Careful Industries

Stewarding meaningful innovation

Engineering and stewardship for a sustainable, inclusive economy

November 2023

How to use this document

This document provides provocations intended as inputs for future strategic development and culture change.

It does not provide a set of tactical recommendations, but strategic advice for approaching the future.

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Contents

“Ideation is not the real problem of innovation; it is how to mobilise action around an idea.”

John Seely Brown

“We now live surrounded by technological systems of nearly unimaginable scale, extent and complexity.”

Deb Chachra

“Every increment of global warming will intensify multiple and concurrent hazards (high confidence).”

IPCC, “Climate Change 2023: Synthesis Report for Policymakers

About

Project Purpose

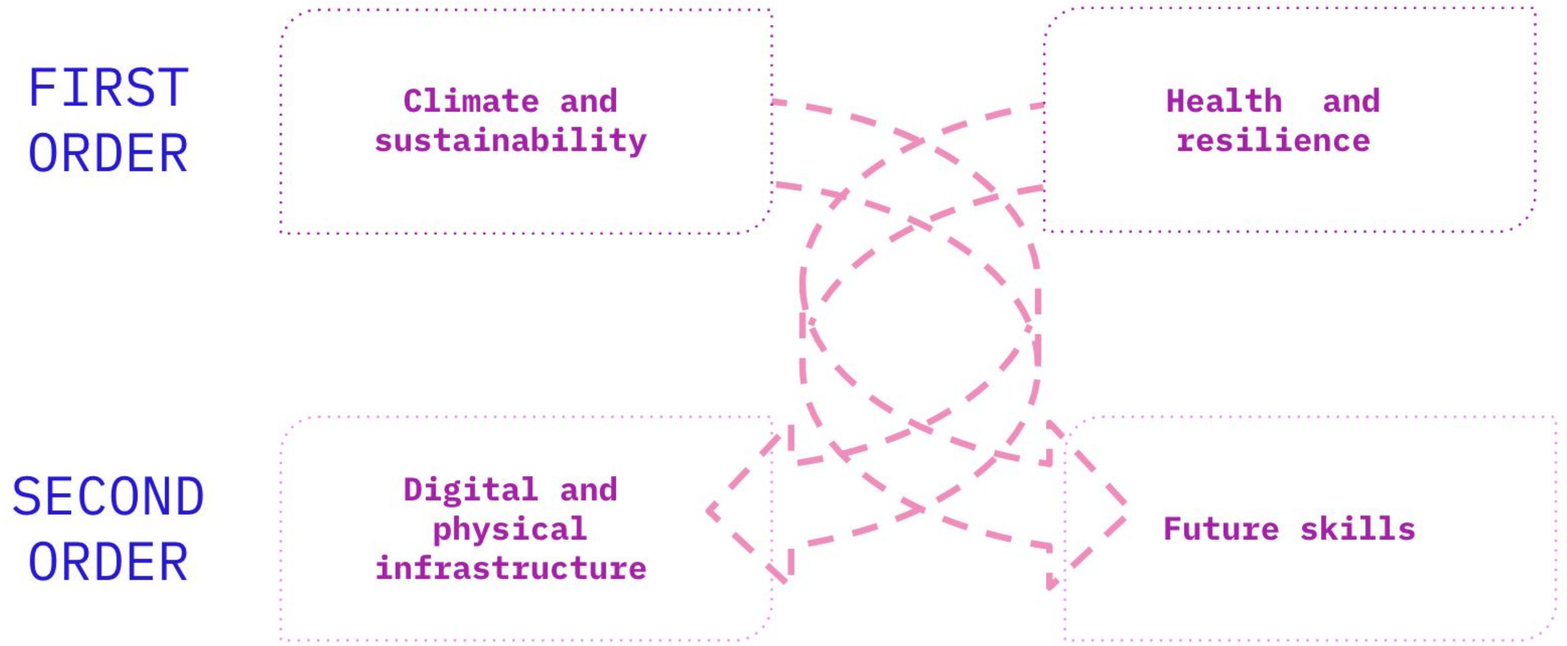
This piece of foresight was commissioned by the Royal Academy of Engineering in Spring 2023.

It aims to identify **pathways for meaningful innovation** that ensure **engineering plays a positive role in tackling major societal challenges** in ways that **empower society, communities, and individuals** and **increase inclusivity and advancing sustainability**.

This final report offers some **provocations** about the role the Royal Academy of Engineering might play in the wider innovation community and how the engineering practices of **systems change and stewardship** might expand and interact with other disciplines and sectors. This is a **sociotechnical challenge**, that requires openness to cultural change as well as flex in programme delivery.

Subject-Matter Focus

The subject-matter focus of this commission was on two main topics: climate & sustainability and health & resilience. The role of skills and infrastructures were considered as secondary, enabling factors in achieving meaningful innovation in these areas.



A Plural, Relational View

Careful Industries is a sociotechnical research and foresight studio.

The provocations in this document draw upon desk research, horizon scanning, and foresighting workshops conducted with 22 expert contributors. More information on our ways of working is included in the sections on Activities and Methodology.

Our approach understands the past, present, and future as fundamentally plural: many related and unrelated personal, social, political, environmental, and technological realities are constantly and simultaneously unfolding. As such, we do not anchor our foresight practice in a single version of the present or future; we look instead for commonalities and emergent factors. These include **indicators of future trends** and **blockers** and **enablers** for preferred outcomes.

Activities

What We Did

Kick-off:

Implosion mapping

Mapping and research:

Understanding weak signals

World building workshops:

Situating technologies in the future

Backcasting workshops:

Designing interventions

Mapping and research:

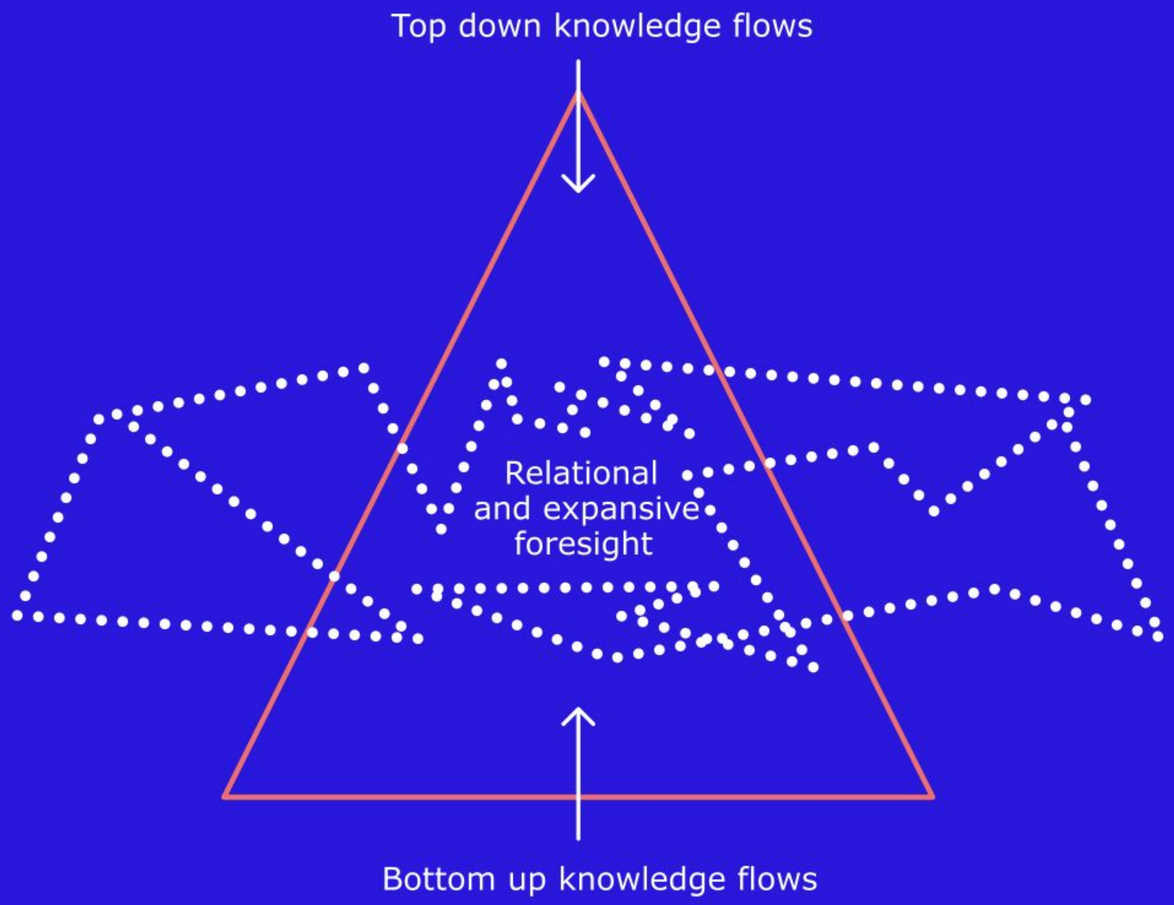
Developing themes

Observations and write-up

Careful Industries' relational foresight methodology is designed to enable expansive and inclusive visions of the future to emerge, situating technology within their broader political, social, economic, and cultural context.

