

## FOREWORD BY SIR TIM BERNERS-LEE



# Ten Frontier Technologies for International Development

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## Executive Summary

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As new technologies and digital business models reshape economies and disrupt incumbencies, interest has surged in the potential of novel frontier technologies to also contribute to positive changes in international development and humanitarian contexts. Widespread adoption of new technologies is acknowledged as centrally important to achieving the United Nations Sustainable Development Goals by 2030.

But while frontier technologies can rapidly address large-scale economic, social or political challenges, they can also involve the displacement of existing technologies and carry considerable uncertainty and risk. Although there have been significant wins bringing the benefits of new technologies to poor consumers through examples such as mobile money or off-grid solar energy, there are many other areas where the applications may not yet have

been developed into viable market solutions, or where opportunities have not yet been taken up in development practice.

Against this background, the Department for International Development (DFID) commissioned the Digital and Technology Research Group at the Institute of Development Studies to undertake a review of frontier technologies in five areas as shown below.

The development of this report formed a major element of a learning process that has led to the establishment of a new Frontier Technologies Livestreaming initiative at DFID, which over the next three years will seek to pilot a number of the technologies and recommendations of this report in practice.



## MANUFACTURING AND CONSUMPTION

New digital tools that enable new approaches to manufacturing using novel materials, and new digital platforms that bring together producers and consumers in novel ways.

- 3D printing for development
- Collaborative economy tools



## CONNECTIVITY

New approaches to expanding digital connectivity and growing the range of things that are online.

- Alternative internet delivery
- Internet of things



## TRANSPORTATION AND LOGISTICS

Autonomous aircraft and airships, enabling more efficient and lower cost transportation and logistics to less accessible areas.

- Unmanned aerial vehicles/drones
- Airships



## FRESH WATER

New approaches to sustainably extract fresh water from seawater and brackish water, and from the atmosphere.

- Solar desalination
- Atmospheric water condensers



## CLEAN ENERGY AND AIR

Distributed energy generation and storage technologies, and novel ways to reduce smog in different settings.

- Household-scale batteries
- Smog-reducing technologies

## Overview and methodology

This report is based on an extensive review of literature on the ten selected frontier technologies in these five areas, as well as consultations with expert informants. Each technology is explored in more detail in the second half of this report. The ten frontier technologies selected for study arose out of consultations with DFID staff and advisers. It should be noted that technologies are constantly evolving and so these reviews need to be seen as a snapshot in time, synthesising existing evidence, ideas and insights.

The first part of the report describes the nature of frontier technologies and their specific relevance to international development; presents the potential and challenges of the ten technologies; and explains key cross-cutting findings from the technology reviews. It concludes by setting out a number of potential roles for development actors in facilitating and targeting the use of frontier technologies so as to make a positive contribution while mitigating the risks these technologies may also present.

## Importance of frontier technologies

Drawing lessons from across the ten technologies considered, as well as wider literature and informant interviews, the report finds clear evidence of the potential of frontier technologies to contribute to social, economic and political development gains in a number of ways, by:

- Driving innovations in business models, products and processes that provide new goods and services to 'bottom of the pyramid' consumers;
- Providing the means by which to make better use of existing underutilised household and productive assets;

- Catalysing increases in demand, nationally and internationally, which create new industries and markets, leading to macro- and microeconomic growth; and
- Changing demand for labour and capital, leading to direct job creation and transformation of the workforce.

For all of the potential upsides, potential downsides must also be considered. While it will largely be the private sector that will drive deployment of these technologies, the public sector through national regulation, as well as development financing, will have a major role in mediating the pace and direction of technological change, both to achieve development objectives, and to protect potential losers.



