lower emissions footprints will be important to deploying the next generation of clean energy technologies. Advanced market commitments have successfully been used to induce innovations in other fields, from lifesaving vaccines to commercial spaceflight. Several demand aggregation initiatives are collecting medium-term purchase commitments for materials produced through near zero emission routes or zero emission long-haul vehicles, among others, that can be translated into bankable agreements for prospective demonstration and follow-on clean energy projects.

Progress towards net-zero emissions will be expedited by funding demonstration projects in emerging market and developing economies. Clean energy R&D and patenting is currently concentrated in a handful of places: Europe, Japan, United States, Korea and China accounted for around 90% of all clean energy International Patent Families generated between 2010 and 2019. In addition to swiftly sharing their experience with emerging market and developing economies that are not involved in their initial development, technology vendors will find their technologies are more commercially successful in these regions if they are tested in the same climatic, regulatory and market conditions. Such a dynamic would also help these countries prosper from new technology supply chains and respond more effectively to the imperative of people-centred transitions.

"Follow the money" - the IEA will track progress

The IEA is stepping up efforts to assess progress towards commercialisation of the relevant technology areas. Building on IEA's ETP Clean Energy Technology Guide, the IEA is working with international partners, including Mission Innovation and IEA's Technology Collaboration Programmes, to develop a database to track progress on how public and private funds translate into real-world demonstration projects, which will be made publicly available. Mission Innovation is also coordinating a range of technology missions, several of which aim to deliver large pilot and demonstration projects in the coming years.

By mid-2022, the signals for investment in clean energy demonstration projects are encouraging. As core elements of their plans to transition their energy systems to net zero emissions, major economies including the United States, Japan, the European Union and China have highlighted innovation and proposed or invested increased levels of funding. Such programmes include as part of their overall portfolio demonstration projects in the technology areas mentioned above as well as other type of projects.

- In the United States, the 2021 Investment Infrastructure and Jobs Act funds a new Office of Clean Energy Demonstration with an initial USD 21 billion.
- Japan's Green Innovation Fund allocates around USD 19 billion to low-carbon energy technology demonstration between 2021 and 2031, complemented by USD 15 billion in tax credits for private involvement in such projects.
- The EU Innovation Fund has budgeted USD 11 billion to demonstrate innovative energy technologies this decade, including large-scale solutions for industrial emissions. A further USD 3 billion was pledged as part of the REPowerEU plan in 2022. As the price of emissions allowances, which are sold to fund the projects, has risen, the funds may expand further.
- In China, documents in support of the 14th Five-Year Plan 2021-25 give a central role to energy innovation: China's National Science and Technology Major Projects budget could rise above the current level of around USD 3 billion per year and include more energy-related projects. Furthermore, 7% annual increases in clean energy R&D have been announced for the period to 2025.
- Germany is supporting a range of hydrogen projects with USD 9 billion, a number of which could contribute to a net zero demonstration project portfolio.
- Australia, Korea, Norway and the United Kingdom are all scaling up their expected spending on a range of technology demonstrations, including CCUS and hydrogen.

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