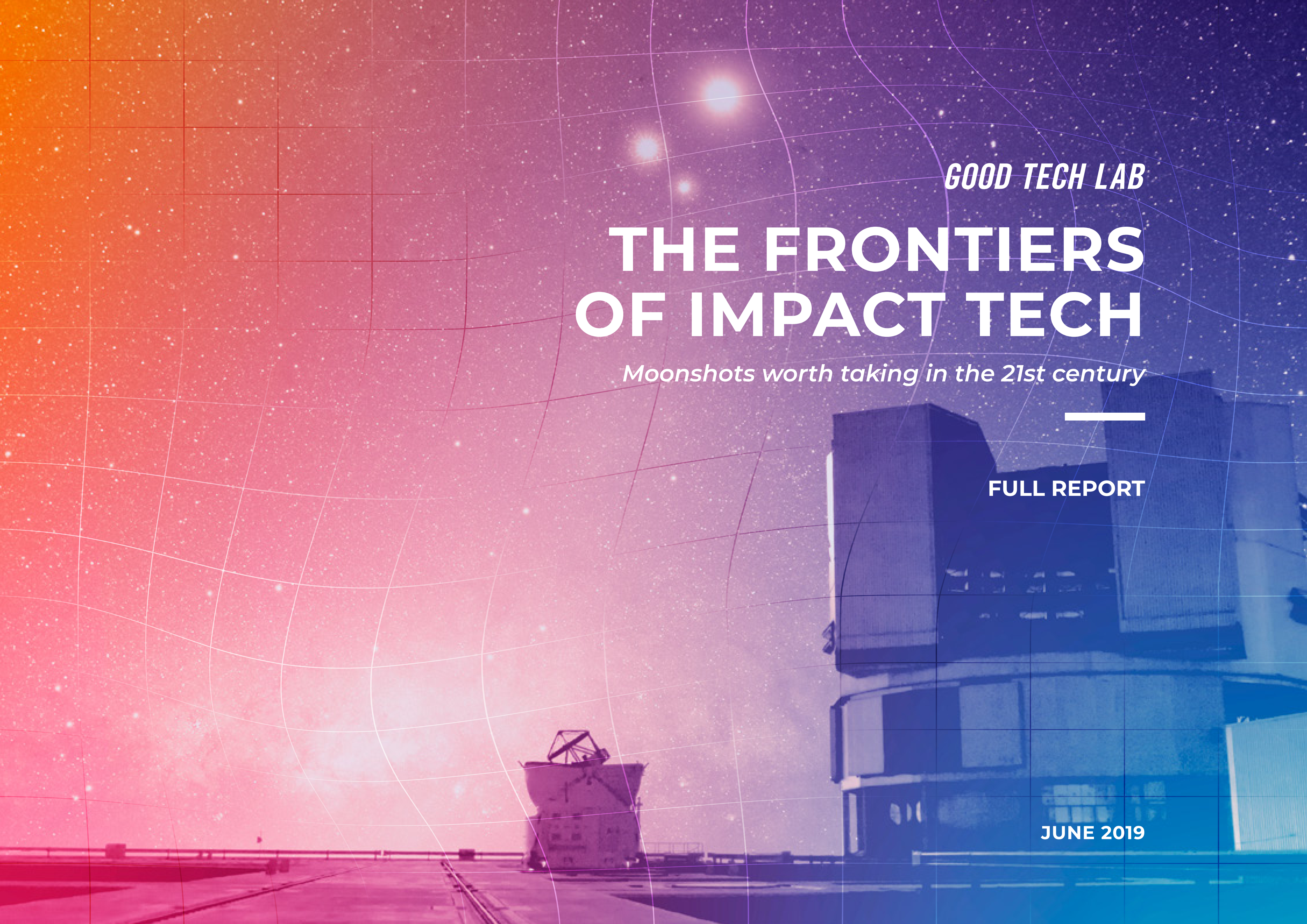

GOOD TECH LAB

THE FRONTIERS OF IMPACT TECH

Moonshots worth taking in the 21st century

FULL REPORT

JUNE 2019

Acknowledgements

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Its contents are intended for entrepreneurs, investors, incubators, scientists, businesses, policymakers, and civil society organizations willing to better understand how technology, and system entrepreneurship could play a role in solving some of the world's biggest problems. We hope this report will inspire them to grow the Impact Tech movement.

Our work draws on 400+ interviews of innovators from 30+ countries on five continents and 18 months of extensive desk research.

This publication would not have been possible without the valuable input from key contributors, the review and comments from our expert panel and collaborating organizations, and the time generously granted to us by our interviewees. All of these incredible people are listed under the Contributors appendix at the end of the report.

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GOOD TECH LAB

Good Tech Lab is a research and innovation firm focused on the moonshot of the 21st century — reversing climate change while ensuring people and nature thrive.

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FOREWORD

Over the next decade, we need to start reversing climate change and the loss of natural capital, while achieving the Global Goals and making all humans thrive. In times of unprecedented technological acceleration, we never had so many tools at our disposal to address this challenge. We should use them wisely—managing both the impact and the risks.

This report, the first of a two-part series, is our humble contribution to this global conversation. We looked at how “Impact Tech” can help address the 17 Sustainable Development Goals, exploring its opportunities and challenges. The second volume will dive into how investors, accelerators, corporates and development organizations partner with Impact Tech entrepreneurs.

We embarked on this journey with a diverse team, with backgrounds ranging from engineering to international development, deeptech startup ecosystems and social innovation. We are grateful to be backed by visionary sponsors and supported by inspiring organizations sharing our values, who helped us with their network and expertise.

We hope our findings will inspire you as much as they inspired us. The “frontiers” featured in this report are meant to be pushed, for only then can we hope to tackle problems without borders.

This publication is the first step in a long journey. Our dream is to help foster a new model for global cooperation based on mission-driven innovation—a global Apollo program where talent and capital flow toward the moonshots of the 21st century.

The “Good Tech” in our name is a nod to the 10 Principles of Good Design enacted in the 1970s by design legend Dieter Rams. It means that technology could and should be a force of progress.

Today more than ever, we believe that science, technology and system entrepreneurship can provide leverage points to address the world's biggest problems.

Benjamin Tincq

Manuella Cunha Brito

Ludovic Sinet

EXECUTIVE SUMMARY

Fifty years ago, humans set foot on the moon for the first time. Today, the future of our very existence depends on another *moonshot*—reversing climate change while ensuring people and nature thrive.

The window of opportunity is closing fast, but success is still within our grasp. Science, technology and system entrepreneurship could provide leverage points to help us achieve this ultimate moonshot.

The Moonshot of the 21st Century

We are living in the Anthropocene, an era in which human activities are no longer compatible with the planetary boundaries. Our carbon budget will be exhausted by 2030 (IPCC), leading us to catastrophic climate change beyond 1.5C. Meanwhile, a million species—one in eight—face near-term extinction (IPBES). **Global warming and the collapse of biodiversity are two faces of the same coin: an existential threat** to the life-support systems on which we depend for food, clean water, and a stable climate. Only a quantum leap can reverse that trend.

For climate change to remain below 2C—ideally 1.5C—global CO2 emissions should peak by 2020 at the latest, then halve every decade to reach carbon neutrality by 2050. Scientists called this trajectory the Global Carbon Law. It is a nod to Moore's Law, which drove the digital revolution forward during 50 years by stating that computing power would double every two years.

Following an exponential roadmap for carbon drawdown and ecosystem restoration requires rapid and far-reaching changes. We need a shift toward a New Carbon Economy, a prosperous economy which captures more greenhouse gases than it emits. We also need to bring the Circular Economy to its maximum potential, and "*design waste out of the system.*"

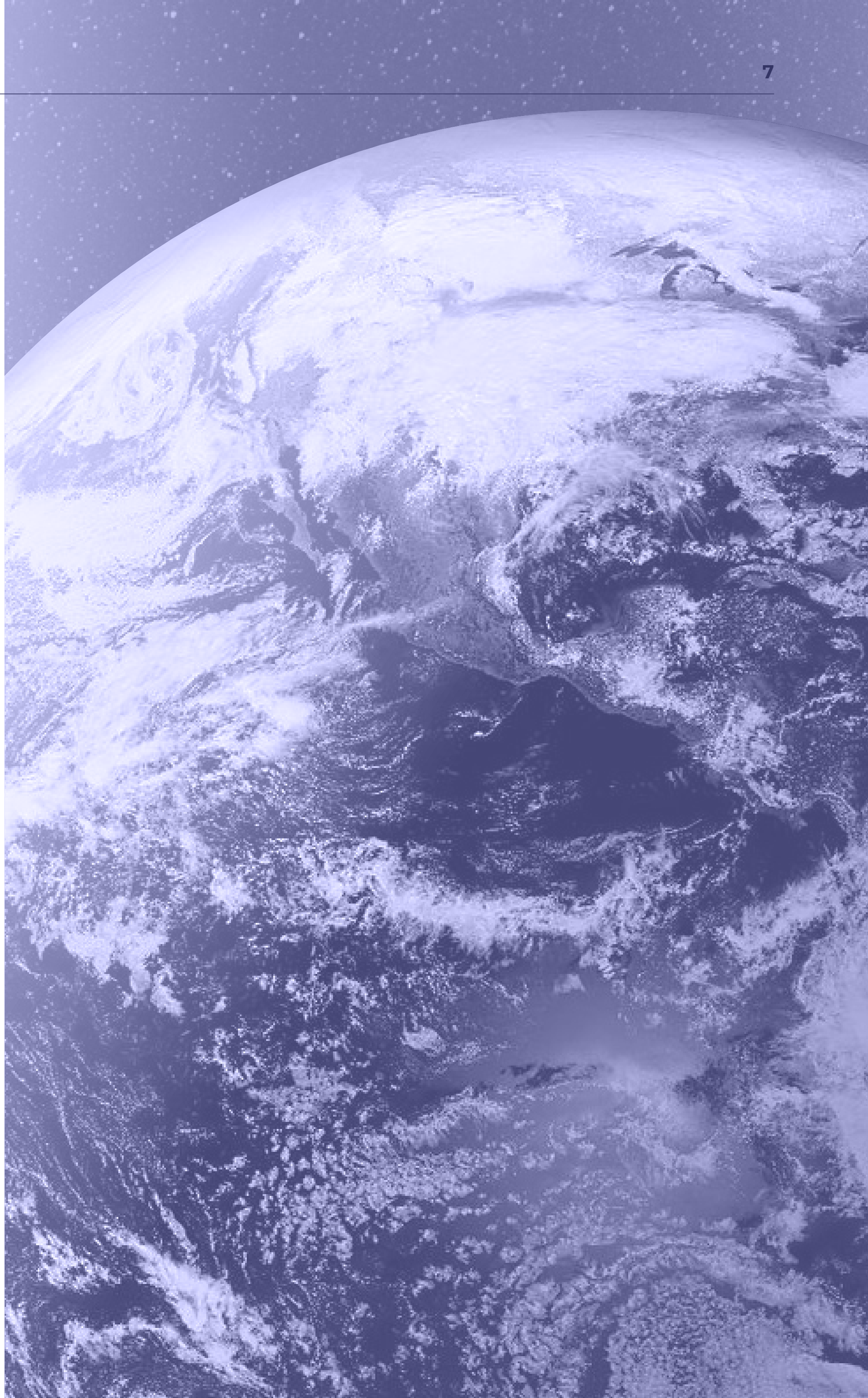
This radical shift will only succeed if it leaves no one behind. That means everyone should have access to decent housing and basic services, good food, quality education, and healthcare. It also implies an inclusive economy which reduces inequalities, alleviates poverty, and make cities more liveable. Those are among the **17 Sustainable Development Goals** (SDGs) set by the UN for 2030—also known as the Global Goals. Combined with the planetary boundaries, they provide a holistic framework to "*meet the needs of all within the means of the planet,*" as the economist Kate Raworth puts it.

Fifty years after we first landed on the moon, the ultimate moonshot of the 21st century is to reverse climate change and the collapse of biodiversity, while making all humans thrive.

This global effort would be environmentally restorative and socially just—but also economically attractive. Removing 1000 gigatons of CO2 from the atmosphere could create a $45 Trillion net financial gain according to Project Drawdown, while SDG solutions represent a $12 Trillion annual market and 380 million new jobs by 2030, according to the landmark report *Better Business, Better World*.

Business as usual is no longer an option, but those economic incentives could steer market forces and innovation in the right direction. Today "*doing the right thing*" goes much beyond corporate social responsibility—it is about creating future-proof companies.

Moreover, science and technology could provide leverage points to address planetary emergencies. The tools at our disposal have never been more powerful: the digital revolution has matured and deeply transformed most industries, while a *Fourth Industrial Revolution* is already underway. The latter is enabled by deep technologies like AI, synthetic biology, new materials, robotics, 3D printing, the internet of things, blockchains, clean tech and satellites.



The Rise of Impact Tech

We call Impact Tech the intentional use of science and technology to benefit people and the planet. Around the world, that emerging sector is growing, under the influence of several factors: i) a talent convergence between the tech and impact worlds, ii) a feeling of emergency in regards to global challenges, iii) economic incentives, iv) the growing influence of new generations as consumers, workers, and investors, and v) the possibilities offered by emerging technologies.

Impact Tech entrepreneurs could put us on course toward the ultimate moonshot. The various transformative solutions they provide include bio-based materials, animal-free meat, AI for faster diagnosis, satellite imagery to protect human rights, zero-emissions transportation, mobile payments for financial inclusion, and many more.

Impact Tech takes many shapes—some strategies may seem contradictory, but are in fact complementary.

Tech-push vs demand-pull. Impact Tech innovations result either: i) from a technological advance which allows new applications with a positive impact for society, or ii) from the intentional response to social and environmental issues using available technology. In both cases, success depends on a deep understanding of the problem.

Root causes vs symptoms. While a long-term cure requires to address the root causes of an issue, one should not dismiss the need to reduce harm on the short term. For instance, cleanup technologies and the circular economy are both needed to tackle ocean plastic pollution.

Impact depth vs impact scale. Impact Tech innovators constantly juggle between impact depth (the degree of change) and scale (how many people experience it). Corporate sustainability efforts often occur at scale but lack depth, while the opposite is common for social enterprises. Achieving both depth and scale is hard, but possible.

Innovation vs replication. Technological breakthroughs and new business models can be instrumental in addressing wicked problems. However, innovation should not get all the credit—the high-quality replication of the best ideas also deserves some. Project Drawdown attempts to balance both methods, by featuring 80 existing solutions to the climate crisis, while also listing 20 potential game-changers.

Startup vs systemic initiative. Startups excel at solving well-defined problems with a scalable tech solution, such as better water purification. Systemic collaborations, on the other hand, create momentum across multiple stakeholders to achieve collective impact on wicked problems like climate change and inequality. The system entrepreneurs driving those efforts can be companies, non-profits, or international organizations.

Low-tech vs deep-tech. While low-tech refers to simple tools that are frugal in resources, deep-tech pushes technology frontiers like AI and synthetic biology. Impact Tech opportunities exist across the spectrum, from solar concentrators to mobile payments, to biofabrication. The key is to choose wisely which tech is the most appropriate in a given context.

Platforms vs applications. Impact Tech mostly stems from the direct use of technology to address specific social and environmental issues. However, those applications rest on platform technologies, from the Internet to AI and CRISPR. The development of those platforms will likely influence our capacity to address the ultimate moonshot.

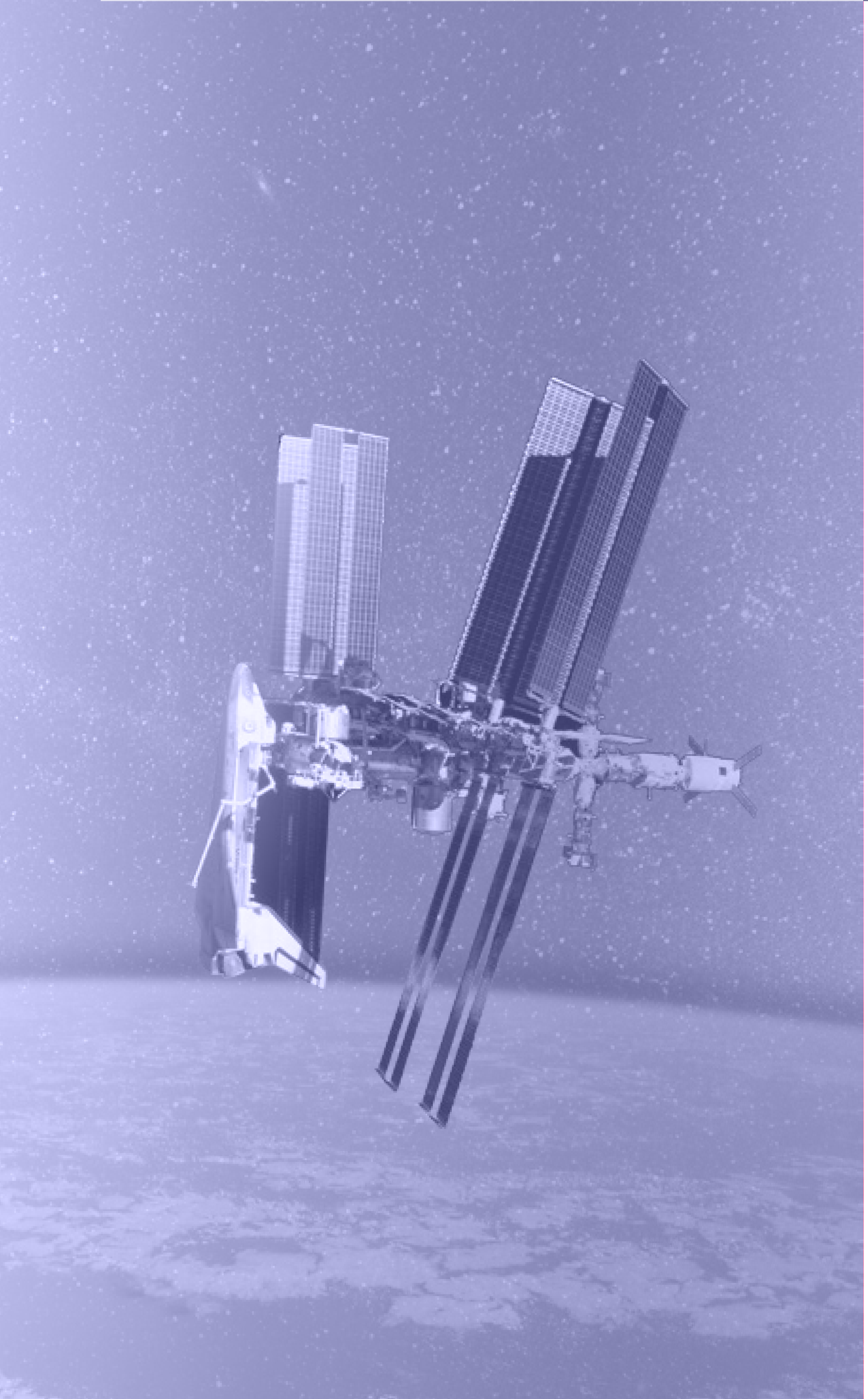
Impact-first vs finance-first. There may be times when Impact Tech innovators need to prioritize between their mission and financial returns. Strategies to balance both include business models where profit is tied to impact, the definition of impact and financial "floors," and mission lock-in in the company charter.

Impact Tech could unlock the future of global development.

Development actors are embracing Impact Tech. Development institutions and international organizations have recently increased their focus on technology and innovation. Many have launched dedicated programs, such as the British, French, German, and US cooperation agencies, the World Bank, and various UN agencies. Meanwhile, tech firms and philanthropists have entered the space—from the Gates Foundation to Airbnb to the many startups profiled in our report.

For entrepreneurs in the Global South, Impact Tech offers an opportunity to leapfrog old solutions and move straight to advanced ones. Some can replicate proven leapfrogs like mobile banking for financial inclusion. Others innovate with the drone delivery of medical supplies, or blockchain records to secure land rights for the poor. Moreover, such endeavors could also unlock the tremendous economic rewards mentioned above, and **"leapfrog old capitalism"** by channeling entrepreneurial energy toward social good.

These new development stories should give us hope, but beware of pitfalls. Among them, the fetishization of innovation in the form of "development gadgets," and the over-reliance on digital leapfrogs at the expense of long-term investments—in infrastructure, academia, and capacity building. The Global Goals will not be achieved thanks to silver bullets and will require collective intelligence.



Impact Tech opportunities across the Global Goals

The Global Goals provide a great lens to analyze how Impact Tech can address some of the hardest global issues. Our research profiles over 180 Impact Tech trends and their contribution to the 17 SDGs. Hundreds of examples illustrate them—including tech startups and social enterprises, but also initiatives from corporates, non-profits, and the public sector. The trends are associated with a specific SDG target for easier readability, although many are relevant to several goals.

The overview below summarizes the main themes behind those Impact Tech opportunities.

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1 NO POVERTY

- **Mobile connectivity for financial inclusion**, including payments, credit, local currencies, and affordable health insurance
- **Digital records that empower the world's poor**, allowing them to prove their identity, secure their land rights, and share their address even when it is not officially registered
- **Disaster risk reduction technologies** using machine learning, drone mapping, and 3D printed homes

2 ZERO HUNGER

- **AgTech for sustainable farming**, including precision agriculture, agroecological data platforms, small farm robotics, and substitutes to synthetic fertilizers and pesticides
- **Digital technologies for smallholder farmers** that improve their productivity and livelihood: soil and plant health analysis, weather forecasts, farming knowledge networks, and access to markets, credit, and insurance
- **Postharvest technologies** to increase food preservation and reduce the waste occurring between harvest and distribution
- **New protein sources** to sustainably feed 10 billion humans, such as meat-like products (plant-based or cell-based) that appeal to omnivores, and insect protein feed for aquaculture
- **Food science and genomics** to develop food ingredients and crops with higher nutritional value

3 GOOD HEALTH AND WELL-BEING

- **Digital health** to improve preventive care, aftercare, quality-of-life support, and to reduce infant mortality with pregnancy and childcare advice
- **New diagnostic devices and AI tools** for early detection of infectious diseases like malaria, or chronic diseases like cancer, in a fast, affordable, and non-invasive way
- **Genome editing applied to medicine**, such as improved gene therapies, genomic vaccines, and gene drives
- **Big data analytics and machine learning** for epidemiology, medical research, and precision medicine
- **Emerging technology platforms** such as regenerative medicine, microbiome therapies, and nanomedicine

4 QUALITY EDUCATION

- **Digital classrooms solutions** that empower teachers and students—in the developing world and beyond—with devices, multimedia lessons and personalized learning
- **Lifelong learning platforms**, such as mobile lessons, MOOCs, gamified apps, remote yet immersive programs, and mentor marketplaces
- **Alternative schools and bootcamps** for coding
- **New learning mediums** such as VR, video games, and hands-on experimentation kits

5 GENDER EQUALITY

- **Apps and devices** to help women navigate cities safely, and to report sexual offenders more effectively
- **Digital services and technology products** for female and reproductive health
- **Initiatives to empower women at work** by preparing women for future tech jobs and supporting HR professionals to improve workplace equity and reduce the gender pay gap

6 CLEAN WATER AND SANITATION

- **Pumps, collectors, and generators** that harvest freshwater from aquifers and atmospheric moisture
- **Water purification technologies** for point-of-use filtration, desalination, circular wastewater treatment with resource recovery, and decentralized wastewater systems
- **Waterless toilet solutions** that allow safe sanitation in urbanizing areas that lack sewage systems, which also reuse the energy and nutrients in human waste
- **Water efficient technologies, systems and processes** in agriculture, industry and the residential sector
- **Water supply management** using remote sensing, satellite imagery, and water-tracing technologies

7 AFFORDABLE AND CLEAN ENERGY

- **Energy access solutions** that sustainably improve the livelihoods of the world's poor in rural areas, such as pay-as-you-go solar, microgrids, and improved cookstoves
- **Advanced renewable energy:** more efficient photovoltaic cells, better turbines for wind and marine energies, enhanced geothermal systems, and ongoing developments in sustainable fuels (e.g. hydrogen, bioenergy, sunlight-to-fuel)
- **Breakthroughs in energy storage** for electric vehicles and grid balancing, including battery technology, ultracapacitors, power-to-gas, thermal storage, and mechanical storage
- **Smart grid and grid edge technologies** to increase energy efficiency and leverage decentralized energy resources
- **Energy fintech platforms** to fund renewable infrastructure and unlock peer-to-peer energy trading

8 DECENT WORK AND ECONOMIC GROWTH

- **Digital tools for inclusive employment**, including targeted job boards and bias-free recruitment software
- **Digital services to improve employability**, such as worker upskilling platforms and AI advisors for job seekers
- **Technologies for better working conditions**, including cobots, exoskeletons, and wearable devices that enhance safety and wellbeing in physical labor, as well as digitized social protection for freelancers
- **Data-driven prevention of human trafficking**

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

- **Innovative logistics for sustainable development**, including clean container ships, cargo airships, and drone deliveries of medical supplies
- **Internet access technologies** to bring the second half of humanity online in remote areas, such as airborne backhaul infrastructure and innovations for last-mile access
- **Advanced technologies for sustainable industry:** additive manufacturing, biofabrication, AI for new materials discovery, short-loop recycling, circular and flexible factories
- **Data-based SME financing** for developing markets

10 REDUCED INEQUALITIES

- **Assistive technologies** to improve the lives of people with disabilities, from real-time captions and audio description to new wheelchair designs, and affordable custom-fit prosthetics
- **Digital solutions for displaced populations**, supporting them with access to information, education, work, healthcare, social inclusion, as well as affordable remittances
- **Tools and initiatives to spread the "digital dividends"** more widely, such as digital literacy programs and ownership structures aimed to decentralize capital gains in the digital economy

11 SUSTAINABLE CITIES AND COMMUNITIES

- **Sustainable transportation systems** that emerge at the convergence between electrification, autonomy, ride-hailing, new vehicles, mobility-as-a-service and public transit
- **Air pollution control and mitigation technologies**, such as sensor networks that allow hyperlocal monitoring, as well as large-scale air purifiers
- **Various solutions that improve urban metabolism** through organic resources looping, local food production, energy and water efficiency, advanced recycling, and other circular economy mechanisms
- **Digital tools for urban planning**, like citizen participation, urban data management, and advanced simulations
- **Infrastructure and basic services for fast-growing urban areas**, as well as their informal settlements

12 RESPONSIBLE CONSUMPTION AND PRODUCTION

- **Digital solutions to reduce food waste** at the retail, catering and consumer levels: optimized procurement, dynamic pricing, and redistribution platforms for unsold food
- **Product reuse, repair, and upgrade** relying on digital technologies, circular business models and modular designs
- **Sustainable materials and chemicals**, either using feedstock derived from biological sources, captured greenhouse gases, or recycled waste, as well as advanced materials with superior longevity and robustness
- **Responsible retail technologies** like online farmers markets, product sustainability ratings, and blockchain records to certify ethical supply chains
- **Fintech for sustainable consumption**, such as digital ethical banks, retail impact investing platforms, digitized local currencies, and civic crowdfunding

13 CLIMATE ACTION

Emissions reduction (see also SDG2, 7, 9, 11, 12)

- **Decarbonized energy:** substituting fossil fuels with clean energy, adding storage and flexibility into the grid, and reducing the emissions from existing fossil fuel plants
- **Decarbonized agriculture:** reducing food waste and the share of animal food products, and adopting regenerative farming methods
- **Decarbonized industry:** scaling the circular economy, replacing fossil-based feedstock with sustainable alternatives, increasing production efficiency, and safely phasing out HFC refrigerants
- **Decarbonized transportation:** scaling electric vehicles, low-emission fuels, and mobility-as-a-service, increasing logistics efficiency, and reducing air travel emissions
- **Decarbonized buildings:** scaling energy efficiency, improving the competitiveness of low-carbon construction materials, and reducing demand for new buildings

Negative emissions (carbon removal)

- **Carbon removal *via* engineered solutions** like enhanced weathering, direct air capture, carbon capture and use (e.g. construction materials, fuels, chemicals, plastics, protein, carbon fiber, and nanomaterials)
- **Carbon removal *via* natural and hybrid solutions** like carbon farming, biochar, and the restoration of carbon-dense natural ecosystems—other potential solutions, such as phytoplankton stimulation and bioenergy with carbon capture and storage, still need to demonstrate system sustainability

Cross-cutting strategies

- **Digital enablers of mitigation**, including data-driven climate strategies and blockchain-based carbon credit systems
- **Climate adaptation technologies**, especially for the resilience in agriculture, urban areas, and low-lying islands

14 LIFE BELOW WATER

- **Marine cleanup technologies** to remove plastic pollution from oceans, lakes, and streams
- **Ocean plastic prevention** through marine biodegradable materials, digitized recycling, and other circular models
- **Marine biodiversity protection**, using satellites and AI to monitor fisheries, or aquatic drones and robots to detect threats to marine life (e.g. invasive species, pollution, ocean acidification)
- **Coastal ecosystem restoration**, including genetic engineering to strengthen coral reefs, and drones to restore mangroves
- **Sustainable seafood solutions** like traceability blockchains, improved aquaculture systems, plant-based and cell-based fish

15 LIFE ON LAND

- **Terrestrial ecosystems and wildlife monitoring** using satellite imagery, drones, remote sensing, machine learning, DNA analysis devices, and citizen science apps
- **Computational conservation science**, including soil modeling and analysis, geospatial data platforms, and biodiversity genomics databases
- **Reforestation and desert greening technologies**, ranging from low-tech innovations in agroecology to drones and algorithms used for industrial-scale reforestation
- **Fintech for ecosystem restoration** like impact investing platforms, crypto-tokens, and more

16 PEACE, JUSTICE AND STRONG INSTITUTIONS

- **Data and algorithms for peace and justice:** crime forecasts, early warning systems to protect civilians during conflicts, or tools to investigate human rights violations and identify victims faster
- **Remote demining technologies**, including drones
- **Digital government solutions** to increase the quality of public service, and to reduce corruption in procurement
- **Civic Tech platforms** to ensure transparent and accountable institutions, and increase citizen participation
- **Automated fact-checking** against fake news

17 PARTNERSHIPS FOR THE GOALS

- **Fintech solutions** to mobilize additional SDG funding in developing countries
- **Online collaboration platforms** for technology research and capacity building on sustainable development
- **Multi-stakeholder partnerships** to harness technology in the achievement of the SDGs
- **Data collaborations**, including open data programs, data philanthropy, and multi-stakeholder data partnerships to provide high-quality information on social and environmental issues.

> **Technology** is not good nor bad, **nor is it neutral.**
>
> *MELVIN KRANZBERG, TECHNOLOGY HISTORIAN*

Technological Risks and Challenges

Although this report adopts a cautiously optimistic tone overall, technology introduces its own set of risks and challenges which should not be overlooked.

At least eight critical risks should be mitigated for technology to deliver positive outcomes.

Psychological hijacking. Mobile screens, social media, and the attention economy have damaged our mental health and social fabric, while the effects of new media like VR are still poorly understood.

- ***Mitigation strategies:*** *ethical design, "digital wellness" habits, regulation*

Privacy and surveillance. Six years after the revelations of Edward Snowden, China is now exporting its mass surveillance technology to other countries, while targeted advertising has established surveillance capitalism as the new normal.

- ***Mitigation strategies:*** *privacy by design, standards and regulation (GDPR and beyond), privacy tools*

Algorithmic discrimination. When trained on biased datasets, AI algorithms can lead to systematic and unfair discrimination. Left unchecked, the large-scale implementation of those biases can fuel injustice in law enforcement, education, healthcare, financial services, democracy, and at the workplace.

- ***Mitigation strategies:*** *increase diversity in tech, ethical design, standards and regulation (beyond GDPR)*

Media manipulation. Against all the odds, social media now appears among the main threats to democracy. Recommendation algorithms increase political polarization, amplify fake news, and allow micro-targeted propaganda based on psychological profiling. Fake news has also led to the lynching of innocents and propelled the anti-vaccine movement to new heights. In the future, AI video manipulation could make things even worse.

- ***Mitigation strategies:*** *fact-checking tools, regulation, digital literacy, and education programs*

Economic and labor disruption. The fear that machines will replace human labor too fast for us to adapt is widespread. However, predictions vary widely on how many jobs are concerned. Essential questions include: i) what will be the quality of new human jobs? ii) how can we drive more investment in AI that enhances human work instead of automation? iii) who will own the robots, and how do we contain the power of tech giants?

- ***Mitigation strategies:*** *investment in labor-enhancing AI and lifelong learning, new social protections, regulation*

Increasing inequalities. Technological acceleration could widen the wealth gap at all levels—between companies, between countries, and between workers of different skill levels. In the future, technology could even translate economic inequality into biological inequality.

- ***Mitigation strategies:*** *new social protections, addressing the root causes of inequality, regulation*

Unsustainable electronics. Clean and digital technologies are neither clean nor immaterial. Upstream, components are produced at a terrible human and environmental cost and rely on a stressed supply of critical metals. Downstream, the amount of e-waste is exploding due to planned obsolescence and low recyclability.

- ***Mitigation strategies:*** *circular product designs and business models, sustainable materials, ethical sourcing tools, clean mining and advanced recycling technologies, regulation*

Security and safety. AI is quickly expanding the scale and scope of cyber threats. Those include digital risks (cyber attacks), political risks (election hacking) and physical risks (using drones, self-driving vehicles, and attacking critical infrastructure). Moreover, synthetic biology, solar geoengineering, and nanotechnology are introducing entirely new hazards.

- ***Mitigation strategies:*** *security-enhancing development processes, interdisciplinary research on risks, regulation*

Four root causes underpin technological and sector-specific risks. They stem from deep economic, social and cultural norms.

A lack of diversity in tech and science. Left unchecked, the chronic underrepresentation of women and minorities in technology and science is leading to abuse, injustice, and harmful products.

- ***Responses:*** *Education and mentoring for underrepresented talents, bias-free hiring tools, diversity-focused funds, advocacy groups, research on inclusive design*

A prevalent ideology of solutionism. The idea that the “right” technology could fix any problem is commonplace in the startup community. This reductionist view of the world is the opposite of systems thinking and stems from insufficient knowledge—or consideration—of problems.

- ***Responses:*** *Education on systems thinking, diverse teams, integration of additional responses (business model innovation, policy, behavior change, etc)*

Economic incentives that hinder positive outcomes. A large part of government funding for tech remains associated with military research, including in AI, robotics and gene editing. Moreover, venture capital is increasingly under scrutiny. The hypergrowth VC depends on has several flaws: i) it does not suit most companies, and turn startups into speculative assets, ii) it can incentivize futile innovation, and iii) it often comes with hidden societal costs. Overall, commonly available funding in tech and science have several blind spots—companies driven by impact, by science, and which are not fit for “growth at all cost.”

- ***Responses:*** *Impact investing, new fund structures, strategic venture philanthropy, policy incentives.*

Unfit technology governance. How can we steer technological progress in a way that maximizes societal benefits and minimizes adverse effects? Today tech governance lies de facto within industry and academia. However, self-regulation is hardly enough, as Facebook scandals and CRISPR babies have taught us. National and regional policy can help, but many issues require international cooperation—from killer robots to climate change and the new space race. Global institutions need a serious upgrade to regulate technology in a way that i) is compatible with the pace of change, ii) can handle conflicting interests and cultural differences, iii) fosters a better dialogue between science and society.

- ***Responses:*** *better global frameworks for technology governance, and platforms for science-society dialogue at all levels*

Impact Management

Impact Tech could make a dent in solving some of the world's biggest problems. However, that possibility depends on our capacity to maximize positive outcomes while mitigating adverse effects. Achieving this will require to equip innovators with the right compass—impact management.

What does "impact" mean?

The Impact Management Project (IMP) is a forum for building global consensus on how to talk about, measure and manage impact. Gathering 2,000 organizations, they reached consensus that ***"Impact is a change in an important positive or negative outcome for people or the planet"*** and that it can be deconstructed into five dimensions:

- **What:** what outcomes the enterprise is contributing to and how important the outcomes are to stakeholders
- **Who:** which stakeholders are experiencing the outcome and how underserved they were prior to the enterprise's effect
- **How Much:** how many stakeholders experienced the outcome, what degree of change they experienced, and how long they experienced the outcome for
- **Contribution:** whether [efforts] resulted in outcomes that were likely better than what would have occurred otherwise
- **Risk:** the likelihood that impact will be different than expected

Impact management can be challenging, especially in the context of technology and science. Many Impact Tech innovators are either unaware of, confused about, or reluctant to use those methods.

- **They are often complicated and time-consuming to use** for entrepreneurs who operate on limited resources.
- **Most of them were intended for well-defined activities in established industries.** Meanwhile, innovators explore uncharted territories, using breakthrough technologies and disruptive business models—sometimes with multiple pivots.

A common misconception is to see impact management as a static set of processes. Instead, it should be an iterative process—starting with simple tools, then increasing the level of sophistication as the organization grows and matures.

The full report provides an overview of methods, tools, indicators and resources for the three pillars of impact management—planning, measurement, and reporting. We also suggest a simplified approach for Impact Tech ventures. That experimentation can be the first step toward the development of agile impact management processes adapted to the context of science and technology.

Impact planning is about understanding the problem, defining the solution hypothesis, and preventing adverse effects.

Positive Impact Planning aims to i) understand the problem from a systemic perspective, and ii) define the solution hypothesis and its components (technology, business model, partnerships, etc.)

- ***Resources:*** *issue-specific (e.g. SDGs, IPCC) and sector-specific knowledge, research on other tech solutions, and the Theory of Change*

Negative Impact Planning aims to iii) estimate the societal cost of the solution to reduce it, and iv) anticipate potential adverse outcomes (risks) and how to mitigate them.

- ***Resources:*** *design and development guidelines (e.g. EthicalOS), material libraries, software tools and datasets (see SDG Compass)*

Impact measurement consists in defining relevant impact indicators and tracking their evolution.

Measuring impact enables an organization to evaluate its progress toward positive outcomes, and the existence of adverse effects. It requires to i) collect the right data, ii) analyze it and transpose it into useful formats and timely fashion, and iii) create an organizational capacity to apply the knowledge gathered to update strategy and processes.

Key Performance Indicators (KPIs) should be SMART: specific, measurable, achievable, relevant, and time-bound. A rule of thumb is to start with simple ones and refine them over time. Impact Tech innovators should, however, keep a holistic view to avoid burden shifting—the improvement of a few KPIs at the expense of more important ones. Approaches like Agile Measurement and Acumen's Lean Data aim to lower barriers of collecting the right data.

- ***Resources:*** *IMP impact data categories, the SDG indicators, and indicator catalogs like IRIS (see also SDG Compass)*

Monitoring and measuring frameworks can be broadly categorized into four main categories, which are complementary:

- **Social Return on Investment (SROI)** attributes a monetary value to the social benefit of a project to evaluate its efficiency
- **Scorecards and dashboards** aim to track the progress of pre-selected indicators to monitor an organization's performance, such as the B Assessment for B Corps
- **Contribution assessment** like randomized control trials (RCT) and other statistical methods use counterfactuals to evaluate what would have happened independently of the intervention
- **Environmental assessments** include the Life Cycle Assessment (LCA) of a product's footprint from materials sourcing to end-of-life, and various specialized methods like the Greenhouse Gas Protocol (GHGP), the Natural Capital Protocol (NCP) and Material Flow Analysis (MFA)

Impact reporting refers to the communication of impact to all relevant stakeholders.

Effective reporting requires valid data, transparent and appropriate evaluation methods, and results that are easy to understand for the target audience. With growing expectation from customers, investors, government and civil society, impact reports are quickly becoming strategic in the private sector.

- ***Resources:*** *certifications like B Corp, Solar Impulse and the Trustable Technology Mark, and reporting standards like GRI and CDP*

A look into the future of Impact Management

The impact management landscape is continuously evolving. Global standard-setters are coming together to increase their compatibility, assessment tools are adapting to the SDGs, while tech startups are offering new solutions to streamline impact measurement.

Meanwhile, Impact Tech innovators, impact advisors, and scientists should partner to develop complementary tools and methods that could reach mainstream adoption in technology.

Those efforts should aim to:

- **Allow different levels of sophistication,** in assessment and the choice of indicators, according to the maturity stage
- **Use data and scientific knowledge** to facilitate the comparison between different innovations aimed to address a societal problem
- **Take multiple types of impact risks into account,** including those related to specific technology domains

The Way Forward

The last IPCC and IPBES reports on global warming and the sixth mass extinction are alarming. At the same time, inequality remains at unacceptable levels in most parts of the world and will likely worsen with AI and climate change. **These planetary emergencies could lead to the collapse of civilization as we know it**, unless we operate rapid and far-reaching changes in every aspect of our economic system.

The speed and scale of the transformation we need—at the pace of the Carbon Law—has no historical precedent. The closest comparison would be wartime mobilizations, during which entire economies are directed against an existential threat. Investments made during such times have played a substantial role in the emergence of Silicon Valley and led to the Apollo Program, which put the first humans on the moon.

Fifty years passed since Apollo 11. Today, the world needs a new moonshot—reversing climate change while ensuring people and nature thrive. This time, no superpower can achieve that effort alone. On Spaceship Earth, we are all crew.

Science, technology, and system entrepreneurship could be our wildcards. Impact Tech is rising everywhere, providing leverage points to address almost every SDG target. However, to achieve the ultimate moonshot we need a plan—a “Global Apollo Program” for the 21st century.

To say that the 2020s will be decisive would be an understatement: by 2030 we need to achieve both the SDGs and the first halving of the Carbon Law. **The 12 priorities listed below could help us maximize the potential of Impact Tech in the next decade.**

Impact Tech leadership

1. **Think in systems—and data.** Wicked problems resist any reductionist solution. Addressing them requires to understand system dependencies, differentiate effects from root causes, prioritize the best leverage points on which to intervene, and anticipate unintended consequences:
   - **Learn about systems thinking** (or hone those skills)
   - **Dive into key frameworks,** including the SDGs, the planetary boundaries, carbon cycles, and the circular economy
   - **Rely on science and data** to craft strategies

2. **Raise ambitions.** A growing cohort of startups and corporates claim to be purpose-driven. Not only should their number increase fast, but their ambitions should also match what planetary emergencies require—10X improvements. As Extinction Rebellion activists frame it:
   - **Tell the truth:** acknowledge the extent of the environmental and social emergencies into the company's mission
   - **Act now:** set aggressive short-term and long-term targets in every aspect of strategy

3. **Embrace impact management.** Impact Tech innovators and investors should embrace agile methods for impact planning and measurement, and include them within existing processes—research, design, engineering, operations. They should also contribute to the development of new frameworks adapted to science and technology.

4. **Leverage diverse teams.** The diversity of a team's demographics and skill sets can help prevent the biases and blind spots that routinely occur during innovation. Moreover, interdisciplinarity, diverse viewpoints, and collective intelligence can lead to breakthrough solutions.

5. **Form partnerships to drive system change.** Businesses should join or create coalitions with sector peers and other stakeholders, to unlock bigger Impact Tech opportunities, and help solve wicked problems:
   - **Map and join relevant networks,** clusters, and consortiums
   - **Leverage outcome-driven open innovation** to foster effective startup-corporate cooperation.
   - **Support (or become) system entrepreneurs** that act as "central gears" to align the interests of various stakeholders

Impact Tech ecosystems

6. **Expand the talent pool.** Attracting the best talent is often the biggest bottleneck in Impact Tech—even more than raising capital, many have told us. To expand the talent pool, we need to:
   - **Upgrade university programs,** by integrating global sustainability, the SDGs, systems thinking, and collaborative problem-solving into the curricula of all science, engineering, business, and design colleges. Combine theory with project-driven practice.
   - **Develop innovative Impact Tech programs** for initial and vocational training, that combine engineering and systems thinking
   - **Promote Impact Tech** success stories and role models
   - **Attract experienced mentors** from technology, business, and sustainability to support Impact Tech entrepreneurs

7. **Increase funding capacity.** Impact Tech funding needs to reach much higher proportions. Although strategic government funding is critical (see item 10), private investment should get up to speed and rely on various capital instruments that meet different kinds of financing needs:
   - **More impact investing capital** with sufficient access to technology expertise and dealflow
   - **More tech VC flowing into impact sectors,** with access to impact management knowledge
   - **Patient capital:** investment funds with flexible, long-term time horizons (e.g. 12-15 years rather than 7-8 years in VC)
   - **New fund structures:** revenue-based investment, small infrastructure funds, blended capital, impact bonds
   - **Strategic philanthropy to bridge funding gaps:** in early-stage impact and science-based ventures (too risky for commercial investors) as well as non-profit Impact Tech
   - **Cross-cutting efforts to increase diversity** among founders who receive investment

8. **Strengthen venture support.** Increase the availability of incubators, accelerators, company builders, and other entrepreneurial support organizations (ESO) focusing on Impact Tech:
   - **Build capacity within existing ESOs** on global sustainability, the SDGs, impact management and systems thinking
   - **Channel public and philanthropic funding** toward ESOs that are on a mission to help achieve the ultimate moonshot
   - **Develop ESOs responding to underserved needs,** such as late-stage support, science venturing, open-access testbeds, systemic initiatives with multiple stakeholders, and founders from underrepresented backgrounds

9. **Bring corporates and cities onboard.** Corporates and cities can help bring Impact Tech to scale, either as partners, customers, or (in the case of corporates) solution providers. They should:
   - **Establish training and leadership programs** for both executives and management teams, focusing on Impact Tech, the SDGs, global sustainability, and systems thinking
   - **Adopt the five priorities for Impact Tech** (see above)
   - **Leverage procurement and outcome-driven open innovation** to support Impact Tech innovators with access to customers, funding, expertise, IP, testbeds, sales and distribution channels

10. **Shape markets with strategic government.** National and federal states could help unlock the carbon-negative, restorative, and inclusive economy we need by shaping markets. They could:
    - **Use mission-oriented innovation policy** (Mazzucato) to steer innovation toward a "*Global Apollo Program*" which could achieve the ultimate moonshot—with the strategic use of public funding and private sector incentives
    - **Update regulation and taxation** to drive large-scale behavior change among consumers and companies (e.g. carbon pricing)
    - **Leverage procurement** to support Impact Tech innovators

11. **Establish shared roadmaps and research agendas.** Academia, governments, businesses, civil society and international organizations should work together to:
    - **Define 10-year roadmaps** to deliver the ultimate moonshot, in all sectors and at all scales (country, city, organization). Review those plans yearly as new information arises
    - **Set research agendas** which establish the R&D priorities to develop, scale and deploy the necessary technologies
    - **Develop an impact culture within research institutions,** such as impact management and incentives (e.g. HR policy, funding criteria, etc) to maximize societal value

12. **Reinvent international cooperation.** Impact Tech could be decisive in the fight against "*problems without borders*"—such as planetary emergencies, as well as emerging threats like antibiotic resistance and AI risks. Better global cooperation could help unlock that potential:
    - **Adopt platform strategies within international organizations and development actors** to support Impact Tech innovation and deployment—for instance by harnessing the collective intelligence from private, public, academic and civil society actors
    - **Upgrade global governance frameworks** to manage emerging technologies and existential risk

All stakeholders have an opportunity to step up and do their part to deliver the ultimate moonshot. Good Tech Lab will further explore those strategies in a second report on Impact Tech innovation ecosystems—focusing on investors, accelerators, corporates, academia, foundations, and development institutions.

Today more than ever, we believe that science, technology and systems entrepreneurship could be one of the keys to unlock a brighter future—one in which people and nature thrive.

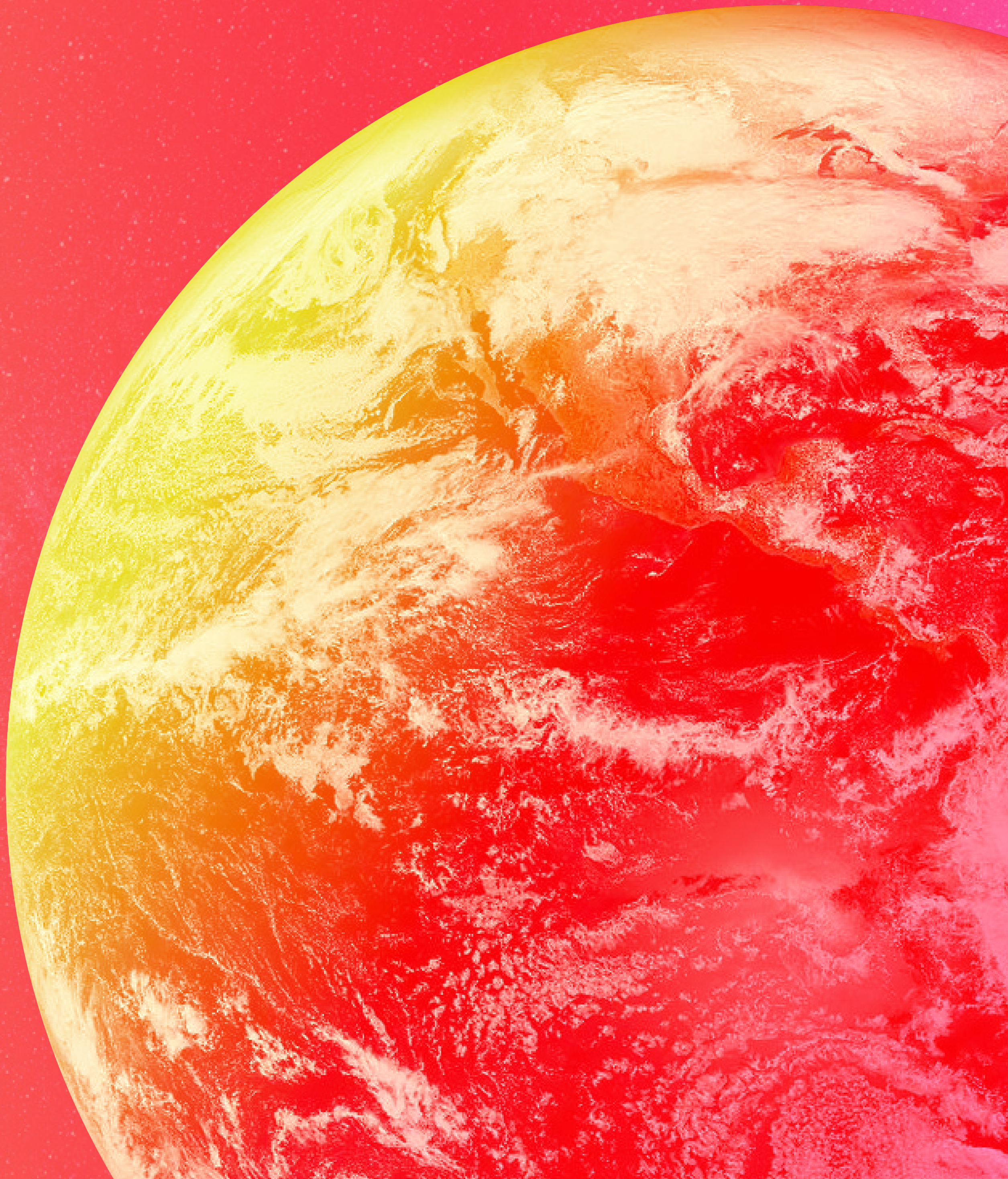
1

INTRODUCTION

THE ULTIMATE MOONSHOT

Fifty years ago, humans set foot on the moon for the first time. Today, the future of our very existence depends on an even more ambitious *moonshot*—reversing climate change while ensuring people and nature thrive.

The window of opportunity is closing fast, but success is still within our grasp. Science, technology and system entrepreneurship could provide leverage points to help us achieve this ultimate moonshot.



Reversing climate change and the collapse of nature...

Over the last two centuries, living conditions have vastly improved on a global average: extreme poverty and violence have dropped, health and education levels have soared. However, not only this trend has been uneven and recently stalled, but the system we built to deliver this progress is no longer compatible with the planetary boundaries—the environmental limits of the *"safe operating space for humanity."* Our impact on the biosphere has exploded so much that a new geological era was named after us: the Anthropocene.

Our rapidly shrinking carbon budget to stay within 1.5C of global warming is equivalent to a decade of current emissions, according to the last IPCC report. Today the effects of 1C of warming are already felt through coral bleaching, invasive species and extreme weather events like the 2018 summer heatwave. At 2C or 3C though, consequences on heat stress, sea level rise, crop yields, and water scarcity will get considerably worse. Up to 300 million climate refugees could be displaced by 2050, and some of the world's biggest cities could face irreversible damage.

Worse: temperature rise above 1.5C increases the risk of crossing Earth-system tipping points. This would cause a domino effect where feedback loops, from dying forests to melting ice, would greatly amplify human-induced emissions, leading to a "Hothouse Earth" beyond 5C.

"We are all astronauts on a little **spaceship called Earth.**"

R. BUCKMINSTER FULLER,
ARCHITECT, DESIGNER, AND INVENTOR

Photo: NASA

In addition to climate change, the loss of natural capital is also moving us past critical planetary boundaries. A million species—one in eight—could disappear in the earth's sixth mass extinction, according to the new report from IPBES, the "IPCC of biodiversity." Already 75% of land areas are degraded, threatening the well-being of half the world's population. A third of arable land has been lost to erosion and pollution, putting at risk our capacity to meet growing food demand. Forests are cleared for animal agriculture. Overfishing and plastic pollution mean by 2050 oceans may contain more plastic than fish. By the same date, coral reefs could disappear along with the quarter of marine life they support.

Global warming and the collapse of biodiversity are two faces of the same coin: an existential threat to the life-support systems on which we depend for food, clean water, and a stable climate.

Only a quantum leap can reverse that trend. In 2017 top climate scientists led by Johan Rockström calculated the roadmap we should follow to achieve the Paris Agreement. Following what they call a Global Carbon Law, emissions should peak by 2020 at the latest, and then halve every decade, while the capacity of carbon sinks doubles.

Moore's Law predicted in the 1960s that computing power would double every two years, a heuristic which has driven the digital revolution. Now, we must use the Carbon Law as an exponential roadmap to reverse climate change and the loss of natural capital. This trajectory looks technologically feasible and economically attractive but requires no less than what the IPCC calls *"rapid, far-reaching and unprecedented changes in all aspects of society."*

We need a radical shift in our relationship to carbon and natural resources. A central piece would be a New Carbon Economy which captures and sequesters more greenhouse gases than it emits. Another would be a Circular Economy which the Ellen MacArthur Foundation describes as *"decoupling economic activity from the consumption of finite resources, and designing waste out of the system."*

...While making all **humans thrive**.

However, this shift will only be attractive to citizens, businesses, and governments if it leaves no one behind. A future that is not only resilient but also worth living includes making sure everyone has access to decent shelter, clean water, healthy food, affordable energy, quality education and healthcare. Furthermore, we need a thriving economy that reduces inequalities, eliminates poverty and makes our cities more liveable.

> The Sustainable Development Goals are a **purchase order from the future.**
>
> ***JOHN ELKINGTON****, FOUNDER AND EXECUTIVE CHAIRMAN OF VOLANS*

Based on an original idea from Lorraine Smith

Here as well, the path is very steep. The world population is expected to rise from 7.5 billion to 10 billion in 2050, of which 70% will live in urban areas. Still, today 844 million people lack even a basic drinking-water service, 1 billion have no electricity, and almost a third of humanity suffers from nutrient deficiencies. Meanwhile, 26 people own as much as the 3.8 billion who make up the poorest half of humanity. These numbers could even worsen if we fail to prevent the collapse of the biosphere.

The 17 Sustainable Development Goals (SDGs) agreed by the UN in 2015 provide a holistic framework to address these social, economic and environmental challenges. Achieving these "Global Goals" would bring the world much closer to what economist Kate Raworth calls "*meeting the needs of all within the means of the planet.*"

The good news is that market forces could help us achieve significant progress. According to the Business and Sustainable Development Commission, the SDGs represent at least a $12 Trillion annual market opportunity on just a few economic sectors. Furthermore, the net financial gain of removing 1000 gigatons of carbon from the atmosphere has been estimated to $45 Trillion by Project Drawdown. These may very well be the biggest innovation opportunities in history.

Here is the ultimate moonshot: within the next decade, we need to start reversing climate change and the loss of natural capital, while achieving the Global Goals and making all humans thrive.

The scale and speed of the required effort have "*no documented historical precedent*" according to the IPCC. Some compare it to the Apollo Program which put the first human on the moon in 1969, or to how the US economy prepared for World War II. However, today the effort cannot be driven by the will for global dominance, and no superpower can win this battle alone.

Everyone holds part of the key to what is the archetype of a super wicked problem—one that resists simple resolution because of the many parameters involved, complex interdependencies, and incomplete knowledge, among other factors.

We choose to go to the Moon in this decade and do the other things, not because they are easy, **but because they are hard;** because that goal will serve to organize and measure the best of our energies and skills; because that challenge is one that we are willing to accept, one we are unwilling to postpone, and **one we intend to win.**

John F. Kennedy

> Missions provide a way to harness and direct the power of research and innovation, not only to **stimulate economic activity and growth** but also to find **innovative solutions** to the most pressing challenges of our time.
>
> ***MARIANA MAZZUCATO**, ECONOMIST AND PROFESSOR AT UCL*

Harnessing science and technology for good

Meeting this challenge is not only economically attractive but also technologically feasible. Two technology waves give us reason for optimism. First, the digital revolution has now matured and is profoundly transforming all industries, from finance to transportation, energy, and agriculture. It has enabled innovative products and business models already addressing the SDGs, from mobile payments to digital education platforms and crowdfunding for renewable energy.

The internet also makes it easier than ever to document, promote and finance proven climate and poverty solutions based on appropriate technology, like clean cookstoves and low-tech water filters.

The second, more profound wave is the rapid advance of emerging technologies, which are converging in what the World Economic Forum calls a Fourth Industrial Revolution. It includes fields like synthetic biology, new materials, robotics, the internet of things, artificial intelligence, blockchains, satellites, additive manufacturing, nanotechnology, and breakthroughs in cleantech and medical devices.

Harnessing science and advanced engineering, pioneer entrepreneurs are building groundbreaking solutions to some of the world's most pressing problems: from bio-based chemicals to animal-free meat, zero-emissions transportation, secure land registries that empower smallholder farmers in the developing world, and satellite imagery preventing human trafficking.