Drones were deployed by the United Kingdom International Search and Rescue UK ISAR to help identify the most vulnerable areas after the 2015 earthquake in Nepal. For more on drones, see p.75. Photo credit: Jessica Lea/DFID, CC BY Creative Commons licence: BY

## Key findings

### Technology development and diffusion

**Frontier technologies are defined and shaped by context** – What is ‘frontier’ very much depends on particular economic, social and technological contexts, and the problems and challenges faced in those contexts. Although some frontier technologies are globally new, in other cases they may also be a new application or bundling of more established technologies, applied to a long-standing development problem. Catalytic converters are a good example of how a mature and well-established technology in developed country contexts can be viewed as frontier in many developing countries.

**Frontier technologies are often in reality a blend of different solutions** – Broadly speaking, technology blending for development involves combining frontier technologies with techniques and procedures found in low- and middle-income countries. The off-grid solar sector is an example blending internet of things (IoT) sensors and connectivity, latest renewable and battery technologies, and mobile money.

**Frontier technologies can help redefine and navigate ‘wicked problems’** – ‘Wicked problems’ are seemingly intractable development challenges. Some of the technologies discussed redefine critical challenges in transformative ways that make them more amenable to change. A technological fix is not always the answer to a problem, but frontier technologies can highlight the limits of current thinking and suggest new ways of approaching challenges. For example, solar desalination has the potential to overcome water insecurity by moving beyond approaches to better management of existing freshwater sources, to focus on novel sources of fresh water, as well as being a sustainable means of accessing that water.

**Diffusion takes time and can have multiple pathways** – A number of factors determine the success of new technologies in achieving ‘take-off’ and widespread use. These include public infrastructure, government regulation and compatibility between technologies. While innovations emerge rapidly, and create continual pressures for reforms, institutions tend to change more slowly. Moreover, wider contextual factors – social, political, financial and environmental – may slow or accelerate a technology’s progress. For example, the rise of collaborative economy approaches such as Airbnb and Uber has been especially pronounced since the financial crisis of 2008, and the growing need for alternative, low-cost ways to supplement income, and indeed to access services.

### Managing quality and risks

**Frontier technologies can lead to unequal benefits** – The benefits of new technologies have tended to accrue to those people who already enjoy material and other advantages. It is vital to ensure inclusive and participatory principles are at the forefront of technological development in bridging the ‘digital divide’. For example, a number of digital innovations rely on good levels of connectivity (specifically, 3D printing, the collaborative economy and the IoT). Here, existing forms of digital divides – from access to digital literacy – may inhibit their widespread dissemination among the poorest groups. Although many of the technologies may offer the potential to expand goods and services to more people, some of them simultaneously pose a threat to existing livelihoods and jobs.

**Frontier technologies require skills and capacities to manage high levels of risk and uncertainty** – The path from invention to innovation impact is usually non-linear and difficult to predict. Forecasts depend on a series of cascading and interdependent challenges, and are shaped by wider factors such as privacy, security, safety regulations and willingness to adopt new technology. For example, the challenge of managing uncertainty underpins how development actors deal with risk in relation to innovation, too often working to minimise risks in their investments rather than to strategically manage them.

