Global Innovation Needs Assessment

Yield-enhancing technologies

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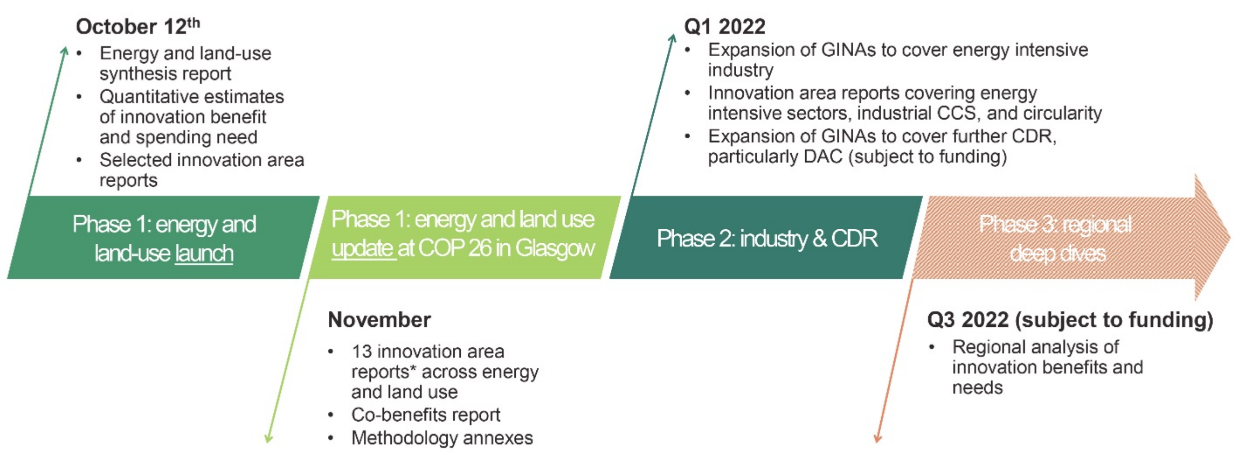
The Global Innovation Needs Assessments

The Global Innovation Needs Assessments (GINAs) is a first of a kind platform for assessing the case for low carbon innovation. The GINAs take a system wide perspective, explicitly modelling the impact of innovations across the global economy. Uniquely, the analysis quantifies the economic benefits of low carbon innovation and identifies the public investment levels—from research and development to commercialization—needed to unlock these benefits. The analysis is divided into 3 Phases: Phase 1 on global energy and land use, Phase 2 on global industry, and Phase 3 on regional deep dives. This brief forms part of Phase 1, and will be followed by a more detailed yield-enhancing technologies report when Phase 1 concludes.

The analyses do not assess all relevant technologies, nor do they evaluate all relevant factors for policy judgements. Instead, the work is intended to provide a novel evidence base to better inform policy decisions. The Phase 1 analysis looks across a broad range of climate mitigation technologies in energy and land-use, ranging from demand response to protein diversification, to model the economic value of related innovation investment. Later phases expand the research. As with all technologies, there are risks and potential downsides to their adoption, and some remain controversial. Which innovations to invest in is ultimately a policy judgement, and this analysis does not provide policy recommendations to invest in any specific technologies.

Phases of the Global Innovation Needs Assessments



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The findings and views expressed across this project do not reflect the view of ClimateWorks, the Government of the United Kingdom or Mission Innovation.

Phase 1 GINA outputs

The suite of reports across innovation areas methodological annexes and a synthesis report for GINAs are available on the GINA website at: https://www.climateworks.org/report/ginas/.

The suite of outputs for Phase 1 of the Global Innovation Needs Assessments

1. **Energy and land use synthesis report –** *slide based summary for policymakers and executives*
   Synthesis of the findings across the innovations considered in energy and land use

2. **Energy and land use & agriculture innovation reports –** *in depth quantitative analysis for industry and policy analysts*