However, it is crucial to be aware that technology also brings its own set of challenges and risks. What is the future of work when automation displaces most traditional jobs? How do we ensure technology does not increase inequalities even more? Can we reduce the terrible social and environmental cost of electronic products? How can we manage the security, safety and democracy risks in the age of AI and biotech? These are only a few of the hard questions we need to answer. Only then can we maximize positive outcomes and minimize negative ones.

Historian Melvin Kranzberg famously said, "*Technology is not good nor bad, nor is it neutral.*" If we can adopt the right "impact compass" and a system perspective, maybe it could become a force for good.

The way forward: the frontiers of Impact Tech

There are reasons to be hopeful. Every day we hear about new scientific discoveries and entrepreneurial endeavors addressing some of the world's wicked problems. We also see pioneers of social impact and sustainability embracing technology to bring their mission to the next level. We believe these purpose-driven "Impact Tech" innovators can be at the forefront of the ultimate moonshot outlined above, if only they can steer technological acceleration in the right direction.

This report has four main chapters. First, we look at the rise of what we called the "Impact Tech" movement, its growth drivers and the different strategies we have observed. Second, we dive into each of the 17 SDGs and identify the scientific and technological trends that can help achieve their sub-targets. Third, we reflect on technology risks and challenges. Fourth, we look at how impact management methods can help innovators adopt the right compass to maximize their positive impact while mitigating the risks and negative footprint of their solutions.

This report is the first in a two-part series. The second one will be published later this year and dive into Impact Tech innovation ecosystems. We will map notable international players and analyze how investors, incubators, corporates, foundations, development organizations and more, are inventing new ways to partner with mission-driven tech innovators.

Finally, we should state that our focus on science, technology, and entrepreneurship does not imply a disregard for the potential of non-tech innovation, nor a naive belief in techno-solutionism—the idea that technology alone can fix any problem. On the contrary: in times of exponential change and unprecedented challenges, there has never been a greater need for thinking in systems and embracing complexity. **Policy, behavior change, human-centered design, and regenerative economics are all equally important.**

Photo: SpaceX

2 THE RISE OF IMPACT TECH

CLICK IT!

With a myriad of concepts used to describe the intersections between technology and society, it was not easy to pick one term for this report. This chapter is our best attempt to characterize what we will, for the sake of convenience, refer to as Impact Tech.

We start by defining the concept and how it relates to others. Then we identify the main drivers leading to the rise of the Impact Tech movement, and the different strategies we have observed. Finally, we conclude by highlighting its potential as a new narrative for global development.

2.1 Defining Impact Tech

Photo: Carl Attard

One can easily get lost in the galaxy of concepts where technology and society intersect: tech for good, impact tech, social tech, cleantech, responsible tech, positive tech, transformative tech, humane tech, ICT for development, digital social innovation, factor-4 innovation, and more. Some relate to social good, others to sustainability. Some emphasize avoiding harm, others creating solutions. Yet others focus on specific sectors like civic tech, health tech, peace tech, and carbon tech. All of them have been used to describe projects featured in these pages.

To make things easier, we settled on using Impact Tech as the main term within this report, as we felt its current usages seem to better reflect the story we want to tell. We will define it within this section.

> *"Not everyone has the same definition of impact. We chose to start simple: you need to have a financially sustainable business that improves the quality of life for the Bottom of the Pyramid, or you tackle one of the 17 SDGs."*
>
> ***Mariana Fonseca,***
> *Co-founder at Pipe.Social*

The "tech" part refers broadly to any technology, or "*the application of scientific knowledge for practical purposes*" (Oxford Dictionary). This includes digital, hardware and bio-based applications, from high-tech to simpler tools known as low-tech (see part 1.3), though the former is more widely represented within this report.

But what does 'impact' mean, anyway?

This question is probably the most frequent we encountered. To answer it we rely on the work of the Impact Management Project (IMP), a forum for building global consensus on how to measure, report, compare and improve impact performance. The IMP has brought together over 2,000 organizations to agree on the following definition:

> **"Impact is a change in an important positive or negative outcome for people or the planet. It can be deconstructed into five dimensions: What, Who, How Much, Contribution and Risk."**
> — The Impact Management Project.

Photo: Abbie Trayler-Smith

AN ORGANIZATION'S GOALS CAN RELATE TO THREE TYPES OF IMPACT A, B, OR C

By assessing performance and data across the five dimensions, one can classify an organization's impact in three categories:

- **A = Act to avoid harm**
  Preventing or reducing significant effects on important negative outcomes for people and planet. Such organizations are often labeled **"responsible"**.
- **B = Benefit stakeholders**
  Not only acting to avoid harm, but also generating various effects on positive outcomes for people and the planet. Such organizations are often labeled **"sustainable"**.
- **C = Contribute to solutions**
  Not only acting to avoid harm, but also generating one or more significant effect(s) on positive outcomes for otherwise underserved people and the planet.

Contribute to solutions

"We want to provide a solution to the ocean plastic problem"

"We want to help tackle the education gap among the world's poor"

Benefit stakeholders

"We want to have a positive effect on public health and natural resources to sustain long-term performance"

"We want to promote diversity and inclusion across the company"

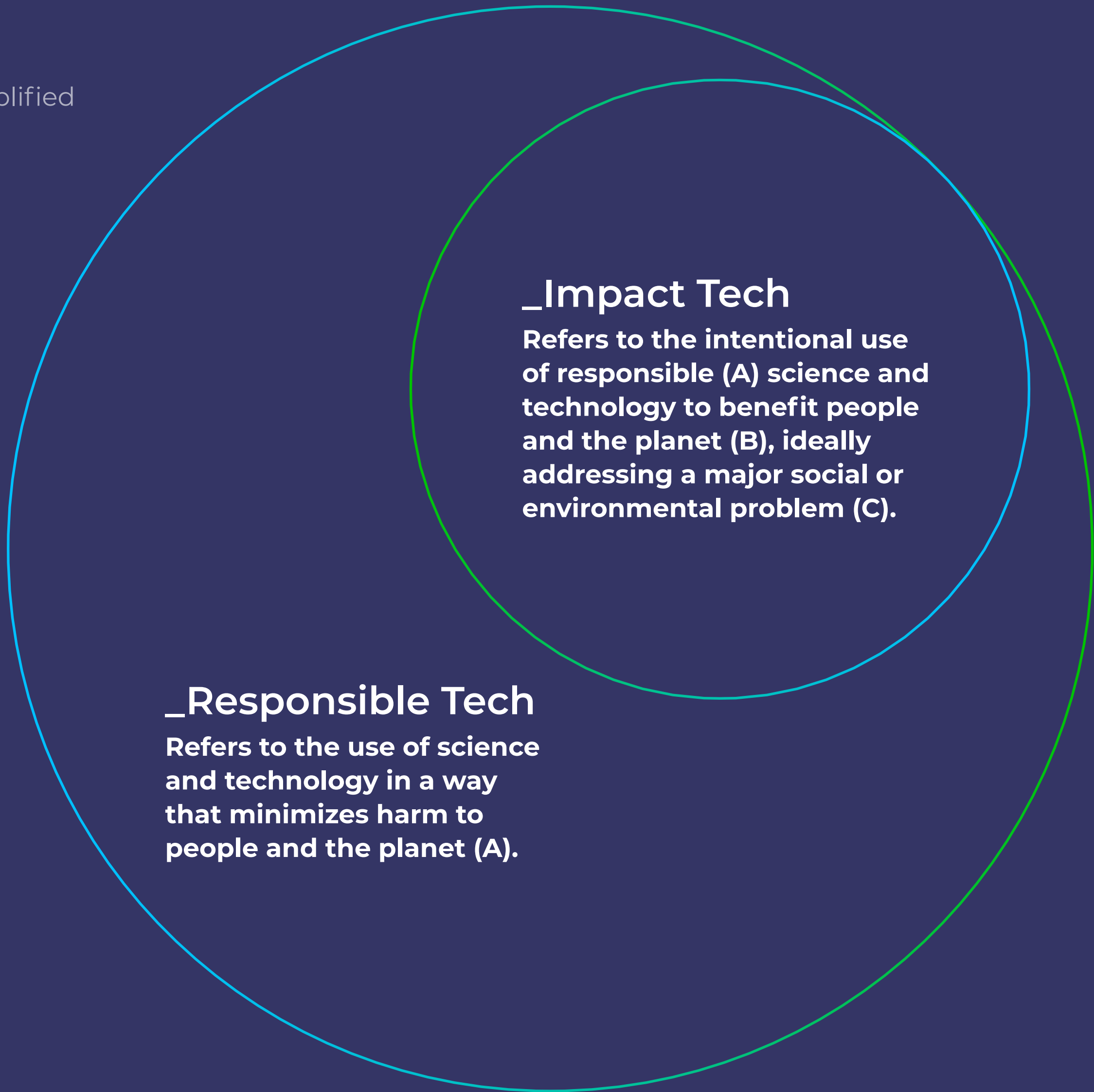
Act to avoid harm

"We want to reduce our environmental footprint"

"We want to mitigate risk and behave responsibly"

Credit: Inspired from the Impact Management Project

In the context of science and technology, we propose the simplified terminology used in this report:



Most of this report focuses on impact tech.

Responsible Tech

Responsible Tech *"considers the social impact it creates and the unintended consequences it might cause"* according to British charity Doteveryone. Unintended consequences can take many forms, including electronic waste, digital surveillance and bioethical challenges. Chapter 4 provides an overview of some of the most critical technology risks.

Many voices within the tech industry increasingly emphasize responsibility. Examples include the Copenhagen Letter and Catalog published at TechFest, the Center For Humane Tech which aims to tackle screen addiction, and declarations from the Canadian Tech community or US tech giants invited by French President Emmanuel Macron.

The use of "Tech For Good" in the two latter examples illustrate however how loosely defined that term is. Critics especially point to the risks of "good-washing" and "impact-washing"—especially when companies like Palantir are included, despite their pivotal role in global surveillance and their association to the Cambridge Analytica scandal.

Besides industry-led initiatives, NGOs have been campaigning for responsible technology for decades. The protection of an open and fair internet, digital privacy and freedom of speech have been the focus of the Electronic Frontier Foundation in the US, La Quadrature Du Net in France, or Tim Berners-Lee's Web Foundation. Others like ThingsCon in Germany specialized on the ethics of connected devices. Meanwhile, research groups like Data&Society (US), Eticas (Spain), Data Justice (UK), ITS (Brazil), AI Now (US), and CIPESA (Uganda) have emerged.

Impact Tech

By contrast, Impact Tech aims to create positive social and environmental benefits. This goal is not tied to a specific kind of organization, and is observed among startups, nonprofits, social enterprises, academia, the public sector, and even corporates.

However, not everyone likes the impact label. Many tech investors and entrepreneurs told us they avoid it despite being mission-driven. The most frequent reason is the feeling it could send an implicit signal that financial returns would be lower—which is not necessarily the case, as we will see in our second report—and thus prevent them from raising funds.

> *"The word 'impact' is too often associated with lower returns. We think that if you solve the biggest problems in the world you should make a lot of money. Therefore we prefer to avoid this term."*
>
> ***Andrew Beebe,***
> *Managing Partner at Obvious Ventures*

Another reason is that many mission-driven tech entrepreneurs and investors do not measure their social and environmental impact, and thus do not wish to carry a responsibility they cannot uphold. Explanations for the lack of measurement vary: i) they are not familiar with the methods; ii) they feel too resource-constrained to invest in it, especially at the early stage; iii) they do not think any method is relevant for their industry or their technology; iv) or sometimes they merely estimate that intent is enough, and measurement adds too much of a burden.

We understand these hurdles, but we believe it is possible to overcome them. In chapter 5, we attempt to demystify impact management.

At the same time, charities, foundations and social enterprises sometimes worry about words like "impact" and "for good" being used by for-profit companies, in potentially misleading ways. Indeed, not every social problem can be addressed by market-based solutions alone, especially in sectors like education and healthcare where so far only public services have a track record of universality.

"There is a huge disconnect between those who understand the possibilities of technologies like satellites, and those who truly understand social and environmental problems. It is our role to connect those two groups."

Bruno Sanchez-Andrade Nuño,
former VP Social Impact, Satellogic

Despite these concerns, we see encouraging signs of convergence from both ends of the Impact Tech spectrum.

Photo: NASA

2.2 Drivers of Growth

The *Rise of Impact Tech* can be understood as a convergence of ideas, talents, and resources from the tech sector and the impact sector.

We identified six key drivers for this movement.

Drivers

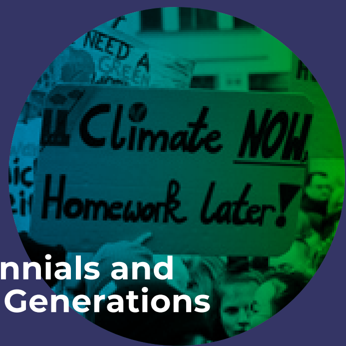
1.
Tech Shift Toward Impact

2.
Impact Shift Toward Tech

3.
Emerging Technology and Science

4.
Massive Global Challenges

5.
Economic Rewards and Costs



6.
Millennials and New Generations

Photos: 1. *Fairphone* ***2.*** *Neil Palmer* ***3.*** *Ousa Chea* ***4.*** *Dan Gold* ***5.*** *Aditya Vyas* ***6.*** *Jonathan Kempe*

Tech Shift Toward Impact

Over the past few years, an increasing number of tech industry veterans have been investing into social and environmental ventures. Though critics may dismiss some of these initiatives as PR moves or purely commercial efforts, overall they help bring to the impact space not only money, but also the skills and methods which made tech companies successful.

Tech billionaires are now among the biggest contributors to both philanthropy and impact investing. In the US, Tech Philanthropy accounts for no less than 60% of the $14.7 Billion contributions from the top 50 donors. Besides super wealthy individuals, the Founder's Pledge incentivizes all entrepreneurs to give a percentage of their capital gains to a social cause. Furthermore, impact investing is an increasingly popular way to reinvest one's wealth into societal issues, often used in combination with philanthropy.

Much of this wealth gets channeled toward entrepreneurs, inventors, and nonprofits using technology and science to address problems like global health and climate change. Examples include the Gates Foundation, the Chan-Zuckerberg Initiative, Omidyar Network and the Sköll Foundation (eBay's Pierre Omidyar and Jeff Sköll), Obvious Ventures (Medium's Ev Williams), the Allen Institute For AI (Microsoft's late Paul Allen), Kapor Capital (Lotus' Mitch Kapor), the Case Foundation (AOL's Steve and Jean Case), Khosla Impact (Sun's Vinod Khosla), Norrsken (Klarna's Niklas Adalberth), Zennström Philanthropies (Skype's Niklas Zennström), Schmidt Futures and the Schmidt Foundation (Google's Eric Schmidt), OSFund (Braintree's Bryan Johnson), the Moore and Dell Foundations, and Salesforce's Marc Benioff.

Tech entrepreneurs are also starting mission-driven ventures themselves. Despite recent stories that have tainted his reputation, Elon Musk has been the poster child of successful entrepreneurs reinvesting gains into tackling global problems. Furthermore, impact now makes headlines on tech media like TechCrunch as the next big thing. Chief editor Mike Butcher personally launched Techfugees during the height of the Syrian conflict, to help foster the tech community's response to the needs of displaced people around the world.

Finally, there is a flourishing of impact tech incubators, accelerators, company builders, bootcamps, and more. Examples include Katapult (Norway), ImpacTech (Singapore, Thailand), Zinc (UK), BitsxBites (China), SenseCube (France), CcHub (Nigeria), Norrsken (Sweden), Ship2B (Spain), Liberté (France), and players who have been active for over 10 years such as Unreasonable (US), Bethnal Green Ventures (UK), VentureWell (US) and Village Capital (US).

> *"We are very interested in companies tackling wicked problems in energy, water, health, conservation, etc. We now have dedicated programs on these verticals."*
>
> ***David Cohen,***
> *Founder and Co-CEO of TechStars*

Even more revealing, established players in the tech industry are taking notice. For instance, leading accelerators like TechStars (US) and Rockstart (Netherlands) have launched programs focused on energy, food, social impact, and conservation, while Y-Combinator (US) recently increased its effort to invest in carbon removal moonshots. The Lean Startup community now has a Lean Impact program and some players like Singularity University (US) have increased the impact focus within their market positioning and communication.

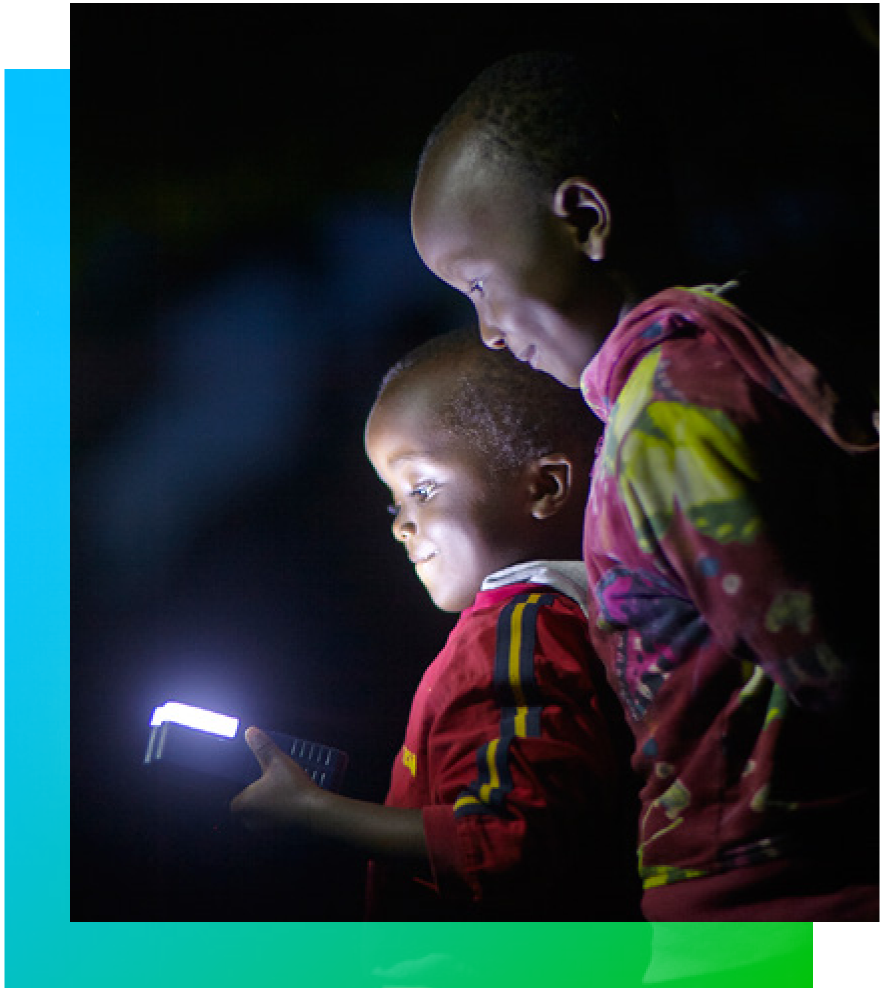


Photo: Matthieu Young

Impact Shift Toward Tech

From NGOs to social entrepreneurs, foundations and development organizations, the traditional "impact sector" has taken notice of the leverage that technology allows.

Foundations show an increased interest in technology as an enabler for social change, with dedicated funding programs. Examples include some of the biggest names in US philanthropy like the Ford Foundation or the Rockefeller Foundation. In the UK, Comic Relief and the Paul Hamlyn Foundation launched a Tech For Good Hub. Fundación Avina partnered with Omidyar Network to launch the Latin American Alliance for Civic Technology (ALTEC). And new players such as the PRIME Coalition are mobilizing philanthropic capital to support science-based solutions to climate change. The MIT Innovation Initiative writes in a paper co-authored with PRIME: "*Building on deep issue expertise, foundations can and should take the next step, drawing on all their resources to help science-based innovation bear fruit.*"

Nonprofits and NGOs are either building capacity or partnering with tech firms to build and support tech-based solutions. For instance, WWF develops conservation technology with various partners including Google. Amnesty International has been working with satellite imagery providers and VR producers to document human rights abuses during Rohingya crisis in Burma. FHI 360 has established its own Tech Lab to "*use the multiplying effect of innovative and basic technology*" across their health and well-being interventions. Finally, organizations like CAST support traditional charities to develop digital services and build capacity.

"We need to help the social sector organisations and public institutions transition to be fit for purpose in a digital society and able to respond to the future. Technology can act as a trojan horse for what is actually a fundamental redesign of these organisations."

Cassie Robinson,
Head of Digital Grant Making at The National Lottery Community Fund

International organizations and development agencies have also embraced technology collaborations to achieve their mission more efficiently, as highlighted in section 2.4 of this report. Many have established dedicated units like the GIZ Blockchain Lab or UNICEF Innovation, which identifies, prototypes, funds, and scales tech solutions that strengthen UNICEF's work with children.

Finally, important success stories in social entrepreneurship have been enabled by technology. Past recipients of the prestigious Sköll Award for Social Entrepreneurship include crowdlending platform Kiva which funds low-income entrepreneurs, Indian solar energy pioneer SELCO, online education platform Khan Academy, and Code For America which helps governments deliver better digital services.

"At Ashoka we see more scientists who have decided to lead systems level social change. We call them "social scipreneurs," and seek ways to recognize, encourage and work with them through our network."

Bill Carter,
Founding Board Member at Ashoka

Organizations which have supported social entrepreneurs for years have also increased their focus on technology, such as Ashoka which opened a Tech For Good program within the Station F startup campus in Paris, and is increasing its focus on social sci-preneurship. More recent endeavors like MakeSense, led by digital natives, tend to naturally focus on digital-enabled social enterprises.

Photo: Faircap

Emerging Technology and Science

Technological progress and the rise of science entrepreneurship (see also "deep-tech" in section 2.3) open a whole new range of possibilities for wicked problems that software cannot tackle alone.

Consider how synthetic biology and material sciences could eventually replace fossil-based products with bio-based and carbon-negative alternatives. How machine learning makes it possible to leverage the microbiome of plants and soil to sustainably feed 10 billion people without toxic pesticides and fertilizers. Or how satellites and data analysis can help vulnerable communities build climate resilience.

"From synthetic biology to AI and new materials, Deep-Tech could help us engineer a new symbiosis between humans and the environment, and restore what we have degraded in the past."

Arnaud de la Tour,
Co-Founder and VP of Hello Tomorrow

Yet many applications are still unknown, as technological progress is likely to continue on the same accelerated path. Experts mention several factors for continued acceleration, which UNCTAD refers to in its 2018 report on *Frontier Technologies for Sustainable Development*:

- Moore's Law and the exponential increase in computing power
- Technologies are combinatory and building on each other, from gene editing to machine learning, nanomaterials, and more
- Platform technologies similar to the Internet and the GPS will enable a whole new range of applications.
- The decreasing costs of scientific experimentation and business creation brings down the barrier to deep tech entrepreneurship

Massive Global Challenges

The global challenges the world faces are of unprecedented magnitude, but never have we so well understood what should be done to address them. In 2015 the world's nations signed the 17 Sustainable Development Goals for 2030, as well as the Paris Agreement aiming to limit global warming to 1.5C—which is included in the Goals.

"The SDGs represent one of the most ambitious roadmaps for improving human lives and reversing global warming. Yet, incremental approaches will not be sufficient. Rather, leading companies recognize it is critical to employ emerging technologies, new mindsets and new business models to generate the disruptive change required to achieve the Global Goals."

Rosedel Davies-Adewebi,
former Senior Manager, Innovation at UN Global Compact

The SDGs can be a catalyst for innovation and collaboration across the public and private sectors. They are the closest thing the world has to a strategy, and provide a common language for companies, governments, investors, citizens, and academia to co-create solutions. While the SDG investment gap is currently at $2.5 trillion annually, the Goals indicate market gaps, development needs and investment priorities which "*provide a roadmap for businesses to seek opportunities and manage risk*" according to the Global Reporting Initiative.

"*Technology enables us to address the SDGs faster, better, and in a more scalable manner*" in the words of Singularity University faculty and foresight expert Banning Garrett. Indeed, most of the goals feature technology-related targets as transversal enablers. Regarding climate change, the Exponential Climate Action Roadmap estimates that technology, and especially the digital revolution, "*may well be the biggest wildcard in the economic transformation*" that is required to keep us well below 2C, and ideally below 1.5C.

Photo: Markus Spiske

Economic Rewards and Costs

Economists, scientists and social thinkers have often argued that capitalism, or at least its current form which relies on infinite growth and profit maximization, is not compatible with planetary boundaries. A recent UN-commissioned paper even writes that "*we have moved into a new, unpredictable and unprecedented space in which the conventional economic toolbox has no answers.*" While the search for a future-proof system is still a work in progress, one can nevertheless argue that existing market forces may be harnessed for the better.

First, the economic prize for solving the world's biggest problems is gigantic: $12 trillion and 380 million jobs. That is the estimated annual market potential for meeting the SDGs in just four sectors (food, cities, health, energy/ materials) according to *Better Business, Better World*. This landmark report commissioned at Davos by some of the world's top CEOs, civil society leaders, and international organizations, also estimates that "*the total economic prize from implementing the Global Goals could be 2-3 times bigger*" beyond the four sectors evaluated.

"The greatest value creation over the next 50 years will come from companies that solve large global needs."

Alexandre Terrien,
Founding Partner at Future Positive Capital

Second, capital markets may shift toward SDG investing as it aligns with investors' long-term interest. Institutional investors who manage assets in the billions or even trillions (like pension funds) have a double incentive to do so. As mentioned above the "economic prize" for achieving the Goals promise good returns, which are especially attractive in a world of superabundant capital where "*too much capital will be chasing too few good investment ideas for many years.*" For these reasons, some even see the SDGs as "*a gift to investors*."

Additionally, large asset owners need to hedge against systemic risks like catastrophic climate change and other issues addressed by the SDGs, like clean water shortage, inequality, and biodiversity loss. A recent essay co-authored by PGGM, one of the biggest European pension funds, warns against the "linear risks" associated to business practices such as using non-renewable resources and prioritizing the sales of virgin products. During the COP24 in Katowice, 400+ investors representing $32 trillion in assets urged governments to slash emissions, phase out coal, end fossil fuel subsidies and set a high carbon tax to avoid financial collapse.

Millennials and New Generations

Even though consultants and pundits may have overused the argument, one cannot ignore the increasing weight of millennials.

Millennials expect more from companies they buy from and work for. While 43% of millennials are planning to leave their current job in the next two years (Deloitte 2018), 83% would be more loyal to a company that enables them to solve social and environmental challenges (Cone 2016). Unilever finds that their Sustainable Living Plan is one of the key motivations for 60% of job applicants under 40. On the consumer side, 73% of millennials are willing to pay more for sustainable goods (Nielsen 2015). At the end of 2018, thousands of French students have even publicly pledged not to work for polluting companies after their studies.

Private wealth will soon shift to Millenials. Accenture estimates that in the next 30-40 years, intergenerational wealth transfer between boomers and millennials will represent $30 trillion in North America only, increasing the influence of the latter in the economy. Thankfully a survey from the Morgan Stanley Institute for Sustainable Investing reported that US millennials are twice as likely to invest in companies and funds that target social and environmental outcomes.

Having grown with the digital revolution, Millennials also tend to be more tech-savvy. Investing in the latest technology is becoming critical to attracting and retaining top talent, according to several studies. One could thus expect that new generations who are both more sensitive about having a positive impact on society and more likely to harness the potential of technology, will embrace and drive Impact Tech forward.

Photo: Jonathan Kemper

2.3 Impact Tech Strategies

The use of technology to address social and environmental problems can take many forms. This section highlights several tensions we have spotted between different Impact Tech strategies.

Tensions

Techno Push ↔	Demand Pull
Root Causes ↔	Symptoms
Impact Depth ↔	Impact Scale
Innovation ↔	Replication
Startup ↔	Systemic Initiative
Deep Tech ↔	Low tech
Platforms ↔	Applications
Impact First ↔	Finance first

Technology Push vs Demand Pull

Since the 1960s, management professors have argued whether innovation is more successful as a result of technology developments (tech push) or as an integration of new customer needs (market or demand pull).

At the minimum, technologists should answer society's expectations that negative consequences are mitigated, for example with effective cybersecurity, reduced electronic waste, and fair algorithms (more in Chapter 4). We defined this approach as Responsible Tech.

When it comes to addressing a social or environmental problem though, understanding that problem sounds like an elementary first step. Unfortunately, many of our interviewees stressed that Impact Tech innovators sometimes lack a deep enough knowledge of the problem, the kind that would be necessary to inform solution design. Throwing sensors and blockchains at a social problem may attract a few investors hungry for buzzwords, but without proper systems thinking it can only get us that far.

"If you have an X amount of resources, you should spend 60% understanding the problem, and the rest solving it."

Maurizio Vecchione,
Executive VP of Intellectual Ventures Global Good

The road to failure is paved with good intentions: nothing replaces problem research, even the noblest cause. One Laptop Per Child (OLPC) famously failed to improve children's learning in countries like Peru, despite a million computers deployed. Explanations for this failure range from logistical issues, high costs, US-centricity, and the lack of children and teacher training. Although to be fair, a smaller program in Uruguay called Plan Ceibal helped reduce the digital divide.

In another example, Maurizio Vecchione from IV Global Good told us about a company that donated low-cost fish drying technology to a fishing village in Africa. But as fishermen in that village are paid on a weight-basis and not per product, it ended up decreasing their revenue instead of increasing and was ultimately not used.

Human-Centered Design (HCD) is one approach to facilitate problem research and the design of appropriate solutions. Building upon user-centered design, the HCD process consists of four main stages. First, use empathy to put yourself in the shoes of the users and communities who are affected by the issue. Second, ideate on solutions together with them. Third, use rapid prototyping to test the best ideas inexpensively. Fourth, create a pilot program at the community level.

"It is easy to come up with new ideas, but one must not forget the users and the wider context. Good design rests on a rigorous understanding of the problem, so we can serve the needs of people with respect to our planet's resources."

Liza Chong,
CEO of The Index Project

Photo: One Laptop Per Child

Several organizations support Impact Tech innovators in the problem research journey. Catapult Design provides strategic design expertise to social enterprises, ideally before they even build anything. Brooklyn-based incubator Blue Ridge Labs, which focuses on services for low-income populations, connects entrepreneurs with direct user insights and focus groups. In London, Science Practice helps entrepreneurs identify Good Problems that science can tackle, and advises corporates and governments on running meaningful innovation challenges.

However, using design effectively also requires to project oneself in the future. HCD critics point to its "*inability to push the boundaries of available technology by solely tailoring to the demands of present-day solutions, rather than focus on possible future solutions.*" As Henry Ford famously said: "*If I had asked people what they wanted they would have said: faster horses.*" Interdisciplinary collaboration between designers, scientists, and entrepreneurs can help solve this shortcoming.

Besides, many transformative and life-saving innovations have been the product of technology push: some resulting from unexpected discoveries like penicillin, others from long-term and large-scale scientific endeavors. The Human Genome Project required the collaboration of twenty academic institutions from six countries over 14 years, unleashing much of recent progress in molecular medicine.

Governments can also shape policy to direct innovation toward the Sustainable Development Goals. Mariana Mazzucato, director of the Institute for Innovation and Public Purpose at UCL, calls for "Mission-Oriented Research and Innovation" to "*direct the power of research and innovation [to also] find innovative solutions to the most pressing challenges of our time.*"—the centerpiece of a 2018 report she delivered to the European Commission.

Impact Tech can result both from technology push and demand pull, and most often from a combination of both.

Root Causes vs Symptoms

Another tension is the one that exists between treating the effects of a problem and addressing its root causes. For example, air pollution is responsible for seven million deaths annually, which creates an urgency to reduce its harm with anti-pollution masks and smog-sucking towers. However, none of these address the root causes of air pollutants: vehicle emissions, fossil fuel power plants, and industrial facilities.

Similarly, the Ocean Cleanup project uses a giant collector to remove plastics from the oceans, another intractable problem requiring a massive response. Critics argue this project only deals with the symptoms of plastic pollution. Solving it would require a shift toward a circular economy, including reduced or reusable packaging, the end of single-use plastics, and a shift toward marine-degradable and bio-benign materials.

While both of these cases illustrate the strategic imperative to focus on the root causes of problems, it would be too easy to dismiss "symptom solutions" altogether. In an analogy with the human body, treating the symptoms can be an immediate necessity to stop the pain, as long as they do not come at the expense of a long-term cure.

To better address problem root causes, Impact Tech entrepreneurs should adopt a systems mindset and leverage root cause analysis.

Impact Depth vs Impact Scale

The Impact Management Project defines impact depth as "*the degree of social or environmental change experienced by the stakeholder*" and impact scale as "*the number of people experiencing the outcome*". For instance, halving carbon emissions on a given perimeter would qualify as deep impact, while achieving 15% energy efficiency across all of China would be impact at scale.

The installation of a community makerspace can have a transformative impact (high depth) in a slum or a remote rural area if disadvantaged populations learn how to use the tools to meet their needs; however, such a project will remain very local (low scale) without proper replication.

Corporates initiatives around sustainability or inclusive supply chain can reach scale quickly when appropriately resourced, Nevertheless, critics would argue most of them lack the impact depth required to put a dent in the problem. To incentivize businesses to level up their ambitions, organizations like the Science-Based Targets Initiative invite them for instance to set absolute GHG emissions reduction targets aligned with climate science, as opposed to internally defined ones.

The combined ambition for scale and depth is characteristic of Moonshot Thinking: a concept popularized by Silicon Valley firms like Alphabet subsidiary X—formerly Google X—and Singularity University. The latter aims to "*positively impact a billion people*" with a "*10X rather than 10%*" improvement. Historic examples include platforms such as the Internet and the GPS, and applications such as Wikipedia and the electric light bulb. French think-tank Fing refers to sustainability moonshots as "Factor 4 Innovation", which combine depth, scale, as well as intentional mitigation of negative externalities.

Photo: Eric Parker

Based in Mumbai and Berkeley, the Institute For Transformative Technologies has pioneered a way to deliver Impact Tech both deep and at scale. Having pre-identified technology breakthroughs that could put a dent in global poverty such as ultra-low-cost refrigeration, they scout the world for high-potential inventions meeting these criteria. Then, they work with the creators to turn these inventions into affordable, attractive and robust products, which can be deployed at scale through partnerships with corporates like Tata Group.

"It is hard for small organizations to achieve economies of scale for hardware products. Even in industrialized economies, hardware startups must leverage existing supply chains of larger companies to be financially sustainable. Today many corporates in emerging markets can offer similar leverage. I believe it is critical for Impact Tech innovators to find such companies and partner with them."

Shashi Buluswar,
CEO of the Institute For Transformative Technologies

Impact Tech companies will continuously be juggling scale and depth of impact as they grow, and both are valid strategies. Simultaneously achieving impact that is deep and at scale can be done and should be celebrated. However, we should recognize it is the exception rather than the rule.

Innovation vs Replication

Another polarizing idea is that innovation is often fetishized and *"gets all the press and prizes [while] it should not,"* in the words of Mulago Foundation director Kevin Starr. In a critique of international NGOs opening innovation labs, and funders obsessed with sexy novel ideas, he writes in SSIR: *"The most urgent challenge in the social sector is not innovation, but replication. No idea will drive big impact at scale unless organizations—a lot of them—replicate it. And there are plenty of high-impact ideas awaiting high-quality replication."*

Several organizations have specialized in finding, assessing and spreading proven solutions. Technology Exchange Lab hosts a crowdsourced database of 650 technologies for poverty alleviation, and partner with solutions providers, local communities and NGOs to design and implement appropriate solutions for last-mile development initiatives. ImpactOn takes a similar approach, while Sustainia's Global Opportunity Explorer focuses on connecting solution providers with corporate partners.

"The real need for innovation is not on the technology side, but on the implementation side"

Brennan Lake,
CEO of the Institute For Transformative Technologies

Noteworthy upcoming initiatives include the UN Technology Facilitation Mechanism platform, and novel approaches such as Sphaera which breaks down projects and ideas into simpler "building blocks" reusable across different sectors—such as global health and agriculture. This modular approach is reminiscent of the open source philosophy, which promotes the dissemination of knowledge in the forms of software, hardware design or scientific discovery so that others can build upon it.

A related tension exists between proprietary and open source licensing. Although open source favors replication, achieving impact at scale can be hard, in part because of the challenge of finding a good revenue model without a proprietary component. This is true especially beyond pure software projects like Wikipedia and Linux.

In any case, massive hurdles remain on the path toward the replication of proven solutions. A major one is the lack of appropriate funding mechanisms for projects that are "not innovative enough" for both venture investors and philanthropists, yet too small for project finance. Emerging tools addressing this include new fund structures for decentralized renewable energy projects or funding programs like D-Prize aimed at entrepreneurs who increase the access to proven poverty interventions, through "distribution innovation."

In the end, there is a case for both innovation and replication. Massive global problems like global health and climate change need to be urgently addressed at scale with proven solutions. At the same time, many present and future issues cannot be solved with existing technology alone, and game-changers are around the corner. As an example of a dual and balanced approach, the Drawdown solutions platform that accompanies Paul Hawken's book features 80 existing solutions to the climate crisis, but also 20 "coming attractions" based on frontier technology, which may hold the key to keep us under 1.5C.

Photo: Ashok Boghani

Startup vs Systemic Initiative

What is the most effective way to tackle a massive problem? It depends: startups and systemic initiatives can offer complementary approaches, as they aim to solve different types of issues.

Startups excel at using technology to solve a well-defined problem with high market potential. Following Silicon Valley mantras like "lean startup" and "blitzscaling", many entrepreneurs assume the way to go is to achieve "product-problem fit" then scale the company as fast as possible. This approach can work well for specific solutions such as providing a better water purification technology, or more affordable credit for smallholder farmers.

Systemic initiatives, on the other hand, create momentum across multiple stakeholders to achieve a coordinated effort. Such initiatives often revolve around a facilitator who acts as "central gear" to align the interests of various companies, nonprofits, governments, academia, development agencies, and more. Organizations which specialize in this role include UN agencies, the WEF, the Ellen MacArthur Foundation, the Forum For The Future, the Co-Impact philanthropy collective, and Uncharted. In some cases, startups can also play the coalition-building role. For entrepreneurs, the ability to drive collective impact is increasingly referred to as system entrepreneurship.

On its own, no single actor can solve climate change, end world hunger, or future-proof cities for the 21st century. These wicked problems resist simple resolutions and require a coordinated effort. Startups can be instrumental in providing innovative solutions, while systemic initiatives can help align interests and create coalitions. Ultimately, the combination of those approaches can lead to system-level change.

> *"Given the recognition that many of our social challenges or wicked problems are both complex and interdependent, it becomes obvious there is no single magic bullet, start-up or intervention, which can drive the change necessary. This requires a new model of innovation— one in which the 'theory of change' cannot be restricted to singular services— but instead requires coordinated, collaborative and institutional innovation."*
>
> ***Indy Johar,***
> *Co-Founder of 00 and*
> *Dark Matter Labs, Advisor to UNDP*

Low Tech vs Deep Tech

Another factor where we have noticed a strong variability in strategies is the required level of technological complexity. A key part of this debate is the opposition between high-tech which is usually R&D intensive (e.g. electronics and computing), and low-tech which refers to simple tools and techniques that require few resources (e.g. bikes and solar concentrators).

Proponents of low-tech solutions point to their extreme accessibility due to lower costs, robustness, easier maintenance, and their capacity to operate with limited infrastructure and scarce resources. Organizations like Low-Tech Lab aim at documenting low-tech innovations to ensure their maximum replication. Others like French engineer and author Philippe Bihouix see in low-tech the only technological path compatible with the limited supply of metallic resources which could not sustain a fully high-tech society (see chapter 4 for a more detailed analysis).

The appropriate technology concept popularized by E.F. Schumacher in *Small is Beautiful* (initially as “intermediate technology”) attempts to bridge this divide. As its name implies, it promotes **the most appropriate level of technology necessary to achieve the intended purpose, while being socially and environmentally acceptable.** Today its main promoters include Engineering For Change and Practical Action, which focus on improving the life of underserved communities with the most effective and sustainable use of technology, often using open source. Modern examples of appropriate tech include for instance SMS-based platforms for mobile payments (M-Pesa) or information sharing between smallholder farmers without any internet access (WeFarm).

> **DNA** is the **Next Silicon.**
>
> *HELLO TOMORROW*

Appropriate technology is often a key enabler for inclusive, grassroots and frugal innovation, which focuses on including local communities and previously excluded groups, either as users or participants in the innovation process, using the resources that are locally available. In the example of the Enable Makeathon, which focuses on technology for disability in India, *"the end user knows immediately when a solution works or not"* says co-founder Sanjana Govindan. UNCTAD explicitly refers to these approaches in its 2018 report which acknowledges the many ways that technology can address the Sustainable Development Goals.

On the other side of the spectrum, terms like deep-tech have emerged to describe the new frontiers of high-tech. Propel(x) CEO Swati Chaturvedi defines deep-tech as *"companies that are founded on a scientific discovery or meaningful engineering innovation"* as opposed to those using commonly available technology (e.g. most internet companies). Deep-tech encompasses many disciplines ranging from life sciences to materials, cleantech, high-end medical devices, space technologies and even "deep software" like blockchains and artificial intelligence. This term became popular in the startup world, where the broad use of "technology" created the need for investors to better distinguish companies built around unique IP.

Many deep-tech companies are addressing some of the world's biggest problems. While there is little data available on how this compares to the software sector, past winners of the biggest deep-tech startup challenge Hello Tomorrow are telling: mass reforestation with drones, sanitary pads made of waste banana fiber, a therapy for spinal cord injury, and an electric flying car with bold sustainability ambitions. Besides, a new breed of investors like Fifty Years and Future Positive Capital have built their entire thesis around deep-tech for impact, from clean meat to bio-based chemicals.

In recent years deep-tech entrepreneurship has become increasingly popular, especially in advanced economies with a thriving startup scene like North America, Europe, Israel, China, and Singapore. VC funding is now even more abundant for deep-tech startups than for digital ones, even though AI alone is the biggest contributor to this phenomenon.

Furthermore, science entrepreneurship is now more accessible for at least two reasons. First, new platform technologies such as synthetic biology and gene editing (including tools like CRISPR-Cas9) may have the same catalytic effect as the Internet and the transistor had in the 1970s. Second, the barriers to science venturing are falling. UK-based company builder Deep Science Ventures argues that science startups are now often created in direct response to market pull rather than basic research, and spring from the intersection of existing fields more often than from new scientific breakthroughs. This lowers the barriers to entry, as IP is cheaper while being defensible, and this innovation is often within reach of early career scientists (PhDs, commercial R&D professionals).

> *"We must transcend the debate on low-tech versus high-tech. What is important is wise-tech: how we create and use technology wisely."*
>
> ***Navi Radjou,***
> *innovation scholar, author of Jugaad Innovation and Conscious Society*

From deep-tech to low-tech, high-tech and appropriate technology, there are worlds of opportunities to harness science and technology for global good—as long as we choose wisely which approach is the most effective and efficient for each problem. This is what innovation scholar Navi Radjou calls "wise-tech."

In some cases low-tech innovation can also emerge from deep-tech R&D. For instance, new research on the soil microbiome and its interaction with crops are leading to breakthroughs in agroecology, thanks to advanced biology and bioinformatics.

Platforms vs Applications

Most Impact Tech innovations directly address specific social and environmental problems. As such, they are applications resting on platform technologies—defined as the foundations which enable many other technologies and applications.

The most transformative platforms are akin to the technological revolutions described by economic historian Carlota Perez. Such “platforms of platforms” include silicon chips, the Internet and the GPS which unleashed the digital revolution since the 1970s. These foundations in turn have enabled other platform technologies like the mobile web, the internet of things, and the race toward artificial intelligence.

AI will be like electricity, it will be everywhere. Voice AI is already making technology accessible even for the illiterate.

Banning Garrett,
foresight expert, Singularity University Faculty

Given how platform technologies can transform society and equip us with new tools for positive change, continued progress is essential. New institutions like OpenAI and the BioBricks Foundation strive to make the next platforms like AI and synthetic biology beneficial to humanity. Others like SoScience advocate that **societal impact analysis should be embedded by default in the work of all research labs**—in the same way that CSR became a standard in the corporate world.

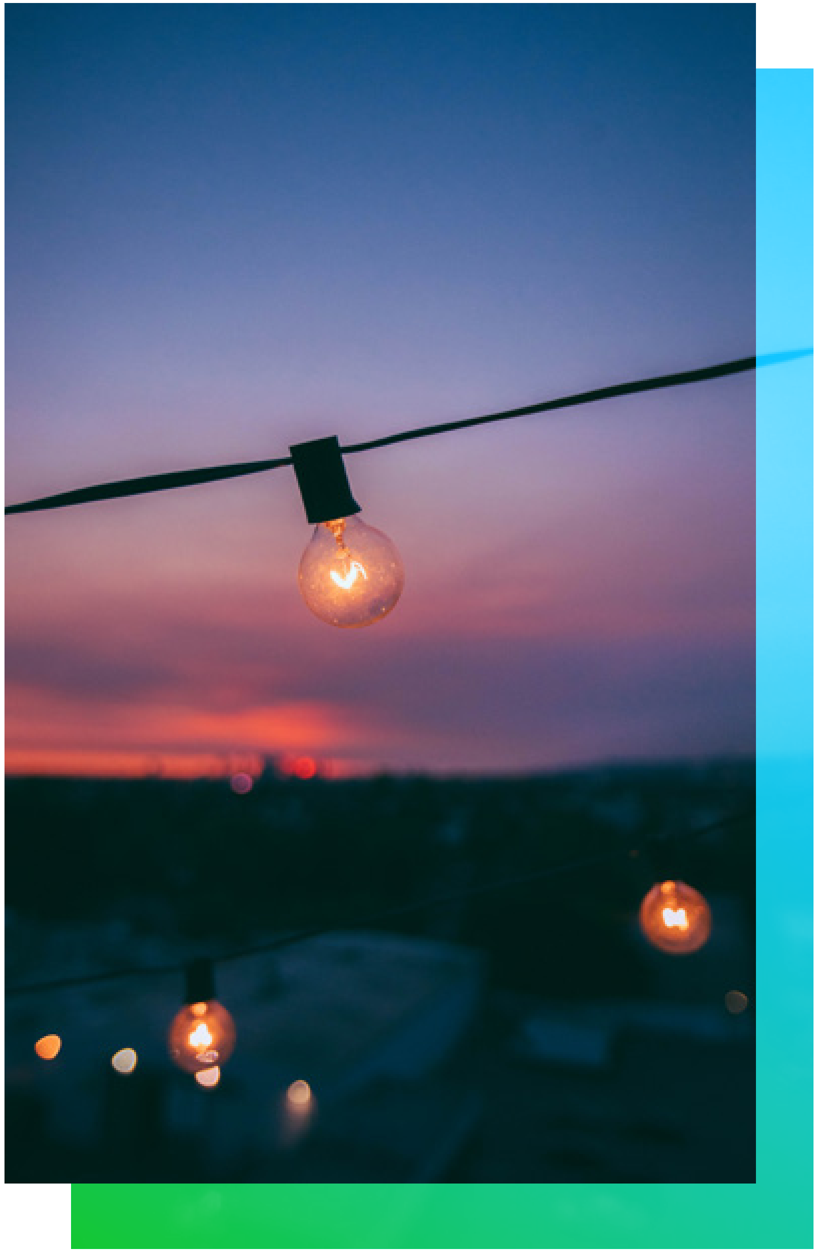


Photo: Roberto Nickson

> *"Science should be driven by the mission to serve society, but today both academic and corporate research labs only value their research in economic terms. We need to mainstream the use of social indicators."*
>
> ***Mélanie Marcel,***
> *Founder and CEO of SoScience*

Current platform technologies are largely based on publicly funded research. In *The Entrepreneurial State*, Mariana Mazzucato writes: *"the private sector only finds the courage to invest after an entrepreneurial state has made the high-risk investments."* This principle has been verified not only in the IT sector but also in biology, physics, chemistry and materials science.

While one could hope public funding could help maximize public benefits from platform technologies, sadly the availability of these funds has been declining. MIT scientists warned the US government of this phenomenon in the 2015 paper *The Future Postponed* and its 2017 follow-up, which highlight key areas of basic research in need of unrestricted funding. Though corporate R&D labs contribute a lot to research, they have two limitations. First, they focus primarily on applied research with a short-term commercial horizon (with a few exceptions like Google X and Sony CSL). Second, the output of corporate R&D is private property, while platform technologies benefit more from free access.

In addition to renewed government support, the MIT Innovation Initiative and PRIME Coalition call for philanthropy to bridge *"gaps in financing along the idea-to-impact pathway."*

Different from platform technologies, platform business models refer mostly to companies relying on network effects. A paper co-authored by Sangeet Paul Choudary further distinguishes transaction platforms (ex: Airbnb, Uber) and innovation platforms that provide a technological foundation for third-party developers to build applications (ex: Microsoft, SAP), while tech giants often combine both. **Innovation platforms can be seen as "platform technology as a service"** like Amazon Web Services, Google Cloud AI, open source frameworks such as TensorFlow for machine learning and Baidu Apollo for autonomous vehicles.

Such platforms can also accelerate the R&D process for Impact Tech innovation. In recent years researchers have enjoyed new digital tools allowing them to raise additional funding (e.g.: Experiment), perform distributed experiments (e.g.: ScienceExchange, Just One Giant Lab) and publish their results more widely (e.g.: Mendeley, Figshare, PLOS, ResearchGate). Lab automation is another promising trend, with pipetting robots like OpenTrons and materials discovery platforms like Kebotix.

Overall, **while technology applications will likely remain the bulk of the Impact Tech movement, the development of future platforms should be driven by the same philosophy**, as they will greatly influence our capacity to address the "ultimate moonshot."

Photo: Billie Grace Ward

Impact First vs Finance First

Within the "big tent" of Impact Tech, one tension will be familiar to impact investors: prioritization and trade-offs between impact and financial returns. While most innovators aim for *"doing good while doing well,"* it can be tough to maximize both, especially in difficult times. Generally, too much emphasis on profitability can lead to mission drift, but too little can hinder the capacity to scale, and even lead to bankruptcy.

"Not everyone working on Impact Tech would agree on the best balance between impact and financial returns. For some, money and impact are equal. In my work on digital social innovation, one of our criteria is that profit is always secondary to impact. Others still would believe that making any profit off Impact Tech is wrong."

Matt Stokes,
Senior Researcher at Nesta

Impact Tech organizations cover a full spectrum ranging from non-profits to social enterprises, to tech firms providing a solution to a societal need. In the case of for-profit companies, strategies to balance impact and profitability include: business models where profit is directly tied to impact; the definition of impact and financial "floors"; and legal tools to lock-in the mission in the company charter, such as Benefit Corporations.

At the end of the day, every entrepreneur can only optimize impact performance within the context of its financial goals and constraints. Impact Tech encourages all to focus on reducing negative effects and creating as many positive effects as possible for all stakeholders.

2.4 Leapfrog Into the Future of Development

Photo: Martino Pietropoli

In the last few pages, we showed that a broad and diverse Impact Tech movement is emerging globally and could help tackle some of humanity's most pressing challenges. To conclude this chapter, we argue that this movement could be one of the foundations of a new story for global development in the 21st century.

Impact Tech in the development sector

Development agencies and international organizations have embraced the potential of technology since the early days of ICT For Development in the 1990s. Today many have set up their own innovation units to cope with the speed of technological change and find new solutions to constantly evolving global challenges. Indeed, the Center For Global Development estimates that without rapid and ubiquitous innovation, the SDGs are unlikely to be met by 2030. Innovation units allow these large institutions to be more agile in the way they engage with tech innovators, pilot new development solutions and invest in the best ones to scale them quickly where needed.

The UN Development Programme (UNDP) Innovation Facility invested in over 140 proofs-of-concept globally between 2014 and 2018. Many are featured in the report *Moonshots and Puddle Jumps: Innovation for the SDGs* including: an app developed with Baidu to better recycle electronic waste in China; DJI drones in the Maldives to map island topographies and build climate resilience; the UN Biodiversity Lab data portal to support countries in conservation decisions, and the support of public policy labs in Thailand, Serbia, Armenia, Bangladesh, Indonesia, and more. The agency has made innovation a focal point of its 2018-2021 strategic plan and the expansion of its partner network, including IBM, Microsoft, Alibaba, Impact-Hub, and the Partnership on AI.

Across the UN system, a broader network of similar innovation programs have emerged, at UNICEF, the World Food Programme (WFP), the UN High Commissioner on Refugees (UNHCR), and soon the UN Environment Programme (UNEP). These teams and others came together in 2018 to form the UN Innovation Network (UNIN), where all members commit to principles for digital development, such as designing with the user, open standards, and a focus on privacy and security.

The World Bank Group has a number of initiatives to "*build, boost and broker*" technology for development, while the ITU is promoting the use of ICT to achieve the Global Goals. National development agencies also understood that technology could help some countries leapfrog the traditional path to prosperity. Examples include DFID Frontier Technology and Ideas to Impact programs, the GIZ Blockchain Lab, the AFD Africa Tech Fund and USAID's Global Development Lab.

> *"Technological innovation can be a great enabler for development. This is why at GIZ we are looking into the transformative power of technologies and their potential impact towards sustainable development."*
>
> ***Insa Illgen,***
> *Project Management Tech Innovation for Sustainable Development at GIZ*

Additionally, private actors have brought tech-enabled solutions to the development sector in recent years. This includes philanthropies like the Gates Foundation which plays a pivotal role in the global development agenda—so big that some are even worried about its influence. But also what UNDP Asia Innovation Director Giulio Quaggiotto calls 'development mutants', from Airbnb launching a humanitarian division, to the many startups and social enterprises featured in this report.

Photo: Tom Page

Leapfrogging through Impact Tech entrepreneurship

The concept of leapfrogging referred initially to radical innovations helping new firms get ahead of incumbents, but more recently the concept became popular in the development sector as well. The idea is that a country can "*skip steps in the development ladder*" (IFC) by bypassing inferior, more expensive and polluting technologies and moving straight to advanced ones. Notable examples include mobile phones skipping landlines and solar energy skipping fossil fuels.

> *"Technology is evolving at such a fast pace that countries cannot afford to be in catch-up mode."*
>
> ***Makhtar Diop,***
> *VP for Africa at the World Bank Group*

Impact Tech offers an opportunity for entrepreneurs in the Global South to be at the forefront of the effort to achieve the SDGs, by leapfrogging old solutions straight into new ones.

Some will focus on replicating "proven leapfrogs" like drone deliveries of medical supplies and pay-as-you-go solar. **Others will innovate where further progress is needed**, for instance on better bio-based and compostable materials that outperform plastics, and data-enabled regenerative agriculture that restores soil carbon while increasing the yields of smallholder farmers.

Some will focus on providing immediate solutions to pressing symptoms like using sensors and satellite imagery to prevent illegal logging of rainforests. **Others will contribute to a system-level response** by digitizing and monetizing the biodiversity capital of the Amazon, unleashing a sustainable bio-economy which benefits all stakeholders, including indigenous populations.

Not only would such endeavors leapfrog inferior solutions and technology to adopt better ones directly, but it could also **"leapfrog old capitalism."** For instance by driving entrepreneurship and innovation toward missions serving a societal purpose, as advocated by Mariana Mazzucato.

Beyond obvious social and environmental benefits, the economic rewards of enabling such an economy are immense: $12 Trillion annually by 2030 to achieve the SDGs on only four sectors, $45 Trillion to remove 1000 gigatons of greenhouse gases from the atmosphere, and gigantic systemic risks avoided—see section 2.2. for more references. These economic benefits could unlock a new kind of development model for the Global South—and beyond—that would not only fit within planetary boundaries but also regenerate climate and biodiversity.

Pitfalls to avoid

While these new perspectives on development give us hope, one should avoid the pitfalls of over-fetishizing innovation above everything else. Several voices have pointed to the weaknesses of innovation labs in the development sector, such as Mulago Foundation's Kevin Starr and the NGO Ground Truth Solutions: *"Absent a clear sense of direction, labs tend to focus on 'innovation by gadget'."*

UNHCR acknowledges we may have reached "peak lab" if being a lab means developing, technology-driven solutions on its own. Instead, the team describes the virtue of adopting the role of facilitators *"who bring innovation tools, and learning environments to those who require support, in order to help contribute to improvements."*

Another pitfall is to expect leapfrogging alone will be enough for the developing world to catch up with rich countries. In its 2018 report *Readiness for the Future of Production*, the WEF points to significant gaps among countries: *"as the new technological paradigm brings forth a cluster of new industries, there is potential for leapfrogging, but only a handful of countries are positioned to capitalize."*

Today hundreds of millions of Africans still lack power, clean water, and internet access, while corruption is widespread and economies still depend too much on commodity exports, as The Economist summarizes. They also note that *"technology is advancing far more slowly in Africa than it is in the rich world, so the gap has been widening in recent years."* Indeed, today the continent generates only 1% of the world's research.

This gap cannot be bridged by technology transfer, but rather by capacity building. According to the World Bank, the conditions for meaningful leapfrogs include proper investment in infrastructure, regulatory improvements, a stronger academic field, and most importantly *"a properly trained workforce and a robust education system."*

Last but not least, technology also comes with its own set of risks and challenges, covered within the chapter 4 of this report.

A systems view through collective intelligence

The most acute development challenges among the Global Goals are wicked problems, especially in times of climate emergency and rapid technological acceleration. As we wrote in 2.3. we cannot rely on silver bullets to achieve them, and need to rely on systems thinking.