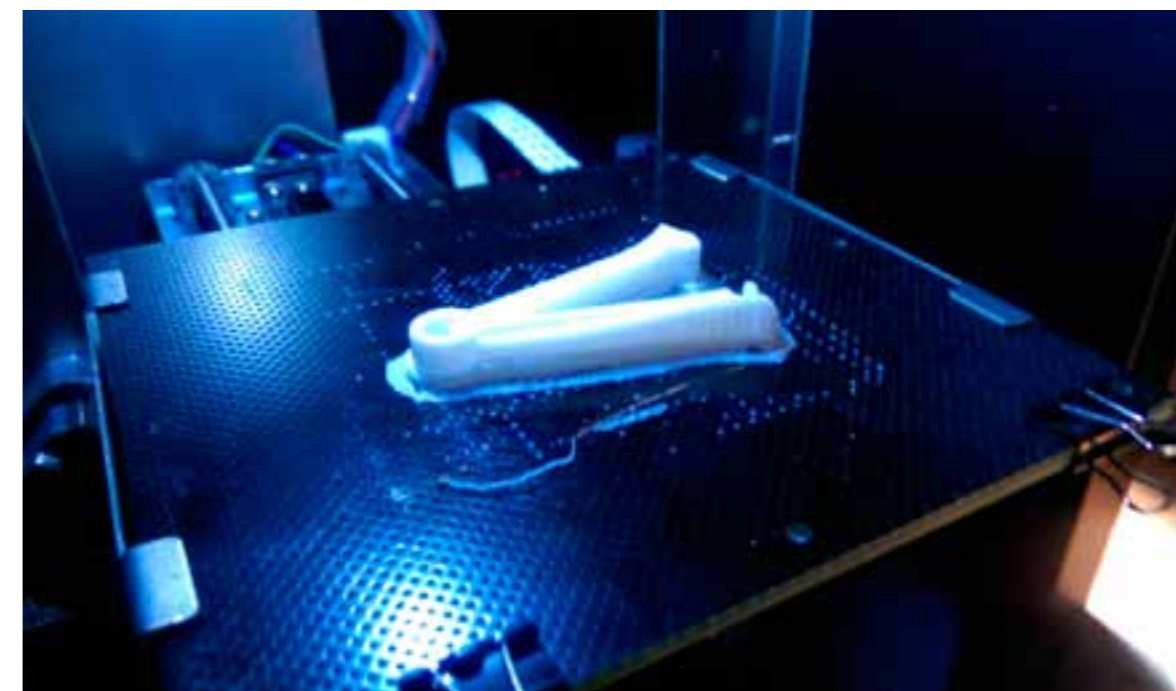
### Achieving impacts

**Frontier technologies can deliver many different types of outcomes and impacts** – These include: providing access to essential goods and services that would otherwise be unavailable due to physical, social or economic constraints; reaching remote or excluded populations; reducing transaction costs; catalysing new collaborative business models; and generating new sources of income and welfare. For example, the Hello Tractor initiative, also known as the Uber for tractors, offers African farmers access to low-cost tractors when and where they need them, enabled by an SMS (text message) booking system that connects owners to farmers. This service, like numerous other collaborative economy tools, is making assets and services available to those who need them most, improving income and livelihoods.

**The ‘leapfrogging’ potential of frontier technologies needs careful analysis** – New technologies enable groups or sectors in developing countries to skip over or ‘leapfrog’ established technologies used in more developed countries, but which might be more expensive, less efficient, more polluting, of inferior quality or simply not economically feasible. But it is necessary to understand if a new technology will replace, complement or extend existing infrastructure and services. For example, aerial-based alternative internet delivery initiatives seek to overcome the need to build ground-based infrastructure in connecting the four billion people who are currently offline.

**Frontier technologies can deepen and extend value chains** – Frontier technologies can enable more efficient delivery of goods or services to more people, especially the poor and those living in remote areas or off grid. For example, unmanned aerial vehicles (UAVs) – commonly known as drones – provide the opportunity to transport packages the ‘last mile’ from areas that are served by infrastructure to areas nearby where roads may be impassable, inadequate, or non-existent, and are already being used to expand logistics infrastructure for national health systems. Greater coordination and information sharing across critical value chains are needed, as well as the ability to track where frontier technologies can: (a) fill critical gaps; (b) extend value chains to new groups or areas; or (c) enhance the nature of the value being delivered through complementary and additional services.

**Frontier technologies can accelerate green transformations** – Many of the technologies discussed in this report could enhance more climate-compatible strategies and approaches along major global value chains. For example, catalytic converters, catalytic paints and smog-reducing towers convert dirty gases already in the air into less harmful ones. More work is needed to understand how these and other technologies could be combined with each other and other technologies to increase their effectiveness, achieve sustainability and create a ‘green ecosystem’ of frontier technologies to meet the needs of the poor and underserved.