Relational foresight is a process that attempts to show the continuous coexistence and interconnection of multiple realities for different communities.

Relational foresight is a creative, intentional practice that aims to disrupt traditional power hierarchies and dominant narratives about history, the present, and possible futures.



Workshops

We kicked off the project with an Implosion Mapping workshop with Royal Academy of Engineering staff. Implosion Mapping is a technique drawn from material philosophy that helps externalise existing knowledge and break down complex abstract concepts into tangible information. Using the themes that emerged during the implosion mapping workshop, we conducted desk research to understand trends and emerging weak signals in climate and health engineering.

We then led two worldbuilding workshops with engineering experts working across industry, academia, civil society, and policy. The theme for the first workshop was climate and sustainability and for the second workshop, health and resilience. The activities took participants through a creative, imaginative process to explore a range of possible futures and the social, political, environmental, economic, and technological conditions that shape those futures.

Next, we facilitated two backcasting workshops with additional groups of engineering experts. Backcasting is a foresight methodology used to visualise a range of possible futures and work backwards to identify the possible events, institutions, policies, infrastructure, and skills that might bring about the futures visualised in the first round.

The goal of these backcasting workshops was for expert participants to bring their expertise to imagine and craft interventions for the critical issues raised through the worldbuilding activities.

The goal of these workshops was not to build consensus towards one specific future scenario but to show a plurality of futures. The process purposefully embraces uncertainty, discomfort, and imagination in order to understand the components of successful innovation. We then used the outputs from the workshops to conduct further desk research to develop a final set of themes, which were then used to identify considerations and pathways for meaningful innovation.

A Critical Lens

This research is informed by and situated within critical technology scholarship and the broader field of Science and Technology Studies (STS). It centres the social, political, economic, environmental, and historical factors that influence technology innovation, development, adoption, and management.

As such, inputs from desk research focussed on inputs to and outputs from technological interventions rather then the technological components of those interventions, and discussions in workshops explored the impacts of technologies rather than their specific make-up or methods of construction. For more on this, see the section, The Wider Social Context.

This perspective builds on sociotechnical approaches that stress the complementary importance of both “man and machine”.

Executive Summary: Stewarding Meaningful Innovation

Pathways for meaningful innovation

This piece of work is focussed on **pathways for meaningful innovation**.

Rather than identifying specific challenges or solutions, we have explored the **affordances** of meaningful innovation in order to understand how it might become both more **prevalent and more effective**.

Our conclusion is that meaningful innovation is not a fixed set of repeatable processes but a set of **values and behaviours**. It does not need a fixed map or blueprint, but it does require **stewardship**.

What is Stewardship?

“Technological stewardship stands as a commitment to **anticipate and mitigate** technology’s potential for disruption and especially harm and to guide innovation toward beneficial ends … Dialogue and collaboration across diverse perspectives is essential for **developing actionable technological solutions that attend in responsible ways to the evolving needs of society**.”

Caron et al., “Technological Stewardship and Responsible Innovation: A Mindset, an Ethos, and an Interdisciplinary Undertaking”, *IEEE Technology and Society Magazine* (2022)

Our recommendation

Pathways for meaningful innovation are not naturally occurring.

"Superwicked problems" such as the climate emergency will need many such pathways to be created — but creating them is not enough. They must also be **effectively completed**, and **managed**, **maintained**, **adapted**, and **protected**. In short, these pathways require good stewardship.

The Royal Academy of Engineering should act as a good steward for **meaningful innovation** — at an organisational level, across the fellowship, as engineering leaders, and as part of the wider innovation landscape.

Stewardship and power

Stewarding good pathways is an interdisciplinary undertaking: it requires collaboration, power sharing, good governance, relationship building, adaptability, and network sensing.

In recommending that the Royal Academy of Engineering act as a good steward, we are not suggesting a centralising of power or the adoption of a formal cross-sector governance model. Our intention is that the Royal Academy can model and facilitate effective pathways for meaningful innovation, and play a vital part in establishing sustainable and inclusive methods as an important paradigm for C21st innovation.

1. Introduction: What are Pathways for Meaningful Innovation?

Meaningful Innovation

We have understood meaningful innovation to:

- Be vital for achieving a sustainable and inclusive society
- Be multiply effective, delivering short-term benefits for people and planet *while also* contributing to mitigating the "superwicked" problems of the 21st Century
- Be inclusive and equitable and not knowingly cause secondary harms
- Extend beyond invention to include adaptation, maintenance, and repair of existing technologies and infrastructures

The “How” of meaningful innovation is as important as the “What”

We understand the *methods* and the *impacts* of meaningful innovation to be as important as the outcomes.

This is particularly important because, in complex sociotechnical systems, there are many variables that cannot be controlled; as such, pathways to meaningful innovation must often be **adaptive** and **responsive**.

These pathways are created by **values and behaviours** rather than through the application of a fixed set of processes.

Themes and questions

- How might pathways for meaningful innovation contribute to a more sustainable and inclusive society?
- What are the **blockers and enablers** for meaningful innovation?
- How can the practice of meaningful innovation become **more widespread**?
- How might the Royal Academy of Engineering **champion and advocate for meaningful innovation** in the wider innovation landscape?

1.1 Towards a plurality of innovation paradigms

Meaningful innovation is not currently the dominant mode of innovation. Other innovation paradigms at play in 2023, within engineering and beyond, include:

- Digital disruption
- Faith in exponential technological progress
- Techno-optimism

Each is driven by different aims and value sets; some operate entirely within market conditions, others also extend to influence political and power structures.

Engineering is a wide-ranging field that encompasses invention, innovation, adaptation, and maintenance.

Mitigating and untangling complex and emergent problems requires collaboration within and beyond the field of engineering.

To be successful, meaningful innovation must be adopted as a **preferable approach** both **within engineering** and in the **wider innovation landscape**.

The real-time backdrop to this piece of work is a broader policy and investment environment in which **disruption** and **faith in the exponential growth and impacts of technologies** have significant influence on narratives relating to and understanding of technological developments.

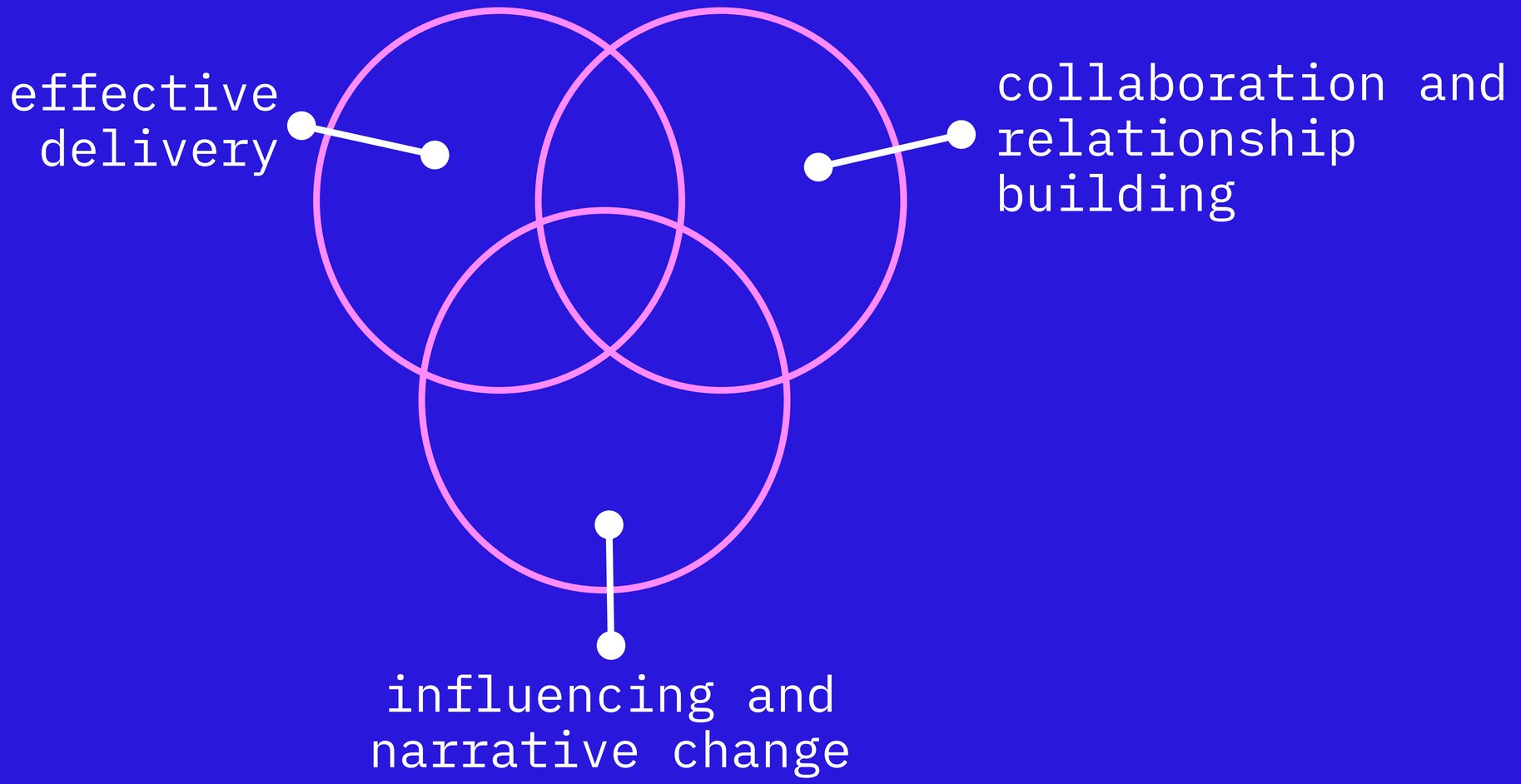
Introducing meaningful innovation as a credible alternative requires **narrative development**, **convening**, and the **creation of an evidence base**.