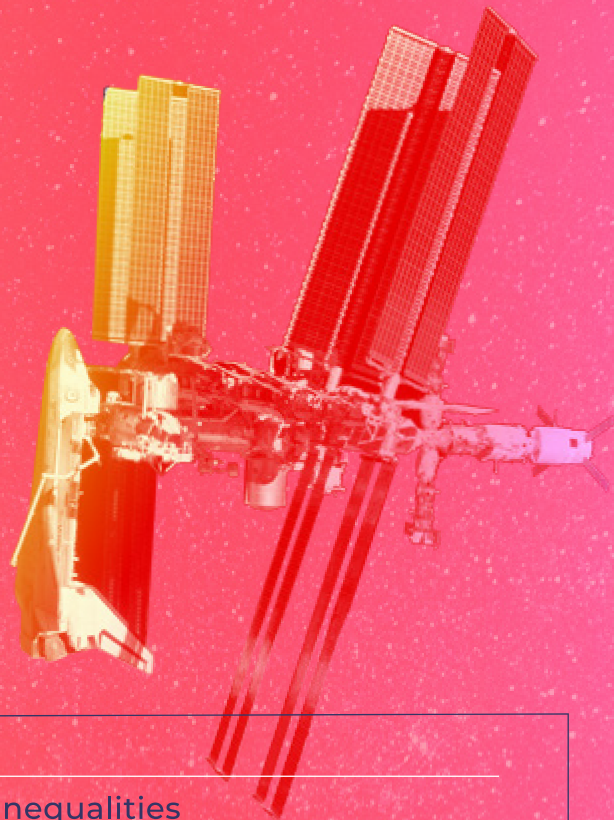
A powerful enabler is collective intelligence which Nesta CEO Geoff Mulgan describes as: *"harnessing more data and more brain power of all kinds and at every level and learning faster."* This includes using new data sources to better understand problems like the UN Global Pulse does, but also open innovation platforms to harvest ideas, take decisions and run experiments. Mulgan argues that collective intelligence efforts are most effective at the intersection of bottom-up (local labs and task forces) and top-down (curated knowledge, digital tools, deep skills). Development institutions and international organizations like UNDP could then act as platforms to coordinate these two sides.

> *"Minds on the margin are not marginal minds. More often than not, the vulnerable people who face a problem are the best-placed to provide a creative solution for it"*
>
> ***Anil Gupta,***
> *Founder of Honey Bee Network, SRISTI, GIAN, & NIF*

In the next chapter, we dive into many of the possibilities offered by Impact Tech innovations across the 17 SDGs and their sub-targets, to understand the technological 'building blocks' that could help achieve them.

3

IMPACT TECH ACROSS THE GLOBAL GOALS



- **Goal 1:** No Poverty
- **Goal 2:** Zero Hunger
- **Goal 3:** Good Health and Wellbeing
- **Goal 4:** Quality Education
- **Goal 5:** Gender Equality
- **Goal 6:** Clean Water and Sanitation
- **Goal 7:** Affordable and Clean Energy
- **Goal 8:** Decent Work and Economic Growth
- **Goal 9:** Industry, Innovation and Infrastructure
- **Goal 10:** Reduced Inequalities
- **Goal 11:** Sustainable Cities and Communities
- **Goal 12:** Responsible Consumption and Production
- **Goal 13:** Climate Action
- **Goal 14:** Life Below Water
- **Goal 15:** Life on Land
- **Goal 16:** Peace, Justice and Strong Institutions
- **Goal 17:** Partnerships for the Goals

CLICK IT!

> The scale and ambition of the Sustainable Development Goals **demand a major shift** in how development is done. Massive breakthroughs in innovation are required to truly **Leave No One Behind** and achieve the **ambition of the 2030 Agenda.**

FOREWORD OF UNDP REPORT ***MOON SHOTS AND PUDDLE JUMPS***

In September 2015, 193 UN member states agreed on a 2030 Agenda for Sustainable Development, replacing the Millennium Development Goals. The new Agenda features 17 Sustainable Development Goals (SDGs), also known as Global Goals, which have been described as *"the closest thing the world has to a strategy."* Each goal comes with specific targets—169 in total, and 232 indicators.

The SDGs provide a useful lens to understand Impact Tech across many sectors and issues. Hence, we adopted them as the editorial structure of this chapter. The 184 Impact Tech trends mapped in these pages contribute to the global effort we called the "ultimate moonshot": *reversing climate change and the loss of natural capital while making all humans thrive*. Examples of companies and projects illustrate each trend.

The SDGs as an innovation compass

The Global Goals offer a common framework for all stakeholders to collectively address the world's biggest problems: not only social organizations and governments, but also companies, investors, and academic institutions. Beyond social responsibility, many in the private sector increasingly use the SDGs as a compass for innovation and investment—tapping into a $12 Trillion annual opportunity.

The 2030 Agenda requires countries to address all SDGs with equal importance and simultaneously instead of "picking favorites". The indivisibility of the goals also stems from their correlations, documented by the International Science Council (ISC) in *A Guide to SDG interactions: from Science to Implementation*. For instance, health and well-being require access to sufficient and nutritious food, while the clean energy revolution both creates new jobs and requires workforce upskilling.

"The true power in SDGs is their indivisibility and the coherence across themes. This systemic view is a clear improvement on the previous Millenium Development Goals, which had a more siloed approach."

Nadia Isler,
Director of SDG Lab, UN Office of Geneva

However, certain goals can be in contradiction with one another. Analyzing four goals in detail, the ISC paper found 316 target-level interactions with other goals, of which 238 are positive, 12 are neutral, and 66 are negative—such as the impact of increased agricultural production on oceans through nutrient runoff and pollution. **Impact management** (see chapter 5) is thus required to minimize negative outcomes while maximizing positive ones.

Furthermore, to deliver the "ultimate moonshot" described earlier, the SDGs will be necessary but not sufficient. Critics stress that the goals do not acknowledge all the root causes of problems such as inequality and environmental collapse. Overall, **the goals should be combined with science-based frameworks like the planetary boundaries and the Carbon Law roadmap for climate action.** Despite these limitations, the catalytic effect of the Global Goals across the public and private sectors cannot be understated.

We hope this Impact Tech overview across the Global Goals will inspire you as much as it inspired us.

"The SDGs are a great change-making framework and future learning platform. We think that challenge-based learning is the best approach to foster the growth of innovators, and the SDGs are the biggest challenges we can prepare them for."

Luping Xu,
Director of Open FIESTA Center, Tsinghua University

How to read this chapter

This section is not intended for linear reading. Feel free to switch between the themes you are the most excited with.

We associate each Impact Tech trend with a specific SDG target, even though many are relevant to multiple targets, and often to more than one goal. Although we shortened the title of several targets for easier readability, we always added their official number for the full reference. The comprehensive list is available on the UN SDG knowledge portal.

Our research is not meant to be exhaustive: there is too much happening. We mostly wanted to give a representative picture of the potential of Impact Tech. Additionally, we do not pretend to have a full grasp of all the positive and negative impacts of each example.

The companies listed here only serve as examples, and do not constitute investment recommendations whatsoever. We do, however, believe that more funding should go towards Impact Tech solutions.

Finally, although this chapter is meant to be inspirational, each SDG sub-chapter features its own "challenges" section. Besides, the general optimism in these pages is balanced by Chapter 4 on technology risks and challenges, as well as Chapter 5 on the need for impact management.

Goal 1

NO POVERTY

End poverty in all its forms everywhere.

1 NO POVERTY

650 MILLION
PEOPLE LIVE IN EXTREME POVERTY

UNDP, 2017

ABOUT 1/5
OF THE PEOPLE IN THE DEVELOPING WORLD LIVES WITH LESS THAN U$ 1.25 A DAY

UNDP, 2015

> **Poverty is not just a lack of money**; it is not having the capability to realize one's full potential as a human being
>
> ***AMARTYA SEN,*** *NOBEL PRIZE IN ECONOMICS*

Photo: Dazzle Jam

Photo: Simprint

Tech for SDG 1

According to the Oxfam 2019 inequality report, almost half of the world population still lives with less than $5 a day. The solutions featured below revolve around identity, land management and financial services. To further grasp the potential of technology to tackle the multifaceted aspects of poverty, we invite the reader to go through this entire chapter. In particular, the sections about food and agriculture (SDG2), healthcare (SDG3), education (SDG5), water (SDG6), energy (SDG7), inequality (SDG10), and cities (SDG11).

Implement appropriate social protection systems, and achieve substantial coverage of the poor and the vulnerable *[1.3]*

Mobile Health Insurance

For uninsured families in the developing world, illness and accidents rank among the biggest risks of falling back into poverty. Thanks to a **mobile payment platform**, Swedish startup Bima already brings affordable health insurance to 30 million users in 15 countries across Africa, Asia, and Latin America, 93% of whom living on less than $10 a day. Bima also relies on a trained **managed agent force** for distribution and user education, and **partners with local telcos** to embed microinsurance within their offering.

Ensure equal rights to economic resources, access to basic services, ownership, and control of land and property, inheritance, natural resources, appropriate new technology and financial services, including microfinance *[1.4]*

Secure Digital Identity

The World Bank estimates that one billion people lack a way to prove who they are, including 40% of the population in low-income economies, who cannot access health care, social and financial services. Examples of digital solutions include Simprints, a British firm making low-cost and robust **fingerprint scanners**, as well as the Indian government's Aadhaar ID. Launched in 2009, the latter is accessible via the IndiaStack API to anyone aiming *"to solve India's hard problems,"* although the system recently encountered security issues. ID2020, a partnership of governments, companies, and NGOs working on digital identity, launched in 2019 a **Certification Mark** to recognize systems that meet high standards of **portability, persistence, privacy, and user control.**

Trusted Land Registries

While land and housing often represent the most valuable assets of the poor, only 30% of land rights are registered worldwide, according to the World Bank. Projects like BenBen in Ghana, propose using **a blockchain to secure land records and overcome the corruption** associated with existing paper records. The low maturity of blockchain infrastructure and the complexity of partnering with government represent significant challenges, but the development opportunity is enormous.

Inclusive Addressing Systems

From slums to refugee camps, many people lack a reliable way to share their address. Not only does this invisibilize entire communities, but it also limits their access to basic services like postal delivery. Beyond occasional efforts such as Google's participatory mapping of favelas in Rio de Janeiro ahead of the 2016 Olympics, **alternative geocoding** could fill the gap.

British firm What3Words has divided the world into a grid of three-meter squares and assigned each one a unique 3-word address, which can specify a location more precisely than a street address. While the Mongolian government has already adopted the technology, the British startup has met criticism for embedding a proprietary database into a **necessarily public addressing system**, raising questions on future fees. Open alternative includes Geohash and plus.codes.

FinTech For Financial Inclusion

According to the World Bank, 1.7 billion adults remain unbanked, yet two-thirds of them own a mobile phone that could help them access financial services.

A poster child is M-Pesa, an **SMS-based mobile payment system** launched by Kenya telco Safaricom. After becoming hugely popular in the country, it has since expanded to Tanzania, South Africa, Afghanistan, India, and Romania.

Many companies entered the microfinance market since the Grameen Bank success story. Some in East Africa now rely on **mobile data for alternative credit scoring,** including M-Shwari by Safaricom—which connects to M-Pesa—and US-based Tala. However, critics point to very high interest rates: between 7.5 and 15% per month. In India, CreditVidya uses alternative data and machine learning to **help lenders extend credit** to first-time borrowers. Others provide custom solutions for smallholder farmers (see SDG2) and emerging market entrepreneurs (see SDG8), among which crowdlending pioneer Kiva.

Finally, a new breed of companies are betting on blockchain technology, like decentralized currency transfer network Stellar which offers an **open platform for financial inclusion** services. Swiss cryptocurrency exchange Bancor enables digital versions of **community currencies,** which it helped to launch in Kenya and Bangladesh. Others include Humaniq (UK/Africa) and Moeda (Brazil).

Build resilience against climate-related extreme events and other economic, social and environmental shocks and disasters. *[1.5]*

Disaster Risk Reduction

"There is no such thing as a 'natural' disaster, only natural hazards," says UNISDR, the UN Office for Disaster Risk Reduction. Reducing the damage caused by natural hazards like earthquakes, floods, droughts, and cyclones, is critical to lowering the vulnerability of the poor, especially as extreme weather events have quadrupled since 1970. DRR Technology examples include OneConcern, which uses data and machine learning to help cities **better plan** for and **recover from natural hazards.**

NewStory uses **crowdfunding** to quickly build affordable and quality housing post-disaster, including **3D printed homes**—which are especially suitable for pieces that are not easily available locally. In the Maldives, UNDP partnered with Chinese drone leader DJI to identify physical vulnerability of the islands coasts through **aerial risk mapping.**

Photo: M-Pesa

Challenges

Financial inclusion or literacy? While financial inclusion is red-hot among fintech companies and impact investors, financial literacy may represent an even bigger need—to prevent the financially less educated from falling into debt. The impact of microfinance has been questioned since Indian farmers suicides in 2010, and high fees came into the spotlight. While digital lending can reduce fees thanks to lower transaction costs, they bring up new challenges. According to J-PAL, easy access to mobile money may increase over indebtedness, while new credit scoring algorithms using non-traditional data can be inaccurate and systematically biased. Furthermore, borrowers do not always fully understand all the fees associated with digital loans, according to CGAP. The organization calls for a greater focus on consumer protection features such as SMS-based educational content on personal finances management.

"Financial literacy is much more important than financial inclusion. Several companies really exploit the innocence of those who have never taken loans in the past."

Nathaniel Calhoun,
Co-Founder of Code Innovation, Vice Chair of Global Grand Challenges at Singularity University

"Many fintech companies say they deliver massive financial inclusion, but most of them are getting more people in debt without real financial education."

Laura Ortiz Montemayor,
Founder and CEO at SVX Mexico

Waiting for the blockchain's promises. In 2018, blockchain technology passed the "peak of inflated expectations" in the infamous Gartner hype cycle and entered the "trough of disillusionment." The waning of interest also holds in the development sector, where promising ideas around digital identity, financial inclusion and land records still need to bear fruit. Many projects have moved beyond proof-of-concept, but have not demonstrated measurable impact yet. Furthermore, several of these projects do not seem to exploit the actual possibilities offered by a blockchain and mostly consist of fancy databases whose efficiency gain are yet to be proven. Although one of the biggest roadblocks is the lack of maturity of blockchain infrastructure in general, which hinders scalability.

Owning your digital identity. Digital identity endeavors raise legitimate privacy concerns, especially as the most vulnerable have little knowledge about how companies and governments can exploit their data without their consent, in a way that does not serve their interests. Another area of concern is the centralized infrastructure of many identity records, increasing their vulnerability to security breaches. A prominent case in point is Aadhaar, the world's largest biometric ID used by 1.22 billion Indians, which attracted heavy criticism for its weak security standards. Educating users would probably not be enough: giving them control over their data should be the logical next step for real digital inclusion.

Goal 2

ZERO HUNGER

End hunger, achieve food security and improved nutrition and promote sustainable agriculture.

2 Billion

PEOPLE SUFFER FROM **MICRONUTRIENT DEFICIENCIES,** WHILE 2 BILLION ARE **OVERWEIGHT OR OBESE.**

WEF - GLOBAL FOOD SYSTEMS, 2017

1/3

OF THE FOOD PRODUCED IN THE WORLD FOR HUMAN CONSUMPTION EVERY YEAR — **ABOUT 1.3 BILLION TONNES** — GETS **LOST OR WASTED**

FAO

“I have the audacity to believe that peoples everywhere can have **three meals a day** for their bodies, education and culture for their minds, and dignity, equality and freedom for their spirits”

MARTIN LUTHER KING, *NOBEL PEACE PRIZE*

Photo: Arthur Yeti

Photo: Plantix

Tech for SDG 2

According to FAO, the global food supply need to increase by 70% by 2050 to feed a population of 10 billion—up from 7.5 billion today. Achieving this goal within planetary boundaries will require a complete overhaul of our food system, from reducing food waste to empowering smallholder farmers, and ensuring sustainable production.

End hunger and ensure access by all, in particular the poor, infants and vulnerable people, to safe, nutritious and sufficient food *[2.1]*

Postharvest Food Preservation

A third of the food produced for human consumption is lost or wasted. This represents a missed opportunity for food security, as well as a staggering 8% of greenhouse gas emissions. While in rich countries, waste mostly happens at the retail and consumer levels (see SDG12), **in the developing world losses mainly occur post-harvest.**

Companies like Inspira Farms (UK/Kenya) and Coldhubs (US/Nigeria) help agribusinesses reduce losses with **refrigerated storage solutions.** Focusing on African smallholder farmers, Wakati (Belgium) has developed a low-cost and open-source preservation unit based on **solar-powered humidification**. A third approach is to increase shelf life with an edible coating applied on fruits and vegetables. Examples include Apeel Biosciences (US) and Coating+ (Nigeria), who produces coating from chitosan—a sugar extracted from shrimp shell waste—and soy protein.

Food Science and Genomics For Nutrition

Nutrient deficiencies impair a third of the world population, especially in the poorest countries. While the diversification of local diets remains a priority, food and life sciences also enable **products and ingredients with higher nutritional value.** For instance, humanitarian food science pioneer Nutriset (France) has developed since 1993 a wide range of therapeutic food products for children and mothers affected by malnutrition.

In the genomics field, the Golden Rice project is a genetically modified (GM) rice crop with high levels of beta-carotene, which could fight vitamin A deficiency—a major cause of child mortality and blindness. However, after 25 years of R&D the rice is still not available, and also attracted much controversy because of its GMO nature (see "challenges" below). More recently, companies have been **combining AI and genomics to invent nutrient-rich ingredients.** Irish company Nuritas (Ireland) can discover bioactive peptides with health benefits when used as food ingredients.

> *"The real challenge is not organic, superfood, and other premium products, but to create sustainable and nutritious food for the mass market."*
>
> ***Matthieu Vermersch,***
> *Founder and Managing Partner, VisVires New Protein*

Double the agricultural productivity and incomes of smallholder food producers *[2.3]*

Smallholder farmers, which make up a large share of the world's poorest, provide up to 80% of the food supply in regions like Sub Saharan Africa and Southeast Asia, according to FAO. Various technology solutions aim to support these farmers, by increasing yields, improving livelihoods, and helping them grow nutritious food with regenerative practices. In addition to the innovations featured below, smallholders can also benefit from other solutions described in this chapter (such as crop science and bio-inputs) as well as efficient irrigation techniques described in SDG6.

Smallholder AgTech

While most ag-tech innovation focuses on large industrial farms, several new solutions cater to smallholders. Sweden-based Ignitia provides **hyper-local weather forecasts** to African farmers, which they can receive by SMS on a pay-as-you-go model. German firm Peat has developed Plantix, a mobile app using image recognition with machine learning to **identify crop diseases** and get recommendations on the spot. SoilCards, a spinoff of UK research firm Science Practice, offers simple and affordable paper tests for **DIY soil nutrient analysis.**

Smallholder FinTech

Only a quarter of the $200 billion financing needed by smallholder farmers is currently provided. To bridge that gap, FarmDrive (Kenya) uses mobile data and machine learning to offer an **alternative credit scoring system**, while **crowdlending** platforms Crowde (Indonesia) and FarmCrowdy (Nigeria) match farmers and individual investors. Smallholders also require weather protection to stabilize their income, which Kenya-based Pula provides through **data-driven crop and livestock insurance**—bundled with seed, fertilizer, credit, and other farm inputs.

Smallholder Networks

Platforms like M-Farm (Kenya) connect farmers them directly to buyers to sell their produce and optimize planting according to price trends. Others like WeFarm (UK) and Digital Green (India) offer communication and content platforms for smallholder farmers to share agricultural knowledge and learn how to improve yields.

Ensure sustainable food production systems and agricultural practices that increase yields, maintain ecosystems, build climate resilience, and improve land and soil quality *[2.4]*

During the 1950s and 1960s, the Green Revolution increased agricultural productivity worldwide and saved an estimated one billion people from starvation. Today its underlying practices—intensive monocultures and the use of agrochemicals—are among the top drivers of soil erosion, water pollution, biodiversity loss, and greenhouse gas emissions, all of which undermine agricultural productivity itself.

Meat and dairy consumption vastly amplify the issue, because of the land area required for animal-feed crops, methane emissions from ruminants, as well as the pollution, animal cruelty, and antibiotics associated with industrial livestock production. Overall, animal farming is a major cause of deforestation, climate change, water scarcity, and antibiotic resistance.

We split this part into two sub-targets: first, enabling the global transition to regenerative agricultural practices; second, developing new protein sources that are healthy, tasty and sustainable.

Photo: Trace Genomics

Theme 1: scale up regenerative farming practices

Data-Driven Regenerative Agriculture

Regenerative agriculture refers to a wide range of farming practices that restore soil organic matter and biodiversity, with the notable benefits of improving carbon sequestration (see SDG13) and water cycles, in addition to increased yields. As some of these farming methods rely on complex synergies between plants, animals, humans and natural ecosystems to reduce or avoid the use of chemical inputs, their development can benefit from **computer simulation and data analysis.**

For instance, the Sony Computer Science Lab is developing a method called synecoculture based on **complex systems science,** with the help of software and data tools including a biodiversity database, machine learning, and virtual farm management. The result is an ecosystem of more than 150 species in small parcels, with compelling ecological and economic outcomes in Burkina Faso and Japan.

Small Farm Robotics

The miniaturization of farm machinery provides cheaper and more sustainable alternatives to heavy tractors, which can **incentivize smaller farms as opposed to industrial ones.** In addition to reducing the use of chemical inputs, small farm robotics are lighter and do not crush soils, supporting the development of regenerative farming practices.

For instance, Small Robot Company's (UK) lightweight robot can feed and spray only the crops that need it, resulting in 95% less chemicals and 90% less energy use compared to heavy farm machinery. BlueRiver and Rowbot (US) offer similar features, while Naio (France) provides a range of weeding robots for vineyards and vegetable farms, and Agrobot (Spain) allows the robotic harvesting of strawberries. The EU-funded ROMI project is developing open-source robotics for polyculture farms, including a weeding robot, a crop monitoring drone and a 3D scanner for phenotyping.

Precision Agriculture (PA)

Precision agriculture aims to deliver higher yields with fewer agronomic inputs—seeds, fertilizers, pesticides, water—by applying the right amount where needed. This approach uses **data from environmental sensors, drones, satellites, and soil sampling** to perform predictive analytics and provide farmers with the right soil, crop and weather insights. Examples include Agrosmart (Brazil), Kilimo (Argentina), aWhere (US) and Parrot Airinov (France). Agricultural robots and self-driving tractors can also help apply inputs with **variable rate technology.**

Most PA vendors cater to industrial farms, and thus do not question issues associated with "conventional" farming. However, we can hope PA helps bend agrochemicals use and water consumption, in parallel to a shift toward regenerative agriculture.

Soil Microbiome Testing

Like our human bodies, the soil hosts millions of microbes which influence the health and growth of plants. California-based startup Trace Genomics helps farmers **understand soil microbiome through DNA testing**—the same way that 23andme does it for humans. Farmers can then take action based on their soil report, such as aligning crops to soil or adjusting their soil microbiome. Using machine learning on their entire database, Trace Genomics can reveal patterns and improve recommendations over time.

Biopesticides and Biostimulants

Biopesticides and biostimulants refer to the use of **biological processes to control pests and stimulate plant growth,** as opposed to chemical pesticides and synthetic nitrogen fertilizer.

For instance, Pivot Bio (US) and Azotic (UK) use genetically engineered soil microbes to **help plants fix nitrogen from the air,** instead of relying on synthetic fertilizers to deliver the nutrient. Micropep (France) uses natural peptides to boost plant growth and disease resistance, by increasing the levels of microRNA which **regulate gene expression.** Indigo (US) harnesses the microbiome of plants that live in harsh environments to develop **microbial seed coatings,** which increase **water use efficiency and drought resistance** in crops like wheat, corn, soybeans, rice, barley, and cotton.

On the biopesticide front, Pheronym (US) has developed a soil probiotic solution which uses **pheromones to attract nematodes**—microscopic roundworms—and direct them to fight off insects. Other examples include Elephant Vert (Switzerland) and Aphea.Bio (Belgium), both of which also develop a range of biostimulants.

"Indian startups developing sustainable inputs are now onboarding the networks which purchase the seeds, fertilizers, pesticides, farming equipment, etc. They are the ones with direct access to the farmers."

Vijay Nadiminti,
COO, a-IDEA Incubator

Gene-Edited Crops

In addition to microbiome engineering techniques described above, gene-editing could revolutionize agriculture by **improving crop yields, nutritional value, and resistance to disease and drought—**which could reduce the use of agrochemicals. As opposed to GMOs, gene-editing does not insert foreign DNA into crops but instead rearranges sequences of the plant genome in an "accelerated breeding" fashion, using a genetic "cut and paste" tool. Among those, CRISPR-Cas9 is currently the most popular because of its simplicity and affordability, among other techniques like TALEN and ZFN. The most prominent companies in this space include US-based Calyxt, Cibus, and Benson Hill Biosystems.

Theme 2: develop new protein sources

Plant-Based Meat

While meat substitutes like tofu and veggie burgers have been available for ages, their appeal has been limited to vegetarians. However, a new generation of companies is targeting carnivores and flexitarians with **products that look, feel and taste like the "real thing".** Backed by -Bill Gates and Leonardo DiCaprio, Beyond Meat (US) makes plant-based "burgers, sausages, and chicken strips" that are sold in the meat aisle. Seattle Food Tech (US) does "nuggets" for canteens, Right Treat (Hong Kong) focuses on "pork meat" for Asian cuisine, while Just (US) and NotCo (Chile) sell "egg and dairy products". The estimated environmental impact of plant-based meat is 10 to 100 times lower to regular meat.

Plant-based meat companies are driven by science and technology for **protein sourcing and isolation, product formulation, processing and distribution,** according to advocacy group Good Food Institute. They rely on AI, big data analytics, robotics, and advanced manufacturing, while scientists are **decoding the structure of meat to recreate it from plants.** One company stands out: Impossible Foods famously created a plant-based burger that "bleeds", thanks to a genetically modified yeast that produces heme protein, an iron-rich nutrient which is responsible for the color, smell and taste of blood.

"Industrial animal agriculture is destroying the world. There is no problem more urgent. Many people have cognitive dissonance when they eat meat and will quickly jump to sustainable alternatives once they're tasty, convenient, and affordable."

Seth Bannon,
Founding Partner at Fifty Years

Photo: Mosa Meat

Clean Meat and Cellular Agriculture

Despite the progress of plant-based meat, one can expect that many will still crave "real meat", for various cultural and religious reasons. Aimed primarily at this demographic, **clean meat—or cell-based meat—is produced from in-vitro cultivation of animal cells,** instead of slaughtered animals. It is part of the broader field of **cellular agriculture (cell-ag): agriculture products made from cell culture.** Examples include MosaMeat (Netherlands), Memphis Meats (USA), SuperMeat (Israel) and Integriculture (Japan) which all focus on beef and chicken. However there is now a or cell-ag versions for almost every animal product: Finless Foods (fish), Perfect Day (dairy), Clara Foods (eggs), and Geltor (gelatin) to name a few.

The first lifecycle analyses are encouraging: under the right conditions, clean-meat production could emit 10 to 20 times fewer greenhouse gases compared to regular meat, cut land-use by a similar factor, use less water and about as much energy. However, a recent Oxford study warns that *"the climate impacts of cultured meat production will depend on what level of sustainable energy generation can be achieved, as well as the efficiency of future culture processes."*

In five years, the estimated cost of a pound of clean meat dropped from $300K to a few hundred dollars. While it is a significant improvement, **achieving price parity will require substantial progress** on key technologies and processes, including the production and recycling of the medium used to grow cells. **Other concerns include regulation, consumer appeal, and product scaffolding**—to reproduce the texture of meat. The sector attracted high-profile investors, from billionaires Bill Gates and Richard Branson to meat giants Tyson and Cargill.

Insect Protein

From soy monocultures to feed cattle to the fishmeal used in aquaculture, animal-feed production plays a big part in the terrible environmental footprint of animal products. Several companies use large-scale **automated insect farms** to produce low-footprint protein feed, including Ynsect (France), Protix (Netherlands), and Agriprotein (South Africa). Additionally, insects offer potential as a protein ingredient for humans, such as flours and snacks like Hakkuna (Brazil). Livinfarms (US) makes insect farming equipment for professional and domestic use.

Algae Protein

Seaweed is another novel protein source with many health benefits and high nutritional value. Several entrepreneurs have developed various growing technologies for specific algae types, such as **spirulina**. One of the most notable examples is Energaia which makes rooftop farming kits in Bangkok, Thailand. US-based Triton chose another species of algae for bioproduction of proteins used in plant-based meat and milk.

Photo: Mosa Meat

Challenges

From intensive to regenerative ag-tech. Despite ag-tech's potential to reduce the environmental footprint of agriculture, very few innovators question the intensive monoculture model, which degrades soil health and biodiversity. To deliver on their promises to feed 10 billion humans sustainably, tech innovations like plant-based meat and precision farming need to converge with regenerative agriculture. This approach rests on a set of core practices like low/no-tillage, crop rotation, cover crops, perennial crops, and the limited use of agrochemicals—if any. Today these principles are applied at all scales and in a variety of farming systems, with promising results on yields and pest control, including carbon farming (see SDG13), agroecology, synecoculture (see above), and more.

Consumer appeal for animal-free diets and products. While a global and radical shift towards plant-rich diets is critical for "planetary health", consumer acceptance remains a big unknown. This holds in regions like the US, Europe, and Brazil with a long history of meat consumption that is rooted in culture, but also in emerging countries where the rising middle class is aspiring to the same standards of living. While weak signals indicate a possible shift toward reduced meat consumption per capita, the appeal for "lab-grown" clean-meat, "fake" plant-based meat, cricket snacks and algae smoothies, is far from being mainstream.

Avoiding the "Frankenfood" stigma. Although the World Health Organization and 90% of the world's scientists agree that GMOs are as safe to eat as conventional food, only a third of consumers agree. One explanation is that current GM "killer apps" are pesticide-resistant monoculture crops. While there is no clear consensus on whether GMOs increase or decrease pesticide usage, the connection remains problematic. Another reason is that agro-biotech monopolies like Monsanto have a history of shady practices and toxic products like DDT and Agent Orange. A third may be irrational fear: for instance as 80% of Americans also support the labeling of "food containing DNA"—which means every single product. This situation severely hinders the real potential of GM technology to serve life-changing applications, such as crops that are resistant to tropical diseases and droughts. It could also make it more difficult to build trust in better gene-editing techniques (see above). The world is already divided on how to regulate gene-edited crops: in the US they are treated like accelerated breeding, while the EU Court of Justice ruled in 2018 that such crops fall under GMO regulation. This decision could jeopardize adoption not only in Europe, but also among African farmers who export to the old continent.

Goal 3

GOOD HEALTH AND WELLBEING

Ensure healthy lives and promote well-being for all at all ages.

> Progress is not measured by national or global averages, but by how well the health of the poor improves. **If we miss the poor, we miss the point**
>
> ***DR. MARGARET CHAN,*** *FORMER DIRECTOR-GENERAL, WORLD HEALTH ORGANIZATION (WHO)*

1Million CHILDREN (AGED 5-14 YEARS) DIED IN 2016, MAINLY FROM **PREVENTABLE CAUSES**

WORLD HEALTH STATISTICS, 2018

12.6 MILLION DEATHS EACH YEAR CAN BE ATTRIBUTED TO **UNHEALTHY ENVIRONMENTS,** SUCH AS AIR, WATER AND SOIL POLLUTION, CHEMICAL EXPOSURES, CLIMATE CHANGE, AND ULTRAVIOLET RADIATION

WHO, 2016

Photo: rawpixels

Photo: LivingGoods

Tech for SDG 3

Good health is a human right. Still, many people around the globe do not have it guaranteed. In this section, we focus mainly on how technology can help achieve the global health targets of SDG3, improving access to doctors, medicine, and treatments. We also chose to feature selected scientific breakthroughs, but given the breadth and speed of innovation in the sector, we leave aside many developments.

End preventable deaths of newborns and children under five years of age, and reduce neonatal deaths *[3.2]*

Digital Health for Pregnancy and Childcare

According to WHO statistics, 2.6 million newborns died in 2016, and 15,000 children under five died every day that year. Though these deaths had multiple causes, better access to health information could have helped many families in the developing world to avoid them. Digital platforms and social networks focused on pregnancy and childcare have been popping up to address this issue, such as Healofy in India, GiftedMom in Cameroon, and MOBicure in Nigeria. Most use **mobile apps** aimed at pregnant women and infant mothers, enabling them to **monitor their child's health, and access parenting information and medical expertise.**

End the epidemics of AIDS, tuberculosis, malaria and neglected tropical diseases and combat hepatitis, water-borne diseases and other communicable diseases *[3.3]*

Genomic Vaccines

Standard vaccines consist of dead and weakened pathogens, as well as proteins derived from those microorganisms. Instead, genomic vaccines are made of DNA or RNA which, upon injection, enter human cells which then churn out the desired proteins. As industrial protein production is lengthy and expensive, this technology has the potential to make **cheaper and faster-designed vaccines,** while also targeting other diseases such as cancer. Moderna Therapeutics and Synthetic Genomics are two US biotech companies developing such vaccines.

Gene Drive

One of the early application proposals of gene-editing technique CRISPR-Cas9, gene drives aims to **spread genetic modifications** in an entire species population to **eradicate a communicable disease.** Supported by the Gates Foundation, the high-profile Target Malaria project seeks to achieve this among malaria-transmitting mosquitoes.

The stakes are paramount: on the one hand, every year malaria kills 300,000 children under five in Africa alone, and gene-drives could be a game changer. On the other, critics stress that **consequences** on natural ecosystems are **hard to predict,** and question the morality to use African countries as a “guinea pig”. Hence, although the technology is ready, scientists are proceeding very cautiously. As of February 2019, the mosquitoes have been released in a high-security lab in Terni, Italy.

Diagnostic Tech for Infectious Diseases

Though research still has a long way to go to understand the outbreak of infectious diseases, early diagnosis can help save many lives. At the intersection of AI, mobile and hardware innovation lie **new solutions for cheap, fast and non-invasive diagnostic.** Matibabu (Uganda) is a kit to better diagnose malaria, with a simple mobile application attached to a hardware “matiscope”. On the low-tech side, Stanford scientist Manu Prakash developed an ultra low-cost hand-powered centrifuge, made of paper, string, and plastic, that could revolutionize diagnostics.

Reduce premature mortality from non-communicable diseases, and promote mental health and well-being *[3.4]*

Diagnostic Tech for Chronic Diseases

New medical devices allow **non-invasive cancer diagnosis:** India-based iBreastExam can detect breast cancer with **tactile sensors,** while French company Damae Medical uses a new **optical technology** for skin cancer detection. In the future, machine learning may allow US startups Grail and Freenome to detect cancer through **liquid biopsies**—like a simple blood test. A low-cost approach more adapted to developing countries, echOpen is an **open-source echo-stethoscope** (ultrasound probe) connected to a smartphone. It allows cheap and fast preliminary diagnosis, to support a better orientation for further medical care.

Patient-Centered Healthcare

While traditional care happens mostly face-to-face with doctors, digital technologies enable new opportunities to provide patients with remote **follow-up, quality of life advice, and preventive care.** A pioneer is PatientsLikeMe (UK) which connects those with rare medical conditions together so they can share data and experiences.

Wefight (France) created a chatbot called Vik that helps cancer patients communicate with their doctor about the effects of their treatment. In Kenya, Baobab Circle provides those suffering from diabetes and hypertension with personalized insights, and the support of doctors and nutritionists on their mobile phone. Finally, Italian startup Tommi offers VR experience to support children in hospitals undergoing painful and stressful medical treatments.

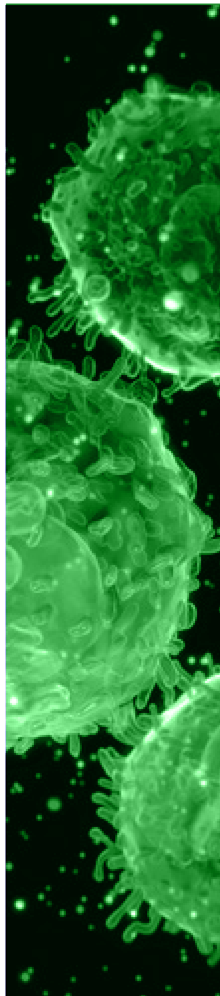



Photo: Open Bionics

Data-Driven Epidemiology

Despite the short-lived Google effort to predict flu and dengue outbreaks based on search queries, new data-driven approaches could bring a revolution in epidemiology—the study of the incidence, distribution, and control of disease in a population. Co-hosted by the Senseable City Lab and the Alm Lab, the MIT Underworlds project uses **sewage data to monitor urban health patterns** in near real-time and with a fine spatiotemporal resolution. The first application focuses on infectious disease surveillance and outbreak prediction.

Achieve universal health coverage, including financial risk protection and affordable access to quality essential healthcare services, medicines and vaccines *[3.8]*

Digital-Enabled Last-Mile Healthcare

The **last-mile delivery of essential services,** including healthcare, is one of the most significant challenges in global development. While mobile health can undoubtedly play a role, impactful innovations lie at the **intersection of online and offline.** For instance, Living Goods (US) delivers life-saving products to the doorstep of the poor in East Africa, thanks to a network of local entrepreneurs called "health promoters". Each of them gets basic medical supplies, as well as a smartphone loaded with **diagnosis and pregnancy apps.** In India, eVIN—the Electronic Vaccine Intelligence Network—developed a real-time information app on **vaccine stocks and flows.** The whole immunization supply chain is reinforced, especially for last-mile healthcare workers.

3D Printed Prosthetics

3D printing enables **low-cost and personalized prosthetics** for people with disabilities or amputated members. Social enterprise Andiamo (UK) offers custom-fitted orthoses for children within 2-weeks. Open source firms Open Bionics (UK) and MyHumanKit (France) developed prosthetics for upper-limb amputees, whose open blueprints can be further optimized by a worldwide user community. 3D printed prosthetics can be essential to improve the livelihood of war-wounded people and refugees, which are the focus of Jordanian NGO Refugee Open Ware.

Emerging "platform technologies" which are not linked to any specific SDG target but could support new developments

Regenerative Medicine

A promising field in biotech-based medical innovation, the goal of regenerative medicine is to make it possible to **produce artificially any organ with stem-cells engineering.** US-based Epibone is working on artificial bones, while Prellis Biologics is developing an organ production technology platform, enabled by the printing of blood capillaries.

Microbiome Therapies

A better understanding of the human microbiome has unleashed a wave of biotech innovation in the last decade. Indeed, harnessing the wide array of **micro-organisms that live within our bodies** could allow us to manage health and treat diseases more effectively.

Microbiome-based therapies could also help fight off **superbugs**, which developed a **resistance to antibiotic**s that we have overused—an issue which may kill 10 million people a year by 2050, more than cancer. French startup Eligo is creating CRISPR-enabled phages (viruses) that tell harmful bacteria to make fatal cuts to their DNA, without impacting other microbes like antibiotics do. The head of Institut Pasteur has said this technology could be *"as important as the discovery of penicillin."*

Nanomedicine

Nanotechnology creates new opportunities for diagnosis, treatment, and drug supply chains. For instance, Nanoly Bioscience (US) encapsulates polymers that **shield vaccine proteins against degradation,** allowing safe transportation until the point of care. For cancer radiotherapy, Nanobiotix (France) has developed nanoparticles that accumulate in cancer cells and **magnify radiation within tumor cells** without causing additional damages in surrounding healthy tissues.

Precision Medicine and Big Data for Medical Research

At the intersection of **life sciences, bioinformatics and data analytics,** the emerging field of precision medicine can be defined as *"the effort to collect, integrate and analyze multiple sources of data in order to develop individualized insights about health and disease."* While the vision remains long-term, a first step is to **understand diseases through the lens of patient typologies**, including their environment.

Current endeavors focus on building large databases for medical research. Data sources range from **genetic information** to **medical records** and **health tracking devices.** While companies like Fitbit and 23andMe already own huge datasets, new comprehensive efforts have emerged. Examples include the NYU Human Project which is collecting the data of 10,000 New Yorkers, as well as Verily's Project Baseline—both Verily and 23andMe being subsidiaries of Alphabet, Google's parent company. In mental health, new data-driven efforts like the German-Belgian project AETIONOMY attempt to compensate a 70% cut in psychiatric medicine research since 2006. On a broader scale, the Human Cell Atlas project aims at **mapping all human cells** for medical research.

As noted by research group data&society, such endeavors raise concerns as **bias could arise** both in datasets and the outcome—see chapter 4 of this report for more on machine bias.

Challenges

Ensuring the safety of gene-editing. To maximize the positive outcomes from gene-editing, scientists need to precisely and carefully evaluate its consequences on humans and ecosystems. Concerning CRISPR, the most popular gene-edited technology at the moment, Nature magazine withdrew in March 2018 a previous controversial paper which had found off-target effects in mice, due to lack of reliable data to confirm the claims. However, more work is needed to assess in-vivo use, especially when CRISPR babies are now a reality in China, and the development of gene-drive on malaria mosquitoes is getting closer to public launch.

Privacy and control over health data. Digital health records raise serious concerns around sensitive patient data. A case in point is the debate over the security of Australia's My Health Record, as well as the 2018 hack of Singapore's largest healthcare provider, during which the data of 1.5 million citizens were stolen, including the Prime Minister. A related concern is the monetization of patient data as precision medicine rises to prominence—with 23andMe receiving a $300 million investment from pharma giant GlaxoSmithKline. Interesting responses include Estonia's use of a blockchain to secure medical records, and initiatives helping citizens to retain control over their data during its use. For instance, SalusCoop (Spain) is a citizen cooperative of health data, which facilitates sharing for medical innovation that serves the common good. Supported by famous geneticist George Church, Nebula Genomics (US) aims to compensate users with a cryptocurrency when their genomic data contributes to private pharmaceutical research.

Photo: James Gathany, Judy Schmidt, USCDCP

Fake news and the anti-vax threat. The reluctance or refusal to vaccinate despite the availability of vaccines now ranks among the top 10 threats to global health according to the WHO, alongside ebola, HIV, air pollution, and antimicrobial resistance. The situation is acute across Europe and the US, which now experience a resurgence of measles outbreaks. Social media, messaging apps and video sharing websites have been massive purveyors of the fake news, dubious research and conspiracy theories fueling the so-called anti-vax movement, and tech firms are only starting to grapple with the situation.

Healthcare systems on the brink of failure. In many parts of the world, the expensive novel therapies entering the market, combined with an aging society and higher rates of non-communicable diseases—such as cancer, Alzheimer's, and depression—will make national healthcare budgets even harder to balance. There is a case for a future-proof healthcare system. Although more real-world data on treatment efficiency is needed to optimize costs, governments and industry players will also have to agree on how to share these costs in the future.

Goal 4

QUALITY EDUCATION

Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.

6 OUT OF 10

CHILDREN AND ADOLESCENTS, OR 617 MILLION WORLDWIDE, ARE NOT LEARNING (I.E. NOT ACHIEVING MINIMUM PROFICIENCY IN READING AND MATHEMATICS), EVEN WHEN THEY ATTEND SCHOOL

UNESCO INSTITUTE OF STATISTICS, 2017

UP TO 100 YEARS:

THE TIME FOR CHILDREN OF POOR FAMILIES TO CATCH UP TO **THE LEARNING LEVELS** OF THE RICHEST, ON CURRENT TRENDS

BROOKINGS INSTITUTION, 2017

> One child, one teacher, one book, and one pen **can change the world**
>
> ***MALALA YOUSAFZAI,*** *NOBEL PEACE PRIZE*

Photo: epicurean

Photo: Dext Technology

Tech for SDG 4

As influential Brazilian educator Paulo Freire stresses in his masterpiece Pedagogy of the Oppressed, *“Liberating education consists in acts of cognition, not transferrals of information.”* With the profound changes technology brings every aspect of society, it is essential to ensure the best and most inclusive education and lifelong learning opportunities for all. Below are some examples of technology enablers.

Ensure that all girls and boys complete free, equitable and quality primary and secondary education leading to relevant and effective learning outcomes *[4.1]*

Digital Classrooms

EdTech is a flourishing sector, with numerous initiatives to digitize the classroom. Indian charity Meghshala uses mobile apps to equip public school teachers with **multimedia lessons,** in English and vernacular languages. Rumie (Canada) provides students in 20 countries including Liberia, Syria, and Guatemala with **affordable tablets** to access to community-curated content. Through progress monitoring, Literator (US) and Lalilo (France) empower teachers to **personalize literacy education**—helping children to learn how to read at their own pace.

Taking the concept to the extreme, Bridge operates a **network of low-cost private schools,** which use technology to streamline education for the world’s poorest children. Backed by top Silicon Valley investors, it already operates in Kenya, Uganda, Nigeria and Liberia, with the same recipe: teachers follow scripted content from a tablet, while all administrative tasks are automated. The company outperforms national averages for learning outcomes, but critics point to the limits of scripted learning—it cannot teach critical thinking—and question the ethics of making the poor pay for basic education.

In another singular approach, Endless OS is a **free PC operating system** that comes loaded with over **100 free apps and tools** featuring educational content. It was designed to democratize knowledge and computing in the classroom and at home, even in areas with no internet access. The company makes money by selling its own computers, and solutions for business and government.

"How do we upskill teachers so they can inspire the next generation? What we do helps teacher run an excellent class, which excites students. The students then motivate the teacher and we have a virtuous cycle. This kind of scalable solution can have a huge footprint: increasing education levels in the Global South, while raising awareness on issues like climate change, overfishing, and world peace."

Jyoti Thyagarajan,
Founder and Trustee, Meghshala

Learning by Making

Many initiatives aim at democratizing **hands-on experiments** in the science class and beyond, expanding the realm of technical skills children can learn, including in places where such courses were not available. Classroom examples include the biology kits from Amino Labs (US), the electronics equipment from Dext (Ghana), and the experiment guiding apps from Lab4Physics (Chile). Beyond the classroom, the DIY mecca Maker Faire has always targeted "maker kids" as a primary audience, while many Fab Labs and Fab Cafés run maker education for children.

Data-Driven Education Policy

UNICEF is on a mission to **map every school in the world,** which could help better assess the digital divide and support governments in defining education policies and investment priorities. In addition to official census data, the UN agency relies on **crowdsourcing** via OpenStreetMap, as well as a new tool using **deep learning** to identify missing schools on high-resolution **satellite imagery.** The system relies on Magic Box, UNICEF's collaborative data sharing platform which combines datasets from the public and private sector to generate insights.

Increase the number of youth and adults with relevant skills for employment, decent jobs and entrepreneurship *[4.4]*

Digital Platforms for Lifelong Learning

According to the WEF Future of Jobs report, 35% of the core skills in most occupations will have changed between 2015 and 2020. As automation is expected to displace many jobs in the coming years, learning will evolve from something that happens once to a lifelong journey. Digital platforms for **personalized learning** will be instrumental in that transition.

Massively Open Online Courses have pioneered that space. Global MOOC brands Coursera and EdX partner with **universities** to bring their courses online—from free enrollment to paid Master's degrees. Udacity (US) and OpenClassRooms (France) focus on **vocational training** to upskill professionals with tech and business skills in high demand. Others include CodersTrust (Bangladesh) and Platzi (Colombia). Finally, while it does not define itself as a MOOC, Khan Academy has been offering free video lessons on most academic topics since 2008.

Mobile apps with downloadable lessons can be critical enablers in low-income countries, such as Eneza which provides offline mobile courses for five million Kenyans. **Mentor-matching platforms** can also bridge the gap with the need for face-to-face interaction, such as LearnX (Thailand) which focuses on English courses.

Gamified Learning

The use of "serious play" in pedagogy is not new, but an increasing number of edtech platforms rely on gamification to improve learning outcomes. One of the most famous examples, Duolingo helps 300 million users learn a new language, among the 85 offered, using its gamified mobile app. Brilliant (US) offers **guided problem-solving courses** in math, science, and engineering, for STEM learners and teachers in search of interactive learning experiences. Geekie (Brazil) helps schools increase student motivation and learning, thanks to **gamified courses** and tests combined with personalized learning journeys.

Coding Bootcamps and Schools

While online education enjoys success, it can hardly replace live interaction with a teacher and other students. For vocational training, the **bootcamp model** can fill the gap between MOOCs and university. Typical coding bootcamps deliver intense programs in small classes, over 8 to 12 weeks, teaching you enough to become a junior programmer. The most successful ones have scaled internationally thanks to a proprietary content platform, such as French-born LeWagon which operates in 30 cities around the world, with tuition fees ranging from 4,000 to 8,000 euros.

As this price point can be out of reach for disadvantaged populations, certain players provide **free or subsidized courses.** In Brazil, Mastertech offers scholarships with the support of its **corporate clients and partners,** including Facebook, whose local incubator Estação Hack also hosts free coding classes for women taught by Reprograma. In the US, Pursuit offers free courses to high-potential students, by taking a **12% fee of any future income above $60,000** during the first 3 years post-program.

Finally, several **tuition-free, innovative coding schools** have emerged in recent years. Founded in 2013 by French billionaire Xavier Niel, 42 trains students in 2 to 5 years without any teachers, and is funded by companies in need of top talents. The school **selects students via online logics tests and video interviews,** with no previous diploma required. Andela adapted the model for Africa, hiring students on a 4-year contract and making money through outsourcing operations for US tech firms.

Ensure all learners acquire the knowledge and skills needed to promote sustainable development *[4.7]*

Empathetic Technology

Immersive VR experiences can be a powerful way for children to engage with science: taking a bus to Mars to learn about space or visiting the Amazon rainforest to understand biodiversity and climate change. Research also shows **VR can generate empathy** by putting oneself in someone else's shoes, be it refugees or victims of sexual assault.

Empathy can also be generated by **chatbots** like Yeshi the Ethiopian girl, who walks you along her daily two-hour journey to collect water. **Video games** are another powerful medium: for instance, Never Alone won many awards for restoring confidence and fighting depression among the Alaskan indigenous population, while bringing revenue to the community.

Photo: Olabi

Challenges

Starting with the learning model, not technology. Michael Horn from the Christensen Institute estimates that it is critical to *"focus on the learning model first, followed by the technology in service of that learning model. Initiatives that start with the technology almost always fail"*. The One Laptop Per Child project was a case in point, as discussed in Chapter 2.3 of this report. To measure the success of learning models *"we need a clear goal and outcome of education,"* according to Viria Vichit-Vadakan from Thai lifelong educator Learn Corp.

Photo: Nikhita S

Skills for the 21st century. In its 2018 Leapfrogging Inequality report, the Brookings Institution estimates that today's biggest education challenge is to simultaneously address both skills inequality and skills uncertainty, especially in developing countries. As the author writes, *"the current ways of helping schools better reach and teach the most marginalized often reinforce the education structures that hold students back from developing the breadth of skills they need for 21st-century life."* Generally, soft skills like collaboration, creativity, critical thinking and problem-solving are often regarded as the most important to thrive in the future.

Should education be entirely personalized? While this is already technically feasible on a basic level, this vision could go as far as an AI-powered intelligent tutor taking the role of a personal teacher. In her paper about this trend, Monica Bulger from Data&Society sees benefits but concludes that *"the expectations and goals of personalized learning may not necessarily match the interests of students, parents, teachers, or even society."* EdTech innovators should thus include all stakeholders in the definition of success, and carefully measure the psychological impact on students.

EdTech and educational institutions. As François Taddeï, Director of the Paris-based Center For Research and Interdisciplinarity (CRI) reminds: *"MOOCs and other EdTech innovations won't be enough to prepare the youth for the challenges the world is facing. Educational institutions need to become learning ecosystems to support a learning society. Initial training should focus on how to learn, how to solve problems creatively and collaboratively. Then lifelong education can transmit new skills throughout our lives based on new knowledge produced by research."*

Goal 5

GENDER EQUALITY

5 GENDER EQUALITY

Achieve gender equality and empower all women and girls.

23% = GENDER PAY GAP WORLDWIDE

UNWOMEN, 2018

1 OUT OF 3 WOMEN WORLDWIDE HAVE EXPERIENCE PHYSICAL AND/OR SEXUAL VIOLENCE IN THEIR LIFETIME

WHO, 2017

"Culture does not make people. **People make culture.** If it is true that the full humanity of women is not our culture, then we can and must make it our culture"

CHIMAMANDA NGOZI ADICHIE, *BESTSELLING AUTHOR*

Photo: Giacomo Ferroni


Photo: Martin Vorel

Tech for SDG 5

While gender equality has progressed in recent years, the gap remains enormous. Globally, 50% more girls than boys are out of school, the gender pay gap stands at 23%, women hold only 24% of parliamentary seats, and gender-based violence remains a "global pandemic" according to UN Women. The solutions featured below respond to SDG5 targets. Additional efforts toward gender equality can be found in SDG4, SDG6, SDG8, SDG10, SDG11, and SDG16

Eliminate all forms of violence against all women and girls in the public and private spheres, including trafficking and sexual and other types of exploitation *[5.2]*

Urban Safety Devices

Most women living in cities do not feel safe walking around alone, as they face daily harassment and the risk of being robbed, assaulted, or worse. Several tech-enabled initiatives aim to reduce the threat level, which is especially acute in the mega-cities of the developing world. For instance, **crowdsourced navigation systems** like HarassMap (Egypt), Safetipin (India) and Amble (UK) **help identify the safest routes.**

Other apps enable women to **send an SOS alert** to their contacts when facing a stressful situation, including Watch Over Me (Malaysia), and Kitestring (US). As taking out your phone can be difficult under certain circumstances, some companies offer **wearables** like the Safelet bracelet (Netherlands) or the ROAR for Good tracker (US). Sadly, the price point of some of these systems is not yet accessible to all.

Secure Reporting of Sexual Offenders

Targeting college campuses and offices, Callisto (US) empowers survivors with options for **reporting sexual assault in a way that feels safe.** The non-profit uses a secure matching system to connect victims of the same perpetrator and thus identify repeat offenders faster.

Ensure universal access to sexual and reproductive health and reproductive rights *[5.6]*

Female and Reproductive Health Tech

Cultural barriers and taboos still prevent many girls and young women in the global south from accessing information on puberty and reproductive health. Though not solving the root causes of the problem, technology can help **access information without embarrassment.** Aurat Raaj is an AI chatbot that answers the daily questions of Pakistani girls and women, based on the feminist heroine of an animated web series.

Embarrassment and the lack of appropriate menstrual hygiene items can lead girls to drop out of school during their period, potentially leading to early marriage. SaathiPads has created **bio-based sanitary pads** which are comfortable, affordable, and sustainably produced from banana waste fiber by rural women workers. In advanced economies, the femtech market is dominated by apps and devices for **period tracking and habit-building**, such as Cue (US) and B-Wom (Spain). However, many have expressed concerns over how some of these apps monetize very personal data.

Enhance the use of enabling technology to promote the empowerment of women *[5.B]*

Digital Skills For Women

The UN Women 2018 Report found that the gender pay gap stands at 23% globally and that without decisive action, another 68 years will be necessary to achieve equal pay—even 217 years according to WEF. Furthermore, women are more likely to be employed in low-skill jobs and remain a minority among STEM students. Therefore both UNCTAD and WEF expect that **technological progress may amplify gender gap dynamics,** as women will be more affected by automation and in a less favorable position to reap benefits from technology.

Photo: allWomen

One way to break this vicious circle is to prepare girls and women for the jobs of the future, of which 90% will require ICT skills according to ITU. In-person courses and online platforms have popped up around the world to **equip women with digital skills**, such as Peru-born Laboratoria across Latin America, AllWomen (Spain) and Google-backed Womenwill in India, Indonesia, Japan, Brazil and Mexico. Girls In Tech and the Technovation challenge are examples of global communities supporting the careers of women in technology. At a younger age, **educational games** like Erase All Kittens (UK) can help spark girls' interests for coding.

"The more diverse your group is, the more it will be able to tackle a diverse range of problems."

Carolina Hadad,
Co-Founder of Chicas en Tecnología

Tech-Enabled Workplace Equity

Equipping women with future skills will not be sufficient if the workplace remains inequitable. Several HR Tech startups like Blendoor and Pipeline in the US **help employers improve gender equity** and their bottom line at the same time. They achieve this by **removing unconscious biases** from the hiring process through **semi-automated processing**, or using AI to identify concrete action plans in HR policy. Meanwhile, in countries like Pakistan socio-cultural barriers restrict female doctors at home, a dire situation that DoctHERs bypasses by connecting them with the many patients facing underserved medical needs in the country.

Photo: Olabi

Challenges

The need for a deep cultural shift. While digital solutions, policy and behavior change all have a role to play, gender equity requires profound cultural change. Even in countries with strong women rights, the rape and harassment culture is still a reality, as the #MeToo movement illustrated. Digital platforms can help put the issue under the spotlight, but long-lasting change will require a shift in the way we educate boys around the world.

Overcoming social barriers, especially in the developing world. Those include the education gap between young girls and boys, as well as the digital gender gap in which low-income women generally enjoy less access to the internet and its benefits, compared to men. Other social barriers include the need for gender-neutral toys, to stimulate all children toward all life and career paths, as well as the need for female role models in roles that have been historically dominated by men, such as technology and science jobs as well as positions of power.

Gender and diversity challenges in the tech industry. Studies on female engineers' work satisfaction and reasons for departure generally point to an unwelcoming workplace, including lower compensation, poor working conditions, and a lack of recognition. We further discuss these issues in Chapter 4.

"Women's empowerment with technology should not be considered an afterthought or side effect. For true gender equality in the digital age to be realized, gendered considerations must be at the heart of all tech and policy work"

Nanjira Sambuli,
Senior Policy Manager at the World Wide Web Foundation

Goal 6

CLEAN WATER AND SANITATION

Ensure availability and sustainable management of water and sanitation for all.

NEARLY 1000 CHILDREN DIE EACH DAY DUE TO PREVENTABLE **WATER AND SANITATION-**RELATED DISEASES

UNDP, 2016

1/2 PERSON WILL LIVE IN A **WATER-STRESSED AREA** IN 2025

UNICEF / WHO, 2017

2 BILLION PEOPLE DRINK **CONTAMINATED WATER**

UNICEF / WHO, 2017

> At the **beginning of all humanity is water**. At the beginning of all dignity, health, education, development. In the order of priorities, nothing precedes access to water
>
> ***ERIK ORSENNA,*** *MEMBER OF THE ACADÉMIE FRANÇAISE*

Photo: Abigail Keenan

Photo: Desalitech

Tech for SDG 6

Most solutions to SDG6 targets involve **water purification processes, which aim to remove contaminants and suspended solids and gases, to produce water fit for a specific purpose:** drinking, irrigation, industry, and residential use. The many available purification methods are used in various combination, depending on the water source: groundwater, surface water, seawater, wastewater.

Water purification technologies rely on physical, chemical and biological processes. Physical processes such as filtration, distillation, and adsorption use forces like gravity and barriers to disinfect water. Chemical processes, including chlorination, flocculation, UV light, and oxidation, are used for disinfection and the removal of heavy pollutants. Finally, biological processes aim to reproduce the degradation that naturally occurs in rivers and lakes; they happen within human-made bioreactors or as part of natural treatment systems.