A freshly 3D-Printed umbilical clamp which will be used in a rural Haitian medical clinic to aid the safe and healthy delivery of a newborn. 3D printers can potentially lead to the wholesale transformation of material production, supply chains and logistics processes by enabling and making use of local, flexible, efficient, on-the-fly production of the supplies, parts and tools required for critical tasks. See p.40. Photo credit: Field Ready.

## Recommendations for development organisations

Across all the following recommendations, increased effective collaboration at different levels – between the development sector, entrepreneurs and innovators, business and industry, researchers, governments, local organisations and target communities – will be critical to success. The figure opposite sets out the recommendations in visual form.

### Enhance development, testing and diffusion of frontier technologies

- **Deepen understanding, recognition and the search for frontier technology needs and opportunities** – Undertake careful research and analysis on the challenges, opportunities and risks various frontier technologies present, working with a broad range of collaborators, and building on previous work, particularly among scientists and investors. Effort should be made to catalyse the search for appropriate frontier solutions by defining problems, establishing challenges and finding ways to share risks.
- **Build skills and capacity in understanding and using frontier technologies** – Ensure expertise and understanding of frontier technologies in the development sector are adequate and appropriate, especially at senior levels; and by building capacity in developing countries.

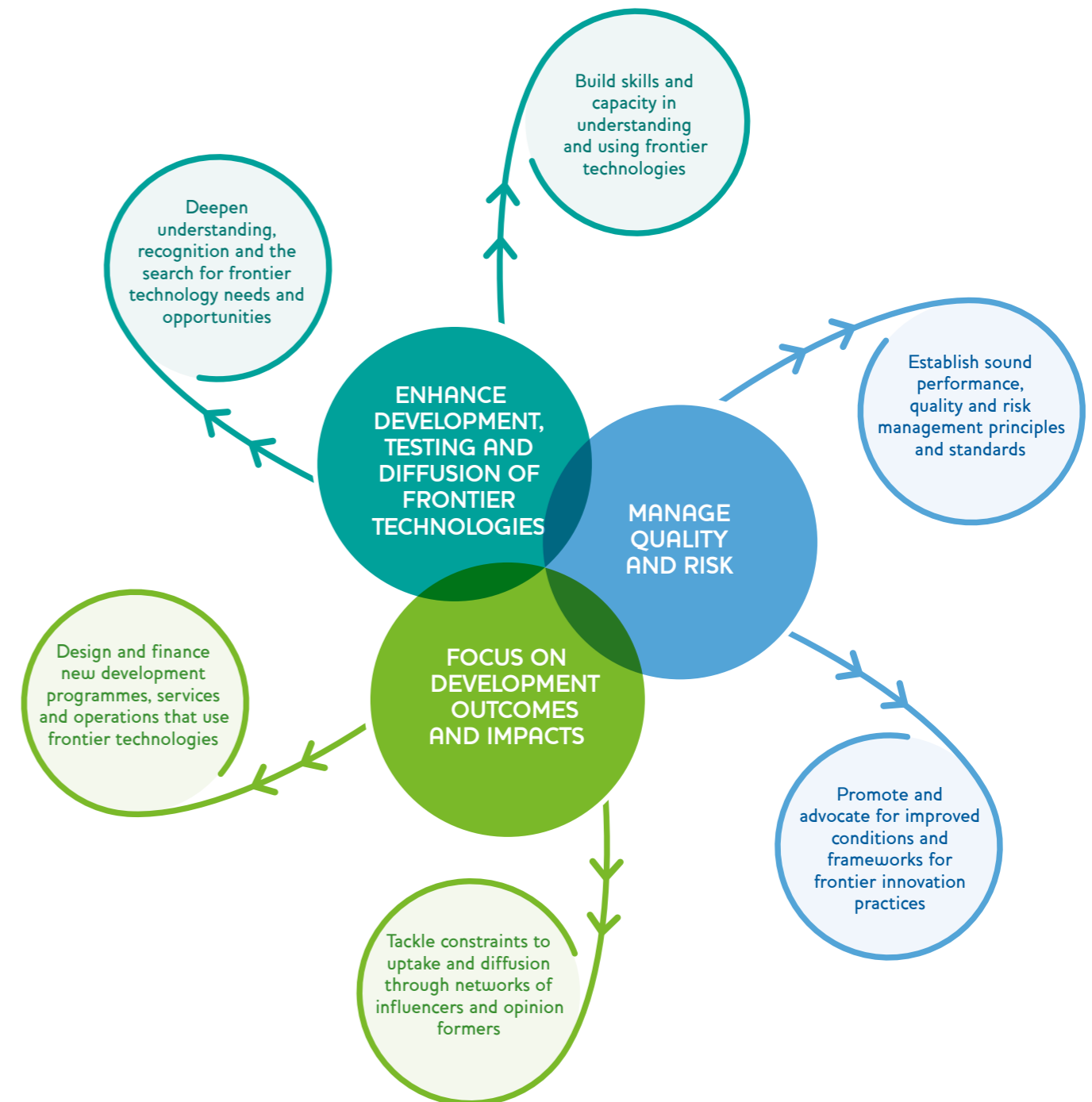
### Manage quality and risk

- **Establish sound performance, quality and risk management principles and standards** to ensure that innovation is undertaken responsibly and ethically, and is specific to individual contexts. Clear and flexible protocols are needed to ensure product performance, safety and quality assurance for users and consumers, and to facilitate interoperability.
- **Promote and advocate for improved conditions and frameworks for frontier innovation practices** that promote safety and privacy, managing risks by using ‘regulatory sandboxes’, and overcoming obstacles that may limit frontier technologies wider uptake and use.

### Focus on development outcomes and impacts

- **Design and finance new development programmes, services and operations that use frontier technologies** – Development sector finance can signal and underwrite tested technologies’ market potential. Actors in the sector should also promote their use in development programmes and use purchasing power intelligently to support novel solutions in becoming mainstream. Considerable scope also exists to use frontier technologies – especially digital ones – to improve processes, leading to more agile and adaptive development programmes that flex and change as technologies improve.