This “upstream” behaviour will lead to changes in both **investment** and **policy development**.

“Adoption is a communication process in a social system.”

Denning and Dunham, *The Innovator’s Way* (2010)

Stewarding meaningful innovation requires a systemic approach that includes:



Influencing and narrative change

Not only developing pathways for meaningful innovation but championing and advocating for meaningful innovation as a desirable behaviour.

This requires showing as well as telling: narrative interventions, policy influencing, purposeful financial and resource investment.

Collaboration and relationship building

Being mindful not just of equity and inclusion but of **power dynamics** when building relationships — and redistributing power to less traditionally dominant perspectives and cultures

The climate emergency is a “superwicked problem” that requires active collaboration and strong relationships to develop and diffuse new ways of working

Build on the engineering mindset: take stewardship and systems change within engineering to **stewardship and systems change in inter- and multi-disciplinary contexts**

Effective delivery

Attending to and mitigating or working around the common factors that prevent the roll-out of beneficial technologies

Continuing to address issues of power distribution, equity, diversity, and inclusion within the engineering profession

Attending to the full life cycle of innovations and technologies — supporting programmes that promote responsible closure, maintenance, and repair

Places to Champion Meaningful Innovation

- Within the engineering profession
- Within other innovation domains
- In existing multi-stakeholder environments
- In policymaking, which can get trapped in short-term, political cycles
- With investors.

2. The Opportunity of Stewardship

Complex challenges require new models for problem solving

Technological breakthroughs do not define social progress on their own.

The climate crisis represents a multitude of increasingly urgent and interconnected challenges. Multiple, simultaneous crises borne out of legacy systems cannot only be solved by the deployment of novel emerging technologies; social, political, and economic change is also needed.

This project has shown that the potential solutions to these complex crises are just as connected to one another — and to the real world — as the problems they are created to solve. Innovation does not exist in isolation and its social and environmental impacts must be considered and, where appropriate, mitigated for.

Stewardship of meaningful innovation

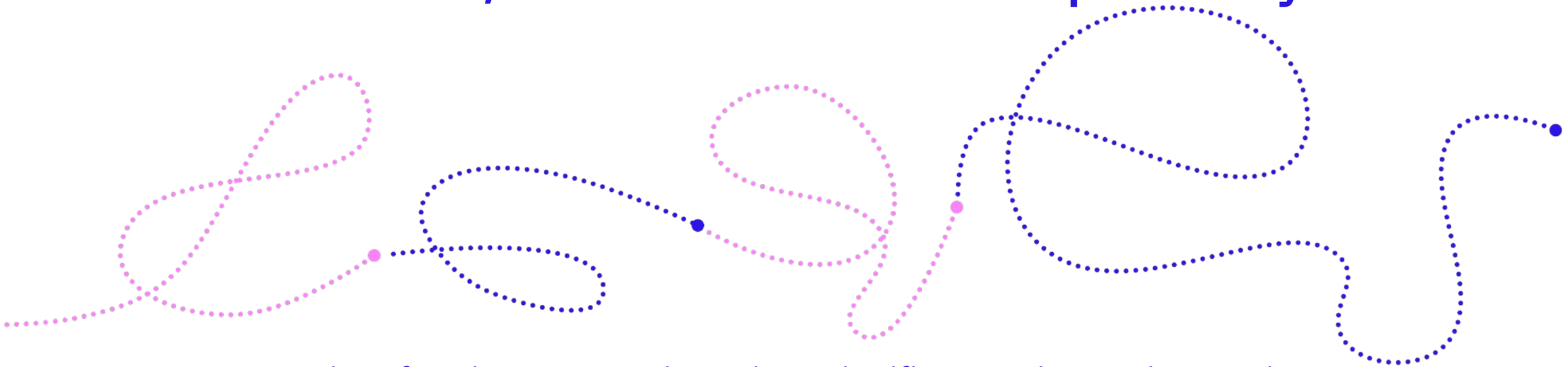
- Stewardship within and between projects and programmes
- Anticipation of unintended, or often unforeseen, harmful outcomes
- Convening a diversity of perspectives and approaches at many different levels: not simply diversity of people, but diversity of cultural and philosophical approaches
- The normalisation of responsive and adaptive methods.

Stewardship behaviours

imposing a singular paradigm	⋯⋯▶	stewarding multiple approaches
rational	⋯⋯▶	relational
invention as primary model of innovation	⋯⋯▶	more repair, adaptation, and closure
telling	⋯⋯▶	listening and reframing
extractive	⋯⋯▶	regenerative

2.1 Meaningful innovation as a collaborative, relational activity

Non-linear, sociotechnical pathways



The complexity of rapidly converging crises signifies that industries as vital as engineering need to be expanded beyond the purely technological domain. The Journey to Net Zero does not consist of straightforward pathways; it’s littered with obstacles and countervailing social, political, and economic forces.

A complex set of challenges requires flexible approaches, and the acceptance that **most technologies are unfinished until they have been adapted and reused by others**.

The chief blockers of innovation

Through our workshops and desk research, we observed the following recurring obstacles and diversions for meaningful innovation pathways:

- **Innovation does not operate in isolation:** it is subject to the context of the real world, and therefore operates within it.
- **Understanding how new technologies fit into a global context**, rather than just at a local level is essential to foreseeing challenges in the coming century
- **Legacy systems, maintenance, and repair** are important considerations when developing long-term infrastructure
- **Adoption and roll-out of beneficial technologies is not a solved problem:** the invention of new technologies does not guarantee uptake, because there are myriad real-world processes that are often overlooked
- **Everything is connected**: materials, labour, and environmental impact
- **Not all future impacts are knowable**: It is not possible to predict every social, political, economic, or environmental impact of any given technology

The urgent case for collaboration

Creating the conditions for achieving Net Zero is simultaneously complex, urgent and worthwhile. As the IPCC noted in 2023:

“Deep, rapid, and sustained reductions in greenhouse gas emissions would lead to a discernible slowdown in global warming within around two decades, and also to discernible changes in atmospheric composition within a few years (high confidence).”

Achieving this requires working in collaborative, multi- and inter-disciplinary relationships. Maintaining these relationships is an active process.

Pathways for meaningful innovation require non-technical expertise

Within some innovation paradigms, it is often presumed that technological interventions are sufficient: that progress is linear, and can be enabled by technological breakthroughs alone. But sociotechnical change is complex: **people, money, power,** and **environmental events** all have a part to play in the rollout and adoption of any new technology.

These exogenous factors should not be regarded as secondary. Participation in, and engagement with, these non-technical domains is an essential for the success of any emerging technology or approach to innovation.

Meaningful innovation is socially engaged

Higher rates of adoption and roll-out of beneficial technologies requires navigating these obstacles via a persistently outward-facing mode of engineering that:

1. draws on **domain expertise**
2. spots **opportunities**
3. seeks to understand **context and consequences**
4. shapes, and is shaped by, **social interaction**.

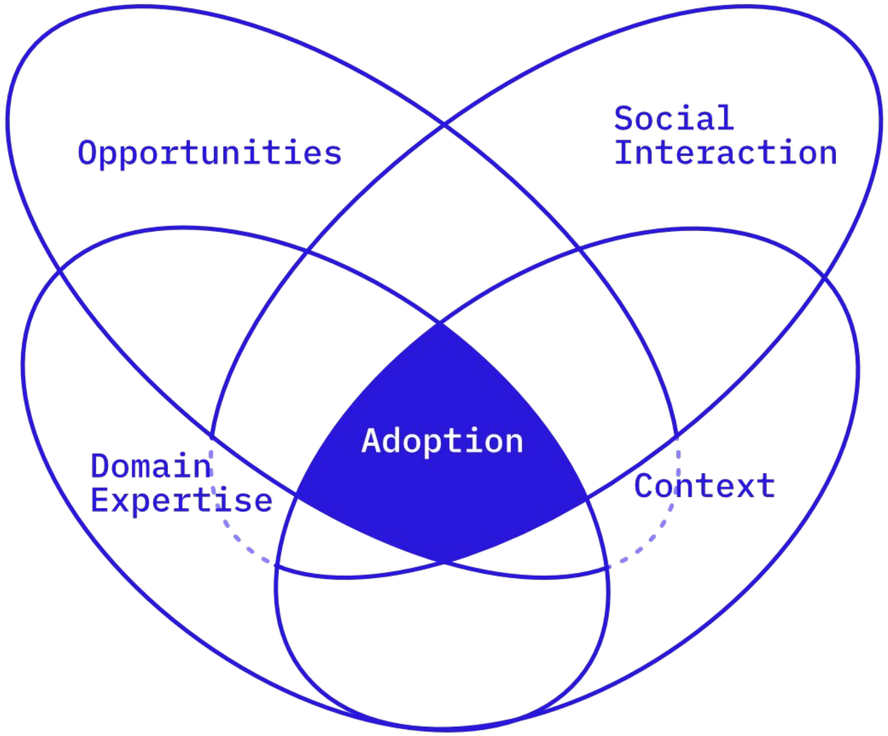


Image: Adaptation from Denning and Dunham, The Innovator's Way (2010)

2.2 Engaging effectively with complex problems

“The capacity to hold the weight of multiple moving layers of complexity in tension, without the impulse to flatten these layers into a coherent, controllable and predictable whole is a prerequisite for approaching the Climate Nature Emergency (CNE) as a superwicked challenge”

Vanessa Andreotti et al, “Moving with Storms” (2022)

Connection and complexity

Over the last century, globalisation, data collection, and the rise of communications technologies have all contributed to increased awareness of the global interconnectedness of political, environmental, economic, and social factors.