Mapping all these techniques would extend well beyond the scope of this report, especially as new ones continuously emerge—membrane innovation, microbial fuel cells, nanotechnology, and nature-based solutions. The curious reader can dive into sources like the World Water Development annual thematic reports from UN-Water, the science and technology whitepaper from the 7th World Water Forum, and the SoScience Future of Water report.

Nevertheless, the few examples listed below illustrate the role of science and technology to achieve SDG6. Additional solutions are featured in the SDG2, SDG9, and SDG11 sections.

Achieve universal and equitable access to safe and affordable drinking water for all *[6.1]*

Groundwater Pumps

Groundwater is still the most important source of freshwater globally, providing drinking water for 2 billion people and irrigation for most of the world's food supply. Proven solutions to extract water from the ground include solar pumps like Futurepump (UK), and new systems appear regularly. For instance, **smart water pumps** developed at Oxford can predict failures and estimate groundwater levels, while US nonprofit One Million Wells came up with an innovative **low-cost drilling** technology, which is being implemented in India. Nevertheless, groundwater pollution and overdraft pose **high risks of water scarcity** in many regions, which calls for sustainable water management (see Target 6.4) and the exploration of alternative water sources illustrated below.

Desalination

As 97.5% of all water on Earth is salt water, desalination is often considered as the holy grail of freshwater. Existing methods are **energy-intensive** but technological breakthroughs could be within reach. Israel is home to global leaders in traditional utility desalination like IDE Technologies, and startups like Desalitech which uses an improved reverse osmosis (RO) membrane with energy recovery. Anfiro (US), DeMem (Singapore) and Nereo (France) are also working on **advanced membrane technologies** which could bring efficiency to another level.

Decentralized solar desalination is a promising new segment. According to a 2016 DFID report, the main approaches include: (i) solar-powered RO like Mascara (France) and Elemental Water Makers (Netherlands), (ii) adsorption desalination, which uses evaporation together with adsorbent material, (iii) membrane distillation, in which thermal distillation is combined with a porous membrane, and (iv) seawater greenhouse desalination, which is used by companies like SundropFarms (Australia) to grow vegetables in arid regions. Meanwhile in Israel, Tethys produces modular kits for evaporation-based solar desalination, which can be stacked together to fit the needs of the served community.

Sundrop Farms. Photo: Mansouraboud68

Atmospheric Water Harvesting

While rainwater harvesting has been around for ages with rooftop and on-farm collections, an emerging method consists in extracting clean water directly from the atmosphere. **Fog and dew collectors** make sense especially in (semi-)arid, (sub-)tropical and mountainous regions, where fog and dew are abundant. Modern collector technology has been pioneered by Californian nonprofit FogQuest, with a pilot in the Chilean Andes, and German company Aqualonis, with a pilot in Morocco.

Atmospheric water generators (AWGs) are high-tech devices which extract water from humid ambient air, and could work under most climates. Israeli company Watergen makes AWGs for different scales of use, three times more efficient than existing alternatives. US-based Zero Mass Water created an 'Hydropanel' which uses sunlight and air to produce the equivalent of 12 to 20 bottles a day.

Point-of-use Water Purification

Where adequate water supply does not exist, point-of-use purification is essential, and thankfully many proven solutions already exist. Looking like a small suitcase, Solvatten (Sweden) uses the **heat and UV light** from the sun to purify water from pathogens in only a few hours. Faircap (Spain) is a **personal membrane filter** that can be screwed on any bottle. The Wata system developed by the Antenna Foundation (Switzerland) can create chlorine on-the-spot via a low-cost electrolysis device. The Spouts Purifaaya (Uganda) is a low-cost **ceramic filter** made from local materials.

High-tech solutions can help remove the hardest contaminants like arsenic, fluoride, iron, etc. For instance, Drinkwell (India) uses a nanoparticle-enhanced RO membrane, and the SolarBag by Puralytics (US), relies on a photochemical process activated by sunlight and enhanced by a nanomaterial. These new companies often have several business models corresponding to different products (portable, household, community-sized units) or customers (e.g. corporates).

"Reverse osmosis can lose most of water during purification. And in India, a third of clean water is lost in the utility infrastructure. This is where innovation is needed: how do we make these systems more efficient?"

Priya Balijepalli,
Sustainability and Foundation Manager, Autodesk India

Achieve access to adequate sanitation and hygiene for all and end open defecation *[6.2]*

Waterless Toilets

According to data from WHO and UNICEF, three out of five people do not have access to safely managed sanitation, and 12% still practice open defecation. The issue primarily affects women, as well as children under five who die or get sick from water-borne diseases. As a large part of the urbanizing world lacks sewage systems, **waterless solutions** could be game-changers. For instance, the Tiger Toilet, a low-tech vermicomposting toilet piloted by the ITT in rural India, and concepts like the MYCOmmunity Toilet, designed for refugee camps and featuring a compostable tank made from mycelium mushroom.

Since 2011, the Gates Foundation's Reinventing The Toilet Challenge has granted millions to waterless toilets projects for households, such as the Nano Membrane Toilet. The self-contained system separates water from human waste and turns remaining solids into gas and energy to power itself. The prototype is expensive, but the British inventors hope to drive down costs with local manufacturing and a pay-as-you-go model, with local entrepreneurs in charge of maintenance. This **"pay-as-you-go meets the circular economy"** idea is at the heart of decentralized utilities like Sanivation in Kenya, which operates container-based household toilets and collects the human waste to turn it into fuel briquettes.

Improve water quality by reducing pollution, eliminating dumping and minimizing hazardous releases, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse *[6.3]*

In its 2017 annual report, UN-Water breaks down the wastewater cycle in four stages: prevention of pollution at the source, collection & treatment, water reuse, and resource recovery—energy, nutrients and byproducts. This report covers the first stage across SDGs 2, 9, 11 and 12, and the last three ones below. For this, we look at the two main scales of wastewater treatment: centralized utilities and decentralized systems.

Circular Wastewater Utilities

UN-Water sees a key development in *"the paradigm of wastewater management shifting from 'treatment and disposal' to 'reuse, recycle and resource recovery'."* Depending on the treatment, reclaimed water can be used for industry, in agriculture (40% of Israeli irrigation comes from wastewater), or to recharge aquifers. It can even be used to produce drinking water, as in the Windhoek plant in Namibia and the NEWater system in Singapore. These reclaimed water systems rely on many of the purification processes introduced at the beginning of this chapter.

Wastewater can be an efficient and sustainable source of nutrients, energy—heat, biogas, hydraulic—and by-products. For instance, wastewater-derived nitrogen and phosphorus can be used in the production of fertilizer. Microalgae-based processes can help capture high-value by-products and turn them into aviation fuel, cosmetics, and bioplastics, such as those produced by the Italian firm Eggplant.

Finally, **nature-based solutions** use or mimic natural processes to enhance water availability and quality while reducing flood risks. For instance, Agua Inc combines plant-based phytoremediation—the use of living plants to clean water and absorb contaminants—with a bacteria which breaks down the remaining nutrients. The system needs no electricity, no chemicals, and requires simple maintenance.

Decentralized Wastewater Treatment (DEWATS)

DEWATS are low-cost solutions which combine on-site and cluster systems, intended to serve individual houses, scattered communities, and rural areas. Born at Cornell University, AguaClara is a social enterprise that designs no-electricity, **gravity-powered water treatment systems** for low-income communities, with a pilot plant in Honduras. Their designs rely on simple chemical and physical processes like flocculation, sedimentation, and sand filters.

Substantially increase water-use efficiency across all sectors, ensure sustainable withdrawals of freshwater *[6.4]*

Water-Use Efficiency

Agriculture and industry—including energy generation—account for 70% and 20% of freshwater withdrawals according to UN-Water data, with industry using a larger share in developed economies. Water-use efficiency is thus a low-hanging fruit to prevent water scarcity.

In agriculture, solutions fit into three broad categories. First, **efficient irrigation systems** like drip irrigation (SunCulture, Kenya) and closed-loop systems for urban farming. Second, **precision agriculture** to optimize water-use; and third, **new protein sources** with a lower water footprint than animal products (see SDG2).

Industrial water-use efficiency solutions (see SDG9) are more diverse but fit broadly into four groups: shifting to **materials and energy sources** with less embedded water; **water-efficient design and manufacturing**; on-site **water recycling**; and **monitoring platforms** to prevent leaks and continuously optimize consumption.

Water Supply Management

Technology can help municipalities and utilities manage their water supply efficiently. **Monitoring platforms** like Takadu (Israel) and Apana (US) can detect leaks, faulty assets, and operational failures while enabling predictive analytics. Israel-based Utilis uses **satellite imagery to detect leaks** from space. In Chile, Capta Hydro provides a **telemetry and automation platform** to manage water distribution in river basins and irrigation canals. US-based SweetSense deploys **low-cost remote sensors** to improve the transparency and efficiency of water and sanitation programs in the developing world.

Water-tracing is another emerging technology, in which invisible, environmentally-friendly "tracer" particles encapsulate DNA sequences that **fingerprint the water**, allowing to monitor its flow and characteristics like temperature, pH, and composition. Examples include Swiss startup Haelixa—spun off ETH Zurich—and an Australian research project which looks at how mining and subsurface engineering affect groundwater quality.

Challenges

The food-water-energy nexus. As UN-Water writes: *"The inextricable linkages between these [three] critical domains require a suitably integrated approach to ensuring water and food security, and sustainable agriculture and energy production worldwide."* Aquifers are already highly depleted in the driest regions with intense irrigation like India, Pakistan, Mexico, and US Midwest, a situation which could also soon affect Africa and Eastern Europe. Consider solar pumps, which allows to pump water for irrigation in dry climates: when farmers view solar energy as free, over-irrigation can deplete aquifers and lead to water scarcity. An interesting response in the Indian state of Gujarat incentivizes farmers to sell excess power back to the grid, providing a triple win: preserved freshwater, income for farmers, and additional electricity for the local state.

"There is a lack of appreciation for how natural ecosystems support human ecosystems. You cannot aim for positive impact in only one area, ignoring negative outcomes in others. The food-water-energy nexus is a clear example of this: entrepreneurs need to think holistically, with interdisciplinary approaches."

Fumiko Kasuga,
Global Hub Director for Japan, Future Earth

Technology breakthroughs needed. Massive roadblocks remain to purify water sustainably and cost-efficiently. Existing desalination plants use massive amounts of energy, often derived from fossil fuels, and decentralized RO systems can waste as much as 95% of the water entering the system, because of insufficient pressure.

Photo: Simone Wenth

Goal 7

AFFORDABLE AND CLEAN ENERGY

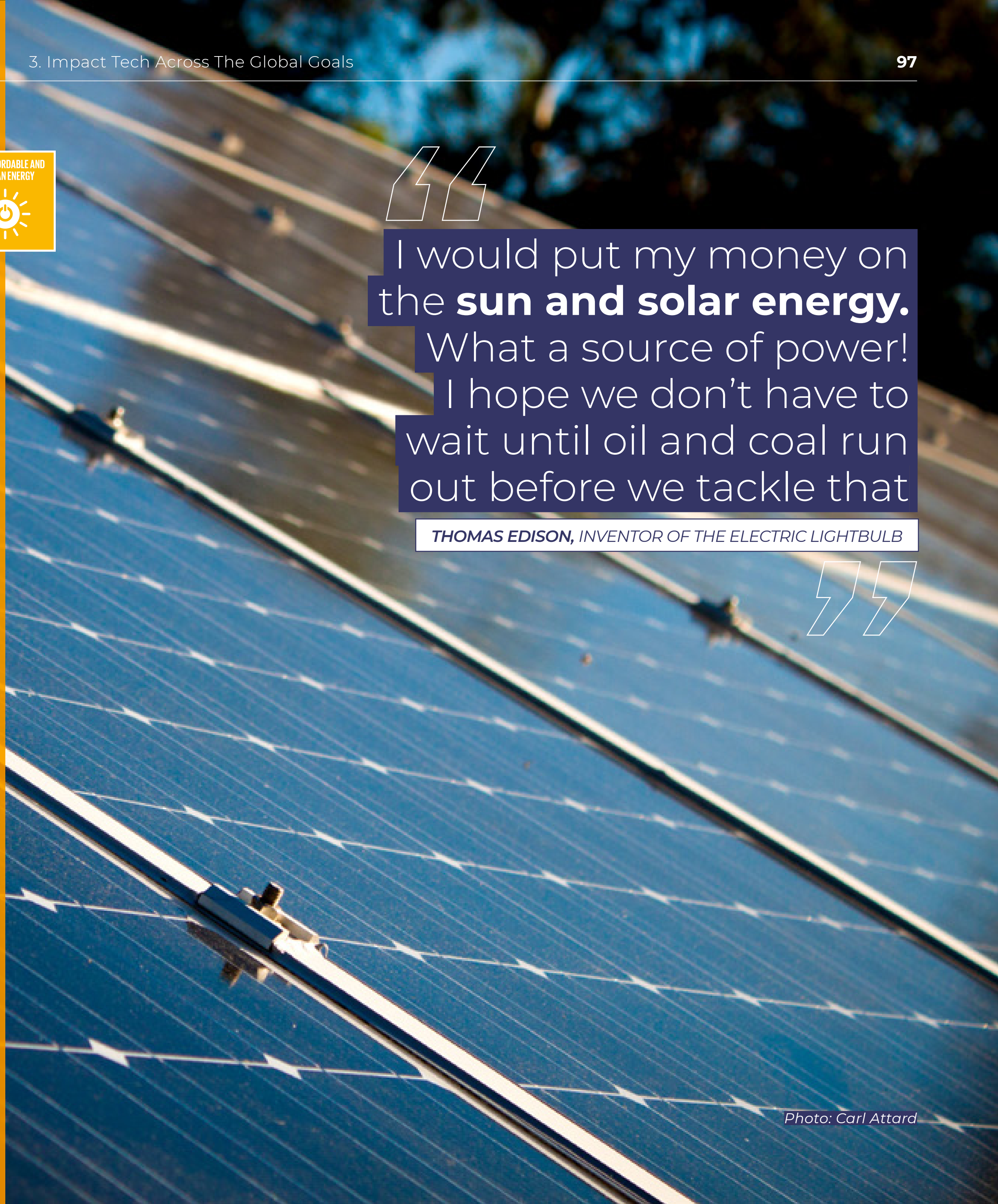
Ensure access to affordable, reliable, sustainable and modern energy for all.

ALMOST 1 Billion
PEOPLE STILL LACK ACCESS TO ELECTRICITY

IEA WORLD ENERGY OUTLOOK, 2018

35%
OF GLOBAL GREENHOUSE GASES ARE EMITTED BY THE ENERGY SUPPLY SECTOR

IPCC FIFTH ASSESSMENT REPORT, 2014



"I would put my money on the **sun and solar energy.** What a source of power! I hope we don't have to wait until oil and coal run out before we tackle that"

THOMAS EDISON, *INVENTOR OF THE ELECTRIC LIGHTBULB*

Photo: Carl Attard

Photo: Kingo Energy

Tech for SDG 7

Ensure universal access to affordable, reliable and modern energy services *[7.1]*

In 2018, almost 1 billion people still lacked access to electricity—600 million in Africa alone—while 2.7 billion depend on biomass, coal, and kerosene for cooking, according to the International Energy Agency (IEA). For the world's poorest living in rural areas, access to better energy is a game-changer. It prevents respiratory diseases, increases productivity, enables children to study and women to feel safer at night.

Solar Home Systems (SHS) and Solar Lamps

SHS combine solar power with the **pay-as-you-go (PAYG) model,** which allows users to acquire the system via small daily payments made in cash or mobile money, after an initial down-payment. Entry-level SHS cost between $0.5 and $1.25 per day—which is competitive with fuel—and typically include a solar panel, LED lights, a phone charging port, and a radio or a TV. High-end models can power fridges or fans. East Africa is home to some of the most prominent players like M-Kopa (Kenya), Zola Electric (Tanzania), BBOXX (UK), and Mobisol (Germany). Based in Guatemala, Kingo is bringing the model to Central America, with recent backing from Leonardo DiCaprio.

Solar lamps constitute an even cheaper alternative and range from basic models to multifunction lanterns that can also recharge mobile phones. With 91 million users in 62 countries, US-based d.light is the leader in that space, who also entered the SHS market recently.

Clean Energy Microgrids

Combining a **small generation unit**—solar, wind, biomass, hydro—with a **local distribution network,** microgrids of 5-100kW deliver AC electricity to about 25-500 households and small businesses, according to inclusive business consultancy Hystra. These microgrids can **either serve off-grid communities or provide a grid extension** in urbanizing regions.

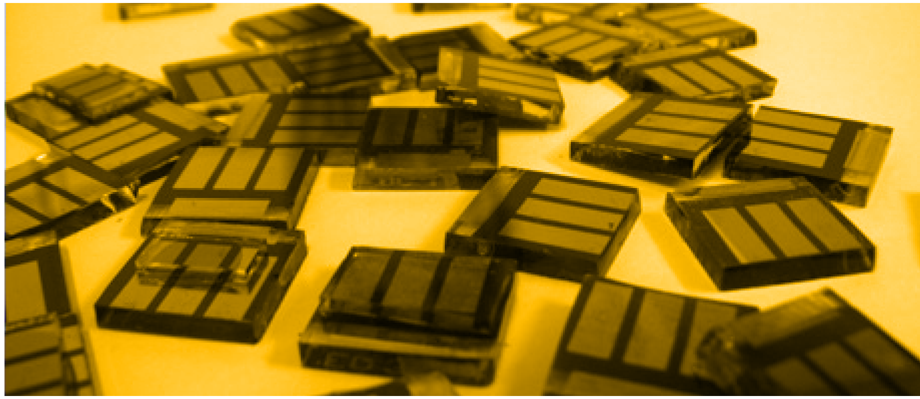
A pioneer in this sector, India-based Husk Power uses hybrid solar-biomass units to generate 24/7 power, with a basic plan starting as low as $2.5 per month. While it initially relied on cash payments, the company began accepting mobile money to expand in East Africa. In Kenya, PowerGen is another microgrid operator, while SteamaCo is a startup developing an energy IoT suite dedicated to microgrid systems.

Clean Cookstoves

Every year 4 million people die from indoor air pollution caused by the use of inefficient cooking stoves paired with solid fuels and kerosene, according to WHO data. While **improved cookstoves** have been widely disseminated in the past ten years, reaching 250 million households, Hystra notes that tough questions remain such as **how to include fuel collectors**, who have few economic incentives in these new stoves. The Technology Exchange Lab features many clean cookstoves on its directory, from US suppliers BioLite and Envirofit, to open source projects by Practical Action and the MIT D-Lab.

Increase substantially the share of renewable energy in the global energy mix *[7.2]*

Achieving this target requires innovation in the areas of power generation, energy storage, and grid management. It also requires substantial investments on infrastructure deployment.



Perovskite solar cells. Photo: Oxford University

Theme 1: Breakthroughs for renewable energy generation

Technology breakthroughs can significantly improve the efficiency of renewable energy sources and enable future energy revolutions like artificial photosynthesis. We left aside two categories: hydropower, which makes up 70% of global renewables capacity but generates substantial environmental cost with little innovation; and waste heat recovery which depends on the heat generated by coal and gas power plants.

Solar Photovoltaics (PV)

Next-generation PV cells aim to convert light into electricity more efficiently and from any surface. Companies like OxfordPV (UK) use a crystalline material called **perovskite** to boost the efficiency of silicon panels by a third. **Concentrated PV** uses an optical layer to concentrate light beams and improve efficiency by about 50%, according to Insolight (Switzerland). Further down the line, **thermophotovoltaics could double PV efficiency** by first turning sunlight into heat, before converting it back into a light focused on the spectrum PV cells use.

Organic PV cells are made of carbon instead of silicon, which makes them flexible, lightweight and transparent to cover windows. Companies include Sunew in Brazil and Heliatek in Germany, while Chinese labs have recently achieved new efficiency records.

Photo: Shaun Dakin

Solar Thermal

Concentrated solar power (CSP) uses **mirrors to reflect sunlight** into a receiver to generate heat. New designs like US-based SkySun's aim to drive down the cost of CSP plants. Solar thermal energy can also directly provide heat to buildings, through **solar water systems**, a key climate solution on Drawdown's Top 100.

Wind Energy

Real-time data analytics and machine learning can help boost the output of entire wind farms up to 15%, enough to motivate turbine leader Vestas to acquire Utopus Insights (US) for $100M. Also high on the IRENA radar, **floating foundations** such as X1Wind (Spain) could decrease the cost of offshore turbines while giving them access to stronger winds. Other areas of interest include **airborne wind turbines**, which could mature by 2025, and new designs like **vertical-axis** and **multi-rotor turbines**.

Marine Energy

Many attempts have been made to harness power from the waves, tides, salinity, and temperature differences in the oceans. So far, high costs have prevented the sector from taking off, but a new generation of companies like Eco Wave Power (Israel), EEL Energy (France) and Calwave (US) could reignite interest in the technology.

Geothermal

Geothermal energy is heat derived from below the earth, carried to the surface by steam and water. This old process meets a sizeable share of energy demand in countries like Turkey, Iceland, New Zealand, Kenya, and the Philippines, but **until recently was restricted to where the heat is easily accessible**, such as near earthquake zones. In the last ten years, **Enhanced Geothermal Systems** developed by players like AltaRock (US) made it possible to bypass that limitation. More recently, the first **home geothermal** startup Dandelion was spun off from X, the moonshot factory of Google's parent company Alphabet.

Hydrogen

The idea of an hydrogen-powered economy dates as far back as 1970. On paper, the H element boasts many qualities: it is the most abundant element in the universe, it can fuel a combustion engine, generate electricity via a fuel cell, be stored and distributed as a gas or liquid, and serve as an ingredient to make other fuels and various chemicals. Unfortunately, so far hydrogen has been too **expensive to harvest, store and convert** back into useful energy, which is why hydrogen cars have not taken off.

Recent advances include **better electrolyzers** developed by HyTech (US) to pull hydrogen from water more efficiently. The company has a three-step strategy. First, retrofit diesel engines to use a hydrogen and oxygen mix, increasing fuel efficiency and reducing air pollution. Second, equip gasoline vehicles to run on hydrogen only. Third, develop hydrogen home storage systems which outperform batteries. Among other developments, scientists have also been working on ways to produce sustainable hydrogen from seawater and atmospheric moisture instead of natural gas.

> *"Deploying renewable energy is becoming cheaper than operating existing coal plants: this is a turning point. The biggest challenge now is to scale them quickly, including by organising energy storage."*
>
> ***Mark Campanale,***
> *Founder and Executive Director of Carbon Tracker*

Bioenergy (biomass, biogas, biofuels)

Bioenergy is produced by burning biomass (organic material) in a solid, liquid (biofuel) or biogas form. The process is **in theory carbon-neutral** because plants previously absorbed the CO2 released during combustion. However **first-generation biofuels** derived from food crops—corn, sugar cane, palm oil—**require land-clearing** which generates indirect GHG emissions. **Second-generation (cellulosic)** biofuels rely on agricultural waste and by-products, which addresses the issue but lacks efficiency. **Third-generation (algae-based)** biofuels like Solazyme's jet fuel received paramount investment yet remain a long-term bet.

The **fourth-generation** refers to emerging processes relying on feedstock like **gene-edited algae, solid waste, or greenhouse gases** (see below). **Sewage biomass** is an exciting bioenergy development, which taps into the abundant flow of municipal and household solid waste. Biogas is a common output: for instance Waga Energy (France) upgrades landfill gas into grid-quality biomethane. Other approaches include Enerkem (Québec) which converts solid waste into bioethanol, and the Omni Processor, which turns fecal sludge into electricity and water in Senegal.

CO2-To-Fuels and Solar Fuels

The use of **greenhouse gases (GHG) as a biofuel feedstock** ranks among the most exciting clean energy developments. LanzaTech (NZ/US) has pioneered a gas fermentation technology in which microbes grow on gases, instead of sugars as in traditional fermentation. These microbes can transform carbon-rich flue gas from industrial plants into bioethanol and other useful chemicals. In 2018, Virgin Atlantic performed the first commercial flight partially powered by LanzaTech.

Another pathway is to **reproduce photosynthesis**, the process in which plants harness sunlight to turn water and CO2 into carbohydrates. Using solar energy—as photons, heat or electricity—an artificial equivalent would combine the same two ingredients to produce **solar fuels.** Technologies are still early, but several players are making significant progress. Backed by Bill Gates, Canadian firm Carbon Engineering uses solar power to extract hydrogen from water, then combines it with atmospheric CO2 to synthesize biodiesel and jet fuel. Berkeley-based Opus12 has developed a new catalyst for "reverse combustion"—or electrochemical reduction of CO2—which makes it efficient enough to produce biofuels and biochemicals. The ultimate frontier consists in truly **replicating photosynthesis with a photochemical process,** to synthesize either hydrogen or carbon-rich fuels.

Photo: LanzaTech / Dave Malkoff

Theme 2: Breakthroughs in energy storage

Low-cost and long-duration energy storage (ES) remains the holy grail for mass adoption of renewable energy and electric vehicles. Innovators and scientists are thus hard at work to bring better ES to market for different needs: EVs, grid, micro-grid, etc. Technologies fall under five main categories: electrochemical, electrical, chemical, mechanical, thermal.

Electrochemical Storage (batteries)

Lithium-ion (Li-ion) technology currently dominates the battery market, with a global production capacity in the hundreds of GWh led by Asian giants CATL and LG, along with Tesla. However, Li-ion batteries face issues like prohibitive costs at utility scale, limited lifespan, low recyclability, and unsustainable mineral supply.

A first approach consists in **improving Li-ion technology with better electrodes.** Lithium-silicon batteries like Sila (US) replace graphite in the anode, while lithium-sulfur batteries like Oxis Energy (UK) could replace cobalt and manganese in the cathode. Another way is to swap lithium for its much cheaper neighbor in the periodic table: **sodium batteries.** Examples include sodium-ion from Tiamat (France) and saltwater batteries like Aquion (US) and AquaBattery (Netherlands).

Flow batteries store energy within two liquid tanks containing a positive aqueous solution and a negative one. Though highly scalable and long-lasting, these batteries have remained expensive so far. Form Energy (US) uses sulfur instead of lithium to make ultra-low-cost flow batteries, at a tenth of the cost of Li-ion. Another long-term bet, **solid-state batteries** like Solid Power (US) could achieve higher energy density and safety by replacing liquid electrolytes with glass, ceramics and polymers.

Electrical Storage (capacitors and magnets)

Electrical systems based on **ultracapacitors** and **superconducting magnets** offer a promising alternative to battery storage. As they rely on physical properties instead of chemical reactions, they allow super-fast charging and discharge, last longer, and do not require cobalt and lithium. However, low energy density often requires them to be used together with Li-ion batteries. Examples include Skeleton Technologies (Estonia) and Nawa (France).

Chemical Storage (power-to-x)

Power-to-Gas (P2G) technologies **connect the power grid with the gas grid** through water electrolysis and methanation. Excess power is converted into a gas fuel such as hydrogen, methane, and ammonia, with certain designs reaching up to 80% conversion efficiency. Notable P2G firms include McPhy (France) which stores hydrogen in a solid-state form, and Carbon Recycling International (Iceland) which uses methanol as the storage medium—a variant called Power-to-Liquid.

Mechanical Storage (potential and kinetic energy)

Mechanical systems **convert electrical energy into kinetic and potential energies,** which are especially useful for long-term grid storage. Pumped hydroelectric storage (PHS) still represented 95% of global capacity in 2017, but deployment is limited by geography and environmental impact. Alternative ways to store potential energy include Swiss firm Energy Vault, which uses a crane to **stack concrete blocks instead of pumping water**, and US startup Quidnet, which **pressurizes water into abandoned oil wells** and releases it to produce energy. Another option is to store kinetic energy by using **flywheels**, such as Energiestro (France) and Teraloop (Finland/Japan).

Thermal Storage (heat and cold)

Thermal energy can be captured from natural sources like solar heating, as an industrial byproduct, or converted from electricity through a heat pump. It can then be stored in media like rocks, fluids, molten salts, and phase-change materials. While simple **solar air and water heating** like Simply Solar (Germany) allow daytime and nighttime demand balancing for residential use, seasonal and grid-scale thermal storage often involve **advanced heat pump systems**. Examples include Airthium (France), Ecovat (Netherlands), and Malta (US), a spin-off from Alphabet's moonshot lab X, which stores heat in molten salt and cold in chilled liquid, and received funding from Gates' Breakthrough Energy Ventures.

Theme 3: Renewable energy enablers

Internet of Energy (Smart Grid 2.0)

For renewable energy to displace fossil fuels, the power grid itself needs an upgrade. It needs to **handle both centralized plants and distributed energy resources (DER)**, allow bi-directional flows of power, and provide real-time grid balancing. Sensors, big data and machine learning lie at the foundation of this shift, with companies offering **Energy IoT platforms** like Kiwigrid (Germany), **DER management** like Advanced Microgrid Solutions (US), and **grid analytics** like CosmoTech (France). More recently, the idea of using blockchains for **peer-to-peer energy trading** was tested in pilots such as the Brooklyn Microgrid by LO3 Energy and PowerLedger (Australia).

Renewable Energy FinTech

Deploying renewable energy infrastructure quickly enough to prevent the worst of climate change remains a major challenge—especially in the case of distributed generation and storage which neither attracts venture capital nor large-scale project finance. Several fintech companies focus on that gap, such as Mosaic (US), a **marketplace** connecting homeowners, contractors and third-party capital providers to facilitate residential solar projects. Another example is Lumo, a French renewable energy crowdfunding platform recently acquired by Société Générale.

Double the global rate of improvement in energy efficiency *[7.3]*

Efficiency is *"the one energy resource that every country possesses in abundance and is the quickest and least costly way of addressing energy security, environmental and economic challenges."* says the IEA.

Energy-Efficient Buildings and Districts

Smart building solutions like Enlighted (now a Siemens company) enable owners and tenants to control HVAC, lighting and smart appliances. Smart home solutions like Tado (Germany) allow similar features for residential use. Recently, Google handed the cooling of its data centers to an AI which achieved around 40% energy savings. District-level heat recovery offers another way for cities to meet efficiency targets. The Open District Heating by Stockholm Exergi is providing heat to 25,000 apartments with excess heat recovered from data centers and other commercial buildings.

Energy-Efficient Appliances

Alternatives for energy-intensive appliances such as lighting, heating and cooling can also contribute to increase global energy efficiency. Examples include retrofits like Radiator Labs (US) which can redistribute wasted steam heat across buildings, and new radiator designs like Lancey (France) which offers a heating-and-battery combo, and Qarnot Computing (France) whose radiators reuse the heat produced by computing servers.

Photo: Tesla

Challenges

Li-ion sustainability. While they represent the vast majority of battery production capacity and investment, lithium-ion (li-ion) batteries are hard to recycle. First, the technology to separate battery cells from other materials is not mature yet. Second, there is still no standard for battery design, which makes recycling even harder. This low recyclability is especially worrying given the short lifespan of li-ion batteries, and the social cost of mining cobalt, one of their key components (see chapter 4).

Life-cycle analysis of solar PV. Contrary to popular belief, solar energy is not entirely clean. Solar PV requires rare-earth metals which are currently mined in terrible conditions (see chapter 4), and the production process itself is energy-intensive. As most PV panels are produced in China where coal represents 60% of the energy mix, their embedded carbon footprint can partially cancel out CO2 savings during use.

Scaling energy access. Hundreds of millions of low-income rural families still do not have access to energy. According to development consultancy Hystra, bridging this gap requires that providers focus on customer care and behavior change, and that large companies, donors and governments step in where market-based approaches have failed.

Goal 8

DECENT WORK AND ECONOMIC GROWTH

Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all.

8 DECENT WORK AND ECONOMIC GROWTH

192 MILLION PERSONS ARE **UNEMPLOYED** GLOBALLY

ILO WORLD EMPLOYMENT AND SOCIAL OUTLOOK, 2018

1.4 BILLION PEOPLE ARE IN **VULNERABLE EMPLOYMENT**

ILO WORLD EMPLOYMENT AND SOCIAL OUTLOOK, 2018

800 MILLION JOBS COULD BE AUTOMATED BY 2030

MCKINSEY GLOBAL INSTITUTE, 2017

> "There will be new jobs. The big question is whether people will **be able to reinvent themselves**"
>
> *YUVAL NOAH HARARI, BESTSELLING AUTHOR, AND HISTORIAN*

Photo: Fancycrave

Photo: Pixabay

Tech for SDG 8

This goal aims to promote better working conditions and economic opportunity for the many. Achieving the Sustainable Development Goals could create 380 million new jobs by 2030 according to *Better Business, Better World*. Institutions such as the World Bank and the International Labor Organizations (ILO) see clean energy, land restoration, and the circular economy as future job creation sources. However, critics point to SDG8's focus on high GDP growth, which does not guarantee shared prosperity, and so far has been at odds with environmental preservation.

The solutions featured below highlight how technology can help workers thrive, even though it can also be a double-edged sword, as we discuss in Chapter 4. In many other parts of this report—SDG 2, 6, 7, 11, 12, 13, 14, and 15—we feature examples of science and technology which could lead to a more sustainable economy.

Achieve full and productive employment and decent work for all, and equal pay for work of equal value *[8.5]*

Many predict that automation will displace most current jobs in the next two decades—though no one agrees on the scale of it. Village Capital also summarizes in a 2018 report that AI *"will play an increasingly large role in how organizations source, recruit, hire, and onboard employees."*

AI Employment Advisors

Bayes Impact is a French NGO developing **citizen-led public services** for a fair and inclusive society. Their flagship product Bob is an AI employment advisor, which **helps job-seekers assess and improve their employability with data-driven advice.** Bayes Impact initially trained the machine learning model on anonymized data from the French unemployment agency, thanks to a partnership with the government.

Inclusive Job Boards

These platforms **curate job opportunities** that are relevant for specific demographics, **while helping employers achieve diversity targets.** For instance, Kerjabilitas in Indonesia focuses on people with disabilities, while Harambee has already helped more than 50.000 young South Africans find their first job. In the US, PowerToFly streamlines job placement for women in top remote technology jobs, while Jopwell focuses on career advancement for Black, Latin, and Native Americans.

Bias-Free Recruitment Software

Blind hiring platforms can help employers to **remove unconscious biases** from their recruitment process. Examples include Textio (US) which takes the subjectivity out of writing job ads, and Interviewing.io (US) which enables applicants to pass anonymous technical interviews with engineers from top software companies. Blendoor (US) goes a step further by aggregating multiple sources to broaden its customers' talent search, combined with blind review and analytics.

Worker Upskilling Platforms

To cope with the quickly changing nature of jobs, regular upskilling is a critical need for workers and their employers. Degreed (US) provides users with a **lifelong learning platform** to discover content and certify newly acquired expertise. Verb (US) uses **on-demand microlearning** combined with mentorship and the opportunity to try out new skills on social impact projects. For operational work, SpeechMe (France) allows **mobile video-recording** and sharing for **peer-to-peer learning,** while UpSkill (US) uses **AR to learn new skills in context**.

Photo: Rawpixel

"There is no job which can be entirely automated, I think that is science fiction. However, many jobs will be redefined with automation, and workers will continuously need to learn how to work in collaboration with machines. If we can make this upskilling process fun and relatively worry-free, and if we provide a social safety net, automation will not be much of a problem."

Audrey Tang,
Digital Minister of Taiwan

Photo: EksoVest

Eradicate forced labor, end modern slavery and human trafficking, and end child labor in all its forms *[8.7]*

Anti-Slavery Technology

Getting a clear picture of human trafficking is a daunting task, due to both its complicated legal definition, and the **lack of relevant data.** New tech solutions aim to address the latter. For instance, Associated Press partnered with space tech company DigitalGlobe to provide irrefutable visual evidence of slavery in the fish industry thanks to **satellite imagery.** Thanks to their SeeFreedom program, the Indonesian Navy could identify the slavers' boats, arrest them and release the exploited workers.

Protect labour rights and promote safe and secure working environments for all workers, including migrants *[8.8]*

Worker Safety and Well-being Technology

Factory work on assembly lines can be painful and cause irreversible health damages. US-based Ekson Bionics recently adapted their **exoskeleton technology**—initially designed for rehabilitation and the military—**to support industry and construction workers.** The EksoVest, which provides additional strength to manipulate heavy tools and objects, is already experimented by companies like Ford.

Cobots are another trend on the factory floor. In comparison with traditional industrial robots, **cobots are not meant to replace humans but to augment them with collaborative work.** Their goal is to improve worker productivity while using sensors and safety mechanisms to protect them from injury. Examples include Veobot and Universal Robots.

Fatigue and microsleep can be life-threatening for truck drivers and heavy machinery operators. Developed within a consortium of Australian universities and industry partners, SmartCap is a **wearable device that monitors fatigue and alerts workers in real-time,** while enabling proactive intervention from colleagues in case of need.

Digital Freelancers Insurance

Freelance workers are the fastest-growing labor group in many parts of the world, and may even represent over 50% of the workforce in the US by 2027—up from 35% today. While many freelancers aspire to a better quality of life, they often experience **anxiety and precariousness due to irregular income and weaker social security.** Companies like WeMind (France) offer digitized insurance for independent workers which provide similar social protection compared to corporate benefits.

Challenges

The dark side of the future of work. The impact of technological progress on labor has been controversial since at least the first industrial revolution. On one side, technology is expected to create new jobs, and some of its applications can help improve working conditions. On the other, it is already displacing many jobs through automation, introducing algorithmic bias and surveillance in the workplace, and contributing to the erosion of worker benefits through a precarious gig economy. We explore these themes in greater details in Chapter 4.

Limits to growth. Target 8.4 on resource efficiency relies on the hopes that "green growth" could deliver prosperity within the means of our planet, but scientists have been pessimistic on the **physical limits to how efficiently we can use resources.** UNEP's International Resource Panel does estimate in the last Global Resources Outlook 2019 that **absolute decoupling** is possible—by increasing human well-being while reducing environmental degradation related to the use of natural resources. However, resource efficiency alone is unlikely to achieve this decoupling, given future population growth and the rise of the global middle class. Instead, a **quantum leap will be necessary** to increase human well-being within planetary boundaries. This would likely require a fully circular economy, regenerative agriculture, climate mitigation, carbon removal, strict biodiversity protection measures, and some degree of sobriety.

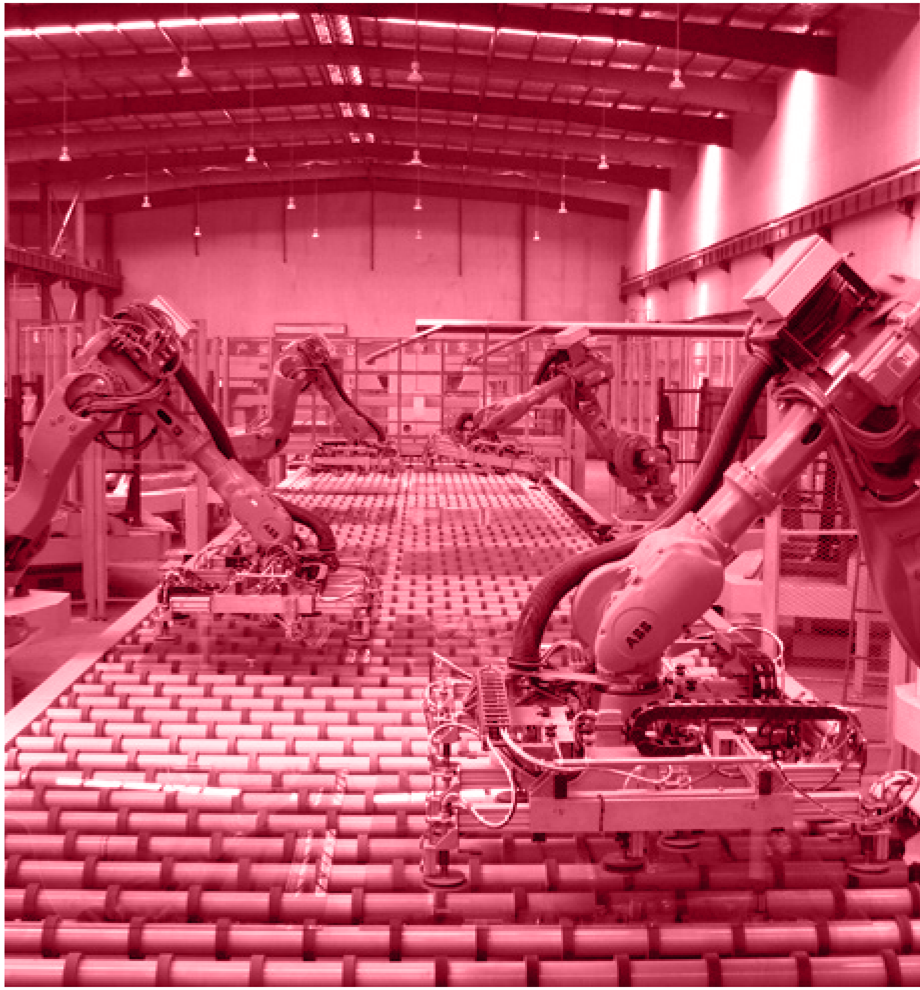


Photo: ICAPlants

Goal 9

INDUSTRY, INNOVATION AND INFRASTRUCTURE

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation.

> The changes are so profound that, from the perspective of human history, there has never been a time of **greater promise** or potential peril
>
> ***KLAUS SCHWAB,*** *EXECUTIVE CHAIRMAN OF THE WORLD ECONOMIC FORUM*

Photo: NASA

75%

OF THE **INFRASTRUCTURE** THAT WILL EXIST IN 2050 **HAS NOT BEEN BUILT YET**

UNEP AND GLOBAL INFRASTRUCTURE BASEL, 2016

49%

OF THE WORLD'S POPULATION STILL DOES NOT HAVE **ACCESS TO THE INTERNET**, MOST OF WHOM ARE WOMEN IN DEVELOPING COUNTRIES

ITU - ICT ESTIMATES, 2018

Photo: Zipline

Tech for SDG 9

Develop reliable, sustainable and resilient infrastructure to support economic development and human well-being, with affordable and equitable access for all *[9.1]*

Drone Delivery of Medical Supplies

While postal services are just starting to use drones for parcel delivery in a few countries, in Rwanda the lack of infrastructure is driving the country to become the world leader in drone logistics. In a partnership with the health ministry, Zipline (US) uses **drones to deliver blood supplies** in rural areas. The company already serves most of the country and is now expanding to Ghana, where it will deliver a broader range of urgent medicine. Furthermore, the **public-private partnership** in Rwanda has been a testbed for innovative policymaking on emerging technologies, a process supported by the WEF. Other companies are following Zipline's path, such as the German Wingcopter.

Airship Logistics

Airships, or dirigible balloons, are **lighter-than-air vehicle**s held aloft with lifting gas—helium—and navigating with a propulsion system. A DFID-commissioned report on *Frontier Technologies for International Development* estimates they could be a **potential gamechanger for hard-to-reach areas.** With little ground infrastructure required and a significantly lower environmental impact compared to airplanes and road transport, airships could **leapfrog conventional logistics** in the delivery of goods, supplies, raw materials, machinery, and even pre-assembled wind turbines. Modern airship companies include Hybrid Air Vehicles (UK), Aeros (US) and Flying Whales (France).

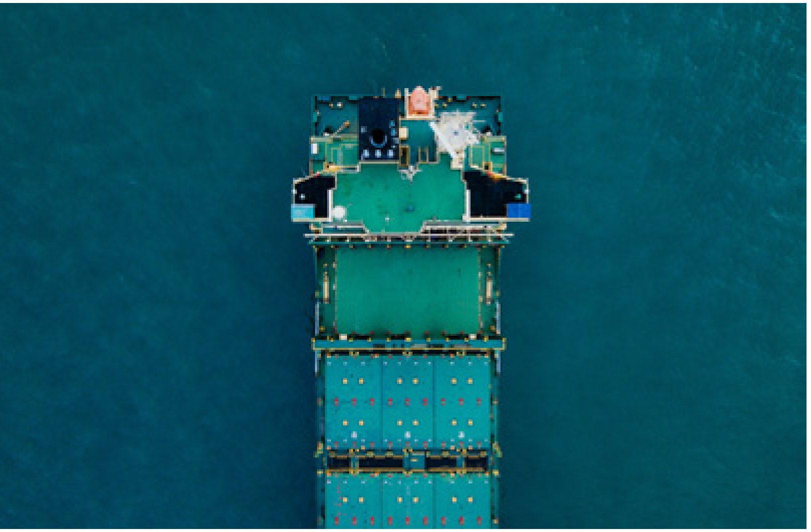


Photo: Chuttersnap

Clean Shipping

Shipping is the most efficient mode of cargo transport, especially compared with air freight. However, as container ships account for far more tonnage, they are among the most polluting vehicles on the planet. Various innovators promise to slash the sulfur and greenhouse gases emissions associated with these ships. For instance, Zéphyr&Borée (France), Norsepower (Finland) and Bound4Blue (Spain) are developing **innovative sail designs for cargo ships,** while Neoline (France) is opening a 100% sail-powered transatlantic route.

Increase access to financial services and market integration for small-scale enterprises, in particular in developing countries *[9.3]*

Data-Based Finance for SMEs

According to the IFC's SME Finance Forum, half of SMEs in developing markets—200 million—have unmet credit needs totaling over $2.1 trillion. The Forum estimates that over 800 SME fintech services in 60 countries now address this segment, using previously unavailable financial data.

For instance, SMEs can contract loans through **P2P lending platforms** such as Moldaku (Indonesia), CreditEase (China) and FundingCircle (UK). Meanwhile, **e-commerce and payment giants** Alibaba, Tencent, PayPal, and Amazon rely on end-user popularity, AI and partnerships with financial institutions to develop new SME offerings. **Mobile data-based lenders** rely on alternative credit scoring derived from mobile usage patterns, such as KCB M-Pesa (Kenya), Avante (Brazil), and Tala (Mexico, Philippines, Tanzania, Kenya). Finally, **supply chain finance** platforms like Kinara (India) use data from sales, accounting, and more to support B2B companies with faster and cheaper trade credit.

Upgrade infrastructure and retrofit industries to make them sustainable, with increased resource efficiency, as well as clean technologies and processes *[9.4]*

Globally, manufacturing accounts for 21% of greenhouse gas emissions, and industry as a whole for 20% of freshwater withdrawals—the shares being much higher in advanced economies. The sector is also the biggest driver of natural resource extraction, waste, and pollution. Emerging technologies could, however, help chart a path toward sustainable production, according to a recent WEF report.

Five innovation areas are especially promising: **design and research tools, production efficiency, after-use, new materials, and supply chain traceability.** The paragraphs below focus on the first three categories, while all five appear across SDG 11, 12, 13 and 14.

Automated Materials Discovery

Breakthroughs in new materials are critical for sustainable manufacturing and clean energy. However, **the discovery process requires complex computer simulation**—to model molecules and material properties—as well as **years-long lab experimentation.** Several firms aim to automate as much as possible, letting scientists focus on value-add work. Exabyte (US) provides cloud software and computation for collaborative materials research. Kebotix (US) aims to create a **modular "self-driving lab"** using big data, AI, robotics, and materials genomics. The MIT Tech Review also anticipates that **quantum computing** will first play a decisive role in the area of chemistry, notably for new materials research.

Cloud Biofabrication Platforms

Biofabrication (biofab) refers to the **design and production of materials and objects using biology.** At the intersection of synthetic biology and materials science, the field harnesses organisms such as bacteria, cells, yeast, algae, or mycelium. The SDG12 section features several examples of biofabricated sustainable products. Below we describe the main building blocks that make this exciting new industry possible.

Like what happened in software, many tools have emerged along the synthetic biology stack to facilitate the development of engineered organisms. At the bottom of the stack, companies like Twist can produce **on-demand synthetic DNA/RNA.** Above, **bio-CAD platforms** like Asimov and TeselaGen offer the equivalent of AutoCAD for genetic engineering. At the top, Ginkgo Bioworks designs and produces **custom organisms on-demand.** To further support this movement, the BioBricks Foundation is developing OpenMTA—Material Transfer Agreement—the equivalent of open source licenses for biology.

Additive Manufacturing (AM)

From resource efficiency to local fabrication and extended product life, many advocate 3D printing as the future of sustainable manufacturing. Cambridge University scientists have identified four areas where this could happen: **product and process redesign, materials processing, make-to-order production, and "closing the loop."**

First, AM can leverage complex material shapes such as porous mesh arrays and open cellular foams to reduce material use: GE has already achieved 25% weight reduction on engine nozzles using this technology. **Second, AM feedstock can be produced from recycled waste or through simpler processing of raw materials** such as mineral powder. **Third, make-to-order production** could optimize inventory, mainstream the use of spare parts to extend product life and create incentives for product-service business models. **Fourth, better recycling and remanufacturing infrastructure** could help divert material from waste streams and into new 3D printed products. Examples include the Filabot filament made from plastic waste, and the Ekocycle printer from 3D Systems.

Nevertheless, it is still early to draw definitive conclusions on AM sustainability. A 2017 special issue from the Yale Journal of Industrial Ecology estimates that *"we need to know much more about the material footprints, energy consumption in production, process emissions and [the] various stages in the production process."* The same year, an OECD report on the Next Production Revolution suggested three ways to maximize AM sustainability: using compostable biomaterials, reducing energy consumption through chemical bonding processes instead of melting, and sharing printers among several companies.

Circular and Flexible Factories

Innovative factory designs also have the potential to reduce the footprint of manufacturing. These include **on-site wastewater treatment** (see SDG 6) and **waste heat recovery.** PRIME-funded Redwave (US) aims to harness the most abundant low-quality waste heat (below 250C) with a nanoantenna technology.

An even more radical idea is to decentralize production across a network of **automated micro-plants** located as close as possible to the customer, using robotic assembly, make-to-order technologies and a higher share of locally available materials. This "Smart Flexible Factory" was suggested by Industry 4.0 groups and the FabCity Foundation—a FabLab spin-off focused on urban production. The Adidas Speedfactory and its city-specific sneakers give an early idea of what it could represent.

Advanced Remanufacturing

Short loop recycling aims to maximize circular material flows within the same economic sector or the same company. Advanced remanufacturing technologies can enable this, including **reverse logistics, robotic/cobotic disassembly** and **component/material sorting**—with optical or image recognition. Apple's Daisy robot can disassemble nine different versions of the iPhone, at the speed of 200 per hour. The collected parts can be remanufactured into new products or recycled into new components.

"Active Disassembly could improve recycling at the end-of-life, using smart materials as fasteners. But it will work only if the government enforces it. Maybe China will lead, as they take both manufacturing and sustainability seriously."

Duncan Turner,
Partner at SOSV and Managing Director at HAX

Increase access to ICT and provide universal and affordable access to the Internet in the least developed countries *[9.C]*

For the first time in 2018, half of the world's population could use the Internet, according to ITU. Hence the other half, or 3.7 billion, have not yet reaped any "digital dividend"—the broader benefits from digital access. Bringing the other half of humanity online will require not only innovation to extend connectivity in hard-to-reach areas, but also drastic cost reduction. Today the Alliance For Affordable Internet (A4AI) estimates that 2.3 billion people live in areas where 1GB of data is unaffordable.

While telecoms investments have slowed down, universal internet access has attracted the interest of startups, tech giants and consumer brands, as well as development agencies like USAID, DFID and GIZ.

Middle Mile Moonshots (backhaul)

Telecommunications networks have three main layers: the backbone connects countries and regions, the backhaul—or middle mile—passes throughout countries, and the last mile brings internet to the end-user. **In rural and remote areas of the developing world, the backhaul rarely exists:** low-income, low-density areas are not attractive enough for telcos, and too expensive for governments alone. Thus, tech firms are racing to fill the void with **airborne network infrastructure,** such as high-altitude platforms (HAP) in the stratosphere, and satellites.

One of the first "moonshots" incubated at X—formerly Google X—the Loon project uses **solar-powered, helium-filled balloons** traveling at 20km above Earth to expand the coverage of mobile operators. The signal is transmitted from the ground, relayed across the balloon network, and sent back to users in remote areas. Facebook had similar ambitions with the Aquila solar drones but shelved the project in 2018.

With Softbank, Virgin, Airbus and Qualcomm as investors, Oneweb plans to put 600 **satellites in low-earth-orbit** (LEO—1200 km above ground) and beam broadband internet to remote areas. SpaceX and others have announced similar goals with up to 12,000 satellites. Astranis is making another bet: sticking to the **geosynchronous orbit** (GSO—34,000 km above Earth) traditionally used for telecommunications, and using **micro-satellites** that are ten times cheaper. The GSO orbit could allow the company to cover the Earth with only a few satellites.

Last-Mile Access Innovation

In rural areas where backhaul is available, last-mile access innovators are deploying **network expansions to connect remote populations,** such as Airjaldi in India and Mawingu in Kenya. Spun out of Microsoft Research, the latter uses **TV white space technology**—unused TV frequencies with a greater range than Wi-Fi. Users pay $0.5 per day (300MB) or $10 for three-month (8GB) to use Wi-Fi hotspots and free charging stations. Another approach is to **empower local communities to operate their own network,** such as in the Rhizomatica co-operative in Mexico.

In urban areas where coverage exists but subscription remains expensive, several companies offer **sponsored access.** Examples include BRCK's Moja public Wi-Fi network in Nairobi, and Google Station, which partners with local providers to install **Wi-Fi hotspots** across India, Indonesia, Mexico, Thailand, Nigeria, and the Philippines. Through its Free Basics program, Facebook also sponsors mobile data plans to let users access its apps and a few other services, but the initiative attracted harsh criticism for breaking **net neutrality** and promoting western content.

Photo: Loon

Challenges

Risk of deepening global inequalities. UNIDO estimates that "*Inequalities between the economic development of industrialized, emerging economies and developing countries could further deepen if countries of the Global South cannot tap into digital development benefits.*" In the *Readiness for the Future of Production* report, the WEF further writes that "*the future of production could become increasingly polarized in a two-speed world.*" The answer to this challenge cannot come from technology transfer alone: it must also include capacity building. In the words of Fai Wechayachai from the Aspen Network of Development Entrepreneurs (ANDE), "*local entrepreneurs often lack access to capital, talents, and markets in developing countries.*"

Connecting the last billions. While half of the world is now online, universal internet access remains an elusive goal. The Alliance for Affordable Internet stresses in its 2018 report that *"the pace of policy change remains far too sluggish and incremental to effect the change needed,"* especially on infrastructure development. Without investment in the latter, countries risk being trapped in a "consumer internet" perpetuating the digital divide. Additionally, a report from SSG supported by USAID and fhi360 noted that existing models for last-mile access face *"a lack of early-stage financing, limited partnership opportunities, and unfamiliar or restrictive regulations."* Business model and service delivery innovations are thus needed.

Goal 10

REDUCED INEQUALITIES

10 REDUCED INEQUALITIES

Reduce inequality within and among countries.

82% **OF THE WEALTH CREATED IN 2017 WENT TO THE WORLD'S 1% RICHEST**

OXFAM INEQUALITY REPORT, 2018

68M **PEOPLE WORLDWIDE HAVE BEEN FORCIBLY DISPLACED, EQUIVALENT TO THE POPULATION OF FRANCE**

UNHCR, 2018

> Inequality is not an economic necessity: **it is a design failure**
>
> ***KATE RAWORTH,*** *ECONOMIST AT OXFORD AND CAMBRIDGE AUTHOR OF DOUGHNUT ECONOMICS*

Photo: Lindrik


Photo: Millejoh

Tech for SDG 10

Reducing inequalities—of all nature—is not only a wicked problem but also a very political one. While progress on this front has historically been achieved through social movements and inclusive policy, tech-enabled solutions can also bring valuable contributions. In addition to the examples highlighted below, the reader will find complementary solutions in SDG1 to 11, SDG16, and Chapter 4.2 of this report.

Achieve and sustain income growth of the bottom 40% of the population at a rate higher than the national average *[10.1]*

According to Oxfam, 26 people owned as much as the 3.8 billion who make up the poorest half of humanity in 2018. Other sections of this report focus on solutions improving access to basic services—energy, mobility, education, healthcare, finance, etc. Impact Tech can also address structural inequality factors like ownership and access to opportunity.

Decentralized Ownership

In most parts of the world, wealth accumulation occurs primarily through equity and capital gains, as opposed to compensation. New ownership structures could provide systemic answers to economic inequality.

One approach is to **democratize company ownership**. Startups like Carta and Upstock (US) provide digital tools for startup founders, public companies and investors to manage cap tables, valuations, and equity plans so that they can distribute shares more widely and fairly among employees. Platform cooperatives offer a more radical approach: the co-operative ownership of digital platforms by users and workers. Examples include driver-owned Uber alternative Cotabo (Italy) and co-operative ethical marketplace Fairmondo (Germany).

Digital commons allow anyone to freely access, use, adapt and share the knowledge and tools co-created by communities around the world. They include open source and free software like Linux and Mozilla Firefox, open hardware designs like the echOpen echo-stethoscope (see SDG 3), open data sets, open science publications, and creative commons.

On a long-term view, various blockchain projects aim to provide tools for **decentralized organizations**, such as Aragon, DAOStack, and Colony, as well as **decentralized data exchange**, such as Ocean Protocol.

Digital Inclusion

Even where internet access is no longer an issue, **the digital divide takes the form of a skills gap,** which prevents many from seizing the opportunities offered by technology. In answer, a growing number of initiatives aim to stimulate rural and periurban areas through **digital literacy and training.** In Polish villages and small towns, FRSI is transforming public libraries into activity centers where inhabitants can learn to use digital tools. In France, the public Digital Agency sponsors third-party locations—like coworking spaces, cafés, libraries—to provide a similar service.

