European Environment Agency

With people and for people: Innovating for Sustainability

With people and for people: Innovating for sustainability

Innovation is both a primary source of systemic environmental and sustainability challenges and an essential element in society's response to such challenges. Technological innovation, which is a policy priority across Europe, has historically been a major 'driver of change' for society and the ecosphere. Although technological innovations deliver a multitude of benefits, they are also associated with significant collateral hazards and new challenges.

Key messages

- The outcomes and impacts of innovation are often unpredictable, e.g. technological innovations can have rebound effects in that improved efficiency can lead to increased consumption.
- A society-wide innovation system needs to serve a collective, social purpose — promoting all-round sustainability rather than generating private returns and externalising social and environmental costs.
- Such an innovation system requires governance that balances experimentation and precaution and addresses the unpredictable outcomes and impacts of innovation.
- Good governance of innovation enables citizens and societies to meet grand challenges through their choices and actions — and not only what they buy — through extended participation and engagement.

This narrative is part of a series called ‘Narratives for change’ published by the EEA

This narrative belongs to a series called ‘Narratives for change’, which explores the diversity of ideas needed to transform our society to achieve sustainability goals and the ambitions of the European Green Deal. This briefing considers the ambiguities of technological innovation and the wider role of innovation in achieving sustainability.

Question

How can society steer its innovation systems towards being open enough to unleash human creativity while avoiding technology-driven, man-made environmental problems?

Innovation as a driver of change

Society is undergoing rapid change. Numerous drivers of change interact in a highly complex interplay of human needs, desires, activities and technologies (EEA, 2019a) and contribute to ‘the Great Acceleration’ in human consumption and environmental degradation. The pace of change and the speed of innovation are also accelerating, as indicated by the massive uptake of innovative products and services and the mainstreaming of a technology-driven culture. For example, digitalisation is now part of everyday life for most individuals and for virtually all economic sectors.

Technological innovations are also rapidly converging into new clusters and applications that fuse digital technologies (e.g. big data analytics, artificial intelligence and blockchains) with physical (e.g. nanotechnology) and biological (e.g. biotechnology) fields, constituting the core of the ‘Fourth Industrial Revolution’.

These changes are occurring at an unprecedented rate and at a scale that brings both significant opportunities and major challenges for sustainability (EEA, 2020b). As long ago as 2001, an EEA report concluded: ‘The growing innovative powers of science seem to be outstripping its ability to predict the consequences of its applications, while the scale of human interventions in nature increases the chances that any hazardous impacts may be serious and global' (EEA, 2001).

Innovation and novelty are the guiding principles of the EU's new industrial strategy (EC, 2020b), one of the forces behind the European Green Deal (EC, 2019a). The same was true of the Europe 2020 strategy (EC, 2010). However, we cannot know the outcomes and impacts of innovation processes in advance.

Innovation may bring about gradual change that can be steered towards desired outcomes, but it may also bring disruptive change and unintended consequences. Technological innovations may also lead to lock-ins and path dependency, when large-scale adoption of a technology requires infrastructure development, influences market organisation and affects social order.

Innovation clearly has tremendous potential to transform society. But market forces and public policies have, so far, failed to channel that potential towards sustainability. There is a growing sense that far too much human and financial capital is invested in creating wasteful or actively harmful products (e.g. sophisticated weapons or financial instruments) rather than addressing society's most important challenges. Too often, society's interests are marginalised in market-driven innovation processes. The public is frequently a passive observer, and public interest is seldom the primary motivation for innovation (Mulgan, 2019).

Another key lesson from the history of innovation is to prepare for uncertainty. For example, innovations that may work in the restricted domain of cause-effect for which they were designed may have contradictory or even paradoxical effects when scaled up (Kovacic et al., 2020).

Technology alone won't save us

Many sustainability issues highlight the challenges arising at the interface of multiple policy domains (e.g. agriculture, industry, economy and environment), leading to both synergies and tensions across various goals. For instance, the need to reduce greenhouse gas emissions may conflict with growing energy demand. In such cases, innovation is often invoked with the promise of a win-win solution that overcomes the tensions created by conflicting yet equally legitimate policy targets, irrespective of whether the innovation works or not. In this case, the danger is twofold: the imaginary of technological innovation may obscure the need for a political and societal debate and justify business-as-usual models disguised as green and sustainable solutions.