More recently there has also been an increase in complex, interconnected crises whose impacts “reverberate more widely” and “are converging at faster rates and causing new types of tipping points across borders and across critical areas” (UNDP RBAP 2022).

These include and are not limited to extreme weather events, Covid-19 and possible future pandemics, political unrest, and military conflict.

> “A polycrisis is not just a situation where you face multiple crises. It is a situation like that mapped in the risk matrix, where the whole is even more dangerous than the sum of the parts.”
>
> Adam Tooze, **Chartbook #130 Defining polycrisis - from crisis pictures to the crisis matrix** (24 June 2022)

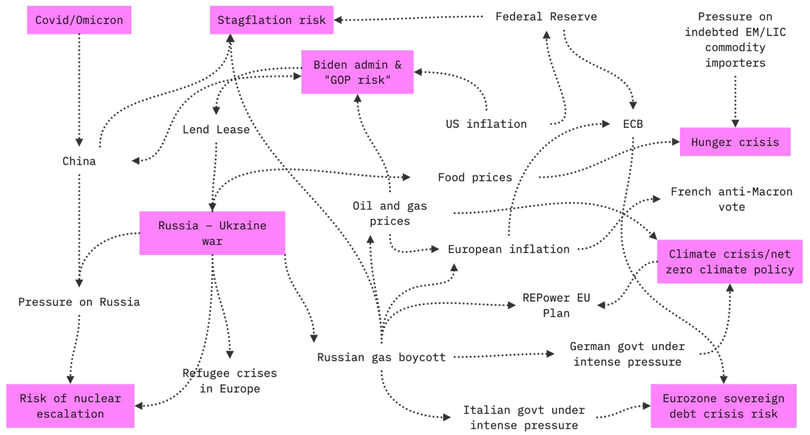


Image: Adaptation of Risk Matrix, Adam Tooze (2022)

Solving superwicked problems

The Peter Wall Centre for Advanced Study's Climate and Nature Emergency Catalyst Programme views "the Climate and Nature Emergency (CNE)" as a "superwicked problem" (Andreotti et al., 2022).

The Programme's analysis shares some common ground with Tooze's definition of the polycrisis and the UNDP's recognition of increased interconnections between global events quoted on slide 49. Andreotti et al. describe "wicked problems" as:

> "an assemblage of interlocked problems, where every problem is a symptom of another problem and the solution for one problem creates problems in other layers. They also involve many unknowns and they have longer and uncertain timescales."

"Superwicked problems" feature additional layers of complexity: Andreotti et al. explain that not only is time running out to solve them but existing power dynamics and knowledge structures — which are complicit in creating the systems that led to the climate emergency — tend to exacerbate these problems rather than offer solutions.

Working with plural, ecological models - not against them

"[E]cology is just as interested in how the availability of nesting materials affects bird populations, or how urban planning shapes the spread of diseases, as it is in how honeybees pollinate marigolds and cleaner wrasses delouse surgeonfish."

James Bridle

"The unfinished Chthulucene must collect up the trash of the Anthropocene, the exterminism of the Capitalocene, and chipping and shredding and layering like a mad gardener, make a much hotter compost pile for still possible pasts, presents, and futures."

Donna Haraway

"Move from systems to assemblages, from knots to nodes. Acknowledging the entanglements without the desire to have the "full overview", keeps us open to surprising possibilities. And it reflects the deeply entangled co-evolution of humans and non-humans."

A More Than Human Manifesto (Superflux, 2021)

"[M]y overriding concern is with difference, and how difference is effaced or normalized— and, conversely, how it can be nourished. This concern embraces difference in the biological realm ..., epistemic difference ..., cultural difference, and—as one might say today—ontological difference, or the pluriverse. Today, difference is embodied for me most powerfully in the concept of the pluriverse, *a world where many worlds fit*, as the Zapatista put it with stunning clarity."

Arturo Escobar

From social and technological mastery to stewardship

Post-Enlightenment rationalism has tended to centre the concept of a singular or “correct” approach to social progress. This is a learnt default that extends from the establishment of scientific norms, such as Eurocentric taxonomies, and from political interventions that have depended on social dominance and conflict, including colonisation and resource extraction.

Setting these norms and behaviours aside and recognising the legitimacy of other perspectives and forms of power is essential for good stewardship.

As Graeber and Wengrow describe in *The Dawn of Everything* (2022), this historic imposition of European conceptions of progress was “largely for the purpose of neutralizing the threat of indigenous critique”; it served to narrow conceptions of innovation and equality, giving rise to the illusion of a single, shared conception of “civilisation”. This, in turn, minimised Western understanding of the wide range of possible modes and approaches to social organisation and human flourishing.

From rational to relational

Birhane (2021) outlines how this imposition of rationalism is reductionist and insufficient for understanding “complex, adaptive systems” as it privileges the knowledge accrued by “mainly elite, Western, cis-gendered, and able-bodied white men”. They instead advocate for a relational approach that draws on “overlapping frameworks… [that] centre the knowledge of the most marginalised”.

Shifting focus from a single perspective to the stewardship of many creates an opportunity for a more expansive and holistic approach to inclusion: rather than simply striving to include more kinds of people within a single dominant ideology, it includes *more ideologies* within the conception of innovation. This kind of inclusion allows for greater participation and, crucially, different potential models for success.

Invention is not the only form of innovation

The adoption of a stewardship model will represent a significant cultural change within some parts of the innovation landscape; supporting this will require equitable governance and a commitment to sharing power and resources.

This coexistence of differing priorities may lead to conflict between established and minoritised approaches, but — if well managed — it may also generate new approaches, skills, and methods. This is not a technological or innovation challenge, but a social and political one.

"As we consider the field of education for sustainability, and move into an ever-more-uncertain future, questions arise: *What are we sustaining? Why? Just what do we mean by "sustainability" anyway?*

"Perhaps instead of asking *What is worth sustaining?* we might begin with the question *What do we need to let go of?* Most prescriptions for sustainable culture and education for sustainability presuppose a continuance, in some (perhaps modified) form, of a world in which people in Western industrialized countries continue to enjoy the comforts and prosperity of modernization (a process) and modernity (a social system) … driven largely by the extraction of non-renewable energy stored in the body of the earth for millions of years."

Kathleen Kesson and Emily Hoyler, "Education for the End of the World (as we know it)" (2022)

3. The wider social context

Current drivers of complexity

The complex landscape of challenges faced at the present is shaped by a shift away from established economic structures and geo-political relationships (European Commission 2021; Coburn et al 2021). Some of the drivers of this complexity include:

- Changing trade agreements
- Different types of regulation
- Disruptions in supply chains
- Frequent extreme weather events
- COVID-19 and other possible future pandemics
- Advanced communications technologies
- Expanded data collection and use

Existing risk analysis frameworks are unequipped to handle these emerging risks and their unfolding complexity (UNDP RBAP 2022).

Complex crises and vulnerabilities

It is reasonable to assume that everyone will experience some level of disruption and risk from interconnected, complex crises, but significant inequality means not everyone will share the same vulnerability to the risks (Lahsen and Ribot 2022; Vaughn 2022). Or, as Francesca Sobande puts it in *We're All in this Together*: “even if ‘we’re’ all impacted by this crisis, ‘we’ not all experiencing it in the same way” (1035).

- Countries across Asia and southern Europe are already experiencing extreme heat waves and it is predicted that some countries, including Nigeria, Pakistan, Afghanistan, and Panama are at particular risk.
- It is predicted that by 2030 global demand for fresh water will surpass supply by 40-50% with China, India, and the Philippines facing higher risk of water scarcity (Jacob 2023).

Vulnerability to such crises has multiple causes, including policy decisions and historical contexts (Cottier et al. 2022; Lahsen and Ribot 2022; Sultana 2022). As Kawshawn and Ribot (2021) put it, the, "precarities that climate change finds already in place are taken as given—as ‘initial conditions.’ But these conditions have histories and causes that can be traced back to the same powers that generate carbon emissions".

This indicates that, when considering how new innovations could help us through something as complex as the climate crisis, it’s important to widen the scope beyond technological potential — and bring into view historical decisions that brought us where we are.