   - **Wind power** – Offshore and onshore wind turbines
   - **Low carbon hydrogen** – Electrolysers and gas reforming with CCS
   - **Solar power** – Utility-scale and distributed PV
   - **Low carbon fuels** – 2nd generation biofuels, synthetic fuels (H_2 + CO_2)
   - **Nuclear power** – Small modular and large-scale advanced reactors
   - **System flexibility** – Battery storage, power-to-X, demand response
   - **Buildings** – Heat pumps, building fabric
   - **Power CCS** – CCS in power generation (coal, gas and biomass)
   - **Zero-carbon road transport** – Battery electric vehicles, fuel cell electric vehicles
   - **Protein diversity** – Replacement food and novel vegan food
   - **Decarbonizing agrochemical inputs** – Innovative fertilisers and pesticides
   - **Yield enhancing technologies** – Digital agriculture and vertical farming
   - **Irrigation** – Improved irrigation methods and systems

   The selected innovation areas were selected for their potential for further innovation and the potential magnitude of the associated system benefits. Their selection here is because they could play a key role in a net zero pathway but does not imply that an optimal net zero pathway necessarily includes them. Further notes on the rationale behind their selection is provided in the methodology annex on the GINA website

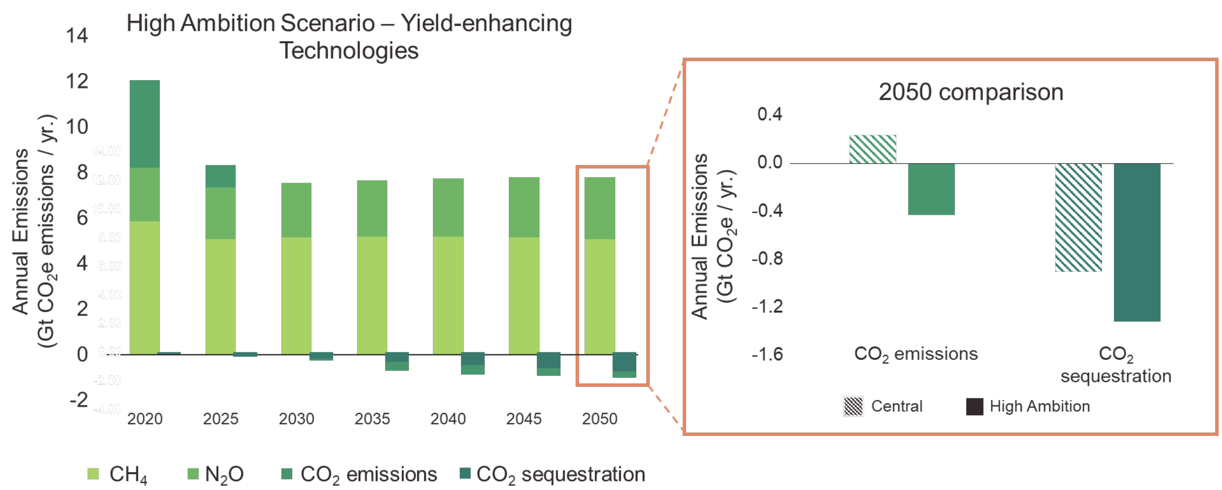
3. **Co-benefits of innovation report –** *qualitative analysis of the environmental and other non-economic benefits of net-zero innovation*
4. **European case study –** *Analysis of jobs and growth benefits in Europe specifically*
5. **Methodology annex–** *A description of the modelling approach taken for analysts*

Yield-enhancing technologies

The development of yield-enhancing agricultural technologies could help make a 1.5ºC temperature target US$ 1.33 trillion cheaper to meet between now and 2050. Yield-enhancing technologies are broadly engaged with the measurement and management of agriculture using novel scientific approaches as well as data, information and communication technologies. By leading to better decision making with more information, and greater efficiency of inputs and approaches, these technologies lead to greater yields and better management of emissions and waste. A few key technologies are expected to play a critical role in the market, in some instances building upon and enhancing one another:

- **Vertical agriculture**: growing crops in vertical layers using advanced environment technologies to produce food efficiently while using less land. Controlled-environment farms are expected to expand the range of crops they produce relative to the select few currently commercially viable but will remain limited to high-value specialty crops given the challenge posed by row and tree crops. Vertical agriculture does require renewable electricity supply in order to be represent a net reduction in emissions.
- **Digital agriculture**: robotics and software technologies that allow monitoring and management of food and agricultural supply chains, to facilitate decision-making, reduce input needs, and reduce loss and waste.
- **Gene technologies**: adaptation of plant and livestock genetics, ranging from traditional selection and breeding practices to more recent direct editing techniques enabled by scientific advances like CRISPR. They can dramatically improve crop resilience to pests, disease, and unfavorable weather conditions like drought, as well as enhance both the volume and nutrient profile of yields.