- **Tackle constraints to uptake and diffusion through networks of influencers and opinion formers** – Development actors should use their influence to adopt and consolidate innovations that are useful and generate value, and to overcome non-technological barriers such as potential users’ lack of financial capacity or leaders’ lack of engagement.

## Recommendations for development organisations





The Digital and Technology Research Group is a team of internationally recognised thought leaders and researchers with multi-disciplinary expertise across a range of areas, including mobiles for development, inclusive innovation, civic technology, globalisation, epidemiology, resilience, data-driven development, complexity science and participatory approaches.

We bring critical, constructive, participatory, systemic and politically grounded perspectives to advance knowledge, shape policy and inspire practice across the growing field of digital and technology for development.

Our current research programme explores the impacts of digital and technology in four key areas: economy and productivity, government and service delivery, citizenship and rights, and environment, sustainability and resilience.

The group is part of the Institute of Development Studies (IDS), a leading global institution for development research, learning, teaching, impact and communications.



Evidence on Demand supports the professional development of Climate, Environment, Infrastructure and Livelihoods Advisers at DFID. Technical Competency Frameworks for the advisory groups guide the support provided. Evidence on Demand also supports cross-cutting or development competencies which cover areas of technical knowledge and skills needed by advisers to effectively deploy their core technical skills and knowledge in development policy and operations.

The Evidence on Demand team is led by a DAI (which incorporates HTSPE Limited) and IMC Worldwide Limited Joint Venture. Both firms are established development consultancies with considerable experience in managing resource centres. The Joint Venture is backed by a core consortium of specialist organisations. The consortium provides technical support for developing quality assured resources, answering helpdesk enquiries and supporting consultancy services. Please go to the Evidence on Demand website ([www.evidenceondemand.info](http://www.evidenceondemand.info)) for further details).

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