While many sustainability-driven technologies promise positive outcomes, the consequences of technological innovations are difficult to anticipate. Because they are non-linear, technological 'solutions' to complex problems (e.g. climate change) may have unintended consequences when scaled up to the system level (e.g. indirect land use change, loss of biodiversity and increased competition for land resulting from biofuel production) (EEA, 2019b). For this reason, a systemic approach to studying innovation and its consequences is needed.

Yet, expectations for certain solutions may be so strong that they remain at the center of policy discourses even if they do not function well in the material world. Previous EEA reports (EEA, 2001, 2013) give many examples of innovations that lingered long after their negative side effects had been documented. They describe cases where ‘early warnings’, and even ‘loud and late’ warnings, were clearly ignored, where the scope of hazard appraisal was too narrow and where regulatory action was taken without sufficient consideration of alternatives or of the conditions necessary for their successful implementation in the real world (e.g. bisphenol A, DDT, PCE, asbestos[1]) (EEA, 2001, 2013).

This work on the hazards arising from economic activities for the environment and human health emphasises the need to strike a better balance between maximising innovation and minimising hazards to people and the environment. For instance, bisphenol A is a classic example of the widespread uptake of a chemical with endocrine-disrupting properties without understanding its health implications and subsequently trying to resolve public health questions in the face of intense pressure over the serious economic consequences of phasing out.

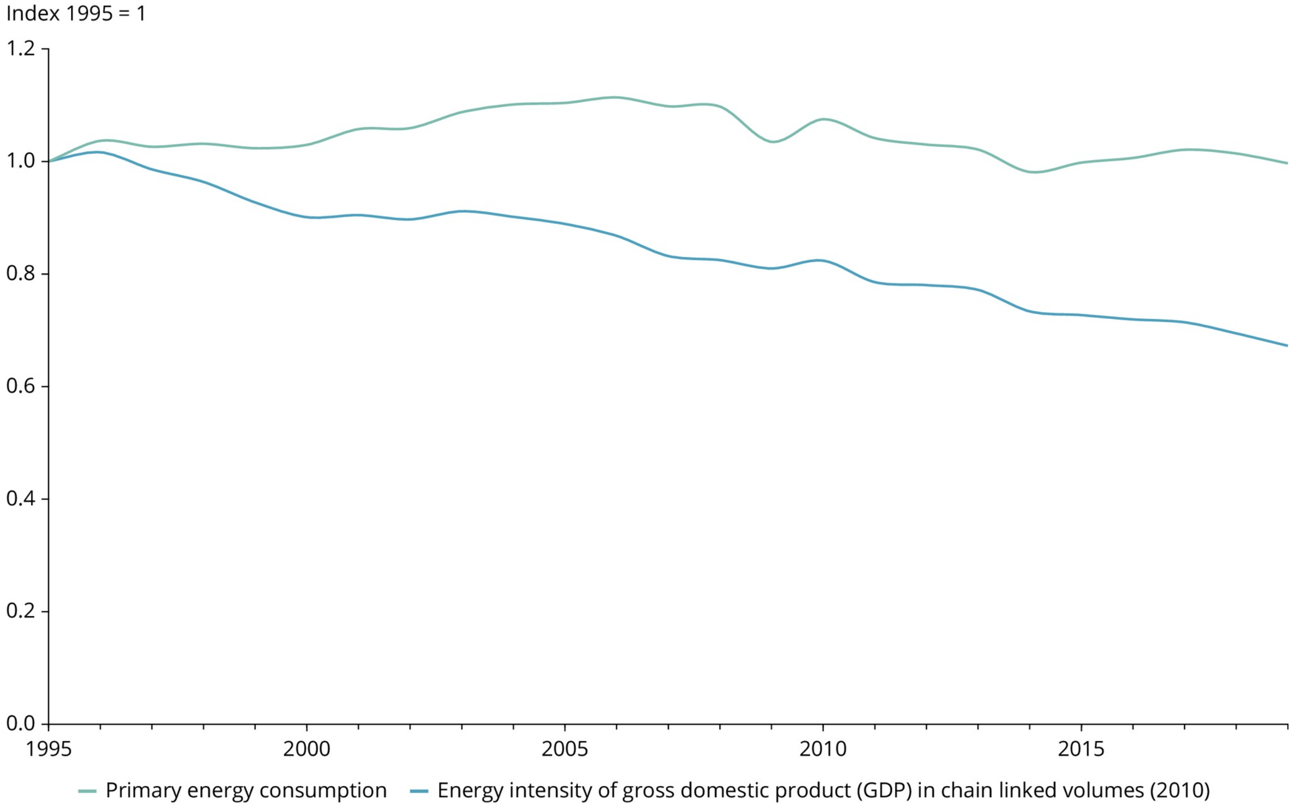
Biofuels are another case in point. Once seen as a win-win solution, large-scale production of first-generation biofuels in the 1990s and 2000s created competition with food production for land. This resulted in indirect land use change, affecting ecosystems and biodiversity, for example through deforestation. Consequently, EU policy shifted from setting a minimum target for biofuel use in transport (EU, 2003) to putting a cap on the amount of crop-based biofuels permitted (EU, 2015).