Figure 1 Left side: The combination of policy and innovation in the high ambition scenario reduces anthropogenic land system emissions substantially compared to today.
Right side: The innovation present in the high ambition scenario (and not in the central scenario) is responsible for nearly 1 Gt CO_2 per year less in the atmosphere in 2050.



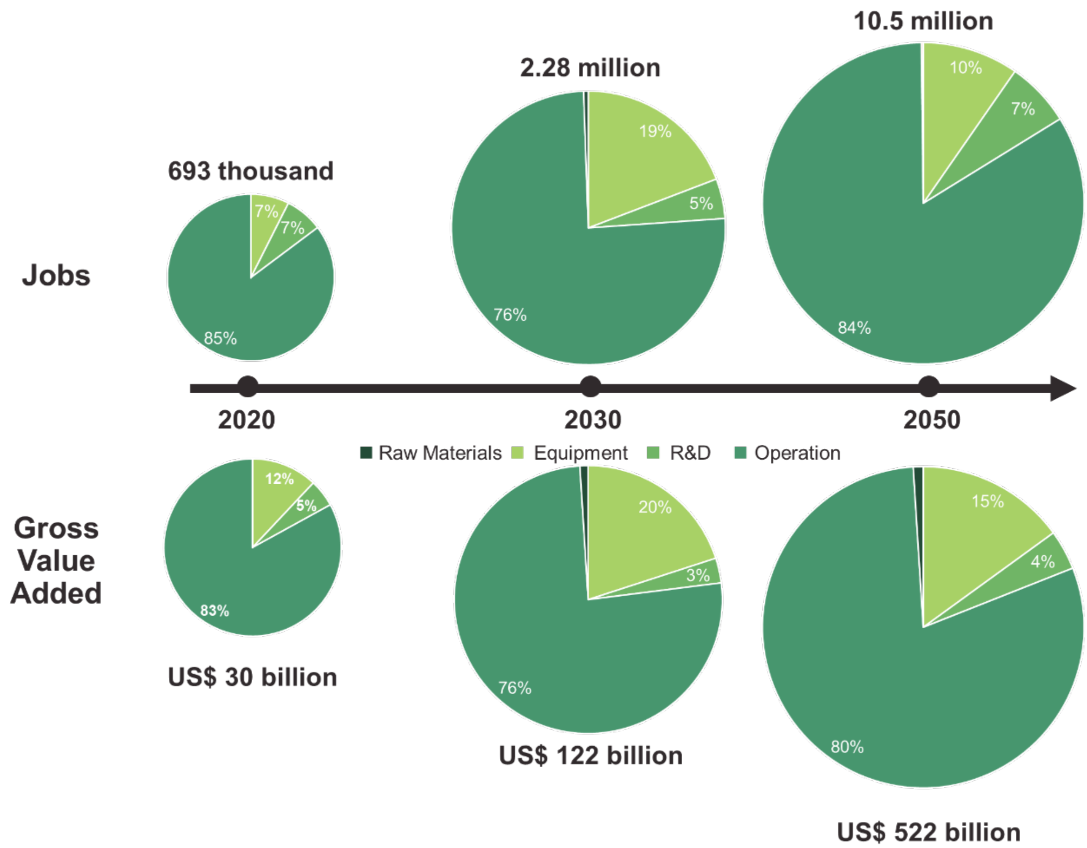
Source: Vivid Economics

If these technologies are taken-up to their potential, it would reduce the need to expand agricultural land and improve land management practices, leading to lower emissions from land clearing and incentivizing sequestering land restoration practices. The measuring and monitoring of soil health, for example, could help enable robust participation of agricultural lands in soil carbon markets. As Figure 1 reflects, CO_2 emissions reach zero, and sequestration increases substantially by 2050.

The potential climate benefits of gene technologies are especially uncertain and could result in even greater emissions reductions if any of them become deployable on a large scale. Currently deployable gene technologies mostly reduce CO_2 emissions through land sparing from increased productivity, but gene technologies could also reduce N_2O and methane emissions Some advances have been made toward enabling crops other than legumes to fix nitrogen, reducing demands for synthetic fertilizers that are a dominant source of N_2O emissions. Technologies that enable control of the sex of livestock births would dramatically improve the efficiency of dairy and egg operations, with an associated reduction in emissions, particularly methane. Gene technologies could also be a critical contributor to climate adaptation, allowing for even greater land sparing as the productive ranges of crops shift.