Empower and promote the social, economic and political inclusion of all, irrespective of age, sex, disability, race, ethnicity, origin, religion or economic or other status *[10.2]*

Assistive Technology

According to the World Bank, one billion people, or 15% of the world's population, experience some form of disability—with 110 to 190 million suffering from significant ones. Technology has the potential to foster social inclusion among this population, with examples ranging from **better wheelchair designs** like Whill (Japan) to **custom-fit prosthetics** (see SDG3) and devices aiming to **compensate for sensory disabilities.**

Orcam (Israel) is a wearable AI assistive device for the blind and visually impaired which can instantly read text, recognize faces, and identify objects. BeMyEyes (Denmark) uses a free video call app to connect the

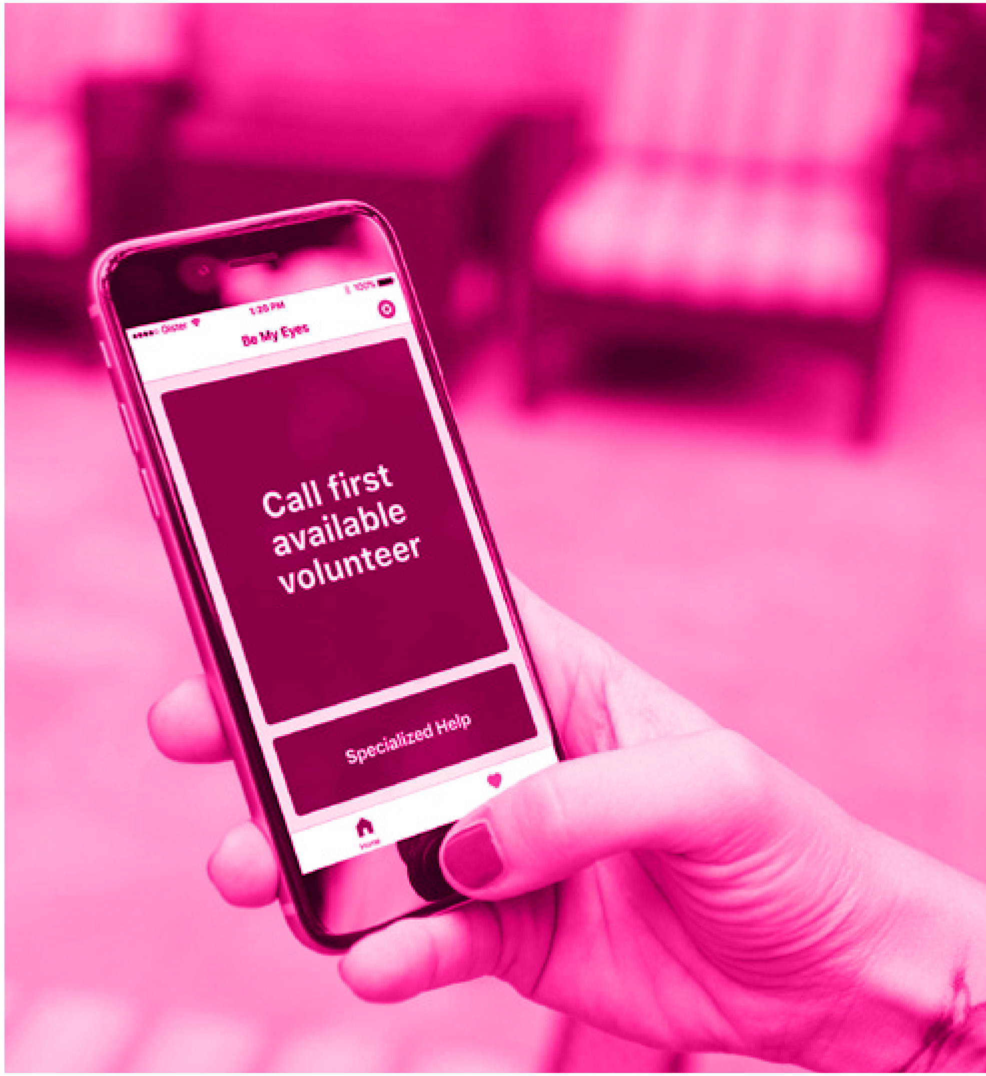


Photo: Be My Eyes

visually impaired with sighted volunteers who can give visual assistance. Blitab (Austria) is a braille tablet devices which generates tactile text and graphics in real-time. For the deaf and hearing-impaired, Ava and RogerVoice (France) add real-time captions to phone and live group conversations. HandTalk (Brazil) uses a virtual assistant named Hugo to translate online content into Brazilian sign language.

Facilitate orderly, safe, regular and responsible migration and mobility of people *[10.7]*

Refugee Support Technology

Every two seconds, one person is forcibly displaced by conflict or persecution, according to UNHCR. International impact-driven organisation Techfugees identifies **five main needs for these populations,** once settled in a new place, which can be met efficiently through digital technology: information, education, employment, healthcare, and social inclusion.

Access to information comes foremost, especially to learn about their rights and locally available services. In Germany, the largest app for newcomers Integreat has been featuring locally relevant information since 2015. The International Organization for Migrations (IOM) has also developed Migapp. To help families reunite after conflicts and migrations, Refunite (US) has built the largest database of missing persons.

Education is critical, as one out of two migrants is under 18. Antura and the Letters is a free mobile game to help young Syrians learn Arabic letters. Another essential need is the digital certification of skills and past diplomas, potentially using blockchain records.

Several digital platforms aim to **help displaced people find new jobs in their host country.** Examples include Refugee Talent (Australia) which match refugees with employers, NaTakallam (US) which connects them with remote work opportunities as a translator or language teacher, and TaQadam (US), a gamified app allowing young migrants to earn money by optimizing image annotation for AI applications.

Access to healthcare, especially mental health support, is of utmost importance for those who left everything fleeing conflict and persecution. The ALMHAR app (Germany) aims to help refugees cope with emotional problems associated with PTSD. Shifra (Australia) helps women find sexual and reproductive information and services in their native language.

The final challenge is to foster the social inclusion of migrants, for them to feel accepted in their new home. UN Global Pulse and UNHCR extracted insights from social media to monitor perceptions of host communities towards refugees. The winner of the Global Techfugees Competition, Refugees Are is an online dashboard created by a female refugee which uses data extracted from media sources to understand how narratives on refugees and migrants spread in the news.

> *"When using digital services, refugees are weary of sharing personal information. They are fleeing death threats and persecutions, they do not want to be easily tracked down. Any technology that does not protect their privacy is problematic."*
>
> ***Joséphine Goube,***
> *CEO of Techfugees*

Reduce to less than 3% the transaction costs of remittances and eliminate those with costs higher than 5% *[10.C]*

Decentralized Money Transfer

Blockchain technology can help democratize migrant remittances, by **lowering the cost of money transfers** while making them available to those who do not have a bank account or a valid ID. Several UN agencies are pursuing this goal, such as UNDP through its internal startup AltFinLab. The World Food Programme (WFP) also developed Building Blocks, which facilitates cash-for-food transfers to refugees living in camps, with pilots in Jordan and Pakistan. Additionally, various startups are betting on cryptocurrencies for low-cost remittances, such as Celo (US) and others mentioned in the SDG1 section.

Challenges

Technology, finance, and inequality. As we further discuss in Chapter 4, whether technological progress will increase or reduce inequality remains an open question. Furthermore, the financial returns of Impact Tech investing will likely benefit the already wealthy—as the general public has too few occasions to participate in those. This is especially true in venture capital, in which gains follow a power law. However, even impact investing could become *"the latest example of inadvertently widening inequality in the course of making money,"* according to BALLE's Executive Director Rodney Foxworth. In *Winners Take All*, Anand Giridharadas goes even further and heavily criticizes the global elite's efforts to *"make the world a better place."* According to him, such endeavors do good on the surface while preserving the status quo, and avoid questioning the wealthy's role in causing the problems they later seek to solve.

Open-source, co-operatives, or decentralization? Activists often point to these strategies to prevent technology from widening inequalities. However, so far none has been successful enough to loosen the grip of tech giants on the global economy. Open source does empower everyone with use value, but economic value still accrues mostly to the biggest players. Digital co-operatives could help to spread financial gains, but the administrative overhead has not made these legal structures very attractive for tech entrepreneurs. Finally, while decentralized consensus protocols could, in theory, lead to a greater distribution of power, in practice, cryptocurrencies have led to even higher concentrations of wealth. Maybe these new approaches need more time to bear fruit. Or perhaps fiscal reforms and global cooperation against tax avoidance could help redistribute digital dividends more fairly.

Za'atri refugee camp in Jordan

Goal 11

SUSTAINABLE CITIES AND COMMUNITIES

Make cities and human settlements inclusive, safe, resilient and sustainable.

68%
OF THE WORLD'S POPULATION WILL BE URBAN IN 2050 UP FROM 55% TODAY

UN-DESA, 2018 WORLD URBANIZATION PROSPECTS

CITIES
ACCOUNT FOR
70% OF CARBON EMISSIONS,
60% OF ENERGY CONSUMPTION,
70% OF WASTE PRODUCTION,
AND OVER
80% OF GLOBAL GDP

UN-HABITAT, THE NEW URBAN AGENDA, 2016
WORLD BANK, URBAN DEVELOPMENT OVERVIEW, 2018

OVER
80%
OF CITIES EXCEED **WHO GUIDELINES** FOR AIR POLLUTION. AIR POLLUTION **KILLS 7 MILLION** PEOPLE EVERY YEAR

WHO 2018 DATA, BREATHE2030 CAMPAIGN

> Cities have the capability of providing **something for everybody**, only because, and only when, they are **created by everybody**
>
> ***JANE JACOBS,*** *AUTHOR AND URBAN THEORIST*

Photo: Viktor Kern

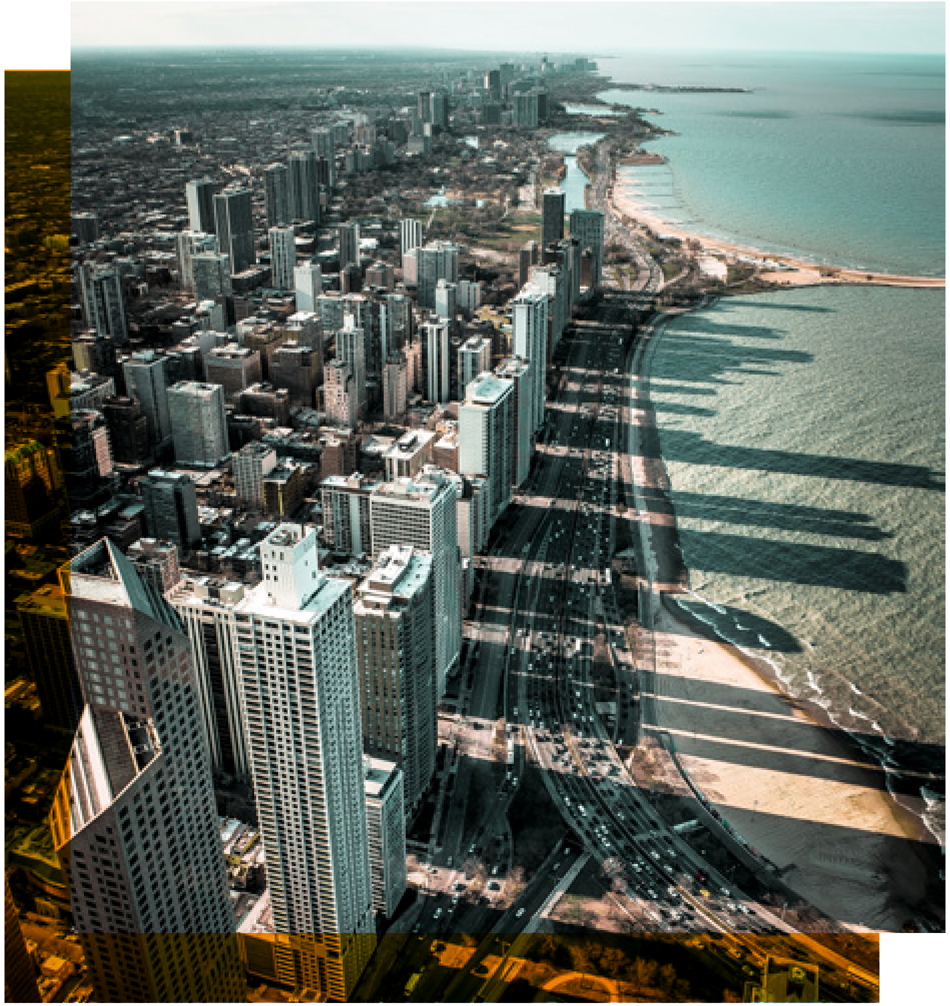


Photo: Alex Powell

Tech for SDG 11

Cities around the world need to provide safe, inclusive and liveable space for a growing urban population, while also drastically reducing their environmental footprint. 2.5 billion more people will live in urban areas by 2050, and 90% of them in Asia and Africa.

Vast differences exist between affluent cities in rich countries and the fast-growing urban areas of the Global South—especially slums. As UNICEF and Arm wrote in a recent report, *"The way urbanization shapes our world will define the chances for individuals, communities, cities and entire regions to either thrive or collapse, making the task of guiding urban growth towards sustainability and equity a global imperative."*

The tech solutions featured in these pages cover many urban issues: some are specific to the developing world, others more immediately aimed for advanced economies. Other parts of this report are also relevant in urban contexts, in areas like health (SDG3), education (SDG4), work (SDG8), clean water and sanitation (SDG6), energy (SDG7), sustainable lifestyles (SDG12), crime and violence (SDG16), and more.

Access to adequate, safe and affordable housing and basic services for all *[11.1]*

The housing crisis is a major urban challenge globally. However, the gaps in urban infrastructure, basic services, and public safety are most acute in impoverished neighborhoods. While urban planning and policy interventions remain crucial, technology can bring additional leverage.

Rapid Housing Fabrication

Architecture innovations can help build pop-up houses faster, cheaper, and more sustainably. Wikihouse (UK) is an **open construction platform** enabling users to custom design and locally manufacture wooden house frames, using simple design software and digital fabrication. Icon (US) uses a **large-scale 3D printer** to assemble a house in less than a day for $4000. The company works with charity NewStory (see SDG 1) to use them in disaster relief. **Prefab modules** for eco-homes like Noem (Spain) and Popup House (France) are also getting popular. Finch (Netherlands) uses modules which can be stacked to form larger buildings.

Smart Water Metering

In many parts of the developing world, the urban poor lack access to a basic water service—leading to waterborne diseases and affecting the lives of women and girls, often tasked with fetching water. Multiple challenges prevent water utilities from bridging that gap, from a stressed supply to high costs of connecting piped water, irregular payments, leakage, and theft. Various IoT companies aim to overcome these barriers with **leak-detection sensors** and **pay-as-you-go smart meters,** such as NextDrop (India), Upande (Kenya), and CityTaps (France, Niger).

Emergency Response Platforms

While the first few minutes are crucial to save a life, traffic and weak infrastructure slow down ambulances in poor and dense urban areas. Flare connects Kenyan users in urgent need with the best available medical transport. The app selects a provider based on distance, traffic, and level of life support, ensuring medical assistance under 15 minutes—a solution listed by UNICEF Innovation as one of their urban tech bets to improve the lives of vulnerable populations. In Israel, United Hatzalah even reaches patients within 3 minutes, thanks to "ambucycle" scooters and a community of 5000 volunteers.

Slums 2.0 and Microcities

Slum, favela, and shantytown are among the many names given to informal settlements. While they differ in size and aspects, slums broadly refer to impoverished neighborhoods with inadequate living conditions. Common traits include overcrowding, insecure tenure, low structural quality of buildings, weak infrastructure (water, sanitation, energy, transportation, connectivity, waste management) and poor access to basic services like healthcare and education.

While technology is often heralded as the solution to all urban issues, "smart city" promoters have shown little interest so far in improving the life of slum residents. Things could change. Urban innovation firm Utopia is working with Jakarta, Mumbai, and Ulaanbaatar to **convert slums into micro-cities** that are more liveable and sustainable. The company plans to use solar-powered, modular prefab buildings clustered around community spaces and digital solutions for service essentials.

UNICEF is investigating tech solutions to improve the lives of the youth in rapidly urbanizing areas, focusing on five pain points: infrastructure, basic services, violence and hazards, connectivity, and transportation.

"Slums don't have to be seen as a problem, they are actually an asset. They can inspire a new model for the cities of the future–the microcities. Slums are highly decentralized and adaptive, the very characteristics we're looking for from our cities today."

Jonathan Hursh,
Founder and Executive Producer, Utopia

Home Sharing Marketplaces

Digital marketplaces can help match students and young professionals with available rooms in elderly households. Such platforms like Nesterly in Boston and Cette Famille in France reinforce the social bond between generations to prevent loneliness among seniors, while also addressing the urban housing crisis.

Access to safe, affordable, accessible and sustainable transport systems for all *[11.2]*

Cities face a twin challenge: they need to upgrade mobility infrastructure for a fast-growing urban population while reducing its adverse impacts. Gasoline and diesel powered vehicles are major culprits in urban GHG emissions and air pollution, yet the International Energy Agency (IEA) expects twice as many cars on the roads by 2050. At the same time, electrification, digitalization, and new modes of transportation are profoundly transforming urban mobility.

Electric Vehicles (EVs)

The EV market is driven by tech firms like Tesla (US) and BYD (China), as well as brands of legacy companies like Nissan Leaf, Chevrolet Bolt, Renault ZE, and BMW i3. These vehicles are called **BEV, or battery EV**, as opposed to hybrid EVs which use an onboard generator. The success of BEVs ultimately rests on future improvements in batteries (see SDG7), carbon-neutral electricity, and economies of scale.

Hybrid EVs include **plug-in hybrids (PHEVs)**, which use an internal combustion engine alongside electric propulsion, and **fuel cell electric vehicles (FCEVs)**, in which liquid hydrogen reacts with oxygen to produce electricity. While automakers like Toyota and Hyundai have invested massively in FCEVs, the technology is hampered by high production costs—for vehicles, charging stations, and hydrogen fuel derived from energy-intensive sources. Estimates place FCEVs at four times the kilometric cost of BEVs, but breakthroughs are possible (see SDG7).

Electric buses are the low-hanging fruit for cities. China is now adding 9500 new units every five weeks—the size of the entire London fleet. Meanwhile, **electric motorbike**s could replace petroleum vehicles in the Global South. Ampersand (Rwanda) aims to deploy them across East Africa, saving riders half of what they spend on fuel while cutting pollution and emissions. Users will be able to buy or lease the motorbikes and to swap batteries in Ampersand stations.

Overall, the IEA estimates that 125 million EVs will be on the road by 2030—likely a conservative forecast given the agency's history of vastly underestimating the speed of clean energy adoption.

Autonomous Vehicles (AVs)

Self-driving cars, or AVs, use sensors and automated navigation to move with limited or no human input—ranging from level 1 (assisted driving) to level 5 (no steering wheel). Expected benefits include fewer accidents, reduced traffic, inclusive access to mobility, free time for passengers, and new urban transport systems. OECD research estimates that AVs could avoid 90% of road deaths and eliminate 90% of cars in cities while increasing travel capacity.

Photo: Olli / Local Motors

AVs are a platform technology rather than an Impact Tech application (see Chapter 2.3). The net benefits of AVs will depend on many factors, such as how they integrate with public transport, whether they are electric, and how the associated risks are mitigated (see "challenges"). As C40 Director Mark Watts summarizes: *"AVs are not a magic bullet to cut emissions or reduce traffic. However, with the right policies and regulations, they can certainly be part of the solution."*

Market data firm CB Insights lists **three categories in AV technology: perception, localization, and full systems.** All of them rely heavily on machine learning and abundant traffic data.

Perception technologies enable AVs to sense their environment. They include computer vision (CV) cameras like Prophesee (France); light detection and ranging sensors such as RoboSense (China); radar antennas like Lunewave (US); and wireless communication with nearby vehicles and IoT devices. Others use simulation data to train the AIs, such as Cognata (Israel) and chips giant Nvidia. **Localization players** like Here (Netherlands) and DeepMap (US) use prebuilt HD maps, which offer more accuracy than GPS to determine a car's precise location.

Full AV systems include **driverless solutions** such as Momenta (China), Waymo (Alphabet) and Apollo (Baidu) which provide automakers and fleet operators with AV technology. They also include **AV manufacturers,** such as Navya (France) and Olli (US). These companies make autonomous electric shuttles which could offer great potential for mass transit once they operate in open urban environments—today their usage remains limited to private locations such as campuses.

Electric Bikes and Scooters

A rapid increase in cycling and e-biking (electric bikes) could save society $25 trillion between 2015 and 2050, and cut transport emissions by an additional 10%, according to the Institute for Transportation and Development Policy. Many startups sell **lightweight e-bikes** designed for urban mobility, such as MATE (Denmark), Faraday (US) and Cowboy (Belgium). **Electric standing scooters (e-scooters)** are also popular, with Chinese giants Xiaomi and Ninebot leading production. SnikkyBike (Canada) offers a cross-over between the two models. In Taiwan, Gogoro makes **electric mopeds and battery swapping stations.** Vehicle sharing is a key driver of adoption (see MaaS below).

Mobility-as-a-Service (MaaS)

The MaaS concept refers to an array of mobility solutions used according to travel needs, thanks to digitalization and vehicle innovations.

While car ownership is declining in some cities, mobility services have become widely popular. Global tech firms like Uber, Didi, Ola, Grab, Taxify, Lyft, and Cabify dominate **ride-hailing** globally, and new **moto-taxi apps** like SafeMotos are emerging in Africa. **Car-sharing** players include Zipcar (US), Drivy (France), and a BMW-Daimler joint venture formed by the merger of DriveNow and Car2go. Carpooling for urban commuting is also starting to take off, with French giant BlaBlaCar opening BlaBlaLines in addition to its long-distance travel service.

Bike and scooter services range from municipal bike-sharing like the iconic Vélib to **dockless systems.** The latter include Chinese giant Mobike (bikes), US-based Jump and Indian Mobycy (e-bikes and e-scooters), the Mexican-Brazilian Grow (bikes and e-scooters), and the French Cityscoot (electric mopeds). In spite of their popularity, **free-floating bike and scooter systems** have been heavily criticized. The main concerns relate to an unregulated deployment by multiple competitors leading to an overuse of public space, along with the very low durability of most vehicles.

The holy grail of MaaS is to integrate all these options with public transportation, in a unified gateway that manages the entire trip. UK transit app CityMapper aggregates data from public transport, walking, cycling, driving, and ride-hailing to help users navigate their city. The firm recently added their own fleet of shared vehicles into the app, using data to optimize routes. Finnish startup Whim charges a monthly fee for unlimited public transport combined with subsidized bike-sharing, car-sharing, and taxi rides. Launched by auto giant PSA, Free2Move integrates the cars, bikes, and scooters from several sharing services.

Research firm RethinkX estimates that MaaS—or TaaS, Transport as a Service—will get mainstream during the 2020s and lead to the collapse of car ownership. In their forecasts, EV, AV, and ride-hailing combined could be two to ten times cheaper per mile than owning your car.

"Thanks to the impending advent of autonomous cars, we might actually get a chance at a do-over — of our cities, our fossil fuel dependence, and the social contract with labor."

Robin Chase,
Co-Founder of Zipcar, Veniam, and NUMO
(in WIRED Magazine)

Flying and Floating Taxis

Beyond road and rail, new categories of vehicles could soon hit the skies and waters of our cities. Designed for urban waterways, SeaBubbles (France) is an electric **hydrofoil water taxi** currently tested in Paris and Geneva. In Amsterdam, Roboat is an **autonomous floating vessel** designed by MIT and the AMS Institute.

Autonomous flying taxis could soon become a reality with electric vertical take-off and landing (eVTOL) aircrafts. Key players include German startup Lilium, as well as aerospace giants Airbus, Boeing and Embraer. Lilium expects that a flight will be cheaper than a taxi ride and that in the long-term, eVTOLs could tackle congestion, air pollution, and the urban housing crisis by allowing users to commute further.

Intelligent Transportation Management

Sensors, data analytics, and machine learning can optimize urban mobility. **Focusing on public transit,** companies like Swiftly (US) help municipal agencies leverage real-time movement data to improve service quality. WhereIsMyTransport (South Africa) uses smartphone data to map informal transport networks in the Global South, and integrate these maps with the official public transit system into one journey planner.

Aiming to improve road transport, the Waze Connected Cities Program uses data from the popular navigation app to help cities monitor roads, reroute drivers to avoid traffic, and make infrastructure decisions. Brisk Synergies (Canada) uses computer vision and machine learning to understand traffic and prevent accidents. Coord (US) and Mapillary (Sweden) help cities enhance their maps with fresh street-level imagery uploaded by individuals and organizations.

Singapore was the first country to implement Electronic Road Pricing to charge vehicle owners according to road usage and alleviate congestion during peak hours. Clear Road (US) offers similar technology to help local governments capture revenue for road infrastructure.

Enhance inclusive and sustainable urbanization and capacity for participatory planning and management *[11.3]*

Participatory Urbanism Platforms

One of the most fertile grounds for civic tech adoption is the involvement of citizens in the process of improving their cities and neighborhoods. **Street reporting platforms** like FixMyStreet (UK) and Colab.re (Brazil) are well-known examples, allowing residents to report potholes and other issues that need fixing.

Local civic participation platforms go one step further and involve citizens through surveys, ideation, and participatory budgeting. Municipalities like Barcelona and Paris have been using such platforms —Barcelona even shares its code on Github for other cities to use. Companies like CitizenLab (Belgium) and Fluicity (France) offer similar features with a software-as-a-service model. Others like Spacehive (UK) and Neighborly (US) allow residents to donate and invest money into urban renewal and real estate projects around them.

Reduce the negative environmental impact per capita of cities, especially air pollution and waste *[11.6]*

Cities account for 70% of waste generation, 70% of carbon emissions and over 60% of energy use, while 80% of urban areas exceed WHO safe air guidelines. Mitigating these adverse environmental impacts requires a dual approach: reducing immediate hazards from waste and air pollution, while improving urban metabolism through the efficient and circular use of materials, food, energy, and water. The SDG2, SDG6, SDG7, SDG9 and SDG12 chapters feature additional solutions to the ones below.

Air Quality Monitoring

With 7 million deaths every year, *"air pollution is the new tobacco"* says the head of WHO. While air quality indexes (AQI) feature aggregated views at the municipal level, new tech firms aim to provide a more granular understanding through **distributed sensor networks.** Examples include AirVisual (China), PlumeLabs (France), Oizom (India), and Aclima (US). At the grassroots level, citizen sensing communities are developing their own sensors based on open source platforms like Airbeam and SmartCitizen—addressing the trust gap with official AQI.

Air Purification Systems

Fossil fuels, motorized vehicles, and industrial emissions are the main air pollution culprits in the 80% of cities globally exceeding WHO safe air guidelines. Root-cause solutions thus involve clean energy (SDG 7), clean mobility (see above), and sustainable industry. France-based Terrao developed an **air-water heat exchanger** which, in addition to recycling thermal energy, can filter particulate matter and other air pollutants, which then flow to wastewater treatment plants.

Several innovators have designed filters and “vacuum cleaners” to purify ambient air directly. Examples include the German City Tree which uses a moss-culture wall, and the Dutch Smog Free Tower—piloted in China and Poland—which filters 30,000 m3 of air per hour and recycles carbon particles into jewelry. India-based Graviky Labs is developing its capture device after a successful launch of Air-Ink, the first ink entirely made out of air pollution. Finally, high-tech masks like R-Pur (France) can filter even high levels of particulate and gas pollution.

Waste Picking Platforms

In many developing and newly-industrialized countries, rapidly urbanizing areas lack the infrastructure to manage the increasing amount of waste. A large portion could be recycled, but ends up in landfills in the absence of separate collection. Digital platforms can help tackle the issue, by **connecting informal waste pickers with citizens and businesses** who need to discard recyclable items and materials. Examples include I Got Garbage in India, New Hope EcoTech in Brazil, and the Baidu Recycle App developed with UNDP China to recycle electronic waste.

Smog-Free Tower. Photo: Studio Roosegaarde

Advanced Recycling Infrastructure

As widely documented in research from the Ellen MacArthur Foundation, achieving a circular economy requires investment at all levels, including an adequate after-use infrastructure. When it comes to recycling, harmonized guidelines should be complemented by processes which maximize the purity of recovered material streams. Innovations in that space fall into three categories: collection, sorting, and reprocessing.

Advanced material sorting often combines robotics, image recognition to recognize product types, and optical sorting such as near infrared spectrometry to identify chemical composition. Examples include ZenRobotics (Finland), AmpRobotics (US), and the textile-sorting machine Fibersort (Belgium). Another approach is to **embed easily detectable markers within products**, such as barcodes, fluorescent inks, RFID tags, or invisible bio-based markers like Applied DNA Sciences (US).

Reprocessing methods vary depending on product type, but fall into two broad families. **Mechanical reprocessing** conserves higher-value materials by cleaning and separating their different parts, such as metals in electronic products (see the Apple Daisy in SDG 9), fiber types in textile, or polymers in plastics such as Quality Circular Polymers (Netherlands).

Chemical reprocessing breaks down complex or degraded materials into new virgin feedstock. For instance, Infinited Fiber (Finland) and re:newcell (Sweden) turn cotton and viscose into new cellulose-based fibers; Worn Again (UK) recycles the polymers from PET bottles and clothing (cotton, polyester) into new textiles; Carbios (France) and Ioniqa (Netherlands) break down polymers into monomers to further recycle plastics.

Organic Resources Looping

Cities should divert organic waste and compostable materials from landfill and incineration, in addition to preventing avoidable food waste upstream. Looping organic resources helps recover valuable nutrients and byproducts, which can be turned into organic fertilizer for peri-urban agriculture, as well as bioenergy and other products.

At the municipal level, Loveyourwaste (France) turns catering waste into biogas and compost through anaerobic digestion (AD)—decomposition without oxygen. In the US, Industrial/Organic uses a multi-step process called anaerobic fermentation to break down food scraps into energy, water, and compounds used to make fertilizers, fragrances, and cleaners. Compared to AD this process is cheaper, faster, and does not produce methane, thus fitting within urban areas as a distributed network of micro-facilities. To increase volumes, utility giant Suez launched Organix, a marketplace connecting organic waste producers with bioenergy plants. Others like Canada-based Ostara and Lystek harvest nutrients from wastewater treatment plants (see SDG6).

At home, most urban residents still lack access to adequate organic waste collection and outdoor composting. Whirlpool has developed the Zera home appliance, which uses a plant-based additive to turn food scraps into fertilizer within 24 hours—including animal products. Notwithstanding, a lifecycle analysis would be necessary to evaluate this high-tech approach.

Urban Farms

Growing food within city boundaries can improve the diversity and resilience of the food supply, and offer several social and environmental benefits—under the right conditions. Urban farms fall into two broad categories: soil-less vertical farms and soil-based planting.

Soil-less vertical farms use stacked layers and vertical surfaces to grow crops with hydroponics, aquaponics, and aeroponics. Compared to conventional agriculture, they require up to 20 times less water and little or no pesticides. Many tech firms operate indoor farms in warehouses and shipping containers with artificial light—Aerofarms (US), Plenty (US), Infarm (Germany), Growing Underground (UK), and Agricool (France) are only a few of them, along with MIT OpenAg (US) and Japanese high-tech giants repurposing idle factories like Toshiba, Sharp, Fujitsu, and Panasonic. Vertical farms can also be located in greenhouses to harness natural sunlight, either on rooftops like BIGH (Belgium) and Lufa (Québec), or in the suburbs like Bright Farms (US).

Photo: Chris Barbalis

Soil-based planting includes outdoor farms, community gardens, and soil greenhouses. Though yield potential is limited, these farms can provide various co-benefits, such as additional green space, reconnecting urban dwellers with food, carbon sequestration, reduced air pollution, mitigating the urban heat island effect, and improved water retention which reduces flood risks. Several projects aim to automate outdoor farms and greenhouses, including Farmbot (US) and Romi (EU project).

However, urban farming alone is unlikely to feed our growing cities. The Ellen MacArthur Foundation estimates in a recent report that *"a theoretical maximum of one-third (by weight) of the food needed for urban consumption could be grown within cities"*—even with high-yield indoor farms. Three issues prevent urban farmers to even reach this threshold: high competition for urban space; limited diversity of indoor crops (leafy greens, herbs, strawberries, etc.); and the adverse environmental impacts of high-tech indoor fams (high energy costs and the need for synthetic liquid fertilizers). These impacts could be partially limited by using circular flows of water and nutrients, as well as renewable energy.

Energy-Efficient Street Lighting

Street lighting is often a large share of a city's energy consumption as well as its municipal budget. In regions like India and the Philippines, street lights can represent up to 10% of municipal budgets in large cities, up to 20% in smaller towns, and 65% of their electricity consumption according to the World Bank. **LED lights** are 40 to 60% more energy-efficient and last four times longer, despite a higher upfront investment.

France-based Sunna Design produces **solar-powered LED modules** for street lamps, adapted to urban areas in the developing world where grid connectivity is limited. These modules are remotely monitored and can also power other applications such as Wi-Fi hotspots, environmental and traffic sensors. Others like Dutch company Tvilight provide intelligent lighting solutions, where **lighting levels change in real-time** depending on daylight and the presence of vehicles and pedestrians nearby.

Photo: Safira Moreira / Olabi

Data-Driven Urban Planning

Hyperlocal urban data can allow planners to get granular insights and craft strategies accordingly. For instance, Aclima (US) uses mobile environmental sensors—mounted into cars—and a software platform to map urban air pollution and GHG emissions at a block-by-block resolution. Google's Environmental Insights Explorer combines proprietary data from Maps, Waze, and Project Sunroof with public sources like NASA. The new platform enables cities like Pittsburgh, Melbourne and Buenos Aires to create carbon baselines and inform their climate strategies.

Urban data management platforms like Stae and Urbint (US) enables cities to integrate disparate datasets—transportation, land use, population census, sensors, and more. Such platforms allow planners and operators to reveal hidden patterns in urban data to make better decisions. Others like UrbanFootprint (US) help assess the social and environmental impacts of development program in terms of emissions, accessibility, mobility, water and energy use, conservation, resilience, and more. The platform uses parcel-based datasets, urban design toolkits, and interactive features for scenario building and data visualization. Azavea (US) offers similar features, also covering themes like civic participation and social impact.

Finally, advanced simulation tools can help planners better anticipate impacts by providing a bridge between theory and experiment. Realistic "SimCity" models could help predict unintended consequences on mobility, emissions, land valuation, and more. Examples include UrbanSim, the Participatory Chinatown video game, and synthetic population simulators like Onhys (France) and Replica, a product from Sidewalk Labs. The latter uses de-identified mobile location data to generate travel behavior models, which are then combined with demographic data to generate a virtual population that is statistically representative of the real population. The software then applies each virtual citizen a travel behavior model, thus simulating an entire week of trip patterns across the city.

Photo: Abderrahim Chaouni

Challenges

Citizens versus the smart city. At the turn of the century, the "smart city" was all the rage: technology would improve cities by optimizing their use of resources. Today many dismissed the idea as top-down, techno-centric, and with little focus on maximizing residents' well-being. Recently, much controversy has surrounded a futuristic neighborhood project on the Toronto waterfront by Sidewalk Labs—a subsidiary of Google's parent company Alphabet. The tech utopia would be filled with climate-positive buildings, driverless shuttles, and tunnels for last-mile delivery and garbage collection robots. Unfortunately, the company has run into local resistance because of insufficient democratic participation and unclear intentions about IP and data ownership. As an alternative, cities like Barcelona have been promoting a citizen-driven smart city.

The urban tech divide. *"The benefits from technological innovation and urban growth are not yet reaching all of those in greatest need (...) While vulnerable populations, and children in particular, stand to gain the most from access to emerging tech (...) these require constant connectivity, and are not designed for, or with, the urban poor."* — UNICEF and Arm.

New mobility and urban planning. The unplanned and rapid emergence of innovative urban transport can have potentially adverse effects. Examples include ride-hailing's impacts on worker rights and public transit, the invasion of streets and curbs by thousands of free-floating bikes, and the regulatory limbo surrounding personal mobility devices. Moreover, as Robin Chase argues, AVs will soon require proactive action from cities aiming to reap social and environmental benefits. First, AVs should ideally all be electric and shared. Second, safety nets and reskilling programs should support taxi and truck drivers whose jobs are likely to be displaced. Third, governments will need to rethink car-related taxes to compensate for the loss of gasoline tax, fines and parking revenues.

Automated recycling shows limitations without proper waste source separation upstream. For instance, so-called *Mechanical-Biological Treatment (MBT)* has been found to produce compost that does not meet quality requirements, because of toxic pollution.

Goal 12

RESPONSIBLE CONSUMPTION AND PRODUCTION

Ensure sustainable consumption and production patterns.

12 RESPONSIBLE CONSUMPTION AND PRODUCTION

> If we could build an economy that would **use things rather than use them up**, we could build a future

***ELLEN MACARTHUR,** SAILOR AND CIRCULAR ECONOMY ADVOCATE*

44.7M

TONNES OF **ELECTRONIC WASTE** GENERATED IN 2016

GLOBAL E-WASTE MONITOR 2017

1.7 PLANETS

ARE NEEDED TO **SUPPORT HUMANITY'S DEMANDS** ON ECOSYSTEMS

GLOBAL FOOTPRINT NETWORK / EARTH OVERSHOOT DAY

Photo: Paweł Czerwiński

Photo: Rocks Lab

Tech for SDG 12

Achieve sustainable management and efficient use of natural resources. *[12.2]* Significantly reduce the release of chemicals and waste to air, water and soil *[12.4]*

Even an ambitious circular economy cannot eliminate the need for virgin material. This demand could be sustainably met using feedstock derived from biological sources and greenhouse gases (GHG), or advanced materials. Additional solutions for food production are featured in SDG2.

Bio-based Materials and Chemicals

Bio-based products are made of feedstock derived from living organisms, in whole or in a significant part. Such products include conventional materials like wood and pulp, and new products engineered to replace unsustainable resources.

Physical and chemical processes can split biomass into compounds like starch, cellulose, protein, and lignin, which can be transformed into new materials. Seaweed can be processed into edible cutlery and food packaging by companies like Evoware (Indonesia) and Skipping Rocks Lab (UK). The latter created Ooho, an edible sachet replacing plastic packaging for outdoor consumption of beverages and condiments. Using the company's machine, retailers and caterers can produce 100 Oohos in minutes.

Coco Pallet (Netherlands) makes export pallets from coconut waste to replace timber and halt deforestation in Southeast Asia. Pond (Denmark) and Cellucomp (Scotland) produce bio-based resins, fibers and granulates which serve as ingredients in paints, coatings, and natural composites. Renmatix (Canada) makes bio-ingredients for the food and beauty industries. Orange Fiber (Italy) invented a silk-like textile fiber made from citrus juice byproducts, already used by fashion brands like Salvatore Ferragamo. Tipa (Israel) makes compostable plastic packaging, while Origin Materials (US) invented a recyclable bio-PET plastic, drawing interest from Danone and Nestlé.

Industrial biotechnology is an increasingly popular way to create "biofabricated" materials. Most often this involves a fermentation process: micro-organisms like yeasts, bacteria, and fungi are cultivated to grow the desired products from biomass-derived sugars.

A biofabrication pioneer, Ecovative (US) uses mycelium fungi to create products like bio-based foam packaging and construction materials, supplying customers like Dell and IKEA. In the textile industry, Pili (France) uses cell factories to transform sugar into colors with a drastically lower footprint than petrochemical dyes. Other examples include animal-free leather from Modern Meadow (US) and bio-based cement from BioMason (US). In the future, one could even hope for bio-based electronics, such as the nanowire produced by scientists using common soil bacteria.

"I think there are amazing opportunities in bio-based materials, but the sector is hyped so finding the good projects takes time. The best examples are not super visible, the technology is proprietary, and a lot happens within large companies, too."

Ditte Lysgaard Vind,
CEO of Lendager The Circular Way

GHG-based Materials and Chemicals

Most of the examples above rely on second and third generation biomass—agricultural byproducts and algae. The fourth generation refers to emerging feedstock like captured greenhouse gases (GHG), which can be recycled into fuels (see SDG 7) and other valuable products. Under the right conditions, the entire process could be carbon-negative.

A simple way to capture CO2 is to avoid its release when plants die, by baking biomass into **biochar** (see SDG 13). German startup MadeofAir then transforms it into building materials such as design facades, made of 90% sequestered carbon.

CO2 captured from flue gas can also replace cement in concrete production, a major source of emissions. XPrize finalists CarbonCure and CarbiCrete (Canada) tackle this opportunity: the former by injecting CO2 into the wet concrete mix to reduce the need for cement, the latter with a cement substitute made from CO2 and steel slag—waste from steel production. California-based Blue Planet sequesters CO2 into a bagged aggregate used in concrete and roofing tiles.

Finnish company Soletair uses **electrochemistry** to split water into oxygen and hydrogen, then combines the latter with atmospheric CO2 to synthesize fuels and high-value chemicals (see also Opus12 in SDG 7).

Other companies capture methane—from farms, landfills, sewage and energy plants—and combine it with oxygen in a **gas fermentation** process. Newlight (US) makes Aircarbon, a carbon-negative bioplastic already used by IKEA. Mango Materials (US) produces packaging and polyester fibers. String Bio (India) is currently refining a process to create monomers for plastics and chemicals production.

Photo: Pili

Advanced Materials

This category generally refers to any material engineered to provide superior performance, which can enable longevity and robustness. For instance, Bolt Threads (US) uses gene-edited yeast to produce spider silk, a textile fiber which combines high-performance (strong, durable, soft, elastic) and sustainability.

In the construction sector, Woodoo (France) aims to mainstream the use of wood, known for its sustainability features, by improving its performance characteristics tenfold. The company extracts the lignin (an organic binder) from wood and replaces it with a plant-based resin, which increases its resistance to shock, fire, and moisture. The new translucid product will be piloted in the design industry first, to achieve economies of scale.

Recycled Materials

Another kind of sustainable feedstock can be found in the recycling of industrial and urban waste into new products. For instance, French design studio Maximum uses industrial waste streams to make furniture.

The opportunity is substantial in the built environment, which represents the majority of total material use and wastes globally. Raw materials and other elements like window frames and inner walls can be reclaimed for circular construction. New products and materials can also be made from recycled plastics, such as the ByFusion (US) alternative to concrete cinder blocks, the Plastic Road (Netherlands) street building blocks, and the urban furniture made by Zicla (Spain) for cycle lanes and accessibility.

Sustainable Design Tools

Software tools used daily by designers, engineers and manufacturers can help them improve their products' footprint. Leading editors like Autodesk (one of the patrons of this report) have released tools for energy efficiency and support inventors in using their software for sustainable design. Online libraries like MateriaBrasil help designers and companies choose materials based on sustainability features, while Materiom even allows users to make their own bio-based materials with open-source recipes.

ResCoM is an EU-funded collaboration of academia and industry which developed software tools to embed circularity in product design, business models, material selection, and supply chain strategies. Among industry-specific tools, Circular.Fashion (Germany) is a circular design software dedicated to fashion brands and their material suppliers.

Halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains *[12.3]*

Food Waste Reduction Platforms

Globally, about a third of the food produced for human consumption gets wasted. In developed countries, this waste primarily happens at the retail, catering and consumer levels. Many address this problem with software tools targeted to these segments. For instance, Copia (US) connects food stores with charities to provide them with unsold produce. In Europe, Too Good To Go is a mobile app where users can find stores and restaurants around them selling cheap yet delicious meals that would otherwise be wasted.

Others focus on the catering side, such as Winnow (UK) which helps professionals measure how much food they waste so they can optimize procurement. Wasteless (Israel) uses machine learning to offer dynamic pricing based on produce expiration date.

"Starbucks is opening one store every 15 hours in China, a country that used to drink tea, not coffee. They made it aspirational and attractive. If we can do the same with sustainable lifestyles, we can change the world. That is our mission: making plant-based diets cool."

David Yeung,
Founder of Green Monday and Green Common

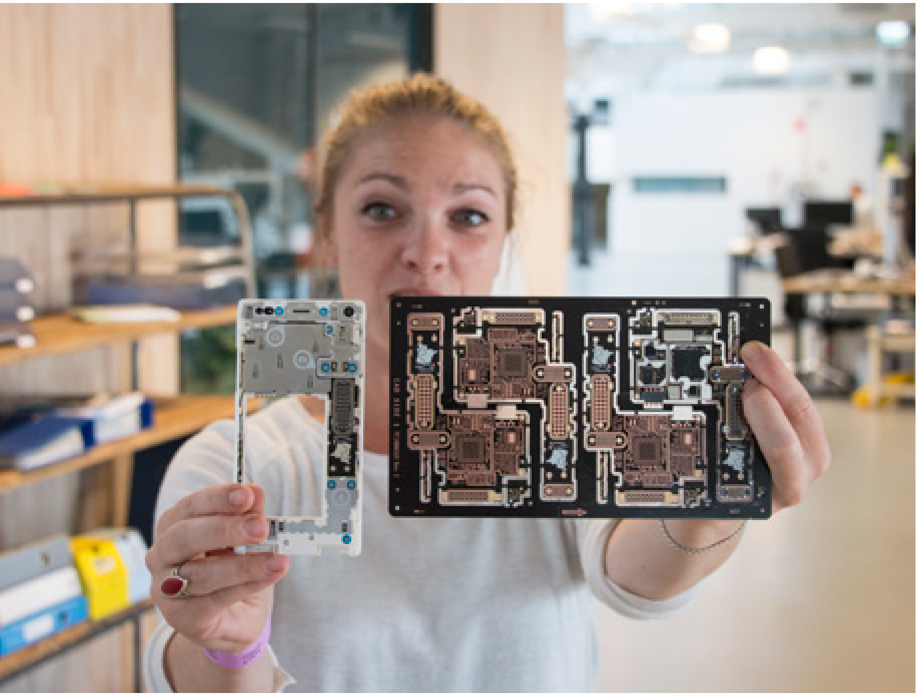


Photo: Fairphone

Substantially reduce waste generation through prevention, reduction, recycling and reuse *[12.5]*

In the circular economy, inner loops should always have priority as they preserve more material value. Products should thus be recycled only when reuse and repair are no longer possible. The examples below focus on inner loops, while SDG9 and SDG11 feature recycling systems.

Product Reuse Platforms

The last ten years have seen the rise of the **sharing economy**, a model in which assets circulate between individuals. For instance, marketplaces like LeBonCoin (France), Geev (France), Tem Açucar (Brazil), and Peerby (Netherlands) can facilitate the resale, gift, rental, lending, or barter of products between consumers. Product-service systems like Vigga (Denmark) enable parents to lease babywear.

New proposals to scale **reusable packaging** include Loop by TerraCycle (US), an e-commerce platform selling products from the world's biggest brands in returnable containers. However, in this example and some of the ones listed above, lifecycle analyses are required to evaluate environmental trade-offs and possible rebound effects.

Some of these B2C systems also get translated in B2B. Examples include Phenix (France) and Revivn (US) which collect old and surplus goods and repurpose them for social organizations. On the packaging and logistics front, the Physical Internet offers an ambitious long-term vision, summarized by the Ellen MacArthur Foundation as a "*system based on standardised, modularised and reusable containers, using open networks across industries with pooled assets and protocols.*"

Product Repair and Upgrade

Modular design and business models which include the provision of spare parts can increase product life and reduce material consumption. Based in the Netherlands, Fairphone is the world's first modular smartphone made from responsibly sourced minerals, which users can repair and upgrade with parts provided by the company. Italian-Chinese carmaker Open Motors took a similar route with its open, modular platform for autonomous electric vehicles designed for distributed assembly.

Online platforms allow users to **learn how to repair** products themselves like iFixit (US), or to **order and 3D print spare parts,** such as Happy3D by French retailer Boulanger.

Companies like Autodesk and IDEO (with the Ellen MacArthur Foundation) and universities like TU Delft share many resources online for designers to learn how to improve their products lifespan.

Ensure that everyone has the relevant information and awareness for sustainable development and lifestyles *[12.8]*

Product Rating Platforms

Various apps and websites help consumers choose sustainable products. Based in Australia and accessible in Europe and North America, the GoodonYou app provides 5-star ratings for a thousand fashion brands based on their impact on workers, animals and the planet. It aggregates publicly available data, including certifications like Fair Trade. Other examples in the food sector include HowGood (US) which aggregates over 350 data sources to rate 250,000 products, and Mi Código Verde (Chile).

Transparent Supply Chains

When blockchain developers started to explore use cases beyond Bitcoin, they realized that a **tamper-proof ledger** could serve many purposes other than financial transactions. Improving supply chains is one of them.

UK-based Provenance helps businesses **record verified information about how their products are made**—images, locations, claims, identities—so they can present it to customers, online and in stores through radio-frequency information (RFID) tags. The startup partnered with many food & beverage producers and retailers (see SDG14) as well as fashion brands like Martine Jarlgaard, which used the software to track the journey of an alpaca jumper from the farm to the finished garment.

IBM recently launched its Food Trust platform with companies like Walmart, Carrefour, Nestlé, and Unilever. These retail and food giants will be onboarding their suppliers in hopes of improving food safety and freshness, reducing food waste, and more.

Most of these initiatives currently rely on private blockchains, which critics say have more in common with shared databases than a technological revolution. That does not undermine their value.

Online Farmer's Markets

Online marketplaces can help local farmers sell their produce directly to consumers, bridging the convenience of e-commerce with the ethics of farmer's markets—local healthy food and a fair price for producers. Examples include France-based The Food Assembly which operates in several European countries, UK-based Farmdrop, and Australia-born Open Food Network, a free software platform for food communities.

FinTech for Good

Finance has been deeply transformed by the digital revolution, from payments to mobile banking, investment, credit, insurance, and more.

Several companies aim to harness fintech for good, for instance by **combining ethical banking with a modern user experience.** US mobile bank Aspiration enables its customers to invest in sustainable companies. OpenInvest is a **robo-advisor for retail impact investing** which lets users choose the causes they care about, then creates and manages a diversified investment portfolio aligned on these choices. In Denmark, Matter helps bring sustainable investment in the pension space, which represents substantial financial assets in Nordic countries.

Sardex is a regional mutual credit network born in Sardinia. Thousands of local SMEs use its digital currency and payment app to trade with each other, and other Italian regions are testing the system. In Canada and France, Impak is developing a mobile app helping consumers find responsible brands and stores around them. Purchases are rewarded with a dedicated cryptocurrency, which users can spend within the network.

Crowdfunding is also increasingly used for impact. Kickstarter is now a certified B Corp and many smaller platforms have specialized in social impact projects. Examples range from donations for public space renewal like Spacehive (UK) to investments in social enterprises like Lita (France).

Challenges

Rebound effects occur when behavior changes and systemic responses offset the expected gains from resource efficiency. These effects are of three kinds. First, direct rebound effects when savings and rewards from a green purchase lead to an increased consumption of the same product. Second, indirect rebound effects when the gain is reinvested in activities which increase overall footprint, such as taking one more flight. Third, economy-wide effects when efficiencies lead to more growth and increased resource consumption overall. One way to counter rebound effects could be to reinvest economic gains into products with a net-positive impact on the biosphere.

Sustainable materials depend on the after-use infrastructure. As the Ellen MacArthur Foundation writes: *"The development and introduction of new packaging materials and formats [is] happening far faster than and is largely disconnected from the development and deployment of corresponding after-use systems and infrastructure."* As an example, compostable products only make sense when they are actually composted, which often is only possible in industrial facilities.

Social media, e-commerce, and overconsumption. Despite laudable attempts to drive sustainable consumption with digital technology, mainstream platforms tend to incentivize the opposite. One out of ten British shoppers admit buying clothes only to post a picture on social media before returning them, thanks to the "try before you buy" policy of e-commerce giants like Amazon.

Photo: Jezael Melgoza

Goal 13

CLIMATE ACTION

Take urgent action to combat climate change and its impacts .*

420 GIGATONS: HOW MUCH CO_2 WE CAN **STILL EMIT FROM 2019 ONWARDS** TO STAY **UNDER 1.5C** OF WARMING—OUR CARBON BUDGET. **ABOUT 10 YEARS OF CURRENT EMISSIONS.**

IPCC SPECIAL REPORT ON 1.5C

150 TO 300 MILLIONS OF POTENTIAL CLIMATE REFUGEES **BY 2050**

GEMENE 2011 (ELSEVIER GLOBAL ENVIRONMENTAL CHANGE)

$20 TRILLION: MINIMUM **REDUCTION IN ECONOMIC DAMAGES** IF GLOBAL WARMING REMAINS UNDER 1.5°C INSTEAD OF 2°C.

BURKE ET AL. 2018 (NATURE)

> Climate change is the single biggest thing that humans have ever done on this planet. The only thing that needs to be bigger is **our movement to stop it**

BILL MCKIBBEN, *FOUNDER OF 350.ORG*

Photo: Tama66

Tech for SDG 13

Photo: musicFactory lehmannsound

Goal 13 aims to translate into national policies the measures agreed within the UN Framework Convention on Climate Change. Its cornerstone is the 2015 Paris Agreement, which aims to limit global warming to well below 2C this century, and ideally below 1.5C to avoid the worst consequences of climate change.

Our remaining carbon budget for 1.5C is about ten years of current emissions according to the last IPCC report. While we already experience the effects of 1C of warming through extreme weather events and coral bleaching, our current trajectory leads us to 3C warming with catastrophic effects on sea level rise, heat stress, water scarcity, crop yields and forced migrations. The situation could get even worse if we cross Earth-system tipping points allowing natural feedback loops to kick in.

The threat of climate collapse requires a *"rapid, far-reaching and unprecedented"* response (IPCC) on two levels. First and most importantly, **mitigation aims to decrease the level of GHG in the atmosphere, to limit and possibly reverse climate change.** It involves both a drastic reduction of anthropogenic emissions, as well as the removal of excess carbon already in the atmosphere. Second, **adaptation aims to reduce the impact of climate change** which is already in the pipeline and cannot be avoided. Most of this report focuses on mitigation strategies.

Sometimes proposed as a third category and last resort response, **albedo modification** aims to increase the Earth's capacity to reflect sunlight and limit the rise of temperatures, through solar radiation management (SRM). These highly controversial geoengineering techniques could have dire environmental, safety and security consequences (see chapter 5) and falls out of the scope of this report.

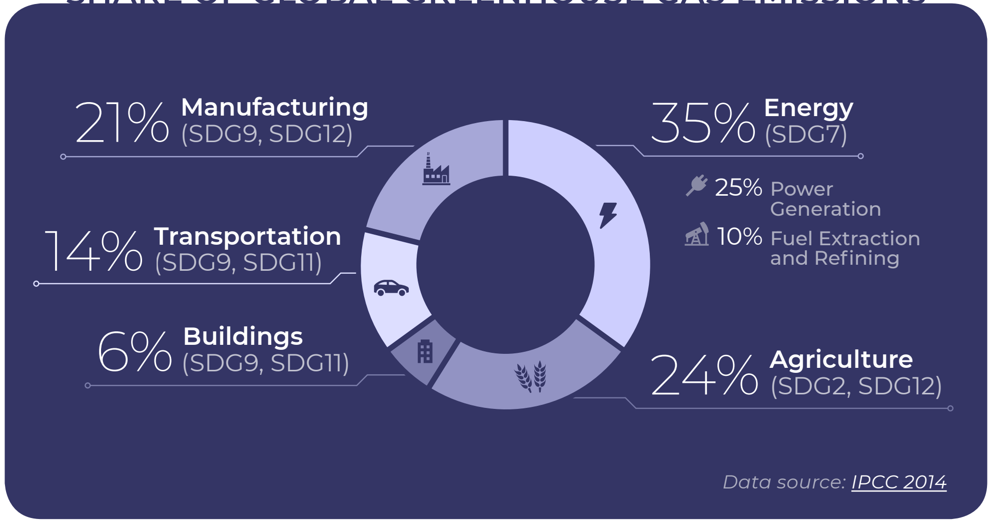
1. Mitigation through emissions reduction

The Paris Agreement target can be achieved if humanity follows a Global Carbon Law: GHG emissions should peak by 2020 at the latest, then halve every decade until 2050—a 7% annual reduction.

This ambitious trajectory was calculated in 2017 by top climate scientists from the Stockholm Resilience Centre. It takes inspiration from how Moore's Law drove computing forward since the 1960s by predicting that computing power would double every two years.

Following the Carbon Law requires unprecedented action, with a specific focus on the five sectors emitting the largest share of GHG.

SHARE OF GLOBAL GREENHOUSE GAS EMISSIONS



The next paragraphs provide an overview of how technology could help to slash GHG emissions across these sectors, based on research produced by Project Drawdown (2017) as well as the Exponential Climate Action Roadmap (2018) led by Future Earth and the Stockholm Resilience Centre. We refer to the SDG2, SDG7, SDG9, SDG11, and SDG12 sections of this report where the solutions are featured.

Energy

The energy sector is the biggest climate culprit with 35% of GHG emissions, split between 25% for electricity and heat generation, and 10% for fuel extraction, refining, processing and transport.

Technology can help us halve energy emissions every decade in three main ways (see also SDG7):

- **Substituting fossil fuels with clean energy,** especially from renewable sources like wind, solar, hydrogen, geothermal, marine energy, next-generation biomass and hydropower, as well as advanced nuclear energy.
- **Transforming the power grid** so it can handle decentralized energy resources and the intermittency of renewables, mostly through better energy storage and grid flexibility.
- **Reducing the emissions from existing fossil fuel plants** as a one-off improvement until decommission, trough methane leakage avoidance and carbon capture and storage (CCS).

Agriculture

Agriculture and land-use change (deforestation) are responsible for 24% of GHG emissions. According to Project Drawdown, the sector has the highest mitigation potential when both emissions reduction and carbon removal are considered. Their research indicates that better food and land-use systems could achieve respectively 30% and 16% of a 1000 gigatons target reduction in CO2 levels by 2050.

Technology can help us halve agriculture emissions every decade in three main ways (see also SDG2 and SDG12):

- **Reducing food waste,** via postharvest conservation systems as well as retail- and consumer-level waste prevention.
- **Reducing the share of animal food products** through plant-rich diets and new protein sources, including clean-meat.
- **Substituting harmful agricultural practices and chemicals** with regenerative agriculture—see "carbon farming" below—and sustainable alternatives for pest control and fertilizers.

Manufacturing

Manufacturing is responsible for 21% of GHG emissions. The Exponential Roadmap breaks down this figure between light industry (e.g.: textile, wood, printing, food) and heavy industry (e.g.: cement, refineries, metal fabrication, paper, fertilizers).