Innovations may also have different outcomes at different levels of implementation, creating paradoxes that make it challenging to steer them in the desired direction. For example, incremental efficiency improvements in technologies often fail to produce desired reductions in resource use because of indirect effects on consumption. This phenomenon was first identified in relation to steam engines by Jevons in the 1800s (Jevons, 1866). Efficiency improvements made steam power affordable not only to coal mines but also to weavers and spinners, leading to increased consumption from new businesses. The Jevons’ paradox points to the fact that consumption is seen as both declining (in engine use — efficiency) and expanding (in market use — overall consumption).

This paradox can also be observed for energy demand and energy intensity in the EU economy (Figure 1): while less energy was used per unit of gross domestic product, total energy consumption stayed more or less the same over the period 1995-2019. Overall, energy consumption is not overly responsive to changes in efficiency.

The Jevons paradox can also be seen in other sectors, e.g. when water savings in agriculture are followed by an increase in the irrigated area (Vivanco et al., 2018), and in transport, e.g. when mileage and overall fuel consumption increase as a result of improved engine efficiency (EEA, 2019b).

Figure 1. The Jevons paradox for energy consumption in the EU-27, 1995-2019



Sources: Based on Eurostat (2021a, 2021b).
More info

The circular economy is at the heart of the European Green Deal and the EU new industrial strategy, and the innovation processes driving change may be challenged by the Jevons paradox (Zink and Geyer, 2017; Vivanco et al., 2018; Warmington-Lundström and Laurenti, 2020). For example, achieving circularity will require new production processes, new business models and new cultures (sharing economies, repair and recycle cultures).

Recycling, repair and reuse may paradoxically lead to an increase in material consumption, rather than a decrease, mainly due to indirect effects. For example, in the case of smartphones, Makov and Vivanco (2018) argue that overall material consumption increases when savings arising from improvements in the efficiency of phones lead to new spending and consumption elsewhere. Increased material consumption can also be caused by ‘imperfect substitution’ (Makov and Vivanco, 2018) between new and recycled goods.

Balancing creativity and precaution

Deploying technological innovations alongside changes in infrastructure and social practices forms ‘socio-technical systems’. The complexity of such systems and their interaction with their environment is the main source of unpredictability in innovation outcomes (Wynne, 1992) and the reason why a command-and-control type of governance is so difficult for innovation (EEA, 2019a, 2019b). Governing innovation is similar to herding cats. They will move, but not necessarily to where you ask them to go. The complex and emerging character of innovation often means that, by the time the social and environmental implications of technologies are apparent, they may be widely embedded in societal structures, leading to the ‘dilemma of control’ (Collingridge, 1980).