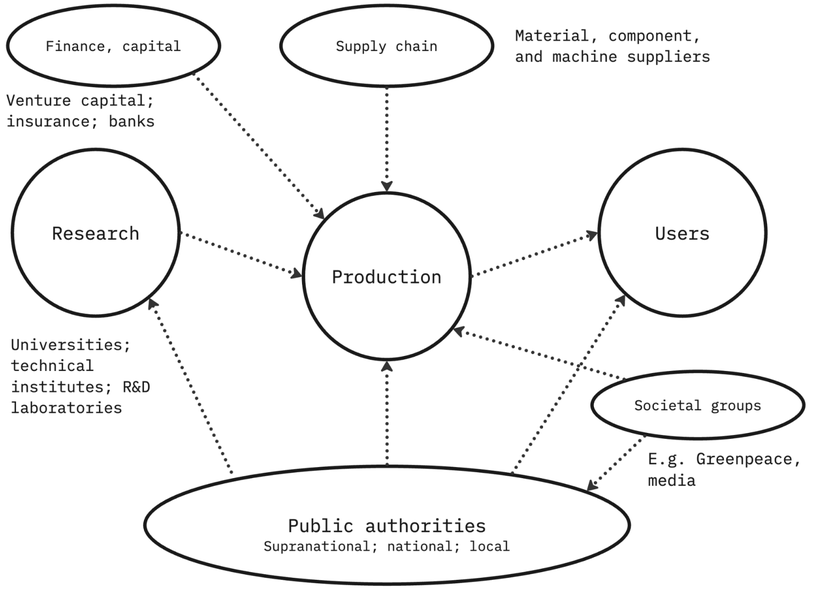


Image: Adaptation of ‘Social groups which (re)produce sociotechnical systems’, F. W. Geels (2005)

Indicators of future trends

Through our research we've identified a series of ongoing socioeconomic events which are likely to have broad societal impacts as they continue.

These indicators relate to health and resilience:

- **Generational inequalities:** In the UK, age is now the biggest likely indicator of wealth, social status, and political affiliation.
- **Impacts of austerity:** Worldwide, life expectancy is tending to increase, but healthy years of life are declining in the UK, falling out of step with other G7 nations.
- **Cost of living crisis:** The cost of living has made energy bills a talking point with "heating or eating" becoming a necessary choice for some households living in poverty.
- **Health disinformation** is recognised as a threat to wellbeing.
- **Post-lockdown, pandemic-era health and social norms are still emerging.** In the UK, latest ONS figures estimate that 2.9% of the population is experiencing symptoms of Long Covid.
- **"Self-care" technologies and data collection** have different connotations based on a person's affluence, migration status, and vulnerability to surveillance.
- **Attitudes to health and genomic data collection among diverse groups is affected by broader government policies**, and bias in data collection and analysis and product development can have provably negative outcomes for people from minoritised ethnic backgrounds.

Indicators of future trends

These indicators relate to climate and sustainability:

- **Air quality, wildfires, and water shortages** demonstrate that the climate emergency is also a health crisis.
- **Shifting global supply chains:** Global agriculture and food security are being reshaped worldwide by the impacts of climate change; there are tomato shortages in the UK, flooding farms in California, and farmer activism in the EU.
- **Local vs global:** Migration policies are local, highly politicised, and viewed in a short-term context, rather than as a long-term necessity on a hotter planet.
- **Car ownership**: the rights of car owners and drivers is likely to be a defining component of the 2024 UK General Election.
- **Disinformation and misinformation** regarding sustainable interventions, including 15-minute cities, can be a lucrative source of income for social-media influencers.
- **The climate maths** of new and emerging technologies — from the compute power needed to support generative AI to the mineral costs of new hardware and the water used by server farms — are still being worked through.
- Meanwhile, the GLA has announced that housebuilding in three London boroughs — Hillingdon, Ealing, and Hounslow — will be delayed for a decade to enable electricity supplies to reach a level where new homes can be built; this is because data centres have taken the available capacity.
- **Differing trade, tax, and regulatory conditions** make different territories more attractive to climate innovators: e.g. AMTE in rumoured talks to move to US, ARM have chosen to list only in the US, and post-Brexit divergence from GDPR are affecting UK businesses.

4. Workshops

“...the rhetorical construction of future worlds directly (and indirectly) influences which technologies are brought into existence by, for example, providing justifications for funding, rallying public support, instigating policy directives, etc.

“The rhetoric supporting new technologies derives legitimacy from the expertise of those making the claims yet also from the widespread belief in the determinacy of scientific and technological progress” (Selin, 2008).

As part of our research, we conducted a series of four foresight workshops, to which we invited engineering experts working across industry, academia, civil society, and policy.

The first two workshops were worldbuilding workshops on Climate & Sustainability, and Health & Resilience. In these sessions, participants imagined a range of possible futures, and how existing, new, and emerging technologies might fit into them.

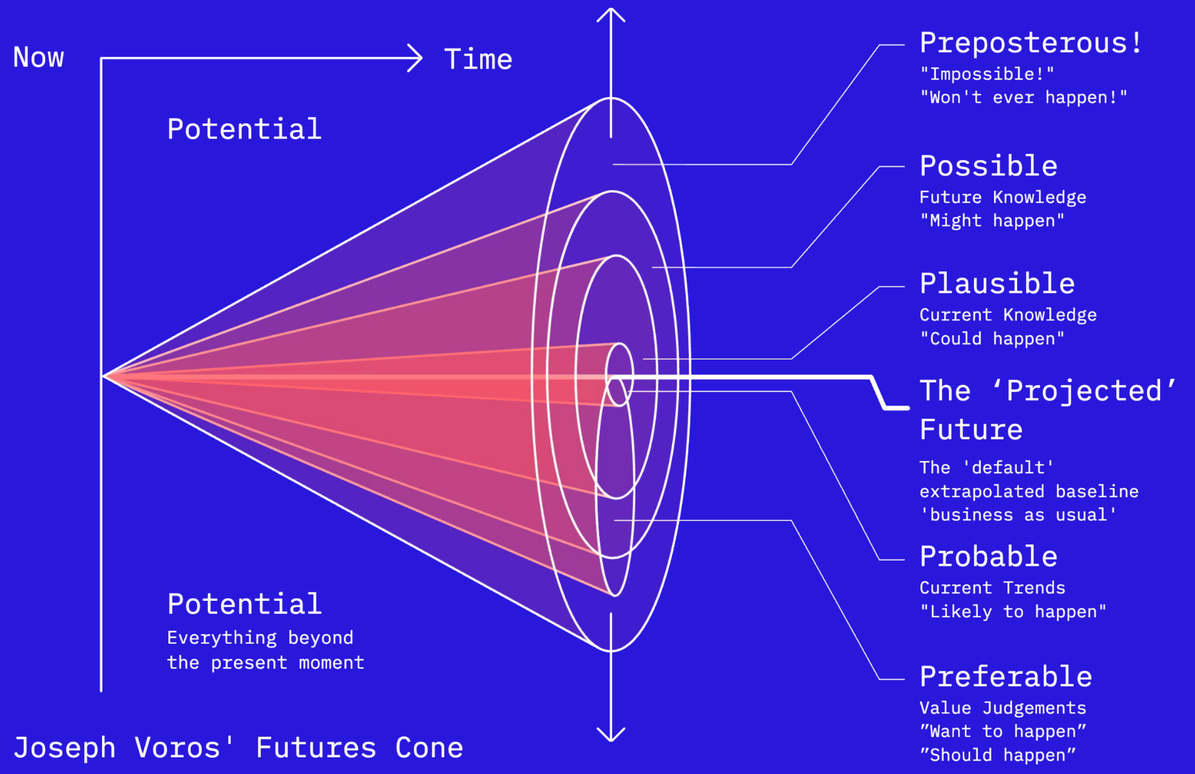
The final two were backcasting workshops, where an additional group of engineering experts looked at the imagined futures from the first group, and worked backwards to identify the possible events, institutions, policies, infrastructure, and skills that might lead to these imagined futures.

The goal of the worldbuilding and backcasting workshops is not to build consensus amongst participants towards one specific future scenario but to unveil a plurality of futures. The process purposefully embraces uncertainty, discomfort, and imagination in order to understand the components of successful innovation. Through this, we were able to better understand the blockers and affordances outside of the context of everyday projects.

The future is plural, nonlinear, and not predefined

The outcomes from our workshops provided rich insights into how a sample of experts are currently thinking about the present and the future: we illuminated what was missing, and revealed present-day obstacles that may need to be overcome when seeking preferred futures. Our goal with these workshops was not to identify a single idealised future, but to support pathways to multiple potential futures.