Technology can help us halve industry emissions every decade in four main ways (see also SDG9 and SDG12):

- **Scaling the circular economy** through closed-loop business models, better product design, and advanced remanufacturing.
- **Substituting fossil-based feedstock with sustainable alternatives** in the production of materials and chemicals, such as recycled, bio-based (gen-2, 3, 4) and GHG-based feedstock.
- **Increasing production efficiency** through process innovation (additive manufacturing is a candidate), better factory design to reuse water and energy, and shortened supply chains.
- **Quickly and properly phasing out HFC (hydrofluorocarbon) refrigerants** in air conditioners and refrigerators. These fluids have a 1000X to 9000X higher warming potential than CO2 but can be replaced by sustainable alternatives like propane.

Transportation

Transportation drives 14% of GHG emissions globally, with a higher share in rich regions like Europe and North America.

Technology can help us halve transportation emissions every decade in five main ways (see also SDG9 and SDG11):

- **Scaling electric vehicles (EV) and low-emission fuels,** from better biofuels to hydrogen and solar fuels.
- **Enabling the Transportation-as-a-Service model for clean urban mobility,** combining mass transit and shared fleets of bikes, e-scooters, and self-driving EVs.
- **Making logistics more efficient,** through low-emission trucks, trains, alternative cargo (airships, clean freight), shorter supply chains, and a global shared logistics network (physical internet).
- **Cutting emissions from air travel,** through reduced demand (e.g. remote work and meetings, rail, road, shipping) as well as continued efforts to make low-emission flights a reality (e.g. electrification, advanced biofuels, solar fuels).

Buildings

Buildings generate 6% of GHG emissions, including emissions from existing buildings (split 60/40 between residential and non-residential) and the construction of new buildings. The latter is expected to grow mostly across Asia in the coming decade, followed by Africa.

Technology can help us halve buildings emissions every decade in three main ways (see also SDG7 and SDG12):

- **Unlocking the vast potential for energy efficiency** in buildings, through better appliances, smart building solutions, retrofitting, as well as low-carbon heating and cooling.
- **Making sustainable construction more competitive on cost and performance,** with materials like carbon-negative concrete and bio-engineered wood, and more efficient building processes.
- **Reducing the demand for building space,** through optimization, remote work, and dematerialized services.

2. Mitigation through carbon removal

As our 1.5C carbon budget is almost depleted, reducing emissions will not be enough to avoid catastrophic climate change: we also need to remove excess GHG from the atmosphere. The most optimistic IPCC scenarios for 1.5C and 2C, as well as the Carbon Law, all require substantial “negative emissions” through carbon removal.

Carbon removal restores and creates carbon sinks to absorb GHG and rebalance the Earth’s carbon cycle. Using a bathtub analogy, it is about increasing the size of the drain, while reducing emissions lowers pressure in the shower head—and we need to do both. Cradle-to-cradle inventor Bill McDonough described climate change as a design failure in which airborne carbon ends up “*in the wrong place, at the wrong dose, and for the wrong duration*” instead of being used in plants, soils, and durable materials.

A New Carbon Economy which *"removes and sequesters more carbon from the atmosphere than it emits"* has been proposed by groups including John Elkington's agency Volans, Berkeley-born Carbon180 advocacy, and the New Carbon Economy Consortium (NCE) which gathers US academic institutions working on carbon removal. The latter two recently published a report compiling R&D priorities for the sector.

Meanwhile, innovators like LanzaTech and corporations like Covestro already sell products from captured carbon. The Airminers platform indexes many of these companies, while iconic startup accelerator Y-Combinator is actively scouting for carbon removal technologies.

> *"The next frontier is to set targets that go beyond zero emissions — aiming instead for a net positive impact on the climate."*
>
> ***Richard Roberts,***
> *Inquiry Lead, Volans*

2.1. Natural solutions for carbon removal

Natural carbon sinks in soils and vegetation rely on photosynthesis to convert CO2 into biomass carbon (soils, sugars, wood, plant fibers).

Restoration and Forest Management

High-carbon natural ecosystems (forests, peatlands, wetlands, seagrass meadows) could store at least 150 gigatons of carbon by 2050, with many co-benefits on water quality, biodiversity, and job creation in forestry. The SDG15 section of this report features **tech solutions to protect and restore terrestrial ecosystems,** from monitoring to drone-based reforestation. In coastal areas, Danish research project Novagrass is developing new tools for large-scale restoration of eelgrass.

Carbon Farming

Methods like **agroforestry, regenerative agriculture** (low/no tillage, crop rotation, cover crops, perennial crops, rotational grazing) and the use of **soil amendments** (compost, algae, biochar) can increase the carbon content in soils. Carbon farming could store 170 gigatons by 2050, over half of the entire food sector's potential. The 4 per 1000 initiative launched at COP21 estimates that a 0.4% annual increase in soil carbon could cancel out anthropogenic GHG emissions entirely.

Science and technology enablers include **rapid soil carbon assessments** (e.g. Quick Carbon), **carbon accounting tools** (e.g. COMET-Farm), **soil modeling**, and innovative agricultural inputs which enhance soil microbial communities. NCE also suggests that engineered crops could store more carbon with improved photosynthesis, deeper roots, or perennial grains.

2.2. Engineered solutions for carbon removal

Technology can be harnessed to remove carbon from the air and oceans, and store it into rocks and useful products.

Direct Air Capture (DAC)

DAC separates CO2 from ambient air or seawater. The concentrated CO2 gas can then be stored, used as it is, or converted into new products. Companies like Climeworks (Switzerland) and Carbon Engineering (Canada) have demonstrated feasibility with pilot plants, but the current cost of $400-$600 per ton remains much higher than the $100 target. This could drop with better contactor materials like Metal-Organic Frameworks (MOFs) which can trap and release CO2 more efficiently in their small tunable pores. Players include NuMat (US), Mosaic Materials (US) and MOF Technologies (UK). Additionally, significant development is needed to make DAC ultra-low energy and truly carbon-neutral.

Photo: Climeworks

Enhanced Weathering (EW)

Weathering is *"the natural process in which rocks are broken down and dissolved on the land surface."* Minerals react with CO2 under rainwater to form bicarbonates, which then wash into oceans and precipitate in their depths as sediments. On geologic time (thousands of years) this creates the largest carbon sink on Earth, with the notable co-benefit of increasing ocean alkalinity, which counters CO2-induced acidification.

EW aims to accelerate this process down to a few hours or a few months, using either natural or anthropogenic (e.g. steel slag) minerals. The CarbFix2 project in Iceland uses CO2 captured with a Climeworks DAC and injects carbonated water in basaltic rocks. Terrestrial approaches consist in spreading pulverized silicates over agricultural land to speed up natural processes while boosting soil nutrient levels. Electrochemical methods could, in theory, produce negative-emission hydrogen gas through saline water hydrolysis powered by marine energy—an idea which caught the attention of Y-Combinator.

Carbon Capture and Use (CCU)

CCU is the process of **creating new products from captured carbon**, with a resulting footprint ranging from reduced to negative emissions. It is also called carbon conversion, carbon-to-value, and carbontech.

This approach is a cornerstone of the New Carbon Economy, in which GHG become valuable resources instead of waste. Many companies are developing various CCU products such as:

- **Construction materials** like cement substitutes (CarbonCure, CarbiCrete, Blue Planet) and biochar-derived facades (MadeofAir)
- **Fuels and chemicals** through gas fermentation (LanzaTech, Kiverdi, Enobraq) or electrochemistry (Opus12, Soletair, Antecy)
- **Plastics and polymers** through methane gas fermentation (Newlight, Mango Materials)
- **Food and feed** products (String Bio, Kiverdi)
- **Advanced materials** like carbon fiber, nanotubes and graphene (Carbon Upcycling Technologies)

Biochar. Photo: Ncat Caes

Several of the firms listed above are profiled with greater detail in the SDG7 and SDG12 sections of this report.

Despite all these, the NCE estimates that *"like DAC, [CCU] faces a material science challenge, with a strong need to develop new catalysts, electrolyzer anodes, and membranes."* Besides materials and process improvements, the consortium also identifies lifecycle analyses and the development of clean heat sources as top research priorities.

2.3. Hybrid solutions for carbon removal

Hybrid solutions harness both photosynthesis and technology to sequester atmospheric CO2 with biomass and micro-organisms.

Biochar

Biochar is charcoal used as a soil amendment instead of fuel, and a stable form of solid carbon. It is produced by the pyrolysis (burning without oxygen) of biomass such as *"woody material or agricultural waste that would otherwise decompose and release carbon back to the atmosphere."* Biochar can sequester the carbon absorbed by photosynthesis over millennia. Applied as a soil amendment, it enhances microbial activity, nutrient availability, and water retention. It also helps with soil remediation. CarboCulture is one example of a startup making biochar from walnut shell waste.

Bioenergy with Carbon Capture and Storage (BECCS)

The idea of BECCS is to produce bioenergy—growing biomass crops for fuel—and use carbon capture at smokestack. The resulting process is, on paper, carbon-negative. However, conventional bioenergy relies on biomass crop monocultures, and require an enormous land area to be produced at scale. This process generates indirect GHG emissions and adversely impacts natural ecosystems, water usage, and food production. Those issues could one day be resolved, should new-generation biomass (cellulosic, algae, sewage) demonstrate efficiency and environmental sustainability (see SDG 7). In that case, BECCS could become a viable part of a broader portfolio of carbon removal solutions.

Phytoplankton Strategies

Phytoplankton accounts for half of the world's photosynthetic activity, which makes it a serious candidate for carbon removal. Scientists have initially considered iron fertilization of mineral-poor ocean areas to stimulate phytoplankton growth, but due to unknown environmental consequences, iron dumping was banned by a UN treaty in 2008.

Y Combinator recently proposed radical new ideas—acknowledged as speculative—such as genetically engineering phytoplankton to grow without minerals, and deploying it across millions of 1-km2 artificial oases in the desert, with the potential co-benefit of creating new habitable areas. Another YC proposal is to use cell-free enzyme systems instead of living organisms, which would be dedicated to carbon fixation instead of cellular growth, thus eliminating the risk of uncontrolled bloom.

3. Mitigation enablers

Crypto Carbon Credits

Carbon pricing has been around since the 1997 Kyoto Protocol: countries across Asia, North America, and the EU have implemented carbon taxes and cap-and-trade systems. However, so far those have failed to curb emissions for many reasons, including the price level, the number of allowances, double-counting fraud, sector differences, and cost shifting.

Making carbon offsets work is essentially a financial problem. Hence, several blockchain projects are **turning carbon credits into crypto tokens,** with the goal to improve transparency and simplicity. These include Veridium (in partnership with IBM and Stellar), Poseidon, ClimateCoin, the Blockchain For Climate Foundation, and CarbonX which works with companies to offset the carbon footprint of consumer products.

Potentially even more ambitious, Nori is a **carbon removal marketplace** which connects carbon removal suppliers directly with buyers. Using its own Ethereum tokens as carbon removal certificates (CRC), the platforms aims to fund projects that remove carbon from the atmosphere, starting with agricultural projects that store carbon in the soil.

Data-Driven Climate Strategies

Big data analysis and machine learning can play a crucial role in establishing climate strategies consistent with the Carbon Law trajectory required to stay under 1.5C of climate change. First, AI can improve climate modeling by speeding up the highly complex calculations of geophysical processes, and making it possible to downscale impact assessments to regional levels with better precision.

Second, it can help policymakers take smarter climate decisions based on large and diverse datasets, thanks to modeling, forecasting and visualization software. Examples include Google's Environmental Insights Explorer for city planners and startups like MapLauncher which provides climate roadmap software for governments, with a pilot in Sweden and a collaboration with the Stockholm Resilience Centre.

4. Adaptation

Adaptation aims to reduce vulnerability to the delayed impacts of global warming. Although this report focuses on mitigation efforts which remain the most critical, we listed below a few key adaptation strategies.

Agricultural resilience, with a specific focus on vulnerable smallholder farmers. Strategies include: drought-tolerance crops, rainwater storage, efficient irrigation systems, crop and weather forecasting.

Urban resilience, especially in coastal areas, hot regions, and slums. Strategies include: flood defenses (seawalls, raising street level, restoring and creating riverbeds, water permeable pavements); green spaces and corridors; sustainable water management (efficiency, reuse); local food production; green roofs and lighter-colored roofs; retrofitting critical infrastructure (power and wastewater plants); monitoring, modelling and forecasting software; early warning systems.

Specific action for low-lying islands like Fiji and the Maldives, at risk of disappearing with sea level rise. Exotic proposals include the construction of floating cities, with a pilot project from the Seasteading Institute in French Polynesia—a project which has however raised doubts about possible intentions of becoming a tax haven for rich elites.

Photo: Markus Winkler

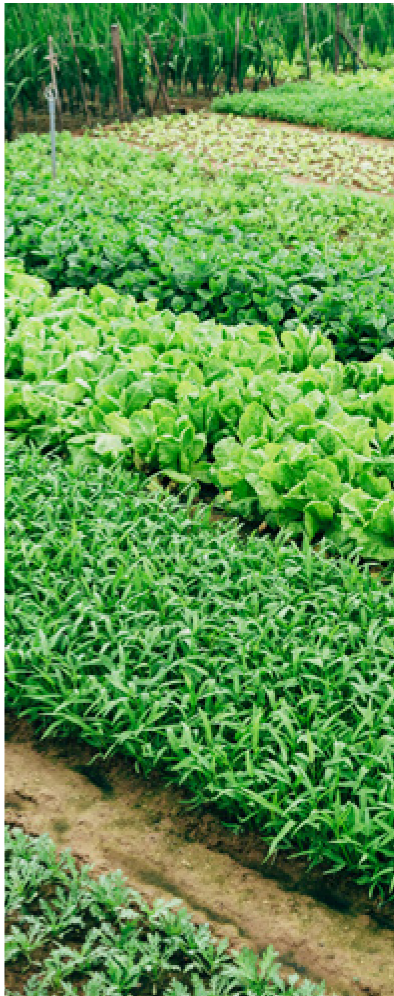


Photo: Patrick Hendry

Challenges

A super wicked problem with no silver bullet. A lot has been said about the daunting challenge posed by the climate emergency, and the hurdles preventing the swift and far-reaching response we need. Technology breakthroughs will be necessary, but not sufficient. For instance, a recent report from the Brookings Institution does acknowledge the potential of AI yet stresses that policy will be instrumental to steer it. In the Exponential Roadmap for Climate Action, scientists insist on the complementarity of technology, policy, and behavior change. The latter includes things like a plant-rich diet, reducing air travel, or women and girls' education which rank among the top Drawdown solutions. The various technologies and strategies harnessed to slash GHG emissions also have their own set of challenges, detailed in different sections of this report.

Public perception of carbon removal. Though the scientific consensus indicates that negative emissions will be required to stay within 1.5C or even 2C of warming, carbon removal (CR) approaches still generate substantial concerns. One is the moral hazard argument that it would distract us from quicky slashing emissions, even though CR proponents fully acknowledge that both are required and urgent. Another concern relates to the potential adverse effects of certain CR techniques like BECCS and phytoplankton strategies when deployed as large-scale interventions—also known as geoengineering. The risks seem too large for these two approaches to be socially accepted unless future progress can demonstrate system sustainability.

Climate change adaptation and technology justice. Vulnerable populations in the developing world will likely be the most affected by climate change, even though they bear the least responsibility for it. Unfortunately, solutions that would help them adapt to climate change attract little investment according to Practical Action. The NGO calls for accessible and affordable adaptation technologies.

Goal 14

LIFE BELOW WATER

Conserve and sustainably use the oceans, seas and marine resources for sustainable development.

93%
OF THE WORLD'S FISHERIES ARE EITHER **OVERFISHED** OR **MAXIMALLY SUSTAINABLY FISHED**

FAO, 2018 / STATE OF THE WORLD'S FISHERIES AND AQUACULTURE

8 Million TONS OF PLASTIC
LEAK INTO THE OCEAN EVERY YEAR, EQUIVALENT TO ONE GARBAGE TRUCK EVERY MINUTE. THIS NUMBER IS EXPECTED TO QUADRUPLE BY 2050, WHEN **OCEANS WILL CONTAIN MORE PLASTICS THAN FISH**

ELLEN MACARTHUR FOUNDATION, THE NEW PLASTICS ECONOMY 2016

50%
OF CORAL REEFS HAVE DISAPPEARED IN THE LAST 30 YEARS. AT CURRENT RATES OF OCEAN ACIDIFICATION AND TEMPERATURE RISES, THEY WILL BE LOST ALTOGETHER BY 2050, **ALONG WITH THE 1/4 OF MARINE LIFE THEY SUPPORT**

WWF REPORT: LIVING BLUE PLANET, 2015

"The most important thing the ocean delivers to humankind is our **very existence**"

SYLVIA EARLE, *OCEANOGRAPHER*

Photo: Francis Taylor

Photo: *The Ocean Cleanup*

Tech for SDG 14

Prevent and reduce marine pollution of all kinds *[14.1]*

Every minute, the equivalent of one garbage truck of plastic is dumped in the sea. This number is expected to quadruple by 2050, at which point the oceans will contain more plastic than fish, by weight.

The response to marine pollution involves both cleanup downstream, and prevention upstream through sustainable products and practices. While the former addresses the effects, the latter focuses on the root causes (more about this duality in Chapter 2.3).

The solutions highlighted below are specific to marine pollution. Others which are related to the broader circular economy are featured in the SDG9, SD11, and SDG12 sections of this report. The New Plastics Economy report is also a recommended read.

Marine Cleanup Technologies

Companies like Ichthion (UK) and the Great Bubble Barrier (NL) aim to capture plastic pollution in canals and rivers, before it can reach the ocean. By pumping air from the bottom of the waterway, the Dutch firm creates **an air curtain which prevents plastics from flowing past** yet allowing fish and ships to pass through. While most solutions catch only floating debris, this approach also captures those traveling lower.

Also from the Netherlands, The Ocean Cleanup project uses **a giant collector** to remove plastics from areas where it accumulates in the ocean, such as the Great Pacific Garbage Patch between Hawaii and California. The system uses a 600-meter-long floater with a 3-meter-deep skirt attached below, to concentrate plastic with the help of natural oceanic forces and then take it out of the sea. Though the prototype broke during its first trial in early 2019, the team remains determined.

Ocean Plastic Recycling

Many projects aim to reduce plastic leakage into oceans through **private recycling schemes and products made from plastic waste.**

Plastic Bank enables the **exchange of plastic for money, items or Blockchain-secured digital tokens** to incentivize plastic recycling in high-leakage countries. Plastic collectors are offered above-market rates for plastic at stores managed by local entrepreneurs, lifting people out of poverty. Plastic Bank then recycles and sells the material at a premium, under the brand Social Plastic. The Canadian non-profit partnered with IBM which provides the technological platform.

An increasing number of brands have been selling **products made from plastic waste.** These include Interface carpet tiles made from old fishing nets and Adidas sneakers made from ocean plastic collected by NGO Parley. Companies like Thread (US) and Bureo (Chile) produce new materials from plastic waste and fishing nets, and partner with brands to use this material in new products, from clothing to sunglasses, skateboards, and office chairs.

Combining both ideas in a decentralized and low-tech approach, Precious Plastic (Netherlands) features a set of **open source recycling machines** and instructions for micro-entrepreneurs.

Marine Biodegradable Materials

Even in a best-case scenario, improvements of the global recycling infrastructure would only stabilize, not eliminate, the leakage of plastics into the ocean, according to a 2015 report from Ocean Conservancy. Protecting marine ecosystems thus requires additional efforts, such as circular business models (see SDG12) and **bio-benign materials.**

Among such materials are **marine degradable plastics,** which in addition to being compostable (and ideally bio-based), rapidly break down in marine environments without harming ecosystems. Plastics labeled as "biodegradable" fall short of this requirement according to UNEP, but a handful of startups have made progress in making these materials a reality. These include Full Cycle Bioplastics (US), which won the Ellen MacArthur Foundation's Circular Materials Challenge, and Solubag (Chile) which made headlines in 2018 with its water-soluble plastic bag.

Sustainably manage and protect marine and coastal ecosystems, and take action for their restoration *[14.2]*

Marine ecosystems include nearshore systems like mangroves, corals, and seagrass meadows, as well as offshore systems in the ocean waters and the seafloor. While they provide vital services to humans and nature at large, these ecosystems are threatened by overexploitation and pollution.

Collaborative Ocean Planning

Geospatial platforms like SeaSketch aim to **democratize ocean planning,** by involving all stakeholders including scientists, professionals, and local communities. Such participatory restoration efforts include the SeaChange project in the Hauraki Gulf, New Zealand's north island.

Marine Drones and Robotics

Robots and drones have been used in ocean exploration since the end of the 1950s. In addition to defense, maritime surveillance and resource extraction, these vessels are used for **weather and environmental monitoring,** as well as in **scientific research,** to study marine biodiversity, climate change, and ocean acidification.

Uncrewed surface vehicles (USV), which navigate above the water surface, are manufactured by companies like Ocean Alpha (China), Ocius (Australia) and Liquid Robotics (US), and Saildrone (US) which offers a service model to harness an entire fleet. The use of sailing drones to clean up marine pollution was pioneered by French-Japanese inventor Cesar Harada, who developed Protei after the BP oil spill crisis in 2010.

Below the surface, **uncrewed underwater vehicles** (UUV) are used to sample ocean microbes to understand carbon cycles better, to fight invasive starfish species threatening corals in the Great Barrier Reef, and as fish-shaped "soft robots" which can swim alongside real fish to study them more closely. A poster child of the maker movement, OpenROV is an open source underwater drone for citizen science. The company partnered with National Geographic to launch OpenExplorer, a collaborative platform where users document their explorations.

Coral Preservation Science

Coral reefs, which cover less than 0.1% of the ocean surface yet support over a quarter of all marine life, are threatened by bleaching events induced by climate change and ocean acidification, even in a 1.5C scenario. Several research teams in Australia, Brazil, Singapore, Florida, and the UK are working hard to preserve these highly valuable ecosystems. One idea is to **create "super corals"** with higher resistance to heat, through accelerated breeding or genetic engineering. Others include techniques to increase the number of coral spawning events, and the use of probiotics to strengthen corals against pollution.

End overfishing, illegal, unreported and unregulated fishing, and destructive fishing practices. Implement science-based plans to restore fish stocks *[14.4]*

Fisheries Monitoring

Global Fishing Watch uses satellite imagery and machine learning to offer **free and near real-time tracking of global commercial fishing activity.** The organization was born from a collaboration between Google, satellite firm SkyTruth, and conservation NGO Oceana, with the support of the Leonardo DiCaprio Foundation. It has since partnered with countries such as Indonesia, Peru, and Costa Rica, which made their national vessel monitoring data available through the platform.

On individual fishing boats, Nature Conservancy uses **cameras to monitor fishing activities.** In 2017, the NGO partnered with Kaggle, an online community of machine learning engineers, to develop algorithms that can automatically identify species of tuna, shark and other fishes, thus speeding up the video review process.

Photo: Saildrone

Seafood Traceability

mFish is a partnership between the US and Indonesian governments and Singaporean company Eachmile, to develop sustainable fishing while improving the livelihoods of coastal communities. Fishers use a **mobile app** (with free data) to **access real-time weather information, learn about best practices and log their catch**—a process incentivized through rewards in the Fishcoin cryptocurrency.

Others aim to **track seafood from fishing vessel to fork,** by recording each step along the supply chain with **permanent blockchain records.** Pilots have been implemented in Southeast Asia by British startup Provenance (see also SDG12) and in Fiji by WWF and ConsenSys.

Sustainable Aquaculture Technology

Aquaculture is the farming of fish, crustaceans, mollusks, and algae. It is the fastest-growing food production sector according to FAO, and currently provides **half of the world's seafood.** As the world's fisheries are in decline, aquaculture will likely be crucial to feeding a growing population.

Photo: Green Wave

However, the farming of piscivorous species like salmon has major adverse impacts on wild fish populations because of the fish feed required, the introduction of parasites, and the pollution of coastal ecosystems. Shrimp aquaculture has also been found to drive mangrove deforestation, and additional concerns include animal welfare and the excessive use of growth hormones and antibiotics.

In recent years, innovators have attempted to tackle these issues and **make aquaculture sustainable.** Many are producing **fish-free feed** from insects like Protix (Netherlands), Ynsect (France), Entocycle (UK) and AgriProtein (South Africa) or through the fermentation of greenhouse gases like StringBio (India), Calysta (US) and NovoNutrients (US). Others provide **immune-boosting alternatives to antibiotics,** such as IctioBiotic (Chile) and Prospective Research (US). Alternative farm designs could also mitigate the ecosystem pollution associated with inshore aquaculture. Examples include **offshore systems** in which Norwegian companies like DNV GL have been making substantial investments, and **land-based systems** powered by renewable energy, such as Matorka (Iceland).

While remaining concerns are associated with salmon and shrimp farming, The Nature Conservancy (TNC) notes that they represent only a small portion of the industry. A recent paper co-authored by TNC and the University of Adelaide found that when done right, **seaweed and shellfish farming can provide not only seafood, but also many ecosystem services** like improving water quality, replacing lost reefs, providing habitat for marine life, and sequestering carbon. A pioneer of this regenerative aquaculture model is US non-profit GreenWave, winner of the Buckminster Fuller Challenge in 2015 with its multi-species 3D ocean farms.

Clean and Plant-Based Fish Meat

New protein sources which look, feel and taste like seafood could help curb demand and alleviate the pressure on fisheries and aquaculture farms. These include **plant-based seafood** like New Wave Foods, Ocean Hugger (US) and Odontella (France), as well as **clean meat companies focusing on fish meat tissue**, like Finless Foods (US). The SDG2 section of this report features additional background and technical details about clean meat and plant-based meat technologies.

Challenges

Dual-use technologies. As pointed in a WEF report, *"many of the technologies that can enable better fisheries management could also be used to accelerate exploitation."* Risks include the rapid development of underwater mining that could damage deep-sea ecosystems, the use of real-time ocean data by illegal poachers, and the possible negative consequences of introducing genetically engineered species on ecosystem balance (see also "gene drives" in SDG3 and chapter 4).

The need for digital infrastructure. Small-scale fishers and coastal communities on small island developing states require better connectivity and capacity building before they can benefit from innovations that aim to improve their lives.

Photo: ILO - Tran Vinh Nghia

Goal 15

LIFE ON LAND

Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, halt and reverse land degradation and halt biodiversity loss.

75%

OF EARTH'S LAND AREAS ARE **SUBSTANTIALLY DEGRADED, UNDERMINING THE WELL-BEING OF 3.2 BILLION PEOPLE**

IPBES 2018 ASSESSMENT / NATIONAL GEOGRAPHIC*

40%

OF THE WORLD'S MAMMALS HAVE LOST 80% OF THEIR DISTRIBUTION BETWEEN 1900 AND 2015. THIS **"BIOLOGICAL ANNIHILATION"** AS SCIENTISTS CALL IT, SHOWS THE SIXTH MASS EXTINCTION IS WELL UNDERWAY, **WITH SPECIES DISAPPEARING 100 TIMES FASTER THAN A CENTURY AGO**

CEBALLOS, EHRLICH ET AL. 2017 (PNAS / THE GUARDIAN)

*** IPBES** *– Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, or "the IPCC for Biodiversity".*

"Most of the damage we cause to the planet is the result of **our own ignorance**"

***YVON CHOUINARD,** FOUNDER OF PATAGONIA*

Photo: Pixabay


Photo: Rainforest Connection

Tech for SDG 15

Ensure the conservation, restoration and sustainable management of all types of forests and other freshwater ecosystems (wetlands, mountains, drylands). Halt deforestation and substantially increase afforestation and reforestation globally *[15.1 + 15.2]*

Terrestrial Ecosystems Monitoring

Digital and sensing technology enables new ways to monitor and protect natural ecosystems. Global Forest Watch is a partnership between the World Resource Institute and the satellite firm Orbital Insight, to provide free near real-time data on the world's forests. Rainforest Connection uses real-time acoustic monitoring systems to prevent illegal logging. Sensors are built from old cell phones rigged to a microphone and tiny solar panels, and the non-profit uses machine learning to analyze audio streams. Conservation Drones is a nonprofit that shares knowledge on the building and use of drones for conservation in tropical regions, including the monitoring and mapping of ecosystems, surveying wildlife, and supporting the enforcement of protected areas.

Taking a long view, the Atlas of Deforestation and Industrial Plantations in Borneo compiles historical data from satellite imagery, land ownership and soil maps to identify the companies responsible for deforestation.

Soil Modeling and Analysis

Conservation and restoration efforts benefit from a better understanding of soil formation and its properties. Data analytics and machine learning can **help soil scientists perform experiments** like soil mapping and soil spectroscopy—using light to analyze soil composition. For instance, SoilGrids is an automated soil mapping system developed by World Soil Information, which also offers an open sharing platform for soil data.

Photo: Maria Mekht

Spatial Data Platforms

The ability to **manipulate and research spatial data** is essential for conservation efforts. UNDP, UNEP and the UN Convention on Biodiversity have launched the UN Biodiversity Lab platform, which supports countries with access to the right data for conservation decisions. The platform is powered by MapX, a UN-backed geospatial mapping software which aggregates verified scientific data and provides various tools for analysis, visualization, and knowledge sharing.

On a more operational level, OpenForests (Germany) offers a software platform for forest managers with maps, 3D models, inventory data, project tools, as well as drone and satellite mapping capabilities.

Drone-Based Reforestation

Winner of the 2015 Hello Tomorrow challenge, Biocarbon Engineering (UK/Australia) is a **drone and analytics platform for industrial-scale reforestation.** It uses drone mapping, planting optimization algorithms, and drone-delivered compostable seed capsules, with the goal to plant one billion trees per year. DroneSeed (US) offers a similar service.

Desert Greening Technology

Human-made **reclamation of deserts** could help restore natural capital while tackling global food and water crises. A landmark achievement was the greening of a third of the Kubuqi desert in Inner Mongolia over the last three decades, in large part thanks to a series of low-tech innovations developed by Chinese firm Elion. These include water-jetting into deep sand to plant trees, flat sand barriers to stabilize sand dunes, greenhouse technology, and agroecological methods including the use of alkali and saline tolerant plants, and on-site production of organic fertilizer. The company also established a Genetic Resources Centre to help conserve the plant genetic diversity in the region.

Conservation FinTech

A 2014 study from WWF, Credit Suisse, and McKinsey found that $300 to $400 billion per year is needed to protect and restore natural ecosystems, while only $52 billion currently flows to conservation efforts—mostly from public and philanthropic sources. **Impact investing and FinTech** could help bridge this gap. Examples include retail investing platforms like OpenInvest (US) and agroforestry crypto-funds like Tree Token (France). Another clever model is Ecosia (Germany), an alternative search engine which already planted 50 million trees with advertising revenues.

“Economic ‘science’ is dominated by obsolete, pre-anthropocene ideology that treats forests and oceans as infinite resources and dumping grounds. We need to apply ‘Biosphere Positive’ thinking to everything we extract, build, produce, consume and discard. Doing this would enrich biodiversity, store carbon, purify water and prevent eutrophication. It would enhance the resilience of the Earth-system itself.”

Owen Gaffney,
Director at Stockholm Resilience Center

Urgently and significantly reduce the degradation of natural habitats, halt the loss of biodiversity, protect and prevent the extinction of threatened species *[15.5]*

Field Analysis Devices

To quickly identify species on the field, **DNA barcoding** compares a genetic sample to a database of already known species. Conservation X Labs is working on a low-cost, open source, portable DNA barcode scanner designed for the developing world, which can identify timber and wildlife. More sophisticated projects involve **portable sequencers**

and lab equipment kits. Others aim to collect the DNA profiles of an entire animal population, such as the South African rhinos database RhoDIS. Some even use 3D printed animal figurines to attract their species as close as possible to observation equipment.

Digital technology also allows **citizen scientists** to contribute. For instance, the iNaturalist mobile app currently has over 16K observations of 200K+ species, and now uses its database to train a neural network which can automatically identify species on pictures.

Promote appropriate access to genetic resources, and the equitable share of benefits arising from their utilization *[15.6]*

Biogenomics Data Monetization

The Earth Bank of Codes aims to create a **database of genetic assets** derived from the Earth's biodiverse life, starting with the Amazon, and using a blockchain record of the assets' provenance. Scientists and companies could use AI to search the database for useful DNA, enabling discoveries such as life-saving medicine derived from frog skin and viper venom. Smart contracts would then allow the fair sharing of economic benefits with the local communities which maintain the ecosystems where these assets originate. The project has partnered with the WEF and the Earth Biogenome Project, a global initiative to sequence the genome of all eukaryotic species within the next ten years.

Urgently end poaching and trafficking of protected species and address trade of illegal wildlife products *[15.7]*

Real-Time Wildlife Protection

Vulcan, the company of late philanthropist Paul Allen, offers a **software platform for real-time wildlife protection** which aggregates GPS readings of animal movements, camera trap photos, and tracking of anti-poaching teams. The technology integrates into SMART, an open source software suite used by the world's leading conservation actors. Vulcan's platform is also used by tracking apps, like the one from the Kenyan NGO Save The Elephants. Meanwhile, AirSheperd uses drones and sensors to protect elephants and rhinoceros from poachers.

Photo: Frans Van Heerden

Synthetic Wildlife Products

Another way to protect species against poaching is to reduce the demand for illegal wildlife products. Pembient is a synthetic biology startup which **biofabricates artificial rhino horns** identical to the original, to be used by artisans, carvers, and designers.

"We see countless ways that technology can support conservation, from sensors and satellites for predictive modeling, to sustainable materials and vegan fish. But established non-profits can be tech-averse and a bit political, so change is slow."

Cassie Hoffman,
Field Director at Conservation X Labs

Photo: evva

Challenges

Conservation and restoration remain a niche sector, for which most people do not perceive the urgency in comparison with others like climate change and financial inclusion. Only $52 billion annually flow to conservation projects while $400 billion would be required, and funding opportunities are highly competitive. Overall, the sector remains dominated by a handful of well-funded organizations such as WWF and Conservation International, and very few new players have emerged.

Conservation players are conservative. Many traditional players have been wary of using technology to protect nature and wildlife, though things have been changing in recent years. Conservation tech projects remain small and isolated, while they would benefit for a coordinated effort.

Ecosystem conservation and restoration remain anthropocentric concepts. As Mélanie Marcel from SoScience puts it: *“we need to move instead toward a rationale based on a win-win partnership between humans and nature.”*

Goal 16

PEACE, JUSTICE AND STRONG INSTITUTIONS

16 PEACE, JUSTICE AND STRONG INSTITUTIONS

Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels.

$2Trillion LOST TO CORRUPTION ANNUALLY. THIS IS ENOUGH TO ERADICATE HUNGER AND MALARIA, PROVIDE BASIC EDUCATION TO ALL CHILDREN, AND BRIDGE THE GLOBAL INFRASTRUCTURE GAP

WORLD ECONOMIC FORUM, 2017. (BASED ON IMF 2016 DATA)

2Billion PEOPLE LIVE IN COUNTRIES WHERE DEVELOPMENT OUTCOMES ARE AFFECTED BY **FRAGILITY, CONFLICT AND VIOLENCE**

WORLD BANK, 2018

13% OF THE WORLD'S POPULATION ENJOYS A **FREE PRESS**

FREEDOM HOUSE, 2017

> For to be free is not merely to cast off one's chains, but to live in a way that **respects and enhances the freedom of others**

NELSON MANDELA, *NOBEL PEACE PRIZE*

Photo: pixel2013

Photo: Forensic Architecture

Tech for SDG 16

Significantly reduce all forms of violence and related death rates everywhere *[16.1]*

Crime Forecasting

Data analytics and predictive algorithms can improve safety and security in an ethical way—far from the predictive policing dystopia seen in Minority Report. The Igarapé Institute, a Brazilian NGO proposing innovative solutions to the complex challenges of public security, has developed CrimeRadar, a crime forecasting app. The system uses machine learning and historical data from 14 million events to **predict crime rates in different neighborhoods** of Rio de Janeiro, at different times.

Human Rights Investigation Technology

The increased availability of digital content can help prove human rights violations. For instance, VFRAME is *"a collection of open source computer vision tools designed specifically for human rights investigations that rely on large video datasets."* The team has developed tools to detect evidence of illegal munitions used in the Syrian conflict.

Forensic Architecture (UK) is a data-driven research firm specialized in war crimes and human rights violations taking place in urban areas. Through **navigable 3D modeling** and **interactive cartographies of conflict zones,** the company provides international prosecutors and human rights organizations with new forms of evidence.

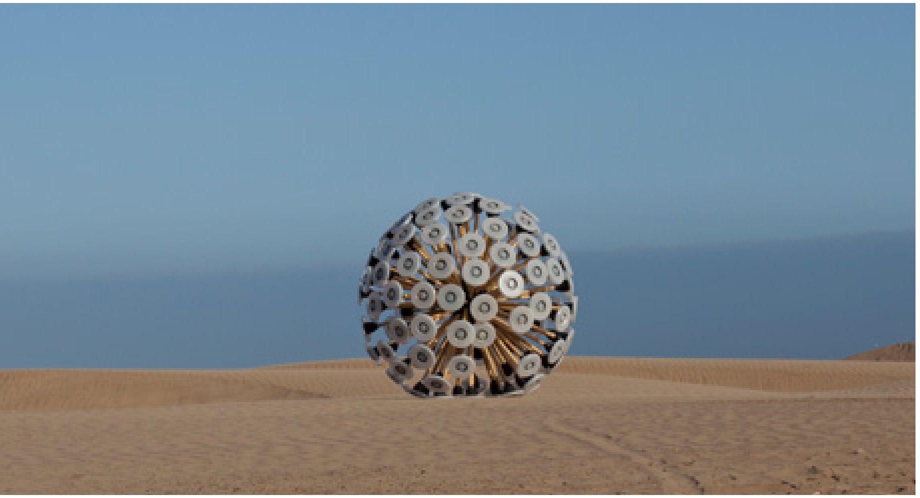


Photo: Mine Kafon

Conflict Prevention Technology

Technology can help prevent conflict in various ways. UNDP Lebanon developed a simple **Whatsapp survey tool** called Speak Your Mind to monitor how Syrians and Lebanese communities were living together and prevent violence. In Brazil, the CopCast app from Igarapé Institute **turns smartphones into police body cameras,** improving both public security and police-community relations.

Hala Systems (US) is developing an **early-warning system to protect civilians from impending threats,** which aggregates critical data and uses AI tools to evaluate the impact of events. The solution was trialed in Syria, with future deployments planned in Ukraine and DR Congo. The company went through the PeaceTech Lab accelerator, which also focuses on the root causes of violence—corruption, ethnic and religious tensions, food and water scarcity, gender discrimination, and more.

Remote Demining Devices

Landmines and unexploded ordnance (UXO) are responsible for thousands of civilian casualties annually and hinder post-conflict development. Founded by two Afghan brothers, Mine Kafon (Netherlands) creates **innovative demining systems,** including an iconic wind-powered device which detonates objects as it rolls on the ground, a range of **drones for detection and detonation,** and a software platform to visualize geospatial data and control the devices.

End abuse, exploitation, trafficking and all forms of violence against children *[16.2]*

Digital Defense From Sexual Abuse

Founded by actors Demi Moore and Ashton Kutcher, Thorn (US) is a non-profit using **AI software to defend children from sexual abuse.** Based on insights from a survey of sex trafficking survivors, the organization developed Spotlight, a tool which **accelerates victim identification** and allows law enforcement to rescue more children—8 per day on average and nearly 10,000 as of May 2019. Thorn also launched Safer, a solution enabling tech firms to **speed up the identification and removal** of child abuse content on their platform.

Develop effective, accountable and transparent institutions at all levels. *[16.6]* Substantially reduce corruption and bribery *[16.5]*

Open Data & AI For Integrity

Open data (see SDG17) is an increasingly popular tool for holding the powerful accountable. OpenCorporates (UK) offers a free **online register of the world's companies** in 125 jurisdictions, and partners with NGOs to find evidence of corruption. QuiénEsQuién (Mexico) visualizes **connections between politicians and the owners of companies** winning contracts in Latin America.

Developed by Transparency International, Integrity Watch provides an interactive **overview of lobbyist activities** in parliament and the potential **conflicts of interest among representatives** in the EU, France, UK, and Chile. In Brazil, the crowdfunded initiative Serenata de Amor created Rosie, an **AI bot which identifies suspicious expenses from congresspeople** and invites citizen to investigate them. The Chinese government also trialed an anti-corruption AI called Zero Trust, which is reportedly being turned off "because of its success".

Citizen Reporting

Founded in response to the 2007 Kenyan election crisis, Ushahidi enables local observers to **report on what is happening around them** using social media, email, and SMS. Each event is recorded on a map in real-time, allowing for election monitoring, crisis response, and human rights monitoring. 50 million events from 160 countries have been logged over the last ten years.

Focusing on corruption, I Paid A Bribe allows Indian citizens to **report bribes**, giving a better picture of their nature, location, and frequency. As of May 2019, the website totals about 180,000 bribes across India and has been adapted in 14 other countries. Meanwhile, Nigerians can use Tracka to **signal abandoned public works** and identify wasted taxpayer money.

Finally, to **document slow-burn issues**, TIMBY allows citizens to safely report on illegal activities through an encrypted app. **Journalists can then compare reports before publishing stories**, on themes such as land issues in Liberia and environmental conservation in Chile.

Open Contracting

Government contracting is worth trillions of dollars a year globally, with a sizeable portion lost to corruption. Inspired by open source principles, open contracting aims to **publish free and timely information on public contracts** so that citizens and businesses can verify that money is spent honestly, fairly and efficiently.

Since 2016, the Ukrainian government has been using ProZorro, an **open data portal built on the Open Contracting data standard**, with the help of Transparency International. The platform relies on three principles: a hybrid between an open source database and certified apps for end-users; mutual checks and balances between the state, business and civil society; and **"everyone can see everything"**—tender participants, their bids, the auction process, committee decisions, and qualification documents. Now a multi-award winning system hailed as the "gold standard", ProZorro holds over 1,500 auctions daily and may have saved Ukraine 1.4% of GDP.

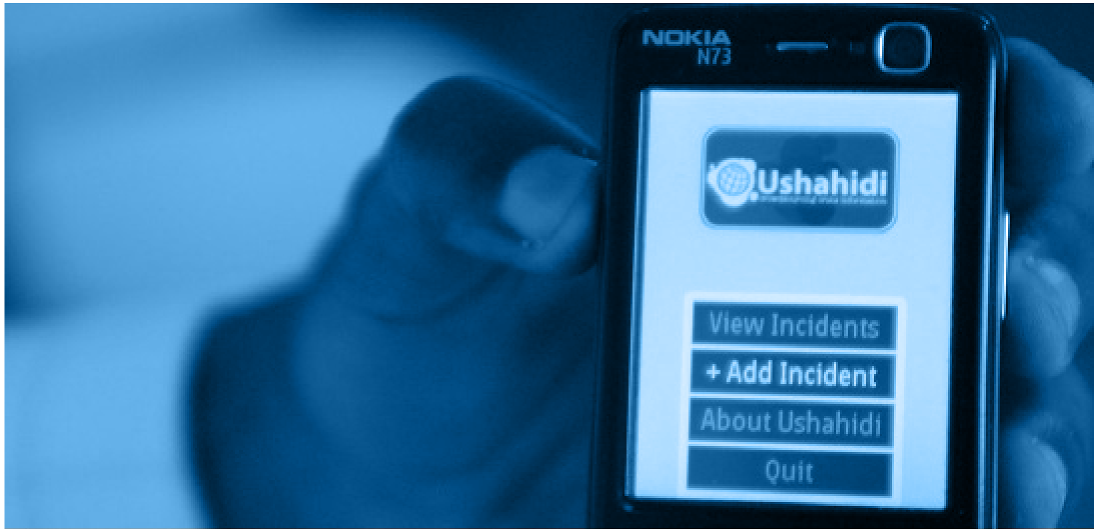


Photo: Ushahidi

Digital Public Services

The digitalization of public services can help rebuild trust in government, by serving citizens with higher efficiency and transparency. Estonia has been lauded for its state-of-the-art digital infrastructure, which allows its citizens to **identify themselves, sign documents, file taxes, vote in elections, and access most public services online.** The e-Residency even allows foreign entrepreneurs to manage an EU-based company online—bringing additional tax income to the country. However, the UCL Institute for Innovation and Public Purpose (IIPP) stresses that so far, Estonia's digital success does not extend to civic engagement, nor to the improvement of key social indicators like inequalities and citizens' satisfaction about healthcare and education.

Apolitical (UK) is a free platform **helping public servants** from 150 countries **to find the ideas, people, and partners they need** to solve society's biggest challenges—or "TripAdvisor for policy meets LinkedIn for government." The social enterprise makes it easier for local and national officials to identify and adapt what has already worked elsewhere, and to consider innovative solution providers in procurement.

Ensure responsive, inclusive, participatory and representative decision-making at all levels *[16.7]*

Citizen Participation Platforms

Many civic-tech efforts strive to **improve citizen participation in the democratic process.** While local platforms (see SDG11) have often met faster success, a few examples stand out at **national scales.**

In the aftermath of the 2014 Sunflower Movement in Taiwan, the new government ran a hackathon which gave birth to vTaiwan, an **open consultation process** run by the civic hacker group g0v. Its distinctive feature is the Pol.is algorithm, in which upvotes and downvotes generate a visual map of participants clustered according to their proposals—with the help of machine learning. Stakeholders then react to the results during **physical deliberations,** leading to a smarter vote.

The process has been used to vote on digital policies such as regulating Uber and the online sale of alcohol, but not for mainstream themes like pension reforms. Recently, the Taiwanese government launched Join, a **new platform to debate petitions** which also uses Pol.is—but is run by public servants themselves. When a petition reaches 5,000 signatures, officials explain why they agreed or rejected the proposal. The platform is aimed at a broader audience, with several million users already.

Among other examples, Mudamos uses a **blockchain to certify collected signatures** in Brazil and make it easier to introduce popular initiative bills in the national Congress. In France, Parlement & Citoyens lets **elected MPs tap into the collective intelligence of their constituents** to find the best legislative answer to a specific issue.

Transnational Citizen Governance

An even more radical proposal among crypto-enthusiasts is to rebuild a transnational democracy from the ground-up. Backed by Y Combinator, Democracy.Earth has built a **decentralized governance platform** named Sovereign where users can vote on anything. The system relies on a transparent and supposedly tamper-proof **blockchain record,** as well as **“vote tokens”** enabling quadratic voting—a decision-making model in which voters can express how strongly they feel about an issue. Though exciting, such efforts remain however mostly at the thought experiment and research phase, with no clear prospects in the short-term.

Collective Action Technology

In addition to individual participation, **civil society organizations** are essential to a healthy democracy. While associations benefit from various dedicated solutions such as **fundraising tools** HelloAsso (France) and GoodBox (UK), other platforms aim to organize communities and movements. Beyond **online petition** pioneers Change.org and Avaaz, examples include Make.org (France) for **citizen-led consultations** and action plans around social causes, Loomio (New Zealand) for **making better decisions**, and Open Collective (US) for informal groups to quickly **raise funds and manage them transparently.** In Brazil, social activism lab Nossas has launched Bonde, a turnkey solution for mobilization campaigns. Focusing on access, Grassroot (South Africa) offers simple tools compatible with **feature phones and low bandwidth.**

Photo: Bartolomeo Rossi

Ensure public access to information and protect fundamental freedoms *[16.10]*

Automated Fact Checking

Although fake news is as old as free press, never has it been as widespread as in today's digital society. As we argue in Chapter 4, media manipulation poses **threats to democracy and public safety**—from hyperpolarization to the rise of populism, the lynching of innocents and the anti-vaccine movement. Tech giants Facebook, Twitter, and Google are now under pressure from governments to intensify efforts against misinformation during elections, which led to tighter control on **political ads** and the deactivation of fake accounts.

Many fact-checking groups have been striving to contain the issue in the public sphere, from Aos Fatos in Brazil to Fullfact in the UK, which has been at the forefront of automated fact-checking in politics. Today companies like Factmata (UK) and Metafact (India) are using **machine learning to detect misinformation** in news stories and on social media, as well as **doctored images and videos.** For Whatsapp—which poses a massive challenge in countries like India because of its popularity and encryption—Metafact also plans to **crowdsource the identification** of suspicious messages and reward contributors. All these systems, designed to work alongside journalists, could be valuable not only for readers and newsrooms but also for companies.

Challenges

Peace-tech and war-tech. Despite uplifting peace-tech stories, the defense industry remains among the biggest investors in technology globally. Moreover, although the Internet and other civilian applications have evolved from military-funded research, new developments such as autonomous weapons, cyber warfare, space forces, and potential bioweapons give much reason to worry.

Data Justice. From surveillance to algorithmic bias and labor disruption, the "datafication" of society is adding new threats to human rights and social justice. For instance, Amnesty International has denounced the "racially discriminatory" Gangs Matrix database of the London Police, among many examples featured in Chapter 4. While civil society groups like Data Justice Lab (UK), Data&Society (US) and Engine Room are documenting these issues, ethical design manifestos and principles are rising to prominence in the tech community. However, public institutions also need to take leadership through smart policy, beyond GDPR.

The challenges of civic-tech and gov-tech. Many of the initiatives fitting in the broad umbrella of "digital democracy and public services" face two main issues. First, accessibility: the users that citizen participation platforms attract are mostly urban and educated, while even in advanced economies like France, as many as 20% of the population struggle to use the Internet. Second, both civic-tech and gov-tech mainly rely on government funding and procurement as their primary income, which makes them highly dependent on political will.

Photo: Fibonacci Blue

"One of the biggest challenges in working with the public sector are the incentives against innovation. Public officials rarely get the recognition for the work they do well, but can get publicly blamed if they took a risk and the results are negative."

Mark Lazar,
Head of Platform at Public.io

The limitations of automated fact-checking. First, training data is lacking for languages other than English. Second, AI systems are unable to fact-check stories that cannot be proven true or false. Third, they cannot see private messages on Whatsapp nor every targeted ad on Facebook. Fourth, to be effective fact-checking needs to occur in real-time on the media where the information is consumed—as most people do not verify information online—and using language that transcends political convictions. Finally, as several private companies are currently investing in AI fact-checking technology, one could wonder whether they should become the arbiters of truth.

Goal 17

PARTNERSHIPS FOR THE GOALS

Strengthen the means of implementation and revitalize the global partnership for sustainable development.

More than ever before in human history, we **share a common destiny.** We can master it only if **we face it together**

KOFI ANNAN, *FORMER SECRETARY GENERAL OF THE UNITED NATIONS*

Photo: Tom Page

SDG Campaign in New York City. Photo: Amaral.andre

Tech for SDG 17

Goal 17 aims to strengthen collaborations for the achievement of the sixteen other goals. Most SDG targets call for system-level change, which requires the combined and sustained effort of multiple stakeholders. Different collaborative mechanisms already foster strategic partnerships for the Global Goals: the UN SDG Fund is a good example. In this section, we will focus particularly on the tools and collaborations which are inspired or driven by technology. We grouped them under the five themes of the SDG17: finance, technology, capacity building, trade, and systemic issues.

Finance: Mobilize additional financial resources for developing countries from multiple sources *[17.3]*

SDG Financing Platforms

SDG investment still faces an annual gap of $2.5 Trillion. Fintech offers various ways to help bridge that gap by mobilizing additional private capital, through **decentralized remittances, microfinance platforms, and impact investing marketplaces.** In addition to the innovations profiled in SDGs 1, 2, 7, 9, 10, and 12, several promising initiatives stem from multi-stakeholder collaborations. For instance, UNDP and the UN Capital Development Fund (UNCDF) have partnered with online microfinance pioneer Kiva and the government of Sierra Leone to create a **digital ID system** based on distributed ledger technology, aimed to increase investment flows toward the unbanked.

Technology: Promote the development, transfer, and diffusion of environmentally sound technologies to developing countries *[17.7]*

Open and Citizen Science

Various platforms allow scientists to fund, perform, and publish their research (see Chapter 2.3 and SDG9). However, certain initiatives focus specifically on **increasing science collaboration**. For instance, iGEM has advanced the field of synthetic biology since 2003 with its global team competition, while the BioBricks Foundation develops collaboration tools such as the OpenMTA license—the open source equivalent in biology.

Citizen science is scientific research conducted with the help of citizen participation. Early examples include SETI@Home, which harnessed the computing power of participants to search for extraterrestrial life, puzzle game Foldit in which players discover new protein folding patterns, as well as citizen science portals Zooniverse and iNaturalist. Launched recently, Just One Giant Lab aims to go even further by running participatory research focused on the SDGs, using a **mass collaboration platform** where citizens can contribute to various micro-tasks.

Sustainable Solutions Platforms

As we discussed in Chapter 2.3, the large-scale deployment of proven solutions is instrumental in achieving the SDGs. Several **platforms curate solutions to connect them with scaling partners.** For instance, the Solar Impulse Foundation (Switzerland) assesses the efficiency of cleantech solutions to promote the best ones among investors, corporates, and governments. Other examples include the Global Opportunity Explorer (Denmark) which features companies addressing the 17 Global Goals, as well as Sphaera (US), ImpactOn (UK) and Technology Exchange Lab (US) which focus on projects which can be replicated globally.

Capacity-building: Enhance capacity-building to implement all the sustainable development goals *[17.9]*

SDG Education Platforms

Online education can provide a powerful complement to traditional capacity-building. Led by the UN Sustainable Development Solutions Network (SDSN) under the direction of Jeffrey Sachs, the SDG Academy creates and curates free online educational resources, which cover various disciplines related to the 17 SDGs. Meanwhile, Sulitest (France) provides an online test designed to measure and improve sustainability literacy among students, professionals, and individual citizens, in partnership with several UN programs.

> *“Many still see the SDGs through the lens of zero-sum games, as trade-offs between social, economic and environmental goals. This is a coordination problem, which digital technology can help tackle by aligning many stakeholders transparently, and with accountability.”*
>
> ***Audrey Tang,***
> *Digital Minister of Taiwan*

Trade: Promote a universal, rules-based, open, non-discriminatory and equitable multilateral trading system *[17.10]*

Transforming global trade into a more sustainable and equitable system is an intractable challenge—which should be on the WTO reform agenda. Some innovations profiled in this chapter could support that shift, including **responsible e-commerce** (SDG12) and the use of **blockchains for transparent and fair supply chains** (SDG10, 12, 14, 15).

Photo: Neil Baynes / SDG Action Campaign

Systemic Issues: Enhance the global partnership for sustainable development, complemented by multi-stakeholder partnerships that mobilize and share knowledge, expertise, technology and financial resources *[17.16]*

Mission-Driven Technology Partnerships

The Global Goals require far-reaching changes in every aspect of society and the economy. Those changes can only occur if multiple stakeholders join forces—including in the way they harness technology.

Domain-centered coalitions gather diverse stakeholders to maximize the societal benefits of a technology domain. Examples include the UN Secretary-General's High-Level Panel for Digital Cooperation, the Global e-Sustainability Initiative led by ICT companies, the Hydrogen Council which brings together energy, transport, and industry CEOs, and the Partnership on AI which gathers tech giants and international organizations like UNDP, UNICEF, and Amnesty International.

Issue-centered coalitions mobilize innovators and other stakeholders around specific grand challenges. For instance, the Digital Impact Alliance (DIAL) founded by the UN Foundation, Gates Foundation, USAID, and the Swedish government aims to advance digital inclusion and digital development. Initiated by semiconductor company Arm, 2030Vision fosters technology partnerships for the Global Goals. Other examples include ID2020 which focuses on digital identity, the Global Alliance for Humanitarian Innovation (GAHI), the Alliance for an Affordable Internet, the New Carbon Economy Consortium, and business networks focused on global warming, such as the We Mean Business coalition.

Industry-wide coalitions gather incumbents, innovators, and other stakeholders to address the systemic issues in specific sectors. For instance in the textile industry, various initiatives have emerged at the intersection of technology and the circular economy. Examples include the Ellen MacArthur Foundation's Make Fashion Circular initiative, multi-stakeholder research programs like Mistra Future Fashion, and closed-loop recycling experiments like Relooping Fashion in Finland. Examples in other sectors include MaterialWise, NewCities, Sustainable Energy for All and Sustainable Mobility for All.

Finally, a few organizations facilitate several coalitions in parallel, as long as they fit in their general theory of change: the World Economic Forum (with the Fourth Industrial Revolution), the Ellen MacArthur Foundation (Circular Economy), and Forum for the Future (Systems Thinking).

Increase significantly the availability of high-quality, timely and reliable data disaggregated by relevant characteristics (17.18) Develop measurements of progress on sustainable development that complement gross domestic product *[17.19]*

Data Partnerships for the SDGs

Some of the most exciting collaborations on the Global Goals relate to the access to timely, high-quality, machine-readable datasets which help to generate insights, train algorithms, and measure progress.

Open data initiatives can support SDG innovation with high-value government data—published in a way that is free to use, modify, and share. Although data portals have existed for years in the US, the EU Member States, and Singapore, UNDP is running challenges to incentivize open data for the public good in places like the Western Balkans and the Black Sea region. In the case of sensitive public data, usage can also be agreed upon bilaterally. For instance, NGO Bayes Impact could access anonymized unemployment data from the French government to train its AI algorithms, improving the quality of the advice it delivers to job-seekers. The sections on SDG15 and 16 feature additional examples.

Data philanthropy refers to private companies sharing data for public benefit. For instance, the UNICEF platform Magic Box relies on mobile, social media, and satellite data provided by Telefonica, Google, IBM, Amadeus, and Red Hat. Magic Box can offer critical insights into the needs of vulnerable populations and how to best respond to disaster, epidemics, and other crises. Similarly, the GSM Association's Big Data for Social Good uses mobile data from 20 operators to support NGOs and governments during emergency response. Movement data and satellite imagery are frequent datasets provided by firms like Waze, Uber, Google, Planet, and DigitalGlobe, to support climate change mitigation, urban planning, human rights protection, and more. GovLab, Omidyar and UNICEF have called Data Collaboratives this new form of collaboration, in which the public and private sectors exchange data to create public value.

Multi-stakeholder data coalitions could help to democratize the access of data for public good. A prominent effort in that domain, the Global Partnership for Sustainable Development Data is an alliance of over 300 members from academia, government, civil society, and the private sector. The network hosts various data initiatives, such as 50X2030 which seeks to perform regular surveys of farming households in fifty low and lower-middle income countries, and thus inform data-driven policy on agriculture. In another example, Resource Watch is a global partnership of 30 organizations convened by the World Resource Institute to feature hundreds of timely datasets on the state of the planet and citizens.