In **governance** terms, these insights highlight the need to take several complementary approaches to avoid disasters while allowing for creativity. For example, better **anticipation** by engaging stakeholders in exploring implications, e.g. via foresight approaches, could be combined with more conventional approaches such as risk assessment, technology assessment, responsible research and innovation and ethical reviews (EEA, 2013, 2020b). Anticipation may not provide evidence to support action but it can provide a better understanding of uncertainties and a way of exploring alternative pathways for action.

Precaution can provide both a logical response to possible harm as well as the basis for a radical reconfiguration of the science-policy-innovation interface, where the potential for harm is high. In this context, rather than policy being informed by scientific evidence (‘get the facts then act’), the precautionary principle states that policy may need to be formulated in a context of uncertainty (‘act because it may be too harmful to wait for the facts’). For example, the European Commission puts the precautionary principle at the core of the new EU chemicals strategy (EC, 2020a) by adopting an approach to innovation in which all new chemicals and materials must be inherently safe and sustainable, from production to end of life (EEA, 2020a; EC, 2020a).

Promoting diverse innovations can help to mitigate lock-ins, enable learning and increase tolerance of failure for individual innovations. Collective engagement in shaping the innovation agenda may help to shift accountability from delivering results (which depends on certainty) to fostering better adaptive capacity to deal with systemic challenges that are inherently uncertain.

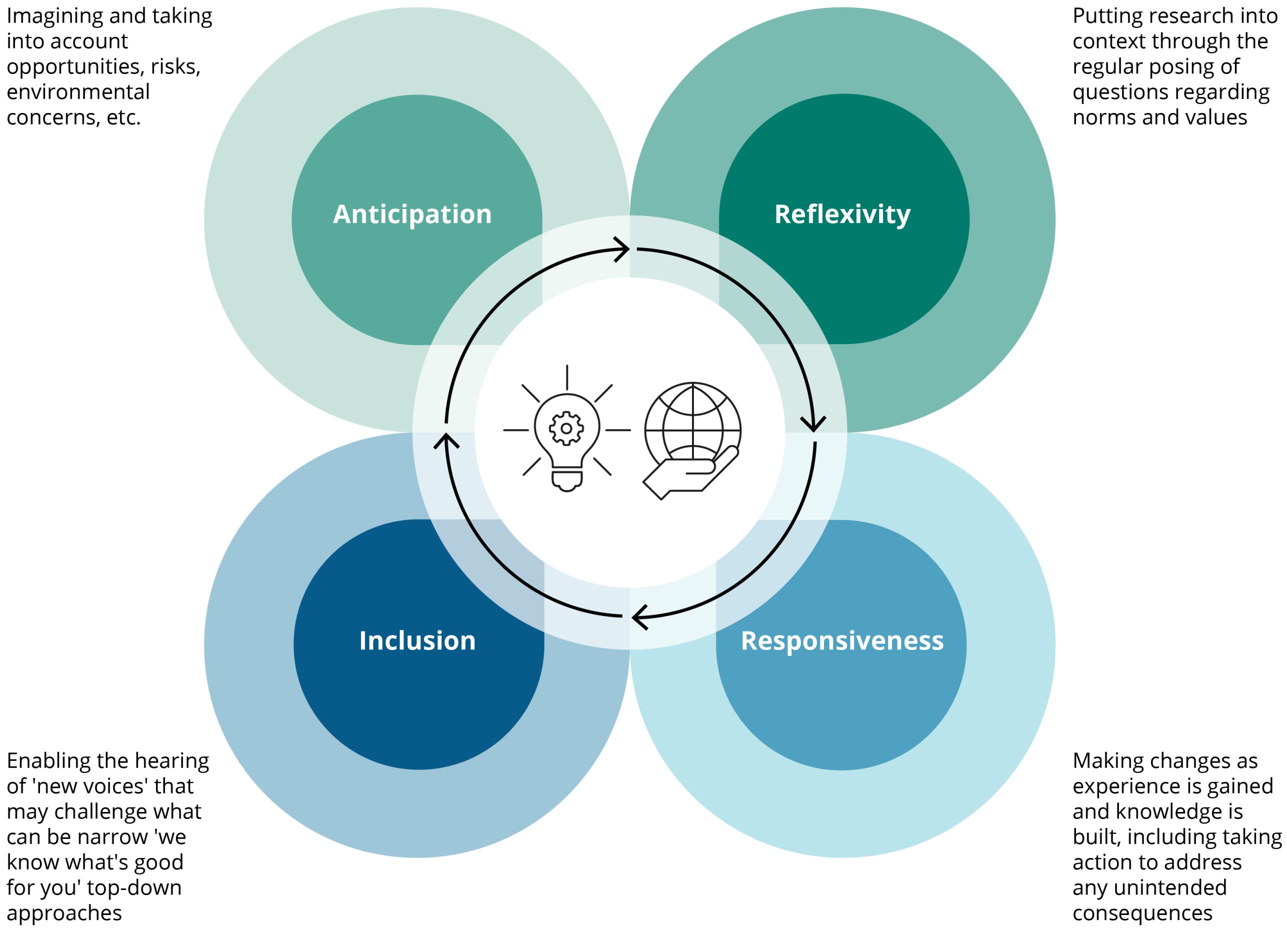
Some scholars have argued for improved **democratic governance** in creating and refining future visions of socio-technical systems to complement scientific and industrial interests and mitigate the risk of technological tunnel vision (Felt et al., 2007; Strand et al., 2018).