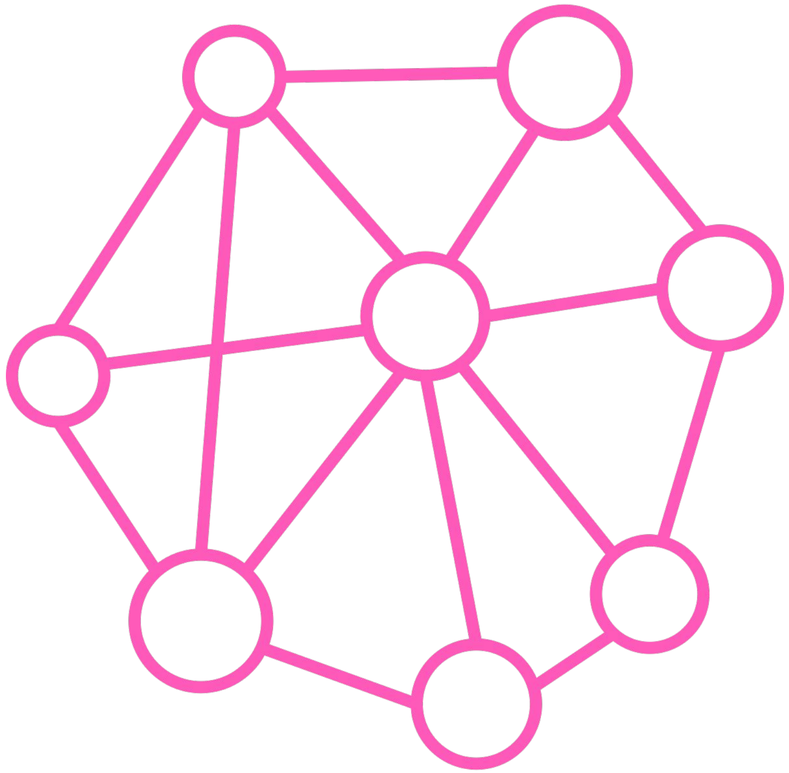
Through the discussions and playful activities within these workshops, some themes emerged, which are outlined on the following slides. These themes represent the **opinions** of our participants, and point to a number of potential obstacles and diversions in achieving a more pluralistic and healthy innovation ecology in the the future. These themes and observations should not be considered in isolation, but exist as part of wider discussions about the future.



Joseph Voros' Futures Cone

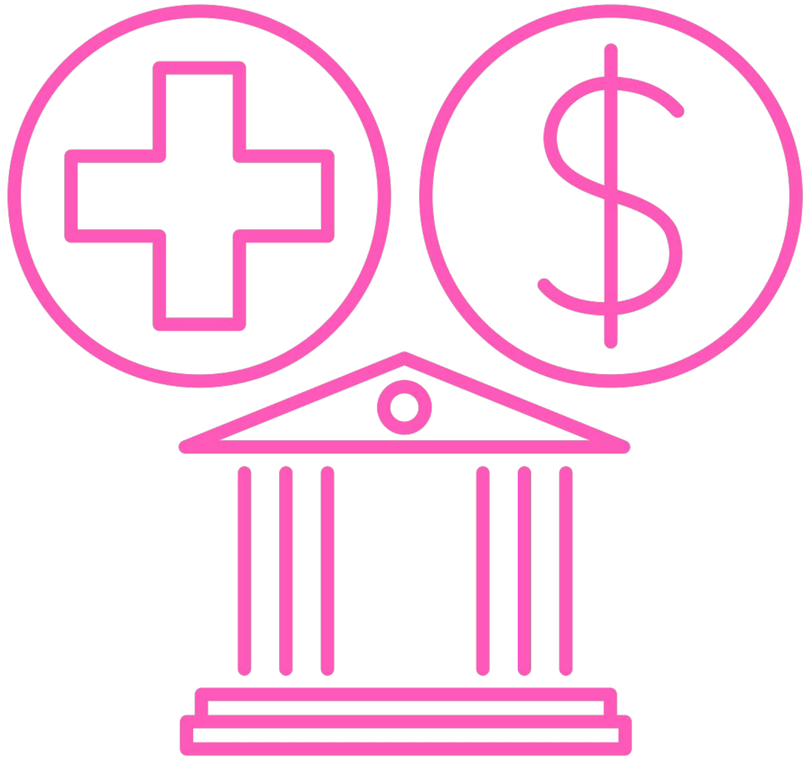
Bottlenecks in existing processes that can be fixed to make them more effective

During the workshops there was a tension observed with respect to resource allocation and usage; some questioned if we should decentralise resource ownership and others argued for greater controls. For example, regulating water usage by increasing prices.



Bottlenecks in existing processes that can be fixed to make them more effective

A recurring bottleneck was observed in health engineering; that pharma do not encourage or fund certain innovations that might reduce consumption of existing drugs or their associated profit margins. It was noted that the health system has a vested interest in treating the disease rather than long-term prevention and this is related to a profit motive and lack of holistic or equitable process.



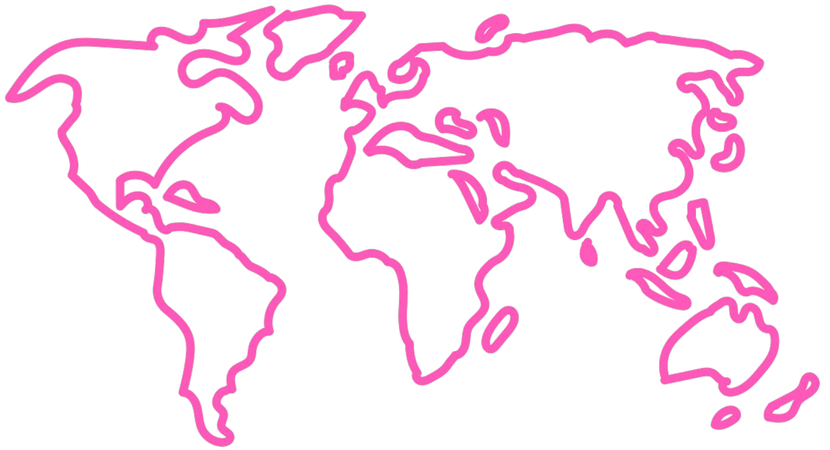
Bottlenecks in existing processes that can be fixed to make them more effective

Participants discussed how R&D structures limit opportunities for innovation. There is short-term funding and specific disciplinary silos (including in funding), profit being primary evaluation criteria for such funding.

Processes that are poorly connected to strategy setting or resource-allocation mechanisms within engineering

Through the workshops participants noted that investment in engineering in low- and middle-income countries does not have to follow the same pattern as countries that are already more developed. They also discussed potential perceived risks for investors in developing countries for innovation pathways that do not follow the same route.

Participants generally highlighted that the provision of funding for engineering solutions in the LMICs is lacking and that this is an issue that needs to be addressed.



The Royal Academy of Engineering in the context of power and history

A topic raised by participants was to understand The Academy's history, and the power this embodies, particularly in the context of the global south.

Notions of power were also explored more broadly: where does power sit? To what extent does engineering innovation happen behind closed doors, in the private sector? Does The Academy need to practically involve itself in this, or even have a viewpoint of it, particularly from a regulation and techno-ethical stance?

Building on this, participants raised the impacts of geopolitical contexts and external factors, such as shifting regulations. What strategies does The Academy need to employ to navigate and respond to new regulations?

Recommendations

Towards stewardship

Summary findings: context

- Single approaches to innovation are derived from post-Enlightenment rationalism, but there is no one 'correct' approach to progress.
- Innovation does not happen in isolation; when building new technologies it is essential to consider the various impacts and consequences of the materials and labour used and the impacts of that technology after and during its adoption.
- Storytelling and relationship building should play a large part in building strategies for the future; embracing multiple possible futures rather than one ideal situation.
- Resilient and beneficial technologies are built in partnership with non-technical communities — technology is never 'finished'; it is always subject to adaption by the communities that use it.

Summary findings: innovation

- Meaningful innovation is not currently the dominant paradigm for innovation in the broader innovation landscape
- There is an opportunity for stewardship within individual projects and programmes and stewardship across domains and sectors
- The Royal Academy of Engineering is well-placed to model and facilitate pathways to meaningful innovation, and to hold the space and opportunity for these methods
- While picking the “right” or “most effective” problems to tackle may be one component of responsible innovation, it is also essential to pay attention to methods and so avoid the conundrum of backing effective projects that exacerbate existing or create new opportunities

Summary findings: opportunities

- Modelling and facilitating pathways to meaningful innovation is a culture-change project not a technological deployment one
- The opportunities for change exist at many levels: within the Royal Academy of Engineering and its networks, across the field of engineering, and in the broader innovation landscape
- The urgency of the climate emergency requires adaptations of many kinds: there is an appetite for effective and inclusive delivery of meaningful innovation

Next Steps

Towards stewardship

Some next steps

- **Power sharing and reparative redistribution**

  Building on existing diversity and inclusion programmes and commitments, the Royal Academy of Engineering can use its platforms and convening power to give resource, space and status to multi- and inter-disciplinary experts from beyond engineering and from the Global Majority.

  The Peter Wall Institute for Advanced Study report Moving with Storms offers an example of interdisciplinary working organised to enable reparative redistribution.

Some next steps

- **Investment as a stewardship behaviour**

  The Royal Academy of Engineering can adopt a stewardship approach to award-giving, investments and support for researchers, businesses and new technologies.

  This would involve not only awarding individual excellence or potential, but also (a) incentivising meaningful innovation through awards and other support programmes and (b) attending to the field, spotting gaps, identifying second- and third-order unintended consequences and inter-relations so that missing inter- and multi-disciplinary working is encouraged, and under-represented perspectives are routinely and actively solicited.