“Only public services can serve everyone at scale without prioritizing users based on profitability, which is critical in sectors like education, healthcare, or fighting unemployment. At Bayes Impact we believe in a new citizen-public partnership, to deliver the digital public services of the 21st century.”

Paul Duan,
Founder and CEO of Bayes Impact

Data and AI Tools for Social Impact

Several organizations provide tools that support the use of data for social impact. For instance, Development Seed (US/Peru/Portugal) and Radiant Earth Foundation (US) develop **machine learning tools** and open **training libraries** to maximize the value of satellite imagery in global development. Others like DataKind (US) act as a matchmaker between social organizations and pro bono data scientists.

Photo: UN

Challenges

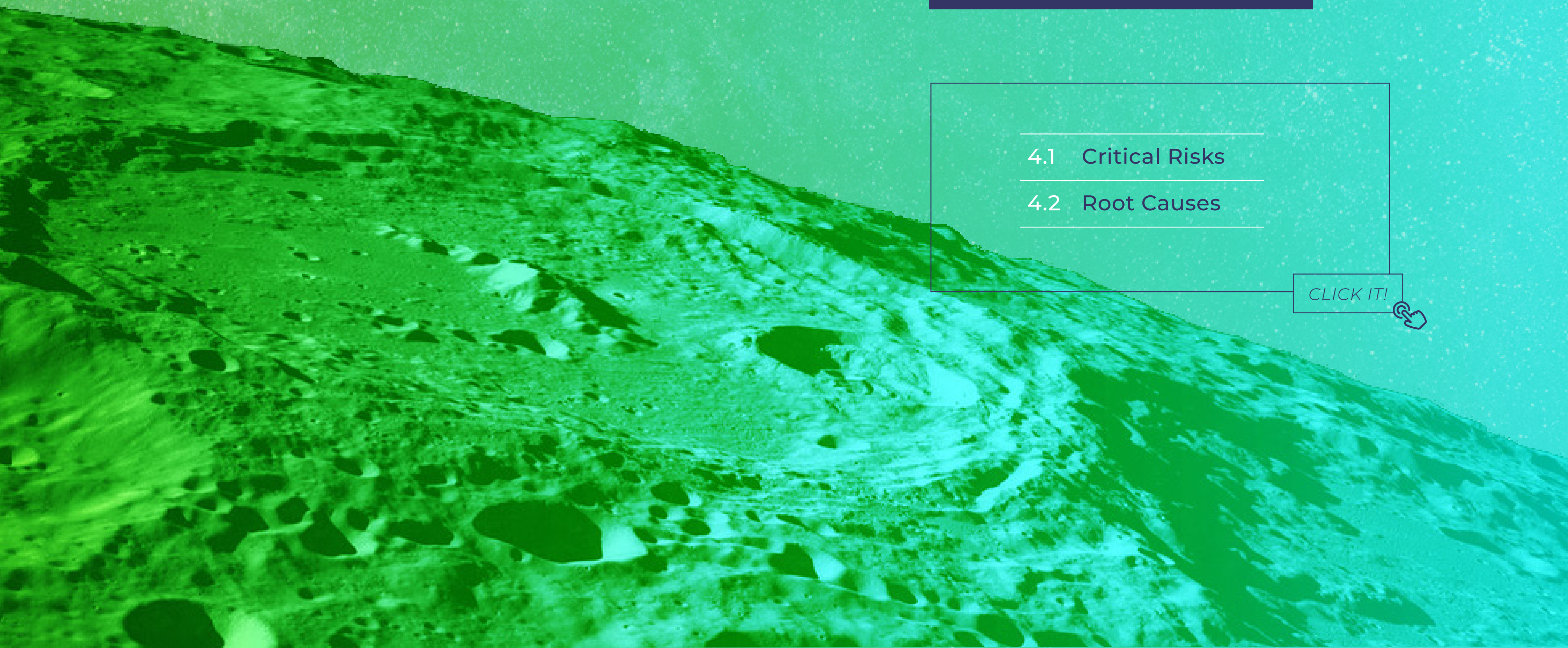
Partnerships can take a lot of time and resources. To be efficient, they should deliver higher value than the costs of engaging in collaboration in the first place. A recent report by the UN Department of Economic and Social Affairs (UNDESA) highlights 11 ways to achieve a "Collaborative Advantage," such as developing standards, sharing risks, and pooling resources together to reach critical mass. However, agreeing on the right metrics to measure mutually shared goals is hard.

"There is a plethora of B2B alliances, networks and platforms for sustainability and innovation, often competing with each other. It is hard for corporations to determine which one they should get into, and filter through the noise, so often this comes down to the human level and personal relationships. In what comes next, a key test will be whether a given B2B platform is mainly trying to slow degeneration, or driving economic, social and environmental regeneration"

John Elkington,
Founder and Executive Chairman, Volans

4 TECHNOLOGY RISKS AND CHALLENGES

CLICK IT!



Going through this report, we hope that you will feel our cautious optimism—that science and technology might help us prevent a climate catastrophe, ensuring that people and nature thrive. The "cautious" part of that message, however, requires us to shine a light on technological risks and challenges which need to be mitigated.

We divided this Chapter into two parts. The first is an overview of eight critical risks, from algorithmic discrimination to existential threats, and possible ways to mitigate them. The second highlights four "root causes" that underpin many of those risks—diversity and inclusion, solutionism, economic incentives, and technological governance.

Technology is **neither good nor bad**, nor is it **neutral.**

Melvin Kranzberg,
Technology Historian.

Photo: Sorry imKirk

4.1 Critical Risks

Photo: Bernard Hermant

Science-Fiction authors have always been prolific in imagining the worst possible future technology could bring upon us, from the novels of George Orwell and Aldous Huxley to cult movies like Terminator and Gattaca. Today's shows like Black Mirror even take direct inspiration from ongoing technology developments, from AI to VR and autonomous weapons. As yesterday's science fiction is becoming today's science facts, we are invited to revisit the warnings of those works.

History also helps us remember that technological breakthroughs can have a dark side. For instance, Pierre and Marie Curie's work on radioactivity unlocked a revolutionary power source, but it also made nuclear weapons possible. As we explore in the next pages, today's technology risks and challenges are multifaceted, from algorithmic governance to biosafety and the human costs of electronic components.

For Impact Tech to flourish, we believe that founders, investors and all stakeholders should fully understand those concerns, both present and speculative. Only then can we maximize the positive outcomes of technology and minimize negative ones.

Photo: Jens Johnsson

Psychological Hijacking

Electronic devices have changed our lives. They make us more productive, bring a world of knowledge and connections at our fingertips, and are contributing to lifting millions out of poverty in the developing world. However, these benefits come with many side effects.

Mobile screens, social media, and business models based on monetizing users' attention have damaged our mental health and social fabric. Addiction, stress, anxiety, shorter attention spans, weaker social relationships, and echo chambers are among the effects that writers like Sherry Turkle and Nicholas Carr have documented.

Recently, several Silicon Valley executives stepped out of tech firms like Google and Facebook to speak out against the dangers of an attention economy that *"hijack our minds"* with **addictive design features** such as likes, push notifications, photo-tagging, infinite scrolling, and auto-play videos. In response, the Center for Humane Technology started by ex-Googler Tristan Harris is building a community of tech insiders addressing the issue. Its actions include the promotion of humane design in tech, practical advice for users to take back control of their digital lives, and lobbying for protective regulation.

Virtual, Augmented and Mixed Realities could pose additional challenges. On one side VR shows potential for treating mental health conditions like phobias, social anxiety, and PTSD, as well as for reducing pain and generating empathy. However, it could also leave users with "existential hangover" and other long-term psychiatric disorders. In its *Ethically Aligned Design* 2.0 guide, the IEEE writes that MR *"raises ethical questions concerning the rights of the individual and control over one's multifaceted identity, especially as the technology moves from headsets to more subtle and integrated sensory enhancements."*

How To Mitigate This Risk

- Digital wellness techniques and tools for users to take back control of their digital lives (e.g. time management apps, grayscale, etc)
- Ethical design principles that minimize screen addiction
- Regulation on themes such as addictive features, devices for children, and tech transparency

Resources

- The Center for Humane Technology — which curates research on the topic, tools and tips for users, and design guide for startups
- The EthicalOS toolkit produced by Omidyar Network's Tech and Society Solutions Lab and the Institute for the Future (IFTF)
- Doteveryone's Tech Transformed initiative

Privacy and Surveillance

Privacy loss and global surveillance have been among the earliest concerns about digital technologies. Edward Snowden's revelations shone the light on how governments around the world use digital systems to spy on populations, from liberal democracies to authoritarian regimes.

Today China is, without doubt, the world laboratory in tech-enabled mass surveillance. The country's data-driven governance efforts have received global media coverage and even sparked the interest of other countries. For instance, the social credit system analyzes behavioral data to evaluate the "trustworthiness" of Chinese citizens. Facial recognition is used to identify suspects in crowds, to publicly shame jaywalkers on giant screens, and monitor the emotions of students in the classroom. In the spring of 2019, the most downloaded app in China is "Study The Great Nation", which ranks users based on their knowledge of President Xi Jinping and the ruling Communist Party.

Moreover, the targeted advertising business model has helped establish the harvesting of user data as a standard among private companies. We now live in the age of what Harvard professor Shoshana Zuboff calls **surveillance capitalism:** *"the unilateral claiming of private human experience as free raw material for translation into behavioral data."* As technology becomes even more pervasive, the risks of privacy breach range from computer activity to payments history, smart home appliances, surveillance cameras, and more.

Recently, several initiatives have attempted to strengthen data privacy. For instance, the EU's General Data Protection Regulation (GDPR) passed in 2018 is a promising first attempt of a regulatory response—though critics point to the complexity of its application. Among many private efforts related to privacy by design, World Wide Web inventor Tim Berners-Lee developed Solid, a web re-decentralization project which would allow users to separate their data from the applications that use it.

How To Mitigate This Risk

- Increased user awareness
- Privacy-enhancing software and devices
- Ethical and secure engineering which enables privacy by design
- Decentralized technologies like blockchains and Solid
- Standards and regulations with clear definitions, going even beyond the general rules in GDPR

Resources

- Research groups like Data&Society (US), ITS (Brazil), Eticas (Spain) and Data Justice Lab (UK)
- Digital rights NGOs like Open Rights Group (US), the Electronic Frontier Foundation (US), La Quadrature Du Net (France), Privacy International (UK), and AccessNow (US/Global)
- The Web Foundation's initiatives such as the Web We Want coalition and the Contract for the Web
- Thingscon's Trustable Technology Mark
- The EthicalOS toolkit and Doteveryone's Tech Transformed

Photo: Franck V

Algorithmic Discrimination

An algorithm is a set of instructions to accomplish a particular task. When implemented in a computer program, it can process large datasets to automate tasks, support decision-making, and even become smarter over time through machine learning.

> *"When machines learn and take decisions alone, based on inputs you have no control of any more, you are bound to have problems."*
>
> ***Gemma Galdon Clavell,*** *Director of Eticas*

While algorithms bring speed and efficiency, they can also lead to systematic and unfair discrimination when trained on biased datasets. Notable examples include crime prediction software biased against people of color, "robo-debt" collectors punishing casual workers as they misinterpret their income, AI recruiting tools that discriminate against women, and potential risks related to precision medicine. In the words of mathematician and former Wall Street analyst Cathy O'Neil: "*Weapons of Math Destruction score teachers and students, sort résumés, grant loans, evaluate workers, target voters, set parole, and monitor our health.*"

While some argue that machines can be less biased than humans, the real danger is that **algorithms implement biases at a much larger scale, and often without any explanation nor means of appeal.** Many algorithms are de facto "black boxes" opaque to outside scrutiny.

A global response is emerging. Engineers, researchers and human rights activists are organizing around Fairness, Accountability and Transparency principles, and initiatives such as the Montreal Declaration on Responsible AI. International engineering bodies like IEEE are issuing ethical design standards. In academia, the emerging interdisciplinary field of machine behavior could help better understand and prevent algorithmic biases, while many universities are now hosting dedicated centers, including the AI Now Institute at NYU and the MIT-Harvard Ethics And Governance of AI initiative. In terms of regulation, the EU has set a new standard with GDPR and is now pushing new ethical AI guidelines. The US may catch up soon with a new bill recently introduced in Congress: the Algorithmic Accountability Act.

How To Mitigate This Risk

- Greater diversity within engineering teams
- Ethical principles for algorithm development and training, including the use of unbiased datasets
- Standards and certificates of algorithm bias verification, such as the ORCAA label from mathematician Cathy O'Neil
- Regulations on algorithmic fairness, accountability, and transparency, such US and EU proposals

Resources

- Research groups like AI Now (US), Data Justice Lab (UK), Data&Society (US), Eticas (Spain), Engine Room (US/Global)
- AI Now's reading list on gender and racial biases
- The IEEE Ethics in Action initiative
- The Montreal Declaration on Responsible AI
- The AI Commons coalition of academia, civil society and international organizations
- The EthicalOS toolkit and Doteveryone's Tech Transformed

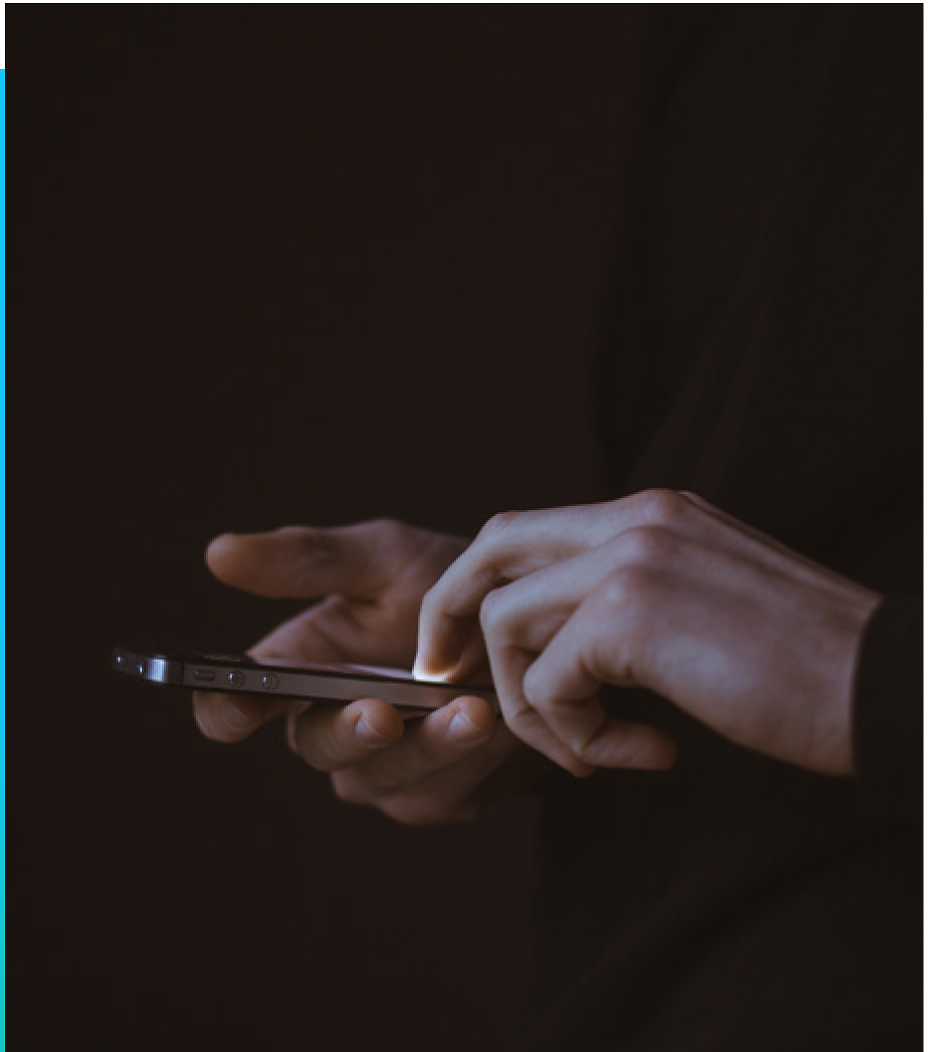


Photo: Gilles Lambert

Media Manipulation

The Economist titled in 2017 *"once considered a boon to democracy, social media have started to look like its nemesis."* The praise for its role in the Arab Spring of 2011 gave way to anger over the political polarization it is now credited for. Not only have we been trapped in online filter bubbles and echo chambers, but as a series of elections have shown us *"an economy based on attention is easily gamed."* So far social media giants like YouTube and Facebook have prioritized algorithms that maximize "engagement" over measures to curb the spread of toxic content.

Media manipulation has emerged in the last three years as the new technological threat to democracy. Most techniques revolve around the creation and amplification of "fake news," with the strategic use of memes, social media, and bots (automated accounts). They also exploit online media's dependence on sensationalism and engagement metrics and the fact that recommendation algorithms are easily gamed. The most sophisticated strategies use a combination of psychological profiling and micro-targeted ads to deliver customized political messaging.

> **If everybody always lies** to you, the consequence is not that you believe the lies, but rather that **nobody believes anything any longer.**
>
> ***HANNAH ARENDT,*** *POLITICAL THEORIST*

This arsenal has been used for years by political parties, governments, hate groups and corporations to advance their agenda online. Though, it was not until the Cambridge Analytica scandal in 2018 that the world understood **how a sophisticated digital propaganda machine could influence the result of high-stakes democratic processes** such as the Brexit referendum and the elections of Donald Trump.

Things could become even worse with AI-enabled video manipulation techniques, including lip-syncing, voice synthesizing, and "deepfakes" which insert someone's face on another person's body. Although researchers are developing AI tools to recognize doctored videos more efficiently, those may not necessarily be available where phony content is spread, preventing real-time viewer awareness.

Fake news can lead to dramatic consequences, including the direct loss of life. In rural India, Whatsapp rumors have already killed several dozens of innocents in 2017 and 2018, who were lynched by angry mobs who suspected them to be child lifters. Online misinformation also largely fuels the anti-vaccine movement, which now ranks among the top 10 threats to global health according to WHO.

Responding to that challenge is hard: there is a thin line between fighting misinformation and restricting freedom of expression. Automated fact-checking (see SDG16) is making progress, but issues may arise from algorithms becoming the new arbiters of truth. Overall, the solution also lies in rebuilding trust in our institutions. According to the 2019 Trust Barometer from PR firm Edelman, 40% of the population routinely share news content online, while 73% worry about fake news used as a weapon, and 47% distrust the media, which *"remains the least-trusted institution"* as the study concludes.

How To Mitigate This Risk

- Fact-checking, moderation, and potentially removal of fake news and harmful content, either manual or automated (SDG16)
- Digital literacy and education programs to help citizens recognize false information more easily
- Regulation of digital platforms regarding harmful content, political advertising, and recommendation algorithms

Resources

- Research groups like the IFTF Digital Intelligence Lab (US), Data&Society (US), ITS (Brazil), and EU Disinfo Lab (Europe)
- Fact-checking organizations (see SDG16)
- Reporter Without Border's Journalism Trust Initiative

Economic and Labor Disruption

The fear that machines will replace human labor goes back to the first industrial revolution. On that matter, the Schumpeterian notion of creative destruction—lost jobs are recreated somewhere else—and the recent work of Carlota Perez on techno-economic cycles have provided compelling economic analyses. However, understanding the past does not allow to predict the future. Going through recent studies on automation and jobs, the MIT Tech Review found in 2018 that predictions differ too widely from one another and concludes that *"we have no idea how many jobs will actually be lost to the march of technological progress."*

Many believe that "*this time is different*" because of the exponential and combinatorial nature of AI, robotics and other emerging technologies. The fear that too many jobs could disappear too quickly is widespread among scholars like Joseph Stiglitz and the late Stephen Hawking, as well as within the tech elite, from Bill Gates and Elon Musk in the US to Jack Ma and Kai-Fu Lee in China. As a response, the idea of a Universal Basic Income (UBI) is increasingly popular in Silicon Valley and beyond, with Y-Combinator even running a pilot in Oakland. However, critics see in UBI proposals a mere *"consolation prize for those whose lives are disrupted"* as well as a justification for precarious wages in the gig economy. Others like European investor Nicolas Colin have called for a broader response: a Greater Safety Net for the entrepreneurial age.

Automation raises a critical question: what will be the quality of the new jobs taken by humans? This question is especially relevant considering that over the last three decades, median income has stagnated in the US while labor productivity skyrocketed. Low unemployment should not distract us: as *Second Machine Age* co-author Andrew McAfee argues, manufacturing job losses have been compensated by more precarious service work. True, new jobs and industries may appear in the future. But there is **no guarantee that vulnerable workers will benefit from them**—at least, not without an overhaul of social protections, and massive investment into what the WEF calls a *Reskilling Revolution*.

> *"The beauty of automation is that it is part of the hacker ethic: if you can solve the problem once, do not solve it many times. Do not reinvent the wheel. I think it can be a liberating force, help to reduce risk and meaningless work. The true question is whether the technology that implements automation is democratized or monopolized."*
>
> ***Audrey Tang,***
> *Digital Minister of Taiwan*

Some economists argue that by focusing on automation, we may have been investing in the "wrong" kind of AI so far. In a recent paper, Daron Acemoglu (MIT) and Pascual Restrepo (BU) describe the "right" AI type as one *"used to restructure the production process in a way that creates many new, high-productivity tasks for labor."* Examples include AI applications that could empower nurses and healthcare technicians to deliver personalized treatment, allow teachers to offer individualized education, and enable factory workers to perform high-precision manufacturing jobs. However, the two scholars estimate that market forces give *"no compelling reasons to expect an efficient balance between different types of AI,"* at least not without proactive measures.

Maybe the right question is not whether AI and robots will take our jobs but: who will own the machines. Karl Marx would probably enjoy reading those lines in the MIT Tech Review: *"whoever owns the capital will benefit as robots and AI inevitably replace many jobs."* That prospect is sobering when one considers **how much power tech giants have already accumulated.** The American GAFAs (Google, Amazon, Facebook, Apple) and the Chinese BATs (Baidu, Alibaba, Tencent) all have market capitalizations above the GDP of most countries. If they were countries, Amazon, Apple and Microsoft could all have joined the G20 when they briefly passed the trillion dollar mark. In addition to labor market disruption, concerns over the power of tech titans also revolve around large-scale tax avoidance, a monopolistic position which stifles innovation, and a business model at odds with data privacy.

Containing the power of tech giants seems like an arduous task. Some US regulators and presidential candidates have floated the idea of breaking up Big Tech into smaller companies, like the railway and oil monopolies, while the OECD is pushing for a global taxation reform for the digital economy. The ITU and various academic partners have proposed "AI and data commons" to mitigate the dominance these companies exert over the future of AI, while others advocate new entrepreneurial forms such as cooperatively owned digital platforms.

How To Mitigate This Risk

- Public and private investment in AI that enhances labor rather than automate tasks
- Public and private investment in lifelong learning, reskilling programs, and new education financing models
- Data science to better estimate the impacts of technology on jobs in a given industry or geography, such as Faethm
- New social protection systems, feeding on successful welfare states and emerging research (UBI, greater safety net)
- International regulation of tech firms to limit monopolies and ensure fair taxation

Resources

- The OECD policy research on the future of work and the global taxation of the digital economy
- The ILO Future of Work Centenary Initiative
- The WEF system initiative on work, education, and gender
- The MIT Initiative on the Digital Economy
- The IFTF Workable Futures program
- The Platform Cooperativism movement
- The World Bank's World Development Report 2019
- The AI Commons coalition of academia, civil society, and international organizations

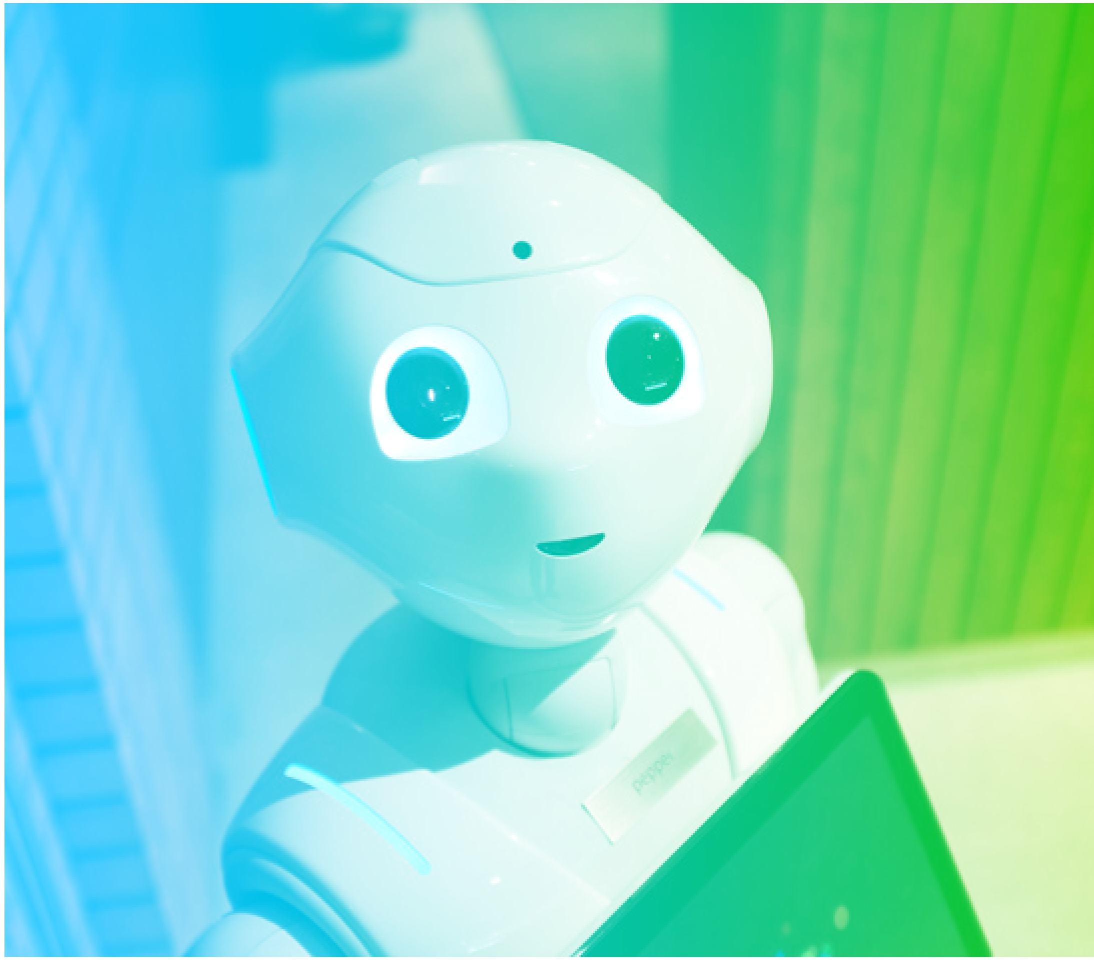


Photo: Alex Knight

Increasing Inequality

At the turn of the century, many were still hopeful that digital technology would be the great equalizer. Today, some of the challenges depicted in these pages tend to tell a different story. As Stephen Hawking wrote in his final Reddit post: *"everyone can enjoy a life of luxurious leisure if the machine-produced wealth is shared, or most people can end up miserably poor if the machine-owners successfully lobby against wealth redistribution."*

Technological acceleration presents high risks of increasing wealth inequalities at all levels. Workers in most advanced economies have earned a declining share of national income since the early 1990s, even as capital owners were capturing a growing share of productivity gains. An IMF study from 2017 found that automation and technological progress are the main factors behind this gap. These results echo the argument made by economist Thomas Piketty in his bestseller *Capital In The 21st Century*, that wealth concentrates when returns on capital are higher than economic growth. The MIT Tech Review sees a case in point in Silicon Valley with the dramatic wealth gap between the tech elite and the very poor.

Technology-induced inequalities could be far-reaching. In a 2018 report, the McKinsey Global Institute predicts that AI could widen the wealth gap by 2030 at three levels: between companies that pioneer or delay AI adoption, between advanced economies and developing nations, and between high-skilled and low-skilled workers.

> **Human societies** in the 21st century might be the **most unequal in history.**
>
> ***YUVAL NOAH HARARI,*** *AUTHOR OF SAPIENS AND HOMO DEUS*

In a dystopian scenario, the wealth gap could even lead to a split of humankind into separate "castes." In one of his bleakest predictions, Yuval Noah Harari, bestselling author of Sapiens and *Homo Deus*, fears that *"for the first time in history, it becomes possible to translate economic inequality into biological inequality"* with advances in AI and biotechnology. Enhancements to the human body and mind could include smart contact lenses, cognition-enhancing "smart drugs," brain-computer interfaces, genetically engineered "designer babies," and longevity treatments. Some of these techniques are already under development. Beyond ethical dilemmas about their nature, those "upgrades" are also likely to be expensive and available only to the rich.

History shows that we can prevent extreme inequality. Based on principles of equal opportunity, fair redistribution, and social security, the European welfare state model has been credited for containing inequality to lower levels compared to the US. That model emerged in the context of previous industrial revolutions—in the late 19th century and after World War II. Today, as technology is reconfiguring the entire economy, society should come together to update its social contract for the 21st century.

Photo: Garry Knight

How To Mitigate This Risk

- Public and private investment to address the root causes of inequality, such as education, climate change, discrimination, and unfair economic rules
- New social protection systems, feeding on successful welfare states and emerging research (UBI, greater safety net, etc)
- International regulation of tech firms to limit monopolies and ensure fair taxation

Resources

- IFTF's Equitable Futures Lab
- The Ford Foundation's Technology and Society program
- Education and inclusion initiatives (see SDG5, SDG8, SDG10, and section 4.2 on diversity and inclusion)
- The World Inequality Database and its associated research lab, co-chaired by Thomas Piketty

Unsustainable Electronics

In spite of their names, digital technologies are not immaterial and clean technologies are not entirely clean. Both rely on circuit boards, batteries, magnets, antennas, displays, solar cells, and various electronic components. Some of these parts often have a social and environmental footprint at odds with the noblest of intentions.

Upstream, the production of electronic components faces three challenges. First, the supply of critical metals may not be able to meet global demand. The American Chemical Society estimates that 44 of the 118 elements in the periodic table could face supply restrictions this century, including rare metals like silver and tellurium, but also fairly abundant ones like copper, zinc, and lithium. Also in high demand, the 17 rare-earth elements (REE) are plentiful in the Earth's crust but are typically dispersed and hard to separate from other minerals. Global reserves for the most strategic metals are concentrated in a few countries, making supply chains vulnerable to political and environmental shocks. China currently mines 93% of the world's REEs and has already used this dominance to exert geopolitical influence with Japan in 2010.

Second, mining and refining activities have a terrible environmental record. The most severe issues include erosion, the destruction of local biodiversity, as well as soil and water contamination by chemicals used in the process. This pollution can also affect the health of local populations: inhabitants from Baotou, the largest Chinese source of rare-earth, show high rates of cancer and other illnesses.

Third, mining also comes with a terrible human cost in conflict areas where certain metals are located. DR Congo is home to a vast mineral wealth estimated in the trillions, including the world's largest reserve of tantalum and an abundant supply of cobalt, tin, tungsten, and gold. These metals, found in smartphones, batteries, light bulbs, and many other devices, have been a curse to the country. Extraction occurs in small mines that are often illegally controlled by armed groups, who terrorize and submit local populations with rape, slavery and child labor.

"There is an exponential need for new materials. Today most solar panels still have a negative carbon footprint over the entire lifecycle, and the supply of critical metals may be stressed by our demand for clean energy and electronic devices. We need to find better ways to manage competing material uses, move towards full recyclability as soon as possible, and continue investing in biotechnology as a long-term alternative."

Chris Monaghan,
Co-Founder and Innovation Director at Metabolic

Downstream, the situation is not much better. In 2016 the world produced about 45 million tonnes of electrical and electronic waste—4500 Eiffel Towers—according to the Global E-Waste Monitor from ITU and UN University. That number is expected to reach 52 million tonnes (+17%) by 2021.

Globally, only 20% of global e-waste is recycled properly, despite an estimated value of 55 billion euros in materials only—gold, silver, lithium, copper, zinc, etc. Even in the EU where recycling rates are better than the global average, as few as five percent of lithium-ion batteries gets recycled. Furthermore, this battery type—the current standard for electronic devices and electric vehicles—is not entirely recyclable, due to technological limitations and a lack of standardization.

Photo: Fairphone

Beyond the waste of economic value, the global e-waste problem has two additional consequences. First, it increases the need for new components and minerals upstream, with the challenges highlighted above. Second, **up to a third of unrecycled parts ends up in the developing world,** according to the Global E-Waste Monitor. The leak of hazardous materials such as lead, mercury, and cadmium often causes environmental pollution and damaging effects on human health. This practice is known as "toxic colonialism."

"The technology to reuse electronic components already exists, people do it in Shenzhen. But the global consumers have to create the demand for it to happen at scale."

David Li,
Founder of SZOIL, Shenzhen Open Innovation Lab

One important factor is that most electronic products are not made to last but planned for obsolescence. Examples include products designed to fail after several uses, cheap materials that weaken durability, the prevention of repairs, and the continual introduction of novelty driving consumerism—in the US, the average user keeps an iPhone for only 18 months. The IEEE expects things will get even worse with what they call "Internet of Trash"—billions of connected devices designed for landfill.

Overall, many potential solutions for this daunting challenge lie in the circular economy—from sustainable lifestyles and business models that increase product lifespan, to modular design and better materials. Innovation in mining and recycling is also deeply needed, although fully sustainable processes remain an elusive goal.

How To Mitigate This Risk

- Product design patterns and business models that maximize lifespan, repairability, and upgradeability
- Sustainable sourcing of critical metals, possibly using new tools such as blockchain certification and AI to detect better sources
- Innovation in sustainable materials, such as new alloys and bio-based materials
- Innovation in clean mining and recycling technologies
- Policy and regulation on minerals sourcing, planned obsolescence and repairability, recycling

Resources

- The Ellen MacArthur Foundation's work on circular electronics
- The Thingscon community on fair and responsible IoT
- OECD's work on responsible mineral supply chains
- Alliances such as the Responsible Minerals Initiative and the China-led Responsible Cobalt Initiative

Security and Safety Risks

Whether development originates from military or civilian research, many technologies have a dual-use—in both peaceful applications and weapons. One could argue that hazard increases when technology gets more powerful and democratized at the same time.

Rapid advances in AI, autonomous vehicles, drones, and the internet of things increase cybersecurity risks. In the *Malicious Uses of AI* report published in 2018, top research institutions consider three types of AI-augmented cyber threats: political, digital, and physical. **Political risks** relate to surveillance and media manipulation, covered in previous sections. **Digital risks** include larger and more powerful cyber attacks, the exploitation of human vulnerabilities in new ways—such as automated impersonation, using algorithms to steal someone's identity—as well as the exploitation of vulnerabilities in AI systems.

Physical risks include the use of drones and self-driving vehicles to deliver explosives and cause fatal crashes. AI could bring these threats to epic proportions, with a swarm of thousands of weaponized micro-drones targeting victims with facial recognition: a nightmare scenario that motivates the call for an international ban on autonomous weapons. Security experts are also worried by potential attacks on critical infrastructures, similar to the Stuxnet virus which targeted Iranian nuclear plants in 2010, and more recent attacks in Ukraine. Some even call for governments to slow IoT innovation and force companies to make security a priority rather than an afterthought.

The "AI apocalypse" scenario, in which super-intelligent machines take over humanity, has been the subject of big headlines. Although that eventuality is very remote, a few research labs focus on preventing it, including, the UC Berkeley Center for Human-Compatible AI, the Leverhulme Centre for the Future of Intelligence, and OpenAI. New interdisciplinary research could be instrumental in understanding machine behavior better and prevent a possible doomsday scenario. A shorter-term risk is the prospect of a global arms race for military AI, with unforeseen geopolitical consequences.

Photo: Pixabay

In addition to cyber threats, we also need to worry about entirely new hazards introduced by emerging technologies. For instance, **synthetic biology**—in spite of its tremendous potential in medical and environmental fields—could increase the probability of engineered pathogens being released. Scenarios considered by the US Department of Defense include re-created deadly viruses, and common microbes modified to churn out lethal toxins. In **genetic engineering**, another concern relates to the potential side effects of gene drives, a CRISPR application aimed to spread genetic modifications in a species population to prevent diseases—see SDG3 section on the case of malaria mosquitoes.

As climate change worsens, a **controversial geoengineering strategy called solar radiation management** could increasingly be considered, to reflect sunlight and heat into space. One method would be to inject sulfate aerosols in the stratosphere, creating a global dimming effect. Although it does not address the root causes of climate change, some see this option as an "insurance policy" to avoid the worst consequences of rising temperatures, and win enough time for deep decarbonization. Unfortunately, we know very little about the associated risks of those technologies, which could lead to irreversible and catastrophic climate destabilization. Furthermore, the relatively low cost of the technology means that a single country, or even a wealthy individual, could deploy it recklessly and unilaterally.

Photo: TechCrunch

> It is crucial to assess which risks can be dismissed firmly as science fiction, and which could conceivably become real.
>
> ***MARTIN REES,*** *UK ASTRONOMER ROYAL, CO-FOUNDER OF THE CAMBRIDGE CENTRE FOR THE STUDY OF EXISTENTIAL RISK*

Mitigating those threats requires not only greater awareness within the tech community, but also research and policy. Cybersecurity experts and publications like the WEF Global Risks Report do great work covering near-term risks. However, **global catastrophic risks** rank low on the public debate. Only a handful of institutions are working on those, including the Oxford Future of Humanity Institute, the Cambridge Centre for The Study of Existential Risk, and the Global Challenges Foundation.

How To Mitigate These Risks

- Increased focus on security within tech development
- Interdisciplinary research on both near-term and existential risks
- International regulation to limit critical risks
- Work toward global governance (see 4.2)

Resources

- The Global Challenges Foundation
- The Cambridge Centre for The Study of Existential Risk
- The Oxford Future of Humanity Institute
- The Future of Life Institute
- The Bulletin of the Atomic Scientists
- The Center for Human-Compatible AI
- The Leverhulme Centre for the Future of Intelligence
- The UC Berkeley Center for Long-Term Cybersecurity
- The Montreal Declaration for Responsible AI
- The Campaign to Stop Killer Robots
- The ICT for Peace Foundation

4.2 Root Causes

Photo: NESA by Makers

Each of the risks and challenges described above has particular origins and possible answers, but they all share root causes which we need to address. Those include a lack of diversity in tech and science, a prevalent ideology of solutionism, economic incentives that do not maximize positive outcomes, and governance systems unfit for the pace of technological change. We cannot wait for another generation to tackle those issues—but it will not be easy, as they stem from deeply rooted economic, social and cultural norms.

Increasing Diversity and Inclusion

The lack of diversity in technology has received widespread attention in recent years. Its symptoms include sexual harassment and how little venture capital goes to women (15%) and people of color (1%).

Left unchecked, the chronic underrepresentation of women and minorities in tech can establish a toxic "brogrammer" culture leading to abuse, injustice, and even harmful product design. For instance, early airbag models used to severely injure and kill women, because all-male design teams had not considered smaller persons.

> *"Network effects in entrepreneurial communities are powerful, but they can play against women and minorities. There is a principle of like-attracts-like in most networks, which tends to cause underrepresented members to be further underrepresented as a network grows."*
>
> ***Lili Torok,***
> *Project Leader at Endeavor Insight*

Algorithms can take this problem to epic proportions, as we discussed in section 4.1. Introducing its Decolonising AI program, the Leverhulme Centre for the Future of Intelligence writes: *"the systemic lack of diversity among AI designers and existing structural injustices are reflected in the technology, which in turn perpetuates those injustices."* In 2016, the biggest AI conference (NIPS) counted only six black people among 8500 attendees, according to Black In AI founder Timnit Gebru. Such a lack of diversity can perpetuate biases in both the design of algorithms and the datasets used to train them. For instance, face-recognition can hardly identify black women if the AI was trained mostly on white faces.

Diversity is a thorny issue because its lack thereof is self-reinforcing. Widespread unconscious biases in the workplace—be it in recruitment, performance reviews, or fundraising—and an unwelcoming tech culture can explain higher attrition rates for women and minorities. Moreover, fewer role models in positions of power—like CEO or Partner in a VC firm—discourage underrepresented people to pursue those careers, as they may be perceived as unachievable.

However, efforts to increase diversity in science and technology should consider the whole picture. Beyond merely hiring women and people of color from privileged backgrounds, those efforts should also aim to bridge the digital divide among low-income populations—not only for internet access but also digital literacy. According to the Web Foundation, poor women in the developing world are 50% less likely than men to access the Internet, and once online 30-50% less likely to use it for economic and social empowerment.

Many in the industry have taken notice, and diversity initiatives are flourishing—in at least five categories. First, **education and mentoring** for underrepresented talents, including programs featured in SDG4, 5, 10, as well as AI4ALL, a non-profit working with leading universities. Second, **bias-free hiring tools**, profiled in SDG8. Third, **diversity-focused venture funds** using positive discrimination as an investment thesis, such as Backstage Capital whose founding story made headlines. Fourth, **advocacy groups** aiming to spark broader ecosystem change, such as AllRaise (US), Sista (France), and DiversityVC, (UK) which partnered with Atomico to publish a diversity guidebook for entrepreneurs. Fifth, **research programs** like the Stanford Gendered Innovations Lab develop practical methods for gender considerations in science and engineering, and case studies about how it leads to better innovation.

Technology is the answer.
But what was the question?

Cedric Price,
Architect.

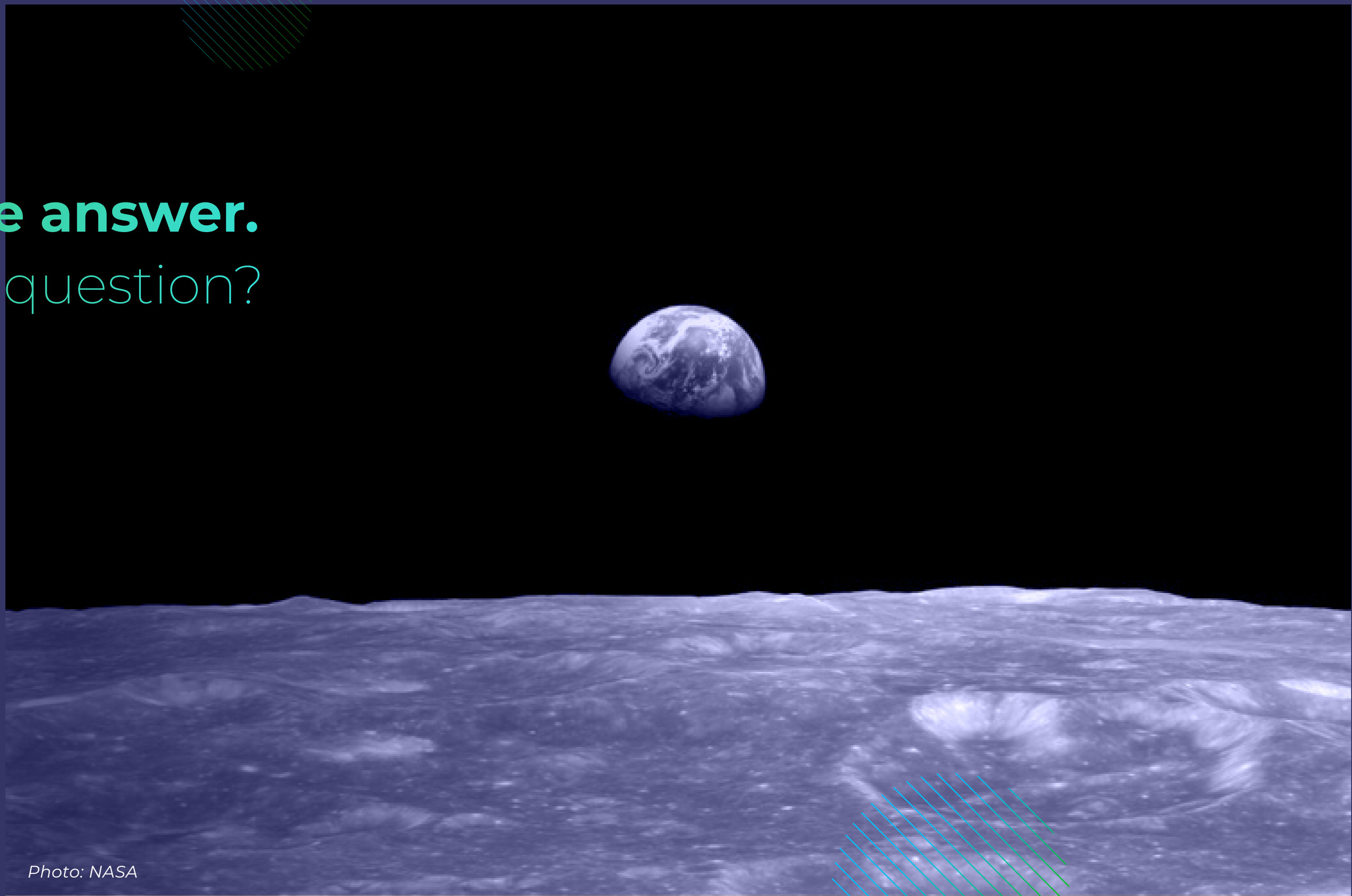


Photo: NASA

Avoiding The Solutionism Trap

Technological solutionism refers to the idea that given the right piece of code, technology could fix all our problems. Brought under the spotlight by Silicon Valley critic Evgeny Morozov in *To Save Everything, Click Here*, that ideology expresses a reductionist view of the world—the opposite of system thinking. As a consequence, solutionists often fail to take interdependencies into account, prioritize the best leverage points, differentiate effects from root causes, and anticipate the unintended consequences of technological fixes.

"AI engineers and scientists are not always trained or incentivised to think about the impact of what they build. Learning to adopt systemic view takes time and experience - which can only be acquired working hand in hand with domain experts."

Julien Cornebise,
Director of Research, Head of London Office at Element AI

This over-simplification stems from insufficient knowledge about—or consideration for—problems and their broader context. This report features many examples, from the fish-drying technology mentioned in Chapter 2.3 to financial inclusion blockchains (SDG1), first-generation bioenergy leading to deforestation and biodiversity loss (SDG7, SDG13) and high-tech urban farming advertised as a way to sustainably feed cities (SDG11). Smart city efforts often start from the premise that citizens will benefit from technology, while in many cases they do not get value from it—unless they are involved early on.

Innovators can bridge this knowledge gap through interdisciplinarity and by gathering diverse points of view—in their teams, from their partner network, and by involving users and communities in the solution design process. As UNDP Innovator Benjamin Kumpf and Nesta CEO Geoff Mulgan write: *"All too often, innovation [is] equated with imported tech gadgets and a Silicon Valley-type heropreneurship discourse. But many of the most valuable ideas come from communities themselves."*

Technological innovation can help move the needle in many fields but is not always the best answer, as stated in the introduction of this report. Innovating on business models, supply chains and distribution, as well as increasing the accessibility of existing technology, can sometimes lead to even more transformative results. Furthermore, policy and behavior change have an equally vital role to play in addressing superwicked problems like global warming. For instance, it is unlikely that cell-based meat alone can curb emissions associated with animal protein—a broader shift toward plant-rich diets would be crucial, and meat taxes also appears to be on the table.

"I am skeptical of any technology presented as the solution to everything. It is not a series of tech innovations that will save us. We should put more energy into building the commons while democratizing access to and control of existing technologies."

Nathaniel Calhoun,
Co-Founder of Code Innovation,
Vice Chair of Global Grand Challenges at Singularity University

Rethinking The Economics of Technology

Knowledge is power, or *"scientia potentia est"* as Francis Bacon allegedly said. Today technology—applied knowledge—is associated with economic and financing models driven by power dynamics which do not necessarily maximize positive outcomes.

To this day, military research has always made up a sizeable portion of technology investment. Founded in 1958 during the cold war, the American DARPA (Defense Advanced Research Projects Agency) is a typical example. It has been credited for inventing the GPS and the networking basis of the Internet, and is now a major funder in AI, robotics and gene editing. Obviously, there are reasons to worry about the defense industry's investment in emerging technologies and its connections with tech giants and academia. As history taught us, the most transformative inventions—drones, airplanes, nuclear energy—can become instruments of war and domination.

During most of the 20th century, military and corporate R&D used to represent the bulk of technology investment. In the 1970s though, the nascent personal computing industry popularized a previously niche model—venture capital. Today VC is the primary source of startup funding and has been instrumental in enabling the digital revolution.

However, despite its success, the VC model is increasingly criticized because the hypergrowth it fuels on does not suit most companies. For every unicorn, countless venture-backed startups have grown too fast and failed, sometimes unnecessarily. That winner-take-all system is particularly unfair for those who cannot afford to fail—such as founders from underrepresented backgrounds. Equity investment also means that entrepreneurs often lose control of their companies and pass on most financial returns. Those returns hence tend to accrue to the already wealthy—as discussed in SDG10.

> *"Exits are where you see the biggest divide between traditional tech startup founders and social entrepreneurs. The latter would usually prefer not selling their company."*
>
> ***Avary Kent,***
> *Executive Director, Conveners.org*

Moreover, the quest for hypergrowth creates an incentive system at odds with Impact Tech values. First, unless a net positive impact is 100% locked into the business model, growth *"at all cost"* can easily come at the expense of society. Second, venture-backed companies tend to become speculative assets for which valuation, not commercial success—let alone impact—is the leading metric. Third, in the quest for the next unicorn, talent often flows toward non-problems, such as making more people click on ads. As Village Capital executives noted, *"only 15% of 'unicorn' companies are solving problems in food, health, energy, agriculture, financial services, and housing."*

> *"Too much energy and intellect are invested in innovation to solve non-problems like remote pet monitoring, or worse, products that are harmless at one scale but when they reach billions of people harm the biosphere and our own health."*
>
> ***Owen Gaffney,***
> *Director at Stockholm Resilience Centre*

Although private tech investors often get credit for taking all the risks, the reality is much more nuanced. In *The Entrepreneurial State*, economist Mariana Mazzucato demonstrates how private tech firms rely heavily on the products of public research—not only the Internet and GPS, but also touch screens, voice recognition, and even Google's search engine algorithm. In *Doing Capitalism In The Innovation*

Economy, venture capital pioneer William Janeway makes a similar argument: VC mostly works in industries that were de-risked by public investment. That insight raises the question of how the upside could be shared between the private and public sectors—potentially increasing the latter's capacity to further invest in science and technology for the common good.

Overall, the most commonly available funding options in science and tech have several blind spots. Those include Impact Tech startups in which profit is not the sole measure of success, science-based ventures needing many years to bear fruit, and the vast majority of companies do not fit for a hypergrowth trajectory. We will further explore these gaps in our second report, along with some of the emerging responses—from impact investing to new fund structures to the strategic role of philanthropy.

Photo: Joseph Barrientos

Upgrading Technology Governance

We conclude this chapter with an overarching issue: how can we steer technological progress in a way that maximizes societal benefits and minimizes adverse outcomes? At the project level, impact management can allow this, as we cover in Chapter 5. At the society level, the question becomes: what should science and technology governance look like in the 21st century?

Science and technology governance should serve three main goals: enable, protect, and choose—with inputs from government, business, academia, and civil society. First, **enable** the potential of technological progress to benefit humanity as a whole. Second, **protect** society against critical risks and challenges, such as the ones profiled earlier in this chapter. Third, support **collective choices** on new ethical debates arising from emerging technologies.

Although the first two goals relate to technologies whose benefits and dangers are mostly agreed upon—such as clean energy and killer robots—**the third one deals with controversial issues** prone to conflicting values and trade-offs. Indeed, new developments in fields like genetic engineering, synthetic biology, AI, and robotics, leave opinions divided. In times where artificially evolved humans and fully autonomous systems could soon become a reality, should progress be pursued as fast as possible? Should a precautionary principle contain it? Or should it be forbidden on moral grounds? Those issues can be politically sensitive and spark intense philosophical debate on what it means to be human.

“Most of the things that people were worried about at one point or another—like railroads, refrigeration and in-vitro fertilization—go through a very brief period of time during which they’re unacceptable, usually when they are technically infeasible. It’s easy to be opposed to something that doesn’t work. The instant that it works and is shown to be safe and effective, suddenly it is hard to resist.”

George Church,
Professor at Harvard and MIT, pioneer of the Human Genome Project, father of synthetic biology

Today, the governance of new technologies lies de facto within industry and academia, which is hardly enough. Yoshua Bengio, one of the fathers of deep learning, presented in 2018 a set of ethical AI guidelines called the Montreal Declaration—co-created by researchers in AI, social sciences and humanities, as well as citizens—but stresses the need for proper regulation. As he told Nature: *"Self-regulation is not going to work. Do you think that voluntary taxation works? It doesn’t. Companies that follow ethical guidelines would be disadvantaged."* That sobering statement is a reminder of limitations faced by other initiatives, such as the Partnership on AI, the Asilomar AI Principles, and OpenAI.

The last 18 months have seen notorious self-regulation failures—from multiple Facebook scandals to the shutdown of Google’s AI Ethics board after just a week, to the birth of “CRISPR babies” in China. In the last example, both the international research community and the Chinese government have condemned the experiment, in which a rogue scientist gene-edited the embryos of twin girls, supposedly to confer them HIV resistance—and maybe enhance their brains. US scientists also appear to have been involved in the process. While many have called for a global moratorium on germline gene-editing, the Nature editorial board doubts it would work without a proper legal framework to avoid loopholes.

Photo: NASA

Hence, smart regulation and innovative policy are required. A lot can be done at the local, national, and regional levels—from cities asking that autonomous vehicles be electric and shared, to Rwanda allowing drone corridors for the delivery of medical supplies, to the EU strengthening rules on data privacy and machine bias. However, many issues fall out of those jurisdictions. Mark Zuckerberg can decline the request of nine countries' parliaments to testify about the impact of Facebook on democracy, and science mavericks can always relocate their rogue experiments where they are not forbidden. Even China, which ambitions to become the main AI superpower by 2030, has called for international cooperation *"so that we can respond to the double-edged-sword effect of new technologies."*

When the UN was established in 1945, humanity had just developed a technology that could lead to its own demise—nuclear weapons. That realization helped make a case for global cooperation to ensure peace and security. In recent years, various multistakeholder initiatives were born out of the UN system to promote the ethical use of technology to address the Sustainable Development Goals—such as the Technology Facilitation Mechanism, ITU's AI For Good community, and the innovation labs from UN agencies profiled in Chapter 2.4.

However, despite many achievements, international institutions have been unable to tackle some critical planetary challenges—from global warming to the new arms race escalating in outer space. Although the Campaign to Stop Killer Robots has received widespread public support, including a pledge from top AI leaders not to develop lethal autonomous weapon systems (LAWS), efforts to ban those weapons under the UN Convention on Conventional Weapons seem to fall apart. Australia, Israel, Russia, South Korea, and the US have blocked the UN talks, while China and Britain have also started to develop LAWS on their own.

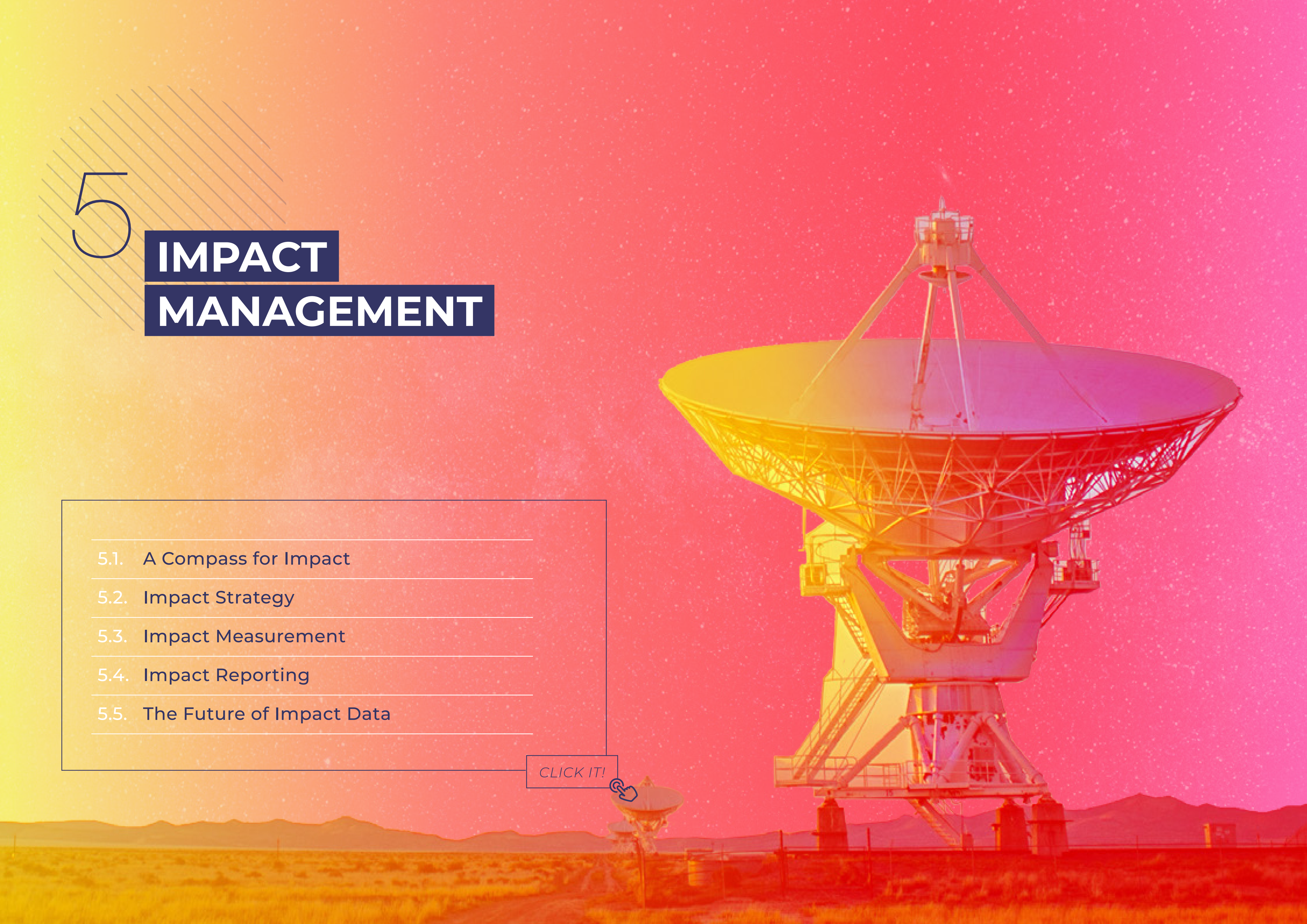
> Nothing in life is to be feared, it is **only to be understood.** Now is the time to understand more, so that **we may fear less.**
>
> ***MARIE CURIE,*** *DOUBLE NOBEL PRIZE IN PHYSICS AND CHEMISTRY*

Global institutions need a serious upgrade. As the Global Challenges Foundation, which focuses on catastrophic risks and global governance, summarizes: *"Global challenges call for global solutions—but the very structures that could offer such global solutions are the ones currently facing the worst gridlock."* The Swedish non-profit runs since 2016 the New Shape Process to help develop proposals of UN reform and more effective global frameworks.