Taking a **systemic approach** and following innovation processes in real time to adjust the trajectory of innovation can have several benefits (Rip et al., 1995; Strand et al., 2018). For example, applying a ‘nexus’ framing can help anticipate potential risks and unintended outcomes by identifying possible synergies and trade-offs between energy, food, water, the environment and other domains (EC, 2019b; EEA, 2019b).

In this context, the EU established **responsible research and innovation** as a cross-cutting policy principle for the EU Horizon 2020 research programme 2013-2020, in response to the call for greater public engagement and better alignment between innovation agendas and the needs and concerns of civil society.

Responsible research and innovation ‘implies that societal actors (researchers, citizens, policy makers, business, third sector organisations, etc.) work together during the whole research and innovation process in order to better align both the process and its outcomes with the values, needs and expectations of society.’ More specifically, four dimensions are key enablers for anchoring responsible research and innovation in practice: anticipation, reflexivity, inclusion and responsiveness (Stilgoe et al., 2013) (see Figure 2).

Figure 2. The process dimensions of responsible research and innovation



Sources: Modified from Wilford et al. (2016) and Stilgoe et al. (2013).

The European Green Deal and related EU policy frameworks support the responsible research and innovation agenda. The principles of transformative change towards sustainability, ensuring fairness and not leaving anyone behind appear appropriately qualitative and broad for a dynamic and adaptive approach to innovation.

From technology to people

Equal attention should be paid to the social and technical aspects of innovation (Wittmayer et al., 2020). Without close interaction between technological and social innovation, the alignments between innovation agendas and societal (and environmental) challenges and concerns are likely to remain superficial. The challenges of sustainability require novel social practices and cultural and institutional change, including in the institutions that govern innovation. A type of innovation that addresses the profound need for change, is **deep innovation**. 'Deep' has three dimensions (Rommetveit et al., 2013):

> First, profound attempts at dealing with the grand challenges themselves and not just the development of consumer products and services that somehow may claim to be related to the challenges.
>
> Second, profound novelty in the interlinkages between the grand challenges.
>
> Third, a deep involvement of members of society in the development of new ideas and new solutions not just as passively receiving consumers but as citizens who participate and through their involvement build new forms of agency. Deep involvement would mean that citizens and governments meet grand challenges also through what they do and not only through what they buy.

Social innovations are important for sustainability transitions, because they often aim to achieve deeper and further-reaching change, including different ways of living (EEA, 2019b). They often have the specific goal of reconfiguring existing practices, relationships and structures. They may be linked to different visions and pathways for sustainability transitions, which tend to be more radical than business-driven greening efforts, e.g. questioning conventional consumerism and advocating changes in user practices and lifestyles (EEA, 2019b). They often respond to local needs and are also more oriented towards social justice or alternative economic rationales, such as community ownership, shortening of supply chains and self-sufficiency.