Some next steps

- **Modelling stewardship**

  The Royal Academy could use its convening power to initiate cross- and multi-sector projects and prizes that center stewardship behaviours, and use its networks and resources to actively support participation from those beyond its traditional networks.

  For instance, a “Meaningful Innovation Award” that mandated interdisciplinary working and attention to social impacts, or an “Engineering Stewardship Award” that encouraged collaboration between projects and programmes to mitigate unintended consequences and network effects.

Some next steps

- **Collaboration and relationship building**

  The convening power of the Royal Academy of Engineering and its Fellows could be deployed to actively build interdisciplinary and cross-sector relationships, strengthening connections in and between communities and creating opportunities for new forms of collaboration.

Some next steps

- **Narrative reframing and storytelling**

  Stories of innovation tend to be heroic, but real change tends to be created by networks of people and communities. While diversity has been at the heart of the Royal Academy's recent strategy, a culture of medals and fellowships still speaks to a "first past the post" conception of success. A broader approach to inclusion – one that includes and reflects many perspectives and ways of getting things done, and the importance of teams as well as individuals – can be sparked and reflected through inclusive storytelling and reframing of the work of innovation as a lone, heroic undertaking. Inspiring stories are a vital part of culture change, and reflecting an interest in stewardship is a vital part of this. See, for instance, the University of Sussex Future Natures programme.

Appendices

Methodology (in detail)

Workshop attendees

Dr Adam Cooper, UCL STEaPP

Amandeep Singh Kellay, Portfolio Manager, Impact on Urban Health

Ana Avaliani, Director, Enterprise, The Royal Academy of Engineering

Dr Andrew Chilvers, Head of Policy, Climate and Sustainability

Anna Studman, Senior Researcher, Ada Lovelace Institute

Beatrice Barleon, Head of Public Affairs and Policy, EngineeringUK

Dr Ben Hawes

Blanche Cameron Dip.Arch Environmental Design Lecturer, Bartlett School of Architecture UCL

Caitriona Hanly, Policy Advisor, Health and Resilience, The Royal Academy of Engineering

Professor Deb Chachra, Olin College of Engineering

Eleanor Stride, Professor, University of Oxford

Professor Emanuela Tilley, Director of Integrated Engineering Programme, UCL

Fozia Ismail, co-founder, dhaqan collective

Giles Lane, Senior Programme Manager, Futures & Dialogue, The Royal Academy of Engineering

Professor Guy-Bart Stan, Department of Bioengineering, Imperial College London

Harry Chaplin, Founder and Director of Tatirano Social Enterprise

Helen Ewles, Head of Innovation, Analysis and Public Affairs, The Royal Academy of Engineering

Jennifer Panting, Department for Energy Security & Net Zero

Professor John Clarkson FREng, Professor of Engineering Design, University of Cambridge

John Cully, Policy Advisor, Health and Resilience, The Royal Academy of Engineering

Juliet Upton, Head of Education and Skills Policy, The Royal Academy of Engineering

Katie Saddleton, Senior Ecosystem Manager, Enterprise Hub, The Royal Academy of Engineering

Kelly Smith, Senior Policy Adviser, The Royal Society

Matt Hastings, Deputy Director Ofgem Strategic Innovation Fund

Matt Jones, Head of Design, Lunar Energy

Mrs Miranda Sharp, CEO and Founder Metis Digital Limited

Dr Natasha McCarthy, Associate Director, Policy, The Royal Academy of Engineering

Dr Rachel Quinn, Academy of Medical Sciences

Rhiannon Williams, Foresight Researcher, Arup

Ryan Leung, Research Manager, Mitigation, Wellcome Trust

Sabrina Fleurimé, Science Policy Officer, Royal Society of Biology

Sarah Hunter

Siobhan Silas, Education and Skills Policy Officer, The Royal Academy of Engineering

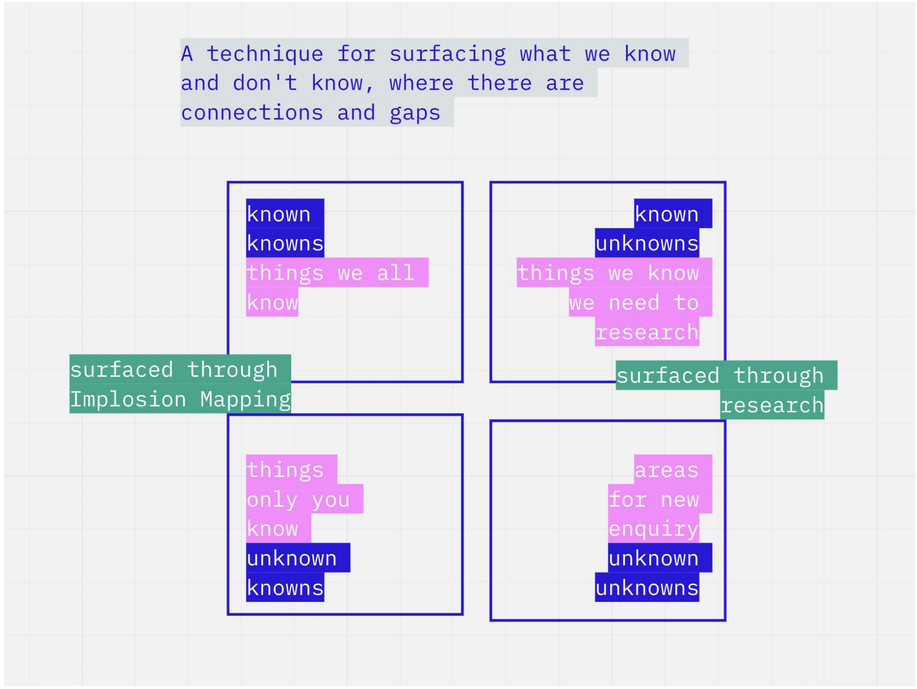
Zayeed Alam, F.R.Eng, Director, Research & Development, Procter & Gamble

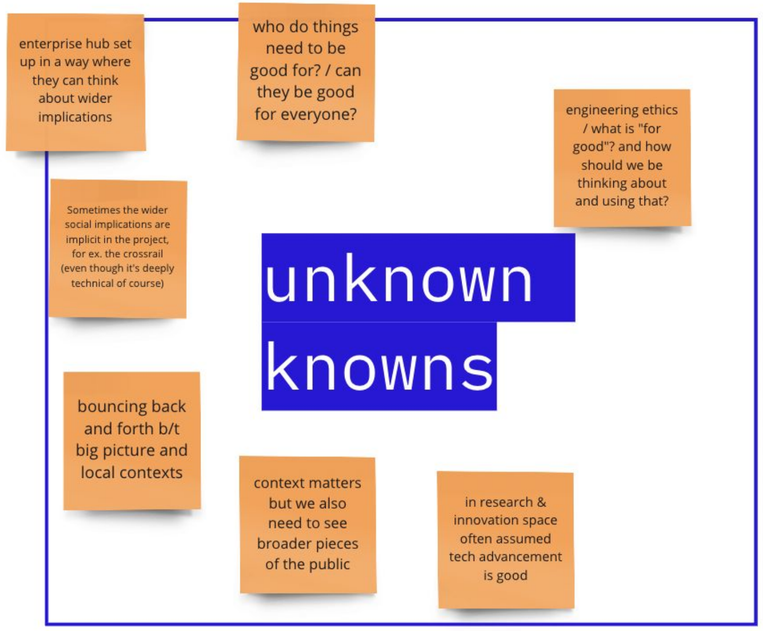
Zoe Rasbash, Climate Action Researcher, Watershed

Kick-off: Implosion mapping

Implosion mapping is a technique based on the writing of Donna Haraway and Giles Deleuze, embedded in our practice via Prof. Jessamy Perriam and also Joseph Dumit's 2014 "Writing the Implosion: Teaching the World One Thing at a Time".