If this adoption of yield-enhancing technologies is realized, investment would be associated with over US$522 billion in gross value added (GVA) and more than 10.5 million jobs globally by 2050. Uptake of these technologies has already begun – the market for vertical farming is currently valued at US$3.9 billion and the market for digital agriculture is valued at US$5.1 billion in 2020. Continued growth of these innovations is associated with a GVA increase of 10% a year through 2050, with the research and development sector individually experiencing a 9% increase annually. An additional 9.8 million jobs will accompany this expansion, spanning technical laboratory development to agricultural implementation. Figure 2 below illustrates size and type of benefits that could be realized.

Figure 2 Estimates of jobs and GVA growth across the technology value chain resulting from the innovation unlocked with robust public support



Source: Vivid Economics

The better management practices enabled by these technologies can support greater biodiversity and have a role in improving food system health and nutrition outcomes. Technologies like vertical farming concentrate agricultural production, enabling land sparing for the restoration of natural ecosystems. Especially when implemented near urban centers or food deserts, vertical farming can also greatly improve access to fresh fruits and vegetables. Improved on-farm measuring and monitoring can also support supply chain transparency and the adoption of regenerative agricultural practices, such as complex crop rotations, that can improve soil health and on-farm biodiversity when implemented well. Resilient crop varietals can dramatically reduce the risk of undernourishment and malnutrition, especially in developing countries for smallholder and subsistence farmers that are susceptible to crop losses from drought, pests and disease. Crops like fortified staples can also contribute to improved access to nutrients and reduced malnutrition.

Both public and private support is required for these technologies to reach their potential. While many of the first generation of yield-enhancing technologies are already commercially available, financing support that takes care not to crowd out private investment will be required for the rapid development of next generation technologies. Money and financing are not the only forms of public support: on-farm uptake of digital agriculture could be enabled by rural broadband initiatives, or regulatory reform that encourages understanding the environmental footprints of farm operations. Similarly, vertical farming may require rezoning or strong local renewables policy to ensure that energy-intensive facilities aren't generating more emissions than mitigation they enable. Technological development needs to be paired with support for agricultural education and extension, as well as other social innovations, to encourage uptake of existing best-practices and technologies. For gene technologies, countries also need to ensure regulatory regimes are clear and efficient, especially regarding the development and release of new varietals. In many developing countries, seed value chains are immature or non-existent, requiring the cooperation of public and private sector to improve grower's access to markets.

Appropriate yield-enhancing technologies will vary substantially by region and development state, meaning that countries will need to tailor support. Not all technologies will be appropriate globally, and different regions will need to take different approaches to encouraging home-grown innovation best suited to their economy and climate while minimizing potential harms. For example, vertical farming is currently expensive, and if adopted at scale in developed countries, has the potential to change regional trade patterns as regions become more able to grow a wider range of the goods they consume. The opportunities for fresher food, reduced transport emissions, and less environmental leakage from the food system that results should be celebrated, but developed countries also need to ensure developing countries that rely on food exports are not left behind because of lost export opportunities. Development finance and encouraging economic growth to create healthy domestic markets that can absorb lost export revenue can help.

A NOTE ON METHODS

Quantitative results in this brief are supported by a modelling exercise using a leading land use model and subsequent estimation of job and GVA creation. The Model of Agricultural Production and its Impact on the Environment (MAgPIE), a leading global land use integrated assessment model developed by the Potsdam Institute for Climate Impact research, underpins the analysis undertaken for this project. Quantitative results on emissions and environmental impact rely on the comparison of two scenario types:

- **Central Scenario –** A scenario that models a world of coordinated global action to limit climate change. The scenario limits warming to 1.5^{o}C using only existing technologies
- **High ambition innovation scenarios –** A set of scenarios that illustrate ambitious but realistic support and uptake of a given family of technologies

Scenarios are compared to estimate how much cheaper it is to achieve a given temperature target with the innovation. GVA and jobs increases are then estimated based on the land use and agricultural production outputs from MAgPIE.