Promoting the emergence and diffusion of social innovations poses many questions:

- If new products, services or business models promote broad social ends, can they survive in market economies among alternatives that externalise social and environmental harms?
- Could radically different lifestyles emerge and thrive?
- What kinds of support could governments or communities provide and would this be sustainable?
- How can social innovations be scaled up or spread?
- How can diverse stakeholders and interests be engaged and represented in innovation processes?
- How can societies promote desired social change when the impacts of innovations are often unclear until widely taken up in society over a long period?

Such questions create new demands for public policies and supporting knowledge systems.

In conclusion: innovation for a sustainable society

Across Europe, innovation is ubiquitous: within business, science and technology, across our institutions of governance, within local communities and civil society more widely. The need for innovation is not in question, rather the types of innovation, their scale-up and how they are governed so they can support efforts towards achieving a sustainable Europe.

The first in this series of narratives for change 'Growth without economic growth' (EEA, 2021) discusses how European societies can grow without harming the environment and climate. It addresses questions such as:

- Can our economies grow endlessly?
- Is a perpetual economic growth feasible and desirable?
- How can society develop and grow in quality (e.g. purpose, solidarity, empathy), rather than in quantity (e.g. material standards of living), in a more equitable way?

As suggested by Pansera and Fressoli (2021), 'untangling innovation from growth is key' and to do so Europe needs a new innovation paradigm that 'looks beyond technology, into cultural and institutional change, and social life and social order'. Can a new innovation system be conceived that pursues goals other than economic growth? Which policies, infrastructures and forms of organisation would be necessary? (see Pansera and Fressoli, 2021). These are questions that Europe should address so that we can learn how to thrive in a sustainable way.

Footnotes

[1] DDT, dichlorodiphenyltrichloroethane; PCE, perchloroethylene.

Acknowledgments

Authors:

Strand, R., Kovacic, Z., Funtowicz, S. (European Centre for Governance in Complexity)

Benini, L., Jesus, A. (EEA)

Inputs, feedbacks, and review:

Anita Pirc-Velkavrh (EEA), Jock Martin (EEA), Mike Asquith (EEA), members of the Eionet NFPs and NRC-FLIS, and of the EU Environmental Knowledge Community

References

Collingridge, D., 1980,The social control of technology, Pinter, London.

EC, 2010, Communication from the Commission 'Europe 2020 — A strategy for smart, sustainable and inclusive growth' (COM(2010) 2020 final, Brussels, 3.3.2010).

EC, 2019a, Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions 'The European Green Deal' (COM(2019) 640 final, Brussels, 11.12.2019).

EC, 2019b,Environmental implementation review 2019: A Europe that protects its citizens and enhances their quality of life, European Commission, Brussels.

EC, 2020a, Communication from the Commission to the European Parliament, the Council, the Economic and Social Committee and the Committee of the Regions 'Chemicals strategy for sustainability. Towards a toxic-free environment' (COM(2020) 667 final, Brussels, 14.10.2020).

EC, 2020b, Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions 'A new industrial strategy for Europe' (COM(2020) 102 final, Brussels, 10.3.2020).

EEA, 2001, Late lessons from early warnings: The precautionary principle 1896-2000, Environmental Issue Report No 22/2001, European Environment Agency, accessed 22 April 2015.

EEA, 2013, Late lessons from early warnings: Science, precaution, innovation, EEA Report No 1/2013, European Environment Agency, accessed 5 July 2021.

EEA, 2019a, Sustainability transitions: Policy and practice, EEA Report No 9/2019, European Environment Agency, accessed 7 February 2020.

EEA, 2019b, The European environment — State and outlook 2020: Knowledge for transition to a sustainable Europe, European Environment Agency, accessed 5 July 2021.

EEA, 2020a, Designing safe and sustainable products requires a new approach for chemicals, EEA Briefing No 29/2020, European Environment Agency, accessed 9 April 2021.