Even with a 21st-century upgrade, the international governance of emerging technologies would still need to overcome significant hurdles. In addition to conflicting interests which may prevent cooperation and the fact that technology and politics run at very different paces, it would also need to take into account how local culture affects ethical choices. A case in point is the MIT's Moral Machine experiment, which crowdsourced preferences on which lives driverless vehicles should save in case of a fatal crash. Results indicate a strong correlation between preferences and cultural traits. For example, *"participants from collectivist cultures like China and Japan are less likely to spare the young over the old—perhaps [because] of a greater emphasis on respecting the elderly."*

Lastly, new global frameworks would need to work in synergy with local processes—including a renewed dialogue with civil society. Governments can organize citizen consultations, such as the "Bio-Ethics General Assembly" that runs every five years in France. Going further, science philanthropists writing in SSIR call for a culture of civic science which *"is not merely about scientists seeking dialogue with the public [or] regulatory processes with as much public input as possible, [but also] a better dialogue between science and society, from patient groups and other affected stakeholders, from religious groups, from diverse populations, and from policy leaders."* Various organizations can support that science-society dialogue, from interdisciplinary centers like the AI Now Institute at NYU to citizen-led community labs such as Public Lab (UK), La Paillasse (France), and GenSpace (US).

To achieve the ultimate moonshot described earlier—reversing climate change, and ensure that people and nature thrive—our biggest obstacle is not technical but human. We need modern technology governance, based on new global frameworks and local civic participation, to **enable** potential benefits, **protect** society from risks, and **choose** which future we want to live in.



5 IMPACT MANAGEMENT

CLICK IT!

Impact Tech could make a dent in solving some of the world's biggest problems. However, that possibility depends on our capacity to maximize positive outcomes while mitigating adverse effects. We need to equip innovators with the right compass—impact management.

Managing and measuring an organization's impact is never easy, but neither is financial management. Yet everyone recognizes the relevance of the latter to managing business performance, reporting to investors, and planning for the future. The same should be true for impact. This chapter provides an overview of impact management methods and tools, as well as ideas on how to use them in science and technology.

5.1 A Compass for Impact

Photo: Valentin Antonucci

While social entrepreneurs, impact investors, and development agencies are generally comfortable with the concepts and tools of impact management, we found that many Impact Tech innovators are either unaware of, confused about, or reluctant to use them.

Why should I manage impact?

Impact management refers to the ongoing identification of an organization's impacts on people and the planet, in a way that supports continuous improvement—to maximize positive outcomes while minimizing adverse effects.

Even if a project stems from the best of intentions, actual outcomes can be quite different from expected. For instance, bioenergy firms tend to overlook indirect emissions associated with deforestation, as well as negative impacts on food prices, biodiversity, and water use. Meanwhile, some ed-tech startups help students perform well on exams, but fail to equip them with the tools for critical thinking.

"More than ever, we need to spotlight technologies that are enabling us to do less bad and more good, for the planet and the people who need it most."

Amanda Feldman,
Investment Director at Nesta Investments

Photo: Lindsay Henwood

The Impact Management Project (IMP) provides a set of approaches for considering the effects of any organization on people and the planet. It convenes a community of over 2,000 enterprises, investors and practitioners—across finance, social entrepreneurship, global development, social science, policy, and more—to agree on what matters when talking about impact.

Through its efforts to build global consensus on how to talk about, measure and manage impact, the IMP reached consensus that impact can be deconstructed into five dimensions:

The IMP reached global consensus that impact can be deconstructed into five dimensions: What, Who, How Much, Contribution and Risk

- **What:** what outcomes the enterprise is contributing to and how important the outcomes are to stakeholders
- **Who:** which stakeholders are experiencing the outcome and how underserved they were prior to the enterprise's effect
- **How Much:** how many stakeholders experienced the outcome, what degree of change they experienced, and how long they experienced the outcome for
- **Contribution:** whether [efforts] resulted in outcomes that were likely better than what would have occurred otherwise
- **Risk:** the likelihood that impact will be different than expected

Source: Impact Management Project

Impact management as an iterative process

A common misconception is to see impact management as a static set of processes. Instead, it should be an iterative process—starting with simple tools, then increasing the level of sophistication as the organization grows and matures. A Harvard report from 2015 suggests that companies and investors should always measure impact according to their capacity at the current development stage.

For instance, British impact fund Nesta Investments relies on such an iterative approach with the Impact Tech ventures in its portfolio. In the early stage, they rely on a simple Theory of Change (see 5.2) and then expect more KPIs as a company matures, all the way up to experimental methods (5.3) to evaluate impact causality.

"Trying to measure too much too early is a risk of wasting time and resources. When considering an investment, we look at the theory of change. Then if we invest, we establish a plan with the entrepreneur to improve measurement over time, and we review it every six months."

Manish Miglani,
Investment Director at Nesta Investments

Managing impact in technology and science

Impact management is particularly challenging in the context of science and tech entrepreneurship—we heard that concern on many occasions during our interviews. Indeed, Impact Tech innovators and investors can find value in available methods and tools (see 5.2 and 5.3), but they frequently mention two main limitations.

First, impact management methods are time-consuming and complicated to use for tech entrepreneurs who operate on limited resources and are more used to the *Lean Startup* mantra.

Second, those tools were not designed with innovation in mind, but rather to compare well-defined activities. As French think-tank Fing stresses in a report, impact management works best with projects whose outcomes and success factors are relatively easy to assess. Meanwhile, Impact Tech innovators explore uncharted territories, often relying on new technologies and disruptive business models—which they can also "pivot" several times. In particular, most methods fit poorly with the riskiest, most innovative endeavors that involve breakthrough technologies, entirely new markets, or which aim to drive systemic transformation.

"I would love to measure how much marine life we can protect and how many greenhouse gas emissions we can prevent, but early on, this is hard to evaluate. Investors who care about environmental impact demand very specific metrics, but it is difficult for an early-stage startup to provide the exact data they are looking for."

Michael Selden,
Co-Founder and CEO of Finless Foods

In consequence, we feel there is a need for simple processes and tools—complementary with established frameworks—that could mainstream impact management in science and technology.

Achieving this would increase our chances to steer innovation and entrepreneurial energy in the right direction: toward the best solutions which could help us achieve the ultimate moonshot.

Impact Tech innovators, impact advisors, and scientists could partner to develop those techniques, which should aim to:

- **Allow different levels of sophistication** in the choice of impact measurement methods and indicators, which should evolve with the maturity of the project
- **Use data and scientific knowledge to facilitate comparison between diverse categories of innovations** which aim to address the same (or a similar) societal problem
- **Take multiple types of impact risks into account,** including those related to specific technology domains, and rebound effects

"We don't need more tools and methodologies for impact measurement, we need simpler ones."

Frida Siwe,
CFO at Norrsken Foundation

The three pillars of impact management

The following pages aim to spark ideas on how to achieve that task. It provides an overview of available impact management methods, as well as reflections on how to use them in an Impact Tech context.

Today there are dozens—if not hundreds—of frameworks, indicator catalogs, and software tools available. Hence, the next pages do not offer an exhaustive comparison, nor a step-by-step guide. Instead, we intend to demystify the logic behind **the three pillars of impact management: strategy, measurement, and reporting.**

5.2 Impact Strategy

Photo: Pixabay

The goal of an impact strategy is to craft a plan on how to maximize positive impact and minimize adverse outcomes.

That first pillar of impact management involves two sides:

- **Positive Impact Planning:** to understand the problem and define the solution hypothesis to address it
- **Negative Impact Planning:** to minimize social and environmental costs, and mitigate the risks associated with the solution

Those tasks rely on the combination of (i) desk research based on scientific literature and other key publications, (ii) strategic design methods, (iii) technology and product development, and (iv) the collection of external feedback.

In addition to surveys, innovators can obtain valuable insights from interviews with potential users and partners, as well as experts from academia, industry, and civil society. Performing these activities early on may save a tremendous amount of time and money in the future.

Finally, impact planning is not a one-off activity. It should be refined continuously as new knowledge arises. For instance, during each iteration on the lean startup process (build, make, learn) or as R&D moves forward in the case of a deep-tech project.

Positive Impact Planning

A strategy to maximize positive outcomes requires to:

- **understand the problem from a systemic perspective**
- **define a solution hypothesis** which could contribute to the problem's resolution in a meaningful way

Problem research

To avoid the pitfalls of technological solutionism, Impact Tech entrepreneurs should move beyond superficial knowledge about the issues they target. Problem research should be extensive enough to offer a deep understanding of root causes and effects, along with local context when relevant. It should be holistic to acknowledge system dependencies and the leverage points on which Impact Tech innovators can intervene.

For instance, the restoration of natural ecosystems depends on a wide array of interventions. Obvious ones include sustainable forest and fisheries management, regenerative agriculture, plant-rich diets, and consumer demand for ethical products. Additional systemic responses include economic incentives that take natural capital into account, mainstream adoption of responsible investment, better global governance, and giving legal rights to nature.

Impact Tech innovators may initiate that analysis with either the problem, a technology, or both, as a starting point. For instance, social entrepreneurs and tech startups often pick an issue they care about and then consider which technologies are relevant to address it. Conversely, a scientist who achieved a recent breakthrough, or a company with access to specific patents and engineering expertise, may investigate how those could be leveraged to address global challenges.

Adopting a whole system view can help identify the right opportunity faster and anticipate unintended consequences.

IN PRACTICE

- **An overview of global challenges is a good starting point.** Innovators should get familiar with key frameworks like the SDGs, the planetary boundaries, and the circular economy, along with landmark reports from institutions like IPCC, IPBES, the UNEP Resource Panel, and the World Bank.
- **In-depth research can provide a system view of the targeted problem.** It should cover related issues, sectors, regions, and technologies, as well as broader societal and technological trends which could influence the ability to offer a solution.
- **A review of past and present efforts to address the targeted problem** will provide valuable insights—on the pros and cons of different strategies and technologies, the market potential, the main hurdles and lessons learned from past failures.
- **Patent landscaping** is a no-brainer for science-based ventures to assess their IP viability, using the WIPO Patentscope.

Solution hypothesis

With a systemic view on the problem and its context, Impact Tech innovators can formulate a solution hypothesis. Its goal is to support the collection of feedback on the following questions: can the proposed solution achieve a meaningful outcome regarding the problem? Would it be technically feasible and economically viable? Would society find it both desirable and sustainable?

The solution hypothesis should include:

- The summary of the proposed solution and its rationale for believing in its potential to address the problem
- The overview of solution's components—including the technologies and business model it relies on
- Ideally, an early prototype to help elicit feedback from potential customers, partners, and experts

This work will also provide a first assessment of the inputs required for the new Impact Tech venture: technology components (to develop, outsource, or license), talent, funding, partnerships, office and lab space, and more. It can also help **define milestones, identify key success factors, and get a sense of financials.**

IN PRACTICE

- **The Theory of Change (ToC) is a simple way to outline the rationale behind a proposed solution.** It is widely used in the development sector and among impact investors. The ToC often takes the form of a logic model which describes the assumed chain of causes and effects leading to desired goals, with four main components: **Inputs, Outputs, Outcomes, and Impact.** However, the ToC is not a standardized tool, and its visual representations vary—from Nesta's DIY Toolkit to custom graphics used by Impact Tech firms like SweetSense.
- **Prototypes, patent descriptions, flowcharts, mockups, and other technical elements** can help to make the hypothesis more tangible. Those range from lab-stage demonstrators in the case of deep-tech, to rapid prototyping techniques designed to collect feedback on the concept for a new product or service.
- **The Business Model Canvas and Value Proposition Canvas** developed by Alex Osterwalder have become de-facto standards to describe how a business creates, delivers, and captures value in a visual chart. These tools are most relevant for high-level concept generation and ideation.
- **Market research** can help validate the opportunity in the case of commercial ventures, including market sizing and a quick assessment of market and industry trends.
- **Keeping in mind IMP's five dimensions of impact** during hypothesis formulation can help clarify the potential impact

Photo: Miguel Bruna

Photo: George Evans

Negative Impact Planning

A strategy to minimize negative outcomes requires to:

- **evaluate the social and environmental cost (footprint) of the solution and act to reduce it—or cancel it out**
- **anticipate the risks and act to mitigate them**

Footprint optimization

Every Impact Tech solution comes with its own footprint—a social and environmental cost. Those include energy and water consumption, materials sourcing, CO2 emissions, pollution, or labor conditions.

In some cases, a low footprint product can be the centerpiece of the intended positive impact. For instance, Pili makes sustainable bio-based colors to replace petrochemical dyes, while Fairphone offers a smartphone made with ethically sourced minerals, which is also easier to repair.

In other cases, Impact Tech innovators strive to minimize the footprint of their solutions. Energy access solutions can improve livelihoods in the rural areas of the developing world, but at the cost of increasing material consumption. To compensate these costs, and guarantee that the positive outcomes significantly outweigh the adverse effects, a higher focus on the circular economy is needed—such as durable energy devices that are easy to repair and recycle.

The ultimate goal of any Impact Tech endeavor is a net-positive footprint: products which are environmentally restorative and generate positive outcomes for all stakeholders—employees, supplier, local communities.

IN PRACTICE

- **Sustainable design principles and methods** can help optimize the environmental footprint. The resources compiled by organizations like VentureWell or the Ellen MacArthur Foundation (which published a Circular Design Guide with IDEO) can be a good place to start for designers, engineers, and entrepreneurs.
- **Materials databases** like the Cradle to Cradle Material Library, Granta MI, Materiom, and MateriaBrasil allow designers and engineers to select materials that combine sustainability with the performance features they need.
- **Software tools** can further support sustainable design. Examples include Sourcemap, which helps visualize complex supply chains, or the ResCoM software suite to "*support decision-making and implementation of closed-loop product systems.*"
- **More broadly, the SDGs offer an excellent checklist of social and environmental issues to keep in mind.** The Global Reporting Initiative (GRI) compiled the SDG Compass, an inventory of business tools mapped against the SDGs.

Risk mitigation

Impact Tech initiatives face a wide range of risks which can influence the achievement of the desired goals. As the IMP writes: "*When enterprises and investors set financial goals, they always face the risk of not achieving them. The same is true for impact.*"

Building on the nine impact risks identified by IMP, as well as our own analysis, we suggest that **Impact Tech innovators should always consider three broad categories of risks:**

- **Impact Delivery Risks:** all the reasons why the intended positive impact might be different than expected. Those include risks related to project execution, efficiency, mission-drift, and misalignment between stakeholders. Identifying those risks helps to define **key success factors**.
- **Impact Evidence Risks:** what the IMP defines as "*the probability that insufficient high-quality data exists to know what impact is occurring (or will occur) [...] for all stakeholders.*"
- **Unintended Impact Risks:** the unexpected negative impacts that the solution may cause to people and the planet. For instance, the estimated footprint may be much worse than initially thought, or previously ignored adverse effects may occur. Innovators should especially look for technological risks (4.1) and rebound-effects.

Impact Tech entrepreneurs should ideally include risks analysis and mitigation within their existing processes, such as R&D, product design, engineering, and operations.

IN PRACTICE

- **EthicalOS is a step-by-step toolkit helping entrepreneurs to anticipate digital risks** in order "*not to regret the things [they] will build.*" It was published by The Institute for the Future and Omidyar Network and includes eight risk zones such as "machine ethics and algorithmic biases." The toolkit also features mitigation strategies and practical checklists for developers.
- **Agile development, a popular approach for engineering, could be enriched with steps aimed to anticipate risks.** British NGO doteveryone suggests adding a “consequence scanning” event within the iterative development cycle, inviting tech teams to anticipate and mitigate potential harms before they happen.
- **Chapter 4 of this report provides an overview of critical technological risks** and how to mitigate them.
- **Issue-specific datasets** can help understand the key factors and risks to consider in a given area. Examples include the Water Footprint Network's WaterStat database and the WBCSD Global Water Tool to reduce water-related risks, or the Social Hotspot Database to identify social risks in supply chains—like areas and suppliers which may not respect worker rights.

The Blueprint of Change

The following diagram is an example of how Impact Tech innovators can visually capture the core elements of their impact strategy—how they intend to achieve desirable outcomes while minimizing adverse effects. Inspired by the Theory of Change and the IMP's approach, it is a first-draft proposal which needs to be refined with feedback from practitioners. **We call it the Blueprint of Change.**

We believe such a chart—or its future iterations—could help spark conversation with investors, customers, partners, experts, and other stakeholders. However, it should be used in combination with other materials, such as a prototype and a pitch deck.

Completing the chart should be fairly easy with the following indications:

- The **Input** includes all the human, material and immaterial resources required to deliver the solution
- The **Output** refers to tangible products and services derived from the inputs, and which make up the solution.
- The **Positive Impact** describes the intended positive social and environmental outcomes. They should be expressed from the point of view of stakeholders who experience them and also relate to established frameworks like the SDGs and climate targets.
- The **Negative Impact** covers the expected footprint of the solution, and how to minimize it.
- The **Risks** section identifies the main risks associated with the solution, related to impact delivery and evidence, along with unintended negative effects.

INPUT

- HR / Talent
- IP / Tech
- Materials
- Energy and Water
- Facilities and Land-use
- Partner Inputs
- Other Assets

OUTPUT

- Products
- Services

POSITIVE IMPACT

- **What & Who:** the targeted positive outcomes and who they affect
- **How Much:** the intended degree of change on a defined timescale
- **Frameworks:** SDG Targets, IPCC, Carbon Law, IPBES, ...

NEGATIVE IMPACT

- **What & Who:** the most important drivers of negative footprint
- **How Much:** the intended footprint level, minimized or canceled out
- **Methods & Tools** to optimize footprint

RISKS

- **Impact Delivery:** what could prevent us to deliver positive outcomes?
- **Impact Evidence:** which high-quality data do we need to show impact?
- **Unintended Effects:** what are the possible negative outcomes we want to avoid?

5.3 Impact Measurement

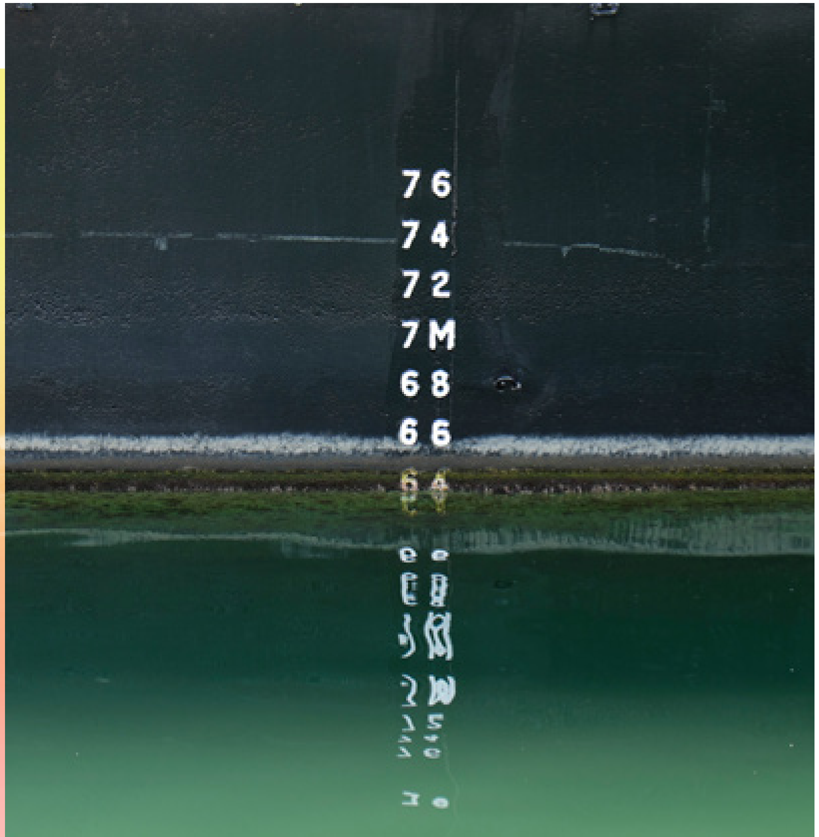


Photo: Miguel A. Amutio

Measurement is the second pillar of impact management, and arguably the toughest.

It involves two main activities:

- **Indicators** which monitor progress toward positive outcomes and the mitigation of adverse effects
- **Measurement frameworks** that define how data is collected and evaluated to monitor indicators

More information is not always better. It should be actionable and support decision-making. Conversely, when organizations collect more data than necessary—or that they can analyze—they struggle to find what is relevant for them. Hence a good practice is to collect the right data, report it in useful formats and timely fashion, and create an organizational capacity to act on the knowledge gathered.

A practical approach to impact measurement is to start simple, then increase sophistication as the project matures. Former USAID Chief Innovation Officer and Lean Impact author Ann Mei Chang advocates for a Lean Startup mindset within the social impact sector. Meanwhile, leading impact investor Acumen spun-off an impact measurement startup built around their Lean Data methodology.

> *"Measuring impact is not different from measuring other types of success. You should do it because otherwise you will miss out opportunities and make the wrong decisions."*
>
> ***Frida Siwe,***
> *CFO at Norrsken Foundation*

Indicators Definition

Good indicators should help monitor progress toward the intended positive impact and mitigate adverse outcomes. They should not only make impact measurement and reporting effective but also support decision-making and continuous improvement. Impact metrics should be an integral part of the Key Performance Indicators (KPIs), which gauge an organization's success relative to its strategic and operational goals.

There is no silver-bullet method for choosing indicators: impact entrepreneurs need to identify the most relevant to their context. A well-thought impact strategy will make that choice easier. The preferred data collection methods, measurement frameworks, and reporting standards can also influence that process.

Impact Tech innovators should start with simple KPIs directly related to their business, and refine them over time. However, they should keep a holistic view and avoid burden shifting—the improvement of a few indicators at the expense of more important ones.

"Creating systemic impact requires us to avoid burden shifting. We can't simply improve some KPIs like increased energy efficiency at the expense of others like material toxicity or inequality. A holistic set of KPIs is critical to assessing the unintended outcomes of a proposed solution and make informed trade-offs."

Chris Monaghan,
Co-Founder and Innovation Director at Metabolic

KPIs should be SMART: specific, measurable, achievable, relevant, and time-bound. The challenge is to find the right balance between custom indicators, which measure impact more accurately, and the need for standards to allow comparisons with other solutions. Impact advisor Sara Olsen advocates for bounded flexibility to manage KPI variations within certain limits—a common practice in financial accounting.

Photo: Andrea Sonda

IN PRACTICE

Progress on the 17 SDGs is monitored by 230 indicators (*) such as the share of degraded land or the percentage of the population with access to electricity. Those high-level indicators can be a valuable resource to define your own impact KPIs.

Indicator catalogs (**) feature generally-accepted metrics to measure social, environmental and financial performance. IRIS+ is the most popular catalog and is managed by the Global Impact Investing Network (GIIN). Today IRIS+ aligns with 50+ standards and assessments, including the SDGs, the Global Reporting Initiative (GRI), and the B Impact Assessment.

Sector- and issue-specific indicator frameworks (**) provide good starting points. Examples include the Higg Index for the textile sector and the Poverty Footprint, developed by Oxfam and the UN Global Compact. The Circularity Indicators developed by the Ellen MacArthur Foundation and Granta Design are also a helpful set of indicators. The SDG Compass platform from the GRI lists many indicators applicable in a business context.

The IMP defined 15 impact categories which can serve as a "checklist" to select indicators that capture what you need to know. The detailed worksheet can help to use them.

"Measuring impact only by the number of jobs created is a very obsolete metric. Having a full-time job is no guarantee of graduating out of poverty: the 'working poor' is an increasing phenomenon in Mexico and beyond. We should aim for higher impact standards than business-as-usual practices."

Laura Ortiz Montemayor,
Founder and CEO at SVX Mexico

(*) Among the 230 SDG indicators, 84 are labeled "Tier III," which means no methodology exists yet to measure them.

(**) As we hinted earlier, traditional indicators do not always fit with any innovative venture—especially those which involve radically new technologies, markets, and business models. Nevertheless, they make a baseline comparison much easier.

Entering and investors can assess their impact performance by assessing and reporting 15 categories of data

IMPACT DIMENSION	IMPACT CATEGORY
WHAT	**1.** Outcome in period **2.** Importance of the outcome to stakeholder **3.** Outcome threshold **4.** SDGs and SDG targets
WHO	**5.** Stakeholder **6.** Geographical boundary **7.** Baseline **8.** Stakeholder characteristics
HOW MUCH	**9.** Scale **10.** Depth **11.** Duration
CONTRIBUTION	**12.** Depth **13.** Duration *Accounting for the counterfactual*
RISK	**14.** Type of risk **15.** Level of risk

Source: Impact Management Project

Measurement Frameworks

Available frameworks for impact measurement are very diverse, and should be considered as early as possible. The framework selection should occur in parallel with the definition of indicators, and when possible during the impact strategy phase. Impact management being an iterative process, that choice should be reviewed when necessary.

The following overview focuses on four main categories of impact measurement frameworks—drawing from previous analyses such as the Harvard paper Measuring Impact (2015) and the Fing-led report *Innovation Factor 4* (2017), along with our own research.

The four categories are:

- **Scorecards and dashboards** for personalized monitoring
- **Social Return On Investment (SROI)** which uses a monetary proxy to evaluate impact efficiency
- **Contribution assessments** to evaluate what would have happened without the intervention
- **Environmental impact assessments** which consider how products and systems affect various sustainability metrics

"Designing your impact measurement process from the very beginning, at the same time you design your product or service, is the best way to reach your goals effectively."

Abbie Jung-Harada,
Co-founder at Synergy Social Ventures

Scorecards and dashboards

A balanced scorecard is a tool used to monitor an organization's performance in achieving its strategic and operational goals. It usually takes the form of an indicator dashboard.

To ensure effectiveness, Impact Tech ventures should ideally combine impact KPIs and business KPIs in a single dashboard. While we covered the first kind in the previous section, the second one relates to themes like customers, finance, operational processes, and organizational learning.

IN PRACTICE

- **The B Impact Assessment is a popular self-assessment tool** for companies to evaluate their impact on workers, community, environment, and customers. Based on their answers, respondents can compare their performance with the baseline, which is derived from thousands of responses. The online questionnaire is offered by B Lab, a non-profit leading a movement to turn business into a force for good, and which also certifies B Corps—the firms meeting the highest standards.
- **Indicator dashboards can be implemented on various software tools,** from standard data analytics platforms like Tableau and Geckoboard, to impact data solutions like Sopact, Sinzer, Clear Impact, and Socialsuite.

Social Return On Investment (SROI)

The SROI method consists in attributing a monetary value to the societal benefit of a project to evaluate its efficiency. Inspired by how investors calculate the expected returns of financial investments, the idea is to convert social and environmental value—realized or forecasted—into a monetary proxy. This result is then discounted to today's value and compared with the investment to determine the SROI.

The formula is:

$$\text{SROI} = \frac{\text{[Present Value of Future Impact]}}{\text{[Value of Inputs]}}$$

For instance, let us consider a renewable energy project which aims to replace a fossil fuel plant. In that case, the total present value of impact would include (i) energy cost savings over the project lifecycle, (ii) the price of avoided CO_2 emissions, and (iii) the reduction in healthcare spendings due to lower air pollution. The SROI is the sum of these present values, divided by the investment cost.

The SROI is popular because it simplifies resource allocation and communication between stakeholders. However, it has limitations: certain outcomes cannot be easily converted into monetary value, the financial proxies can become subjective, and the whole process falls short of demonstrating impact causality.

IN PRACTICE

- **The Guide to SROI** by Social Value UK remains a good starting point to the methodology, which is being refined. The organization also features various case studies.

"If you want entrepreneurs to practice triple bottom line management, you need good arguments why they should dedicate time and resources to it. Impact investing, talent attraction and retention, risk management, brand value are just some of the incentives that might work. Especially as more and more founders aspire to contribute to a better world in addition to making a profit."

Florian Hoos,
Director of the Centre for Entrepreneurship TU Berlin

Contribution assessments

These methods aim to answer a fundamental question: to what extent did a project contribute to an outcome, compared with what would have happened anyway? That inquiry is also known as counterfactual analysis—the "counterfactual" being the alternative scenario in which the intervention did not occur.

Experimental methods are widely recognized as the best way to determine causality. They have been championed by leading scholars like Esther Duflo, professor of poverty alleviation and development economics at MIT and co-director of the Abdul Latif Jameel Poverty Action Lab (J-PAL). **Among those methods, Randomized Control Trials (RCT) are the gold standard.** As the name implies, they involve a randomized control group of users as the counterfactual. Development actors and foundations frequently rely on RCTs to assess the effectiveness of their programs and investments.

"Impact measurement creates accountability and should be seen as a quality management system. Ideally, it should be baked into the different phases of the project from day one."

Anne Thibault,
Former Deputy Director for Latin America and the Caribbean of The Abdul Latif Jameel Poverty Action Lab (J-PAL)

Although RCTs yield the best results, sometimes it can be unfair, or even immoral, to deprive one group of a life-changing innovation—especially in domains like education and healthcare. To overcome those ethical dilemmas, **quasi-experimental methods** use alternative counterfactuals, built through statistical techniques like historical baselines, regression discontinuity, and the analysis of "differences in differences" between groups.

Photo: Ian Camp

Another challenge with RCTs is their very high cost, which can range from $50,000 for a small project to over $1 million for large interventions. **Data collection is the most expensive part of the process,** especially as an impact evaluation is only as good as the data it relies on. When data and baselines are readily available, RCTs become a lot cheaper.

More accessible methods can lower the cost of impact evaluation while still providing valuable insights. Among other analytical tools to assess contribution, the IMP mentions stakeholder feedback (on large enough samples) and relying on existing market research and impact studies (evidence-based research) checked for rigor.

Tom Adams, former Chief Impact Officer at Acumen where he led the Lean Data approach, makes a case for those methods: "*Impact measurement can often seem scary. People throw big words around like causality, attribution, and additionality. You don't need an intimate understanding of these terms before you start to learn if you're doing any good. (...) If you're cautious with what you claim you can start to measure impact absent of a formal control group.*"

IN PRACTICE

- **J-PAL publishes numerous RCT case studies and other resources.** In most cases, those methods will be far too costly and time-consuming for early-stage ventures—but understanding their value early on can help to invest in them later. Interestingly, RCTs are also used by tech firms like Uber and Airbnb to evaluate how users react to product changes.
- **Impact data startups aim to streamline evaluation with a fast and low-cost collection of high-quality user data.** Examples include Impact Atlas, Shanzhai City, IXO Foundation (see 5.5) and 60 Decibels. The latter is a spin-off of impact investing pioneer Acumen, based on its Lean Data approach which recommends mobile survey tools—like EchoMobile, mSurvey, Viamo and others—to reduce the costs and increase efficiency of data collection.

Environmental impact assessments

Environmental sustainability can be evaluated at the product level and the system level—such as a region, a company, a value chain, or an entire economic sector.

At the product level, the Life Cycle Assessment (LCA) is the most comprehensive approach. It covers all the environmental impacts that occur over a product's life, from materials extraction and processing to manufacturing, transport, distribution, use and reuse, maintenance, and end-of-life—recycling or disposal. The LCA takes into account all the inputs (energy, materials, water) along with substances released in the environment. As a result, it gives a holistic view of the main impact categories, such as climate change, natural ecosystems, soil health, pollution, water quality, natural resources, and more.

There are four main phases in an LCA: a) the definition of goal and scope, b) the inventory analysis, c) the assessment of impacts, and d) the interpretation phase. The insights should help identify and prioritize improvement opportunities over the product life cycle. It can also offer a sound basis upon which communicate its sustainability features.

The main drawback of an LCA remains, here as well, the time and cost it requires. Besides, as an environmental impact assessment, the method—obviously—provides little insight about the social impact of the product. The other frameworks listed earlier are thus complementary.

At the system level, several methods evaluate the environmental impacts of human activities in a given location, organization, or an entire sector. The Greenhouse Gas Protocol (GHGP) is the leading standard for GHG emissions, but new frameworks are under development to assess carbon neutrality, led by the Net Zero Initiative. Meanwhile, the Natural Capital Protocol (NCP) aims to identify impacts and dependencies on natural resources—plants, animals, air, water, soils, minerals. Another example is the Material Flow Analysis (MFA) method, used in urban metabolism and industrial ecology to quantify material flows and stocks.

IN PRACTICE

- **SHIFT is a handy online platform to find and compare sustainability tools,** curated by the MIT Sloan Sustainability Initiative. The indexed resources can be browsed per sector, issues, job functions, and tool types.
- **The Life Cycle Initiative hosted by UNEP** curates learning material, practical tools, datasets and case studies on LCA and lifecycle thinking.
- **Systemic methods** like the GHGP and NCP feature templates, calculation tools, and other resources to help you get started.

COMPARISON OF IMPACT MEASUREMENT FRAMEWORK CATEGORIES

	BENEFITS	LIMITATIONS
Scorecards and Dashboards	▸ Simple and adaptable ▸ Improve communication with funders and other stakeholders	▸ Only monitor effects which can be quantified ▸ Depend on data quality ▸ Do not assess contribution
SROI	▸ Makes resource allocation straightforward ▸ Improves communication with funders and other stakeholders	▸ Only monitors effects which can be quantified and converted in monetary value ▸ Subjective valuation can limit comparability ▸ Does not assess contribution
Contribution assessments	▸ The only way to determine contribution and causality ▸ Allow strategic resource allocation (where change would not have happened)	▸ Costly and time-consuming, especially RCTs ▸ Better suited to evaluate social outcomes rather than environmental ones ▸ Do not take unexpected impacts into account
Environmental impact assessments	▸ The best way to assess environmental outcomes ▸ Help to improve product performance and innovation	▸ Costly and time-consuming, especially LCAs ▸ Do not evaluate social outcomes

Source: Good Tech Lab analysis and Fing, Innovation Facteur 4

5.4 Impact Reporting


Photo: Bhavesh Jain

Reporting is the third and last pillar of impact management. The goal is to communicate to relevant stakeholders the work performed during the two previous phases.

The two main ways to communicate impact are:

- **Labels and certificates** to help stakeholders quickly assess how a company or a product performs on some impact criteria
- **Sustainability reports,** which are appropriate for mature organizations, in combination with certifications

Impact reporting is strategic to meet the new expectations of all stakeholders. Investors and funders need to demonstrate the impact of their portfolio. Consumers become sensitive to how purchases reflect their values. Businesses want to attract talent, customers, and investors. Meanwhile, civil society applies pressure on the private and public sector, and governments introduce regulation and incentives in response.

Effective reporting depends on the validity of data, the transparency and relevancy of evaluation methods, along with a communication of results that is easy to understand for the target audience.

Certificates

Labels and certifications offer a simple way to communicate the impacts that a product or a company creates—be it positive outcomes or a reduced footprint. Certification processes vary in length and cost and can represent a sizeable investment. However, respected labels allow differentiation and can help attract talent, investors, and customers.

IN PRACTICE

- **The B Corp certification** identifies companies committed to benefit stakeholders and the planet. As of May 2019, there are over 2500 certified B Corps in 50 countries, from small firms to large ones like Patagonia and Natura.
- **New labels focus on ethical tech products.** Thingscon's Trustable Technology Mark evaluates IoT devices on security, user privacy, transparency, durability, and openness. Cathy O'Neil's ORCAA signals that an algorithm has been audited for bias and fairness.
- **Various certificates assess the environmental footprint of products and buildings.** They include EnergyStar for energy efficiency, LEED for green buildings, FSC for sustainable forestry, and Cradle to Cradle which considers several criteria like material health and reuse, carbon footprint, and water stewardship.
- **Sustainable food labels** can signal produce and ingredients which are, for instance, derived from fair trade (e.g. Max Havelaar) or sustainable agriculture (e.g. Rainforest Alliance)
- **The Solar Impulse Foundation issues a label** proving the technological feasibility and economic profitability of 1000 solutions that protect the environment.

Reporting Standards

Sustainability reports are not a high priority in the early stage. Their complexity means they are used mainly by large and medium-size companies. Nevertheless, Impact Tech innovators can use reporting standards to find inspiration about how to present impact KPIs in a convincing way to investors and other stakeholders. This will also help them get familiar with the standards they may use in the long-run.

IN PRACTICE

- **The IMP facilitates Structured Network, an unprecedented collaboration of global standard-setting organizations** that are coordinating efforts to provide complete standards for impact measurement, management and reporting. Its members include GRI (Global Reporting Initiative), SASB (Sustainability Accounting Standards), UNDP, OECD, among others.
- **Other notable standards** include the Integrated Reporting and the CDP (formerly Carbon Disclosure Project).

"It takes time to know what the real impact is.
Should we expect an impact in our generation or in the future?"

Liza Chong,
CEO of The Index Project

5.5 The Future of Impact Data

Photo: ITU/R.Farrell

The impact management landscape is continuously evolving. While global standard-setters are working toward more compatibility, the Sustainable Development Goals and the climate crisis provide new lenses to manage the impact. For instance, B Lab is working with UN Global Compact to adapt its online assessment platform to the SDGs, while Science-Based Targets invites the private sector to set ambitious climate goals aligned with a 1.5C or 2C pathway.

Many innovators are offering new tools aimed to streamline impact data collection—to lower the cost of measurement and increase trust in impact investments. Examples include digital dashboards and the "Lean Data" survey tools mentioned earlier.

One exciting trend is the use of blockchain technology to provide a "proof-of-impact"—a nod to proof-of-work, the protocol which secures Bitcoin transactions. For instance, the IXO Foundation is leading R&D into core protocols and data tools that help verify impact claims to "count what matters." The resulting data generates impact tokens to "value what counts" and incentivize capital flows toward impact investing.

Another example is Shanzhai City, which uses smart contracts to incentivize local communities and social enterprises to contribute last-mile data. Grassroots users are compensated for sharing data and can influence how projects are implemented in their communities. The company is using private blockchains which allow impact evaluation while ensuring data privacy for vulnerable populations.

"Impact measurement is often presented as rocket science, which does not invite grassroots communities to participate. We think there is a massive opportunity to democratize the tools and information."

Tat Lam,
Founder of Shanzhai City

Deriving strategic insights from impact data requires not only better data collection tools but also joining up data from different sources. Impact advisor Karl Richter cal`ls "Internet of Impact" the idea of distributed impact data pulled in real-time and merged into customized visualizations. The challenge is that although frameworks like the SDGs already provide a common language, **this Internet of Impact would also require interoperable data.**

A 2019 report co-authored by Canadian innovation hub MaRS identifies pathways toward this goal. **Not only should data formats be compatible, but the numbers and words within datasets also need to share a common meaning—even for complex ideas like "poverty." This semantic interoperability** would allow machines to read and combine impact data without human intervention, creating the potential for machine learning. However, it should be implemented in a way that preserves the flexibility for bespoke indicators that are locally relevant.

"The SDGs now provide a common language for impact, but we also need standardized data architectures. The idea behind the Internet of Impact is to allow customized viewpoints on top of a global data commons, readable both by humans and machines."

Karl H Richter,
Executive Director, EngagedX

Meanwhile, as explained in the opening of this chapter, there is a need for simple and agile methods which could reach mainstream adoption in science and technology—while remaining compatible with existing standards and key frameworks.

Impact Tech innovators, impact advisors, and scientists should partner to develop those new tools and methods. Good Tech Lab may hopefully play a role in facilitating those conversations in the future.

Photo: Markus Spiske

6 CONCLUSION

THE WAY FORWARD

The last IPCC and IPBES reports on global warming and the sixth mass extinction are alarming. At the same time, inequality remains at unacceptable levels in most parts of the world and will likely worsen with AI and climate change. **These planetary emergencies could lead to the collapse of civilization as we know it,** unless we operate rapid and far-reaching changes in every aspect of our economic system.

The speed and scale of the transformation we need—at the pace of the Carbon Law—has no historical precedent. The closest comparison would be wartime mobilizations, during which entire economies are directed against an existential threat. Investments made during such times have played a substantial role in the emergence of Silicon Valley and led to the Apollo Program, which put the first humans on the moon.

Fifty years passed since Apollo 11. Today, the world needs a new moonshot—reversing climate change while ensuring people and nature thrive. However, this time, no superpower can achieve that effort alone. On Spaceship Earth, we are all crew.

To say that the 2020s will be decisive would be an understatement. By 2030 we need to achieve both the SDGs and the first halving of the Carbon Law. At the same time, the new perils introduced by technology could accelerate our demise. In the next decade, we need to prevent breakdowns and hatch breakthroughs—the solutions to global challenges that sustainability pioneer John Elkington calls “Green Swans.”

Impact Tech is rising everywhere, providing leverage points to address almost every SDG target. What was our intuition a year ago is now a strong belief: **science, technology, and system entrepreneurship could be our wildcards.** However, to achieve the ultimate moonshot, we need a “Global Apollo Program” for the 21st century.

The 12 priorities listed below could help us maximize the potential of Impact Tech in the next decade. We divided them into two categories: (i) those aimed to build capacity within organizations, and (ii) those aimed to build capacity at the ecosystem level.

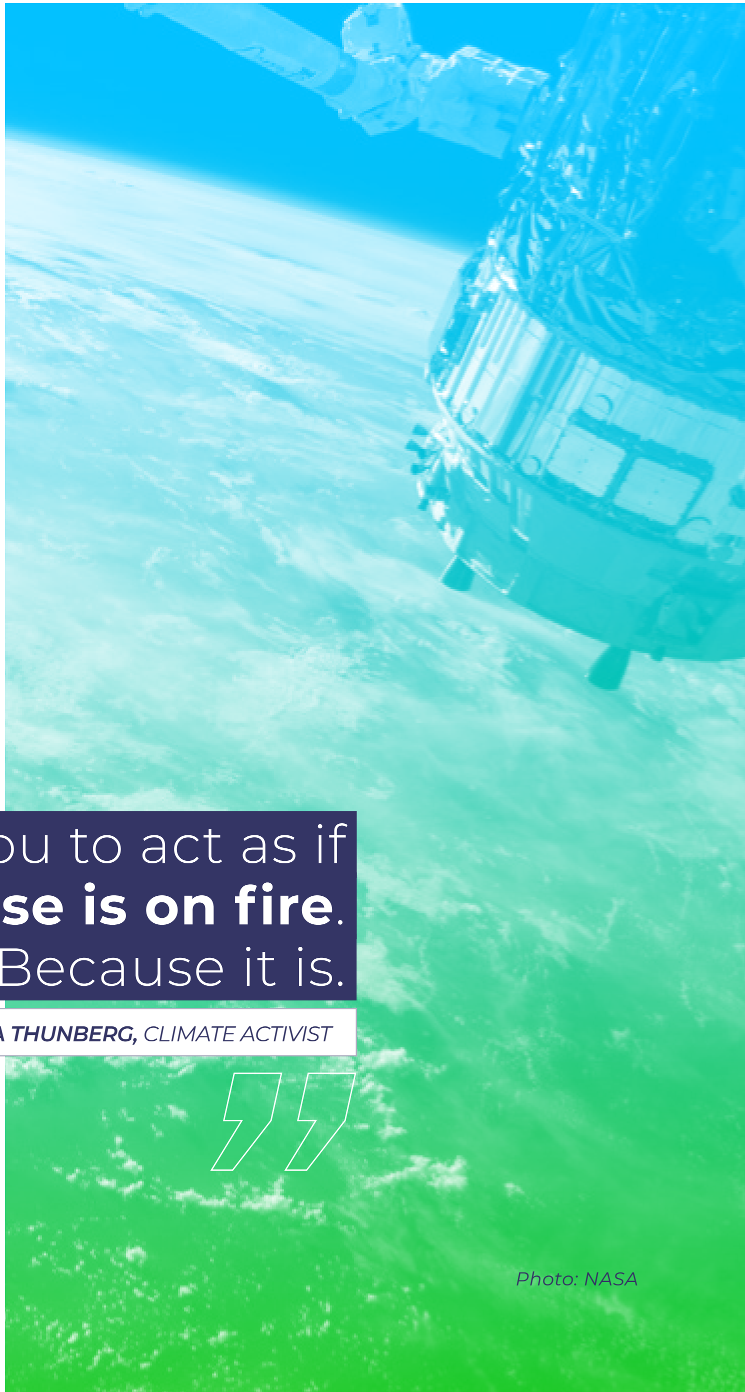


Photo: NASA

Impact Tech leadership

1. Think in systems—and data.

Wicked problems resist any reductionist solution. Addressing them requires to understand system dependencies, differentiate effects from root causes, prioritize the best leverage points on which to intervene, and anticipate unintended consequences. Today, that mindset is not evenly distributed among Impact Tech stakeholders. They should:

- **Learn about systems thinking** (or hone those skills).
- **Dive into key frameworks**, including the SDGs, the planetary boundaries, and the circular economy, along with landmark reports from IPCC, IPBES, and other institutions.
- **Rely on science and data** to craft impact strategies that could make a dent in global challenges.

2. Raise ambitions.

A growing cohort of startups and corporates claim to be purpose-driven. Indeed, companies with a net positive impact on society will be best positioned to attract and retain talent, keep their license to operate, and thrive on both existing and new markets. However, not only the number of such firms need to increase fast, but their ambitions should also match what planetary emergencies require—10X improvements. The demands from Extinction Rebellion indicate what companies should do:

- **Tell the truth:** acknowledge the extent of the environmental and social emergencies into the company's mission.
- **Act now:** set aggressive short-term and long-term targets in every aspect of strategy. This will require to escape the tyranny of short-term results, to focus instead on long-term value creation.

3. Embrace impact management.

Strategic insights derived from impact management can help Impact Tech endeavors deliver the best outcomes. Innovators and investors should embrace agile methods for impact planning and measurement, and include them within existing processes—be it research, design, engineering, operations. They should also contribute to the development of new frameworks adapted to science and technology.

4. Leverage diverse teams.

The diversity of a team's demographics and skill sets can help prevent the biases and blind spots that routinely occur during innovation. Moreover, interdisciplinarity, diverse viewpoints, and collective intelligence can lead to breakthrough solutions. Impact Tech entrepreneurs and investors must improve diversity and inclusion, starting with simple principles.

5. Form partnerships to drive system change.

Businesses should join or create coalitions with sector peers and other stakeholders, to unlock bigger Impact Tech opportunities and tackle problems too big for one organization alone. They should:

- **Map and join networks**, clusters, and consortiums which are most relevant to the problem they tackle—be they centered on a sector, a technology, a region, or the issue itself.
- **Leverage outcome-driven open innovation** to foster effective startup-corporate cooperation—beyond vanity metrics. Harness those partnerships to address grand challenges while opening new business opportunities. Adopt entrepreneurial management on the corporate side to manage those projects.
- **Support (or become) system entrepreneurs** that act as "central gears" to align the interests of various stakeholders.

Impact Tech ecosystems

6. Expand the talent pool.

Attracting the best talent is often the biggest bottleneck, in both tech and social impact—even more than raising capital, many told us. Increasing the global Impact Tech talent pool is a top priority. We need to:

- **Update university programs,** by integrating global sustainability, the SDGs, systems thinking, and collaborative problem-solving into the curricula of all science, engineering, business, and design colleges. Combine theoretical foundations with hands-on projects focusing on social and environmental issues.
- **Develop innovative Impact Tech programs** for initial and vocational training, that combine engineering and systems thinking.
- **Promote Impact Tech** success stories and role models.
- **Attract experienced mentors** from technology, business, and sustainability to support Impact Tech entrepreneurs.

"The biggest challenge is to bring more talent in the Impact Tech space. Creative and empathetic people with a great mindset, who have strong tech and business skills yet understand impact investing."

Tharald Nustad,
Co-Founder of Nordic Impact and Katapult

7. Increase funding capacity.

Impact Tech funding needs to reach much higher proportions to make a dent in global challenges—as SDG funding faces a $2.5 trillion annual gap. Although strategic government funding is critical (see item 10), private investment should get up to speed. It should also rely on various capital instruments that meet different kinds of financing needs:

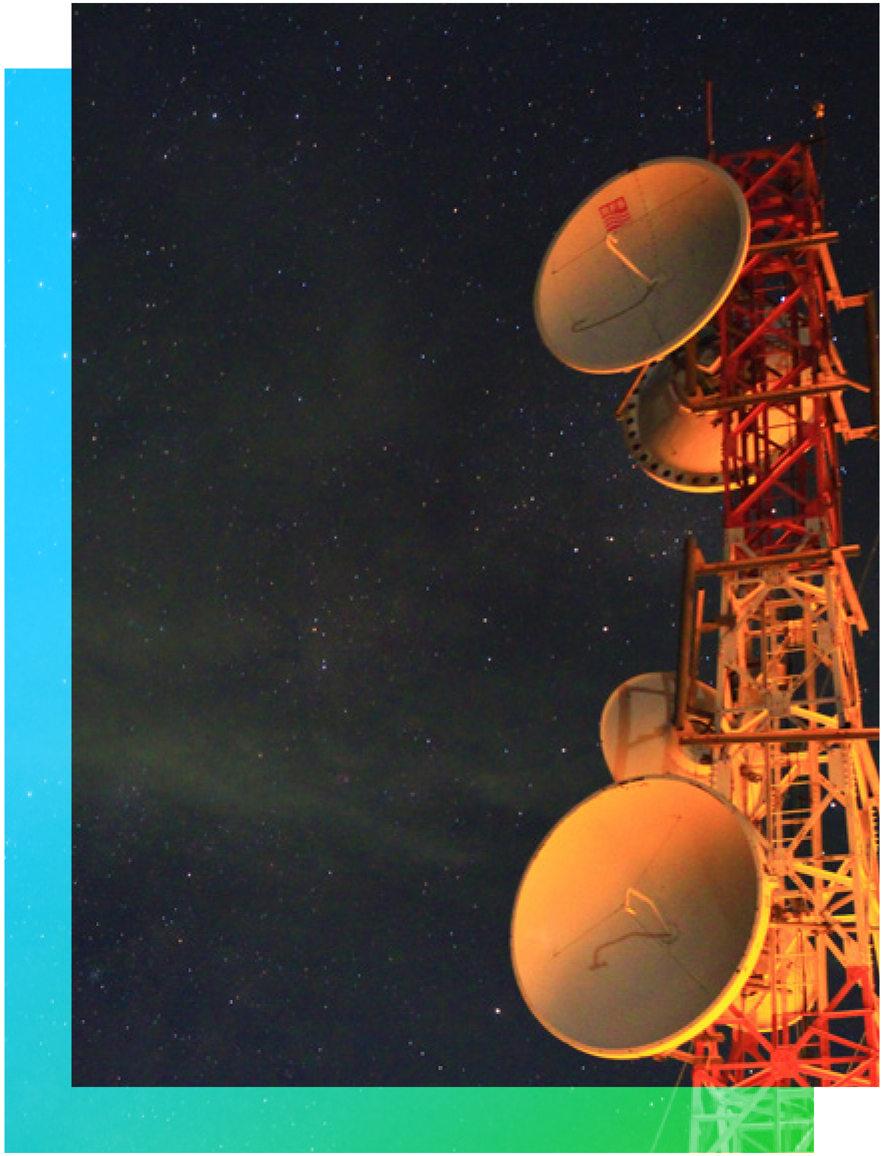


Photo: Atik sulianami

- **More impact investing capital** with sufficient access to technology expertise and dealflow.
- **More tech VC flowing into impact sectors**, with access to impact management knowledge.
- **Patient capital:** investment funds with flexible, long-term time horizons (e.g. 12-15 years rather than 7-8 years in VC).
- **New fund structures:** revenue-based investment, small infrastructure funds, blended capital, impact bonds.
- **Strategic philanthropy can play a catalytic role** not only supporting non-for-profit Impact Tech initiatives but also bridging the gap in early stages impact and science-based ventures (often too risky for commercial investors).
- **Cross-cutting efforts to increase diversity** among founders who receive investment.

8. Strengthen venture support.

Innovation flourishes in dense ecosystems with easy access to talent, capital, mentors, customers, and service providers. By aggregating those ingredients, innovation hubs and venture programs usually play a vital role in ecosystem-building. Hence, we need to increase the availability of incubators, accelerators, company builders, and other entrepreneurial support organizations (ESO) focused on Impact Tech. In particular:

- **Build capacity within existing ESOs** on global sustainability, the SDGs, impact management and systems thinking.
- **Channel public and philanthropic funding** toward ESOs that are on a mission to help achieve the ultimate moonshot. Doing this is especially critical as most programs struggle financially despite the value they create for entrepreneurial ecosystems.
- **Develop ESOs responding to underserved needs,** such as late-stage support, science venturing, open-access testbeds, systemic initiatives with multiple stakeholders, and founders from underrepresented backgrounds.

9. Bring corporates and cities onboard.

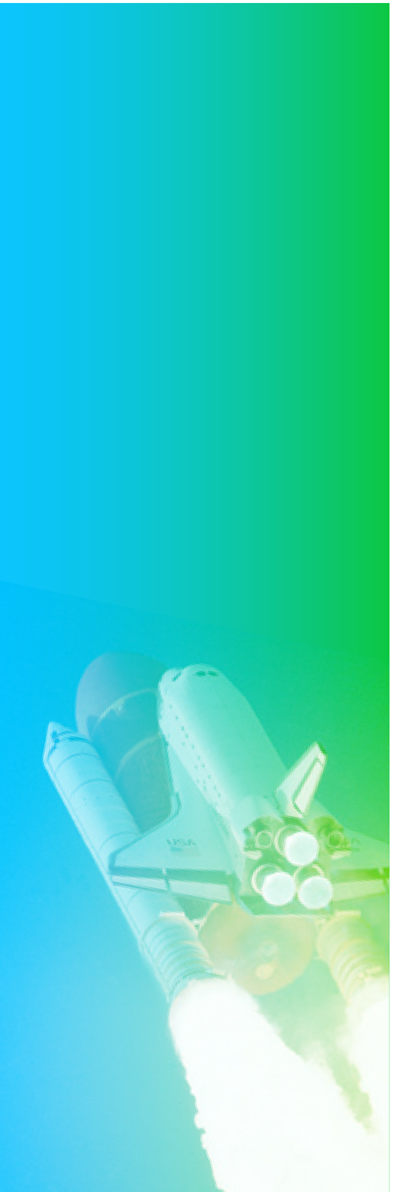
Given their economic and political weight, cities and large companies can play a decisive role in bringing Impact Tech to scale. They can do so either as partners, customers, or even solution providers in the case of corporates. To play this role, they should:

- **Establish training and leadership programs** for both executives and management teams, focusing on Impact Tech, the SDGs, global sustainability, and systems thinking. Foster knowledge sharing between cities and between corporates.
- **Adopt the five priorities outlined above for Impact Tech leaders**—raising ambitions, nurturing diversity and partnerships, embracing impact management and a systems view.
- **Leverage procurement and outcome-driven open innovation** to collaborate with Impact Tech innovators—providing them with access to customers, funding, expertise, IP, testbeds, sales, and distribution channels (see also item 5).

10. Shape markets with strategic government.

National and federal states could help unlock the carbon-negative, restorative, and inclusive economy we need. They can do so by shaping markets according to collective goals. In particular, they should:

- **Use mission-oriented innovation policy** to steer innovation toward the world's most pressing challenges—as advocated by economist Mariana Mazzucato. With the strategic use of public funding and private sector incentives, a "Global Apollo Program" could help us achieve the ultimate moonshot.
- **Update regulation and taxation** to drive large-scale behavior change among consumers and companies (e.g. carbon pricing).
- **Leverage procurement** to support Impact Tech innovators while solving problems in the public sector at the same time.



"Technology alone cannot solve the climate crisis. Technology, policy and behavior change need to be used together to generate system-level change."

Owen Gaffney,
Director of International Media and Strategy at Stockholm Resilience Center

11. Establish shared roadmaps and research agendas.

Academia, governments, businesses, civil society, and international organizations should work together to:

- **Define 10-year roadmaps** to deliver the ultimate moonshot, in all sectors and at all scales (country, city, organization). Review those plans yearly as new information arises.
- **Set research agendas** which establish the R&D priorities to develop, scale, and deploy the necessary technologies.
- **Develop an impact culture within research institutions.** For instance, adapt impact management frameworks for scientific research, and align incentives (e.g. HR policy, funding criteria, etc) to maximize societal value.

12. Reinvent international cooperation.

Humanity faces an increasing number of "*problems without borders.*" Those include not only the planetary emergencies described in the opening of this report, but also emerging threats like antibiotic resistance and AI risks. Impact Tech can provide tools to address those intractable issues, but no single country, let alone one organization, can do it alone. Seizing the potential of Impact Tech depends on agile and effective global cooperation, which requires to:

- **Adopt platform strategies within international organizations and development actors** to support Impact Tech innovation and deployment—for instance, by harnessing the collective intelligence from private, public, academic and civil society actors.
- **Upgrade global governance frameworks** to manage emerging technologies and existential risks.

Onward

All stakeholders have an opportunity to step up and do their part to deliver the ultimate moonshot. We will dive into those strategies in a second report about Impact Tech innovation ecosystems—focusing on how investors, accelerators, corporates, academia, foundations, and development institutions are partnering with innovators.

Beyond those publications, Good Tech Lab will develop new programs and tools to fulfill our mission: **empower those who use technology to address planetary emergencies**—to focus on moonshots worth taking. If that goal resonates with you, please reach out to us.

Today more than ever, we believe that science, technology, and systems entrepreneurship could be some of the keys to unlock a brighter future—one in which people and nature thrive.

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CONCLUSION

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