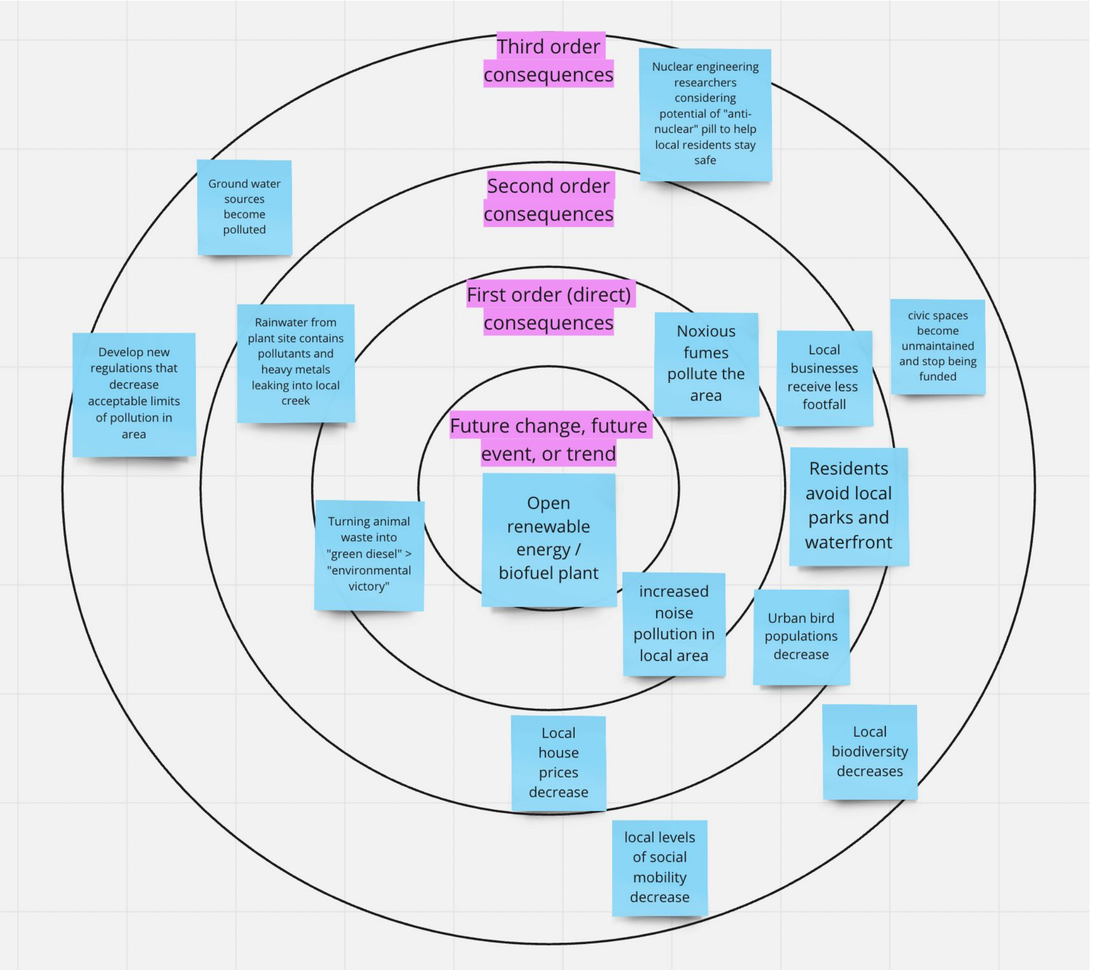
We asked participants to consider something they think represents a hopeful technology. Some examples considered by participants included an e-reader, a passport, an automated external defibrillator, a home, and a bicycle. The process asks participants to consider the material, labour, technical, economic, and other elements that make up the technology. Through this process we are able to collectively externalise existing knowledge and break down complex abstract concepts into tangible information.





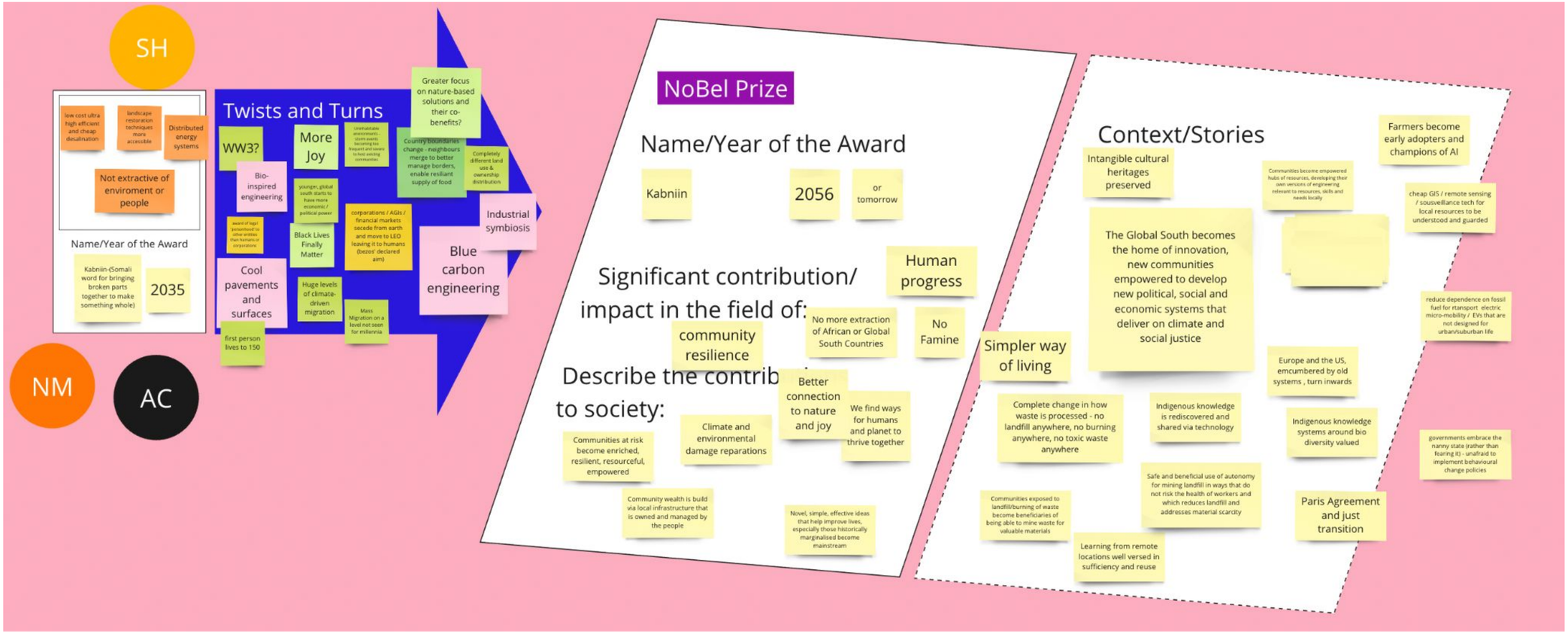
Mapping and research

Collating weak signals and contextual markers that situate the creation, development, and adaptation of technologies in social contexts.



Worldbuilding workshops

- Two virtual 2-hour creative workshops
- One workshop on Climate and Sustainability; one on Health and Resilience
- Each attended by a diverse group of subject-matter experts



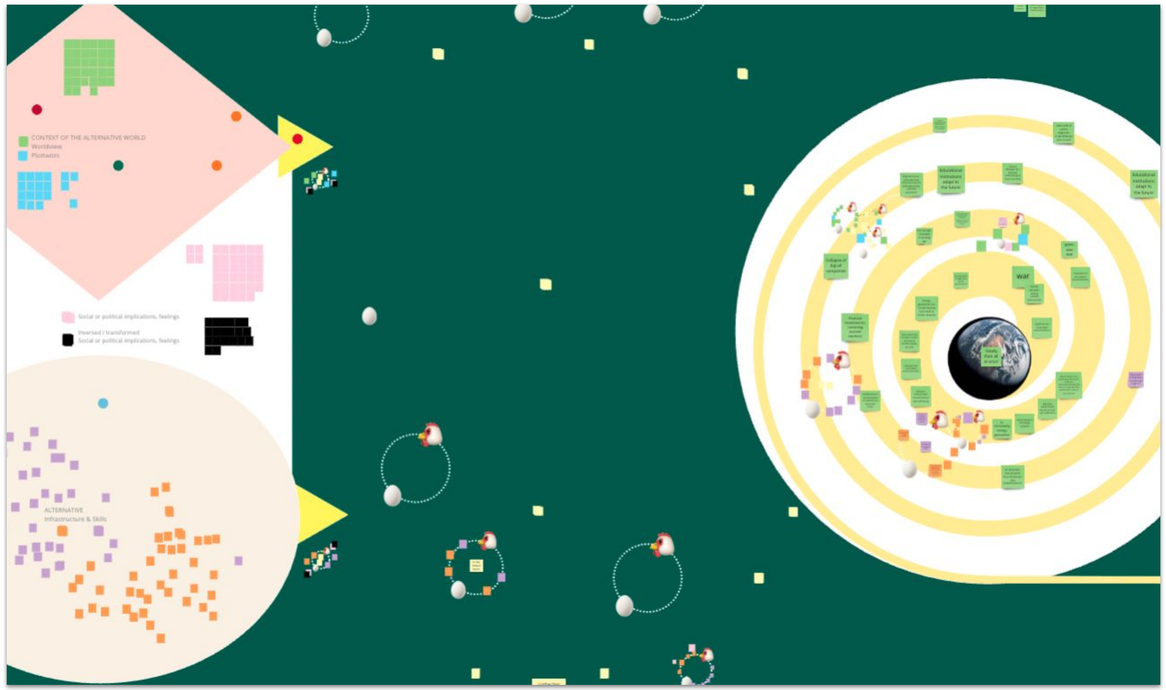
The activities took participants through a creative, imaginative process to explore a range of possible futures and the social, political, environmental, economic, and technological conditions that shape those futures.

Backcasting workshops

Backcasting is a way of looking ahead to a desired future and working backwards to understand what needs to be in place to make that happen.

Facilitators selected one desired future (per theme) from the worldbuilding workshops, and asked participants to imagine the infrastructure, skills, worldviews, and external contexts that might need to exist to make that future reality.

The process also asked participants to consider what are the wild cards and disruptions that might get in the way of achieving the desired future(s)?



About Us

Careful Industries is a research organisation based in the UK. Through research and prototyping, we help our clients understand the social impacts of technologies and create new futures. Our sister organisation, Promising Trouble, is a not-for-profit exploring the potential of community technologies.

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