EEA, 2020b, Drivers of change of relevance for Europe's environment and sustainability, EEA Report No 25/2019, European Environment Agency, accessed 8 December 2020.

EEA, 2021, Growth without economic growth, Briefing No 28/2020, Copenhagen, accessed 18 March 2021.

EU, 2003, Directive 2003/30/EC of the European Parliament and of the Council of 8 May 2003 on the promotion of the use of biofuels or other renewable fuels for transport (OJ L 123, 17.5.2003, p. 42-46).

EU, 2015, Directive (EU) 2015/1513 of the European Parliament and of the Council of 9 September 2015 amending Directive 98/70/EC relating to the quality of petrol and diesel fuels and amending Directive 2009/28/EC on the promotion of the use of energy from renewable resources (OJ L 239/1, 15.9.2015, p. 1-29).

Eurostat, 2021a, 'Energy efficiency [nrg_ind_eff]', accessed 22 May 2021.

Eurostat, 2021b, 'Energy intensity of GDP in chain linked volumes (2010) [NRG_IND_EI]', accessed 22 May 2021.

Felt, U., et al., 2007,Taking European knowledge society seriously, Report of the Expert Group on Science and Governance to the Science, Economy and Society Directorate, Publications Office of the European Union, Luxembourg.

Jevons, W. S., 1866,The coal question: An inquiry concerning the progress of the nation, and the probable exhaustion of our coal-mines, Forgotten Books, London.

Kovacic, Z., et al., 2020,Report on the quality of the assessment of technical innovations, MAGIC (H2020 689669), European Commission, Brussels.

Makov, T. and Vivanco, D. F., 2018, 'Does the circular economy grow the pie? The case of rebound effects from smartphone reuse', Frontiers in Energy Research6, pp. 1–11.

Publications

Mulgan, G., 2019,Social innovation: How societies find the power to change, Bristol University Press, Bristol, UK.

Pansera, M. and Fressoli, M., 2021, 'Innovation without growth: frameworks for understanding technological change in a post-growth era',Organization28(3), pp. 380-404 (DOI: 10.1177/1350508420973631).

Rip, A., et al., eds., 1995,Managing technology in society: The approach of constructive technology assessment, Thomson Learning, London.

Rommetveit, K., et al., 2013,What can history teach us about the prospects of a European Research Area?, Publications Office of the European Union, Luxembourg.

Stilgoe, J., et al., 2013, 'Developing a framework for responsible innovation', Research Policy42(9), pp. 1568-1580.

Strand, R., et al., 2018, 'New narratives for innovation', Journal of Cleaner Production197, pp. 1849-1853.

Vivanco, D. F., et al., 2018, 'Roadmap to rebound: how to address rebound effects from resource efficiency policy', Sustainability (Switzerland)10(6), pp. 1–17.

Warmington-Lundström, J. and Laurenti, R., 2020, 'Reviewing circular economy rebound effects: the case of online peer-to-peer boat sharing', Resources, Conservation and Recycling: X5, p. 100028.

Wilford, S., et al., 2016, Guidelines for responsible research and innovation, Centre for Computing and Social Responsibility, De Montfort University, Leicester, UK, accessed 5 January 2021.

Wittmayer, J. M., et al., 2020, 'Beyond instrumentalism: Broadening the understanding of social innovation in socio-technical energy systems', Energy Research & Social Science70, p. 101689.

Wynne, B., 1992, 'Uncertainty and environmental learning: reconceiving science and policy in the preventive paradigm.', Global Environmental Change2(2), pp. 111–127.

Zink, T. and Geyer, R., 2017, 'Circular economy rebound', Journal of Industrial Ecology 21(3), pp. 593–602.

Identifiers

Briefing no. 09/2021

Title: **With people and for people: Innovating for sustainability**

HTML - TH-AM-21-009-EN-Q - ISBN 978-92-9480-387-0 - ISSN 2467-3196 - doi: 10.2800/89007

PDF - TH-AM-21-009-EN-N - ISBN 978-92-9480-388-7 - ISSN 2467-3196 - doi: 10.2800/56160

Published on 09 Sep 2021